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A Study of the Temperature-humidity Effect and Luminous Environment design for Urban Green Space

Na Chang, Dengwu Li*

College of Forestry, Northwest A&F University, China
dengwuli@163.com

Urban green space is important role to temperature reduction and introducing humidity, sunshade effect. The research objects are the woodland, Lawn and raged pavement in Baoji Botanical Garden. With a sustained observation during spring, summer and autumn, the study compares and contrasts these sites with continuous 5d temperature, relative humidity and illumination. There are significant changes of temperature reduction and introducing humidity during summer time but not a huge difference in spring and autumn. The weakest light in forest but the illumination is similar between the lawn area and the rigid pavement area. In the forest area, the temperature and illumination is lower but humidity is higher, which has cooling and humidifying effect. In the lawn area, the temperature and illumination is higher but humidity is lower. In the rigid pavement area, the temperature and illumination is the highest but humidity is the lowest. The study shows proposed forest under the sunny windless environment has the most effective area to adjust the micro-climate.

1. Introduction

As one of urban landscape elements, green space is the only that is close to the natural ecosystem in cities. It can be the sunshade with multiple forms of efficiency such as humidifying the air, decreasing the temperature and improving the partial microclimate, and thus directly affects urban residents' life quality. Ecological benefits produced by urban green spaces can be various owing to their different underlying surfaces and inner structures. Research concerning the ecological environment of urban green spaces has become one of the hot issues in fields like landscape ecology, urban landscape ecology and environmental science (Su et. al, 2011). Urban green spaces have multiple forms of ecological efficiency such as the improvement of the partial microclimate (Wu et. al, 2007). Furthermore, they have obvious cooling and humidifying effects (Kong et. al, 2013) in comparison with their surrounding areas, especially these hard bare grounds. Research results related to the humidifying and cooling effects of urban green spaces keep growing (Lin et. al, 2006; Huang et. al, 2007; Liu et. al, 2007; Ji et. al, 2012) and large numbers of experiments have been carried out on various green plants and different ecological effects of green spaces. However, studies concerning small-scale urban green spaces are relatively few. Small-scale green spaces are scattered in almost every border and corner in cities. This paper attempts to provide evidence for rational choices of recreational time and spaces regarding the environmental quality of urban green spaces in northwest cities of China. The research goal of this paper is the three types of representative areas in green spaces characterized mainly by deciduous trees in northwest cities. The research objects are the woodland, lawn and rigid pavement in the southwest corner of Baoji Botanical Garden. Through tests on three indexes closely related to environmental health, air temperature, air humidity and illumination, a quantitative comparing study was done on the three underlying surfaces to explore urban green spaces effects of regulating the microclimate in spring, summer and autumn.

2. General situation of study areas and research methods

2.1 General Situation of Study Areas

Located at 106°18′~108°03′ east longitude and 33°35′~35°06′ north latitude, the study area in the Baoji Botanical Garden is in the warm temperature zone of sub humid climate. The seasons are distinct with a large temperature difference in winter and summer. The annual mean temperature is 13.0℃. July is the hottest month with a mean temperature of 30.9℃,while January is the coldest of -3.5℃. With abundant sunshine, the

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annual average sunshine duration is between 2000 to 2200h in most of the regions. Three types of green spaces chosen in the Garden (1.woodland; 2. lawn; 3.rigid pavement) are the common ones in urban green spaces and are of high utilization rate. They are all located in the northwest corner of the Garden with an average land area of 1733㎡. The pedestrian road around the experimental area is 4 meters in width, with which the experiment could be comparable under similar environmental conditions (see Figure 1)

2.2 Experimental Research Methods

2.2.1 Test Instruments

The specific type and observation accuracy is described as following (1) aspirated psychrometer (DHM2A, produced by

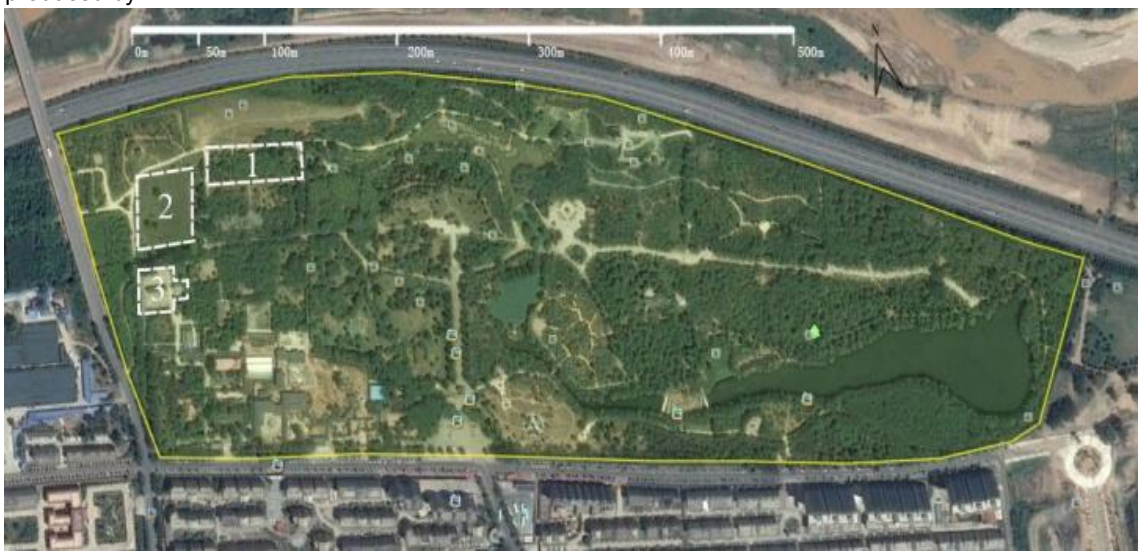

Figure 1: Distribution of the Three Sample Plots

Tianjin Meteorological Instrument Factory): the minimum division value on the thermometer is 0.2℃; the measuring range is 10%RH～100%RH for humidity and -36℃～46℃ for temperature.(2) illumination meter (TES-1339): the technical parameter is 0.01Lux and the value is read by 999,9 digit numbers.

2.2.2 Test Content and Methods

Five-point observation method was used in this experiment. The first point of each sample area is the geometric center inside of it. Other four points are set on diagonal lines in equidistance (5m) from the first point. The standard observation height of meteorological louvered screen is 1.5m from the ground for humidity and temperature measurement. The test was done every 2 hours in the daytime from 8:00 a.m. to 18:00 p. m, during which the temperature, relative humidity and illumination were synchronously measured. Five consecutive days were tested one time in April 2014(04.29～05.03), July (07.03～07.07) and October (07.20～07.24) respectively. Every three sunny calm days (04.29, 04.30, 05.03; 07.04, 07.05, 07.06; 11.21, 11.23, 11.24) were chosen in each season respectively for data analysis.

3. Results and Discussion

3.1 Comparison Among Temperature of Woodland, Lawn and Rigid Pavement in Different Seasons

3.1.1 Comparison among Average Day Temperature

The overall temperature change of the three sample areas in different seasons is basically the same (see Table 1), with the maximum temperature appearing at 16:00. Among them, the average temperature of the rigid pavement is higher than those of the lawn and woodland, which indicates that the latter two can decrease the temperature and improve the microenvironment. According to the cooling effect of the hottest period, the three seasons are ranked as: summer > autumn > spring. It can be seen that the general temperature trend is similar in spring, summer and autumn, among which summer is the season with the strongest change. Obviously, woodland is a better choice than lawn and rigid pavements for outdoor activities in summer. Through a multiple comparable analysis on daily average temperature of the three areas in three seasons, no significant difference is found between the lawn and the rigid pavement (see Figure 2). The cooling effect of the woodland is quite obvious and stronger than the than of the lawn. Nevertheless, the effect of the lawn should not be neglected. With no shade, it can facilitate convection and thus speed up the introduction of fresh air.

Table 1: Average Temperature Changes of Three Seasons on Three Days

Seasons	Sample plot	8:00/℃	10:00/℃	12:00/℃	14:00/℃	16:00/℃	18:00/℃
Spring	Woodland	12.3	16.6	22	23.7	24.5	22.7
	Lawn	12.9	18	22.9	24.5	24.8	23.7
	Rigid pavement	13.2	18.4	23.5	25.4	25.4	23.5
Summer	Woodland	24	26.6	29.6	31.6	32.3	31.6
	Lawn	24.6	27.3	30.3	32	33.3	33
	Rigid pavement	25	28	31	33	35	34
Autumn	Woodland	10.1	16	20.8	22.8	22.8	16.6
	Lawn	10.5	17.1	21.9	23.8	24.2	16.9
	Rigid pavement	11	17.5	22	24.1	24.9	18.7

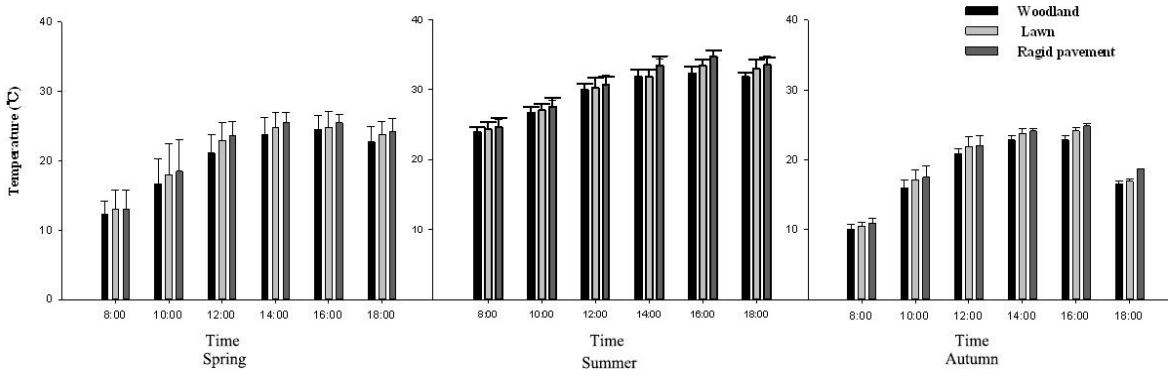

Figure 2: Comparison of Average Air Temperature in Three Seasons

3.1.2 Effect of Daily Environmental Temperature Change on Humidity and Illumination in Areas

The woodland and lawn have humidifying and cooling effect in transition seasons and summer, particularly for the latter. This is in accordance with the research of Wufei, Results in this paper show that in three seasons, the largest temperature change in a day appears in the period (14:00—16:00) of the highest environmental temperature, during which the temperature increases the fastest in the rigid pavement and then comes the lawn. The illumination intensity of a day is ranked as: lawn >rigid pavement >woodland. This is because that trees absorption of the solar radiation heat and their shade effect contribute to the low temperature on the green space. In transition seasons and summer, either in terms of the daily average temperature or the high temperature period, the woodland has a significant humidifying effect and a lower temperature in comparison with those of the lawn and the lard land.

3.2 Comparison of Relative Humidity of Woodland, Lawn and Rigid Pavement in Different Seasons

3.2.1 Comparison of Average Humidity

According to the humidifying effect in spring, summer and autumn (see Table 2); the daily air relative humidity goes from high to low, which is different from the situation of air temperature on the whole. There is constant difference among the three areas. The average humidity of the lawn and the woodland is higher than that of the rigid pavement. The Humidifying range between the morning and evening is small. The lowest humidity appears at the time with the maximum temperature, i.e.16:00. The result indicates that the woodland has the strongest effect followed by the lawn. It can be seen in Figure 3 that the temperature trend in the three seasons is similar. In the period between 14:00-16:00, there is significant difference among the relative humidity of the woodland, lawn and rigid pavement. No significant difference of the humidifying ability is found in other periods. In spring and autumn, the physiological metabolism of plants is at low peak. They consume less energy and water than those of summer. For this reason, the cooling and humidifying range of the former two is smaller than that of the latter.

Table 2: Relative Humidity changes of Three Seasons on Three Days

Seasons	Sample plot	8:00/℃	10:00/℃	12:00/℃	14:00/℃	16:00/℃	18:00/℃
Spring	Woodland	75.9	67.3	45.1	39.4	39.1	45.3
	Lawn	72.8	68.8	44.3	42	39	42.6
	Rigid pavement	70.6	57.3	34.1	37	34.4	38.7
Summer	Woodland	75.4	65.5	57.7	49	46.6	44.5
	Lawn	71.4	63.8	53	48	43	41.7
	Rigid pavement	66.2	58.1	49.4	40.6	36.6	39.6
Autumn	Woodland	92.9	78.2	53.9	46.4	44.7	71.6
	Lawn	92.2	65	50.1	41.8	39.4	72.6
	Rigid pavement	85.6	64.8	49	39.9	35.5	57.8

3.2.2 Influence of Different Spatial Scales on Temperature, Humidity and Illumination

Various green spaces produce spatial differences in the improvement of urban climate. In small partial areas the influence is obvious and in urban areas weak [8]. Nevertheless, they are beneficial to outdoor activities. Especially in hot days, they decrease the temperature as well as weaken the influence of heat [9]. Therefore, green spaces play a crucial role in the cooling and humidifying course. They indirectly reduce the import of external energy while increase the vegetation quantity

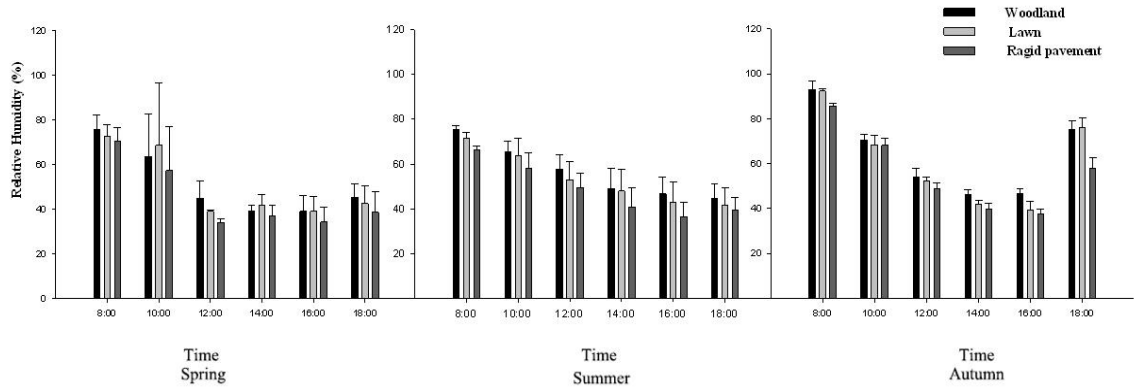

Figure 3: Comparison of Average Relative Humidity in Three Seasons

And thus provide another approach to UHI mitigation (Huang et. al, 2008; Li et. al, 2004). This study shows that in an urban green space with an area of 1600 ㎡,the cooling and humidifying effect of urban green spaces is ranked as: woodland>lawn>rigid pavement .woodlands can improve the urban torridity condition in summer as well as the environmental microclimate in spring and autumn. For this reason, planting more green spaces with a reasonable setting to maximize spatial utilization is beneficial to exerting cooling and humidifying effect and mitigating the UHI effect. Urban greening is a long-term career that needs to be planned and developed by natural time and scale (Liu, 2011). This is also the ultimate goal and significance of the construction of urban green spaces.

3.3 Comparison of Illumination of Woodland, Lawn and Rigid Pavement in Different Seasons

3.3.1 Comparison of Average Illumination

Table 3 shows that the illumination is relatively weak in the morning and evening in the three seasons. The illumination difference increases with the temperature from the 8:00 to 14:00, during which the change range grows large and reaches the peak. After that, it falls to the lowest value at 18:00. This is due to the reflection and absorption of illumination by the plant canopy. Green plants are able to absorb, reflect and shade light. Moreover, they can convert solar energy into chemical energy through photosynthesis to significantly reduce the illumination under the canopy and on the ground (Liu et. al, 2008). Through a multiple comparable analysis on the illumination of three seasons (see Figure 4), significant difference between the woodland and the other two areas is found. The illumination difference increases with the temperature. It is the most significant in the period between 12:00-14:00 in summer. Research has revealed that summer is the season when the solar radiation quantity between the inside and outside of woodlands shows largest difference [14]. Crown density is

the most crucial element that influences illumination. A large area of forest can effectively regulates air humidity, absorbs and shades light, and thus decreases the environmental temperature.

3.4 Influence of Different Seasons on Humidity and Illumination

Various conditions are required for different seasons according to the distinct characteristics of the weather in northwest areas. In summer, days are hot and people prefer dense forest. This is due to the shade, cooling and humidifying microclimate effect of woodland, by which the time for outdoor activities can be prolonged[15,16]. Lawns have a relatively weak cooling and humidifying effect. But people need to enjoy the sunshine in spring and autumn and rigid pavements can provide activity places in the morning and evening. Therefore, the effective planning of spatial allocation for green spaces is of crucial significance.

Table 3: Illuminance Changes of Three Seasons on Three Days

Seasons	Sample plot	8:00/Lx	10:00/ Lx	12:00/Lx	14:00/ Lx	16:00/ Lx	18:00/ Lx
Spring	Woodland	735	1043	2605	2928	1982	1575
	Lawn	21660	64091	91306	77615	53266	7034
	Rigid pavement	25585	63080	92535	78660	54950	7917
Summer	Woodland	1001	2503	2831	2018	1719	976
	Lawn	35137	73233	97460	95608	69620	34287
	Rigid pavement	38380	75423	96571	79379	66063	34543
Autumn	Woodland	512	1735	2072	1723	1998	41
	Lawn	15201	55608	71188	63574	30655	913
	Rigid pavement	15486	54170	71026	66683	34706	1272

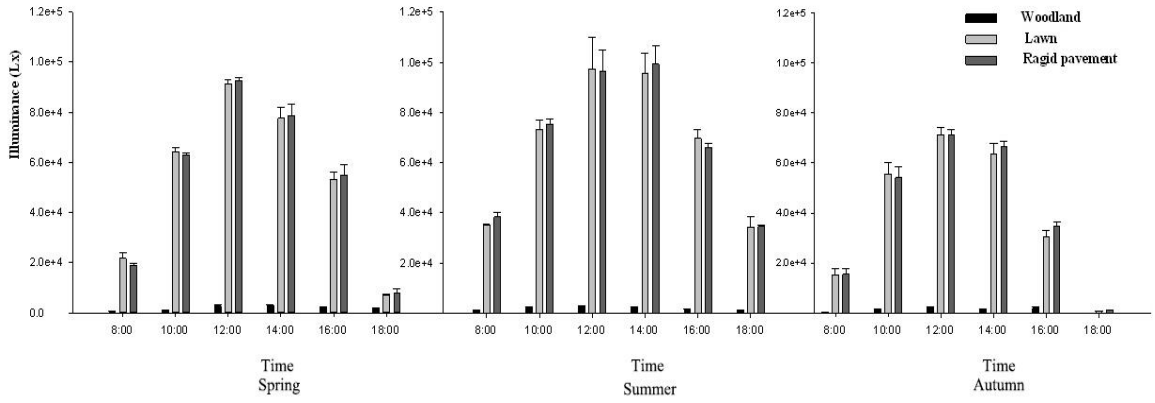

Figure 4: Comparison of Illuminance in Three Seasons

4. Conclusions and discussion

4.1 Conclusions

The cooling, humidifying and illumination effect is the most obvious in summer and of little difference between spring and autumn; in summer, appearing at 16:00, the maximum temperature of the woodland is 1.0℃ lower than that of the lawn and 2.7℃ the rigid pavement; the strongest illumination is from 12:00 to 14:00, during which activities are not appropriate on lawns and rigid pavements; the temperature is comfortable in the forest from 12: 00 to 16:00 that activities are suggested. The three underlying surfaces selected reflect zonal characteristics of green spaces in northwest cities. However, study areas are located in the botanical garden. The cooling effect is obvious there than that of small gardens owing to its large area. In the future, comparable tests should be made on more urban green spaces of different scale to examine the differences among them. In this way, more accurate values will be obtained to provide more applicable theoretical basis for the construction of comfortable recreation green spaces.

4.2 Discussion

Urban green spaces are beneficial to people's health and bring various advantages. However, in the field of landscape architecture, research and practices are mainly concerning garden aesthetics. The application of ecology principles and methodology in combination with aesthetic design is relatively weak. Considered as the evolution and continuation of traditional designing approaches, ecological design should be applied to face

the severe situation of unprecedented urbanization, serious man-human relationship, ecological and environmental deterioration etc. [17]. Through the analysis
On cooling, humidifying and illumination environments of the woodland, lawn and rigid pavement of urban green spaces in Baoji, it can be shown that during the course of planning and designing for urban green spaces, factors such as types and functions of green spaces should be taken into consideration together with ecological experiments for scientific and rational plan and design. And any design that only considers the ecological value and lacks of cultural implication and aesthetic feeling will not be accepted or even be forgotten and discarded by the society. An ecological design should be and have to be a kind of beauty. Harmonious coexistence should be realized through a combination of cities and nature as well as ecological and artificial landscaping so as to solve environmental problems of urban green spaces.

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