Measuring Evapotranspiration in Urban Irrigated Lawns

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Background

Few, if any, studies have utilized micrometeorological measurements to explore the impact of lawn care on community water resources. The increased use of in-ground automated irrigation systems, which are often maladjusted, may consequently increase water wastage and impact local water quality. A greater understanding of the water demand within individual lawns would allow homeowners and landscape managers to more accurately adjust irrigation systems and conserve water. Micrometeorological techniques may help provide better estimates of evapotranspiration (ET) from turfgrass and help determine actual water requirements of urban lawns.

Objective

Determine actual evapotranspiration in residential lawns by employing micrometeorological methods.

The Lawn Coefficient

Reference crop evapotranspiration is not necessarily equivalent to actual ET. However, we proposed that actual ET from a lawn (ET_{lawn}) is related to its local microclimate in the same way actual ET at RFTC ($ET_{actual,EC}$; measured with the EC station) is related to its microclimate. In effect:

$$\frac{ET_{lawn}}{ET_{o,tripod}} = \frac{ET_{actual,EC}}{ET_{o,RFTC}}$$

Rearranging this relationship gives: $ET_{lawn} = \left(ET_{o,tripod} / ET_{o,RFTC}\right) ET_{actual,EC}$

where $ET_{o,tripod}/ET_{o,RFTC}$ is the lawn-specific coefficient ($K_{c,i}$). Averaging all $K_{c,i}$ provides one overall coefficient (K_c) that represents a much larger area (in this case, NW Manhattan).

Site Description and Materials

Location and Tripods

Research was conducted in the fall 2009 and summer 2010 on lawns within the NW portion of the city of Manhattan, KS. Weather data were used to estimate ET from individual lawns using five tripod-mounted weather stations (tripods, Fig. 1). Tripod data were used to calculate reference crop ET (ET_o) via the FAO-56 method (Allen et al., 1998). Four tripods were deployed in residential lawns while one served as a reference in the vicinity of a trailer-mounted eddy covariance (EC) station (Fig. 2) at the Rocky Ford Turf Research Center (RFTC) in Manhattan, KS, within 5 km of the lawns.

Lawn Criteria

- Mostly cool-season turfgrass & landscape vegetation
- Automated irrigation system
- Well-maintained and watered
- Contained distinct/interesting microclimates
    - Shaded vs. open
    - Broadleaf vs. turf
    - Differences in wind breaks, terrain, drainage

Eddy Covariance Station

Eddy covariance is an important micrometeorological technique used for studying water, carbon, and energy exchange near the surface (Baldocchi et al., 1988). The EC station at RFTC directly measured actual evapotranspiration ($ET_{actual,EC}$) from a uniform, unshaded stretch of well-watered and maintained turf. High-speed (20 Hz) measurements of actual ET were made with an infrared gas analyzer and a 3D sonic anemometer that continuously sampled water vapor flux concomitant to tripod deployment.

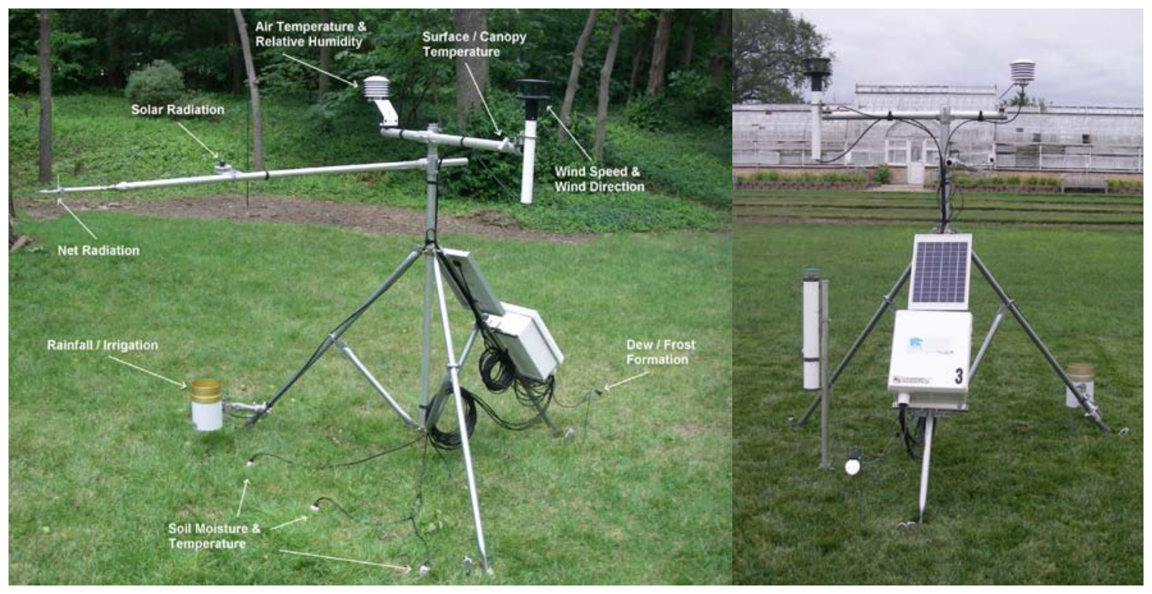

Fig. 1. Left: A tripod deployed in a lawn with instrumentation labeled. Right: Taking measurements in the Kansas State University Gardens.

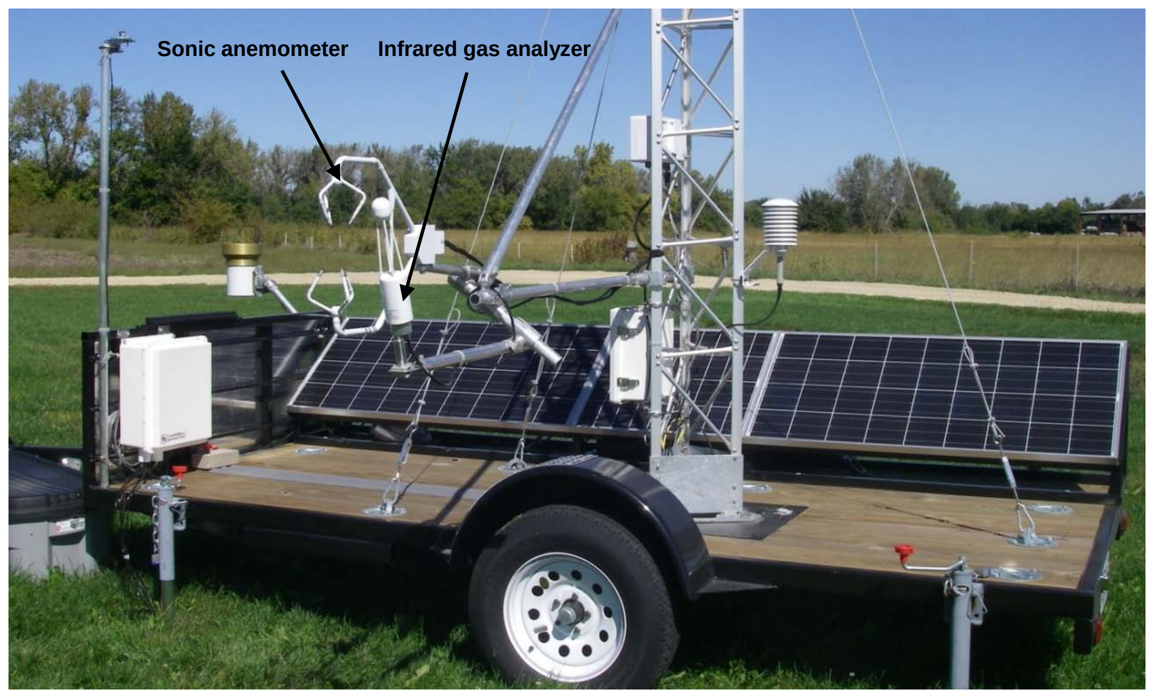

Fig. 2. Trailer-mounted eddy covariance system at RFTC.

Results

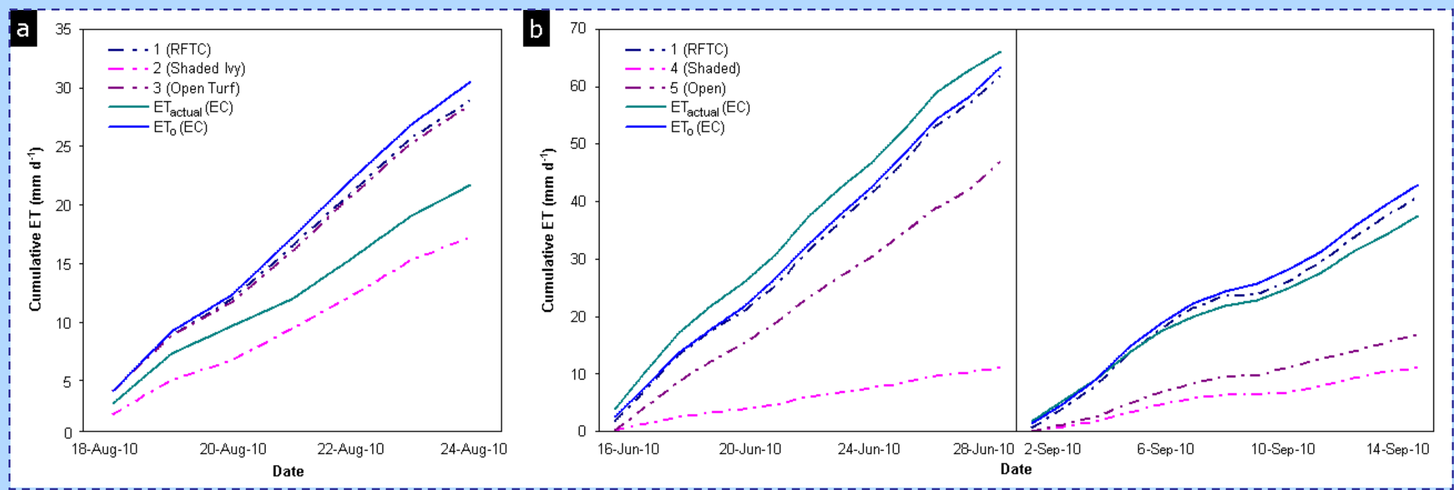

Fig. 3. Cumulative reference crop evapotranspiration (ET_o) reported during deployment on two properties as well as cumulative ET_o and actual evapotranspiration (ET_{actual}) measured by eddy covariance (EC) in 2010. **(a)** Tripods 2 and 3 were both deployed on Property 8 ($ET_{actual} < ET_o$). **(b)** Two different deployments of tripods 4 and 5 in Property 4 in June (left, $ET_{actual} > ET_o$) and September (right, large differences in shaded vs. open). Tripod 1 was at RFTC. Please note scale differences.

- There were large differences in cumulative ET among microclimates within any given yard (Figs. 3 and 4)
- K_c was 0.65 in fall 2009 and 0.67 in 2010 (data not shown)
- $K_{c,i}$ varied by microclimate and vegetation type (Table 1):
    - open turf $K_{c,i}$ was 42 ± 5% greater than shaded turf both years on average, and
    - mean $K_{c,i}$ for shaded ivy tended to be less than shaded turf by 10 ± 29% in 2010, but with moderate uncertainty
- When shady yards were omitted (e.g., Properties 3 and 4 in 2010, ~50% shade), ET_{actual} using K_c was within 14.9% of that using $K_{c,i}$ for the 2010
- Lower wind speeds and shaded areas in lawns contributed to ~37% reduction in ET compared to ET at the more open RFTC dataset (not shown)

Table 1. Yard coefficients ($K_{c,i}$) by microclimate and vegetation type. Individual $K_{c,i}$ calculated from daily ET sums filtered for prevailing wind directions.

	Open Turf			Shaded Turf			Shaded Ivy		
	$K_{c,i}$	SE	n	$K_{c,i}$	SE	n	$K_{c,i}$	SE	n
Oct 2009	0.61	0.07	17	0.36	0.06	9	--	--	--
Jun 2010	0.70	0.06	19	0.42	0.04	26	0.13	0.02	7
Jul 2010	0.94	0.02	18	0.38	0.05	18	0.28*	--	0
Aug 2010	0.78	0.02	30	0.56	0.05	33	0.32	0.06	11
Sep 2010	0.59	0.05	15	0.28	0.05	19	0.46	0.04	8
Oct 2010	0.80	0.03	20	0.55	0.09	14	0.59	0.05	4

*Datapoint extrapolated by linear regression of 2010 dataset due to lack of measurements (see n for Shaded Ivy in the right column).

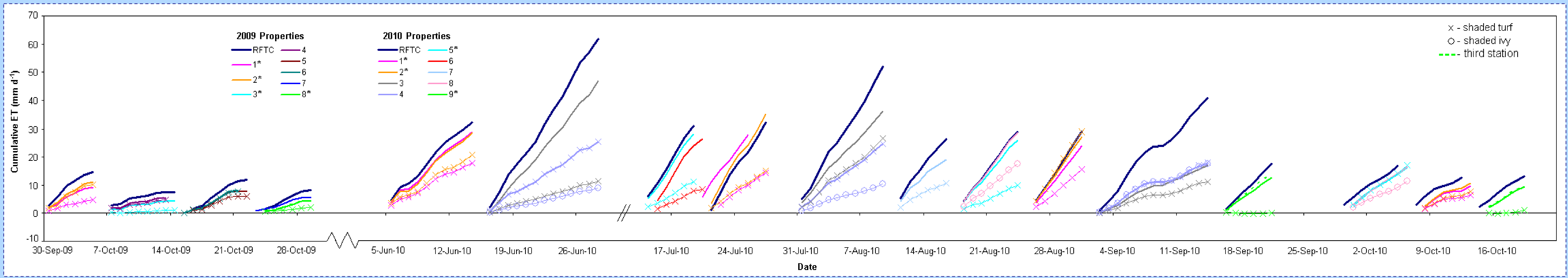

Fig. 4. Cumulative reference crop evapotranspiration (ET_o) from all deployed tripods in 2009 and 2010 compared with (ET_o) from the tripod at RFTC. Unmarked lines indicate tripod data from an open (i.e., non-shaded) portion of the lawn, lines marked "x" are from shaded areas, an "o" indicates a tripod sampling irrigated ivy on Properties 4 (light purple) and 8 (light pink) in 2010, and dashed lines indicate a third tripod on Property 8/Property 9 in both years (light green lines).

*These properties were repeat deployments across both years (i.e., they had the same address) and are marked by the same colors in 2010 as in 2009.

Conclusions

- Microclimates within a lawn have a large impact on ET.
- Using an overall coefficient, K_c, to estimate ET_{actual} for lawns within (a region of) a city is within 22-29% of the ET_{actual} obtained by using individual lawn coefficients ($K_{c,i}$).
- Special considerations must be taken when applying a lawn coefficient to properties with vastly different characteristics of a more typical property in different parts of the city (e.g., for this case yards >50% shade).

References

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Acknowledgments

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