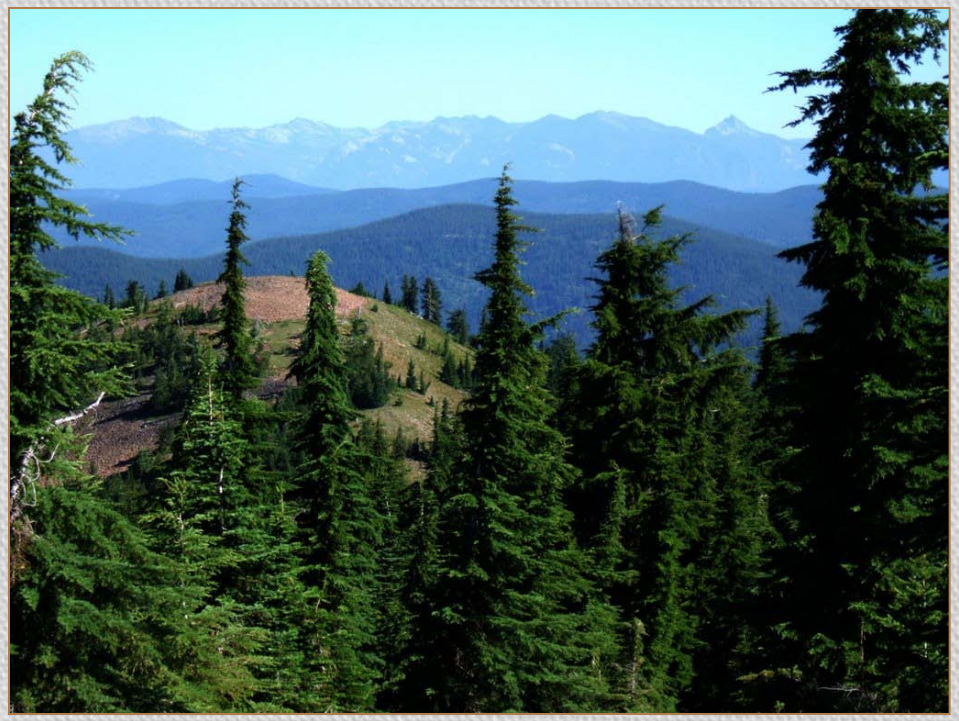

THE EFFECTS OF BIOCHAR ON FOREST SOIL CHEMICAL PROPERTIES AND TREE GROWTH

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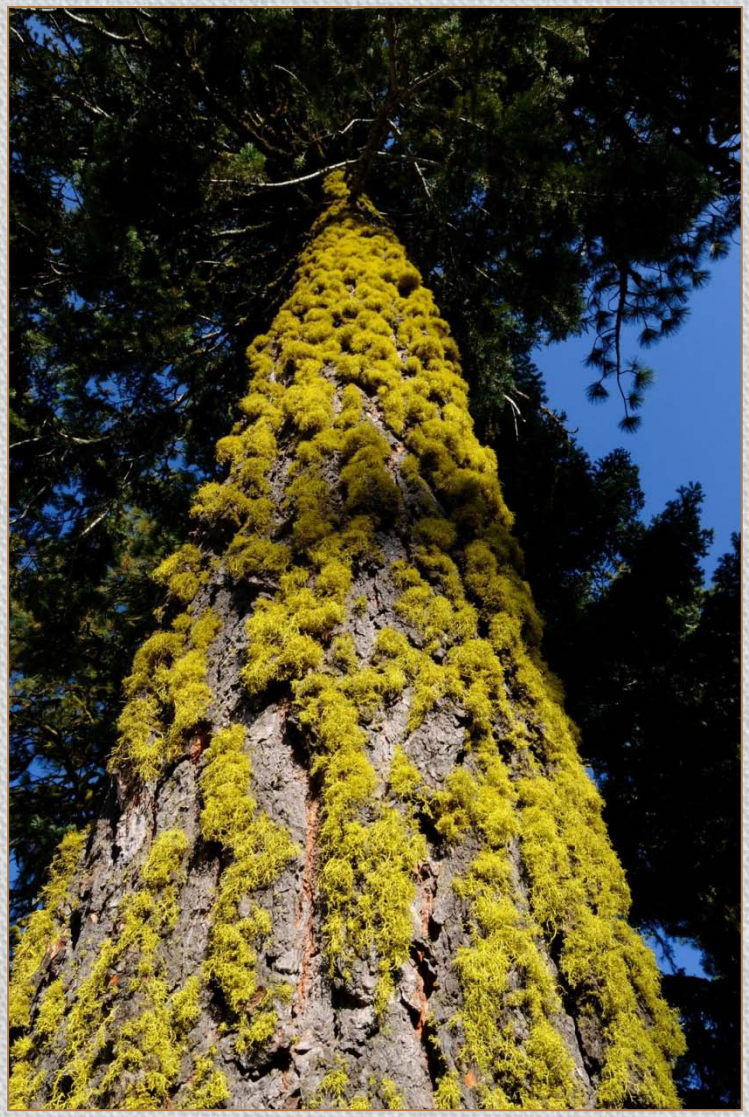
Biochar Application in Forestry

Presentation Overview

- Context and Research Justification
- Positive & Negative Aspects of Biochar
- Research Results
  - Biochar/soil incubation study
  - Greenhouse Bioassay: Poplar growth response to biochar additions
- Application and Feasibility
- Potential Implications for Land Managers



Context

- Remove forest biomass/residues
  - Forest health improvement, fuels reduction
  - Bioenergy production: portable fast pyrolysis units
- Concerns associated with removals
  - Alter nutrient cycling, reduce SOC, site degradation over time?
  - Economics
- Mollify concerns with biochar application?
  - Return/retain site nutrients
  - Improve soil properties
  - Long-term C sequestration

Forestry, Bioenergy, & Carbon

- Forestry: Source of biomass, need for fuels reduction

- Bioenergy: Co-production of biofuels and biochar via pyrolysis
  - Energy extraction without nutrient removals

- Carbon: Biochar is 70-80% C, creates long-term soil carbon sinks

Biochar Pros and Cons

+

- Carbon sequestration potential
- Soil nutrient & water retention
- Bioavailability→plant productivity
- Soil fertility, microbial activity
- Inhibit nutrient leaching
- Reduce N_2O and CH_4 emissions

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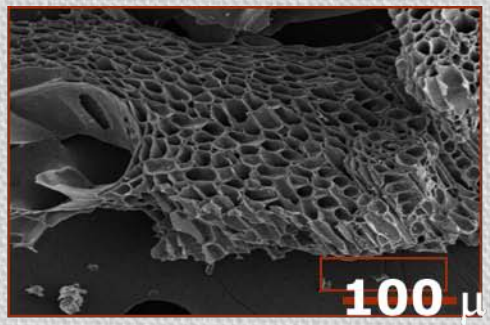
- Polycyclic aromatic hydrocarbons (PAH)
- Heavy metals
- Priming
- Raise pH?
- Reduce plant growth?



Research Justification

- Environmental Implications: Demonstrate effects of biochar on forest soil properties and woody biomass growth

1. Biochar as a forest soil amendment:
   - Compare effects of biochar and application method on forest and agricultural soil chemical properties

2. Greenhouse bioassay:
   - Investigate if plant growth/biomass can be enhanced with biochar

- Uncertainties associated with regions/soils
  - Unique INW soils, volcanic ash inputs
  - Positive and negative results associated with biochar research

Biochar Incubation Study

- Laboratory incubation study (Jan-Aug 2010)
- Demonstrate biochar effects among various soils
  - Spodosol, Andisol, Mollisol
- Demonstrate application methods
  - Top-dressing, Incorporation
- One rate: 25 Mg ha^{-1}
- 3 treatments x 3 soils x 6 replicates = 54 soil columns

Soil Types

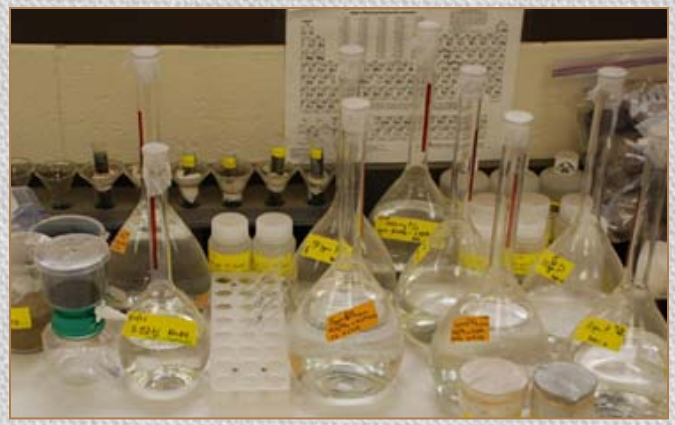
Soil	Classification	Horizon	Location
Forest Andisol	medial over loamy, mixed, frigid Alfic Udivitrand	Bw	Clearwater County, ID
Forest Spodosol	sandy, mixed, frigid Aquic Haplorthod	E	Priest Lake, ID
Agricultural Mollisol	fine-silty, mixed, superactive, mesic Pachic Ultic Haploxeroll	Ap	Moscow, Idaho

Biochar Incubation Study

Properties of interest:

- **pH**
- **OM (%)**
- **Total C (%)**
- Total N (%)
- NH_4-N (µg g^{-1})
- **NO_3-N (µg g^{-1})**
- **Available K (µg g^{-1})**
- Available P (µg g^{-1})
- **CEC (cmol kg^{-1})**
- **K (cmol kg^{-1})**
- Ca (cmol kg^{-1})
- Mg (cmol kg^{-1})
- Na (cmol kg^{-1})
- Microbial Biomass
- Leachate N analysis

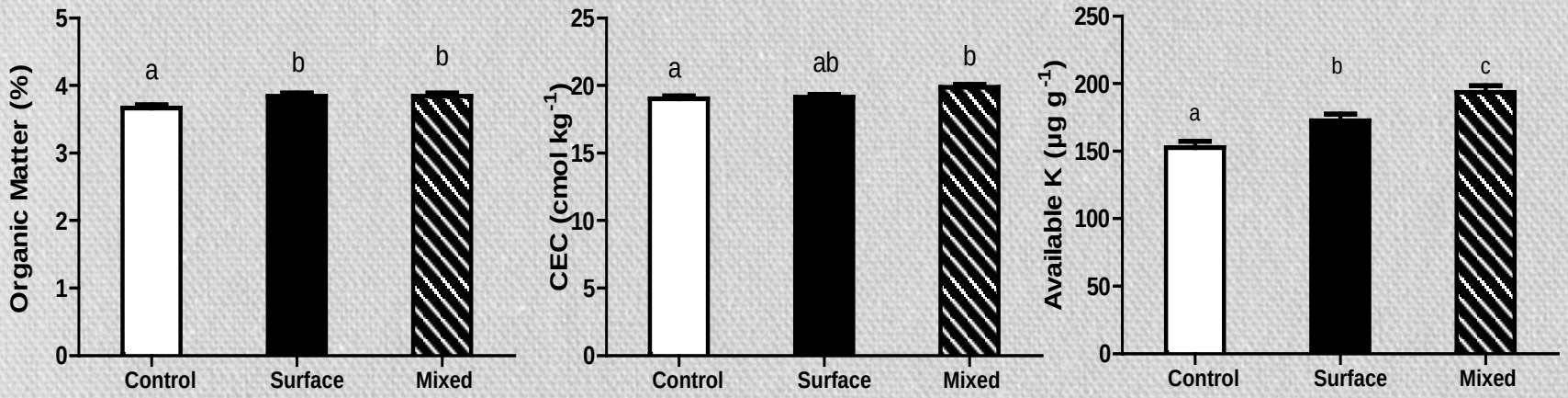
- Hypothesis: Biochar additions will enhance standard soil chemical properties of all soils



Measurements and data analysis

- Cores destructively sampled at 30 weeks
  - Soil chemical properties, leachate N, and microbial biomass
- General linear model used to test for significant effects (α=0.05)
  - Treatment type
  - Soil type
  - Interactions
- LS Means & Tukey's post hoc procedure (SAS)

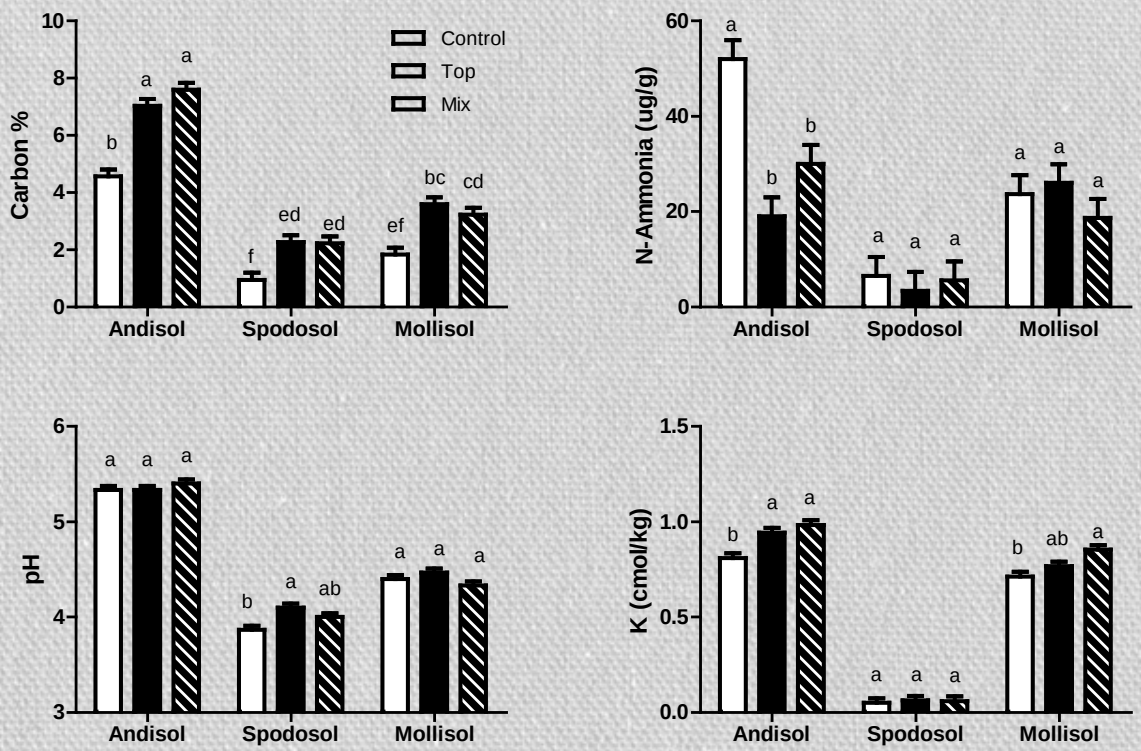
Main Effects on Soil Properties



Biochar effects for all soil types combined. significant differences at $P < 0.05$.

- OM increased by 7%
- Mixed treatment increased CEC by 5% relative to the control
- Available K increased in surface (13%) and mixed (27%) treatments

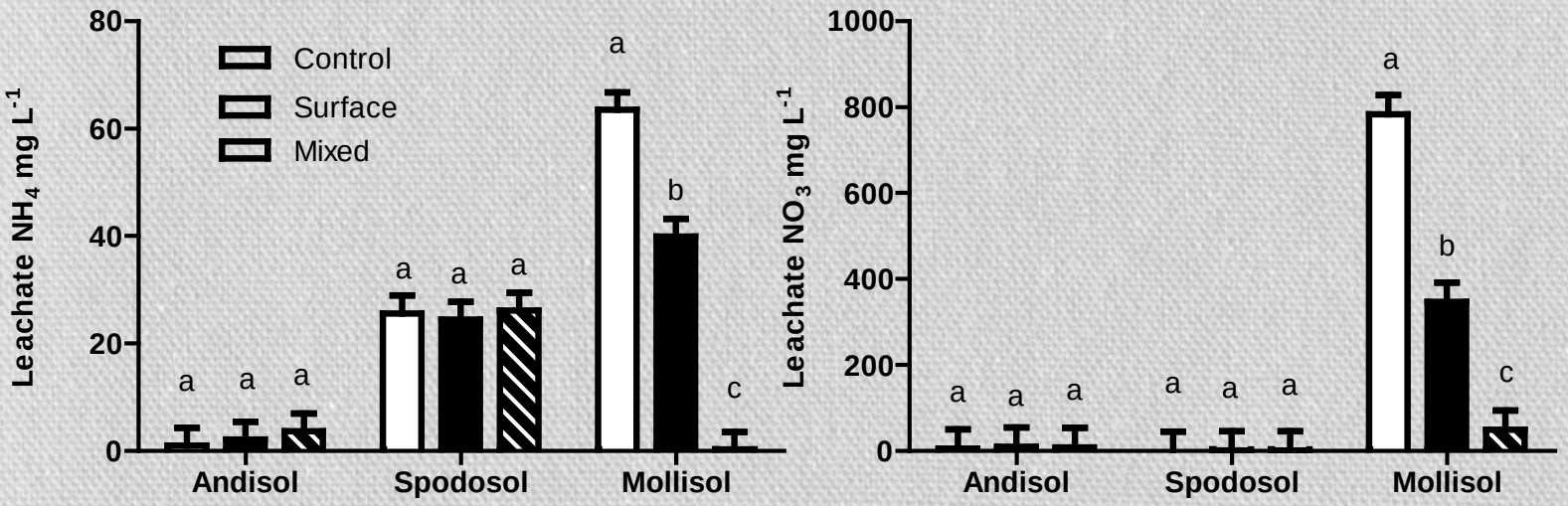
Interactions



treatment*soil interactions

- C increased for all soils - magnitude varies by soil
- Surface and mixed treatment decreased NH_4 (63%, 42%) in the Andisol only
- pH increased by 8% in the Spodosol
- K increased in the Andisol (16%, 21%) and Mollisol (19% mixed trt)

Leachate



Leachate N response to biochar treatments

- Biochar reduces NH_4 (38%, 99%) and NO_3 (56%, 94%) in the Mollisol

Dynamotive CQuest Biochar

- Nutrient Value: direct or indirect effects of biochar?
  - Indirect = nutrient retention, change in physical properties, soil interactions

Test	Value
pH	**6.8**
CEC (cmol kg^{-1})	30
OM (%)	9
Total C (%)	**62**
Total N (%)	0.18
K (cmol kg^{-1})	1.6
Ca (cmol kg^{-1})	2.2
Mg (cmol kg^{-1})	0.35
Na (cmol kg^{-1})	0.17
NH_4^+ (µg/g)	**3.3**
NO_3+NO_2 (µg/g)	< 1.6
Available K (µg/g)	**710**
Available P (µg/g)	17

Results Summary

- Mixed biochar treatments alter exchange sites and increases CEC of all three soils
- Both biochar treatments resulted in significant increases in C and OM among all soil types
- K significantly increased in both the Andisol and Mollisol with biochar additions, but was unchanged in the Spodosol
- NH_4-N significantly decreased with biochar treatments in the Andisol only

Discussion Points

- Application method matters: pH, CEC, and available K
  - Incorporation may accelerate organo-mineral relationships
- Increases in C, OM and available K → direct input from biochar
  - Magnitude of difference varies - Differences in starting colloid properties (OM, C, Clay)
  - Short lived benefits?
- Decreases in NH_4
  - Losses due to leaching, nitrification, volatilization, or immobilization ?
  - Dilution effect, N-depleted amendment
- pH increase in Spodosol only
  - Result of starting pH of soil (3.8) and biochar (6.8)
- Improved nutrient retention
  - Relevant in fertilized systems

Application

- Biochar is effective at significantly enhancing soil C, OM, K, CEC, and pH on a short timescale
  - Improved soil quality and site productivity over time, maybe
  - Concerns with NH_4 reductions in INW soils
- Can we expect these results in the field?
  - Depends on rate, biochar, application method, and plant & microbial interactions, time
- Soil amelioration tool and can
  - increase the recalcitrant soil carbon pool, long-term carbon sequestration
- Repeatable?
  - Likely, using same char source
  - Different char, different results?

Tree Growth Response

- Investigate effects of biochar on woody biomass

- Greenhouse bioassay:
  - Investigate if soil nutrient supply, uptake, and plant growth can be increased with biochar additions

Research Justification

- Current Biochar Research
  - Agricultural Soil
  - Crop-growth response
  - Highly degraded soils
  - Tropical and Arid Regions

- Research Gaps
  - Forest Soils
  - Tree growth response
  - Temperate regions

Greenhouse Bioassay

- Biochar and Sand Rates
  - 0%, 25%, 50%
  - Sand = inert amendment and control
  - With/without fertilizer
  - 8 weeks, 2 harvests, 10 reps
    - 100 total cuttings
- Effects on different soil types?
  - Coarse- and fine-textured Andisol
- Expected an increase Poplar growth with biochar additions

Ashy-pumiceous, glassy Xeric Vitricryands

medial over loamy, mixed, frigid Alfic Udivitrand

Measurement and Analysis

- Harvest = separating the plant into leaves, stems, cutting and roots
- Drying, weighing, grinding
- Leaf C & N

- General linear model used to test for significant effects (α=0.05)
  - treatment type (control, biochar, sand)
  - rate (0, 25, 50%)
  - fertilizer (yes, no)
  - biomass, and leaf N properties
- LS Means, Tukey's post hoc (SAS)

Results Overview

Biochar

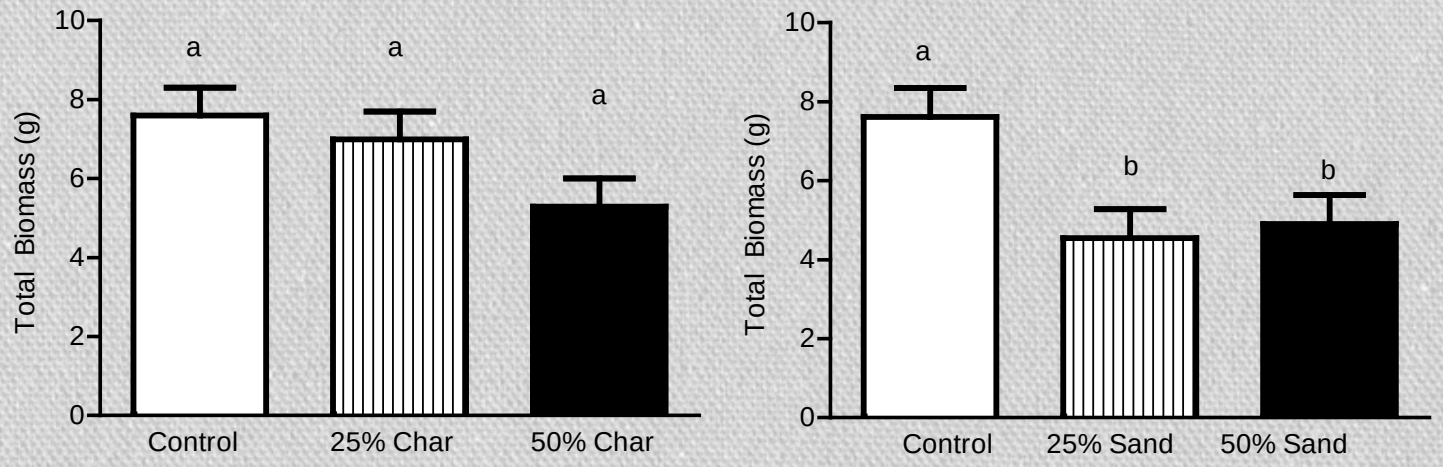
- Soil type is significant
  - Best growth in FA
- No Biochar effect
  - Total, above- and below-ground biomass ($p>0.05$)
  - both soils
- Fertilizer effect
  - Total Biomass FA & CA
  - Above-ground biomass FA

Sand

- Negative sand response in CA only
  - Total and above-ground biomass
- No fertilizer effect

Results

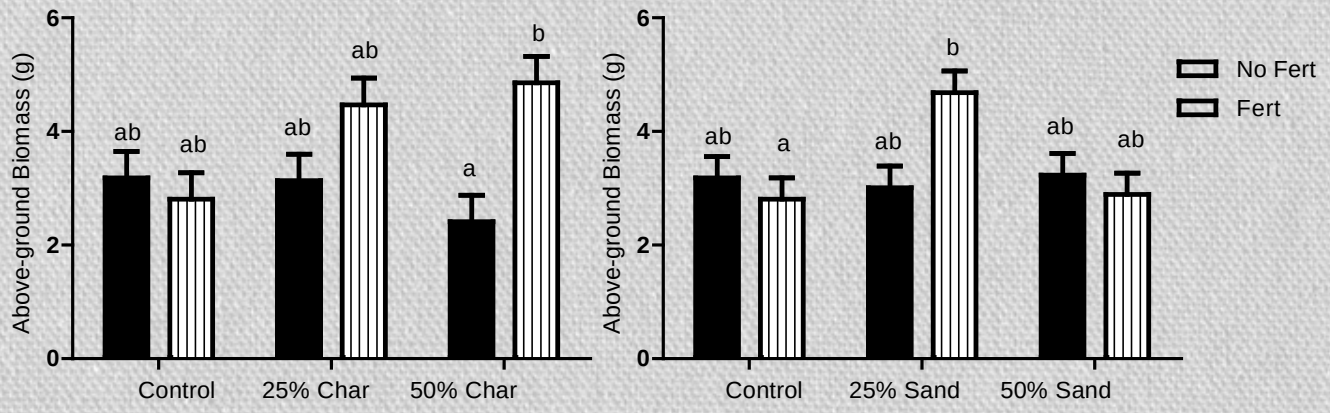
Coarse Andisol



- Biochar has no significant effect on Total Biomass
- Sand amendments significantly reduce Total Biomass

Results

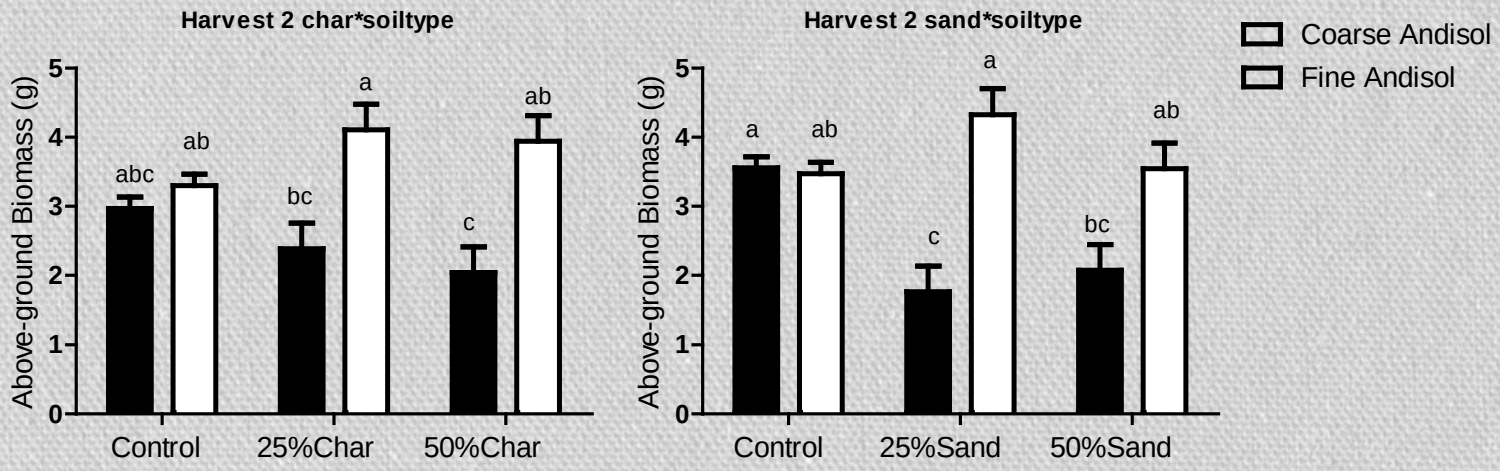
Fine Andisol



- No response with biochar or sand
- Biochar + Fert has greatest positive response
  - Physical properties of char
- Potential negative growth response at high rates
  - Fertilizer additions could avoid negative effects

Results

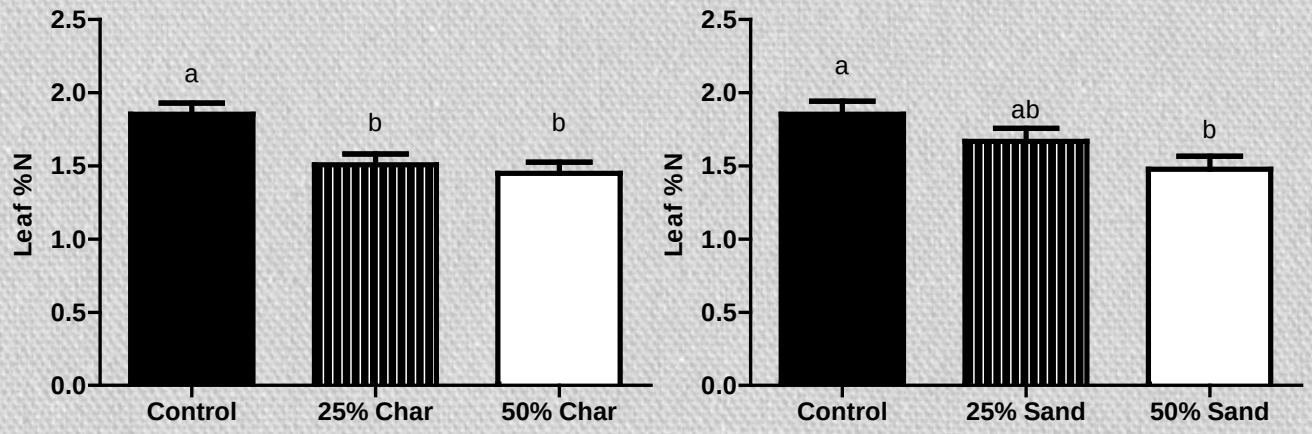
Soil Comparison



- Biochar: no significant differences among rates
  - Follows trend of sand amendment
- Sand: decreased growth for CA and not FA

Results

Leaf N



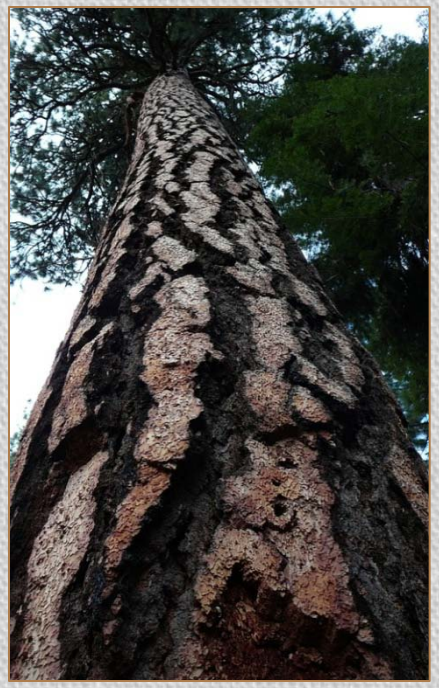
- Biochar significantly reduces leaf N

Bioassay Summary

- Application in forestry → Why not?
- No biochar effect, but potential for negative consequences
  - Decreased leaf N
  - Short- or long-term effects on productivity?
- Soil texture effects response
  - Biochar application rate is important

Implications

- Predicted: Slight effect of biochar on forest soil properties
  - Mostly positive enhancements in nutrient status
  - Direct and indirect
  - Application method
- Do these soil alterations effect forest productivity
  - Probably not - depends on biochar rate
  - Alterations over time
- Short vs. Long-term Effects



Bioenergy & Biochar Co-production Potential

- Reduce reliance on fossil fuels
- Promote rural development
- Improve economics & finance forest management activities?
- Reduce wildfire risk
- Eliminate in-woods burning of biomass
- Sequester C
- Conserve or improve site nutrients
- Enhance forest productivity

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