WFL Publisher
Science and Technology
Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
e-mail: info@world-food.net

Journal of Food, Agriculture & Environment Vol.9 (3&4): 1005-1011. 2011 *www.world-food.net*

Influence of different land use on urban microenvironment in Beijing City, China

Jiaomei Liu [1, 2] and Xiangzheng Deng [3, 4*]

[1] School of Environment,Beijing NormalUniversity, 100875, Beijing, China. [2] Beijing. NO.35 High School, 100032 Beijing, China. [3] Institute for Geographic Sciences and Natural Resource Research, Chinese Academy of Sciences, 100101 Beijing, China. [4] Center for Chinese Agricultural Policy, Chinese Academyof Sciences, 100101 Beijing, China.

**e-mail: dengxz.ccap@igsnrr.ac.cn*

Received 29 May 2011, accepted 28 September 2011.

Abstract

The urban air temperature is gradually rising in all cities in the world. Records of the past years showed that the climate of built-up regions differs significantly from rural regions. One of the most obvious and important modifying effects of urbanization on local climate is the urban heat island (UHI). In order to clarify the spatial distribution of urban thermal field and to evaluate the urban environment quality synthetically, 5 sites including Xidan, the commercial centre of Beijing district; Mudanyuan, the residential areas; Kunming Lake in Summer Palace, the water body; Chaoyang Park, the urban green space; and Wenquan Village, the suburb of Beijing, were investigated from December 2007 to August 2008. The meteorological factors of temperature and humidity of underlying surfaces in these 5 sites were monitored simultaneously in 10 hours period. The results indicate that the temperatures of underlying surfaces in different sampled landscapes were in the order of suburb <water area< green space<residential area<commercial centre in winter, and water area<suburb<green space<residential area<commercial centre in summer; while the humidity was in the opposite order in terms of landscape. The largest temperature difference was 6.3°C at 18:00 h in commercial centre, the largest humidity difference was 25.9% at 8:00 h in residential area compared to rural area. Finally, this paper provides a concise and comprehensive understanding for the temporal and spatial microclimatic dynamics of these four kinds of urban ground cover in the five observation sites. There is influence of urban land use and ground cover on the microclimate of Beijing, monitoring and analyzing urban growth patterns and evaluating their impacts on land surface temperature (LST), provides sound basis for ecological construction, environment improvement, urban planning and management.

Key words: Spatial and temporal distribution, temperature and humidity, urban land use, microenvironment.

Introduction

Anthropogenic activity combined with technological advancement has accelerated the change of Earth's natural land cover. Owen *et al.* [14] states that social, economic and political forcing mechanisms have resulted in expanded urbanization and massive migration of people from rural to urban areas. Current transformations of ecosystems and landscapes by human activities are probably the largest source of global change on Earth [9, 17]. Human settlements modify the materials, the structure and the energy balance of the surface of the Earth and the composition of the atmosphere compared with the surrounding 'natural' terrains. The damages on the natural and built-up environments, caused by the speculative use of urban spaces, have been taking their most serious form. From the climatic point of view, they have been harmful to the cities and their residents, such as excessive heat storage and high concentration of air pollution[1, 5]. Land use intensification has led to rapid changes in communities of plants and animals, which in turn affects ecosystem services and ultimately human well-being [21]. Land use change has a number of effects on the urban climate, which drive urban climate change at large scales or microenvironment. Increased impervious surface area can lead to reduced infiltration and increased surface temperature. The increased urban growth can affect climate.

The most prominent characteristic of urban climate is the urban heat island phenomenon, in which the urban temperature is higher than its rural surroundings[15] . In some regions, the urban heat island effect (UHIE) can create an area of elevated air temperature 5-8°C greater than in the city when compared to the air temperatures in its surrounding rural areas [10, 16]. Many factors contribute to the urban heat island effect, including intense human activity and traffic that release heat and pollutants. In order to prevent these damages and create optimum bioclimatic conditions, the urban climate, urban microenvironment, the urban heat island and urban drought are studied to gain knowledge of numerous secondary effects of the excessive urbanization and also because of very practical needs of town planning [18, 23].

Many studies of the urban climate [6] have been conducted for over 150 years; as long ago as that it was observed in big cities of temperate latitudes. Since then, much research has been done on various interesting and practical aspects of urban climatic phenomena by means of different measurement tools and methodology. Giridharan *et al.* [4] also clearly demonstrated the UHI features. Xiao *et al.* [24] and Fehrenbach *et al.* [3] mainly paid attention to the spatial and temporal distribution, cause and effect; as well as prediction model of the urban climate, the UHI and air pollution, but failed to take climatic considerations of urban design and urban land use into account. Therefore, data provided by climate researchers have a low impact on the urban planning process and do not always meet the demands of urban planners and architects. While rapid changes in microclimate generated by different urban land cover inuence the comfort and health of the inhabitants as well as energy consumption and environment quality, it is important to understand the causes of air temperature and humidity variation in different land use areas and different underlying surface.

Hoyano and Ilno [7] and Tanimoto *et al.* [22] measured the temperature distribution on the exterior of a single building and over two representative buildings having different construction characteristics both in summer and winter. Comprehensive analysis of various urban objects over a 24 hours period on a selected urban area of central city was also conducted using an infrared video radiometer [2]. However, these studies were confronted with problems of spatial and temporal data substitution due to the lack of a long data record and poor spatial sites. High temporal and spatial resolution and the use of concurrent ground truth data are necessary for accurate measurement [19]. From a climatological perspective, the UHI and its negative environmental inuence are also pronounced during the hot season. Experiments on diurnal range basis during a calm winter day demonstrated the most pronounced radiant temperature differences between diverse urban coverage at microscale level. However, few field experiments were carried out in the hot season and cold winter; therefore, it is important to carry out simultaneous field experiments at different sites for monitoring the microenvironment pattern of the urban land cover more accurately.

In order to discuss above important issue, this paper examines the effects of four different types of urban land cover on air temperature and humidity variations between daytime, different months and different weather situations at five types of urban land use in Beijing, China, from 2007 to 2008. We presumed that there would be a most representative type of ground cover at each observation site. Based on the detailed analysis of the variation of these samples of data measured from the sites, this most representative type of ground cover would be classified.

This paper covered the following aspects:

1. An analysis of the air temperature and relative humidity difference from different types of land use.
2. An analysis of the temperature and relative humidity difference from different types of land use between urban and rural.
3. An analysis of the air temperature and relative humidity differences from different types of ground cover and space.
4. A comprehensive and concise understanding of the deviation of the air temperature and humidity in temporal and spatial distribution.
5. A discussion of the application of these results in urban planning and manages.

This study was carried out in one of the big cities in the east-northern part of China. Therefore, its aim was to prove the effect of time and spatial distribution of different land use and landscape surface on urban air temperature and humidity in the city. Temperature and relative humidity data were obtained from 2007 to 2008 by field observation.

Materials and Methods

Study site: Topographically, Beijing is high in the northwest and low in the southeast. It is surrounded with mountains in the west, north and northeast. The rivers running through include Yongding river, Chaobaihe river, Beiyun canal, Juma river and so on; many of which rise in the northwest mountains pass through the mountain ridges in the west, north and northwest and the plains in the southeast and, finally enter Bohai Sea separately. The wind normally blows to the southeast.

Beijing is in the warm temperate zone with half moist climate; the four seasons are distinct, spring and autumn are short while winter and summer are long. The annual mean temperature is 13°C. Weather is cold in January with the average temperature of -3.7°C and hot in July with the average temperature of 25.2°C. The mean annual precipitation is 507.7 mm. Frost-free period is 189 days. The area of Beijing is 16,807.8 km^2 including 10,417.5 km^2 of mountain area, accounting for 62% of the total area of Beijing. The plain area is 6,390.3 km^2, accounting for 38% of the total area. There are 12 districts and 6 counties in Beijing. Our empirical material is drawn from Beijing City where urban parks or open space are found.

Study time and site design: Beijing, which covers approximately 16,800 km^2 and has a total population of more than 13 million, is the political capital of China. Over the past two decades, it has undergone intense urbanization that has seriously impacted the urban thermal environment. According to Song and Zhang [20], heat island effects in Beijing have been very evident since 1961, when the average daily temperature in the city was 4.6°C higher than that in the suburbs. Our study area, which includes the whole of the central urban district, three near suburban districts and nine urban districts; covers 4084.3 km^2 (24.3%) of the greater Beijing Municipality area. Beijing's development pattern is a typical concentric expansion, showing a ring shaped pattern as you move from the inner city to the outskirts. In order to reveal the spatial configuration of urbanization, we divided the study area into five land use-based parts and four spaces on the location of the urban district (Fig.1).

We may consider that the urban area is influenced by a number of factors which complement each other in overall thermal behaviour: physical characteristics of the various urban elements, the air temperature, the relative humidity, surface geometry and colour and the weather conditions. This paper describes the diurnal thermal behaviour of the five types of urban land use both in spatial and temporal series.

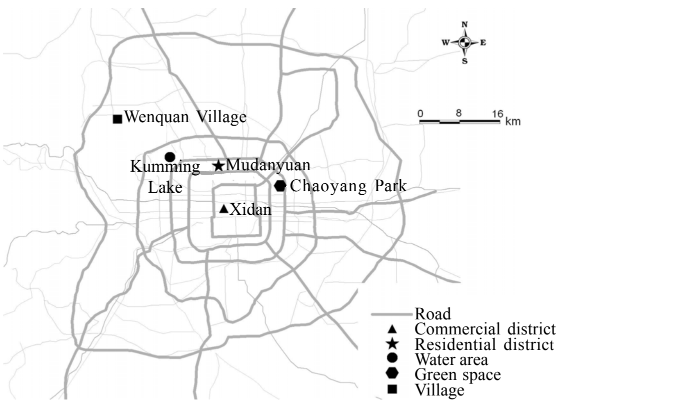

Figure 1. The location of the observation sites and the major road of Beijing.

Observation methods: Temperature and relative humidity were taken during the cold period from December 2007 to August 2008. The daily minimum and maximum temperature and relative humidity were measured from 8 a.m. to 6 p.m. The observation days, selected to study urban environment and the heat island, were chosen to represent a sunny weather conditions except cloudy and snow days. Calm conditions prevailed during all of the diurnal of the experiment. Because of the need to obtain data of high spatial and temporal resolution, our limited budget and manpower were taken into account since we were only able to collect 10 h samples of data on nine occasions: three times in December, three in January and three in February.

Observations were conducted simultaneously on fixed sites, indicated by different signs in Fig.1, consisting of two urban commercial centres (Xidan), urban residential districts (Mudanyan), one green space (Chaoyang Park) and one urban water area (Kunming Lake) as well as three rural areas (Wenquan). The background of the commercial site is the dense buildings and heavy traffic vehicles and population, and the rural area, which is farmland, is separated from the major city. Then, at each site, we selected built-up, lawn, water area and bare concrete as four sample points to collect samples of microclimate data. For the similarity between the observation sites and the sample points in landscape, we defined the four observation sites as mesoscale land cover and the four sample points as microscale land cover. Since it was fieldwork, the areas of the five types of land cover cannot be defined unanimously at two scales. We only estimate land cover type by its area of matrix >60% obviously, and the least area of the microscale land cover 1680 m^2 can be considered as the microscale in the landscape study and microclimatic research [13, 18, 21]. Using hygrothermographs (TESTO), which were calibrated, checked and compared before and after the experiment under the same conditions, we measured each half hour the microclimatic indices of temperatures and relative humidity at 1.5 m height in the middle of the microscale sample points from 8 a.m. to 6 p.m. of the day.

Data analysis: Comparison of the sites air temperatures to that of a single outside reference point such as a nearby meteorological station would lead to wrong conclusions without simultaneous measured data, even when the comparison is done for days of measurements at a single site [15]. The air temperature inside the site usually depends on the shading intensity of a partial shaded area, on the thermal properties of the soil and on the air temperature of its immediate background. The latter varies among different urban sites due to factors affecting the air temperature such as vegetation, built-up geometry, topography, traffic density and other anthropogenic heat-release factors. Therefore, simultaneous observations were applied in the present study during a cold winter on selected fixed observational sites where green areas with trees, lawn, water areas and bare terrain were chosen to represent sample points and microscale land cover. A comparison was conducted as shown in the following steps to get more reliable and accurate calculation and to test our hypothesis:

1. To compare the difference of the air temperature among the sample points at each site, we select the warmest one as the reference point. In our case it refers to the bare concrete cover.
2. To compare the difference of the air temperature among the four observation sites, we also select the warmest one as the reference site. The city center is the most ideal reference in our case.
3. While to compare the deviation of the air temperature in temporal and spatial series at each site, we select the average of the four sample points as the reference 'point' in spatial series, and the average of the 24 hours air temperatures in temporal series.

The temporal and spatial data centralization and normalization are conducted by the following equations, respectively:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \, (i = 1, 2, 3 \cdots, n = 27) \quad (1)$$

$$X_j = X_j - \bar{X}_j \, (j = 1, 2, 3 \cdots, n = 4) \quad (2)$$

$$X_j = \frac{X_j - \bar{X}_i}{\sqrt{\dfrac{\sum_{i=1}^{N} (X_j - \bar{X}_i)^2}{(N - 1)}}} \quad (3)$$

$$(i = 1, 2, 3, \cdots, n, \; j = 1, 2, 3, \cdots n)$$

Equation 1 is j type of urban landscape surface region i at the time of observation of temperature and humidity, roads, green spaces, water bodies and the building space of four surface i related to the average temperature and humidity. In Equation 2 j type of landscape is the region's average surface temperature and humidity. Equation 3 is used after the center of the matrix transformation can be obtained of the observation points of temperature and humidity range of spatial and temporal variability of day.

To emphasize the significant change in thermal behaviour, the target of our research focuses on the temperature and humidity differences of various urban land cover at different scales.

Results

Air temperature and humidity variation among the five types of land use at microscale: The commercial district (Xidan) and residential district (Mudanyuan), urban green space (Chaoyang Park) and water area (Kunming Lake) are located in centre of Beijing City (Fig. 1), where dense population and heavy traffic, concrete buildings, pavements and skyscrapers considered as the site environment are found. For daytime (from 8:00 h to 18:00 h) the thermal peak of air temperature and relative humidity on the five types land use, during the cold winter and hot summer, occurred at 14:00 h (Fig. 2 a-b). The average temperature of the five districts is different. When the daytime average temperature was above 0°C, the temperature of commercial district is higher. The highest temperature was 7.49°C on December, 9.57°C on February, 36.5°C in July and 35.4 °C in August. The temperature of green space in winter and water area in summer was lower. However, when the daytime average temperature is below 0°C at 8 a.m. in winter, the commercial and residential areas were warmer; but the green space was colder at the same time. The relative humidity of rural in winter was higher than in other sites but it was higher in water area in summer. The residential district environment is composed with dense buildings; however, the observation height of hydrothermal graph is 1.5 m. Tall buildings shut the sun light out of the observation spot and, consequently, thermal environment of the male and female face of building was different. The daytime average relative humidity in December (38.7%) and February (18.4%) of

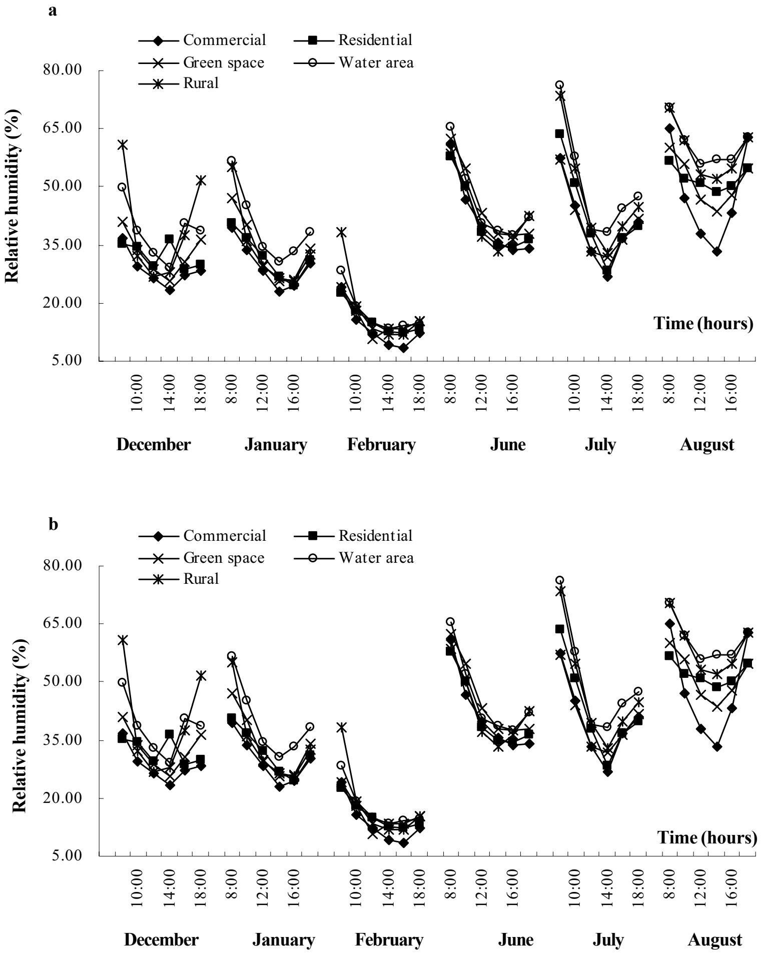

Figure 2. The diurnal changes of the temperature and relative humidity at the five observation sites.

the rural was higher than during winter in the urban water area of other districts. The commercial and residential districts' relative humidity were lower. These two sites take on the same characters that are dense population, concrete buildings, pavements and skyscrapers. So, these two sites were considered as urban dry source area.

To compare the difference of the air temperature and relative humidity in the five sites, we calculate the average air temperature and humidity of the five types of ground cover to represent one of the observation sites, namely site-specific effect [10]. The mean value of the 10 hours air temperature and relative humidity at the five observation sites showed that the commercial centre of the city was the warmest area during the winter and summer period. The water area site and the rural site were cooler than other sites (Fig. 2 b). The water area was the wettish site; the rural and green space as well as the commercial centre were most dry within the five sites and the residential site. A bigger difference between the relative humidity change curve was shown, but it was not seen in the temperature.

Temperature and humidity variation between the urban and the suburb*:* Compared with the rural site (Wenquan Village), the results in detail showed that the largest temperature difference occurred in the urban commercial centre (Xidan commercial street); it was 6.33°C at 18:00 h on December 8th, while the largest temperature difference in the residential area was 5.86°C at the same time. The largest one in urban green space (Chaoyang Park) was 3.38°C at that time and the largest one in water area (Kunming Lake) was 3.78°C at the same time and the same day. Table 1 shows that this day was calm and sunny with wind speed of 3.3 m/s and less cloudy; therefore, it was suitable for monitoring the UHI effect. As in the past studies, the heat island effect which was shown by the temperature difference between the city centre and the surrounding areas increased during the night time [3]. In the 10 hours observation of daytime, the largest temperature difference occurred at 18:00 h in winter and summer; so it was in complete agreement with the early study. Besides at 18:00 h, the second largest temperature difference occurred at 8:00 h in every month that was observed. The lowest temperature difference occurred in urban green space and water area; it was all -1.74°C, respectively, at 12:00 h on 8th June and 14:00 h on 3rd August. The urban centre temperature was higher than that of the rural at most time, but for the urban green space and water area (Fig. 1), the temperature difference decreased during 10:00-16:00 h, especially for Kunming Lake in summer time where the temperature was lower than in rural site in every observed time. This is perhaps due to the evaporation of large water area close to the city centre and north-westward mountainous area; besides this is to radiant intensity in open rural site during the noontime.

The rural site was taken as reference point, but the calculation method is contrary to the temperature difference. The results showed that the largest relative humidity difference occurred at 8:00 h on 8th December; it was 24.4% in commercial centre, 25.9% in residential site, 20.2% in green space and 11.43% in water area. The higher relative humidity difference occurred at 8:00 h and 18:00 h in the daytime, it was low in the noontime. The humidity difference of residential and commercial site was high in almost every time; it is lower in water area, which shows that the relative humidity in commercial and residential areas is lower in the five observation sites. The relative humidity in water area was higher in every time except for 8:00 h and 18:00 h on 8th December and 16th February (Fig. 3 a-b). The largest humidity difference in water area was -9.06% at 10:00 h on 5th January and -6.2% at 12:00h on 8th June; this fact shows that the relative humidity was higher in rural site. This is perhaps due to the evaporation of large water area and plant of green space. However, the relative humidity was lower than rural site in commercial and residential areas; which is perhaps due to the effect of human act, such as excessive heat storage and

Table 1. The weather condition of the observation days during cold period from December to February.

Dates	Temperature		Wind speed (m/s)	Weather condition
	Max	Min		
8th December	7	-2	2.8	Sunny
5th January	5	-5	3.3	Sunny
16th February	6	-6	2.4	Sunny
8th June	32	20	1.0	Sunny
6th July	33	22	0.7	Sunny
3rd August	34	24	0.5	Sunny

high concentration of air pollution, the excessive urbanization, ground cover and buildings.

Spatial and temporal distribution of air temperature and humidity variation: The Xidan commercial street is located in the commercial centre of Beijing City (Fig. 1) where lot of people, heavy traffic, concrete buildings and pavements as well as skyscrapers considered as the site environment is found. For daily behaviour of air temperatures in the four types of space during the hot summer, the thermal peaks and the humid valleys both occurred at 2 p.m., the humid peaks and the thermal valleys both occurred at 8 a.m. The urban centre Xidan business district observation results indicated that nearby the cement or the tar surface, the green space (lawn) or the building on different ground cover and under pad surface as well as the spatial temperature and the humidity diurnal variation difference is obvious in daytime period (8:00-18:00 h), the humidity presents the tendency as roads<built-up<green space (lawn).

Took the road as a comparison; on each ground cover, the spatial and temporal of temperature and humidity difference was compared (Fig. 4 a). The highest temperature difference on green space in winter and summer is 3.2°C on January 5th and 12.7°C on 3rd August with the highest humidity difference of 2.1%. The relative humidity of green space was not obviously higher than road both in winter and in summer. The highest temperature difference beside the buildings was 12.8°C on 3rd August with the highest humidity difference of 4.58%. This is perhaps due to the road ventilated well, but the green space is close to the buildings and was affected by the radiant energy of it, the area of green land is too small compared to the pave and built-up area. So, road microenvironment means higher temperature and lower humidity than other space in residential area. Green space effect is obvious.

The residential area is located near the third circle of Beijing City where dense population, concrete buildings and pavements as well as skyscrapers are found. The highest temperature and humidity difference on green space is -5.9°C and 10.9% at 10:00 h on July 6th; the highest temperature and humidity difference beside the building is -3.9°C at 14:00 h and 4.8% at 16:00 h on the same day. The highest temperature and humidity difference near the water body is -5.0°C at 10:00 h and 4.5% at 12:00 h on the same date. It shows that the green space, water body and building temperature is lower and humidity higher than that of road in residential area (Fig. 4 b). The observation points suffered from the shadow of buildings at sunrise and at sunset.

The urban green space is near to the east third circle, composed by green land, water body and buildings. Different ground cover in the urban park, the temperature and humidity differ from each other. The average temperature on green space is lower than on road (1.0°C) and the humidity is higher (3.1%). Near the building the average temperature is higher (0.5°C) and the humidity is lower (2.4%) than on road. Near the water body, the temperature is lower (1.3°C) and humidity is higher (3.8%). The highest temperature and humidity difference is 6.0°C at 12:00 h on 3rd August and 14.8% at 18:00 h on 6th July between green space and road. It was 6.8°C and 14.7% at 10:00 h on 3rd August between building and road and 6.4°C and 18.2% at 18:00 h on 6th July between water body and road (Fig. 4c). This shows that the temperature on road and near buildings is higher than in other space; temperature is higher near the building, and the humidity of road is lower than in the four ground covered in the large green space.

The temperature and humidity difference is not large as others in water area. Generally speaking, the variation in trend of air temperature and humidity was similar to that of the Chaoyang Park site described above, but the temperature range in contrast to the concrete cover (road) somewhat lower (Fig. 4d). The shade of trees and evaporation of the water body reduced the air temperature significantly during daytime, the detailed maximum temperature difference is 1.8°C at 14:00 h on 8th June on green space (lawn), 1.5°C at 8:00 h on 16th February and at 10:00 h on 6th July near buildings and water body. The detailed maximum humidity difference is 4.1% at 8:00 on 6th July on green space (lawn), 11.5% at 14:00 h on 8th December near building and 12.2% at 16:00 h on 16th February near water body. Moreover, the water area sometimes was warmer than the concrete surface (road) even during daytime; for example, the maximum range came up to 1.5°C at 8:00 h on 16th February . During the evening time, the water area was also the warmest target with temperature range

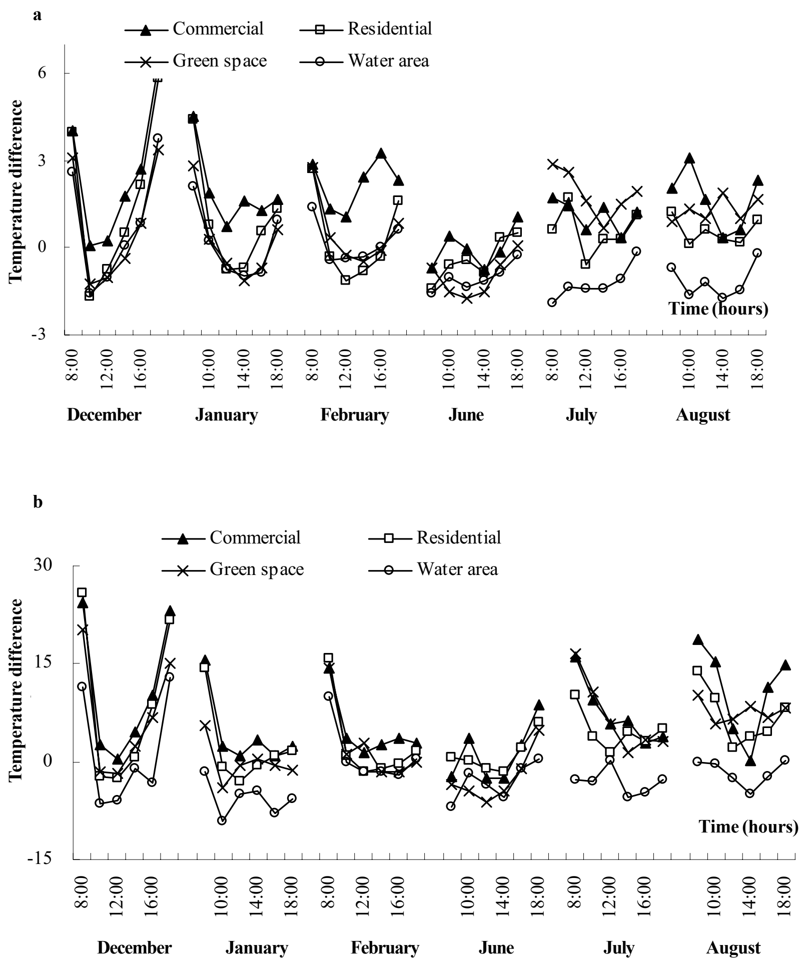

Figure 3. Daily change of temperature and relative humidity difference intensity at different urban sites.

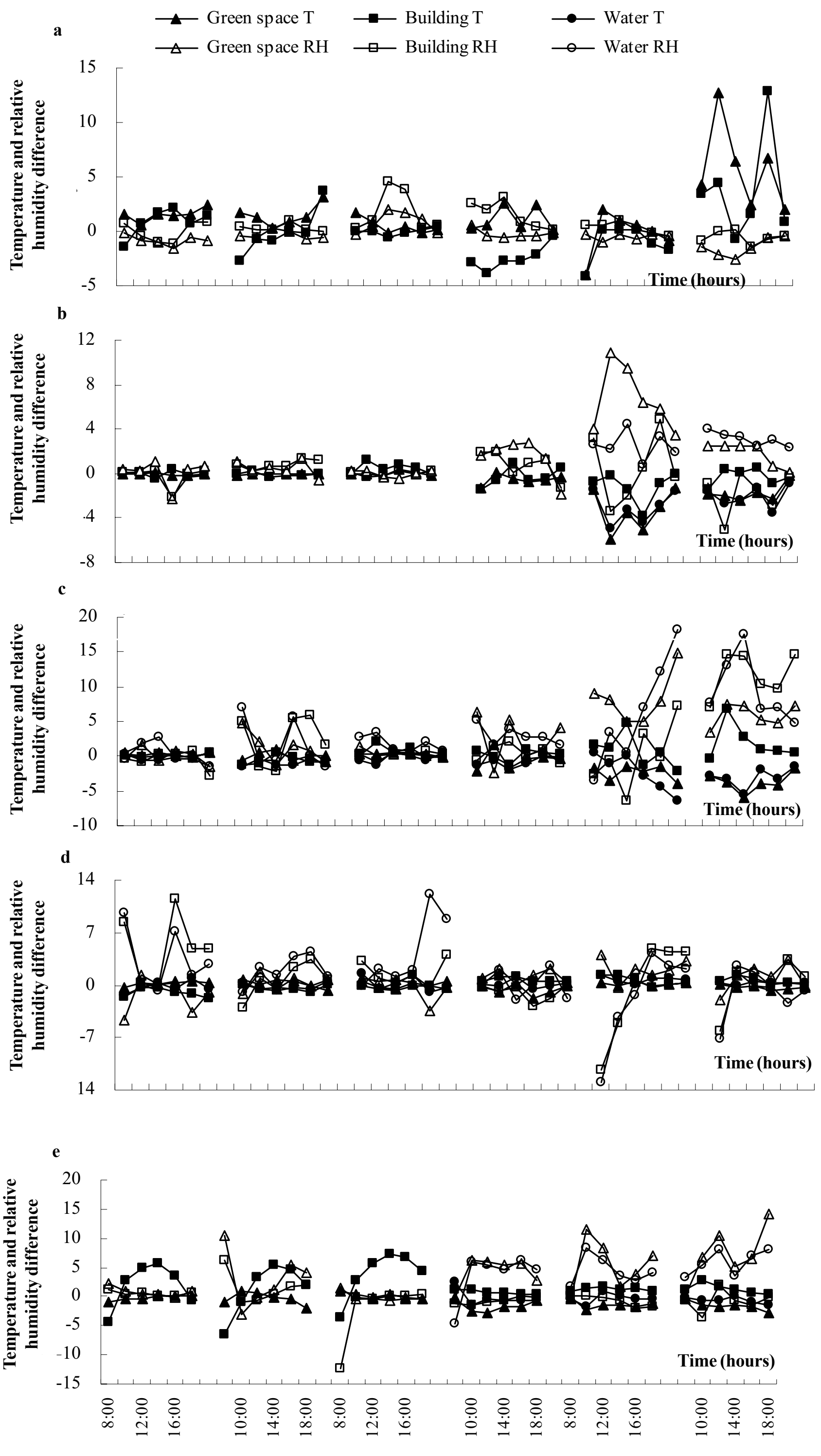

Figure 4. The daytime temperature (T) and relative humidity (RH) change on five kind of sites (green space, building and road surface).

in contrast to the concrete cover by about 0.4-0.7°C. This was the wettest site with humidity range by about 1.2%-8.7% and the lawn was still cooler than the other sites.

The Wenquan Village lies in the north part of the Beijing City (Fig.1). We could distinguish the temperature among these four three types of ground cover obviously. The order was lawn<building<water body<cement cover (road) during the daytime, while the humidity order was building<cement cover<lawn<water body (Fig. 4e). The detailed maximum temperature difference is 2.1°C at 18:00 h on 5th January on green space (lawn), 7.3°C at 14:00 h on 16th February and 2.5°C at 8:00 h on 8th June near buildings and water body. The detailed maximum humidity difference is 10.4% at 8:00 on 5th January on green space (lawn), 12.3% at 8:00 h on 16th February near buildings and 8.4% at 10:00 h on July near water body. In general, the lawn was still the coolest one during daytime.

By the analysis, the green space humidity was higher than the road surface and the construction space. The green space temperature is lower than the road surface and the construction space.

Discussion

The impact of human activities is an important factor in heat island effect. The region is a densely populated area with an intensive artificial buildings, there is a lot of artificial heat sources such as heating systems or air conditioning; therefore, less green areas and spaces result in the exacerbation of the heat island effect. The commercial and residential districts' temperature was higher and relative humidity lower than on other land use (green space, water area and rural area). Comparison of temperature and humidity variation between the urban and the suburb shows that the largest temperature difference was 6.33°C in commercial area and 5.86°C in residential area. The largest humidity difference was 24.4% and 25.9% in commercial and residential area, respectively. These results are consistent with those of previous studies of the thermal behaviour of urban areas, which used satellite data and combined airborne and ground-based measurements [12].

In our study, the most interesting finding was the realization that whereas most urban spaces are cooler than their surroundings and some green space (lawn) areas; contrary to expectations, could be warmer than their surroundings at sometimes. So, what makes a lawn a cool space and what makes a lawn a heat one? This investigation aimed at assessing the impact of urbanization, land use and ground cover on the relative humidity and temperature in Beijing, China. The higher temperature and lower relative humidity observed in the commercial area compared to that obtained at the countryside, as seen in this study is similar to the pattern obtained in cities in other countries such as Dhaka, Bangladesh [5], Brazil [13], Nigeria [1] and Beijing, China [23]. From this study, land use affected by urbanization played a significant role in the distribution of temperature and relative humidity. Air temperature and relative humidity at the height of 1.5 m in Beijing showed that the daytime horizontal temperature and humidity gradient was somewhat different from that reported in other large cities and a marked heterogeneity in a smaller ground cover scale could be detected from the microclimatic spatial pattern. The result shows that green space has faint effect to the surrounding, greening is insufficient to the environment in commercial area. So building greening or large green area need to enhance, especially in building space. Road microenvironment means higher temperature and lower humidity than other space in residential area. Green space effect is relative obviously than in commercial areas.

The most dominant surface elements contributing heat to the city are bare concrete cover and surface of building, which is exposed to solar radiation. Kjelgren and Montague [8] state that this is because there is no evaporation cooling effect over this kind of surfaces. Moreover, they generate more long-wave radiation than the lawn, the water areas and the vegetated surfaces. As a result; not only do they have higher temperatures, but they are also expected to influence the air temperatures and humidity of the near surface air layer. At morning time, their temperatures are lower, whereas some parts of water and vegetated areas are the warmest. Vegetation areas were found to have a relatively small diurnal temperature range compared to bare concrete cover, the lawn and water areas.

Because of the preliminary nature of this study, many factors useful in the planning and design processes, such as the local urban morphology around the sites, the shapes of the parks, the types of pavements, the height of buildings or the spatial arrangement and types of trees, were not studied. The observation was not carried out in spring and autumn, so further research should be necessary to explore the relationship on buildings environment and its planning and design pattern. A quantitative study of the building space is required for the volume of green to improve the living environment.

Conclusions

The study concluded that there is influence of urban land use and ground cover on the microclimate of Beijing, monitoring and analysing urban growth patterns and evaluating their impacts on land surface temperature (LST), provides sound basis for ecological construction, environment improvement, urban planning and management.

Acknowledgements

This research was supported by the National Basic ResearchProgram of China (973 Program) (2010CB950904); NationalScientific Foundation of China (70873118;41171434) is also appreciated. This study was conducted with support from the Environment simulation and contamination control country key union laboratory,Beijing Normal University,School of Environment.Data used in this study were acquired from observation by a group of students and a study team.We are grateful to these individuals and organization for their cooperation.

References

[1]Akinbode, O. M., Eludoyin, A. O. and Fashae, O. A. 2008. Temperature and relative humidity distributions in a medium-size administrative town in southwest Nigeria. J. Env. Manage. **87**:95-105.

[2]Chudnovsky, A., Ben-Dor, E. and Saaroni, H. 2004. Diurnal thermal behaviour of selected urban objects using remote sensing measurements. Energy and Buildings **36**:1063-1074.

[3]Fehrenbach, U., Scherer, D. and Parlow, E. 2001. Automated classification of planning objectives for the consideration of climate and air quality in urban and regional planning for the example of the region of Basel, Switzerland. Atmo. Environ. **35**:5605-5615.

[4]Giridharan, R. and Ganesan, S. S. Y. 2004. Daytime urban heat island effect in high-rise and high-density residential developments in Hong Kong. Energy and Buildings **36**:525-534.

[5]Hossain, M. E. and Nooruddin, M. 1994. Some aspects of urban climates of Dhaka City. Reports of the Technical Conference on Tropical Urban Climates, March 28th–April 2nd, 1993, Dhaka, Bangladesh.

[6]Howard, L. 1883. The Climate of London. Vol. I–III. Harvey and Dorton, London.

[7]Hoyano, A. and Ilno, A. 1999. Analysis of the sensible heat flux from exterior surface of buildings using time sequential thermography. Atmo. Environ. **33**:3941-3951.

[8]Kjelgren, R. and Montague, T. 1997. Urban tree transpiration over turf and asphalt surfaces. Atmo. Environ. **32**:35-41.

[9]Luck, M. and Wu, J. G. A. 2002. Gradient analysis of urban landscape pattern: A case study from the Phoenix metropolitan region, Arizona. Landscape Ecol. **17**:327-339.

[10]Lai, L. W. and Cheng W. L. 2009. Air quality influenced by urban heat island coupled with synoptic weather patterns. Sci. Total Environ. **407**:2724-2733.

[11]Mueller, E. C. and Day, T. A. 2005. The effect of urban ground cover on microclimate, growth and leaf gas exchange of oleander in Phoenix, Arizona. Inter. J. Biom. **49**:244-255.

[12]Kolokotroni, M. and Giridharan, R. 2008. Urban heat island intensity in London: An investigation of the impact of physical characteristics on changes in outdoor air temperature during summer. Solar Ener. **82**:986-998.

[13]Maitelli, G. T., Souza, S. C. and De Pinho, J. G. 2002. The Magnitude of Urban Heat Island in the Tropical Continental Areas in Brazil. Department of Geography, University of Mato Grosso, Brazil, pp. 1-4.

[14]Owen, T. W., Carlson, T. N. and Gillies, R. R. 1998. An assessment of satellite remotely-sensed land cover parameters in quantitatively describing the climatic effect of urbanization. Inter. J. Remote Sens. **19**:1663-1681.

[15]Oke, T. R. 1997. Surface climate processes. In Bailey, W. G., Oke, T. and Rouse, W. R. (eds). Surface Climates of Canada. McGill-Queens University Press, Montreal, Canada, 369 p.

[16]Hardin, P. J. and Jensen, R. R. 2007. The effect of urban leaf area on summertime urban surface kinetic temperatures: A terre haute case study. Urban Forestry & Urban Greening **6**:63-72.

[17]Sala, O. E., Chapin, F. S. and Armesto, J. J. 2000. Biodiversity-global biodiversity scenarios for the year 2100. Science **287**:1770-1774.

[18]Shashua-Bar, L. and Hoffman, M. E. 2000. Vegetation as a climatic component in the design of an urban street: An empirical model for predicting the cooling effect of urban green areas with trees. Energy and Buildings **31**:221-235.

[19]Streutker, D. R. 2003. Satellite-measured growth of the urban heat island of Houston, Texas. Remote Sens. Envi. **85**:282-289.

[20]Song, Y. L. and Zhang, S. Y. 2003. The study on heat island effect in Beijing during last 40 years. Chin. J. Eco-Agri. **11**:126-129.

[21]Tilman, D., Fargione, J. and Wolff, B. D. 2001. Forecasting agriculturally driven global environmental change. Science **292**:281-284.

[22]Tanimoto, J., Hagishima, A. and Chimklai, P. 2004. An approach for coupled simulation of building thermal effects and urban climatology. Energy and Buildings **36**:781-793.

[23]Voogt, J. A. and Oke, T. R. 2003. Thermal remote sensing of urban climates. Remote Sens. Environ. **86**:370-384.

[24]Xiao, R. B., Ouyang, Z. Y. and Hua, Z. 2007. Spatial pattern of impervious surfaces and their impacts on land surface temperature in Beijing, China. J. Environ. Sci. **19**:250-256.