Nature and Human Activities, 1, 51 - 56, 1996

Article

Field Study on Green Canopy as Urban Cool-Spot

Hiroshi MIYAZAKI*, Masakazu MORIYAMA† and Atsumasa YOSHIDA‡

Abstract

In summer daytime, a space where covered by a green canopy is recognized cooler than its surroundings. The aim of this study is to determine the cooling effect of a green canopy of differing scales. In this paper, we define this kind of small and cooler space as a "Cool Spot". Some sets of meteorological elements were measured in Osaka in August 1992. The cooling effect of a large green canopy was remarkable (the minimum of ΔT_{g-u}; the differential of air temperature between a Cool Spot and an urban area, was $1.2°C$ at the measurement in Run 2-7.) This cooling effect became more significant in the early morning (the minimum of ΔT_{g-u} was $1.6°C$ in the early morning while that was $1.2°C$ in day time.) Under the smaller green canopy, air temperatures were higher than larger green canopies, however, surface temperatures were measured approximately equal to larger green canopies. In conclusion, it can be regarded the main difference of thermal priorities between a large green canopy and a small green canopy was the extent of an influence from an outer urban built-up area.

Key Words: urban thermal environment, cooling effects of a green canopy, Cool-Spot, field survey

In summer daytime, the space where covered by green canopy isrecognized cooler than its surroundings. This phenomenon occurs because a green canopy intercepts solar radiation and evaporation at a leaf cools the air temperature around the green canopy. In this paper, we define this small and cooler space as a "Cool Spot". Since the increase at a ratio of an urban artificial surface brings the gain of amount of stored heat. This is regarded as one of the causes that change the urban thermal environment for the worse. A proper arrangement of the "Cool Spot" in urban areas is expected to relieve the present conditions of an urban thermal environment.

Fig. 1. Location of Osaka

For a numerical simulation of an urban thermal environment, one of the authors undertook a field survey (Yoshida et.al.,1991). But still little is known about the thermal influence of green canopies of differing scales. The aim of this present field study is to collect fundamental data to propose this "Cool Spot" as a unit to be considered in urban environmental planning. Some sets of meteorological measurements were carried out of differing scale urban parks in Osaka in August 1992, to determine thethermal effect of green canopies and the relation between the scale of the green canopy and its thermal effect.

SURVEY AREA

Osaka (Long.135°30'E,34°41'N.L.) lies almost in the center of Japan. Its elevation is 0–20m above sea level. Osaka faces Osaka Bay to thewest and is bounded by ranges of mountains on the east and south (Fig.1.)In this research, four urban parks surrounded by built-up areas werestudied (Fig.2.) The scales of the parks are shown in table 1. As areference of an urban built-up area, meteorological measurements in theHon-machi area (an urban built-up area) were taken at Run3–6.

*Institute of Nature and Environmental Sciences, Himeji Institute of Technology Yayoi-ga-Oka 6, Sanda,Hyogo 669-13, Japan
†Architecture and Civil Engineering,Kobe University Nada, Kobe,Hyogo 657,Japan
‡Department of Mechanical Engineering, Okayama University Tsushima-Naka 3, Okayama,Okayama 700,Japan

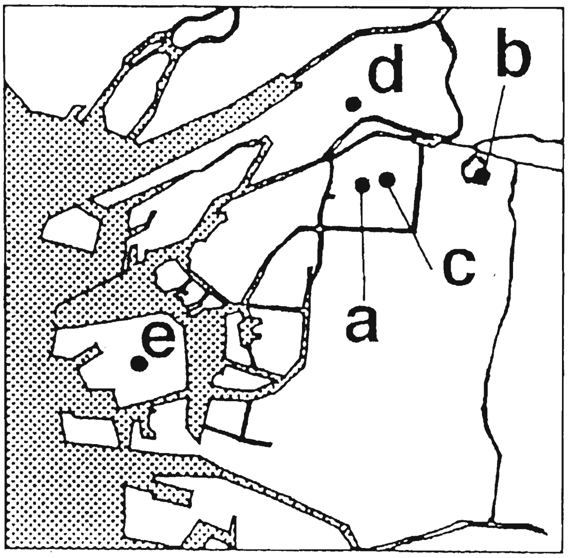


Fig. 2. Survey Area in Osaka
a: Utsubo Park **b**: Osaka Castle Park **c**: Hon–Machi Area
d: the Promenade along Ume–Shin **e**: Nanko Port Town Park

Table 1. Scale of the measured urban parks

	Osaka Castle Park	Utusbo Park	Promenade Ume Shin	Port Town Park
area	108 ha	19 ha	0.9 ha	10 ha
min. Width	860 m	140 m	30 m	62 m

Trees in these parks are 12–15 meters high and cover a wide area.

Table 2. The place and date of each measurement

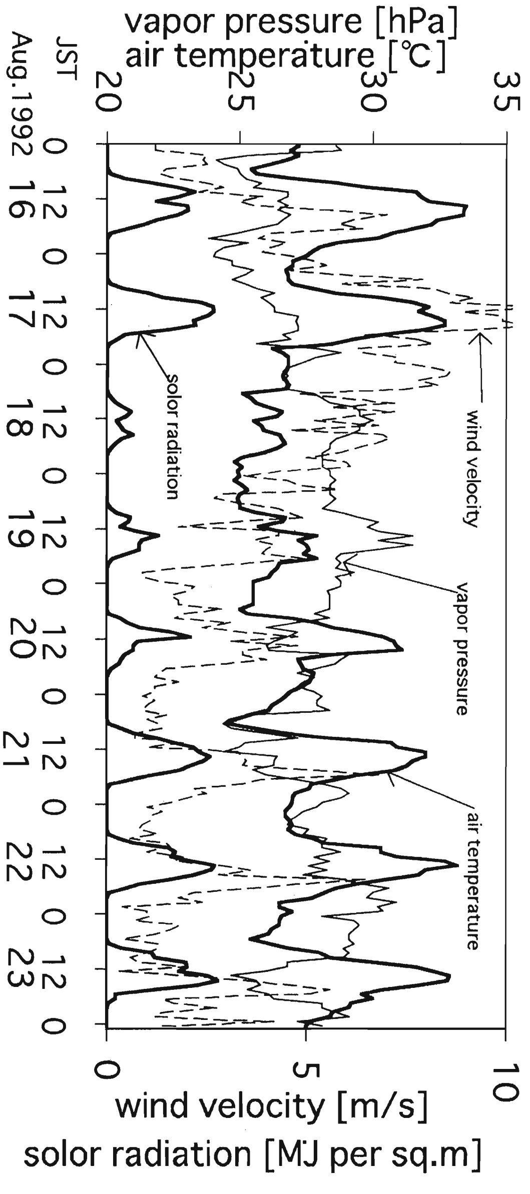
Measured Area (name in Fig.2)				**Utusbo Park (a)**	**Osaka Castle Park (b)**	**Urban Built-up Area Hon-Machi (c)**	**Promenade Ume-Shin (d)**	**Port-Town Park (e)**
Run1	17.Aug.1992	13:30-15:50	fine	o				
Run2	17.Aug.1992	18:00-18:47	fine	o				
Run3	20.Aug.1992	12:50-14:35	cloudy	o	o	o		
Run4	21.Aug.1992	5:00-5:45	cloudy	o	o	o		
Run5	21.Aug.1992	12:30-14:15	fine	o	o	o		
Run6	22.Aug.1992	5:30-5:45	cloudy	o	o	o		
Run7(I)	22.Aug.1992	12:30-14:15	fine	o	o	o		
Run7(II)	22.Aug.1992	12:15-13:15	fine				o	
Run8	23.Aug.1992	12:30-13:40	fine					o

DATA COLLECTION METHOD

This research consisted of eight sets of measurements. The places and the dates of each measurement are shown in Table 2. To correct a dispersion of data, meteorological measurements were taken five times at four measuring points at each run. The fifth measurement was taken at the first point. The first and the final data was used to correct shifts in meteorological elements. The measured meteorological elements and the equipments are shown in Table 3. Researchers traveled to each measuring points on foot. The time needed to finish each run was 45–75 minutes on average.

Table 3. Measured meteorological elements and equipment

measurement item	measuring instruments
air temperature	wet-dry-bulb thermometer
humidity	wet-dry-bulb thermometer
surface temperature	infrared radiation thermometer
wind velocity	three-cup anemometer



90

Fig. 3. Meteorological elements observed at the Osaka Meteorological Station, 16-23 August 1992

RESULTS

Meteorological elements measured by Osaka Meteorological Station in August 1992 are as shown in Fig.3. The research consisted of three groups. The first was to measure meteorological elements in a large urban park and in the surrounding build-up area (Run1,2). Results of Run1 and 2 are shown in Table 4. In spite of a high wind (maximum wind velocity measured at the height of 1.2 m was about 2.5 m per second), Tg (air temperature under the green canopies) was always lower than Tu (air temperature in the urban area). Temperature differential between in the green canopy and the urban built-up area (ΔT_{g-u}) was measured between 0.4°C-1.9°C in the daytime, 0.7-1.3°C in the evening.

The aim of the second group (Run3-6) was to compare large urban parks with urban built-up areas. Results of Run3-6 are shown in Table 5. Early in the morning, the maximum of ΔT_{g-u} was 2.5°C and the minimum ΔT_{g-u} was 1.1°C. In the daytime, the maximum ΔT_{g-u} was 1.8°C, the minimum ΔT_{g-u} was 1.1°C.

The third point was to measure the thermal effect of small urbangreen canopies (Run7,8). Results of Run7 and 8 are shown in Table 6 and Table 7, respectively. The measurement taken at a green covered roadsidepromenade at Run7, ΔT_{g-u} was -0.5°C-0.9°C in daytime. In the case of a square small green canopy at Run8, ΔT_{g-u} was 0.4°C-0.5°C in daytime.

At Run7, a higher air temperature was measured in a linear greencanopy. Surface temperatures under the green canopy were always lower thanthe measurement points in urban built-up areas. The tendency that the windvelocity measured lower under the green canopy was recognized.

DISCUSSION

The thermal effects of a large green canopy as the "Cool Spot" were significant. Especially in the morning, because of the stability of airflow, ΔT_{g-u} was significant. The active air diffusion during the daytime reduces the air temperature differential. But in Run1-2, at the time of ahigh wind, ΔT_{g-u} remained above 1°C.

In the case of smaller green canopies, this same tendency was also recognized. But in Run7; measured in the roadside promenade in daytime, air temperature was higher than that of the urban built-up area at one point under the linear green canopy. The reason is considered to be that the depth of the green canopy (about 10-30 m) was not enough to keep cooled air under the canopy from active air diffusion in daytime. In all cases, surface temperatures in the green canopy was always lower than at other points in the urban area. The tendency of lower surface temperatures in the green canopy was significant in daytime.

From the results of the measurements, the thermal boundary area between a "Cool Spot" and an urban built-up area was not recognized.

Table 4. Results of measurements in large urban parks and the surrounding area

item		Utusbo Park	street A*4	street B*5	street C*6
noon*1					
mean air temp. °C		32.0	32.4	33.9	33.4
ΔT^{*2} °C		0.0	0.4	1.9	1.4
mean surface temp. °C	ground*7	31.9	44.8	48.8	46.7
	wall of a building	–	39.2	47.5	37.8
	leaf	31.7	–	–	–
mean RH %		62.1	56.7	50.1	55.1
mean wind v. m/s		0.6	2.1	1.0	1.9
evening*3					
mean air temp. °C		29.1	29.8	30.0	30.4
ΔT^{*2} °C		0.0	0.7	0.9	1.3
mean surface temp. °C	ground*7	27.6	33.4	35.2	36.0
	wall of a building	–	32.8	31.7	33.0
	leaf	28.7	–	–	–
mean RH %		72.3	66.7	65.5	69.7
mean wind v. m/s		0.8	1.3	0.9	0.9

⋆1; Run1 17.Aug.1992 13:30–15:50 fine
⋆2; compare with the air temp. in Utubo Park
⋆3; Run2 17.Aug.1992 18:00–18:47 fine
⋆4–⋆6; surrounding built-up area, distance from the edge of Utsubo Park
⋆7; ground means a 'bare ground' in the Utsubo Park, and 'a paved ground' in the built up area.

Table 5. Comparison between urban built-up areas and large urban parks

item		Utusbo Park	built-up area Honmachi*1	Osaka Castle Park
early morning*2				
mean air temp. °C		24.1	26.5	25.0
ΔT^{*2} °C		-2.4	0.0	-1.6
mean surface temp. °C	ground	24.6	26.7	24.3
	wall	–	26.3	–
	leaf	24.5	–	24.3
mean RH %		92.5	79.5	83.3
mean wind v. m/s		0.0	0.6	0.0
noon*4				
mean air temp. °C		29.9	31.1	29.3
ΔT^{*2} °C		-1.2	0.0	-1.8
mean surface temp. °C	ground	31.1	39.8	28.2
	wall	–	32.2	–
	leaf	30.5	–	29.7
mean RH %		64.9	60.3	67.7
mean wind v. m/s		0.9	1.3	0.6

⋆1;the central area of Osaka City
⋆2;average value of Run4 and Run6
$Run4; 21.Aug.19925:00--5:45cloudy$
Run6; 22.Aug.1992 5:00–5:45 cloudy
⋆3;compare with air temp. in the built-up area
⋆4;average value of Run3, Run5 and Run7
Run3; 20.Aug.1992 12:50–14:35 cloudy
Run4; 21.Aug.1992 12:30–12:15 fine
Run7(l); 22.Aug.1992 12:30–12:15 fine

Table 6. Results of measurement in a small urban park and its surrounding

item		promenade *1	street crossing	on pedestrian birdge*2	opposite side of promenade
mean air temp.°C		32.5	33.4	32.2	32.0
ΔT^{*3}°C		0.0	0.9	-0.3	0.5
mean surface temp.°C	ground(sunny)	42.4	44.7	45.6	47.1
	ground(shade)	30.2	–	48.4	46.4
	leaf	31.6	32.6	33.0	31.0
	wall	30.9	–	33.6	41.4
mean RH %		56.0	53.6	56.8	56.0
mean wind v. m/s		1.3	1.8	2.5	1.3

⋆1;the promenade along the avenue; Umeda–shin–michi covered by 15m high trees.
⋆2;the pedestrian bridge over National road 2, about 5 meters above ground level
⋆3;comparison with the air temp. in the promenade.
Run7(II):22.Aug.1992 12:15–13:15 fine

Table 7. Results of measurement in a small urban park and its surrounding area (II)

item		park*1	bare ground	motor parking
mean air temp.°C		29.8	30.2	30.3
ΔT^{*2}°C		0.0	0.4	0.5
mean surface temp.°C	ground(sunny)	41.5	44.8	56.1
	ground(shade)	29.2	–	–
	wall	–	–	30.3
	leaf	30.2	–	–
	water surface	32.2	–	–
mean RH %		67.5	65.0	63.9
mean wind v. m/s		1.2	2.5	3.9

rain fall(2.5mm) was observed the day before day before this survay.
⋆1;Port–Town Park (the park in front of the Nankou Port Town Station)
⋆2;comparison with the air temp. in the park
Run8;23.Aug.1922 12:30–13:40

CONCLUSION

In order to propose a green area as a unit to be considered inurban environmental planning, measurements of meteorological elements werecarried out in green areas of differing scales and urban built-up areas in Osaka in August 1992.

Regarding the fundamental thermal properties and the data of green canopies and structural elements in green covered spaces, the following results were obtained.

(1) The cooling effects of large green canopies as the "Cool Spot" werequite significant. The minimum differential in air temperature wasrecognized as more than 1°C.
(2) The cooling effects of green canopies was especially significant in theearly morning.
(3) The cooling effects of small green canopies as the "Cool Spot" wererecognized.
(4) The depth of green canopies influenced the formation of a mass of cool air.
(5)The surface temperature under a green canopy was always cooler than thesurrounding urban built-up area.

The research in the large green canopy was expected to determine the cooling effect of green canopy in an aerial stability. The middle size green canopy (the minimum depth of the green canopy was approximately 150 m) showed almost equal thermal properties to that of the large green canopy. Under the smaller green canopy, air temperatures were higher than larger green canopies, however, surface temperatures were measured as approximately equal to the larger green canopies. In conclusion, it can be regarded that the main difference of thermal properties between a large green canopy and a small green canopy was the extent of the influence from outer urban built-up areas. The thermal boundary area between a "Cool Spot" and an urban built-up area was not measured in this research. To discuss this thermal boundary area, further investigation is needed. Using these results, a new thermal model, which reflects the cooling effects of green canopies, will be expected.

REFERENCE

Yoshida,A., Tominaga,K. and Watatani,S.(1991),*Field Investigation on Heat Transfer in an Urban Canyon,Heat Transfer Japanese Research*,**20–3:230-244.** (In Japanese)

Received: October 2, 1995.
Accepted: February 4, 1996.