BIOCHAR AS AN INNOVATIVE WOOD PRODUCT:

A LOOK AT BARRIERS TO REALIZATION OF ITS FULL POTENTIAL

May 2017

Harry Groot

Jeff Howe, Ph. D
Jim Bowyer, Ph. D
Ed Pepke, Ph. D.
Richard A. Levins, Ph. D.
Kathryn Fernholz

DOVETAIL PARTNERS, INC.

Biochar as an Innovative Wood Product

A Look at Barriers to Realization of its Full Potential

Executive Summary

In the previous Dovetail Report *Biochar 101: An Introduction to an Ancient Product Offering Modern Opportunities* (Groot et al. 2016[1]) the bottom line was: "Biochar is a product with clear benefits but many questions yet to be answered." That remains the case. However, ongoing research has expanded the knowledge base, and the debate about biochar's value and cost effectiveness is narrowing as more is known.

Photo 1. Biochar made from Pecan Hulls (photo by H. Groot)

A barrier to further market growth is that the industry producing biochar is unsettled, with little agreement regarding product standards, message, or carbon accounting. There is an opportunity for more collaboration to resolve these issues, especially among the mid to large-scale producers.

The most common use of biochar is as a soil amendment for high-value fruit and vegetable crops, including use in greenhouse and nursery operations, and there is already significant market acceptance in this sector. Biochar is also used to remove impurities and toxins in water filtration and soil remediation, and these applications appear to offer significant growth potential. Commodity crop production conceivably offers the potential for use of the greatest volume of biochar, but there is little information available about the relative cost and benefits of biochar in this application. This suggests that the commodity crop market is a prime candidate for further research on biochar use.

Coordinating the power of global research efforts with needs of the industry stakeholders, end users, and policy makers would provide much needed data and input for decision-making. The full potential of biochar continues to be viewed positively, and anecdotal evidence indicates growing demand. However, the market potential remains largely untapped. This report explores why interest in biochar is increasing, what the industry is doing to respond, and challenges which complicate market growth. For this report, current US-based producers and users, as well as potential users unfamiliar with biochar were interviewed. In all, over 20 producers and 200 users or potential users were contacted.

[1] Available at: http://www.dovetailinc.org/report_pdfs/2016/dovetailbiochar0316.pdf

Introduction

Biochar is a generic term for a particulate, charcoal-like product[2] used for biological purposes, as opposed to generation of heat. Its earliest uses were as a soil amendment. Biochar can also be used as a filtration element to bind toxic chemicals and heavy metals, an adsorbent[3] for odors (animal litter and bedding amendment,) a feed additive, or as an activated carbon substitute.

Biochar is made from a variety of feedstocks via pyrolysis: an irreversible thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen.

The first reference to biochar's "discovery" was by a European geologist in 1870, noting areas in South America with curiously productive soils—compared to the typically shallow, acidic soils capable only of short periods of productivity. Archeological studies have identified biochar enriched soils in the Amazon Basin from 8000BC. Anthropological analysis has determined that regions of high productivity biochar-enriched soils were created to support early societies in South America with relatively high populations. In many areas of the Amazon Basin there still remains a carbon rich soil mix referred to as "terra preta," literally "black soil" in Portuguese (Mann 2011).

The unusual productivity of terra preta sites is due to the organic carbon (biochar) component, which can be as high as 9% carbon, compared to surrounding areas of 0.5% or less. The organic carbon content in soils has long been known to be a governing factor in soil's ability to hold water, increase nutrient availability, and improve microbial and fungal populations. Soil scientists have been studying terra preta since the 1960s, but there has been little widespread interest from agricultural producers until recently. Current biochar users commonly produce biochar for their own use, and sell the excess.

Biochar Production: Historic Methods and Modern Research

Historically, the production of biochar and charcoal was done in covered pits, beehive-style kilns, and large piles, resulting in mostly anaerobic conditions. Such production was notoriously inefficient, polluting and labor intensive. These un-sophisticated systems were both smoky and largely uncontrollable. More modern methods use kilns and retorts, with manual or computerized control systems, some which incorporate capture of heat and/or synthetic gas[4] for electrical power generation or process heat and all are significantly less polluting. For larger scale units meeting permitting requirements at local, state, and even federal levels is mandatory.

Biochar-focused research worldwide has produced thousands of articles over the last 10 years, primarily focused on agricultural uses, but increasingly including filtration and remediation uses. Studies have consistently found that addition of biochar to soils is beneficial, increasing water

[2] Biochar's physical characteristics vary based on the intended use. The char is screened and classified into sizes ranging from powder to chunks as large as a centimeter. Depending on the application, a mixture to suit can be created. Soil amendments typically use larger sizes as shown in the picture above and filtration uses smaller sizes.

[3] *Adsorbent* is a process by which some liquid or gas gets accumulated on the surface of a solid material.

Read more: http://www.differencebetween.net/science/difference-between-adsorbent-and-absorbent/#ixzz4hA5h7cdL

[4] Synthesis, or syn gas, is the uncombusted volatile gas driven off the biomass by pyrolysis. In the typical biochar retort, 25% of the syngas is used in the combustion process and 75% of the BTUs are "available" for collection or further use. Syngas, or synthesis gas, is a fuel gas mixture consisting primarily of hydrogen, carbon monoxide, and very often some carbon dioxide. The name comes from its use as intermediates in creating synthetic natural gas (SNG) and for producing ammonia or methanol.

retention, friability, carbon content, and long-term carbon sequestration. Biochar also provides a leveling/extension of nutrient availability to crops. Considerable research supports the benefits of biochar as a medium to adsorb chemicals, much like activated carbon, but with the added benefit that biochar can be produced from local renewable biomass sources, often at lower cost (Beck 2011. Kearns 2014. Abdel-Fattaha 2015. Mukherjee 2016).

Source: http://biochar-international.org/biochar /

Biochar can be produced from a variety of biomass feedstocks by production systems at varying scales, but is produced predominantly from woody biomass. Use of biomass can be beneficial to forest restoration efforts and wildfire mitigation. Biochar can provide a market value to a product which has little to no value in many regions due to distance from buyers for energy or pulp uses.

There appear to be few negative consequences from using biochar, and buyers are responding with increased interest in its benefits. While research occasionally finds negative results of biochar on crop production (e.g., a suppression of productivity in the short term), the vast body of research supports the major claims of biochar advocates.

In soils research, biochar has been found to:

- Increase soil carbon for hundreds to thousands of years, therefore also sequestering atmospheric carbon (Matovic 2011)
- Improve friability and/or tilth (Cole 2015)
- Increase water retention and holding capacity (Shackley 2011)
- Adsorb toxins (Kearns 2014. Xie 2013)
- Extend the release of applied fertilizers (Beck 2011)
- Provide significant "homes" for microbes and mycorrhiza (Xie 2013)

And as a filter medium, biochar:

- Binds chemicals and heavy metals in the same way as activated carbon (Kearns 2014)

The most commonly reported problem with biochar is related to its greatest strength. Biochar has a huge surface area just waiting to be filled. When raw biochar is placed in soil, it will fill its open area by pulling elements such as nitrogen, phosphorus, and potassium from the soil. To avoid this problem, most biochar users mix the raw biochar with compost, or soak it in a compost tea in a process called "charging." Some processors quench the biochar coming out of the retort, using water or a compost tea, while others prefer to sell only raw (bone dry) biochar and let the user charge and hydrate it. The latter technique is advantageous in that it avoids the cost of shipping water.

Increasing Market Interest

The production-scale biochar industry is relatively young and is growing. The market is immature at present, and there is little concrete data about aggregate production. Most facilities generating more than a few thousand pounds per year have come on-line since 2000, and number in the tens of plants. Based on recent conference interest and attendance, there may be as many as several thousand operations in North America producing small quantities of biochar in drum style and open retorts such as the Kon-Tiki[5] unit shown to the right.

The concept of small-scale production has recently taken a new twist. There is currently an effort underway to develop biochar as a byproduct of residential cooking and heating systems. The customer is supplied with fuel (wood chips,) which are then used in modified commercially-available stoves or grills. The control system and/or operators manage the process simply by stopping combustion after the heat is extracted, but before the char becomes ash. The system under development has the customer either using the biochar, or returning it to the fuel supplier for a credit. the aggregator sells the biochar after blending and testing.

There is also a mid-range producer class emerging. This is where considerable technology development is taking place, and units capable of producing a thousand to tens of thousands of pounds per year are being developed and refined. Some midrange producers are also collaborating with each other and with interested parties to build a network of rural biochar generators, some with, and some without energy or syngas capture, to create a substantial production base. Some of these units are mobile, others stationary, but they all share common objectives of appropriately scaled production to stimulate rural economic development at an affordable capital investment.

Small and midrange producers have a more significant hurdle to overcome in controlling the quality of their aggregated products than do the larger producers. Since control of processing parameters and consistency of the feedstock are critical to the quality and characteristics of biochar, by aggregating output for marketing purposes, the potential for generating a consistent final product is difficult. However, for small-scale producers working with a local or regional clientele, the biochar may be made more affordable by eliminating or significantly reducing transportation costs. Depending on their process control capability, local producers may even be able to customize their products for their clients.

Interviews with Biochar Producers and Users

For this report, current US-based producers and users, as well as potential users unfamiliar with biochar were interviewed. The producers hailed from the three classes of producer (small, mid-range, and large-scale), and the users and potential users included high-value crop farmers, commodity farmers, and organically certified farmers. Initial contact with many of the interviewees was made in the course of several conferences, including the 2016 US Biochar Conference and the National Small Farm Conference. In all, over 20 producers and 200 users or potential users were contacted.

[5] http://fingerlakesbiochar.com/kon-tiki-kilns/

Through these interviews we determined that the industry's large producers (over 100,000 pounds per year) are selling everything they can make, and all are planning on capacity expansion. The industry currently has producers mainly on the high and low ends, with few mid-range operations. This is expected to change as a number of mid-range producers (in the one thousand to ten thousand pound per year range) will be coming on line in the 2017-2019 timeframe. however, as noted previously, they will have to deal with quality control issues if their business strategy is an aggregation model.

Current users polled were satisfied with their suppliers and cited earlier harvests, reduced water usage, and increased yields as benefits of using biochar. Findings regarding potential biochar users were far less promising. The vast majority of farmers interviewed, who do not currently use biochar, were unaware or only vaguely aware of biochar's potential benefits and many cited its high cost as a reason to dismiss it from consideration.

Although this report focuses on North American biochar development, it is notable that biochar production, research, and use is a worldwide phenomenon. There have been nearly 5,000 biochar-related articles published in the last decade and a number of countries (notably Australia and China) have agencies promoting biochar use and continued research (Xie 2013. Roberts 2010).

Biochar Market Potential

As noted previously, accurate assessment of biochar markets is hindered by a lack of information. However industry sources provide a broad view of those markets. Industry websites[6] were examined to obtain information supplemental to that gained through interviews. A broad-scale marketing effort will be needed to grow the market substantially, with consistent information regarding product use, benefits, and quality.

Agricultural Crop Uses

The agricultural sector is probably the largest user of biochar. However, use as an activated carbon substitute, as in filter media, is also occurring at a high and likely similar level of use.[7]

For agricultural uses, due to the high cost of the product, current primary users are those producing high value crops. As one source noted, "If a grower is going to spend $30,000 per acre on biochar, they need to be able to recover those costs quickly." Another factor cited in the decision process is that lenders will accept the added cost for biochar when it's a small fraction of the investment. For example a vineyard may cost $100,000 per acre to install, so if biochar is 30% of the cost and the returns are going to be $20,000 to $50,000/acre (i.e., a 5 to 10 year payback), then biochar use becomes a more acceptable risk for the lender. For lower value crops, where use of biochar would account for a high cost relative to potential returns, additional cost would more likely be viewed as unacceptable from an investment perspective. But it is important that all involved realize that biochar is a one-time investment rather an annual application that will return value to treated soils for decades and beyond. This reality can markedly change the value proposition. For instance, some high value crop growers have reported doubled yields or halved inputs over multiple crop rotations.

[6] http://biochar-us.org/manufacturers-retailers

[7] The availability of data on production and use of biochar is such that it is difficult to determine which use is actually greater: agricultural or filtration.

Organic Production Systems

Organic Certified growers also represent a significant segment of potential biochar buyers. A biochar producer can easily get listed as an approved amendment supplier by registering their product with the Organic Material Review Institute whose approval makes the biochar an acceptable Organic amendment.[8] 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 (Major, 2010). As the positive experience from Organically Certified growers has spread, so has the demand. These producers are typically growing high-value fruit and vegetable crops intensively, with per acre returns in the $10,000 to $25,000/acre range, making incorporation of biochar affordable. This was noted in a cost benefit analysis looking at the feasibility of using biochar in cereal grains (Kulyk, 2012) and was reinforced in interviews with current producers.

Home Gardens, Hydroponics, and Filtration

A growing use of biochar is in potting soils, both commercially and privately. Inspection of potting products labels at nurseries, big box stores, and the internet shows that a number of these products are biochar-enhanced. While this may not represent a significant market for biochar in terms of volume (percentages are not typically reported), common use as an amendment to potting material confers a level of validation for biochar's "new and improved" status, as well as a de facto acceptance by the general public.

Another use of biochar in the agricultural sector is as part of hydroponic and potting-medium systems. These are also high value production systems and biochar's beneficial characteristics are a near-ideal match for these applications.

Filtration media is a huge potential market. When uses for non-food grade activated carbon are considered – potable water filtration at community, industrial, and residential scales. chemical waste water treatment. air and odor removal (as in kitty litter and air freshening products,) the market potential is quite large. Tests are currently being made for large-scale use of biochar in mine waste water filtration. In this application, large mesh bags are used to dam the effluent stream, forcing flow through the bags of biochar. Heavy metals and toxins are removed as the stream passes through.

Other Uses for Biochar

Other minor, but growing uses for biochar include as an inert filler in plastics manufacturing and as a livestock feed additive. It is currently being used in some poultry and beef operations to provide digestive buffering and reduce the ammonia build-up in excrement. It also provides a higher quality composted finished product since the biochar does not break down in the gut and it carries the active enzymes, bacteria, and other flora into the compost—providing a pre-charged biochar[9].

[8] https://www.omri.org/

[9] Biochar is a carbon-rich "host" material when it comes out of the retort. It has a vast surface area to house fungal and bacterial flora, as well as to adsorb chemicals. Biochar is most often sold in bulk as a raw product, but for retail or ag application it is "charged" with an activated solution (like compost tea) to fill its voids with nutrients and to incubate it with beneficial flora. If raw biochar is used in soils directly research and experience has shown the biochar will pull nutrients from the soil to fill its voids, thus creating an initial negative effect on productivity.

Barriers and Challenges to Biochar Market Development

While there are many benefits of biochar use, there are also a number of problems that need to be addressed if the full potential of biochar is to be realized. In a word, most problems boil down to *consistency*.

In traditional market analysis terms, to grow the biochar market and industry, there needs to be consistency in what consumers see and understand in the end product aimed at specific uses. In marketing lingo, biochar needs consistent product attributes for a customer to anticipate the real benefits. Individual producers can, and are, building their businesses on the basis of individual success and personal credibility. This strategy may be effective for one-on-one relationships and a monopoly, but not for a multidimensional industry with many players seeking to expand.

Standardization

A voluntary standard for biochar has been developed by the International Biochar Initiative (IBI) with producer input.[10] However, as the industry has grown, there has been criticism that some components of the standard, including required testing, are unnecessary and that implementation is too costly. IBI has responded with a classification system aimed at optimizing the sustainable use of biochar in agriculture.

As explained by IBI:

> *"This classification system builds upon biochar product definition and testing guidelines developed by IBI and the European Biochar Foundation, as well as including IBI's biochar carbon stability methodology. This system enables stakeholders and commercial entities to identify the most suitable biochar to fulfil the requirements for a particular soil and/or land use. The potential effects of biochar in soils have been classified in terms of: (i) carbon storage value, (ii) fertilizer value, (iii) liming value, (iv) particle-size significance, and (v) use in soil-less agriculture."*[11]

A frequently heard criticism in the course of our interviews was that the IBI standard requires too much information of relatively minor importance for most end users. As a result, many biochar marketers post their own select test results or make no claims whatsoever. Users of biochar, and even researchers, often accept the product on its historic merits and use it in accordance with their own research, beliefs, or word-of-mouth advice from other users. There is considerable published research regarding use of a percentage of biochar in a soil or potting mix, but little has been published about field trials and larger scale applications. These challenges reduce the broad adoption of the voluntary standard.

The actual characteristics of biochar can vary significantly. Key characteristics which are usually known and made available to buyers are pH, carbon content, particle size distribution, ash content, moisture, and density. To some users, cation exchange capacity[12] is important, and others want to know about the presence of heavy metals and/or oils or tars which could inhibit

[10] http://www.biochar-international.org/sites/default/files/IBI_Biochar_Standards_V2%200_final_2014.pdf
[11] http://www.biochar-international.org/classification_tool
[12] Soils can be thought of as storehouses for plant nutrients. Many nutrients, such as calcium and magnesium, may be supplied to plants solely from reserves held in the soil. Others like potassium are added regularly to soils as fertilizer for the purpose of being withdrawn as needed by crops. The relative ability of soils to store one particular group of nutrients, the cations (a positively charged ion,) is referred to as cation exchange capacity or CEC. https://www.extension.purdue.edu/extmedia/AY/AY-238.html

plant growth or soil flora. For that, the IBI standard includes an "earthworm test[13]" in which the biochar is mixed with soil to check for toxicity. All these characteristics are governed by processing conditions and the feedstock being used.

Feedstocks

In the U.S. feedstocks tend to be "wastes" of some sort and very little biochar feedstock currently comes from material specifically grown for that use. Feedstock supply, in terms of the source of biomass and the species mix, is managed for consistency by large-scale producers (varying maybe +/- 10% in species composition or source) because of the costs associated with generating it. In the Western US, the feedstock often comes from fire reduction and habitat restoration projects on federal forest lands. Some processors use discarded pallets as a feedstock, while some wood products firms with biochar generation capacity use the "waste" from their manufacturing operations as feedstock.

Given a relatively stable feedstock supply, processing conditions are the primary variable in determining biochar's characteristics. Temperature appears to be of greatest concern, with processing temperatures ranging between 300° and 700°C. Other important factors in production are residence time, degree of oxygen deprivation, and whether the process is "fast" or "slow." These factors all combine to offer the opportunity to create "designer" biochars with specific characteristics, but also present a challenge in process control. Controlling high temperature reactions becomes more expensive the more precise that control has to be. Add in additional variables and the complexity and expense increase further. For the developers of the newest generation of biochar processing technology, the specific characteristics and the ultimate quality of the biochar has to be balanced with the cost and operating complexity of the control technology. Since designing a system depends on accurately identifying the finished product (as evidenced by achieving the desired test results,) knowing to what standard you design the process is a critical precondition.

Customer Needs

The most critical outreach needed to expand biochar's customer base is for the attributes identified in both research and field experience to be connected to the benefits customers are seeking. There is a deep and broad body of research supporting biochar's beneficial use, as well as a growing number of satisfied users. Since few customers have the time to exhaustively investigate new products, they look to early adopters and risk-takers who, if successful, become advocates. The current crop of biochar users is largely in the early adopter category and at present there are no "big name champions" to spur deeper penetration of the agricultural community. An example of an effective champion is Joel Salatain, who almost single-handedly created interest throughout the United States in the pastured poultry industry in the late 1990's.[14]

A broad-scale marketing effort will be needed to grow the biochar market substantially, ideally with the support of a high-profile or media-adept champion. And consistent information is needed regarding product use, benefits, and quality. A tool to aid buyers in matching a specific

[13] A sensitivity test for the presence of tars or other chemicals toxic to a very sensitive organism which is also fundamental to good soil health.

[14] Starting in the early 1990's, Salatin began advocating a model of integrated livestock management he developed, of which raising meat chickens was a key component. Having passed thru the early adopter phase to a developed industry, there is now an industry trade association, the American Pastured Poultry Association, which lists 174 members. Read more: www.apppa.org/pastured-poultry-producer-directory Nationally there are an estimated 5 million chickens raised in this manner by members and independent farmers annually.

biochar product (with known characteristics) to a soil or a filtration/ remediation project would also be beneficial. Some industry producers currently provide this service to their customers, whereas others exhibit a take-it or leave-it attitude. In a free market, the level of customer service is an individual business decision, but the current state of affairs is also a reflection of the early stage of development of the biochar business sector and a bit of the "every man for himself" approach. One producer has referred to it as "The wild-wild west of biochar."

Models for a Developing Industry

Merriam-Webster defines commoditization as the process of making (a good or service) widely available and interchangeable with one provided by another company. While biochar is not a commodity in terms of being a homogenous product across producers, a growing supply, without differentiation, could make the product appear to be a commodity and cause prices to fall, perhaps drastically (see sidebar).

Differentiation, on the other hand, provides opportunities for customized service, and development of niche products for specialized markets. Some producers are already providing "custom" blends to specific buyers. Part of the differentiation seen in the biochar industry today can be attributed to marketing claims alone, in contrast to physical customization wherein producers offer biochar with specific properties geared to a specific buyer's needs. Some producers can manage their processes well enough to generate biochar with specific properties, although this is not common.

These examples of differentiation provide two paths to a growing biochar industry: 1) matching a "stock" biochar to its ideal user, or 2) refining the process control technology to generate designer biochars. The first path would need wide-scale collaboration with consistent and standardized testing to inform a database of available suppliers and their products (e.g., coordinated production system). the second would provide individual businesses the ability to customize their products and act independently (e.g., designer business).

Biomass Energy & Biochar

A growing number of biomass energy generators are producing biochar as a secondary product of energy production.

Within the industry there is strong criticism from some quarters of this practice of selling fly ash as biochar. Yet, there are evidently satisfied users of the product and feasibility studies for combined power and heat facilities routinely include that income stream.

The fact that fly ash is a residue which represents a disposal problem for large-scale energy producers means that this form of biochar is often available at much lower cost than biochar produced on a small scale.

The significant availability of low cost product may help to expand the market for biochar, but may also make it difficult for smaller scale producers to compete.

This development strengthens the argument for product differentiation and customization on the part of small-scale producers.

An example of a coordinated production system can be seen in hardwood lumber. Members of the National Hardwood Lumber Association (NHLA) in the U.S. (representing nearly all hardwood manufacturers with permanent facilities) have agreed to use the NHLA's grading rules, so that a buyer can specify a certain NHLA grade and no matter which mill the lumber originates from, it will conform to those rules and the material will have predictable characteristics. The lumber itself is seen as a commodity, but the individual

buyer knows their purchase conforms to certain standards and can be used to produce consistent desired results (i.e., a profitable, quality-consistent, end product).

An example of a designer business in another commodity market is laundry detergent. There are hundreds of permutations of a product which will clean your clothes. Some require tweaking of the basic processing technology, others have an additive with provides the differentiation. Taken as a whole, laundry detergent is a commodity, but when you go shopping, you're confronted with a myriad of choices, from which you can meet your fairly specific needs. P&G's Tide, high-efficiency (for front loading machines), with no scent, and Sun's ALL liquid, stain-lifter, in-wash detergent are examples. To many, they're all laundry detergent (a commodity) but to others, the various identified attributes provide just what they need. From a production standpoint, this kind of strategy begins with production of a base commodity with downstream variations on a theme, bolstered by differentiated marketing.

Next Steps for Biochar

The biochar industry, largely developed out of the laboratories and pilot plants of hobbyists and aficionados, now has large scale producers generating more in a day than most of the early producers hoped to produce in a lifetime. Somewhere in that continuum of production capacities lie opportunities for differentiated products and a segmented market.

Educating potential consumers will be important to expanding the market for biochar, although providing a consistent message will be equally important. In this regard, industry-wide agreement on consistent product standards, message, and position with respect to carbon attributes is important. Development of life-cycle analyses of biochar products would help guide the standardization of products and the harmonization of message. This agenda would be advanced by more collaboration, especially amongst the mid- to large-scale producers.

The market profile of biochar users continues to grow and diversify. High-value crops appear to be a well-established sector, with filtration and remediation users providing significant growth potential. Development of a market in commodity agricultural or forestry crops, where significant amounts of biochar could go, suffers from a poorly established value proposition, and will require further research. Coordinating the power of global research efforts with needs of industry stakeholders, end users, and policy makers would provide much needed data and input for decision-making.

The Bottom Line

In the previous Dovetail Report on biochar (Groot, et al, 2016) the bottom line was: "Biochar is a product with clear benefits but many questions yet to be answered." That still remains the case although research, production, and markets continue to demonstrate growth opportunities.

The potential of biochar continues to be viewed positively and anecdotal evidence indicates demand is growing. However, the real potential for widespread use is yet untapped. Volume biochar producers are suppling producers of high-value crops with clear and/or well understood benefits. However, a significant market opportunity lies with commodity growers, who could use millions of tons of biomass per year if the price were right and the benefits clearly known. Demonstrable, scientifically-proven evidence will be needed before progress can be made in gaining a market for widespread use. Moreover, the wisdom of the investment has to be made clear, and the process of matching the characteristics of the soil and the particular biochar has to be understood and embraced.

The filtration and remediation markets show significant growth potential. Water treatment, both for human consumption and for clean-up purposes such as liquid mine waste, Superfund site remediation, mining tailings stabilization, and urban/industrial site reclamation is an example of a potential biochar application for which demand could be quite large.

Generation of power from biomass while producing quality biochar as a bio product may change the economic profile of biochar production, lowering costs and expanding markets. However, such development may also create challenges for smaller-scale producers, forcing a strategy of product differentiation.

For marketing purposes, of foremost importance is an industry-in-agreement about basic issues, or at least an industry that is NOT in disagreement. Without consistent standards-based product presentation, producers will continue to pursue their own agendas and "bad actors" will continue to damage the reputation of the whole, leaving conscientious producers to fix misperceptions of their products and fight to hold or gain market share. While this kind of situation is often seen in emerging industries, it's not inevitable, nor beyond salvage if addressed on a broad scale early in the life of the industry.

Bibliography

Abdel-Fattaha T., Mahmoudb M., Ahmedb S., Huffc M., Leec J., Kumard S. 2015. *Biochar from woody biomass for removing metal contaminants and carbon sequestration.* Journal of Industrial and Engineering Chemistry.

Beck D., Johnson G., Spolek G. 2011. *Amending greenroof soil with biochar to affect runoff water quantity and quality*. Environmental Pollution.

Cole E., 2015. *Assessing Kiln-Produced Hardwood Biochar for Improving Soil Health in a Temperate Climate Agricultural Soil*. Dissertation UMass.

Groot H., Fernholz K., Frank M., Howe J., Bowyer J., Bratkovitch S. 2016. *Biochar 101: An Introduction to an Ancient Product Offering Modern Opportunities*. www.dovetalinc.org/reports.

Kearns J., Wellborn L., Summers R., Knappe D. 2014. *2,4-D adsorption to biochars: Effect of preparation conditions on equilibrium adsorption capacity and comparison with commercial activated carbon literature data.* Water Research.

Kulyk, N. 2012."Cost-Benefit Analysis of the Biochar Application in the U.S. Cereal Crop Cultivation" (2012). *School of Public Policy Capstones*.
http://scholarworks.umass.edu/cppa_capstones/12

Major, J. 2010. Guidelines on Practical Aspects of Biochar Application to Field Soil in Various Soil Management Systems. International Biochar Initiative.

Mann, Charles C. 2011. *1491*, second edition, Random House, NY.

Matovic D. 2011. *Biochar as a viable carbon sequestration option: Global and Canadian perspective*. Energy.

Mukherjee A., *Lal* R. 2016. *Biochar and Soil Quality*. Encyclopedia of Soil Science, Third Edition. Taylor and Francis. DOI: 10.1081/E-ESS3-120053997.

Roberts K., Gloy B., Joseph S., Scott N., Lehmann J. 2010. *Life Cycle Assessment of Biochar Systems: Estimating the Energetic, Economic, and Climate Change Potential.* Environ. Sci. Technol., 2010, DOI: 10.1021/es902266r.

Shackley S., Hammond J., Gaunt J., Ibarrola R. 2011. *The feasibility and costs of biochar deployment in the UK.* Carbon Management, Volume 2, Issue 3.

Xie G., Wang D., Wu Y., Qiu Z., Zhang M., Wu C., 2013. *Ameliorating effects of biochar application on degraded vegetable soil.* Agronomy for Sustainable Development. January 2013.doi:10.1007/s13593-012-0081-1.

Thanks also to:

Pacific Biochar

Phoenix Energy

Restoration Technologies

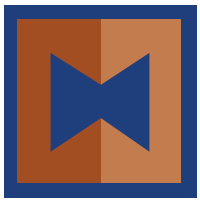
Biochar Now LLC

Light on the Land Services LLC

Dr. J. Barrett, VA Tech Department of Biological Sciences

Mr. Tom Miles (T R Miles, Technical Consultants, Inc.) IBI Director, and USBI Chair

The work upon which this publication is based was funded in whole or in part through a grant awarded by the Wood Education and Resource Center, Northeastern Area State and Private Forestry, Forest Service, U.S. Department of Agriculture.



www.dovetailinc.org

528 Hennepin Ave., Suite 703 Minneapolis, MN 55403 USA

info@dovetailinc.org | **Phone:** +1 612-333-0430 | **Fax:** +1 612-333-0432

Dovetail Partners, Inc. - A Trusted Source of Environmental Information

Dovetail Partners, Inc. is an equal opportunity employer.