Patterns and Controls on Atmospheric Nitrogen, Phosphorus, and Carbon Deposition in Urban Environments

Pamela Templer, Stephen Decina, Lucy Hutyra

BOSTON UNIVERSITY

Human Alteration of the Nitrogen Cycle

Electrical Power Plants

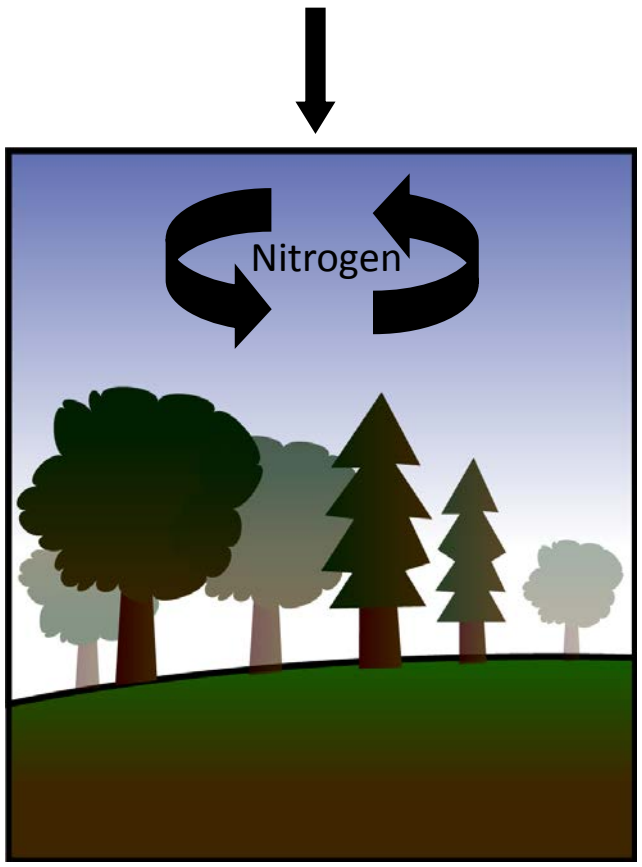
Increased Nitrogen Emissions

Automobiles

Agriculture
(Synthetic Fertilizers & Leguminous Crops)

Human Alteration of the Nitrogen Cycle

Atmospheric Deposition



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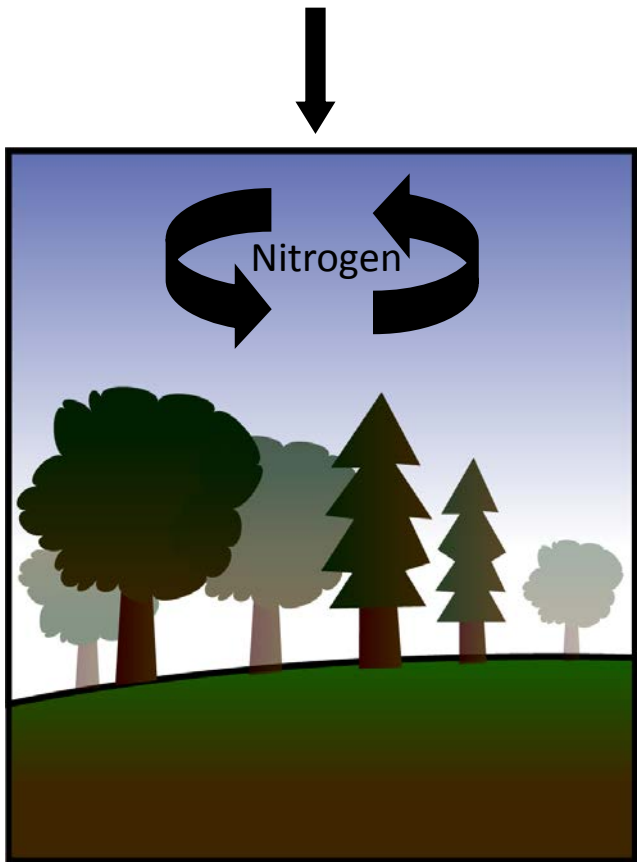

Nitrogen Saturation:
Too much of a good thing!

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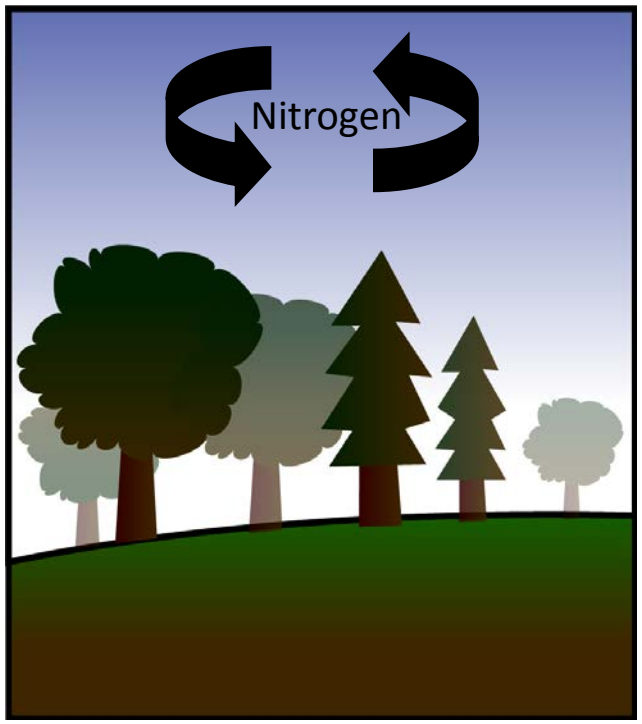
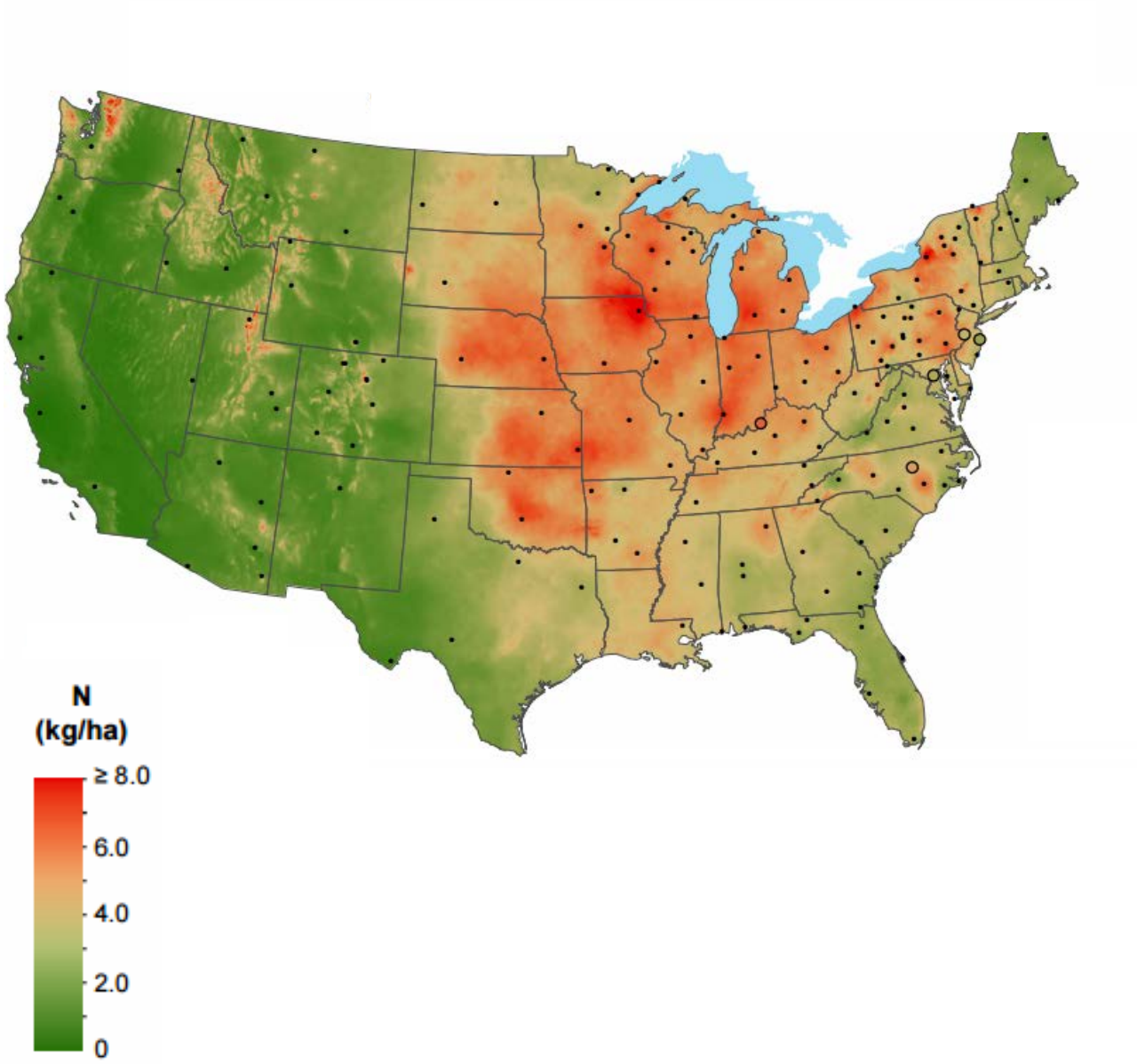


NO_3^- Leaching

Nitrogen Saturation:
Too much of a good thing!

- Release of N_2O
- Reduced forest productivity
- Acidification of stream water
- Eutrophication (algal blooms)
- Blue baby syndrome

National Atmospheric Deposition Program



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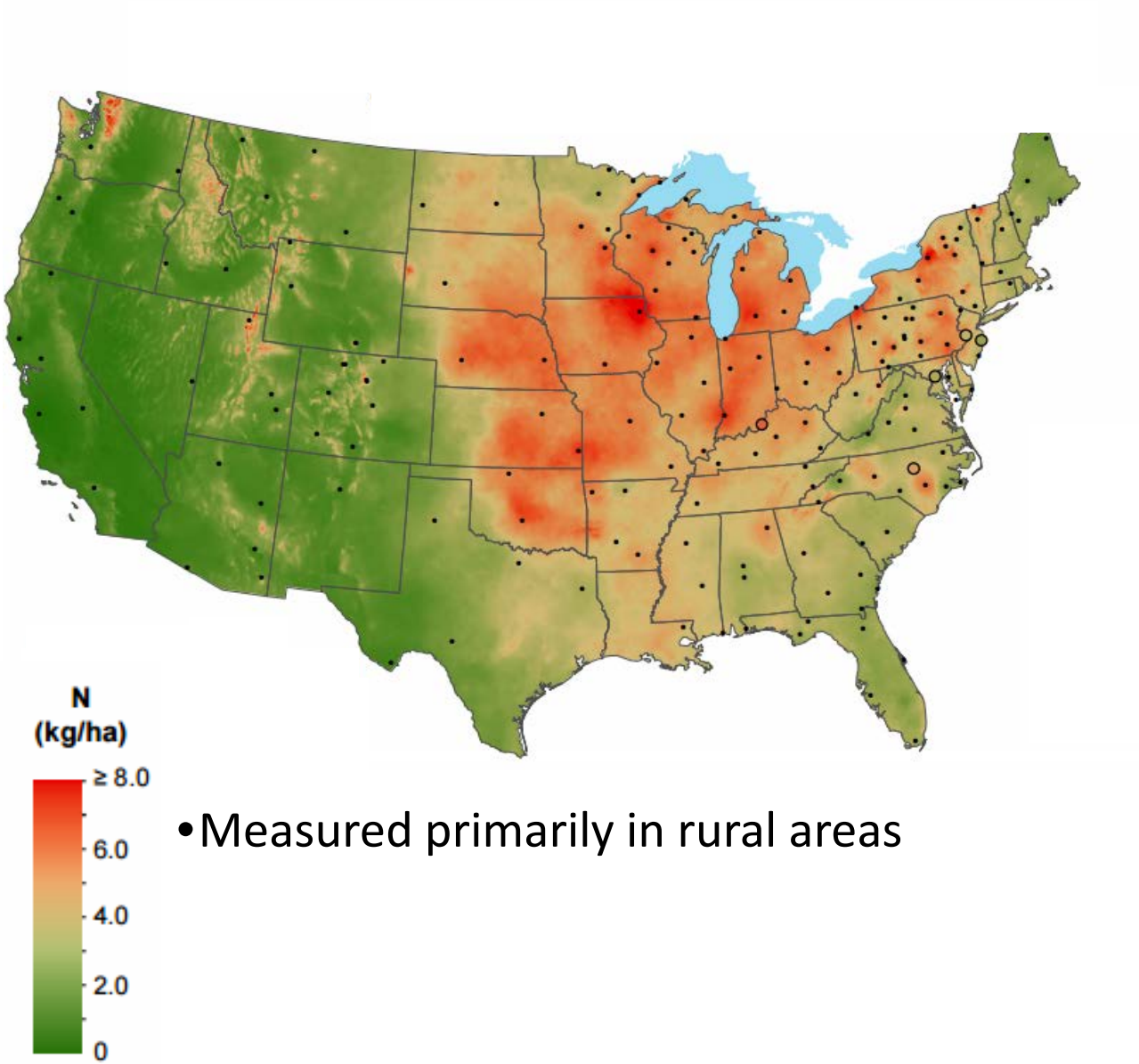
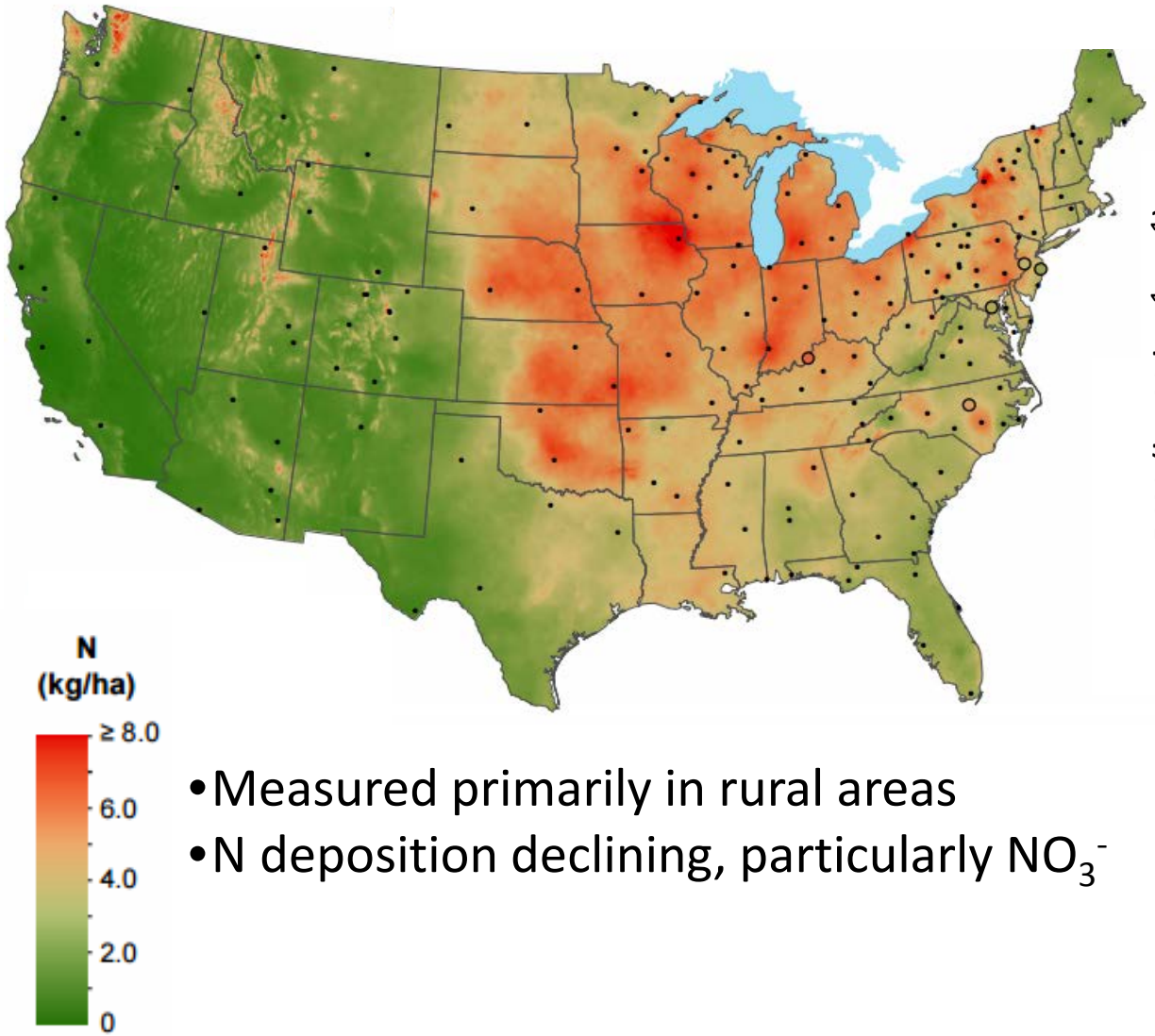
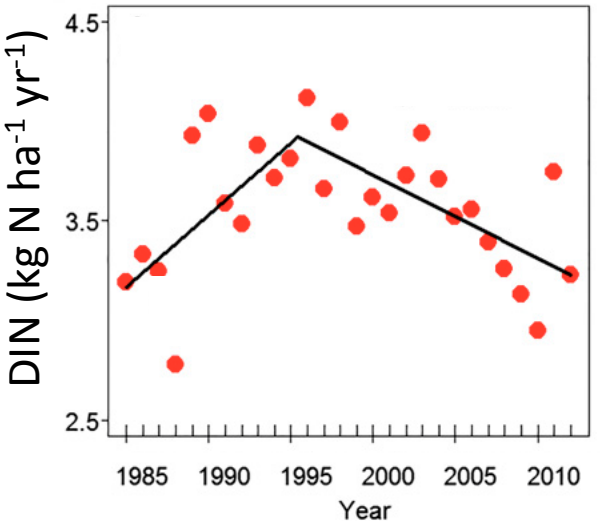


- Measured primarily in rural areas

National Atmospheric Deposition Program



N Deposition Declining



- Measured primarily in rural areas
- N deposition declining, particularly NO_3^-

Du, PNAS, 2016

Hotspots of
N deposition in
urban areas

Why Examine Nitrogen in Urban Ecosystems?

- 2% global land area, but majority of NO_x emissions
- 50% of human population live in urban centers
- Lack studies of nitrogen biogeochemistry in urban areas

Two Types of Urban Biogeochemistry Studies

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Urban-Rural Comparisons

Rural Urban

Bettez and Groffman 2013

Two Types of Urban Biogeochemistry Studies

Urban-Rural Comparisons

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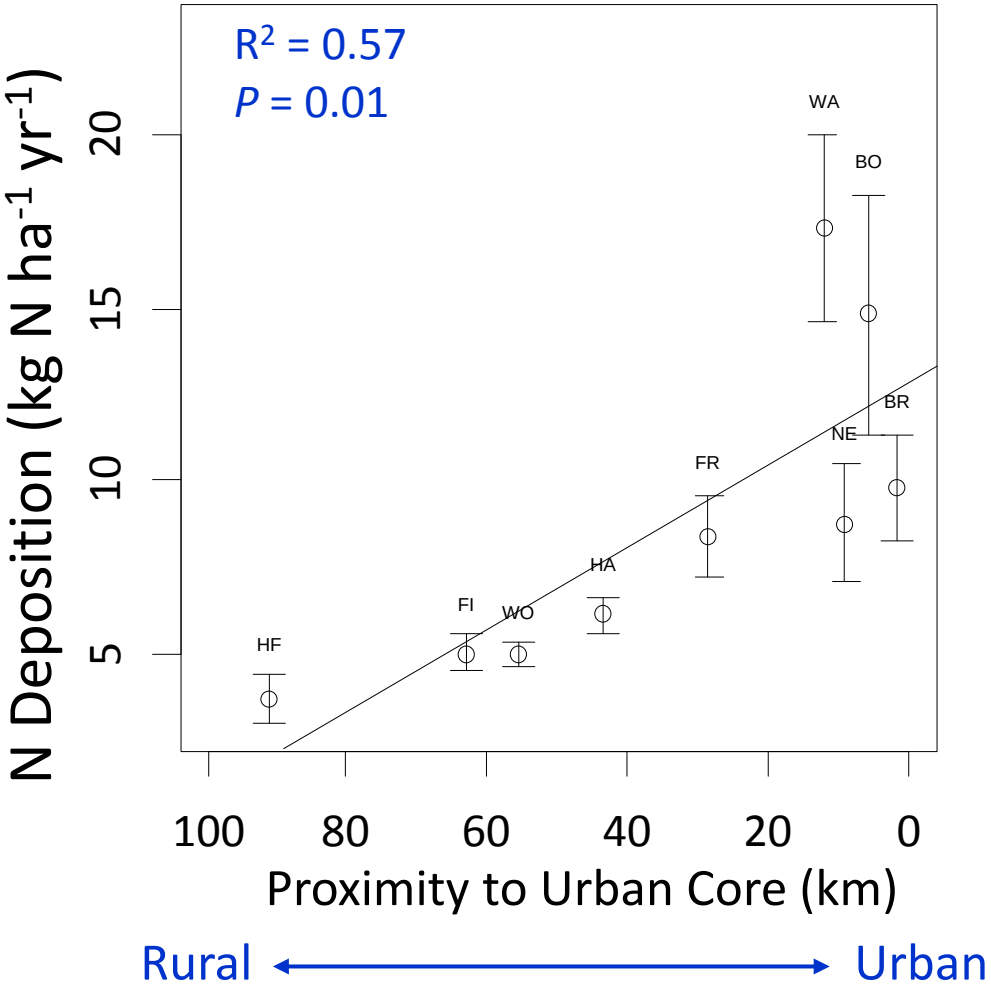
Urban-Rural Gradients



Rao et al. 2014

How heterogeneous is biogeochemical cycling of nitrogen in urban ecosystems and what are the controls on these processes?

New National Atmospheric Deposition Program Sites in Boston

NADP MA22 - Established 2015

NADP MA98 - Established 2016

New National Atmospheric Deposition Program Sites in Boston

Not feasible to set up multiple NADP sites

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Ion Exchange Resin Collector

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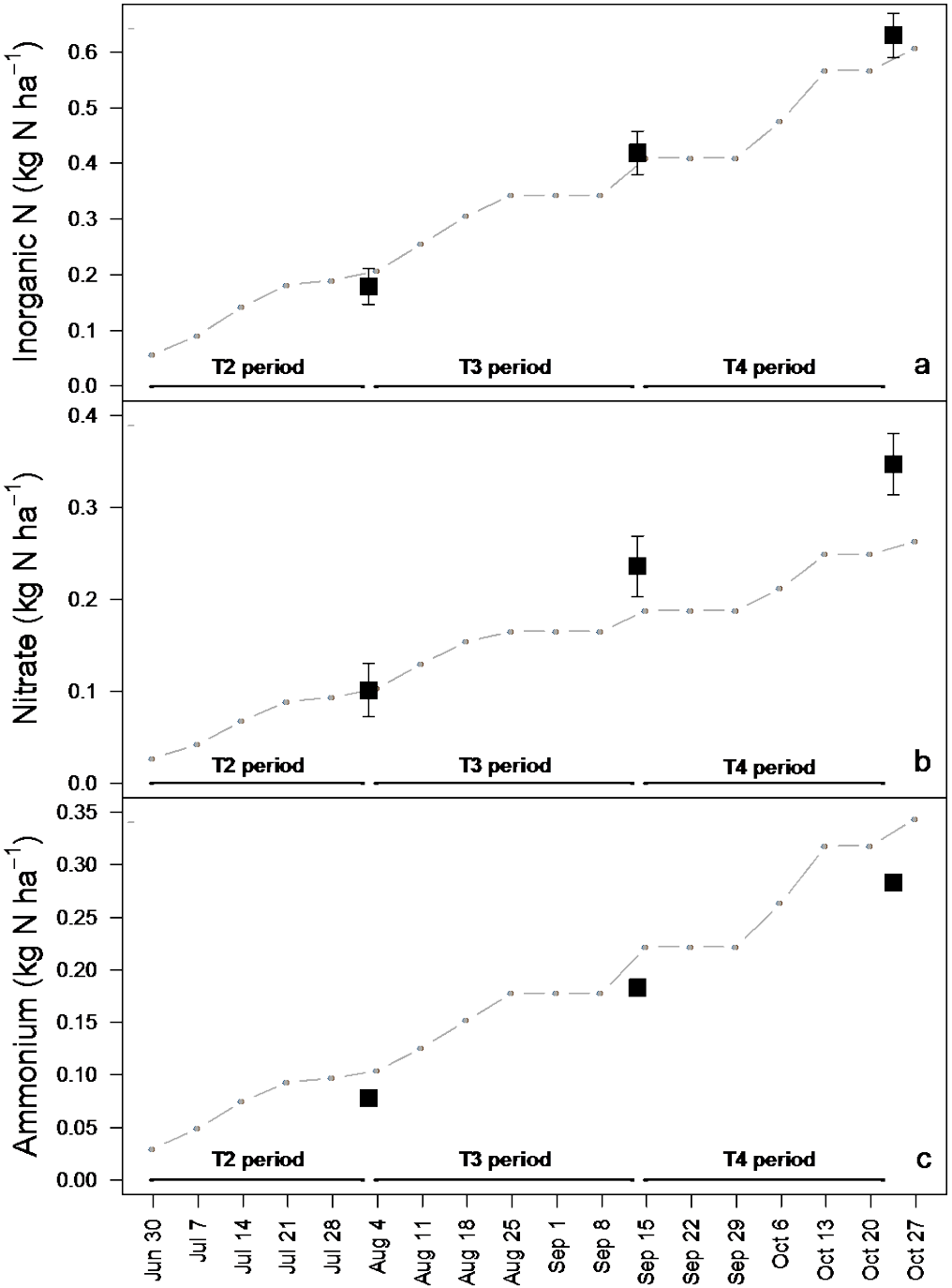
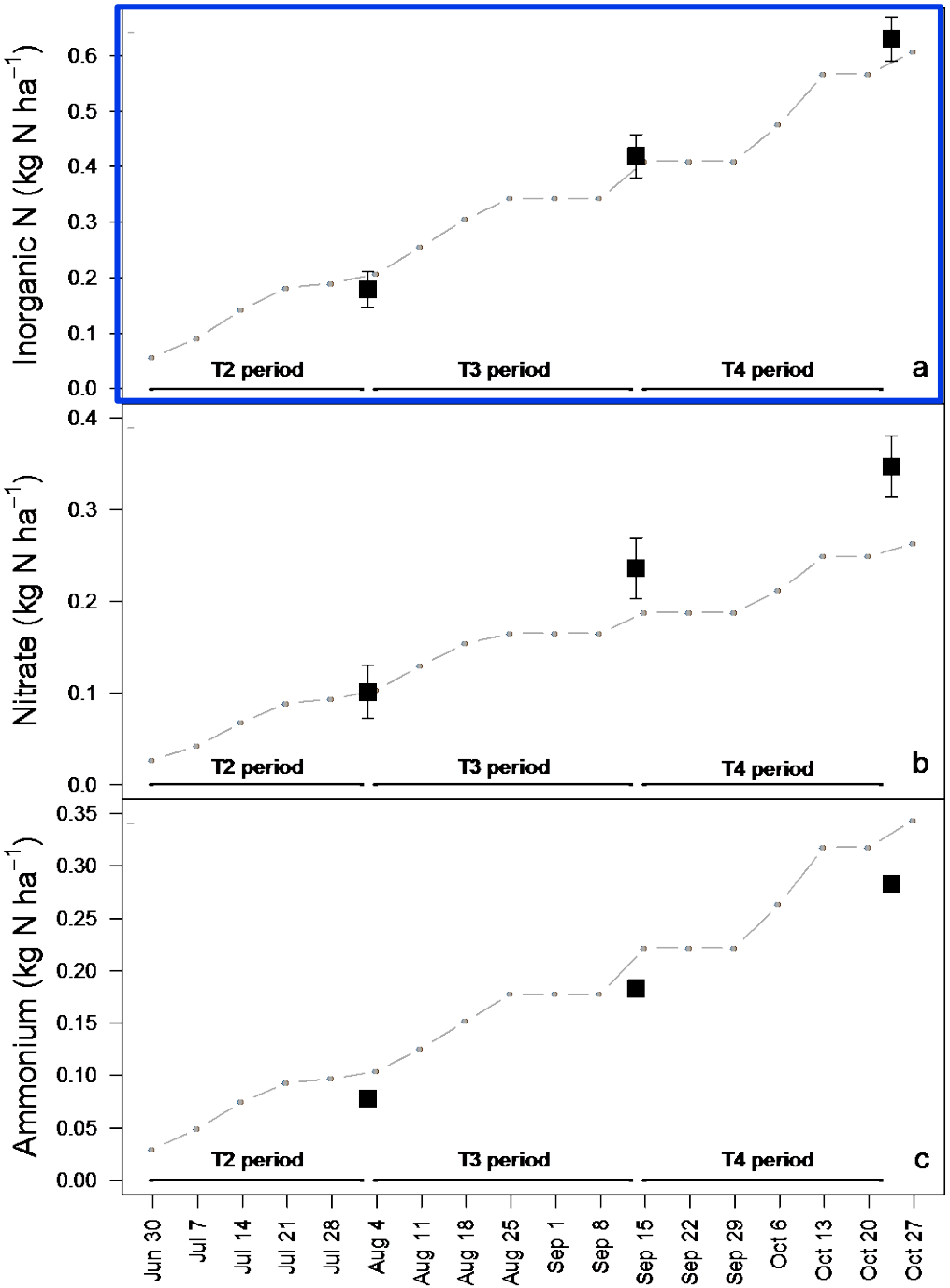
NADP and Ion Exchange Resin Collectors



NADP

Ion Exchange Resin Collectors

NADP and Ion Exchange Resin Collectors



- Cumulative total inorganic nitrogen in agreement

NADP

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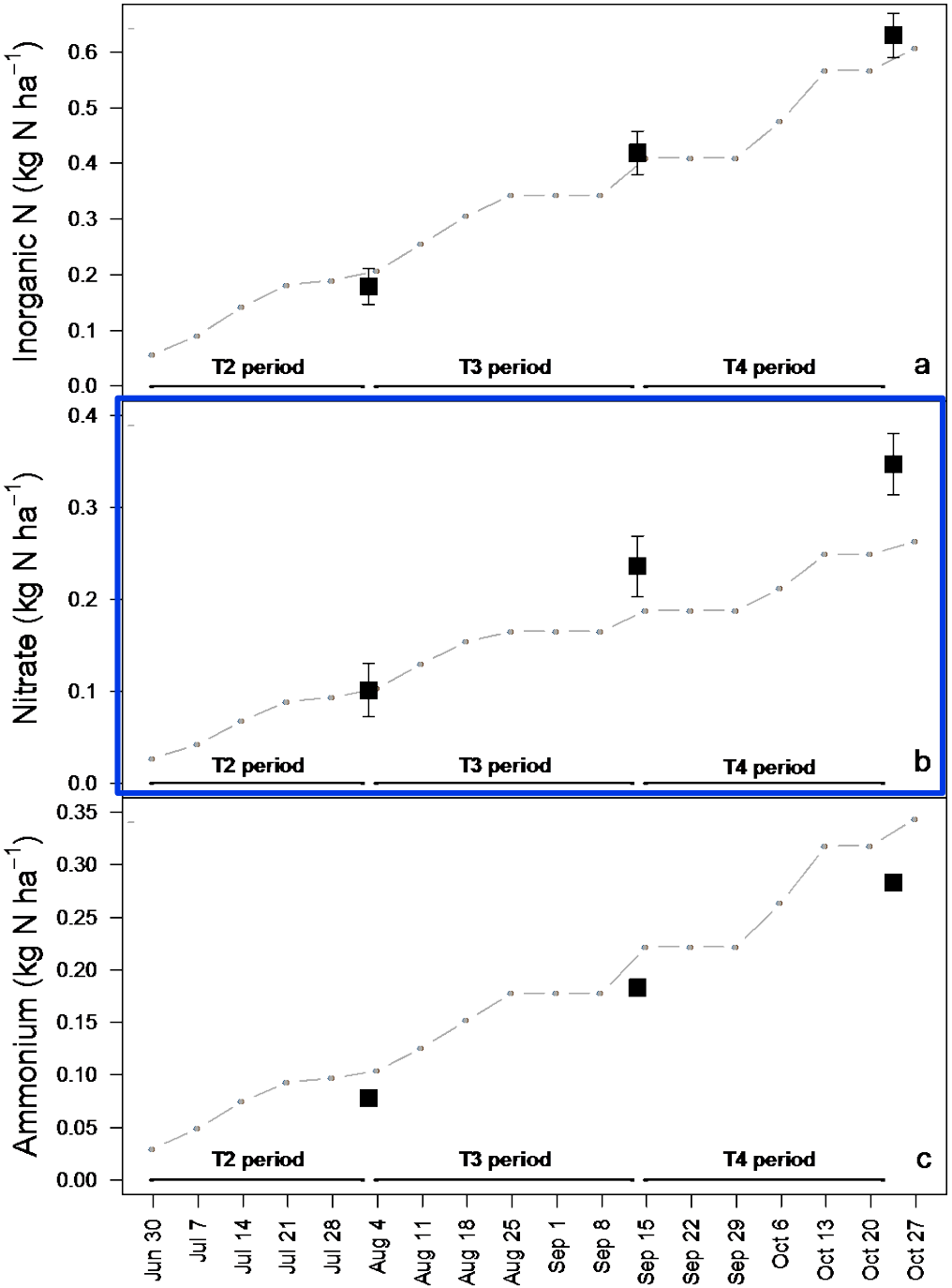

- Cumulative total inorganic nitrogen in agreement
- Ion exchange columns
  - overestimate nitrate

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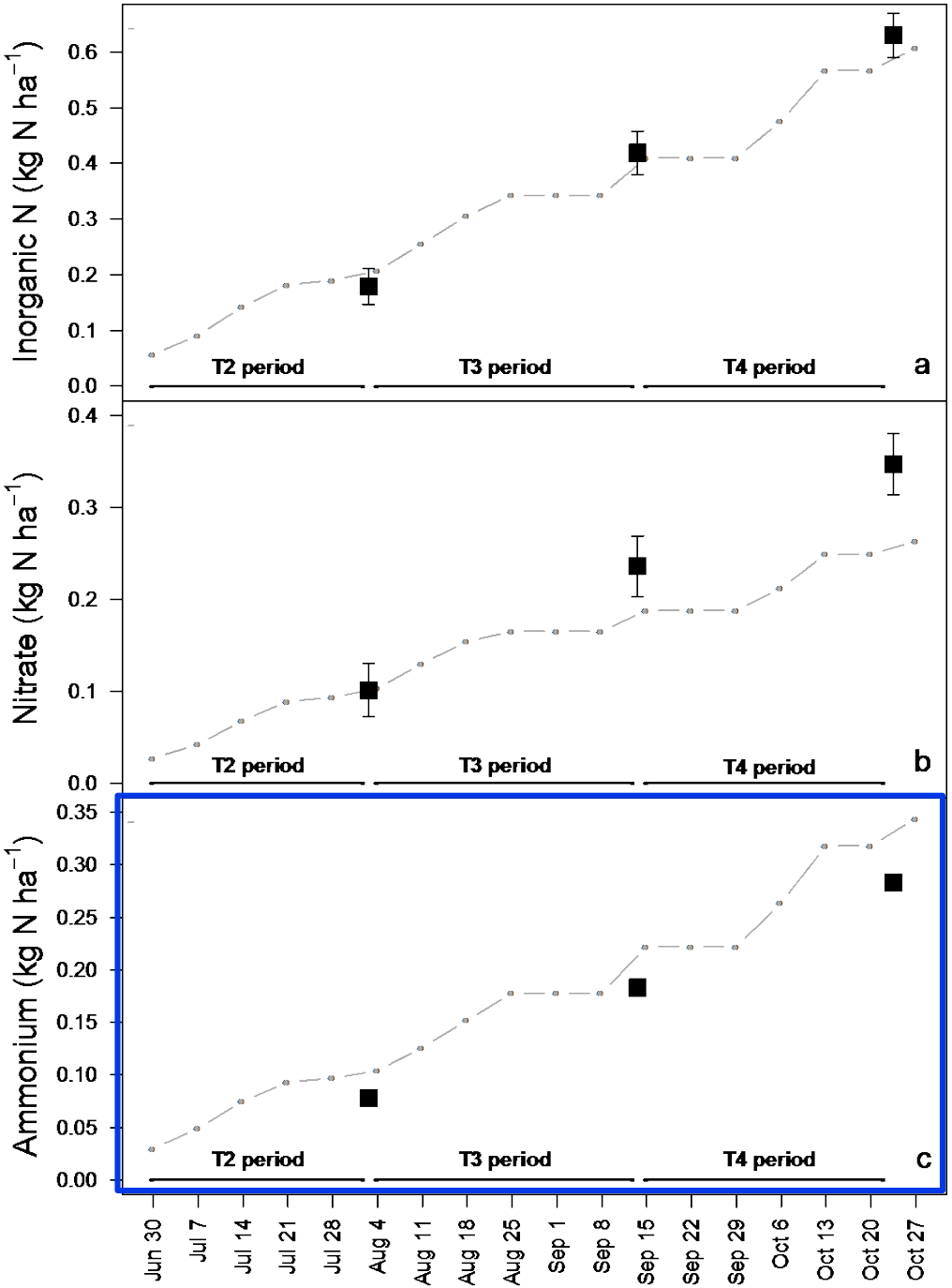
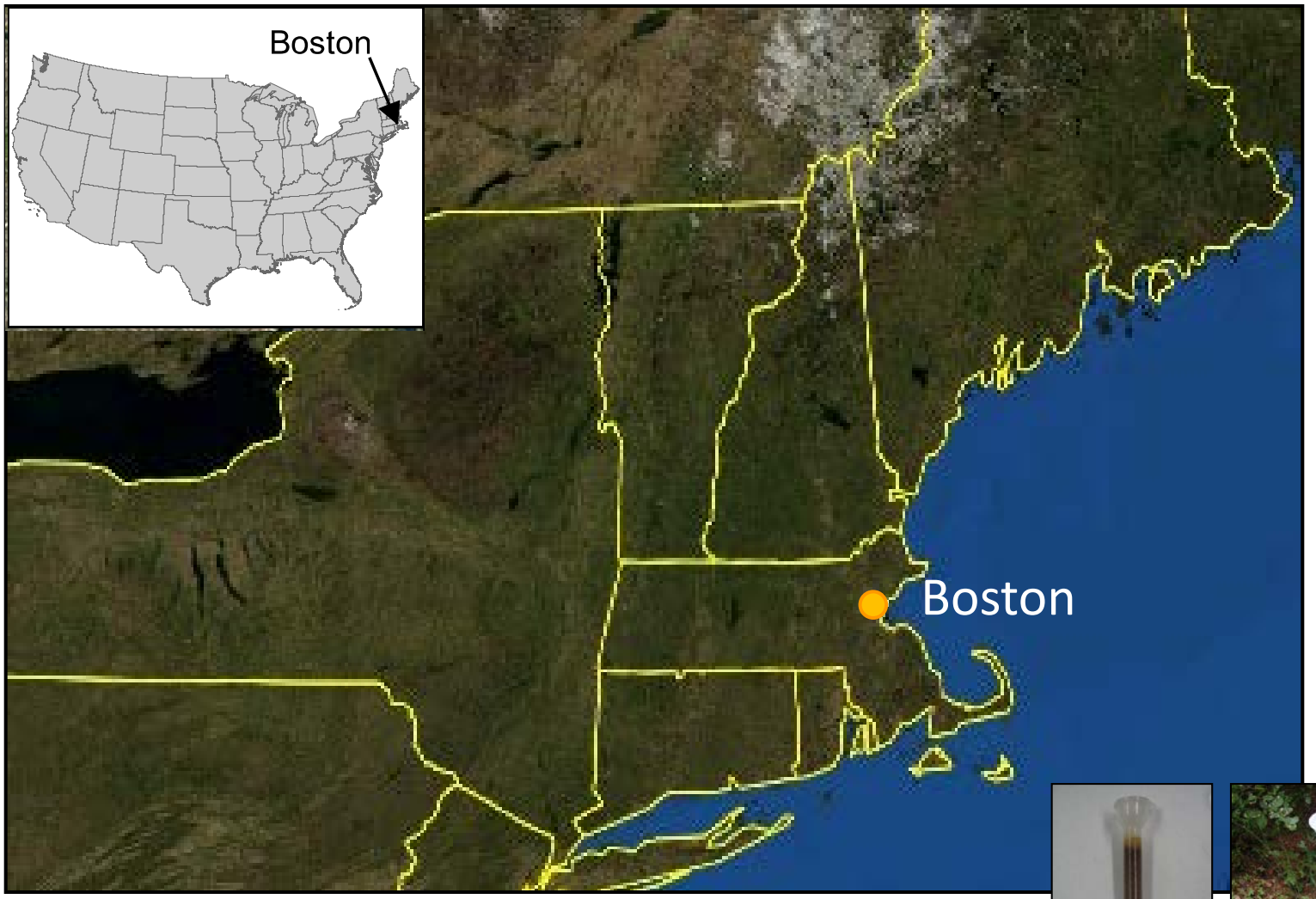


- Cumulative total inorganic nitrogen in agreement
- Ion exchange columns
  - overestimate nitrate
  - underestimate ammonia

NADP

Ion Exchange Resin Collectors

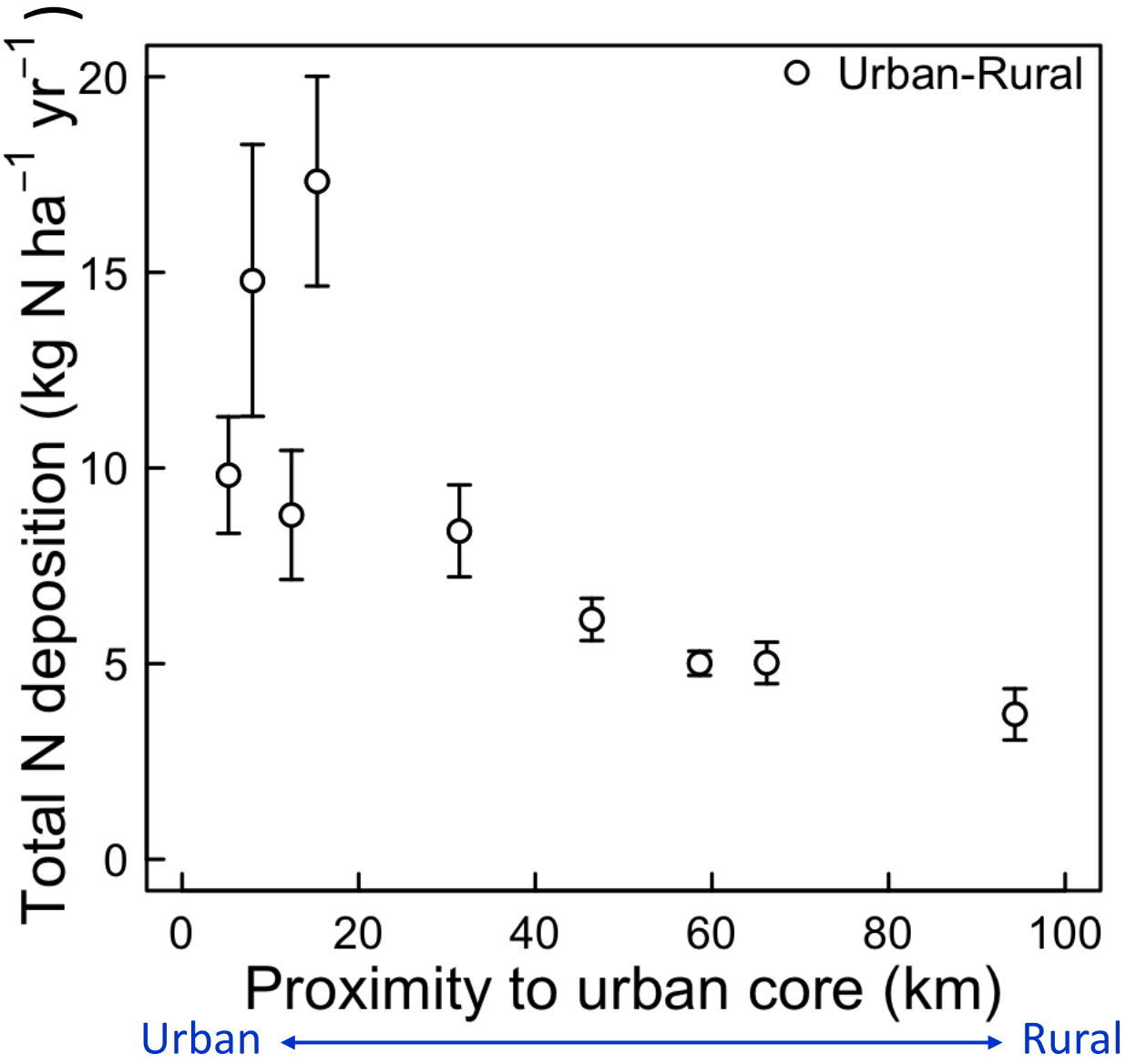
Nitrogen Cycling within Greater Boston Area



Measured Throughfall Using Ion Exchange Resin Collectors at 15 Sites Throughout Boston

Steve Decina, PhD

Atmospheric Deposition High and Spatially Variable



Rao et al. 2014. Biogeochemistry

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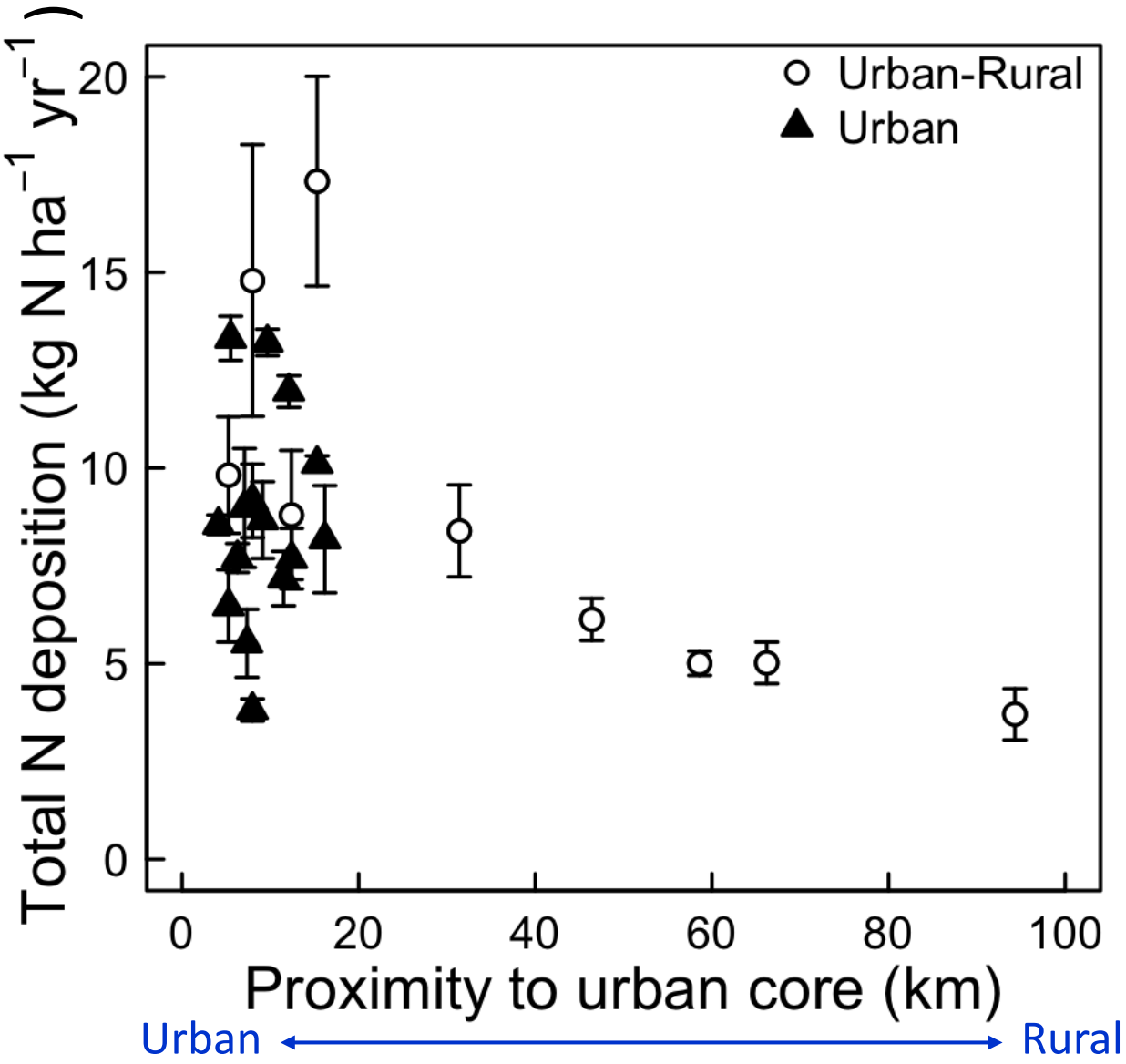

Decina et al. 2017. Science of the Total Environment

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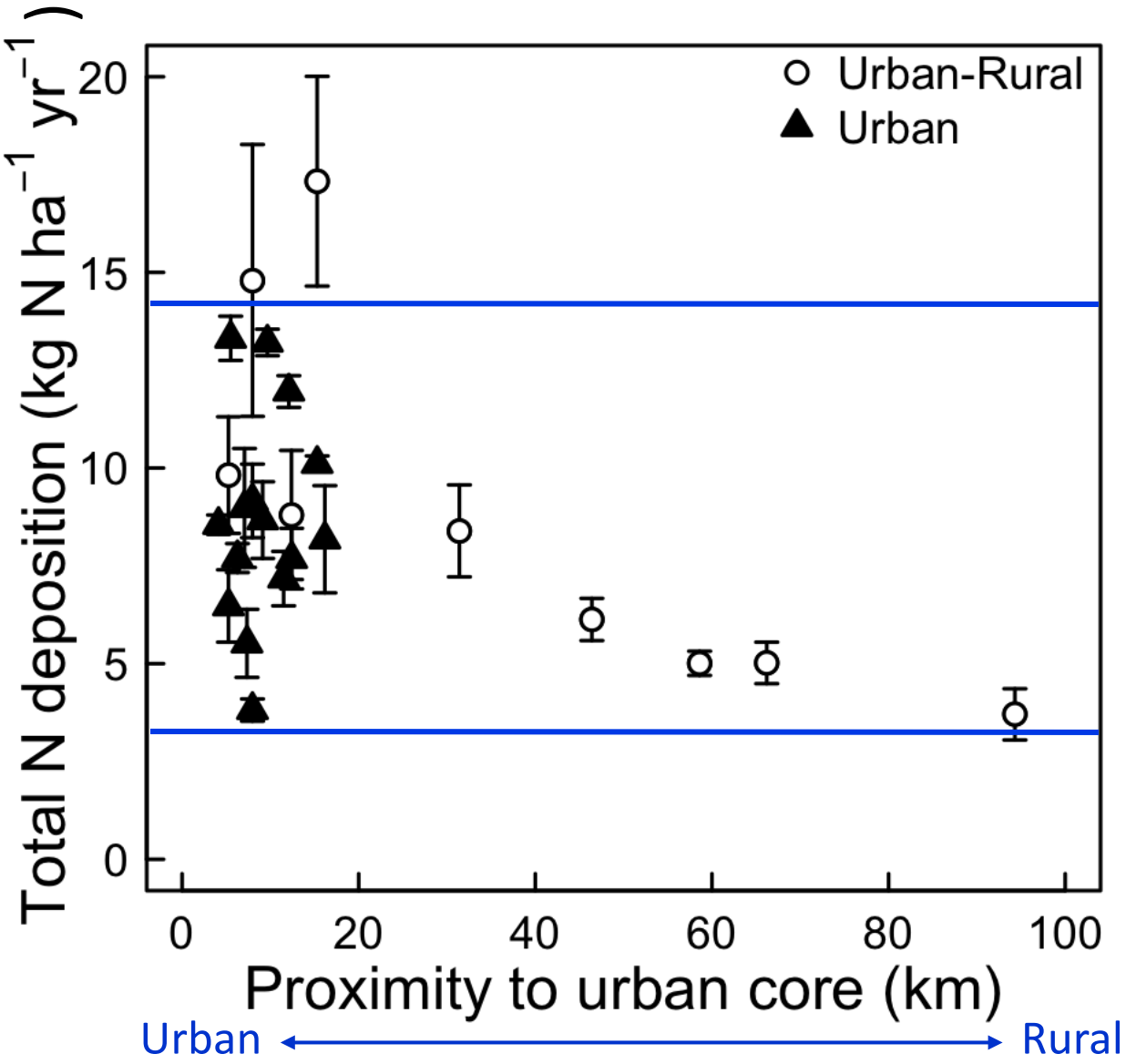

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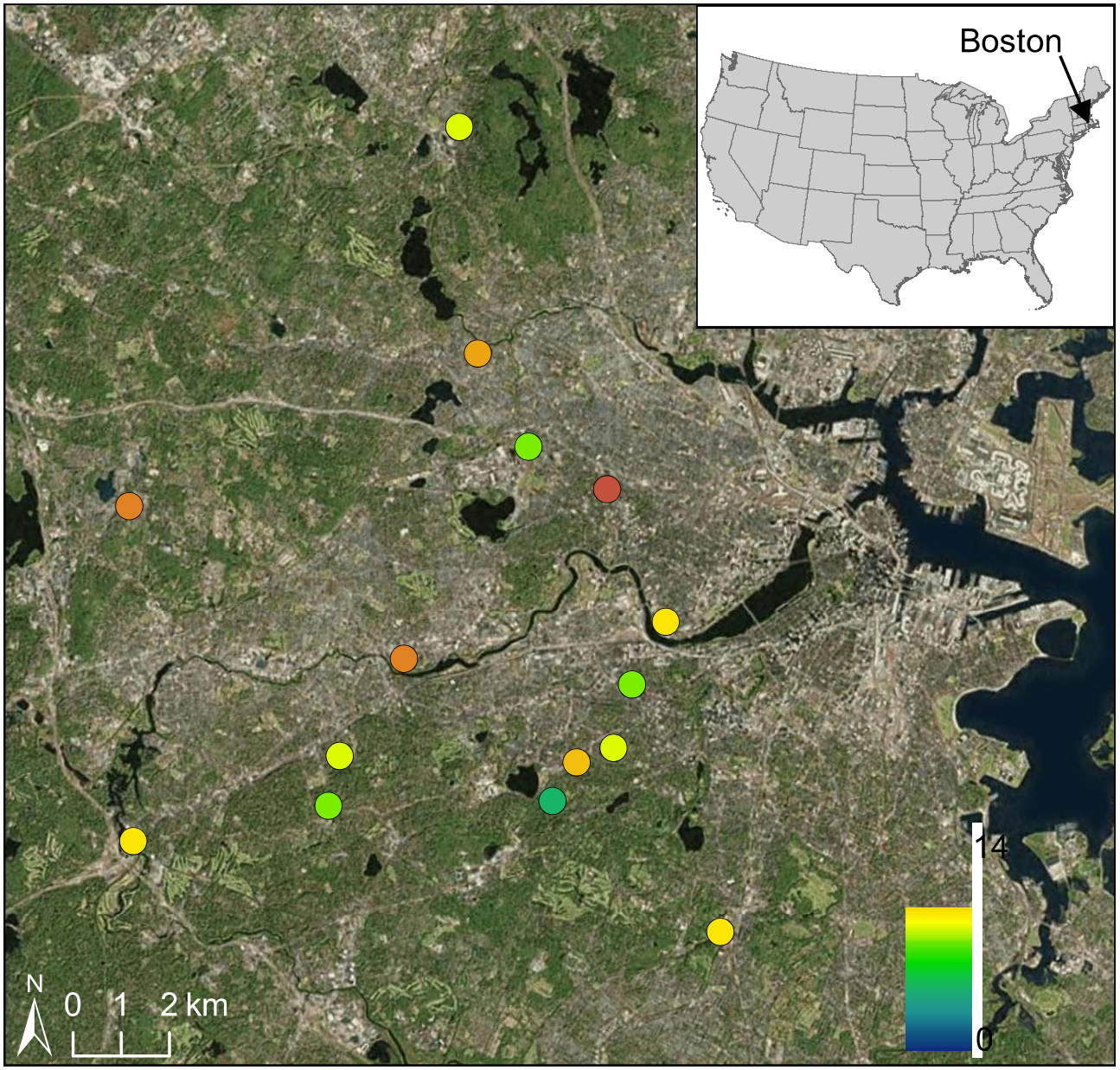
Atmospheric Deposition High and Spatially Variable

N Deposition
- 5 times higher than rural areas
- Vary 3-4 fold



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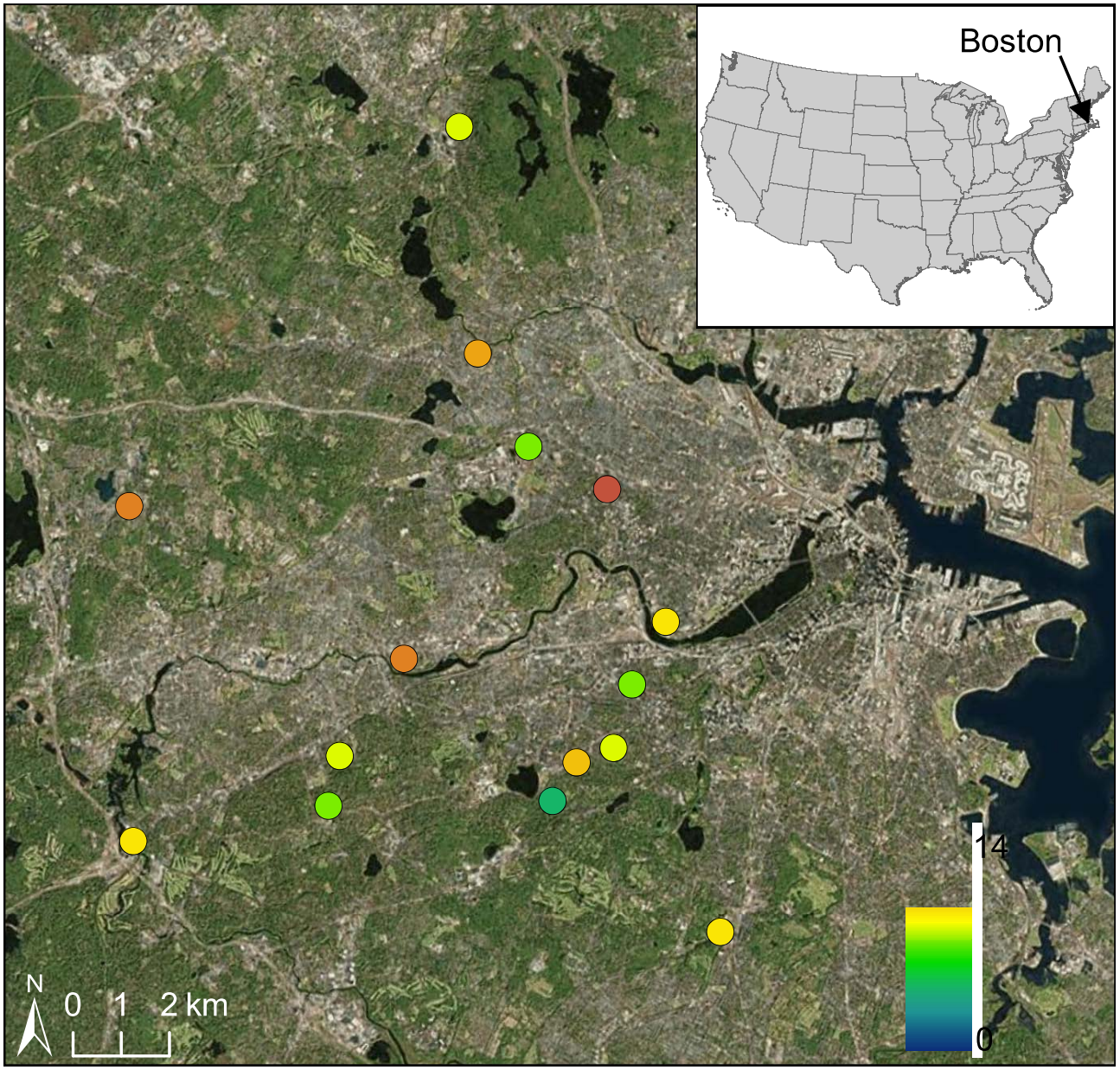
Atmospheric Deposition High and Spatially Variable

N Deposition

- 5 times higher than rural areas
- Vary 3-4 fold
- What controls the variability?



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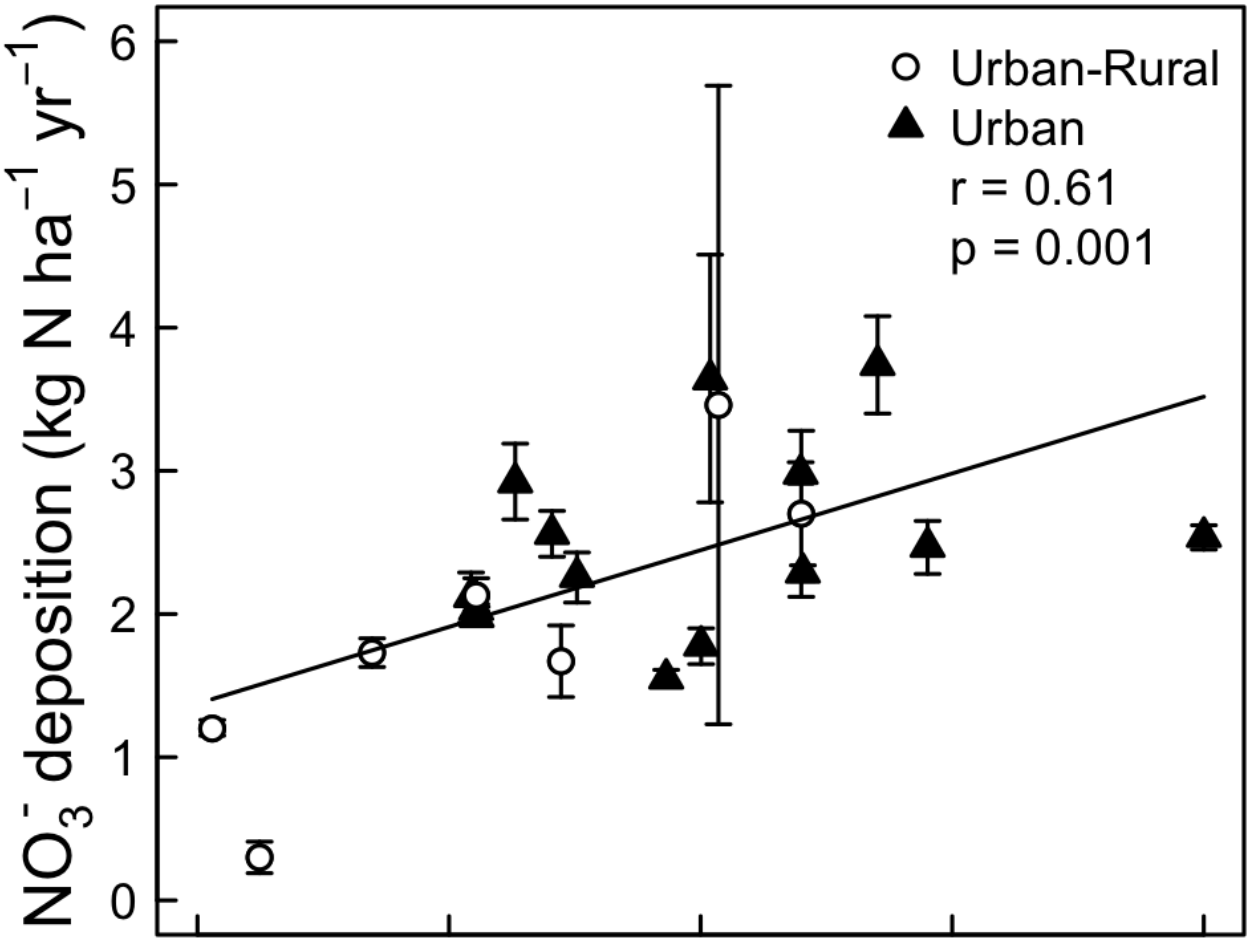
Deposition Correlated with N Emissions from Cars



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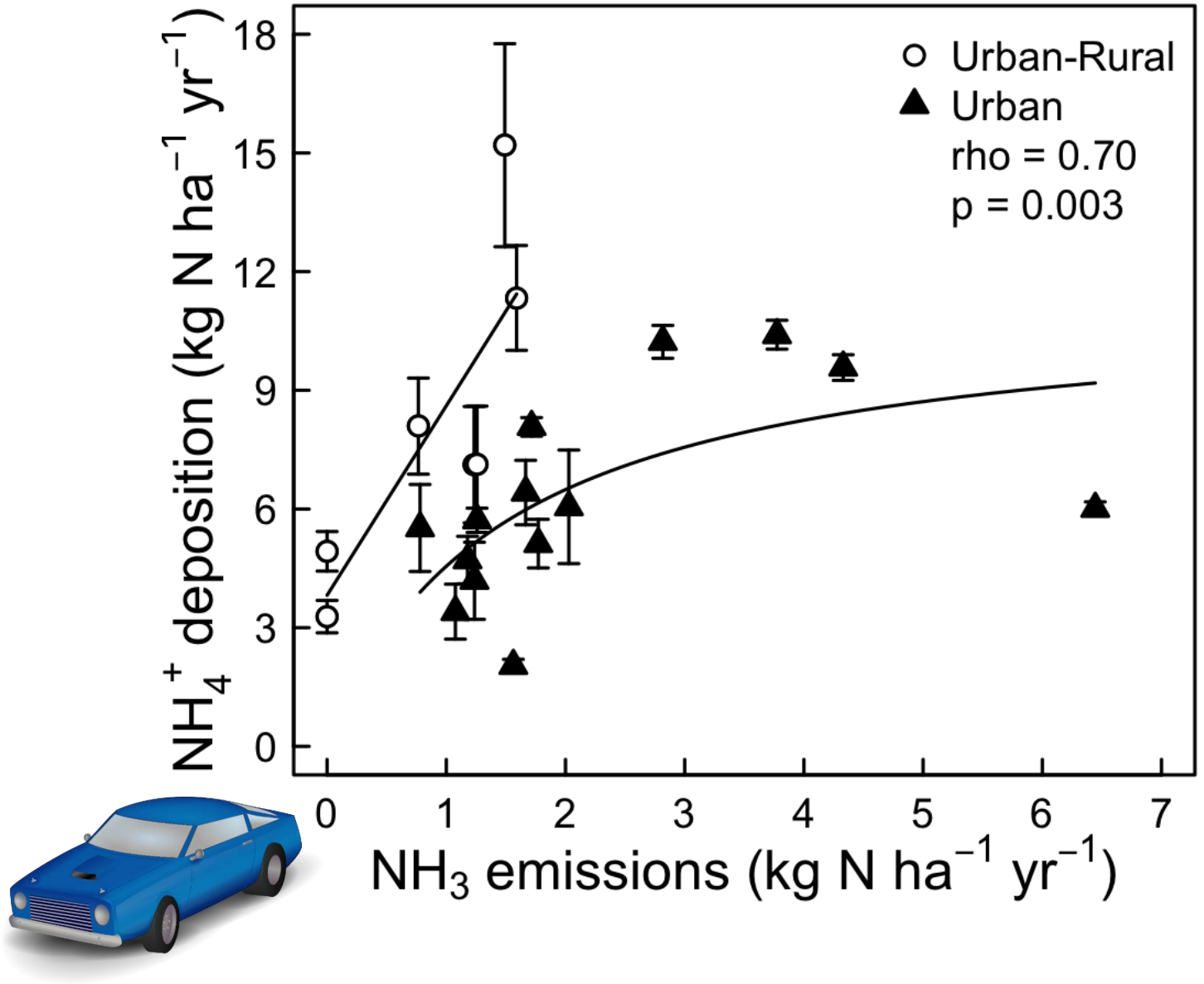
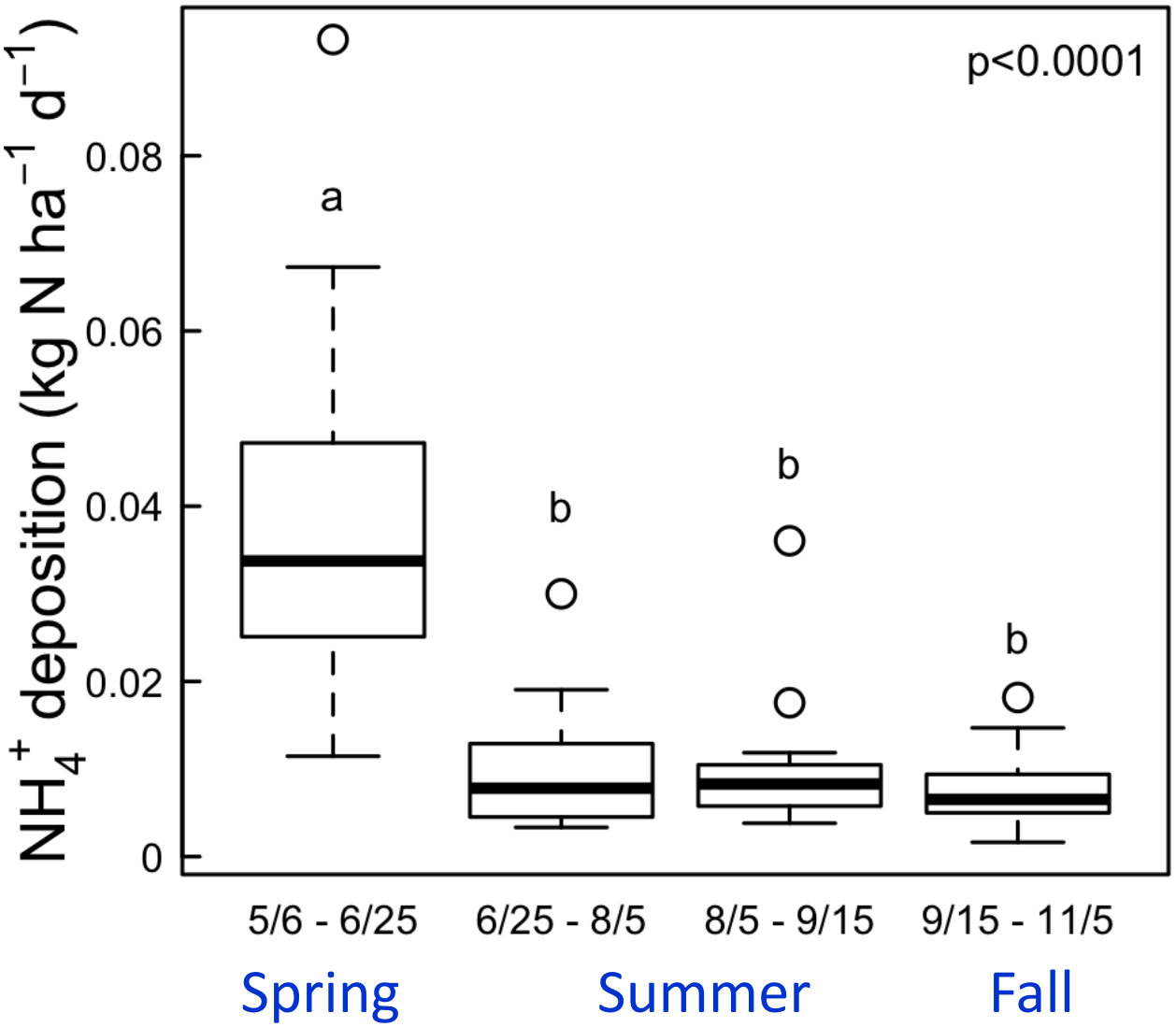


Elevated Ammonia Deposition in Spring Due to Fertilizer Additions and Canopy Processes



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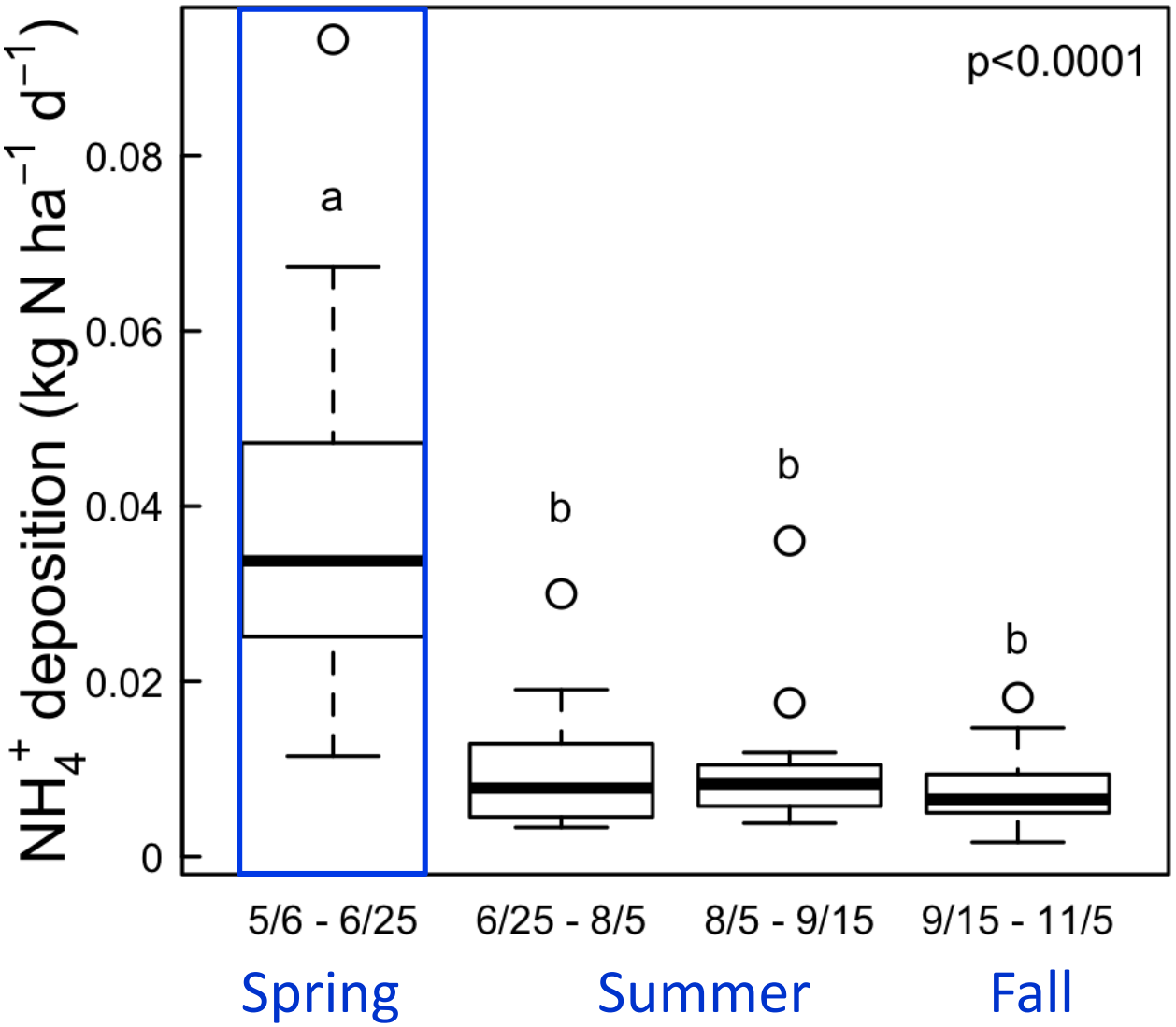

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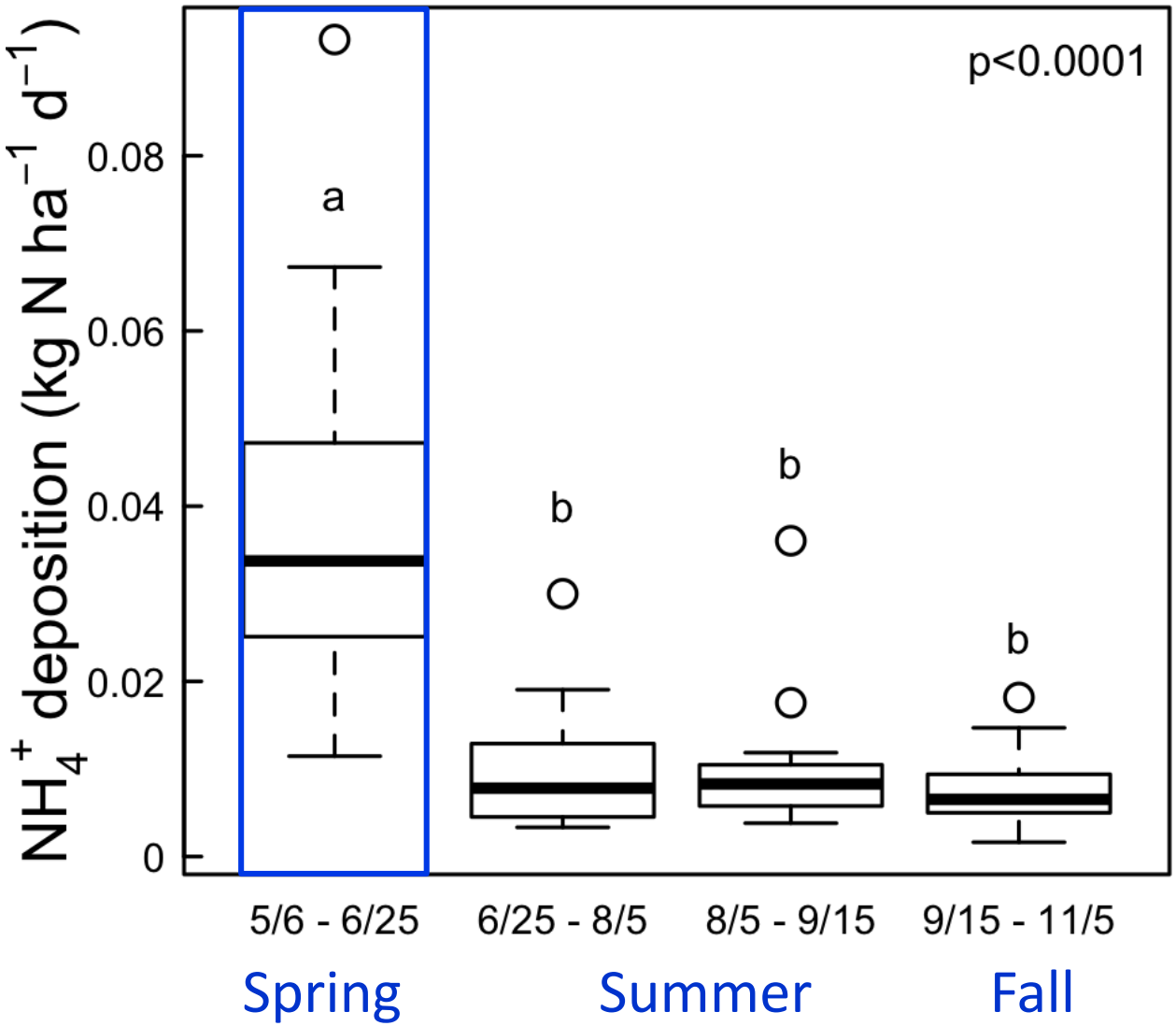

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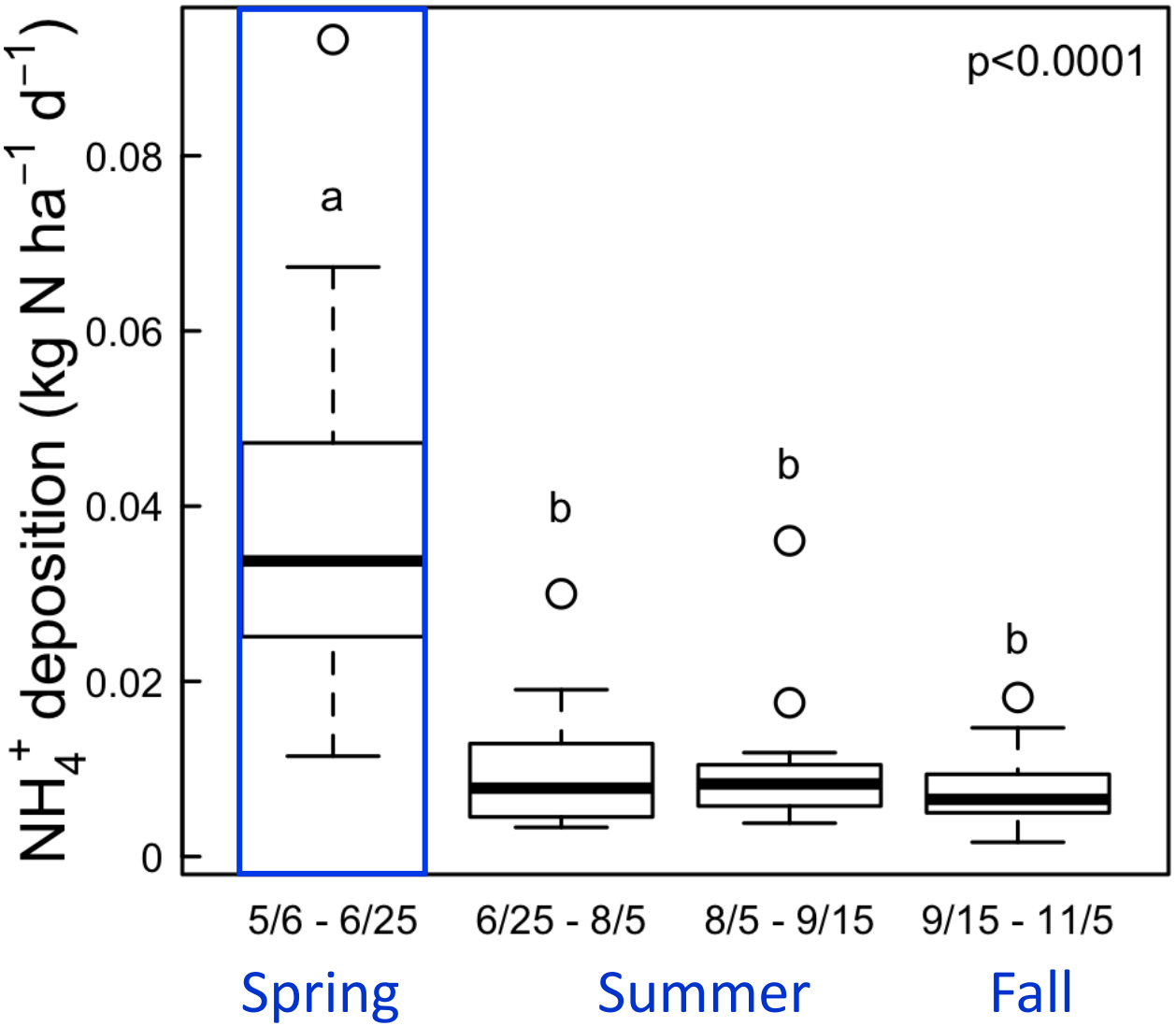

What About Other, Unaccounted Atmospheric Inputs in Cities?

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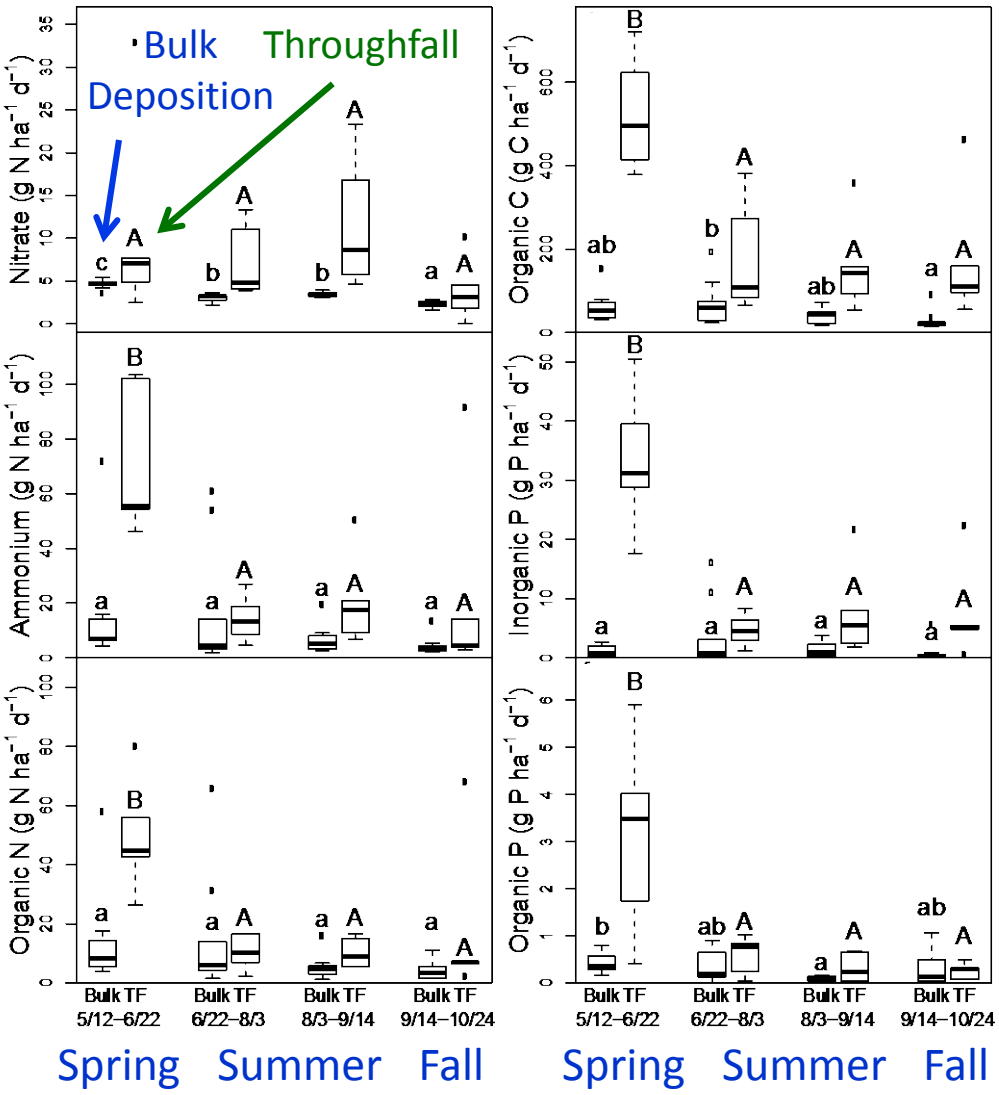
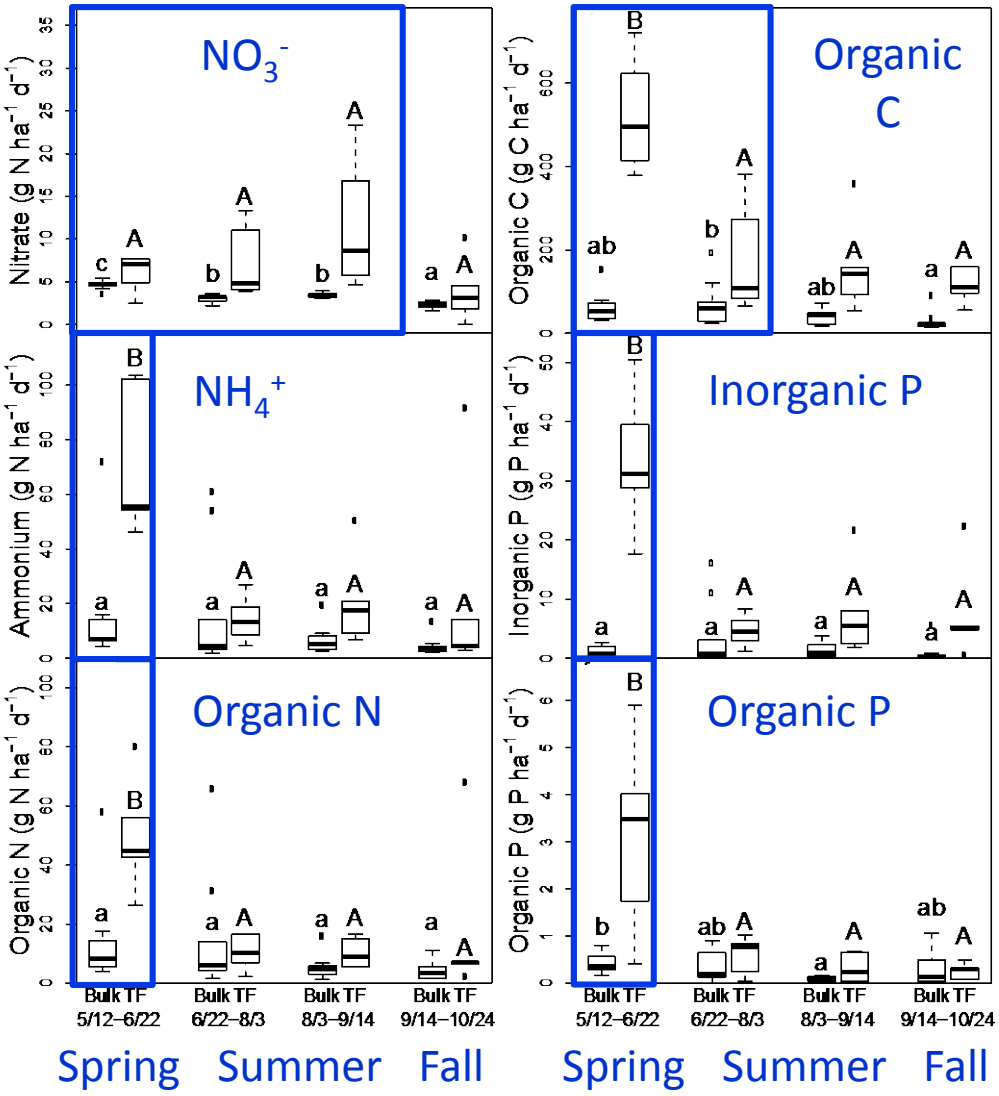
9 New Sites: Measured NH_4^+, NO_3^-, total P, organic N and C

Nitrogen, Carbon, and Phosphorus:



Decina et al. 2018. Earth's Future

Nitrogen, Carbon, and Phosphorus: Elevated Deposition Due to Tree Canopy Processes



- Throughfall > Bulk Deposition

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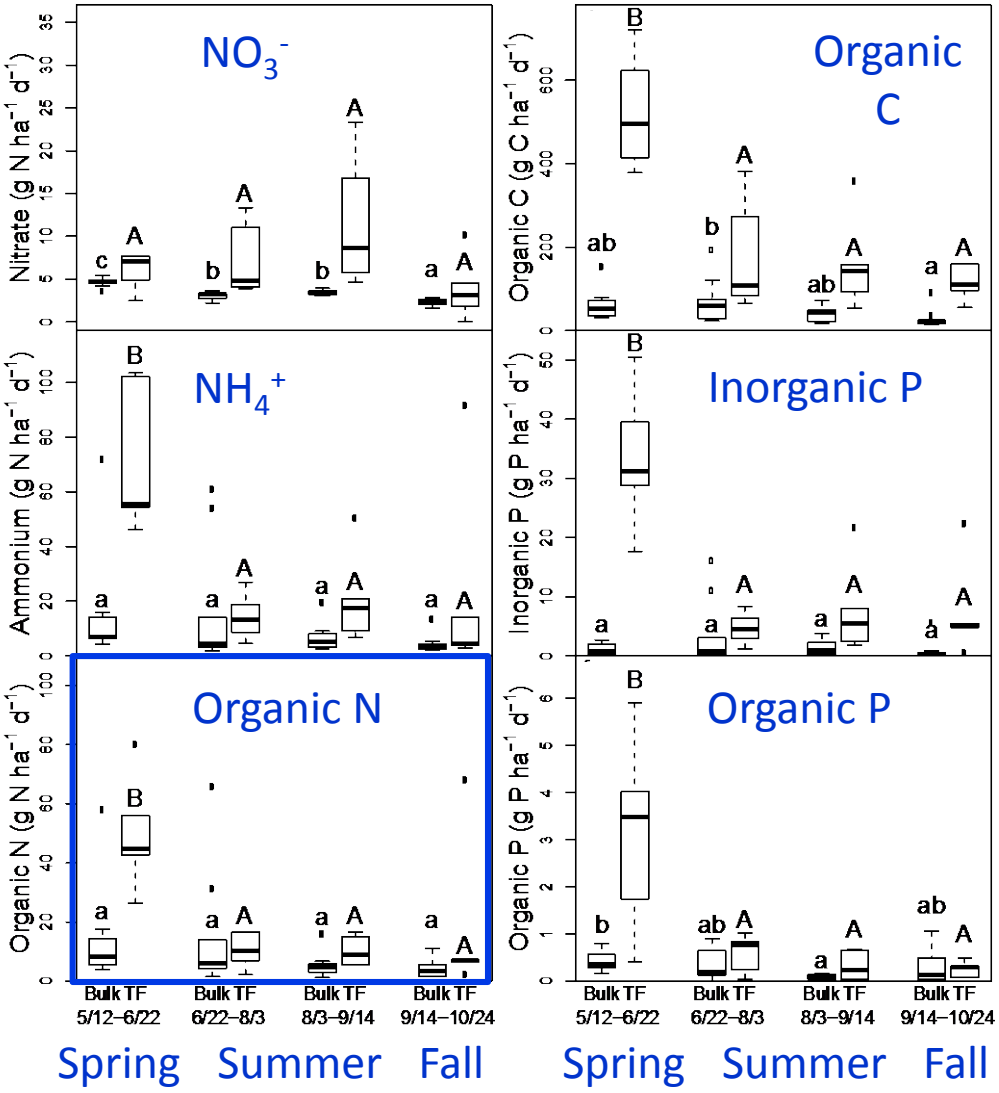

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- Organic N: 35% total N

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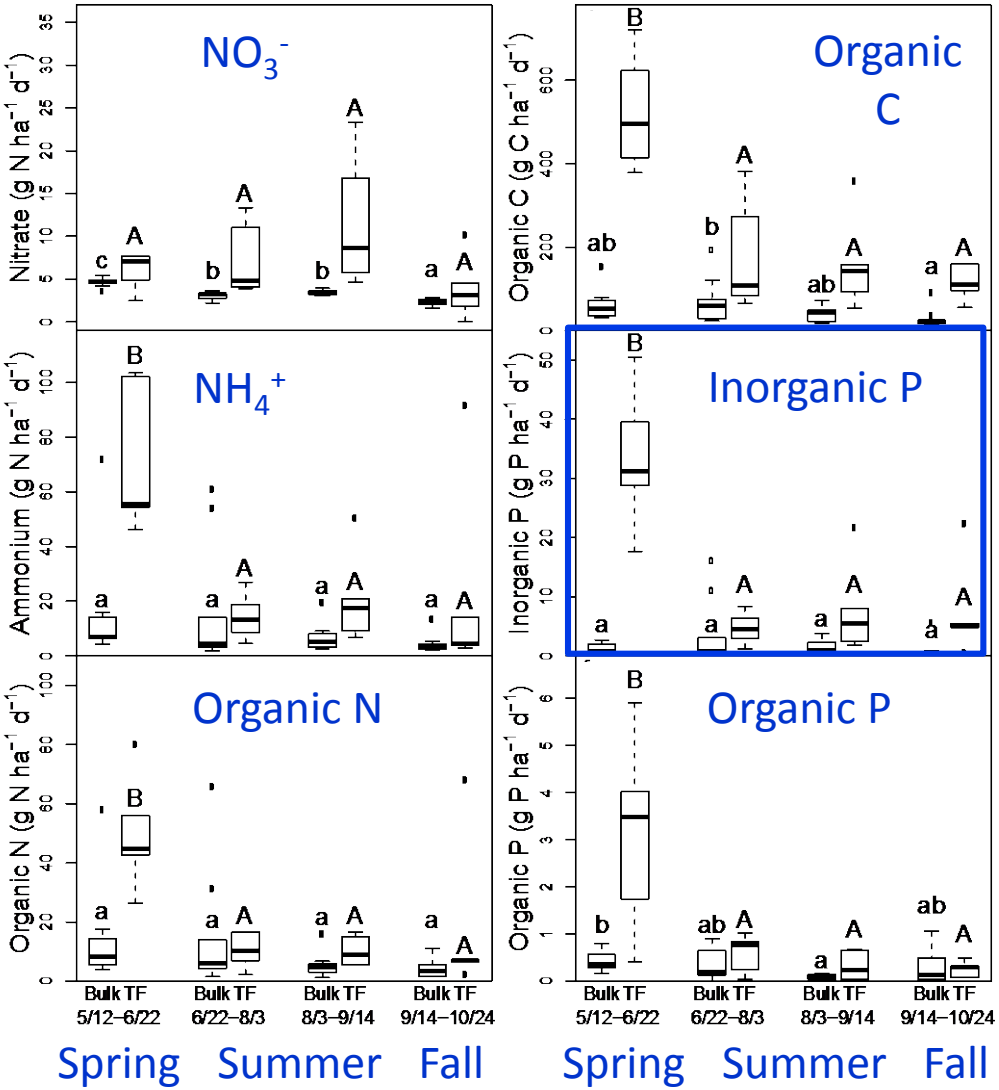

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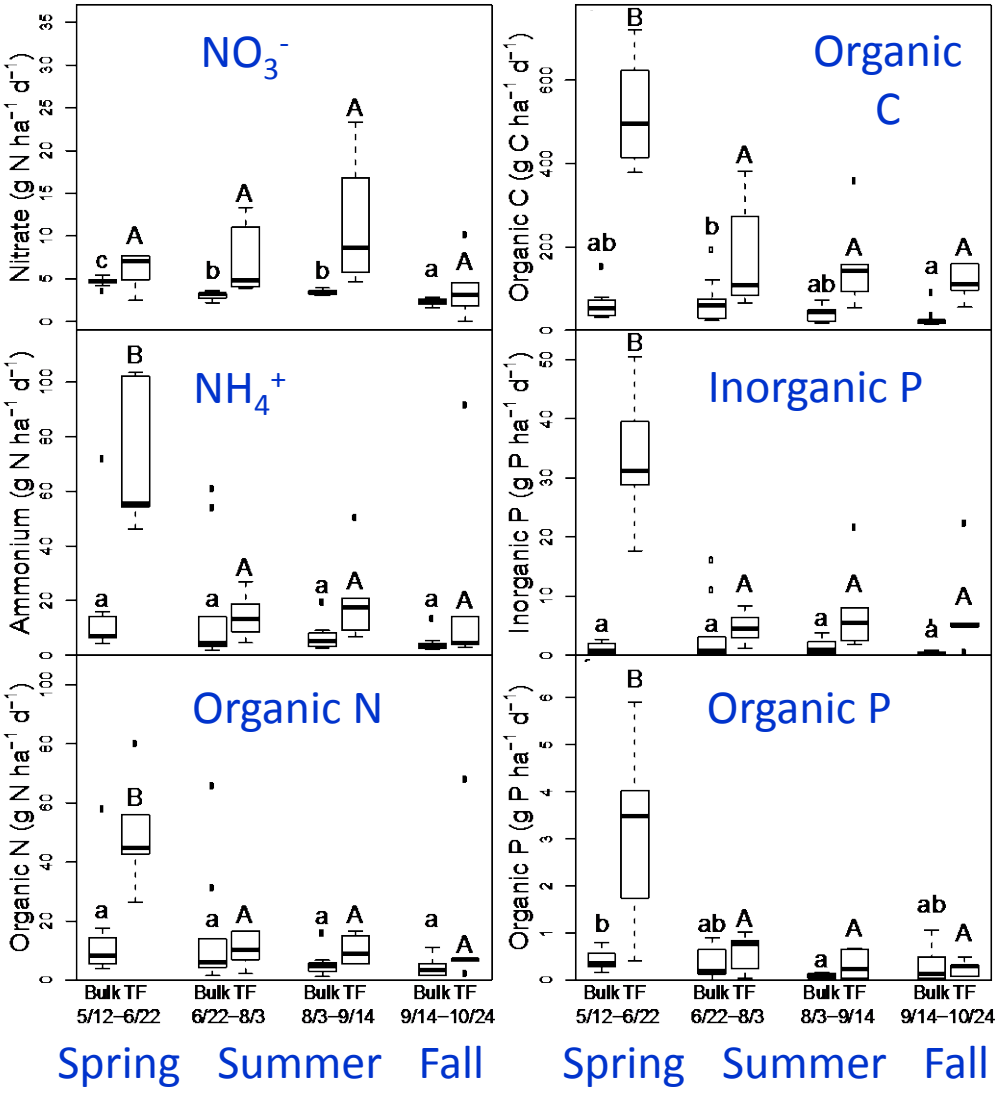

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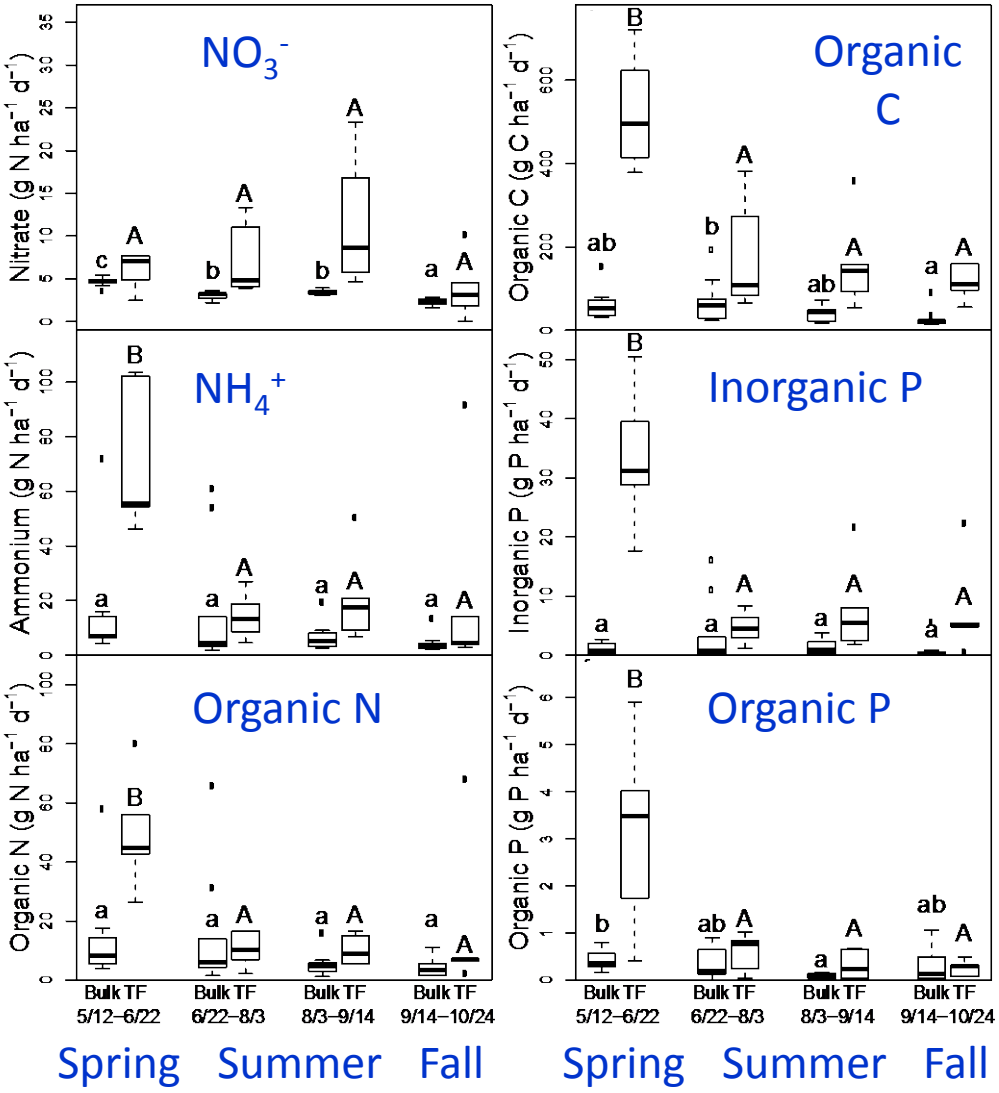

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Decina et al. 2018. Earth's Future

Canopy Amplification of Atmospheric Inputs

Boston canopy cover

- 25.5% (Raciti et al., 2014)

Decina et al. 2018. Earth's Future

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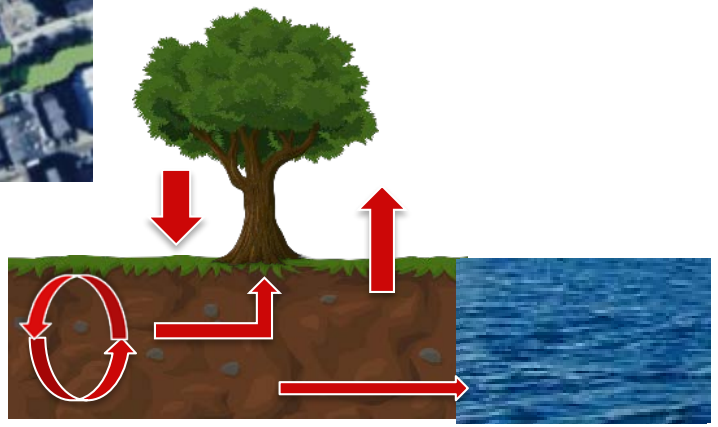

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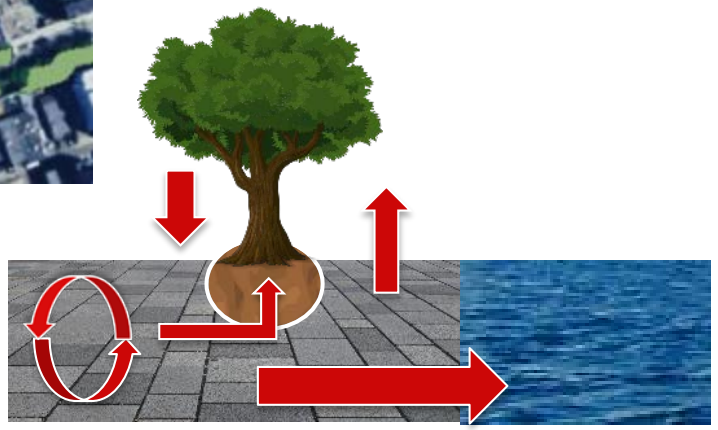

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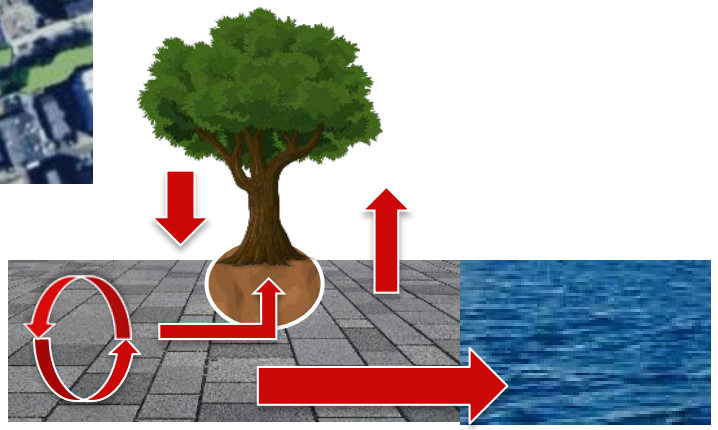
Unknown: How vegetation and soils interact in Boston to retain or lose N, P, and C to nearby waterways and back to the atmosphere



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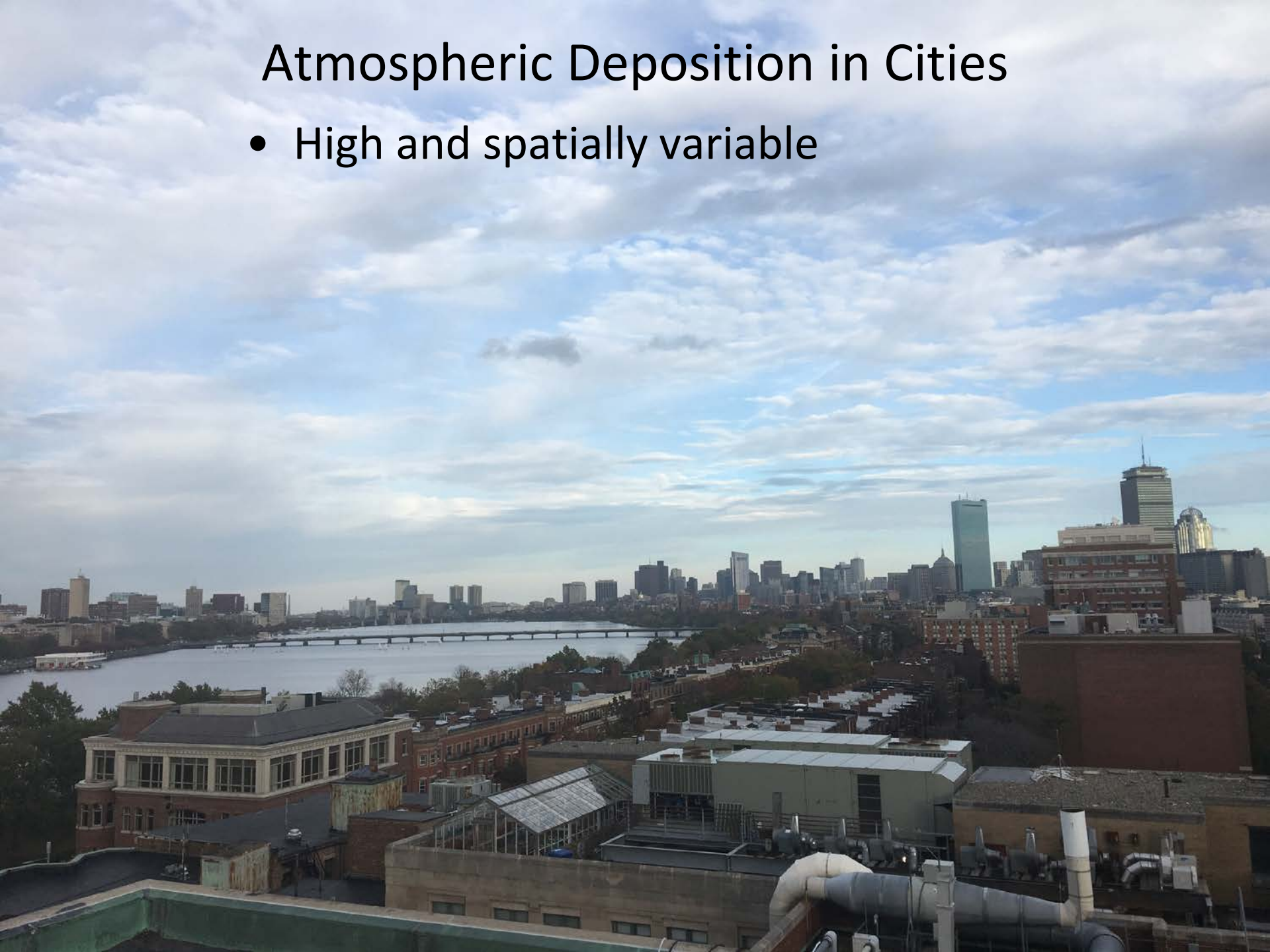
Atmospheric Deposition in Cities

- High and spatially variable



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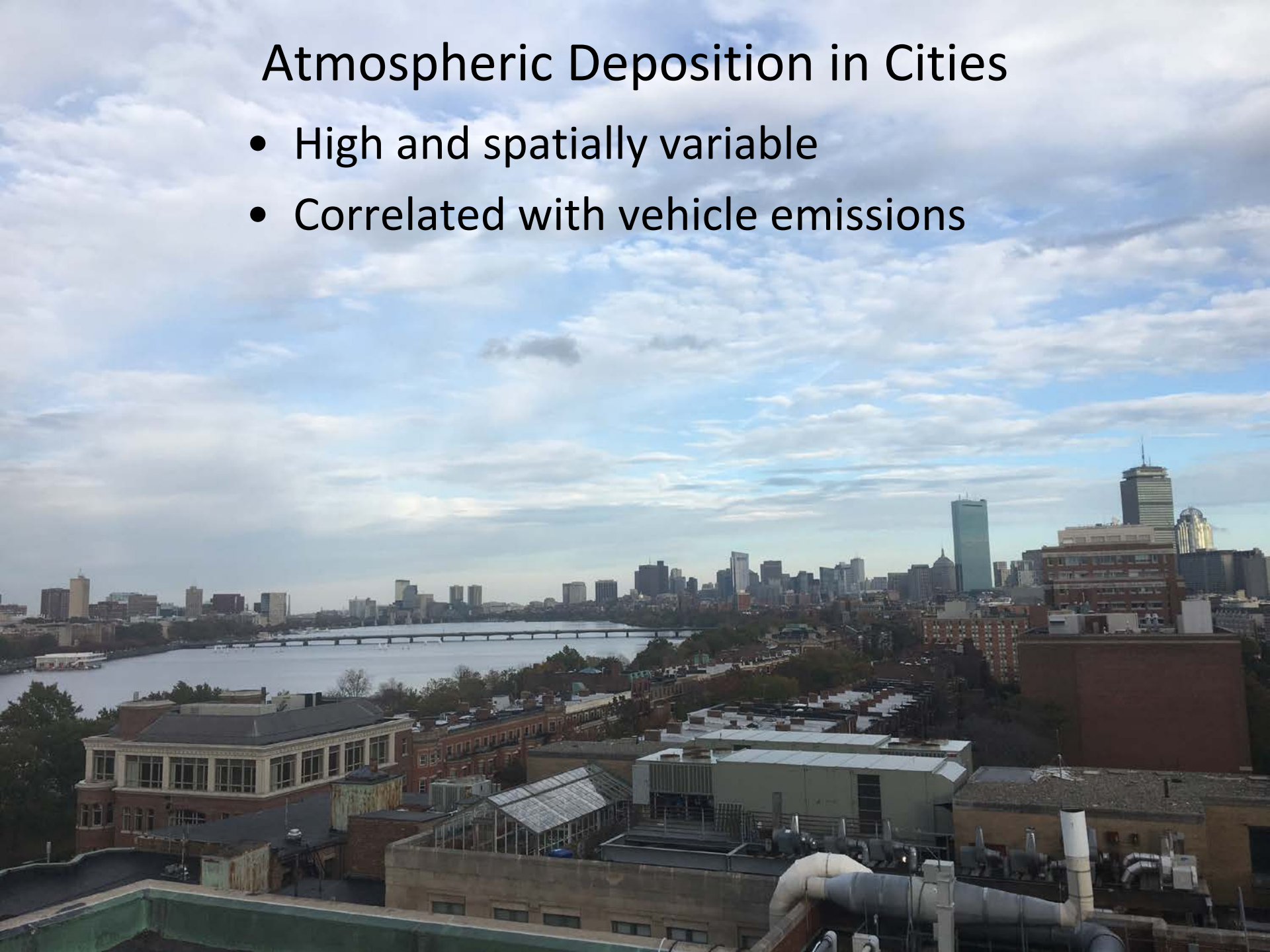
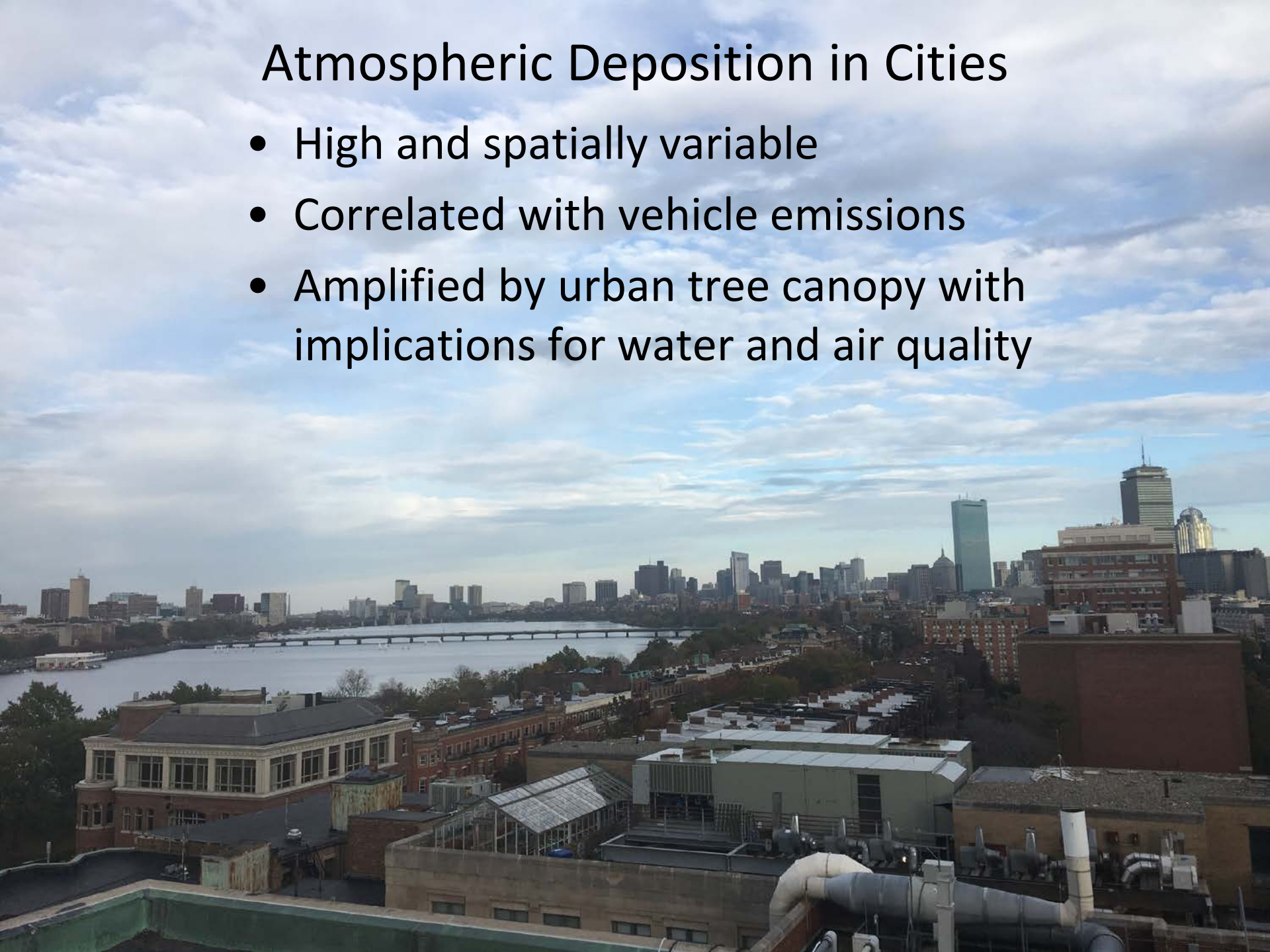


Atmospheric Deposition in Cities

- High and spatially variable
- Correlated with vehicle emissions
- Amplified by urban tree canopy with implications for water and air quality



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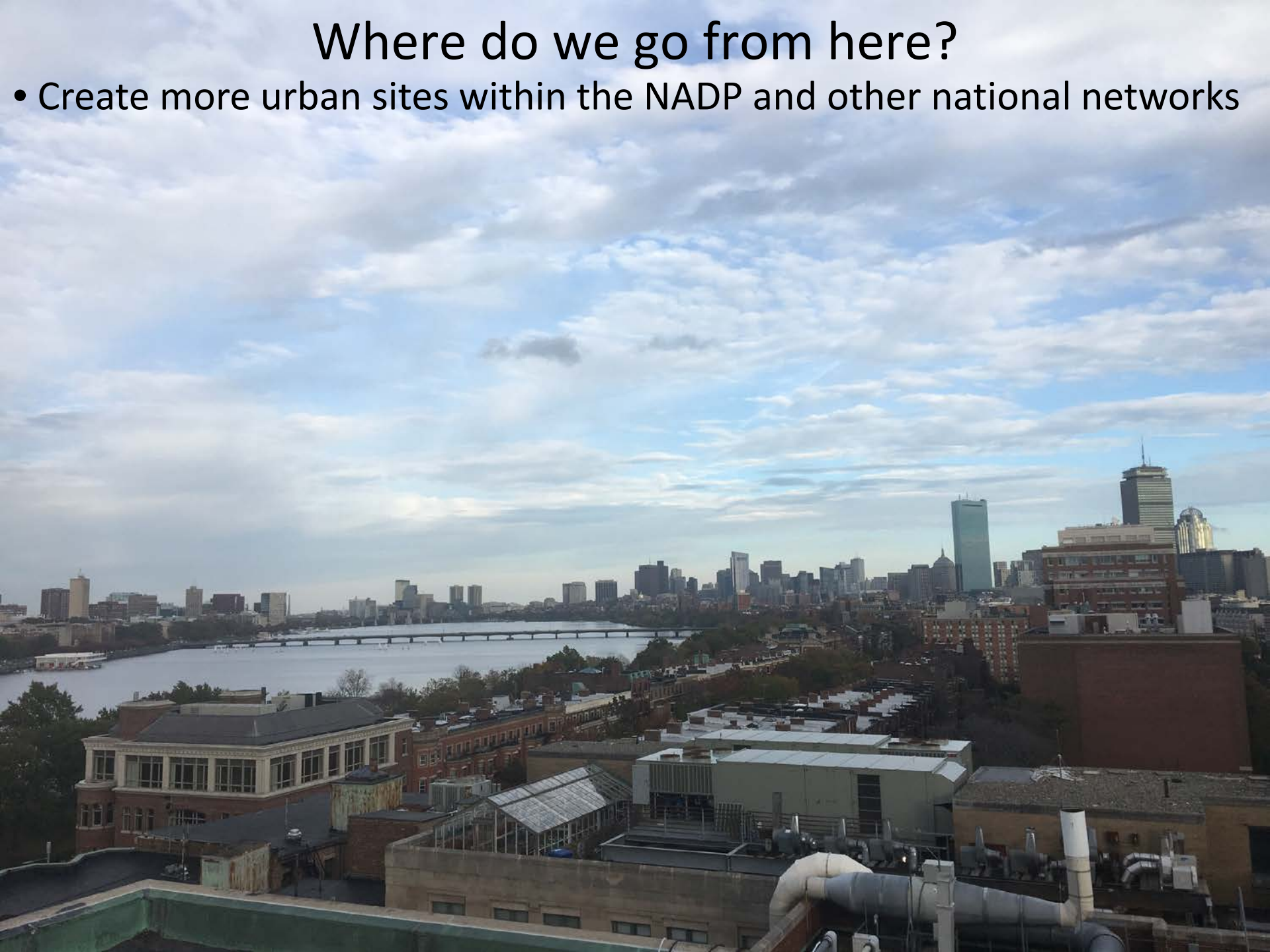
- Create more urban sites within the NADP and other national networks



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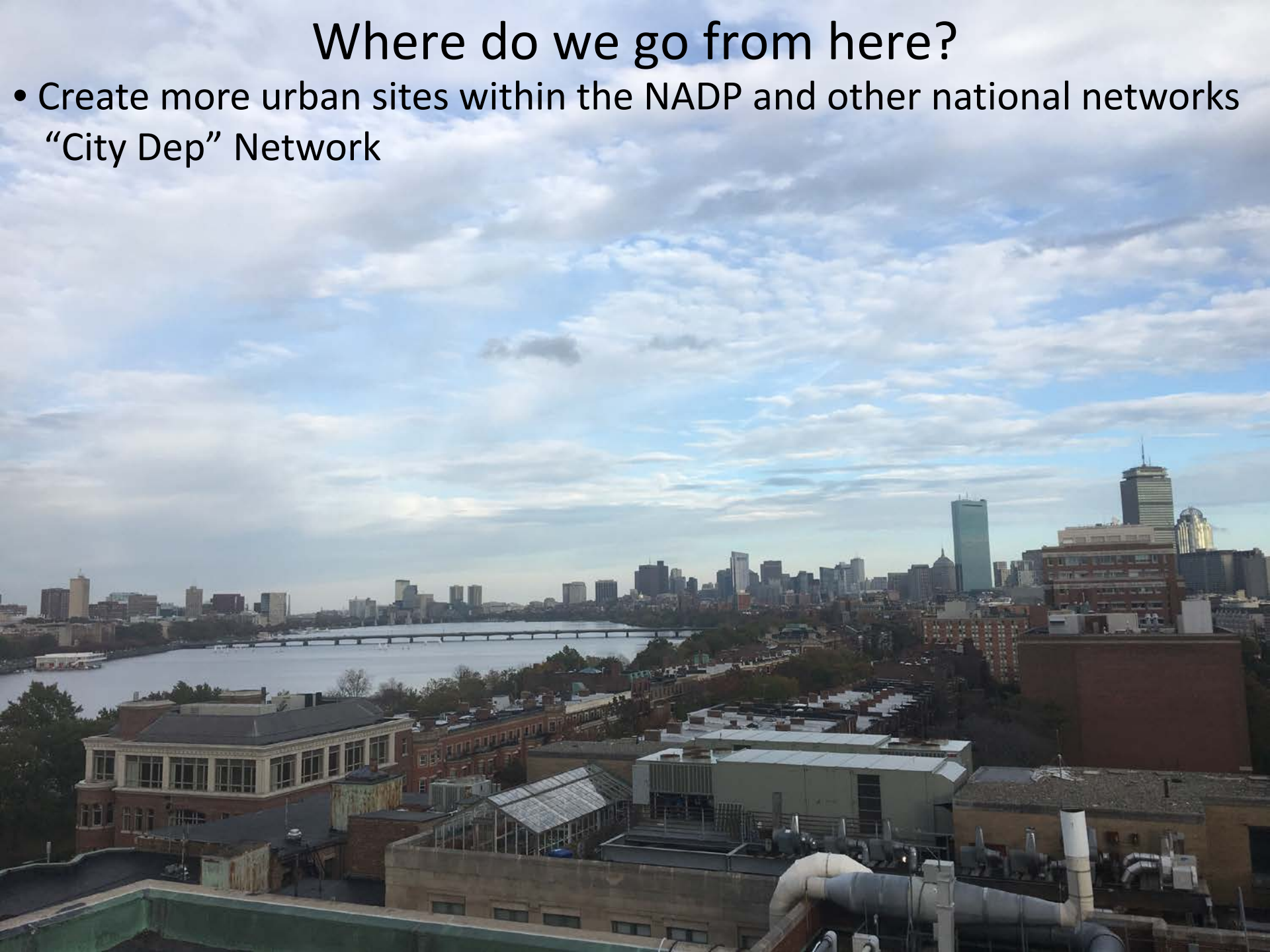
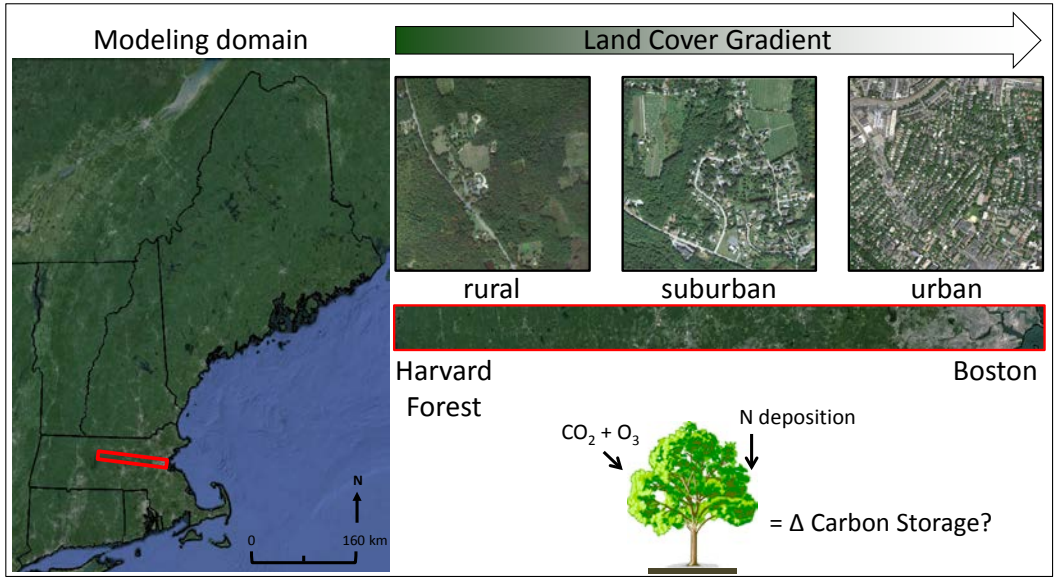


Where do we go from here?

- Create more urban sites within the NADP and other national networks
  "City Dep" Network
- Examine interactions between N deposition with other pollutants, land cover, and climate on ecosystem function

Interacting Effects of N Deposition, Ozone, CO_2, and Land Cover on Carbon Storage Throughout Ecosystems of New England



- N= 8 sites along urban to rural gradient
- Each site: transect from forest interior to edge

Lucy Hutyra

Sarah Garvey

Erin Pierce

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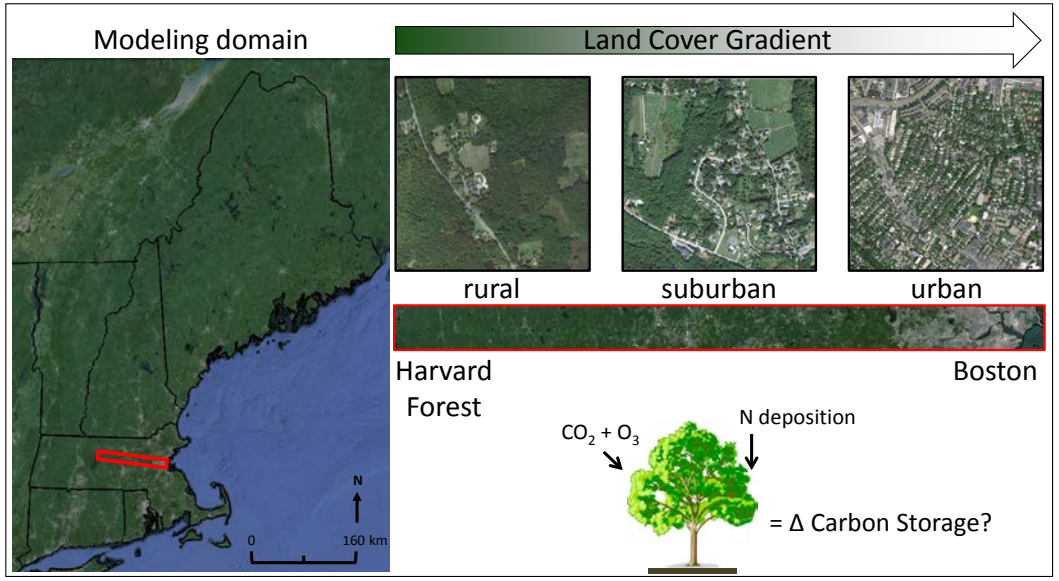

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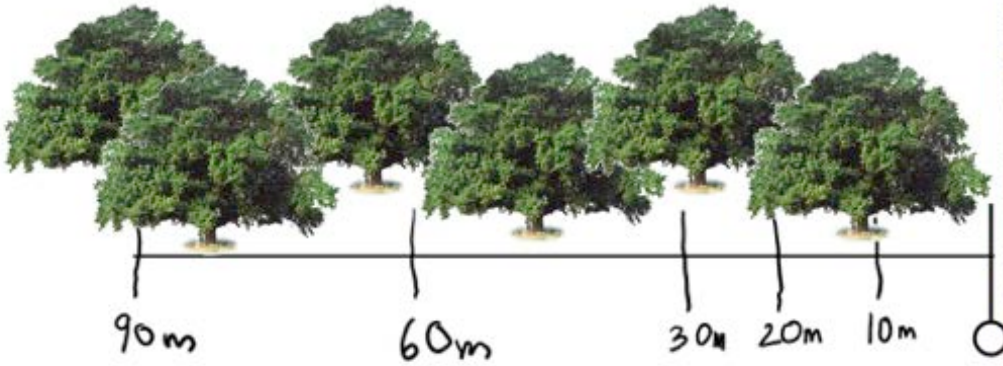

Diagram credit: Erin Pierce

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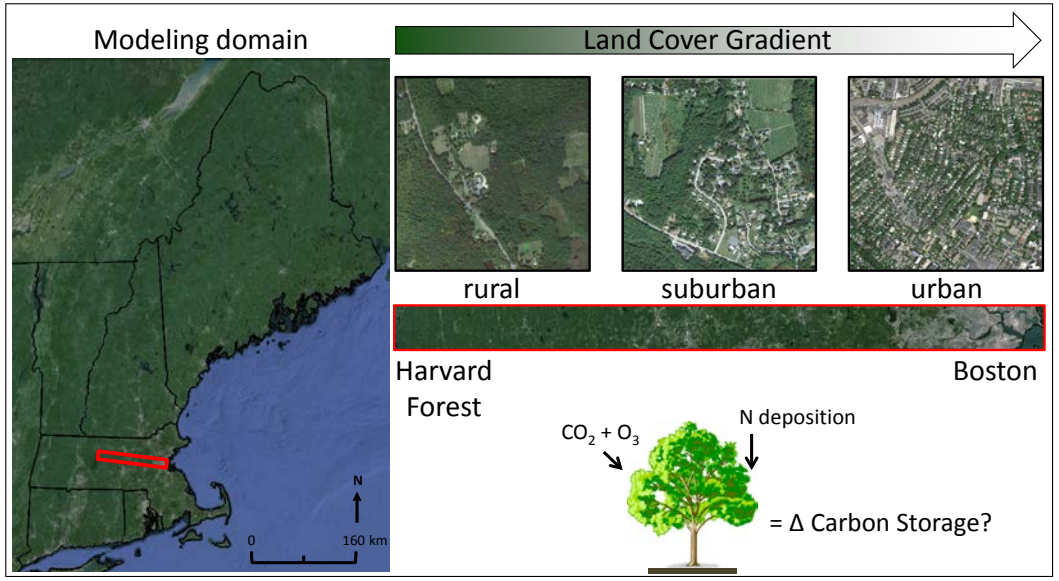

- N= 8 sites along urban to rural gradient
- Each site: transect from forest interior to edge
- Measuring climate, N and C fluxes, NO_x and O_3

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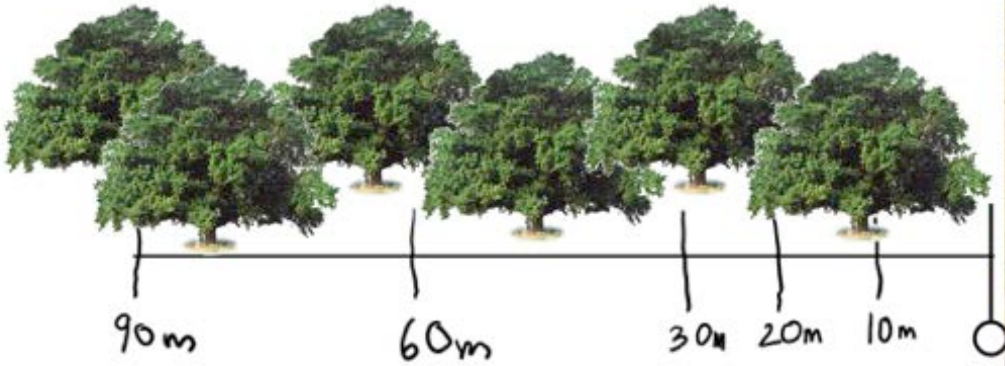

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Acknowledgements

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NASA

NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce

The Arnold Arboretum of Harvard University

Boston Area Research Initiative

DaRin Butz Foundation

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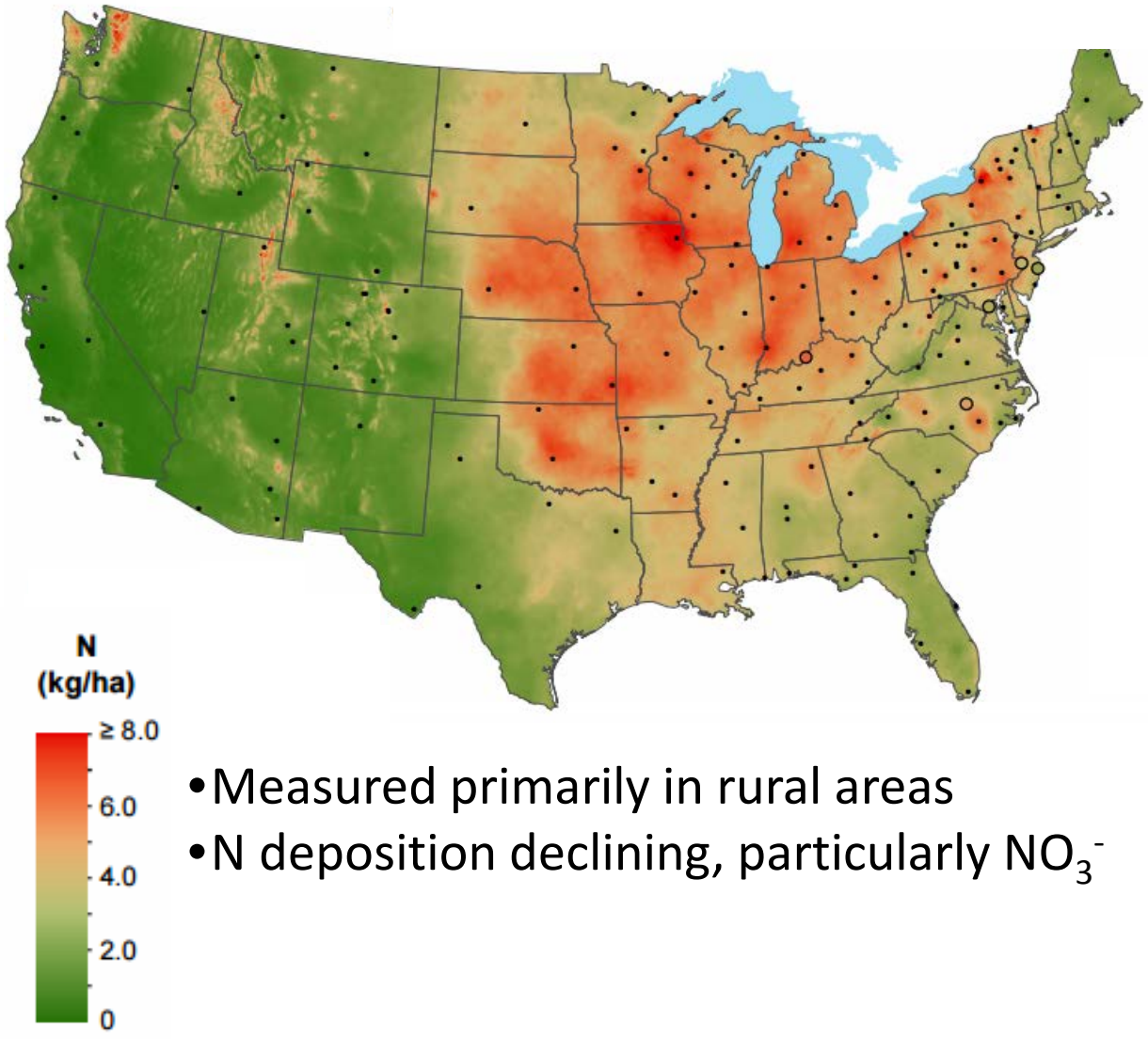
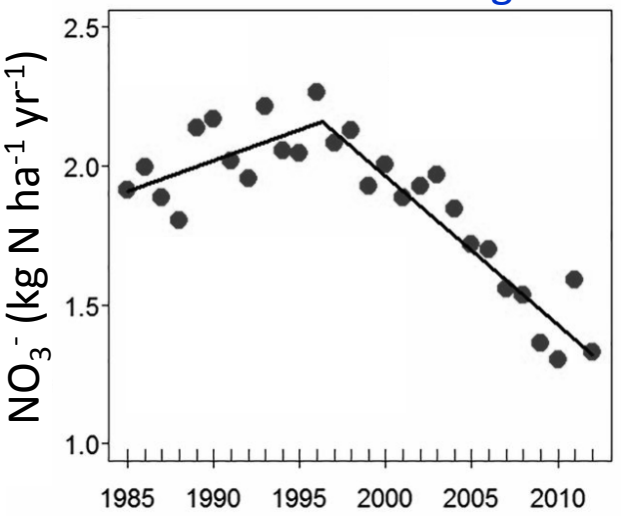
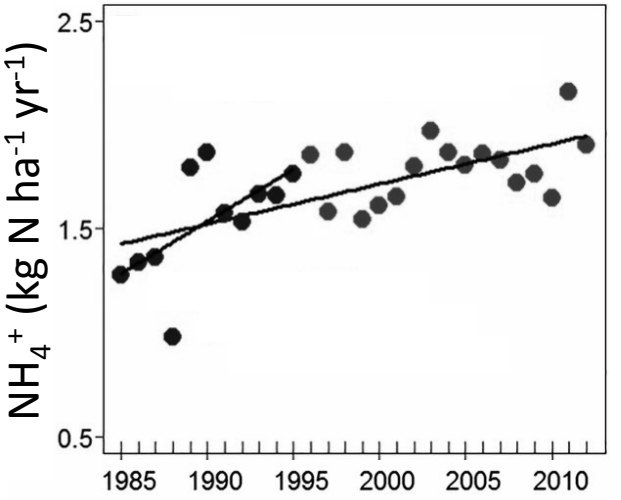


- Measured primarily in rural areas
- N deposition declining, particularly NO_3^-

Nitrate Declining



Ammonium Rising



Du, PNAS, 2016