Researchers at the UKBRC work on the local, regional and global potential for biochar in diverse contexts and its safe and beneficial use in soil, guided by an understanding of processes of production and application and socio-economic considerations.

The objective of the UKBRC is to efficiently and effectively address the many uncertainties that exist around the deployment of biochar technologies, providing robust and inter-disciplinery evidence, disseminating knowledge through publication and developing a network that links the UK research community and connects it to policymakers and other stakeholders and extends to its international counterparts.

The UKBRC is an alliance that currently involves research groups at the University of Edinburgh, Rothamstead Research and Newcastle University. It was launched in Edinburgh on the 1st April 2009, and is underpinned by a Science and Innovation award from EPSRC and with additional backing from the Scottish Funding Council.

The contributions of Angela Fallon, Mathew Ball, Andy Rutherford and the staff of the UK Biochar Research Centre, to the organisation of this conference are gratefully acknowledged.

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Oral Presentation

Biochar: Technology aspects and commercial production

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Abstract

There are many biochar, or charcoal producing technologies around the world, varying in scale, yield, degree of complexity and process integration. There is no "generic" technology suited to all environments and feedstocks. Process conditions influencing char yields are noted and key parameters identified. An overview of technologies from small scale batch systems to large scale continuous production is given. A focus on UK pyrolysis companies will highlight the status of biochar production and an overview of companies selling biochar commercially, in the UK and internationally. Technology issues relating to syngas cleanup for large scale use, with regards to use in engines, will be assessed and limitations on technology development in the UK highlighted.

Oral Presentation

Biochar markets: Closing the technology gap

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Abstract

Carbon Gold is a pioneer in biochar commercialisation. It has brought to market 'Grochar' and works on other formulations and production systems that can be used to deliver a sustainable improvement in soil productivity.

This is of particular interest to organic growers who rely on the soil to provide plant nutrition. Carbon Gold has worked with the Green and Blacks cocoa farmers in Belize and has undertaken to produce 300 tons of biochar from Cocoa prunings.

Carbon Gold reviewed the market for suitable technology, but most of the commercial pyrolysis equipment is too expensive/complex for this type of application, and oil drum based equipment is too small and requires too much feedstock preparation. Stoves were considered, but would need a longer, better resourced project to deliver.

At the start of the project Carbon Gold installed a number of Adam Retorts. These provided the material for initial field trials which were very positive, but this kiln is difficult to use with a low density feedstock resource. Carbon Gold therefore modified the traditional ring kiln to pyrolysis operation. 10 of these units have recently been supplied to the Toledo Cocoa Growers in 2011 and each is expected to produce 30 tons of char.

The 5' Modified Ring Kiln (MRK) used in Belize has a working volume of 1.5 m^3 and will (typically) take 500 kg of air dry feedstock and produce 100-150 kg of char using up to 100 kg of fuel wood. The fuel wood is burnt in a downdraft combustor to dry the feedstock and raise its temperature into the pyrolysis zone. Once gas production is underway the internal combustion process becomes self-sustaining and the 'burn' will run at 450°C for 3-4 hours. The biochar is ground for application to young cocoa trees, and for other field trials.

Carbon Gold is developing the MRK configuration for other applications, and different markets where greater output, lower emissions, higher yield and less labour input are required.

Oral Presentation

Developing added-value biochar products for early-entry markets

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Abstract

Full Circle Biochar is commercializing proprietary biochar products for large scale market opportunities. Recognizing that all biochars are not equal, Full Circle has developed intellectual property around specific biochar designs created by varying feedstocks, process conditions, and post-processing of biochar.

By partnering with key users and financial players, Full Circle is focused on developing well characterized products differentiated and tested for specific applications.

Early efforts are focused on markets with rapid product demonstration opportunities and high product value per volume of biochar.

Full Circle has taken a "platform" approach to biochar development and deployment. Each platform consists of a distinct configuration of feedstock, pyrolysis technology, biochar products and energy outputs.

Given the scale of deployment required to deliver a significant climate impact. Full Circle Biochar believes that a unique opportunity exists for collaboration and partnership between academia and the private sector to accelerate the deployment of biochar at scale.

Oral Presentation

Life cycle assessment of biochar systems in developing countries: Greenhouse gas and economic analysis

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Abstract

Biochar used as a soil amendment holds promise for increasing the climate resilience of smallholder agricultural production systems in developing countries while potentially also reducing greenhouse gas (GHG) emissions. Both aspects can help to improve the livelihoods of small-scale farmers. This study has surveyed 150 biochar projects in developing countries across the world, and biochar systems have been categorized by production technology and scale, geographic location, replicability, project maturity, data availability and quality, degree of integration into local economies, and likelihood to have an impact on GHG reduction and/or climate change adaptation. From these projects, case studies were selected that best meet these criteria and life cycle assessment (LCA) was used to analyze the GHG and economic impacts for each. Example case studies include: a pyrolysis cook stove system on rural farms in western Kenya; biochar from rice wafer stoves used on peanut farms in the central costal region in Vietnam; and a village-scale pyrolysis unit in Senegal. The LCA system boundaries are dependent on the specific case study and incorporate aspects of: feedstock production, collection, and transportation; biochar production technology; kiln/stove construction; co-product generation (cooking energy); biochar application to soils; crop yield effects; and avoided processes (residue burning, decay, traditional cooking, fertilizer production, manure application, transportation).

For each case study, there are net GHG reductions as compared to existing traditional practices. The GHG balance for the Kenya case study is strongly dependent on the sustainability of the feedstock source and the emissions from avoided traditional cooking. For the Vietnam case study, where the biochar is already in production as a co-product of local rice wafer cooking, upstream processes play less of a role and the relative stability of the carbon in the biochar dominates the GHG balance. The economics are largely dependent on how surplus crops are valued. For example, subsistence farmers in Kenya may not sell surplus maize, as any surplus goes directly to feed the family. However, the question of whether that surplus is monetized determines the profitability of the biochar system. Whereas peanut farmers in Vietnam are likely to sell surplus, they profit directly from the increased revenues that result from improved crop yields. Another key factor in assessing the net GHG and economic balance is the duration of biochar's effect on soil properties. Long term biochar field trials (10+ years) are lacking, and sensitivity analyses reflect the importance of this parameter.

Acknowledgements: Core funding for this undertaking was provided by the Program on Forests (PROFOR), and the World Bank's BioCarbon Fund. Additional funding was made available by the Carbon War Room.

Oral Presentation

Biochar research at Bangor University: Plant response, pesticide fate and trace gas emissions

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Abstract

There is currently great interest in the application of biochar to agricultural lands as a means of improving soil quality while sequestering carbon (C) in soils; unfortunately, our knowledge of mechanisms that drive soil C and N dynamics following biochar amendments remains unclear.

In 2008, we established a long-term biochar field trial at the Henfaes Research Centre at Bangor University. Replicated field plots received 0, 25, or 50 mg ha^{-1} of char and all plots received a fertilizer application of 120 kg ha^{-1} N and 50 kg ha^{-1} P. In the first year, plots were seeded to fodder maize, while in the second and third years the plots were rotated into a grass-legume mix. Plots have been monitored for extractable inorganic N and P, pH, total soil C and N, crop biomass production and N uptake. The plots were also evaluated for the capacity of biochar amendments to influence pesticide and polyaromatic hydrocarbon sorption, soil N_2O and CH_4 emissions, and short-term soil C dynamics.

In year one of the field trial, surface soil C contents were increased by the addition rate, but there was no significant influence on fodder maize production or N uptake. In year two, grass productivity was significantly increased on biochar plots as was total N uptake. In field and laboratory trials, biochar was found to readily adsorb pesticides applied to soil, reduce their leaching potential, and significantly reduce pesticide decomposition rates in soil. Biochar amendments to soil generally reduce PAH leaching potential and readily adsorb applied PAHs; however, some low temperature biochars were found to increase total soil PAH concentrations. Biochar additions to soil were found to cause a short-term increase in net soil CO_2 efflux, much of this efflux could be attributed to inorganic C trapped within fresh char. Biochar applications to soils containing ^{14}C labelled humic materials appeared to repress the decomposition of resident humic materials. Ongoing and future biochar studies at Bangor University include the recent establishment of a biochar-poplar plantation, mine reclamation studies, influence of biochar on rhizosphere C dynamics, and the impact of biochar on the behaviour of pre-emergent herbicides.

Acknowledgements: Wales Climate Centre, SEREN Network, KESS

Oral Presentation

Biochar and the nitrogen cycle

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Abstract

One of the gaps in biochar research is the understanding of biochar's short and longer term interactions with the nitrogen cycle, which will inevitably affect crop yields. Some potential effects of biochar on the N-cycle are linked with 1) mineralization of soil organic matter, 2) abiotic N-immobilization due to biochar's charge and high surface area and 3) biotic N-immobilization during respiration of the labile carbon fraction. In the longer term, as biochar ages and its structural characteristics change, it will affect the nitrogen cycle differently. For example, the fertilizer use efficiency could increase if the immobilized nitrogen can be released again.

Therefore, the objective of this study was 1) to investigate the effect of biochar on the availability of mineral nitrogen in the short term and 2) to get detailed insight into the effect of biochar on soil nitrogen dynamics.

For the first objective, a nitrogen mineralization experiment was conducted in which soil was mixed with six different biochar types produced at the University of Edinburgh from pine and willow at three temperatures (450°C, 550°C and 650°C). Three fertilizer doses were added (0, 50 and 150 kg N ha^{-1}). These mixtures were incubated in PVC tubes during 4 weeks. Generally, biochar addition caused net immobilization of mineral nitrogen in the short term. In a pot trial conducted with these biochars, a lower nitrogen uptake by radish and spring barley growing on biochar amended soils as compared with a control treatment was observed. However, these experiments do not explain the mechanisms behind the net nitrogen immobilization. Therefore, to reach the second objective, a ^{15}N tracing experiment was performed. ^{15}N labelled nitrogen was added to soil mixed with two silage maize biochars produced at 350°C and 550°C. Soil extractions were carried out 0.25, 2, 4, 24, 72 and 168 h after fertilizer application and extracts were analyzed for concentrations of NH_4^+ and NO_3^- and their respective ^{15}N contents. As expected, net immobilization of mineral nitrogen in biochar-enriched soil was also observed. Preliminary results indicate that biochar addition stimulates total gross mineralization and nitrification rates after label addition. For a more in depth insight in the effect of biochar on the different processes of the nitrogen cycle, the results from this experiment are used to quantify simultaneously occurring gross N transformation rates using a numerical ^{15}N-tracing model.

Acknowledgements: This work is financially supported by the Interreg IVB North Sea Region project 'Biochar: climate saving soils' and the Ghent University Multidisciplinary Research Partnership 'Biotechnology for a sustainable economy'.

Oral Presentation

Priming effects following incorporation of biochar into soils and the mechanisms involved

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Abstract

Our main aim was to determine the magnitude of the priming effect, i.e. short-term changes in the rate (negative or positive) of mineralisation of native soil organic carbon (C), following addition of two biochars to soils of low and high pH. A secondary aim was to investigate the potential mechanisms of priming effects. We used biochars prepared from Miscanthus giganteus, a C4 plant, naturally enriched with ^{13}C. The biochars were produced at two temperatures, 350°C (biochar350) and 700°C (biochar700) and applied to a clay-loam soil at pH 3.7 and 7.6.

After 87 days, biochar350 addition caused priming effects equivalent to 250 and 319 µg CO_2-C g^{-1} soil, respectively. We measured a total soil organic C loss of up to 3.3% following biochar350 addition to the high pH soil after 87 days of incubation. Our demonstration of the early, and rapid, dynamics of positive priming effects following the immediate incorporation of biochar produced at lower temperatures and in soils of both low and high pH indicates that the effects of biochar on the losses of primed C from soil as CO_2-C are significant. However, biochar700 led to much smaller priming effects, thus to increase the pyrolysis temperatures may be a way of decreasing priming effects following biochar incorporation to soil, if desired.

Our understanding of the mechanisms by which biochar affects priming effects still remains unclear. In our study, the observed priming effects could probably be explained by microbial co-metabolism, indicating an increase in microbial biomass. This increase was probably related to the amount of labile C and the surface area of the biochar, which may provide C as substrate and a very favourable habitat for the soil microorganisms and in turn favour increased soil organic C decomposition. Moreover, the observed priming effect may also be controlled by other factors, e.g. soil aeration, moisture, albedo and pH. These potential mechanisms will also be discussed.

Acknowledgements: Jean Devonshire, Wendy Wilmer, Anne Duffey, Guitong Li, Xiaorong Zhao

Oral Presentation

Interpreting the regulations relevant to biochar

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Abstract

This paper presents a survey and discussion of the regulations we perceive as relevant to biochar deployment in six European countries: UK, Netherlands, Belgium Norway, Germany and Sweden. None of the countries surveyed have dedicated biochar regulations, although charcoal is a permitted agricultural amendment in Sweden and Germany, so long as it is not made from waste.

In general, it appears that if the biochar is considered a waste then it is difficult or illegal to put into soil. Biochar can be considered a waste product if it is made from a waste, or if it is made from a process where it is not the desired product and it is intended to be discarded. If biochar is not considered a waste product, then it must meet certain nationally defined requirements to be considered a safe product to add to soils. These requirements are usually in the form of thresholds of potentially toxic organics or elements which should not be exceeded. Thresholds for composts, sewage sludge, digestate, or other organic wastes have been used for the various countries.

Although there is generally agreement over which organic chemicals or elements should be legislated for, there are numerous ways to measure critical limits. For example, limits may be defined as the total amount to be added to a soil per year, the average per year over a longer period, the maximum in any ten year rolling period; or they may be defined as the maximum amount permitted per tonne of soil amendment, per unit of functional material in the soil amendment, or per unit of carbon in the soil.

Biochar takes much longer to decompose and has a tendency to sorb elements and molecules strongly into its structure. This may mean that although the total amount of potentially toxic elements in a soil may be relatively high following biochar addition, the bio-available amount may be relatively low. Whether availability of potentially toxic organics or elements should be taken into consideration and what methods of testing should be performed remains an open research question.

The unique properties of Biochar mean that existing regulation may not be suitable, and that there is scope for an appropriate risk assessment framework to be developed.

Oral Presentation

Biochar is not just biochar: Effects of pyrolysis technology and process parameter settings

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Abstract

Farmers are interested in biochar to enhance soil fertility and thereby crop productivity. From the point of view of the society this practice results in additional climate change mitigation by sequestering carbon in the soil and could therefore potentially be supported by the government or municipality.

Slow and fast pyrolysis technologies and process parameters like retention time and temperature settings influence the biochar quality. Using wheat straw the two technologies were compared (reactor temperature 525°C) producing biochar with each their distinct physicochemical properties measured by carbohydrate contents, particle sizes, pH values, BET surface areas, porosity, and elemental compositions – obviously with different impacts on soil processes. Thus, there is an important linkage between technology and agroecosystems response.

A 65 day incubation study was conducted showing carbon sequestration potentials with 3% and 6% carbon loss from slow and fast pyrolysis biochar, respectively, as compared to 53% when unpyrolysed straw was incubated. The biochar differences could be explained by a labile unpyrolysed carbohydrate fraction in the fast pyrolysis biochar supporting a higher microbial CO_2 respiration. Furthermore, in the treatments with fast pyrolysis biochar soil mineral N immobilization was found contrary to the slow pyrolysis treatment with net N mineralization. Focusing on relations between fast pyrolysis at different reactor temperatures (475-575°C) and the short-term degradability of biochar in soil a 115 day incubation study showed that 3-12% of the added biochar carbon had been emitted as CO_2 – with 90% of this lost within the first 20 days. The pyrolysis temperature influenced the stability of the biochar produced and by raising the temperatures less labile unconverted cellulosic and hemicellulosic fractions were found. These labile carbohydrates are rapidly mineralized and their presence lowers the biochar C sequestration potential. However, on the other hand none or low contents of these fractions reduce the biochar quantity per feedstock unit pyrolysed.

Pyrolysis technology and settings play an important role for the resulting biochar effects in soil and biochar quality needs to be carefully linked to feedstock, actual pyrolysis unit used and aim for specific agroecosystems functions and service after soil application.

Acknowledgements: The studies was funded by the National Globalization Funding from the Technical University of Denmark with support from the Interreg IVB North Sea Region Programme funding the project: Biochar: climate saving soils.

Oral Presentation

Characteristics of rice straw biochar influenced by pyrolysis temperature and residence time

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Abstract

Large quantities of rice straw produced in southern China each year are often returned directly to paddy fields. This practice usually results in a significant increase of CH_4 emissions. Conversion of rice straw to biochar prior to its returning to rice paddy fields can reduce the production of CH_4. Previous studies show that pyrolysis conditions can influence biochar characteristics. However, there is limited information available on the relationship between pyrolysis conditions and properties of rice straw biochar.

In this study, rice straw biochar produced at five temperatures (ranged from 300 to 700°C) and four residence times (1, 2, 3, 5 hours) were characterized using a suite of analytical techniques, including chemical tests, proximate and elemental analyses, BET specific surface area, X-ray diffraction (XRD), and Fourier transform infrared (FTIR) spectroscopy.

All the different rice straw biochars had high alkalinity and cation exchange capacities, and concentrations of available phosphorus and exchangeable cations, indicating that they can be used as a liming material and soil amendment. Biochar yield, contents of H and O, and atomic H:C ratio decreased with increasing pyrolysis temperature, whereas biochar C content increased with temperature. FTIR spectra showed that higher pyrolysis temperature can promote the occurrence of dehydration reactions. An increased condensation was observed at ≥600°C. The XRD data demonstrated that turbostratic crystallities were evolved at 400°C and biochars consisting of turbostratic crystallities were different from highly ordered graphite. Our results showed that pyrolysis temperature had a greater influence than the residence time on the properties of rice straw biochar.

Acknowledgements: This research was supported by the National Natural Science Foundation of China (40873059) and National Science Foundation of Zhejiang Province, China (R5100044)

Oral Presentation

One step forward to identify chars for beneficial soil use: Combining physico-chemical and biological test procedures (Pyreg project)

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Abstract

Biochar use in soils, i.e. the idea of applying biogenic black carbon to soil that emerged recently from Terra Preta research, has shown positive effects on plant growth, nutrient availability and assimilation and plant-soil water relations. At the same time, biochar has been shown to reduce unfavorable greenhouse gas emissions from agriculturally used soils and could, due to its recalcitrance, be an important tool for global climate change mitigation. Nevertheless, not all biochar is equal, and clear definitions depending on its properties are still underway. To take a step forward towards biochar characterization, we defined some desirable properties of biochar such as recalcitrance in soil, a large inner surface, and as low amounts of harmful substances as possible. Therefore, we analyzed black carbon, BET surface area, elemental composition and polycyclic aromatic hydrocarbon (PAH) contents of a variety of charred material, ranging from biochar from different production processes to hydrochar.

Our results showed that the production process significantly influences biochar as well as hydrochar properties. Furthermore, the parameters analyzed are suitable to reveal differences of biochar/hydrochar varieties. Therefore, based on our results, we propose to use an H:C ratio <0.4, an O:C ratio of <0.6, black carbon contents of >15% C, a surface area >100 m^2 and PAH amounts lower than soil background values to define biochar for soil amendment. Some of the characterized biochars were used to perform a series of quick biotoxicity tests such as the cress germination test for phytotoxic gas emissions, the earthworm avoidance test , the barley germination and growth test and the salad germination test. The biological quick-tests demonstrated that the parameters favorable for soil application were also favorable for plants and soil fauna, whereas a biochar with high PAH contents showed distinct negative effects on plant germination and growth, and was nearly 100% avoided by earthworms.

The proposed combination of physico-chemical and biological characterization may serve as a starting point for the larger goal to identify, and probably clearly define biochars suitable for beneficial soil use.

Acknowledgements: The project was funded by the BMBF (Federal ministry of research and education, Germany)

Oral Presentation

Assessing controls on the hydrologic behavior of biochars

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Abstract

Here we show that biochars produced under varying temperatures from varying feedstocks can have more than ten-fold difference in field capacity and in hydrophobicity when these properties are assessed on the biochar alone (without soil addition). However, the effects of feedstock and pyrolysis temperature are greatly reduced with the addition of soil. This dilution is a function of the interaction between biochar chemical and physical structure and the clay minerals present in amended soils.

We report the hydrophobicity and field capacity of biochar samples prepared from 3 feedstocks at 4 temperatures. We chose apple wood and corn stover as feedstocks representative of potential woody and grass crop biomass, and added a third feedstock (magnolia leaves) rich in plant waxes to explore the controls of feedstock biochemistry on biochar hydrologic properties. We pyrolyzed each feedstock at 300, 400, 500, and 600°C with a temperature ramp rate of 5°C $minute^{-1}$ and a hold time of 4 hours at temperature. We assessed bulk biochar chemistry using solid state ^{13}C nuclear magnetic resonance (NMR) and we assessed the surface chemistry of biochar particles using Fourier-transform infrared spectrometry (FTIR) in attenuated total reflectance (ATM) mode. We measured biochar small pore surface area via N_2 adsorption at 77°K (BET). We measured these properties both before and after treatment with extractants designed to remove nonpolar surface groups (a 2:1 mixture of dichloromethane:methanol).

We found large variation in biochar bulk and surface chemistry in response to variations in feedstock and pyrolysis conditions. However, these variations did not persist in biochar/soil mixtures. We hypothesize this effect results from the ability of clay minerals to fill the interstitial spaces between biochar particles, altering the physical and chemical environment experienced by water molecules.

Acknowledgements: We acknowledge support from NSF EAR-0911685, NSF EEC-064742, and DOE SUN grant DE-FG36-08GO88073. We appreciated the help of Krystle Hodge in generating elemental analysis data.

Oral Presentation

Can greenhouse gas fluxes (CO_2, N_2O, CH_4) be stimulated by biochar and hydrochar amendment?

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Abstract

So far, biochar has often been reported to reduce N_2O emissions; however, biochars were mostly fresh, and studies short-term. Thus we focused on situations where in particular larger N_2O emissions may result from biochar or hydrochar amended soils. (The brown-coal-like substance generated via hydrothermal carbonization is termed "hydrochar" here.)

In a first experiment (greenhouse), ryegrass was grown in sandy loam mixed with equal amounts of peanut hull biochar, compost, biochar + compost, double-compost or no addition (control); wetting-drying cycles and N-fertilization were applied. Biochar with or without compost significantly reduced N_2O emissions and did not change the CO_2 emission or CH_4 uptake.

In a second experiment (lab), zero (control) or 8% (w/w) of four biochars (BC) and two hydrochars (HC) was mixed into a soil and incubated at 65% water-holding capacity for 140 days. Treatments included simulated ploughing and N-fertilization. Biochar reduced N_2O emissions on average by >60% while hydrochar addition reduced N_2O emissions only initially. After N-fertilization, N_2O increased significantly, resulting in 302% (HC-beet) and 155% (HC-bark) of the control emissions, respectively. Large HC-associated CO_2 emissions suggested that microbial activity was stimulated and that hydrochar is (at least initially) less stable than biochar.

In a third experiment (lab), a long-term incubation over 1.5 years at 70-80% WHC with stepwise increasing biochar amendment did not alter N_2O emissions. However, N_2O emissions increased strongly after N fertilization with increasing biochar amounts. This potential danger in long-term biochar use will be discussed.

In a forth experiment (lab and field), the same carbon amounts were applied as feedstock, biochar or hydrochar (Miscanthus; plus no-amendment control) together with swine manure and the CO_2, N_2O and CH_4 fluxes were measured; the first results will be discussed.

In conclusion, biochar reduced N_2O emissions under a broad range of conditions and has the potential to improve the GHG-to-yield ratio. However, the results of hydrochar and of the long-term biochar incubations suggest that the risk of increased N_2O emissions with char use must be carefully evaluated and that a reduction effect is not granted.

Acknowledgements: We gratefully acknowledge the financial support of the Hessian Agency for the Environment and Geology and the technical assistance of Nicol Strasilla.

Oral Presentation

The effect of biochar and stover amendments on the soil physical environment and plant growth

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Abstract

This paper reports part of an on-going investigation into the effects of biochar on soil physical properties in Ghana. Biochar from sawdust (B1) and maize stover (B2) were prepared using a muffle furnace at The Reading University. The effect of local charcoal (B3) from Ghana was also studied. The three types of biochar were applied to three soil types from Ghana, at 5, 10 and 15 t ha^{-1} to determine water holding capacity (WHC) and moisture retention characteristics.

Pyrolysis results indicated that low heating rates (LHR) delays alteration of original biomass structure, and thus slower formation and escape of pyrolysis vapours, or slower physical mass transfer. However, depending on length of exposure to the heat source, biochar yield may be more than or same at LHR as at HHR. There was not enough evidence to suggest that LHR favours carbon (C) recovery despite a higher percentage of C retained in the sample after charring at LHR than at HHR. Decomposition properties differed from B1 and B2, which resulted higher biochar yield of the later than the former in terms of percent by weight. This was because of the higher total mineral content (dominated by K, Mg, Fe and Al). Chemical analysis revealed that different elements behaved differently or similarly at a given particle size of the B1. After charring, material becomes richer in C-content, but N decreases at certain point, thus increasing the C:N ratios. The pH of soils amended with biochar generally increased, magnitude depends on soil and biochar material. WHC was increased when biochar was applied at all rates compared to zero application. However, there wasn't much difference in effect on WHC between the rates. It is suggested that water repellency of the biochar partly explains this behaviour. Improving WHC by biochar application was more effective in sandiest-textured soils.

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Oral Presentation

The beginnings of a biochar integrated assessment model (BIAM)

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Abstract

UKBRC is developing an integrated assessment framework for biochar and other uses of biomass resources. Drawing upon social science, techno-economic modelling, life cycle assessment, spatial analysis techniques and scenario generation, a loose framework has been created to assess the viability and likely impacts of widespread biochar use and deployment, and may later be expanded to include the impacts of other advanced uses of biomass.

Following establishment of the conceptual foundations, the first step is to assess the feedstock resources available. We present a summary of all likely biomass feedstocks for pyrolysis such as bioenergy crops (miscanthus, switchgrass, short rotation coppice), agroforestry residues (sawmill, forestry and crop residues) or biodegradable municipal or industrial waste (i.e. sewage or paper sludge, cardboard, garden and green, food, or wood waste). Qualitative multi-criteria assessment on available quantity, competition with other uses, locations and constraints, viability for pyrolysis, and implications for quality of biochar produced will be made. For selected feedstocks, prospective estimates for carbon abatement, energy generation, cost of processing and location of facilities will be given. An example case investigating the spatial configuration of Pyrolysis-biochar system (PBS) will be discussed. This includes identification of the biomass source, the biochar sinks and to infer where pyrolysis units might be appropriately located in Scotland. A spatial multi-criteria suitability analysis (alternatively known as GIS-Multi-Criteria Decision Analysis, or GIS-MCDA) will be used to weigh up the various needs and constraints upon different locations.

Poster Presentations – Towards Deployment & Commercialisation

Poster Presentation

Pyrolysis and heat transfer: A pragmatic engineering approach

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Abstract

Pyrolysis, as many other thermo-chemical processes, intrinsically relies on heat transfer. Additionally pyrolysis is constrained by the fundamental prerequisite of occurring in the absence of oxygen, consequently the number of engineering solutions available to heat up and maintain the feedstock at the designed temperature is significantly limited.

Direct heating not being a viable option, alternative heating strategies range from straightforward external indirect heating, where the reactor walls are externally heated, to more complex indirect heat transfer schemes, designed to effectively convey the thermal energy required for pyrolysis from an external heating system into the reactor.

In the last decade Sea Marconi developed and tested, together with research partners, a proprietary “intermediate pyrolysis” system known as Haloclean® (Patent EP1217318), initially designed to process electronic waste and subsequently applied to the conversion of biomass into intermediate energy carriers. The Haloclean® system was essentially a gas tight rotary drum enclosing a coaxial auger to convey the feedstock along the reactor. Process energy was provided through externally heated and continuously recirculated “heat carriers” (steel spheres).

This technology was extensively tested from lab scale to industrial scale with good results from the process side, but revealing major design issues from the engineering perspective. Such technical issues were deeply investigated together with other engineering solutions claimed from alternative state-of-the-art technologies, leading to a complete reengineering of the original Sea Marconi design.

The new design still maintains the underlying principles of the original Haloclean® reactor, together with its flexibility in terms of feedstock and process conditions (temperature, residence time). On the other hand it implements engineering solutions engineered to intrinsically prevent mechanical jams and to allow for a more effective heat transfer and homogeneous process conditions. Finally the new technology is modular, i.e. based on a fundamental “building block” that can be replicated in parallel or series, depending on the application.

Even though the new Haloclean® technology was primarily designed as a three stage gasification system, i.e. where pyrolysis, oxidation and reduction occur in distinct interconnected reactors, nevertheless the modular design allows the implementation of a pyrolysis system, if requested by the specific application, such as biochar production.

Poster Presentation

Where there's muck, there's brass: The economics of biochar

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Abstract

Little is known about the costs of producing biochar and this study attempts to provide a 'break-even selling point' for biochar in the UK. A high degree of uncertainty surrounds the indirect impacts of biochar in soils (effects on productivity, water retention, pollution reduction, etc.) which precludes precise valuation of costs and benefits. A more modest approach is to attempt to calculate the biochar production cost, taking account of the full value-chain from feedstock cultivation to biochar application to soils including capital and operational costs, transport, storage and feedstock preparation costs; including revenues from electricity generation and waste management. This does not by-pass uncertainty, but limits it to some extent.

Three indicative sizes of pyrolysis technology were modelled: small (< 2000 t yr^{-1} feedstock), medium (< 16,000 t yr^{-1}) and large (< 185,000 t yr^{-1}). The costs were provided for a medium sized demonstration plant, and estimated for the small- and large-scale unit by comparison with the demonstration unit as well as existing plants. Three scenarios for the UK context were developed to estimate the potential biomass resource available for the production of biochar: A lower, higher and high scenario are presented. A distinction between virgin (no chemical or biological amendment) and non-virgin (all other) bio-feedstocks is introduced; this is important with respect to regulatory and risk assessment issues for biochar. Economies of scale is an important factor in reducing capital and operational costs of production in larger units. The costs of producing biochar in the UK context range from between -£148 to £389 per tonne delivered and spread on fields - a provisional carbon abatement cost of -£144 tCO_2 per t to £208 tCO_2 per t for the higher resource scenario. (A negative cost indicates a profit-making activity). A marginal carbon abatement cost can be estimated by plotting biochar production levels from the three production units against costs, though the latter are static with respect to feedstock supply.

The greatest expense incurred in pyrolysis-biochar systems are the capital costs, feedstock costs and operational costs, while the largest sources of revenue are from electricity generation and from received gate-fee for wastes. Biochar from imported wood chips, miscanthus and short rotation forestry are among the most expensive types, while straw-based biochar is close behind; wood waste and greenwaste-derived biochar are much cheaper (with a carbon abatement cost from (-£144 tCO_2^{-1} to £19 tCO_2^{-1}). The attractiveness of wastes as a feedstock requires concerted effort on the risk assessment and appropriate regulation of the resultant biochar; it also assumes continued gate-fees and landfill tax at current levels.

Acknowledgements: Funding from the EPSRC and DEFRA is gratefully acknowledged.

Poster Presentation

Small-scale continuous pyrolysis apparatus: capabilities and initial results

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Abstract

This poster describes apparatus forming Stage II in the UKBRC equipment strategy. The current configuration and capabilities of the unit are described together with developments planned to increase its potential. A summary is given of materials processed and initial results. Current and future research objectives for the unit are outlined.

Poster Presentations – Biochar Systems & Other

Poster Presentation

Detoxification of the residue of squeezing jatropha oil with carbonisation

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Abstract

Jatropha (Jatropha curcas L.) is an energy plant that accumulates oil in the seed. Growth rate is higher among the C3 tropical tree plants. However, the seed includes phorbol ester, toxic to humans and domestic animals. The oil derived from Jatropha seeds is not suitable for food. Therefore, Jatropha oil is utilized for bio-diesel fuel (BDF) currently, as an alternative product to diesel. The residue of squeezing oil (seed cake), stem, leaves, and husk also contain phorbol ester. By-product should be used as biomass resources for the Jatropha farming system. However, those biomasses are risky to use without detoxification for the grower and worker. These confirming safe conditions are necessary to maintain the sustainable agriculture.

In this study, Jatropha was carbonized in order that detoxifying phorbol ester. Seed cake, stem, leaf and husk were carbonized by the muffle heating for 1 h at 500°C under N_2 purge conditions. Dry mater of Jatropha plant parts and its charcoals were analyzed for phorbol ester content with HPLC. Seed cake contained 739.3 ng g^{-1} DM of phorbol ester and decreased until 53.3 ng g^{-1} DM by the carbonization. We succeeded in the reduction of more than 90% by the carbonization. Stem, husk and those charcoal were analyzed phorbol ester content, it decrement as the seed cake. It was confirmed that Jatropha charcoal was safe for humans and domestic animals. In addition, Jatropha charcoal had some elements efficient for plant growth. Seed cake charcoal included a lot of P and N, husk was higher K content. As leaf and stem included higher Mg, Ca, S, and Mn content, the charcoal can be used to these deficiencies.

In conclusion, carbonizing is one of the methods with easy and less cost for detoxification of phorbol ester. Charcoal should be utilized as for soil conditioner and fertilizer to continue the sustainable agriculture producing Jatropha BDF. BDF production from Jatropha curcas is important as a carbon neutral system, moreover carbonization will contribute to reduce CO_2 in the air.

Poster Presentation

Pyrolysis products yields and thermogravimetric analysis of biochar produced from hardwood and softwood at different temperatures

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Abstract

Pyrolysis technology can be used for producing biochar and bio-oil simultaneously, as an effective and sustainable mean to produce a carbon rich soil amendment and renewable bioenergy. However, pyrolysis products yields are strongly affected by the feedstock and the pyrolysis variables, especially the final temperature. This study was carried out to evaluate the effect of pyrolysis final temperature on solid (biochar), liquid (bio-oil) and gas yields for different sources of biomass and the effect of pyrolysis final temperature on the thermal stability of the solid products (biochar).

For this experiment, two species of hardwood (*Eucalyptus dunnii* and *Eucalyptus urophylla*) and two species of softwood (*Pinus caribbea* and *Pinus taeda*) with particle size between 0.5 and 2.0 mm were pyrolysed with a heating rate of 10°C min^{-1} at three different temperatures (350, 450 and 550°C) for 60 minutes in a muffle furnace adapted with Liebig condensers to collect the condensable gases in order to obtain the bio-oil. The thermogravimetric analysis (TGA) was performed using a DTG-60H Shimadzu equipment with a heating rate of 10°C min^{-1}, up to 600°C, under a nitrogen atmosphere (20 mL min^{-1} gas flow).

As the temperature increased, the biochar yield decreased and the bio-oil yield increased. However, as the temperature increased, the biochar thermal stability increased as well, indicating that these materials would be more resistant to degradation when applied into soil.

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Poster Presentation

Biochar's potential to sequester persistent organic pollutants

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Abstract

Persistent Organic Pollutants (POPs) present a globally significant problem in soil and water management due to their recalcitrance, tendency to bio-accumulate and their effects on human health. The carbon rich nature of biochar suggests that it may have strong potential for the long-term sequestration of POPs that could otherwise become mobilised in groundwater and contaminate other areas. Previous research has noted biochar's ability to sequester heavy metals and certain pesticides present in contaminated soils and water.

The present work aims to determine waste feedstock biochar's potential to sequester POPs through a series of sorption experiments and to investigate the capacity for remediating these contaminants within biochar once its potential has been established. Initial experiments will characterise the properties of the biochar being used for experimentation. The sorption capacity of biochar derived from a variety of sources for a range of POPs will be determined. This will underpin work on sorption and desorption of POPs to biochar and remediating POPs within biochar through ozone treatment and fungi inoculation.

Proving biochar's remediation ability would add another facet to the multidisciplinary potential of this substance. In addition to biochar's potential in water and soil management, biochar's capacity for carbon sequestration, both through its production feedstock and its subsequent application, makes it attractive for climate change mitigation. Incorporating its use on a worldwide scale may prove an affordable way to improve food security as well as reduce the agricultural footprint by enhancing soil fertility and sequestering potential contaminants. With this potential, biochar may become an important tool in achieving the Millennium Development Goals and may also contribute to climate change mitigation targets.

Poster Presentation

Pyrolysis biochar systems for recovering biodegradable materials: A Life cycle carbon assessment

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Abstract

A life cycle assessment (LCA) focused on biochar and bioenergy generation was performed for slow pyrolysis and compared with other thermal treatment configurations (fast pyrolysis and gasification). Ten UK biodegradable wastes or residues were considered as feedstocks in this study. Carbon abatement and electricity production indicators were calculated.

Slow pyrolysis systems offer the best performance in terms of net carbon (equivalent) emissions, with results varying from -0.13 to -1.08 t CO_2 net t^{-1} feedstock treated. On the other hand, gasification achieves the best electricity generation outputs, with results varying around 1.3 MWh net t^{-1} feedstock. Moreover, selection of a common waste treatment practice as the reference scenario in an LCA has to be undertaken carefully as this will have a key influence upon the carbon abatement performance of pyrolysis or gasification biochar systems (PBS/GBS).

Results suggest that PBS could produce important environmental benefits in terms of carbon abatement, but several potential pollution issues arising from contaminants in the biochar have to be addressed before biochar and bioenergy production from biodegradable waste can become common practice.

Poster Presentation - Absent

Using biochar to recycle nutrients from human urine back to agriculture

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Abstract

Biochar has several application areas within agriculture and environmental management. Waste water filtration is one area being investigated as a means of capturing plant nutrients for their re-use in agriculture. Human urine is a nutrient rich waste stream which has been calculated to be the source of 90% of N, 60% of P, and 70% of K found in wastewater. In Norway, however, even source-separated, non-pathogenic urine is not permitted to be applied directly to agricultural fields. Our experiment hypothesized that biochar could be used for sorption of nutrients from urine, and be later added to soils, thereby allowing for the recycling of nutrients without direct application of urine. Biochar (500 ml) derived from Miscanthus x giganteous, was mixed with 500 ml undiluted urine in closed 1L plastic bottles, and machine shaken 0.5 hr, 3 hr, and 72 hr. The results were compared with wheat straw biochar (72 hr), a commercially available activated carbon (72 hr), and the original nutrient concentrations in both the urine and the biochar. Nutrient sorption from urine to biochar was rapid, the greatest amounts of N, P and K taken up within 0.5 hr of shaking. Concentrations of N, P, and K in the urine saturated biochar increased by 1380%, 227% and 50% respectively in comparison to the background biochar concentrations. An increase of nutrient concentrations in the biochar was not always followed by an inverse decrease in the urine. In fact, P and K showed a trend of increasing concentrations in urine over time treated by biochar. The high content of ash (26%) in the miscanthus biochar and its effect on sorption properties was the suspected cause of this increase. Therefore, washed biochar with reduced ash content (19.6%) and activated carbon with low ash content (9.18%) were used in a second set of experiments to evaluate the effect of ash content on sorption efficiency. The fertilizer value of miscanthus biochar can be increased by mixing with urine, but the biochar did not act to significantly reduce the nutrient loadings in the urine itself.

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Poster Presentation

Effects of biochar application to goat manure on irrigated radish in Northern Oman

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Abstract

Year-round high temperatures promote microbial turnover of soil organic matter in traditional irrigated agricultural systems in Oman leading to nutrient and carbon (C) losses through leaching and gaseous emissions.

This study was aimed at examining a putative yield increasing effect of biochar added to manure (i) by adding at 3% to feed before ingestion and (ii) by mixing with manure before application to radish (*Raphanus sativus* L.) in a pot and in a field experiment. At a nitrogen (N) level of 135 kg ha^{-1}, both amended manures were compared to an unamended manure treatment and an equivalent application of mineral fertilizers.

Compared to the unamended manure, biochar applied directly to manure increased radish shoot dry matter by 15-49%, root dry matter by 16-1% and the shoot/root ratio by 1-49%. Manure amended with biochar via the feeding pathway, however, led to increases of 8% of shoot dry weight and 11% of root dry weight in the pot experiment whereas this could not be observed in the field experiment. Further research is under way to examine differences in volatilization and leaching losses as possible causes for the observed effects.

Poster Presentation

Developing Biochar Engineering Technology for Low Carbon Agriculture in China

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Abstract

For meeting the demand of reducing C emission intensity by 40-45% per unit of GDP, low carbon agriculture has been received much attention for reducing GHG emissions from agriculture. Totally, 0.7 Gt of crop straw is produced in croplands annually in China. Biomass engineering technology has been given great attention in China for the last 5 years. By 2010, new and high technology for continuous conversion is succeed from crop straw to new energy and biochar as well as biogases by vertical kiln devices equipped with totally 15 techniques and devices patented at Sanli Biomass Engineering Corporation, Hennan, China. The large production system can treat, per hour, 1 metric ton of straw and produce biogas of 800 cubic metres for gas electricity of 600 kw, 300 kg of biochar and 50 kg of biofuel. By the end of 2009, a small scale carbonizing pool system has been developed for local use treating, per hour, 30 kg of straw and producing 10 cubic meters of biogas, 10-12 kg of biochar. With this system, 30 farmer households could be facilitated with biogas for heating and cooking. In 2010 is available a total straw treatment capacity of 400,000 metric tons per year, producing 240,000 tons of char based fertilizer (CBF, char at 45%, urea at 45% and biammonium phosphate at 10%). In March 2010, a new system of biochar production from municipal biowaste using pyrolysis with a rotary kiln is available at Shanghai Zhangkeanda Company/ Runye Environmental Technology Company, Shanghai, China. Char-base fertilizers and soil amendment products are being developed and applied to cropland as new agro-chemical products. For developing biochar-based low carbon agriculture, a network of field experiments at 8 sites has been established across China, which covers rice paddies, wheat and corn croplands, vegetable lands and fruit gardens as well as herbs fields. Changes in crop yield and greenhouse gas emissions with biochar application are monitored using closed chamber systems. One year's results have shown already that application of biochar could enhance soil C, increase crop productivity and reduce N use in croplands as well as reducing heavy metal uptake by crops.

Poster Presentation

Too many cooks spoil the broth? Biochar and cook stoves

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Abstract

It has been proposed that micro-gasification cook stoves are a potential technology for producing biochar. There are two main designs that can be used: the single-chamber top-lit updraft (TLUD) (autothermal method) and the double-chamber design in which biomass is placed in the outer fuel chamber (allothermal method). The single-chamber stove is the most frequent design (e.g. Champion, Sampada, Everythingnice, etc.). The Anila stove is one of the better known two-chamber designs. Tests have been conducted in two countries (India, Cambodia) on: a) User-reactions to the use of such stoves compared to traditional stoves; and b) user-reactions to the use of such stoves for producing biochar. It was found that micro-gasification stoves are not as highly rated in user-tests as might have been expected given their apparent advantages compared to traditional stoves (e.g. with respect to reduced smoke and efficiency). This may be due to lack of familiarisation with the stoves over the three-week trial period. It is also due to the disadvantages of such stoves - the disadvantages of a batch stove compared to a rocket-type stove where fuel can be fed in from the bottom; and the problem of turning-up or down the heat to adjust the heat intensity to the demand.

We found that users were somewhat puzzled and / or negative regarding the production of biochar for soil application. There were three main reasons. 1. The difficulty in removing char from the stoves after cooking (requiring quenching with water, possibly causing corrosion of the stove; hot handling of char was associated with safety issues). 2. The competing uses of the biomass and 3) competing users of the char (mostly as a fuel). Biochar production seemed an unnecessary waste of fuel to many respondents, as the potential benefits of biochar in soil could not be demonstrated in the short time period of the trial; and the carbon storage aspects did not 'sell' the concept. (May be if carbon financing could be made to work, and if obvious and significant benefits to food production could be demonstrated, it would be a different story). We conclude that biochar-producing stoves, at least with current designs, may be over-complicating an already rather confused and complex 'improved' cookstoves landscape. There is a pressing need for better understanding of the 'cook stove user space'. Biochar production could be one function of a stove but this requires much more extensive demonstration and design work, in particular that there is a demand for this from users and that it does not compromise other required design features of micro-gasification stoves.

Acknowledgements: We acknowledge funding from the IDRC-CRDI and support from the AIT.

Poster Presentation

Life cycle analysis and economic assessment of pyrolysis biochar systems using residues from orchard management in the UK and Republic of South Africa

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Abstract

Pyrolysis biochar systems (PBS) have the potential to address the pressing global concerns of soil degradation and climate change. To ensure that the manufacture and application of biochar has beneficial environmental impacts, careful consideration of the full life cycle is required.

A life cycle analysis (LCA) model was developed to assess various scenarios for the greenhouse gas (GHG) and economic balances of a PBS using woody residue feedstocks in the Republic South Africa (RSA) and the UK based on case study field data from orchards. The GHG balance for all scenarios demonstrate a highly beneficial result with a minimum avoided emissions' balance of 1.7 t CO_2e and a maximum of 7.0 t CO_2e per tonne of biochar produced. The difference between the two extremes is explained mostly by the inclusion of assumptions about avoided N_2O and CH_4 emissions from composting and decomposition in the upper figure. The lower figure excluded such assumptions as determination of the level of anaerobic decomposition in the baseline case requires further research.

According to the model presented, PBS is not economically viable as there is no market, either for sale of carbon credits or for biochar as an agricultural amendment. Nonetheless, biochar may generate profits of up to £4.8 k per hectare in RSA, and £2.8 k per hectare in the UK if yield assumptions can be demonstrated and a carbon market established, demonstrating the potential for biochar use with high value crops. Due to the generally poorer soil conditions, the greater economic returns and the potential development benefits that may result, biochar production and application in the context of developing countries makes for the optimum approach in the near-future.

Acknowledgements: Data supplied by Colors Fruit, supplier to Marks & Spencer

Poster Presentation

New application of bagasse charcoal for energy absorbing materials

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Abstract

Bagasse is produced as a by-product in sugar mills in tropical and subtropical regions all over the world. Almost of the bagasse is now consumed as the fuel for boilers in the sugar mills. We think bagasse is the most useful material among the many kinds of biomass.

So, we started the research on the application of industrial field using bagasse. We can easily obtain the bagasse charcoal by heating and carbonizing the raw bagasse at 500-600°C under N_2 gas conditions. The obtained bagasse charcoal has many characteristics such as a large amount of porosity with higher than 90vol%, higher specific surface area larger than 500 $m^2 g^{-1}$, and many micro pores less than 10 nm, etc.

We are now studying the industrial applications using the above mentioned unique bagasse charcoal. One of them is the activated carbon use and another one is the heat absorbent material use presented in this conference. A characteristic of the bagasse charcoal is to be dispersed perfectly into water due to its unique structure and properties mentioned above. This is an extremely important and original property which can not be observed in case of any carbon black particles. Bagasse charcoal particles with diameter less than 150 μm were obtained by sieving after milling and were dispersed in water by the content of 0, 0.1, 0.3, 0.5 and 1wt%. The absorbing ability of light or heat by bagasse charcoal was estimated by observing the transparency of each suspended water sample at the range from UV to IR light.

As the result, it can be revealed that only 30% of light can transmit through 0.3w% suspended water and light can be perfectly absorbed at contents larger than 0.5w%. Therefore it can be recognized that the bagasse charcoal dispersed in water is very useful material for the absorption and accumulation of solar light as well as heat.

We are studying the new type of solar energy collecting system using this new solar light absorbing materials and the most effective home and local community energy systems. Goal of our project is to serve at least the half of the energy consumption in the public welfare section by an energy system using this solar heat system.

Poster Presentation - Absent

Biochar production and the empowerment of women in developing countries

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Abstract

The World Health Organization (WHO) estimates that 1.5 million people, mostly women and children, die annually from cooking fumes in developing countries. Fuels for cooking are usually obtained by women in the form of wood or charcoal and not always combusted efficiently. Based on the current situation, it is obvious that developing countries will need more efficient energy practices to address the demand for cooking as well as to benefit women and children.

This paper presents a framework for bottom-up societal change with women acting as key stakeholders using Improved Cooking Stove (ICS) methods as a source of renewable cooking energy. The ICS needs less fuel compared to conventional stoves and byproducts from agriculture or forestry can substitute large amounts of wood and charcoal required for conventional stoves. While the stoves are used to cook they can also provide biochar produced during the biomass pyrolysis. The biochar can provide a secondary income from sales to farmers who can mix it with cow dung and other types of natural manure and applied to the soil as a fertiliser. The amount of biochar produced is sufficient for small scale farmers. It will help to mitigate the use of expensive artificial fertilizers and climate change. The proposed framework is based on a closed loop of community-driven development where production, advertisement and selling of the stoves is done by local females, uniting the community for societal change by spreading ICS in the village. As entrepreneurs, women can obtain higher status and earn revenue by selling the stove and the biochar residue. Other stakeholders play supporting roles by providing micro-finances, technical solutions and awareness. The use of ICS, fueled by locally available by-products, results in symbiotic economic progress and environmental stewardship. There are multiple benefits besides addressing the scarcity of cooking energy and poor indoor air quality. Such as, the strengthening of local economies and the empowerment of women, while enhancing climate change mitigation and production of biochar.

Poster Presentation

Pyrolysed digestate = Straw turned into gold?

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Abstract

Scotland's anaerobic digestion (AD) infrastructure is expanding rapidly in an effort to divert food waste from landfill while generating renewable energy. As an inevitable consequence the production of digestates, the non-gaseous residues of the AD process, is also increased. Markets for the solid digestate fraction (called "fibre") as soil amendments are being sought, so far with little success. Much of Scotland's agricultural land lies close to settlements and within Nitrate Vulnerable Zones (NVZs). Barriers to the uptake of digestate fibre by Scottish agriculture include odour, potential pathogen load and high concentrations of available nitrogen. Pyrolysing the fibre could address these issues while also increasing liming value and nutrient retention. Since the fibre would need to be dried prior to pyrolysis, the process would be costly and justified only in situations where it would add significant value for a particular application.

This study investigated which of the planned and operational AD sites in Scotland could have access to high-value markets for biochar from fibre. In a GIS-based suitability analysis, factors likely to affect a land manager's choice of soil amendments were combined to estimate overall suitability of land for biochar application. Suitability criteria were selected, weighted and scored based on the assumption that biochar would be advantageous over digestate fibre:

a) in high value crop systems,
b) within NVZs,
c) on coarse-textured soils,
d) in areas where productivity is going to be significantly impacted by drought in coming decades,
e) on land where high-value crops can be grown (prime agricultural land).

Assuming that biochar would be applied to soil by incorporation, sealed, stony and lithic soils, as well as those high in organic carbon (>6%wt) were excluded from the potential landbank.

Results of the spatial analyses suggest that suitability of land for biochar application varies considerably between AD sites. Only few AD sites in Scotland have immediate access (40 km) to high-value agricultural markets for biochar. Since the effects of biochar and fibre on soils have not yet been systematically compared, it is often hard to gauge potential advantages of biochar as a soil improver. Future research efforts therefore need to focus on characterising both substrates and assessing their functional effects on local soils.

Poster Presentation

Adsorption and desorption of natural and synthetic hormones using biochar

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Abstract

Natural steroidal oestrogens are hormones produced by the endocrine systems of humans and livestock that elicit specific effects on endocrine activity at very low concentration. Synthetic oestrogens are structurally similar, man-made pharmaceuticals designed to mimic natural hormones. Both forms of oestrogen are organic, persistent and regularly detected as pollutants of surface waters and sewage sludges due to incomplete removal during water and sewage treatment processes.

Numerous studies have shown oestrogens in the environment to be potent endocrine disrupters, unintentionally disturbing the biological development/functioning of many species (eg causing feminisation). As global water demand necessitates reuse of wastewaters and food scarcity encourages use of manures/sewage sludges as fertilisers, oestrogens - given their range of effects at low-dose - pose a threat to all consumers.

Biochar is a form of charcoal created through pyrolysis or gasification of carbon-based biomass, predominantly of plant origin. The resultant carbon-rich product can potentially enrich soils by helping to retain essential nutrients, whilst simultaneously storing carbon.

This research seeks to determine whether biochar may act as a suitable, low-tech, low-cost medium to sequester environmental oestrogens from wastewaters and soils. Natural (17b-oestradiol, oestrone) and synthetic (17a-ethinyloestradiol, mestranol) oestrogens have been selected for study.

Poster Presentation

Very long-term sequestration of solid phase carbon: Geo-engineering facilities for biochar storage

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Abstract

Biochar is a breakthrough technology allowing for efficient and cheap sequestration of atmospheric carbon in the solid phase. In comparison to gas-phase storage of sequestrated carbon, biochar storage offers the additional advantages of world distributed production, and cheap, efficient, and stable transport and storage. Large storage built-facilitates could be designed for geologic, marine or surface sites and would represent a geo-engineering application with a low level of geo-intervention.

However, the major menace to the stability of biochar in the very long term (ie, millennia) is smoldering fire. Biochar, as all carbon-rich solids, is known to be a reactive material and prone to self-heating. Self-heating is the natural process of spontaneous oxidation reactions taking place at ambient temperature. Initially small amounts of heat are released and accumulate during longer times and the process self-accelerates, leading to a smoldering fire without external intervention. This would lead to the accidental release to the atmosphere of the sequestrated carbon.

The methods for designing stable very-long-term storage facilities use technological concepts borrowed from infrastructure protection such as size limits, compartmentation, sealing, inertation, cooling and wetting. This talk presents the science and technology to understand the problem and allowing for the design of economic and efficient facilities to store sequestrated carbon in large volumes for very long times.

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Poster Presentation - Absent

Green roof substrates: A potential application of biochar?

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Abstract

A WRAP funded project examined the use of BSI PAS 100 compost in green roof substrates. Biochar was included in some of the mixes to examine whether it offered the opportunity to increase the amount of green compost included in the substrate. The claimed properties of biochar in soil, i.e. improved water and nutrient retention, as well as its light weight, may be beneficial in green compost based green roof substrates.

Model green roofs, containing five substrate mixes using different proportions of PAS100 compost, biochar and crushed brick, were planted with five calcareous grassland plants and sited outside. The biochar used was provided by Forest Research. Various plant parameters were recorded at regular intervals and leachate was sampled weekly with nutrient content determined at regular intervals. The experiment ran for 10 months.

No significant effects ($P<0.05$) of biochar inclusion were determined in plant height or on mean total leachate volumes recorded through each substrate mix for the duration of the experiment. However, in terms of leachate quality, a significant increase ($P<0.05$) in K concentration in the leachate was determined in the treatments containing biochar. This significant increase ($P<0.05$) due to biochar was also determined in the EC in leachate. No significant effects ($P<0.05$) of biochar were determined in leachate pH, P, Mg or NO_3. Some interesting trends in weekly substrate moisture content were also seen suggesting that the use of biochar may have increased water retention.

Our understanding of biochar continues to progress and further work into the effects of biochar in this application are required.

Acknowledgements: The project was funded (2009-2010) by WRAP (Waste and Resources Action Programme).

Poster Presentation

Characterization of Biochar through Proximate Analysis

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Abstract

Biochar is a solid carbonaceous material derived from thermo-chemical conversion of biomass. Properties of this material will be defined by feedstock (soft/hard wood, grasses, algae, wastes, crop residues, etc.), processes and operating conditions (hydrothermal liquefaction, gasification, slow/fast/flash pyrolysis, etc.) and also, chemical and physical pretreatments of the biomass (torrefaction, moisture and dirt removal, grinding, alkaline/acid pretreatments, etc.). Therefore the great variability would be inherent of biochar thus its difficulties associated with its definition, characterization and application. ASTM standards of Biomass, Coal and Charcoal for thermo-gravimetric analysis' are being developed, and modifications are being studied for the implementation of a biochar proximate analysis standard.

Poster Presentations – Biochar Functions in Soil

Poster Presentation

The effects of biochar on soil physical properties and wheat growth

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Abstract

Biochar has been shown to improve soil quality and crop yields, however less is known about its effects on soil physical properties. This study looks at two important attributes of biochar to agricultural land; its potential ability to improve water retention and crop growth through a short term pot trial using biochar concentrations of 0, 1.5, 2.5 and 5% w/w. X-ray Computed Tomography, used to measure pore size characteristics, showed that pore size was significantly affected by biochar concentration ($P < 0.001$) with increasing biochar decreasing average pore size. Increased biochar concentration also decreased saturated hydraulic conductivity ($P = 0.001$) and soil bulk density ($P = 0.001$). Another important effect of increased biochar was a decrease in soil water repellence ($P = 0.006$). Increased water retention was also observed at low matric potentials when increased biochar was able to retain more water even as the soil dried. In this study the application of biochar had little effect on wheat growth but did improve water retention through a change in soil porosity, pore size, bulk density and wetting ability.

Biochar and rhizosphere nitrate and pH

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Abstract

The rhizosphere is the zone of soil influenced by plant roots. It is a zone of intense activity where several processes occur: Root uptake of nutrients and water; soil-plant-microbial interactions; root exudation and root growth; nutrient cycling, etc. The rhizosphere is regarded as distinct from the bulk soil due to quantifiable differences in soil chemistry (e.g. pH, nutrient ion concentrations) and biology (e.g. microbial diversity and activity). Two approaches are described where biochar-rhizosphere dynamics are being explored.

1. Experiments using a rhizobox approach are being conducted in order to assess biochar interactions within the rhizosphere. The soil used is an agricultural sandy loam soil with low carbon (C) content which would benefit from C remediation. Nitrate was incorporated into soil (18 mg N kg^{-1}) containing 0, 20 or 60 t biochar ha^{-1} (wood-based biochar). Pre-germinated wheat seeds were sown and an extensive root system was allowed to develop. After 3-4 weeks' growth, the wheat seedlings were harvested and soil collected as 'rhizosphere' (R) or 'bulk' (B) soil sub-samples. R and B soils were analysed for pH, NO_3^- and NH_4^+. Roots were washed and root architectural traits were determined. Dried leaves and roots were analysed for total C and N. The main outcome was evidence of a 'localisation' effect of biochar within the rhizosphere, which suggests that nutrients such as nitrate may be conveniently stored within reach of plant roots, thus improving plant nutrient use efficiency. Further rhizobox experiments are being conducted, where the biochar will be modified further to simulate 'weathering'. The manipulated biochar has been characterised and the rhizobox approach will be used to compare nutrient localisation effects between fresh and aged biochar.

2. Another approach is to measure rhizosphere pH or nitrate concentrations using microelectrodes, a technique developed by Tony Miller (John Innes Centre). A preliminary study has sampled the soil pH around biochar particles in close proximity to plant roots (millimetre distances) to gauge the effect of a strongly alkaline material on soil pH dynamics. Further experimentation will help us determine the extent of the influence of the 'biochar-soil interface' on the surrounding soil micro-environment.

Acknowledgements: Mike Duvall, Jason Cook, Dr Tony Miller at John Innes Centre, and Rothamsted Research

Poster Presentation

Will the yield increase after biochar application to fertile soils in Sweden?

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Abstract

Cereal yield as affected by biochar application to Swedish soils has not been reported earlier. Therefore, two field experiments were performed in 2010. One at Lyckås, Husqvarna, FE 1, at the highlands of Småland and the other at Ejlertslund, Simrishamn, FE 2, in Scania. The box experiments had 3 and 5 treatments, respectively, all replicated. At FE 1, only biochar application varied, while both biochar and fertiliser rate varied at FE 2. Spring barley was sown in a silt loam with 10% clay and 3.5 % organic matter at FE 1 and in a sand with <5% clay and 1.5% O.M. at FE 2.

The results at FE 1 indicated that application of 10 t ha^{-1} biochar at optimal fertilization increased the grain yield by 6% (5% significance) already this first year. The precipitation during this growing season was higher than normal for the area. Doubling the amount of biochar resulted in a somewhat lower yield increase (5%) as compared to no biochar application. The reason could be competition of soil nitrogen between plants and soil micro organisms.

At FE 2, there was no difference in yield between biochar application or not if fertilizer was not applied. When adding both fertiliser and biochar, there was a dramatic yield increase (33%) when tripling the biochar application from 10 to 30 t ha^{-1}, while 18 t biochar ha^{-1} resulted in an intermediate yield increase. Experiment design did not permit yield determination from fertilized soil without biochar in 2010. The extremely dry growing season at FE 2 this year is expected to have favoured plant growth at increased biochar application via a larger stock of plant available water in the sandy soil. Also, a high P content (9 g P kg^{-1} biochar) may have contributed to the yield increase. This will be further evaluated in the 2011 trials. In conclusion, the first official field trials with biochar in Sweden demonstrated markedly increased yields in highly fertile but drought sensitive soils.

Poster Presentation

Biochar amendment shows great capacity for enhancing crop productivity and decreasing GHG emissions in poor calcareous croplands in central China

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Abstract

Production of biochar by pyrolysis of crop straws has been under development with state incentive. Amendment of biochar to croplands and the effects on crop productivity and greenhouse gas mitigation has been under field test across China. This paper reports the results of a field experiment with application of biochar from wheat straw to an OC-poor calcareous sandy loam under corn growing from Henan, central China great Plain. Biochar was applied before corn sowing at rates of 0, 20 and 40 t ha^{-1} with and without N fertilization. Soil emissions of CO_2, CH_4 and N_2O were monitored with a closed chamber method at 7 day intervals throughout the whole corn growing season (WCGS). Biochar amendments of 20 t ha^{-1} and 40 t ha^{-1} increased corn yield by 15.8% and 7.3% without N fertilization, and by 8.8% and 12.1% with N fertilization, respectively. Total N_2O emissions were decreased by 10.7% and by 71.8% under biochar amendment at 20 t ha^{-1} and 40 t ha^{-1} compared to no amendment with N fertilization. Whereas, there were no significant differences between the biochar treatments without N fertilization. Overall, the GWP decreased by 9.8% and by 41.5% without N fertilization, and by 23.8% and 47.6% with N fertilization under biochar amendment at 20 t ha^{-1} and 40 t ha^{-1} respectively. Meanwhile, estimated agronomic fertilised N use efficiency was increased from 1.25 kg kg^{-1} N under no biochar to 2.28 kg kg^{-1} N under biochar amendment at 40 t ha^{-1}. Significant effects of biochar amendment on improving soil structure and N storage were also observed. Therefore, Application of biochar to infertile croplands as a soil amendment will enhance crop productivity and reduce a great deal of GHG emissions in dry croplands.

Poster Presentation

Biochar amendment to improve soil properties and sequester carbon

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Abstract

Current knowledge suggests that biochar can be applied to agricultural soils in order to boost crop yields and simultaneously sequester atmospheric carbon. Biochar could therefore have a role in ameliorating two of the major environmental problems facing humanity – climate change and food scarcity. Further benefits ascribed to biochar include reduced water demand (for irrigation), less downstream pollution and reduced emissions of greenhouse gases (e.g. N_2O) from the soil. Evidence suggests that some of these effects are influenced by soil type.

This ongoing PhD project is investigating the effect biochar has on a wide range of soil properties that influence productivity, in relation to soil type. Four distinct textural classes of soil widely found in eastern England (and surveyed in detail) are being compared, using four biochar treatment doses: 0, 0.1%, 0.5% and 2.5% w/w (equivalent to 0, 4, 20 and 100 t ha^{-1}). The influence biochar has upon soil water relationships are being considered with respect to water storage and water release and the implications of these processes for plant viability.

The project will provide data which is lacking for this region, and extend our knowledge about the significance of soil type to biochar, which is also very scarce and fragmentary. It is the intention to use these results along with existing soil survey data, to compare the relative suitability of specific temperate soil types for amendment in an agricultural context. The poster presents three key facets: (i) the context and importance of the research; (ii) methods and experimental design; (iii) results from pot trials to test available water capacity (AWC)and bulk density.

Poster Presentation

Effect of biochar addition on soil respiration partitioning and root dynamic in an apple orchard

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Abstract

The present experiment was carried out in an apple (Malus domestica Borkh.) orchard located in the experimental farm of the Faculty of Agriculture of Bologna University (Italy). In May 2009, 10 mg ha^{-1} of biochar from fruit trees pruning wood were incorporated by hoeing into the first 20cm of soil. A similar soil perturbation without biochar incorporation was applied to control plots. The trenching method was adopted in order to partition soil respiration (Rsoil) into its autotrophic (Ra) and heterotrophic (Rh) components. Rh was measured bi-weekly, from May 2009 to January 2011 on 16 collars (8 per treatment) positioned in the trenched plots while Rsoil was measured on 16 identical collars placed outside the trenched area. Ra was then calculated as difference between Rsoil and Rh. Fine root dynamics were evaluated using wide-view CCD sensor scanner inserted in polycarbonate boxes previously buried into the soil. Images were recorded every two weeks from June to November 2010 and analysed with WinRHIZO software.

Biochar addition increased microbial and reduced rhizosphere respiration significantly. While the sensitivity to soil water availability of both components of soil respiration was unaffected by biochar addition, the apparent sensitivity to soil temperature, expressed as Q10, significantly increased in biochar-enriched soil. Number, length density, diameter, and longevity of fine roots significantly increased in biochar plots. A decrease in root metabolic activity, in line with the higher root lifespan, could probably explain the decrease in root respiration observed with biochar addition, notwithstanding the higher root density.

Biochar suppression of N2O and CO2 emissions from a wetted agricultural soil

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Abstract

Soil cores (clay soil from Mis Gig X. plantation) were collected from the field and disturbed to a depth of approximately 8 cm. Hardwood biochar (< 2 mm) was added to half of the cores at a rate of 2% of dry soil weight to the disturbed layer. The cores were incubated at three different temperatures (4, 11 and 17°C), and maintained at field moist conditions (~ 23% gravimetric moisture content). Half of the cores were subjected to wetting events (~ 28% gravimetric moisture content). Greenhouse gas emissions (CO_2, CH_4 and N_2O) from the soil cores were measured throughout the experiment using the static chamber method. It was observed that N_2O emissions were suppressed by at least 59% in the biochar treatments compared to controls for all of the wetting events at 11 and 17°C.

We hypothesised that the observed suppression of N_2O emissions was due to the higher relative water holding capacity of the biochar compared to the soil. 25 g (dry wt.) of field moist, ground soil was mixed with varying levels of biochar (between 0 and 10%), then incubated at 17°C. Maximum water holding capacities of the treatments were pre-determined; water was then added to raise the moisture content to 87% of water holding capacity. The headspace was sealed and greenhouse gas emissions monitored for 7 days. It was observed that N_2O emissions were suppressed by 22%, 65% and 97% in the 2, 5 and 10% biochar treatments respectively. CO_2 emissions were higher relative to control in the 1 and 2% biochar treatments, but were suppressed with greater biochar additions.

We conclude that the increased water holding capacity of biochar was not able to explain the suppression of N_2O emissions. Further research is needed focusing on other potential mechanisms, such as the interaction of labile substances on the biochar surface on the soil, the effect of biochar on the immobilisation of nitrogen by soil microbes, and the effect of biochar on stabilising native soil C.

Poster Presentation

A multi-assay approach to assess the potential of biochar to immobilise phytotoxic concentrations of trace elements in soil

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Abstract

Applying amendments to multi-element contaminated soils can have contradictory effects on the mobility, bioavailability and toxicity of specific elements, because each element responds in a different way to subsequent modifications to soil characteristics. In a multi-assay investigation, the efficacy of a hardwood biochar for reducing the mobility of cadmium, zinc and arsenic was assessed.

In the first experiment biochar was mixed with a multi-element contaminated soil from the proximity of a former heavily industrialized area, in a lysimeter arrangement on a 30% amendment (by volume) basis. Concentrations of the elements were measured in soil pore water at regular intervals during 60 days field exposure. Biochar had the greatest effect on Cd, decreasing concentrations of this metal in soil pore water 10 fold, resulting in a significant reduction in phytotoxicity, assessed by a simple bio-indicator test using Lolium perenne L. var Cadix. Arsenic mobility however was increased by biochar addition, probably due to pH and soluble carbon increases, which may have released As retained in soil.

In the second experiment the mechanism of trace element immobilisation and retention was evaluated by a laboratory column leaching experiment, using the same soil as experiment 1, in which pH and leaching times were standardised. This was followed by scanning electron microanalysis (SEM/EDX) of soil and biochar before and after the column test. Adsorption of soluble Cd and Zn from the soil to biochar's surface reduced concentrations of Cd and Zn in column leachates 300 and 45 fold respectively, supporting the results of the first, field-based experiment. Retention of both metals was not affected by considerable leaching of water soluble carbon from biochar. Unlike Cd and Zn, retention of As on biochar's surface did not reduce leachate concentrations.

By these experiments it was concluded that biochar has the potential to rapidly reduce the mobility of selected cationic contaminants in this polluted soil system, which reduced phytotoxicity. Further investigation is ongoing on the potential adverse effects of adding biochar to soils and the wider applicability of this material for assisting contaminated land remediation.

Charvester for co-generation of biochar and electricity

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Abstract

The low bulk density of biochar and of organic raw materials such as straw and wood chips will cause high transportation cost when the pyrolysis is performed at at a centralized plants. In this case it is also difficult to return the biochar produced to the local of origin of the raw material, thereby possibly resulting in contamination of soil for food production with toxic heavy metals. These problems may be counteracted by decentralized pyrolysis and use of the biochar at the site of its origin. However, decentralized pyrolysis confronts two challenges: A) a short annual operation time bearing the comparably large investment costs, and B) increased difficulties in utilizing by-products such as excess heat. In the Charvester project, funded by Mistra, we are decreasing the problem with short annual running time by developing a mobile pyrolyzing unit, a Charvester, which can be moved to local stocks of straw, forest cut residues etc adjacent to farm fields and forest areas, respectively. Returning the biochar to the areas of its origin eliminates the risk of increased levels of toxic heavy metals in soil.

In order to utilize waste heat from the pyrolyses, we are developing an approach where waste heat will be converted to electricity to motors for mobility, feeding of the raw material and for transfer of produced biochar. Excess electricity may be stored in batteries or used to other processes such as transforming air nitrogen into nitrogen fertilizer. The patented technique of the equipment is an organic Rankine cycle (ORC) where the liquid media is expanded by heat in an air-motor connected to a generator. Due to the temperature and tough running conditions, without proper lubrication, special materials with uniquely treated surfaces will be used (http://www.vasatech.se/). The effect of the generator will be around 2 kW, thereby qualifying for EU 2020 program & Smart Grids, being under Swedish supervision.

In conclusion, a mobile charvester, which co-generates electricity, could be a solution for securing biochar application to the sites of its origin and at the same time utilize part of the excess heat generated.

Poster Presentation

The effect of biochar on mineral nitrogen dynamics in a highly SOM-depleted soil

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Abstract

Biochar may offer an important strategy for mitigation of climate change by storing plant-derived carbon. It has also been seen to affect the dynamics of soil N in laboratory experiments, decreasing leaching and gaseous emissions. As part of a wider field experiment we studied the dynamics and fate of mineral nitrogen (NH_4^+ and NO_3^-) in a soil initially very low in soil organic matter and amended with biochar at a rate of 30 t ha^{-1}. Mineral nitrogen was added at a rate of 120 kg N ha^{-1} (20 kg N ha^{-1} to the seedbed and the remainder after emergence) in the form of ammonium sulphate and ammonium nitrate. The biochar contributed 153 Kg N ha^{-1} in stable form, in the amended plots. Mineral N was assessed monthly during the first cropping season having no significant difference in soil NH_4^- concentration at either 0 to 25 cm or 25 to 50 cm depth whether the soil was planted or unplanted, with or without biochar amendment. Not surprisingly, NO_3^- was significantly different between plots with and without maize, from the second month onward at both depths. However, with respect to biochar, the amended and non-amended plots, unplanted, showed, at the end of the season that the concentration of NO_3^- significantly lower than the non-amended, indicating a biochar interaction specific to this ion. The effect was more pronounced in the topsoil but was also present in the subsoil. The yield of maize was 28.8 t ha^{-1} in unamended plots and 33.7 t ha^{-1} in amended soil, with the N taken up into plant being 264.6 kg and 292.84 kg ha^{-1} respectively. Soil N uptake represents 90% of the total nitrate under both conditions – with and without biochar in soil – but the presence of biochar decreased NO_3^- concentration by 36% in topsoil, although the biochar effect on N output represents around 10% more than the unamended maize yield. That difference can be due not only to the lower respiration in these plots and consequently less N consumed by microorganisms, but also to chemical interactions between the soil solution and biochar matrix.

Acknowledgements: The authors are grateful to the Embrapa and Rothamsted Research for the financial support.

Poster Presentation

Eucalyptus biochar changed microbial dynamics and nitrogen mineralisation

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Abstract

The porous structure of biochar has led to it being proposed as a habitat to provide protection for microbial colonisation, particularly in coarse textured soils that lack aggregation. We hypothesised that addition of biochar to a coarse textured soil would cause an increase in (i) microbial population size, (ii) microbial activity, and (iii) microbial community functional and genetic diversity. To test these hypotheses Jarrah (*Eucalyptus marginata*) biochar (pyrolysed at 600°C; 0, 5, or 25 t ha^{-1}) was mixed into pots filled with soil from the A horizon of a coarse textured agricultural sand. In addition three nitrogen (N) treatments were added (organic N, inorganic N, and a control) in full factorial combination. Wheat (*Triticum aestivum*) was grown for 10 weeks, after which plant and soil samples were collected for analysis. Microbial biomass carbon significantly (degrees of freedom (df)=2; F=3.3; P=0.05) decreased with biochar addition while microbial biomass nitrogen was unaltered. This led to a decrease in the C:N ratio of the microbial biomass from 8:1 in the control to 5:1 at 25 t ha^{-1} biochar. Microbial community functional diversity indices (as assessed by community level physiological profiles) increased significantly with biochar addition in the presence of both organic and inorganic N. Analysis of terminal restriction fragment length polymorphism of the ammonium oxidiser bacterial community data showed no significant effect of biochar on diversity indices, but there were significant differences in ammonia oxidiser community structure when biochar was added in conjunction with organic or inorganic N (df=4; F=1.5; P<0.001). Biochar addition caused a negative priming effect on soil organic matter mineralisation; net N mineralisation was highest in the control soil (176 g N kg^{-1} soil day^{-2}), and significantly decreased with the addition of biochar at both 5 t ha^{-1} (102 g N kg^{-1} soil day^{-1}) and 25 t ha^{-1} (15 g N kg^{-1} dry soil day^{-1}) (df=2; F=71.8; P<0.001). These findings could not be attributed to sorption of inorganic N to the biochar. We conclude that the activity of the microbial community was decreased in the presence of biochar, this led to a decrease in soil organic matter decomposition.

Acknowledgements: Funding was provided by the Grains Research and Development Corporation (GRDC) and the University of Western Australia (UWA)

Poster Presentation

Effects of biochar on the nutrient dynamics of sandy arable soils: Comparing organic and conventional agricultural systems

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Abstract

Many farms rely on inorganic fertilizers for high crop productivity, leading to overworking and reductions in soil organic matter. This has led to a decrease in the nutrient and water retention capabilities of the soils; resulting in an increased reliance on inorganic fertilizers. Interest in biochar is increasing for both organic and conventional systems.

Research on biochar remains in its infancy; the effects and mechanisms of biochar on the nutrient dynamics of soil is poorly understood with inconsistent conclusions drawn due to the differences caused by feedstock, production parameters and soil type. Research does conclude however that, with respect to nutrient dynamics, the most benefit may be provided by biochar on sandy soils. As such this research will aim to determine the extent to which the nutrient and water dynamics will change according to application of biochar and the mechanisms that control these changes.

Field trials have been established on organic and conventional farms in Scotland (Dumfries) and England (Silsoe and Bury St. Edmunds). This will monitor the effects of applying 10 t ha^{-1} and 40 t ha^{-1} of biochar on 2 x 5 m^2 plots with a randomized block design. Control plots were also set up where no biochar was applied and all plots were replicated three times. Pot experiments have also been set up to establish Ryegrass (L. perenne) on soils originally collected from a conventional and organic farm applied with inorganic fertilizer and compost respectively. A pot experiment will help to elucidate mechanisms of biochar influence on mineralization of nutrients from compost and inorganic fertilizers and influence on crop response.

Preliminary results from the field trial have showed significant changes in soil parameters with biochar application including pH and extractable nitrogen (NH_4^+ and TON) but no changes to crop yield.

Results from the pot trials show increases in L. perenne yields as the rate of biochar application increases for soils that are organically managed, but decreases in yield with biochar rate under conventional. This suggests that the use of biochar may be better suited under organically managed farms and potentially detrimental to conventional within the short timescale of this experiment.

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Poster Presentation

Biochar amendments change microbial community structure and activity and nutrient dynamics in loamy soils

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Abstract

The search for solutions to mitigate climate change has lead to the development of new technologies, of which the pyrolysis of biomass residues seems to hold potential. The addition of pyrolysed biomass (biochar) into soils contributes to stable organic C sequestration. However it also changes physico-chemical soil properties, microbial activity and nutrient dynamics.

An incubation experiment was conducted over 98 days with two silt loam soils, with different management histories (arable land and recently converted grassland), to which four biochar types were added. Biochar, prepared from either poultry litter (PL) or pine wood (P) and pyrolysed at both 400°C and 500°C, was added at a rate of 20 mg ha^{-1}. Mineral N (NO_3^-, NH_4^+), plant available phosphorus (PAP) and soil microbial parameters, namely phospholipid fatty acid analysis (PLFA) as a measure of the microbial community structure, microbial biomass (by the fumigation-extraction method) and dehydrogenase enzyme activity were measured.

Depending on the pyrolysis temperature and the biomass feedstock, N dynamics differed significantly among the treatments. Higher pyrolysis temperatures decreased the rate of N mineralization. In pine wood biochar amended soils even an immobilization of N was observed. PAP increased in PL amended soils, with highest PAP levels in PL500 soils. At the end of the incubation the activity of dehydrogenase was highest in the P500 biochar treatment for both soils. Microbial biomass C (MBC) of the control treatment decreased during the incubation. In the arable land the 400 °C biochar additions induced a MBC increase compared to the control treatment, while this was the case for all biochar additions in the converted grassland. PLFA analysis, followed by Fishers Canonical Discriminant Analysis (CDA) revealed that pyrolysis temperature had a stronger influence on the microbial community structure than the biochar feedstock. Biochar amendments seemed to decrease arbuscular mycorrhiza (AM) PLFA in both soil types, however in arable land this decrease was more pronounced than in converted grassland.

We conclude that biochar additions changed the nutrient dynamics and soil biological parameters; however the responses are dependent on the biochar feedstock, pyrolysis conditions and the soil management.

Poster Presentation

Elucidating the immediate response of total and culturable soil bacterial communities to biochar

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Abstract

The longevity (microbial population profiles and fertility) of the Brazilian Anthrosols validates current/potential attempts to upgrade nutrient–poor soils, enhance agriculture and ameliorate contaminated ecosystems by biochar application. Consequently, to ensure sustainable practices, comprehensive microbial analyses of historical and contemporary applications using respiratory and culture-/molecular-based approaches – PLFA, t-RFLP, DGGE and sequencing, are underway. Contrasting results highlight the effects of site-/soil history-/biochar-/application regime-specific parameters on indigenous microbial community response and, thus, the requisite investigations prior to field applications. The current study entailed DGGE profiling of total and culturable (10% R2A - RA, soil extract – SE, and Congo Red - CR agars) bacterial communities in response to a 1:4 (w/w) biochar:soil ratio during a 21-day incubation at room temperature in the dark. Original soil moisture content (8% w/w) was maintained with either sterile deionised water or a basal mineral salts solution (MSS).

Despite the colony forming units (CFU) trend of CR > RA > SE, the counts generally peaked at Day 4 with the subsequent decrease until Day 21 more pronounced in the absence of biochar. Also, the control soil with water-based moisture maintenance recorded increased counts while the biochar and MSS augmentation produced decreased CFU. In contrast to our previous 1:1 (w/w) regime, the 1:4 (w/w) biochar addition resulted in total community profiles with relatively increased microbial diversity and numerical dominance of specific components in response to biochar and basal mineral salts solution. On Day 0, similar higher diversity culturable profiles, although characterised by faint bands, were recorded on SE while CR showed pronounced shifts in the numerical dominance of select OTU, with and without biochar. Generally, peaks in richness that reflected the increased CFU counts were recorded on day 4. By day 21, the highest increase in diversity and numerical dominance was recorded following cultivation on Congo red agar. While the medium produced highly similar profiles, their relative species richness was increased by MSS-based moisture maintenance. Furthermore, biochar supplementation increased the relative abundance of numerically-dominant OTU, especially for the N-fixing sub-community. Culture on RA produced low diversity profiles characterised by high-GC bands but with variation in the numerical dominance of some, particularly on Days 8 and 15, in both the control and biochar-augmented treatment.

In summary, biochar augmentation increased the numerical dominance of some components in the total and culturable communities, while the habitat (SE) and selective (CR) media, by supporting higher diversity/richness, reflected the effects of biochar and MSS addition better than the commercial oligotrophic (RA) medium.

Acknowledgements: Prakash Barakoti would like to acknowledge some consultative support from Dr Pattanathu K.S.M. Rahman

Poster Presentation - Absent

Short-term positive effect of biochar on maize yield in north-east Italy

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Abstract

Biochar is an organic material produced via pyrolysis from several different possible feedstocks and its application to soil has been suggested as a viable option for both carbon sequestration and soil properties amelioration. However, the effects on crop growth and productivity after biochar addition to soil are not always predictable. The objective of this study was to assess the effect of biochar addition on productivity of maize on fertilized, nutrient-rich agricultural soil. The field trial started in 2008 on a silty-loam soil which has been cultivated as irrigated maize in the last 30 years, with a pH of 7.8 and optimal plant availability in terms of P and K. Two treatments were compared: Control (C) and biochar addition (B). In this last treatment, biochar was added to the soil at the rate of 10 t ha^{-1} yr^{-2} before sowing both in 2008 and in 2009, while no biochar was added in 2010 to evaluate residual effects. Grain yield, above-ground total biomass and harvest-index were measured in 20 m^2 plots replicated three times per treatment.

Biochar significantly improved crop yield, determining an increase in grain yield of 24% and 21% compared to the control in 2008 and 2009, respectively. In 2010 maize yield was not significantly different in B (+5% in comparison to C). Harvest index and the average weight of 1000 seeds were not significantly affected by biochar, although in 2010 average weight of 1000 seeds was 12% higher in biochar compared to the control. In conclusion, these preliminary results indicate a positive effect of biochar on productivity soon after its application and a declining effect in the medium term. However, more observations are necessary to determine the real long-term duration effect of biochar application to soil.

Poster Presentation

Using Biochar as a potential environmental management tool in barley production systems

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Abstract

Various studies have shown some significant agronomic benefits due to biochar applications but there is still a lack of published data on the impact of biochar on pathogens in soil and *in-planta* systems. However, some studies have shown some effects on soil borne pathogens, indicating that the control of some pathogens maybe achieved using some biochar forms. Matsubara et al., (2002) demonstrated that charcoal inoculated with AM fungi can be effective in reducing Fusarium root rot disease in asparagus. Another study by Nerome et al., (2005) showed the reduction of bacterial wilt in tomatoes observing an optimum disease suppression with a biochar rate of 20% (v/v). In another study the addition of biochar to soil also increased asparagus crop weight and significantly reduced the Fusarium root rot pathogen (*Fusarium oxysporum*).

Knowing that with biochar the chemical, physical and biological environment in the soil changes, the mechanisms for suppressing soil-borne plant diseases by biochar are likely related to these improvements. However, a recent study by Elad et al., (2010) also suggests that soil amended with biochar could induce systemic acquired resistance to the foliar fungal pathogens on both pepper and tomato plants.

This project in combination with a series of short-term glass house and long-term field experiments aims to explain the effects of different biochar products on the susceptibility of spring barley to major barley pathogens with a particular focus on *Rhynchosporium secalis* and *Ramularia collo-cygni* . The aim of this poster is to demonstrate the outline of the current experimental approach as well as some preliminary data from the interactions of biochar in UK arable barley production systems.

Poster Presentation

Effects of biochar on physical properties of bare soil

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Abstract

Biochar and its applications have known a growing interest in these last years, due to its carbon sequestration capacity and its generally positive impact on soil and agricultural productivity. Next to the numerous studies assessing the positive effect of biochar on crop yield, little research has been published elucidating the mechanisms responsible for the reported benefits of biochar on crop growth, production and soil characteristics. Few studies cited soil moisture as the key factor attributing the increased yield to the higher soil water availability.

Aim of this study was to investigate the effect of a biochar, produced from horticulture waste by pyrolysis, on the physical properties of a North-Italy (Cadriano, BO) agricultural soil. The soil has a loam texture, with a long history of cropping and a pH = 6.95. The biochar total C content is equal to 57.8 mg kg^{-1}, its pH = 9.8. A preliminary experiment was held in 2009 in plots, to first explore the biochar influence on soil moisture. Results of the first year suggested us to replicate the same experimental scheme with higher biochar rates. During the second year three rates of biochar (10, 30 and 60 t ha^{-1}) were investigated. Water content probes were inserted in 2 x 2 m^2 plots at a depth of 10 and 30 cm. The trial was set on bare soil, to understand the direct effect of biochar on its characteristics. Irrigations were applied, to obtain reliable calibration curves for all probes and a wide range of soil moisture. Soil water content, bulk density, electrical conductivity and soil water retention were measured.

Biochar induced a significant change in soil bulk density (making the soil lighter) and electrical conductivity. No significant differences in soil moisture were detected considering both electronic and gravimetric water content data. This may be due to the quite good hydrological characteristics of the studied soil, while biochar effects in literature were found for poor soils.

Poster Presentation - Absent

Biochemical activity increased after addition of biochar to an acid soil

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Abstract

Several studies have shown that biochar application to soil has beneficial effects on several parameters affecting soil fertility: pH, cation exchange capacity as well as physical properties. By contrast few studies investigated soil biological and biochemical properties after biochar application. It is important to know if and how the latter properties are affected, because higher microbiological activity implies better biogeochemical cycling of soil nutrients.

Biochar was applied at two rates (22 and 50 t ha^{-1}) in a vineyard (Tuscany, Italy). Soil had a pH (water) of 5.8 which increased by about one unit after biochar application. Soil samples, taken in September 2010, were assayed using a rapid method based on enzyme desorption and fluorescent substrates. Six enzymatic activities (arylsulfatase, beta-glucosidase, chitinase, esterase, leucine-aminopeptidase, alkaline phosphatase) were quantified in order to have a global evaluation of microbial activities. We detected a big increase (up to four times) of soil alkaline phosphatase (an enzyme produced exclusively by soil microorganisms), leucine-aminopeptidase and chitinase. The other enzymes were affected to a lower extent. These results showed that biochar, besides affecting positively chemical and physical properties, can increase to a great extent biochemical activity of soil, thus improving biogeochemical cycling of soil nutrients.

Acknowledgements: Marchesi Antinori srl; Italian Biochar Association (ICHAR); This work contributes to the EuroCHAR project (FP7 – ENV – 2010 ID – 265179)

Poster Presentation

Impact of biochar on the biodegradation of organic contaminants in aged soil

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Abstract

Biochar is a carbon rich product from the combustion of biomass and it has been utilized in waste management, carbon capture, crop improvement and energy production. Currently, it has shown to adsorb organic contaminants and reduce their bio-availability.

This study investigated the influence of 0, 1, 5 and 10% of two different particle sized wood biochars on the relationship between microbial mineralisation and Hydroxypropyl-β-cyclodextrin (HPCD) extraction of ^{14}C-phenanthrene (10 mg kg^{-1}) in 1 yr aged soil. The amendment conditions were aged for 0 and 40 days. The total extent of ^{14}C-phenanthrene mineralisation was assessed by monitoring ^{14}C-phenanthrene mineralisation over 14 days in respirometric assays using phenanthrene-degrading Pseudomonad inoculum and compared to HPCD aqueous extraction. Desorption behavior of ^{14}C-phenanthrene was also assessed by monitoring over 6 days.

The 5 and 10% BC (2 mm) amendment showed significant reduction in extent of mineralisation compared to 0% BC and cumulative HPCD extraction. However, cumulative total of ^{14}C-phenanthrene extracted exceeded amount mineralised by >30% at each sampling point (0 and 40). Linear correlation between HPCD extractability and total amount mineralised over 14 days revealed very good correlation in all concentrations of biochar amendments with 10% (3-7 mm) BC showing best fit of (r2 = 0.99, slope = 1.31, intercept = 0.14). This paper thus shows that biochar used in this study can reduce the bioavailability of phenanthrene to microorganisms at high concentrations and that HPCD extraction strongly predicts the bioavailability of phenanthrene in soils such as the one tested in this study.

Poster Presentation

Do fungi affect the sorption and degradation of organic contaminants in biochar?

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Abstract

Biochar is a carbon-rich material produced from the pyrolysis of biomass. As a soil amendment, it has the ability to improve soil structure, and has been shown to be effective in reducing the mobility of certain soil contaminants. However, it remains unclear how biochar applied to soil can alter the behaviour of micro-organisms due to a potential influx of nutrients and carbon available for use in microbial metabolism. Further, increased microbial action including fungal activity could lead to the degradation of biochar.

We currently examine the effects fungi have on the stability of biochar and contaminant breakdown, by monitoring: 1) rates of biochar degradation by fungi utilising biochar as a source of carbon; 2) degradation of polycyclic aromatic hydrocarbons by fungi in biochar amended conditions; and 3) biomass and microbial activity associated with biochar and PAH degradation. The presence of fungi and extra-cellular enzymes can affect the degradation of organic contaminations, but they may also affect the integrity of the char which may release sorbed contaminants. Currently, it is not clear which process will dominate.

Poster Presentation

Assessing the influence of biochar in controlling diffuse pollution from arable soils

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Abstract

Application of biochar to soil may reduce off-site pollution by firstly, retaining nutrients such as nitrogen (in the form of ammonium and nitrates) and phosphorus (in the form of phosphates) in the soil and lowering the amount of soil nutrients leached into groundwater or eroded into surface water. Secondly, biochar would reduce pollution by improving nutrient retention in the topsoil, thereby reducing the amount of fertiliser needed to grow a crop. The reductions in erosion have not been fully tested; erosion reductions based on the movement of nutrients adsorbed to sediments are debatable, whereas reductions in soluble nutrients can be expected. This work aims to assess the impact of applying biochar to soil mixed with compost in terms of its retention potentials to adsorb nutrients in leachates.

The experimental entailed setting up an erosion experiment using sandy loam obtained from Cranfield University Farm in Silsoe, Bedfordshire. The sandy loam soil was mixed with green waste compost at 80 kg ha^{-1} N. The crop chosen for the experiment was white mustard (Sinapsis alba.L). Mustard was planted in trays (24 x 29 x 10 cm with a base made of perforated plate and fabric, in order to drain water and avoid any soil loss) in the glasshouse. Two application rates of biochar at 10 t ha^{-1} and 40 t ha^{-1} added in the top 3-4 cm were used together with a control. The biochar was sourced from a supplier who uses a mixed broadleaf. The biochar used in this experiment was sieved to 5 mm from a supply of mixed sizes. Lehmann et al (2009) showed that the size of biochar particle has a link with the nutrient retention. Once mustard had reached maturity, the trays were placed under a rainfall simulator (equipped with a water tank attached to hypodermic needles that can discharge water droplets at required size to simulate rainfall). The rainfall intensity deployed was 60 mm $hour^{-1}$ for 30 minutes. The reason we chose this rainfall intensity was because it reflected a 1 in a 100 year rainfall event for this region in the UK.

The results show that the leachate collected from trays added with 40 t ha^{-1} of biochar and compost had the significantly smallest ($p < 0.05$) level of total oxidisable nitrogen (4 mg kg^{-1}) compared to the control (10 mg kg^{-1}). The ammonium levels in leachate also showed similar trends. This shows that biochar amended trays has the capacity to adsorb total oxidisable nitrogen which may be a way of controlling diffuse pollution. However addition of biochar did not significantly affect phosphate levels in leachates. More work in under way to investigate the detailed mechanisms that could explain this observation.

Acknowledgements: I would like to thank the Douglas Bomford Trust and Crichton Carbon Centre for funding this work.

Poster Presentation - Absent

Effect of biochar on growth, productivity, nitrogen uptake and microbial biomass on Sorghum-sudangrass

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Abstract

Biochar has been proved to increase the soil nutrient adsorption capacity due to negative charges on its surface and this could explain the increase in crop productivity often observed on tropical soils. However, little is known on the effect of biochar on nutrient-rich agricultural soils in temperate regions.

To evaluate the effect of biochar combined with different soil soluble nitrogen (N) levels, a pot experiment (15 L volume) was established growing three plants per pot of Sorghum-sudangrass. The soil used was a silty-loam agricultural soil, with pH of 7.8 and optimal plant available P and K. In order to create a range of soil soluble N content, the following four N levels were compared: a control (untreated soil), addition of crop residues (R, at a rate of 3 mg g^{-1} soil), addition of N-fertilizer (F, at a rate of 0.0503 mg g^{-1} soil as ammonium sulphate), and the combination of both. These treatments were combined with two biochar levels (no biochar and biochar at a rate of 10 mg g^{-1} soil). The biochar was obtained from pyrolysis at 500°C of fruit tree pruning residues. In summary, the following eight treatments, replicated six times, were compared: untreated soil, biochar (B), crop residues only (R) and with biochar (RB), fertilizer only (F) and with biochar (FB) and the combination of both factors (FR and FRB). Each pot received 0.0157 mg g^{-1} soil of N as ammonium sulphate at sowing as starter N application. Treatments were evaluated in terms of germination, soil soluble N, plant growth rate and productivity, N uptake and soil microbial biomass.

Plant growth, above-ground N content and biomass of Sudangrass were positively affected only by the soil available N treatments although biochar had no appreciable effect on any of these parameters. Moreover, biochar did not increase soil microbial biomass confirming its low availability as C and N substrate for soil microorganisms. Preliminary results from this study point out that the benefits of biochar additions for improving crop productivity appear to be limited in nutrient-rich agricultural soils.

Poster Presentation

The effects of spruce chip biochar application on N mineralisation dynamics from organic fertilisers

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Abstract

The importance of increased nutrient recycling in agro-ecosystems by use of organic fertilisers is increasingly acknowledged and the effects of biochar application on nutrient dynamics are of particular interest. This study explores how different biochar application rates affect the net N mineralisation dynamics from two organic fertilisers on a sandy loam (Gleyic Phaeozem).

Spruce chip biochar (at rates corresponding to 0, 4.6, 9.1 and 13.6 g kg^{-1} soil DM) and two organic fertilisers were incubated under standardized conditions (15ºC, field capacity water content 0.24 g g^{-1}) in PVC beakers for 133 days. The organic fertilisers Aito-Viljo (AV, a meat and bone meal based commercial fertiliser) and composted manure (CM) were added at rates 1.7 and 12.4 g kg^{-1} soil DM, respectively. Fertilisation rates corresponded to 290 kg ha^{-1} total N (assuming a furrow slice of 2200 Mg ha^{-1}). For monitoring soil N mineralisation dynamics, four replicate beakers from each treatment were sampled destructively on days 0, 14, 28, 56, 84 and 133, and mineral N was extracted with 2 M KCl and determined by FIA colorimetry.

According to the preliminary results, N mineralisation from AV was significantly faster than from CM and control soils. Nearly all mineral ammonium originally present in the different biochar levels of AV fertilised soil seemed to have been nitrified already by Day 14. Since then the ammonium concentrations remained low and soil mineral N was dominated by nitrate in all treatments. Biochar additions decreased the mineral N concentrations in all treatments. The effect increased with time and became stronger with larger biochar additions. The largest reductions were found in AV fertilised soil, where the net mineralisation was largest. As the WFPS was about 45% and the air-filled porosity >0.31 m^3 m^{-3} during the incubation, we argue the reductions in NH_4^+ and NO_3^- contents are attributable to N immobilization by microbes rather than to denitrification. However, as the experiment is still going on, the longer term effects remain to be explored.

Poster Presentation

Biochar and biological carbon cycling in temperate soils

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Abstract

The response of soil carbon (C) pools to biochar addition are not yet well understood. Studies have shown that biochar has highly variable effects on microbial C cycling and thus on soil C storage. This discrepancy may be partially explained by the response of soil invertebrates at higher trophic levels which regulate microbial activity.

This experiment aims to understand the role of soil invertebrates (i.e. Collembola and nematode worms) in biochar-mediated changes to soil C dynamics across a range of plant-soil communities.

An open-air, pot-based mesocosm experiment was established at the Centre for Ecology and Hydrology in Edinburgh in May, 2011. Three treatment levels (presence of biochar, soil type, and vegetation type) were included in a fully-factorial design, with four replicate pots of each combination. Carbon fluxes are being measured over the course of three years, along with invertebrate and microbial abundance and species composition.

Poster Presentation

Effects of bagasse charcoal application on sugarcane production and soil CO_2 efflux

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Abstract

On Miyako island of Okinawa, approximately 300,000 t of cane is annually harvested for sugar, which dominates 2/5 of the total cane production in Japan. In a milling process, the large amount of bagasse, almost 1/4 of the total yield (with 50% in moisture) is generated. Although the bagasse is used for heat generation in mills, extra bagasse still exists. In this context we launched a project to make biochar from bagasse in Miyako, in 2000. Bagasse charcoal retains the structure of plant tissue (e.g. vascular bundle) and, has a high specific surface area, 600 m^2 g^{-1}. Available moisture and water holding capacity in the bagasse charcoal is high, and it contains plenty of inorganic ions, especially potassium, suggesting its potential use as a soil amendment and fertilizer. Furthermore, since sugarcane shows a high carbon assimilation rate and vigorous growth, bagasse is also a good material for carbon sequestration. Our goal is to introduce bagasse charcoal to the sugar industry with positive feedback on cane production.

In this study, we apply bagasse charcoal to cane fields to analyze the effect of the charcoal on cane and sugar yield. Additionally, we measure the soil CO_2 efflux to assess the potential impact of the bagasse charcoal. The results showed that the charcoal application with 6t ha^{-1} increased total sugar yield by 34% mainly due to increase in cane yield by 33%. Although decrease in sucrose content in the 3 t ha^{-1} by 28% was detected, it was not in the case of the 6 t ha^{-1} application. Potassium content in the cane juice was the highest in the 3 t ha^{-1}, which possibly played a negative role in lowering the sucrose. However, how the higher absorption of potassium in 3 t ha^{-1} occurred was unknown. The effect of the charcoal on CO_2 efflux wasn't observed while over twice as high CO_2 efflux rate, up to 8.7 umol m^{2-1} s^{-2}, was detected in the manure application. Since the temperature dependence of the CO_2 efflux wasn't different with or without the charcoal application, we conclude that the impact of the bagasse charcoal application on CO_2 efflux was small.

Acknowledgements: The Ministry of Agriculture, Forestry and Fisheries of Japan (Rural Biomass Research Project Cm-6400).

Poster Presentation

The studies of durian shell biochar as a nutrition enrichment medium for agricultural purposes

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Abstract

The biochar from durian shell in this research is studied as the nutrition enrichment medium for plant growth media. The durian biochar is pyrolysed in a non-oxygen condition at 400-500°C which is giving a yield of 3-4 kg durian biochar per 100 kg of fresh durian shell.

The durian char is ground and separated to the size of 0.3 to 1.7 mm with a bulk density of 0.3 g ml^{-1}. XRF is used to analyze the chemical composition of durian biochar.

It is found that the durian biochar has higher phosphorus and potassium content than other biochars such as char from palm shell and bamboo. The durian biochar can be fortified with nitrogen and the pH can be adjusted with the mixture of urea and wood vinegar solution. The obtained durian char from this experiment has a stable pH value in the range of 6.5 to 7.5. The surface topography is determined by SEM and surface porosity is determined by iodine number using ASTM D 4607-94. It is found that the durian biochar has pore size of < 20 µm and iodine number of 202.32 mg g^{-1} which shows higher porosity than the other biochars in this study. Also the durian char developed in this study shows interesting results of a slow release characteristic of phosphorus in a phosphate form.

Poster Presentations – Biochar Production & Characterisation

Poster Presentation

Innovative nuclear magnetic resonance techniques for the assessment of biochar physico-chemical properties

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Abstract

Soil amendments with biochar are often reported to increase agricultural productivity by improving soil quality and fertility. Biochars are obtained from different biomass feedstocks and their nature differs according to the production process. Due to its effect on soil dynamics and plant growth, biochar quality must be carefully tested prior to any soil application. In fact, according to the nature of the biomass involved in biochar production and soil type, either negative or positive effects on soil fertility can be achieved.

The present study reports about applications of innovative nuclear magnetic resonance (NMR) techniques in order to investigate biochar physical and chemical properties. In particular, three different chars (from conifer wood, poplar wood and marc residues) obtained from a gasification process (i.e. a thermo chemical conversion consisting in a partial oxidation of biomasses to gas and char) were analyzed by low resolution ^{1}H fast field cycling (FFC) NMR relaxometry and high resolution solid state NMR spectroscopy. While the latter technique was unable to reveal differences among chars, FFC-NMR differentiated the three chars through their interactions with water.

This study reveals the usefulness of fast field cycling NMR as a promising tool in assessing agronomic potential of biochars retrieved from different biomasses.

Poster Presentation - Absent

Structural investigation of biochar by analytical pyrolysis: Relationships with environmental stability and the occurrence of polyarenes

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Abstract

The structural assemblage of biochar is connected to the nature of feedstock and the conditions of production and has important implications to its fate in the environment. However, the relationships between the molecular characteristics of biochar and its agro/environmental behavior have not been fully understood yet. Pyrolysis coupled to gas chromatography-mass spectrometry (Py-GC-MS) is a well-known technique to gather information on the structure of complex organic materials at a molecular level. The aim of this study was that to evaluate possible correspondences between the structural data of biochar gathered by Py-GC-MS and microbial respiration rates as well as the content of noxious contaminants such as polycyclic aromatic hydrocarbons (PAHs).

A set of biochars produced from pyrolysis of different biomass feedstocks (hardwood, softwood, shell nuts, wastes, etc.) and produced under different pyrolysis conditions (400°C-800°C) were analysed by Py-GC-MS at 900°C. The yields of pyrolysis products were evaluated by internal calibration with o-isoeugenol. PAHs were determined after solvent extraction and SIM-GC-MS analysis. The method was validated by the use of perdeuterated surrogate PAHs.

Total yields of pyrolysis products covered a wide interval (230-16000 μg C g^{-1}) and were positively correlated with volatile matter (VM). The proportion of products associated to the charred fraction (benzene derivatives, PAHs) ranged from 32 to 99%. The remaining fraction was associated to partially preserved "uncharred" biomass (anhydrosugars, furans, methoxyphenols) and its molecular composition reflected the nature of the starting material. In particular, relatively high levels of protein fragments (pyrrole, indole) were evolved from biochars characterized by high nitrogen content.

The short term CO_2 suppression/stimulation of biochar amended soils presented large differences without marked correlations with bulk analyses. With regard to Py-GC-MS, in general, biochars characterized by large yields of pyrolysis products from holocellulose exhibited a positive priming effect on mineralisation rates in incubated soils. PAHs were detected in all the examined biochar samples and correlations with chemical/microbial characteristics are currently under investigation. Py-GC-MS resulted a rapid and reliable method to complement VM data with a molecular picture of the less thermal recalcitrant component of biochar probably associated to its lability in soil.

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Poster Presentation - Absent

Hydrothermal carbonisation of digestate and cellulose – a comparative analysis

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Abstract

In the age of biochar, a new industrial raw material, new sources of biomass, which are presented in large quantities, are always needed. This includes fermentation residue (digestate) which is produced in many industries. Hydrothermal carbonisation is one way to produce biochar for different applications.

This study aims to investigate the influence of different process settings, such as temperature, residence time and pH value on the physical and chemical properties of the hydrothermal carbonisation product by using the digestate as a feedstock and the microcrystalline cellulose Avicel PH-101 (Fluka) as a reference material.

For the experimental investigation a 1 L stirred batch reactor (Parr, USA) was used and distilled water used as a process medium. The digestate was obtained from a laboratory digester using maize silage as a sole substrate. Digestate and Avicel were treated at different temperatures of 190, 230 and 270°C, pH values (3, 6 and 9) and residence times (2 h, 6 h and 10 h) by using citric acid as a catalyst.

In addition to the elemental compositions (C, H, N, S), specific surface area and pore structure as main physical properties were determined. Finally, the impact of various temperatures, pH values and residence times on the physicochemical properties of bio-coal was analyzed. The statistical software "Design-Expert" was used for the implementation and evaluation of the hydrothermal carbonisation tests.

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Poster Presentation

Palm frond biochar production and characterization

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Abstract

Palm oil has been the world's main source of oil and fats since 2004 producing over 45 million tonnes in 2009. Malaysia alone has over 4.5 million hectares planted with palm oil and based on common practice, around 300 palm fronds are pruned per hectare per year. This agricultural waste is currently either being used as roughage feed or is more commonly being left between rows of palm trees to prevent soil erosion or for nutrient recycling purposes. This paper proposes an alternative use for palm fronds as a source of biochar.

Biochar was produced from palm fronds in a traditional method commonly used by gardeners in Malaysia to improve soil fertility. A shallow earth pit was dug in the ground for the carbonisation process. The process is described and the impact of carbonisation on the earth wall was analysed and presented.

The process was later re-assessed by using TGA-FTIR. It was found that most of the hemicelluloses to be fully disintegrated but the depolymerisation of the cellulose was still incomplete at the carbonisation temperature used at site. Most of lignin aromatic structure was still present and this could be seen from the still intact aromatic vibration at 1598 cm^{-1} in the biochar's FTIR spectrum. The biochar was also characterised using BET, SEM and FTIR. SEM cross-section images showed the existence of macropores (> 50 nm) that most probably originated from fused lignin molecules during carbonisation. The BJH adsorption average pore diameter was 10 nm and this demonstrates the existence of mesopores that play an important role in adsorbing larger molecules like colour molecules and probably other organics.

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Poster Presentation

Classification of biochar in relation to its stability in soil

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Abstract

The carbon stabilization potential of biochar is still unknown and depends on the feedstock and charring conditions used to produce it. Because different biochars vary in their stability, it is useful to characterize them. This poster will present the concept of a PhD project in which the recalcitrant fraction of different biochars will be estimated. These estimated stabilities will then be correlated to chemical and structural properties of the biochars. The characterizations involved will be achieved both by cutting-edge methods as well as by less time-demanding methods.

Biochars will be produced from two feedstocks, corn cob and miscanthus, and using three pyrolysis methods: slow pyrolysis (including a temperature gradient ranging between 250 and 800°C), flash pyrolysis, and hydrothermal carbonization (HTC). It is expected that biochars produced at higher temperatures will be more recalcitrant and that the HTC method produces relatively labile biochar.

Biochar stability will be estimated through a 1.5 year lab incubation study using natural abundance isotope ratios to allocate respired CO_2 to C4 plant derived biochar and C3 derived soil organic matter. The advanced techniques used to characterize the chars will include BPCA (benzene polycarboxylic acid) method, NMR (nuclear magnetic resonance spectrometry), and SEM (scanning electron microscopy), and other analyses included will be elemental and proximate analysis, thermogravimetry (TG) and differential scanning calorimetry (DSC), MIR/NIR (mid- and near-infrared spectrometry), CEC (cation exchange capacity), and BET surface area. As many of the methods as possible will be performed on mixtures of biochar and soil, before and after the incubation. It is expected that MIR/NIR characterization can be used as a proxy for the NMR and BPCA characterization methods, and that the proximate analyses will give a general indication of the biochars' stabilities.

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Poster Presentation

Production and characterization of slow pyrolysis biochar

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Abstract

The purpose of this work was to examine specific biochar characteristics that can predict its behavior in soil applications, and to relate these characteristics to the type of biomass feedstock used and to the process conditions that were applied during biochar production, more specifically, production by slow pyrolysis. Process conditions that were investigated are the treatment temperature and biomass residence time during slow pyrolysis of several biomass feedstocks. The pyrolysis set-up used for the experiments consisted of a heated vertical stainless steel reactor whith a nitrogen purge flow of 800 ml min^{-1} through the packed bed.

Chars were produced at different treatment temperatures (300-600°C) and at different residence times (10-60 min). The characterization of biochar is meant to predict its behavior in soil conditions. Biochar evaluation included yield, elemental and proximate analysis, higher heating value, BET surface area, pH in solution, cation exchange capacity, biological oxidation degradation and soil incubation.

The results indicated that biochar yield was negatively correlated with ash content of the feedstock. When considering the fixed carbon yield of the different biochars, it was found that although the fixed C content strongly depended on the intensity of the thermal treatment, the actual yield in fixed carbon was practically insensitive to the treatment temperature or residence time. The higher heating value is correlated with the fixed C content and consequently, higher HVs were found in chars that were produced during more intense thermal treatments.

Finally, in soil incubation tests, it was found that the addition of biochar to the soil initially reduced the C-mineralization rate, indicating that the soil microculture needs to adapt to the new conditions. This effect was more pronounced when adding chars with high fixed C content, as chars with low C content had a larger amount of volatile, easier biodegradable, C compounds.

Poster Presentations – Linking Characterisation & Function

Poster Presentation

Physicochemical characterisation of woodchip biochar from gasification and its initial effect on root growth

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Abstract

Biochar generated as a by-product of combined heat and power gasification is classified as waste, for which the UK does not currently have a safety protocol for use in the open environment. The UEA is working with the Environment Agency to determine environmental tolerance limits, in order to minimise risks and adverse compound contamination. This study aims at assessing the effect of biochar on plant growth under controlled conditions.

We characterised physical and chemical properties from woodchip biochar obtained from the UEA gasifier (800°C for 30 minutes). The organic structure appeared to be retained. Heavy metals were present in very low concentrations (>350 ppm). Relatively high concentrations of Ca^{+} and K^{+} were present. Lettuce (Lactuca sativa) seeds were germinated and put in pots containing 0, 3, 10, and 50% of biochar mixed with compost in a short-day growth chamber at a constant 22°C.

The preliminary results show no difference in root-shoot growth between the biochar and control treatments. High concentrations (50%) do not appear to inhibit or enhance root-shoot growth compared to the control. A further experiment will be carried out to determine the long term (180 day) root-shoot growth of plants under several biochar (0, 3, 10, 50%) and fertiliser (0, 50, 75, 100 kg ha^{-1}) rates.

Poster Presentation

Biochar pyrolysis temperature effect on the germination and growth rates for corn and Chinese cabbage

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Abstract

This study aims to investigate the effect of pyrolysis temperature of biochar on the rates of seed germination and plant growth. We hypothesise that sources of biochars produced at low temperatures have better effects on plant germination than those produced at higher temperatures. We tested these hypotheses using biochar, utilizing four different pyrolysis temperatures (240, 300, 600 and 700ºC). We evaluated percent of germination in seedling growth and plant growth parameters (leaf length, leaf wide, leaf number and stem size) of corn (Zea Maize) and Chinese cabbage (Brassica Rapa).

Results showed that pure bamboo biochar pyrolized at 300ºC had a positive effect in corn and Chinese cabbage seed germination. Bamboo biochar produced at 260 and 300ºC used in a 50-50% relation combined with soil, showed positive results in corn, seeds germinated in a 100%. In Chinese cabbage, positive germination was observed with biochar pyrolized at 260ºC, followed by 300ºC. Biochar produced at high temperature inhibited germination and seedling growth whereas biochar produced at lower temperatures had the opposite effect. Biochar can have positive or negative effect in plant germination and growth depending on its pyrolysis temperature, when used alone or in combination with soil.

Poster Presentation

PAHs burden and partitioning in ten biochar matrices

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Abstract

When organic matter undergoes a pyrolysis process biochar is formed to obtain heat and power. During this process the proportion of C increases by over 50% by weight with respect to the original feedstock; the structure of the matrix becomes porous and rich in biological nutrients (e.g. potassium, phosphorous) and microelements (e.g. magnesium, calcium, manganese). Thus, it has been suggested that biochar can be amended to soil with a view to improving plant growth. Moreover, as a consequence of biochar's stable composition, the release of carbon (as CO_2) back into the atmosphere is slow. Thus, there is the opportunity to sequestration of CO_2 into biomass (used as feedstock for biochar production) and then to store this carbon when biochar is used as a soil amendment.

However, as pyrolysis products, biochars may contain significant levels of polycyclic aromatic hydrocarbons (PAHs). Amounts of these priority pollutants dependent upon feedstock type and the production processes (e.g. temperature). Establishing PAH concentrations and partitioning within biochar is essential to ensure safe incorporation of biochar in the environment.

This study investigated exhaustive and non-exhaustive concentration of PAHs from ten complex carbonaceous matrices, produced from different starting material and under different pyrolysis temperature. We intend to present validation data for the extraction of PAHs from biochar to exemplify approaches that indicate PAHs partitioning and bio-availability. In light of these results, assessment of the risk represented by biochar and the risks associated with biochar incorporation into the soil will be evaluated, considering the toxic impact of biochar also in relation to the feedstock and pyrolysis temperature.

Poster Presentation

The biochar project: An overview

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Abstract

The use of biochar (biomass-derived black carbon) as a soil amendment is gaining interest to mitigate climate change and improve soil productivity. The potential benefits include a reduction in gas emissions, an increase in carbon sequestration and also improvements in soil fertility and crop yield. These findings constitute a great incentive for the implementation on a large-scale of biochar-based strategies. However, studies to date show great variability in the obtained results depending on both raw materials and pyrolysis conditions used to produce biochar.

In order to assess the benefits associated with the application of biochar to soil, a Spanish multidisciplinary research project was started in 2011 at the Córdoba University in collaboration with a private company ZeroEmissions and the Pablo Olavide University. The 3 year project is funded by the Spanish Ministry of Science and Innovation under the subprogram INNPACTO. The main objectives of the project are: 1) To produce biochar from representative agricultural and forestry residues under different pyrolysis conditions and characterise its main physico-chemical properties, 2) to determine the stability of biochar in soil and assess its use as a long-term carbon sink, 3) to evaluate the main effects of biochar on soil properties, nutrient retention and plant growth, and 4) to develop a carbon offset protocol based on the results obtained from a life-cycle analysis for the use of biochar in emissions reduction projects. Therefore, this project proposes a detailed analysis of all stages from biochar production to its use in agriculture. We will present a detailed diagram of the different experiments that will be carried out. At this point in time, the authors would appreciate any comments and suggestions to the proposal. The knowledge gathered from this type of project is a key tool to implement pyrolysis as a management option for waste materials, guaranteeing both agricultural and environmental benefits.

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Poster Presentation

Chemical-physical characterization, bioassay and germination tests on different charcoals from gasification process

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Abstract

Gasification is a thermo-chemical conversion process in which a biomass (or other different organic matrices) is partially oxidized by heating at high temperatures (< 1000°C) in gas and charcoal.

The gas (generally called syngas) is a mix of carbon monoxide and dioxide, hydrogen, methane and nitrogen. It is used to power a diesel-cycle endothermic engine in order to produce electricity and heat or as fuel for direct use.

Gasification creates a fine-grained, highly porous charcoal that may significantly vary in its chemical and physical properties depending on the process typology and starting material. Different charcoals from different feedstocks were analyzed for the main physical and chemical properties (bulk density, pH, salinity, humidity, total carbon and nitrogen, ash) and tested with bioassay (using *Lactuca sativa*) and germination tests (using *Lepidium sativum*) in order to assess the presence of plant toxic compounds and investigate the growing effects at different rate. The treatments were calculated to simulate field soil application. Charcoals were obtained from 1) conifer wood, 2) poplar wood, 3) wheat straw, 4) vinace, 5) olive residues.

The present work reports in detail the results of these laboratory activities, confirming that different feedstocks give charcoals that differ greatly in their physical and chemical properties, as total organic content, ash content, salinity; reaction is instead always very alkaline, typical for the products from gasification processes.

Regarding bioassay and germination tests, the data generally show positive effects on plant growth, but dynamics and consequently optimum rates are different depending on the starting feedstock. Only vinace charcoal shows negative effects on *Lepidium s.* growing and its soil application seems to be not suggested.

In conclusion, by reason of materials strong heterogeneity, the study reveals that charcoals must be tested and checked with careful laboratory screenings prior to field application, in order to better understand soil dynamics and growing benefits avoiding counter-effects that can damage soil productivity.

Poster Presentation

Establishing release dynamics for plant nutrients from biochar

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Abstract

In order to assess the value of biochar to direct supply of crop nutrients we considered the magnitude and dynamics of phosphorus, magnesium and potassium release from hardwood biochar in a sequential leaching experiment. To account for the contribution of physical abrasion/weathering on the release of crop nutrients, the biochar was crushed and sieved to four particle size ranges before testing. Repeated deionised water extraction was undertaken, with and without orbital shaking to simulate different levels of contact with soil solution. The filtrates obtained at each step were analysed for phosphorus (P), potassium (K) and magnesium (Mg). Curve-fitting allowed an evaluation of nutrient release not only in terms of quantitative release but to compare rates occurring in earlier extractions to those in later extractions. There was no significant difference between P concentrations released from samples that were shaken versus samples that were left to soak, but shaking the samples had a significant impact on Mg and K release. Particle size affected release rates for all three elements. Although cumulative P release was relatively small (13-29 mg kg^{-1} from the first extraction), the rate of the last extraction was 44–73% of the rate in the first extraction, indicating that this release would be sustained for several seasons in the field. Conversely, K release from the first extraction was much higher (1.48-2.47 mg kg^{-1}), but the rate of release from the last extraction was only 6-18% that of the first extraction. Only 6-27% of the total Mg was leached from the biochar in six extractions, indicating that much of the Mg was rendered unavailable by pyrolysis. These results indicate that these three elements have different solubility and adsorb differently to the biochar, perhaps at different locations within the biochar structure.