Introduction to Biochar in Agriculture

by Jack Kittredge

Most readers of this journal have heard of biochar. It is hard not to, if you are an informed citizen concerned about contemporary issues. Biochar use has been heralded as a breakthrough development in soil health, crop production, carbon sequestration, environmental cleanup and pollution control, among other positive social purposes. Sales of the product have been tripling every year since 2008 and powerful players on the world stage, including China, have been studying its potential for solving varied growing problems.

We thought it might be time to take a closer look at biochar, especially its applicability to agricultural soils and enabling them to provide more and healthier food.

History of Char

Charring is produced by pyrolysis, which is heating biological material – agricultural residues, wood chips, virtually any organic matter – in a low-oxygen environment. The lack of adequate oxygen prevents normal burning, but enables volatile or semi-volatile materials to off-gas. Depending on the material and the temperature, other materials may be driven off and chemical changes will occur, potentially leaving just a porous carbon structure.

Black carbon is the generic term given to all solid chemical-thermal conversion products of carbonaceous materials, including charred residues. Biochar has been recently added as one material in the black carbon spectrum.

Char has an ancient history. The use of charcoal in cave paintings has been dated to 30,000 BC. Its use as a fuel began over 7000 years ago in the smelting of copper and more recently in smelting iron and producing glass. The Egyptians were pyrolyzing biomass 5000 years ago to form pyroligneous acid (composed of wood vinegar, tars and smoke condensates) for embalming.

Wood pyrolysis has been used for extracting valuable gases and oils for commercial purposes for hundreds of years. At its peak a standard distillation apparatus or retort could process 10 cords of wood within a 24 hour period. For these “industrial” purposes the gases and oils were the product, and char a secondary byproduct. In the 1800s, however, coal burning began replacing charcoal as an energy source and by the 1920s petroleum refining replaced biomass pyrolysis as the leading source of chemicals, distillates and volatiles.

One of the earliest examples of the agricultural uses of char is terra preta, the rich, fertile dark soils of the Amazon Basin which the indigenous people created by adding the remains of fire pits and middens full of bones and trash to the normally light tropical soils. Other similar char uses in agriculture date back to the early 1600s in Japan and potentially earlier in China. These, along with the natural deposition of char from forest fires, prairie fires, volcanoes, etc. have resulted in the widespread presence of it in soil organic matter.

Historically, char has been a waste product because the primary purpose of making it had been on optimizing the liquid and gas products of biomass for energy conversion and other uses, not on biochar for carbon sequestration. Thus despite the long research history of pyrolysis, more study is needed to optimize yields of biochar itself, and standardize its properties.

Biochar in agriculture

A number of studies have taken place concerning the effectiveness of biochar in promoting yields. According to those studies the positive impacts of biochar seem to outweigh the negative ones. A 2011 meta-analysis found an overall average yield increase of 10%, rising to 14% in acidic soils, from use of biochar. Approximately 50% of the compiled studies observed short-term positive yield or growth impacts from use of the material, 30% reported no significant differences, and 20% noted negative yield or growth impacts.

Results of some studies have found that biochar’s greatest potential might be in places where soils are weathered or degraded and fertilizer scarce, in part because it helps the soil to better retain any nutrients that it does have. One study of such degraded soils in western Kenya suggests that farms using biochar averaged 32% higher yields than controls.

According to a 2014 World Bank report biochar probably holds the most potential for small farmers.
Biochar in Agriculture?

by Jack Kittredge

Blessed by its historical antecedents in Amazonian terra preta, char is seen by proponents as a traditional appropriate technology for soil building that just happens to also confer singular benefits towards stabilizing weather extremes because it removes carbon from the atmosphere and buries it underground. Critics, however, see it, at worst, a silly fad; at best, a naïve evasion of life cycle thinking. The enthusiastic climate claims made for biochar they see as akin to belief in a free lunch. More and more opportunities are presenting themselves for use of biochar in organic growing.

Farmers in developing countries, not just because they are working with infertile soils most likely to benefit, but because biochar may be a key element of ‘climate-smart’ agriculture — practices that both help to mitigate climate change and reduce vulnerability to its effects. Biochar additions to infertile soils have also been found to improve soil cation exchange capacity (CEC), the ability of soils to hold onto crucial nutrients. Applying biochar has been demonstrated to improve availability of potassium, for instance. But studies have found that not all biochar–soil combinations cause an increase in CEC. Experts suggest ways to “charge” biochar with fertility before applying it so it doesn’t absorb nutrients and water already in the soil, slowing plant growth. Many farmers soak it for a day or two in compost tea, fish emulsion, aged manure or other nutrients before application. They also recommend inoculating it with microbes before use.

The mechanisms by which biochar reduces vulnerability to climate change effects are somewhat speculative so far. Some researchers suggest the most important feature of the substance is its porosity and the presence of many connected spaces. Clays tend to be composed of flat grains and sand tends to be of circular grains. Even though clays can hold large amounts of water, that moisture has a hard time moving through the grains and reaching plant roots. But biochar is very amorphous so it creates many convoluted pathways that help to slow down drainage in sand and speed it up in clays. These same spaces provide protection for microbes from predation by larger creatures.

Other scientists are exploring how biochars can mitigate climate change by cutting emissions of nitrous oxide, a greenhouse gas. According to a Chinese study, after biochar had been applied to corn and wheat fields once, nitrous oxide emissions declined over the following five crop seasons, a period of three years. Recent studies have also indicated a complex biochar and fertilizer interaction with respect to yield response. Others have observed that some biochars raise pH, particularly useful in regions like the northeastern US.

Many analysts report, however, that biochar’s effect on agronomic crop yield is variable, with crop production improvements ranging from negative to more than twofold, compared to controls. Some suggest that this inconsistency is because feedstocks, production methods and temperatures have not been standardized. Grass and nonwoody biomass biochar is more easily mineralized than wood-derived biochar, for instance, resulting in longer predicted soil-residency times for wood biochar. From a soil fertility perspective, this increased mineralization from non-woody feedstocks could provide nutrient resources to plants. On the other hand, food waste biochar and that with high volatile matter contents have also suppressed plant growth.

Others feel that the material itself changes as it ages. Soil nutrient improvements may take some time to be observed. Delays may occur if the particular element is enclosed in a chemical ring structure that only slowly decays. Most of the existing studies have been limited to less than 3 years, which may not be enough time for the soil nutrient cycle to be fully affected.

Lastly, it is not clear whether biochar use will be economical in agriculture. Recommended application rates vary from 0.1 pound to 1 pound per square foot, or 2 to 22 tons per acre. At $1000 to $3000 per ton, that is a lot of expense for many growers. In the Third World particularly, poor soils and poverty often go hand-in-hand. Studies in Africa have found that few local farmers are willing to buy biochar at the price necessary to create it.

Environmental and Industrial Uses

Biochar’s capacity to bind to heavy metals in soil can keep them from reaching plants or entering water supplies. This interests governmental and other groups concerned about reclaiming land that has been destroyed by mining. The product’s large and numerous pores also give it a large surface area which enables it to tie up contaminants in polluted water and could remove chemical wastes and provide low-cost water treatment where little funding is available.

Scientists are just beginning to explore biochar’s potential for treating fluids in industrial settings. Oil and gas drilling fluids, print toners and paint products all have been suggested as markets for its ability to clean and process materials that flow.

The Natural Farmer, Fall, 2015
Biochar Production

Plant responses to biochar soil additions are the net result of production conditions (feedstock types and pyrolysis methods) and postproduction storage or activation activities. These processes can confer unique properties on each batch of biochar, even from the same pyrolysis unit and biomass feedstock.

The raw feedstock biomass characteristics impart specific properties to the resulting biochar, such as ash content and elemental constituents like density and hardness. Currently char is being made from such diverse materials as chicken manure and nut hulls, wood scraps and plant residue. Such various sources of organic matter will provide quite different kinds of char.

Specific biochar nutrient concentrations may be greater or lesser than what was in the original feedstock nutrient concentration. Occasional volatilization and loss of nutrients during pyrolysis may be linked to higher production temperatures. The large range of operational maximum temperatures common to slow pyrolysis processes determines the extent of volatilization taking place and therefore the final composition of the resulting biochar.

There are also important differences in biochar quality not only as a function of the production process but also linked to postproduction storage or activation. Surface oxidation of black carbon in storage, even at ambient conditions, alters surface chemical groups, which correspondingly influences potential interactions with soil nutrient cycles.

Activation can occur by simply cooling the biochar with water or exposing hot biochar to atmospheric oxygen during cooling.

However you make your char, you should cool it afterward – either with water or air. This cooling process, sometimes called “priming”, significantly alters the chemical and physical properties of the char. Unfortunately, researchers are still unclear how to best prime different chars to maximize their benefits.

Whether you own a large farm or tend a kitchen garden, you can produce your own biochar. The key is to heat waste biomass in a low or zero oxygen environment at temperatures ranging 200 to 800˚C. Many small farms or homesteaders can only afford low-tech systems that generally produce less than a yard of char per burn.

The International Biochar Institute provides free open-source instructions for constructing many low-tech, small-scale biochar production systems. Materials range widely in cost. You could build a simple burner out of scavenged materials, spend $300 on a cone kiln, or pay upwards of $5,000 plus labor for an Adam Retort. Instructions and designs are available at [www.biochar-international.org](http://www.biochar-international.org) as well as [www.backyardbiochar.net](http://www.backyardbiochar.net).

Biochar in the Future

The possibility of engineering “designer biochars” for improving a specific soil deficiency is one direction in which biochar could develop. There have been efforts, for example, to impregnate biochar with various inorganic fertilizers to serve as diverse slow-release nutrient sources. Biochar could also be blended with specific composts, which could increase its value for both fertility and microbial inoculation.

Biochar is expensive as a carbon sequestration agent or as a soil supplement for crop yield improvements. The high production cost for biochar, however, could be offset if these specialty or boutique markets are more fully developed. Also, if biochar applications to other sectors besides agriculture are expanded, it could result in reduced costs of production.

Critics of biochar are quick to point out, and rightly, that the ultimate future of biochar depends on the sustainability of the feedstocks. In a completely ecological world there is no waste and every product or process must be evaluated for completing cycles efficiently. We need to carefully analyze use of biochar by this standard and see if there are more efficient uses for organic matter than charring and burying them.
The Real Black Gold: Experimenting with an Ancient Technology in New England

by Ian Back and Anita Dancs

Ancient Amazonians built populous civilizations in rain forests incapable of supporting more than small tribes of hunter-gatherers. How? They applied charcoal as a soil amendment and transformed nutrient poor dirt into rich, dark, fertile soil. Elsewhere in the world, plowing and irrigation drained the soil of nutrients and led to salinization making fertile land barren. We know about the Amazonian people’s farming technology not because they kept records, but because we can still see it in what scientists call Terra Preta, the dark earth created by ancient farmers.

Today biochar – a term coined by Peter Read in 2005 to refer to charcoal applied as a soil amendment – is growing in popularity in the U.S. and elsewhere. This ancient technology is being applied around the world to enhance soil fertility. Farmers in Japan call it “kuntil” or “barazumi,” while Chinese and South Korean farmers refer to it as “fire manure.” Farmers in Sri Lanka have been passing down the technique for generations. The reason we are hearing more about it is because it creates an environment in which fungi and bacteria can thrive, leading to increased yields in food production compared to other organic methods.

Ian Back, a recent graduate in Sustainable Food and Farming at the University of Massachusetts-Amherst, aims to demonstrate the advantages of biochar through an experimental forest he planted this year.

Why Biochar?

Back first became hooked on biochar during his junior year when he learned that it could sequester carbon and mitigate climate change. Cooking biomass in a high heat, low oxygen environment, a process called pyrolysis, carbonizes the biomass applying the heat of the process – the biochar – in topsoil removes the carbon from the atmosphere and locks it into the earth. Johannes Lehmann, a professor in crop and soil sciences at Cornell University, estimates that any one of three approaches to pyrolysis – using forest residues, fast-growing vegetation, or crop residues – could sequester 10% of U.S. fossil fuel emissions.

Because biochar is produced by burning biomass, carbon sequestration may seem counter-intuitive. Indeed, traditional methods of producing charcoal create greenhouse gas emissions and noxious smoke hazardous to those operating the kilns. Modern retorts, however, not only radically reduce smoke and emissions, but create larger amounts of biochar out of biomass feedstock. And they can have other benefits.

For example Chris Adam designed the “Adam Retort” for farmers in developing countries as an experiment from Pioneer Valley biochar producer, Other systems exist which produce energy or heat and can be made relatively inexpensively out of local materials. Vee-Go, a Massachusetts company, uses a catalytic vacuum process to convert agricultural materials. Back’s co-conspirators at Pioneer Valley Biochar, John Gerber, Professor of Sustainable Food and Farming, and Stephen Herbert, Professor of Agronomy, he accessed an additional $5,000 for the project. In part because he was graduating in May of 2015 and in part because he wanted the project to become a lasting student enterprise he and his co-conspirators started a student organization which they named Spiritual Ecology and Regenerative Systems Initiative (SERSI). Officially recognized by the UMass Student Government Association, they ensured that the Fruit Forest would be a learning enterprise for future students.

With the paperwork done and money obtained to finance materials, the physical work began. Back and his team were given a three-quarter acre plot in the UMass Agricultural Learning Center just behind the Pollinator Garden. There they hoped to establish a regenerative ecosystem. In late June they inoculated five cubic yards of biochar from the Pioneer Valley Biochar Initiative. His win put the experiment in motion. Thanks to two UMass professors, John Gerber, Professor of Sustainable Food and Farming, and Stephen Herbert, Professor of Agronomy, he accessed an additional $5,000 for the project. In part because he was graduating in May of 2015 and in part because he wanted the project to become a lasting student enterprise he and his co-conspirators started a student organization which they named Spiritual Ecology and Regenerative Systems Initiative (SERSI). Officially recognized by the UMass Student Government Association, they ensured that the Fruit Forest would be a learning enterprise for future students.

Back obtained the biochar for the fruit forest experiment from Pioneer Valley Biochar producer, Adam Dole. The biochar was produced using the “Adam Retort” design. The retort was constructed by Bob Wells and Peter Hirst, founders of New England Biochar, for about $30,000.

Carbon sequestration and increased food production are not the only benefits of biochar. The material can be an excellent amendment in drought-stricken areas since it acts like a sponge retaining nutrients and moisture for plants to draw upon. Added to animal pastures, it can assist in the breakdown of manures and reduce methane emissions. It can also be used as a feed additive to prevent toxicity or bood and may even work to reduce radiation. According to Hans-Peter Schmidt, Director of the Dilenat Institute for Ecology and Climate Farming in Switzerland, there are at least fifty uses for biochar from insulation to air decontamination to water treatment in aquaculture, almost all of which are carbon sinks.

The Fruit Forest Experiment

Back’s experiment really started at his home in the summer of 2014. He bought four cubic feet of biochar and made new beds with it in his greenhouse. While he felt his results were good, he yearned for a concrete experiment that would yield not just fruits and vegetables, but hard data. With two fellow students, who initially did not know much about biochar but were game to participate in the experiment, Back entered and won a competition for $1,000 and six cubic yards of biochar from the Pioneer Valley Biochar Initiative. His win put the experiment in motion. Thanks to two UM professors, John Gerber, Professor of Sustainable Food and Farming, and Stephen Herbert, Professor of Agronomy, he accessed an additional $5,000 for the project. In part because he was graduating in May of 2015 and in part because he wanted the project to become a lasting student enterprise he and his co-conspirators started a student organization which they named Spiritual Ecology and Regenerative Systems Initiative (SERSI). Officially recognized by the UMass Student Government Association, they ensured that the Fruit Forest would be a learning enterprise for future students.

Within the Fruit Forest are various plantings, many of which are indigenous to the area. The team planted fruit trees and shrubs, such as cherries, raspberries and sea berries; and perennials, such as buffalo berries, chokeberries, elderberries, and cornelian cherries. Many of the plantings are nitrogen fixing such as the sea berries, Siberian peas, alders, New Jersey tea, and bay berry. Some plantings are pollinator habitats like spicebush and sassafras along with native wildflower mixes and comfrey, all of which are spread throughout the Fruit Forest. The plantings cross the biochar and control plots. This will enable the students to assess and test the same plants and fruits grown in different plots to evaluate the health of developing ecosystems.

Students today as well as future students will examine the results over the years. The fruit forest experiment is not just about testing biochar and other amendments, but will be a bountiful place of teaching and learning. Students will assess the health and vibrancy of the plants visually. They will conduct soil tests and analyze the results, comparing results between plots and over time. They will use a refractometer to assess the sugar level of fruits. In two or three years, the students will hopefully see some results of the biochar acting with the soil.

The fruit biochar was disked into two plots where it made up 4% of the top six inches of soil, two plots where it made 3% and one plot where it made 2%. Each plot has a control plot alongside of it so that there are ten distinct plots each of which is 15 feet wide. Plots vary in length from 60 feet to 120 feet, depending on application. The control plots mimic the molasses and fertilizer content of their companion biochar plots so that the role of the biochar can be isolated from the benefits of the other amendments.

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Not just biochar, but regenerative systems

The results will not just be about the benefits (or inadequacy) of biochar. The fruit forest experiment is intended to be a regenerative environment, the results of which will demonstrate the importance of the combination of the fruit forest with biochar. Back argues that the fruit forest is just as important in mitigating climate change as the biochar. It is in the balance that is critical: the biochar, the growing perennials and fruit trees, and the untilled, undisturbed soil. The combination gives the biochar the best chance to build organic and microbial life.
Like other biochar advocates, Back believes that biochar was not the single factor creating Terra Preta in the Amazon, and it will not be the only element necessary to build regenerative systems today. Biochar used in harmony with other regenerative methods will supply organics, microclimates for microorganisms, microhabitats for small mammals and birds as well as food for humans.

Moving forward, more ancient and traditional agricultural techniques need to be scientifically tested. For example, Back would like to start another multi-plot experiment where he can gather data on the differences between biochar, rockdust and bokashi. Bokashi is another centuries old technique used by Japanese farmers where microorganisms are applied to waste which results in fermentation. Addressing climate change and food security and rebuilding healthy ecosystems will require multiple solutions. Those solutions are more likely to come from organic farmers sharing information than those advocating geo-engineering, genetic modification and other so-called “high tech” solutions.

Readers who would like to find out about the results of the Fruit Forest experiment may contact the authors. The SERSI webpages will also post information about the fruit forest experiment in the future at: https://umassamherst.collegiatelink.net/organization/SERSI

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I’ve been asked more than once recently how landscapers could incorporate the use of biochar into their businesses. Not being in the biz myself, I decided to do some investigating to understand a bit more about the specific services landscapers provide to better understand how to answer this question. Obviously services will vary significantly by region, but in my neck of the woods services generally seem to fall into a few basic categories: lawn care, tree care and some are now offering environmental services such as rain & roof gardens. (Hardscaping is also a big service area, but I’ll leave that one out for now.) Below are some ideas on how biochar might be used in various landscaping services:

On the lawn care front there are at least two services where biochar could be very useful. Establishing new lawns is required for newly built homes and office buildings. Unfortunately many times builders scrape away the topsoil to facilitate building and then sell it off, leaving poor quality subsoil that contributes to poor lawns and significant runoff in some places. Adding biochar prior to establishing new lawns will provide much needed carbon, improve water management and reduce leaching and erosion.

Aeration services are provided for already established lawns that suffer from compaction caused by heavy lawn equipment, heavy rainfall, foot traffic, etc. Compaction reduces the soil’s ability to absorb water and oxygen resulting in thatch, rapid drying, rain run-off and other issues. Typically this is dealt with by pulling out soil plugs to allow for improved air and water penetration. Instead of leaving these new holes empty, filling them with highly porous biochar would likely prevent holes from caving in while still allowing for air and water to enter.

Tree care and biochar is a great closed loop opportunity. Many times when trees are pruned or removed the debris is chipped and transported offsite, incurring increased cost for the homeowner and sometimes logistical headaches for the landscaper if there are no local places that will accept chips. Thus charring leftover biomass on-site could not only make debris management cheaper, but could provide high quality biochar for various uses for the homeowner or the landscaper. Planting trees with biochar has been shown in various trials to improve survival rates as well as to improve growth rates.

Environmental services such as rain gardens and bioswales seem to be increasingly popular, at least in the Finger Lakes region. No doubt this is in an attempt to better manage the increasing number of heavy precipitation events and reduce costly flooding impacts. In contrast to using sand in rain gardens and bioswales, biochar makes an excellent light-weight, highly porous filtration medium.

Overall I’d have to say biochar production and use within the landscaping industry makes for a great closed loop scenario! One model that has been popping up in different locations is for landscapers to purchase portable kilns such as the Kon-Tiki, and either rent these to homeowners for a few days so they can char on their own, or to provide charring services in lieu of chipping & shipping debris. (Note: it is recommended to wait a few days after pruning to lower the moisture content.)

Kathleen blogs at http://fingerlakesbiochar.com/blog/
Replace chipping & shipping with clipping & charring, then use biochar for:
• Rebuilding topsoil in new developments
• Aerating lawns
• Planting trees

Rain gardens and Bioswales

WHAT IS A RAIN GARDEN?
A rain garden is a depression created in your landscape to allow rainwater from your roof or driveway to slowly soak into the ground, instead of running off into the nearest stream or Puget Sound. Native soils are removed and replaced with a special blend of high organic soil; rain gardens are then planted with beautiful, hardy, low-maintenance perennial plants.

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Biochar first came into broad public awareness through the example of the Amazon, where the hypothesis is that Amazonian inhabitants added biochar along with other organic and household wastes over centuries to modify the surface soil horizon into a highly productive and fertile soil called Terra Preta, which is in direct contrast to the typical weathered Oxisol soils in close proximity. Biochar is exciting to many people because of its role in such soil-building processes. Those who have used biochar for several years may obtain tangible positive results, but they may not have solid concepts and theories about how it works. Biochar is a heterogeneous and chemically complex material and its actions in soil are difficult to tease apart and explain mechanistically.

### The Role of Carbon in Soil

The evolution of soil shows how the soil building process works. Before photosynthetic bacteria transformed Earth’s atmosphere by filling it with oxygen, soil was nothing more than a mineral mixture of anoxic green clay. After oxygen entered the atmosphere, minerals started reacting with the oxygen, and red iron oxides appeared in the soil. Good organic, rich, productive soils developed from the sea to dry land and plants took root. Life colonized land and began shedding its wasted, used up and discarded parts onto the earth where they formed a carbon-rich banquet that allowed new life to feed and grow, using photosynthesis to pump ever more energy into the system.

Soil building is the product of a self-reinforcing, positive feedback loop. But soil decline is also a negative feedback loop. Natural charcoal is present in some of the most valuable agricultural soils in the world, such as the Chernozems of the Russian steppe and the Mollisols of the US Midwestern prairie states. Recently scientists have looked more closely at the Mollisols and found that they contain charcoal that is “structurally comparable to char in the Terra Preta soils and much more abundant than previously thought (40–50% of organic C).”

### Biochar - the Electric Carbon Sponge

To understand biochar, we must first appreciate the role of soil carbon. Soil carbon comes in many forms and the terminology used to describe it can be confusing. There are two main pools of carbon -- organic and inorganic. Organic forms can be further divided into “recalcitrant carbon” or that resistant to decay, like humus, and “labile carbon.” Labile carbon will be quickly consumed by soil organisms because it is both bioavailable (in the form of easily degraded compounds such as oils, sugars and alcohols) and physically accessible to microbes (not bound up with minerals). These labile compounds include hydrogen and oxygen in the form of hydrocarbons and carbohydrates. The organic carbon pool includes both the living bodies and the dead, decomposing bodies of bacteria, fungi, insects and worms, along with plant debris and manure. Inorganic carbon includes the carbonates such as limestone, and even though some life forms use carbonates to make their shells or skeletons, these compounds are still termed “inorganic”. The main distinction of the inorganic carbon pool, however, is that it does not fundamentally provide microbes with energy for feeding the soil building reactions.

Mineral carbon refers to carbon solids like diamond and graphite as well as the gases of carbon (CO$_2$, CO and many others). There are numerous ways a carbon atom can be arranged in a solid which leads to different physical structures, which are called allotropes. Allotropes of mineral carbon, include diamond, graphite, graphene, buckyballs and carbon nanotubes (Figure 1).

So what is biochar then? Organic or mineral carbon? Actually biochar is a mixture of both, depending on the conditions of formation. But let’s first look at how biochar is produced. Biochar is made by heating biomass under the exclusion of air. This process is called pyrolysis, which includes the drying of the biomass and the subsequent release of flammable vapors. Technically this can be done by many different methods. Some methods use a retort, which is a closed vessel that is externally heated. Heat is transferred through the metal vessel and vapors pass out of a vent where they can be burned and help heat the retort. Gasification is another method that supplies enough air to burn the biochar.

Biochar is made by heating biomass under the exclusion of air. This process is called pyrolysis, which includes the drying of the biomass and the subsequent release of flammable vapors.
vapors, but prevents the complete combustion of the biomass material by excluding air from the charcoal zone, thus preserving the biochar. Many other methods of charcoal making exist that range from simple pit kilns to multi-million dollar machines producing energy in gas or liquid form from the vapors.

The resulting charcoal resembles a blackened, shrunken version of the original biomass. But it now has very little hydrogen and oxygen. Microscopically, it inherits much of the structure of the original biomass. The only difference is the material now has been converted from lignin, cellulose and hemicellulose to many of the allotropes of carbon shown above (Figure 1); however, you will not find any diamonds in biochar! Rather, you will find a collection of disjointed graphite crystals based on hexagonally-shaped carbon rings, with some leftover hydrogen and oxygen attached, along with minerals (ash) that were in the original feedstock. These hexagonal carbon compounds are fused carbon rings. Fused carbon rings are also called “aromatic” carbon, (another confusing chemistry term - it does not mean that the compound has a strong aroma, although some of them, like benzene, do. In chemistry it refers to the molecular structure containing a planar unsaturated ring of atoms that is stabilized by the bonds forming the ring.) They are very stable and it takes microbes a long time to degrade them. The more you heat the biomass, the more of these fused carbon rings are created. The rings hook up with each other to form layers and layers of discontinuous, rumpled sheets - the graphite crystals. Biochar’s jumble of carbon crystallites is an important source of its porosity – imagine all the tiny spaces in the wrinkles between sheets.

Biochar starts out as organic and becomes more mineral-like with heating. This mineral transformation creates the skeletal structure that looks like a carbon sponge (Figure 2). While the mineral, fused–carbon ring structure is hardly biodegradable, the recondensed vapors that can be found in the biochar pores and on its surfaces are less aromatic and more biodegradable and can thus be considered organic phases of the biochar.

The fused carbon rings are also responsible for the electrical activation of the biochar carbon sponge. Fused carbon rings form a special bond with each other that allows electrons to move around the molecule producing electrical properties like those that are found in engineered carbon materials such as graphene sheets and carbon nanotubes. Depending on the pyrolysis temperature and resulting arrangement of atoms, biochar can be an insulator, a semi-conductor or a conductor of electricity. Electrically active fused carbon rings also support “redox” or oxidation and reduction reactions that are important to soil biochemistry, by acting as both a source and sink of electrons. In soils, microorganisms use aromatic carbon both as an electron donor and as an electron acceptor during metabolic chemical reactions. Biochar seems to not only serve as an electron buffer for redox reactions, but it also helps bacteria swap electrons among themselves, improving their metabolic efficiency as a microbial community.

With its pores and its electrical charges, biochar is capable of both absorption and adsorption. Absorption (AB-sorption) is a function of pore volume. The larger pores absorb water, air and soluble nutrients like a normal sponge. Adsorption (AD-sorption) depends on surface area and charge. The surfaces of biochar, both internal and external,
Porosity will also depend on the feedstock, with this reason, HTT is a key variable to know when temperatures approach 1000 degrees C, pores begin to collapse or melt. For surfaces). Also, at temperatures approaching 1000 degrees C, vapors are incompletely driven off and condense on the forming biochar (hydrogen and oxygen containing compounds) will be driven off and how much pure carbon graphite (labile carbon) that feed a bloom of microbes that make up nitrogen in the soil, deprivating plants. These problems are easily corrected by adding nutrients to the charcoal application to compensate for this effect. Once the labile carbon fraction is used up, biochar enters a new phase - a deep time dimension where its carbon matrix is stable for hundreds to thousands of years and may become the core of humic substances that crystalize around the fine biochar particles; at least this is what the existence of ancient fertile black earth soils suggests.

Biochar is not soil. The electric carbon sponge is only an ingredient in the mineral and organic stew that makes up soil. The dish is usually potluck, a well-aged cheese. However the Terra Preta soils are different. The fertility of these black, humus-rich soils is many times greater than the surrounding, highly leached red soils. They may have been deliberately created over centuries by people living on densely settled high bluffs along the Amazon River. It is thought that the ingredients included charcoal, ash, food scraps and human excrements, but how they actually combined to form Terra Preta is unknown. Explaining the formation of the Terra Preta is like determining the recipe for a fine Camembert cheese. You can analyze all the ingredients and still have not the faintest idea how to make one if you don’t learn it from the artisans. One thing that is becoming obvious after a decade of biochar scientific research and the first results from multi-year field trials is that, just like a good cheese, the time dimension is critical. From the moment that biochar is pulled from the kiln, its surfaces begin to oxidize and form new compounds. These changes result in different molecules attached to the surface, called “functional groups,” composed primarily of oxygen, hydrogen and carbon. The functional groups are able to bond with nutrients and minerals, while the underlying fused carbon rings support redox reactions (shuttle electrons) and shuttle electrons around the microbial community attached to biochar surfaces, potentially enhancing microbial metabolism and the cycling of nutrients. The end result of this ferment could be any one of many “terroir”-distinct Terra Preta flavors, depending on what kind of soil, organic matter, minerals, water and life forms come into contact with the biochar, and how long it has to ripen. But, if you sample the cheese before it is mature, it’s just sour milk.

Raw biochar placed in soils before it has a chance to collect a charge of nutrients can actually reduce crop yields because 1) it reduces the availability of plant nutrients by binding and immobilizing them and/or 2) it may add volatile organic compounds (labile carbon) that feed a bloom of microbes that use up nitrogen in the soil, deprivating plants. These problems are easily corrected by adding nutrients to the charcoal application to compensate for this effect. Once the labile carbon fraction is used up, biochar enters a new phase - a deep time dimension where its carbon matrix is stable for hundreds to thousands of years and may become the core of humic substances that crystalize around the fine biochar particles; at least this is what the existence of ancient fertile black earth soils suggests.

In fact, biochar, whether naturally created or man-made, may be the base of many humic materials found in soils (Hayes, 2013). Very little humus...
naturally forms in tropical soils, where high temperatures and moisture accelerate microbial decomposition, yet Terra Preta soils have a high content of humus. To understand why, scientists added new organic matter to both a Terra Preta soil and an adjacent, poor natural soil. They found that more of the organic matter was retained as stable humus in the Terra Preta soil. A combination of factors may lead to this result. Biochar surfaces adsorb carbon and retain it in compounds with minerals, supporting at the same time a large microbial community that potentially makes more efficient use of organic debris containing carbon and other nutrients. The existence of this mechanism raises the possibility that Terra Preta soils are thus able to accumulate additional carbon more efficiently than adjacent soils.

If tropical soils need biochar to make humus, what about compost? Well balanced compost, with the optimum C:N ratio, will contain lots of humus. However, if there is not enough stable carbon (from wood, straw or other lignin sources), then the easily degradable sugars, fats and proteins will be completely consumed by microbes leaving very little substrate behind. This is what happens in tropical soils where heat, moisture and high microbial activity will decompose a fallen leaf nearly as soon as it hits the ground, allowing very little soil to form.

A number of studies have demonstrated that biochar has value as an ingredient in compost that can help capture nutrients and form humus. In the next section, we review some of these results and explain why biochar is valuable in compost. The answers will also tell us a lot about how biochar behaves in soil, because compost accelerates many of the processes that occur in healthy soil.

Kickstarting Compost with Biochar

If you look at a list of things biochar is supposed to do in soil, you’ll find it is very similar to lists you see for compost. Both biochar and compost are said to provide these benefits, taken from various claims made by biochar and compost manufacturers:

- Improves tilth and reduces soil bulk density
- Increases soil water holding capacity
- Becomes more stable by combining with clay minerals
- Increases cation exchange capacity (CEC - the ability to hold onto and transfer nutrient cations: ammonium, calcium, magnesium, and potassium)
- Improves fertilizer utilization, by reducing leaching from the root zone
- Retains minerals in plant available form
- Supports soil microbial life and biodiversity
- Helps plants resist diseases and pathogens
- Helps plants grow better in high salt situations
- Adds humus carbon to the soil carbon pool, reducing the atmospheric carbon pool

Figure 2. The skeletal structure of biochar looks like a carbon sponge.

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If compost really can do all these things, why do we need biochar? The answer is twofold.

First, unlike biochar, compost is quickly broken down by microbial action in soil over months to at most, decades, depending primarily on climate. Biochar lasts at least ten times longer in most soils. Recently, Rachel Rough, a California High Sierra extension agent with a question about adding compost to fields to improve water holding capacity. I was told that because of the hot climate, at least two applications a year are needed to maintain enough soil organic matter to make a difference in water holding capacity. Aside from the expense of applying that much compost, there is simply not enough compost available to support such large application rates.

Second, biochar has important synergistic effects when added to compost. Researchers find that biochar makes faster, more nutrient rich, more biologically diverse and more humified, stable compost. Below, I examine several of the most important biochar effects and summarize some recent research results.

1. Biochar keeps compost moist and aerated, promoting increased biological activity.

The composting process is governed by various physical parameters that are subject to alteration by the addition of biochar materials as bulking agents. Some of the parameters that most affect compost are: aeration, moisture content, temperature, bulk density, pH, electron buffering and the sorptive capacity of bulking agents. Water and air are both held in biochar pore spaces and voids, and the spaces between particles. Moisture is also the vehicle for bringing dissolved organic carbon, nitrogen and other plant nutritive compounds into contact with biochar surfaces where they can be captured. Biochar’s stable carbon matrix accepts electrons from decomposing organic compounds, buffering electric charges that might otherwise impair microbial activity and be responsible for the production of greenhouse gases like methane and hydrogen sulfides.

All these properties of biochar promote microbial activity in compost. Researchers tested 5% and 20% additions of pine chip biochar to poultry litter compost and found that the addition of 20% biochar caused microbial respiration (measured as CO2 emissions) to peak earlier and at a higher level than either the 5% or 0% biochar treatments.

2. Biochar increases nitrogen retention

When nitrogen-containing biomass materials decay, they can release large amounts of ammonia. Ammonium (NH4+) is the aqueous ion of ammonia. Ammonium is generated by microbial processes and nutrient cascades that convert nitrogen from organic forms found mainly in proteins and nucleic acids into mineral forms (ammonium, nitrate and nitrite) that can be leached from the soil. Ammonium (NH4+) can also be emitted to the atmosphere as NH3. The ammonia retention ability of biochar can actually improve during the composting process. Adding 9% bamboo charcoal to sewage sludge compost reduced the rate of ammonia volatilization and increased total nitrogen retention by as much as 65%. The ammonia retention ability of biochar can actually improve during the composting process. Adding 9% bamboo charcoal to sewage sludge compost reduced the rate of ammonia volatilization and increased total nitrogen retention by as much as 65%.

Several studies have looked at effects of biochar on the timing and results of compost maturation and found that adding biochar to compost reduced the amount of dissolved organic carbon (labile carbon) in mature compost while increasing the fraction of stable humic materials (stable carbon).

3. Biochar improves compost maturity and humic content

Several studies have looked at effects of biochar on the timing and results of compost maturation and found that adding biochar to compost reduced the amount of dissolved organic carbon (labile carbon) in mature compost while increasing the fraction of stable humic materials (stable carbon).

4. Biochar compost improves plant growth

Biochar seems to improve the composting process, but how do plants like those biochar-composts? Several researchers have experimented with various combinations of compost and biochar added as separate amendments. These studies found improved plant growth response when biochar was added to soil along with compost. A 2013 study in Germany looked instead at biochar composted together with other materials. It tested six different amounts of biochar in compost, from 0 to 50% by weight, and also three different application rates of each compost type. Using oats in greenhouse pots on two different substrates (sandy soil and loamy soil), researchers found that plant growth increased with increasing application rates of each type of biochar compost, which is not surprising since the amount of deliverable nutrients was increased, at least by the compost fraction. They also discovered, however, that plant growth was increased as the amount of biochar in the compost increased. The biochar may either have improved nutrient retention during the composting process with subsequent enhancement of nutrient delivery to plants, or it promoted plant growth through some other mechanism. However, the researchers confirmed that synergistic effects can be achieved by adding biochar to composts.

How could we put biochar to work in soils?

One of the basic principles of good compost production is that the wider the variety of materials you use, the better the compost. The ideal biochar compost system is based on a speculative reconstruction of the Terra Preta soils. According to this model, these areas began as garbage dumps where accumulation of waste materials, ashes and manure were dumped. However, once they grew, it is possible that they began to realize that the waste sites were developing into very fertile and productive areas. They may have begun to deliberately manage the material flows of plant biomass, mammal and fish bones, ash, biochar, and human excreta that likely resulted in the Terra Preta soils we see today.

For maximum conservation of resources, it is important to remember another principle: use the less degradable carbon sources like biochar to help preserve the more easily degradable but nutrient-laden sources like manure and food waste. I believe there is much exciting work ahead to determine optimum recipes for biochar-based organic composts and ferments, exploring the effects of different kinds of biochar in combination with other compost ingredients.

From past and on-going research, we realize that biochar has numerous possible mechanisms for its action in soils that can occur on a variety of different scales. But if the results from recent biochar compost research prove to be consistent, we now have the beginnings of a recipe book for biochar-enhanced super compost that can kickstart the process of returning carbon to soils today. Our industrial legacy has left us with a rapidly deteriorating climate and soils that are shrinking and eroding. Biochar, as a form of recalcitrant carbon, may be just the medicine that degraded and unproductive soils need.

Kelpie Wilson is a writer and a mechanical engineer who has worked in the biochar field since 2007. She was a project developer and writer for the International Biochar Initiative (from 2008-2012) and now works as editor of the Biochar Journal and with her company Wilson Biochar Associates. She has been a tree hugger, an auto mechanic, a science fiction author, and has lived off-grid in the Oregon woods since 1990. Have a look at her valuable backyard biochar website with many low budget biochar production devices developed by Kelpie & others.

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** From Northeast organic farmers to Northeast organic farmers **
Biochar Gardening – 2011 Trial Results

by Hans-Peter Schmidt and Claudio Niggli

Over two years more than 200 hobby gardeners took part in a biochar trial coordinated by the Delinat Institute. Different sorts of vegetables were planted on two 10 m² garden plots, the one with compost only and the other with compost and biochar. The analysis of the results showed very interesting differences, once again underlining the importance of specifically applying biochar.

In early 2010, the Delinat Institute launched a project in which hobby gardeners were asked to carry out tests with biochar in their gardens. Participants were each provided with 10 kg of biochar taken from the same batch made from green cuttings by the company Swiss Biochar. In addition the gardeners were given detailed instructions on how to apply the biochar as well as a standard questionnaire (in German) for recording their findings. By the end of 2011, 65 individual tests had already been evaluated, with the findings published in the Ithaka Journal.

On the basis of the experience gained in the first year of tests the instructions and questionnaires were revised in early 2011 and a further 150 test packages sent out. A number of the previous year’s participants repeated the test, using the revised instructions and the same plot of land. By the end of 2011 the Delinat Institute had received 144 questionnaires from participants. The test findings were evaluated individually and then summarized in a meta-analysis. In the following we will be taking a first look at the results.

Methodology

All test plots had the same size. Part of each plot was treated with organically activated biochar, while the control area was treated only with compost or manure and being kept damp for two weeks. The control area was also covered with the same amount of compost or manure as had been mixed with the biochar. On both test areas the same amount of plants was sown. The harvest was weighed, with – wherever possible – the weight of the unused green biomass (for example the leaves of tomato plants) also being ascertained. Qualitative characteristics such as the taste of the harvested vegetables, their shelf-life and plant health were also to be assessed using a scale ranging from 1 to 10.

Results

The difference in the yields relates to the increase or decrease of yields in the biochar sample compared with the non-biochar sample. The overall analysis covering all tests shows that in 45% of cases yields from the biochar-treated plots were at least 10% better, in 31% of cases yields were at least 10% worse than non-treated plots and that in 24% of cases there was a difference of less than 10% between the two samples (see Fig. 1). The evaluation of all 144 tests shows a wide range of results, even after removing the extremes. In some cases yields were more than twice as high, while similarly there were cases where there was a significant negative impact on yields. This shows that biochar has a major influence on the interaction between plants and the soil. The better these interactions are understood, the more specifically biochar can be applied. The average for all tests showed a 7.5% improvement in yields.

The comparison between the first and second test year shows no significant difference. What is however surprising is that the range of results in the second year was much wider than in the first year. A detailed analysis is needed to ascertain the causes.

The most important outcome of the whole test can be seen when looking at the results per plant family (Fig. 2). Only plant families where more than 10 test results were available were included in the analysis. Whereas brassicaceae (cabbage plants), cucurbitaceae (cucurbits) and apiaceae (umbelliferae) did particularly well, the opposite was true for solanaceae (nightshade plants). No trend in either direction was noticeable for legumes or asteraceae (lettuce).

Test vegetables by plant family

Brassicaceae: red cabbage, white cabbage, Brussel sprouts, mustard cabbage, Chinese cabbage, cauliflower, broccoli, kohlrabi, radishes
Solanaceae: tomatoes, potatoes, eggplants, peppers / chili, Physalis
Leguminosae: beans, peas
Cucurbitaceae: cucumbers, melons, zucchini
Umelilliferae (Apiaceae): fennel, parsnips, carrots, celeri Asteraceae: lettuce, salsify

With regard to the qualitative assessments of taste, shelflife and plant health, slightly positive tendencies were seen, though differences were all below 5% and not statistically significant.

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The application of biochar has a more or less significant effect on each of these soil properties, influencing a plant’s ecosystem. Dependent on the starting conditions of a soil, any shift in these key soil properties can lead to a positive or negative change in the ecosystem for a certain plant family.

This underlines the importance of analyzing the type of soil before applying the biochar, thereby ascertaining its suitability for certain families.

For example, the application of biochar results in an increase in a soil’s pH value. For plants which do better with a more acid soil – such as strawberries, blueberries or such nightshade plants as potatoes or tomatoes – the application of biochar will often lead to a worsening of results. On the other hand, the application of biochar on acid soils improves the living conditions of such plants as cucumbers and cabbage, plants preferring a more alkaline environment.

Similar to the effect on the pH value, the effects of biochar on all other soil aspects referred to above can be ascertained and associated with the requirements of different plant families.

Only when this has been done will we be able to plan the specific application of biochar and biochar substrates with a view to obtaining the best yields.

Certain effects of biochar, such as increasing a soil’s ability to store water, to provide better aeration or to increase electrical conductivity, are deemed positive for all families. These positive aspects can, however – at least in the short term – be overweighted by more significant changes in soil-ecosystems, thereby leading to an overall decline in yields.

Looking for instance at brassicaceae, one explanation for the positive tendency could be the high potassium requirements found in many types of cabbage. The biochar produced by Swiss Biochar has a relatively high potassium content. The dosage of 10 t biochar for one hectare (1 kg/m²) in the hobby garden tests corresponds to a fertilizer dosage of 80 kg K₂O per hectare. Cucurbitaceae also require a lot of potassium, a fact that could also account for them doing better. On the other hand, the very positive tendency seen in the effect of biochar on brassicaceae, cucurbitaceae and apiaceae confirms the findings of the first test year. The fact that the different effect of biochar applies not just to various types of plants but also apparently to whole families is quite understandable as within a plant family there is a tendency for similar specializations to be found with regard to certain environmental conditions and metabolic commonalities.

There are a number of possible reasons for the different effects biochar has on different plant families. To achieve optimal growth, each family has different requirements regarding its ecosystem. The availability of nutrients represents just one aspect here. Other important aspects include pore volume, soil density, the pH value, the microbial environment, the availability of oxygen, water dynamics and electrical conductivity.

The following discussion deals mainly with the differences in the results in the different plant families. The 7.5% average increase in yields confirms the results of the previous largest meta-analysis carried out by Jeffery in 2011. In this Jeffery evaluated 782 published biochar tests, finding that on average yields were 10% better. (Fig. 3).

The big question-mark hanging over this hobby gardener test is the quality of the organic activation process. As a series of scientific experiments have shown, the quality of the compost plays a decisive role in the biological activation of biochar. The quality of an organically activated biochar substrate is dependent on how well the activation process is controlled. Biochar mixed with rotten cow manure will not do the soil any good, no matter how much biochar is used. And if the compost with which the biochar is mixed has only been turned a couple of times and is full of mould and rot, the biochar might just be able to bind a few toxins, but will definitely not become a substrate working wonders.

As nearly all participants used only their own compost, the very great fluctuations in the quality of the compost can probably be seen as the main cause for the wide range of results. In the first year, in many cases the compost was applied straight, without mixing it with compost, which is probably why the results were more uniform.

In a joint action carried out by Delinat and Swiss Biochar in early 2012, 1000 sacks of high-quality biochar substrates (specially developed by the Delinat Institute) were made available for window gardeners. These are the same substrates as the ones used for the Delinat vineyard trial. Even if this action is nothing more than a mass experiment, we hope to gain more results confirming the effectiveness of specially produced Terra Preta substrates with added biochar in (hobby) gardening. The scientific field and plant-pot experiments of the University of Giessen and the Delinat Institute have already been able to show that such Terra Preta substrates achieve better results in six of seven cultures than peat substrates with added fertilizers. The latter results will soon be published in the Ihaka Journal.

We would like to use this occasion to thank all participants in what has probably been the most extensive gardening mass test ever carried out in Switzerland. Enthusiasm for biochar and Terra Preta methods show some interest in biochar, this could possibly be attributable to the efficient way they apply it.

Hans-Peter Schmidt and Claudio Niggli are researchers and writers associated with the Ihaka and Delinat Institutes in Switzerland.
A Photo Workshop on Making and Using Biochar

by Jack Kittredge

On a beautiful sunny weekend recently I attended a 2-day workshop presented by David Yarrow on making and using biochar. It was at a local farm, there were 20 or so attendees, and the workshop involved us making a burner out of a recycled 55-gallon barrel, burning biomass in it to create char, and then making a growing bed using the char as well as David’s favorite minerals, activators, and inoculants for it.

I took photos throughout the workshop, and print some of them here in chronological order, along with notes about the photos and the information we gleaned at that part of the presentation.

Making the Biochar

Here is presenter David Yarrow, showing us the materials we will use to make the burner. They include a barrel with removable lid, some stovepipe pieces, a roll of ceramic insulation, a roll of chicken wire fencing, some wire and hardware. Tools needed were a power drill and disk grinder, a metal saw, and various hand tools.

Biochar is charcoal that is made by particular methods to yield carbon for effective use in soil. David presented from his experience on how to activate raw biochar with various minerals and inoculants, and also showed how biochar can then be put into a raised “lasagna” bed with biomass and other materials to make fully fertile soil.

David teaches how to use a TLUD (Top-Lit Up-Draft) burner to make biochar. A TLUD is a two-stage device with a biomass gasifier in a 55-gallon barrel, and a secondary gas flare in the chimney. It is smokeless, cheap and easy to make, and reliable. It makes small 15 to 20 gallons batches for test plots.

The TLUD we are making is a much simpler and less dangerous design than one involving a retort. In this design the biomass itself is burned, but with limited oxygen allowed to enter. At the end of the burn, most of the biomass will have been oxidized, but 20 to 30% of biomass carbon will remain as char.

The barrel must suck fresh air up from the bottom to oxidize the biomass and provide heat. The more holes, the more air gets in. Too few, and the fire will burn smoky; too many, and it will burn so well that little char will remain.

The top of the drum is removed and a 6" diameter hole cut into it. Then an 8" to 6" stovepipe reducing thimble is inserted from the top.

Here we cut vents into the reducing thimble to allow air to enter it. The thimble is a crucial element of the design, creating a venturi effect when the hot gases leave the drum and enter the thimble. These gases must be burned in the stovepipe for the combustion to work properly.

Once vents are cut into the thimble, they are pressed open to admit air. Again, the exact amount is something that you must play with. As with the holes in the bottom of the barrel, too little air and the burn goes smoky, too much air and you burn up most of the char.

3 guy wires secure the chimney in case of high winds
To keep the internal temperature high during the burn the drum is insulated. A piece of poultry wire fencing is laid out, a section of 1” thick insulation is laid on top, and the drum is rolled onto this. The ends of the chicken wire are then pulled tight and wired together, holding the insulating jacket on the drum.

A piece of 8” diameter stove pipe is where the flammable gases given off from the smoldering biomass in the barrel will burn. It is inserted into the 8” end of the (now vented) thimble in the top of the drum. Guy wires are attached to hold the pipe vertical in a wind.

We start filling the drum. The most important thing is that the biomass be fully dry, to minimize steam and assure a hot burn. Virtually any biomass can be made into char – wood, hay, manure, bones. Very small stuff (sawdust and leaves) don’t burn well in a TLUD because it will not pull air very well up through the contents of the drum. Very large woody chunks (3” thick logs) will not char totally in the fast burn this device creates.

Now the barrel is filled and ready to be lit and the lid and chimney put on. The fire is lit. This can be done many ways. A little paper under a top layer of kindling works well. An accelerant like kerosene can be used, but for purists is cheating. The fire needs to burn to the state of having bright, glowing red embers before the lid and chimney–top is put on, because closing it will drastically reduce the presence of oxygen. From now on until the end of the burn, fresh air must be sucked up from the holes in the bottom of the barrel.

David checks the burn by peeking under the lid. White smoke coming out the chimney means that the fire in the barrel is not hot enough yet to ignite and sustain the gas flare in the chimney. More burning needs to happen in the barrel.

Once the burn seems well established the rest of the chimney is added before it gets too hot. David checks the progress of the burn again. Now the burn is going well. Little smoke is coming out and you can hear the intake of air swooshing in the slots cut in the chimney adapter. The drum is set up on three short cinder blocks to provide stability and room for air to enter under it.

Volatile gases are being boiled out and driven from the biomass by the heat inside the barrel. When the hot gases enter this vented thimble they ignite and burn in the chimney. Once the barrel burn is established, if the gas flare combustion in the chimney goes out (which you know immediately because all of a sudden the chimney will smoke), it can be easily reignited with a match or lit piece of paper being inserted into one of these vents.

In the middle of a good burn there is no smoke visible at all, yet you can see the flames through the thimble vents.

In the drum is full.

During a good burn the fire is visible through the slots in the venturi. The burn is ended with water from hose. Water is sprayed into the barrel with a hose to kill the remaining fire and embers. A charcoal fire in the barrel bottom is very hot, very stubborn, and very hard to put out. It helps to have an extra lid to tightly close the barrel top and hold in steam. Apply a water spray at 3 minute intervals until steam subsides.

The burn is ended with water from hose.

The fire is lit.

Here is what we got for biochar. David said he let the burn go too long, and part of the charcoal was burned to ash, so the yield was about half of what he hoped. In a good burn, perhaps 30% of the biomass will remain as char. Still, for a first burn with new equipment and new operators, this was an adequate success.
For the next burn, David will open the thimble vents wider and add more holes in the barrel bottom to get more air in for a hotter smokeless burn, and will shut the burn off sooner.

We run the biochar through a ½ inch screen. The smaller parts will be used in the planting bed, the larger ones returned to the next burn.

**Making the Garden Bed**

We are making a planting garden bed perhaps 4' wide by about 10' long. David uses a “lasagna” or “sheet layering” style, adding thin layers of various materials that will allow microbes and minerals to blend rapidly together. He starts with a layer of sticks and coarse, rotten woody debris right on the ground. This will provide plenty of air spaces at the base, as well as a substrate guaranteed to attract and feed fungi. Here, the layer of sticks is in place and we are covering it with wood chips.

After the wood chips we add a thin layer of leaves, then straw and then cover that with a thin sprinkling of compost and/or manure. Compost and manure serve more as an inoculant for digestive microbes than a major nutrient source.

After the compost layer goes the first layer of screened biochar.

Much to David’s dismay (he considers calcium the basis of good growing) we did not have any limestone, gypsum or other calcium source, so the workshop host, Marty, adds some liquid calcium-magnesium he had, mixed with water.

David often uses SamaGrow, a microbial inoculant that he knows is effective. Here it is sprayed onto the biochar and minerals as the next layer after the Calcium-Magnesium blend. It features 16 bacteria and 9 fungi in a 12% humate solution to perform their microbial wonders with the crops to be planted.

Another layer of straw goes on after the inoculant spray.

Marty blended a teaspoon of mycorrhizal fungi spores in a pint of very fine biochar dust to bulk the tiny spores up in volume, then scatters the dust onto the bed after the whole thing is inoculated.

Marty then shakes fine biochar dust that David saved from previous burns onto the bed after the whole thing is inoculated.

Topsoil from a horse farm is lightly scattered on after the fine char dust and fungal spores. This seals the first stack of layers that forms the base of the new bed. Next comes a second stack of layers that create a primary root zone for seeds and seedlings.

High-carbon wood shavings are the first layer of the second stack of layers. This is followed by a layer of lighter weedy biomass such as hay or straw. Old moldy biomass is best for a bed.

We are making a planting garden bed perhaps 4' wide by about 10' long. David uses a “lasagna” or “sheet layering” style, adding thin layers of various materials that will allow microbes and minerals to blend rapidly together. He starts with a layer of sticks and coarse, rotten woody debris right on the ground. This will provide plenty of air spaces at the base, as well as a substrate guaranteed to attract and feed fungi. Here, the layer of sticks is in place and we are covering it with wood chips.

After the wood chips we add a thin layer of leaves, then straw and then cover that with a thin sprinkling of compost and/or manure. Compost and manure serve more as an inoculant for digestive microbes than a major nutrient source.

After the compost layer goes the first layer of screened biochar.

Marty blended a teaspoon of mycorrhizal fungi spores in a pint of very fine biochar dust to bulk the tiny spores up in volume, then scatters the dust onto the bed after the whole thing is inoculated.

Marty then shakes fine biochar dust that David saved from previous burns onto the bed after the whole thing is inoculated.

Topsoil from a horse farm is lightly scattered on after the fine char dust and fungal spores. This seals the first stack of layers that forms the base of the new bed. Next comes a second stack of layers that create a primary root zone for seeds and seedlings.

High-carbon wood shavings are the first layer of the second stack of layers. This is followed by a layer of lighter weedy biomass such as hay or straw. Old moldy biomass is best for a bed.

First cover of screened char goes on after the compost.

After the biochar, David adds a thin scattering of dried sea minerals. They add the full menu of trace minerals that are in sea water.

After the light-colored sea minerals, David likes to add rock dusts to feed the microbes.

Now a layer of rotting apples is applied to bring local fungi and bacteria to the pile and provide a sweet treat for the microbes.
Next Marty adds a layer of rotted hay. Leaf mold gathered from a nearby woodland is next, to bring a wide diversity of indigenous fungi, and even other bacteria and microbes to the bed.

A few more sea minerals are added to boost trace elements in biomass layers of the second stack. Sea minerals are 100% soluble trace elements, and very alkaline, so only a thin sprinkling of trace elements is needed — one cup to one pint on 100 square feet.

Another layer of biochar — in this case a fine powder blended with mycorrhizal spores — can further enhance movement of minerals and microbes. Biochar adsorbs nutrient ions and electrons and keeps these charges available in the root zone. So biochar is like a battery to hold electric charges in soil, and release them to grow plants. Thus several thin layers of biochar, rather than one thick layer, create far greater surface area and charge capture capacity — a bigger battery in the soil.

Finally we add another thin layer of sprinkled soil to cover the biomass and microbes inside, then a loose layer of straw mulch to shade and shelter this microbial mega-metropolis, ending with a good soaking with well water. Water is the trigger to activate and mobilize minerals and microbes.

David says this thinly-layered, well-aerated bed can be planted in a week (unless overloaded with manure or green matter) by depositing a strip of soil on the thin mulch, and seeding into this furrow. Transplants just need a hole opened easily by fingers, dropping in the plant and root plug, and gently pulling the soil up close (be sure your transplants get 5% biochar powder in their potting mix). Roots penetrate quickly, find what they need. Fungi grow quickly, find what they need. Then roots and fungi get together and the explosion of growth begins. It seems to take 30 days for this symbiosis to get into high gear, and it takes a full year for earthworms to move their families in and do their work.

Over winter, a new bed will shrink to 50% of its volume, but underneath, soil microbes are kept fed, sheltered and warm enough to continue digestion and growth. Do not disturb them with any tillage or other soil intrusion. Annual maintenance is simple — add a new stack of layers, usually in fall, to mimic how Nature builds soil by recycling layers of biomass, dust and enrichments (like migrating herds or fire). After this initial loading, a well-made lasagna bed stays fertile and productive for many years, but much lighter annual doses of minerals can be added. Rock minerals digest slowly, and deliver a long-term fertility that easily lasts a decade — longer if intelligently managed. Just a few lasagna beds are so productive they easily (in every sense) deliver enough vegetables for a large family.
Biochar in Temperate Agricultural Soils

Excerpted by Jack Kittredge from a paper by Margiana Petersen-Rockney

Introduction and Background

As the world’s population rises, people will continue to put more pressure on their terrestrial landscapes in order to extract food, fiber, and fuel to meet their growing needs. At the same time that population growth is the need for more efficient agricultural land use the climate is changing and land degradation is an increasing problem. In the industrialized world, modern agriculture relies on heavy chemical inputs that create pollution problems in our waterways and our air. Carbon dioxide, methane, and nitrous oxide are byproducts of modern agriculture that exacerbate climate change. In the third world many do not have access to the expensive chemical inputs of modern agriculture and thus rely on ‘slash and burn’ techniques. These practices volatilize most of the nutrients accumulated in biomass and cause air quality concerns. Alternatively, farmers may incorporate organic wastes that have short residence times in soil, thereby releasing large amounts of methane and other greenhouse gasses as they decompose. In both systems of agricultural production, nutrient cycles are very leaky with nutrients entering the system via crop removal.

Agricultural systems are thus faced with two problems. They are in constant need of nutrient additions, while simultaneously leaky nutrient cycles cause nutrient overabundance elsewhere. In the case of carbon, agricultural soils no longer store nearly as much carbon as undisturbed soils. After conversion to agriculture, soils lose 89% of their stored carbon. Land converted to agriculture thus acts as a carbon source, both directly by releasing stored soil carbon and indirectly by requiring heavy nutrient inputs that release carbon during their production.

In natural ecosystems 90% of soil organic matter turns over in the one to five decades timescales, much of it being very labile.

There are numerous sites, however, among the old and highly weathered tropical Amazon-basin soils where Amazonian Dark Earth, or Terra Preta, is found (see map on page B-10). These Terra Preta soils contain highly stable organic black carbon, or biochar, that was added to the soils by people during the pre-Columbian period, 500-6000 years ago. These dark colored soils have 70% more carbon in them than surrounding soils, and demonstrate unexpectedly low nutrient leaching and high primary productivity, even with extensive agricultural use.

These unusual Amazonian Dark Earth soils often originate in ancient human middens, or trash pits, where the charred organic waste was mixed with other organic soil amendments such as bones and manures. These mixed-waste Terra Mulata soils are also stable on millennial time scales, suggesting that ancient people used biochar along with other organic wastes to convert poor-quality soil into agricultural productive soil that could maintain long-term productivity. There is a clear historic use and benefit of biochar addition to agricultural soils, but the applicability of biochar addition to today’s agricultural systems, especially in temperate regions, is largely unknown.

Biochar Production

Biochar is produced by baking organic materials in the absence of oxygen, a process known as pyrolysis. The resulting biochar is a polycyclic aromatic black carbon and is very stable due to its structure. Pyrolysis of agricultural waste products creates pollution problems in our waterways and our air. Carbon dioxide, methane, and nitrous oxide are byproducts of modern agriculture that exacerbate climate change. In the industrialized world, many do not have access to the expensive chemical inputs of modern agriculture and thus rely on ‘slash and burn’ techniques. These practices volatilize most of the nutrients accumulated in biomass and cause air quality concerns. Alternatively, farmers may incorporate organic wastes that have short residence times in soil, thereby releasing large amounts of methane and other greenhouse gasses as they decompose. In both systems of agricultural production, nutrient cycles are very leaky with nutrients entering the system via crop removal.

Some researchers believe that the best biochar is formed by low temperature pyrolysis at about 500°C, with higher temperature pyrolysis producing a more traditional charcoal. Five hundred degrees C seems to be high enough to achieve maximal surface area but also low enough to retain some bio-oil.

Biochar is a term used to describe any organic waste that has undergone the pyrolysis process. The specific physical and chemical composition of biochar depends on the starting material it was made from. All biochars are part of the same aromatic ring structure that have high surface areas and porous structures. The addition of biochar affects physical properties of soil texture, structure, porosity, particle size, distribution and density that alter the movement of air, water, microorganisms, and roots through the soil. Additions of biochar increase the soil’s cation exchange capacity and provide protection for many living organisms in the soil, such as mycorrhizal fungi that can intercept leachable nutrients. Thus, biochar can act to hold nutrients in soil chemically, physically, and biologically. Biochar thus offers three attractive benefits. First, it can sequester carbon in agricultural systems better than any other agriculture because the recalcitrant form of carbon remains in soils for thousands of years. Second, energy can be harvested during the pyrolysis process. Third, biochar can improve agricultural soil through its beneficial chemical and physical properties. This article will focus on the benefits that biochar can provide to agricultural soils, specifically how it affects the availability of nitrogen in temperate agricultural systems.

Nitrogen

Nitrogen is one of the nutrients that most often limits primary production in ecosystems. Recently disturbed sites, such as those cleared for agriculture or subject to burning, are especially nitrogen limited. Biochar, however, has great potential to be used as a soil amendment in temperate agriculture and of particular interest are the effects biochar addition has had on nitrogen cycling. From the limited scientific research that has been conducted on the effects of biochar on nitrogen there is general agreement that it offers a three-pronged benefit to soil nitrogen.

Biochar additions (1) increase plant-use efficiency of nitrogen, (2) decrease leaching of nitrogen, and (3) decrease nitrous oxide emissions from soil. In addition, biochar appears to alter the microbial community, favoring fungi, and thus providing opportunities to manipulate nutrient cycling through altering the microbial mediators of those nutrients.

Biochar’s three observed benefits to soil nitrogen may be explained by its ability to increase cation exchange capacity in soil, enabling soil to hold on to nutrients for long-term plant growth. By increasing the soil’s ability to hold on to available nitrogen, biochar can reduce nitrogen losses from the system from ammonium leaching and nitrous oxide emissions. Biochar’s physical structure, rich in microsites, coupled with its cation exchange benefits that help hold nutrients in the soil for future plant use favor a microbial community dominated by fungi and rhizobial bacteria that capture and store more carbon and nitrogen. Thus, biochar simultaneously increases carbon storage and nitrogen directly available for plant use.

Biochar temperature versus characteristics

Some researchers believe that the best biochar is formed by low temperature pyrolysis at about 500°C, with higher temperature pyrolysis producing a more traditional charcoal. Five hundred degrees C seems to be high enough to achieve maximal surface area but also low enough to retain some bio-oil condensate. Credits: Temperature effects on carbon recovery, CDC, pH and surface area, Lehmann (2007), Front. Ecol. Environ. 5:381-397.

Structure of Biochar

Biochar’s physical structure increases the ability of soil to retain moisture, while simultaneously increasing porosity and permeability that allows excess water to move through the soil. This favors aerobic microorganisms as opposed to denitrifying bacteria that can produce nitrous oxide. Biochar porosity also offers habitat for microbes that aid in making nutrients available to plants. Thus, a unified understanding of how biochar benefits soil nitrogen chemically, physically, and biologically can help us understand the interactions between these factors and mechanisms.

Some studies find that biochar additions alone can increase production, likely due to its ability to absorb and retain water. Biochar additions alone to temperate rice fields in China showed yield increases of 15%, likely due to its water-holding ability. The greatest benefit, however, is in the addition of biochar alongside fertilizers. One study examined the effects of biochar additions on barley yield alongside different amounts of nitrogen fertilizer. Researchers found that additions of biochar with nitrogen fertilizer could increase barley yields by 30% above nitrogen fertilizer alone. Another field study highlighted the role of biochar in increasing nitrogen fertilizer use efficiency. This field study found that coupled biochar and fertilizer additions produced higher yields of radishes than nitrogen fertilization alone.

One laboratory study measured nutrient losses in three different soils from the US Midwest amended with poultry manure with varying amounts of biochar. As biochar rates increased, the amount of N, P, Mg, and Si leached from the soil decreased, even though the biochar itself contained ‘sequestered’ additions of these elements. Over their 45 week trial, even at the low biochar addition rate of 20 g/ kg soil, total nitrogen and phosphorus leaching decreased by 11% and 99%, respectively. These results suggest that biochar additions to productive Midwest soils could help manage nutrient leaching problems.

These studies provide encouraging evidence that biochar can be used as an additive in current conventional and organic agricultural practices.
in order to increase the use-efficiency of nutrient addition. Some of these studies were short-term experiments, however, conducted in laboratory settings, and thus do not include all of the varied conditions that can affect processes in the field.

Microbes and Biochar

The increased surface area, microsites, and soil structure that biochar provides create environments from which microorganisms can benefit. Surprisingly, the initial addition of biochar can reduce microbial activity, at least in laboratory experiments, while in general biochar additions increase long-term microbial activity. The initial decline in microbial activity followed by a long-term increase may be explained by shifting community dynamics. The original microbial community in highly fertilized agricultural systems is likely dominated by copiotrophs (organisms which predominate in nutrient-rich environments), which may decline when biochar is added to the soil, binding available nutrients in cation exchange and changing the physical properties of the soil. The replacement community may be more oligotrophic (capable of surviving where there is little to sustain life) and competitive when leachable nutrients are less readily available.

The microsites of biochar are particularly favored by mycorrhizal fungi, which form symbiotic relationships with plants and help extract nutrients and water for the plant in exchange for photosynthesized carbon compounds. The fungal hyphae of these mycorrhizas intersect leachable nutrients and thus we observe significantly lower nutrient losses when biochar is added to agricultural land. Fungal dominated soils generally store more carbon than bacterial dominated soils. Biochar’s ability to favor fungi may serve as an additional mechanism by which biochar can increase the carbon-storing capacity of soils and thus even offer humans a tool by which to manipulate microbial communities and carbon storage. Additionally, the fact that microorganisms create soil aggregates may provide an explanation of the observed increase in soil structure found in soils amended with biochar applications.

One of the key microorganisms in the soil is the group of Rhizobium spp bacteria that fix atmospheric nitrogen into bioavailable forms and develop symbiotic relationships with plants. One study found that at maximum nodule development alfalfa amended with biochar in field experiments had 227% greater nitrogen than plots without biochar additions. It appears that biochar stimulates biological nitrogen fixation, and can thus directly alter nitrogen addition to soils by altering the microbial community.

Differences in Biochars

Not all biochar is the same. The way it is made can strongly affect the end biochar. The temperature at which pyrolysis occurs also shapes the end product. In general, as the temperature of pyrolysis increases, the yield of biochar decreases. As the organic material is heated to create biochar, many compounds volatilize, leaving only the most recalcitrant material such as aromatic hydrocarbons.
and basic elements. Nitrogen is one of the first materials to volatilize at about 200˚ K (Kelvin or -73˚ C). Researchers have found that the higher the temperature of pyrolysis, the greater the loss of nitrogen relative to the starting material. It is clear that not all of an element volatilizes at a certain temperature. Biochar made from sewage at 450˚ K (177˚ C) still contained 50% of its original nitrogen and all of its phosphorus, though not in bioavailable forms. A study that examined the amount of the elements P, K, Ca, and Mg in biochars produced at 400˚ C and 500˚ C found that the slightly higher temperature acted to concentrate these elements. Thus, it is clear that the temperature at which pyrolysis occurs has a huge effect on what materials remain in the biochar. Additionally, the form of the nutrients found in the original material affects what elements will remain in the biochar product. In general, biochar produced under low-temperature pyrolysis yields a greater quantity of material that is more labile and has a shorter residence time in soils. Biochar produced at high temperatures, however, is more recalcitrant with a longer resident time in soil.

The temperature at which biochar is formed can also affect its pH. Higher pyrolysis temperatures lead to biochars with higher pH. There is potential for biochar to provide a service to soils by increasing the pH of agricultural soils that have a low pH (often because of long-term inputs of nitrogen fertilizer and acid rain). Changing the buffering effect of biochar through its pyrolysis process is one way that biochar could be created for a specific agricultural use to mitigate a specific agricultural soil problem.

The starting organic material for biochar can also have a large effect on the end product, as well as the conditions under which it is formed. The starting feedstocks (shaded circles) and the materials they contain vary in their properties.

Biochars produced from different feedstocks (shaded circles) and at different temperature vary in their properties.

Credit: http://www.soilquality.org.au/factsheets/biochar-for-agronomic-improvement

Biochar variability graph

Biochars for C sequestration
Biochars for productivity
Nutrient/mineral content
Biological stability


Initial relationships of the starting materials will correlate strongly with the end product. One study measured the element contents of biochars made from different substrates. It found that the final carbon content ranged from 40% in biochar made from poultry litter to 78% in biochar made from pine chips. Interestingly, the amount of nitrogen conserved in the biochar was inversely proportional to the source material nitrogen, with poultry litter and pine chip biochars conserving 24.7% and 89.6% of their starting nitrogen respectively. Additionally, the moisture and lignin content will affect the...
Another way that biochar can aid in nutrient retention is to be added to decomposing materials as a bulking agent before they are composted and applied to fields. In one comparative study scientists mixed poultry manure in a 1:1 ratio with biochar, coffee husk, and sawdust respectively. They found that despite the inert nature of biochar, the biochar manure mixture underwent the highest level of humification of the three trials. The conversion of organic matter to humus (70% in this study) marked the transformation of labile organic matter to more recalcitrant humic acids that have a long-term soil improvement benefit. Thus, biochar appears to have acted as a catalyst by aiding in the transformation of labile organic matter to recalcitrant humus. Other studies have also demonstrated the ability of biochar to enhance the nutrient status of the compost products and reduce nitrogen losses during decomposition of organic matter. While this was a short-term study, it demonstrates how biochar can help enrich the long-term recalcitrance of organic matter in soils.

Biochar can also aid in the retention of nitrogen in the soil through reducing nitrous oxide emissions. Soil nitrous oxide emissions are primarily a function of moisture content and tillage regime in agricultural soils. Biochar alters the physical location of water within the soil matrix by providing increased surface area, porosity, and a more developed soil structure. Denitrifying bacteria produce nitrous oxide in low oxygen conditions, such as waterlogged soil, as a leaky product along the pathway to forming atmospheric nitrogen (N2). Biochar additions in rice fields in China decreased nitrous oxide emissions in nitrogen fertilized fields by 40-51% and in unfertilized fields by 21-28%. This same study found that biochar significantly increased rice yields and reduced methane emissions by as much as 41%. This is significant, as rice cultivation is notorious for emitting greenhouse gases from the soil and biochar significantly reduced the emission factor of nitrogen fertilizer in this conventional cultivation system. In addition rice is a major food staple for much of the world, especially the developing world where agriculture will need to be intensified and more efficient in the future in order to feed growing populations.

Cost

Biochar is expensive to manufacture at large scales such as those needed to sequester considerable amounts of carbon, and requires considerable infrastructure to do so. For the near future, biochar will most likely be created for small-scale agricultural benefits. Even small amounts of biochar additions to soils have been demonstrated to provide real and significant benefits. Small-scale biochar additions incorporated into the rooting zone of plants can help retain phosphate, ammonium, water, and microorganisms that can help rebuild organic matter stocks quickly in denuded landscapes and low-yield agricultural land. Biochar has a particular appeal for small-scale subsistence farmers who can benefit economically and socially from improving their land for the long-term gains that are not often seen at the forefront of corporate farming interests. Such long-term, small-scale experiments provide the greatest benefits for the lowest cost and are a starting point for biochar use.

In order for broader scale applications of biochar to be feasible, for example on industrial farms, production will have to be cheaper. Currently, production costs, infrastructure costs, and transportation costs of such a high bulk-density product, as well as the health hazards that dusty materials pose, make the industrial application of biochar infeasible. Some investigators suggest that biochar could be manufactured into a pelletized product that can be transported easily. They also conclude that if pyrolysis occurs at 550° K or less no crystalline materials form and thus there is little health hazard associated with breathing biochar dust during use. Some argue that, given the political and economic will to sequester carbon, biochar may become a cost-effective way to do so. Whether the broader-scale application of biochar to terrestrial ecosystems is driven by the need to sequester carbon or the need to improve agricultural soils, it will provide multiple benefits to soils and communities across the globe.

One chief concern with biofuels and biochar is where the organic substrate material will come from. With growing populations there are increasing pressures on terrestrial ecosystems. Often biofuels are grown on former food cropland, or are made directly from food crops. But biochar can be made from any organic waste material and is a good way to turn crop residues and long-term soil improvements. Crop residues can be charred (pyrolysed) and added back to the soil in agricultural systems. In addition, forestry waste could be charred and added to forest ecosystems, thus providing a ‘slash and burn’ system for creating agricultural land that has the ability to sustain long-term production. Abandoned and denuded agricultural land also has the possibility to be improved and reclaimed as productive cropland through ‘slash and char’ biochar addition. Though biochar can offer a more sustainable way to clear land for agricultural growth, biochar ought to first and foremost be applied to existing agricultural land for its ability to increase yields and nutrient use efficiency. In addition, there is great potential for biochar to increase the carbon storage ability of any terrestrial ecosystem through its ability to tighten leaky nitrogen cycles in agricultural soils and make nitrogen more available to plants.

One of the great difficulties in better understanding biochar is that there are so many factors that affect its characteristics. Biochar is not one substance, but a family of black carbons that each affect its characteristics. Biochar is not one pyrolysis process and thus the biochar product. For example, due to the high lignin content in nutshells, biochar from nutshell wastes has a higher surface area and more developed micropore structure than many other organic agricultural wastes.

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Biochar: a Critical View Through the Ecosystemic Lens

by Karl North

I have been following the biochar story since it began to gain visibility over a decade ago. I view it from the perspective of forty years of farming informed by study of systems ecology. I began to study ecology in a unique graduate program in anthropology that regarded the knowledge of a society as incomplete without an understanding of its ecological foundation. I still saw the study of ecosystems, however, as one field of knowledge among others. Gradually I have come to see it as the master or umbrella discipline, one that provides an essential framework for all other inquiry.

Similarly, in farming I first saw the enterprise I was creating as sheep farming. As the wellbeing of my sheep and draft horses was heavily reliant on the health and productivity of perennial grasses, it began to make more sense to think of the enterprise as grass farming. But as forage quality and productivity in turn depend on the state of the soil and its food web, I ultimately came to see myself as a carbon farmer, as it became increasingly apparent what an important role the level of soil organic matter (and its carbon) plays in the fitness and success of the farm as an agroecosystem. Others have experienced this evolution, and now there exist increasing numbers of self-proclaimed carbon farmers, for whom a central question is to design a farming system that insures the best regeneration of soil carbon.

Getting past the Greenwash

Given the background described above, it should not surprise the reader to learn that I have tended to approach the subject critically with the habitual skepticism that is or once was part of a living thing (any substance that is or once was part of a living thing) by pyrolysis, which is oxygen-starved combustion, a rather violent process by comparison with the ways biomass is decomposed in most ecosystemic cycling. I am using the term biochar in this article only because that is how the general public recognizes it. A more neutral term used in the scientific literature is black carbon.

A lengthy review of the literature on the subject only tended to confirm my skepticism. Currently it is mostly blatant promotion – garden variety advertising; I could find few attempts to view the subject critically with the habitual skepticism necessary to scientific appraisal. A common kind of statement is the following, which appeared recently in a peer reviewed journal: “Biochar is increasingly being recognized by scientists and policy makers for its potential role in carbon sequestration, reducing greenhouse gas emissions, renewable energy, waste mitigation, and as a soil amendment.” As the biochar feeding frenzy has reached new heights, even the scientific papers tend to begin on a promotional tone, with just enough ambiguity in the language to cover for the caveats buried deep in the studies. For example, Biochar is often described as if it were a fertilizer. A website of Cornell University, a hot spot of biochar research, postulates “the soil fertility benefits of biochar”. To the lay reader that carries the implication that it is a fertilizer. The fact that biochar is not a fertilizer and makes little direct contribution to soil fertility is often buried deep in the scientific literature.

Again for the lay reader, the literature also tends to confuse biochar with terra preta/dark earth by using the properties of the latter to promote the former. The properties of earth darkened with carbon from any source are the result of a complex systemic process of interaction between the carbon and the other soil constituents over a long time frame; they vary in the extreme with the nature of a specific soil and climate and cannot be deduced from the properties of charcoal alone or in a short term laboratory trial.

Stoked by the desire to defy the limits to growth on a finite planet, the business-oriented literature is also full of glowing expectations that biochar production will deliver yet another agro-fuel to replace fossil fuels as the end of cheap oil starts to bite into the global economy. Given the disastrous boondoggle from corn ethanol and soy diesel, production of which steals land from food production and exists only with the prop of massive subsidies because...
it can never deliver any appreciable net energy, it is surprising that anyone has the nerve to suggest another agrofuel project.

Finally, the treatment of this subject, as with most others, suffers from the narrow focus of the dominant reductionist way of doing science. Big questions like sustainability and climate dynamics require a systemic approach. I could find few attempts in the literature to compare biochar use with alternative solutions, or to make the full life cycle energy calculations necessary to any investigation of energy production or consumption in complex systems like ecosystems and human economies.

In this article I will address the following claims of the biochar promoters:

1. Biochar has the unique ability to indirectly enhance soil fertility by encouraging the growth of soil microbial populations and store and retain plant nutrients.
2. It is more stable than more naturally occurring carbonaceous compounds, and therefore a better option for sequestration to mitigate climate change.
3. Some of the gaseous byproducts of biochar production could replace fossil fuel use, also mitigating climate change.

I will demonstrate that the first claim, while true, is misleading because it ignores other, better ways of providing the same benefits. Regarding the second claim, while the relative stability of biochar appears true, I will show that properly designed agroecosystems can achieve the same carbon sequestration results while better serving overall system health and productivity. Regarding the third claim, I will argue that while pyrolysis produces burnable methane, so do other less violent processes. Moreover, like all energy alternatives, it will fail to reduce fossil fuel use due to the Jevons paradox. (The Jevons paradox occurs when the price of a resource still rises because of increasing demand.) As with all attempts to produce biofuels, whether the consequences for society and the planet are good or bad depends greatly on the choice of biomass feedstock and where it comes from. As I will argue, there are no biochar feedstocks produced in any ecosystem on the planet whose massive extraproduction would not damage the normal, necessary function of the carbon cycle in that ecosystem. Unless, of course, one is counting on sourcing them from Mars.

**Seeing the issue through the ecosystemic lens**

The ecosystemic lens is the worldview that frames all inquiry in terms of the dynamics and health of the ecosystem processes. The health of these processes and obedience to their laws are essential to the long-term survival of all species within the system, including us. Although we have been led to believe since the Book of Genesis that Nature is our plaything, Nature rules us, not the other way around.

Using the ecosystemic lens, students of ecosystems soon realize and must come to terms with the complexity of our environment, which derives from the interaction and interdependence of so many of its parts. Within ecosystemic wholes they see further layers of complexity: social wholes and organisms, especially ours. They discover that there is no simple answer to any problem because all problems are ultimately connected and consequences of actions are multiple. They realize that when intervening in complex systems, one can never do just one thing! There are always ripple effects, and consequences distant in space or time are commonly far different from immediate ones. In my view a critical assessment of any human activity or technology needs to be undertaken through the ecosystemic lens. That is how I intend to explore the question of biochar.

Farmers who see agriculture in an agroecological framework know that the health of ecosystem processes includes proper carbon and other mineral cycling. The biochar literature consistently refers to biochar feedstocks as “wastes” or “residues”, a first tip-off of the narrow unecological lens through which promoters are viewing the subject.

I still remember hearing sustainability pioneer William McDonough in a keynote address to the Pennsylvania Association for Sustainable Agriculture years ago stating, “There’s no such thing as waste!” Ecosystems, whether managed or natural, must follow the “law” of the ecosystem food web: waste=food=waste=food. The level of ecosystem health and sustainability depends on how well this law is obeyed. In the language of systems ecology, there exists a mineral/nutrient cycle that must not fail or be broken, and if possible must be enhanced.

1. **Biochar has the unique ability to indirectly enhance soil fertility by encouraging the growth of soil microbial populations and store and retain plant nutrients.**

The main trouble with this claim is not with the truth of the functions of black carbon in the soil, but with the claim of uniqueness of biochar to serve these functions. A typical statement in a peer-reviewed journal is: “The application of biochar (charcoal or biomass-derived black carbon (C)) to soil is proposed as a novel [my italics] approach to establish a significant, long-term, sink for atmospheric carbon dioxide in terrestrial ecosystems.” It should not be necessary to remind readers of The Natural Farmer that ways of getting soil carbon up to optimal levels and keeping it there are hardly new.

There exist numerous ways to get black carbon into the soil and keep it there. The biochar literature, however, rarely considers these other ways of obtaining dark earth and its benefits. Hence, what is worse, it rarely compares them to its favorite, biochar production, an industrial process that occurs outside the agroecosystem. So let’s do the comparison.

From the viewpoint of conventional chemical fertilization – soluble salt fertilizers that can contain...
as much as 40% of N, P or K – neither compost nor pyrolysis rate as fertilizers. Both processes lose nutrients, especially nitrogen and carbon. Figures vary in the scholarly studies, so the following are some purely illustrative figures from different studies and compare nutrient retention in the two processes:

a. Composting: high C/N ratios obtained using deep litter bedding limit N losses to 12–18%, and losses can go as low as 5%. C losses range from a high of about 40% - same as in pyrolysis – down to 19%, depending on how well the compost is made.

b. Pyrolysis: N losses ranged from 10.4% to 72.6% depending on the N concentration in the feedstock. The higher the N concentration vs. C, the higher the loss. “The amount of N converted to CO₂ in the PL biochar was 89.6% in the PC biochar and was inversely proportional to the feedstock C concentration.” PC and PL refer to different feedstocks.

Unlike pyrolysis (a chemical process), composting is a biological process, a version of carbon cycling time-tested through several billion years of natural history. Once brought to full potential, as in the US, these systems can be permanent, barring disturbance – natural ones like landslides or erosive floods or man-made ones like tillage. In the US Northeast these levels commonly attain 5-6% soil organic matter (SOM).

Based on this ecosystemic knowledge, the well-known 30 year project of organic farming research pioneer, Rodale Institute, demonstrated that a combination of animal integration, legume-based forage rotations, cover-cropping and herbicide-free tillage, along with crop rotation, even improve on natural SOM levels in the Northeast and quicken the process. And regarding the carbon sequestration potential of their system, Rodale concluded, “Simply put, recent data from farming systems and pasture trials around the globe show that we could sequester more than 100% of current annual CO₂ emissions with a switch to widely available and inexpensive organic management practices, which we term “regenerative organic agriculture.” These practices work to maximize carbon fixation while minimizing the loss of that carbon once returned to the soil, reversing the greenhouse effect.”

The work of two holistic scientists, French farmer-researcher André Voisin and range ecologist Alan Savory highlights many points from natural ecosystems to bear, and demonstrated systems that accelerated the ability of Rodale’s methods to regenerate soil even more, permanently raising soil carbon levels in the same way.

Unfortunately, most US readers of Grass Productivity, Voisin’s chef d’oeuvre, absorbed only the rotational grazing component of the effort toward healthy agroecosystem design that his title implies. Using long term studies from different European farming systems, Voisin showed that a combination of animal integration, legume-based feed, annual CO₂ emissions, and pasture trials around the globe show that we could sequester more than 100% of current annual CO₂ emissions with a switch to widely available and inexpensive organic management practices, which we term “regenerative organic agriculture.” These practices work to maximize carbon fixation while minimizing the loss of that carbon once returned to the soil, reversing the greenhouse effect.’

As already mentioned, pyrolysis also destroys some of the nutrient-value in the biomass feedstock. Even at the lowest temperature adopted recently in the production of biochar, 50% of the nitrogen in the biomass can be lost. Compare that with well-made (high C/N ratio) compost that can retain larger quantities of nitrogen.

Also, a trade-off exists between fuel and biochar production. Pyrolysis produces a greater quantity of fuel at lower temperatures and more biofuel production at higher temperatures. The same process cannot maximize both.

In the evaluation of any complex production process through the ecosystemic lens, a full life cycle calculation is called for, not only of energy and carbon outcomes, but all other short and long term effects on the health of larger systemic wholes. I found only one such evaluation of pyrolysis in the biology literature – the above illustration from Roberts, K., et al., 2010. Life Cycle Assessment of Biochar Production: estimating the energetic, economic and climate change potential. Environmental Science and Technology, Vol. 44 (2), Pp. 827-833

Yet even this attempt is flawed: Where in this picture is the 40% of CO₂ in the biomass feedstock captured as the atmosphere as greenhouse gas during pyrolysis?

The real agenda of the business community for biochar seems to be the creation of yet another agrofuel boondoggle, dressed up in the green garb of carbon sequestration to save the climate. The capture of fuel gases as a byproduct of pyrolysis will not scale up to any significant degree without further expropriating agricultural land, especially in less developed countries. Already the activists and critics who exposed the disastrous consequences, particularly for the less developed world, of the corn ethanol and other agrofuel projects, are exposing attempts at land grabs for the harvest of biomass feedstocks in the global south for industrial scale pyrolysis and fuel production.

A paper entitled “Land Grabs for Biochar” describes “carbon grabs” as one of the most recent forms of land grab being resisted by the less developed countries, partly because it “threatens a re-run of ‘biofuels vs. food’ controversies and resource appropriations, yet with a new twist as carbon grabs for other biofuels and for biofuel feedstocks threaten to compete with each other too. NGO activists and African governments alike have seized on the land grab spectre to mount vociferous critiques of biochar as a whole.” To what degree that “spectre” will fulfill itself is unclear due to many variables, not least the grinding to a halt of the industrial civilization juggernaut as scarcity looms for its main energy source, oil.
Dynamics of a Hypothetical Sustainable System

There exists one method of biofuel production that, unlike biochar, returns a large amount of mineral fertility as a soil amendment, and can be designed to serve useful functions as an integral part of an agroecosystem when kept small in scale. Anaerobic digesters small and simple enough to have seen wide adoption in peasant communities on several continents produce enough methane for families to cook and light with, and fit well into the carbon cycle of farms that produce wet manures such as from pigs, poultry, and humans. Above is an example of such a design.

Part of the hype of biochar promotion is its proposed provision of carbon credits. As one scholarly paper states, “Bio-char soil management systems can deliver tradable C emissions reduction, and C sequestered is easily accountable, and verifiable.” This too is surprising in a scientific paper, because carbon trading has been exposed for years as a scam used by big business to greenwash itself while allowing it to continue to pollute.

What seekers of alternate energy sources fail to understand is that the present excessive level of energy consumption is the problem. It inevitably entails the resource depletion and damage to essential ecological services that have initiated catabolic collapse of industrial civilization and the way of life it supports. Resource analyst Tim Murray conveys well the meaning of the limits to growth in his blog, Canada the Sinking Lifeboat: “The greatest calamity that could ever be inflicted on human and non-human species alike would be the discovery of an abundant, cheap and perpetual energy source, or unlimited availability of cheap food and universal and uninhibited access to plentiful water supplies.” Those who fight off the fog of denial and willful ignorance that currently blankets most of humanity know that to end the suicidal industrial destruction of the planetary resource base, we need to “power down”, not try to replace current energy sources with others.

Niche uses for biochar

Arguably there exist niche uses for biochar in less developed countries where most cooking is done by burning biomass. Cookstoves designed by Worldstove for less developed countries are an example. They burn the combustible gases from pyrolysis to cook, leaving biochar instead of ash for the soil. If biochar claims are true, the long-term benefits of charcoal are potentially better than ash as a soil amendment. Biochar cookers have tradeoffs and limitations: hot burning stoves reduce particulate air pollution and cook faster but leave less biochar. Cookstoves that use pyrolysis produce biochar but cook more slowly and still smoke somewhat. Better cooking solutions than biochar cookers exist, however. Solar cookers use simple technology and materials, directly address forest depletion, and eliminate biomass burning and its pollution and soil carbon loss entirely.

Biochar also has been proposed as a transitional stop-gap measure. Many areas of production in industrial society are chewing through the global natural resource base at a rate that is unsustainable for much longer. But as long as their termination is not politically feasible, conversion and sequestration of their byproducts (termed “wastes” in the language...
of the ecologically uninformed) as charcoal makes some sense. Low temperature pyrolysis of papermill byproducts is an example.

Conclusion

Apart from the major objections described above, the truth of the claimed benefits to agriculture from biochar application is far from proven. According to one review of the literature, “Fifty percent of the reviewed studies reported yield increases after black carbon or biochar additions, with the remainder of the studies reporting alarming decreases to no significant differences.” Also, in a German comparison of plant growth with pure compost vs. a mixture of compost and biochar, the pure compost trial came out ahead.

Digging deep into one scientific paper I found a long list of sustainability criteria that pose obstacles to adoption.

“Biochar can be produced sustainably or unsustainably. Our criteria for sustainable biochar production require that biomass procured from agricultural and silvicultural residues be extracted at a rate and in a manner that does not cause soil erosion or soil degradation; crop residues currently in use as animal fodder not be used as biochar feedstock; minimal carbon debt be incurred from land-use change or use of feedstocks with a long life expectancy; no new lands be converted into biomass production and no agricultural land be taken out of food production; no biomass wastes that have a high probability of contamination, which would be detrimental to agricultural soils, be used; and biomass crop production be limited to production on abandoned agricultural land that has not subsequently been converted to pasture, forest or other uses. We further require that biochar be manufactured using modern technology that eliminates soot, CH\(_4\) and N\(_2\)O emissions while recovering some of the energy released during the pyrolysis process for subsequent use.”

In sum, the biochar fad seems to be one more of the increasing number of wishful attempts to prolong the inevitable decline of the industrial way of life. Biochar is promoted as one more technological silver bullet. Seen through the ecosystemic lens, silver bullets don’t exist. Seen through the ecosystemic lens, we do not have a shortage of anything, we have a longage of expectations.
The New Horse-Powered Farm: Tools and Systems for the Small-Scale Sustainable Market Grower
by Stephen Leslie
published by Chelsea Green, 2013, www.chelseagreen.com
$39.99, Paperback, 320 pages
review by Eli Rubin

While there are many books about the history of draft horse farming in the past, this 320 page book is about the practical application of farming with horses today. Intended for the organic, or ecologically minded, grower this book covers more than the basics of growing crops, with over 100 pages on market vegetables. The author draws both from his own experience of over 20 years of growing organic produce and from a collection of other respected minds in the fields. The result is a beautiful blend of information from farms (mostly in the northeast) each with their own way of solving the riddles of commercial organic production, all compiled and told in one concise voice.

This book covers the ins and outs of draft horses in agriculture -- from the history of the species, to diet and health, to training methods, to specifics of driving both in the rows and in the field. About a third of the book is specifically for the farmer interested in working horses. Another third of the book is devoted to the general how-to of farming. Four farms tracked all horse related expenses and the hours in which horses were used to calculate the dollars per hour it costs to use a horse, and the yearly horse expense. Also included are the income statements of the four farms. This section is an immensely useful tool for anyone who is actively farming with horses or for anyone who is thinking about farming with horses.

Laid out in an easy to access format, you'll find yourself consulting this book both during those hot July afternoons while making adjustments to your cultivator in the shop, and on cold February nights while inside with pen, paper and calculator, planning out your bed spacing and potato yields.

Defending Beef: The Case for Sustainable Meat Production
The Manifesto of an Environmental Lawyer and Vegetarian Turned Cattle Rancher
by Nicolette Hahn Niman
$19.95, paperback
review by Lucia Stout Huebner, grass farmer, Beechtree Farm, Hopewell, New Jersey

The question of how meat is raised deserves much more discussion and examination. A lucid writer and a thorough researcher, Nicolette Hahn Niman’s 241 page book serves both as an excellent nonfiction reading and reference book on the subject of raising cattle and eating beef. The footnotes she includes on each chapter are worth the price of the book alone. Niman delves into the science behind her arguments but also weaves in her personal voice, which holds the reader’s attention and keeps the subject from becoming too dry.

Niman examines every aspect of the subject of beef: climate change, overgrazing, water use, biodiversity, the important relationship between livestock and people, health issues and why beef is good food. She debunks the myth that cattle are a primary source of global warming while exposing the problems associated with raising cattle in CAFO’s (Concentrated Animal Feeding Operations).

I especially enjoyed her discussion on the effect of grazing animals on soils, the importance of grasslands and the symbiotic relationship that grazing animals have on the environment. “These days it is often suggested that an important step toward correcting past missteps in agriculture would be reducing or removing animals – especially cattle and other grazing animals – from the world’s food system. But as the previous discussion on carbon sequestration, soil, water and biodiversity have illustrated, that would be moving in exactly the wrong direction. Humanity’s greatest agricultural misdeeds have been carried out not with grazing animals but by ripping asunder the earth’s dense protective plant cover.”

In Defending Beef, Niman also clarifies the vast health difference between beef raised on pasture versus raised on grain in CAFOs. It makes no sense for our government to subsidize corn and sugar that lead to chronic health problems, including obesity and diabetes. Kudos to Niman for challenging this perverted and nonsensical system.

Book Reviews
Niman’s voice as a vegetarian turned cattle raiser is an interesting counter to his dependence on conventional grain crops. He is very clear about the differences between animals raised on pasture versus in a factory and sets out specific goals that would make for a huge difference in improving our present detrimental system of livestock production. She also thoroughly covers why grassased meat is such good food.

Niman’s comprehensive examination of raising and consuming beef has already been a great help to me as a grassfed beef farmer. This spring our local adult school invited me to give a short course on grassfed beef. The school received an angry letter from a woman who vigorously objected to the topic. I was very grateful to recommend Niman’s book in my reply to this correspondent knowing that Niman’s arguments were backed up by facts and good science. It helped me to help pursue a reasonable dialogue with this person. Also recently, a friend asked for advice on how to explain to a church leader about the difference between how meat is raised and why this is important. Again I referenced Defending Beef with confidence. This is an excellent book both for people like myself who are producing grassfed beef as well as those who wish to be better informed about the food they eat.

Defending Beef is a book that will remain on my shelf through many vigorous book purges.

Resilient Agriculture: Cultivating Food Systems for a Changing Climate
by Laura Lengnick,
New Society Publishers, BC, Canada, 2015
The New Peasantries: Struggle for Autonomy and Sustainability in an Era of Empire and Globalization
by Jan Douve van der Ploeg
review by Elizabeth Henderson

How are we going to manage to farm in the increasingly chaney conditions of global warming and advanced imperialist capitalism? We are bombarded by products, causes, marketing schemes and advice. How to choose? Here are two books that will help you design or redesign your farm to make it more resilient in these parlous times. Lengnick’s book suggests a method for resilience planning based on climate change predictions and the experience of sustainable farmers. Van der Ploeg provides principles and values from the lives of peasant farmers to ground your decisions.

Laura Lengnick based Resilient Agriculture on interviews with 25 farmers who have been at it for 25 years or more. She emphasizes that these farmers have succeeded in changing their local food systems despite significant barriers without government support, crop insurance, tax breaks or subsidies and minimal research. Her book takes us around the country, providing data on how experts predict climate change will happen in each region as well as those who wish to be better informed about the food they eat.

Using examples from the case study farms, Lengnick derives her insights from design criteria and pairs them with the sustainable agriculture practices that bring them to life. She also suggests indicators drawn from basic ecological processes – “energy flow, water and nutrient cycling, and community interactions” – that a farmer can use to measure progress. (See her chart on pp. 286–7). By carefully managing the biological resources on our farms and working with nature, Lengnick demonstrates that farmers can adopt strategies “that focus on conserving, restoring and using the climate protection services of ecosystems to reduce climate change vulnerability of natural and human-dominated landscapes.” An ecosystems approach to adaption can fulfill objectives for both mitigation and adaptation to climate change, as well as build the foundation for long-term community sustainability and resilience.

Her analysis of the most promising practices is truly affirming for NOFA farmers and homesteaders; she writes that “the adaptive capacity of sustainable models of production arises from the management of smaller land holdings (typically owned), production inputs produced by healthy soils and agrobiodiversity (e.g., natural precipitation, crop nutrients released by soil microorganisms, and biological suppression by beneficial insects) and social capital (e.g., direct markets, community-based research and education) to produce high-value food products that are well adapted to local resource conditions.”

In cool, scientific terms the recent growth in direct markets, community-based research and education may be a shrewd observation, backed up by examples, that pursuit of ever greater efficiency, that bugaboo of industrial farming, degrades resilience.

In the great cauldron of ideas that stew in our heads about the farm, mix Resilient Agriculture with New Peasantries to start-fetched to bring in peasants, but I urge you to set aside whatever bias you may have about peasants as backwards and primitive, and focus on what you can learn from land-based people who have survived for millennia. After all, organic farming as most of us know it in the NOFA world, grew out of peasant practices in Europe and America. Sir Albert (one of Rodale’s teachers) and Rudolf Steiner (inspiration for Biodynamics) both studied peasant farming, Sir Albert in India and Rudolf in Austria. Most likely, none of the farmers Laura Lengnick interviewed for her book would identify as peasants, yet the practices they use and the changes they are making on their farms to better adapt to climate change flow from the peasant principles and design ideas as delineated by van der Ploeg.

He highlights peasant emphasis on craft, their own talents and capacities, making choices calculated for long-term results instead of quick profits, less cash and more human effort, working directly with nature, using the resources at hand instead of imported inputs or outside financing. “By slowly improving the quality and productivity of the key resources – land, animals, crops, buildings, irrigation infrastructures – and by means of a meticulous fine-tuning of the process of production and a continuous re-patterning of relations with the outside world, peasants strive for and eventually obtain the means for enlarging their autonomy and improving the resources base of their farms. Unlike us, all too many in our modern world look down on peasants and view peasant work as repetitive and unskilled, van der Ploeg elevates the value of daily work in nature – skill constantly growing through observation and practice. He defines this as co-production – “the ongoing interaction and mutual transformation of man and living nature.” The organic and biodynamic emphasis on the farm as the self-reproducing organism where you reduce outside inputs to the greatest extent possible is a peasant way of patterning.

Most of The New Peasantries is devoted to stories of peasant strategies to work around control by a globalized multinational corporate agribusiness, the forces of what van der Ploeg calls “Empire,” in Latin American, Italy and Holland. No longer does Empire operate by conquest and occupation. Instead, it imposes “sets of generalized rules and parameters” that govern specific local practices. These sets of generalized rules represent the rules of Empire, that is, a world order where you take over once relatively autonomous and self-governed local constellations …and reassembles them in a way that ensures controllability and exploitability. In doing so, it eliminates the local, transforming it into a “non-place”.

To illustrate Empire’s ruthless quest for dominance, he recounts the remarkable story of Frenkala’s attempt to market his “free blue milk,” highly processed milk protein that is not fresh and consists of molecules derived from actual milk.

In this era of corporate dominance, many in NOFA will relate to van der Ploeg’s descriptions of peasant distrust of outside interference, their resistance to both industry and government regulation and adherence to the principle of autonomy, what we call farmer freedom. In his analysis, peasants concentrate on and sometimes defend fiercely the area that they can control: “…the labor process is a very important arena of social struggle for the peasantry.” Social struggle is also to be seen in the sturdy striving to improve available resources, making small adaptations which together contribute to the creation of better, well-being improved income and better prospects. Co-operation is often a key mechanism in this respect.” Though his language is often dense, van der Ploeg’s recognition of everyday actions as acts of resistance underlines the significance of all the little tasks involved in growing and distributing food through direct sales. When consumers support our farms, they join in this resistance and together producers and consumers connect with peasant farmers around the world.

In designing our farms and deciding whether to adopt new technologies or marketing approaches, we would do well to examine the experiences and attitudes of those who have survived the struggles born out of millennia of surviving in hostile environments. In their relations with markets, peasants try to avoid dependency and “to allow for maximum flexibility, fluidity and autonomy.” Trade-offs and compromises are often necessary in the face of the general tendency in the global economy to unequal and deteriorated conditions of sale, rising costs and changing terms of trade. Like peasants, we may do better having a family member work off the farm, or engaging in more “entrepreneurial” marketing, scaling up to sell to larger stores or processors. In analyzing choices, peasant questions would serve us well – Where does it come from? Where will it lead? What are the costs and benefits? Who will reap the fruit? How to expand the wiggle-room for our autonomy? Success is never
This book is about the unsung heroes of agriculture: Predatory insects, spiders and mites. The book is filled with gruesome action shots of bugs eating bugs, just the sort of thing that will inspire you to go out and make habitat for these beneficial insects. Where this book is unique is its sole focus on native beneficial insects (as opposed to the introduced beneficial insects most common commercially), and the tools and tricks needed to increase their population in your own farm or garden. The book pulls examples from large farms and ranches, but also contains sidebars of what this means for home gardens as well. 

Important to note is that the author clearly is not dedicated back yard gardener, or commercial farmer. While the science behind some of the ideas presented here is a little unconvincing with sentences like “at least one study shows”, the ideas themselves are thought provoking and will encourage those of us who face pest pressure to try some new tactics in our repertoire for organic food production. If you are looking for a comprehensive book on the insects you find in your garden, look elsewhere (like Garden Insects of North America, Princeton University press.) But if you are looking for a guide to be a part of the world of the insect ecosystem happening on the underside of the leaves in your garden and in the brush of dead plant residue, this book is a great starting point.

The Lean Farm: How to Minimize Waste, Increase Efficiency, and Maximize Value and Profits with Less Work by Ben Hartman published by Chelsea Green paperback, 2015, 233 pages, $29.95 review by Andy Fellenz

Ben Hartman grew up on a 400 acre farm in Indiana. Together with his wife, one part-time employee and several seasonal interns he operates a profitable 5 acre market farm. In Part 1 of the book Ben Hartman offers up a Lean Farm Start-Up, The Lean Farm, and Lean Farming for Small Farms. This book provides many excellent examples from his farm showing how these same principles and tools can be used to improve manufacturing practices, and shows how these same principles and tools can be used to improve your farm. Lean was introduced to the US and was the subject of numerous popular business books in the late ‘80’s and early ‘90’s. Adapting a system developed to improve automobile manufacturing to farming seems like a stretch, but Ben does a great job showing how the system can work within the context of farming and provides many excellent examples from his farm showing what continuous improvement using Lean Tools looks like and how it will deliver dollars to the bottom line and improve quality of life for the farmer and workers on the farm.

In Part 1 of the book Ben Hartman offers up a set of tools with examples from his farm and other farms that if applied by the reader could radically change their farm’s growing methods, harvest methods, pack shed procedures, greenhouse procedures – truly any aspect of a farm’s operation – and transform it into a much more efficient and profitable enterprise.

Part 2 seems almost like an afterthought with short chapters on a Lean Farm Start-Up, The Lean Farm, and Lean Farming for Small Farms. This book opens with an excellent description of the classic SS program for cleaning up, decluttering, simplifying a work area and standardizing work methods coupled with many examples of the changes that resulted on his farm. This 240 page book could be reworded in 30 pages. The start of the book may discourage you from ever starting your farm. It begins each chapter with an entertaining short story or quote that leads into the subject. It is followed by a chapter on how to improve your farm. We must make our decisions carefully with full awareness of pitfalls and unintended consequences.

Just like Richard Wiswall did several years ago with his Organic Farmer’s Business Handbook, where he introduced the concept of Lean Farming to improve their farming business, Ben Hartman does the same with Lean Management Principles. He takes a set of practices developed in Japan, most famously by Toyota with the Toyota Production System (TPS) and applies them to farming. Before starting my farm 15 years ago, I worked as an Industrial Engineer and often used Lean principles in initiatives to improve factory operations across the US. I saw the positive impact they can have when used intelligently. I enthusiastically endorse Ben Hartman’s effort. Lean offers a set of excellent tools that can be helpful on any farm. His book Lean Farming is a welcome addition to any farmer’s bookshelf, especially if they would like to reduce waste and improve profitability on their farm.
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This newspaper contains news and features about organic food and farming in the Northeastern US as well as a Special Supplement on Biochar in Agriculture.

Participants in a July on-farm workshop learn how to construct a burner, make biochar, and use it to grow crops. The burned garden bed is the center of attention in the rear left.

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