Fire effects on seedling establishment success across treeline: implications for future tree migration and flammability in a changing climate

Rebecca Hewitt
rehewitt@alaska.eduI
Institute of Arctic Biology, UAF

Overview

- Landscape scale vegetation change
- Previous research on biotic controls on tree establishment
- Proposed research on abiotic controls on tree seedling establishment
- Heuristic and landscape models of tree establishment, migration, and landscape flammability

Landcover Change

- Vegetation change with warming
- Implications for landcover change
  - Carbon storage
  - Change in the surface energy budget
  - Landscape flammability
  - Provision of ecosystem services

Background processes affecting tree establishment

- Fire
- Fire → Seedling germination and establishment
- Fire → Migration
- Post-fire impacts on successful tree seedling establishment
  - Substrate
  - Microbes
  - Nutrient supply
  - Drought stress

Processes that determine post-fire seedling success

- Dispersal: Is there a seed source?
- Germination: If there is a seed source, will that seed germinate?
- *Establishment: If a seed germinates will it grow?*

Establishment: seedling growth, productivity, longevity

What questions will be answered?

Questions:

– What are the factors governing seedling establishment?

– Do wildfire-induced changes in tree establishment at treeline drive landscape patterns of treeline movement?

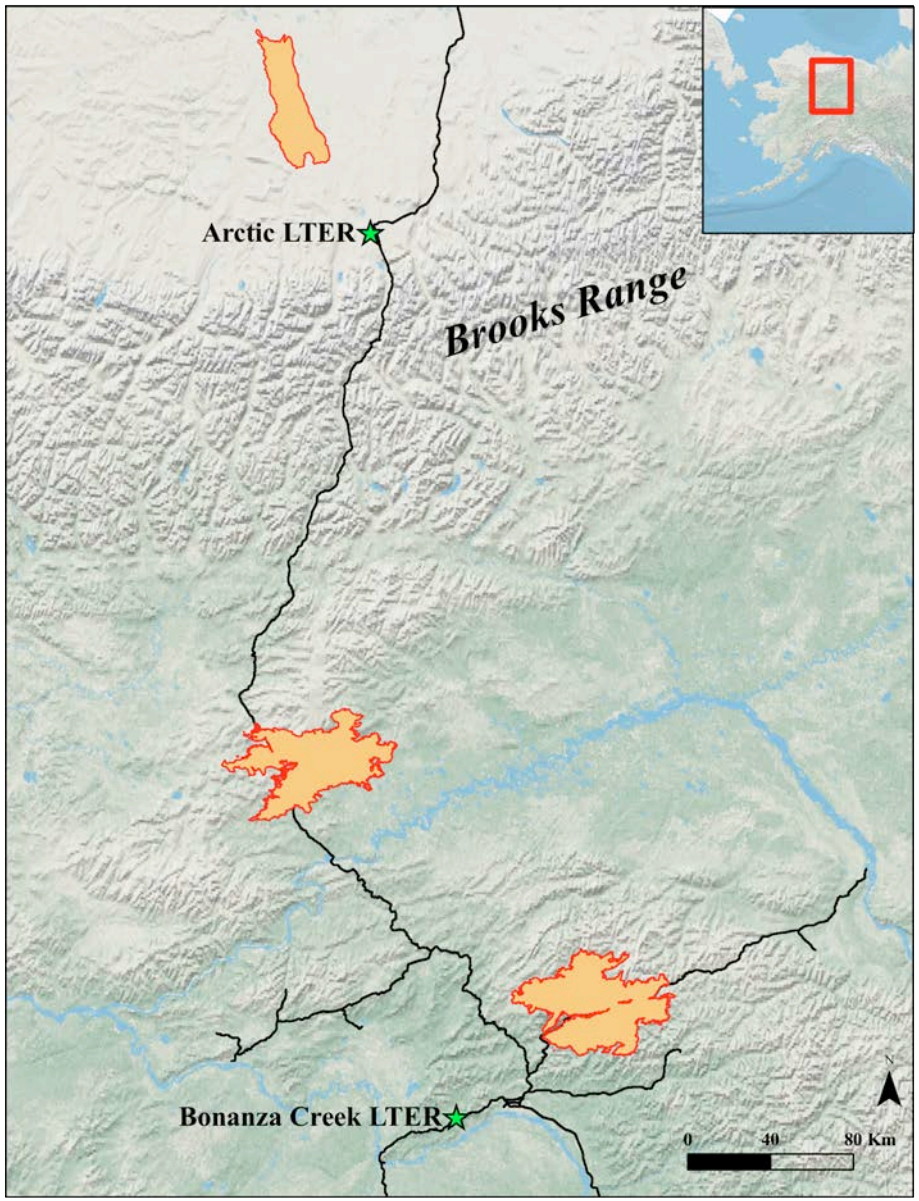
Goal:

– **Assess fire-effects on treeline position and the vulnerability of forest ecotones to future change**

Research

- Previous research has focused on the biotic interaction between boreal tree seedling establishment, growth, and survival and belowground microbial dynamics
- Proposed JFSP GRIN research will examine abiotic factors driving regional seedling establishment success and performance and the potential for tree migration at arctic treeline

Study Area



Biotic Controls on Tree Establishment

- Mycorrhizal fungi
- Mycorrhizae effects on vegetation

Mycorrhizal Symbioses are Ubiquitous

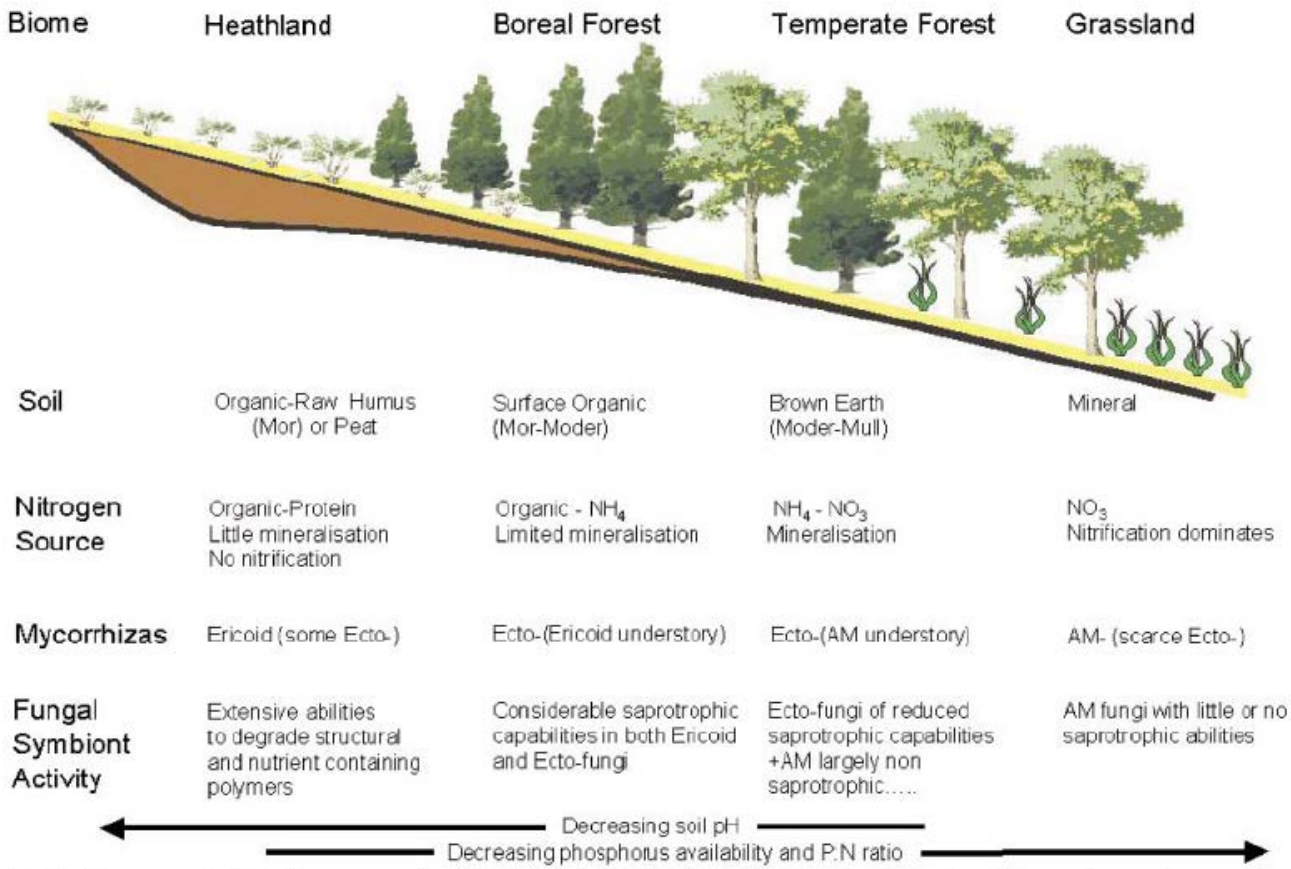


Fig. 10. The proposed relationships, on a northern hemisphere based global scale, between the distribution of biomes along environmental gradients and the roles of the prevailing mycorrhizal association in facilitation of N and P capture by the characteristic functional groups of plant.

Different fungi are associated with different ecosystems and support healthy vegetation in that ecosystem. If trees migrate into tundra they may not find suitable fungi.

(figure from Read and Perez-Moreno 2003)

Fire alters mycorrhizal communities

- Fire effects on mycorrhizae

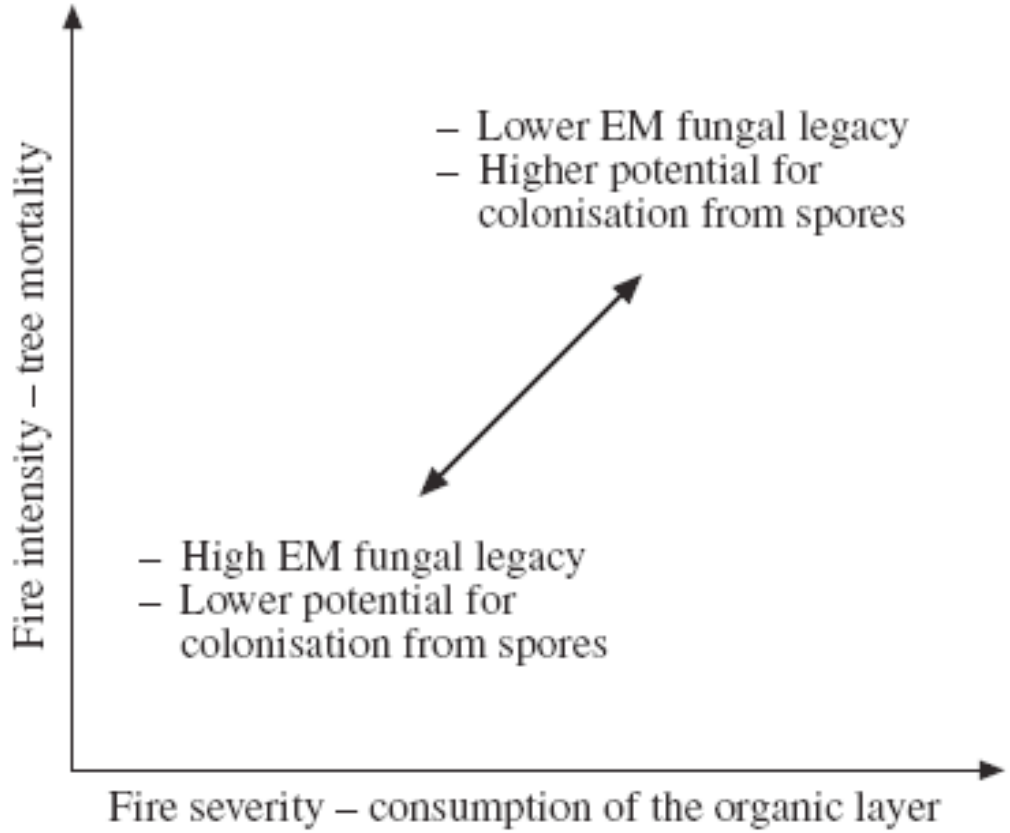
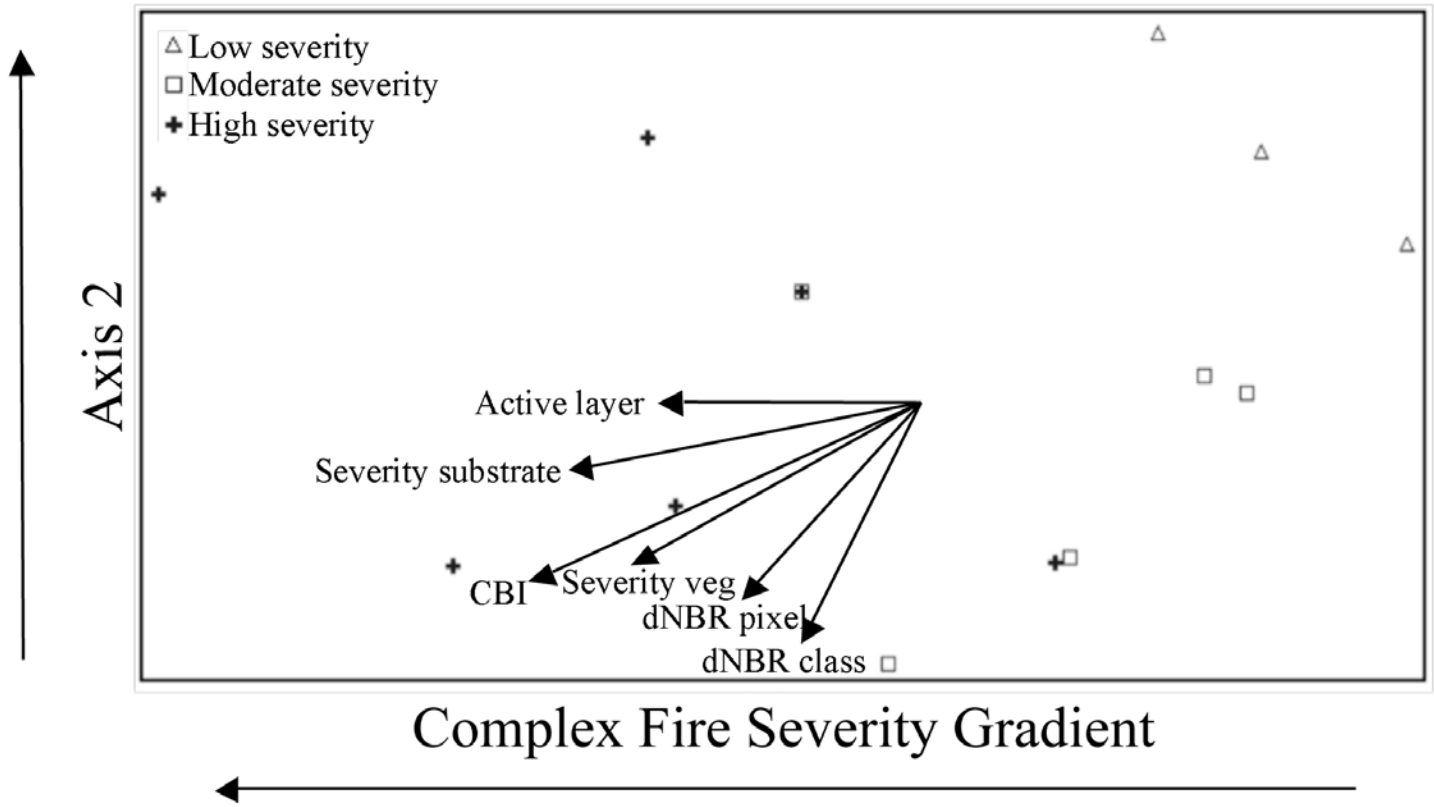


Fig. 1. Schematic relationships between fire intensity, fire severity and survival of the mycorrhizal community.

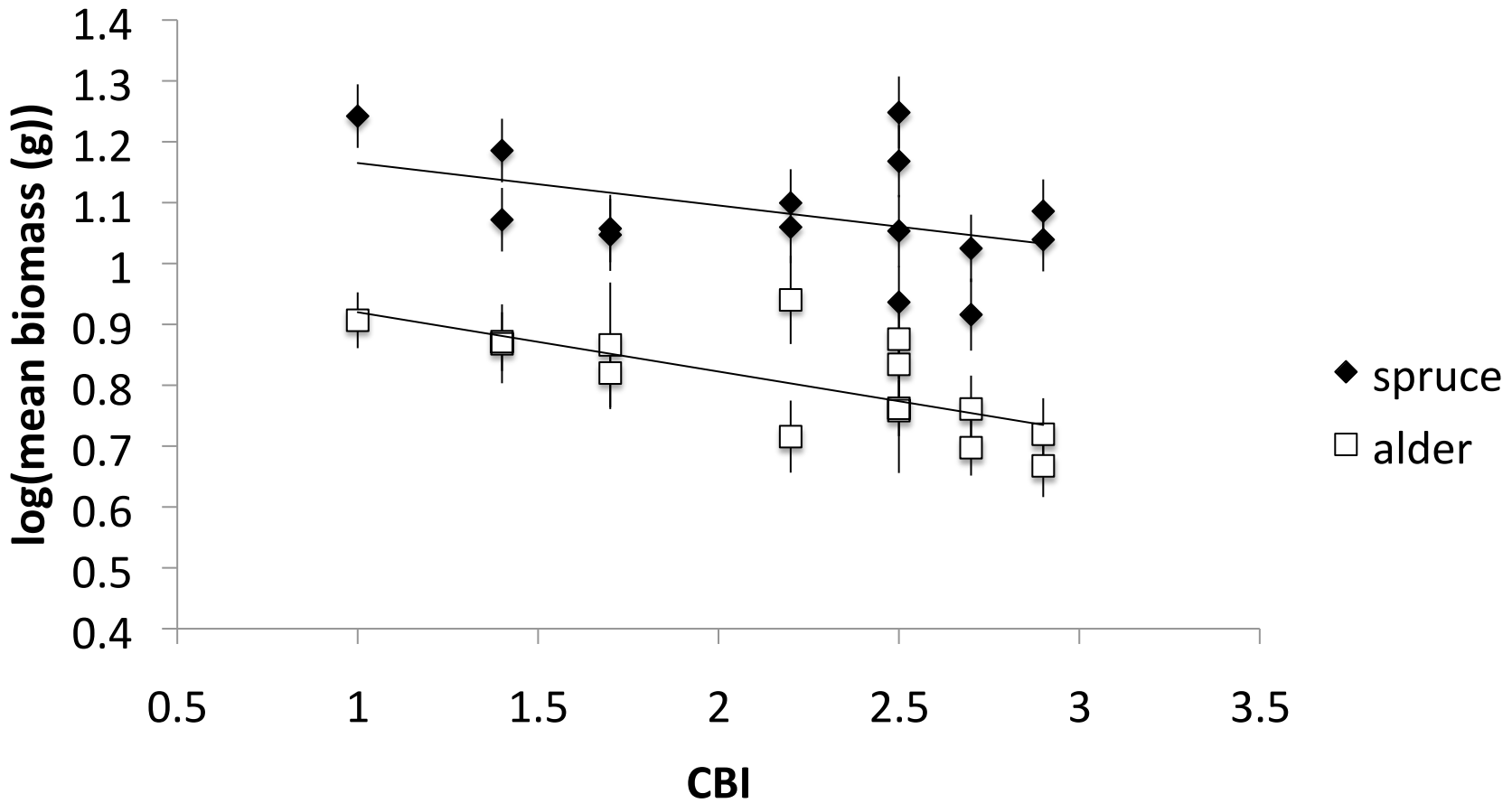
Research on Biotic Controls

- Collect soils across a fire severity gradient to sample fungi
- Grow inoculated trees with post-fire fungi to see how the fungi affect seedling growth and survival

Fire limits the availability of critical fungal symbionts



Post-fire fungi affect seedling performance



Increased fire severity decreases total biomass

Summary of Previous Research

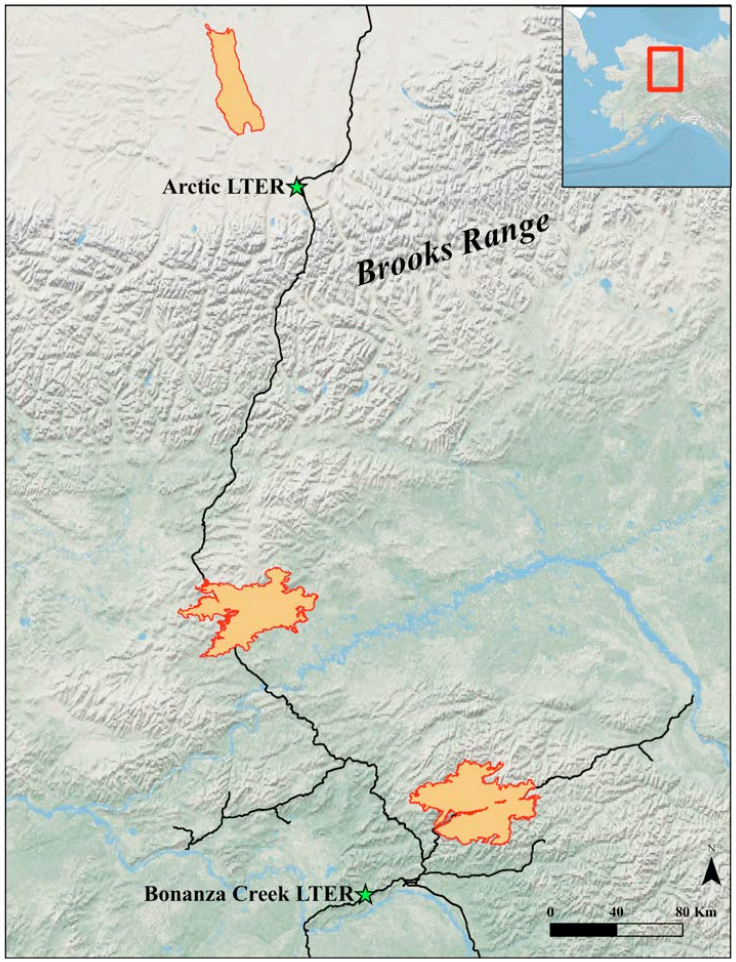
- Increasing fire severity alters fungal communities
- Changes in fungal communities after fire reduce seedling performance
- Under the most extreme burn severity conditions limitation of fungal partners may inhibit tree establishment

Proposed JFSP Research Questions

- What are the regional abiotic factors governing seedling performance and establishment success across treeline after fire?

- How will the hierarchy of post-fire abiotic and biotic factors influence tree migration into previously unforested sites under predicted scenarios of fire disturbance and climate change?

Study Area


Arctic LTER
Brooks Range
Bonanza Creek LTER
0
40
80 Km

N275AL

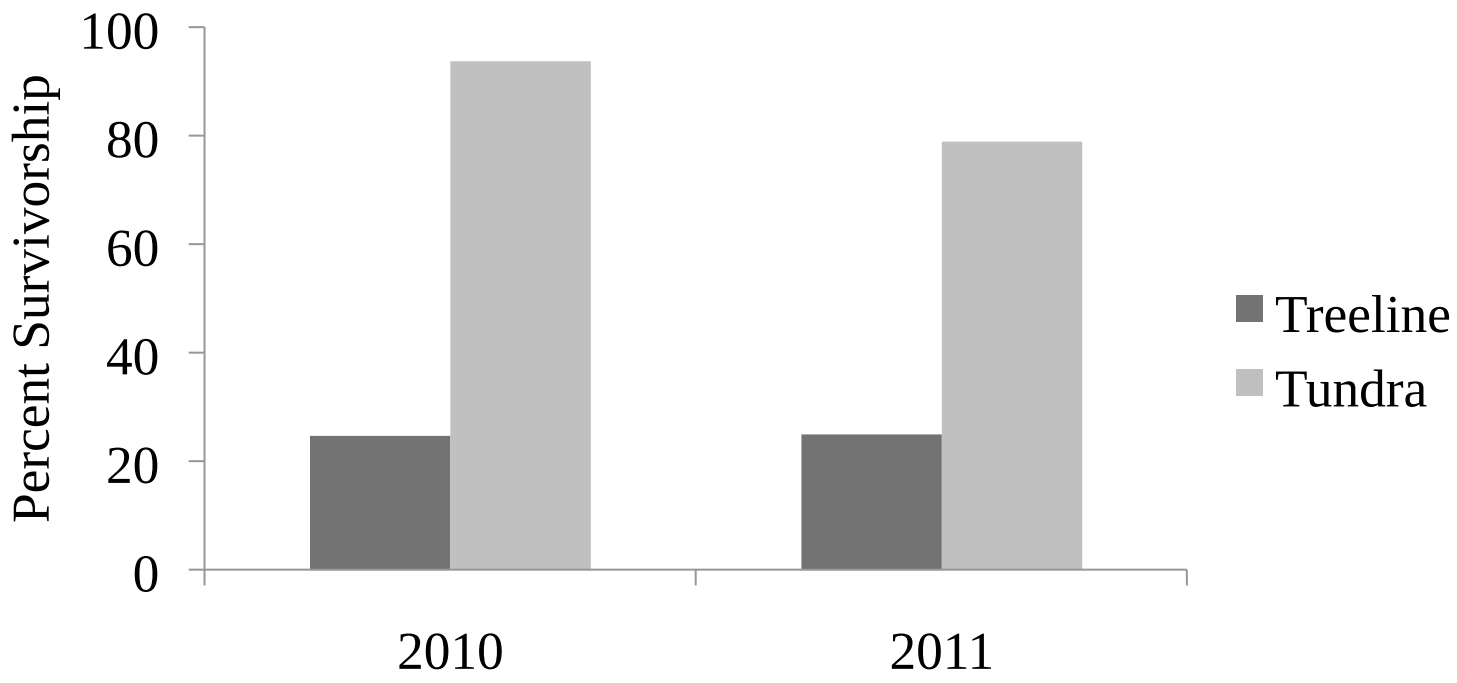
Sampling Design

- 384 out-planted seedlings at and beyond latitudinal treeline
- Inoculated with fungi
  (1) sterile autoclaved inoculum

  (2) unburned boreal forest inoculum

  (3) burned boreal forest inoculum.

Preliminary results



- Abiotic factors may impact seedling establishment success more than fungal symbiont availability at some sites

Abiotic Factors

- Relative importance of drought stress and nutrient availability to seedling establishment
- C and N isotopic signatures
  - foliar isotope signatures, which provide an integrative measurement of seedling performance
  - soil isotopes
  - fungal community profiles for each seedling

Isotopes

- Stable isotope abundance

Hydrogen

Deuterium

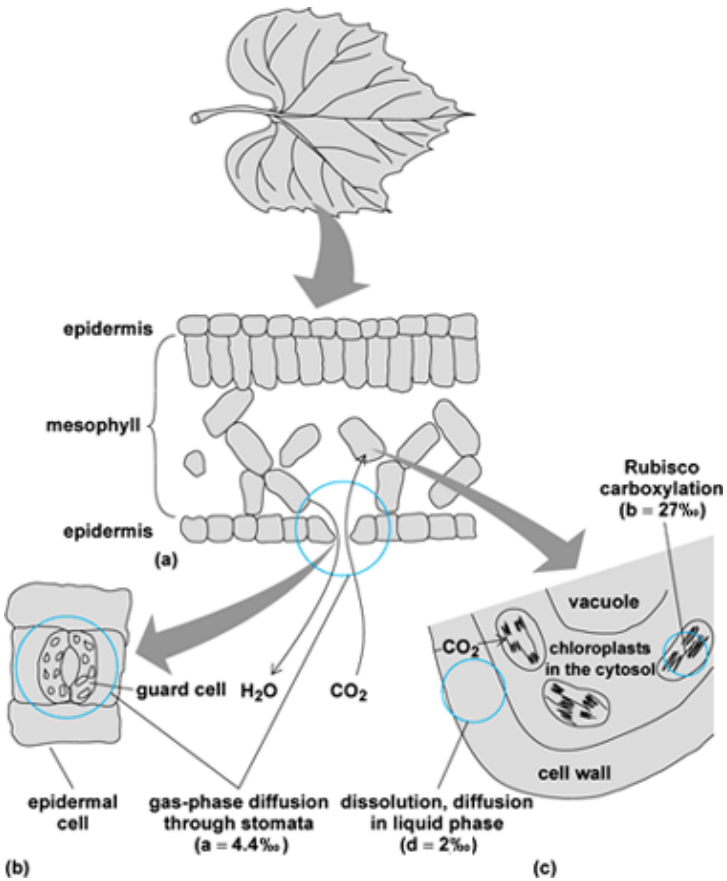
Tritium

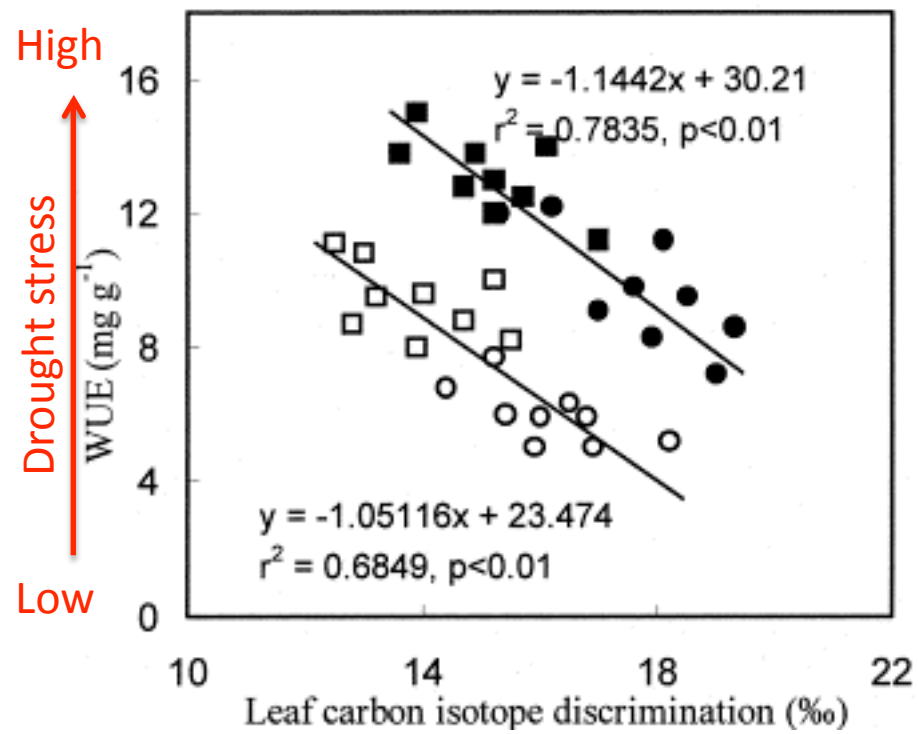
- Atoms with different number of neutrons

$$\delta D = 1000\left(\frac{(D/H)_{sample}}{(D/H)_{ref}} - 1\right)$$

- Discrimination- atomic mass influences behavior

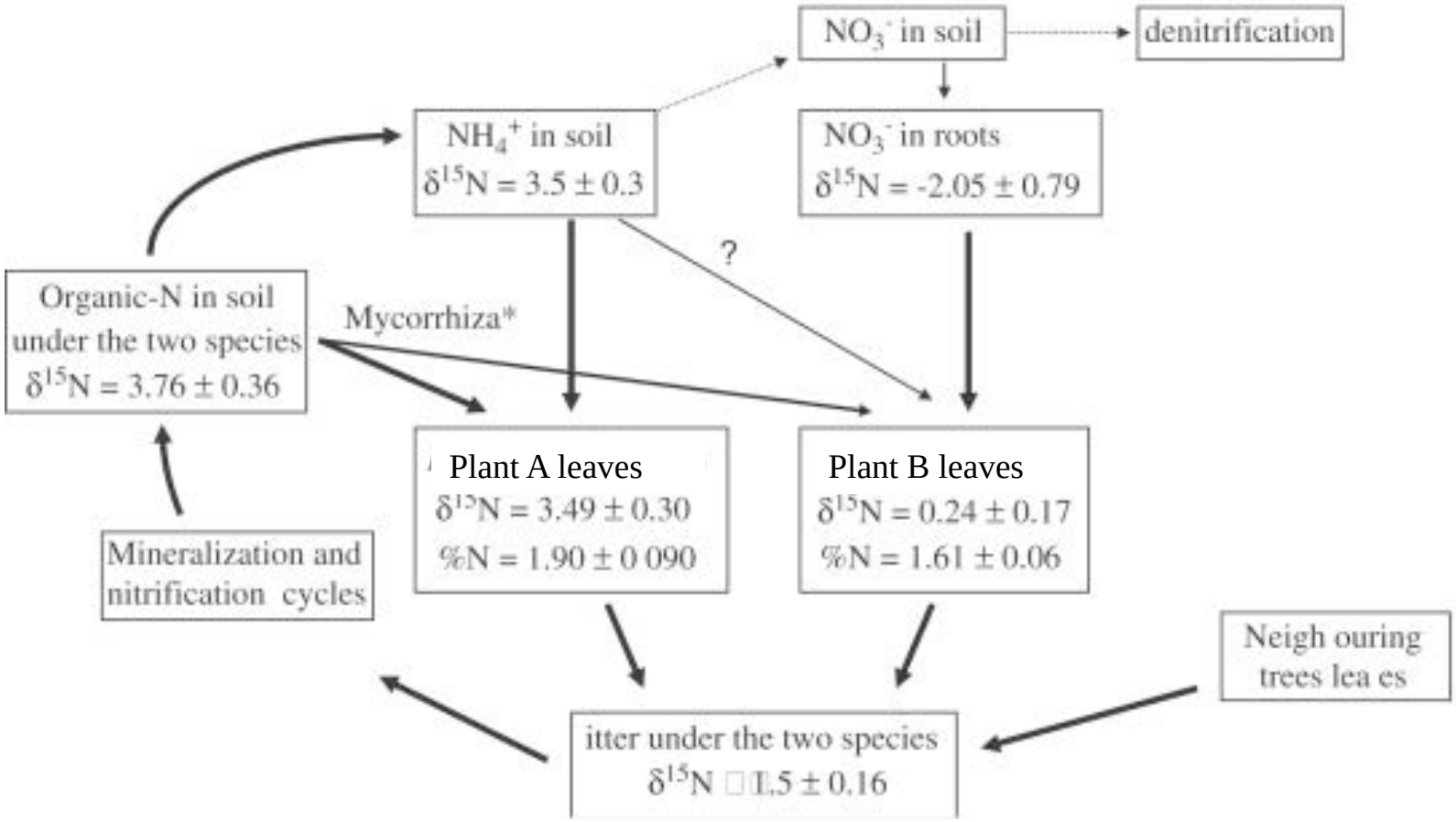
Drought stress and C isotopes





- Foliar $\delta^{13}C$ signatures provide an integrated indicator of photosynthetic activity and water relations with enriched $\delta^{13}C$ signatures indicating greater drought stress.

Nutrient availability and N isotopes

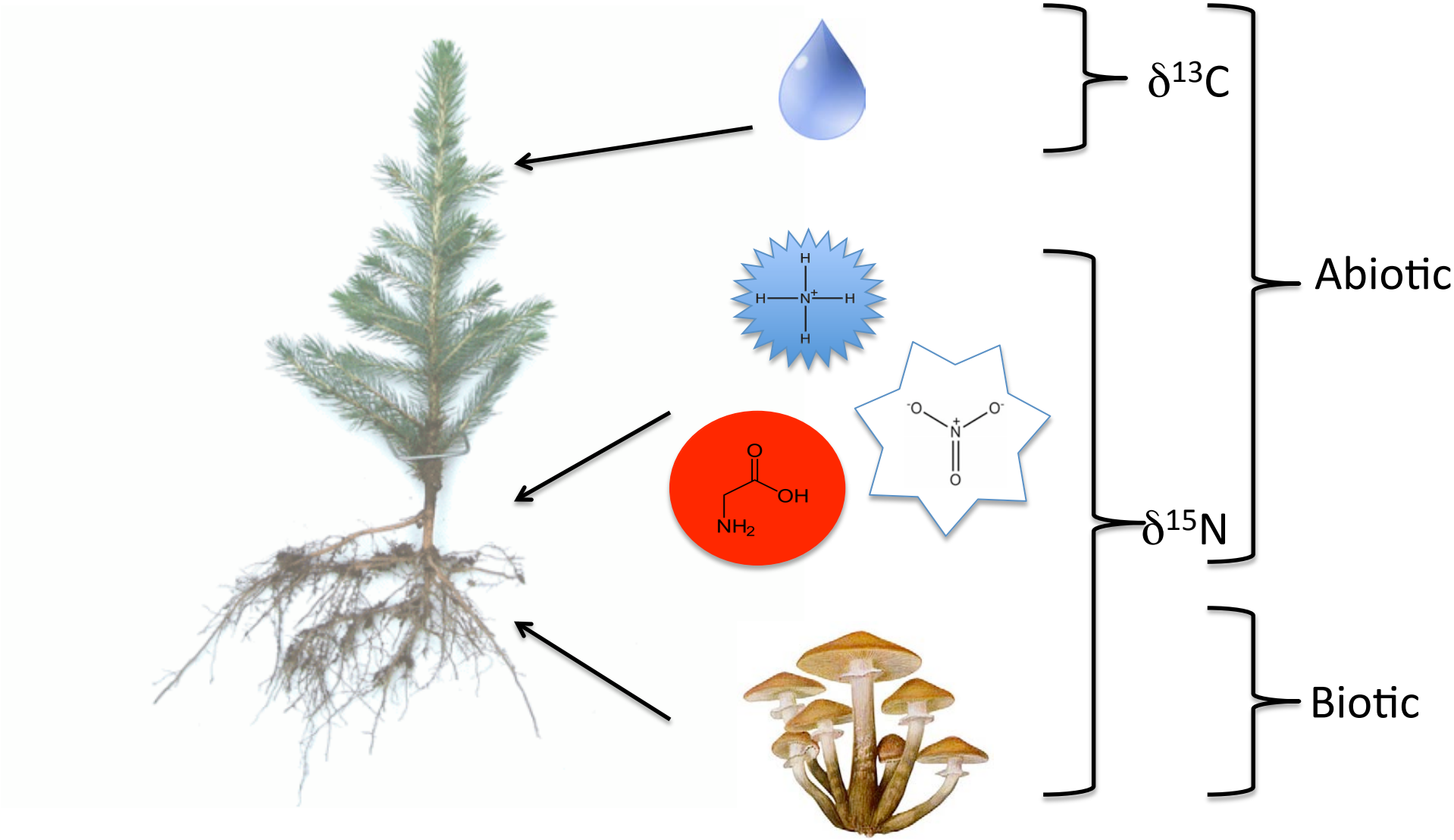


- Foliar $\delta^{15}N$ signatures in comparison with soil $\delta^{15}N$ signatures will indicate soil N pools accessed by seedlings and N uptake by fungal symbionts

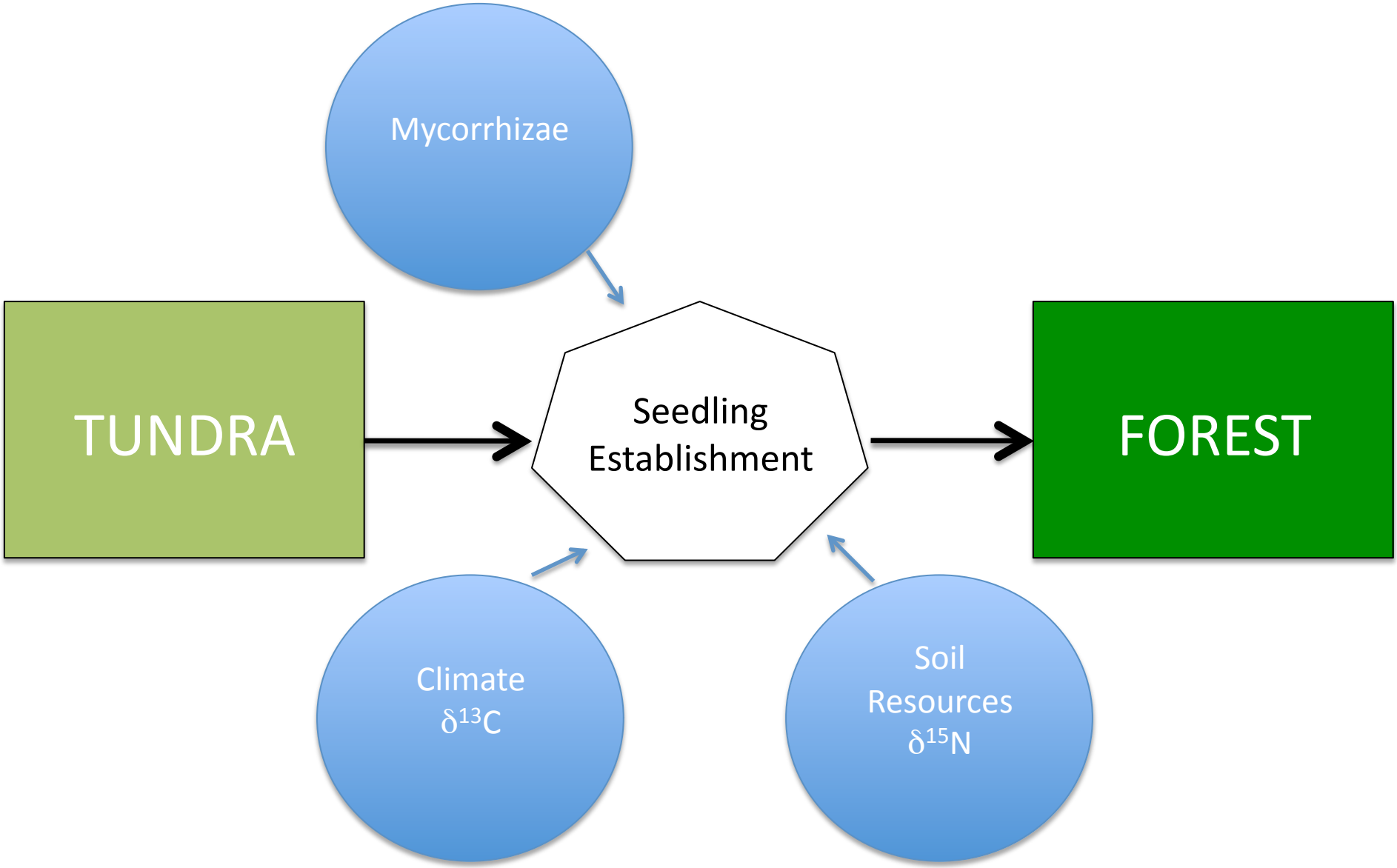
Proposed Research Summary

- Obtain data on drought stress status and nutrient status of seedlings
- Couple with data on fungal communities
- Use the biotic and abiotic data to create a hierarchical model of factors affecting seedling establishment

Heuristic Model



ALFRESCO


Mycorrhizae
TUNDRA
Seedling Establishment
FOREST
Climate
$\delta^{13}C$
Soil Resources
$\delta^{15}N$

Proposed products

- Develop a heuristic model of abiotic and biotic factors influencing establishment success
- Parameterize a regional frame-based model (ALFRESCO) of fire-climate-vegetation dynamics
- Predict tree migration and future flammability

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