Effects of Altered Nitrogen Cycling on Temperate Deciduous Forest Trees: An Urban-Rural Comparison

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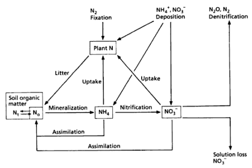
Introduction

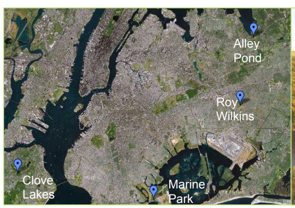
Urban forests provide important environmental benefits, leading many municipal governments to initiate citywide tree plantings. However, the biogeochemistry of urban ecosystems is quite different from that of rural forests, and nitrogen use in urban trees is not yet well understood. An understanding of nitrogen cycling in urban forests and the associated physiological changes among tree species is critical to the success of urban forest restoration. My objective in this study was to examine the response of several native hardwood tree species to a modified urban nitrogen cycle by measuring foliar nitrogen content, δ15N, and nitrate reductase activity (NRA) in young trees in a rural forest and several urban forests.



Nitrogen transformations and processes affecting ^{15}N abundances in forest ecosystems. N_s, total organic nitrogen in soil; N_b, microbial nitrogen; NH_4^+, extractable soil ammonium; NO_3^-, extractable soil nitrate. (From Nadelhoffer and Fry, 1994.)

Study Sites

Tree leaves was collected at four recently reforested urban park sites in Staten Island, Brooklyn and Queens. The trees at these sites were saplings planted in open areas adjacent to intact forest. The rural forest used for comparison was Black Rock Forest in Orange County, NY. Trees at Black Rock Forest were often found under lower light conditions due to the intact forest canopy. Saplings were found for all tree species at Black Rock Forest except for *Nyssa sylvatica*, in which case mature tree leaves were used.



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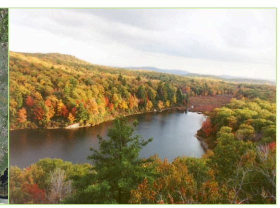

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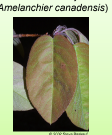
Methods

At each forest site several leaves were harvested from five trees of each of four species: *Quercus rubra*, *Amelanchier canadensis*, *Nyssa sylvatica*, and *Prunus serotina*. Foliar nitrate reductase activity (NRA) was measured in late August at midday on fully expanded leaves by an *in vivo* incubation of approximately 200 mg leaf punches with KNO_3, and subsequent colorimetric determination of NO_2^- after 1 hour (Högberg *et al*., 1986). Leaf material was also harvested and dried for analysis of the abundance of ^{15}N and % nitrogen content. Data was analyzed with the statistical software program R, using a linear mixed effects model with site as the random effect to account for variation between the urban sites, which have different land use histories and may significantly differ in biogeochemistry.

Serviceberry (*Amelanchier canadensis*)



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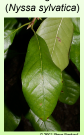
Blackgum (*Nyssa sylvatica*)



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Black Cherry (*Prunus serotina*)

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Red Oak (*Quercus rubra*)

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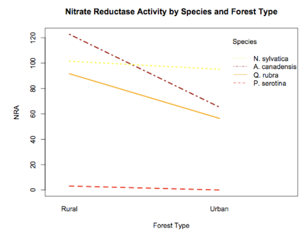
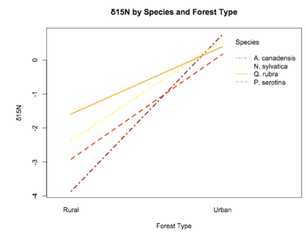
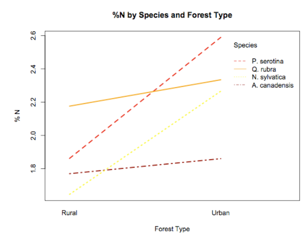
Results

- Foliar NRA varied significantly among the hardwood species in both the urban and rural forests with *Prunus serotina* showing almost no NRA at all.
- Foliar NRA was significantly higher in the rural forest compared to the urban forests ($p<.05$).
- Tree species varied significantly in foliar abundance of ^{15}N.
- Foliar $\delta^{15}N$ was significantly higher in the urban forests compared to the rural forest ($p<.05$).
- %N was not significantly different between foliage of rural and urban forests or between tree species, but significant interaction effects were found.







NRA is expressed in nmol NO_2^- per gram fresh leaf weight per hour; $\delta^{15}N$ is expressed in $^0/_{00}$.

Results of Linear Mixed Models

Observations: 100

Fixed effects: NRA ~ Species * Forest Type

	Value	Std.Error	DF	p-value
SpeciesNs	-21.17184	21.87428	89	0.3357
SpeciesPs	-119.57875	21.87428	89	0.0000
SpeciesQr	-31.04492	21.87428	89	0.1593
Forest_TypeUrban	-57.36096	17.30320	3	0.0452
SpeciesNs:Forest_TypeUrban	50.97444	24.45619	89	0.0400
SpeciesPs:Forest_TypeUrban	54.24162	24.45619	89	0.0291
SpeciesQr:Forest_TypeUrban	22.15833	24.45619	89	0.3674

Fixed effects: $\delta^{15}N$ ~ Species * Forest Type

	Value	Std.Error	DF	p-value
SpeciesNs	1.4820	0.4985729	89	0.0038
SpeciesPs	0.9500	0.4985729	89	0.0600
SpeciesQr	2.2780	0.4985729	89	0.0000
Forest_TypeUrban	4.6225	1.0808747	3	0.0235
SpeciesNs:Forest_TypeUrban	-1.6400	0.5574215	89	0.0042
SpeciesPs:Forest_TypeUrban	-1.5305	0.5574215	89	0.0073
SpeciesQr:Forest_TypeUrban	-2.6400	0.5574215	89	0.0000

Fixed effects: %N ~ Species * Forest Type

	Value	Std.Error	DF	p-value
SpeciesNs	-0.1240	0.2513011	89	0.6229
SpeciesPs	0.0920	0.2513011	89	0.7152
SpeciesQr	0.4060	0.2513011	89	0.1097
Forest_TypeUrban	0.0905	0.3413130	3	0.8081
SpeciesNs:Forest_TypeUrban	0.5290	0.2809631	89	0.0630
SpeciesPs:Forest_TypeUrban	0.6365	0.2809631	89	0.0259
SpeciesQr:Forest_TypeUrban	0.0680	0.2809631	89	0.8093

Discussion

Urban-Rural Comparison

Overall foliar NRA was found to be lower in the urban forests, despite the higher availability of light at those sites. This unexpected result may indicate that NO_3^- is leaching out of the urban parks, which receive heavy stormwater flows because they are often surrounded by impermeable surfaces. The difference in ^{15}N abundance between the forest types is likely due to ^{15}N enriched deposition from fossil fuels and to leaching of NO_3^- from urban forest soils. The lower NRA and higher $\delta^{15}N$ in urban foliage indicates that the available soil nitrogen in these locations may be primarily in NH_4^+ form. The urban forests are have been recently planted and the lack of organic matter in these systems compared to the rural forest means that ^{14}N is more likely to have been leached out of the system. As the urban forest matures, more ^{14}N may be retained in the system through recycling of organic matter.

Species Differences

Although the overall difference between %N in urban and rural forest foliage was not significant, there were significant interaction effects showing that some species were more successful than others in incorporating the available urban soil nitrogen into their foliage. This result is probably linked to the differences in NRA between tree species and may reflect a preference for NO_3^- vs. NH_4^+ nitrogen forms. Little is known about nitrogen use in *Amelanchier canadensis* or *Nyssa sylvatica*, but *Quercus rubra* has been found to prefer NH_4^+ (Bigelow and Canham, 2007), which may explain why NRA was lower in the urban sites where NH_4^+ may actually have been more available. *Prunus serotina* foliage showed very little NRA at either site, although a previous study found this species to grow best in a greenhouse experiment when provided with a high ratio of NO_3^-/NH_4^+ (Horsley, 1988). In this study, it seems that *Prunus serotina* may have responded strongly to increased NH_4^+ in the urban sites, as foliar %N in that species increased significantly from the rural to the urban forests. However, a possible explanation for this result is that *Prunus serotina* reduces nitrate primarily in its roots rather than its leaves. *Quercus rubra* and *Amelanchier canadensis* showed a sharper decline in foliar NRA from the rural to urban forests, and these species showed a smaller increase in %N. If there is significantly less NO_3^- in the urban forest sites, trees with an affinity for NO_3^- over NH_4^+ may not be able to take advantage of the increased available nitrogen in the city. Interspecific variation in ^{15}N abundance may be influenced by the type of mycorrhizal associations formed by each tree species (Craine *et al*., 2009).

Future Steps

A comparison of NRA in both the roots and leaves of these species would provide a more complete picture of their nitrogen use. It would also be beneficial to repeat this experiment earlier in the growing season, as these foliar NRA measurements were taken at the end of a hot, dry summer and some trees may have experienced drought conditions.

Nitrogen use in urban trees has implications for carbon sequestration and water quality, two areas of great concern for urban ecosystem management. NO_3^- is easily dissolved in water and subsequently leaches into and pollutes nearby water sources. Additionally, the ability of trees to utilize nitrogen, including NO_3^- uptake, has implications for growth rates and, therefore, carbon sequestration. Nitrogen-rich enzymes are required for photosynthesis, and increased leaf %N may therefore indicate increased growth rates of the trees (Reich *et al*., 1997). Furthermore, a greater understanding of urban tree physiology and ecosystem nutrient cycling will help future urban restoration efforts ensure the integrity of ecological processes and the creation of suitable habitat for a wide range of biodiversity.

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