International Agrichar Initiative (IAI) 2007 Conference

April 27 – May 2, 2007

Terrigal, New South Wales, Australia

Welcome to the first international conference of the International Agrichar Initiative (IAI). The IAI is an informal, recently-formed coalition of research, commercial and policy-oriented people and organizations devoted to the sustainability of the world's soils, and to sustainable bio-energy production. Agrichar production and utilization can renew the world's soils through the addition of organic carbon, and can additionally help solve the pressing problem of global climate change. The Agrichar production process also converts agricultural waste into valuable bio-fuels.

We expect the conference to be an exciting exchange of information and ideas to further develop this growing field. We look forward to working with you to advance the goals of the conference in the following areas:

Research, Development, and Deployment:

- Review the results of research and development work in the field of Agrichar and energy co-production
- Review demonstration and commercial programs that have been operating in the field
- Identify barriers to commercialization of the Agrichar product and technology, and methods to overcome these barriers
- Visit sites where Agrichar R&D is underway in Australia

Policy and Education Development:

- Review new policy and educational initiatives in the field
- Review economic and environmental studies on the costs and benefits of Agrichar production and utilization

Organizational:

- Review the goals and tenets of the International Agrichar Initiative
- Review initiatives and progress to establishing an International Agrichar Organization
- Prepare a development plan for the International Agrichar Initiative, including funding and development goals, and programs goals and timelines
- Prioritize key management questions to be resolved in order to bring the Agrichar agenda to the next stage

We are gratified by the level of support and commitment that has emerged since the IAI was formed; particularly in response to this conference. With our combined efforts, we can make a difference and help speed development of an issue vital to the world's soils and help to solve the critical issue of global climate change. Thank you for your support and for joining us at this event.

Sincerely,

Debbie Reed
Coordinator, International Agrichar Initiative
Executive Director, Renew the Earth

This document can be cited as: International Agrichar Initiative (IAI) 2007 Conference, April 27 – May 2, 2007, Terrigal, Australia; http://www.iaiconference.org

If citing abstracts, please use page number as well as author's name(s).

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Conference Sponsors ($5,000)

BEST Energies: Best Energies is a leader in the development of slow pyrolysis solutions. Our proprietary process utilizes local biomass to create clean syngas to offset natural gas, green electricity, carbon credits and carbon rich end products. www.bestenergies.com

Biojoule: Biojoule deals in the supply of energy from biomass. The current focus is on the final stages of introducing an innovative pellet mill that will deliver high quality fuel pellets for heat and power from wood and other biomass sources. www.biojoule.co.uk

Clean Air Task Force (CATF): The Clean Air Task Force (CATF) is a nonprofit organization dedicated to restoring clean air and healthy environments through scientific research, public education, and legal advocacy. www.catf.us

Crucible Carbon: Crucible Carbon, a collaboration between the Crucible Group Pty Ltd and Pekabu investors, is committed to energy and resource processing solutions that are carbon neutral or better. An innovative focus is on the pyrolysis of biomass, including algae to produce oils, gas, and char.

The Department of Environment & Climate Change NSW: [formerly Department of Environment and Conservation (NSW)] is the New South Wales State Government Agency responsible for the implementation and delivery of the Government's major policy reforms and programs involving protecting and conserving the environment, natural resources and meeting the challenges of climate change. www.environment.nsw.gov.au

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NSW DEPARTMENT OF
PRIMARY INDUSTRIES

New South Wales (NSW) Department of Primary Industries (DPI): The NSW Department of Primary Industries acts in partnership with industry and other public sector organizations to foster profitable and sustainable development of primary industries in New South Wales, Australia. www.dpi.nsw.gov.au

Renewed fuels

Renewed Fuels is a specialist project developer, focused to optimise resource value and energy recovery from waste materials, or otherwise currently undervalued resources. Renewed Fuels is currently developing a 76,000 (w)t/pa Agrichar production plant to be sited at Australian Paper Maryvale Mill, Victoria.

Conference Supporters ($2,500)

Australian Government
Department of the Environment and Water Resources
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The Australian Greenhouse Office, part of the Department of the Environment and Water Resources, delivers the majority of programmes under the Australian Government's climate change strategy. www.greenhouse.gov.au

OBP

Office of Biorenewables Programs (OBP), Iowa State University: The Office of Biorenewables Programs (OBP) is an outgrowth of the Bioeconomy Initiative—a campus-wide effort, launched in 2002, to investigate the use of biorenewable resources as sustainable feedstocks for producing chemicals, fuels, materials, and energy. www.biorenew.iastate.edu

Conference Contributors ($1,000)

BioEnergy Australia Ltd: Bioenergy Australia has developed a forestry/renewable energy model and process that is unique in the market today. The Company has developed a system whereby a renewable biofuel (high density pellets, charcoal, and energy) can be delivered to the market within 2 to 3 years of planting. www.bioenergyaustralia.org

Biomass Coordinating Council (BCC): The BCC is working to accelerate the adoption of renewable biofuels, biopower, and biobased products into mainstream American society through work in policy initiatives, convening, networking, and communications. www.acore.org/programs/bcc.php

Biomass Energy and Carbon: Biomass Energy & Carbon develops biomass gasification technologies that produce clean *producer gas* streams for electrical and thermal energy as well as oxygen blown gasification systems that produce *synthesis gas* as a feed stock for catalytic gas-to-liquid fuel production. www.biomassenergyandcarbon.com

ICT International: ICT International was established in 1982 with the focus of providing world class quantitative monitoring technologies to commercial agriculture, agricultural scientific research, environmental monitoring, and engineering communities. www.ictinternational.com.au

Renew the Earth (RTE): Renew the Earth (RTE) is a non-profit organization that advocates policies, practices, and investments for increasing energy and environmental sustainability in the United States and globally. www.renew-the-earth.org

Rick Davies is a consultant for international development aid programmes and is interested in applications of bio char that could benefit poor rural communities in Africa and Asia, via increased soil fertility and income from carbon credit and carbon offset sales. www.mande.co.uk

Conference Agenda

Friday, April 27, 2007

Field trip to NSW Department of Primary Industries, Wollingbar, Australia

11:00 am – 3:00 pm

- Field Trip to the NSW Department of Primary Industries, Environmental Center of Excellence, in Wollongbar, Australia, where Dr. Lukas Van Zwieten has field trials underway, utilizing the BEST process applying Agrichar.
- For more information on the Dr. Van Zwieten's work at the NSW Department of Primary Industries, the facility and its operations, go to: http://www.agric.nsw.gov.au/reader/wollongbar

Sunday, April 29, 2007

6:00 pm – 8:00 pm: *Cool Court Terrace, 2nd Floor, Terrigal Crowne Plaza Hotel*
Welcome Barbecue Dinner for Conference Participants

Monday, April 30, 2007: Conference Day 1

8:00 am – 8:30 am: *Henry Kendall Ballroom*
Welcome to Country
Welcome to Conference, Meeting Overview
Stephen Joseph, BEST Energies, Australia
Debbie Reed, International Agrichar Initiative, USA
Johannes Lehmann, Cornell University, USA

8:30 am – 9:00 am: *Henry Kendall Ballroom*
Keynote Address
Mike Mason, Biojoule, UK

9:00 am – 9:10 am: *Henry Kendall Ballroom*
Meeting Logistics
Adriana Downie, BEST Energies, Australia

9:10 am - 9:30 am: *Hawksbury Lobby*
Break and Networking Opportunity

9:30 am – 11:30 pm: *Henry Kendall Ballroom*
Agrichar Research and Development—Understanding the Impacts and Benefits of Agrichar
Chair: Janice Thies, Cornell University, USA
(Each presentation 15 minutes, plus 5 minutes Q&A)

- Blackwell P, Shea S, Storer P, Kerkmans M, Stanley I: Improving wheat production with deep banded Oil Mallee charcoal in WA

- Chan KY, van Zwieten L, Meszaros I, Downie A, Joseph S: Assessing the agronomic values of contrasting char materials on an Australian hardsetting soil
- Lehmann J, Cheng CH, Nguyen B, Liang B, Major J, Smernik R: Permanency and long-term changes of bio-char in soil
- Yoshizawa S, Tanaka S, Ohata M: Proliferation effect of aerobic micro-organisms during composting of rice bran by addition of biomass charcoal
- O'Neill B, Grossman JM, Tsai SM, Lehmann J, Thies JE: Analysis of bacterial communities in Amazonian Dark Earths through community-level molecular analysis and identifying dominant species in soils from the Eastern and Central Amazon
- Smernik R: The influence of soil charcoal on the absorption of organic molecules

11:30 am – 12:00 pm: *Henry Kendall Ballroom*
Agrichar Research and Development—Understanding the Impacts and Benefits of Agrichar
Chair: Janice Thies, Cornell University, USA
(Each Poster Mini-presentation 1 – 2 minutes)

- Singh B, Cowie A: Quantifying char-carbon turnover, and implications for greenhouse balance
- Sohi S, Yates H, Lehmann J: Carbon stabilization in Terra Preta soils
- Downie A, Van Zwieten L, Doughty W, Joseph S: Nutrient retention characteristics of chars and the agronomic implications
- Lopez Capel E, Manning DAC: Characterisation of Terra Preta soils and chars by thermal analysis-quadrupole mass spectrometry
- Major J, Lehmann J, Rondon M: Field maize yield and yield determining factors for four years following biochar application on a Colombian savanna Oxisol
- Hill RA, Harris A, Stewart A, Bolstridge N, McLean KL, Blakeley R: Charcoal and selected beneficial microorganisms: plant trials and SEM observations
- de Arruda, Murilo R., and Wenceslau G. Teixeira: Use of charcoal, chicken manure and bones meal in Guarana (Paullinia cupana var. sorbilis) - preliminary results
- Hongyan J, Zhong, Z, Thies JE: Soil microbial community response to amending rice soils with bamboo charcoal

12:00 pm – 1:00 pm: *Seasalt Restaurant*
Lunch

1:30 pm – 2:50 pm: *Henry Kendall Ballroom*
Agrichar Production and Testing
Chair: Robert Brown, Iowa State University, USA
(Each Presentation 15 minutes, plus 5 minutes Q&A)

- Tadeo BD: Carbonized rice husk and the automated carbonization system in the Philippine rice industry
- Downie A, Joseph S, Crosky A, Munroe P: Assessing the physical and chemical nature of poultry manure chars
- Hawkins B: Influence of pyrolysis conditions on char properties
- Glover M: Renewed Fuel: Consideration of issues to promote commercialization of Agrichar products and applications

2:50 pm – 3:00 pm: *Henry Kendall Ballroom*
Agrichar Production and Testing
Chair: Robert Brown, Iowa State University, USA
(Each Poster Mini-presentation 1 – 2 minutes)

- Novotny EH, Hayes MHB, deAzevedo ER, Bonagamba TJ: NMR characterisation of Biofine's by-products char

- Zhong Z, Flanagan R: The physical and chemical properties of Bamboo charcoal and its application as a soil conditioner
- Hossain MK, Strezov V, Nelson P: Evaluation of agricultural char from sewage sludge
- Joseph S, Downie A, Lehmann J: Classification of chars for agricultural use

3:00 pm – 3:30 pm: *Hawksbury Lobby*
Break and Networking Opportunity

3:30 pm – 4:50 pm: *Henry Kendall Ballroom*
Economics, Environment and Policy
Chair: Mark Glover, Renewed Fuels, Australia
(Each Presentation 15 minutes, plus 5 minutes Q&A)

- Radlein D, Kingston A: The role of Agrichar in the commercialization of Dynamotive's fast pyrolysis process
- Bryant D, Downie A: Agrichar: Building a commercial venture
- Gaunt J, Lehmann J: Prospects for carbon trading based on the reductions of greenhouse gas emissions arising from the use of bio-char
- Larson RW: RD&D issues for agrichar, emphasis on energy and developing countries

4:50 pm – 5:00 pm: *Henry Kendall Ballroom*
Economics, Environment, and Policy
Chair: Mark Glover, Renewed Fuels, Australia
(Each Poster Mini-presentation 1 – 2 minutes)

- Somerville M, Van Berkel R: The utilisation of waste biomass in SA as a renewable resource for agriculture or metallurgy
- Bezerra, JC: How has historical research changed our understanding of the Amazonian environment?

6:00 pm – 8:00 pm: *Pacific Ballroom*
Conference Dinner

8:00 – 10:00 pm: *MacMasters Room*
Poster Sessions: All Topics
(Note: Posters should be set up before 8:00 am, and will hang both days)

- **8:00 – 9:00 pm:** Posters #1 – 12 authors are present at their posters
- **9:00 – 10:00 pm:** Posters, #13 – 23 authors are present at their posters

Tuesday, May 1, 2007: Conference Day 2

8:30 am – 8:45 am: *Henry Kendall Ballroom*
Introduction and Overview of Day 2
Johannes Lehmann, Cornell University, USA

8:45 am – 9:15 am: *Henry Kendall Ballroom*
Panel Discussion: Agrichar Research and Development
Panel Facilitator: Johannes Lehmann, Cornell University, USA
Panel Participants:

- Robert Brown, Professor, Iowa State University, USA
- Lukas Van Zwieten, New South Wales Department of Primary Industries, Australia
- Stephen Joseph, Chief Engineer, BEST Energies and Visiting Professor University of NSW, Australia

- Joe Herbertson, Crucible Carbon, Australia

9:15 am – 10:00 am: *Henry Kendall Ballroom*
Plenary Discussion
Facilitated by Johannes Lehmann, Cornell University, USA

10:00 am – 10:30 am: *Hawksbury Lobby*
Break and Networking Opportunity

10:30 am – 11:00 am: *Henry Kendall Ballroom*
Panel Discussion: Agrichar Production and Utilization: Markets and Commercialization
Panel Facilitator, Peter Read, Massey University, New Zealand
Panel Participants:

- Desmond Radlein, Chair, Research and Development, Dynamotive, Canada
- Neil Young, Co-founder, President and CEO, BEST Energies, USA
- David Bryant, Rural Funds Management, Australia
- Jim Fournier, President, Bioenergy and Charcoal , USA
- Robert Flanagan, SAFFE, China

11:00 am – 11:45 am: *Henry Kendall Ballroom*
Plenary Discussion
Facilitated by Peter Read, Massey University, New Zealand

11:45 am – 12:30 pm: *Henry Kendall Ballroom*
Plenary Discussion: Prioritizing Key Management Questions for the International Agrichar Initiative
Facilitated by Helen Scott-Orr, Director, Health Sciences, Strategic Alliances and Evaluation, Science and Research Division, NSW Department of Primary Industries, Australia
Panel Participants:

- Johannes Lehmann, Cornell University, USA
- Peter Read, Massey University, New Zealand

12:30 pm –1:30 pm: *Seasalt Restaurant*
Lunch

1:30 pm – 2:30 pm: *Henry Kendall Ballroom*
Keynote Reflections: Tim Flannery, Australia
http://www.groveatlantic.com/grove/bin/wc.dll?groveproc~genauth~1497

2:30 pm – 3:00 pm: *Hawksbury Lobby*
Break and Networking Opportunity

3:00 pm – 4:00 pm: *Henry Kendall Ballroom*
Tying it All Together: The Agrichar Business and Development Plan
Chair: Debbie Reed, International Agrichar Initiative

4:00 pm – 5:30 pm: *Henry Kendall Ballroom*
Wrap-up and Next Steps for the International Agrichar Initiative
Stephen Joseph, BEST Energies, Australia
Johannes Lehmann, Cornell University, USA
Debbie Reed, International Agrichar Initiative, USA

6:30 – 8:30 pm:
BBQ (Participants responsible for dinner)
Informal/Arranged Meetings and Discussions

Wednesday, May 2, 2007

Field Trip: Biomass Energy Services and Technology Pty Ltd (BEST), Somersby, Australia

10:00 am – 1:00 pm

- Field Trip to an Agrichar production unit at *Biomass Energy Services and Technology Pty Ltd (BEST*), Somersby, Australia
- Bus transport will be provided to and from the Terrigal conference site for registered participants. Light lunch will be provided at the BEST facility.
- For more information on the BEST facility and its operations, go to: www.BESTenergies.com

Conference Committees

Conference Organizing Committee

Ellen Baum, Senior Scientist
Clean Air Task Force, USA

Adriana Downie, Process Engineer
BEST Energies, AUS

Bill Holmberg, Chairman,
Biomass Coordinating Council
ACORE, Renew the Earth, USA

Debbie Reed, Coordinator
International Agrichar Initiative, USA
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Renew the Earth, USA

Judy Siegel, President
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Lukas Van Zwieten,
Senior Research Scientist
NSW Department of Primary Industries,
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Joe Chaisson, Technical Director
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Johannes Lehmann, Associate Professor
Cornell University, USA

Etelvino Henrique Novotny
Embrapa Soils,
Brazilian Agricultural Research Corporation,
BRAZIL

Don Reicosky
Agricultural Research Service,
U.S. Department of Agriculture, USA

General Conference Logistics

Conference Location:

The Conference is located at the Terrigal Crowne Plaza Hotel
Pine Tree Lane, P.O. Box 20
Terrigal, 2260 Australia

Hotel Front Desk: 61-2-43849111 | Hotel Fax: 61-2-43845798

Event Rooms:

The Main Conference is in the Henry Kendall Ballroom

The Sunday Dinner is on the Cool Court Terrace, 2nd Floor

The Monday Dinner is in the Pacific Ballroom

The Posters are displayed in the MacMasters Room

Breakfast and Lunch are served in the Seasalt Restaurant**

Conference tea and coffee breaks are in the Hawksbury Lobby

**Lunch is included in the conference registration; however breakfasts are on your own. Please mention that you are with the International Agrichar Initiative Conference to receive a reduced breakfast price of AUS$10.

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Agrichar: Building a Commercial Venture

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Assessing the Agronomic Values of Contrasting Char Materials on an Australian Hard setting Soil

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Assessing the Physical and Chemical Nature of Poultry Manure Chars

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Prospects for Carbon Trading Based on the Reductions of Greenhouse Gas Emissions arising from the use of Bio-char

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Consideration of Issues to Promote Commercialization of Agrichar Production and Application

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Influence of Pyrolysis Conditions on Char Properties

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Permanency and Long-term Changes of Bio-char in Soil

O'Neill, B. et al.
Analysis of Bacterial Communities in Amazonian Dark Earths through Community-level Molecular Analysis and Identifying Dominant Species in Soils from the Eastern and Central Amazon

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*The Role of Agrichar in the Commercialization of Dynamotive's Fast Pyrolysis Proces*s

Smernik, R.
The Influence of Soil Charcoal on the Sorption of Organic Molecules

Tadeo, B. D.
CRH and the Automated Carbonization System in the Philippine Rice Industry

Yoshizawa, S. et al.
Proliferation Effects of Aerobic Micro-organisms During Composting of Rice Bran by Addition of Biomass Charcoal

Poster abstracts

THE POSTER NUMBERS MATCH PRESENTATION TIMES. POSTERS 1 – 12 WILL BE PRESENTED MONDAY APRIL 30TH FROM 8:00 PM – 9:00 PM AND 13 – 23 WILL BE PRESENTED MONDAY APRIL 30TH FROM 9:00 PM – 10:00 PM.

AGRICHAR AS A MATERIAL

#1 Hossain, M.F. et al.
Evaluation of Agricultural Char from Sewage Sludge

#11 Joseph, S., A. Downie, J. Lehmann
Classification of Chars for Agricultural Use

#12 Novotny, E.H. et al.
NMR Characterization of Biofine's By-products Char

AGRICHAR TECHNOLOGY

#2 Somerville, M. and R. Van Berkel
The Utilization of Waste Biomass in SA as a Renewable Resource for Agriculture or Metallurgy

#13 Somerville, M. and D. Langberg
The Characterization of Pyrolysis Products Produced from Low Value Fractions of Mallee Gums

AGRONOMIC AGRICHAR RESEARCH AND FIELD TRIALS

#3 de Arruda, M.R. and W. G. Teixeira
*Use of Charcoal, Chicken Manure and Bones Meal in Guarana (*Paullinia cupana *var. sorbilis)—Preliminary Results*

#14 Benites, V. de M. et al.
Use of Charcoal and Wood Carbonization By-products in Agriculture: Learning with "Terra Preta de Indio"

#15 Downie, A. et al.
Nutrient Retention Characteristics of Chars and the Agronomic Implications

#16 Hill, R.A. et al.
Charcoal and Selected Beneficial Micro-organisms: Plant Trials and SEM Observations

#4 Major, J. et al.
Field Maize Yield and Yield Determining Factors for Four Years following Biochar Application on a Colombian Savanna Oxisol

#17 Steiner, C. and **de Arruda, M.R.** et al.
Slash and Char as an Alternative to Slash and Burn—Soil Charcoal Amendments Maintain Soil Fertility and Establish a Carbon Sink

#18 Yoshizawa, S. et al.
Preservation of Woods in Forest Acid Soil by Addition of Biomass Charcoal

STATUS OF SOIL CARBON LEVELS, SOIL HEALTH, USE OF AGRICHAR AS A SOIL CONDITIONER

#5 Jin, H. et al.
Soil Microbial Community Response to Amending Rice Soils with Bamboo Charcoal

#19 Major, J. et al.
Fate of Biochar Applied to a Colombian Savanna Oxisol during the First and Second Years

#20 Van Zwieten, L. et al.
Papermill Agrichar: Benefits to Soil Health and Plant Production

#21 Zhong, Z. and H. R. Flanagan
The Physical and Chemical Properties of Bamboo Charcoal and its Application as a Soil Conditioner

USE OF AGRICHAR FOR CARBON SEQUESTRATION, CARBON CREDITS

#6 Lehmann, J. et al.
Carbon Sequestration and Mitigation of Carbon Dioxide Accumulation in the Biosphere: The Role of Biochar in Tropical Agricultural Systems

#22 Singh, B. and A. L. Cowie
Quantifying Char-Carbon Turnover, and Implications for Greenhouse Balance

CO-PRODUCTION OF AGRICHAR AND ENERGY

#7 Brown, R. C. et al.
Distributed Production of Bio-Oils and Bio-Chars for Agricultural and Energy Applications

TERRA PRETA ("DARK EARTH") SOILS

#8 Cunha ,T. J. F. et al.
Terra Preta de Indio "Dark Earth Soils": Chemical and Spectroscopic Characterization of Humic Acids

#23 Lopez-Capel, E. and D.A.C. Manning
Characterisation of Terra Preta Soils and Chars by Thermal Analysis-Quadrupole Mass Spectrometry

#9 McPhillips, L. et al.
Soil Fungal Communities in Three ADE Sites Characterized by Molecular Fingerprinting, Isolating Unique Species and Assessing Arbuscular Mycorrhizal Fungi

POLICY AND EDUCATIONAL APPLICATIONS OF AGRICHAR AND ENERGY SYSTEMS

#10 Bezerra, J. C.
How Has Historical Research Changed Our Understanding of the Amazonian Environment?

Full Presentation Abstracts

(Presenter's name is in bold)

Improving Wheat Production with Deep Banded Oil Mallee Charcoal in Western Australia

Blackwell, Paul[1], S. Shea[2], P. Storer[3], M. Kerkmans[2], and I. Stanley[4]

[1]Department of Agriculture and Food WA, and the Oil Mallee Company of Australia, Western Mineral Fertilisers , Australia [2]Oil Mallee Company of Australia [3]Western Mineral Fertilisers, Australia
[4]Bungadale farm, Kalannie, WA Australia

Recent agronomic research in Western Australia has shown there can be benefits to wheat income from deep banded oil mallee charcoal in low rainfall areas; the 2005 trials showed up to $96/ha improved income at current wheat prices. There were encouraging effects on Vesicular-Arbuscular Mycorrhiza (VAM) colonisation. Banded oil mallee charcoal can improve VAM colonisation of wheat roots by 3 fold, when used with mineral fertilisers and VAM is inoculated with the seed and fertilizer. The true economic value of oil mallee charcoal will be clearer when the cost of charcoal production and application is better known.

More research would be worthwhile on how low the banded charcoal rate needs to be to encourage better yields from mineral fertiliser with inoculated VAM.

In 2005, Oil mallee charcoal was crushed and sieved to <2 – 3mm and placed at 50 – 200mm depth with an air seeder and knife point system (DBS). Four passes were needed to apply 6 t/ha. Controls were established to test the effect of cultivation alone.

The yield benefits from the banded charcoal treatments ranged from 76 to 640 kg/ha (table1). With a realistic value of grain for the varieties used the improved income ranges from $11 to $96/ha. These benefits are most encouraging for the use of the mineral fertiliser; a low minimum rate of banded charcoal was needed to obtain the yield benefit

Table 1. Summary of grain yield responses, charcoal rates and financial benefits from the trials in 2005 near Pindar or Kalannie in the NE wheatbelt of WA.

site and fertilizer 1.= Pindar 2.= Kalannie	Benefit from wheat yield, kg/ha	minimum rate of banded charcoal, t/ha	rate of broad acre charcoal, kg/ha	benefit of charcoal from wheat value#, $/ha
1. 100 kg/ha mineral+ microbes[1]	640	1.5	250	96
1. 30 kg/ha soluble[2]	344	6	1000	52
1. 55 kg/ha soluble[3]	0			0
2. 110 kg/ha soluble	76	6	1000	11
2. 110 kg/ha soluble	83	3	620*	12

[1]cost $46.5/ha [2] $15.3/ha [3] $28/ha * 300 mm row spacing and adjusted to 6% moisture # $150/t

Agrichar: Building a Commercial Venture

Bryant, David[1] and A. Downie[2]

[1]Rural Funds Management Ltd; [2] BEST Energies, 56 Gindurra Road, Somersby, NSW 2250, Australia

The potential of Agrichar to improve agricultural sustainability, mitigate greenhouse gas emissions, sequester carbon, manage waste biomass and assist in rural development can only be realised with the large scale commercial uptake of the technology. To realise this potential the construction and operation of pyrolysis plants must provide satisfactory returns and moderate risks.

Rural Funds Management (RFM) has been assessing the business case for implementing BEST Pyrolysis technology in regional NSW. Their diverse agribusiness portfolio puts them in a unique position to build a business where the biomass wastes generated from their poultry sheds could be pyrolysed to generate energy and an agrichar product which could be used to benefit their horticultural interests. With the interest of investors a priority, an assessment of the economics of the technology was an essential first step. Using a simple economic model, developed by BEST based on their process flow calculations; it became clear that the feasibility hinged on several key factors. These critical factors include: the local price of energy, cost of biomass feed (including transport), and the value of the char product. Given the price of electrical energy in the area and the additional capital expenditure required to install an engine for electricity generation, the sale of electricity from a pyrolysis plant is marginal. However, due to the increased conversion efficiencies, selling thermal energy to replace natural gas or liquid petroleum gas should achieve acceptable returns. It is considered essential that a reliable customer for this energy stream is available. The logistics of delivering thermal energy in the forms of high pressure hot water or steam means that the customer must be in close proximity to the pyrolysis unit. This in turn needs to be relatively close to the biomass source to minimize materials handling costs. Placing a value on the char product was also essential to support the economic model. In real terms, the preferred assessment of the char would be to conduct large scale field trials and quantify the values of the char in terms of increased profits gained from increased crop yields. However, the time and cost involved does not fit the criteria of the quick business case assessment intended. For this reason, an evaluation has been attempted on the basis of comparing the nutrient contents (fertilizer value) and liming value of the chars and equating them with commercially available sources. Although it is understood that there is a considerable non-fertiliser value in char, these are very difficult to quantify by simple analytical techniques and they do not represent a mainstream, established agricultural commodity.

	CCI Results		**DPI Results**						
	Ash Constituent (%)	**Total db (%)**	**Total (%)**	**"Available" forms (mg/kg)**	**Available %**	**Value $/kg**	**Value - total CCI ($/tonne)**	**Value - total DPI ($/tonne)**	**Value - available ($/tonne)**
N		4.3%	2.8%	8.6	0.0009%	$1.08	$46.59	$30.13	$0.01
P	18.0%	7.5%	3.6%	5200	0.52%	$2.02	$151.26	$72.72	$10.50
K	9.7%	4.0%	3.5%			$0.94	$38.09	$33.04	$0.00
Ca	22.0%	9.2%				$0.61	$56.04		
							$291.99	**$135.89**	**$10.51**

A valuation of nutrients provided in the accompanying table demonstrates that there is considerable variance in dollars per tonne terms due to the test methods and assumptions made regarding nutrient availability. Considering that this variability represents the difference between an economically feasible project or otherwise, significant investigations into the accurate prediction of the agronomic value of char were conducted.

Assessing the Agronomic Values of Contrasting Char Materials on an Australian Hard Setting Soil

Chan, K.Y.[1], L. van Zwieten[1], I. Meszaros[1], A. Downie[2] and S. Joseph[2]

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Beneficial effects of char in terms of increased crop yield and improved soil quality have previously been reported. As chars can be produced from a range of organic materials and under different conditions, resulting in products of varying properties, research relating the quality of the char products to their effects on crop growth and production is needed. Such understanding is essential for development of agricultural markets for chars and for elucidation of the mechanisms responsible for the reported beneficial effect of chars. This paper reports research on the agronomic values of 3 chars produced from 2 different feedstock materials involving laboratory characterization and pot experiments. The soil used was a degraded hard setting soil (0 – 10 cm, Chromosol). Properties of the chars and soil are presented in Table 1.

Table 1: Properties of chars and soil used in the investigation

Char	Feedstock	Activated	pH_{CaCl2}	EC dS/m	C %	Total N%	Total P%	Mineral N (mg/kg)	Extractable P (mg/kg)	Carbon-ate %*
GO	Garden organic	Yes	9.4	3.2	36	0.18	0.07	<0.5	400	<0.5
PM1	Poultry manure	Yes	13	14	33	0.9	3.6	2.5	1800	35
PM2	Poultry manure	No	9.9	5.6	38	2.0	2.5	2.4	11600	15
Soil	-	-	4.5	0.05	1.8	1.2	-	18	34	0.0

* as calcium carbonate

The char samples had varying levels of total N, total P and carbonates but all had negligible mineral N. The pot trials growing radish in temperature-controlled glasshouse had randomized block design with different rates of char and ± N fertilizer at 100 kg N/ha. Results showed that, with no N fertilizer, dry matter production (DM) of radish did not increase with char application (to 100 t/ha) for GO but significant increases were observed for both PM chars (average 80% at 50 t/ha). For GO, DM reduction was observed at low char rate (10 t/ha) compared to nil char control.

With N fertilizer, significant increases in DM were observed with all 3 chars and the increases were higher at higher char rates. For GO, 95% and 266% increases respectively for 0 and 100 t/ha were observed. The significant N x char interaction effect was probably due indirectly to the improvement of soil physical properties of the hard setting soil. DM of radish using activated PM was on average 7% lower than non-activated.

Results highlight the unique characteristics of the different chars which need to be considered during market development. Agronomic value of GO is due mainly to its physical soil conditioning effect and to be effective, would require fairly high rate of application (>50 t/ha). For PM, they work both as organic fertilizers as well as soil conditioners and agronomic benefits were observed at lower rate (10 t/ha).

Assessing the Physical and Chemical Nature of Poultry Manure Chars

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There are a number of analysis tools available to assess the physical and chemical nature of materials. It is desirable to develop laboratory methods to characterise different chars and to correlate these results with gross agronomic outcomes. Ultimately the effectiveness of various chars for use as carbon sequestering soil amendments or otherwise will be predictable using simple tests without the need for large crop trials for each soil, char or crop type. The physical and chemical structure of the Agrichar material will not only have implications on its behaviour and interactions in soil systems, but also in post-processing operations such as ammonia scrubbing, pelleting or prilling and for materials handling.

Poultry manure chars were chosen as the subject of this study due to several factors combining to make it a prime biomass source for pyrolysis, energy, and Agrichar production.

A range of analysis techniques were assessed for characterisation of poultry manure chars made under different processing conditions. Techniques investigated included x-ray diffraction (XRD), Scanning electron microscopy energy dispersive spectroscopy (SEM/EDX), electron microprobe analysis (EPMA), nuclear mass resonance (NMR), Raman Spectroscopy, and Fourier Transform Infrared Spectroscopy (FTIR). Sample preparation techniques and methods were developed to obtain the most accurate and meaningful results possible for these types of samples. The results were correlated with ultimate, ash constituent, surface area (BET), and nutrient analysis results, as well as with agronomic trials conducted by the NSW DPI.

It was found that processing conditions made a significant and detectable impact on not only the bulk constitution of the Agrichar product but also the nature and distribution of carbon forms, the types of bonding arrangements, the proportions and surface presentation of mineral complexes, the surface area, pore size distribution, and general morphology.

The most significant limitation of the techniques assessed was their suitability to cope with the heterogeneity on a microscopic level. Analysis equipment coupled with a SEM, including the EDAX and raman, were found to be well suited due to sample selection being possible on a micron scale. Analysis methods that were capable of bulk sampling, on the gram or more scale, also gave reasonable results. However, site specific analysis of samples in the millimeter range, for example on the Bruker FTIR, was found to give highly variable results. This can be overcome to some extent by careful sample selection.

Prospects for Carbon Trading Based on the Reductions of Greenhouse Gas Emissions Arising From the Use of Bio-Char

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Conversion of organic matter contained in plant biomass to char (Agrichar) and bio-energy using pyrolysis enables the stabilization of the carbon contained in the organic matter as Agrichar while also producing energy. The application of pyrolysis in this way offers the prospect to create a long-term sink for atmospheric carbon dioxide in terrestrial ecosystems while also offsetting fossil fuel use for energy.

In addition to these benefits, it has been established, both through field research and through observation of situations where historically char has been applied to soil, that in addition to carbon stabilization Agrichar can act as a soil conditioner enhancing plant growth. The application of Agrichar to soil influences the supply and retention of nutrients as well as providing other services such as improving soil physical and biological properties. These benefits are not only relevant to improving crop yields but also lead to decreasing off-site effects by runoff, erosion, and gaseous losses of methane and nitrous oxide which are important greenhouse gases.

Thus Agrichar soil management systems combined with the application of pyrolysis to produce bio-energy will deliver reductions in greenhouse gas emissions through i) the offsetting of emissions associated with fossil fuel use, ii) stabilization of organic matter resources used as feedstock, and iii) the influence of Agrichar on greenhouse gas emissions from soil.

In calculating the benefits of such a practice it is necessary to take full account of all energy inputs used in producing and processing the feedstock. However the prospect of a strategy that not only reduces fossil fuel use but also leads to stabilization of biomass carbon and a reduction in greenhouse gas emissions is particularly exciting.

These avoided emissions appear to be compliant with the requirements of the Kyoto protocol and this paper we present indicative examples of the tradable emissions in three contrasting situations:

1. The introduction of pyrolysis in tropical slash and burn situations
2. The application of pyrolysis as a bio-energy solution in crop based agricultural situations
3. The application use of Agrichar derived from the pyrolysis of organic waste streams

We use these examples to highlight and discuss policy implications and constraints that may influence the adoption of Agrichar technologies.

Consideration of Issues to Promote Commercialization of Agrichar Production and Application

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The literature is fast expanding on the perceived and probable benefits of increasing the fixed carbon content of soils, particularly by the application of Agrichar. While the precise science to confirm and establish these benefits and positive properties is a collective work in progress, the confirmed performance trials suggest that broad scale commercialisation of Agrichar production and application is, while currently nascent, inevitable in the medium to long term.

If a commercial Agrichar sector is to evolve in a genuinely sustainable form, certain operating parameters will need to be considered in detail, rather than left to chance or “short termism”. Issues such as:

- Sustainable sources of biomass for conversion to Agrichar
- The selection, operation, and efficiency of the selected conversion technologies
- The emergence and development of the Agrichar market and beneficial uses
- The use and application of the Agrichar sector by-products

Renewed Fuels is currently developing a fully commercial Agrichar production facility on the site of Australia’s largest and oldest pulp/paper plant in Victoria, Australia. This facility will take pulp waste as the primary input. This paper will introduce: 1) the broad detail and timing of this vanguard project and the strategic planning process that selected Agrichar as the product of choice; 2) the subsequent technology selection process; 3) Resource Productivity as the overriding principle for project scoping and design; 4)some early work completed by CSIRO on behalf of the Australian Joint Venture Agro-forestry Program (http://www.rirdc.gov.au/reports/AFT/05-190.pdf) to explore the sustainable supply side issues if and when Agrichar production becomes mainstream; and 5) potential replication and expansion once this initial project is confirmed and proven.

Influence of Pyrolysis Conditions on Char Properties

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Research resulting from the discovery of Terra Preta has led to the investigation of char as a soil amendment and a carbon sink. Charcoal has many properties that influence soil fertility. The impact on char properties due to the conditions of pyrolysis is investigated here. For this study, chars were produced under a variety of conditions. Production variables include temperature, pressure, starting material, and carrier/sweep gas composition. Char was produced in both a batch system and a continuous process. The resulting chars were tested for char yield, pH, nutrient content, nutrient availability, C/N/S composition, CEC, and surface acid concentration, which correlate the ability of char to adsorb ammonia. Char's properties are influenced by pyrolysis conditions as well as by biomass type. The biomass that is chosen as the feedstock has the largest influence on all of the char properties. Other production variables can create large differences within each biomass type. Utilization of varying char production techniques can create chars that are tailor made for a specific soil type or crop. (The final data is being calculated, and is awaiting the arrival of a few test results.)

RD&D Issues for Agrichar, Emphasis on Energy and Developing Countries

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This paper summarizes recommendations for RD&D to promote the integrated use of agrichar for energy, sequestration, and soil improvement. Clearly, the energy objective will necessarily be reduced while promoting the two co-achieved objectives. This paper will concentrate on how several novel developing country opportunities can achieve all three objectives. The paper will also touch on several other announced session topics: market development (#3), economic impacts (#4), policy (#5), and the future (#6).

- Example opportunity #1—replacing wood in household cooking in developing countries. For the past 10 years, following early 1980's leadership of a USAID project in Sudan, the author has been developing the use of charcoal-making (**not** charcoal-using) stoves at the residential level. The initial motivations were to prevent desertification and provide cost savings. Then the emphasis shifted to indoor air quality and income generation. Although these all still hold, for the last six years the perceived best driver for this technology has been diversion of the char to the twin Terra Preta objectives. The present status of the technology will be described, with some initial economic estimates. Although only a few kilowatts in scale and in use only a few hours per day, this could be a winner because wood-burning stoves are used by half of the world.
- Example opportunity #2—improving bagasse use. Bagasse is a pain to the world's sugar industry—there is so much that inefficiencies in its combustion are encouraged. If the bagasse were to be pyrolysed, there would still be plenty of energy released to handle the required thermal loads. Surplus electric generation is regularly sold into the local grid at low prices because these plants presently only operate for about half a year. With an emphasis on agrichar, these facilities can be operated year-round—even as combined heat and power (CHP) units, with waste heat also reliably sent out year round at low cost to co-located industries.
- Other topics to cover briefly: international ultimate and annual potentials; interactions with the US RE-agricultural organization: 25x25 and sustainability presenters at the February 2007 AAAS meeting; Colorado community buildings using beetle-kill trees; opinions of US pyrolysis experts; possibilities for solar, co-firing and on-farm permutations; combined

use with biologic conversion approaches; and recommended exclusions from receiving climate credits.

Permanency and Long-Term Changes of Bio-Char in Soil

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Bio-char (biomass-derived black carbon) is commonly perceived to be highly stable in soils. Global budgeting of natural production and stocks in the environment, however, suggest that bio-char must eventually be broken down. How rapidly this decay actually occurs is quite unclear, but plays an important role for the sustainability of an agrichar soil management. Dating of biomass-derived black carbon in soils which is very similar to bio-char produced for soil application seems to suggest ages of up to several thousand years, being older than the oldest non-bio-char carbon in soil. Amazonian Dark Earths (terra preta de indio) maintain a very dark colour for thousands of years after bio-char was deliberately or accidentally added and are a vivid proof of the longevity of bio-char. Decomposition experiments, on the other hand, suggest relatively rapid decay if extrapolated over the long term. A closer look at the ages of a range of black carbon forms in soil yielded varying ages from a few to several hundred years. Point measurements of bio-char ages may be problematic for calculating turnover times, as different fractions of bio-char may have different decay rates. Chronosequence studies seem to suggest a rapid initial decay as already shown by incubation experiments, followed by low losses over subsequent decades. Initial rapid changes in oxidation are also followed by constant oxidation over the 100 years study period. Bio-char particles from 7000-year-old terra preta still show highly aromatic and therefore recalcitrant chemical properties, which resulted in similar decomposition rates as much younger bio-char dating about 1000 years B.P.

Another question is what half life is required to make agrichar a sustainable land management practice and sequestration option for atmospheric carbon dioxide that will have a monetary value in terms of carbon trading. It appears that for the purpose of agricultural sustainability and long-term carbon sequestration, even low estimates for permanency of a half life of only a few hundred years would still be sufficient to make an agrichar soil management a viable technology.

Analysis of Bacterial Communities in Amazonian Dark Earths through Community-Level Molecular Analysis and Identifying Dominant Species in Soils from the Eastern and Central Amazon

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The sustained fertility of Amazonian Dark Earths (ADE) is thought to be due to the organic matter, such as charcoal and household wastes, that was incorporated into them by the Indios who occupied the region 500 – 5000 years ago. The resulting physical and chemical properties of ADE make for a unique ecosystem that supports a large population of soil microbes which, in turn, contribute to stabilizing the fertility of these soils. The beneficial changes wrought by the presence of charcoal in ADE make it an exciting prospect to use biochar to improve and sustain the fertility of today's agricultural soils. Compared to adjacent, unmodified soils, ADE contains demonstrably different bacterial communities and niches for highly-adapted, un-described, bacterial species and consortia. We used terminal restriction fragment length polymorphism (T-RFLP) analysis to capture community-level differences in bacterial populations between ADE and background soils. To identify bacteria unique to ADE, we placed charcoal pieces obtained from ADE on ADE soil extract media to isolate organisms growing on the charcoal surfaces. The 16S rRNA genes from the isolates obtained were amplified, cloned, and sequenced. To identify and characterize community-level differences, we examined soils from five ADE sites in comparison to their adjacent background soils. Two locations were sampled in the Eastern Amazon and three were sampled in the Central Amazon. Statistical analyses of the molecular data indicate that bacterial communities from ADE are distinct from those in adjacent soils, although adjacent soils were sampled in the same locations and were subject to the same environmental conditions. Of the bacteria isolated from charcoal pieces, several were found to be unique species based on comparisons to public sequence databases. Using gene sequences from these isolates, fluorescent probes are being designed that will be used to determine which species are active on the surface of charcoal in ADE soils and ultimately in agrichar-amended soils. By establishing the identity and common physiological characteristics of bacterial populations that flourish in the unique physical and chemical environment in ADE, we may be able to use these microbes to stimulate the biogeochemical interactions needed to recreate this beneficial environment in agrichar-amended soil systems.

The Role of Agrichar in the Commercialization of Dynamotive's Fast Pyrolysis Process

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Dynamotive's mission is the commercialization of its patented fast pyrolysis process (DFPP) for producing a liquid fuel, Bio-oil, from waste biomass. Bio-oil yields are around 60 – 70 wt% (maf basis) for the most common feedstocks while the major by-product is a finely divided (~1 mm) char in yields around 20 – 25 wt%. The carbon content of the char is of the order of about 60%. Furthermore, nearly all the mineral content of the biomass feed accumulates in the char.

Current economic conditions indicate that, besides the bio-oil product, it is important to be able to generate additional monetary value from the char. Various options exist; for instance it could be pelletised for use as fuel or converted to activated carbon. However the recent advances in work on Biochar/Agrichar for carbon sequestration suggest that this application may indeed be an interesting and viable option. Since the char from the DFPP is finely divided, its handling is a technical issue. Pelletization or slurrying with water are two possible, relatively simple and cheap, ways to deal with this.

In DFPP, the optimal pyrolysis temperatures for bio-oil maximizing bio-oil yields are in the range 450 – 500 °C. The pyrolysis temperature has a noticeable effect on the stability of the char against rapid microbial decomposition in the soil, as reviewed recently by Lehmann et al (Mitigation and Adaptation Strategies for Global Change (2006) 11: 403 – 427). The present evidence seems to suggest that the pyrolysis temperature for optimal char stability is in the range 250 – 600 °C. It seems therefore that Dynamotive's process is probably nearly optimal for producing Biochar.

The attractiveness of Agrichar is of course that it achieves carbon sequestration by a means that gives additional positive economic value (in the form of increased soil fertility and crop yields). This is not true for most of the other proposed carbon sequestration schemes which are mostly all cost and no benefit.

The challenge is to establish the real economic value of Agrichar based solely on its soil fertility enhancement effects. This would, at least partially, offset the cost for carbon sequestration application. A particularly attractive niche market would be biomass energy plantations so it will also be important to evaluate the added value, in terms of energy yield, from the main energy crops.

Dynamotive is prepared to supply substantial quantities of its char to enable large scale tests.

The Influence of Soil Charcoal on the Sorption of Organic Molecules

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Charcoal has a very high sorption affinity for hydrophobic organic contaminants (HOC)—in fact charcoal can be orders of magnitude more sorptive than soil organic matter. For this reason, the addition of charcoal to soil has been considered as a method for limiting the mobility, toxicity and transport of xenobiotics in contaminated soils. However, our studies have found the situation in the field to be much more complex than one might expect. We have found that while soils that are naturally high in charcoal are indeed more sorptive than low-char soils, the difference is usually only a factor of 2 – 3, even for soils that have 50% of their C as char. There are a number of possible reasons for this. For example, the chemical and biological weathering of charcoal may reduce its sorption affinity through the addition of polar functional groups such as carboxyl and phenol. Alternatively, over time the charcoal surfaces may get covered with clay or organic matter or they may become saturated with organic molecules naturally present in the soil. We have evidence for each of the above processes.

The potential importance of these findings extends beyond just implications for HOC sorption. Since the sorptive properties of the charcoal reflect their chemical structure and environment, they can be used to probe the processes occurring on and in charcoal particles. For example, amendment of soil with agrichar would result in an immediate and substantial increase its sorption affinity. One would then expect this sorption affinity to decrease over time. The rate of decrease would depend on the relevant process—oxidation of the charcoal (slow timescale, possibly decades to centuries), association of charcoal with clay minerals and incorporation into aggregates (medium timescale, possibly years to decades), or blocking of sorption sites with organics (fast timescale, possibly weeks to years). Careful selection of experimental conditions and combination with chemical treatments (e.g. HF-treatment to remove clays or Soxhlet extraction to remove organics) would allow all three processes to be probed.

A complete understanding of what happens to charcoal that is added to soil requires more than just being able to determine how much of the C is still there after a certain period of time. The techniques we have already developed to study char naturally in soils are equally suited to the important task of following the changes that occur to agrichar once it is added to soil.

CRH and the Automated Carbonization System in the Philippine Rice Industry

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Full Advantage Phils International Inc. and Philippines Rice Research Institute (PhilRice)

The rice milling industry, composed of more than 9,000 registered rice mills dispersed across the Philippines, is pressured by social and environmental impacts. In 2005, the industry generated about 3.14 Million metric tons of rice husks that are mostly dumped in open fields and burnt that result in methane and CO^2 emissions. Social issues are also raised because smoke and gases are eyesore and barriers to on-road traffic. Passers-by and playing children suffer up to third degree burns since husk ashes are deceivingly cold on the surface but red hot inside. During times of heavy rains, winds, and typhoons, bulks of ashes are carried away and cover houses and growing rice plants that affect the general welfare of the community. However, this amount of rice husks represents a big resource to agriculture with energy generation potential of more than 2,000 GWh.

The issues above clearly call for technological modifications, change and/or development specific to cleaner production and pollution prevention to meet the growing public expectations for quality environment and demands of the existing legislative and regulatory requirements such as the Ecological Solid Waste Management Act, Philippine Clean Air Act, and Philippine Clean Water Act.

The paper summarizes the outputs of several researches and practices on the use of carbonized rice husk (CRH) and the establishment of an Automated Carbonization System (ACS) in one of the biggest rice mills in the Philippines. The 3-ACS units produce a metric ton of CRH per hour continuously for three days. CRH is porous and bulky with uniform intact black particles and silica. It contains phosphorous, potassium, calcium, magnesium, and micronutrients vital for growing plants. It has many uses ranging from agricultural to industrial purposes.

Proliferation Effects of Aerobic Micro-organisms during Composting of Rice Bran by Addition of Biomass Charcoal

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Charcoal, ashes and compost from biomass waste as a soil improver and fertilizer in a farm have been used for a long time in Japan, and their effect on farming was described in the Encyclopaedia of Agriculture published in 1697. It was also reported that charcoal has a proliferation effect of symbiosis micro organisms such as root nodule bacteria and mycorrhiza in farm soil. It is well known that symbiosis micro organisms play an important role in growing plants. Recently, both carbonizing biomass waste such as wasted construction wooden materials, wasted paper and thinned wood and bamboo in forest, and garbage composting generated by homes, restaurants and food industries, and livestock waste and their utilization are receiving attention from the viewpoint of biomass waste recycling and food safety by organic cultivation. As wood and bamboo have pores of several to several ten micrometers originated from tracheae, charcoal prepared from carbonized wood and bamboo has also almost the same size of the pores. The size of the pores is similar to the size of the micro organisms. By adding charcoal from the beginning of composting, the proliferation of micro organisms was enhanced. It is expected, therefore, that the time required for making compost is shortened and that the compost contains a lot of micro organisms. In this conference, on various charcoals made from various kinds of biomass, bamboo, wood and corn-cob, added with aerobic complex micro organisms used for composting, the proliferation of micro organisms was studied by measuring incubation time dependence of adenosine triphosphate (ATP) concentration from the micro organisms, and morphology of the micro organisms in the mixture was observed by a scanning electron micrograph (SEM) technique.

Full Poster Abstracts

(Presenter's name is in bold)

AGRICHAR AS A MATERIAL

Evaluation of Agricultural Char from Sewage Sludge

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Due to industrialisation and urbanisation, production of sewage sludge is increasing rapidly worldwide and this is expected to continue in the future. Consequently, disposal of sewage sludge has become one of the main concerns for modern society. Currently, the common sludge disposal routes are applications in agriculture, land fills, and incineration but these disposal methods do not completely remove the risk of contamination. Pyrolysis of sewage sludge as an alternative route for sludge treatment may prove a beneficial and more environmentally benign option for sewage sludge management. This work investigates the fundamental properties of sewage sludge charcoal and their assessment against its application as an agricultural fertilizer and soil supplement.

In this study, two types of sewage sludge samples were analysed. The samples were collected from two different environments, including domestic and industrial origin. All the sludge samples were characterised for their volatile matter, fixed carbon, and ash content. Trace elements present in the samples were analysed and quantified by Inductively Coupled Plasma—Atomic Emission Spectrometer (ICP_AES). The concentration of metals like arsenic, selenium, cadmium, and copper were found to be larger in industrial sludge than domestic sludge.

The sludge samples were pyrolysed in a laboratory furnace to produce char at 10^{o}C/min heating rate and pyrolysis temperature of 500^{0}C. The gas composition was monitored with a micro gas chromatograph attached to the outlet of the carbonisation apparatus. The concentration of trace elements and metals were found to be different in the sludge and sludge charcoal, due to the effect of heat treatment on devolatilisation of the sewage sludge and mobility of the trace elements.

Classification of Chars for Agricultural Use

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Char (Agrichar or Biochar) is the term used to collectively refer to all products made from the pyrolysis of biomass which is not used as a fuel but for other purposes such as a soil amendment. Given the huge range of biomass sources and the flexibility of the pyrolysis processing conditions it is understandable that the resultant char products vary greatly in both their physical and chemical characteristics. The need to develop, curate, and share controlled vocabularies that describe these products was identified.

To date only minor details of the chars used in soil amendment experiments have been recorded and reported in the literature. Agronomic tests however, when done on a range of chars, showed markedly different results, with overall soil properties and crop yields influenced both by the biomass feedstock and the processing conditions. Some of the physico-chemical factors attributed to these differences include; recalcitrance to microbial and abiotic decay (solubility, nutrient availability), surface chemical properties (charge, functional groups, etc), bulk chemical properties (degree of aromaticity, ash content, pH, etc), and physical structure (surface area, pore size distribution, tensile strength, etc).

To achieve the greatest collective benefit from the work being conducted by increasing numbers of research groups around the world it is considered paramount to develop a classification standard for the chars. This would be analogous to soil classification systems that have been developed and are used throughout the soil science community.

The proposed structure of the char classification systems includes a description of the key parameters to be reported in conjunction with experimental programs. Once adopted it will ensure char experimentation reported in the literature will be replicable by providing essential information on various properties of the biomass feedstock, process conditions, and char product.

Several char samples with contrasting characteristics have been analysed and the data sets used to form a classification for each. Input from the IAI members regarding the format, vocabulary and general systems will be requested through the presentation of this initial work.

NMR Characterization of Biofine's By-Products Char

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The Biofine Process converts cellulose and hemicellulose components into levulinic acid [an excellent platform chemical that yields the range of chemicals that now are obtained from petroleum (Hayes et al., 2006)], and formic acid. Furfural from pentoses can be recovered as an intermediary. The residual char can amount to 25 – 35% of the biomass material introduced. This char has a calorific value similar to that of bituminous coal. On the other hand, the char could be used as a soil conditioner to achieve enhanced and sustainable soil fertility along the lines observed for the Amazonian Dark Soils ("*Terra Preta de Índio*"). The enhanced fertility of these soils is characterised, mainly, by the higher contents of partially humified Anthropogenic charcoal, and the humification process has been taking place since pre-Columbian times. The transformed products are recalcitrant, highly condensed aromatic structures rich in carboxyl functionalities.

The char-like by-products from the Biofine process show the symmetrical aromatic resonance characteristic of charcoal materials. Additionally these maintain some characteristics of the precursor materials, as observed for the products from the biorefining of paper and of straw. In the case of the paper substrate signals typical of cellulose (e.g.: O-alkyl and di-O-alkyl) are evident, and in the case of char from straw there is evidence for typical lignin resonances (e.g.: O-aryl and methoxyl). Such characteristics can be important in the transformations of these materials in the soils because the presence of labile compounds would facilitate colonization by micro-organisms (primer effect) in the added char and also, after alterations, could produce other reactive functionalities (e.g.: uronic acids).

It is possible to pyrolyse the Biofine char to release energy producing gases and to yield residual products with the compositions of conventional chars. Thus the Biofine process has the ability to produce platform chemicals with the potential to replace petrochemicals, and to provide residual materials with considerable potential for soil amendment.

AGRICHAR TECHNOLOGY

The Utilization of Waste Biomass in SA as a Renewable Resource for Agriculture or Metallurgy

Somerville, Michael and R. Van Berkel

Centre for Sustainable Resource Processing and CSIRO Minerals

At least 200,000 tonnes of waste biomass is produced in the mid north of South Australia each year. This biomass includes residues from agriculture, forestry, wood milling operations, and municipal green and domestic waste. The inherent value of this material can be recovered and utilised either as an organic soil conditioner, transformed into charcoal and utilised as a soil additive or as a coal substitute in metallurgical processes. The transformation of the biomass into charcoal using pyrolysis can provide a renewable supply of reductant to replace fossil based sources of carbon. The optimum use of the biomass will depend on various financial and environmental factors. In this work an estimate of the value of using biomass derived charcoal in metallurgical applications has been made and is compared to alternative uses such as soil additives and conditioners.

The Characterization of Pyrolysis Products Produced from Low Value Fractions of Mallee Gums

Somerville, Michael and D. Langberg

Centre for Sustainable Resource Processing and CSIRO Minerals

Many potential benefits are available when charcoal derived from biomass is substituted for coal in metallurgical processes. These advantages include: lower ash and sulphur and higher reactivity and carbon content. CSIRO Minerals through the Centre for Sustainable Resource Processing (CSRP) is exploring synergetic opportunities for utilisation of the charcoal derived from Mallee biomass in metallurgical processes where high tonnages of low grade fractions could be used as a fuel and reductant. The approach not only makes the WA Mallee project more viable, it also reduces the net GHG from high temperature metallurgical processes. For example charcoal derived from these fractions has been shown to increase the reaction rate of solid state reduction processes such as ilmenite reduction in Becher kilns. The chemical process which transforms the biomass into charcoal is called pyrolysis. This work highlights the characterisation of the pyrolysis products as applied to the Mallee tree leaf/twig fractions.

AGRONOMIC AGRICHAR RESEARCH AND FIELD TRIALS

Use of Charcoal, Chicken Manure, and Bone Meal in Guarana (Paullinia Cupana Var. Sorbilis)—Preliminary Results

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Guarana (*Paullinia cupana* hbk. var. *sorbilis*) is an important agricultural product for small farmers in the Amazonas, Brazil. Guarana belongs to the Sapindaceae family and is dicotyledonous, open-pollinated (mainly by bees); in forest it is a liana and in open field is a shrub. An experiment in a factorial design with confounding technique was installed on March, 2003 with the objective of evaluating the influence of levels of chicken manure and

charcoal (0, 8 and 16L per plant) and bone meal (0, 0.2kg and 0.4kg per plant). Physical and chemical properties of the soil were evaluated. The cultivar planted was the BRS-Maués with six plants per plot, at Embrapa Research Station, Manaus, Brazil. The charcoal was triturated in fragments smaller than 10mm. All products were applied surrounding guarana plants in October, 2003. Soil samples were collected at 0 – 10cm depth in April, 2004. The soil of the experiment was classified as a yellow clayey Oxisol. The original value for pH in water was 3.1 and very low levels of available P, Ca, and Mg. The results of soil analyses showed an interaction between charcoal and chicken manure; with enhanced charcoal levels, Mg increased. It is probably because a reduction of leaching of Mg from the chicken manure. The highest level of chicken manure increased soil pH from 4.3 to 5.7, and decrease H+Al content from 7.7 to 4.4 $cmol_c\ dm^{-3}$. Chicken manure also increased P from 68 to 388 mg dm^{-3}, K from 23 to 72 mg dm^{-3}, Ca from 0.8 to 4.3 $cmol_c/dm^3$ and Mg from 0.1 to 1.1 $cmol_c/dm^3$. The results after six months of the application showed no statically difference ($p<0.005$) between treatments with bone meal and charcoal concerning values of P, K, Ca, Mg, H+Al, and pH. The results indicate no difference in the P values with enhancement of P levels from bone meal is probably due the statistical design used that confounded the level of bone meal and chicken manure. Another relevant result is that the sodium levels in soil reached a high concentration enhancing the original level of 8.0 to 67.7$cmol_c/dm^3$. It showed that use of chicken manure may cause salinization. There wasn't difference in clay dispersion between treatments, despite substantial changes in pH and Al, probably because organic matter worked as cementing, maintaining soil flocculated. The experiment is still being evaluated and long term evaluations are needed to indicate the effects of charcoal and its interactions with other products to be used as conditioner for tropical soils.

Use of Charcoal and Wood Carbonization By-Products in Agriculture: Learning With "Terra Preta De Indio"

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Brazil is the world's highest producer of charcoal, which is responsible for 38.5% of the world production. During the traditional process of carbonization, around 35% of the wood carbon is fixed in the charcoal and the rest is released to the atmosphere in smoke form and by non condensable gases (CO_2, CO, CH_4, etc.). Some technologies are adjusted in Brazil that can recover up to 50% of lost carbon in the form of condensed gases that are explored commercially for industry. The condensed smoke can be distilled producing a wide range of composites, and some by-products such as wood tar, aromatic oils, and pyroligneous liquor. Some of these by-products present chemical characteristics that are similar to the humic substances extracted from Anthropogenic Black Earths and other pyrogenic carbon rich soils suggesting its potential use as raw material for the organic conditioner production. Another important by-product generated in the process is fine charcoal that, in some cases represents up to 15% of the produced charcoal. Reactive organic molecules could be produced from acidified charcoal. These molecules have functional groups that are able to hold nutrients and water in the soil, and are very stable due its polycyclic aromatic structure. The development processes that allow the transformation of charcoal and its by-products into composites with appropriate characteristics for the use as organic conditioner, with high reactivity and stability, is highly desirable and strategic for the agricultural and forest activities in Brazil. Products with these characteristics can enhance the value to the charcoal by creating an innovative uses for a traditional product and to represent a clean development mechanism that has the ability to receive carbon credits considering its long term carbon fixation potential due to the transference of the carbon from the atmosphere to a steadier soil organic matter basin. This work has the objective to congregate experiences and expertise on the agricultural use of coal and its by-products, and to supply information on the availability of these products in Brazil. In such a way one expects to present to the reader the dimension of the impact and

the perspectives of use of the traditional knowledge contained in Terra Preta de Indio and the possibility to reproduce these properties in other tropical soils.

Nutrient Retention Characteristics of Chars and the Agronomic Implications

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The possible influence of pyrolytic chars on the nutrient retention characteristics of soils has been identified by several groups (Glaser *et al*., 2001; Lehmann and Rondon, 2006). Glaser *et al* (2001) attributed the high nutrient retention qualities of *Terra Preta de Indio* soils to the extraordinarily high proportions of black carbon. Increases in the availability of major cations, phosphorous and nitrogen have been demonstrated through the addition of wood–based chars to soils (Glaser et al., 2002; Lehmann et al., 2003a). This occurs despite the very low levels of P and N in these chars. Experiments conducted by the NSW DPI and BEST have demonstrated that low nutrient value chars made from greenwaste can increase the nutrient use efficiency by plants of applied N and P This could be explained by; a) char is surface sorbing nutrients maintaining them in the root zone and minimising leaching, b) char is influencing the physical and/or chemical structure of the bulk soil (eg. pH) in a way that positively alters its nutrient cycling and CEC.

We investigated the rates and mechanisms of the interactions between several chars and N and P in a series of batch sorption/desorption tests with nutrient containing effluent. The char, soils and char/soil mixtures were analysed both before and after the addition of nutrients to quantify the nutrient retention characteristics, including the rates of reactions. Phosphorous sorption appears to be correlated with pH and Ca content of char. Both poultry litter and paper sludge chars with high Ca contents have high P sorption capacities (>3000 mg/kg), similar to high sorbing soils, whereas the green waste char has relatively low P sorption capacity (~1000 mg/kg). Examination of the char products after P addition using SEM and EDAX confirmed the precipitation of P in Ca-P complexes. The P sorption kinetic experiments showed that the majority of P sorption occurs within 1 hour, a result consistent with concurrently run column leaching trials, and the precipitation of Ca-P complexes. None of the chars were found to retain significant quantities of N.

When considering that total soil P (0-15cm) ranges from 50 to 3000 mg/kg (Frossard et al., 1995), the results from the experimental program demonstrate that the addition of char can certainly have a positive influence on the P nutrient cycle by increasing the sorption capacity, especially for low P sorbing soils. However, increases in N availability can not be explained via the same mechanism. This work highlights the need for differentiation between the concepts of nutrient retention (or sorption) and nutrient use efficiency by plants when assessing the influence of char on nutrient cycling in soil systems.

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Charcoal and Selected Beneficial Microorganisms: Plant Trials and SEM Observations

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Pilot studies on various charcoals, from a variety of sources and produced at different pressures and temperatures, suggest that the contribution of charcoal to soil fertility and plant growth is a complex combination of nutrient retention and microbial interaction.

Plant trials with charcoal, established in 2006, included *Pinus radiata*, *Solanum tuberosum*, *Pisum sativum*, *Brassica oleracea*, *Cucumis sativus*, *Lactuca sativa*, *Lycopersicon esculentum*, *Zea mays*, *Trifolium repens*, *Lolium perenne*, *Triticum aestivum*, *Abutilon hybridum*, *Viola tricolor* var *hortensis*, *V. cornuta*, *Narcissus tazetta*, *Freesia armstrongii* and *Dahlia excelsa*. Charcoals made from various hard and soft-woods, bamboos, bark, corn stover, and mixtures of these, were used with and without selected 'beneficial micro-organism' formulations.

The results of these trials and SEM studies on the charcoals used in these studies, together with the initial results of an SEM study on charcoal micro-organism interactions will be presented and discussed in the context of the structural basis of the influence of charcoal on nutrient retention and soil microbiology.

Field Maize Yield and Yield Determining Factors for Four Years Following Biochar Application on a Colombian Savanna Oxisol

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Biochar, when used as a soil amendment, has repeatedly shown to increase crop productivity. However, the mechanisms that underlie such increases have yet to be explained. This talk will report findings from a four-year field study on an Oxisol of the Oriental savannas of Colombia. Maize was grown each year with optimal fertilization, after a single biochar application in late 2002. Biochar application of 20 Mg ha^{-1} increased maize yield by 22, 23 and 58% in 2004, 2005, and 2006, respectively. Nutrient contents in biomass and soil, crop root density and soil hydrology data will be presented in order to explain the yield increase and determine the nature of the durable beneficial effects of biochar on crop growth.

Slash and Char as Alternative To Slash and Burn—Soil Charcoal Amendments Maintain Soil Fertility and Establish a Carbon Sink

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The aim of the presented research was to examine the use of charcoal in agricultural practice and management of a highly weathered Xanthic Ferralsol in Amazonia. This presentation summarises the results of a doctoral theses, comprising field and laboratory experiments. The influence of charcoal and condensates from smoke (pyroligneous acid, PA) on the microbial activity was assessed. Various field trials assessed the effect of charcoal, organic, and inorganic fertilization. In a field trial, 15 different amendment combinations based on equal amounts of applied C in chicken manure, compost, charcoal, and forest litter were tested during four cropping cycles.

When PA or fresh charcoal was applied the microbiological parameters increased linearly and significantly with increasing concentrations. Long-lasting soil fertility improvement due to organic fertilization and a synergistic effect if both charcoal and mineral fertilizer were applied was observed in a field experiment. Charcoal doubled grain production if fertilized with NPK in comparison to the NPK-fertilizer without charcoal.

Soil charcoal additions reduced exchangeable soil aluminium (Al) significantly. Mineral fertilized soils amended with charcoal and TP soils had a significantly higher potential for microbial population growth coupled with a low microbial respiration in absence of an easily degradable C source. These results reflect the relatively high biodegradable OM content of primary forest topsoil but low available nutrients, in contrast to refractory TP SOM with high available soil nutrient contents.

Total 15N recovery (in soil, crop residues and grains) was significantly higher on charcoal (18.1%), charcoal plus compost (17.4%), and compost (16.5%) treatments in comparison to only mineral fertilized plots (10.9%).

Preservation of Woods in Forest Acid Soil by Addition of Biomass Charcoal

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Forest decline caused by acid deposition has become a serious problem of global concern. It is mentioned that sulfuric acid originated from fossil fuel is one of causes bringing blighted wood in forest. Harmful effects of the acid deposition include increase in toxic metallic ions such as Al^{3+} and Fe^{3+} ions and decrease available symbiosis micro-organisms to tree growing. Biomass charcoal was sowed in the acid soil around trees in order to preserve them. The pH of charcoal is dependent on the carbonization temperature; the pH of carbon carbonized at $650^{o}C$ was around 9. It was expected that the sowed carbon powder can neutralize acid soil to lead to decreasing the ions concentration in the soil and to increasing the micro-organism concentration. It was found that the proliferation of the micro-organisms was enhanced on and in the charcoal as a medium.

STATUS OF SOIL CARBON LEVELS, SOIL HEALTH, USE OF AGRICHAR AS A SOIL CONDITIONER

Soil Microbial Community Response to Amending Rice Soils with Bamboo Charcoal

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Charcoal has received increasing attention in recent years for its beneficial effects on soil fertility and its influence on a wide range of soil biological and chemical processes. We are studying the effects of bamboo charcoal on the abundance, activity and diversity of microbial populations in rice soils. Bamboo charcoal was prepared by combustion at 400-500°C and used as a soil amendment in field trials conducted in Hangzhou, China, in 2006. Bamboo charcoal, at a filling density of approximately 0.58 g cm^{-3}, was incorporated into the rice soil surface at a rate of 0.5 ton/667M2 or 1.5 ton/667M2 (667M2 = one Mu, a traditional Chinese area unit). Control plots received no charcoal. Treatments were replicated three times in a randomized complete block design. Paddy rice was transplanted into the plots, grown to maturity and harvested. The plots were drained and left fallow for four months prior to sampling for soil microbial community analyses. Six soil samples from 0 – 10 cm depth were taken in a random pattern from each plot and combined. Each composite soil sample was well mixed and obvious root material was removed with forceps. Half the sample was retained at the Chinese Bamboo Research Centre in Hangzhou, China, and the other half was express shipped for biological analysis at Cornell University, NY. The biological activity of soils sampled from control and bamboo char-amended plots was measured by monitoring soil respiration. Abundance was estimated by measuring soil microbial biomass. Soil respiration and microbial biomass are key indicators of soil biological health. Soil DNA was extracted from all samples for use in molecular analyses. DNA fingerprints of the soil microbial communities in each sample were generated using terminal restriction fragment length polymorphism (T-RFLP) analysis. Multivariate statistical analysis was used to assess the effect of bamboo charcoal on soil microbial community composition. Community level analyses show the degree to which microbial populations change in response to bamboo-char amendments. Understanding the soil microbial community response to bio-char additions is vital for using bio-char productively and sustainably in agricultural ecosystems in the future.

Fate of Biochar Applied to a Colombian Savanna Oxisol during the First and Second Years

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While biochar applied to soil must undergo mineralization to some degree, a fraction of it is most likely highly durable and thus biochar could serve as a vehicle for soil carbon (C) storage. We will show data from two field plots where ground biochar was applied either in late 2004 or early 2006, at rates that increased initial Colombian savanna Oxisol C content by 50%, and doubled or multiplied it by 10. The plots were allowed to be re-colonized by native savanna vegetation, and no further amendments were applied. Soil respiration was measured weekly or bi-weekly using soda lime during the 2006 rainy season. Soil sampling was carried out to 2 m depth on the older plot, 1 and 2 rainy seasons after biochar application. The biochar application rate that doubled initial soil C showed increased soil respiration

throughout the sampling period and on both plots, compared to the unamended control. The maximum difference in respiration observed between biochar and control plots was of 84 kg CO_2 ha^{-1}. Stable C isotope data indicating the fraction of respired C originating from biochar will be given. The movement of biochar through the soil profile will also be assessed using C amounts and stable C isotope data. Knowing the amount of biochar-C respired, and the magnitude of movement of biochar down the soil profile to layers where biological and chemical degradation are less prominent, will improve our understanding of biochar stabilization in this soil.

Paper mill Agrichar: Benefits to Soil Health and Plant Production

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Agrichar made from paper mill wastes produced in the BEST pilot scale pyrolysis unit at Gosford has been shown to deliver very significant improvements in soil health indicators and plant growth. Two paper mill agrichars having a liming value of 33% and 29% (equivalent to $CaCO_3$) and carbon content of 50% and 52% respectively were tested in a pot trial at a rate equivalent of 10t ha^{-1}. Both agrichars significantly increased crop growth (measured as height and dry weight of plants) in an acidic ferrosol from northern NSW, Australia. Only minor advantages in crop growth were found in a loamy textured alkaline calcarosol from Victoria. Key benefits of agrichar in the acidic soil included raised pH, significantly increased total soil carbon, reduced Al availability (from ca. 2cmol (+)/kg to below 0.1 cmol (+)/kg) and improved cation exchange capacity (CEC).

	pH *	**Al** cmol(+) /kg***	**Ca** cmol(+) /kg***	**K** cmol(+) /kg***	**Mg** cmol(+) /kg***	**Na** cmol(+) /kg***	**CEC** cmol(+) /kg	**Total N** %	**Total C** %
Control	**4.2**	**1.9**	**1.3**	**0.099**	**0.33**	**0.46**	**4.1**	**0.33**	**3.6**
Control + fert**	**4.1**	**2.3**	**1.2**	**0.84**	**0.5**	**0.41**	**5.3**	**0.37**	**3.6**
Agrichar A	**6.0**	**<0.1**	**9.2**	**0.13**	**0.43**	**0.51**	**10**	**0.29**	**3.9**
Agrichar A+ fert	**5.7**	**<0.1**	**8.2**	**0.66**	**0.55**	**0.48**	**9.9**	**0.33**	**4.1**
Agrichar B	**5.4**	**<0.1**	**6.2**	**0.083**	**0.43**	**0.45**	**7.2**	**0.34**	**4.7**
Agrichar B+ fert	**5.1**	**0.13**	**5.9**	**0.7**	**0.58**	**0.47**	**7.8**	**0.37**	**4.4**

Soil properties from a pot trial following a wheat crop in ferrosol soil. (*$CaCl_2$ **luxury nutrient addition, ***exchangeable)

Agrichar amendment in the ferrosol soil significantly increased growth rate and weight of the three species tested, wheat, radish and soybean. Increases of nearly 100% in plant height of wheat were found with char addition when luxury nutrients were present. In the absence of fertiliser, wheat height was increased by 30 – 40% over the no-agrichar control. Agrichar amendment of the alkaline soil positively influenced growth rate only in soybean, however, it did not have a significant effect on final plant weight of any species. Agrichar had no effect on germination of the three test species.

Ecotoxicological analysis demonstrated that earthworms had a very strong preference for agrichar amended soils. Microbial activity, measured using the fluorescein diacetate hydrolysis method, was reduced slightly by the addition of agrichar.

This project has demonstrated the excellent potential for beneficial agricultural reuse of a recalcitrant waste product. Apart from significant improvements to soil chemistry and agronomic performance, especially in acidic soils, tangible increases in total soil carbon were demonstrated.

The Physical and Chemical Properties of Bamboo Charcoal and Its Application as a Soil Conditioner

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There are approximately 22 million ha of bamboo forests mainly distributed in the tropical and subtropical areas. They are characterized with high biomass yield, short rotation, as well as high ecological benefits. Therefore, they are usually considered as one of the best suitable species for charcoal production. In this paper, some study results on physical and chemical properties of bamboo charcoal related to production processes were presented. Additionally, a laboratory incubation experiment, in which the bamboo charcoal-base fertilizer (compounded of charcoal and urea) was applied, the results showed that the bamboo charcoal can significantly reduce the N leaching, increase the microbial activities in the incubated soils.

Keywords: Bamboo charcoal; Production process; Compounded charcoal-based fertilizer; N leaching

USE OF AGRICHAR FOR CARBON SEQUESTRATION, CARBON CREDITS

Carbon Sequestration and Mitigation of Carbon Dioxide Accumulation in the Biosphere: The Role of Biochar in Tropical Agricultural Systems

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Soil organic matter build-up and stabilization is not only fundamental to increased crop production but also to the reduction of carbon dioxide (CO_2) emissions from agricultural systems. Though there has been increased advocacy for the use of high quality organic resources (eg *Tithonia diversifolia*) for the supply of plant nutrients, information on the impact of such inputs on soil organic matter stabilization and their contribution to green house gas emissions is still scanty. The use of highly recalcitrant organic inputs like charcoal has also been studied but little information is available on their importance in agricultural production. Due to its high recalcitrance and the resultant stability in the soil, biochar (charcoal) could be a breakthrough in increasing C sequestration and reducing CO_2 accumulation in the atmosphere.

A series of experiments were established along the western highlands of Kenya to investigate the link between application of organic C amendments and C stabilization in soils at different stages of degradation. Field experiments were conducted to quantify carbon dioxide (CO_2) evolution from three treatments (control maize and maize treated with tithonia biomass and maize treated with charcoal) using soda lime traps. Two reference plots (a fallow plot and a primary forest site) were also included in the study. Data obtained over a period of 545 days after initial application, indicated that in the highly degraded soils, the cumulative carbon loss as CO_2 from biochar (charcoal) plots was about 5.5 mg g^{-1} C lower than CO_2-C loss observed in a control plot (about 36% decrease in C loss). Cumulative carbon loss as CO_2 from Tithonia (high quality organic input) plots was about 2.6 mg g^{-1} C above control treatment (about 17% increase in C loss). Even with continuous tilling of the soil in the biochar plots, the patterns of CO_2-C loss was similar to the non-disturbed fallow plot and about 3-fold increase above a primary forest site while the control plot had about 5-fold increase in CO_2-C loss above the forest site and 43% above a fallow plot. No significant differences were noted in less degraded soils. This could be an early indication of the importance of biochar in C sequestration and mitigating CO_2 accumulation in the atmosphere.

Quantifying Char-Carbon Turnover and Implications for Greenhouse Balance

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There is growing interest in the use of char as a soil amendment, with potential to increase soil carbon (C) and enhance agricultural productivity. The long term benefits of artificially-produced char for increasing soil C sequestration and mitigating rising atmospheric CO_2 will depend on its ability to persist in soil. Char produced during pyrolysis of biomass at temperatures ≥ 200 ºC and under limited oxygen is considered highly resistant to biological degradation, and reputed to have a turnover time of hundreds to thousands of years. The low bioavailability of this thermally altered biomass has been ascribed to its increased chemical recalcitrance compared with the parent feedstock. However, little research has been undertaken to document the properties of bio-char produced by controlled pyrolysis. Specifically, there is a need to (i) measure the turnover of C in chars produced from different feedstocks and under different process conditions, (ii) evaluate stabilisation mechanisms of char-C with focus on chemical and physical recalcitrance, and (iii) quantify interactive effects of char and native soil C on overall C cycling following char application to soil. Interactive priming effects of char-C on native soil C can potentially affect the estimation of char-C turnover rate. In order to determine the sources and magnitude of C turning over in soil following char addition, a long-term (up to 5 years) experiment is being conducted using a novel method that is based on measurable natural difference in C isotope content between bio-char and soil. Briefly, the method utilises char materials produced from a range of C_3-vegetation feedstocks (with $\delta^{13}C$ values range from 23.6 to 28.2%), applied to soil collected from a C_4-pasture field ($\delta^{13}C$ = ~14.6%). Additionally, detailed chemical characterisation of decomposing C fractions (separated physically) is being performed to gain insights into the causes of stability of char with focus on chemical recalcitrance. At this meeting, we will present the initial results from our laboratory incubation experiment on char-C turnover and the associated priming effects of char on native soil C. Further, based on preliminary estimates of char-C turnover, and simulation results, we will provide an analysis of the greenhouse gas balance and soil C sequestration benefits of using char.

CO-PRODUCTION OF AGRICHAR AND ENERGY

Distributed Production of Bio-Oils and Bio-Chars for Agricultural and Energy Applications

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Economical and environmentally responsible production of bio-chars will probably benefit from co-production of bio-oil for energy applications. Bio-oil production via fast pyrolysis requires an increased level of equipment sophistication and feedstock preparation compared to simple char kilns. Economical production of these co-products will require careful consideration of the optimal size of fast pyrolysis plants and their geographical distribution. This presentation describes the technology options for simultaneous production of bio-char and bio-oil from biomass crops and performs a techno-economic analysis of this process.

TERRA PRETA ("DARK EARTH") SOILS

Terra Preta De Indio "Dark Earth Soils": Chemical and Spectroscopic Characterization of Humic Acids

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The HA of Amazonian dark earth soils (Terra Preta de Índio) from Brazilian territory were characterized using ultraviolet-visible, Fourier transform diffuse reflectance infrared, fluorescence excitation and emission, electron paramagnetic resonance, and nuclear magnetic resonance spectroscopy, thermogravimetric analysis, elemental composition, and measurement of acidity (total, carboxylic, phenolic). The HA fraction was extracted using the method of International Humic Substances Society. The samples were separated in 3 groups based on the corresponding land use of the area: anthropogenic soils under forest (SAF), anthropogenic soils under agricultural use (SAC), non-anthropogenic soils under forest (SNAF). The SNAF soils were representative of Amazonian soils. This way the SNAF group was a reference group for comparison purposes to the anthropogenic soil groups (SAF and SAC). The anthropogenic soil groups (SAF and SAC) showed better fertility characteristics than the non-anthropogenic soils (SNAF) (pH: SAF = 5.1, SAC = 5.4, SNAF = 4.4; base saturation [V%]: SAF =59, SAC = 51, SNAF = 18; calculated cation exchange capacity [CEC]: SAF = 17.5, SAC = 17.2, SNAF = 9.5 $\text{cmol}_c\ \text{kg}^{-1}$; available P: SAF = 116, SAC = 291, SNAF = 5 mg kg^{-1}). In the SAF and SAC soil groups ~44% of the total carbon was found in the humin fraction, ~32% in the humic acid fraction, and ~13% in the fulvic acid fraction. These values for the SNAF soils were 49, 19, and 16%, respectively. The most relevant characteristics of the HA of anthropogenic soils, compared to the non-anthropogenic ones were their superior reactivity, stability, and humification degree. The HA of the SAF and SAC groups featured higher total acidity (SAF = 612, SAC = 712, SNAF = 575 cmol kg^{-1}) and carboxylic acidity (SAF = 435, SAC = 454, SNAF = 320 cmol kg^{-1}), higher concentration of organic free radicals (SAF = 4.07, SAC = 6.59, SNAF = 2.11 spin $\text{g}^{-1}\ 10^{17}$), higher thermogravimetric index (ITG) (SAF = 3.0, SAC = 3.3, SNAF = 2.3), lower E_4/E_6 ratio (SAF = 4.2, SAC = 4.2, SNAF = 6.0), higher aromaticity index (IADRIFT: SAF = 0.87, SAC = 0.85, SNAF = 0.77; NMR(%): SAF = 36, SAC = 39, SNAF = 25), higher hidrophobicity index (SAF = 0.37, SAC = 0.48, SNAF = 0.35), higher humification degree (A4/A1: SAF = 2.574, SAC = 3.313, SNAF = 1.713; I485/I400: SAF = 2.004, SAC = 2.161, SNAF = 1.510), and were more recalcitrant (recalcitrant C/labile C: SAF = 2.0, SAC = 2.0, SNAF = 1.0) than the HA of the SNAF group.

Characterisation of Terra Preta Soils and Chars by Thermal Analysis-Quadrupole Mass Spectrometry

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The artificial addition of black carbon derived from combustion of plant material from pyrolysis and biofuel materials form other sources beneficially modifies the properties of soils, increasing their productivity (e.g. Liang et al., 2006). Understanding the processes and functions which black carbon influences within a soil requires many different investigative techniques. In this paper we report the use of thermal analysis-differential scanning calorimetry (TG-DSC) coupled to on-line evolved gas analysis (a) to quantify proportions of different organic matter components and (b) to describe the chemical environment of nitrogen within treated and untreated soils. The samples described in this paper are: terra preta soils and adjacent oxisols supplied by Johannes Lehmann and co-workers; and chars collected from southern Spain supplied by Francisco J Gonzalez-Vila and co-workers.

Thermal analysis gives a direct measurement by weight of components of soil that decompose at different stages in a heating cycle. For soil organic matter, weight losses between 250 – 350°C correspond to labile material, 350 – 500°C to recalcitrant and 500 – 650°C to refractory OM (Lopez Capel et al, 2005). Using this approach, terra preta soils can clearly be distinguished without substantial sample preparation, and are enriched in recalcitrant organic matter, as would be expected.

The DSC traces for the samples very clearly show the addition of black carbon as a sharp peak corresponding to the exothermic decomposition of recalcitrant organic matter. Corresponding oxisols have a much broader peak, at lower temperatures, reflecting the decomposition of oxy-hydroxide minerals. The DSC traces are mirrored by the evolution of CO_2, which clearly demonstrates the presence of recalcitrant OM. Evolved gas analysis of nitrogen species from chars from Southern Spain shows a redistribution of nitrogen species towards more recalcitrant SOM forms. The implication for Terra Preta soils is that the addition of charcoal to soils adds nitrogen in a slow turnover reservoir. This work underpins our understanding in how chars from bioenergy production can be used beneficially in soil systems.

Liang, B. et al. 2006 Black carbon increases cation exchange capacity in soils. SSSAJ 70, 1719 – 30.
Lopez-Capel, E. et al. 2005. Use of thermogravimetry-differential scanning calorimetry to characterize modelable soil organic matter fractions. SSSAJ, 69, 136 – 140.

Soil Fungal Communities in Three ADE Sites Characterized by Molecular Fingerprinting, Isolating Unique Species, and Assessing Arbuscular Mycorrhizal Fungi

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Understanding the unusual biogeochemical properties of ADE remains central to the goal of using agrichar beneficially in present-day agricultural systems. We characterized the fungal populations in three Amazonian Dark Earths (ADE) and studied how they may be contributing to the unique fertility of these soils. Microbial populations, which have been shown to be orders of magnitude higher in ADE as compared to adjacent, unmodified soil, play a dynamic role in ADE soil fertility. Specifically, soil fungi provide many important ecosystem services, from degrading highly recalcitrant organic substrates to forming symbiotic associations with plant roots. We assessed the fungal populations in ADE by isolating fungi on selective nutrient media made from extracts of ADE soil and partially sequencing the 18S rRNA genes of fungal isolates to identify species unique to ADE. Given that mutualistic, arbuscular mycorrhizal fungi (AMF) can enhance plant nutrient acquisition, we isolated, counted and compared the number of AMF spores in nutrient-rich ADE and nutrient-poor adjacent soils. We also characterized the fungal community composition in the ADE and adjacent soils using terminal restriction fragment length polymorphism (T-RFLP) DNA fingerprinting analysis. All of these approaches showed significant differences in the fungal community in ADE when compared to adjacent background soils. In particular, partial sequencing of 18S rRNA genes of fungal isolates revealed that ADE soils contain species from the phyla Zygomycota and Ascomycota that are unique from any of those found in public databases. Isolating and enumerating AMF spores showed that at multiple ADE sites, the spore counts were significantly higher in surface soils of ADE compared to background soils. The high AMF spore counts in ADE indicate that these fungi are highly active in these soils, despite the presence of ample nutrients for plant growth, particularly soil phosphorus. These results suggest that in charcoal-rich ADE soils, both the physiological and ecological diversity of fungi represent a biological component that may be particularly important for successfully replicating ADE technology in modern agriculture.

POLICY AND EDUCATIONAL APPLICATIONS OF AGRICHAR AND ENERGY SYSTEMS

How Has Historical Research Changed Our Understanding of the Amazonian Environment?

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For most of the last century the Amazon rainforest was seen as a ‘counterfeit paradise’. Its harsh environmental conditions were the reason given for this classification. The changes that happened in the last three decades have completely altered our understanding of the South American rainforest. Hidden away was the soil that has triggered these changes. Amazonian Dark Earths (ADEs) are anthropogenic soils made by indigenous people that inhabited the region before the arrival of the Europeans. These people not only adapted to the Amazonian environment, but they also created a soil that could change agriculture in Brazil and in the world. In this paper I will look at how the discovery of ADEs changed our understanding of the Amazonian environment and the role of people in the formation of this environment. I will begin by looking at the intriguing characteristics of ADEs. By doing so I intend to show how unique this soil is. In the second part of the essay I will concentrate on the formation of dark earths. In the third, I will focus on how the environment in question was seen before ADEs research and the restricted role that humans were thought to play in the human-environment interaction. I will fourthly look at how this view changed and human participation went from passive to active. I will lastly look at how the Amerindians created dark earth as well as being able to adapt to the environmental conditions that were once believed to be limiting, and how this has changed our understanding of the Amazon. The South American rainforest is the result of centuries of interactions between its inhabitants and nature with neither party being subject to the other. ADEs has transformed not the only our understanding of the Amazon itself, but also the history of Brazil.

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