Are nitrogen availability, forest carbon uptake, and canopy albedo enhanced along a nitrogen deposition gradient in the central Appalachian Mountains?

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Introduction & Approach

• MODIS-based extrapolations from empirical relationships developed at AMERIFLUX sites suggest that central Appalachian forests have among the highest rates of N availability, atmospheric C uptake and canopy albedo of all North American forested ecosystems (Figure 1).

•To begin testing a hypothesis that the high rates of atmospheric nitrogen deposition to these forests could be responsible for this pattern, we have measured N deposition proxies and ecosystem responses along a deposition gradient (Figure 2).

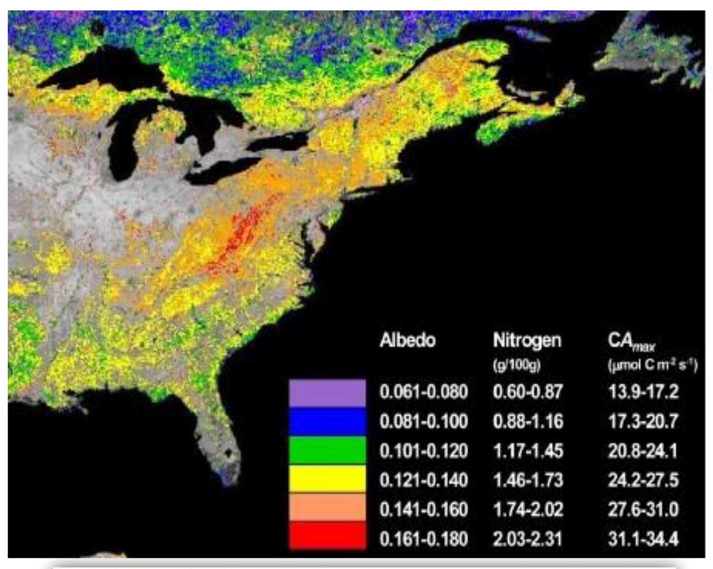


Figure 1. *Map developed by applying empirical relationships of canopy nitrogen, forest carbon sequestration, and canopy albedo to MODIS albedo measurements. From Ollinger et al. 2008*

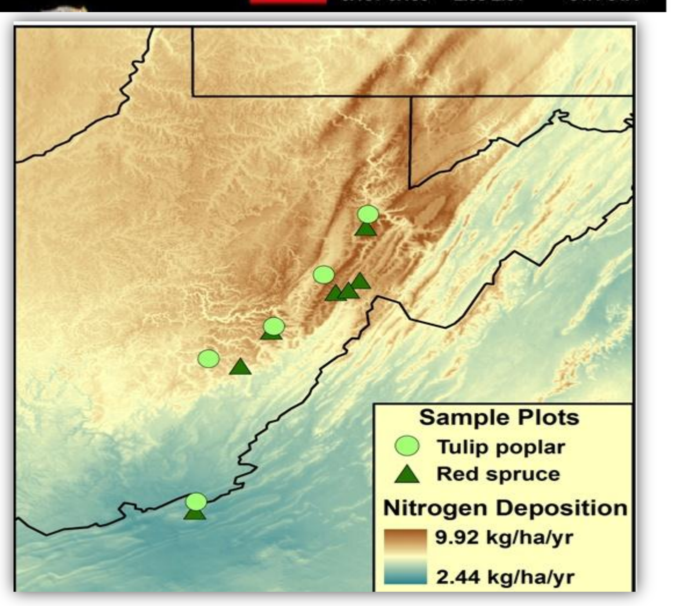


Figure 2. *Study area map showing the 5 tulip poplar (Liriodendron tulipfera) and 7 red spruce (Picea rubens) sample plots on an interpolated map of atmospheric N deposition (map is courtesy of Jeff Grimm, and shows mean annual wet deposition between 1985 and 1995).*

Research Questions & Objectives

1. Has the deposition gradient been a persistent spatial feature that affects tree growth?

• Measure soil lead, an index of cumulative deposition amount, along the gradient to confirm atmospheric deposition patterns interpolated from recent monitoring data (e.g. Figure 2).

•Use tree-rings to examine patterns in tree growth along the gradient and through time.

2. Do field-measured values of N availability, C cycling, and albedo increase along the gradient?

• Measure foliar N, foliar $\delta^{15}N$, foliar albedo (400-2500nm), soil C:N, soil $\delta^{15}N$, soil respiration, and tree growth along the deposition gradient.

Field Methods

• We collected leaves from three canopy heights of three individuals, and pooled leaves by height (Figure 3).

• We pooled 8 soil cores from each of the organic and top 5cm of the mineral horizons

• We took 2 tree-ring cores from 20 trees per plot

• In red spruce plots we also:
  • Made monthly measures of soil respiration and temperature in 4 cores per plot
  •Used dendrobands on 20 trees to monitor current tree growth

Figure 3. *2011 NSF REU student collecting tulip poplar samples used to measure albedo, foliar N and foliar* $\delta^{15}N$.

Laboratory Methods

• We measured foliar albedo using an ASD Fieldspec 3 spectrometer (Figure 4) and foliar and soil N and $\delta^{15}N$ at the Central Appalachian Stable Isotope Facility.

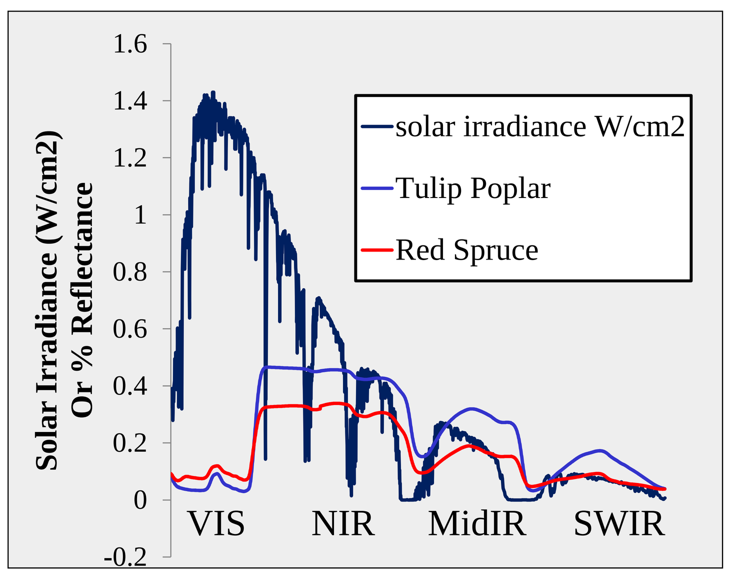


Figure 4*. Calculation of foliar albedo. Tulip poplar leaves have a higher albedo than red spruce because they reflect more solar irradiance, particularly in the near infrared (NIR).*

• We measured soil Pb on an AA, and used cross-dated tree-ring widths to measure the yearly plot-average basal area index (BAI). We normalized soil respiration by temperature.

Results

• Strong relationships with among mineral soil lead and mapped deposition (Figure 5), as well as a marked tree-ring signal in red spruce stands (Figure 6) indicate that the deposition gradient has been a persistent spatial feature since c. 1955.

Figure 5 (right). *Mineral soil lead was highly predictive of mapped deposition (see Fig. 2).*

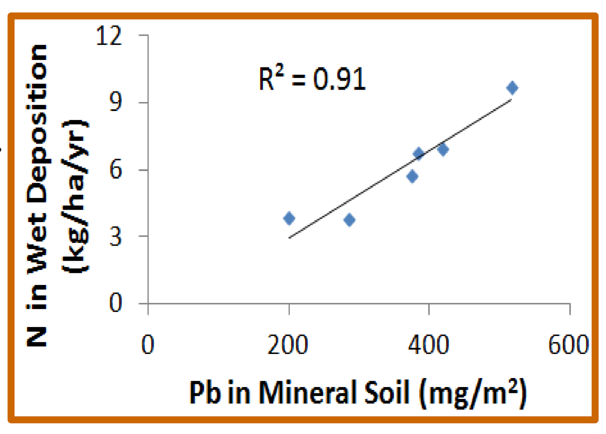
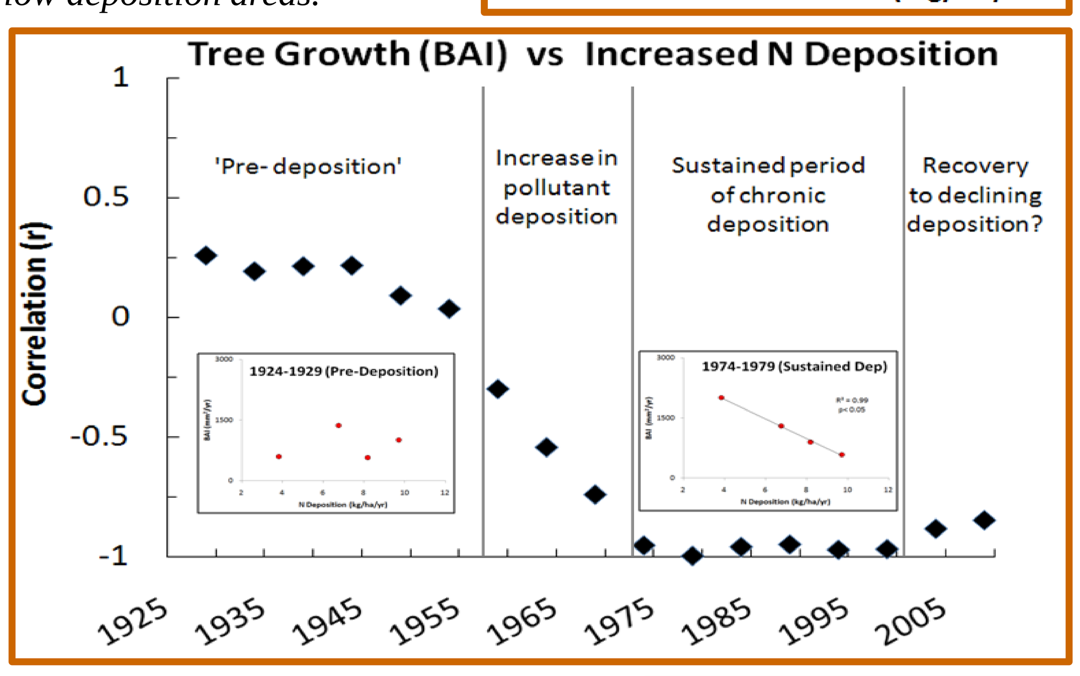


Figure 6 (below). *Starting in the early 1950's, spruce trees in high deposition areas declined in growth relative to low deposition areas.*



• Surprisingly, we found ***no significant changes*** in albedo, foliar N or foliar $\delta^{15}N$ along the N deposition gradient.

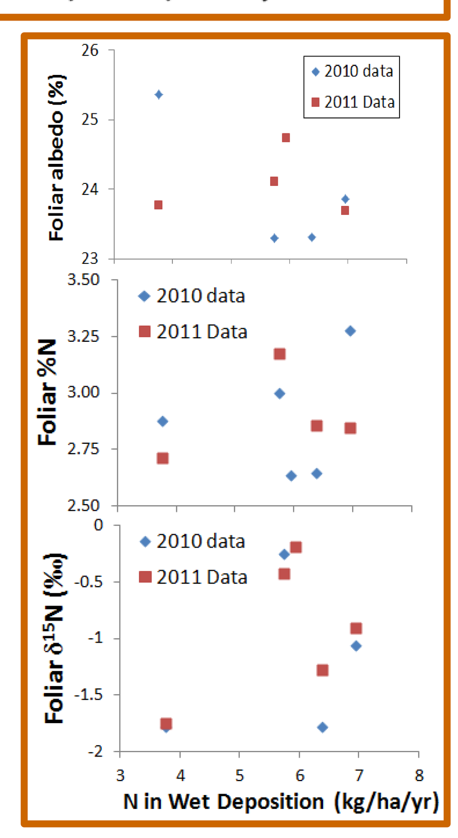


Figure 7. *Non-significant relationships among N deposition and tulip poplar foliar albedo, % N by mass, and* $\delta^{15}N$*. Spruce leaves also had non-significant relationships. All data are from high canopy leaves. Relationships at low, mid, and pooled heights were also non-significant.*

• However, in our red spruce plots where we also measured C fluxes, we observed tight correlations among N availability, above-ground growth, and soil respiration.

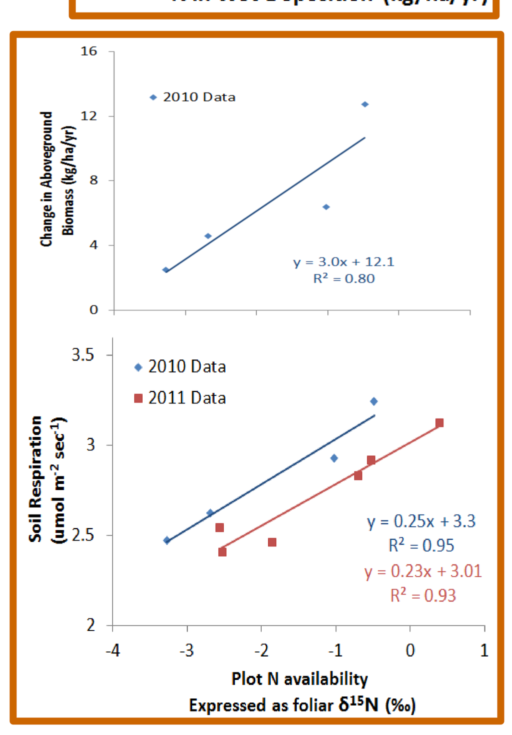


Figure 8. *C fluxes of above ground biomass accumulation and soil respiration increase with increasing N availability. Foliar* $\delta^{15}N$ *was strongly correlated with other measures of N availability such as soil* $\delta^{15}N$*, and soil C:N.*

Discussion

• Our data **do not support** the hypothesis that N deposition has directly caused the spatial pattern of elevated N availability, C uptake, and albedo in forests of the central Appalachian Mountains. But, **they do suggest** a tightly-coupled C and N cycle.

• We suggest three explanations why our field-data do not support a direct linkage to N deposition:

1. The data informing our hypothesis (Figure 1) were observed by satellites at a canopy level, but our measurements are on a leaf-level.
2. A larger sample size may be needed.
3. Atmospheric deposition may affect change in an indirect and non-uniform manner, especially via long-term changes to species composition.

• We suggest future research should explore these non-mutually exclusive explanations by also collecting canopy compositional (e.g. species abundances) and structural data (e.g. leaf angle distribution, leaf area index[LAI]) at a greater number of sample sites across the N deposition gradient.

Conclusions & Future Studies

• If there is a linkage among N deposition and the pattern of increased canopy N, carbon uptake, and albedo, it does not appear to be manifested at the leaf-level in these two important tree species.

• Future research should focus on possible canopy-level drivers that could increase canopy N, carbon sequestration, and albedo. Some likely drivers could be species composition, increased leaf angles, and increased LAI (Ollinger 2011).

• Our future work will use existing (Figure 10) and new field, forest inventory, AVIRIS, Hyperion, and GIS data to explore these likely drivers of canopy N, albedo and carbon fluxes.

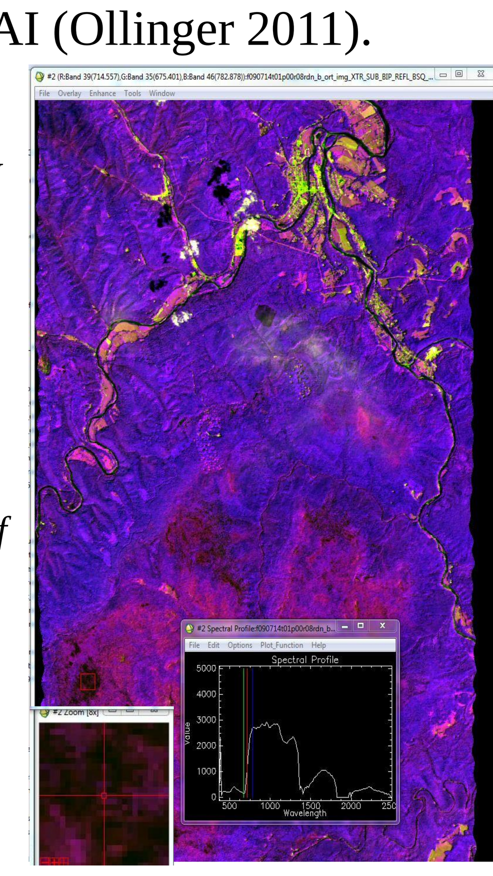


Figure 10. *Red-edge AVIRIS image of Fernow Experimental Forest and Parsons, WV, showing reflectance spectra from our highest deposition red spruce plot. Also visible are patterns related to forest harvest treatments, geology, fertilization treatments, and species composition.*

Acknowledgements & References

Questions? Contact: bemcneil@mail.wvu.edu

References:

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