The role of soils and lawns in urban-atmosphere exchange of carbon-dioxide

Andreas Christen (1), Nicholas Coops (2), Ben Crawford (1), Kate Liss (1), Tim Oke (1), and Rory Tooke (2).
(1) University of British Columbia, Department of Geography / Atmospheric Science Program, Vancouver BC, Canada
(2) University of British Columbia, Department of Forest Resource Management, Vancouver, Canada, Vancouver BC, Canada.

Suburban lawns represent a significant fraction of the urban land cover in North America. Major controls on respiration and photosynthesis of urban lawns are highly manipulated by irrigation, management and fertilization. Further, enriched carbon-dioxide concentration, air pollutants, and a significantly higher soil temperature due to a sub-surface urban heat island potentially affect their response.

Using a combination of closed chamber measurements, urban ecosystem-level eddy covariance measurements of carbon-dioxide fluxes, LIDAR and satellite remote sensing, we estimated the magnitude of soil respiration and photosynthesis of urban lawns in the diurnal and annual cycle and compared their magnitude to total urban emissions of carbon-dioxide.

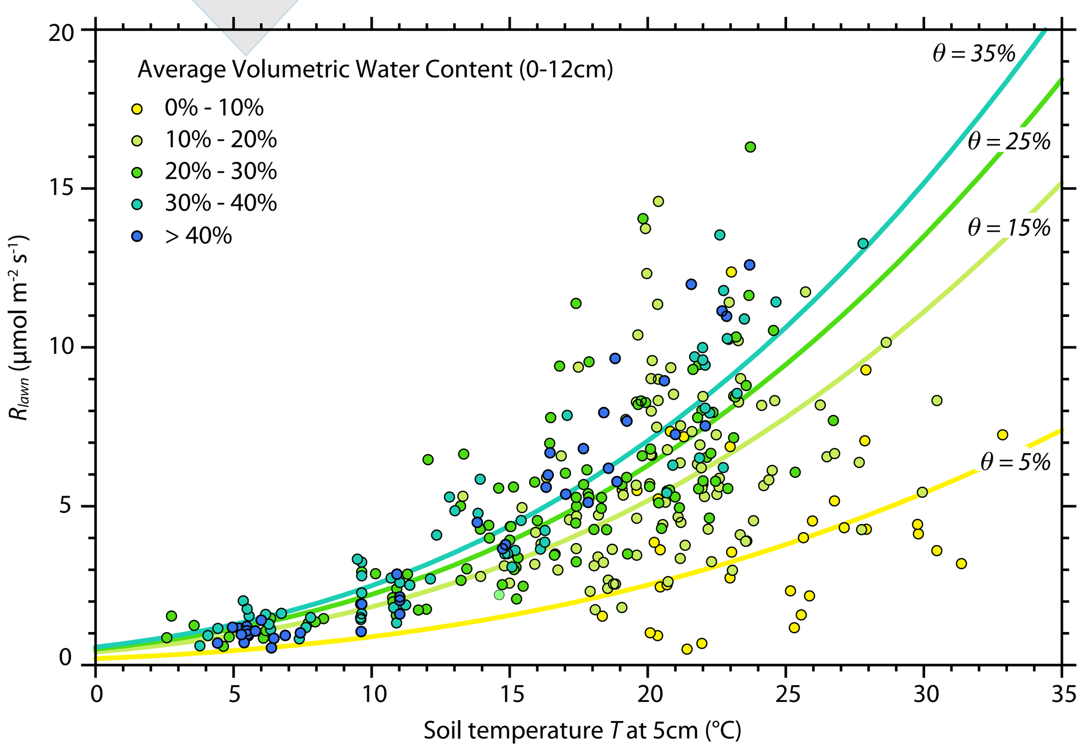
Our two study areas are located in Vancouver, BC, Canada. They are characterized by contrasting densities and different lawn irrigation systems:

Site	Vancouver-Oakridge	Vancouver-Sunset
Land-use	Residential suburban	Residential suburban
Homes / ha	9	19
Plan area fractions	Buildings 23% Lawns / Gardens 56% Impervious 21%	Buildings 21% Lawns / Gardens 44% Impervious 35%
Lawn irrigation systems	61% automatic 34% manual 1% none	1% automatic 79% manual 20 % none

Measured and modelled lawn respiration

In each study area, we measured lawn respiration (R_{lawn}) manually using non-steady state chamber system with an opaque chamber. A total of 315 measurements were taken in 2008 and 2009 on four representative lawns per neighborhood. Each lawn represents a specific irrigation and management regime. All lawns had automatic measurement systems installed providing 5-min averages of soil temperature T and soil volumetric water content θ over the course of a full year (Liss *et al.* 2009).

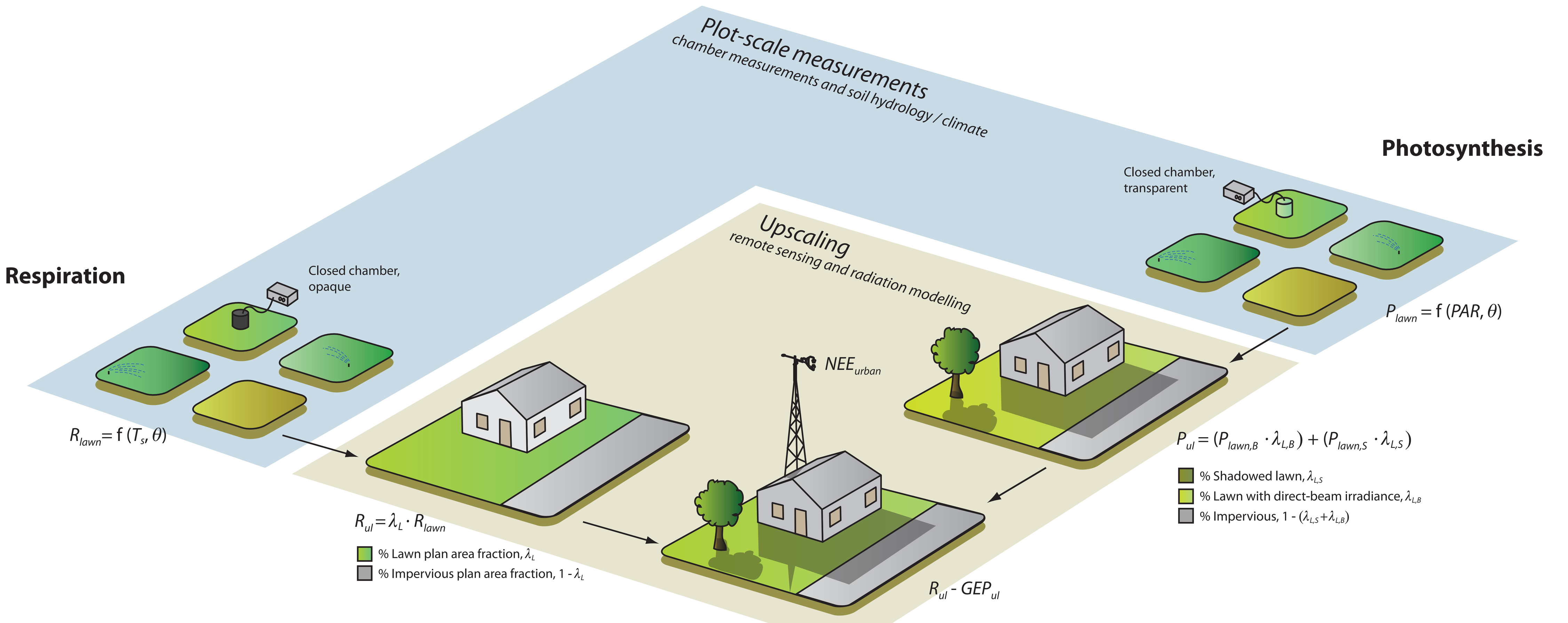
Relationship of lawn respiration vs. soil temperature, expressed as CO_2 flux per m² lawn. Plotted are all chamber measurements from both urban neighborhoods. The water limitation of R_{lawn} can be inferred from soil volumetric water content (color of markers) . A semi-empirical relationship based on Lloyd and Taylor (1992) was used to model R_{lawn} and is shown for scenarios with different volumetric water content.



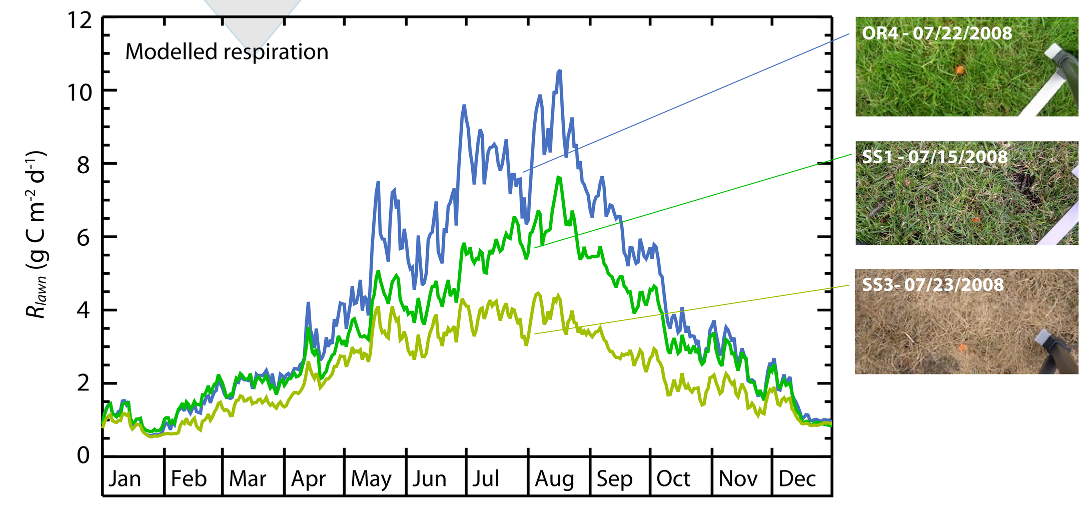
$$R_{\mathrm{lawn}}(T,\theta) = R_{\mathrm{ref}}(T_{\mathrm{ref}},\theta_{\mathrm{ref}}) \exp\left[E_0\left(\frac{1}{T_{\mathrm{ref}}-T_0} - \frac{1}{T-T_0}\right)\right] \frac{(\theta-\theta_0)^b}{(\theta_{\mathrm{ref}}-\theta_0)^b}$$

Reference Respiration — Temperature-dependence: Arrhenius-equation based on Lloyd and Taylor (1994) — Empirical correction for water limitation (new)

Model inputs: T - Measured soil temperature, θ — measured volumetric water content
Empirical model parameters (determined for each lawn): R_{ref}, E_0, b
Preset model parameters: T_{ref}, T_0, θ_{ref}, θ_0



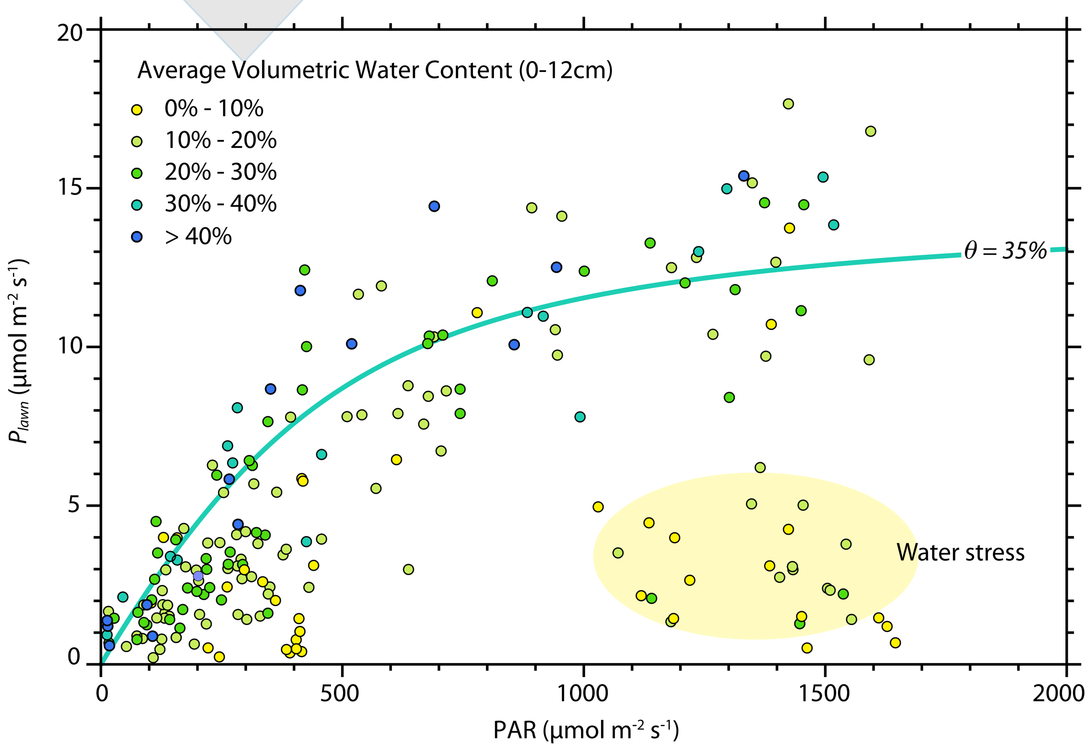
Year-round modelled respiration in g carbon emitted from one m² of lawn at OR4 (automatic lawn irrigation), SS1 (manual lawn irrigation) and SS3 (no irrigation). Water availability is a significant control on the magnitude of annual emissions.



Measured and modelled lawn photosynthesis

Using the same chamber system, but with a transparent chamber, R_{lawn} - P_{lawn} was measured for 190 samples from all lawns. With known R_{lawn}, photosynthesis P_{lawn} was calculated. Simultaneous measurements were made of photosynthetically active radiation (PAR).

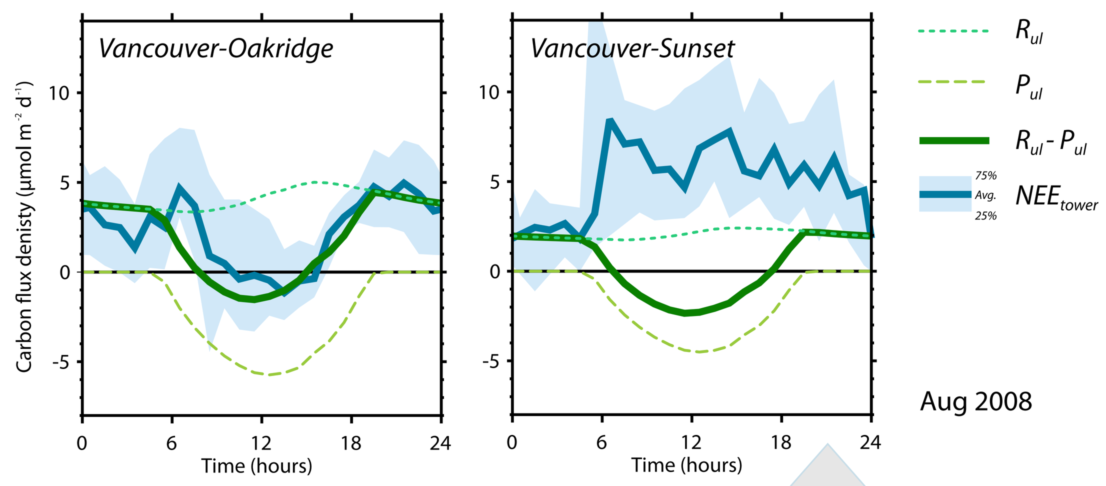
Light response curve of lawn photosynthesis for 1 m² of lawn vs. PAR (x-axis) and soil volumetric water content (colors). The light-response based on Ögren and Evans (1992) was fitted to model the light response of P_{lawn} and an empirical correction for water stress was added to the model.



Land-cover fractions and modelled irradiance from remote sensing systems were used to upscale plot-level results. Based on a combination of satellite imagery (Tooke *et al.*, 2009) and an urban 3d-surface model extracted from LIDAR measurements, a 1 m raster of land cover of the neighborhoods was developed. The urban 3d-surface model was used to calculate detailed shadowing for situations with direct-beam irradiance.

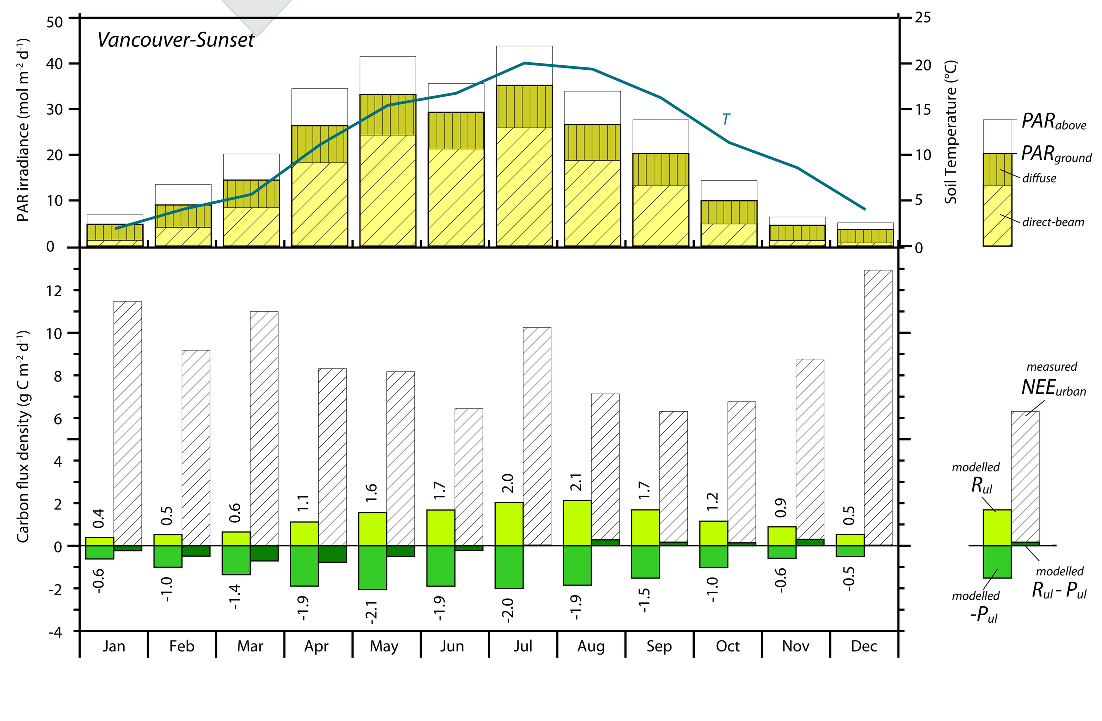
Measured and modelled net fluxes from lawns

In both neighborhoods, a tower system with ecosystem-level eddy covariance measurements of carbon-dioxide fluxes was operated at 30 m. Those tower-measurements integrate CO_2 fluxes from fossil fuel emissions, urban lawns, bushes and trees, and human respiration. and provide urban net ecosystem exchange (NEE_{urban})



Modelled diurnal cycle of summertime neighborhood-scale fluxes originating from lawns vs. tower flux-measurements of urban NEE for the average diurnal course in August 2008. In *Vancouver-Oakridge*, extensive lawn areas are a stronger control on summertime NEE than in the higher-density neighborhood *Vancouver-Sunset*. *Vancouver-Oakridge* has a higher lawn land-cover fraction, more intense lawn irrigation, and negligible traffic load.

Year-round modelled net fluxes from urban lawns vs. tower measurements of urban NEE for the higher-density neighborhood *Vancouver-Sunset*. The monthly net carbon-dioxide exchange from lawns (R_{ul} - P_{ul}) is small compared to anthropogenic emissions.



Although our model suggests that lawns are a small net sink of carbon in those two neighborhoods, this result is sensitive to model parameters and does not take into account that a significant part of accumulated carbon on lawns may be exported, when lawns are mowed and therefore is released at a different place (compost etc.)

References

Liss K., Crawford B., Jassal R., Siemens C., Christen A., 2009: Soil respiration in suburban lawns and its response to varying management and irrigation regimes. *Proc. of the AMS Eighth Conf. on the Urban Environment*, Phoenix, AZ, January 11-15, 2009.

Lloyd J., and Taylor, J.A., 1994: On the temperature dependence of soil respiration. *Functional Ecology*, 8, 315-323.

Ögren E., Evans J. R., 1993: Photosynthetic light-response curves, 1. The influence of CO_2 partial pressure and leaf inversion. *Planta*, 189, 182-190.

Tooke, R., Coops. N.C, Goodwin, N.R., Voogt, J.A, 2009: The Influence of Vegetation Characteristics on Spectral Mixture Analysis in an Urban Environment. *Remote Sensing of Environment*, 113, 398-407.