Nutrient Cycle Impacts on Forest Ecosystem Carbon Cycling

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The goal of our project is to develop a predictive framework for improving and integrating plant-soil carbon (C) and nutrient dynamics into Earth system models through a combination of recent advancements in plant nutrients modeling and measurement techniques. We have thus far found 5 main results:

First, we discovered two types of ecosystem nutrient economies governed primarily by the type of dominant mycorrhizal association - arbuscular mycorrhizae (AM) or ectomycorrhizal (ECM). AM-dominated forests result in inorganic nutrient economies, whereas ECM-dominated forests result in organic nutrient economies.

Second, drought resiliency is significantly different between AM- and ECM-dominated forests. During the middle of our project in 2012, one of the worst droughts to hit the US Midwest was centered on our long-term study site (i.e., AmeriFlux site Morgan-Monroe State Forest, Indiana). We leveraged our on-going measurements to show that the increased water stress outweighed the benefits of the longer growing season on C storage.

Third, we conducted a girdling manipulation experiment, and found that severing belowground C allocation led to strong and persistent declines in rhizosphere C and N mobilization of ECM-dominated forests, but not AM-dominated forests. This supports the understanding of a strong coupling between belowground C allocation in ECM soils with the mobilization of limiting nutrients.

Fourth, we included the C costs of nutrient acquisition from mycorrhizae into the C economics optimization framework of the Fixation & Uptake of Nitrogen (FUN) model, and found that the performance of FUN significantly improved against in situ measurements. We coupled FUN into three larger land surface models - CLM, JULES, and Noah-MP.

Fifth, we were able to detect mycorrhizal association from satellite remote sensing across large scales, explaining 81% of the variance from 66,000 trees within mixed-mycorrhizal forests. This approach represents a significant paradigm shift in understanding how mycorrhizal association influences canopy spectral signatures, and will enable improved prediction of nutrient cycling across large scales.