Tree species identity governs foliar nutrition regardless of historic acid deposition and soil chemistry in high-elevation red spruce (*Picea rubens* Sarg.) forests

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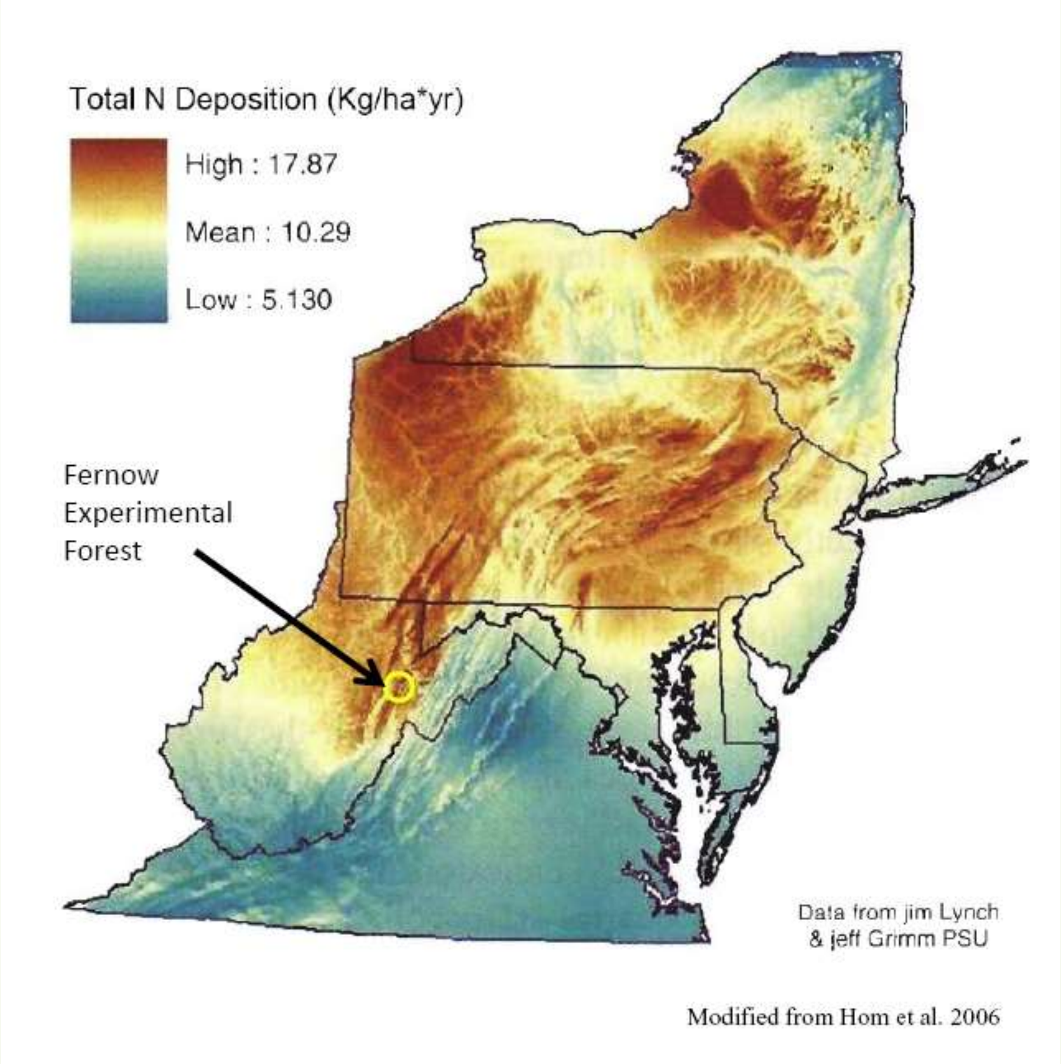
Appalachia and Acid Deposition



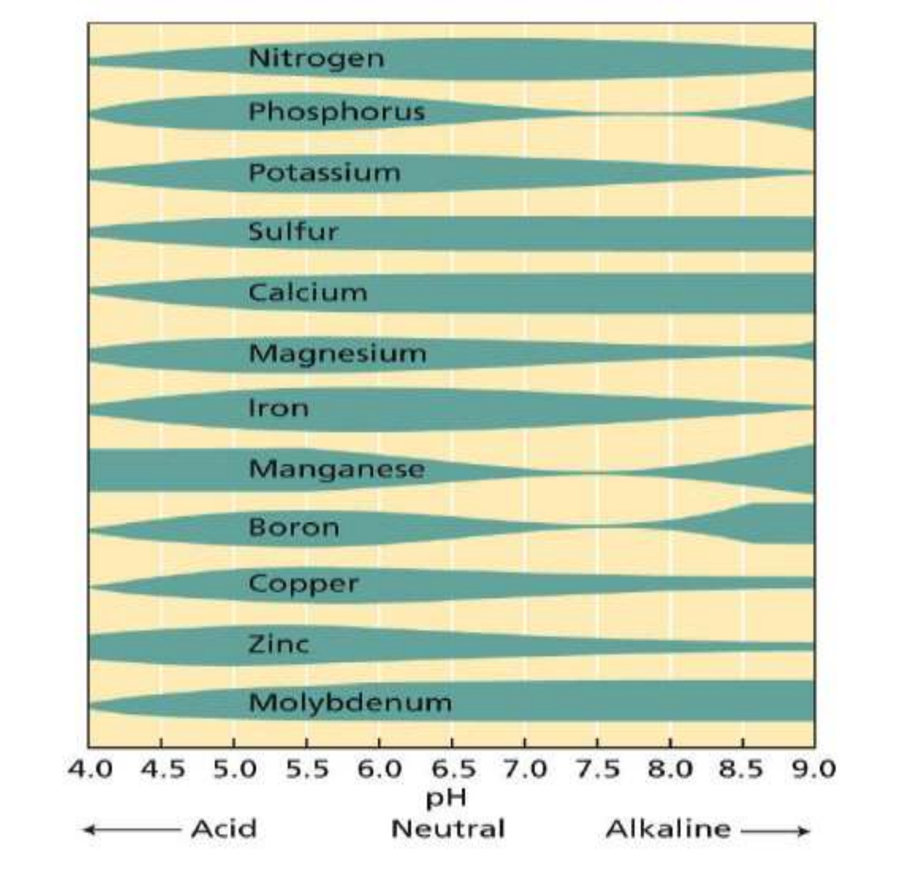
http://www.as.wvu.edu/fernow/Assests/Images/Central%20appalachian%20N%20deposition.jpg

Effects on Trees

- Weakening of cell membranes and leaching of cations from foliage
- Loss of stomatal control
- Loss of winter hardiness in conifers
- Decreases in conifer winter photosynthesis

Nutritional Impacts

- Nutrient fertilization
- Soil acidification
- Increases in bioavailable aluminum
  - Cation Leaching
  - Nutrient Binding

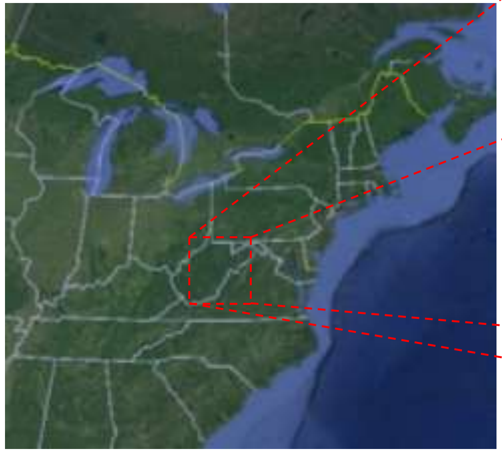


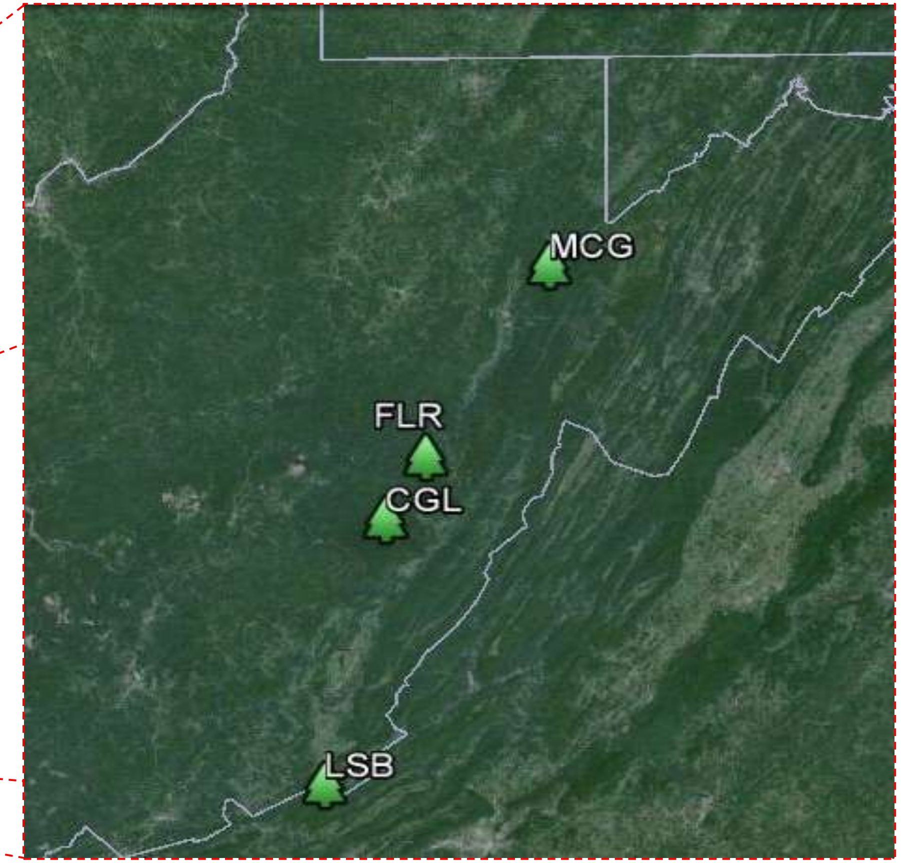
Hopkins and Huner 4th Ed. (2009)

Study Sites

Site	Code	Location	Estimated Total N Deposition (kg N/ha)	Elevation (m)
Flat Ridge	FLR	Little Levels, WV	399.6	1320
McGowan Mtn.	MCG	Slaty Fork, WV	380.2	1270
Cranberry Glades	CGL	Little Levels, WV	366.4	1160
Little Spruce Bog	LSB	Pembroke, VA	326.1	1179

As of 2012, this gradient ranged from 3.5-6.6 kg total N/ ha/yr





- Four high-elevation red spruce stands were selected across a gradient of historic total N deposition
- All four sites have similar species composition; same red spruce-yellow birch cover type (SAF)
- National Atmospheric Deposition Program (NADP) data was used to estimate total N deposition at each site

Field Methods

- Four tree species: red maple, yellow birch, red spruce, and eastern hemlock
- Foliage taken from mid-canopy of three replicate canopy-dominant or codominant trees, >18" DBH
- Only pristine foliage (free of damage from shot) was utilized

Field Techniques

- Bulk soil sampled beneath five individuals of each species at all sites
- Soils samples taken from the top 15cm and divided into organic and mineral horizons
- Soils dried in the lab and plant-available elements assayed via Mehlich-III extraction

Lab Methods

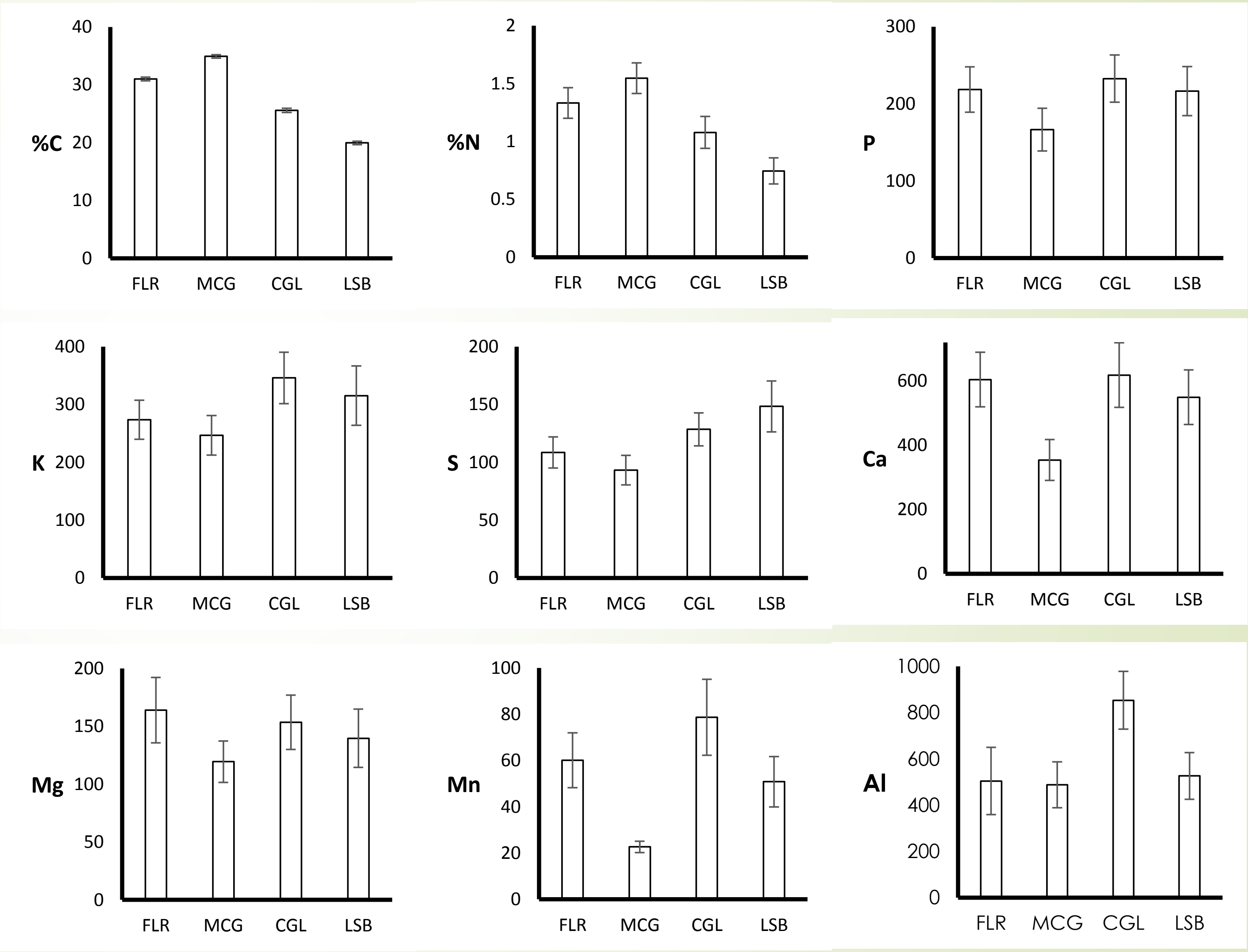
- 2g of soil extracted in 20ml of Mehlich-III solution and filtered
- Extracts analyzed using ICP-OES
- Samples digested in 75ml Teflon digestion tubes in MARSXpress™ 5 microwave digester
- Elemental analysis of foliar tissue digests performed via ICP-optical emission spectroscopy

Results

- Evidence ($a<0.05$) for significant differences between species for every foliar element measured (macronutrient and trace)
- Significant differences due to site were observed for some elements including Ca, Mg, and K, but did not follow the modeled pattern of deposition
- No evidence for differences in soil chemistry across sites following the expected pattern of historic acid deposition

Results

Soil element distributions following deposition trend are generally absent



Results

- No evidence for foliar samples from higher-deposition sites containing more Pb, or soil samples reflecting higher Pb or Cd
- Evidence for a significant interaction between site and species for Sr
- Eastern hemlock had highest tissue Al
- Yellow birch had relatively high foliar Zn, roughly 10x that of other species

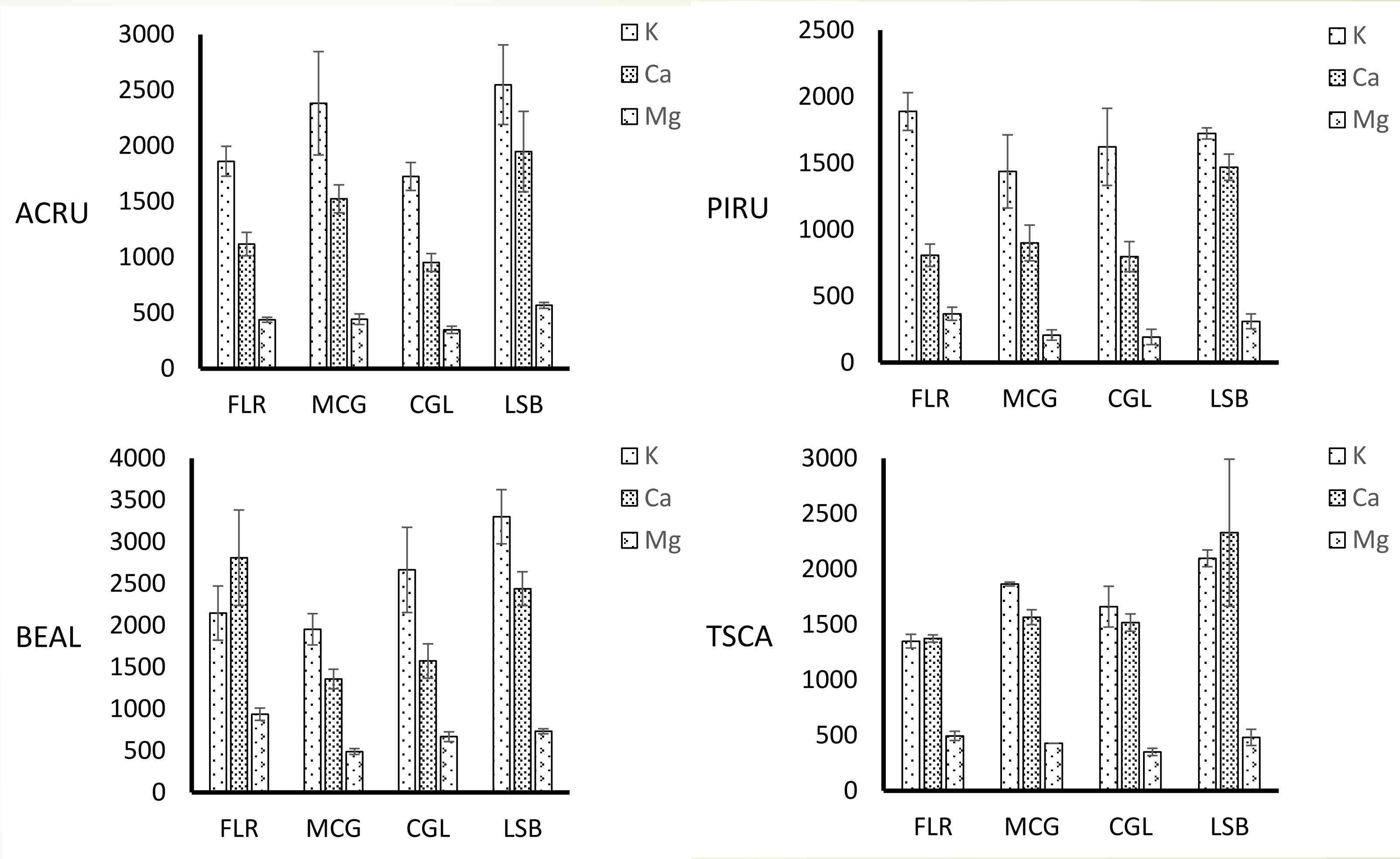
Ghosts of Deposition Past?

- Elevated soil Al in organic and mineral horizons at higher deposition sites?
- Higher levels of heavy metals in soil organic horizons at higher-deposition sites?
- Higher soil and foliar Sr and lower Ca/Al ratio at higher deposition sites?

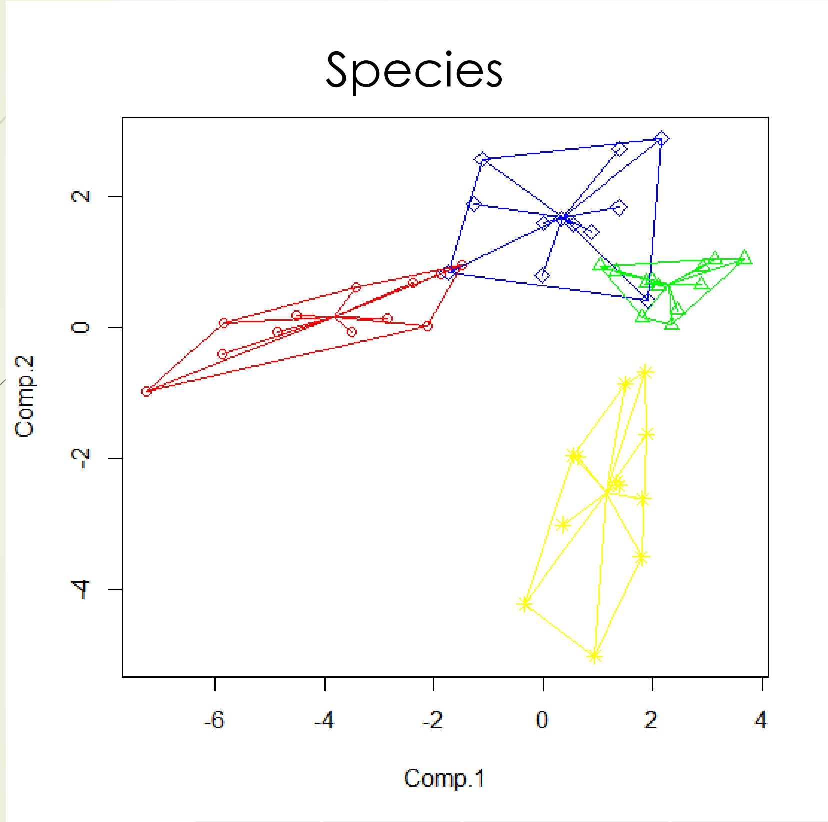
Results

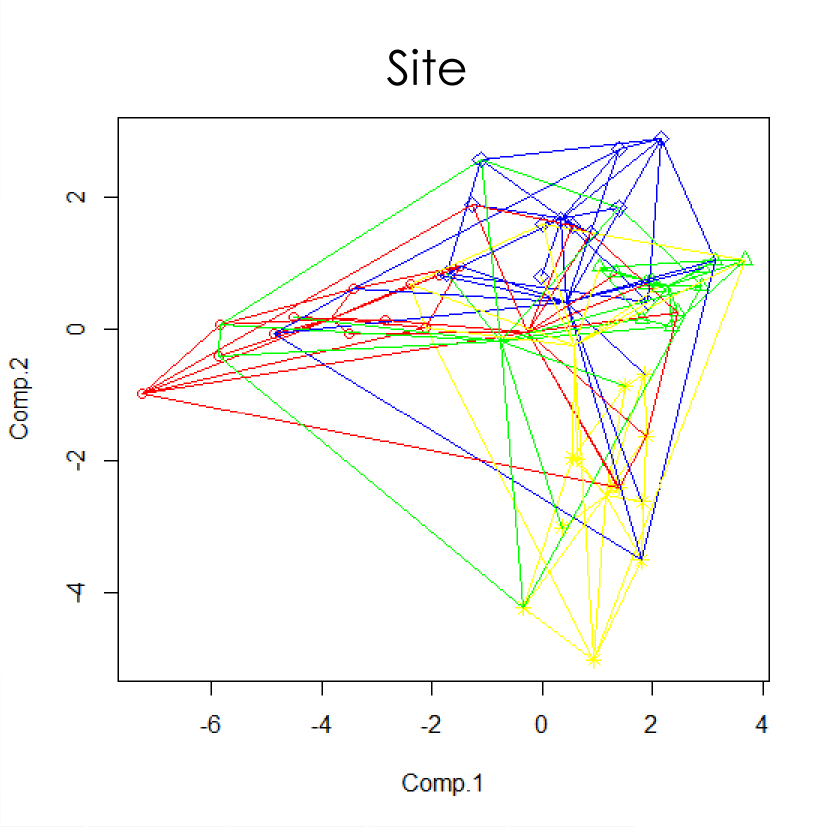
Consistent with other reported foliar measurements for these species

No indications of limitation or nutrient deficiency



Principal Component Analysis



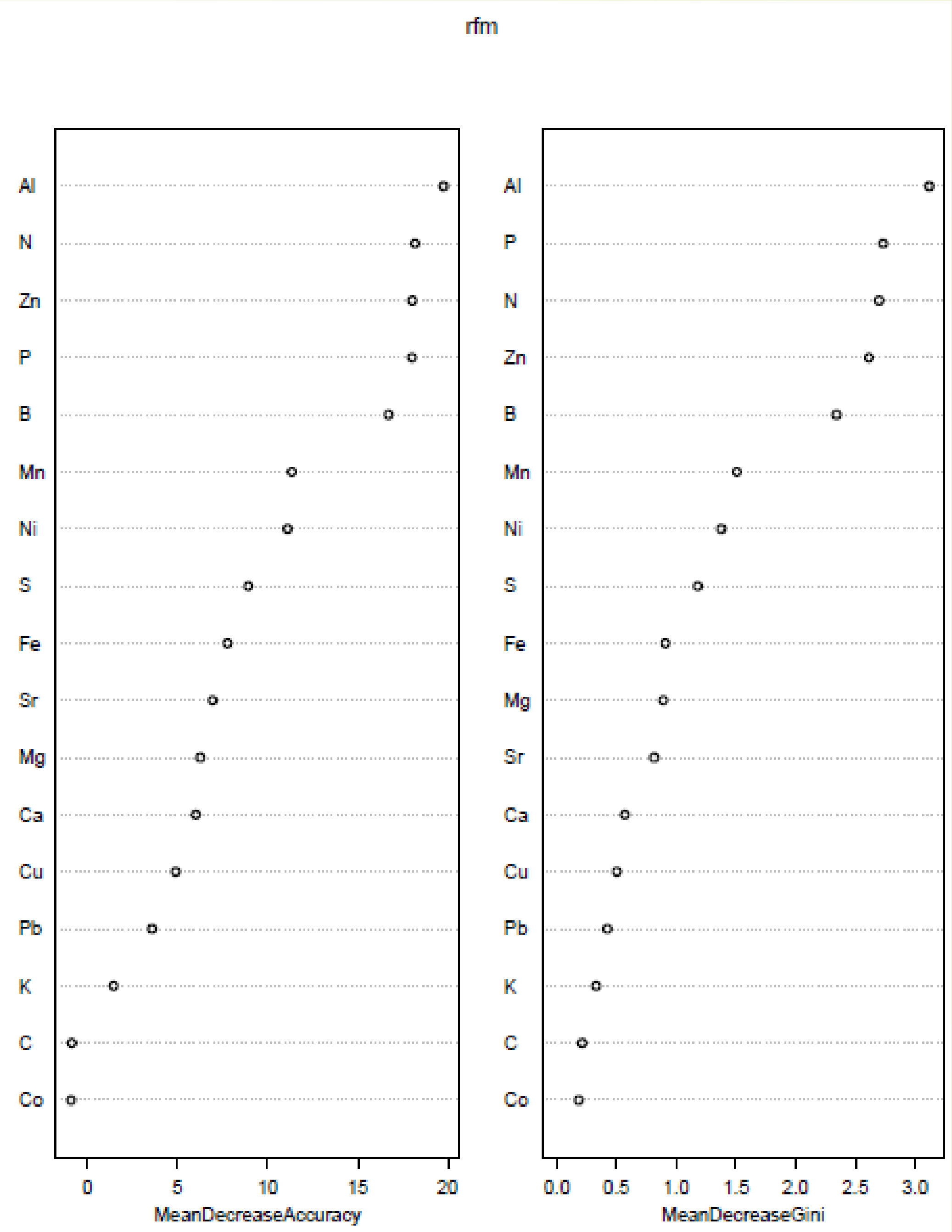


Species

	Al	B	C	Ca	Co	Cu	Fe	K	Mg
PC1	0.114822	-0.52366647	0.53843666	-0.73091	-0.0407	-0.74459	-0.81209	-0.69027	-0.89052
PC2	-0.82562	-0.74686572	-0.18195194	-0.34763	0.609571	0.369633	0.256219	0.051104	-0.04863
	Mn	N	Ni	P	Pb	S	Sr	Zn	
PC1	-0.62159	-0.81035798	-0.52747819	-0.82145	-0.26577	-0.64324	-0.76521	-0.87328	
PC2	0.06077	0.22812108	0.21631156	-0.1688	0.165815	-0.5325	-0.03818	0.093845	

Random Forest Modeling

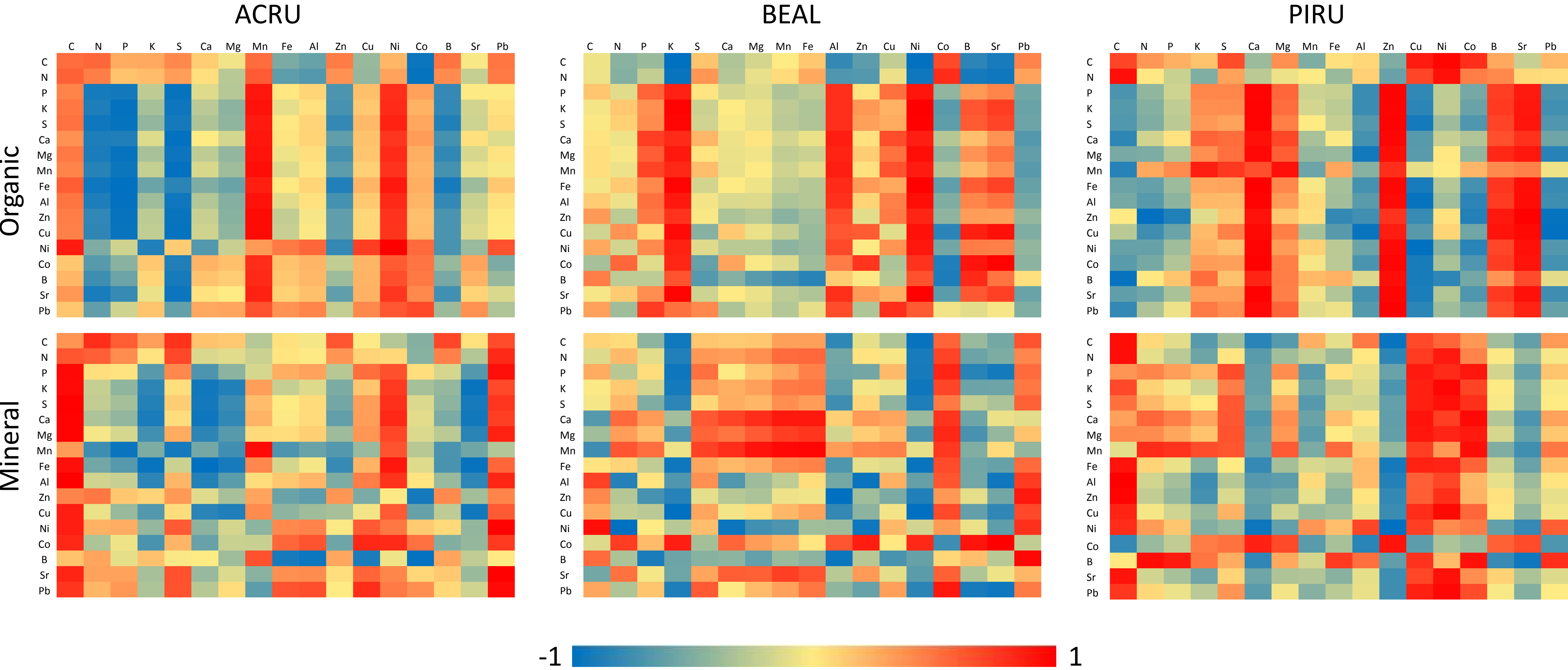
- Al, N, Zn, P, B being some of the most important model variables is in line with the major factor loadings from the PCA
- Soil B, Al, Zn all directly influenced by acid deposition, however no evidence from soil data of AD influences on the concentrations of these elements



Discussion

- Species-specific differences are the current drivers of the accumulation of most elements in plant biomass
- No evidence for acid deposition and associated legacy effects driving significant differences across these four sites, in foliar tissue or soils
- Smith et al. (2016) noted a similar result pattern with respect to site N status, with broadleaf deciduous tree species RIV being the strongest predictor of N status at these four sites
- More appropriate to treat these sites as replicated red spruce stands rather than being representative of a putative depositional gradient

Pearson Pairwise Correlations for soil and foliar elements



Summary and Future Work

- No evidence for legacy effects of historic acid deposition on soil element concentrations
- Foliar element concentrations differ strongly by species, but exhibit no effect due to site
- Foliar element concentrations generally did not increase as soil concentrations increased, indicating a state of nutrient sufficiency
- Dendrochronology as a tool for creating a time-integrated series of historical nutrient status (*just how bad did it used to be?*)
- Utilize the foliar chemistry database provided by the Northeastern States Research Cooperative to further investigate species differences in foliar nutrition
  - -Application for classification models?

NSRC Northeastern States Research Cooperative

Knowledge to guide the future of Northern Forest communities

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