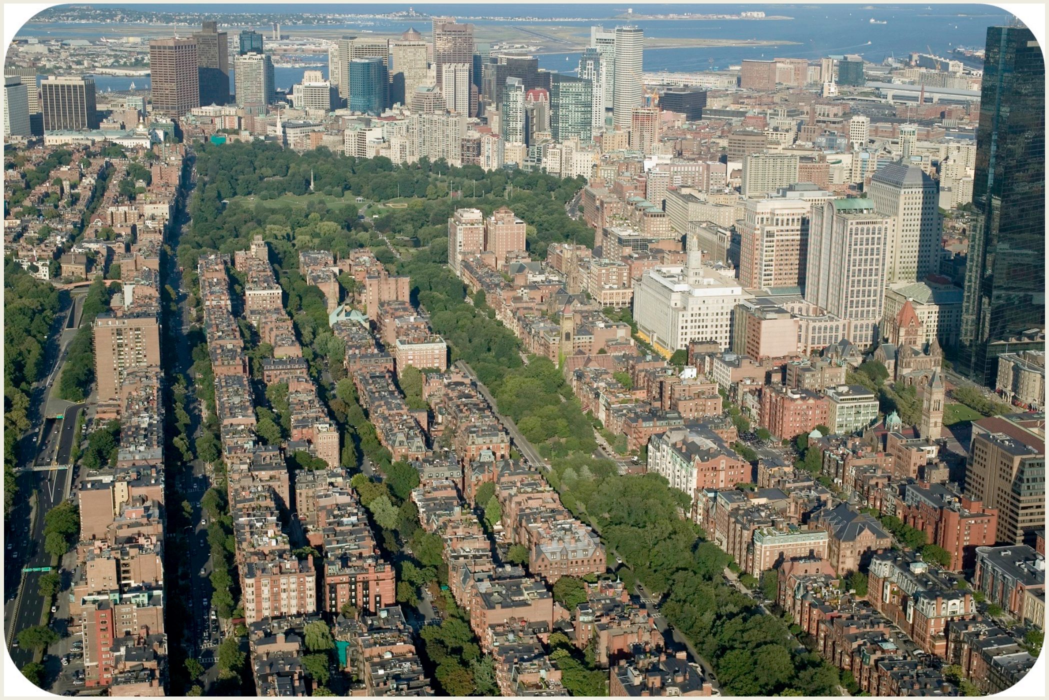
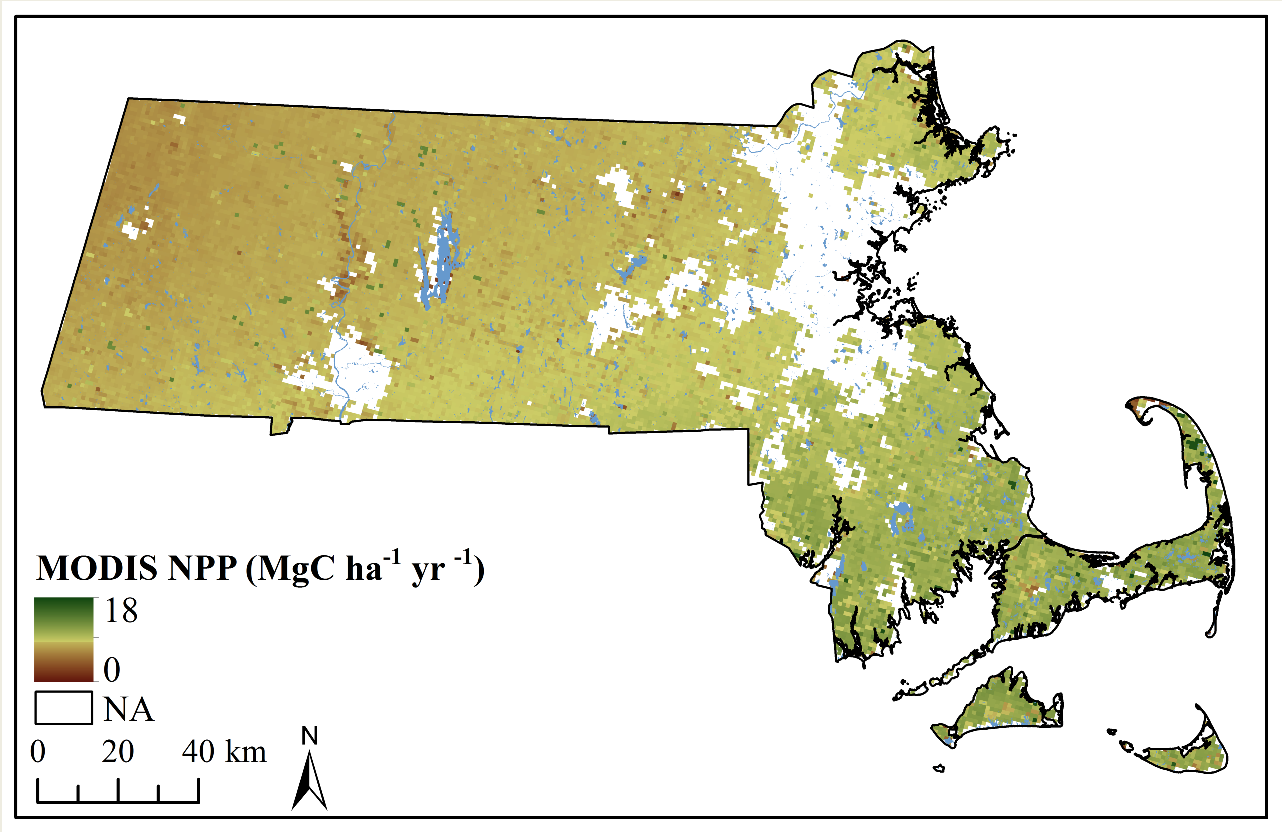
Biosphere flux inventories for cities



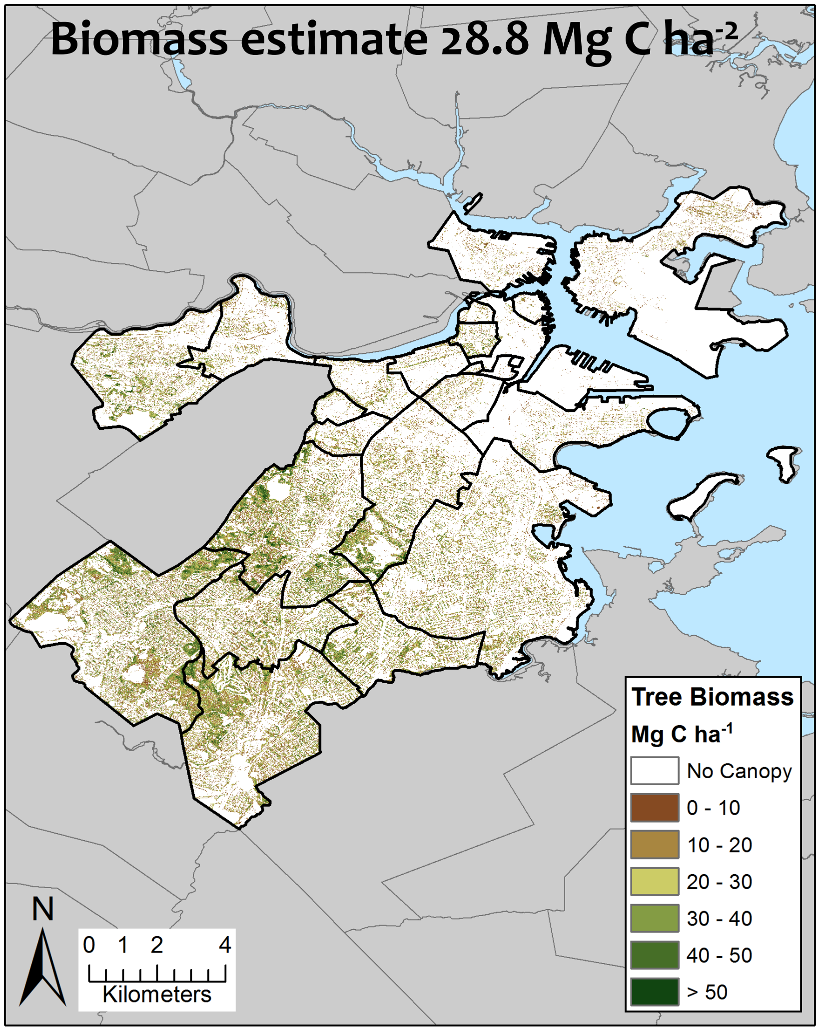
Lucy R. Hutyra
Boston University, Department of Earth & Environment

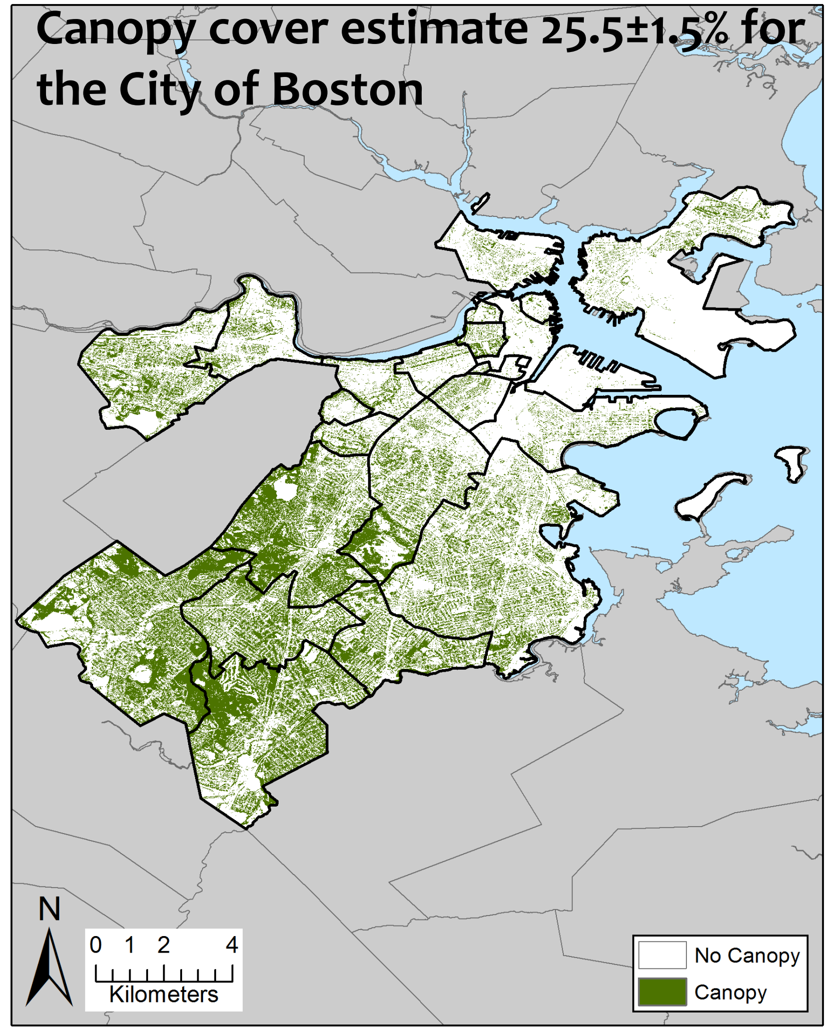
Existing biosphere flux models?



Most ecosystem C models and land surface products exclude urban areas.

Urban Vegetation Density



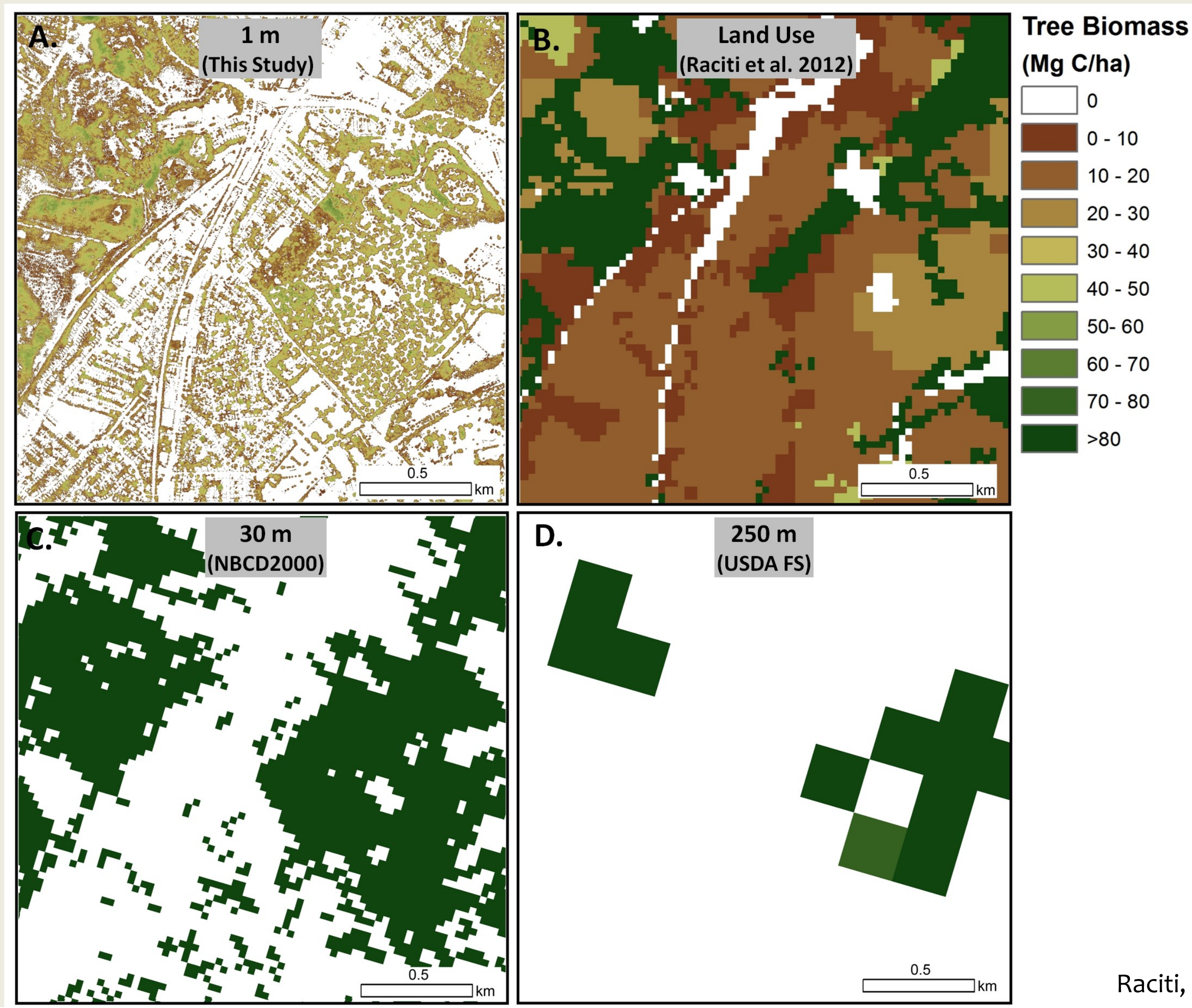


Raciti, Newell, & Hutyra 2014

Urban Vegetation Density

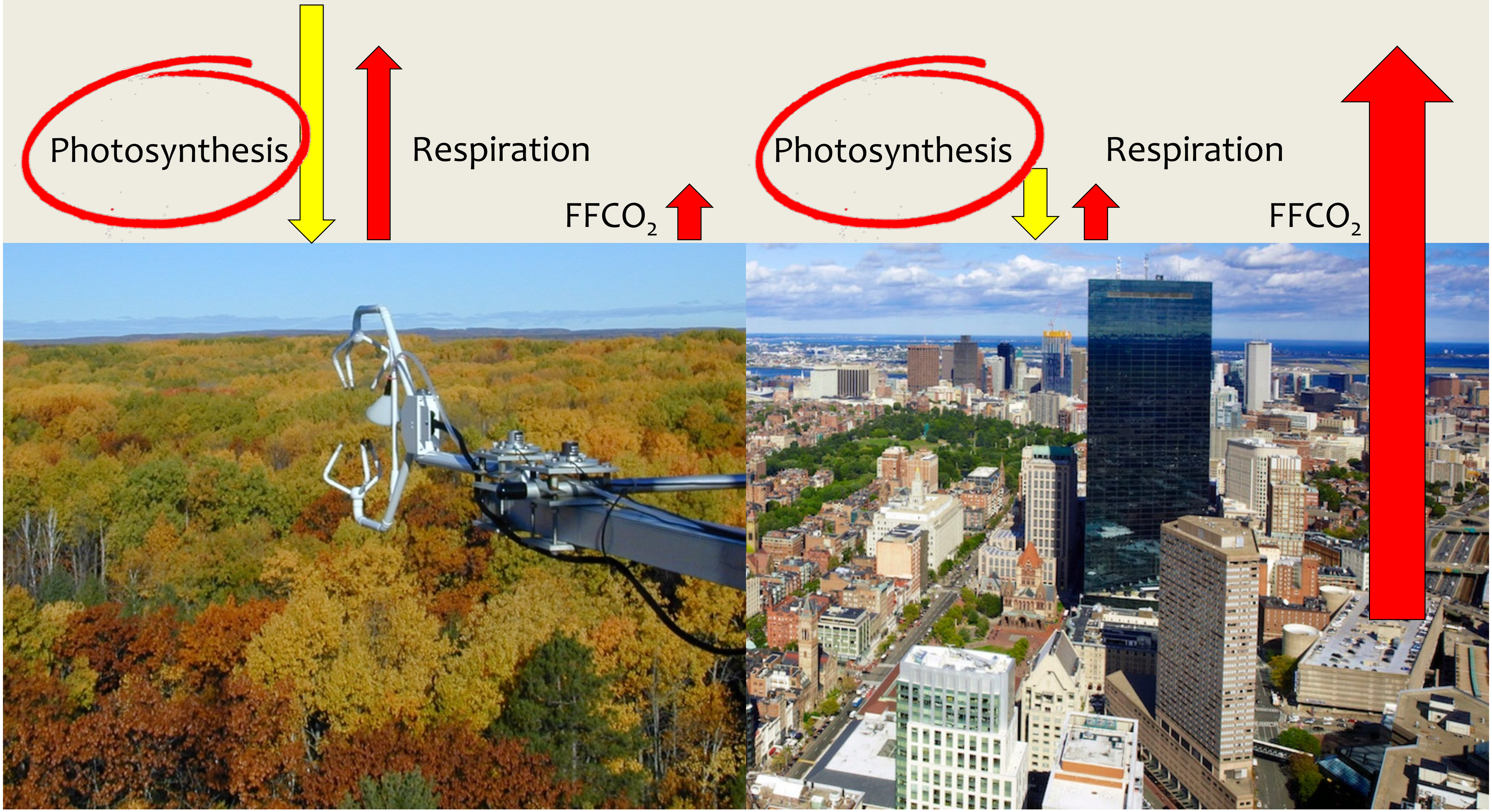
National biomass maps exist, but don't perform particularly well for urban areas…

Need better national urban biomass inventories.



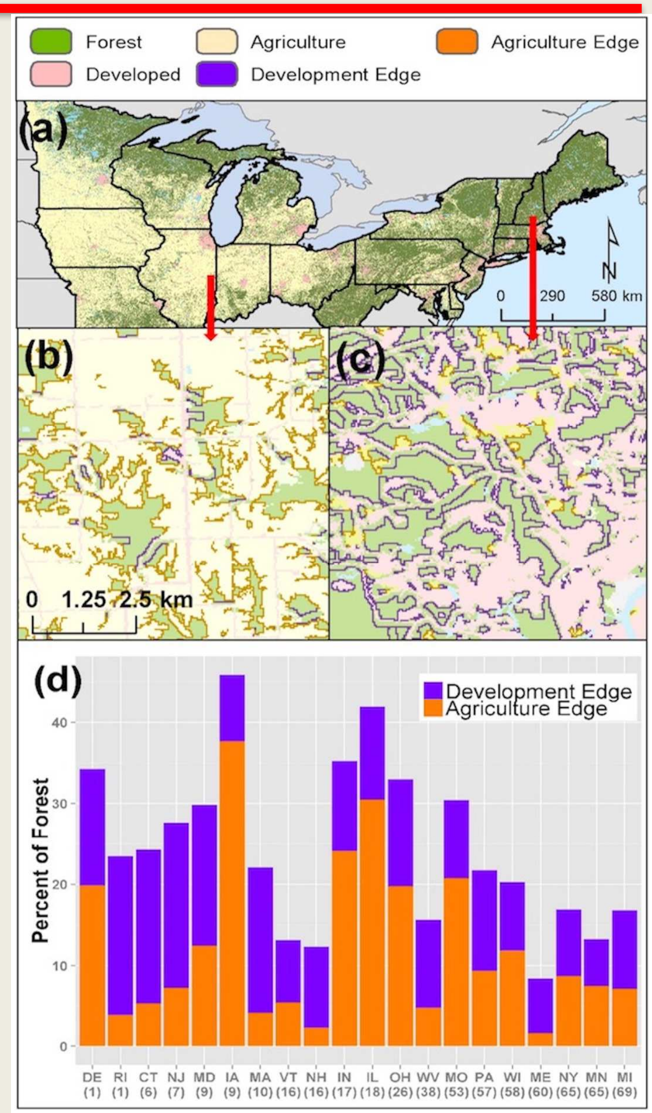
Raciti, Newell, & Hutyra 2014

The Terrestrial Carbon Fluxes



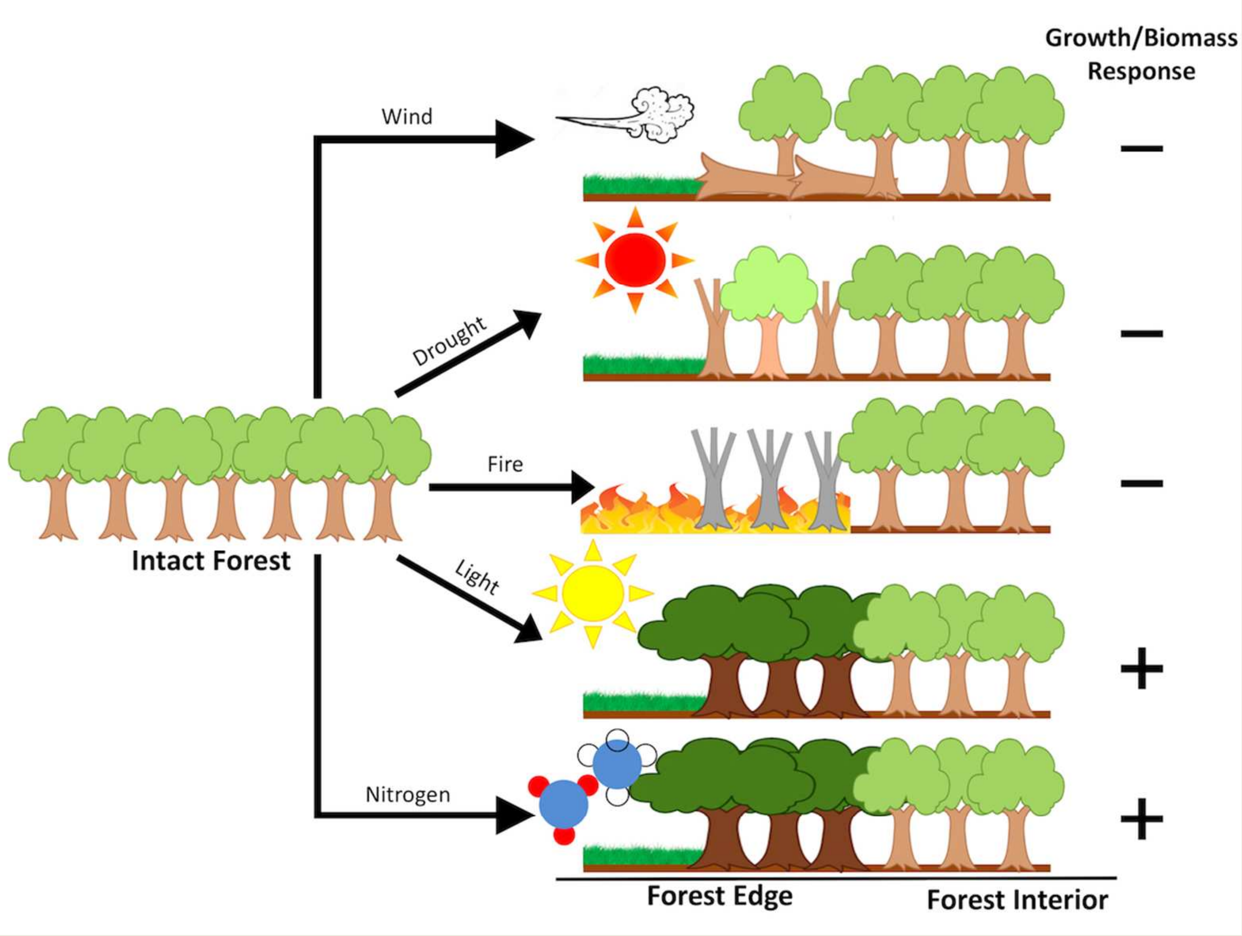
Fragmented Forests

In Northeast, over 23% of the forest area is just 30m from an agricultural or developed edge



Smith et al. in press

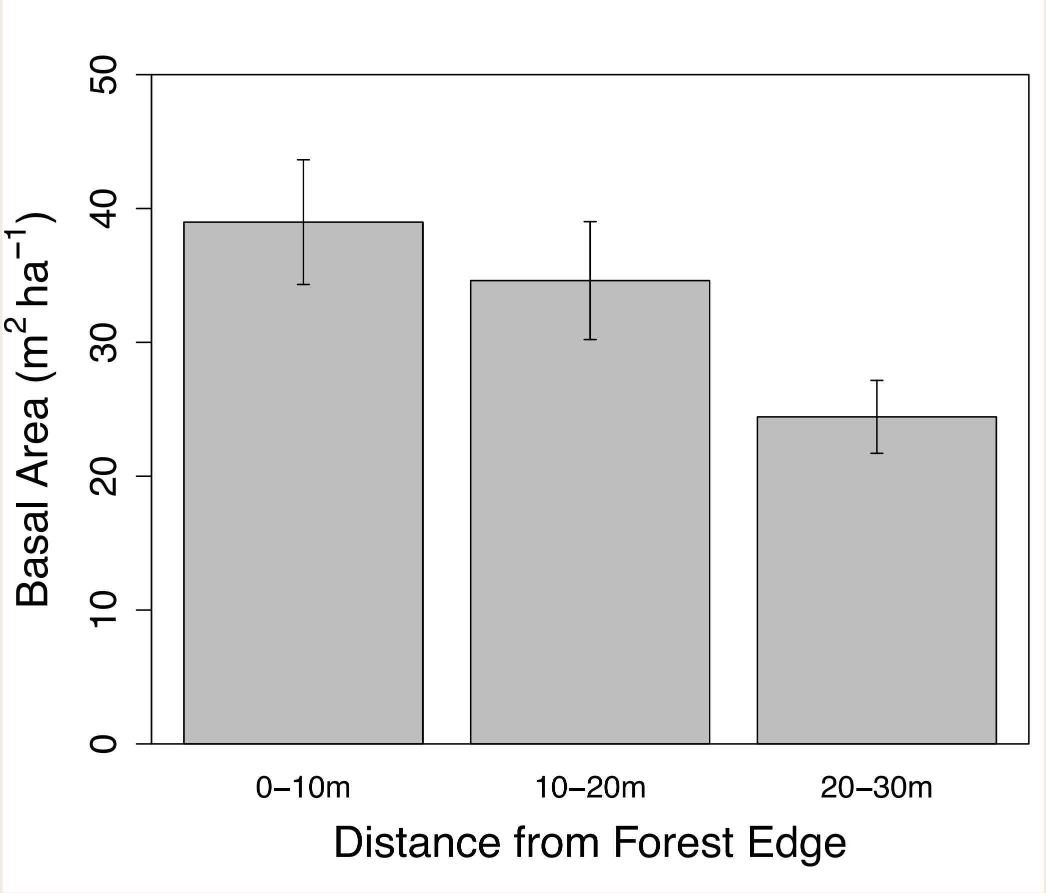
Fragmented Forests



Smith et al. in press

Fragmented Forests

Forest biomass increases by 64% from interior to edge

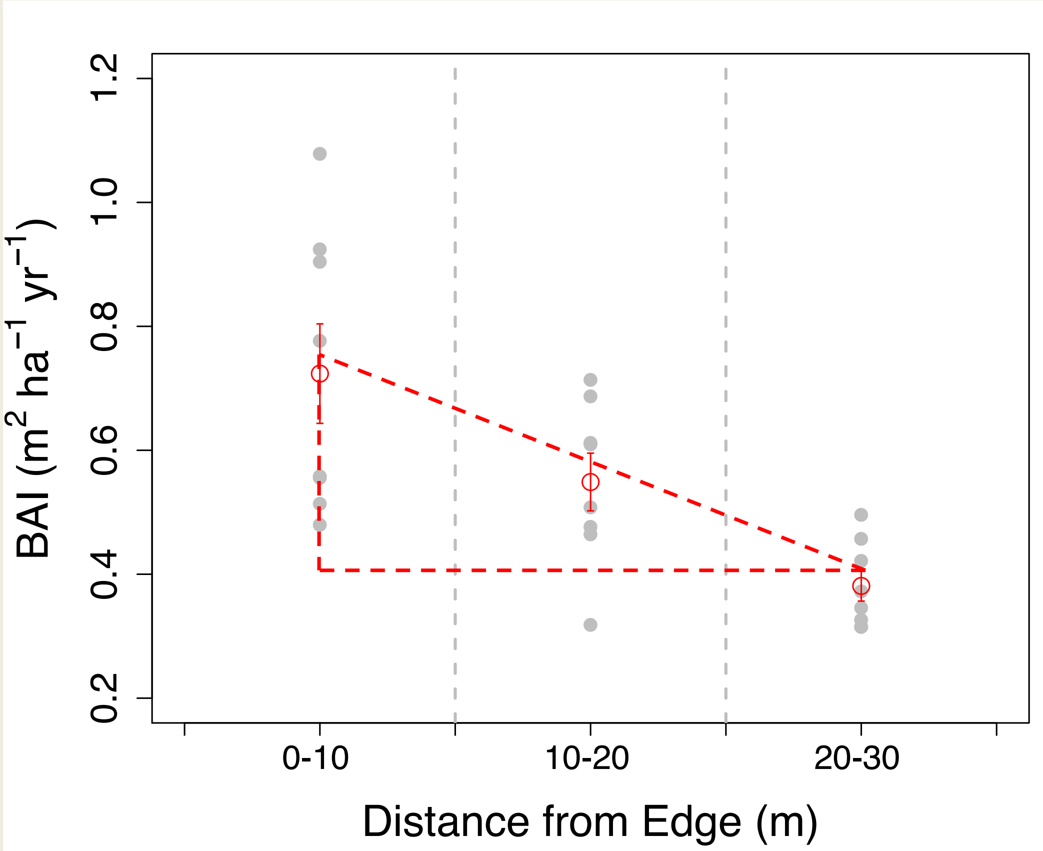


Reinmann & Hutyra 2017

Fragmented Forests

Basal area increment

Forest growth increases by 90% from interior to edge

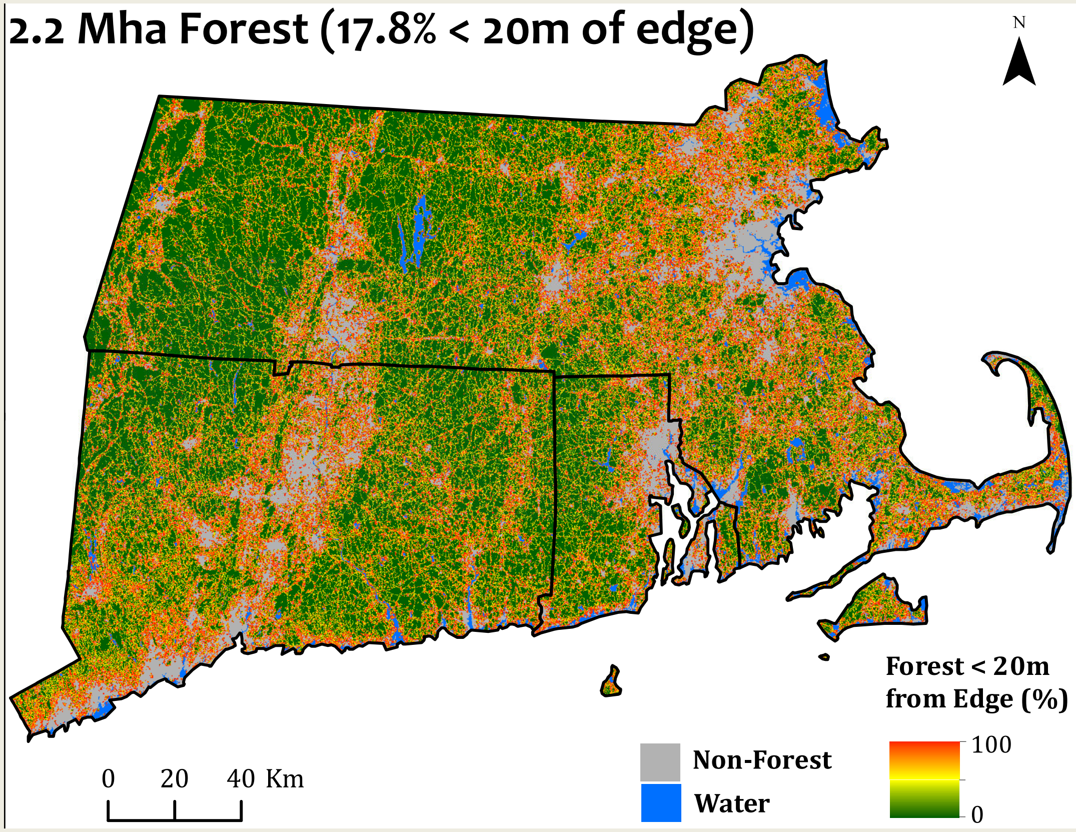


Reinmann & Hutyra 2017

Fragmented Forests

Disclaimer: These findings do not justify fragmentation as a management strategy!

2.2 Mha Forest (17.8% < 20m of edge)

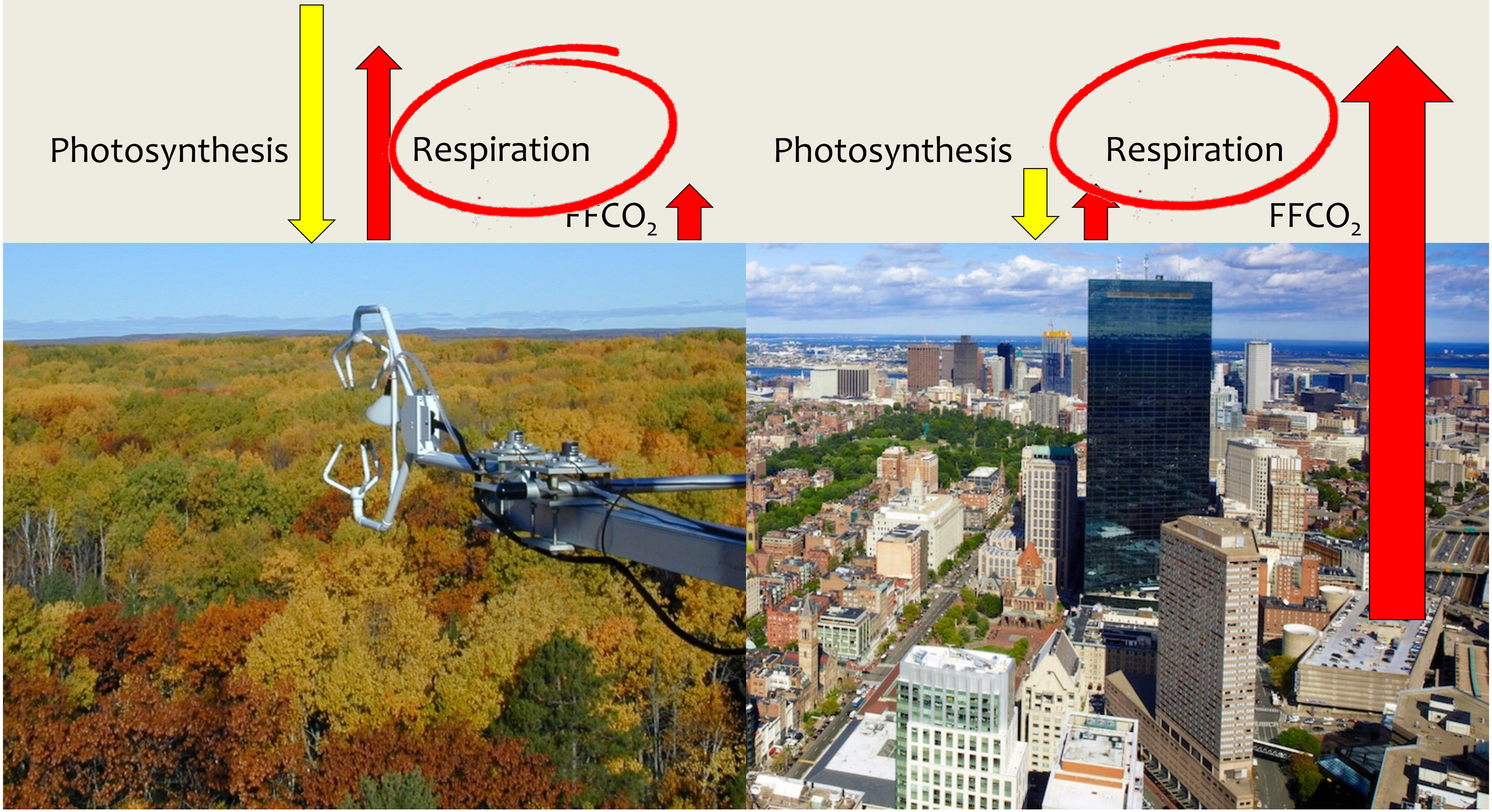


Uptake: 13 ± 3% (0.6 Tg C yr^{-1})

Aboveground Pool: 10 ± 1% (17 Tg C)

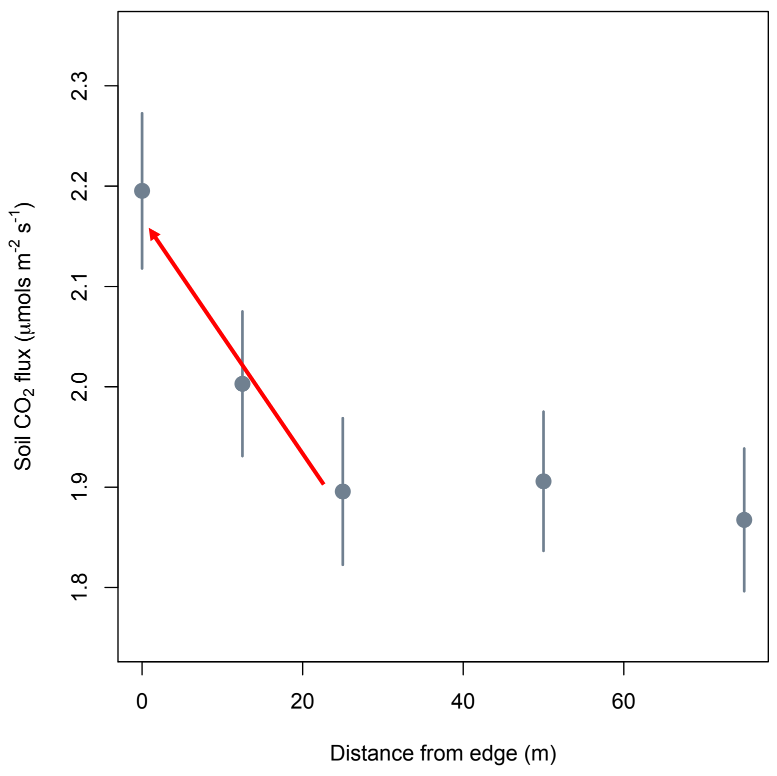
Reinmann & Hutyra 2017

The Terrestrial Carbon Fluxes

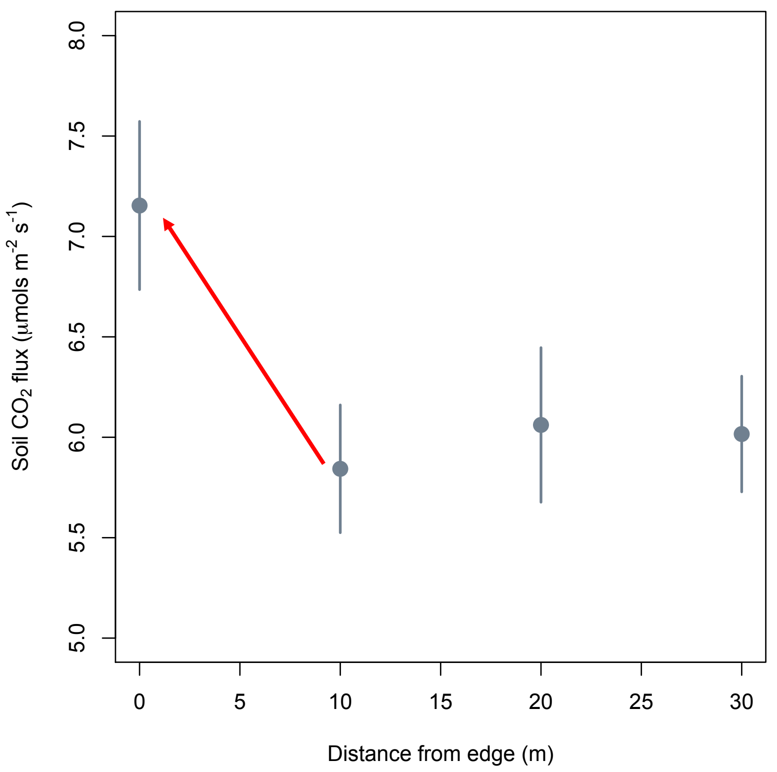


Soil Respiration & Fragmentation

NIST (MD)

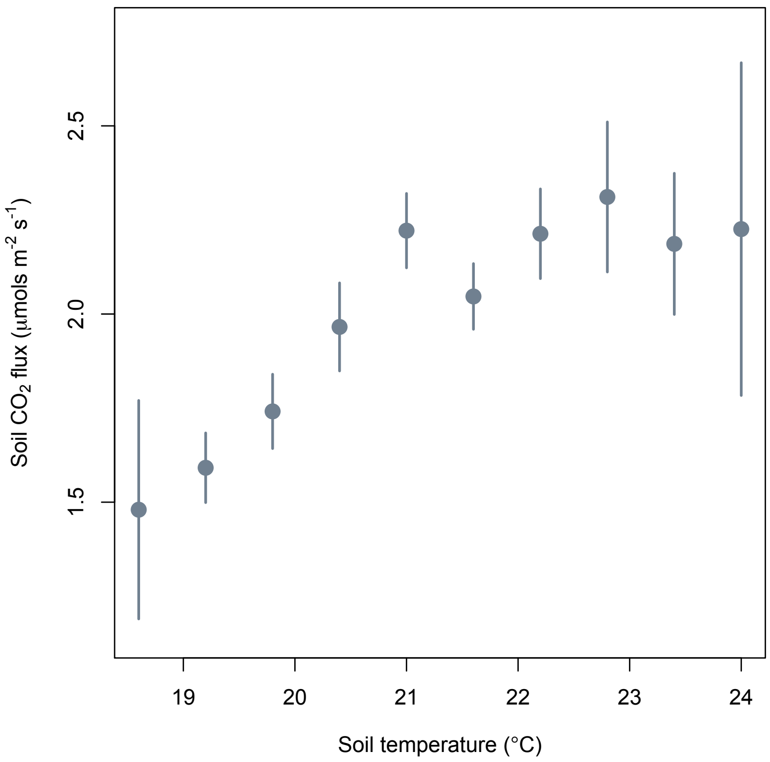


Harvard Forest (MA)

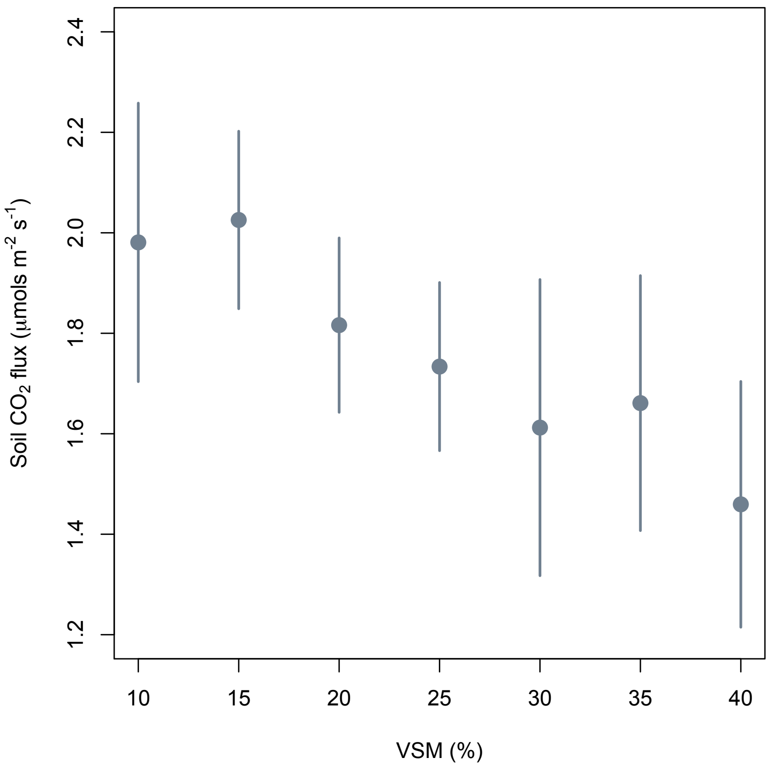


Soil Respiration & Fragmentation

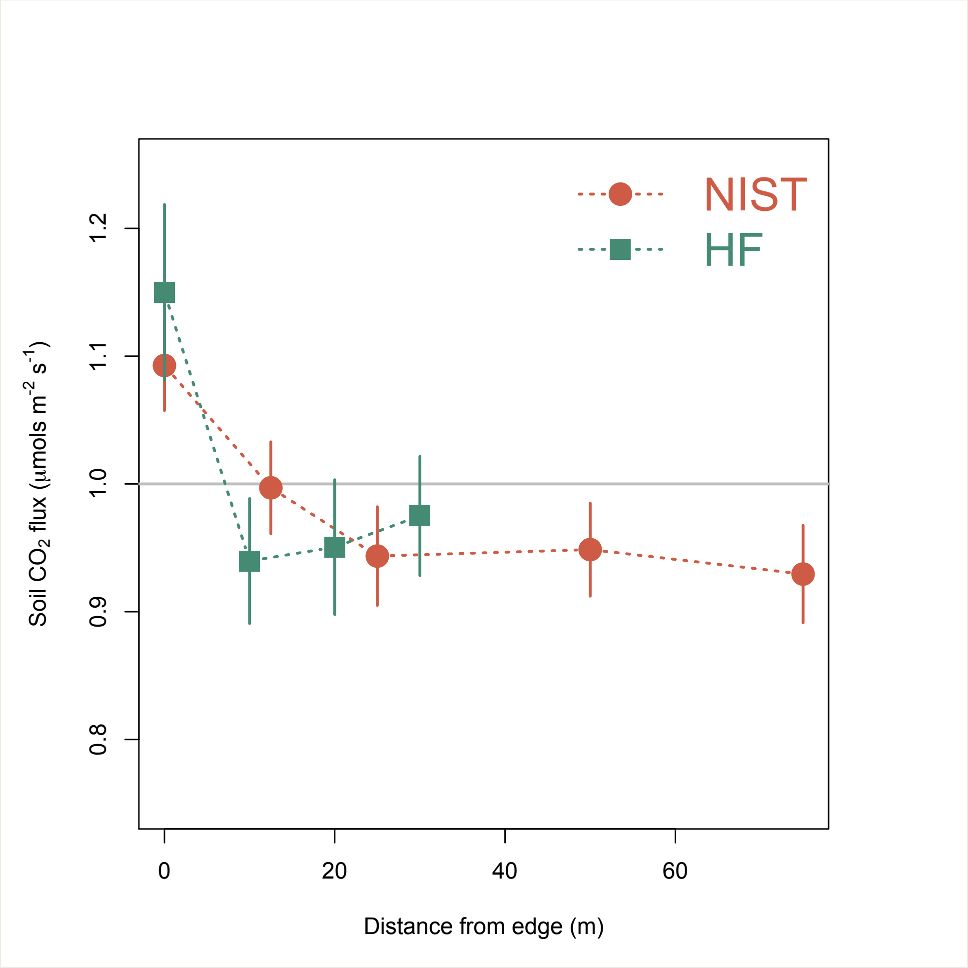
NIST (MD)



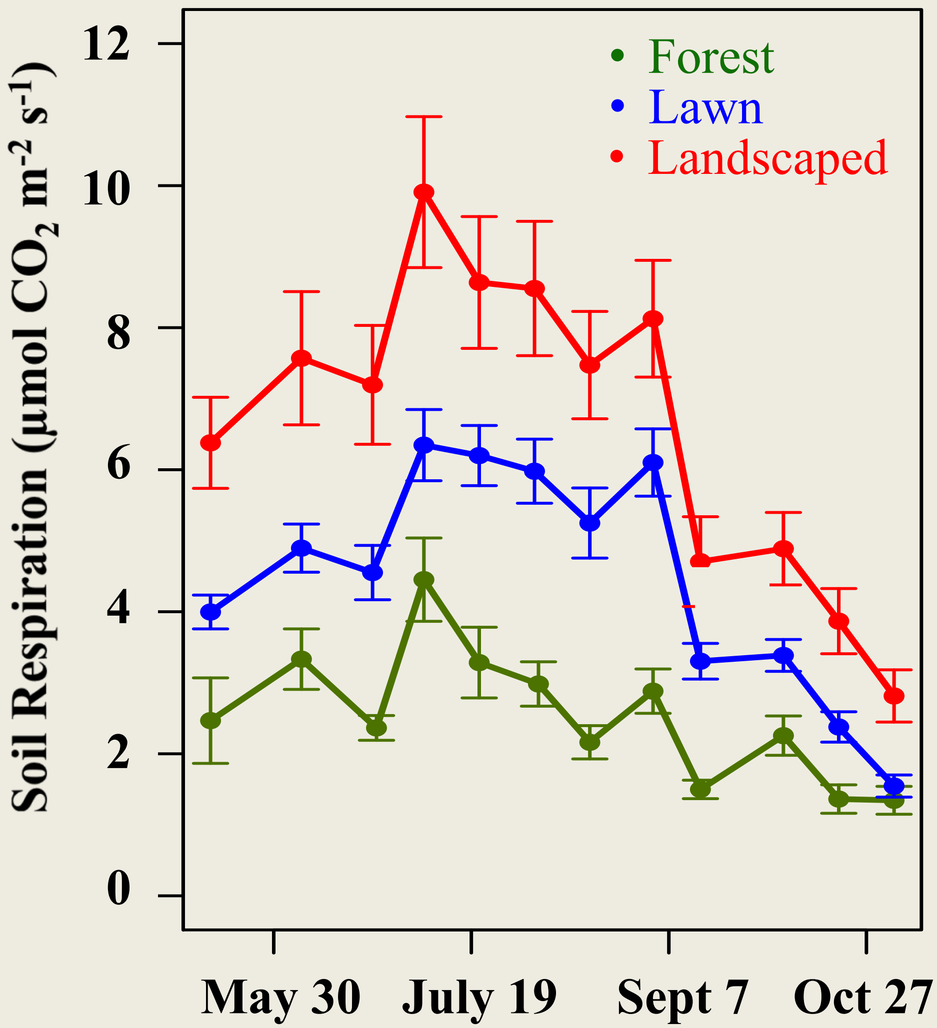
NIST (MD)



Soil Respiration & Fragmentation



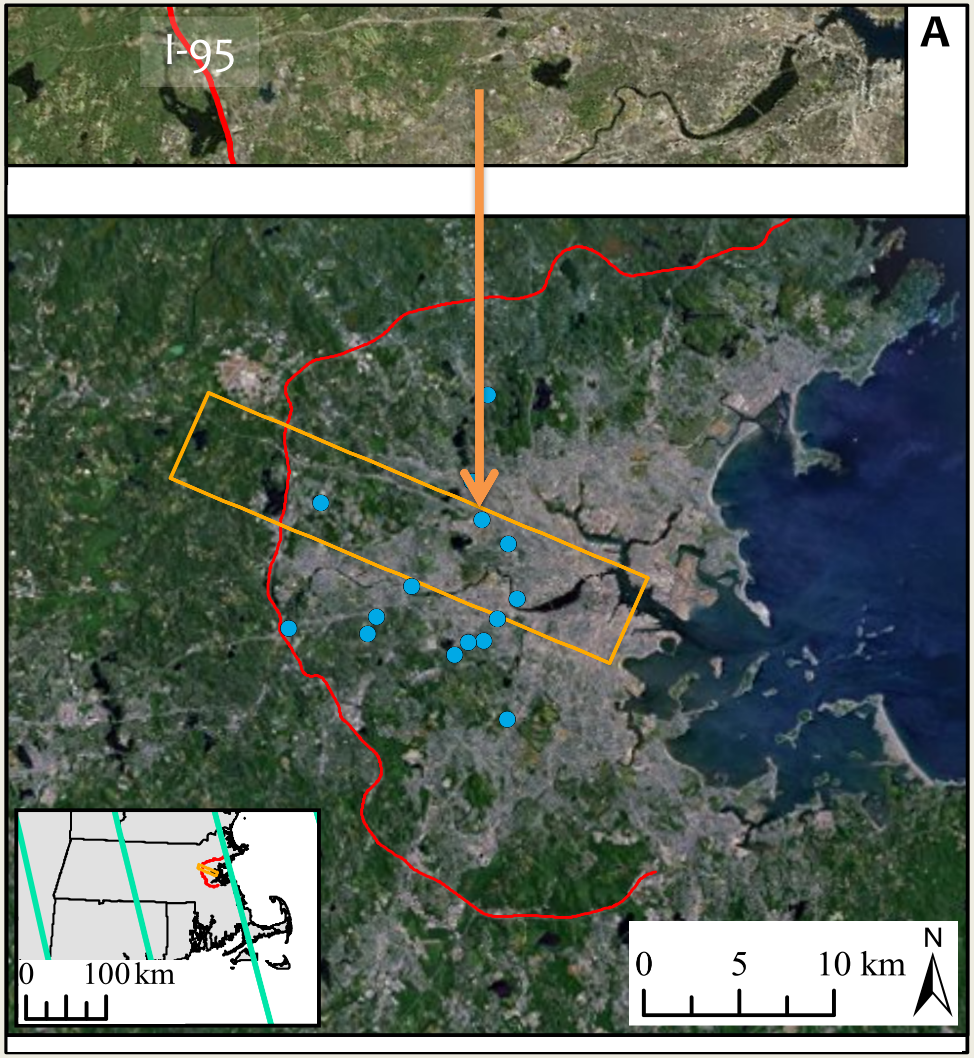
Soil Respiration Varies by Land Use



Decina et al., 2016

Modeling Soil Respiration

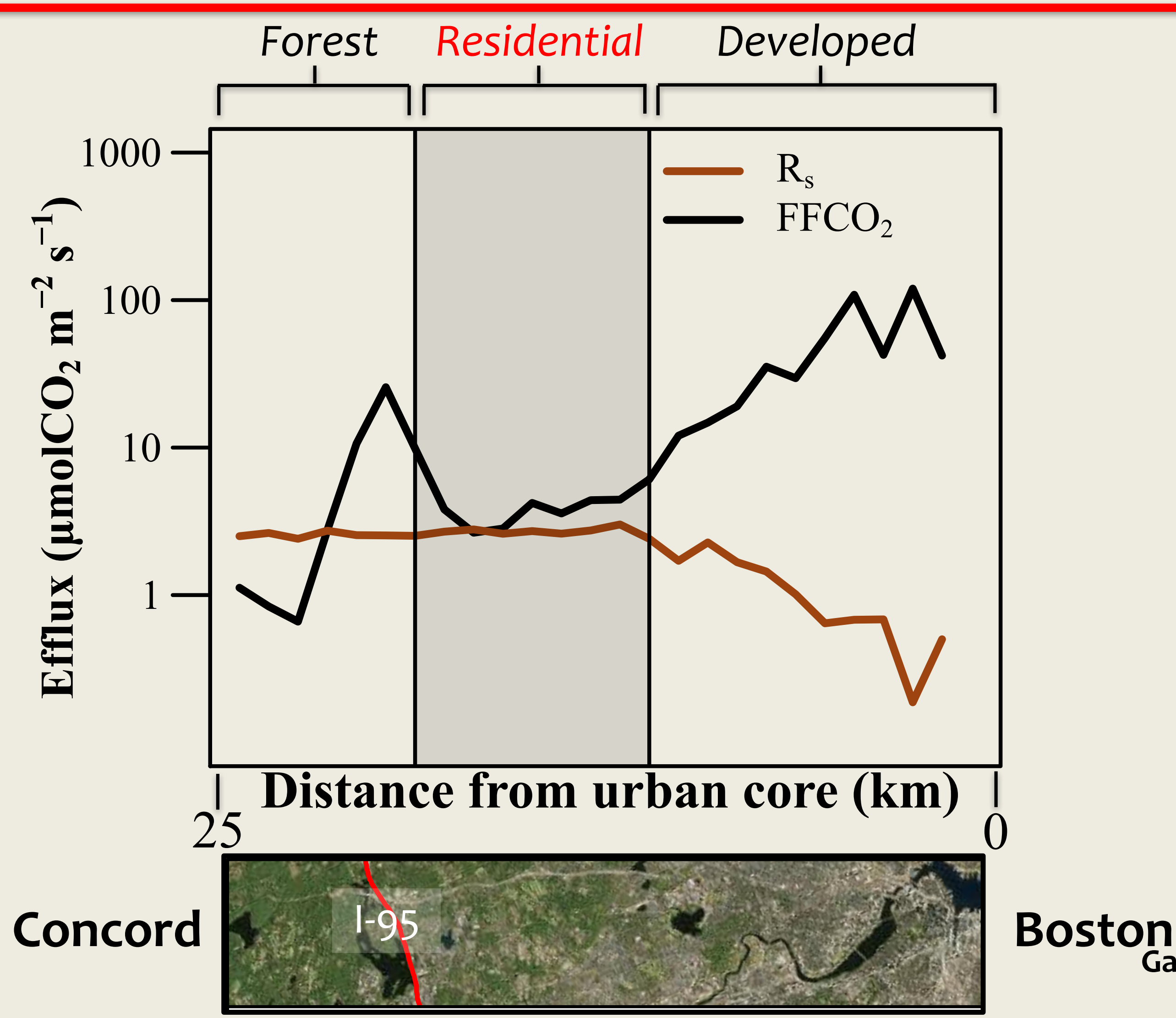
Concord



Boston

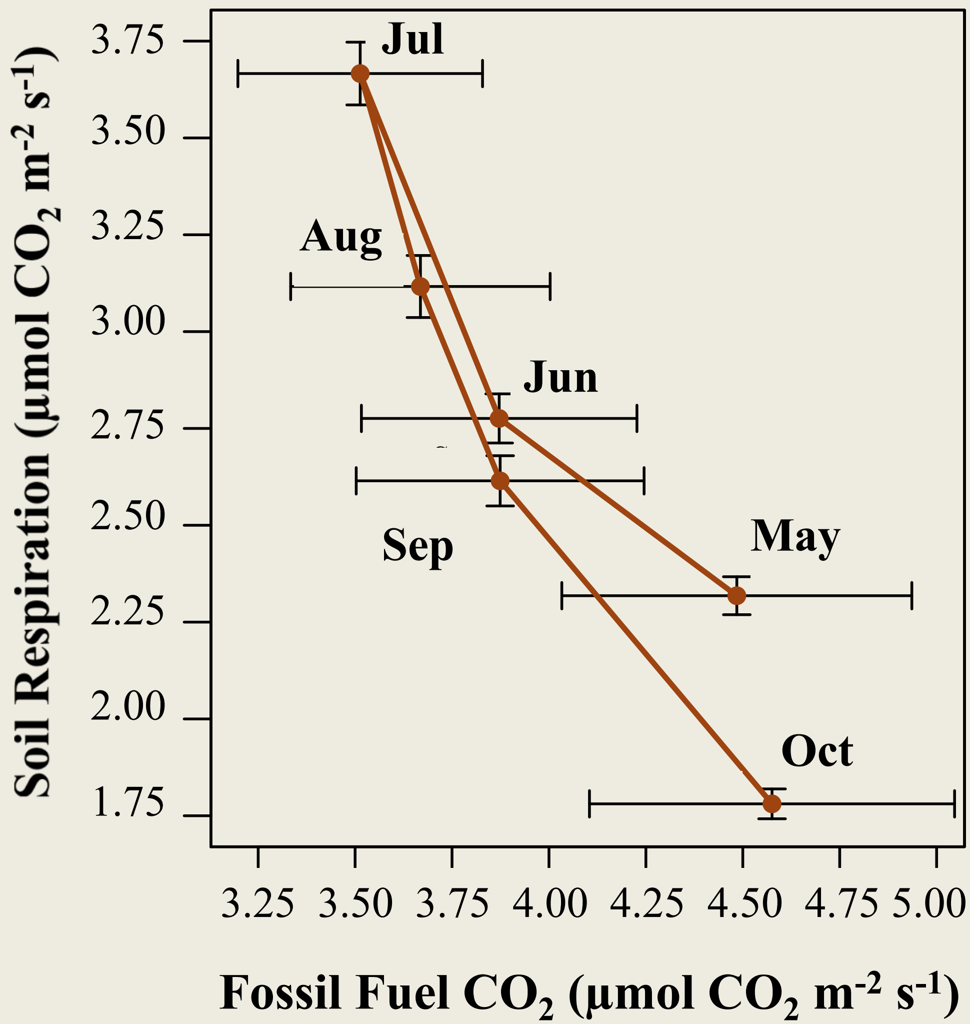
Decina et al., 2016

Soil Respiration is 75% of $FFCO_2$ in Residential Belt



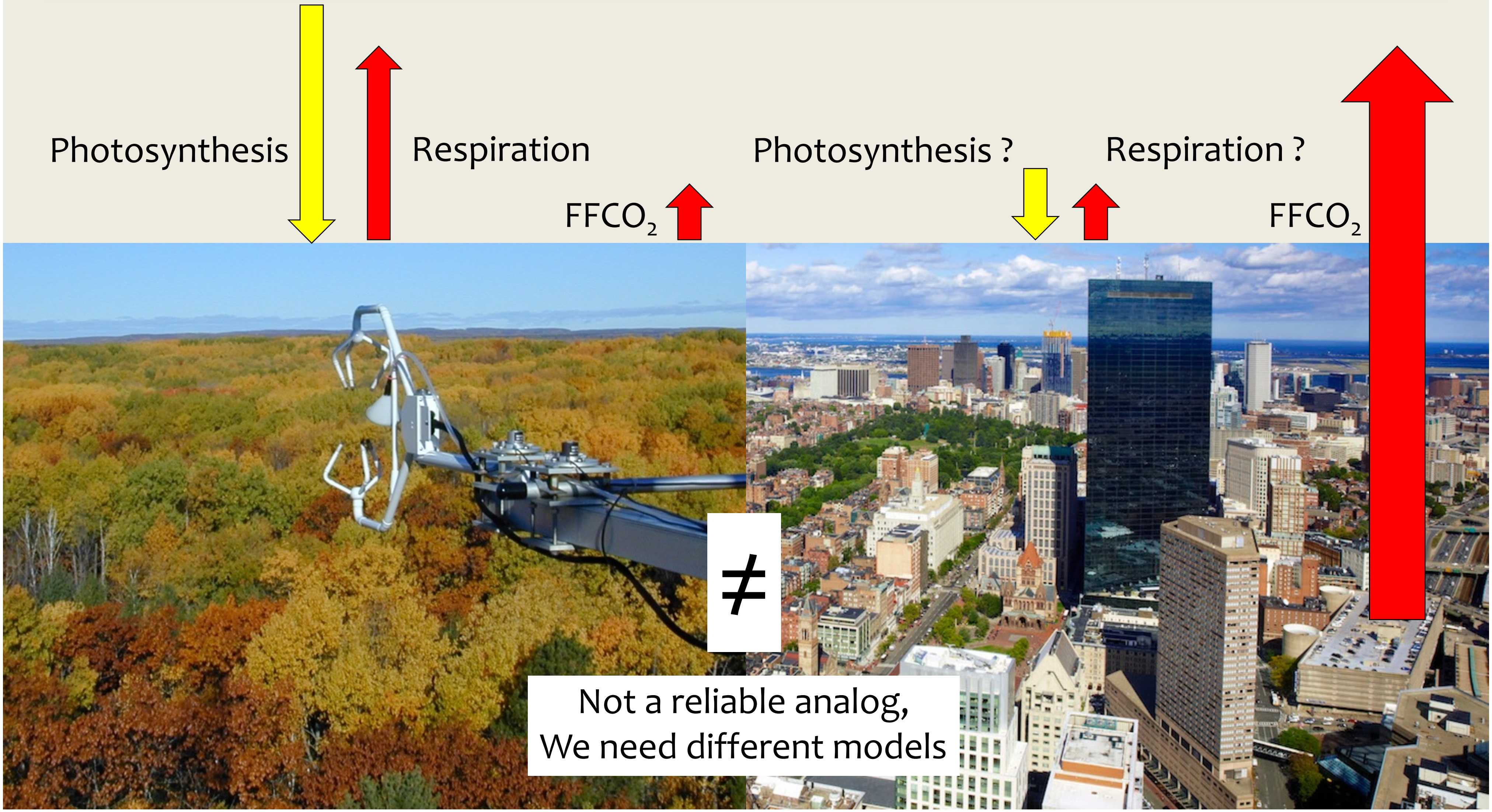
Gately & Hutyra in press
Decina et al., 2016

Soil Respiration is Temporally Variable



Gately & Hutyra in press
Decina et al., 2016

The terrestrial Carbon Fluxes



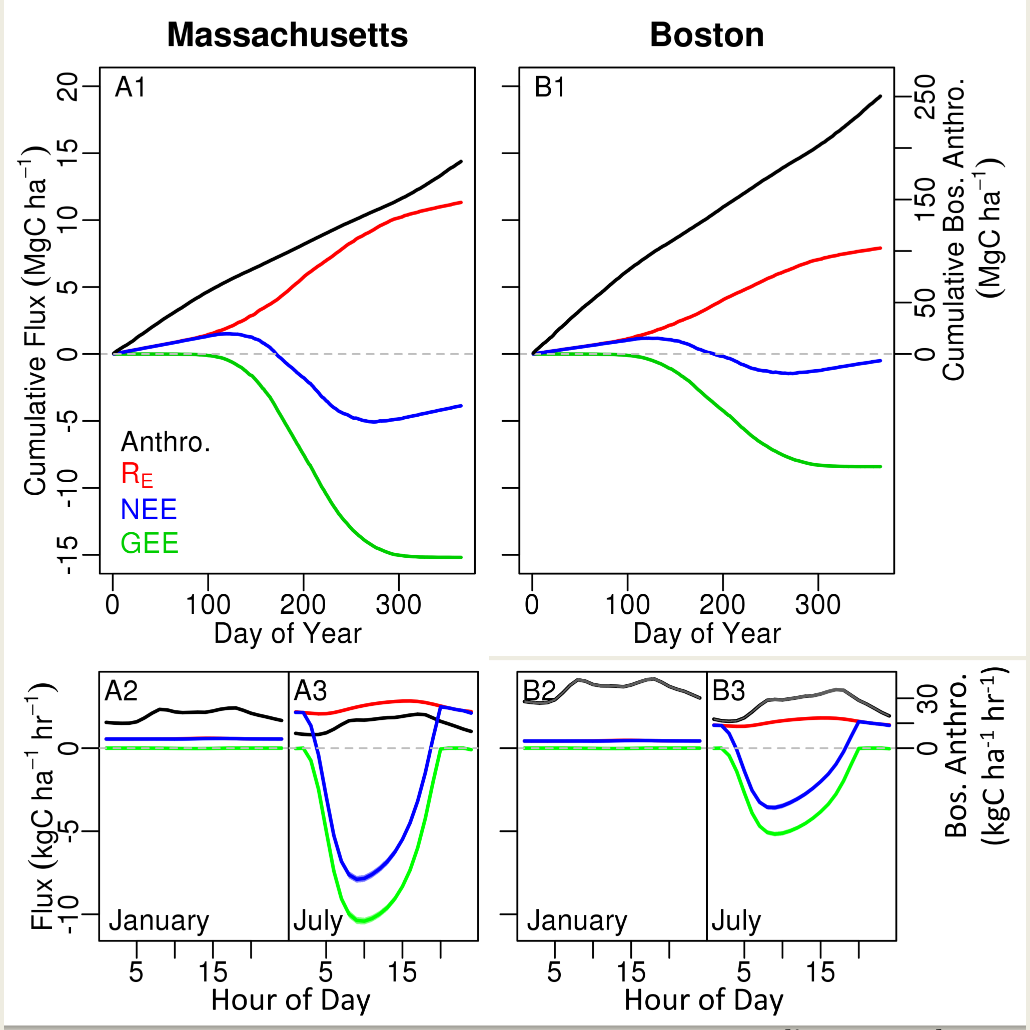
Urban biosphere flux models

- Biogenic fluxes (respiration, photosynthesis, net ecosystem exchange)
  - Vegetation Photosynthesis and Respiration Model (VPRM Mahadevan et al., 2008)
  - Light-use efficiency model driven by MODIS EVI, LSWI, PAR, Temperature, and Land Cover; empirically parameterized with flux tower data.
  - Modified to include Urban Heat Island (UHI), Impervious Surface Area (ISA), and altered urban phenology

Hardiman et al. 2017

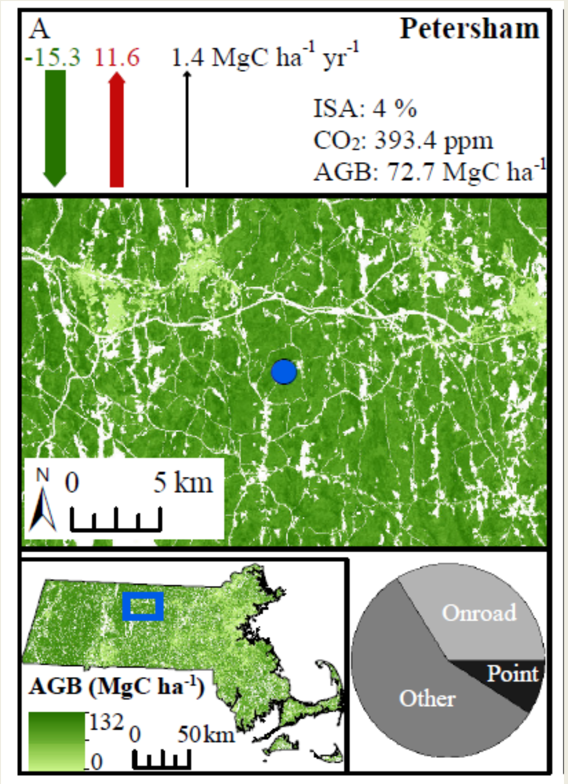
Urban biosphere flux models

- Statewide, vegetation offsets ~25% of anthropogenic emissions.
- Vegetation in the City of Boston is a negligible C sink (note secondary axis).
- Anthropogenic emissions peak during morning/evening and in winter.
- Biogenic fluxes peak midday and during summer.



Hardiman et al. 2017

Urban biosphere flux models

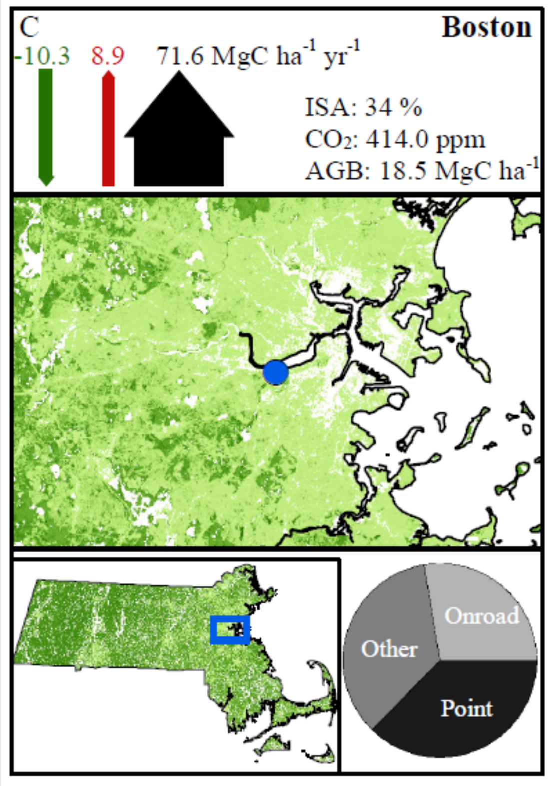


Petersham area vegetation is a strong net C sink , storing 2-3x the area's anthropogenic emissions.

Gross Ecosystem Exchange
Ecosystem Respiration
ISA: Impervious Surface Area
AGB: Aboveground Biomass
Onroad (traffic)
Point (electric generation, industrial, airports)
Other (residential, commercial, industrial, non-road mobile, and rail sources)

Hardiman et al. 2017

Urban biosphere flux models

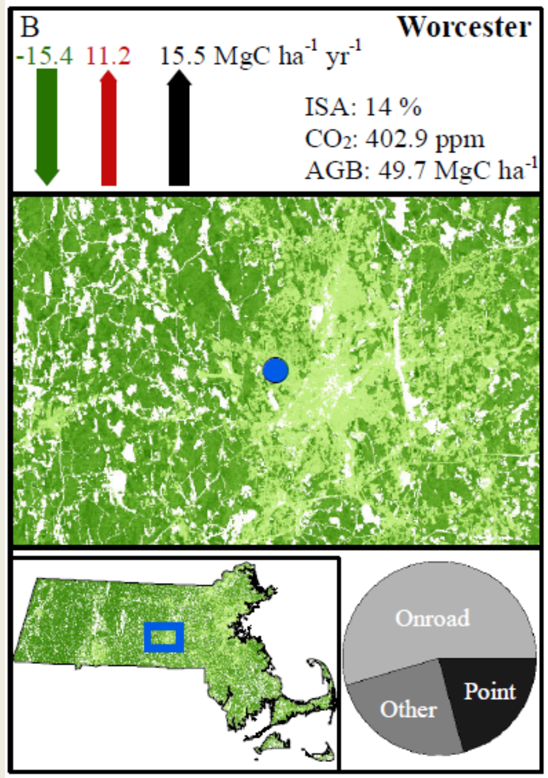


Boston area vegetation is a small net C sink, offsetting ~2% of anthropogenic C emissions.

Gross Ecosystem Exchange
Ecosystem Respiration
ISA: Impervious Surface Area
AGB: Aboveground Biomass
Onroad (traffic)
Point (electric generation, industrial, airports)
Other (residential, commercial, industrial, non-road mobile, and rail sources)

Hardiman et al. 2017

Urban biosphere flux models

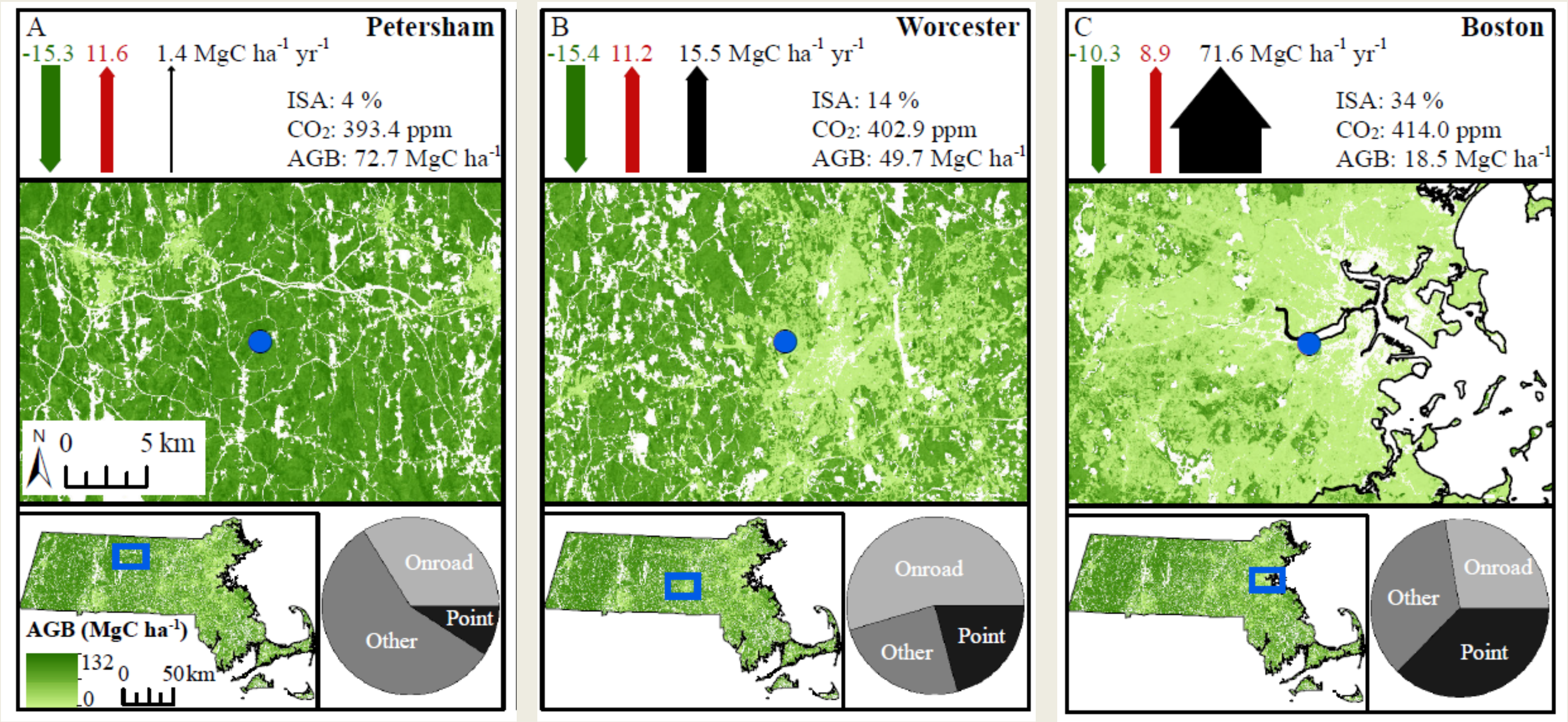


Worcester area vegetation absorbs ~¼ of anthropogenic C emissions.

Gross Ecosystem Exchange
Ecosystem Respiration
ISA: Impervious Surface Area
AGB: Aboveground Biomass
Onroad (traffic)
Point (electric generation, industrial, airports)
Other (residential, commercial, industrial, non-road mobile, and rail sources)

Hardiman et al. 2017

Urban biosphere flux models



- While vegetation is found throughout urban areas, its capacity of offset urban anthropogenic emissions is limited
- The extent of temporal aliasing of fluxes depends in part of the local $FFCO_2$ sources.

Hardiman et al. 2017

Urban biosphere flux models

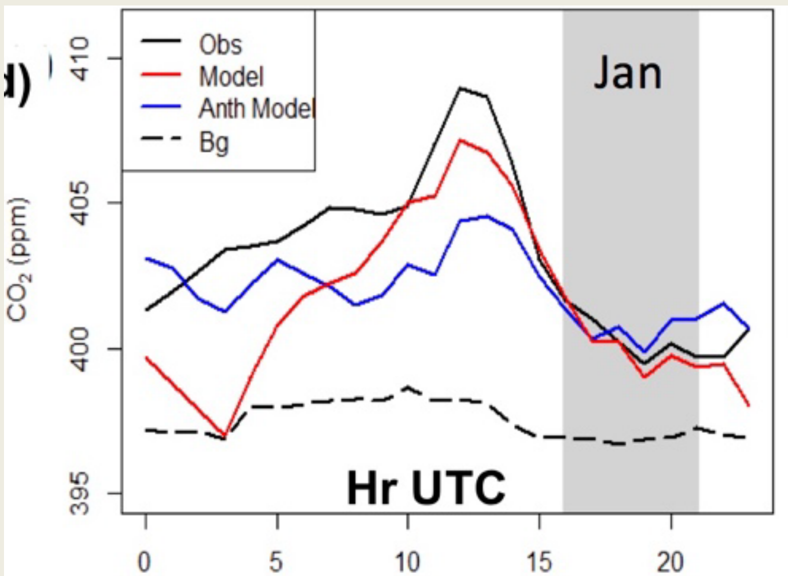
- Urban net biogenic fluxes are small. Component fluxes (GEE, R_E) can be a substantial large, particularly during the hours when inverse models perform most reliably.

- Urban growing conditions enhance C fluxes, but urbanization reduces biomass density.
  - Kilogram-for-kilogram, urban vegetation cycles C faster than rural forests (up to 2x).

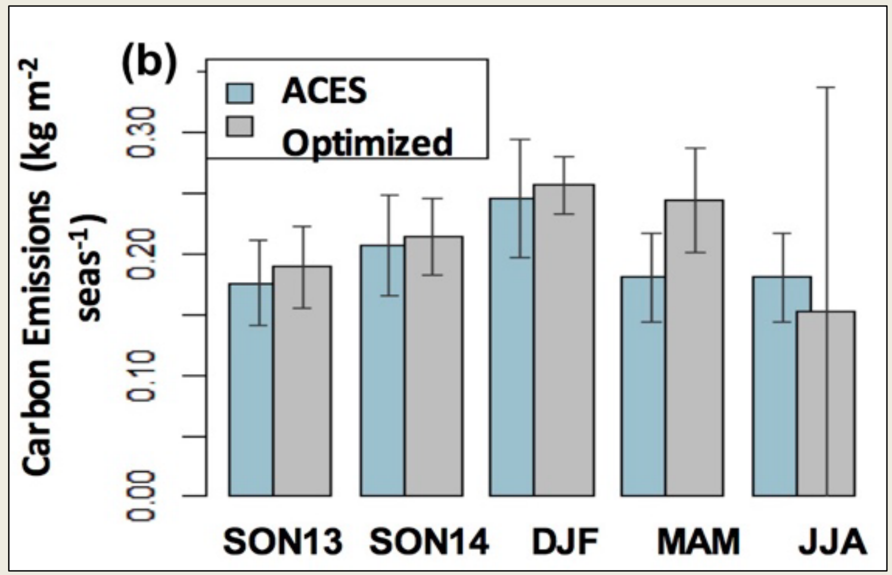
- Model results suggest a suburban "Goldilock's Zone" in which high ISA suppresses soil respiration, but other urban growing conditions enhance GEE, yielding high NEE.
  - Urban form may constrain or facilitate C storage and flux capacity of urban vegetation.

Inverse model results

ACES fluxes produce simulated concentrations that agree very closely with observations.



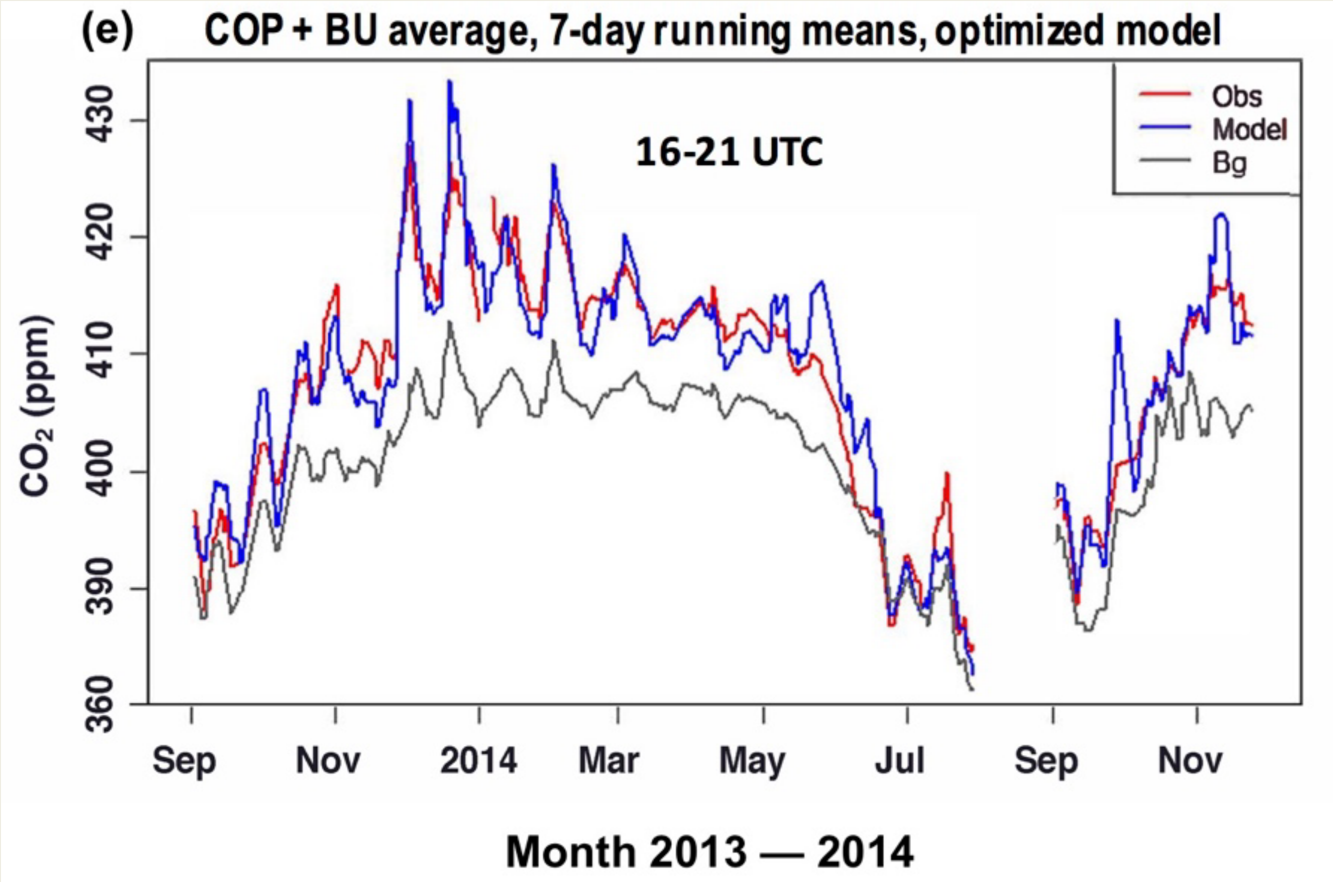
In all seasons, optimized model emissions agree within confidence intervals with optimal emissions.



Sargent et al. in prep

Inverse model results

The model reproduces the afternoon rural-urban gradient...



…but vegetation uptake in summer gives ~ 0 gradient!

Urban biosphere flux models

- Biogenic fluxes (respiration, photosynthesis, net ecosystem exchange)
  - Vegetation Photosynthesis and Respiration Model (VPRM Mahadevan et al., 2008)
  - Light-use efficiency model driven by MODIS EVI, LSWI, PAR, Temperature, and Land Cover; empirically parameterized with flux tower data.
  - Modified to include Urban Heat Island (UHI), Impervious Surface Area (ISA), and altered urban phenology

- We are starting to apply urbanVPRM to SF, LA, SLC, Indy, DC/Balt.
- We are working on replacing simplified greenness representation (EVI) with solar induce fluorescence (@ NIST and across the NE).