Greetings

I'm Dick Stein, Professor of Chemistry at UMass, Amherst who has retired for about 20 years and is involved with environmental problems. I am not an agricultural expert but wish to exert some "oversight" into environmental considerations to assure they follow good science. I am a member of and one of the founders of the Pioneer Valley Biochar Initiative (PVBI) in Belchertown, MA.

What is the PVBI?

We are a group of about a dozen, mostly volunteers, that meets at the site on the New England Small Farm Institute (NEFSI) in Belchertown, MA. We have a variety of backgrounds in science, engineering, farming, and forestry and recognize the need for dealing with energy and global warming problems. We believe that biochar can serve as a renewable resource that can help meet these goals and are working on a non-profit basis toward this objective.

Biochar, Mother Nature's Nanotechnology

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What is biochar?

- **Biochar is a form of carbon, somewhat like charcoal, which can be made by heating biomass (like wood) with limited air.**
- Biochar differs from ordinary charcoal and coke in that it is very porous, having a low density and a very high surface area per unit weight.

Heating with limited or absence of air is called **PYROLYSIS** which differs from **COMBUSTION** or **BURNING** which involves a chemical reaction with the oxygen of the air to form carbon dioxide CO_2.

The **PYROLYSIS** of biomass results in the emission of a vapor consisting of water, low molecular weight organic compounds, carbon monoxide and some hydrogen. These could be burned as fuel or part could be condensed to give a liquid called **BIO-OIL** leaving behind solid residue called **BIOCHAR**. It is desirable to prevent the biochar from burning down to ash.

PYROLYSIS of the biomass is started by heating it to start **BURNING** which provides heat to cause decomposition of the remaining biomass. This results in the evolution of burnable vapors which can provide more than enough heat to continue the **PYROLYSIS**. Hence, there is an excess of net energy.

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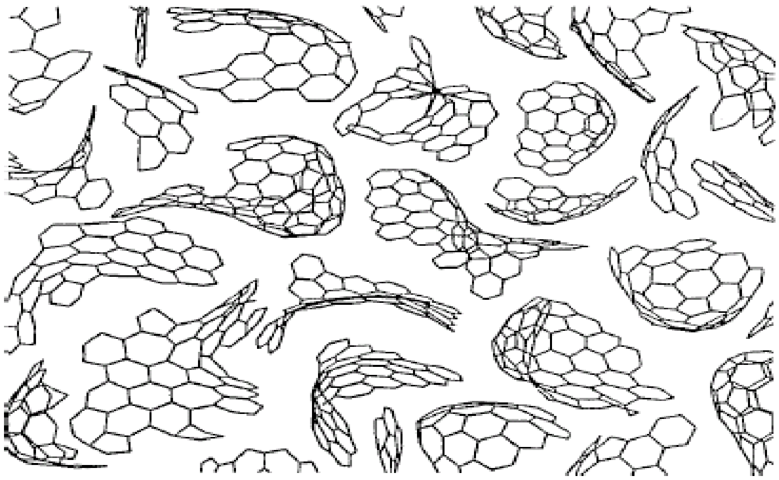
Amorphous Graphite = Domains of Graphene



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Consolidation into local Graphene domains during carbonization

The porosity, low density, and high surface area offers a template upon which fungi and bacteria may grow, leading to enhanced agricultural value. Some organic material resides on the surface, providing nutrients and increasing this biological activity.

Principal Constituents of Biochar:

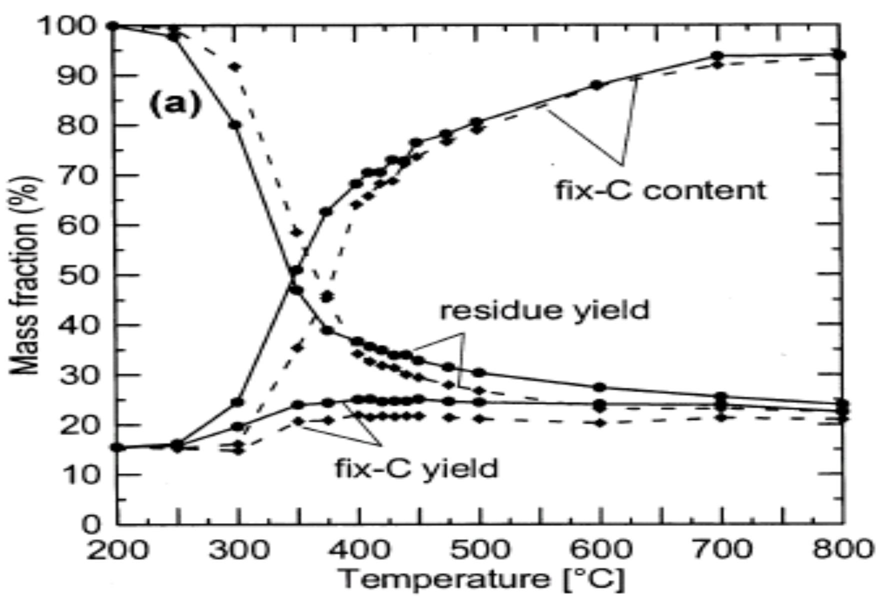
- **Moisture (as delivered)**
  - Moisture is not a bad thing, but it is not worth paying for ……
  - Moisture is added after char production, usually to cool or passivate the char
  - Moisture in the bag does not mean the char will have superior moisture retention in soil – it means moisture was added …

Principal Constituents of Biochar:

- Moisture (as delivered)
- Ash (as delivered and from what)
- **Mobile Matter versus Resident Matter**
  - Mobile - can migrate out of the char
  - Resident - stays with the char & soil
  - Matter = Carbon and H&O portions
  - Carbon is measured for CO_2 sequestration, but plants care about soluble organics and plant nutrients available in the soil

Principal Constituents of Biochar:

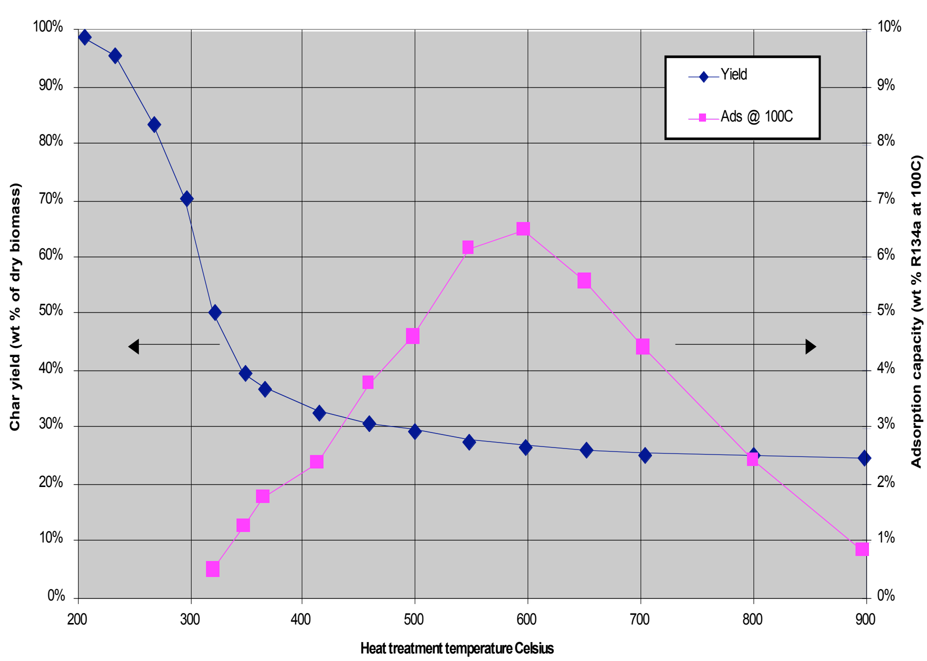
- Moisture (as delivered)
- Ash Content (as delivered and from what)
- Mobile Matter versus Resident Matter
- **Cation Exchange Capacity ion exchange resin behavior**
- **Adsorption Capacity activated carbon behavior**



Excerpt from: The Art, Science, and Technology of Charcoal Production, Antal, et.al., Ind. Eng. Chem. Res., Vol. 42, No. 8, 2003 (page 1621).

What causes the variations in Mobile and Resident Matter?

What it was made from and the way it was made.



Biochar and Bio-oil

We are cooperating with a group in the Chemical Engineering Department of the University of Massachusetts led by Prof. George Huber that is supported in a project to produce bio-oil as a potential source of mobile fuel. We are considering possibilities of an effort that may produce both bio-oil and biochar, having satisfactory properties and that may be economical.

Advantages of Biochar

- **Its application to the soil helps promote agricultural growth.**
- Its use reduces synthetic fertilizer needs. reducing fertilizer run-off.
- It retains water, decreasing irrigational needs.
- Its use reduces the CO_2 content of the atmosphere.
- Equipment needed for its production can be simple and inexpensive.

How does Biochar work in the Soil?

- **Biochar works in conjunction with the existing soil, crop and climate**
  - Improves soil aeration – if soil is too tight
  - Improves flooded water capacity & retention
  - Stabilizes soil humidity during drought
  - Retains fertilizers and nutrients
  - Adsorbs and desorbs soluble soil carbon, which stimulates biological activity in the soil and microbe-plant synergisms

When initially used, **BIOCHAR** absorbs nutrients from the soil and actually retards growth, but this does not occur with subsequent use. This initial period can be avoided by treating the biochar with a nutrient solution prior to use.

It is found that in some soils, growth of some biomass is increased by 200% or more. Its effect is greater in poorer than in good soils. Hence, its use can enhance biomass growth and CO_2 capture.

Soil degradation is a concern, resulting from heavy use of synthetic fertilizers, herbicides, and sterilants in industrial-scale agriculture. **BIOCHAR** has been shown to help restore such soils.

BIOCHAR may make agricultural use possible for soils previously too poor to use. Thus, it may increase the land area available for biomass growth leading to an increase in growth of food, and trees, and offering more CO_2 capture through photosynthesis.

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Extensive synthetic fertilizer use can be detrimental to soils and waterways. **BIOCHAR** use reduces its need to as much as 50%. Fertilizer requires energy for manufacture. Its cost can be a burden to poorer countries. Excessive fertilizer can get washed out during rainstorms leading to waterway pollution.

Excess synthetic fertilizer can be washed out, leading to pollution of waterways. This leads to growth of algae, bacteria, etc. and can give rise to “dead zones” in lakes and oceans. **BIOCHAR** can immobilize the fertilizer and prevent this. It may also reduce emission of other greenhouses or noxious gases like such NOX’s.

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Agriculture is demanding in its need for fresh water. This is becoming increasingly scarce in parts of the U.S. and much of the world. The capillaries of **BIOCHAR** soak up water rapidly and slowly releases it to the growing plant reducing irrigation requirements. More gradual application of water decreases washout problems.

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BIOCHAR does not readily directly enter into chemical reactions and is relatively inert in soil. It lasts much longer than decaying biomass (a few years to decades) and may remain for centuries or more. Its residence time depends on the type and preparation conditions and it greater for chars having lower organic content, although such chars may have less agricultural effectiveness.

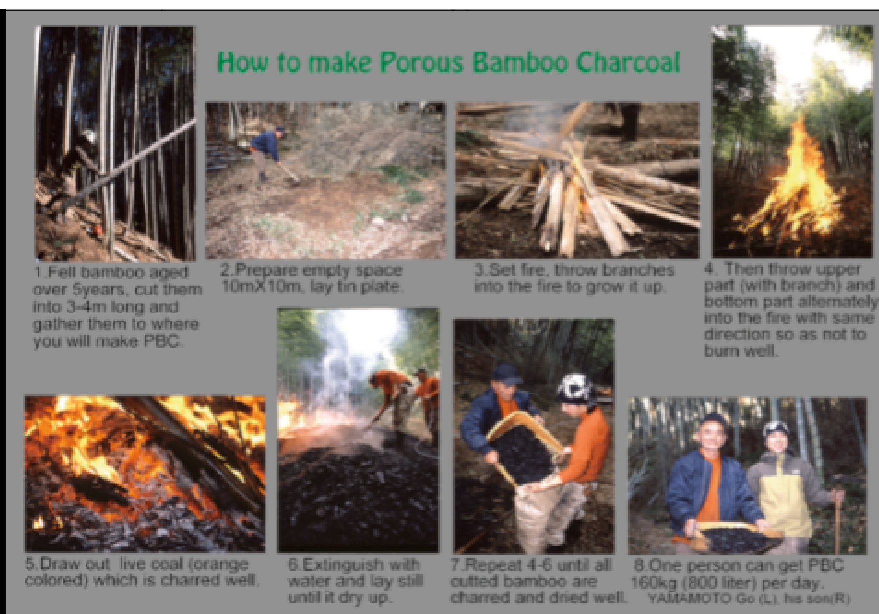
Coal Mining in Reverse!

In coal mining, one removes carbon from the ground which is then burned to produce CO_2 in the atmosphere. With **BIOCHAR**, CO_2 is removed from the atmosphere by photosynthesis during the growth of biomass. This is converted to biochar which is returned to the ground. Thus, while not a "silver bullet" for solving all environmental problems, there are many advantages for its use.

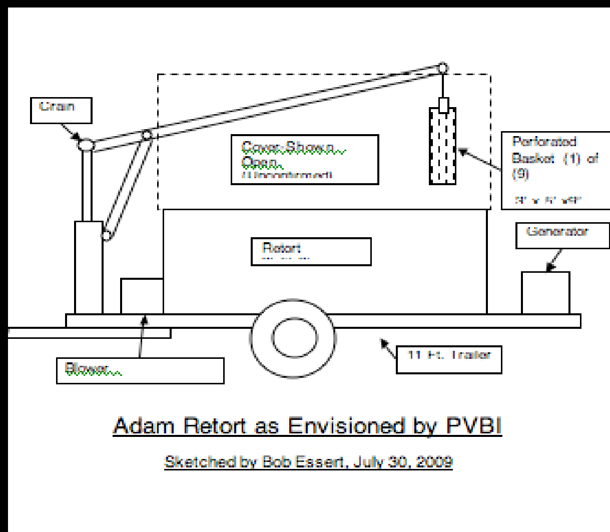
Advantages of Biochar

- Its application to the soil helps agricultural growth.
- Its use reduces synthetic fertilizer needs and reduces fertilizer run-off.
- It retains water, decreasing irrigational needs.
- Its use reduces the CO_2 content of the atmosphere.
- **Equipment needed for its production can be simple and inexpensive.**

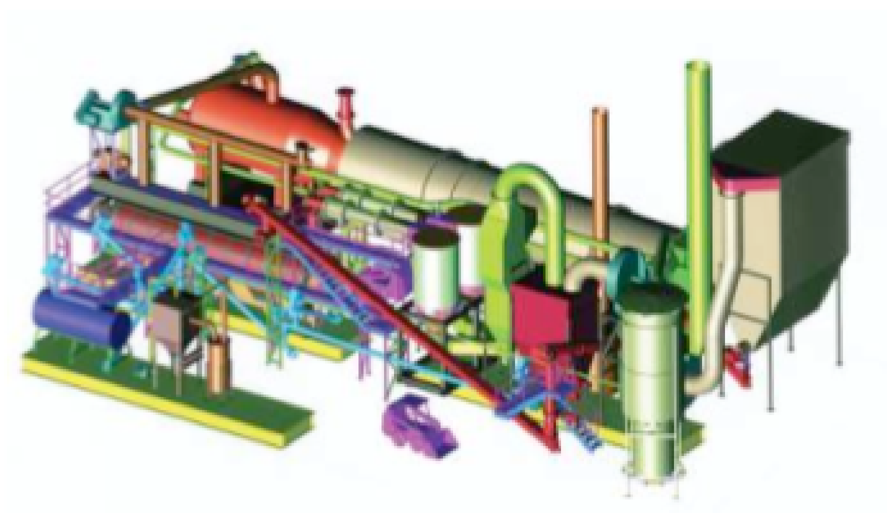
Many farmers cannot afford expensive equipment and may not have the skill or not the wish to devote the time for its operation. **BIOCHAR** production is quite "low tech" (having originated with primitive societies) and can be accomplished with relatively cheap and home-made equipment. However, if appropriate, this may be "scaled-up".



This is often called "campfire charcoal"



This, and an upgraded version, is currently being tested at PVBI



Process data collected from the pilot unit has been used for the detailed design and modelling of modular commercial units.

BIOCHAR is primarily a soil amendment.

The fuel value of **BIOCHAR** is only about half as much as might be obtained from totally burning the biomass. Its use is justified because of its agricultural value, reduction in fertilizer use and run-off, and because of its CO_2 sequestration. Its value as a heat source is peripheral, although its preparation as a byproduct of cooking may have value in “third world” countries.

BIOCHAR use is beneficial for net energy

BIOCHAR may be made from biomass with little expenditure of energy. However, even if one burns the vapors evolved in its preparation to provide heat to continue the pyrolysis, there is some excess heat available that may be used. This may be used for heating farm buildings, drying, etc.

The desired scale of operation

The gathering of biomass for biochar preparation should be done at a scale that will not be a burden on the environment. This is not a problem if one uses farm and forestry waste. A portion of this waste should be left to add to the organic content of the soil. If such waste is not used to produce biochar, it will decay in the soil in a few years, releasing CO_2 to the atmosphere.

The desired scale of operation

If one harvests growing material, it should be done **SUSTAINABLY**. That is, it should not be harvested at a rate that exceeds its replacement in the CO_2 absorption by new growth. This assures a steady state of growing biomass. Harvesting should be done using acceptable forest and agricultural management procedures to assure forest heath and less infestation

Improving the Forest

Proper forest management can be thought of as "**weeding a garden**". One may remove poor growth to allow more desirable stands to flourish. Decreasing brush can reduce forest fire hazards and lower forest debris decay which may give rise to release of CO_2, other "**greenhouse gases**" such as methane (about 22X as potent as CO_2) and some which are noxious such as the NOX's.

A Modest Start

Thus, we favor a modest start, trying it out at the level of individual farms or groups of them. There is much to learn, and it may be a mistake to "scale up" before acquiring sufficient understanding. At this level, it is probably not practical to recover the bio-oil (although it is attempted by some), but rather to use it as a fuel to continue the pyrolysis. Doing so in the future may be a possibility.

Some Needs:

It is apparent that the task of matching ways to prepare and use biochar may be too complex for the occasional user.

- The formation of cooperatives among groups of farmers is desirable. These should be located close to the source of biomass.
- Analyzing biomass sources to match them with preparation and use procedures is needed. This may be best done regionally.
- Networking to share information should be encouraged. International cooperation should be facilitated.

CHAB Camp 2010:

Hands-on Development of "Combined Heat And Biochar" Devices

A weeklong workshop will be held in western Massachusetts on 8-13 August 2010 to study and develop CHAB (Combined Heat And Biochar) devices. The fundamentals of biomass pyrolysis, biochar characterization, carbonization conditions (that promote higher performing biochars) and heat capture and transfer will be examined in technical and practical terms. The daily schedule has flexibility, with mainly a series of morning study groups and afternoons and evenings devoted to the design, fabrication and testing of prototype CHAB devices. The only criteria for the CHAB devices are that they must A) generate a useable form of heat, B) provide for the recovery of biochar, and C) produce acceptably low emissions for untreated discharge at the intended application or via flues to the outside environment.

This has now been held with success.
Repeated sessions are planned.