Canopy structure, albedo, and nitrogen in New Hampshire Forests

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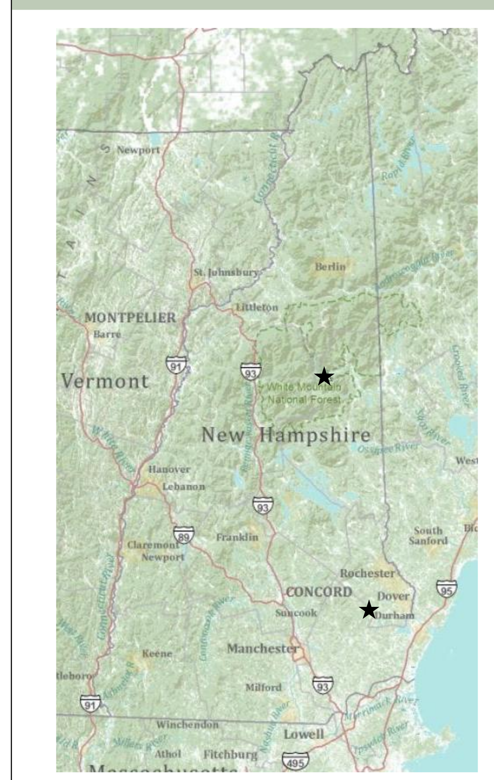
ABSTRACT

Canopy %N in boreal and temperate regions of North America have been shown to be strongly and positively correlated with shortwave surface albedo. This suggests that nitrogen may play an important part in climate beyond its role in CO_2 uptake, but the mechanistic driver is unclear. Previous work has suggested that leaf-level reflectance may not be a driving factor in the N-albedo relationship in broadleaf deciduous forests, and there is a lack of consensus among modeling studies about the factors that are most important to understanding canopy albedo.

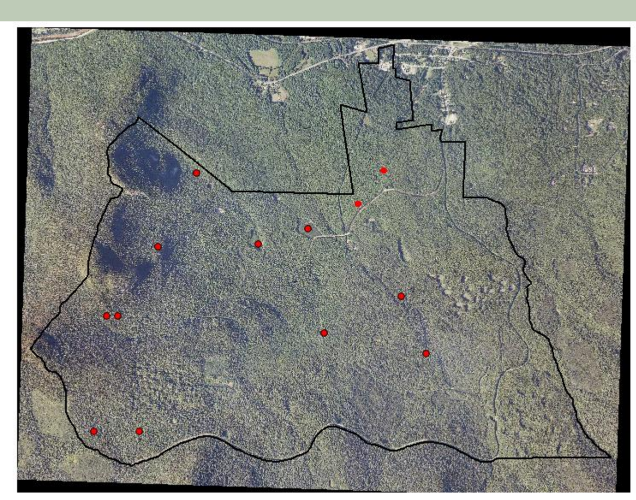
The objective of this study was to investigate relationships among various canopy structural and leaf structural traits and to examine their potential roles in canopy and leaf nitrogen variability through an intensive field study at Bartlett Experimental Forest in the White Mountain National Forest in Bartlett, NH and at Burley-Demeritt Farm in Lee, NH. Preliminary results suggest that more than one factor may be contributing to the relationship at both scales. Earlier studies of deciduous leaves found that leaf albedo does not appear to influence canopy albedo; however, including needle-leaf species appears to show different results. Still, leaf albedo alone does not explain the N-canopy albedo relationship, which suggests that other factors, such as canopy structure, are important to consider.

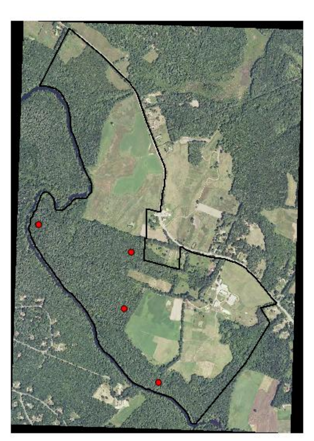
STUDY SITES



Locus Map of New Hampshire

★ Study sites:
Bartlett Experimental Forest, Bartlett, NH
Burley Demeritt Farm, Lee, NH





● Plots studied

Plots were selected after preliminary field and remote sensing studies at both BEF and BDF in order to incorporate variation in species composition, canopy albedo, and canopy nitrogen concentrations.

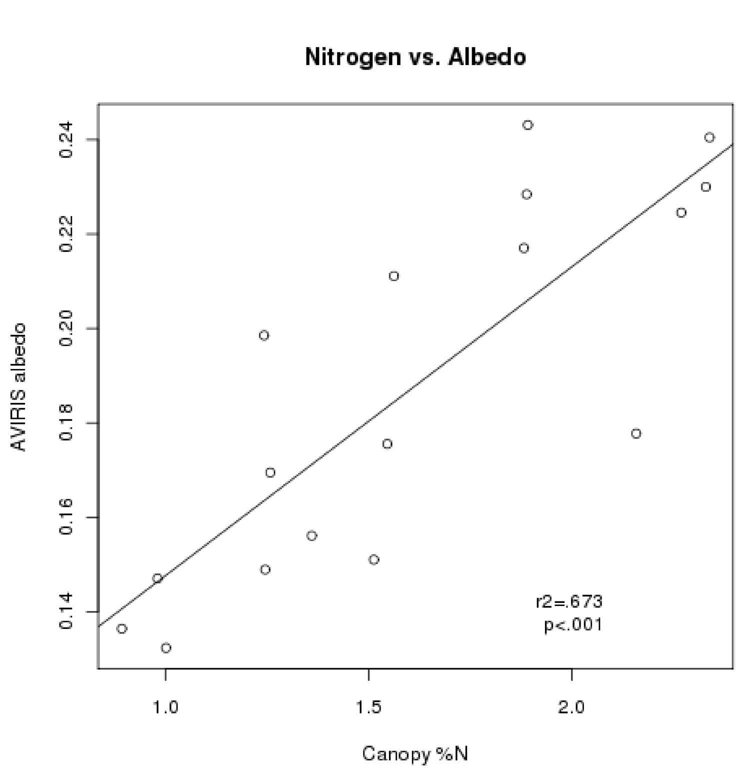


Figure 1: As shown in previous canopy level studies, there is a significant positive relationship between canopy nitrogen concentrations and canopy albedo. Included in this analysis are all thirteen BEF plots, as well as all four BDF plots. Albedo measurements were calculated from 16m spatial resolution AVIRIS imagery acquired in 2009.

References
Ollinger, S.V., Richardson, A.D., Martin, M. E., Hollinger, D.Y., Frolking, S.E., Reich, P.B., Plourde, L.C., Katul, G.G., Munger, J.W., Oren, R., Smith, M.-L., Paw U, K.T., Bolstad, P.V., Cook, B.D., Day, M.C., Martin, T.A., Monson, R.K., Schmid, H.P. (2008). Canopy nitrogen, carbon assimilation, and albedo in temperate and boreal forests: Functional relations and potential climate feedbacks. *PNAS* 105(49), 19335-19340.
Wicklein, H. et al. (*in review*.) Variation in foliar nitrogen and albedo in response to nitrogen fertilization and elevated carbon dioxide.

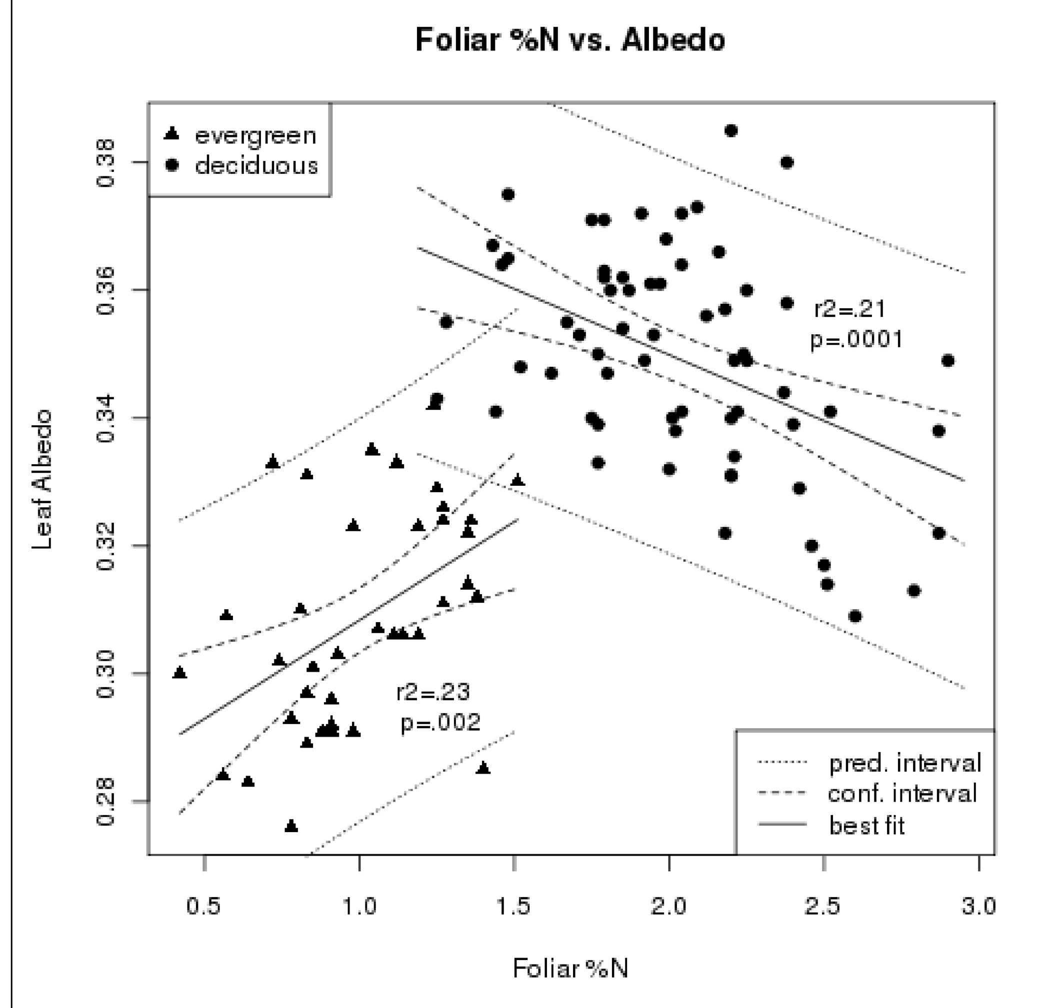


Figure 2: Previous studies have shown a negative relationship between leaf albedo and nitrogen concentration in deciduous leaves; however, incorporating evergreen species into an analysis of leaf albedo and %N results in an overall positive trending relationship (r^2=.3052, p<.01). Analyzed separately, deciduous leaves exhibit a significant negative relationship and evergreen leaves exhibit a significant positive relationship. Multiple regression shows a significant relationship in deciduous with LMA, %N and an interaction (r^2=.75,p<.01), and evergreen with LMA (r^2=.58,p<.01)

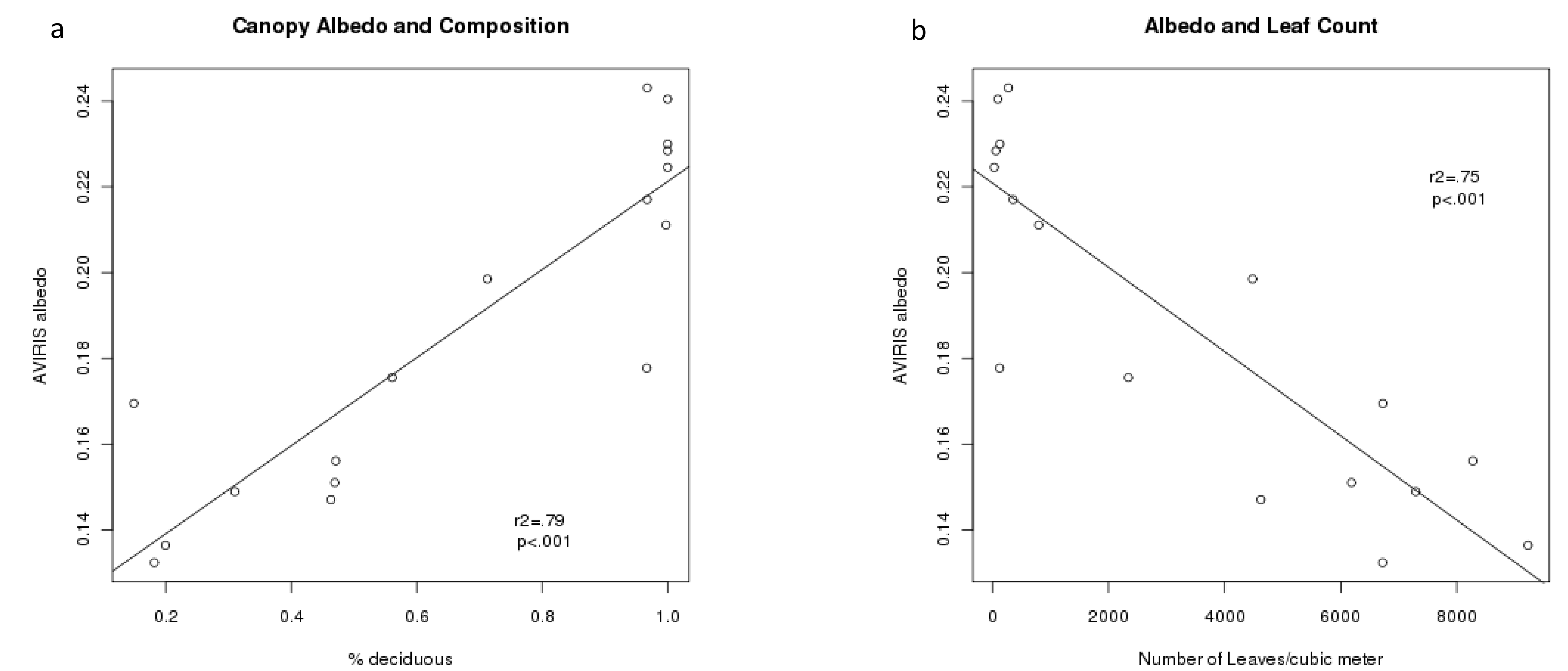


Figure 4: AVIRIS measured canopy albedo and species composition (in terms of percent deciduous species on a plot) are significantly and positively related (r^2=0.79,p<.01), suggesting that the differences in structure and leaf level characteristics along a composition gradient may be an important factor in the relationship demonstrated previously. Regardless, it is important to understand what structural characteristics may be driving this trend. An estimate of the number of leaves per cubic meter on each plot was calculated from vertical profiles describing leaf area index (leaf area per projected square meter) distribution, average individual leaf area for each species, and the maximum height of a plot. A significant negative relationship results (r2=.75,p<.01), indicating that fewer leaves per cubic meter results in higher albedo. This may be due to reduced scattering of radiation with fewer leaves; with fewer leaves, there are fewer possible outcomes of incoming energy.

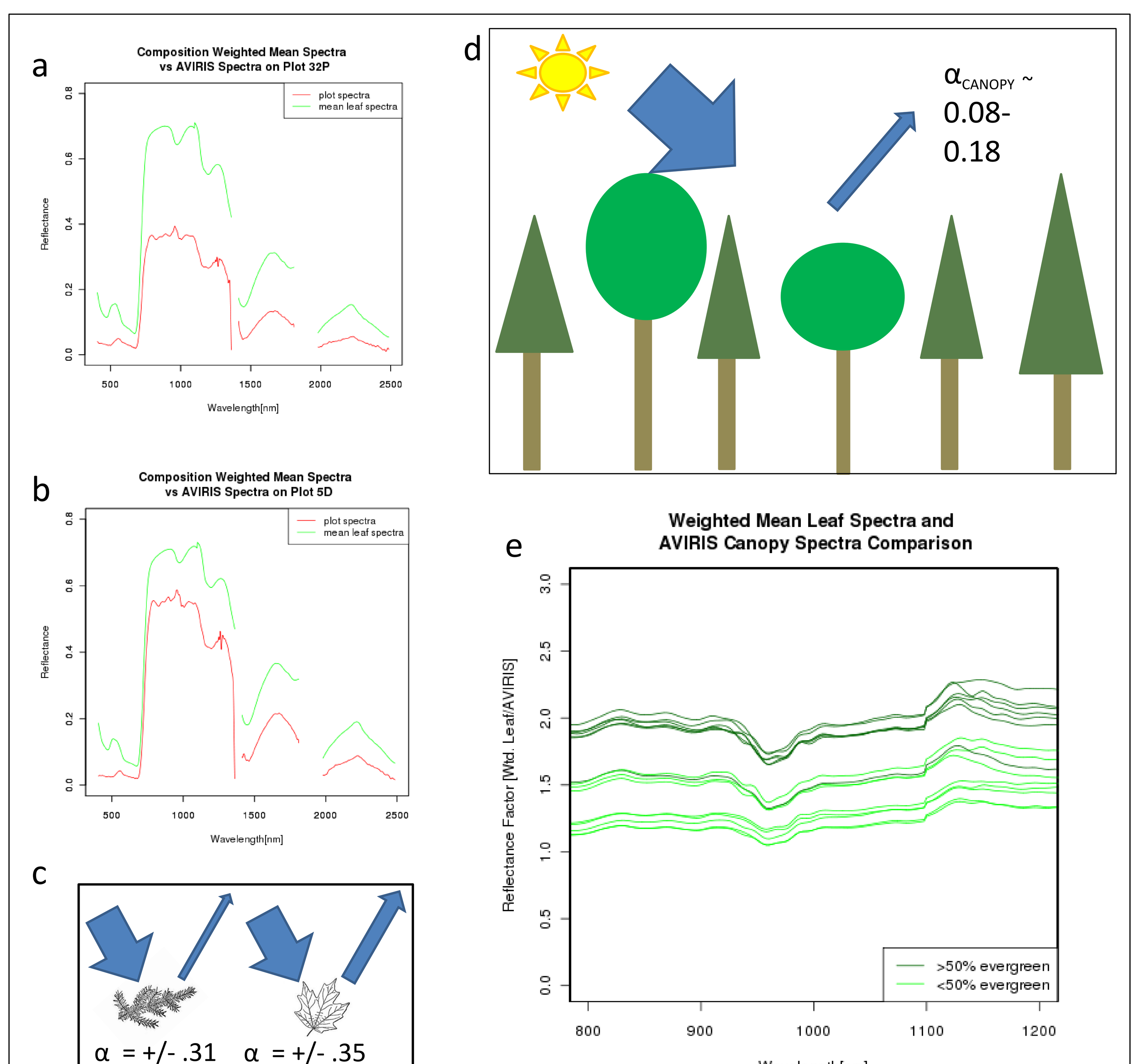


Figure 3: Leaf and canopy spectra exhibit similar patterns across all sampled wavelengths (a, b); however, leaf reflectance is typically higher throughout the entire 400-2500nm spectral range, resulting in higher albedo (c, d). Graphs show typical canopy-level and leaf-level reflectance for a conifer and deciduous plot at the Bartlett Experimental Forest (a and b, respectively). The differences between leaf and canopy reflectance are more extreme in conifer stands, especially in the 800-1200nm range (NIR; e). This suggests that structure may be a more important driver in conifer stands.

PRELIMINARY CONCLUSIONS AND FUTURE WORK

Conclusions

-Previously demonstrated on broad geographic scales using spectroscopic estimates of canopy nitrogen concentrations, the canopy %N-albedo relationship holds up on more local scales (Figure 1).

-Contrary to previous studies (Wicklein et al., in review), a significant positive relationship emerged between foliar %N and albedo at the leaf level; however, the overall positive trend exhibited is better described as two separate relationships in this study, based on species functional type. Similar to previous work, deciduous foliage exhibits a significant negative relationship, yet conifer foliage a significant positive relationship (Figure 2).

-Large differences between leaf and canopy spectra exist across all wavelengths for conifer and deciduous functional types. NIR reflectance is driven by plant and leaf structure, and it is in these wavelengths that the most drastic differences emerge. When compared across a range of functional composition, there appears to be a clear difference between evergreen and deciduous dominated plots, suggesting that structure plays a more important role in evergreen dominated stands (Figure 3e).

-As structure appears to be an important driver in the canopy %N-albedo relationship, structural parameters were investigated ranging from simple coarser scale characteristics, such as functional composition, to finer scale characteristics like canopy height diversity and estimates of the number of leaves per cubic meter on a plot. While significant relationships emerge at all scales, it is important to remember the scales at which we should anticipate light and energy to interact before drawing any conclusions about the nature of this relationship. Coarse scale gradients appear to play a role (Figure 4a), but it may only be through finer scale patterns that covary, to some extent, with broader general patterns (Figure 4b).

Future Work

-Continued investigation into the role of canopy structure in the canopy %N – albedo relationship – leaf orientation, canopy gappiness and clumping of foliage, foliage distribution, canopy layering, and other structural parameters may be possible to investigate using lidar and other remote sensing tools.

-Efforts to understand the implications of nitrogen deposition in forests of the northeast on canopy albedo and climate change

Acknowledgements
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