New Zealand
2011 Biochar Workshop
Opportunities, risks and acceptance

10 - 11 February 2011

Massey University Palmerston North New Zealand

New Zealand Biochar
Research Centre

MASSEY UNIVERSITY

http://www.biochar.co.nz

ORGANISING COMMITTEE

Marta Camps
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BIOCHAR WORKSHOP 2011

Acknowledgments
Layout: Liza Haarhoff
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PROGRAMME

Thursday 10th February

09:00-09:25	**Registration**
09:25-09:30	**Welcome and Opening Remarks**

PLENARY SESSION

09:30-10:00	**Ralph Sims** (keynote speaker) *Massey University* **BIOCHAR AND THE COMPETING USES FOR BIOMASS**

SESSION 1: PRODUCTION TECHNOLOGY

10:00-10:30	**Jim Jones** *Massey University* **PYROLYSIS TECHNOLOGIES AND OVERVIEW OF THE SCIENCE**
10:30-11:30	**Morning tea. DEMONSTRATIONS OF DIFFERENT UNITS** (Outside Shelter)
11:30-13:00	**PRESENTATIONS ON DIFFERENT NZ BIOCHAR PRODUCTION UNITS AND APPLICATIONS**
13:00-14:00	**Lunch**

SESSION 2: BIOCHAR ECONOMICS

14:00-14:30 **Stephen Joseph** (keynote speaker)
Anthroterra
FROM RESEARCH AND DEVELOPMENT TO PROFITABLE BUSINESS

14:30-14:45 **Adriana Downie**
Pacific Pyrolysis
COMMERCIAL OPPORTUNITIES FOR WASTE ORGANICS TO BIOCHAR IN NEW ZEALAND

SESSION 3: LIFE-CYCLE ASSESSMENTS

14:45-15:00 **Jim Jones/Ruy Anaya de la Rosa**
Massey University
A COMMON APPROACH TO CONDUCTING LCAs ON BIOCHAR

SESSION 4: BIOCHAR AND GHG MITIGATION

15:00-15:15 **Ruy Anaya de la Rosa**
Massey University
CARBON OFFSETTING AND BIOCHAR

15:15-15:30 **Dorothee Quade**
Victoria University
SCIENCE, PERCEPTIONS & POLICY IMPLICATIONS REGARDING BIOCHAR AS A CLIMATE CHANGE MITIGATION TOOL IN NEW ZEALAND

SESSION 5: CHARACTERISATION OF BIOCHARS

16:00-16:15 **Roberto Calvelo-Pereira**
Massey University
METHODOLOGIES FOR DETERMINING THE LABILE FRACTION OF CARBON IN BIOCHAR

16:15-16:30 **Tao Wang**
Massey University
METHODOLOGIES FOR DETERMINING THE N AND P FERTILITY VALUE OF BIOCHAR

16:30-16:45 **Stephen Joseph**
Anthroterra
ELECTRICAL, ELECTROCHEMICAL AND MAGNETIC PROPERTIES AND STRUCTURE OF BIOCHAR and BIOCHAR COMPLEXES

16:45-17:00 **Panel Discussion and Closing Remarks**

Friday 11th February

Session 6 – BIOCHAR-SOIL-PLANT INTERACTIONS

08:30-09:00 **Saran Sohi (keynote speaker)**
Edinburgh University
THE UK BIOCHAR RESEARCH CENTRE: ORIGINS, ACTIVITIES AND OUTPUTS

09:00-09:15	**Craig Anderson** *Lincoln University* **MICROBIOLOGY OF SOILS AMENDED WITH BIOCHAR**
09:15-09:30	**Arezoo Taghizadeh Toosi** *Lincoln University* **BIOCHAR SUPPRESSES $^{15}N_2O$ EMISSIONS FROM ^{15}N-URINE**
09:30-09:45	**Saman Herath** *Massey University* **BIOCHAR-AMENDED SOILS: DECOMPOSITION AND PHYSICAL PROPERTIES**
09:45-10:00	**Helen Free** *Massey University* **INVESTIGATION OF MICROORGANISMS GROWING IN THE PRESENCE OF BIOCHAR FROM PINE WOODCHIPS**
10:00-10:15	**Marta Camps** *Massey University* **ON-GOING AND FUTURE RESEARCH ACTIVITIES AT THE SOIL SCIENCE STREAM OF THE NZBRC**
10:15-10:30	**Poster presenters give a 1-2 min introduction of their research activities**
10:30-11:00	**Morning tea and poster session**

Session 7 – APPLICATION CASE STUDIES

11:00-11:15	**Hailong Wang** SCION **REDUCING METHANE AND CARBON DIOXIDE EMISSIONS FROM WATERLOGGED PADDY SOIL WITH BIOCHAR**
11:15-11:30	**Girish Kumar** University of South Australia **BIOCHAR INDUCES CHROMATE REDUCTION: IMPLICATIONS TO BIOREMEDIATION**
11:30-11:45	**Jim Jones** *Massey University* **OVERALL ASSESSMENT OF OPPORTUNITIES: WHERE IS THE VALUE?**
11:45-12:00	**Closing Remarks and Panel Discussion**
12:00-13:00	**Lunch**
13:00-14:00	**Visit to the lysimeter experiment at Plant & Food Research Facilities (presented by Erwin Wisnubroto)**

POSTERS

M Hasinur Rahman, Allister W Holmes, Steven J Saunders and K R Islam
PlusGroup Horticulture Ltd
BIOCHAR IMPACTS ON PHYSICAL AND HYDROLOGICAL PROPERTIES OF ALLOPHANIC SOILS

Kiran Hina, James Hanly, Mike Hedley, Mike Bretherton, Marta Camps
Massey University
INVESTIGATIONS INTO THE EFFECTS OF POST-PYROLYSIS TREATMENTS ON SORPTION PROPERTIES

Samuel Gregory, Christopher Anderson, Marta Camps, Michael McManus.
Massey University
THE ROLE OF BIOCHARS IN PROMOTING THE PHYTOREMEDIATION OF ARSENIC AND ORGANOCHLORINES AT HISTORIC SHEEP DIP SITES

Laura Christianson[1,2], Mike Hedley[2], Marta Camps[2], Helen Free[2], Surinder Saggar[2,3]
[1]*Iowa State University*
[2]*Massey University*
[3]*Landcare Research*
INFLUENCE OF BIOCHAR AMENDMENTS ON DENITRIFICATION BIOREACTOR PERFORMANCE

Don Graves
Nelson Bays Mycorrhizas
COMPARISONS OF NO-TILLAGE TECHNOLOGIES TO INCORPORATE BIOCHAR AND SOIL MICROORGANISM INOCULA INTO BIOLOGICALLY-DEGRADED SOILS

Erwin Wisnubroto, Mike Hedley, Marta Camps
Massey University
THE USE OF BIOCHAR FROM BIOSOLIDS TO IMPROVE SOIL FUNCTIONS OF SANDY SOILS

Roberto Calvelo-Pereira[1], Marta Camps[1], Juan Antonio Macía-Agulló[2]
[1]*Massey University*
[2]*INCAR-CSIC*
METHODOLOGIES FOR DETERMINING SURFACE CHARGE IN BIOCHAR

Michele Hayward, Jim Jones
Massey University
LOW COST BATCH BIOCHAR REACTOR AND FORMULATION FOR NEW ZEALAND.

Erwin Wisnubroto[1], Calvin Ball[1], Kyle Gardine[1], Mike Hedley[1], Steve Green[2], Marta Camps[1], Surinder Saggar[3], Markus Deurer[2]
[1]*NZBRC, Massey University, Palmerston North*
[2]*Plant & Food Research, Palmerston North*
[3]*Landcare Research, Palmerston North*
MITIGATING CLIMATE CHANGE BY SOIL CARBON SINK ENHANCEMENT INCLUDING BIOCHAR: A LYSIMETER STUDY

Abstracts

BIOCHAR AND THE COMPETING USES FOR BIOMASS

Sims, Ralph

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The diverse biomass resource available in any locality can be collected and used for a variety of purposes as well as for biochar production. These include uses such as feedstocks for bioenergy heat and power, liquid biofuels, bio-chemical production in a bio-refinery, bio-materials, or for more traditional uses such as animal bedding, mulch, compost, soil conditioning. So what is the "best" use of this biomass and how is this determined? This paper endeavours to compare biochar with other biomass potentials and discuss why it needs to be of low value to achieve the best bang-for-your-biomass-buck!

Biographical Note

Ralph Sims began his career in Sustainable Energy at Massey University, New Zealand in 1971 making and testing biodiesel. He has now returned to his position of Professor of Sustainable Energy, and Director, Centre for Energy Research after 4 years based at the IEA (International Energy Agency) in Paris as a senior analyst working on Renewable Energy and climate change mitigation.

He has been a lead author for 4 reports of the Intergovernmental Panel on Climate Change (IPCC) that was awarded the 2007 Nobel Peace prize jointly with Al Gore. Currently he is working on the forthcoming IPCC Special Report on Renewable Energy and will be leading the "Transport" chapter of the IPCC 5th Assessment Report over the next 3 years. He is a Fellow of the Institute of Professional Engineers and of the UK Institute of Agricultural Engineers, a Companion of the Royal Society of New Zealand and received the 2010 Outstanding Achievement Award from the Energy Efficiency and Conservation Authority (EECA) of which he was a ministerial Board Member appointee for 3 terms.

PYROLYSIS TECHNOLOGIES AND OVERVIEW OF THE SCIENCE

Jim Jones

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Pyrolysis is the thermal decomposition of organic matter in the absence of oxygen. This talk will explain the chemistry and kinetics of decomposition, the range of co-products that are produced, the differences between slow and fast pyrolysis, the range of heating methods, the effect of holding temperature, and the mechanisms that cause secondary reactions. This talk is intended to inform those less familiar with the engineering-science behind biochar production.

DEMONSTRATIONS OF DIFFERENT UNITS

Two pyrolysers will be demonstrated; (i) the BEK purchased by Massey from All Power Labs, USA; and (ii), the KILNZ Bio Energy kiln. The BEK is a continuous unit intended for experimental investigations with a kiln capacity of ~30 litres. The KILNZ Bio Energy kiln is a double barrel batch unit designed for remote operation without need for power, water, or gas utilities. It has a kiln capacity of ~2000 litres.

PRESENTATIONS ON DIFFERENT NZ BIOCHAR PRODUCTION UNITS AND APPLICATIONS

Those active in pyrolysis are invited to describe their pyrolysis methods. This is intended to be a series of brief presentations that share with the audience the range of technology options currently being explored.

RECENT DEVELOPMENTS IN BIOCHAR AND BIOCHAR MINERAL COMPLEX PRODUCTION UNITS AT ANTHROTERRA

Stewart McGlashan[1] of AnthroTerra Pty Ltd

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AnthroTerra is a world leader in the development and commercialisation of biochar and Biochar Mineral Complex (BMC™) technology. We are able to review individual agricultural production systems, then design and manufacture customised equipment to produce biochar and BMC™ specifically formulated to meet customer requirements.

Our vision is to be a leading supplier of equipment and services for sustainable agriculture and a stable climate.

Currently we are developing two production units. A mobile (trailer mounted) biochar production unit, the Charcolater™ and a torrefier capable of manufacturing BMC and other biochar-based value-add products.

The Charcolater's nominal production capacity is 150kg/hr for timber feedstock that is delivered to the reactor, in this model, by a wood chipper.

The torrefier nominal production capacity is 500kg/hr for BMC, but can vary with different production run requirements.

Research and development is underway to produce an integrated unit that combines the Charcolater and a torrefier.

The presentation will focus on the progress made to commission and commercialise this equipment.

Figure 2: The Charcolater in operation on site in western NSW.

Figure 1: Torrefier being commissioned at AnthroTerra's workshops.

SMALL SCALE CHARCOAL PRODUCTION WITH APPLICATION TO COMMERCIAL SYSTEMS

William Hughes-Games

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Traditional methods of charcoal production are messy, often operate in batches, produce variable yields and use the volatile fraction of the pyrolysis process only to create the heat to char the wood. A higher yield, continuous system is suggested which utilizes the combustion of the volatile fraction of the pyrolysis process to protect already pyrolyzed wood from further oxidation. In a commercial operation based on this system, considerable heat energy will be available for drying the feed stock or for whatever other purpose is required. Continuous harvest should be easy to mechanize.

FROM RESEARCH AND DEVELOPMENT TO PROFITABLE BUSINESSES

S Joseph[1, 2]

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[2]*Anthroterra Pty; 31 Pile Rd Somersby 2250 NSW, Australia*

There has been an exponential increase in the number of research papers and other publications that have appeared on biochar[1]. Understanding of the properties of different biochars is well advanced and there is more information on the agronomic benefits of different biochars for specific crop in specific environments and soil types. Benefits for site remediation using biochars of different origin has now been demonstrated at a laboratory scale. Recent publications have highlighted the role of biochar in climate change mitigation[1,2]. Japan and China already have a small but viable biochar industry and there has been a renewed effort to increase the use of biochar though improved production methods. A small number of companies are now selling biochar and biochar equipment both in Japan, China, Europe, Australia and North America. Aid projects are underway in Central and Latin America, Africa and Asia. Some of the biochar is produced in simple batch charcoal kilns, some in simple pits or open pans while some manufacturers are offering continuous kilns that have the latest in process and emissions control. However the world wide biochar production is still probably below 100,000 tonnes/annum. Biochar sells in developed countries for up to $1500/tonne which greatly limits its market. Quoted prices of biochar in China and Indonesia are approximately $250-350/tonne (Robert Flanagan pers comm.). This presentation will examine the potential of biochar, identify different markets, explore the economics of utilisation of biochar, identify roadblocks to the wide scale commerialisation and propose a road map to grow the industry both in developing and developed countries.

[1] Lehmann, J., Joseph, S., 2009. Biochar for environmental management. Science and technology. Earthscan, London, 416 pp.

[2] Macías, F., Camps Arbestain, M., 2010. Soil carbon sequestration in a changing global environment. Mitigation and Adaptation Strategies for Global Change 15, 511-529.

[3] Woolf D, Amonette JE, Street-Perrott FA, Lehmann J and Joseph S 2010 Sustainable biochar to mitigate global climate change. Nature Communications 1: 56.

COMMERCIAL OPPORTUNITIES FOR WASTE ORGANICS TO BIOCHAR IN NEW ZEALAND

Adriana Downie

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Pacific Pyrolysis (PacPyro) has been working with various clients in Australia and New Zealand in an effort to develop a commercial business case around slow-pyrolysis projects. Adoption of slow-pyrolysis technology may eventually occur within stand-alone businesses whose core business is the production of biochar. It is likely, however, that the first projects will be driven by the advantages gained through integration with existing industry, which makes the technology more economically viable in the short-term.

PacPyro has been working with strategic partners in some major existing industries who may utilise slow-pyrolysis technology to overcome some of the challenges they face. Each industry has a unique organics resource to manage. Resource recovery, energy security, greenhouse gas savings and economic outcomes for each industry present unique opportunities and challenges. The drivers for different industries to adopt slow-pyrolysis technology vary. Some are driven by organics waste management, others by a requirement for a cheaper and more secure source of electricity.

Adoption of the technology relies on demonstrating a convincing business case. This includes, not only demonstration of the technology to process waste organics in a way that meets regulatory requirements, but also the demonstration of biochar made from industry relevant feedstocks being beneficial utilised in a valuable application. The current level of uncertainty regarding biochar price and market size is a major contributor to lack of confidence in the business case for the technology.

A COMMON APPROACH TO CONDUCTING LCAs ON BIOCHAR

Jim Jones, Ruy Anaya de la Rosa and Ralph Sims

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Life cycle assessments (LCA) are defined by goal and scope statements, but these vary depending on the audience and system boundaries to the extent that LCAs can be hard to compare. To reduce this variability, this paper recommends a common code of practice be developed so that all biochar LCA studies can be compared against some baseline, and are directed at an audience who possess a single environmental code of ethics pertinent to LCA without bias towards biochar. A biochar LCA should be consistent with the definition of biochar, which encompasses; (i), the substance, charcoal; (ii), its use as a soil amendment; and (iii), the intentions of that use, which are many and are captured within a list of integrity criteria. Considering these, the functional unit should be management of the manufacture of a unit mass of biochar originating from biomass and its amendment to soil. The timeframe should be one hundred years to align with global warming potential (GWP) calculations. With well defined goal and scope, all biochar LCA studies can be arranged into the model elements of harvest, processing, delivery and land. Three simple-to-interpret levels of investigation (LOI) are proposed with respect to the amount of interaction permitted between the biochar and the land. By establishing a common code of practice in this way, biochar LCAs can be easily compared at common LOIs and, when nested into groups, can be enveloped within subsequent studies at higher LOI. This approach demonstrates how biochar LCA studies should be presented in an industrial ecology context.

CARBON OFFSETTING AND BIOCHAR

Ruy Anaya de la Rosa

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Despite serious reasons to not consider biochar as a carbon offset, a number of researchers advocate for inclusion of biochar in carbon offsetting schemes. Carbon offsetting, however, is often poorly understood, even by those participating in such mechanisms. While carbon offsets could be seen as a means to stimulate innovation and investment in greenhouse gas emission reduction projects, their effectiveness to mitigate climate change is questionable.

The proposal to make biochar eligible for carbon trade has resulted in strong opposition to biochar by a number of civil and non-governmental organisations concerned with the risks that land grabbing and carbon offsetting might raise. Others have argued that application of biochar into soils could bring atmospheric CO_2 concentration levels down, but not if linked to carbon markets. There is a need to analyse the social implications of carbon trading before promoting biochar as a carbon offset.

SCIENCE, PERCEPTIONS & POLICY IMPLICATIONS REGARDING BIOCHAR AS A CLIMATE CHANGE MITIGATION TOOL IN NZ

Dorothee Quade[1]

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Biochar is a relatively recent addition to the greenhouse gas mitigation toolbox available to policymakers. This research surveys the scientific understanding of biochar and the institutional framework pertinent to climate change mitigation and potential future biochar deployment in NZ. Empirical data was gathered via interviews and surveys with six stakeholder groups: agriculture (predominantly organic), forestry/wood processing, bio-energy/biochar businesses, research institutions and government agencies.

There is no recognition of biochar in international compliance carbon markets. Scientific uncertainties remain in relation to permanence of carbon storage in biochar, its agronomic benefits when applied to soil and its life cycle performance in terms of greenhouse gases and energy. In this context, public policy is faced with decision-making under conditions of risk and uncertainty. Theory suggests some guidance in the form of environmental policy principles such as the sustainability and Precautionary Principles. General policy criteria, including compliance with international obligations and political and social acceptability, as well as innovation theory are used as theoretical lenses through which the viability of biochar in NZ is assessed.

Results suggest that biochar deployment in NZ may be a boutique solution for niche applications rather than a large-scale commercial opportunity. Domestic biochar research is nascent, yet crucial for enabling NZ policymakers to assess the merits or otherwise of biochar for NZ. Diffusion of biochar technology in NZ would need to be preceded by careful crafting of legislation and incentive structures to ensure a sustainable pathway. A transparent and inclusive decision-making process may build trust and understanding about the potentials and pitfalls of biochar deployment and facilitate an environmentally beneficial outcome endorsed by a wide range of societal sectors.

METHODOLOGIES FOR DETERMINING THE LABILE FRACTION OF CARBON IN BIOCHAR

Calvelo Pereira, R.[1,*], Kaal, J.[2], Camps-Arbestain, M.[1], Pardo Lorenzo, R.[3], Aitkenhead, W.[1], Hedley, M.[1], Macías, F.[3], Hindmarsh, J.[4], Maciá-Agulló, J. A.[5]

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If biochar is to be accounted in C trading schemes, an accurate estimation of the lability of C in biochar over time, under the pedoclimatic conditions where it is deployed, is needed. In this study, biochars were produced from different feedstock types (pine, poplar and willow; PI, PO, and WI, respectively) at two pyrolysis temperatures (400 and 550 °C). The main objective of this study was to assess the intrinsic lability of biochar-C by using different spectroscopic techniques (pyrolysis-GC/MS, solid-state ^{13}C NMR), thermogravimetry (TGA), elemental composition and wet oxidation using either potassium permanganate or potassium dichromate. Short-term incubations (110 h) of two A horizons (from an Umbrisol and a Podzol) amended with these biochars at two doses (7.5 and 15 t ha^{-1}) were also carried out. Data from spectroscopic techniques evidenced that the degree of carbonisation of the biochars depended on the type of feedstock and pyrolysis conditions. The degree of thermal lability of the biochars generally agreed with the information provided by the spectroscopic methods. The fraction of total C oxidised by potassium permanganate (C_{per}/C_{total}) was < 5% in all biochars, whereas that oxidised by potassium dichromate (C_{dichro}/C_{total}) ranged between 18 and 55%. The highest values of oxidised C always corresponded to the biochars produced at low temperature. The estimated fraction of biochar-C mineralised 110 h after amending the soils, correlated well with the different estimates of the intrinsic labile C fractions considered. Results suggest that low-cost methodologies, such as dichromate oxidation and TGA, could be used to estimate the labile fraction of C in biochar.

METHODOLOGIES FOR DETERMINING THE P AND N FERTILITY VALUES OF BIOCHAR

Tao Wang, Marta Camps, Mike Hedley, and Peter Bishop

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Biochars are highly variable in nutrient composition and availability, this being determined by type of feedstock and pyrolysis conditions. Bioassays are the defining method to assess the agronomic effectiveness of nutrients in biochars, however, these methods are time and cost-consuming. Results from bioassays should therefore be related to more simple and low-cost measurements to be used for routine analysis. In the present study, methodologies are being developed to measure N and P bioavailability in biochars. The biochars have been produced from two different feedstocks (cattle manure-wood mixture and biosolid-wood mixture) at four different pyrolysis temperatures (250, 350, 450 and 550 °C). A bioassay test using rye-grass grown in a sandy soil amended with a P-free nutrient solution was used to compare P availability of biochars and standard fertilisers. Phosphorus availability was estimated using three routine methods used for fertilisers: 2% formic acid, 2% citric acid, and a neutral ammonium citrate extraction. A N mineralisation study (under aerobic conditions) is currently being conducted to estimate N availability. Nitrogen extractability after acid hydrolysis (6 N HCl) was also determined. Results showed that all P present in the feedstocks was recovered in the biochars produced. Concentration of P in biochars correlated well with ash content (R = 0.995). After 8 weeks of growth, the bioassay indicates that the biochars have initial P availability comparable to the P fertilizers tested (phosphate rocks and calcium dihydrogen phosphate), but differences are not significant ($P > 0.1$). Phosphorus precipitates present in these biochars are probably amorphous in nature, as no clear peaks of P compounds were identified by XR-diffraction. Amorphous Al phosphate may dominate in biochars from biosolids and Ca phosphate in those from manure. Nitrogen extractability by acid hydrolysis decreased with pyrolysis temperatures increased, as expected. About 50% N in acid hydrolysates was in mineral N forms (mainly NH_4^+). Future work will be dedicated to relate biological to chemical methods.

ELECTRICAL, ELECTROCHEMICAL AND MAGNETIC PROPERTIES AND STRUCTURE OF BIOCHAR and BIOCHAR COMPLEXES

S Joseph[1], S Donne[2], M Dupont[2], J Horvat[4], A Ziolkowski[3], C Chia[1], N Kempers[3], P Munroe[1], Y Lin[1]

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[2]Discipline of Chemistry, University of Newcastle, Callaghan, NSW 2308, Australia
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[4]School of Physics and ISEM, University of Wollongong, NSW 2522, Australia

Considerable research has been carried out to determine the chemical and physical properties of both aged and fresh biochars[1,2] and black carbon micro-agglomerates from the Amazon and other areas. When biochars are added to soil a complex series of abiotic and biotic reactions take place at the interface between the soil and the biochar. One of the most important classes of reactions involves the oxidation and reduction of both the carbon and the mineral matrix within the biochar and between the redox active compounds in the soil and the biochar surfaces. Previous work[3] has indicated that graphitic deposits can act as voltaic cells where electrons flow through the graphite from which is in a reducing environment (away from the surface) to an area where the graphite is in an oxidizing environment (near the surface). In the reducing environment, anions flow to the graphite surface and cations away from the surface (vice versa for the oxidizing environment). The nanoscale structure is complex with formation of nanoparticles, some of which are redox active, on the surface of the biochar[1]. Interactions between paramagnetic and magnetic cations and/or minerals could also take place resulting in biochars having complex magnetic properties. In this presentation, results of electrochemical and magnetic characterisation of Terra Preta, biochars and biochar-organo-mineral complexes (BMC) will be presented. It will be shown that high mineral ash biochars and BMC have distinct electrical, electrochemical and magnetic properties. These will be related to the physical and chemical properties of the biochars under investigation.

[1] Joseph, S.D., Camps Arbestain, M., Lin, et al. 2010. An investigation into the reactions of biochar in soil. Australian Journal of Soil Research 48, 501-515.

[2] Lehmann, J., Joseph, S. (Eds.), (2009) Biochar for environmental management: science and technology. Earthscan, London, pp. 183-205.

[3] S.M. Hamilton 1998 Electrochemical mass-transport in over burden: a new model to account for the formation of selective leach geochemical anomalies in glacial terrain, Journal of Geochemical Exploration 63 155–172

MICROBIOLOGY OF SOIL AMENDED WITH BIOCHAR

C. R. Anderson[1*], L .M. Condron[1,2], T. J. Clough[2], A. Stewart[1], R. A. Hill[1], and R. R. Sherlock[2]
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It is generally accepted that biochar-C is largely unavailable to soil microbes but changes in soil physicochemical properties and the introduction of metabolically available labile-C compounds associated with the biochar may shift the soil microbial community structure. In the event that biochar becomes widely applied to agricultural soils as a soil conditioner, this research focuses on understanding how biochar application to soil influences bacterial community structure and biogeochemical function. A controlled pot experiment was designed to investigate temporal changes in soil microbial ecology and physicochemical parameters in the presence and absence of biochar. Bacterial communities were investigated in both the rhizosphere and bulk soil.

When comparing biochar amended soils with controls, temporal changes in bacterial family abundances that were > 5% included: *Bradyrhizobiaceae* (~8%), *Hyphomicrobiaceae* (~14%), *Streptosporangineae* (~6%) and *Thermomonosporaceae* (~ 8%), where the biochar had a positive influence – either promoting an increase in abundance or reducing the magnitude of loss, and; *Streptomycetaceae* (~ -11%) and *Micromonosporaceae* (~ -7%), where biochar was perceived to have a negative effect on bacterial family abundance. The *Bradyrhizobiaceae* and *Hyphomicrobiaceae* have significant involvement in the nitrogen cycle with genera/species identified involved in NO_3^- denitrification through to N_2. The data also suggests that organisms involved in nitrification of NH_4^+ to NO_2^- are less abundant while mycobacterial dissimilatory nitrate reduction to NH_4^+ increases along with N_2 fixation. Coupled to the observation that biochar can adsorb NH_4^+, these results can provide an explanation for the significant reductions in N_2O emissions observed from pastoral soils when biochar is added. Other benefits from biochar incorporation include promotion of phosphate solubilising bacteria, improvements in C-flux through increases in bacterial families that can degrade more recalcitrant C compounds and potential decreases in plant pathogens.

BIOCHAR SUPPRESSES $^{15}N_2O$ EMISSIONS FROM ^{15}N-URINE

Arezoo Taghizadeh-Toosi[1]*, Tim J. Clough[2], Leo M. Condron[1,2], Robert R. Sherlock[1], Craig R. Anderson[2], Robin A. Craigie[3]

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Nitrous oxide (N_2O) is a potent greenhouse gas and precursor to stratospheric compounds that degrade ozone and its atmospheric concentration continues to increase linearly (0.26 % yr^{-1}). Emissions of N_2O grazing ruminant excreta are estimated to be responsible for 1.5 Tg of the total 6.7 Tg of anthropogenic N_2O emissions. Moreover, this in situ study was conducted to determine the effects of incorporating biochar into soil (0 to 30 t ha^{-1}) on ruminant urine-derived N_2O fluxes, N uptake by pasture, and pasture yield during an 86-day spring-summer period. The N_2O fluxes from ^{15}N labelled ruminant urine patches were reduced by >50%, after incorporating 30 t ha^{-1} of biochar. Taking into account the N_2O emissions from the control plots, 30 t ha^{-1} of biochar reduced the N_2O emission factor from urine by 70%. The atom % ^{15}N enrichment of the N_2O emitted was lower in the 30 t ha^{-1} biochar treatment, indicating less urine-N contributed to the N_2O flux. Soil NO_3^--N concentrations were lower with increasing biochar rate during the first 30 days following urine deposition. No differences occurred, due to biochar addition, with respect to dry matter yields, herbage N content, or recovery of ^{15}N applied in herbage which emphasised no negative effect of biochar on pasture yield. Incorporating biochar into the soil can significantly diminish ruminant urine-derived N_2O emissions. However, further work is required to determine the seasonality and persistence of the observed effect, and to fully understand the mechanism(s) of the observed reduction in N_2O fluxes.

MINERALISATION OF CARBON FROM FRESH AND CARBONISED CORN STOVER IN TWO NEW ZEALAND SOILS

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Biochar is charcoal produced by pyrolysis of biomass and is intended to be applied to soils for an agronomic and/or environmental benefit. After pyrolysis char carbon (C) is highly aromatic in nature and orders of magnitude more resistant to microbial decomposition than C in the original biomass. The objective of this study was to investigate the decomposition of C from fresh corn stover (CS) (a C_4 plant) and from biochar produced from CS after their addition to a Typic Fragiaqualf soil (TK) and a Typic Hapludand soil (EG). Both soils were taken from C_3 ecosystems so that the fraction of CO_2 evolved from either biochar or native organic matter (NOM) could be estimated by determining $\delta^{13}C$. The biochar was produced at two final temperatures of pyrolysis (350 and 550 °C). All treatments received the same amount of C (7.18 t ha^{-1}), except the controls. The rate of CO_2 evolution was determined by trapping in I M NaOH solution, conversion to $BaCO_3$ and back titration against 0.5 M HCl. After 203 days of incubation the EG soil with greater organic C than the TK soil (107 and 38 g C kg^{-1} of soil, respectively) has emitted slightly more CO_2 ($P<0.05$). The application of fresh CS has resulted in an increase of total C-CO_2 evolved by 115.2% in the EG soil and 128.7% in the TK soil, compared to their respective controls. Soil organic C (2.6% and 6.3%) and feedstock C (81.4% and 54.8%; estimated assuming decomposition of NOM is not affected by the amendment) from EG soil and TK soil, respectively, have been evolved over 203 days. The rate of C mineralisation (mg C-CO_2 kg^{-1}soil hr^{-1}) was significantly ($P<0.05$) higher in uncharred CS-amended pots compared to the rest of treatments, irrespective of soil type. No significant differences were observed ($P>0.05$) in the rate of CO_2 evolution between the control and soils amended with either type of biochar. The trial is continuing and the determination of the isotopic signature of evolved CO_2 will be crucial for the quantification of the fraction of C in CO_2 that originates from biochar.

EFFECT OF DIFFERENT TYPES AND DOSES OF BIOCHARS ON THE WATER RETENTION CAPACITY OF A TYPIC FRAGIAQUALF AND A TYPIC HAPLUDAND

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The use of biochar as a means to ameliorate the physical properties of soils and, particularly, increase soil water retention has been hypothesized. The objective of this study was to investigate to what extent the addition of biochars produced from different feedstocks and at different temperatures affects the water retention of two soils. Four biochar types – produced from corn stover (CS) and *Miscanthus* (MS) at 350 and 550 °C (CS350, CS550, MS350, MS550) – were incorporated into a Typic Fragiaqualf (Tokomaru silt loam; TK) and a Typic Hapludand (Egmont silt loam; EG), at the rates of 0, 2.5, 5.0, and 10.0 t ha^{-1}. Volumetric moisture contents (θ_V) at different matric potentials (-15, -1, -0.3, -0.1, -0.08, -0.06, -0.04, and -0.02 bar) were determined. The results indicate that biochar addition increased the microporosity (e.g., increase in θ_V at -15 bar) of both soils, although only significantly ($P < 0.05$) for the TK soil when CS biochar was added at the highest rate; this effect was independent of type of feedstock and temperature of pyrolysis. The same trend was observed at -1 bar in the TK soil, but no clear effect in θ_V was observed in the allophanic soil (EG). Biochar amendments significantly ($P<0.05$) increased macroporosity in the allophanic soil (e.g., increase in θ_V at ≥ -0.1 bar), for CS biochar produced at 350 and 550 °C, but no clear trends were observed in the TK soil. The results thus suggest that these specific biochars at the doses studied improve drainage in the EG soil, and increase microporosity for the TK soil. These measurements represent the effect of biochar right after its application to soil, and before the "natural" structure is re-developed. More research needs to be done on how biochar affects soil water retention capacity as it interacts with soil particles with time.

INVESTIGATION OF MICROORGANISMS (FROM CHARCOAL-RICH AND –POOR ENVIRONMENTS) GROWING IN THE PRESENCE OF PINE BIOCHAR

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Biochar has significant potential as an agriculturally-based greenhouse gas mitigation strategy, but there is a lack of research into its environmental interactions. Research trials have shown that particular soil micro-organisms have the ability to decompose biochar, although there is a lack of studies of activity of microorganisms associated with charcoal residues in soils. In this study, we investigate the effect of adding biochar on the growth of micro-organisms from a charcoal-rich environment and from a low charcoal environment. Soil samples were taken from a Manawatu fine sandy loam fire-exposed site and a site adjacent to the former. Pine feedstock was pyrolysed at 550°C in a gas-fired rotating drum kiln, and ground to particle size 75 µm or less to facilitate suspension in agar. A sample of this biochar was treated with an acetone:methanol:water solution to extract labile carbon. Pine biochar (PB), extracted pine biochar (EPB) and soil from the fire-exposed site was characterised using Thermo-Gravimetric Analysis. Six types of agar were prepared: nutrient agar (NA) and minimal salts agar (MSA) were the base solutions (and controls) to simulate optimum and limiting growth conditions. An extracted biochar NA, extracted MSA, unextracted NA, and unextracted MSA were made up from these solutions. One gram of each soil sample was mixed with sterile ROH water to produce soil dilutions of 10^{-4} and 10^{-5}. Plates were incubated at 25°C and examined at 2-4 day intervals. Number of colonies and rate of increase in size were recorded. Results indicate a significant ($P<0.05$) smaller number of colonies growing in the cultures made with PI biochars, compared to those with either EPI biochars or the controls. This trend was observed in both the NA and MSA media. The numbers of colonies was also affected by the type of soil from which the microbes were extracted (fire-exposed soil > than adjacent soil; significant $P < 0.05$). Implications of the results, including fungi versus bacterial presence, are discussed.

ON-GOING AND FUTURE RESEARCH ACTIVITIES AT THE SOIL SCIENCE STREAM OF THE NZBRC

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As soil scientists, it is our responsibility to understand the characteristics of biochars and how they relate to process conditions and type of feedstock, before they are added to soils. It is also our duty to understand the extraordinarily heterogeneous nature of soils, to be able to anticipate how the internal organization, components and properties of soils will vary in response to biochar addition. Only with this knowledge, we will be able to develop predictive capabilities related to the agronomic and environmental performance of specific biochars on specific soils. Two years of research has provided knowledge on (i) the intrinsic stability of biochars; (ii) the availability of nutrients present in ash-rich biochars; (iii) how type of feedstock and process conditions affect (i) and (ii); (iv) the influence of specific biochars on soil water retention and availability, (v) the potential role of biochar to filter wastewaters, and (vi) the development of methodologies to evaluate the above properties. Current research is also focused on the logistics of biochar application to soil and the effect of biochar on native soil OM, soil aggregation, root growth, soil microbiology and emissions of N_2O and CH_4. Field trials to assess the role of biochar in soil C sequestration will start this autumn on two sites for which two specific biochars will be produced. Future research will also include the development of a framework for a spatially-enabled systems analysis that will integrate output layers from a number of established GIS resources of national relevance. This will enable us to obtain realistic estimates of the land surface to which biochar can be potentially applied and what type of biochar is needed. This information will be crucial for the selection of representative case studies for future field trials. These will be carried out through joint research with the biochar engineering discipline, which is also responsible for developing the technological and economical aspects of the production of biochar.

REDUCING CH_4 AND CO_2 EMISSIONS FROM WATERLOGGED PADDY SOIL WITH BIOCHAR

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A potential means to abate increasing levels of CO_2 in the atmosphere is the use of pyrolysis to convert biomass into biochar, which stabilizes the carbon (C) that is then applied to soil. Before biochar can be used on a large scale, especially in agricultural soils, its effects on the soil system need to be assessed. This is especially important in rice paddy soils that release large amounts of greenhouse gases to the atmosphere. In this study, the effects of biochar on CH_4 and CO_2 emissions from paddy soil with and without rice straw added as an additional C source were investigated. The biochars tested were prepared from bamboo chips or rice straw which yielded bamboo char (BC) and straw char (SC), respectively. BC and SC were applied into paddy soil to achieve low, medium and high rates, based on C contents of the biochars. The biochar-amended soils were incubated at 25±1°C under waterlogged conditions in the laboratory.

Adding rice straw significantly increased CH_4 and CO_2 emissions from the paddy soil. However, when soils were amended with biochar, CH_4 emissions were reduced. CH_4 emissions from the paddy soil amended with BC and SC at high rate were reduced by 51.1% and 91.2%, respectively, compared with those without biochar. Whereas activities of the methanogenic archaeal communities were not affected by biochar treatments, methanogenic activity in the paddy soil decreased with increasing rates of biochar. CO_2 emission from the waterlogged paddy soil was also reduced in the biochar treatments. Our results showed that SC was more effective than BC in reducing CH_4 and CO_2 emissions from paddy soils. The reduction of CH_4 emissions from paddy soil with biochar amendment may result from the inhibition of methanogenic activity or a stimulation of methylotrophic activity during the incubation period.

BIOCHAR FOR REDUCTION OF CHROMATE IN SOILS: IMPLICATIONS FOR REMEDIATION

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Heavy metal contamination is ever increasing since the inception of industrial evolution. Chromium (Cr) is a major toxic pollutant, harmful to biota in soil and water interface. Cr in soils occurs in two forms, Cr(III) and Cr(VI). Cr(VI) is highly toxic and carcinogenic. Remediation by reduction is one of the viable options for the reclamation of the Cr- contamination. The objective of this study was to investigate the efficiency of biochar (BC) on the reduction of chromate in soils.

The chicken waste biochar sample was collected from Pacific Pyrolysis, NSW, Australia. The BC sample was treated three times with 1 M HCl for demineralization. The acid treated biochar again washed 4 times with 1:1 mixture of 1M HCl -1M HF to remove silica and other inorganic materials. The reduction of Cr(VI) in soils was examined by mixing 500mg Cr(VI)/kg of soil and 5% both modified and non-modified biochar and incubated at field capacity. Periodically, the concentration of Cr(VI) in the extracting solution was measured. Diffuse reflect infrared fine (DRIFT) spectra were collected to examine the role of functional groups present in BC for the reduction of Cr(VI) in soils.

The concentration of added Cr(VI) (500mg/kg) was reduced completely in four days after incubation. However non-modified biochar was not much effective, reduced 500mg/kg of Cr(VI) to 238 mg/kg in 12 days. Chemical treatment of the biochar has decreased the inorganic materials and silica, increased the effectiveness on the reduction of Cr(VI).

Chemically modified biochar is a strong reductant of Cr(VI) in soils. Remediation of Cr(VI) using biochar shows promise as a means to solve toxicity while increasing the carbon sequestration and also reducing waste disposal.

OVERALL ASSESSMENT OF OPPORTUNITIES: WHERE IS THE VALUE?

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Biochar will be successful if it makes money for investors. This last slot of the 2011 Biochar Workshop will start with a short presentation about the opportunities and challenges ahead for biochar, followed by an open forum for the audience to add their thoughts. As well as identifying opportunities, it discusses the roles of researchers and entrepreneurs in the context of turning ideas into businesses.

BIOCHAR IMPACTS ON PHYSICAL AND HYDROLOGICAL PROPERTIES OF ALLOPHANIC SOILS

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Biochar is produced by pyrolysis of a wide range of biomass sources including agricultural and forest wastes, animal waste and other waste products under limited oxygen supply. Despite many benefits associated with agricultural use of biochars, there is limited information available related to biochar effects on physical and hydrological properties of Allophanic soils used for kiwifruit production. A lab experiment was set-up to apply biochar produced from pine tree (*Pinus radiata*) to Allophanic soils (Rich vs. Poor Allophanic soil) at 0, 25 and 50 t ha^{-1} in a 2 x 3 factorial combination of completely randomised design. In this study we also incorporated the pine wood chips that were used to produce the biochar to soils at the same rate as biochar. Soil samples were collected from the Bay of Plenty region and selected physical and hydrological properties were evaluated. Incorporation of biochar and wood chips resulted in an increase in total porosity with an associated decrease in bulk density for both soils. The hydrological properties such as maximum water holding capacity, field moisture capacity and hydraulic conductivity of both soils increased with increasing rates of wood chip and biochar. The changes in hydrological properties were more responsive in Rich Allophanic soil with the application of biochar compared with Poor Allophanic soil. The opposite result occurred with the application of wood chip. The positive effects of biochars on Allophanic soil physical and hydrological properties suggested that soil amendment using biochars can improve soil physical quality for sustainable production of kiwifruit. Since the incorporation of biochar in soils with high C/N ratios and abiotic buffering of mineral N can lead to lower N availability to crops. Therefore, non-legume crops such as kiwifruit may require addition of N based fertilizer at the same time as biochar application to maintain optimum yields. Considering the above, in future studies we intend to optimise the application rate of biochar with N, aiming to improve Allophanic soil quality, and minimise any reduction in soil quality caused by kiwifruit production.

INVESTIGATIONS INTO THE EFFECTS OF POST PYROLYSIS TREATMENTS ON ADSORPTION PROPERTIES OF BIOCHAR

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Steam-activated biochars may potentially act as useful filtering materials t
wastewaters. In this study, biochars were produced by low-temperature pyrolys
heating temperature of 550 °C) of fibrous debarking waste from pine (feedstock)
with or without steam post-treatment. Steam activation was carried out in a
furnace heated to 750 °C for one hour and using N_2 as a carrier gas.

The biochars were characterised by FT-IR, TGA, solid state ^{13}C-MAS NMR spectro
N_2 adsorption measurements (BET), pH and for elemental composition (C, N, H).

Upto 60.5 % of char carbon was lost (gasified) during steam activation. Physic
chemical changes to biochar caused by steam activation are discussed.
content of steam-activated biochar was found to be greater (83% wt:wt) than
control biochar (77% wt:wt). The FT-IR spectra revealed that steam activation
increase the amount of acid functional groups compared to the control. Th
spectra of the biochars displayed the presence of a single band at 130 ppm
which corresponds to aryl-C. Control pine also showed a shoulder at 150-16
which contributed to the O-substituted aromatic carbon. The specific surfac
(BET) increased three-fold after steam activation (from 235-735 m^2/g). Amn
adsorption studies were conducted by shaking char samples in solutions of 40 pp
$NH_4(SO_4)_2$. At solid to solution ratio of 1:20 steam activated char did not have enh
NH_4^+-adsorption. Loss of C during of steam activation is not consistent with the
negative purpose of biochar technology.

REMEDIATION OF HISTORIC SHEEP DIP SITES USING BIOCHAR AND PHYTOREMEDIATION METHODS

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The agricultural sector, particularly sheep and beef farming, has been the backbone for the New Zealand economy for decades. We are today realising the detrimental effect that certain historic sheep farming activities have on soil quality around the country. A named example is the presence of sheep dip sites; solid structures that by law were present on every sheep farm in New Zealand and that contained a mixture of organochlorines (DTT, aldrin, dieldrin) and arsenic used to rid sheep of unwanted pests. Residual chemicals in soil now pose a health risk due to their ability to remain in soil for decades.

This research project aims to integrate western science with Matauranga (Maori science) to protect mahinga kai (food gathering areas) from these harmful chemicals. Soil samples will be taken from a sheep dip site in upper Hawkes Bay where arsenic exists at extremely elevated levels. Of greater concern is the observation that this metalloid is leaching into nearby waterways and accumulating in food sources. High biomass crops, such as willow, will be used to enhance the phytoextraction of arsenic and the microbial degradation of organochlorines. Biochar from willow prunings will be produced at two final temperatures of pyrolysis (350 and 550 °C). For the 350 °C biochar, young wood will be used, whereas for the 550 °C biochar, old wood will be used instead. This will produce a low- and high-ash biochar, respectively. The former is expected to promote microbial degradation, and the latter will have a liming effect in the soil through which arsenic solubility will be enhanced and, therefore, arsenic plant uptake. The experiment will be run in a glasshouse. Through this research, Maori landowners will benefit by enhancing their own knowledge of sustainability while coupling the benefits of biochar and its ability to mitigate climate change. Ultimately, a closed sustainable loop system will be in effect where plant biomass used for phytoremediation is returned to the soil as biochar.

INFLUENCE OF BIOCHAR AMENDMENTS ON DENITRIFICATION BIOREACTOR PERFORMANCE

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As a soil amendment, biochar can provide environmental benefits like increased soil cation exchange capacity, microbial growth and soil water retention, in addition to its role as a long-term store of carbon in terrestrial ecosystems. This suggests that biochar can also be a useful addition to treatment systems aiming to reduce nutrient loadings in agricultural drainage. One possible such application for biochar is inclusion as fill denitrification bioreactors for agricultural drainage, where woodchips (carbon source) allow enhanced denitrification as drainage water laden in nitrate (electron acceptor) flows through the woodchip bioreactor. It was hypothesized that biochar additions could improve nitrate removal and decrease ammonium losses from woodchip denitrification bioreactors. This was explored with lab-scale column experiments consisting of woodchips mixed with two application rates of biochar (7% and 14% biochar by dry weight) which was produced from *Pinus radiata* feedstock. Biochar was pyrolysed at a peak temperature of either 380°C or 550°C to investigate effects of different temperature-derived chars on nitrate removal (i.e. more labile carbon remaining in lower temperature char). A nitrate solution was pumped through the columns and outlet stream samples were analysed for ammonium-N and nitrate-N while head space samples were analysed for nitrous oxide. Initial results indicated that there was no observable difference in nitrate removal between the woodchip control and the woodchip plus biochar columns. The columns containing biochar also seemed to release more ammonium upon start-up than the woodchip control though this trend was not significant ($p=0.36$).

COMPARISONS OF NO-TILLAGE TECHNOLOGIES FOR INCORPORATING BIOCHAR AND SOIL MICRO-ORGANISMS INTO DEGRADED SOILS

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This poster summarises research and practical objectives shared in common by three emergent and convergent technologies aimed to improve soil biological fertility; no-tillage seed drills, inoculation of plant roots with beneficial soil micro-organisms, and incorporation of biochar into soils. These shared objectives include optimal spatial placement of soil amendments into plant root zones, maximal retention of existing crop residues, and the maintenance or enhancement of soil microbial nutrient networks.

Research to date has only rarely been undertaken into the use of no-tillage technologies to incorporate biochar or beneficial micro-organisms into soils. Nonetheless, there is a potentially useful and considerable body of research into no-tillage and soil conservation, and many years of practical experience to that aim to achieve best-management practices for improved placement of seed, manures and fertilisers; reduced soil disturbance, minimal surface runoff and eutrophication, minimal soil compaction effects, and minimal energy inputs by agricultural machinery operations.

The biological effectiveness and possible unintended side effects of banded fertiliser application using no-tillage seed drills has been shown to vary according to the shapes of seed drills or soil openers, and the resulting shapes of seed beds (i.e. “U”, “V” or “⊥”), & whether the seed bed is also covered by soil.

THE USE OF BIOCHAR FROM BIOSOLIDS TO IMPROVE SOIL FUNCTIONS OF SANDY SOILS

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Raw sandy soils have low water storage capacity and low cation exchange capacity, which makes their management a challenge to farmers. Application of exogenous organic matter (OM), such as composts and manures, are commonly used to improve the fertility and physical properties of these soils. However, these organic amendments decompose rapidly due to the lack of reactive mineral surfaces able to stabilize OM. Ash-rich biochars produced from high-quality biosolids (e.g., low in pollutants) might be an option to use as amendment to these soils. These biochars are rich in nutrients, minerals and charcoal; these components will not only improve nutrient fertility, but also the long-term retention of these nutrients and that of plant available water. In this study, two biochars were produced at 550°C from biosolids (BS) and a mixture of biosolids and green waste (BG) (50:50; wt:wt). The biochar was applied as amendments to the low fertility Waitarere soil to test the ability of biochar to support rye grass growth and stimulate root growth under glasshouse conditions. The biochar was applied only on the top layer of soil (0 - 15 cm) at different rates (0, 1.5, 5 and 10 t ha^{-1} without N fertilizer and 0, 1.5, 10, 20 t ha^{-1} with N fertilizer at a dose of 113 kg N ha^{-1}). In the absence of N fertilizer, the addition of biochar to the soil significantly ($P<0.05$) reduced the biomass yield (means: 1.24 – 1.78 g) compared to the control (mean: 3.03 g). When fertilized with N, biochar application significantly ($P<0.05$) increased the biomass yield from 3.28 g to 4.86 g. Root length measurements indicated that the addition of biochar to the soil, with and without the presence of N fertilizer, significantly increased ($P < 0.05$) the root length compared to the controls. These results suggest that biochar may stimulate root elongation on poor sandy soil, thus contributing to the increase of the soil carbon sink. Further research on the immobilization of N caused by biochar is needed to understand the influence of biochar on the cycling of N in agricultural systems.

METHODOLOGIES FOR DETERMINING SURFACE CHARGE IN BIOCHAR

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Knowledge of biochar characteristics is fundamental to maximise the positive effect of this amendment in soils. The surface chemistry of biochars is rich and varied. A range of functional groups exist, including phenolic, carboxylic, lactonic, carbonyl, O-quinone-like structures and ether-type oxygen. The first three have acidic properties and provide a pH-dependent cation exchange capacity (CEC) to biochars. The aim of the present work is to characterise the biochar structure and quantify the dominant functional groups present by the combination of different analytical techniques. In this study, two plant residues (from pine and poplar) were used as feedstock and pyrolysed at two final temperatures (400 and 550°C). The elemental composition (C, H, O, N, S) of biochars was determined, as well as pH, N_2 adsorption (BET surface), and thermogravimetric analyses. Results from potentiometric acid-base titrations and X-ray photoelectron spectroscopy (XPS) provided specific information about the types of functional groups present. In addition, potentiometric titrations gave details about the modelling of the acid-base equilibrium. The influence of types of feedstock and pyrolysis conditions on the degree of carbonisation and chemical complexity of biochars was evidenced by the elemental analysis and BET data. The concentration of carboxylic and phenolic groups, as estimated by potentiometric titrations, was always greater in the biochars produced at low temperature. Most of the acidity in the biochars under study was attributable to phenolic groups, independently from the type of feedstock and pyrolysis temperature considered. More research is needed in order to achieve a better knowledge of the surface properties of biochar that can help to implement a safe and beneficial application of biochar in the diverse land-use systems.

LOW COST BATCH BIOCHAR REACTOR AND FORMULATION FOR NEW ZEALAND

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This poster summarises the work that is being conducted to develop a low cost batch biochar reactor for the New Zealand market. The project will explore the nexus between process engineering and biochar application to the soil. Experiments will look at a number of available feedstocks, their pre-treatments and optimum process conditions to determine methods to maximise fixed carbon yield, throughput rate, energy efficiency together with other factors such as surface properties and water retention. The biochar produced will be analysed and further experiments will then investigate approaches of formulating the biochar to improve its ability as a soil conditioner. These will include adding biochar with clay, manures and other dense nutrient materials[1]. Pot trials will be undertaken to investigate the biochar and its formulations with New Zealand soils.

MITIGATING CLIMATE CHANGE BY SOIL CARBON SINK ENHANCEMENT INCLUDING BIOCHAR: A LYSIMETER STUDY

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In New Zealand, approximately 50% of soil C is under grazed pasture management with most of it in the 0-10 cm topsoil depth. There is currently a growing interest to increase the stocks of stabilised soil C in pasture soils as a GHG mitigation strategy. Grazed pasture systems with deep rooting plant species may able to increase the C stocks at depth and, at the same time, stimulate soil mineral weathering, thereby increasing OM stabilisation through organo-mineral complexes. In this lysimeter study, we will investigate the effect of biochar applied below the top 10 cm on the root growth at depth as well as its effect on the soil C pools. Two biochars were used in this experiment: (i) a low-ash biochar from pine sawdust, pyrolised at 350 °C (PI-350), and (ii) a high-ash biochar from a mixture biosolid-greenwaste (50:50 wt:wt) pyrolised at 550°C (BG-550). The PI-350 biochar was intended to improve deep root growth in the Tokomaru silt loam soil (TK), while having a low impact on the pH of the soil to ensure mineral weathering. The BG-550 biochar was used to enhance root growth in the Foxton sandy soil (FX), where plant growth is limited because of the low nutrient content and low water holding capacity. The soil columns (40 cm depth, 20 cm ø) held in PVC pipe were placed on top of 1.3 m tension lysimeters with tipping buckets to record drainage volume. Soils sampled in the field at FX were carefully separated into the 0-10, 10-20 and 20–40 cm depths. The PVC tube was packed with soil from the 20-40 cm depth and then soil from the 10-20 cm depth was mixed with the BG-550 biochar (dose: 10 t/ha) and NPK fertiliser, and repacked, finally soil from the 10-20 cm depth was added to fill the core. The same procedure was followed for the TK soil, except that the PI-350 biochar was used and the 20-40 cm soil depth was obtained intact from the field. Gas sampling was carried out 3 times per week during 4 weeks, and CO_2, CH_4 and N_2O were measured. Three types of grazeable forage were then seeded. Ryegrass and mixture of red clover & cocksfoot were planted on both soils. On the FX soil, lucerne and on the TK soil, chicory and were planted as the third forage type. There were 4 replicates per treatment. Implications of the results will be discussed during the workshop.

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