Development of Ecosystem Structure and Function on Reforested Surface-Mined Lands

Brian Strahm, Bethany Avera, Jim Burger, and Carl Zipper

VirginiaTech

Reforestation and Ecosystem Services: If you build it, will they come?

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Geographic Introduction

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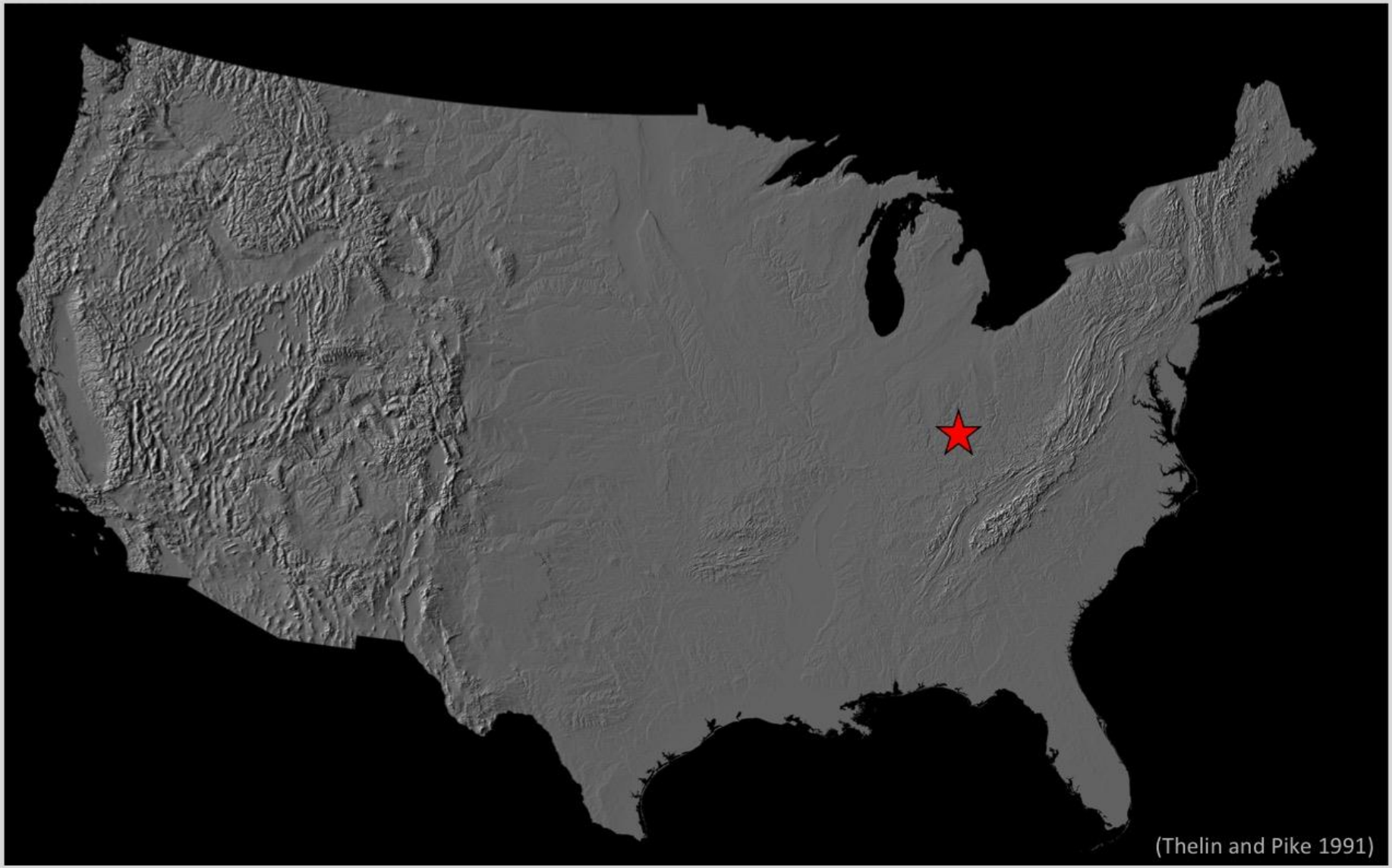
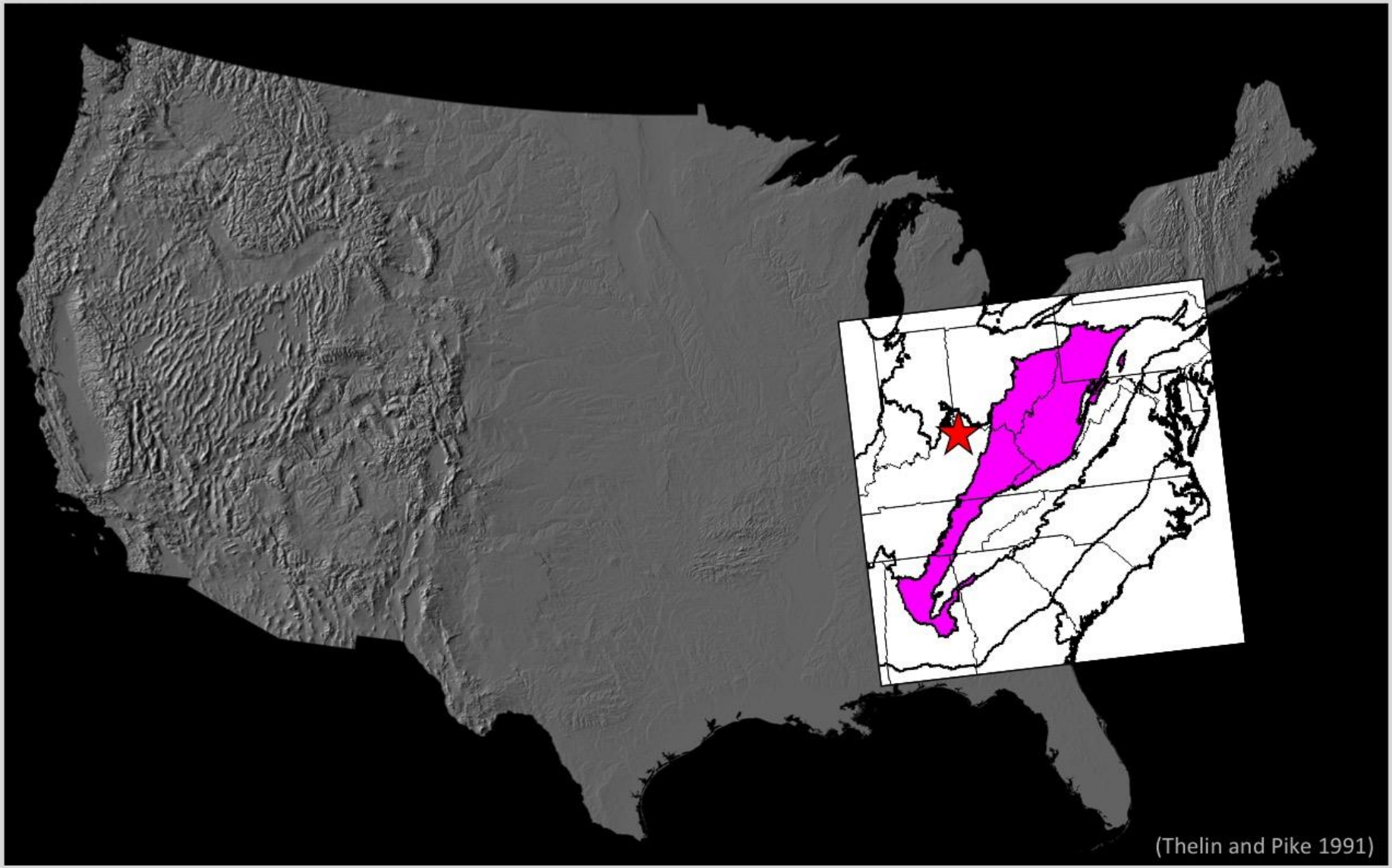
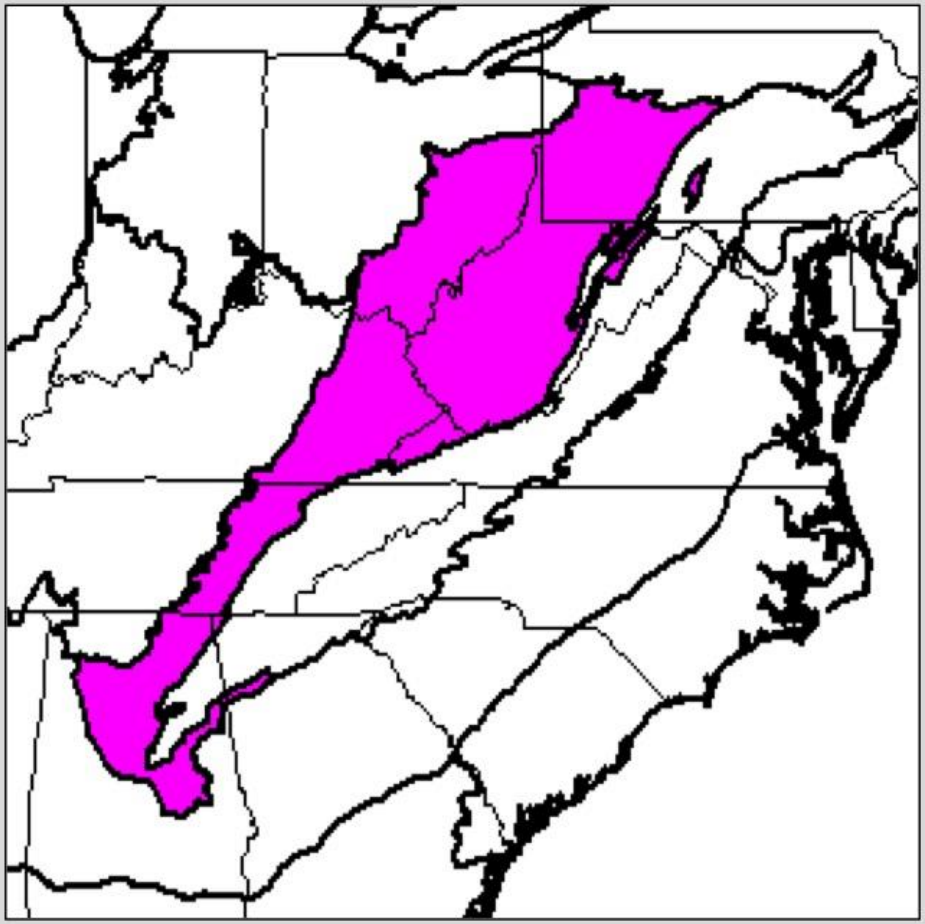


Geographic Introduction



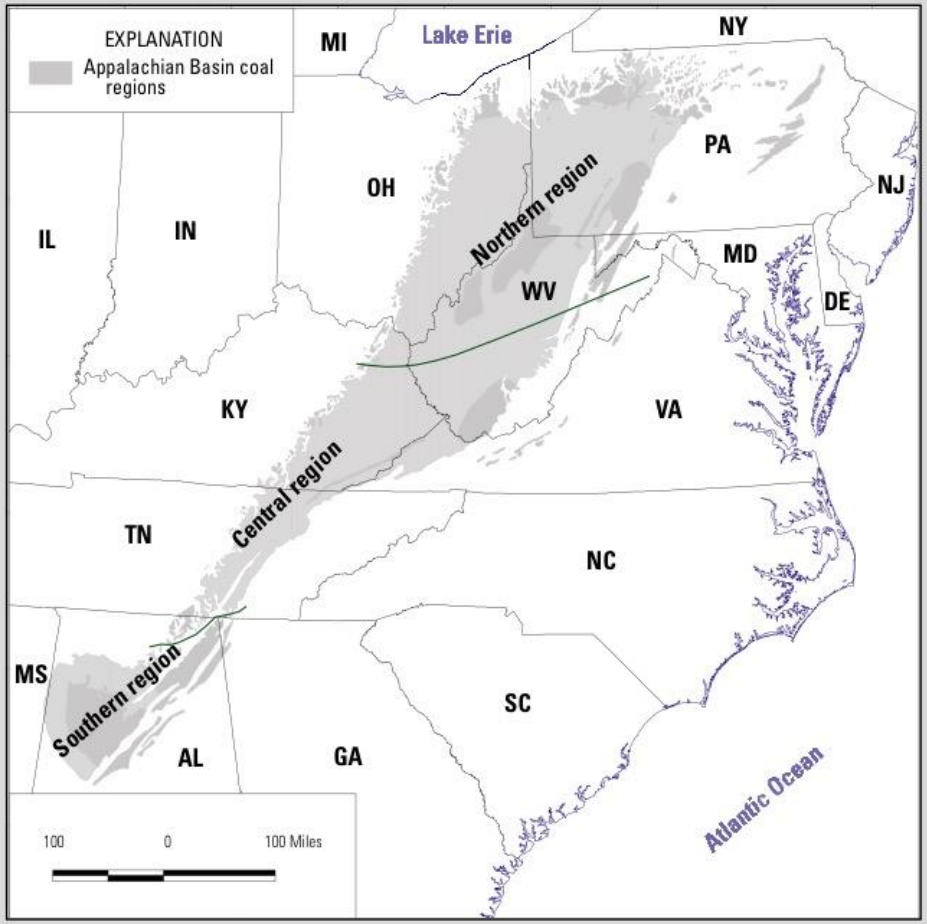
Ecology and Energy

Mixed Mesophytic Forest Ecoregion



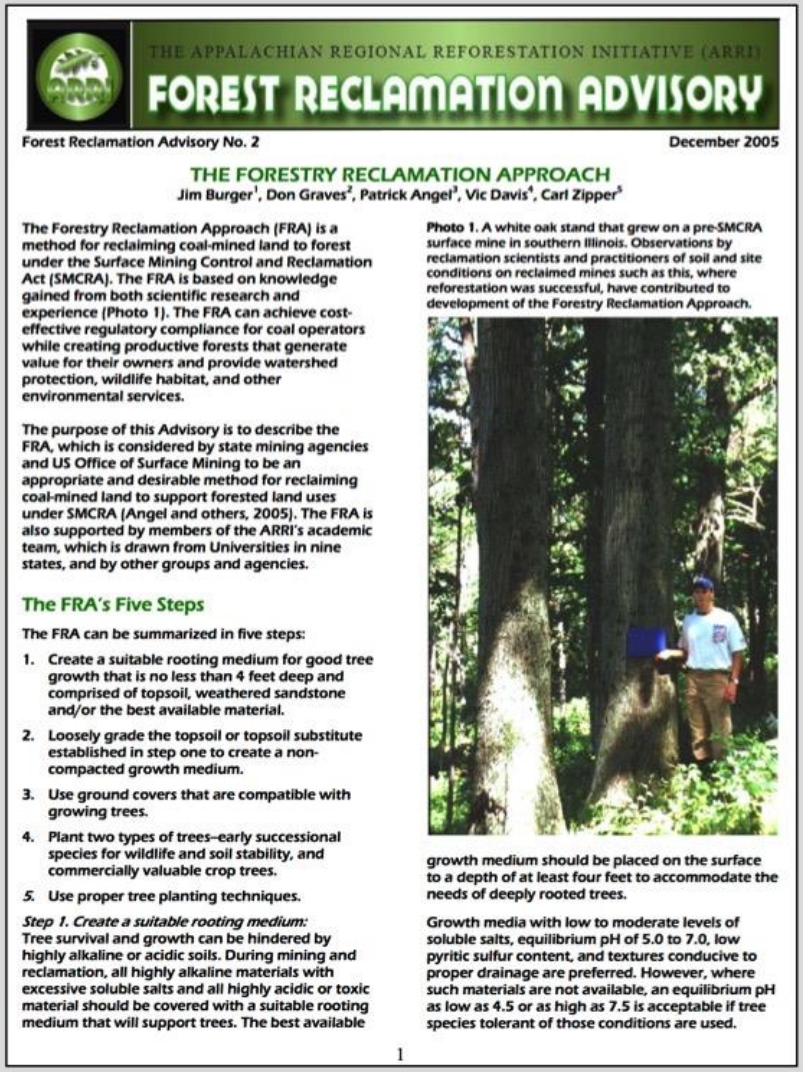
(Olson et al. 2012)

Appalachian Coal Basin



(Ruppert 2001)

Reforestation and the Forestry Reclamation Approach (FRA)



THE APPALACHIAN REGIONAL REFORESTATION INITIATIVE (ARRI)

FOREST RECLAMATION ADVISORY

Forest Reclamation Advisory No. 2 — December 2005

THE FORESTRY RECLAMATION APPROACH

Jim Burger[1], Don Graves[2], Patrick Angel[3], Vic Davis[4], Carl Zipper[5]

The Forestry Reclamation Approach (FRA) is a method for reclaiming coal-mined land to forest under the Surface Mining Control and Reclamation Act (SMCRA). The FRA is based on knowledge gained from both scientific research and experience (Photo 1). The FRA can achieve cost-effective regulatory compliance for coal operators while creating productive forests that generate value for their owners and provide watershed protection, wildlife habitat, and other environmental services.

The purpose of this Advisory is to describe the FRA, which is considered by state mining agencies and US Office of Surface Mining to be an appropriate and desirable method for reclaiming coal-mined land to support forested land uses under SMCRA (Angel and others, 2005). The FRA is also supported by members of the ARRI's academic team, which is drawn from Universities in nine states, and by other groups and agencies.

The FRA's Five Steps

The FRA can be summarized in five steps:

1. Create a suitable rooting medium for good tree growth that is no less than 4 feet deep and comprised of topsoil, weathered sandstone and/or the best available material.
2. Loosely grade the topsoil or topsoil substitute established in step one to create a non-compacted growth medium.
3. Use ground covers that are compatible with growing trees.
4. Plant two types of trees–early successional species for wildlife and soil stability, and commercially valuable crop trees.
5. Use proper tree planting techniques.

Step 1. Create a suitable rooting medium: Tree survival and growth can be hindered by highly alkaline or acidic soils. During mining and reclamation, all highly alkaline materials with excessive soluble salts and all highly acidic or toxic material should be covered with a suitable rooting medium that will support trees. The best available

Photo 1. A white oak stand that grew on a pre-SMCRA surface mine in southern Illinois. Observations by reclamation scientists and practitioners of soil and site conditions on reclaimed mines such as this, where reforestation was successful, have contributed to development of the Forestry Reclamation Approach.

growth medium should be placed on the surface to a depth of at least four feet to accommodate the needs of deeply rooted trees.

Growth media with low to moderate levels of soluble salts, equilibrium pH of 5.0 to 7.0, low pyritic sulfur content, and textures conducive to proper drainage are preferred. However, where such materials are not available, an equilibrium pH as low as 4.5 or as high as 7.5 is acceptable if tree species tolerant of those conditions are used.

1

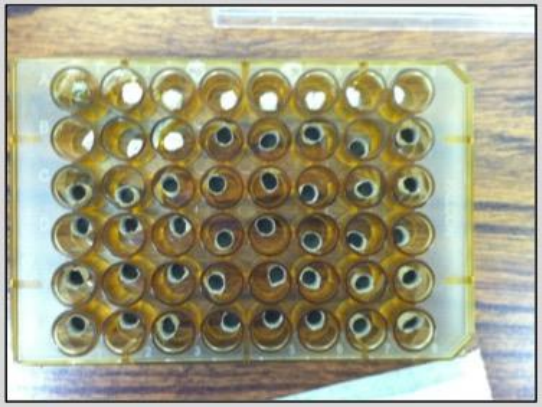
The FRA's Five Steps:

1. **Create a suitable rooting medium for good tree growth that is no less than 4 feet deep and comprised of topsoil, weathered sandstone and/or the best available material.**
2. **Loosely grade the topsoil or topsoil substitute established in step one to create a non-compacted growth medium.**
3. **Use ground covers that are compatible with growing trees.**
4. **Plant two types of trees--early successional species for wildlife and soil stability, and commercially valuable crop trees.**
5. **Use proper tree planting techniques.**

Reforestation Chronosequence

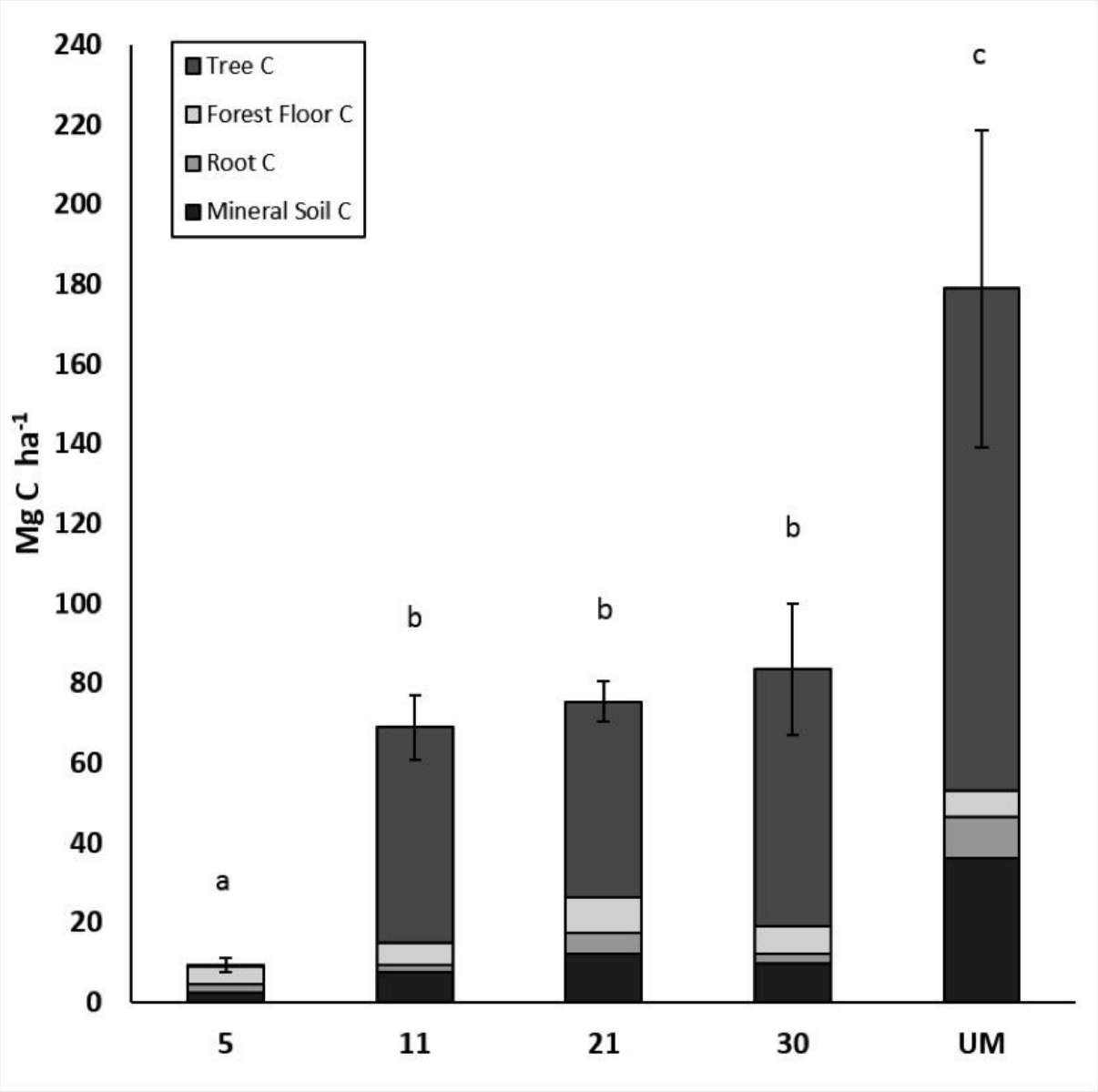
5 years | 11 years | 21 years | 30 years | Unmined

Ecosystem Pools and Fluxes

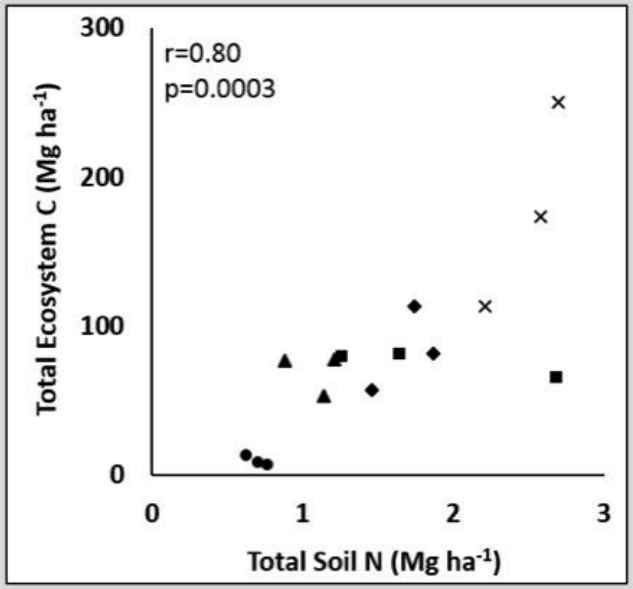


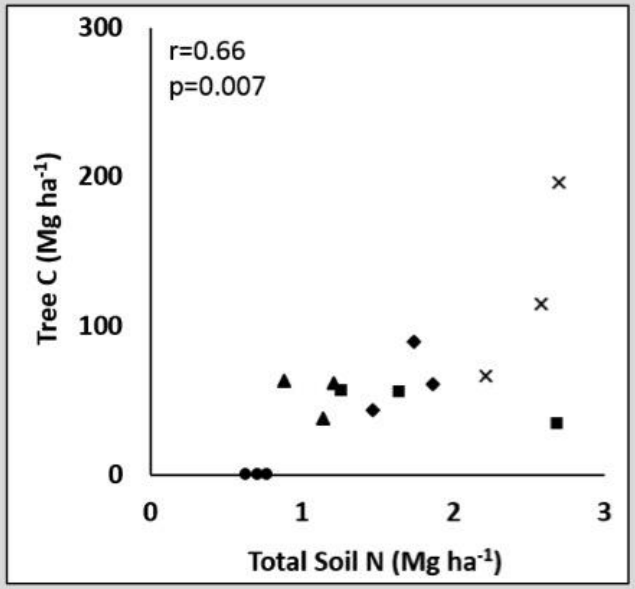
- **Experimental Design**
  - 4 Ages + Unmined Reference
    - 3 Replications
- **Ecosystem C and N Pools**
  - Aboveground Biomass
    - Clip Plots, Allometric Equations
  - Roots, Forest Floor, and Soil
    - Quantitative Soil Pits
- **Microbial Biomass**
  - Total
    - Chloroform Fumigation
  - Active
    - Substrate Induced Respiration
- **Nitrogen Cycling**
  - Cumulative Net Inorganic N
    - Ion Exchange Membranes
- **Greenhouse Gas Fluxes**
  - N_2O, CH_4, CO_2
    - Vented Static Chambers

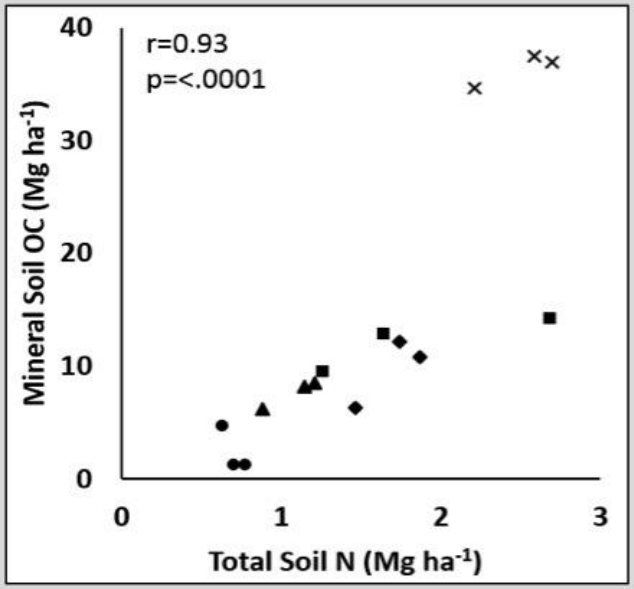
Total Ecosystem Carbon

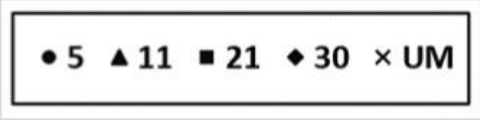


Nitrogen Drives Carbon Accrual

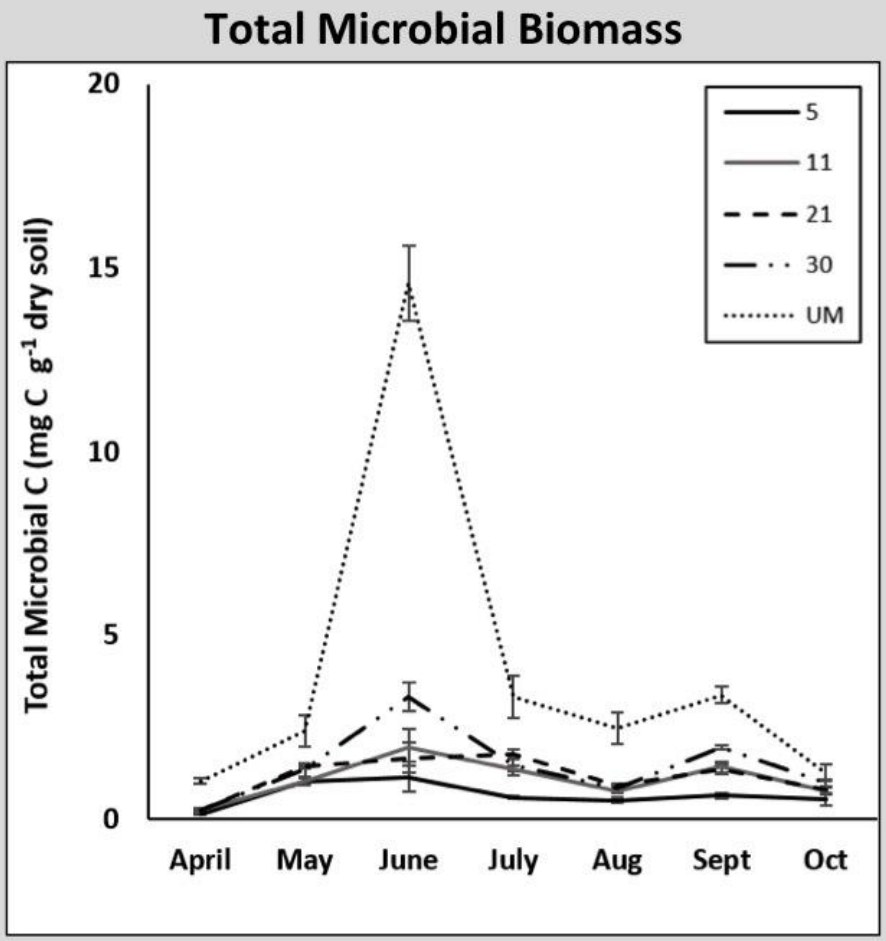


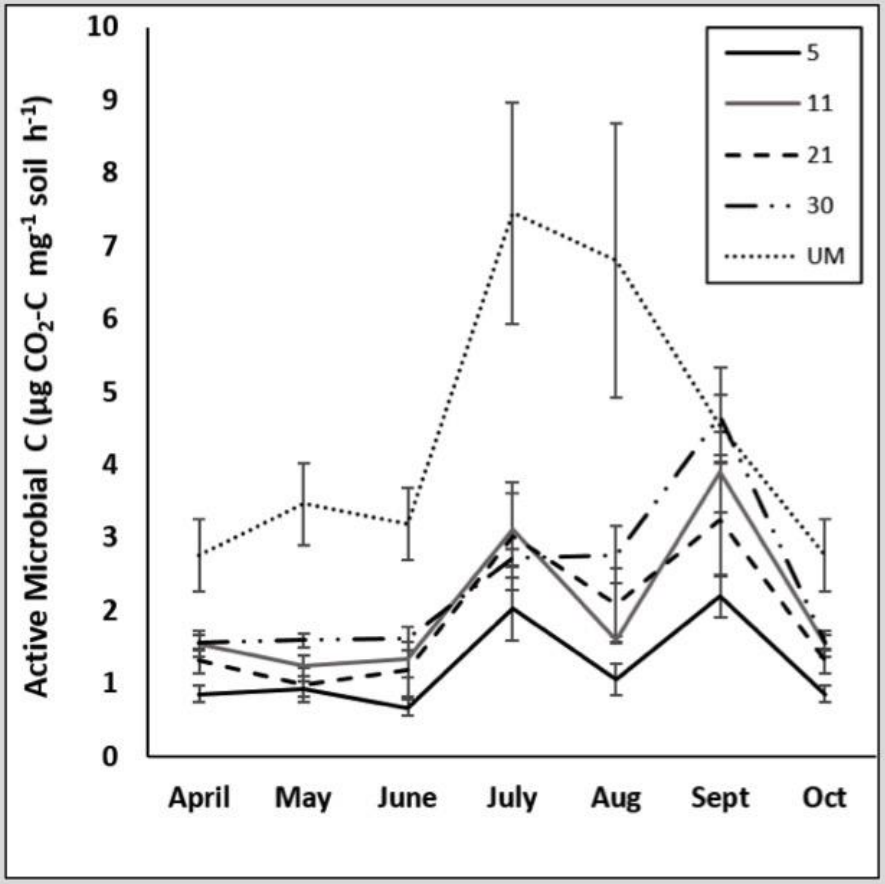




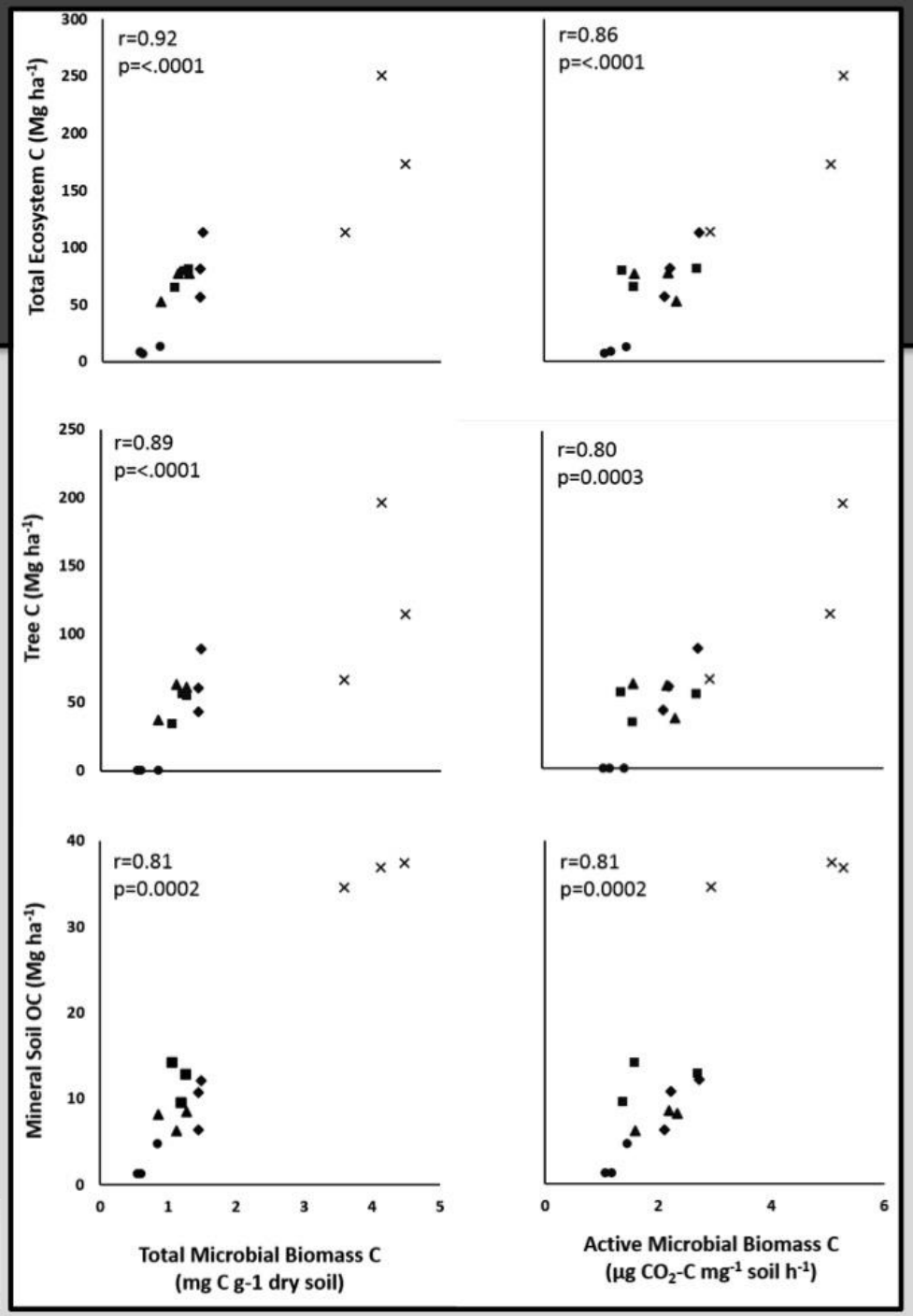


Microbial Biomass and Activity



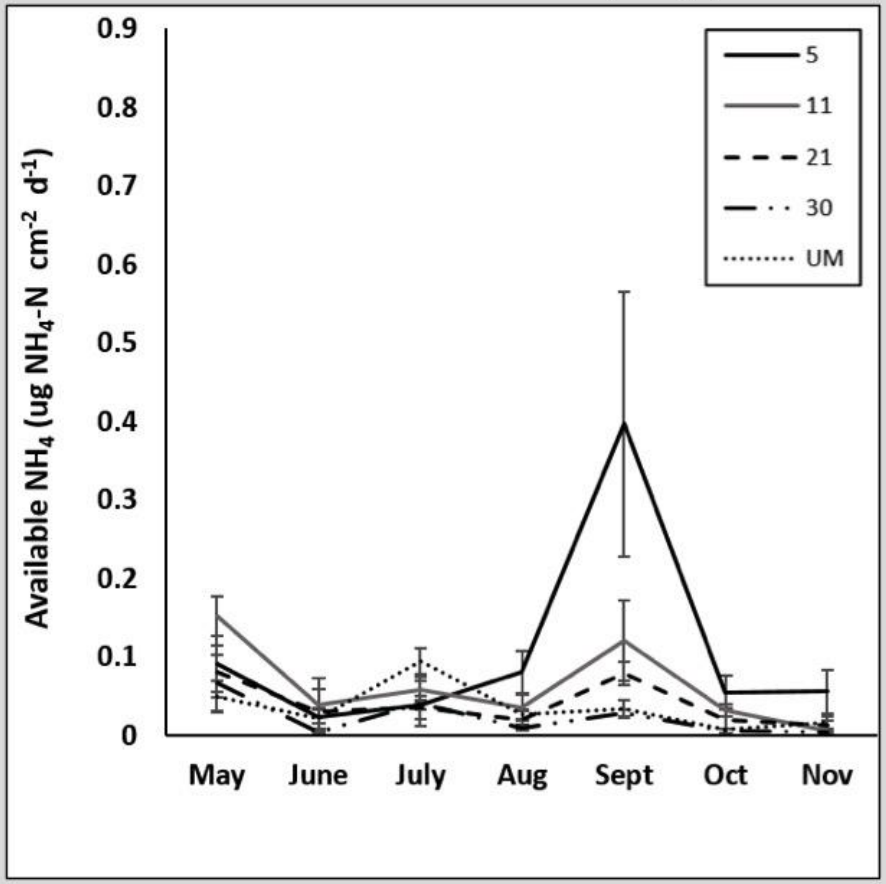


Carbon Fuels the Microbes

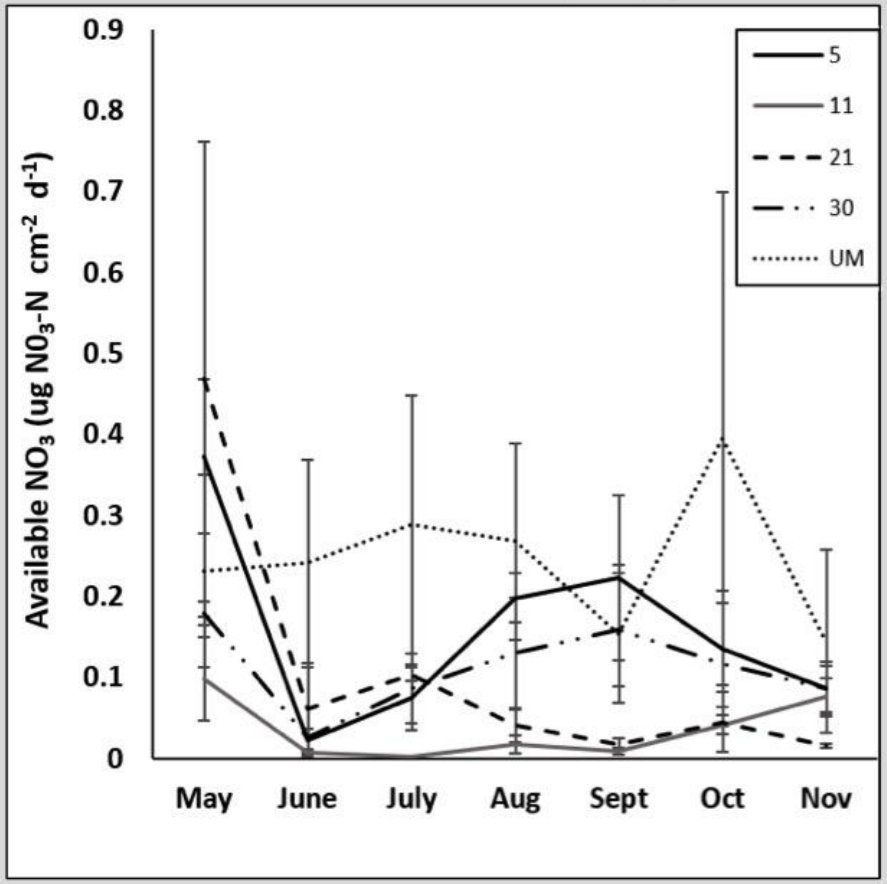


Available Inorganic N

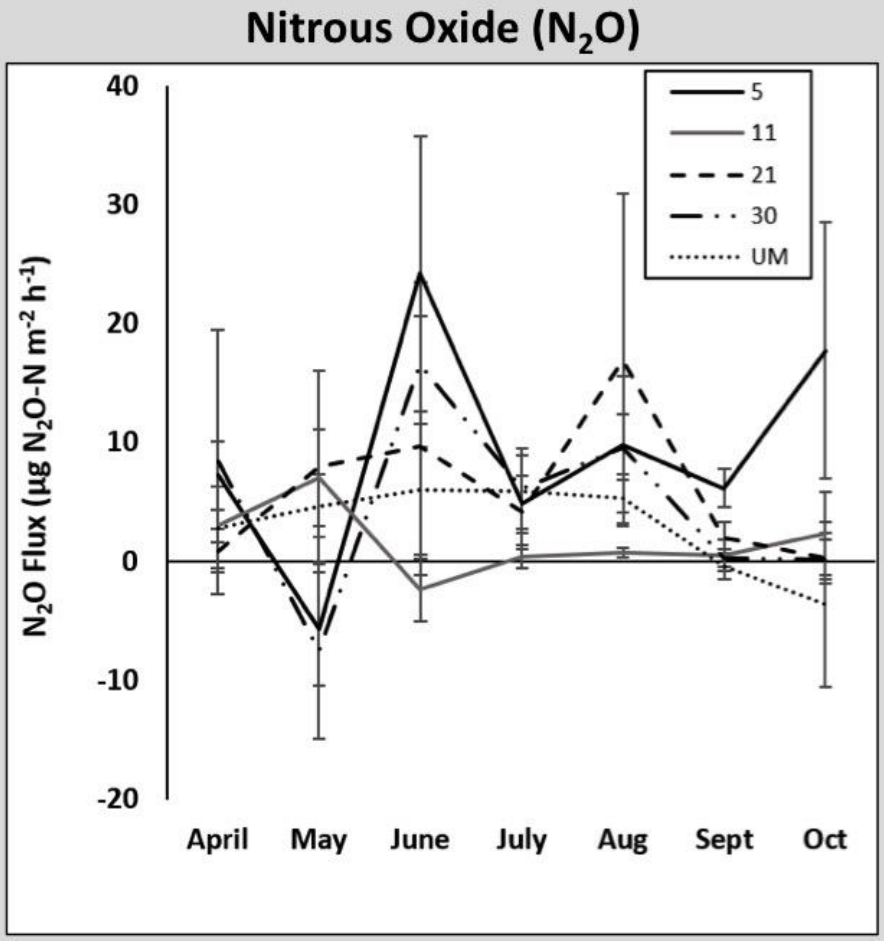
Available Ammonium (NH_4^+)

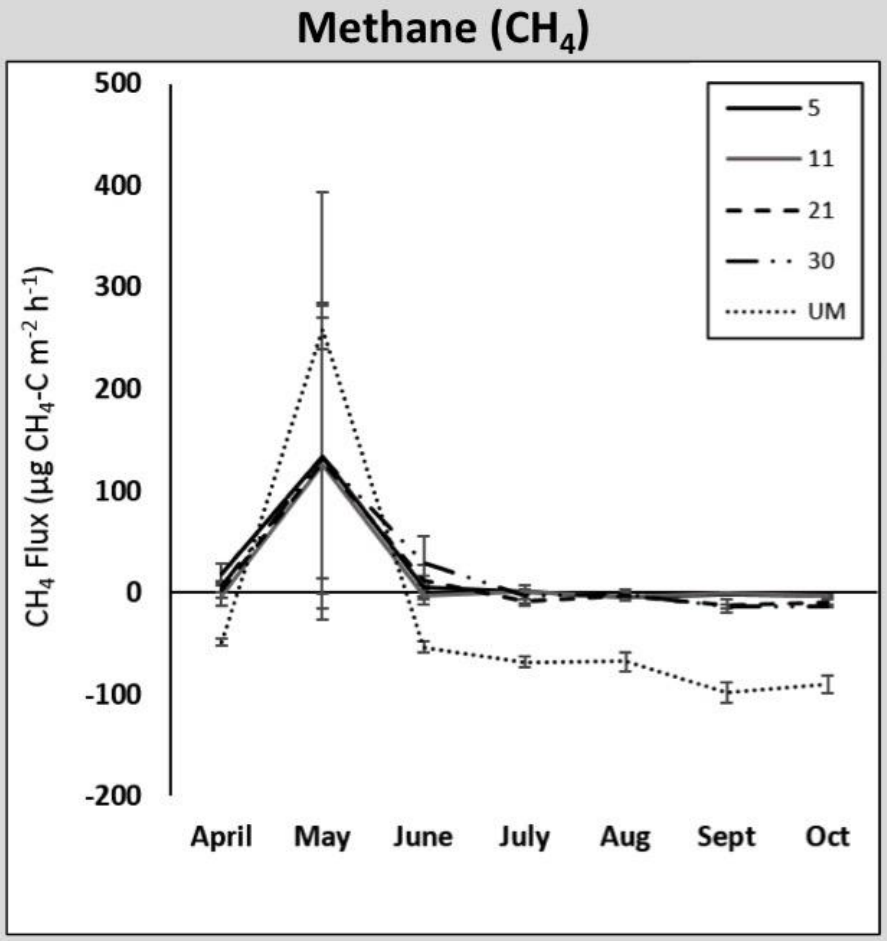


Available Nitrate (NO_3^-)



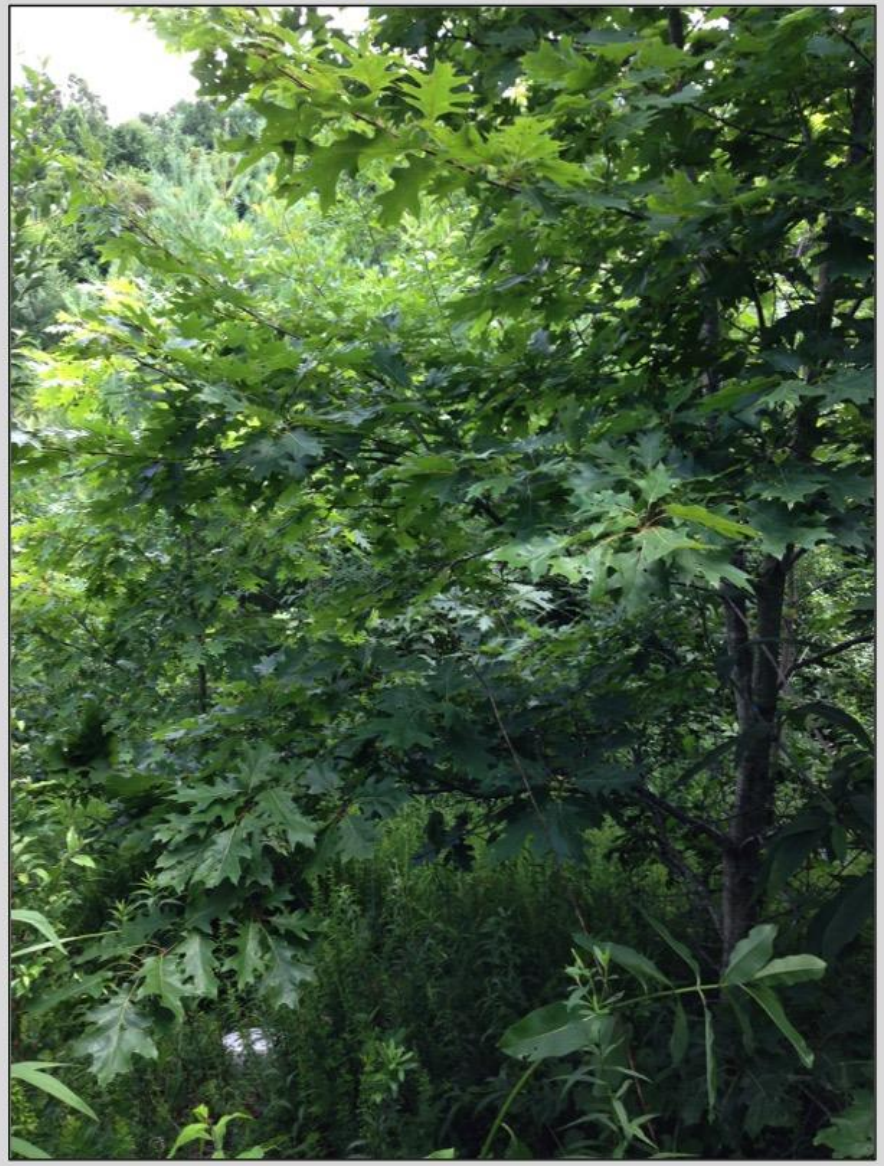
Greenhouse Gas Fluxes





Summary

- Reforested mined lands function just about like any other terrestrial ecosystem
  - Nitrogen drives productivity
  - Carbon fuels microbes
  - Microbes regulate critical ecosystem functions



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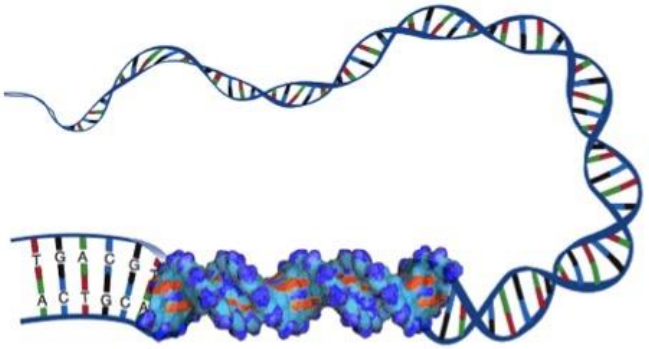
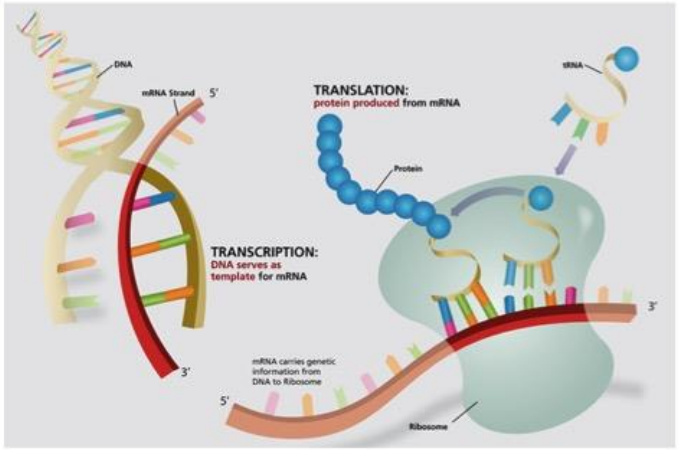


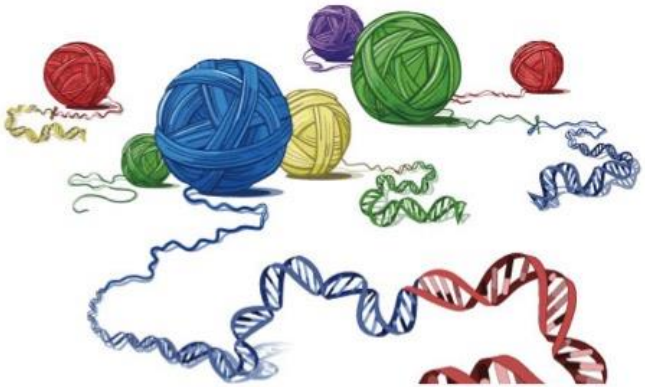
Marker gene (e.g. 16S, ITS)

Who are there?

What are they doing?

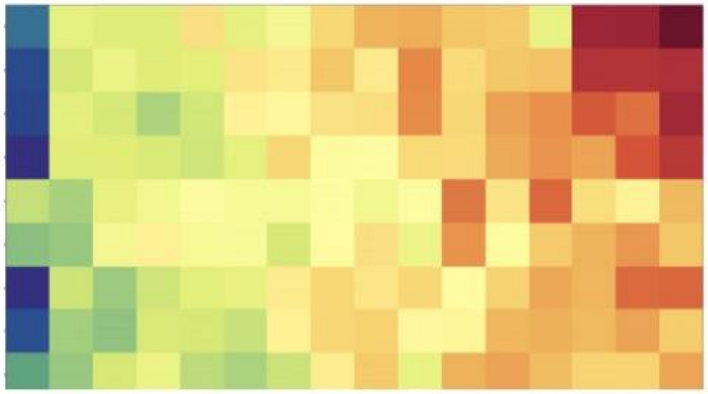


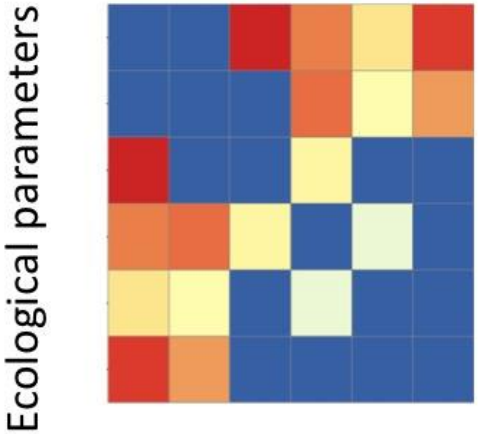
Transcriptome (mRNA)



Genome

Why are they doing it?



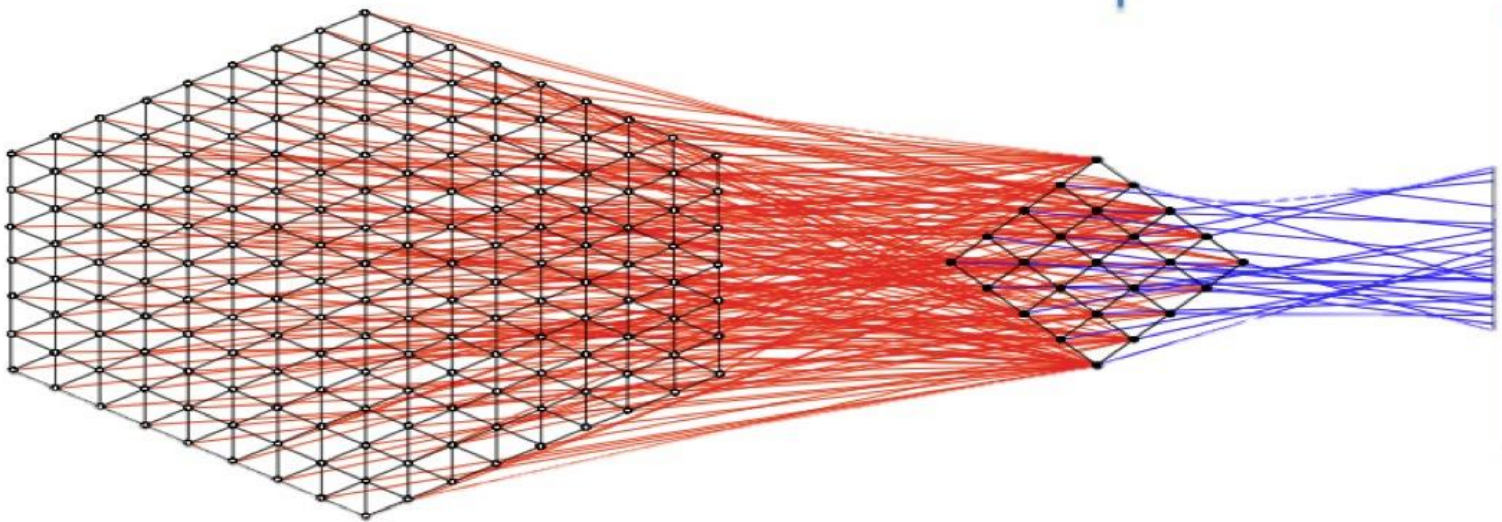


Reforestation age

Microbial taxonomic or functional composition change

Reforestation age

Ecological processes change



Bacterial Community Shifts

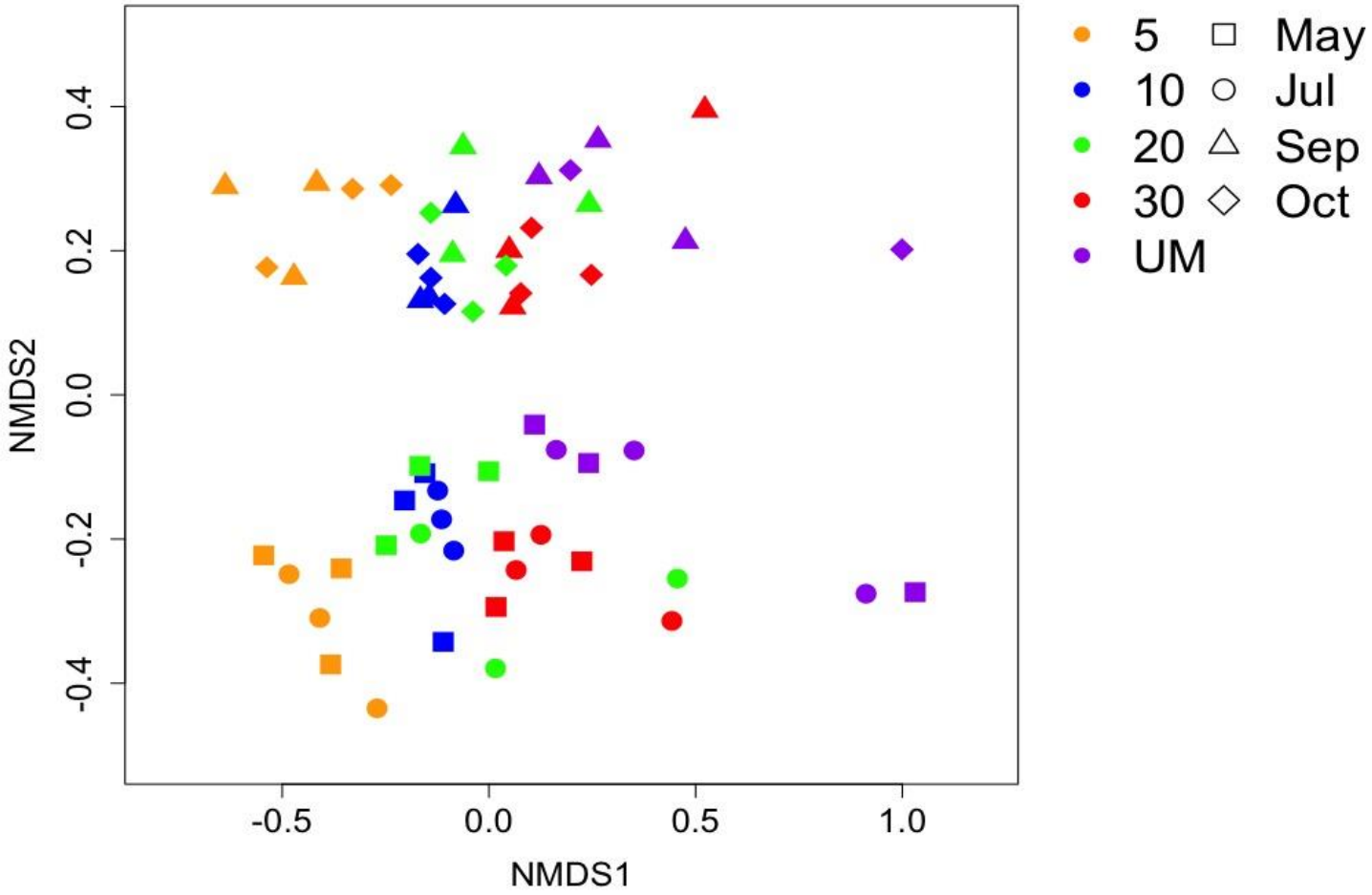


Figure1. Bacterial Non-metric Multidimensional Scaling (NMDS) analysis.

Fungal Community Shifts

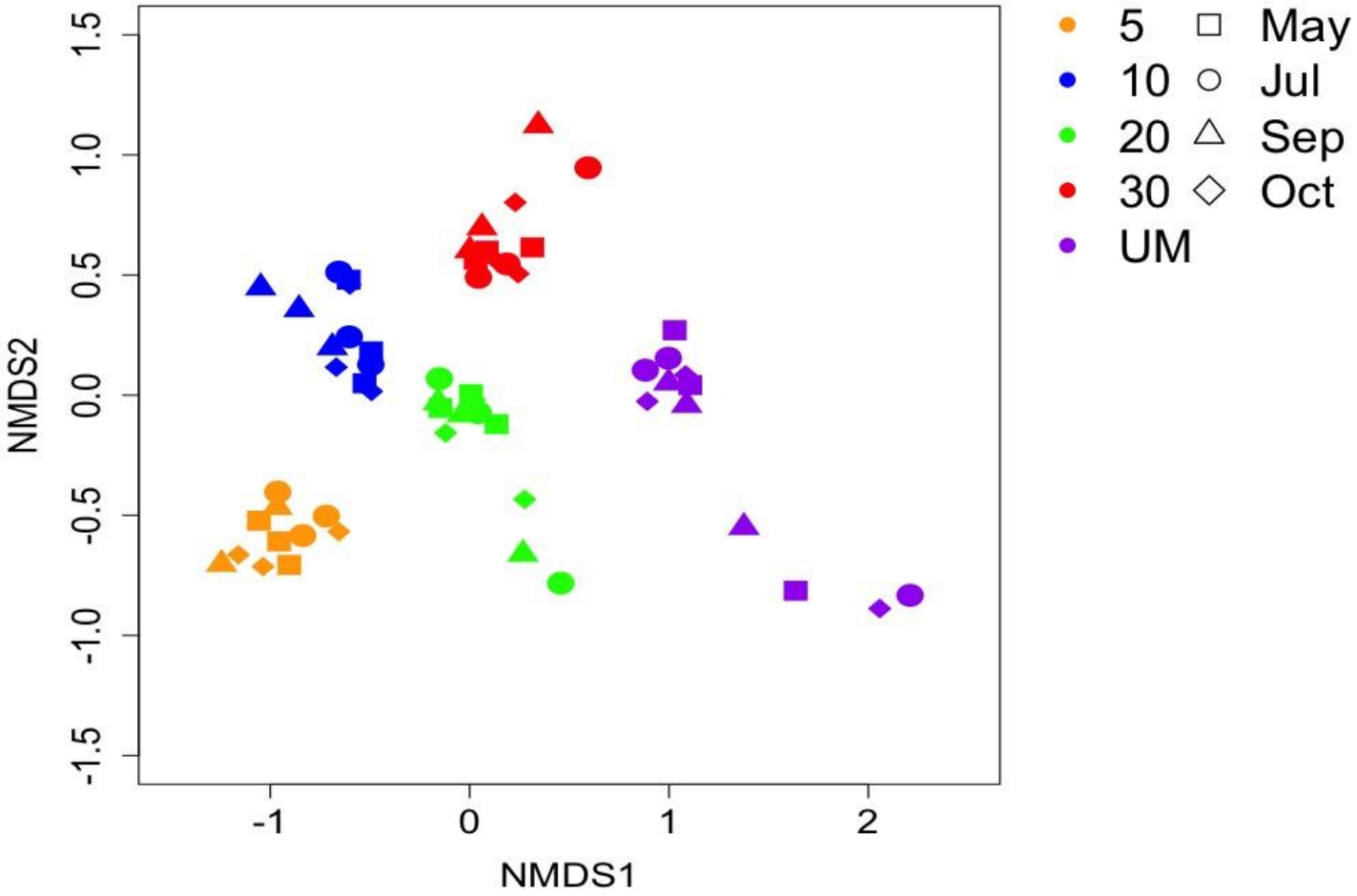


Figure 2. Fungal Non-metric Multidimensional Scaling (NMDS) analysis.

Reforestation and Ecosystem Services: If you build it, will they come?

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Yes.*