Ecosystem respiration of suburban lawns and its response to varying management and irrigation regimes

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Understanding the response of ecosystem respiration (R_{eco}) on residential lawns to changing environmental conditions is necessary to incorporate this source of CO_2 into models of the urban carbon cycle and to identify management strategies promoting carbon sequestration. Results from closed-chamber measurements of R_{eco} on urban lawns were used to identify the primary controls on carbon efflux and to model respiration where environmental conditions are known.

The magnitude of respiration from vegetated surfaces has been shown to be dependent on biophysical factors, including soil volumetric water content (θ), soil organic carbon (*SOC*) content and temperature (T_S), which are manipulated in the highly managed ecosystems created on urban lawns (Luo and Zhou 2006). We explore these relationships in urban greenspace.

Sites and Methods

The study examined respiration on eight residential lawns in two neighbourhoods with different irrigation and management regimes in Vancouver, BC, Canada. The 'Vancouver-Oakridge' neighbourhood (49°13'N, 123°8'W) was characterized by more intensive management practices and more frequent irrigation (sites OR1-4). In the 'Vancouver-Sunset' Neighbourhood (49°13'N, 123°5'W), management and irrigation regimes were less intensive (SS1-4). Two unmanaged (non-irrigated, non-fertilized) grassland sites in the region were also monitored for reference conditions.

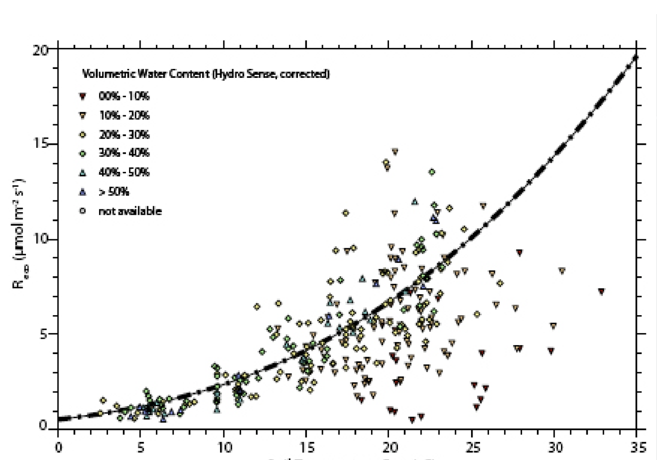
390 measurements of R_{eco} were made between July and December of 2008, using a portable system equipped with a PVC chamber and opaque cover. Concurrent measurements of T_s at 5 cm and θ integrated over 0-12cm depth were obtained using a copper-constantan thermocouple and handheld TDR.

Irrigation regime influences summertime vegetation productivity
Grass conditions at all urban sites during the week of August 18th, 2008, following a period with limited precipitation inputs.

Environmental Controls on R_{eco}

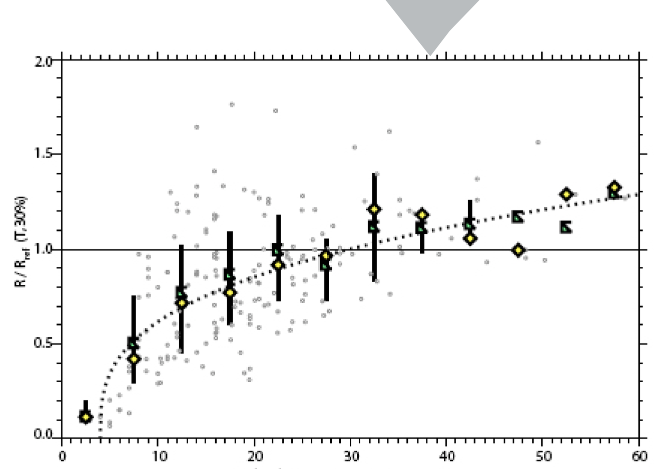
Measured CO_2 flux from urban lawns ranged from 0.5 to 14.6 µmol m^{-2} s^{-1}. R_{eco} on suburban lawns responded to increases in T_s following an exponential increasing relationship, consistent with trends established for other vegetated soils (Lloyd and Taylor 1994).

Under limited soil moisture conditions, R_{eco} was restricted. Respiration declined sharply towards zero as θ approached 5%. At values of θ between 10 and 20%, R_{eco} increased steadily, and attained a maximum value before declining slightly at $\theta > 32\%$ due to lower T_s associated with wetter soils.



T_S response of R_{eco}
Data from all urban sites, sorted by volumetric water content. The black line is the best fit with R_{ref} = 2.4 and E_0 = 383 for θ all classes between 20% and 40%. Note the significant reduction of respiration where θ is below 20%.

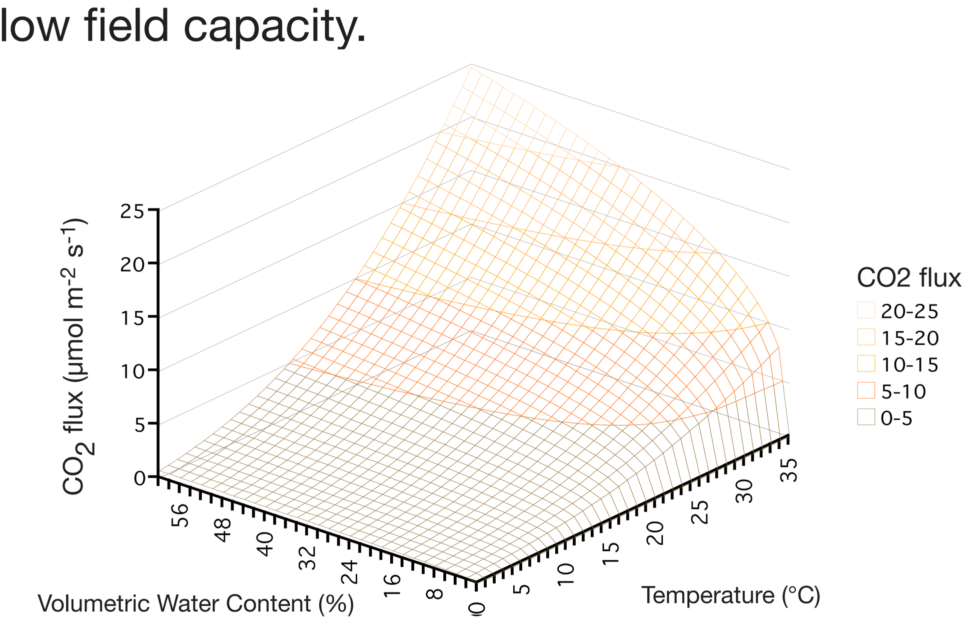
θ response of R_{eco}
Measured respiration as a fraction of calculated respiration R_{ref} at reference soil volumetric water content vs. volumetric water content. Diamonds indicate class median values, squares are class averages, and vertical lines include the 1st and 3rd quartile. The dotted line is the regression with b=0.33 and θ_0 = 4%.



Based on the observed data, a model was developed to determine R_{eco} where T_s and θ are known

$$R_{\rm eco}(T,\theta) = R_{\rm ref}(T_{\rm ref},\theta_{\rm ref})\;\exp\left[E_0\left(\frac{1}{T_{\rm ref}-T_0}-\frac{1}{T-T_0}\right)\right]\frac{(\theta-\theta_0)^b}{(\theta_{\rm ref}-\theta_0)^b} \qquad (1)$$

The T_s dependence was incorporated using a formulation of the Arrhenius equation, following Lloyd and Taylor (1994). The empirical parameters E_0 and R_{ref} were determined for the full urban data set and for individual sites for 20%<θ<40%. Limitations at low θ were incorporated using a function based on the response of R_{eco} below field capacity.



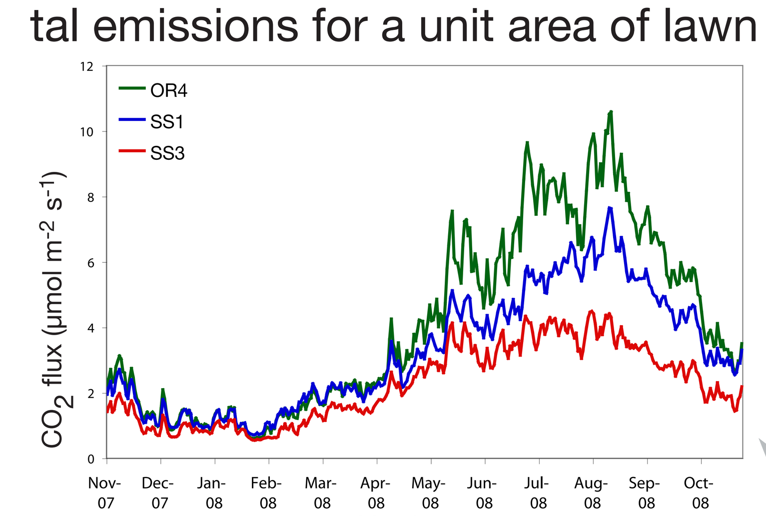
A visualization of the empirical model for R_{eco} (equation 1)
This surface is based on the empirical parameters for all urban data: **R_{ref} = 2.37 µmol m^{-2} s^{-1}, E_0 = 383.9 K, and b = 0.33.**

Using site-specific parameters, the model accounted for 63% of the variability in observed R_{eco}. 56% was attributable to changes in T_s, while 7% could be explained by θ. T_s was the dominant control for 7 of 8 individual urban sites.

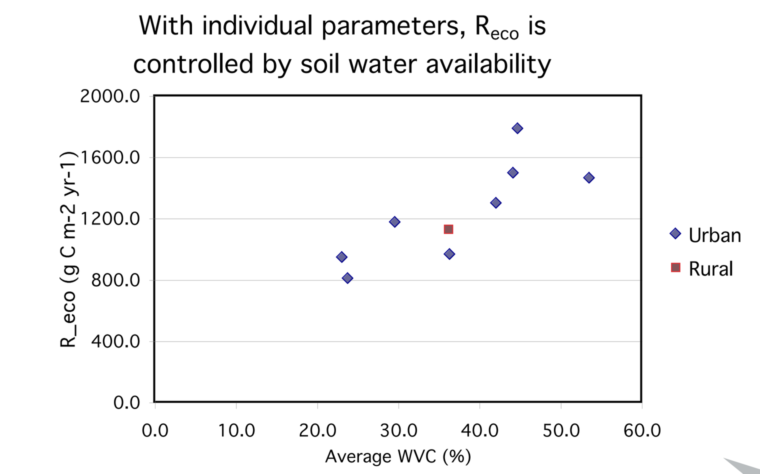
At sites where θ was limited, both total variability accounted for by the model and the proportion attributable to T_S changes were lower than at sites with higher moisture availability.

Annual Totals of R_{eco}

Time traces of T_s and θ from long-term soil hydrology stations installed at each site were used to model the time-series of R_{eco} for one year, and to calculate the total emissions for a unit area of lawn at each location.



Time trace of modeled R_{eco} at OR4 (frequent, automatic irrigation), SS1 (regular, manual irrigation) and SS3 (no irrigation) at 5-minute intervals from November 1, 2007 to October 31, 2008. Variations between sites are limited during winter, when low temperatures restrict respiration despite moisture availability. Differences in summertime emissions reflect the influence of irrigation regimes on θ.

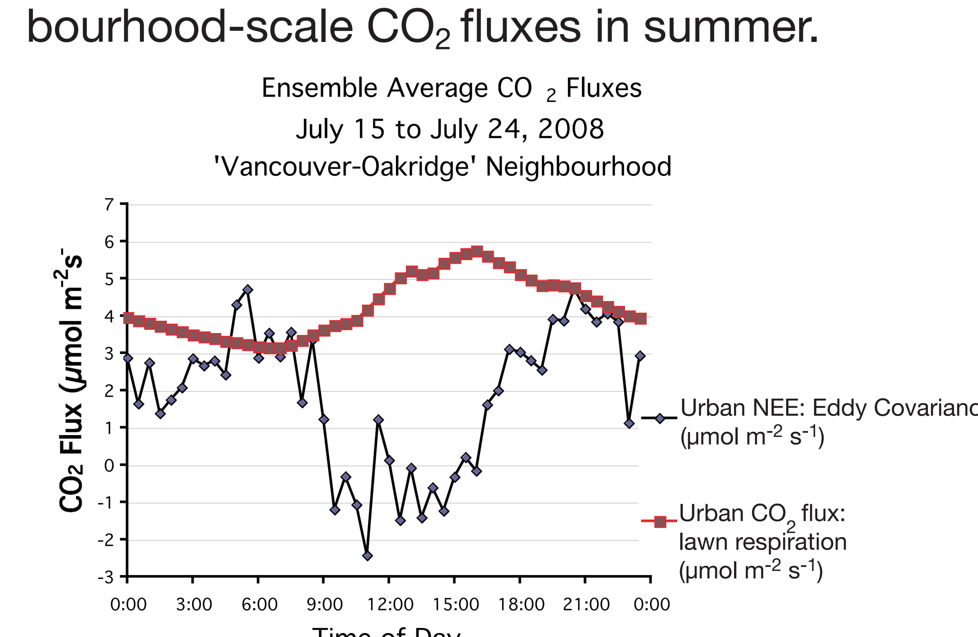


Site	Annual R_{eco} (g C m^{-2} yr^{-1})
OR1	1302
OR2	1790
OR3	1467
OR4	1498
SS1	1177
SS2	968
SS3	810
SS4	949

Annual total of R_{eco} modeled for each site. Average soil temperatures were roughly similar across all urban sites. When site-specific values for E_0 and R_{ref} were used, the more intensive irrigation and management at sites in OR suggested greater total flux from lawns in that neighbourhood.

Contribution of R_{eco} to Total Urban NEE

All urban R_{eco} measurement sites were within the footprint of eddy covariance (EC) towers measuring neighbourhood-scale flux densities of CO_2. The modeled contribution of R_{eco} scaled by the grass landcover fraction for 'Vancouver-Oakridge' was consistent with the measured nighttime tower fluxes, indicating that lawn respiration is a dominant process in controlling neighbourhood-scale CO_2 fluxes in summer.



Neighbourhood-scale CO_2 flux densities at night are in agreement with modeled contributions from R_{eco}. Nighttime CO_2 flux densities in summer should reflect a primary contribution from soil respiration due to the absence of anthropogenic contributions from traffic, home heating, and the lack of photosynthesis at night.

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