Understanding Biochar

Living Web Farms Biochar Crew

Who we are:

Living Web Farms: Mills River based sustainability-minded working farm, permaculture research facility and center for educational outreach on all things permaculture.

Pat Battle - Market gardening expert and director of Living Web Farms.

Dan Hettinger - Biochar facility manager, 4 years.

Johnny Remein - 2+ years with Biochar production. Appstate grad.

Evan Morrow - 1 year with Biochar. Appstate grad.

Biochar at Living Web Farms

- Pat Battle nurtures long time interest in Biochar and its role in building soil health and sustainability
- Jon Nilsson (Chargrow, LLC) is hired to research Biochar production opportunities
- Bob Wells (New England Biochar, Chargrow) is contracted to build farm scale system on Living Web Farms Grandview property.
- Bob and Jon form Chargrow LLC, Dan is brought in to manage facility
- Chargrow continues to operate marketing and distributing biochar products.
- Dan and crew continue to produce and educate about biochar for Living Web Farms

Applying Biochar at Living Web Farms

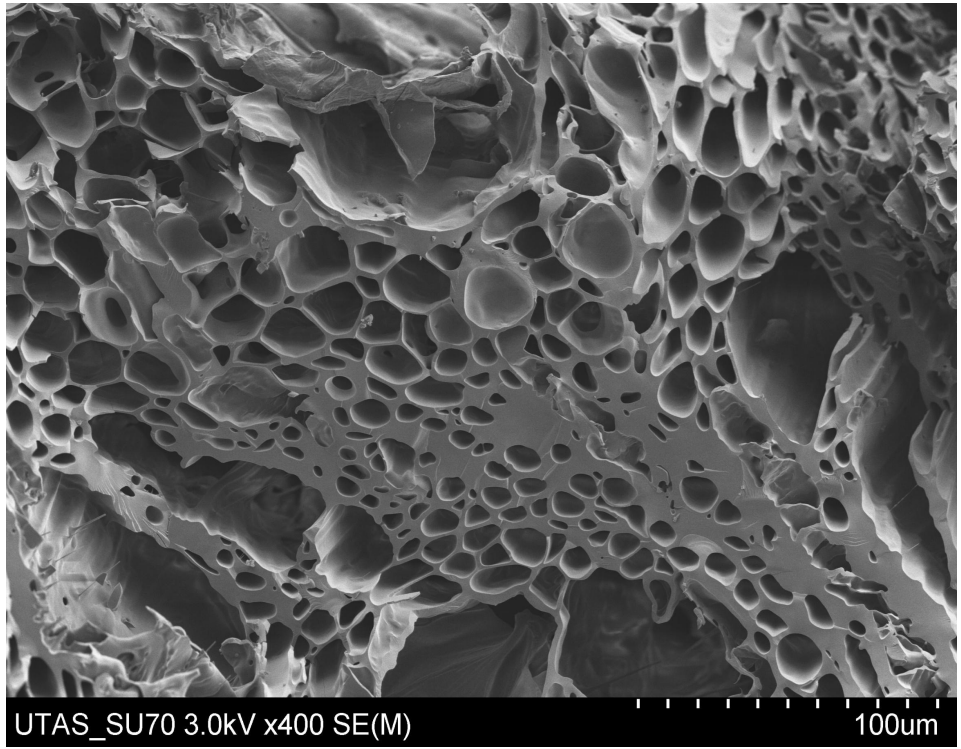
- May be applied in transplant mix prior to field/greenhouse planting
- Amended fields - mixed with compost prior to uniform topsoil application, followed immediately by cover crop
- Mixed in hole for new perennials
- As part of water reclaim project at grandview
- Rooftop growing on BSFL shipping container project
- Will likely have a role in humanure composting system
- May have a role in pasture regeneration work, pending development of application methods
- May have a role as media for experimental aquaponics system
- Demonstrated torrefied sections (<700F) for use as fuel (via gasification) in internal combustion engines; forge fuel (complete combustion)

What we'll (try to) cover today

- A textbook understanding of biochar and its role in the soil
- Fundamentals of quality biochar production
- Overview of TLUD design and operation as an alternate means of DIY production, review of tin-man methods, followed by Q+A session.
- A tour of our facility, with attention to how we make use of heat, syngas and condensate products
- Pyrolyse, Inoculate and apply a batch of TLUD biochar
- Discussion on inoculation techniques and application methods
- Much of what we'll cover today comes from The Biochar Revolution, specifically chapters 6,7,8,9, 14 and 15. Credit is due to the authors and to contributors to the *International Biochar Initiative*.

What is Biochar?

- Carbonized Biomass (charcoal) specifically made for *use in the soil*
- Sequestered Carbon
- Valued for its high porosity and resistance to degradation
- Biomass that has undergone a thermochemical process called Pyrolysis



Many uses in the soil:

- Improved fertilizer efficiency
- Promotes diversity in soil food web as safe harbor for microbes, mycorrhizal fungi
- Very long life in soil – hundreds to thousands of years.
- Improves soil texture and water handling
- Improved nutrient intake/cycling (Cation Exchange Capacity)
- Inside (and Outside) of the soil as a filter medium
- Particularly helpful in establishing fertility in depleted soils - food security!
- ‘Black Carbon’ source in composting

Constituents of Biochar

- Mobile Vs. Resident - Not all parts of biochar will last hundreds of years.
- Organic Vs. Inorganic - Concentration of ash, inert solids.

Mobile Organic: Available carbon as microbial foods.

Mobile Inorganic: Ash. Including nutrients, salts, etc. Liming agent. (raise pH)

Immobile Organic: **Recalcitrant carbon**. Where the magic happens.

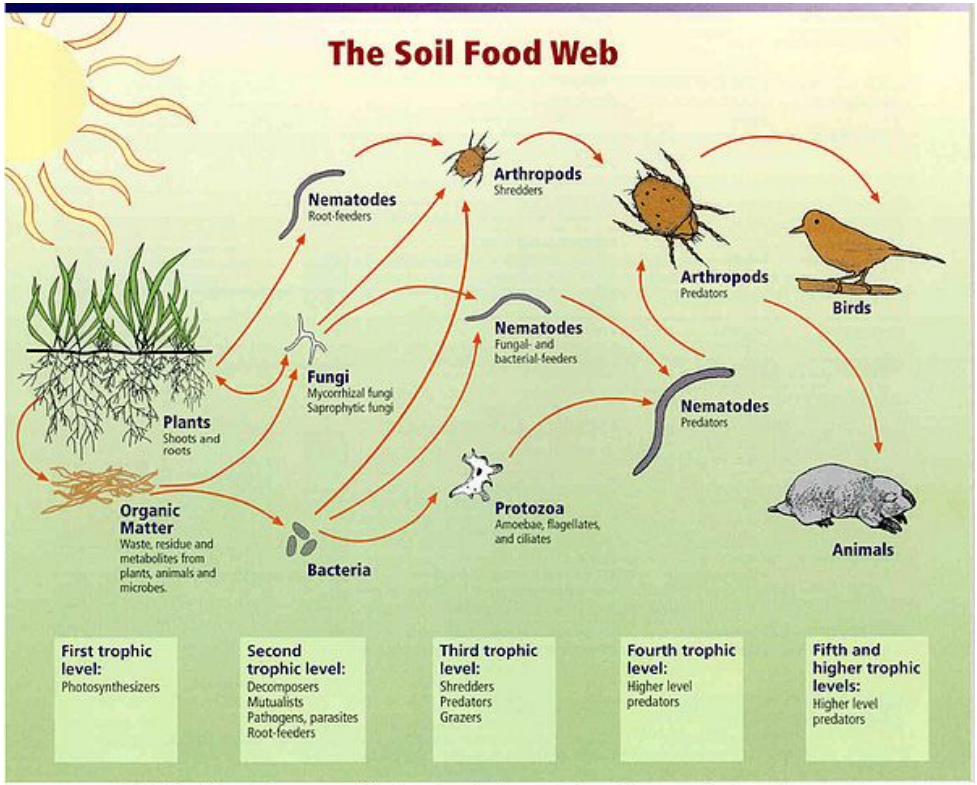
Immobile Inorganic: Stable insoluble minerals. Very small portion of total.

Adsorption Capacity and Fertilizer Efficiency

- Function of the adhesion of molecules to a surface
- Biochar has large amount of surface area through micropores, that are retained in the carbonization process.
  - Jon Nilsson says 2 Tennis Courts in 1 Gram!
- Nutrients can stick to these tiny surfaces
- Microbes mine these nutrients and make more available to plants
- This is all happening in the broader world of the Soil Food Web

Soil Food Web

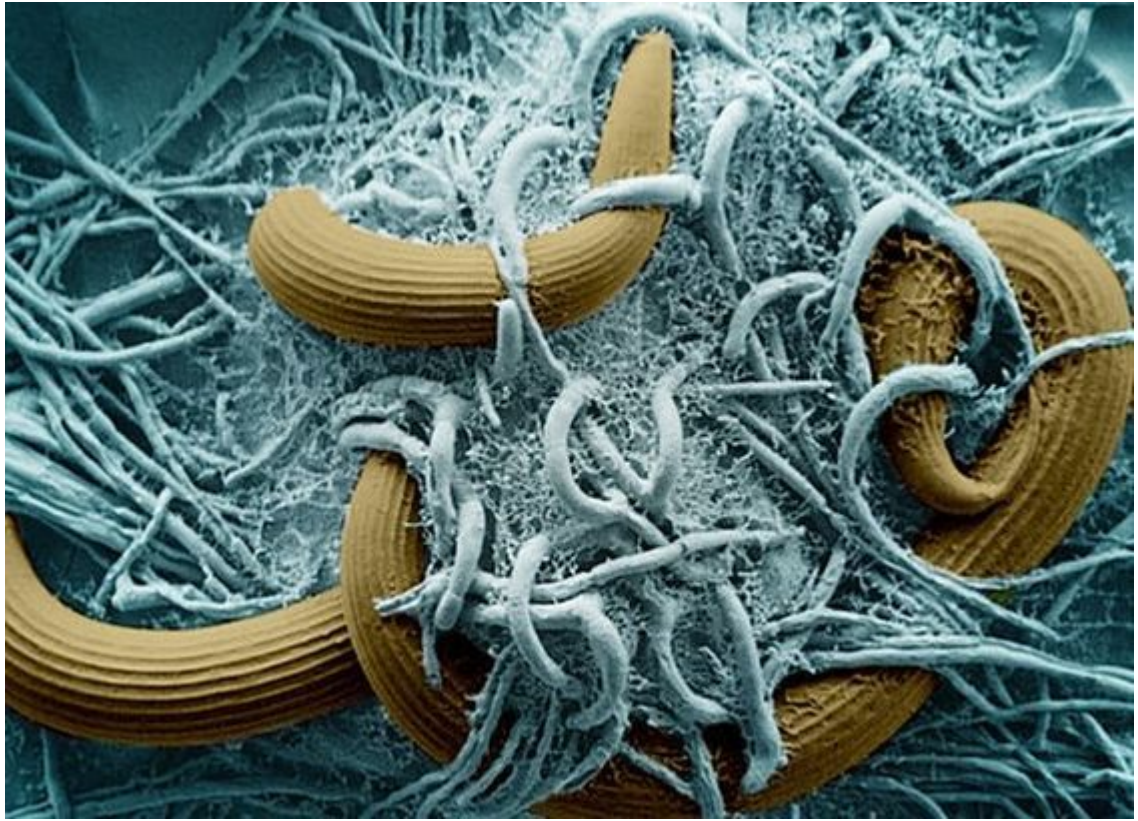
- Emphasizes complex relationships of give and take among organisms in soil.
- Diversity among organisms creates resilience, improves soil structure and nutrient exchange.
- Biochar aids diversity by moderating stressful conditions and creating an ideal habitat for microbes



Relationships between soil food web, plants, organic matter, and birds and mammals
Image courtesy of USDA Natural Resources Conservation Service
http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_food_web.html.

Soil Food Web...Microbes

- Plants secrete specific sugars (exudates) through their roots and feed the microbes in the area immediately surrounding the root (rhizosphere)
- Microbes feed off the exudates, and in return provide nutrients to the plant.
- Exudates can change over the course of the growing season to suit a plant's particular needs
- Microbes can store nutrients in their bodies, or expel nutrients as waste. Think of them as "tiny fertilizer bags" in the soil.
- Maintaining a healthy population of 'good' microbes helps to outcompete the 'bad' microbes



Source: www.carbongold.com via pinterest

Soil Food Web...Carbon

- Rearrangement of biomass molecule structure during production renders portions of biochar effectively non-biodegradable. **(Recalcitrant Carbon)**
- Biochar serves as Catalyst in soil food web - *largely, because it's not consumed in the process*
- Microbes and fungal hyphae move into the spaces in biochar where living conditions are moderated
- An organic carbon food source: compost, leaf matter, etc, is still required to feed this process.

Mycorrhizal relationships

- Mycorrhizae (“fungus-root”) filament-like strands (mycelia) act as root extensions and through use of specific acids/enzymes can mine the soil for minerals that plants need.
- Plants return the favor (and communicate?) through sugar secretions (exudates) from their root hairs.
- Mycelia also break down dead plant matter and store their nutrients. (Even more buried carbon!)
- Biochar, again, provides optimum conditions, and promotes mycelia growth and through filtering growth-inhibiting compounds
- Mycelia can be destroyed with tillage, drought, inhibited by usage of synthetic fertilizers/herbicides
- Biochar amended soil with rich mycorrhizal network will ‘bounce back’ faster when stressed

source: mycorrhizae.com

Improved Physical Properties: structure, water, air

- Provides aeration and lessens compaction problems with clay soils
  - Must be worked into soil root zone
  - Little benefits in this regard when top-dressed
  - No-till: Can be applied in lower rates with banding equipment
- Provides increased water retention for sandy soils
  - Can be top-dressed and will eventually migrate to root zone.
  - Account for erosion control when top-dressing. Mulch over top, water in deep.
- Helps negotiate periods of drought by storing and slowly releasing moisture
- Supports microbes that further improve structure
  - **Glomalin** producing fungi

Much Improved Structure

- Starting with very hard clay soil on 10% slope.
- 200 square foot bed space, amended in the spring with 1 yard compost, 1 yard horse manure, and up to 3% biochar.
- Regular applications of foliar spray compost tea on fall crops that year.
- Added two more beds next spring, later applied more aged manure and brought biochar content in all 6 beds up to 5% or greater.

Improved Nutrient Cycling

- Stores and slowly releases plant available nutrients when needed
- Reduces nutrient losses from leaching
- Measured by Cation Exchange Capacity: basically, the soil's ability to store and exchange nutrients: calcium, magnesium, potassium, etc.
- Helps retain nutrients from decomposing crop residues
- CEC has been shown to improve over time with applied biochar

Biochar as a filter

- Measured as adsorption capacity: the ability of things to stick to the surface of char. A function of available surface area
- Biochar is not activated carbon... although research shows it can be used as a lower cost substitute in some applications:
  - A component of drinking water filtration
  - Stormwater filtration
  - Aquaponics media
  - Heavy metals recovery
  - Air filter, in chicken houses
- Effective way to use larger pieces - >½" screened char
- In some cases, filtered material becomes a microbial food

Biochar in composting

- Speeds up composting
  - Acts as a bulking agent, provides aeration and moisture control
  - Stimulates microbial activity
- Acts as a ‘black’ carbon source, with your ‘browns’ and ‘greens’
  - Estimated 10-30% of char is organic carbon, or mobile
  - James Joyce - Australian producer, has chart with likely C:N ratios of common biochars
- Found to reduce losses of nitrogen as ammonia (one study shows up to 50%) and reduce emissions of greenhouse gases from composting
- Improves texture, uniformity

Terra Preta

- Purposefully made charcoal rich soil amendment
- Ancient civilizations in Amazon Rain Forest: 450BC-950AD
- Loaded with animal feces, bone fragments, pottery shards, Low temperature chars
- Self-regenerating! 1 cm/year

Biochar Carbon Cycle

- Using wood that would otherwise rot
  - Goes without saying: No living woods
  - In our part of the country, specifically wood that is moved away from where it would benefit soils to decompose in place. Sawmills, furniture mills, excess landscape waste
- Decomposing trees - Little carbon stays in ground as soil building ‘food’. Slow decomposition over many years.
- Combustion - No carbon in ground, all in atmosphere, all at once.
- Pyrolysis - ‘Interrupts’ decomposition, converts some carbon to recalcitrant carbon, some immediately out as atmospheric carbon.

References and Resources

- Book for in-depth coverage from a lot of angles: http://www.thebiocharrevolution.com/
- Biochar Workshop with Bob Wells and Jon Nillson
- Biochar Workshop: the carbon cycle https://www.youtube.com/watch?v=E0Lj_SsYpto
- The basics of biochar: https://www.ctahr.hawaii.edu/oc/freepubs/pdf/**SCM**-**30**.pdf
- Biochar application to soils: http://www.compost.org/CCC_Science_Web_Site/pdf/Biochar/Biochar%20Application%20to%20Soils.pdf