Assessing controls on the variation in soil respiration and nitrogen deposition in urban areas

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ABSTRACT

Urban areas comprise about 3% of global land area, but contain over 50% of the world's population and are responsible for 70% of fossil fuel emissions[1,2]. Studies documenting urban carbon fluxes are numerous; however, few of these studies focus on biogenic fluxes which can play an important role in the urban carbon cycle[3,4]. Additionally, studies focusing on urban nitrogen deposition often investigate deposition along an urban-to-rural gradient while little is known about within-urban variability of atmospheric nitrogen inputs[5,6]. During the growing season of 2014, we carried out a field study to quantify rates of soil respiration and nitrogen deposition across the Boston, MA urban area. We selected 15 sites across a gradient of urbanness within the Boston urban area. At each site we measured soil respiration biweekly within each of the dominant cover types (landscaped, lawn and/or forest), and measured nitrogen deposition throughout the growing season. Internal nitrogen cycling, nitrogen leaching, soil organic matter, pH, soil bulk density, and soil C:N ratio were also measured at each site. Results show that soil respiration rates are highest in urban landscaped environments and lowest in urban forests, and that these rates vary increase with increasing litter mass, depth, and soil organic matter. Rates of nitrogen deposition vary widely within the urban area and can be partially explained by degree of urbanness and seasonal effects. This work is important for building budgets of biogenic carbon fluxes and atmospheric nitrogen inputs across urban areas located in temperate biomes.

Background and Introduction

As the world's urban population is projected to approach 70% by the year 2050[1] and urban land cover triples by 2030[7], the impetus to understand the contribution of urban areas to global biogeochemical cycles has never been stronger. Cycles of carbon and nitrogen in urban areas have generally been studied from an eddy covariance or urban-to-rural gradient perspective, but strictly urban studies that investigate within-urban variability are limited. During the growing season of 2014, we measured rates of soil respiration and nitrogen deposition across 15 sites in the Boston, MA urban area in order to quantify these fluxes and attempt to identify the drivers of variability within them. Study sites were located across a gradient of urbanness within 15 km of the Boston urban core and comprised three land cover types: lawn, landscaping, and forest.

Fig 1. Study sites in Watertown, MA (left) and Brookline, MA (right). Sites were deployed in early May in protected yards beneath a hardwood canopy. Gray PVC columns house resin-filled chromatography columns for measuring nitrogen deposition. White PVC collars in the soil function as semi-permanent chambers for measuring soil respiration. The datalogger, mounted to gray PVC, is connected to a soil moisture probe.

Methods

Soil respiration was measured bi-monthly during the growing season using an automated soil CO_2 flux system (LiCor-8100A infrared gas analyzer, LiCor Inc., Lincoln, NB). Each site had four soil respiration collars, two in each land cover type, except for two sites that did not have two land cover types (N=56 collars). Air temperature and soil moisture were also measured at the time of flux measurements.

Fig 2. Soil respiration PVC collar

Nitrogen deposition was measured continuously over the growing season using the throughfall deposition method, by which chromatography columns filled with mixed anion-cation exchange resin were affixed to funnels placed atop 2 m PVC columns. Three columns were placed below hardwood canopy at each site (N=45 columns) and collected every six weeks for extraction with KCl and analysis using the microplate reader.

Fig 3. Nitrogen deposition column

Results: Soil Respiration

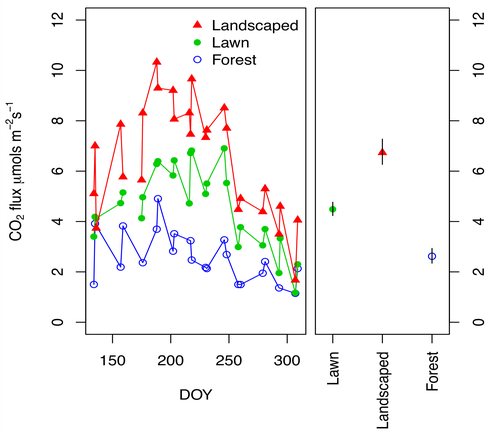


Fig 4. (Left) Time series of mean respiration fluxes at each measurement time point over the growing season. (Right) Mean flux by cover type.

	Mean CO_2 flux	June litter depth	Nov litter depth	Aug litter mass	% Soil Organic Matter	Soil Bulk Density	ISA Fraction
Mean CO_2 flux	1.00						
June litter depth	0.58	1.00					
Nov litter depth	0.34	0.85	1.00				
Aug litter mass	0.40	0.86	0.83	1.00			
% Soil Organic Matter	0.53	0.35	0.18	0.39	1.00		
Soil Bulk Density	- 0.29	- 0.27	- 0.16	- 0.42	- 0.74	1.00	
ISA Fraction	0.35	0.21	0.06	0.12	0.12	0.02	1.00

Tab 1. Correlation matrix for mean soil CO_2 flux and selected variables. "ISA fraction" is "Impervious Surface Area Fraction." Values shown are R values for correlations between variables listed.

Results: Nitrogen Deposition

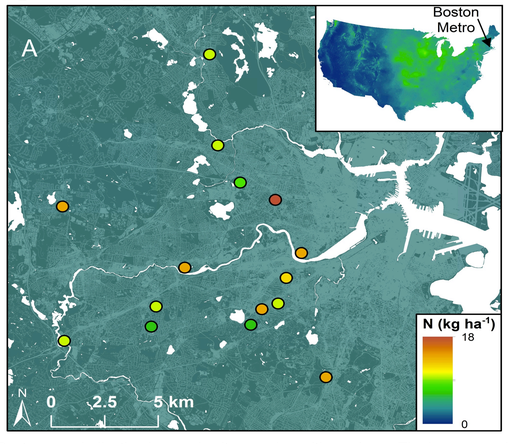
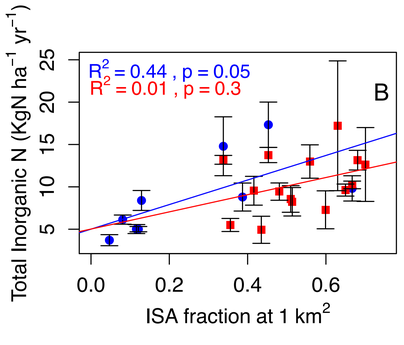
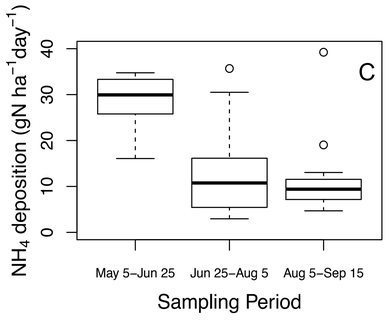


Fig 5. [A - Above] Map of the Boston area indicating inorganic nitrogen deposition values. The base map shows NADP regional deposition values (mean= 3.3 kgN ha^{-1} yr^{-1}) with an impervious surface area layer overlaid atop it. The colored points are deposition values from this study. [B – Bottom left] Plot of inorganic N deposition against local impervious surface area from an urban-to-rural gradient study in the Boston area (blue; Rao et al. 2014) and this study (red). Correlation between the two is significant along the gradient but insignificant within the city with higher ISA values. [C – Bottom left] Ammonium deposition by sampling period indicates higher ammonium deposition in the spring.





Discussion

- Soil respiration differs significantly across cover type. Mean CO_2 flux over the growing season is highest in landscaped areas, followed by lawns, and lowest in forests.
- Soil variables, such as soil organic matter and litter depth, have a stronger control over soil fluxes than degree of urbanness.
- Urban forest fluxes (2.62 ± 0.15 µmol CO_2 m$^{2\ -1}$ sec $^{-1}$) in Boston are comparable to mean forest fluxes from a rural reference area outside of Boston (1.70 ± 0.02 µmol CO_2 m$^{2\ -1}$ sec $^{-1}$)[8].
- Inorganic nitrogen deposition varies greatly across the Boston urban area, from 4.9 to 17.2 kg N ha^{-1} yr^{-1}. The mean across the study area is 10.4 +/- 0.87 kg N ha^{-1} yr^{-1}, while the National Atmospheric Deposition Program regional mean is around 3.3 kg N ha^{-1} yr^{-1}.
- The pattern of increasing atmospheric nitrogen deposition with increasing impervious surface area fraction is only significant across the urban-to-rural gradient and not within the urban area.
- Degree of urbanness affects inputs of atmospheric nitrate, which is significantly positively correalted with impervious surface area (R^2 = 0.28, p= 0.02) and traffic density at 1km x proximity to urban core and distance to highway (R^2 = 0.42, p= 0.03).
- Atmospheric ammonium inputs are higher in the spring as compared to later in the growing season, likely due to urban fertilizer application.

Next Steps

- Build a soil respiration budget for the city of Boston.
- Investigate internal soil nitrogen cycling and nitrogen leaching to determine the fate of excess urban atmospheric nitrogen inputs.
- Compare nitrogen throughfall estimates to bulk nitrogen deposition measurements in the urban area. Also, compare collection methods used by the NADP to the mixed anion-cation exchange resin method used in this study.

Acknowledgments

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