

Guidelines on Practical Aspects of Biochar Application to Field Soil in Various Soil Management Systems



Photo by Josiah Hunt

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IBI and Julie Major are not responsible for any prejudice caused by the application of guidelines given in this manual.

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1. Purpose

This guide provides an overview of current biochar knowledge pertinent to its application to soil, and gives ideas for using biochar in a variety of soil management systems. Very little data is currently available on practical aspects of working with biochar, including labor requirements, economic feasibility and efficacy. This guide summarizes what is known so far and is intended as a practical guide for farmers and others engaged in biochar field trials.

2. Introduction

When it is added to soil, biochar has generally been shown to be beneficial for growing crops; additionally biochar contains stable carbon (C) and after adding biochar to soil, this carbon remains sequestered for much longer periods than it would in the original biomass that biochar was made from. Crop yield improvements with biochar have been demonstrated repeatedly for acidic and highly weathered tropical field soils (Lehmann et al., 2003; Rondon et al., 2007; Steiner et al., 2007; Kimetu et al., 2008), and there is new data on biochar use in temperate soils of higher fertility (Laird, 2009; Husk and Major, 2010). While many reports on biochar trials exist in the scientific literature, the practice of applying it to soil in commercial farm or other “real life” operations is just beginning, and no widely accepted guidelines currently exist.

Although biochar is not officially recognized by any regulatory regime or program as a method for generating C offsets, it holds promise because its mean residence time in soil is estimated to be in the scale of centuries to millennia (Cheng et al., 2008; Kuzyakov et al., 2009; Major et al., 2010a). In order to ensure that biochar management remains a carbon negative practice, special attention must be placed on minimizing the full lifecycle costs of handling and applying biochar at scale.

3. General considerations for biochar application to soil

3.1 Characterization and testing of biochar materials

Determining where and how to apply biochar begins with the characterization of the biochar material. Characteristics of biochar materials will vary depending on what the biochar is made from, and how it is made. Variation in the pH, ash content, surface area, and other characteristics of biochar is the basis for the concept of “designer biochar” (Novak et al., 2009b), where the characteristics of a biochar are matched to the specific needs of a soil and/or soil management system. For example, certain high-pH biochars may be best for applying to acidic soils, while others with elevated contents of highly recalcitrant C (but which are amorphous in structure) might be better suited to situations where C sequestration is the main goal. To date, actual field data is lacking to

address which measurable characteristics of biochar are the most relevant to soil improvement and soil C sequestration, in a range of soil environments and management systems. There is a strong need for a biochar characterization system, to allow testing of biochar products to ensure quality and effectiveness.

Several groups, including the IBI, are currently working on determining which characteristics should be measured in biochar materials, and on adapting analytical methods for carrying out the measurements. Users of biochar should be aware that biochar contains ash (mineral matter, including salts) and usually water. The amount of water in biochar can be significant. Since biochar can hold a great deal of moisture, consumers should enquire about moisture content when purchasing biochar by weight. Ash can provide plant nutrients but biochar with a high proportion of ash, such as biochar made from animal manure, will contain a correspondingly lower amount of recalcitrant carbon.

As the market for biochar evolves, makers of biochar products will be compelled to document and understand differences in these materials, and to work with farmers and gardeners to provide them with the most appropriate biochar for their conditions.

3.2 Regulations pertinent to soil application of biochar

Depending on the country, there may be different permits required for applying biochar to soil. For example, if biochar is applied with the objective of improving agricultural soil (as opposed to, for example, disposing of waste), permits are not likely to be required in the USA, regardless of the scale of application. The same applies for application in urban and residential landscaping settings. However, the definition of waste varies by jurisdiction, and for example in Ontario, Canada, a material which has gone through a process such as pyrolysis or gasification is considered a waste and must be treated as such. Regulations relevant to the use of biochar in soils may evolve or change as the industry develops, and potential users should inform themselves and act in compliance with all relevant standards and regulations pertinent to biochar in their locale.

3.3 Best management practices for biochar storage, handling, and transportation

As explained by Blackwell et al. (2009), biochar can represent a fire hazard. Biochar dust particles can form explosive mixtures with air in confined spaces, and there is a danger of spontaneous heating and ignition when biochar is tightly packed. This occurs because fresh biochar quickly sorbs oxygen and moisture, and these sorption processes are exothermic, thus potentially leading to high temperature and ignition of the material. The volatile compounds present in certain biochar materials may also represent a fire hazard, but the amount of such compounds found in biochar can be managed by managing the pyrolysis temperature and heating rate (Antal and Gronli, 2003). Certain chemicals can be added to biochar to decrease its flammability (e.g. boric acid, ferrous sulfate) (Blackwell et al., 2009). Water can also reduce flammability, although its effectiveness is not known unless

the biochar is saturated and it also increases the weight of the material and thus shipping costs. The best way to prevent fire is to store and transport biochar in an atmosphere which excludes oxygen (Blackwell et al., 2009). Rules for the transport of charcoal exist under many jurisdictions. Formulated biochar products such as mixtures with composts, manures, or the production of biochar-mineral complexes will potentially yield products which are much less flammable.

3.4 Best management practices for biochar soil application

The particle size distribution of biochar materials will vary widely depending on the feedstock and the pyrolysis technique used to produce the biochar. Still, most biochar materials will contain small particles, as biochar is brittle and small particles are formed when the material is handled.

3.4.1 Problem – wind loss

With small particles, it is important to apply biochar in ways that minimize loss due to wind or water erosion. If large amounts of fine biochar dust are lost during the application and incorporation of biochar to soil, documenting the actual application rate of the material becomes complicated, and such losses are obviously undesirable if biochar represents a valuable amendment. This problem was encountered by Blue Leaf Inc. during the establishment of a biochar field trial in Québec, Canada in 2008. Blue Leaf applied a fine grained biochar produced by fast pyrolysis, and estimated that 2% of the material was lost while loading the spreader (a lime spreader was used), 3% was lost during transport to the application area, and 25% was lost during spreading, for a total loss of approximately 30%.

A best management practice to greatly reduce such wind losses is to moisten biochar, however adding water increases the weight of the material and this can increase transport costs. While water is usually added to biochar immediately after exiting the pyrolysis unit in order to quench it, more water could be applied to reduce dustiness prior to field application. Moisture content must always be taken into consideration when determining application rate, whether or not the end user adds water themselves. Biochar that is seemingly dry can contain a high percentage of moisture, and application rates can be overestimated.

3.4.2 Best Management Practices to avoid wind loss

1. Apply biochar under the right weather conditions when winds are mild. Wind varies according to general weather conditions and time of day. It may also be helpful to apply biochar during mild rain conditions where light rain will dampen biochar dust and hold it on the soil surface until it can be tilled in.
2. Apply moisture to biochar. Water can be applied directly to the biochar, or it can be mixed with moist manure, for example.
3. Produce a biochar formulation by pelleting, prilling, and mixing biochar with

other types of amendments such as manures or composts. Different biochar formulations will be best suited to different application methods, and very fine biochar may be desirable in certain cases, for example when applying as a slurry, by itself or mixed with manure (Blackwell et al., 2009). Research on formulating biochar for handling and application is underway, but results of such work are not yet widely available.

3.4.3 Problem – water erosion

In addition to loss by wind during/after application, biochar can also be lost by water erosion. As for soil erosion itself, sloping terrain aggravates this problem. Rumpel et al. (2006) found that surface-deposited biochar was eroded from steep slopes in Laos, emphasizing the need for soil incorporation—especially when biochar is applied to sloping terrain. Major et al. (2010a) also observed significant losses of biochar incorporated into practically flat terrain, in an area where intense rainfall events occur. Biochar can require some time for wetting soon after application, and may float away when a thick layer of standing water pools over the soil and moves towards the bottom of the site's slope.

3.4.4 Best Management Practices to avoid erosion by water

A best management practice to address this problem is to properly incorporate biochar into soil, especially on sloping terrain or where very intense rainfall events occur. The method used for biochar incorporation must itself be chosen to minimize erosion losses. Section 4 of this document presents a variety of methods for achieving these best practices.

3.5 Size of biochar particles

What is the optimum size range for biochar particles? Long-term studies in different soils are required to draw strong conclusions regarding the effect of the size of biochar particles on soil improvement and C sequestration. Ideal particle sizes to improve soil moisture retention have not been determined. It is expected that practical considerations related to handling and applying the biochar will also impact the decision of what particle size is best.

Biochar can be finely divided and can be applied to soil as-is, provided care is taken to minimize wind losses. If particle size must be reduced (for example from biochar made from old pallets or larger pieces of wood), it can be hand crushed inside bags using a large pestle. Small amounts can also be crushed by driving over the material with a roller pulled by a tractor. For crushing larger amounts of biochar materials, hammer mills can be used, as well as compost shredders, for example. Best management practices include moistening the material before crushing it to reduce dust created during the process, and/or crushing the biochar inside closed bags.

3.6 Application rate

Recommended application rates for any soil amendment must be based on extensive field testing. At this time, insufficient field data is available to make general recommendations



Figure 1. Left: Hand crushing biochar inside sacks in Honduras. Photo by J. Major. Right: Crushing moistened biochar using a small compost shredder in Oregon, USA. Photo by D. Dalegowski.

on biochar application rates according to soil types and crops. Also, biochar materials can differ widely in their characteristics, thus the nature of a specific biochar material (e.g. pH, ash content) also influences application rate. In the published literature, several studies have reported positive effects of biochar application on crop yields with rates of 5-50 tonnes of biochar per hectare, with appropriate nutrient management. This is a large range, but often when several rates are used, the plots with the higher biochar application rate show better results (Chan et al., 2007, 2008; Major et al., 2010b). Since the C content of biochar materials varies, it may be appropriate to report application rates in tonnes of biochar-C per hectare, as opposed to tonnes of bulk biochar material. A 10 t/ha application of poultry manure biochar contains much less C (and more ash) than an equivalent application of wood waste biochar. However, “high-ash” biochar can constitute a source of various plant nutrients, and these should be taken into consideration when managing soil fertility at the field level.

Most biochar materials are not substitutes for fertilizer, so adding biochar without necessary amounts of nitrogen (N) and other nutrients cannot be expected to provide improvements to crop yield. Instances of decreasing yield due to a high biochar application rate were reported when the equivalent of 165 t of biochar/ha was added to a poor soil in a pot experiment (Rondon et al., 2007). At this high application rate, yields decreased to the level of the unamended control. This is a very large amount that is unlikely to be practically feasible in the field, at least for a one-time amendment. However, Asai et al. (2009) working in Laos reported greater upland rice yields with 4 t/ha biochar, but when 8 or 16 t/ha were applied, yields were not different from the unamended control. A more recent field study on a poor, acidic soil of the USA showed that peanut hull and pine chip biochar applied at 11 and 22 t/ha could reduce corn yields below those obtained in the control plots, under standard fertilizer management (Gaskin et al., 2010). The reasons for

such a decrease remain to be fully explored and must be understood in order to determine which biochar material are best suited for application, and at which rates, to specific soils in specific soil management systems.

3.7 Frequency of application

Due to its recalcitrance to decomposition in soil, single applications of biochar can provide beneficial effects over several growing seasons in the field (Steiner et al., 2007; Major et al., 2010b). Therefore, biochar does not need to be applied with each crop, as is usually the case for manures, compost, and synthetic fertilizers. Depending on the target application rate, the availability of the biochar supply, and the soil management system, biochar amendments can be applied in increments. However, it is believed that beneficial effects of applying biochar to soil improve with time, and this may need to be taken into consideration when splitting applications over time.

3.8 Formulated biochar products

Since biochar itself cannot be considered a source of nutrients (unless it has a high ash content), there is interest in blending it with other materials such as synthetic fertilizers, compost and manures to enhance its value as a soil amendment. Furthermore, biochar has been shown to retain nutrients against leaching (Major et al., 2009; Novak et al., 2009a), potentially improving the efficiency of nutrients applied alongside biochar.

Adding biochar to sewage sludge or poultry manure during composting has been shown to reduce N losses (Dias et al., 2009; Hua et al., 2009) and the mobility of some heavy metals was also reduced in sewage sludge compost with biochar (Hua et al., 2009). Dias et al. (2009) compared biochar to other bulking agents for compost making, and found that adding biochar resulted in greater humification or “maturity” of the compost at the end of the study period. It is also believed that adding biochar to composts and manures can reduce odors.



Figure 2. Applying biochar-amended compost to planting beds in Hawaii. Photo by J. Hunt.

Dr Makoto Ogawa of the Osaka Institute of Technology in Japan states that: “Making compost from litter and excretions has been common in Japan for a long time. In the 1980s, charcoal compost was made from fresh chicken dung and palm shell charcoal; the more charcoal used, the faster the composting process. Under aerobic conditions the *Bacillus* group became dominant and produced antibiotics that inhibited growth of soil-borne pathogens and suppressed root diseases. Charcoal compost is now sold in Japan as a biological fungicide. Various other organic composts are now being produced from livestock excretions and charcoal and sold commercially.” (Ogawa, 2009).

Another example from Japan is bokashi, an organic fertilizer made by combining “effective” microbes, molasses, biochar, bran, and animal manure with water, and incubating under anaerobic or partially anaerobic conditions (there are variations of this recipe and some do not include charcoal). This amendment was developed by the Japanese philosopher Mokichi Okada in 1935 (Reap Canada), and is now made and used in many developing countries around the world, often incorporating native micro-organisms in addition to the “effective” micro-organisms. The biochar can be made from any convenient source of biomass, such as sugar cane bagasse.

Rice hull biochar is often used due to the availability of rice hulls in many regions. However, great care must be exercised while carbonizing rice hulls, as high process temperatures can lead to the production of carcinogenic compounds. Rice hull carbonization is routinely done on a variety of scales throughout the world, and process temperature is very often uncontrolled, resulting in a potential health hazard. For more information on testing the safety of pyrolysis units, refer to *IBI Guidelines for the Development and Testing of Pyrolysis Plants*, available on the IBI website.

3.9 Meeting standards for Organic agriculture

The National Organic Program of the United States Department of Agriculture states that biochar is considered a “non-synthetic allowed” material, so long as it is made from plant biomass and not animal manures, since ash from manure is prohibited. The use of “wood ash” is also restricted for use on certified organic land by certain programs in the USA (National Sustainable Agriculture Information Service). AsureQuality of New Zealand lists “wood charcoal” and “wood ash” as requiring approval before use in certified organic agriculture (AsureQuality, 2010). In the province of Québec, Canada, the Conseil des appellations réservées et des termes valorisants (Council on reserved designations and value-added terms, which regulates organic certification agencies operating in the province) approves of wood charcoal as an amendment in organic agriculture.

It is expected that with the rise of interest in and availability of biochar individual certification agencies will start regulating biochar as a soil amendment in organic agriculture. Farmers should check with their certifying agency before using biochar. It is foreseeable that individual biochar products will require organic certification, given the large variability in biochar feedstocks and characteristics.

4. Biochar application to soil management systems

When applying biochar to soil for improving its fertility, the biochar should ideally be located near the soil's surface in the root zone, where the bulk of nutrient cycling and uptake by plants takes place. Certain systems may benefit from the application of biochar in layers below the root zone, for example during landscaping for C sequestration or if using biochar for moisture management. Similarly, if biochar were to be applied to soil solely for C sequestration purposes, placement deeper in the soil, for example in new landscaping or construction areas, would be desired since microbial activity that can degrade biochar carbon is reduced deeper in the soil profile.

When deciding how to apply biochar to soil, the specific cropping system must be taken into consideration. The likelihood of wind and water erosion losses of biochar is reduced when biochar is thoroughly incorporated into soil, however, plowing and soil mixing are not possible or desirable in all cropping systems, at all times.

4.1 Conventional field crop systems

In conventional field cropping systems, biochar should ideally be managed using traditional farm machinery and incorporated into routine field operations. This will ensure that the costs of using biochar are kept as low as possible. For example, biochar can be applied and incorporated together with lime, since lime is often applied as a fine solid which must be well incorporated into soil.

4.1.1 Broadcast and incorporate

The majority of biochar field trials reported to date used this method for incorporating biochar into soil (Yamato et al., 2006; Steiner et al., 2007; Asai et al., 2009; Major et al., 2010b). Broadcasting can be done by hand on small scales, or on larger scales by using lime/solid manure spreaders or broadcast seeders. Moistened biochar materials may be



Figure 3. Broadcasting and incorporating biochar by hand in Honduras. Photo by J. Major.

better suited to application with manure spreaders than lime spreaders. Incorporation can be achieved using any plowing method at any scale, including hand hoes, animal draft plows, disc harrows, chisels, rotary hoes, etc. Moldboard plowing is not recommended as it is unlikely to mix the biochar into the soil and may result in deep biochar layers (Blackwell et al., 2009). As mentioned above, wind losses from applying and incorporating fine biochar materials can be significant (see Fig 4) and precautions must be taken to minimize this.



Figure 4. Clockwise from top left: Biochar losses during handling, transportation to the field, application with a lime spreader and incorporation with a disc harrow during the establishment of a biochar field trial in St-Francois-Xavier-de-Brompton, QC Canada. Photos by B. Husk.

4.1.2 Traditional banding

Banding of seeds and fertilizers is a routine operation in mechanized agriculture, and involves applying an amendment in a narrow band, usually using equipment that cuts the soil open, without disturbing the entire soil surface. Banding allows biochar to be placed inside the soil while minimizing soil disturbance, making it possible to apply biochar after crop establishment, for example. However, the amounts of biochar that can be applied in this way are lower than those which can be achieved by broadcast applications. Wheat



Figure 5. Deep banding biochar in Australia. Photo by P. Blackwell.

yields in Western Australia were improved by banding biochar (Blackwell et al., 2007). When working by hand, biochar can be applied in furrows opened using a hoe and closed after applying biochar.

4.1.3 Mixing biochar with other solid amendments

Mixing biochar with other soil amendments such as manure, compost or lime before soil application can improve efficiency by reducing the number of field operations required. Since biochar has been shown to sorb nutrients and protect them against leaching (Major, 2009; Major et al., 2009; Novak et al., 2009a), mixing with biochar may improve the efficiency of manure or other amendment application.

4.1.4 Mixing biochar with liquid manures

Biochar can also be mixed with liquid manures and applied as a slurry. Fine biochars will likely be best suited to this type of application using existing application equipment, and dust problems associated with these would be addressed. Biochar could also be mixed with manure in holding ponds and could potentially reduce gaseous nitrogen losses as it does when applied to soil (Rondon et al., 2005; Yanai et al., 2007; Spokas et al., 2009).

4.1.5 Targeted biochar applications in precision agriculture

Where high-resolution data on soil characteristics and farm machinery equipped with geographical positioning systems are available, it would be possible to apply biochar preferentially to areas of fields where fertility is low.

4.2 Reduced and no-till systems, established pasture vegetation

4.2.1 Relevant Issue: Pesticide sorption and potential inactivation by biochar

Biochar is a precursor to activated carbon, a widely used sorbent for a variety of compounds. Biochar has been shown to sorb herbicides (Yamane and Green, 1972; Cao et al., 2009; Spokas et al., 2009; Wang et al., 2010), heavy metals (Mohan et al., 2007; Cao et al., 2009), and decrease crop uptake of insecticides (Yu et al., 2009). Whether specific molecules sorbed by biochar are biodegraded or remain bio-available must be determined, but several practical advantages could result from biochar sorption, for example the protection of crop seeds from soil-applied herbicides, and the productive use of contaminated soils. Disadvantages could also exist, such as the inactivation of herbicides which carry out their function in the soil.

4.2.2 Subsurface banding

Sistani et al. (2009) applied 9 t/ha of poultry manure to a perennial grassland by subsurface banding using prototype equipment, and observed large reductions in total suspended solids running off from the soil's surface after simulated rain events. Subsurface banding of dry material is a new technique, and farm machinery to achieve this is not yet commercially available. Its developers are interested in solving problems of surface runoff and odor when applying poultry manure to soil, but have also used the equipment to apply

biochar to soil. Subsurface banding could greatly reduce potential wind and water erosion losses of biochar, and may be ideal on slopes, or when using very fine biochar materials. The equipment crushes large pieces of litter or biochar, and the material is then gravity fed into trenches opened by discs, and the trenches are later closed with wheels that cover the material with soil. The equipment functions similarly to no-till planters, but a significant difference is that the spreader crushes dry material before banding it (D. Pote, USDA-ARS, pers. comm.). Liquid slurries containing biochar could also be injected below the soil's surface.



Figure 6. Left: USDA's Agricultural Research Service demonstrates a prototype poultry litter subsurfer in Arkansas. The subsurfer is designed to apply litter under the surface of perennial pasture and other no-till systems, and gives farmers precise control of litter application rates. Right: Subsurfer leaves a "clean" soil surface after application. Photos by Stephanie Jordan.

4.2.3 Surface application in perennial vegetation

Biochar can be top dressed on perennial pastures or other perennial vegetation, such as spaces between fruit trees in orchards. This type of application makes amendments subject to losses, but it is routinely used to apply manures, compost, and synthetic fertilizer to restore fertility in perennial systems. Surface application of biochar to perennial pasture has been done successfully in England (Gathorne-Hardy et al., 2008) without any visual observation of significant losses of biochar, and with observation of incorporation of biochar into the soil by earthworms (A. Gathorne-Hardy, pers. comm.). However, data on biochar movement with surface application to perennial vegetation is lacking.

4.3 Horticultural crops

Apart from application methods listed above for field crops, biochar could be applied with individual plants while transplanting in the field, or mixed with topsoil and other amendments while preparing raised beds. See the example of taro, in Fig. 8, below.



Figure 7. Top-dressed biochar on perennial pasture in England, visible as darker treated square plots. Photo by A. Gathorne-Hardy)



Figure 8. Taro plant transplanted with biochar in Hawaii. Taro is grown under waterlogged conditions. Photo by J. Hunt.

4.4 Tree crops

Biochar should ideally be applied to an area of soil that tree roots will eventually utilize to take up nutrients, i.e. the “drip line”. The drip line refers to the area you would get, once the tree has reached its mature size, if you drew a circle on the soil corresponding to the size of the tree’s crown. To apply biochar to the entire drip line it is necessary to work it



Figure 9. Biochar applied at transplanting oil palms in Costa Rica. Photos by T. Benjamin.

into the soil beyond the tree's planting hole, and this is not always possible. Here we describe different ways of applying biochar when establishing trees.

4.4.1 Surface application

For tree establishment, it may be possible to broadcast and incorporate or band apply biochar over the entire planting area, and add more biochar in planting holes. Before or after tree establishment, biochar could also be applied by traditional and subsurface banding or top-dressed over perennial vegetation in orchards, but care should be taken to minimize root damage and soil compaction. More data on appropriate application rates for planting area treatment and planting hole application are needed, but this technique has been used to study biochar effects on the growth of oil palm in Colombia (D. Molina, Cenipalma, pers. comm.) and Costa Rica.

4.4.2 Localized applications

Nursery seedlings grown in biochar containing medium and transplanted in the field could benefit from biochar early on, but roots will usually grow outside the biochar amended area. Alternatively, if the soil outside the transplant medium is very inhospitable for plant roots (for example of very high or low pH), roots can seek to restrict themselves to the transplant medium, resulting in unstable trees with poor root structures. Biochar can be applied in trenches radiating out from the base of established trees ("radial trenching") or in holes dug at some distance from the base of the tree ("vertical mulching"); biochar could also potentially be applied to soil using "air excavation tools". These tools use pressurized air to deliver compost under the soil surface and reduce compaction. Alternatively, the soil around tree roots can be excavated and biochar applied before covering with soil. This treatment has been shown to benefit valuable old trees in Japan (Japan Biochar Association).



Figure 10. Biochar applied in trenches to established trees in Japan. Photo by Sugiura.

4.5 Landscaping, gardening and turfgrass

Landscaping, gardening, and turfgrass establishment are activities which can take place in the public sphere and can be used to highlight the benefits of biochar application. Increased awareness of biochar technology among the public could improve the acceptability of biochar as a landscaping and gardening amendment, and even drive the demand for its use in such settings, if consumers understand and value its benefits.

When soil is removed for construction and landscaping, there are opportunities to lay down thick layers of biochar under the rooting zone of plants or under buildings or roads. Such uses would not necessarily entail reaping soil enhancement benefits from biochar, but might be valuable tools if rapid C sequestration is desired. In the case of turfgrass, biochar could help to improve moisture retention in greens. The acceptance of new golf courses by citizens may be improved if biochar is used during their establishment, since additionally to C sequestration, biochar has the potential to reduce water requirements by increasing water holding capacity (Tryon, 1948; Chan et al., 2007; Novak et al., 2009b) and also decrease fertilizer use (Van Zwieten et al., 2009), as well as reduce pollution from fertilizer and pesticide application. These characteristics combined with the low density of biochar and its ability to reduce nutrient leaching also make it a desirable substrate for use in green roofs.



Figure 11. Trials of biochar mixed into turfgrass substrate. Photo by M. Woods.

4.5.1 Broadcast and uniform mixing with new topsoil applications

Biochar could be mixed with sand, topsoil, compost, or turfgrass substrate prior to application to the landscape. This includes bulk applications in new areas, as well as topdressing soil in existing landscaping areas such as flower beds. In the case of high-traffic areas of golf courses and sporting turfgrass, resistance to compaction and rapid drainage are important characteristics of man-made rooting zones. Mixing biochar homogeneously with sand for example, could allow the fast drainage and resistance to compaction of sand, while increasing moisture retention and availability to turf.

4.5.2 Localized application

Biochar could be applied in planting holes before transplanting trees and other plants, as mentioned above.

4.5.3 Application in structural layers while constructing golf greens

Biochar could potentially be applied in layers below the rooting zone of grass, to serve as a barrier for leached nutrients and pesticides. In many cases such layers would need to offer adequate drainage and not cause waterlogged conditions above them, and this can likely be managed with the particle size of the biochar. More research is required to verify these potential benefits and determine best management practices.

4.5.4 Application to turf aeration holes

A 1943 report states that biochar was successfully applied to aeration holes made in established turfgrass, using a home-made handheld device which delivered biochar into the aeration holes made by other equipment. Using a very fine material (passing a 0.6 mm sieve), application rates equivalent to 3.9-5.4 t/ha were achieved (Section, 1943, Dec).

4.6 Carbon-sequestering art work in the landscape

Carbon-sequestering designs made with biochar and other materials have been proposed for parks, arboreta, or other locations. Two-dimensional designs in the landscape must be placed on a slope for viewers who are on foot to appreciate, and actual projects are needed to test ways of containing biochar and protecting it from surface runoff with rain or wind erosion. Alternatively, large designs could be made on flat terrain with the goal of being seen from airplanes, for example in deserted areas. Such designs have the potential to serve as good tools for educating the public about C sequestration with biochar.

4.7 Degraded area reclamation and watershed management

Each degraded or contaminated area in need of reclamation is potentially unique. Biochar has the potential to facilitate the establishment of vegetation on such soils, while sorbing a variety of heavy metals (Mohan et al., 2007; Cao et al., 2009), organic compounds (Keech et al., 2005; MacKenzie and DeLuca, 2006; Smernik, 2009), and pesticides (Wang et al., 2006; Spokas et al., 2009).

For degraded area reclamation, depending on the objectives and constraints of a given area, any of the techniques above can be considered. Biochar could also be used to “trap” nutrients or other pollutants in strips near waterways, or even directly inside streams or at the outlet of drainage ditches. Options for engineering trapping systems with biochar are numerous and require investigation.

5. Conclusions

Just as potential benefits deriving from applying biochar to soil are numerous, so are soil management systems in which biochar could be incorporated. Farmers and gardeners

around the world are actively exploring the use of biochar in a variety of field and greenhouse settings; however data collection and documentation of these efforts is to date often limited. Much research and development is required to determine best management practices for using biochar in a variety of systems, taking into consideration the specific characteristics of each biochar material. However, the potential for improving crop production and environmental management with biochar is great.

6. Additional resources

In understanding that the addition of biochar to soils as an agricultural practice will fail to gain traction unless viable application methods are developed, The Biochar Application Network was formed to foster the development of biochar application methods that are technically, economically, and environmentally viable at scale. Through applied research, industry partnerships, and targeted outreach, biochar specific application methods will be developed, verified, and brought to market. The Biochar invites you to continue the discussion provided in this IBI Guide at the website www.biocharapplication.com.

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