Leaf habit versus mycorrhizal fungi association: A framework for predicting tree species effects on soil

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Introduction

- Tree species are known to have differing effects upon the biogeochemistry of soil. For example, leaf litter nutrient content and root associations with different types of fungi can influence soil nutrient availability and subterranean resources in different ways.
- Understanding a tree's effect upon soil provides not only insight into current forest function, but also better informs predictions of how shifting forest composition will influence soils in the future.
- With changing tree species composition comes changing regional patterns of carbon and nitrogen cycling, which can also alter an ecosystem's net primary productivity.[1]
- Developing a trait based framework for predicting interspecific tree effects on soil would aid in the management and mitigation of forest ecosystem nutrient cycling and overall productivity.

Research Objective

To assess if a tree species' phylogenetic leaf habit or mycorrhizal fungi association is a better predictor of soil biogeochemistry in temperate forests

Methods

Study Design:
Three Variables
- **Leaf Habit**
  -deciduous (D) or evergreen (E)
- **Mycorrhizal association**
  -ectomycorrhizal (ECM) fungi or arbuscular mycorrhizal (AM) fungi
- **Soil layer**
  -forest floor (0-5cm deep) or mineral soil (5-15cm deep)

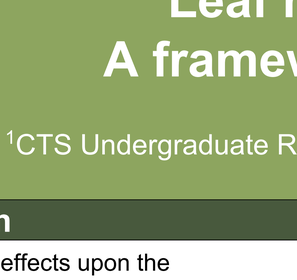

Fig. 1. The four plot types

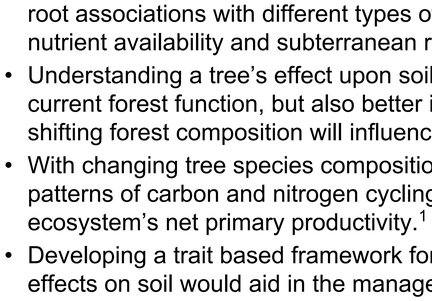

Fig. 2. Forestry plot locations

Site and Sampling:
- Morton Arboretum single–species forestry plots (DuPage County, IL), composite sample of 4 soil cores per plot in June 2018

Statistical Analysis:
- Each soil layer analyzed separately with a two-way ANOVA in R, Replicate= 1, DF= 1, P< 0.05, Post-hoc: Tukey Test

Leaf Habit Predicts % Organic Matter

Prediction: E > D
- Evergreen litter is difficult to decompose.[1,2]

Prediction: ECM > AM
- ECM fungi are slow to convert organic nutrients to inorganic forms.[2]

Results:
- Leaf habit is a predictor of soil organic matter content.
- Evergreen > Deciduous, as expected

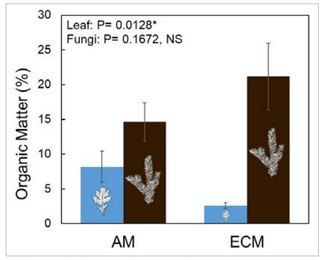

Fig. 3. Mean % organic matter of forest floor

Next Steps: Collect data across seasons, Study litter quality

C Mineralization Predicted by Leaf Habit and Driven by % Organic Matter

Prediction: E > D
- Evergreens have more organic matter available to decompose. [1]

Prediction: ECM > AM
- ECM stands have more organic matter available to decompose.[2]

Results:
- Leaf habit is a predictor of C mineralization rate.
- Evergreen > Deciduous, as expected
- Regression of % organic matter to C mineralization had positive linear relationship, suggesting that C mineralization is driven by % organic matter (R^2 = 0.7482, P= 5.079 e -12).

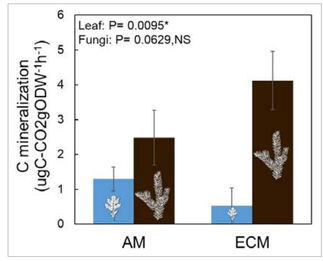

Fig. 4. Mean C mineralization of forest floor

Both Leaf Habit and Mycorrhizal Association Predict C:N Ratio

Prediction: E > D
- Evergreens have high % organic matter.[3]

Prediction: ECM > AM
- ECM fungi have organic N cycling.[2]

Results:
- Both leaf habit and type of mycorrhizal association are predictors of C:N ratio
- Evergreen > Deciduous and ECM > AM, as expected.

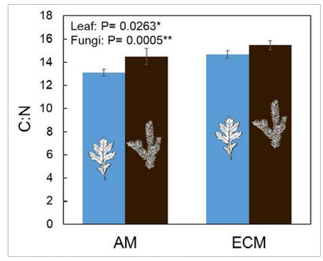

Fig. 5. Mean C:N of forest floor

Plot Twist: Mycorrhizal Association Predicts pH

Prediction: D plots will be more basic (higher pH)
- Evergreens drive down pH due to slower decomposition.[4]

Prediction: AM plots will be more basic (higher pH)
- AM soil has less carbon, which is correlated with more basic soil.[5]

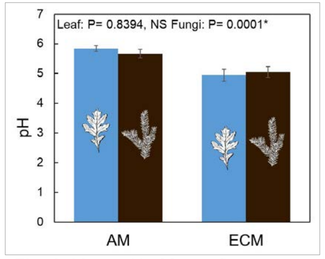

Fig. 6. Mean pH of forest floor

Results:
- Type of mycorrhizal fungi association, not leaf habit, is a predictor of pH in the 0-5 cm layer
- AM is more basic than ECM, as expected

Digging Deeper: Exchangeable Calcium Drives 30% of Differences in pH

Prediction: D > E
- Sugar maples bring Ca to the top soil layer, raising forest floor pH.[4]

Prediction: AM > ECM
- Suspected to follow leaf habit

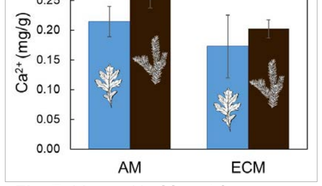

Fig. 7. Mean pH of forest floor

Results:
- Ca^{2+} across plots not significant
- Regression of Ca^{2+} to pH had a positive linear relationship, suggesting that 30% of differences in pH across plots are driven by calcium (R^2 = 0.3038, P= 0.0004943). *What drives the remaining 70%?*

Next Steps: AL and Fe (displace cations), Mg (follows Ca^{2+}).[4]

Conclusions

- Both leaf habit and type of mycorrhizal fungi association matter when predicting tree species' effects upon soil.
- Which factor is a better indicator depends largely upon the nutrient process being measured.
- Predictions could be used by land managers and scientists as carbon or nitrogen cycle mitigation tools as AM associating trees (usually deciduous) become more dominant in the Chicago region.[6]
- Further study would incorporate nitrogen cycling rates.

References

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