Forest Biomass:

A Source for Bioenergy, Nutrition and Carbon Sequestration?

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Utilizing Forest Biomass

- Increased interest
  - Rising fuel costs
  - GHG emissions from fossil fuels
  - Threat of wildfires
- Removal of forest biomass
  - Reduce wildfire hazard
  - Promotes forest health
  - Expands land management options
  - Encourages collaboration

Wildfire Risk Reduction

- Removal reduces fuel
- Common methods
  - Prescribed burning
    - Removes accumulations of limbs and unmerchantable trees to reduce wildfires
  - Mechanical Clearing
    - Felling, removal, piling, and chipping

Other Removal Objectives

- Ecological restoration, employment, forest-stand improvement and overall habitat improvement

- There is an urgent need to understand the short and long-term consequences of forest biomass harvesting - both on the forest ecosystem and on forest economics

Hazard fuel reduction operations are costly

- Biomass lacks the higher value of dimensional lumber
  - Contractors, haul distances, and markets affect profitability
  - Majority is not marketable and remains a fire hazard

- Slash burning
  - Significant cost and waste of energy
  - Releases CO_2 and other GHG into the atmosphere
  - Concentrates site nutrients at burn pile

Economics

- Difficult to estimate
  - Gaps in data and methods for predicting treatment costs
  - Unique stand conditions and terrain
- Median cost per acre = $625
- Sale of low-grade wood= $0.10-$40/ton for chips
  - Ex. cost after sale of chips=$280/acre
- Avoided future cost of fire suppression = $240-$600/acre

Sustainable Bioenergy?

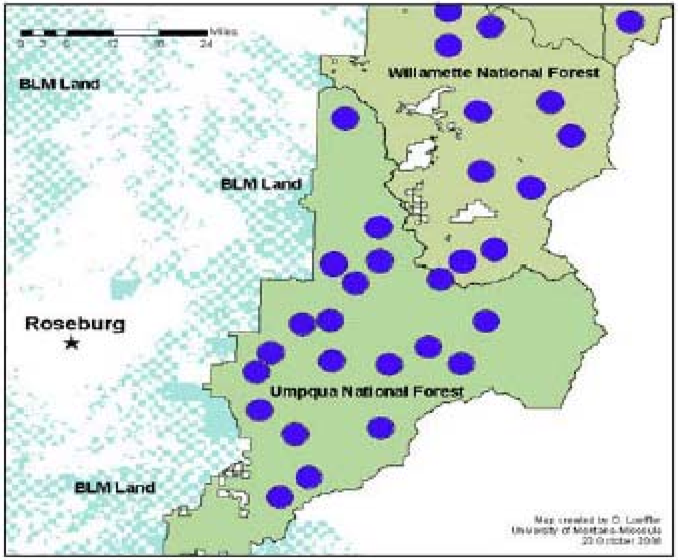
- Native forests in the US create 368 million dry tons of available biomass annually (Perlack et al. 2005)
- Woody biomass from conventional timber harvest can be removed and used as a resource for bioenergy
- Forest biomass can help the US meet energy independence goals

Challenges and Opportunities

- Biomass Removal takes essential nutrients from soil
  - While the site impacts are thought to be low, there is considerable concern that an established bioenergy market would degrade site nutrients overtime.
  - If energy could be removed without taking all nutrients, a bioenergy system might be more sustainable.

- Potential Opportunities of on-site biomass conversion
  - Portable pyrolysis units convert biomass into bio-oil in the woods.
  - Portable pyrolysis units operating on site could improve the economics and decrease the energy inputs required for biomass utilization.

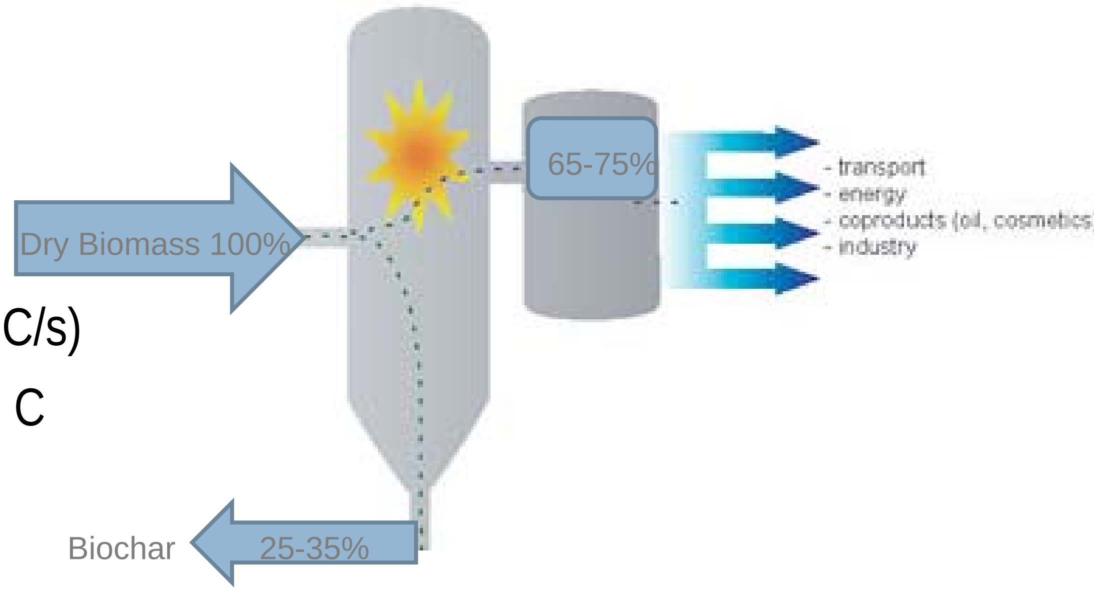
Centralized vs. Portable



Pyrolysis

- Bio-oil and Bio-char co-production using fast pyrolysis

- **Fast pyrolysis** is rapid heating in the absence of oxygen resulting in decomposition of organic material.
  - Rapid heating of biomass (>1000 C/s)
  - Reactor temperatures of 400-600^{o} C
  - Rapid condensation of vapors

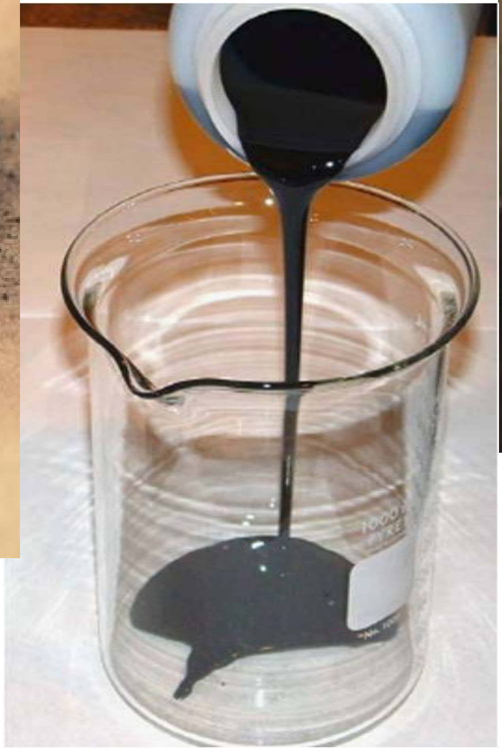


- Small scale plants
  - In-woods processing
  - Centralized plant

Pyrolysis Products

Bio-char

Bio-oil



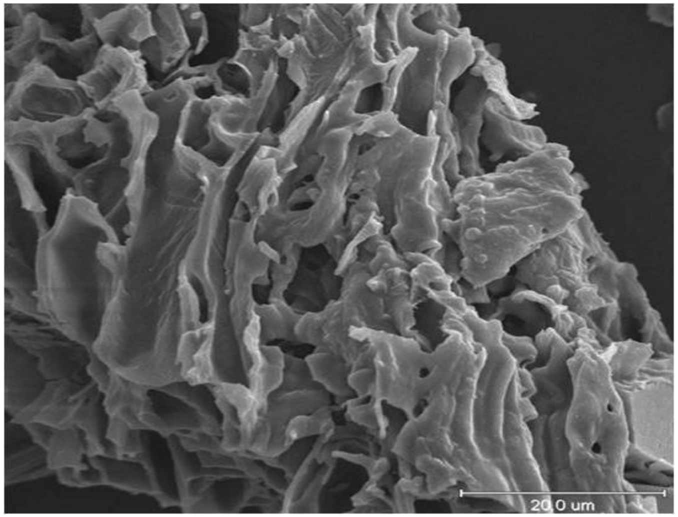
Syngas

Biomass to Bio-oil

- Environmental advantages over fossil fuels
  - Cleaner=less pollution
  - CO_2/GHG neutral→ generate CO_2 credits
  - No SO_x emissions are generated
  - >50% lower NO_x emissions than diesel
  - 1 dt biomass generates ~120 gal bio-oil
  - Catalytic upgrades result in biocrude liquids
  - RENEWABLE

What is Biochar?

- Fine-grained charcoal
  - organic carbon content (70-80%)
- Retains most of the carbon and nutrients contained in biomass
  - soil amendment
  - enhance soil productivity
- Porous structure and extremely high surface area
  - strongly adsorptive
- Recalcitrant soil carbon pool
  - net withdrawal of atmospheric carbon dioxide

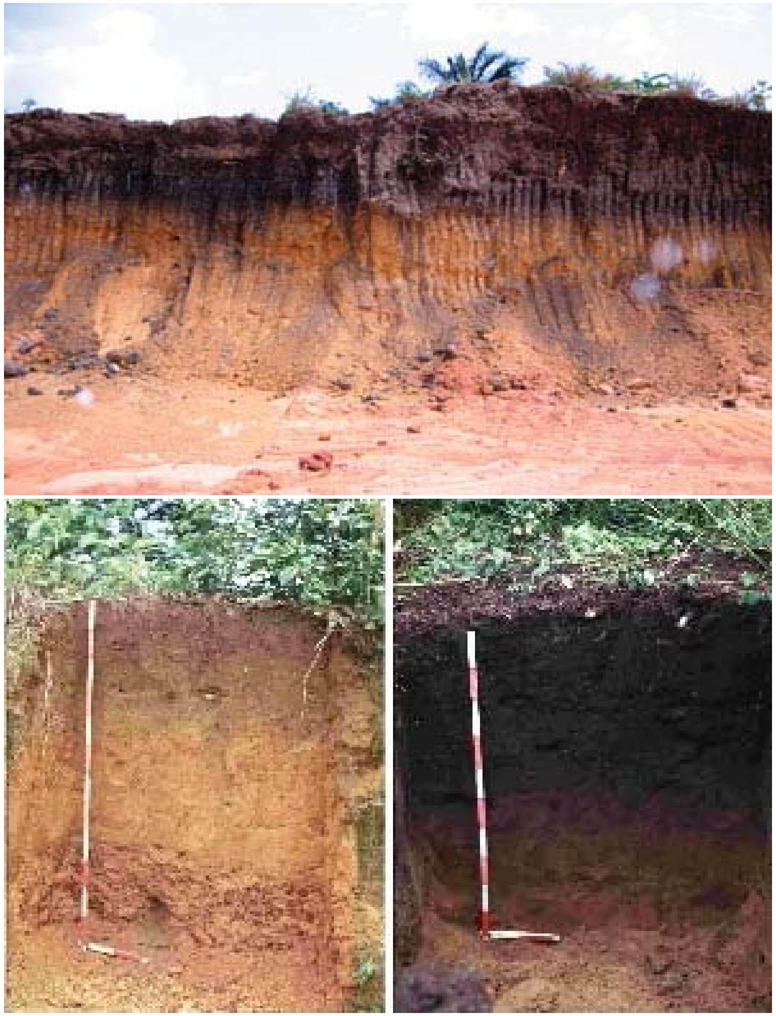


Terra Preta

- The idea that biochar may be beneficial for soil fertility comes from *terra preta*, or Amazonian Dark Earths.

- The biochar process is analogous to a process utilized thousands of years ago (between 450 BC and AD 950) in the Amazon Basin, where rich, fertile soils were created through a process similar to pyrolysis.

- The high fertility and carbon content of these soils have been retained for thousands of years in the absence of additional inputs.



Left: nutrient-poor Oxisol; Right: Oxisol transformed into Terra Preta

Biochar as a Soil Amendment

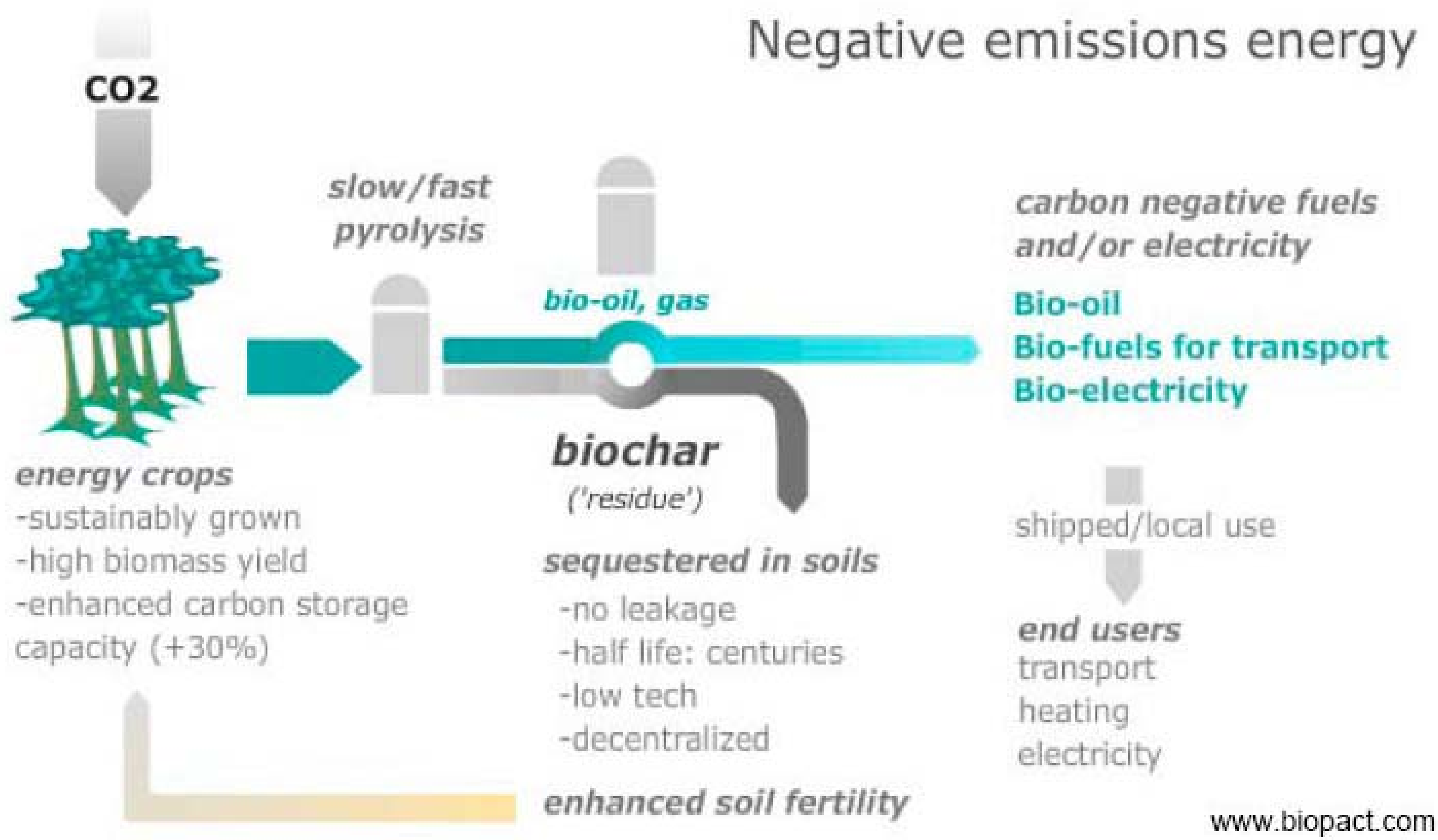
- Biochar is essentially inert
  - Resistant to decomposition
- Improves physical properties
  - Water retention
  - Reduce soil density
  - Increase porosity
- Enhances soil microbial functions
- Decrease soil GHG emissions of CO_2, N_2O and CH_4
- Increase cation exchange capacity (CEC)
- Increase nutrient retention
- It is of neutral or alkaline pH reducing the acidity of the soil

Fighting Climate Change

- Biochar soils are stable carbon sinks that can be built up over time and remove CO2 from the atmosphere.
  - Soils accumulate sequestered C while improving soil functions

- Biochar produced using efficient pyrolysis methods offers clean, renewable energy.
  - Eliminates the emissions from slash burning
  - Replace fossil fuel with bio oil reducing emissions
  - Closed loop pyrolysis--biochar is being returned to the soil where the biomass was obtained

Carbon Negative



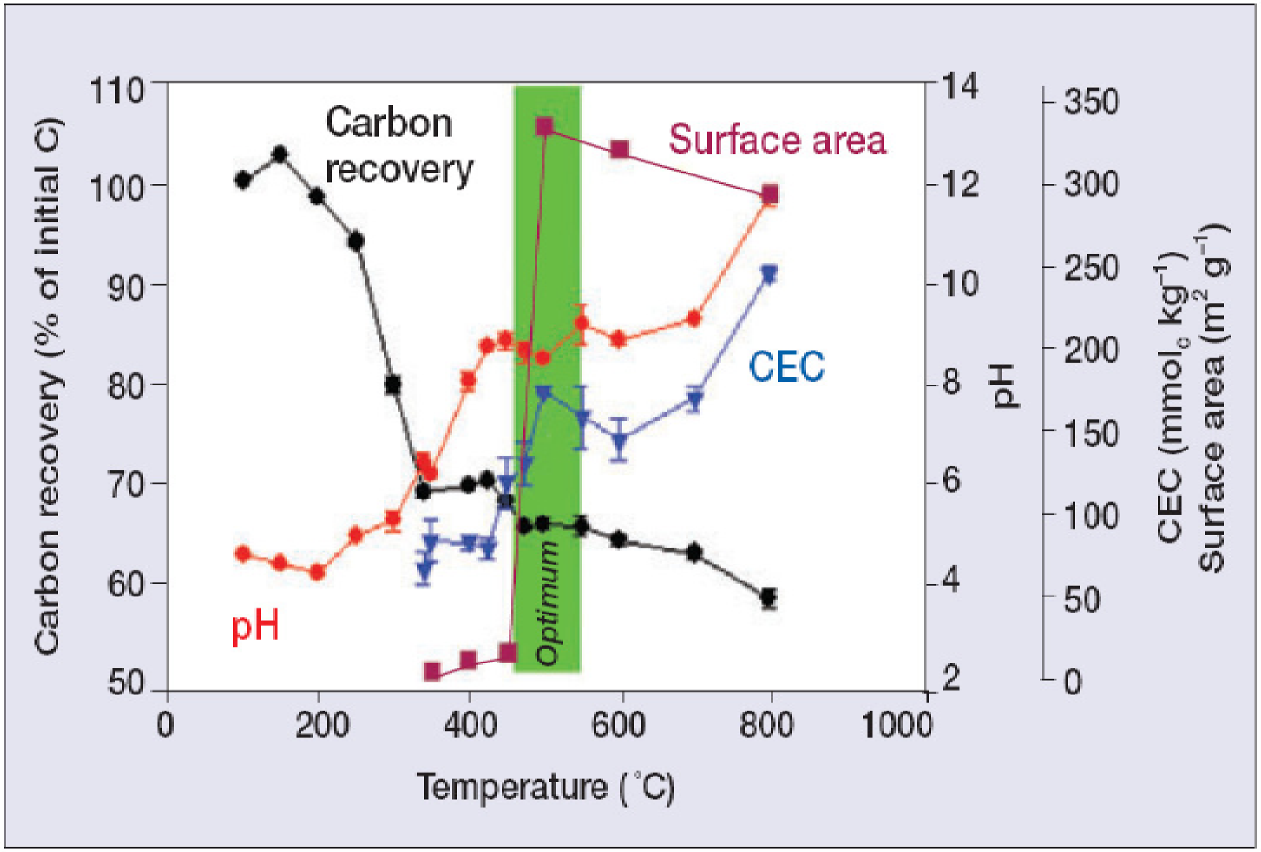
Carbon Surplus

- Natural sinks remove ~4.8 billion tonnes/yr (54%) of anthropogenically produced C
- Remaining C surplus is 4 billion tonnes
- Biochar's potential: remove anywhere from 1-9.5 billion tonnes of C
  - Long-term, stable carbon sequestration

Biochar As We Know It…

- Properties depend on type of biomass and pyrolysis temperature.
  - C recovery, pH, CEC and surface area
- Not entirely inert and not homogenous
  - It will eventually decompose and release CO_2 into the atmosphere
- How rapidly biochar may oxidize in different environments is still largely unknown.
- However, its observed recalcitrance and residence times under many conditions makes biochar one of the only tools available in the near future that can actually remove carbon from the atmosphere in a relatively permanent form.

Variable Characteristics



C recovery, pH, CEC and surface area depend on production

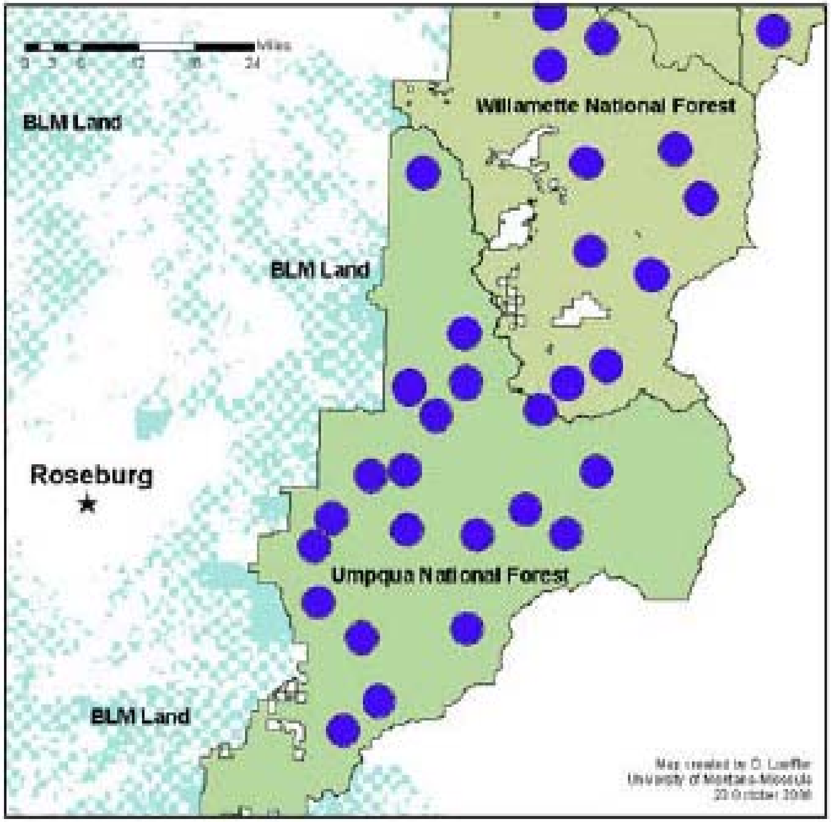
Source: *Lehmann (2007),*

New Research

Biomass to Bio-energy

- Evaluate economics of biomass removal and bio-oil production
- Evaluate adding bio-char as a soil amendment and it's influence on soil properties and tree growth
- Cooperative study with the University of Idaho IFTNC, RMRS, University of MT, Umpqua NF and Renewable Oil International, LLC
- Demonstration planned for August, 2009.

Umpqua National Forest

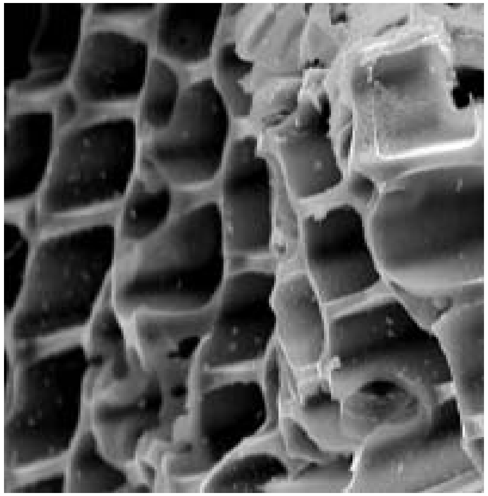


Field Study

- Demonstrate impacts of biochar application
  - Enhanced soil properties
  - Retention of site nutrients
  - Increased forest productivity
- Short and long-term study
  - Measurements will be taken after first growing season
  - Future monitoring
  - Evaluate sustainability

Further Research

- Applicability to different soil types
- Properties of fresh vs. aged biochar
- Does biochar increase microbial activity?
  - Relationship between mycorrhizal fungi and charcoal may be important in realizing the potential of charcoal to improve fertility
- Application rates and effects
  - Does soil fertility increase with application?
  - How long before benefits become apparent?
- Nutrient retention and plant growth



Potential Benefits

- Reduce reliance on fossil fuels
- Promote rural development
- Finance forest management treatments
- Reduce wildfire risk
- Eliminate in-woods burning of biomass
- Sequester carbon
- Conserve or improve site nutrients
- Enhance forest productivity

Summary

- Aim -- manufacture liquid transport fuels from forest biomass residues using portable, fast pyrolysis techniques, to which biochar is merely a byproduct with questionable usefulness—all while reducing catastrophic wildfire risk.

- Pryolysis co-production of bio-oil and biochar will mitigate net GHG emissions (CO_2, NO_2, CH_4) while attaining other economic and environmental benefits

QUESTIONS/COMMENTS?