NOTES

The Energy Balance Microclimate of a Suburban Lawn

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5 November 1979 and 29 January 1980

ABSTRACT

A suburban lawn was instrumented in order to study its energy balance components during summer conditions. Results indicate that substantial latent heat fluxes can be experienced with values exceeding net radiation during portions of some days. On average, the energy balance fluxes were similar to those found in previous studies for rural grass surfaces. Since lawns form a large portion of the suburban landscape, this implies that suburban evapotranspiration is an important and perhaps dominant term in the energy balance.

1. Introduction

It has been commonly assumed that the evapotranspiration rate in a city is lower than that for the rural environs due to the removal of vegetation and its replacement by non-evaporating concrete, asphalt and other impervious materials (Peterson, 1969). The detailed energy balance study of Nunez and Oke (1977) confirms that many urban surfaces such as the street level of an urban canyon have very low evaporation rates. However, recent energy balance studies by Yap and Oke (1974a) and Kalanda and Oke (1980) in Vancouver, Canada indicate that urban and especially suburban areas can have significant evaporative or latent heat fluxes much larger than previously anticipated. These studies have examined the urban situation at a spatially integrated scale. If such spatially averaged urban and suburban latent heat fluxes are important, then the remaining urban green spaces must be evaporating large amounts of water to compensate for the loss of evaporating surfaces. Thus, urban parks and lawns may behave in a manner where the latent heat flux can exceed the net available radiation.

A recent study by Oke (1979) has shown that the evapotranspiration regime for urban vegetation is augmented by advection of sensible heat from drier surrounding urban surfaces. In his study, Oke examined an irrigated suburban lawn for a 4-day period. This paper further examines suburban lawn evapotranspiration for 12 summer days grouped in four periods. Differences between the two studies will be highlighted.

2. Procedure

Whereas the study by Oke (1979) was undertaken for a small lawn (160 m^2) in the front yard located only a few meters from the street, the lawn in this study was in the back yard south of a typical modern one-story suburban home located in the small city of Brandon, Manitoba, Canada (population 37 000). The lawn measured approximately 25 m × 20 m for an area of 500 m^2. The instrument site was in the center of the lawn. No large trees or other structures provided any significant amounts of shade to the instrument site. A small vegetable garden was located on the west side of the lawn and a fence (1.5 m high) surrounded the yard on three sides beyond which neighboring lawns and gardens existed.

The energy balance of the lawn can be expressed as

$$Q^* = Q_G + Q_E + Q_H, \tag{1}$$

where Q^* is net radiation, Q_G the ground or soil heat flux, Q_E the latent heat flux and Q_H the sensible heat flux. The instrumentation used in this study was similar to that used by Oke (1979). A miniature net radiometer (Middleton Instruments) mounted at a height of 0.9 m above the surface was used to measure Q^* while a soil heat flux plate (Science Associates Inc.) embedded at a depth of 0.05 m beneath the surface was used to determine Q_G. In order to estimate Q_E, two circular mini lysimeters were constructed of sheet metal. Each measured 0.25 m in diameter and 0.15 m in depth. Both lysimeters were installed in the lawn ~4 m apart and were removed once each hour (on the hour solar time) to be weighed on a sensitive weighing balance (accurate to within 1 g) allowing Q_E to be calculated from the weight loss. For the surface area of the lysimeters, this weighing accuracy of 1 g represents an error of only 14 W m^{-2} for hourly average fluxes of Q_E. This compares to an estimated ac-

0021-8952/80/050606-03$04.75

curacy of 10 W m^{-2} for hourly values of Q_E given by Nunez and Oke (1977) for the lysimeters used by Oke (1979). The values of Q_E calculated separately from the two lysimeters in this study differed by a root-mean-square error of only 29 W m^{-2} on an hourly basis. For analysis, values of Q_E averaged for the two lysimeters were used. The last term Q_H in the energy balance was calculated as the residual from (1).

Table 1 lists the 12 days during the summer of 1979 that were studied. These occurred during four distinct periods. Also listed are precipitation and irrigation events including amount as measured by a cylindrical raingage (Fisher Scientific). Irrigation was applied on two occasions by sprinklers during the previous evening. A routine similar to that maintained by neighbors was followed for both irrigation events and periodic grass cuttings. Observations were taken for 16 h periods from 0400 to 2000 ST each day.

3. Results

Table 2 summarizes the energy balance fluxes obtained on a daily total basis (averages in W m^{-2} for 16 h daytime periods). The ratio Q_E/Q^* expressed as a percentage and values of the Bowen ratio ($\beta = Q_H/Q_E$) are also tabulated. The value of Q_G was always small (<7% of Q^*). Q_E was greater than Q_H for each day and accounted for an average 65.5% of the disposition of Q^* with a range varying from about 50% to 98%. β was therefore always less than unity and on 23 July was negative since the value of Q_H was negative. The high value of Q_E (98% of Q^*) for this particular day may be attributed to the large amount of irrigation (20 mm) applied on the previous evening. Subsequent days showed a drying trend with Q_E accounting for ~77% of Q^* on 24 July and 71% on 25 and 26 July. Although a larger amount of water was added to the lawn for 30 July (23 mm of precipitation), higher humidity conditions associated with this weather system existed throughout the day resulting in lower evapotranspiration rates than that experienced on 23 July.

TABLE 1. Study days and water application events.

Date (1979)	Water application event	Amount (mm)
27 June	rain around 0930 h	trace
28 June	irrigation previous evening	2.0
29 June	none	nil
19 July	rain overnight	2.5
20 July	dew evident in morning	trace
23 July	irrigation previous evening	20.0
24 July	dew evident in morning	trace
25 July	dew evident in morning	trace
26 July	none	nil
30 July	rain in morning until 0600 h	23.0
31 July	dew evident in morning	trace
1 Aug	rain around 1430 h	2.0

TABLE 2. Energy balance data expressed as average fluxes for 16 h daily totals.

Date (1979)	Q^* (W m^{-2})	Q_G (W m^{-2})	Q_E (W m^{-2})	Q_H (W m^{-2})	Q_E/Q^* (%)	β
27 June	207.5	14.7	103.2	89.6	49.7	0.87
28 June	248.4	14.4	130.8	103.1	52.7	0.79
29 June	282.4	12.9	142.8	126.7	50.6	0.89
19 July	260.9	15.8	148.1	97.1	56.7	0.66
20 July	273.9	14.1	170.2	89.7	62.1	0.53
23 July	216.2	12.1	211.4	−7.3	97.8	−3.45
24 July	212.4	6.3	164.0	42.1	77.2	0.26
25 July	184.4	2.3	131.1	51.0	71.1	0.39
26 July	179.7	3.8	126.8	49.1	70.6	0.39
30 July	213.9	4.7	148.5	60.7	69.4	0.41
31 July	281.2	7.7	168.4	105.1	59.9	0.62
1 Aug	241.6	6.4	175.5	59.7	72.7	0.34

Fig. 1 illustrates the diurnal behavior of the energy balance components for the day with the highest evapotranspiration rates (23 July). Q_E is greater than Q_H for each hour and also exceeds the value of Q^* by mid-afternoon.

Fig. 2 shows the hourly values for each energy flux averaged for the 12 study days. Generally, Q_E and Q_H are similar in magnitude in the morning with Q_E exceeding Q_H by midday and throughout the afternoon. While Q_E accounted for 65.5% of the disposition of Q^* on an average daytime daily basis, a comparison of morning and afternoon values (Table 3) shows that Q_E constituted 55.4% of Q^* in the mornings and 78.3% in the afternoons.

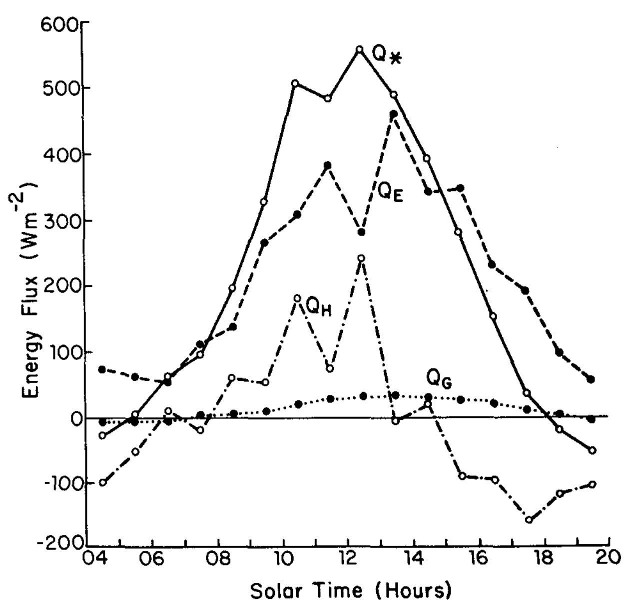

FIG. 1. Energy balance fluxes for a suburban lawn in Brandon, Canada on 23 July 1979.

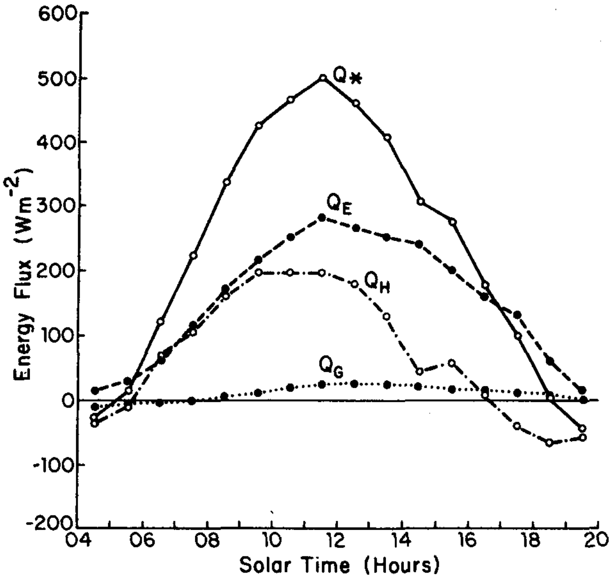

FIG. 2. Energy balance fluxes for a suburban lawn in Brandon, Canada averaged for 12 summer days during 1979.

4. Discussion

The average value of Q_E/Q^* (65.5%) and the largest value (98%) experienced in this study are somewhat lower than those found by Oke (1979) for his study. He found that on a daily basis Q_E/Q^* was consistently greater than 100% (averaging 105% over the 4-day study period). β for his study was always negative whereas it was negative only once in the present analysis. The higher latent heat fluxes in Oke's study can be attributed to different characteristics between the two studies and sites. His study was for one 4-day period under substantial irrigation with complete water availability. In the present study, only 23 July may be comparable since irrigation events were conducted following neighborhood practices. Even for this day, Q_E/Q^* was less than that for all of Oke's study days. Another reason for higher latent heat fluxes in Oke's case may be postulated by comparing the two sites. Oke's site was very close to sources of horizontal sensible heat advection from the street and house. The site in the present study (being a larger lawn in the back yard surrounded by other lawns on three sides) was further away from such sources of sensible heat advection. This would result in comparatively lower latent heat fluxes.

The results in Fig. 2 and the diurnal change in the importance of Q_E as exemplified in Table 3 are similar to the findings for moist rural grass surfaces by Tanner and Pelton [as reported in Sellers (1965)] and Yap and Oke (1974b). In all cases, Q_E is the dominant term. Thus, latent heat fluxes similar in magnitude and behavior to the rural situation can be experienced for suburban grass surfaces. Marotz and Coiner (1973) have shown that grass surfaces constitute a large percentage of the surface materials in cities especially for smaller centers (such as Brandon) and in suburban areas. This implies that suburban evapotranspiration is an important term in the energy balance.

TABLE 3. Energy balance data expressed as average fluxes for 16 h daily, 8 h morning and 8 h afternoon periods averaged for the 12 study days.

	Q^* (W m^{-2})	Q_G (W m^{-2})	Q_E (W m^{-2})	Q_H (W m^{-2})	Q_E/Q^* (%)	β
Daily	235	10	154	71	65.5	0.46
Morning	258	5	143	110	55.4	0.77
Afternoon	212	14	166	32	78.3	0.19

5. Conclusion

This study has shown that a common urban surface cover, suburban lawn, does have a substantial flux of latent heat. On average, the energy balance components were similar to those found in previous studies for moist rural grass surfaces. Since lawns form a large portion of the suburban landscape, this implies that evapotranspiration is an important and perhaps dominant term in the energy balance.

Acknowledgments. This study has been supported, in part, by funds from the Natural Sciences and Engineering Research Council of Canada. The research site was provided with the kind cooperation of Mr. and Mrs. W. Palmer of Brandon. The field assistance of Peter Lafleur and Bruce Palmer of Brandon University is gratefully acknowledged.

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