The influence of char on forest seedlings, soils and trees

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Funding

- US FS R&D program on Woody Biomass
- McIntire-Stennis
- American Recovery and Reinvestment Act
- AFRI Sustainable Bioenergy

Bio-char

CharKing

Dynamotive

BACKGROUND

High interest in thinning small diameter stands

- Private investment returns
- Public lands are over stocked
- Protection: wildfire, pests infestation, drought
- Policy: Healthy Forests Initiative, National Fire Plan, etc., Energy Independence and Security Act
- Adaptation to Climate Change
- Cost prohibitive

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Utilizing Forest Biomass

Provides management opportunities

- Interest in utilizing woody biomass for energy
- What are the ecological consequences of forest biomass removal?
- Can any negative impacts be mitigated?

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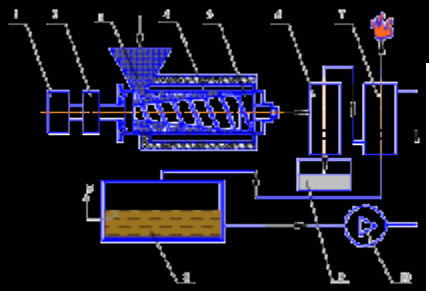
Fast Pyrolysis

Small scale units

- In woods processing
- Avoid biomass transport costs
- High value oil product
- Research required
- Funding scarce



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Pyrolysis Products

Syngas

Bio-oil

Bio-char

Biochar is equivalent to native charcoal in forest ecosystems

- Char is common in fire-adapted ecosystems
- Fire suppression decreases charcoal inputs
- Biomass removal decreases the likelihood of fire occurring
- Applying char as a co-product of pyrolysis removes wildfire hazard *and* retains soil ecosystem function

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Site amendment with charcoal

purports to:

- Return nutrients back tot the site of biomass removal
- Improve soil characteristics
- Enhance site quality

Objective

- Evaluate impacts of biomass removal and char amendments on forest soil productivity

Questions

1. What soil properties are affected by char?
2. Do char amendments alter tree growth; if so in which direction?

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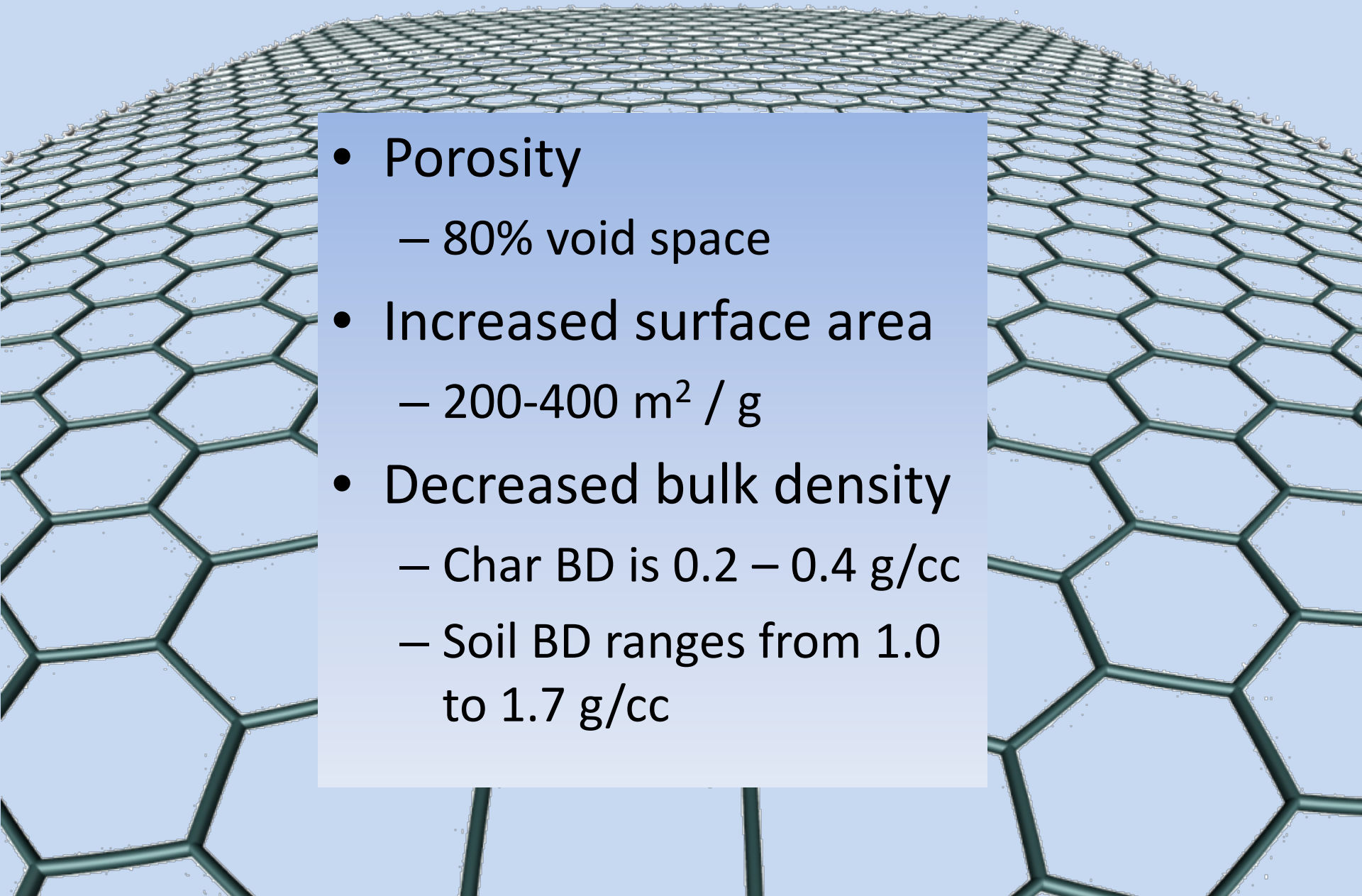
Char porosity alters physical soil properties



- Porosity
  - 80% void space
- Increased surface area
  - 200-400 m^2 / g
- Decreased bulk density
  - Char BD is 0.2 – 0.4 g/cc
  - Soil BD ranges from 1.0 to 1.7 g/cc

Char & soil properties

Incubation studies

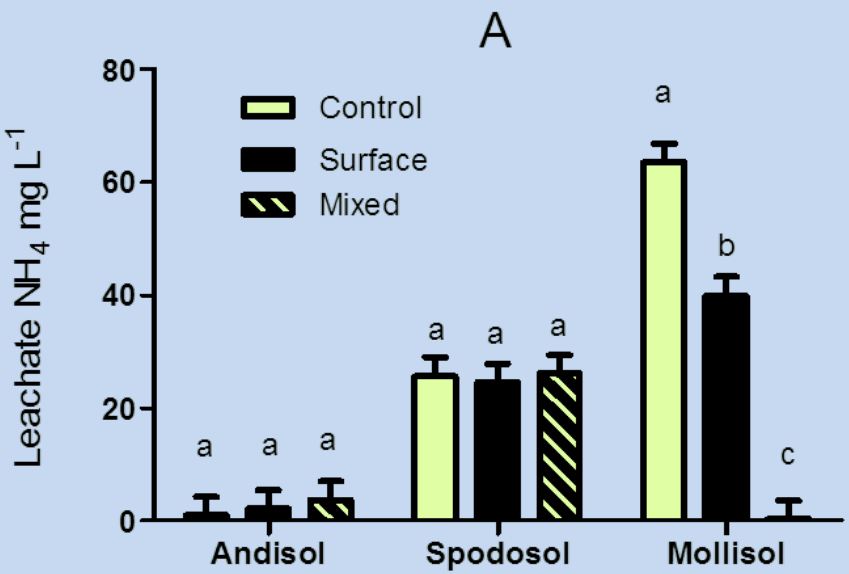
Char responses to char are consistent, but often depend on soil type

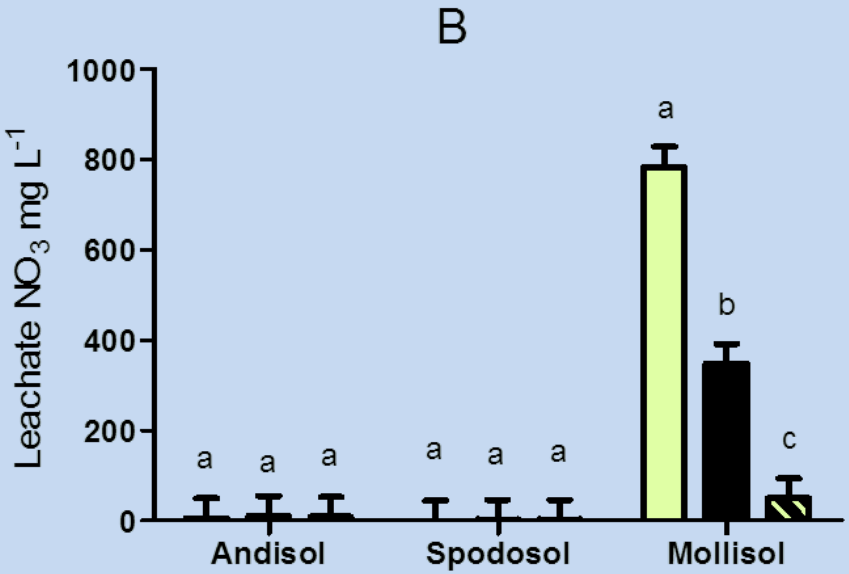
- Increased organic matter
- Increased water holding capacity
- Increased pH

Coleman, Shan & Smith unpublished

Increased sorption and ion exchange capacity retains nutrients from leaching

…. in some soils





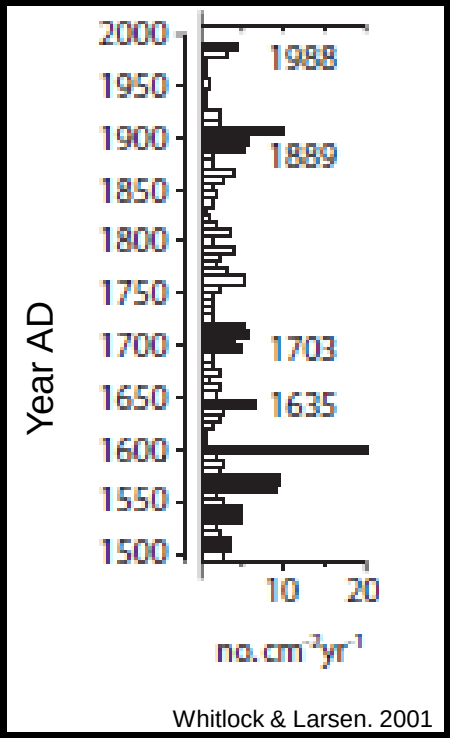
McElligott 2011

Char has long residence time in soil

Carbon sequestration potential

- Stable aromatic ring structure
- Decay resistant

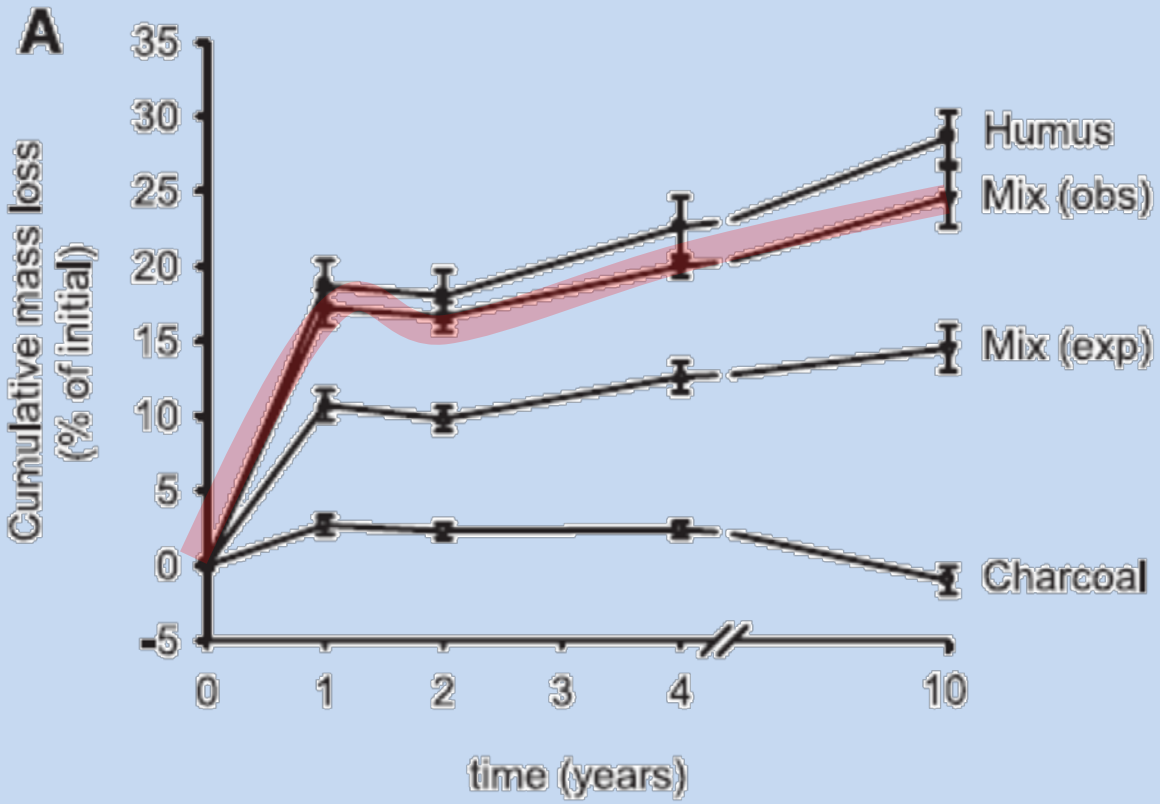
- *But*, char may speed decomposition of native soil organic matter
- Char enhances microbial activity
- Sequestration may not equal the amount applied if active microbes consume more



Whitlock & Larsen. 2001

Charcoal is used to date ancient fires

Does char speed the loss of soil organic matter ?



Wardle et al 2008

- Litter bags containing:
  - humus
  - char
  - humus + char
- Mixing humus with char causes greater mass loss than expected

Does char increases organic matter decomposition?

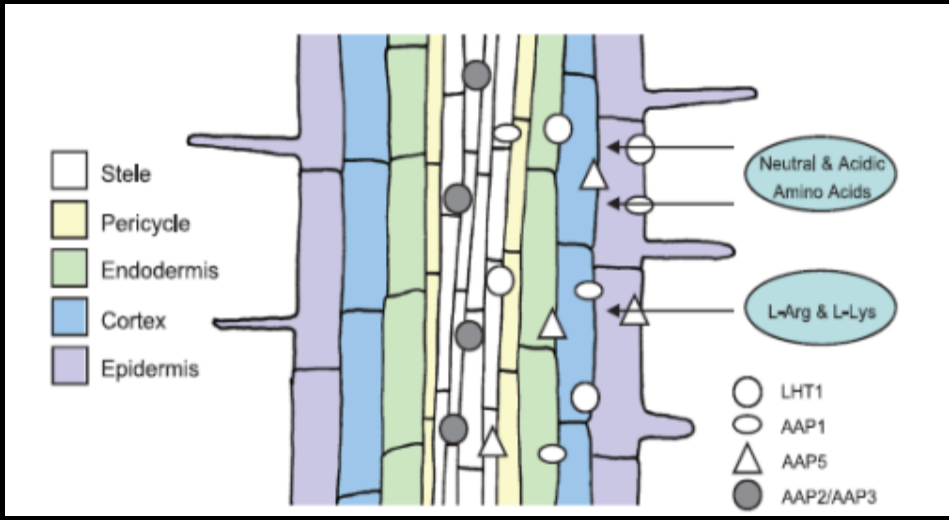
- Activity of decomposition enzymes decreases with greater char
- No effect found on soil respiration
- Conclude OM consumption does not increase with char

Soil Respiration ($\mu mol\ m^{-2}\ s^{-1}$)

Coleman, Shan & Smith unpublished

Does char alter organic nitrogen cycling?

- Importance of organic N in forests now accepted
- Litter organic matter, N mineralization are correlated with productivity
- Amino acids are acquired by roots
- Amino acid pools and fluxes are is easily measured



{Nasholm, 2009 #5834}

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Soluble organic N

Field-collected soils

Amino acid-N (mg/kg)

Organic Layer N (%)

- Amino acid solution concentration increases along an elevation gradient
- Also related to the quality (N%) of the litter layer

Shan, Kimsey & Coleman unpublished

Char increases Organic N cycling

varies with elevation of soil origin

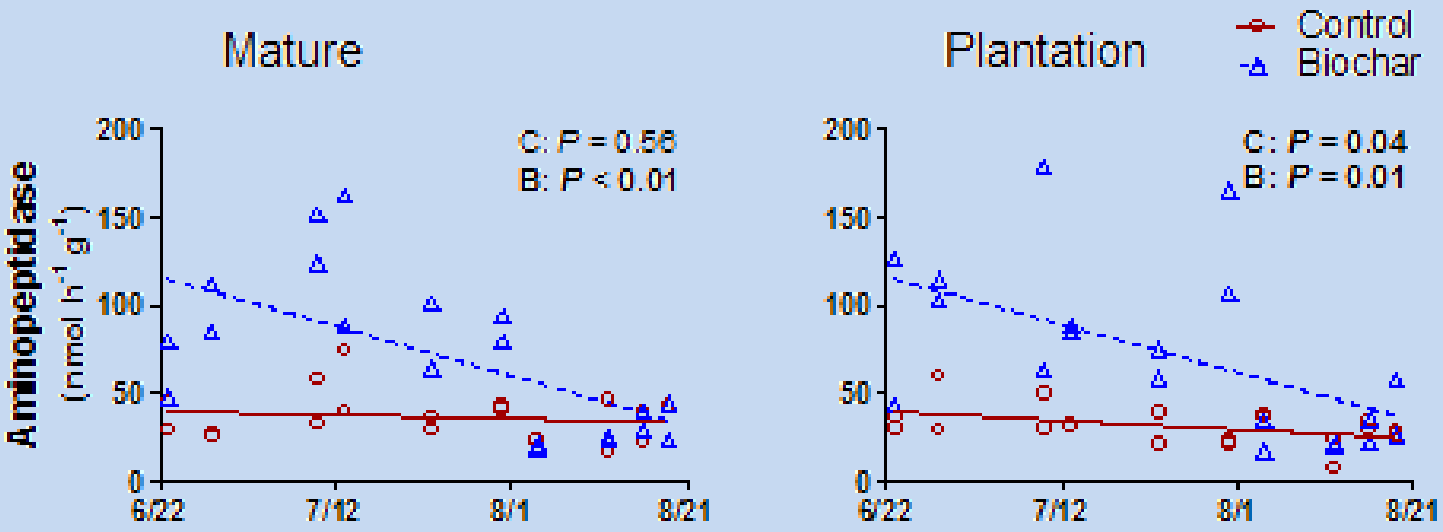
Char causes:

- Decreased Amino-N pools
- Increased amino acid production (Amino peptidase activity)
- Increased amino acid turnover
  - five-fold in low elevation soil
  - 30% increase in high elevation soil

Shan, & Coleman unpublished

Field work confirms char increases AA production

indicates greater N cycling



- Amino Acid production
  - Char rates are twice the control in early season
  - equal in late season

Smith 2013

Potential forestry applications

Does amino acid turnover indicate differences in site quality?

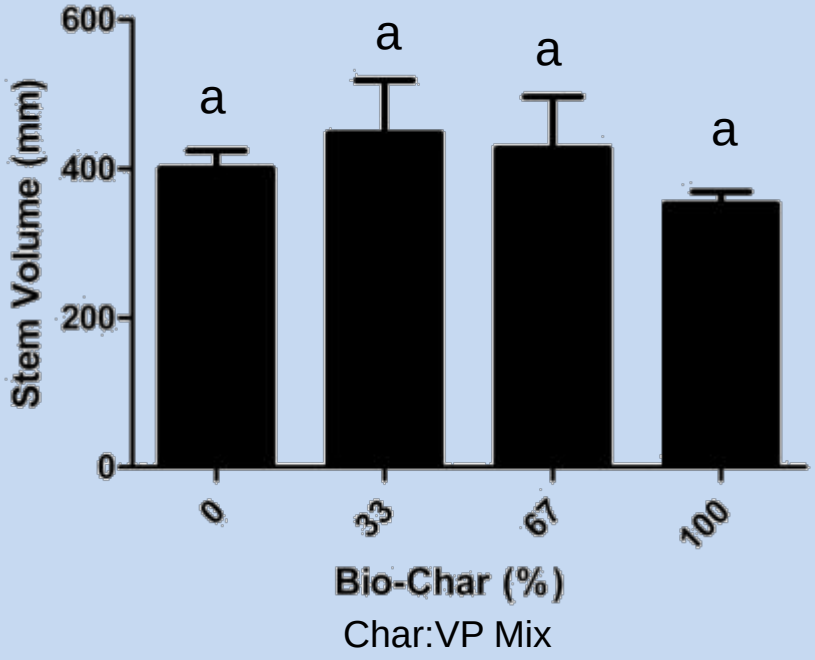
Testable Hypotheses

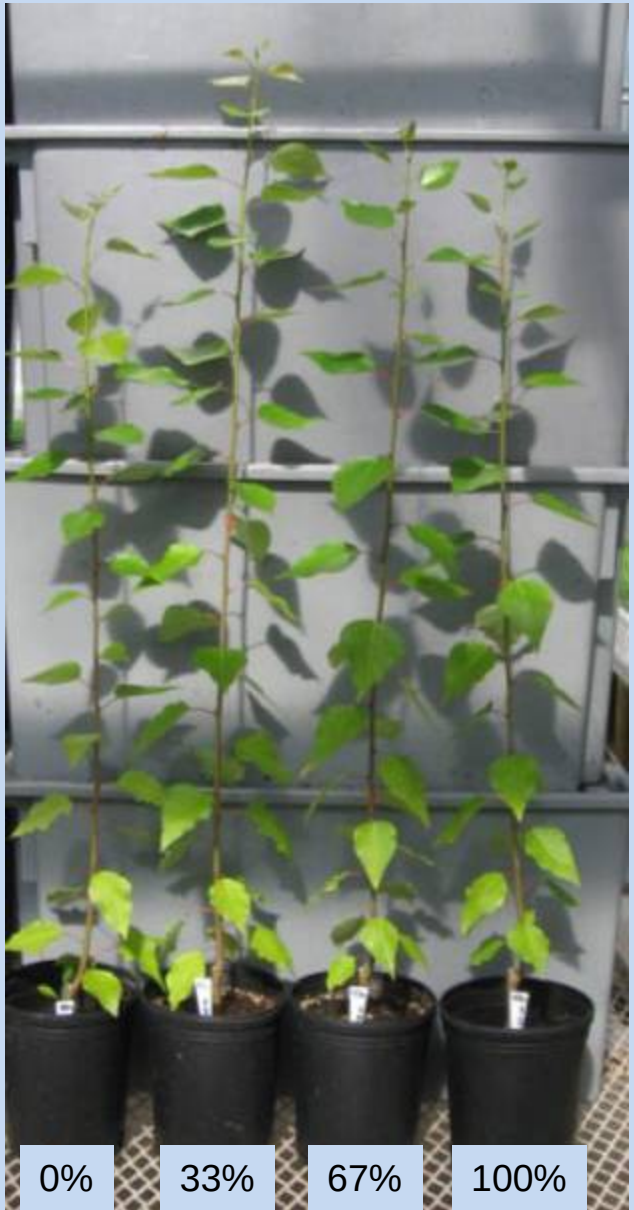
1. Site quality is directly correlated with amino acid production rate.
2. Forest productivity correlates with soil organic matter and organic N cycling rates.
3. Assays of amino acid production in forests are analogous to N mineralization measurement in agronomic soils.
4. Amino acid production rate is consistently high during wet season.

How does char affect tree growth?

Poplar grown with various proportions of char and vermiculite-peat potting mix; fertilized

- There is no growth stimulation

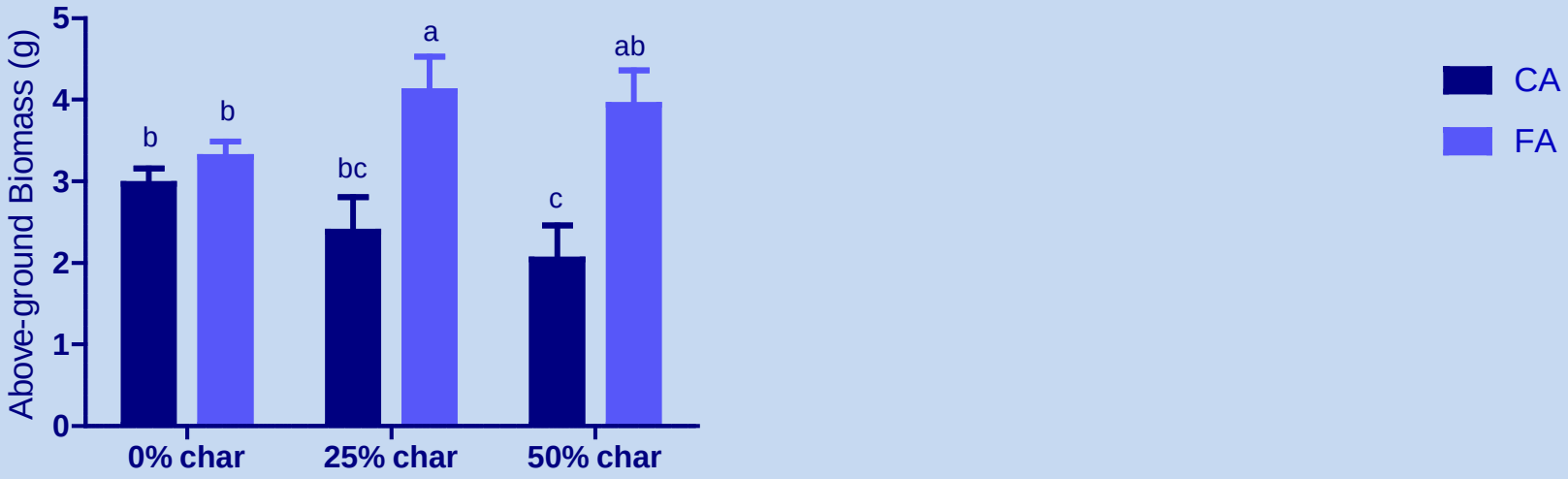




Char mixed in soil

unfertilized

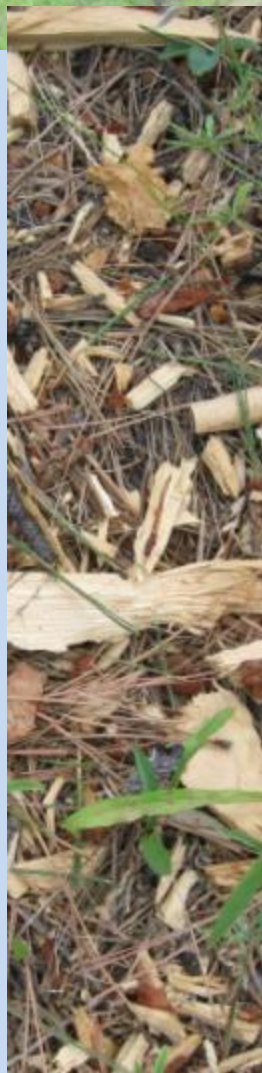
- Tree growth may actually decrease depending on soil type
- Similar response pattern with char and sand suggests the response is not unique to char

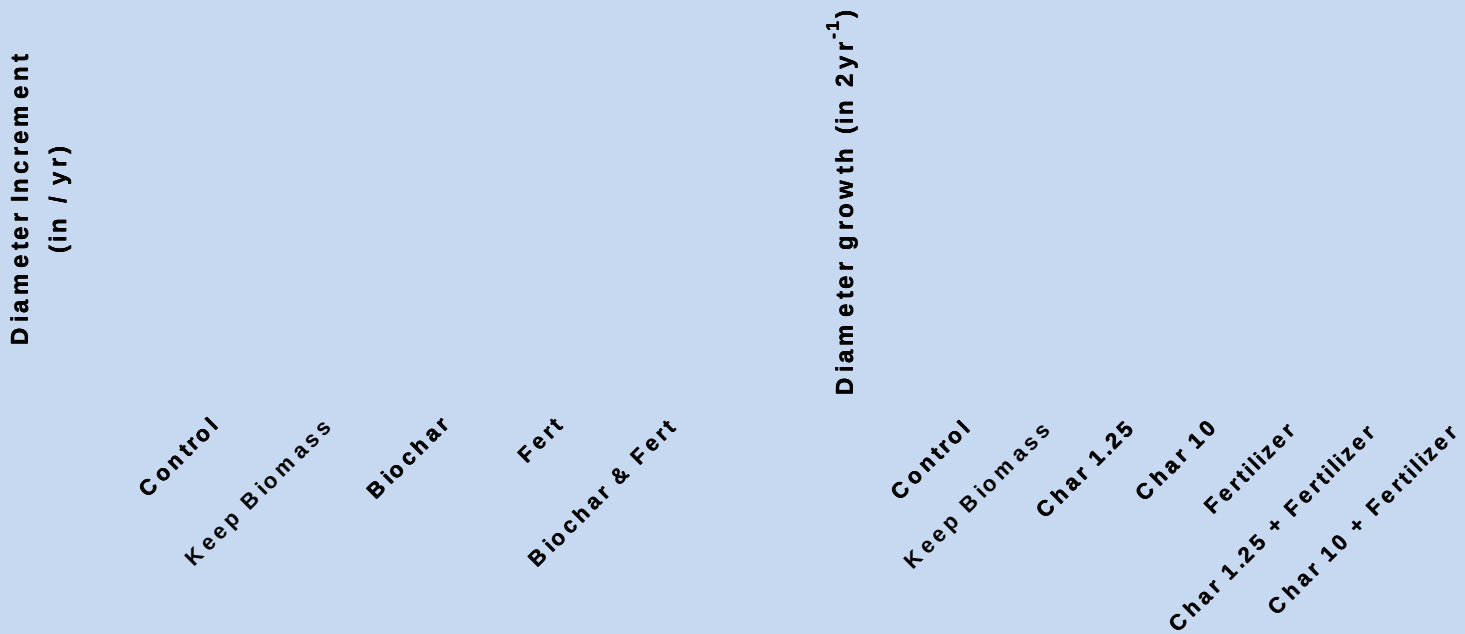


Need assurance that biochar application will not harm forest systems

McElligott 2011

Tree growth response





- Neutral to positive effects of char
- Fertilizer enhances growth, but no added benefit with char
- Slash effect rivals that of fertilizer
- Short-term responses

Coleman, Page-Dumroese et al unpublished

Using PCT stands to evaluate biomass removal impacts

- Established trees have exploited site
- Seedlings need to become established, delayed inter-tree competition
- Young trees are responsive to treatment

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Sustainable Bioenergy

Unthinned control		Thinned and No slash retention (0)	
untreated	fertilizer	untreated	fertilizer
biochar	fertilizer & biochar	biochar	fertilizer & biochar
Thinned and All slash retained (1x)		Thinned and Double Slash retained (2x)	
untreated	fertilizer	untreated	fertilizer
biochar	fertilizer & biochar	biochar	fertilizer & biochar

Utilizing Forest Biomass

Conclusions

- Numerous motivations to develop forest bioenergy
- Portable units appealing, but require development
- Char is a novel forest product
  - Used to sequester carbon and enhance soil quality
- Incubation studies demonstrate soil properties:
  - Water holding capacity, pH, nutrient retention, exchange capacity, etc
- Char doesn't increases organic matter decomposition
- New tools to measure organic N cycling indicates increases char; applications to forest nutrient management
- Monitoring PCT responses is sensitive measure of biomass removal and soil amendments

Bitterroot Bandits 2010

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