Biochar Research Needs and Priorities: Updated Draft March 2010

General need	Need	Researchers/groups with relevant experience
Biochar material characterization	Create a database relating the agronomic effects and stability in soil of a wide variety of biochar materials to their physical and chemical characteristics and feedstocks and pyrolysis conditions (this needs to be done in conjunction with extensive field testing). The goal of the database should be to determine which lab-measured characteristics are most strongly related to effects observed in the field.	Camps, Lehmann, Sarmah, Spokas, van Zwieten
	Identify a specific pyrolysis unit that can produce a useful biochar in sufficient quantity to be used as a standard reference material for biochar testing in laboratories (i.e. a reference material to be used in "ring trials" or by labs who want to compare their results to others').	Boateng
Field application for climate change mitigation	Develop and make available fast and economical ways to measure the amount of biochar-C in a wide variety of soils amended with a variety of biochar materials, over a range of times after application.	Ascough, Baldock, Camps, Gelinas, Gustaffson, Hammes, Han, Hedley, Knicker, Lopez-Capel, Manning, Schmidt, Shindo, Simpson, Skjemstad
	Study the fate of biochar after soil application to a variety of soils (downward and lateral movement, interactions with other soil constituents).	Czimczik, Embrapa research team, Guggenberger, Haefele, Hammes, Hockaday, Joseph, Leifeld, Major, Pignatello, Rumpel, Sarmah, Schmidt
	Determine the stability and decomposition rate, on the long term, of biochar made from a wide variety of feedstocks, in a wide variety of field soils, soil management systems and climates.	Brodowski, Bruun, Camps, Cheng, Cowie, Czimczik, Embrapa's team, Hamer, Hammes, Hedley, Kimetu, Krull, Kuzyakov, Laird, Lehmann, Liu, Major, Masiello, Nguyen, Rogovska, Sarmah, Schmidt, Singh (BP), Sohi, Solomon, Spokas, Steinbeiss, van Zwieten, Zimmerman
	Conduct life cycle analyses of actual projects to determine how much C can be sequestered in soil over given periods of time, considering C emissions of the entire technology system.	Cowie, Gaunt, Ogawa, Roberts
	Study the effect of biochar application to soil on other (non-biochar) forms of organic C.	Camps, Hamer, Hedley, Kuzyakov, Lehmann, Major, Sarmah, Wardle
	Quantify the impact of a wide variety of biochar materials applied to a wide variety of soils/climates on soil emissions of nitrous oxide and methane.	Clough, Condron, Embrapa's team, Hanley, Knoblauch, Kuzyakov, Nguyen, Rogovska, Rondon, Saggar, Spokas, van Zwieten, Wells, Yanai

	Determine the albedo effect of biochar application to soil, compared to other forms of organic matter	
	Determine mechanisms by which biochar impacts nitrous oxide and methane emissions.	Chan, Clough, Condron, Cowie, Embrapa's team, Joseph, Kimber, Saggar, Singh, van Zwieten
Field application for soil remediation	Determine whether biochar can sorb pesticides, heavy metals and other contaminants in the field, and how this sorption can help in the remediation of contaminated sites (by decreasing the bioavailability and mobility of contaminants, for example).	Anderson, Boateng, Camps, Cao, de Leij, Hartley, Ippolito, Keech, Kookana, Mohan, Mukherjee, Pignatello, Qiu, Sarmah, Singh (Balwant), Singh (BP), Smernik, Srinivasan, Wang, Wingate, Yu
	Determine whether biochar can benefit land revegetation and waterway bank stabilization efforts	
	Determine whether biochar can be used to improve water quality (artificial wetlands).	Ballantine
Environmental sustainability of biochar technology	Determine the sustainability of using crop residue that is normally left in the field to make biochar which is returned to the field where the residue was harvested	
	Identify cradle-to-cradle environmentally sustainable biochar production systems at a variety of scales using life cycle analyses for C, measuring emissions, etc.	Gaunt, Jones, Joseph, Kameyama
Safety of biochar use	Determine the amounts and availability of heavy metals, polycyclic aromatic hydrocarbons (PAH), dioxins, and other undesirables in biochars made from a variety of feedstocks and under a variety of pyrolysis conditions.	Downie, Camps, Embrapa's team, Hedley, Lopez-Capel, Manning
	Conduct full environmental risk assessments of biochar systems of all scales. Relate the above to possible human health impacts, comparing impacts to those of alternative technologies. Apart from noxious components of biochar, look at particulate black C in atmosphere, surface runoff of char with water, etc	Downie
Social impacts of biochar technology	Assess the potential social impacts on local communities and benefits related to biochar technology	Joseph, Shackley

Field application for soil fertility improvement	Implementation of geographically widespread and ideally large-scale, long-term field testing of biochar from a variety of feedstocks, produced under a range of pyrolysis conditions. Testing should include wide variations in application rates, soils and climates, and management systems producing a variety of crops. Biochar materials must be adequately characterized, and data should be usable in meta-analyses. On-farm research is also needed.	Asai, Baronti, Blackwell, Chan, Falcao, Foidl, Gaskin, Gatere, Gathorne-Hardy, Haefele, Hill, Keen, Kimetu, Laird, Lehmann, Madari, Major, Novak, Preston, Shinogi, Sinclair, Sohi, Steiner, Teixeira, van Zwieten, Yamato, Yeboah
	Further study the mechanisms by which biochar in soil affects crop yields, and any evolution of these mechanisms in time.	Asai, Baronti, Blackwell, Camps, Chan, de Luca, Falcao, Foidl, Gathorne-Hardy, Gaskin, Gatere, Gundale, Haefele, Hedley, Hill, Keen, Kimetu, Laird, Lehmann, Madari, Major, McKenzie, Novak, Rondon, Shinogi, Sinclair, Sohi, Steiner, Teixeira, van Zwieten, Yamato, Yeboah
	Determine what excessive application rates are for a range of agronomic situations, and what the specific effects of excessive rates are on plants, soil and also off-site.	Baronti, Blackwell, Chan, Falcao, Foidl, Gaskin, Gatere, Gathorne-Hardy, Haefele, Hill, Keen, Kimetu, Laird, Lehmann, Madari, Major, Shinogi, Sinclair, Sohi, Steiner, Teixeira, van Zwieten, Yamato, Yeboah
	Determine whether applying biochar reduces the need to apply nutrients (e.g. in the form of synthetic fertilizers).	Blackwell, Camps, Hedley, Lehmann, Madari, Sohi, van Zwieten
	Determine the effect of applying a variety of biochar materials on high-pH and salt-affected soils	
	Establish best methods for handling/transporting/applying a variety of biochar materials to reduce wind and surface losses and adapt to existing machinery (pelleting, prilling, moistening, applying as a slurry, banding, etc) to ensure safety and efficacy	Blackwell, Gathorne-Hardy, Jones, Riethmuller
	Assess the effect of biochar application in the field on soil water retention, crop water relations and soil hydraulic properties.	Camps, Chan, Deurer, Embrapa's team, Hedley, Laird, Major, Rutherford, Sohi, Souza
	Determine whether biochar application can reduce pollution from agricultural land through surface runoff and leaching reductions.	Downie, Major, Novak, Singh (BP), Singh (Balwant), Sohi
	Determine the effects of adding biochar to forest soils	Embrapa Forestry Team
	Determine the effects of biochar field application on soil biota in general, and on ecological functions performed by soil biota.	Antony, Barrigossi, Das, de Luca, Dornbush, Jin, Liang, Macdonald, Pietikainen, Rillig, Saito, Solaiman, Steiner, Thies, Tsai, Warnock, Yoshizawa

Biochar production	Study the optimization of biochar production vs. using biomass as biofuel.	Boateng, Brown, Gaunt, McHenry, Roberts
	Determine the monetary costs and benefits of biochar production and application for a wide variety of scenarios where biochar is made from several feedstocks and where current inputs to soil are substituted (e.g. biochar from manure instead of manure itself). Also situations where there are competing uses for biochar should be considered, using life cycle analyses.	Bryant, Chrisman, Downie, Gaunt, Glover, Jones, Kung, Mašek, McCarl, Peacocke, Roberts, Sands, Somerville
	Determine production parameters that produce biochar materials that provide soil fertility benefits and/or soil C sequestration (after information obtained under other needs listed here).	Boateng, Brown, Czernik, Jones, Joseph
	Produce large volumes of a variety of biochar materials to allow extensive field testing as mentioned under other objectives.	
	Determine whether uniform biochar can be produced on a large scale.	Jones
	Develop methods to effectively enhance biochar with nutrients.	Dias, Embrapa's Team, Joseph, Wu
	Develop "low tech" methods to safely pyrolyze rice hulls to avoid the formation of crystalline silica compounds	
	Study methods to "age" biochar (e.g. develop surface charge) before soil application.	Camps, Joseph, McLaughlin, Yao
Economics of biochar systems	Determine the economical sustainability of biochar systems on a cradle-to-cradle basis	Roberts