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Biochar production and new products

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Innovative gasification plant for renewable energy micro-generation and biochar production

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Key words: *Gasification, Biochar, Bioenergy*

Introduction

Gasification is a thermo chemical conversion process in which a biomass or other different organic matrices are partially oxidized by heating at high temperatures (1.200°C) in a gas (syngas) and biochar [1].

The syngas, a mix of carbon monoxide and dioxide, hydrogen, methane and nitrogen, is used to power a diesel-cycle endothermic engine in order to produce electricity and heat or, alternatively, as fuel for multiple uses.

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.

Results and Discussions

The AGT researchers have developed a fixed-bed, down-draft, open core, innovative gasifier, which allows to obtain – through low-oxygen combustion – syngas and biochar from organic matrices of different origin.

The presence in the syngas of not combustible particles, as CO_2 and N_2, gives the mixture a low heating value: ≈ 5 MJ/Nm^3.

The gasifier, which has 300 kW nominal electric capability (micro-generation), mainly uses biomass deriving from agricultural feedstock and its by-products.

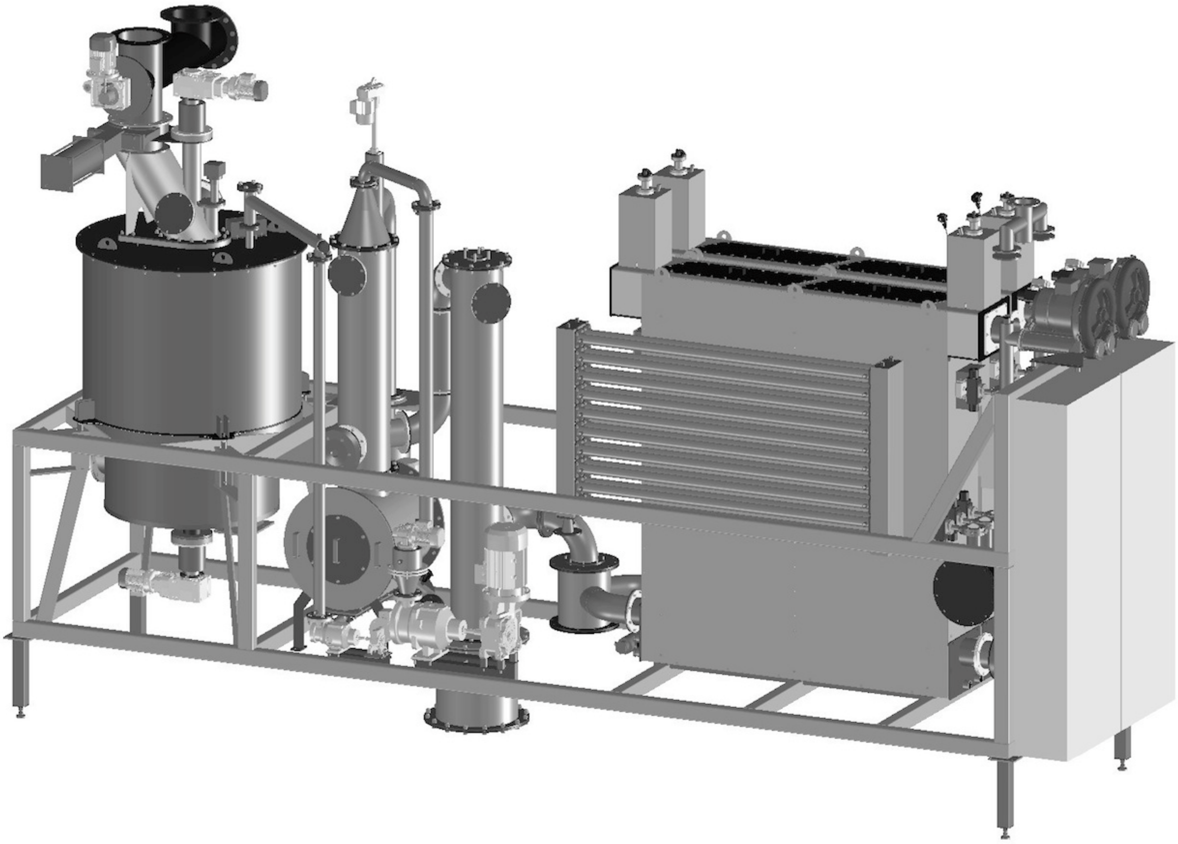

Figure 1. AGT gasifier drawing

The plant is presented in a groundbreaking and efficient way, unique both for the extreme compactness of the gasifier (little more than 10 m^2), the gas cleaning system (by electrostatic filters), the flexibility in the employment of different biomasses and the easiness of management.

Considering woody biomasses, the electric performance is 1 $kWh_e\ kg^{-1}$ dry matter.

Table 1. Gasification plant main technical parameters*

Parameters	Values
Biomass typology	Wood
Biomass requirement	300 $kg_{(d.m.)}\ h^{-1}$
Electric rated power	300 kW
Thermal rated power	1.000 kW
Syngas flow	600 $Nm^3\ h^{-1}$
Syngas LHV	5 MJ Nm^{-3}
Syngas starting temperature	700°C
Syngas final temperature	50°C
Biochar production	10% $w/w_{(d.m.)}$

*Considering woody biomasses

The plant in standard configuration is made up of a gasifier, a drying kiln/feeding hopper and two or three generators; additional accessories are added in order to reach the full automation of the system.

The plant does not generate emissions: TAR, obtained from syngas cleaning, is carried back to the gasifier reactor and quickly eliminated; engines exhaust gas is cleaned in a catalytic converter and then sent to the dryer for biomass conditioning, where it is further bio-filtered; no draining is generated.

The gasification process creates a fine-grained, highly porous pollutant-free charcoal that may significantly vary in its chemical and physical properties depending on starting material.

The system generally produces a quantity of biochar comprised between five and ten percent of starting material (d.m.), depending on biomass typology and characteristics.

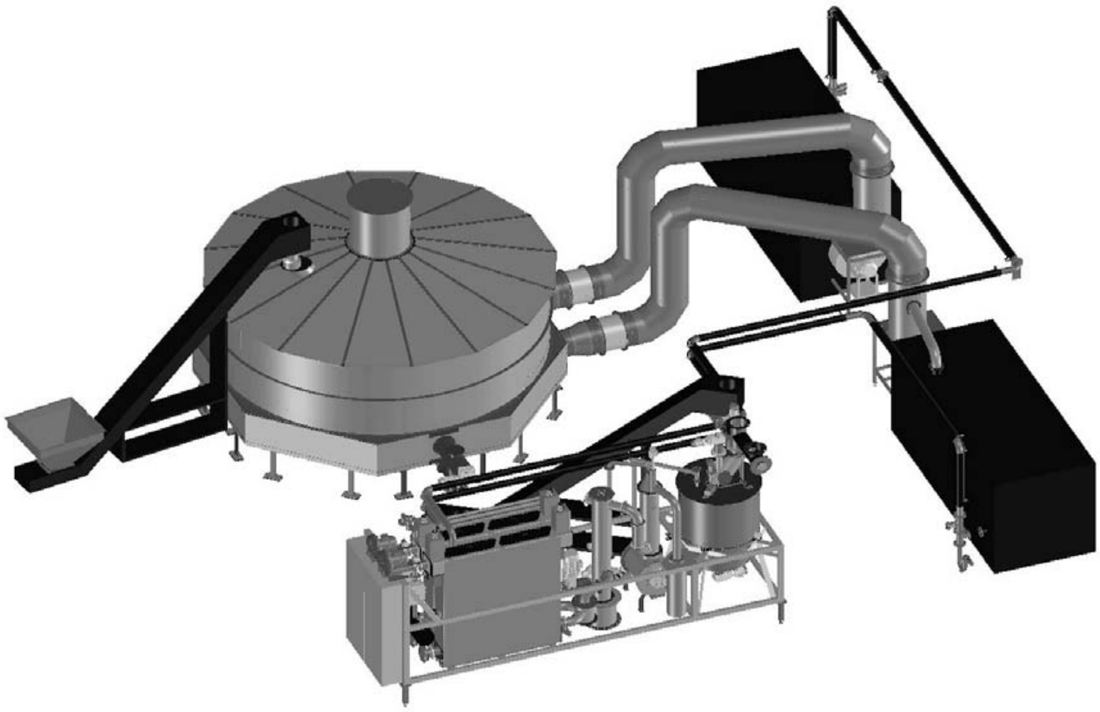

Figure 2. AGT gasification plant lay-out (gasifier, drying kiln/feeding hopper, generators)

Conclusions

The plant puts forward as a candidate in offering a profitable environmental solution: bioenergy may contribute to securing a supply of green energy, biochar can be an important tool to increase agricultural productivity and to stock carbon in the soil.

The plant, thanks to its applications (energy and biochar), can be also considered an opportunity of development for degraded and poor marginal lands in low-income countries.

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[1] Dumbleton, F. 1997. *Biomass conversion technologies: an overwiew*, *Aspects of Applied Biology, 49: Biomass and Energy Crops*, 341-34.

Use of biochar as bulking agent for the composting of poultry manure: effect on organic matter degradation and humification

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Key words: *humic substances, maturity, waste organic*

Introduction

Biochars have been traditionally used as soil amendments because of their potential benefits to soils (1;2). More recently, their chemically stable structure and slow degradation rate has attracted the interest as a potential C sink (3). Despite the potential benefits associated to the agricultural use of biochar, a there is only limited amount of information regarding the use of this material as bulking agent for composting, and on its effect on organic matter stabilisation and humification during the process (4). The aim of this study was to evaluate the use of biochar a bulking agent for poultry manure composting.

Three composting piles were prepared by mixing poultry manure with biochar in a proportion of 1:1 (fresh weight). Biochar was obtained by slow pyrolysis of wood of Eucalyptus grandis in a kiln operating at atmospheric pressure and a temperature range varying from 300 - 450°C. One representative sample was collected at 0, 30, 60, 120, and 210 days of composting by piles six subsamples taken from different locations in the pile.

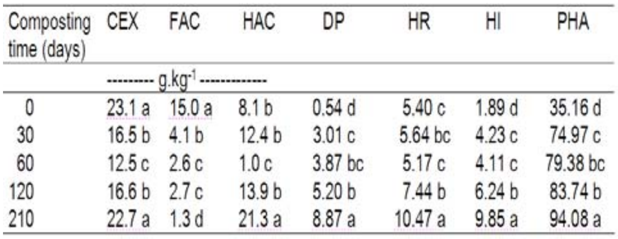
The total extractable C (CEX) was measured on a 1:20 (w:v) 0.1 M NaOH extract and fulvic acid C (FAC) was determined after precipitation of the humic-like acids at pH 2.0 (5); the humic acid carbon (HAC) was calculated by subtracting the fulvic acid carbon (FAC) from the extracted carbon (CEX). The following humification parameters were then calculated (5): humification ratio (HR) = (CEX/TOC) x 100; humification index (HI) = (HAC/ TOC) x 100; percentage of humic acids (PHA) = (HAC/EXC) X 100; and degree of polymerisation (DP) = HAC/FAC.

Data were subjected to univariate ANOVA and treatment means were compared using the Tukey test at $P \leq 0.05$, using the SPSS version 15.0 statistical package for Windows.

Results and Discussions

The evolution of the concentrations of the total extractable C (CEX), humic acid C (HAC) and fulvic acid C (FAC) during the composting process is shown in Table 1. The concentration of HAC increased significantly during the composting process for the PMB mixture from 8.1 g kg^{-1} in the initial phase of process up to 21.3 g kg^{-1} in the mature compost. The FAC content was reduced during the initial phase of composting, probably due to the microbial degradation of soluble compounds, and remained almost unchanged until the end of the process. In the PMB mixture, the increasing trend in the amount of CEX was due to the increase in the concentration of HAC, reflecting the degree of humification and maturity achieved by the mature compost (6).

Table 1. Humification indexes for during composting process.



Composting time (days)	CEX	FAC	HAC	DP	HR	HI	PHA
	--------- $g.kg^{-1}$ ------------						
0	23.1 a	15.0 a	8.1 b	0.54 d	5.40 c	1.89 d	35.16 d
30	16.5 b	4.1 b	12.4 b	3.01 c	5.64 bc	4.23 c	74.97 c
60	12.5 c	2.6 c	1.0 c	3.87 bc	5.17 c	4.11 c	79.38 bc
120	16.6 b	2.7 c	13.9 b	5.20 b	7.44 b	6.24 b	83.74 b
210	22.7 a	1.3 d	21.3 a	8.87 a	10.47 a	9.85 a	94.08 a

CEX: Extracted Carbon; FAC: Fulvic acid carbon; HAC: Humic acid carbon; DP: Degree of polymerization; HR: Humification ratio; HI: Humification index; PHA: Percentage of humic acids. Columns sharing the same letters do not differ significantly according to mean separation by Tukey tests at probability level $P < 0.05$.

Changes in the concentration of the alkali extracted fractions usually depend on the origin and chemical composition of the composted material, which may limit the validity of these fractions as indicators for comparing the maturation in different composting matrices.

The HR index increased during the composting, as a consequence of the increase in the proportion of alkali soluble carbon, reflecting the intense humification underwent by the organic matter. This increase was more intense at the end of composting, during the maturation phase. The increase of PHA and DP in mixtures PMB reflected the large increase of the HAC fraction. The use of biochar as bulking agents has favored the synthesis of more condensed molecules (HAC), rather than the fulvic acid molecules (FAC). The HAC fraction represented 94% of CEX. The high PHA may be related to the chemical composition of biochar, which is composed of a high proportion of condensed aromatic structures (7). The small size aromatic cluster formed during the degradation of biochar may have been incorporated into the structure of the humic acids.

The use of the biochar as bulking agents in the composting piles promoted an increase in the HAC fraction and in the humification indices (Table 2). The increase in humification index for PMB may be related to water-soluble carbohydrates and phenols in the humic structure, since these substances are precursors of humification processes (8). There was a highly significant correlation between the carbohydrate fraction and the HAC/CEX

Table 2. Correlation between water-soluble carbohydrates and phenols and different humification indices during composting time.

	HAC/TOC	HAC/CEX	HAC/FAC
Carbohydrates	NS	-0.930**	NS
Phenols	-0.732*	-0.974**	NS

NS – not significant; **,* - significant at a probability level of $P < 0.01$ and $P < 0.05$ respectively.

There was a highly significant correlation between the carbohydrate fraction and the HAC/EXC index in PMB, in the case another important contribution to the humification pathways may be related to its chemical composition. There was a significant increase of the HAC fraction during the process, because of the incorporation of aromatic fractions into the humic structures (9). During the formation of the biochar, lignin is broken into its building blocks, generating free radicals that regroup and reorganize, into highly aromatic final products (7).

Conclusion

The chemical nature of the organic matter of the poultry manure-biochar mixture is characterised by an enrichment of humic acids in relation to the fulvic acid fraction and by the presence of humic-like substances with the highest degree of polymerisation.

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[1] Chan, K.Y.; Zwieten, L. Van; Meszaros, I.; Downie, A.; Joseph, S. 2007. *Aus. J. Soil Res.* 45, 629-634.

[2] Steiner, C.; Teixeira, W.G.; Lehmann, J.; Nehls, T.; Macêdo, J.L.V.; Blum, W.E.H.; Zech, W. 2007. *Plant Soil.* 291, 275-290.

[3] Lehmann, J. A handful of carbon. 2007. *Nature.* 447, 143-144.

[4] Hua, L.; Wu, W.; Liu, Y.; Mcbride, M.B.; Chen, Y. 2009. *Env. Sci. Poll. Res.* 16, 1-9.

[5] Sánchez-Monedero, M.A.; Roig, A.; Cegarra, J.; Bernal, M.P. 2009. *Bio. Tech.* 70, 193-201.

[6] Tiquia, S.M.; Tam, N.F.Y. Fate . 2000. *Env. Poll.* 110, 535-541.

[7] Trompowsky, P.M.; Benites, V.M.; Madari, B.E.; Pimenta, A.S.; Hockaday, W.C.; Hatcher, P.G. 2005. *Org. Geoc.* 36, 1480-1489.

[8] Stevenson, F.J. *Humic chemistry: genesis, composition, reactions*. 1999. 2. ed. New York, p, 496.

[9] Czimczik, C.I.; Preston, C.M.; Schmidt, M.W.I.; Werner, R.A.; Schulze, E.D. 2002. *Org. Geoc.* 33, 1207-1223

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Biochar Industry Risk Assessment

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Key words: *Risk assessment, Biochar,* hazard identification

Introduction

Biochar technology has been identified as a geo-engineering solution that has potential to actively reduce the atmospheric concentrations of greenhouse gases and enhance the sustainability of agriculture. However, the risk and reward profile associated with implementing various forms of the technology needs to be assessed and communicated to the global community as industry moves toward commercialisation. The magnitude of the technology's net benefit is only relevant when considered in the context of its associated risks. Measures must be applied to manage identified risks, to ensure the sustainability and viability of the emerging biochar industry.

Hazards associated with biochar technology must first be identified in order for their severity and probability to be quantified, so that the scale of the risks they pose, and therefore the level of management and regulation required to mitigate these risks, can be determined. Mitigation of the risks identified is achieved through the introduction of a barrier that prevents the hazard causing an incident of harm. The barrier may be direct, such as the physical installation of air pollution control equipment or safety guards, or indirect, such as regulation dictating eligible biomass sources.

The discussion is intended to identify key considerations that should be included by researchers conducting lifecycle assessments (LCAs) of biochars, and industry participants undertaking biochar project risk assessments. This paper will initiate discussion for policy makers who are seeking to develop appropriate standards, and certification schemes to oversee and direct the implementation of biochar systems both at local and international levels. The aspects identified in this assessment will provide guidance for legislative frameworks so that they may provide effective coverage of biochar. It may also prove useful for those designing accreditation requirements for carbon offset schemes (voluntary or regulated) under which biochar offsets will be offered as a quality-assured product.

Results and Discussions

The biochar concept, for the purpose of this risk assessment investigation, has been divided into three key stages: biomass feedstock sourcing, conversion technology, and biochar product utilisation. Analysis of the risk assessment strategies that can be applied to each of these stages will be discussed with a focus on identifying the possible risks presented and reviewing management methods that may be effective at mitigating these risks.

Biomass feedstock sourcing for biochar projects should consider the risks posed by non-sustainable and competing uses of biomass. There is a risk that the biomass required for biochar production will not be sourced in a sustainable way, leading to negative environmental, social and economic consequences. It is essential that the complete process chain of the biomass, including the production, harvest, transport, pre-processing, in comparison with alternate uses, be considered in order to assess the true net benefit of the biochar pathway.

Pyrolysis feedstocks may contain contaminants, such as chemical and biological pollutants, that pose environmental and/or health risks. Municipal wastes are examples of biomass resources that exhibit contaminant risk. To mitigate the risks associated with feedstock contamination it is recommended that sources of potential contaminants be identified and analysis procedures established as an industry standard.

The assessment of conversion technology considers engineering controls, regulatory controls, energy efficiency and emissions. Process engineering principles are used in the design and operational optimization of industrial biochar production facilities. These principles employ several industry standard methods to identify and manage the technical, environmental, health and safety risks posed. The risks posed by elevated temperatures (e.g. hot surfaces and exhausts), mechanical moving parts, vehicle movements, the generation of gases with significant explosion potential, etc. pose human workplace health and safety concerns. These can, and should, be addressed through engineering controls.

Regulatory controls are a proven mechanism for risk mitigation in process industries.

Technology being implemented, especially if it is at a commercial scale (i.e. not home use applications which process typically < 5t biomass/day), will be required to meet the relevant local jurisdiction's planning, consenting, and licensing requirements. Assurance challenges arise when developing biochar technologies fall outside of existing regulatory mechanisms. This may occur with small, mobile operations, which may fall below the threshold for coverage set by regulatory authorities. Alternatively this may occur, with larger operations in countries where environmental regulations are not legislated or are not enforced.

Biochar utilization risk assessment considers storage, transport and handling issues along with the implications of using biochar as a soil amendment. An assessment of whether the biochar product is suitable for use as a soil additive and poses no environmental or economic (through loss of production) risks requires analysis on a case-by-case basis. The range of biochar properties, especially contaminant levels, mean that some are well suited to grow plants for human consumption, whereas others are only suitable for use in forestry or mine rehabilitation applications.

Where product is unsuitable for land application, for example due to heavy metal contamination, landfilling may be the best way to sequester biochar carbon while minimising risk of environmental harm.

It is recommended that the biochar industry establish quality control guidelines outlining rigorous monitoring of all elements identified as posing a risk. A certification mechanism may also be implemented by the industry to provide confidence to consumers that such risks have been adequately mitigated, and that the product can be used without concern.

Conclusions

Effective risk assessment processes should ensure that biochar technology has a positive impact on the environment, with direct social and economic benefits. To ensure the ongoing sustainability and viability of an emerging biochar industry a fully informed and debated review of risks and rewards should be encouraged.

The use of biochar for environmental management is a growing area of scientific and commercial interest. International cooperation, regulations, certification and accreditation mechanisms must be utilised to manage risks of negative environmental and social impacts from biochar production and use.

Acknowledgements

This abstract is an extract of a full-length paper that has been accepted for publication by *Critical Reviews of Environmental Science and Technology*. Readers are encouraged to access the full paper and use it for reference purposes.

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Ecotoxicity of functionalised Biochar – A case study

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Key words: Biochar,Toxicological tests, Fulvic Acids

Introduction

The term Biochar is used to name the charcoal obtained from the pyrolysis of biomass at temperatures generally lower than 700 °C and in environments with little or no supply of oxygen (O_2). This charcoal is produced to be applied on the soil in a deliberate manner.

In the environment, biological and chemical processes occur, altering the Biochar and generating a new compound where carboxyl groups are directly connected to the charcoal recalcitrant aromatic structures.

This final compound improves the chemical, physical and biological properties of the soil. However, this modified charcoal may take decades to be formed in nature.

Due to this, we are trying to obtain it through the chemical functionalisation of charred material. The chemical functionalisation is a process in which activated charcoal is subjected to a chemical treatment to acquire carboxylic groups linked to recalcitrant aromatic structure. However, besides the chemical and agronomic evaluation of this product, the risks that this product may present to the environment must be analysed.

The toxicological risks of a specific pollutant to the aquatic community can not only be determined through chemical analysis of water and sediment. These analyses alone will not evaluate the toxicity of the pollutant to organisms. Therefore, ecotoxicological tests have been proposed and implemented, to understand and to observe the responses of the organisms, inhabiting the areas of study, to different pollutant concentrations [1].

So, the objective of this study is to demonstrate the use of this methodology to assess the acute toxicity of a soil conditioner prototype derived from the chemical functionalisation of Biochar.

In this experiment, *Daphnia similis*, a planktonic freshwater microcrustacea (Figure 1), was used as bioindicator. The cultivation of the organisms was carried out in basic medium M4. The third generation neonates were used on susceptibility tests with potassium dichromate. The cultures of *D. similis* were kept in an incubator chamber of biochemical oxygen demand (BOD), at temperature of 20 ± 2 °C, under a light intensity of 1000 lux and a photo period of 16 hours of light. The animals were kept in glass crystallisers of 2 L with conductivity of 160 uS cm^{-1}, hardness of 180-200 mg L^{-1} $CaCO_3$ and oxygen above 80% saturation, following the method of cultivation [2, 3].

The median lethal dose with 48 h of exposure (48 h LC50) was calculated using the Probit statistical method. The experiment was conducted two times, each with three replications, using six concentrations (0; 3; 6; 12; 24; 48 and 70 mg L^{-1}) of fulvic-like fractions (the fraction that are soluble in aqueous solution at any pH) obtained from activated charcoal chemically functionalised.

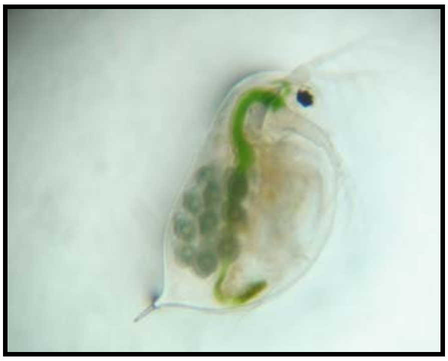

Figure 1. *Daphnia similis* in adulthood (40X magnification)

Results and Discussions

The average values for the reference tests with an aqueous solution of potassium dichromate showed 24 h LC50equals 1.47 mg L^{-1}. This result guarantees the feasibility of the study with the organism *Daphnia similis*, considering that they are within the range established as acceptable, it means, between 0.9 and 2.0 mg L^{-1}.

The value obtained with the aqueous solution of fulvic acids for the 48 h LC50 was 21 mg L^{-1}, with upper and lower limits of 32 and 20 mg L^{-1}, respectively, which classifies the material tested as moderately toxic.

In the analysis of TOC, we obtained values of 190.8 mg L^{-1} of total carbon, 1.25 mg L^{-1} of inorganic carbon and consequently, 189.5 mg L^{-1} of organic carbon.Thus values were used to convert the values oftoxicity. After converting it , 48 h LC50 values for *Daphnia similis*, turned out to be 7.28 mg L^{-1} for total carbon.

Conclusions

The results obtained, proved that *Daphnia similis* is a good bio-indicator to water pollution. It also showed that ecotoxicological tests are good to set the limits of substances in water; allowing to do appropriate corrections as well as to monitor the aquatic ecosystem.

With it this study showed the utility of toxicological tests to assess these new products, not only to meet legislation but especially to be coherent with the main objective of this research, which is environmental preservation and mitigation of anthropic activity.

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[1] Vigano, L.; Arilio, A.; Falugil, C.; Melodia, F.; Polesello, S., *Mar Poll Bull*, **2001,** 10, 887-894.

[2] CETESB - Companhia De Tecnologia De Saneamento Ambiental. São Paulo, **1991**, 17. (Apostila).

[3] ABNT - Associação Brasileira de Normas Técnicas. São Paulo, **1987**, (Proj. Norma), 31.

Comparison of wet digestion and dry ashing methods for total elemental analysis of biochar

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Key words: *ICP-AES, open vessel, borosilicate glassware*

Introduction

Quantification of biochar elemental content can inform effects on soil health and fertility [1] as well as losses during pyrolysis. Analysis of total elemental content can be accomplished with ICP-AES, but requires complete dissolution into a liquid matrix [2,3] and decomposition of organic matter that may affect analysis [4]. Numerous methods have been proposed to prepare plant samples for elemental analysis [5]. Dry ashing is simpler and safer than wet digestion methods, however, the high temperatures employed may introduce error due to volatilization [3] and yet remain insufficient to decompose pyrolytic organic materials [6,7]. Wet digestion methods operate at lower temperatures but employ potentially dangerous inorganic acids [8]. Biochar recalcitrance may resist decomposition by strong oxidizers [9,10]. The purpose of this paper is to identify safe, reliable, and accessible biochar preparation methods for total elemental analysis by ICP-AES.

Materials and Methods

Three biochars were chosen with contrasting properties: (1) corn stover pyrolized at 300°C (Corn300), (2) oak wood at 600°C (Oak600), and (3) poultry manure with sawdust at 600°C (Poultry600). Published wet digestion (PWD) and published dry ashing (PDA) methods for plant tissue, modified wet digestion (MWD) and modified dry ashing (MDA) methods to accommodate biochar recalcitrance, and a perchloric and nitric acid wet digestion (PNW) were used to decompose samples for ICP-AES analysis.

Results and Discussions

MDA was either the most precise method, or demonstrated relative standard deviation (%RSD) within 3.7% of the most precise method, for recovery of K, S, Ca, Mg, Mn, and Zn from Corn300 and Oak600.

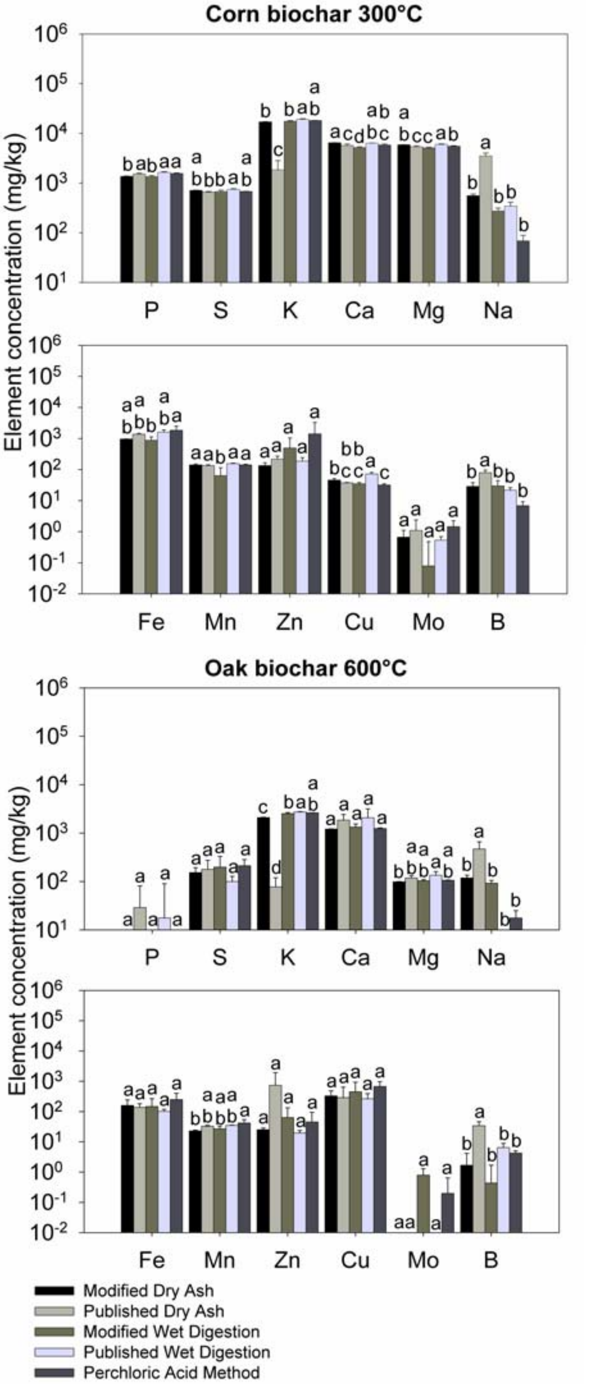

Figure 1. Total nutrient contents of corn stover biochar produced at 300°C and oak wood biochar at 600°C obtained by different digestion methods.

Additionally, MDA was the most precise method for P and Fe from Corn300. Recovery of P, K, S, Ca, Mg, Fe, Mn, and Zn from Poultry600 was 10 to 100 times lower with PWD and PDA than when using all other methods. MDA returned lower levels of Ca than PNW, otherwise there were no differences in recovery of P, K, S, Mg, Fe, Mn, and Zn between PNW, MWD, or MWA from Poultry600. PDA returned significantly more Na than any method for Corn300 and Oak600, suggesting contamination from borosilicate glassware [11,12].

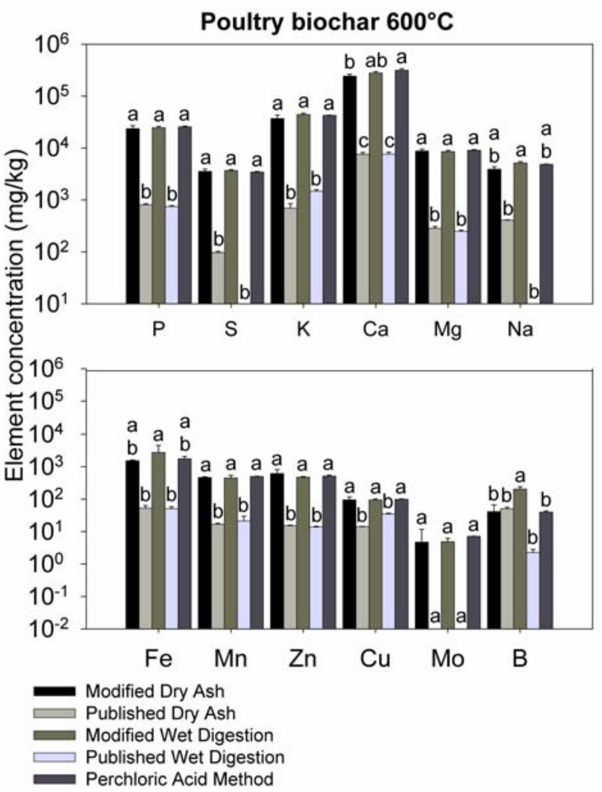

Figure 2. Total nutrient contents of poultry manure biochar produced at 600°C obtained by different digestion methods.

Conclusions

Trace elemental analysis would benefit from closed vessel methods that eliminate volatilization losses [13] or vitreous silica or platinum labware to reduce contamination [14].

MDA is a comparatively safe and effective method to prepare biochar for ICP-AES analysis of plant macro and micronutrients utilizing accessible labware and simple equipment.

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[1] Chan, K. Y.; Xu Z. H. 2009. In: Biochar for Environmental Management, J. Lehmann and S. Joseph (Eds.), Earthscan, Sterling, Va, pp. 67-84.

[2] Huang, C. L.; Schulte E. E. 1985. Commun. Soil Sci. Plant Anal., 16, 943-958.

[3] Ali, M. W.; Zoltai S. C.; Radford F. G. 1988. Can. J. Soil Sci., 68, 443-447.

[4] Wasilewska, M.; Goessler, W.; Zischka, M.; Maichin, B.; Knapp, G. 2002. J. Anal. At. Spectrom., 17, 1121-1125.

[5] Jones, J. B. 2001. In: Laboratory Guide for Conducting Soil Tests and Plant Analysis, CRC Press LLC, Boca Raton, Fl, pp. 203-207.

[6] Hsieh, Y. P. 2007. J. AOAC Int., 90, 54-59.

[7] Tartarelli, R.; Giorgini M.; Ghetti P.; and Belli R. 1987. Fuel, 66, 1737-1738.

[8] Oliva, S. R.; Raitio H.; Mingorance M. D. 2003. Commun. Soil Sci. Plant Anal., 34, 2913-2923.

[9] Masiello, C. A. 2004. Mar. Chem., 92, 201-213.

[10] Hammes, K.; Schmidt, M. W. I.; Smernik, R. J.; Currie, L. A.; Ball, W. P.; Nguyen, T. H.; Louchouarn, P.; Houel, S.; Gustafsson, Ö.; Elmquist, M.; Cornelissen, G.; Skjemstad, J. O.; Masiello, C. A.; Song, J.; Peng, P.; Mitra, S.; Dunn, J. C.; Hatcher, P. G.; Hockaday, W. C.; Smith, D. M.; Hartkopf-Fröder, C.; Böhmer, A.; Lüer, B.; Huebert, B. J.; Amelung, W.; Brodowski, S.; Huang, L.; Zhang, W.; Gschwend, P. M.; Flores-Cervantes, D. X.; Largeau, C.; Rouzaud, J. N.; Rumpel, C.; Guggenberger, G.; Kaiser, K.; Rodionov, A.; Gonzalez-Vila, F. J.; Gonzalez-Perez, J. A.; de la Rosa, J. M.; Manning, D. A. C.; López-Capél, E.; Ding, L. 2007. Global Biogeochem. Cycles, 21, GB3016.

[11] Mizuike, A.; Iino, A. 1981. Anal. Chim. Acta, 124, 427-430.

[12] Morris, A. P.; Dosdale, T.; Knott, P.; Short, N. R. 1980. J. Non-cryst. Solids, 38, 539-543.

[13] Sturgeon, R. E. 2000. Commun. Soil Sci. Plant Anal., 31, 1479-1512.

[14] Zief, M. 1980. ASTM Spec. Tech. Publ., 708, 66-77.

3rd International Biochar Conference
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Progressing from Terra Preta de Índios to the Whole World

Effect of fertilizer produced from bio oil, nitrogen and biochar on maize growth

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Key words: *Pyrolysis, ammonia, sawdust*

Introduction

Agricultural production in Brazil is increasing due to growing demand for food, in response to this agricultural residues increase proportionally requiring a recycle practices to decrease economics and environmental debits, once residues are an abundant and cheap alternative to supply soil nutrients as a fertilizer and energy source. The overall objective of the proposed study is to produce bio-oil from agricultural wastes to produce two high added value slow release fertilizers.

Bio-oil produced from sawdust by fast pyrolysis at ±500° C, was submitted to thermochemical reactions with $(NH_2)_2CO$ (F1) and bio-oil with NH_4OH plus biochar (F2), both mixtures were reacted until powder formation [1]. The hypocotyls growth in maize seedling were monitored in mixtures of sandy and fertilizer additions equivalent to 1.2, 2.4, 4.0, 8.0, 16.0, 24.0, 32.0 e 40.0 t ha^{-1}, plus a treatment with sandy by itself.

Results and Discussions

Both fertilizers F1 and F2 are rich in N and K, Table 1.

Table 1. Elementary analysis of fertilizers F1 and F2

Elementos	F1 (g kg^{-1})	F2 (g kg^{-1})
Nitrogen (N)	96,1	27,8
Phosphorus (P)	0,01	0,09
Potassium (K)	66,6	720,0

The fertilizers were distinctly different from each other in their ability to growth maize ($p > 0.05$). The F2 had the greatest physiological development for maize seedlings. The best performance in seedling growth was 2.5 g kg^{-1} rate (equivalent to 4 t ha^{-1}), supplying 111 kg ha^{-1} of nitrogen and 2880 kg ha^{-1} of potassium to the plants, both above the recommended level for corn crop, it does not cause damage to plant development, since the F2 release N and K slowly to the soil solution. Although doses above 4 t ha^{-1} showed a depressing effect on seedlings development, Figure 1.

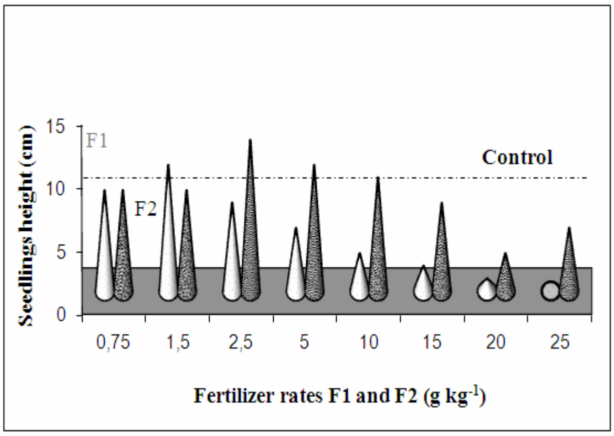

Figure 1. Fertilizers F1 and F2 responses on maize seedlings growth.

The F1 had its better effect on 1.5 g kg^{-1} doses (equivalent to 2.4 t ha^{-1}) providing levels of nitrogen and potassium, respectively 230 kg ha^{-1} 159 kg ha^{-1}, both higher than the recommended for corn production. Higher doses presented negative effect on seedling development, it probably happened because the process of F1 formation provide a fast bioavailability N and K to soil solution, becoming toxic to the plant.

Conclusions

Both fertilizers are nitrogen and potassium sources for plant nutrition. However F2 presented better development for maize seedlings than fertilizer F1.

Acknowledgements

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[1] Bridgwater, A.V.; Meier, D.; Radlein, D. An overview of pyrolyses fast for biomass, *Organic Geomestry*, v.3, p.1479-1493, 2000.

Artificial soil for earthworm growth: initial stage for chemical modification of charcoal by earthworm.

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Key words: *coal, biological transformation, artificial bed*

Introduction

Chemical modification of soil organic matter by earthworm activity is well known. In Brazil, charcoal fines are useless residues in many industrial processes, and their use as soil conditioner is a current topic of interest.[1]

Terra preta do índio (TPI) studies showed the presence of charcoal-like material in soils providing suitable conditions for high fertility in these soils and that knowledge was grasped by researches to promote a way for sustainable tropic agriculture. In fact, charcoal-like material detected in TPI is substantially functionalized when compared to an ordinary charcoal. These differences are thought to be caused by natural degradation of charcoal through the years.[2]

In order to produce functionalized carbon material from charcoal many chemical transformation studies have been conducted around the world. Biological transformation, such as that caused by earthworms in soils, is expected to yield a chemically modified charcoal, but no study has been conducted yet. In order to verify the potential transformation of charcoal by earthworm, some analytical questions must be considered, for example, the analytical technique to detected the chemical transformations from the original charcoal into a new biofunctionalized material.

In such context, a very simple soil matrix is desirable to the earthworm growth, since a complex soil matrix, with *e.g.* presence of natural organic matter, could difficult the comprehension about the origin of chemical transformations.

The present study evaluated the earthworm growth in an artificial soil with and without charcoal. The artificial soil matrix was manufactured as a mixture of sand (70%) , kaolin (20%) and coconut fibre (10%) with extra amount of charcoal (0%, control, 1.0%, 2.5% or 5.0%), sugars (glucose, and fructose), nutrients and vitamins.

Results and Discussions

After 30 days the corporeal ratio of initial mass and final mass (im:fm), mortality and coprolite yields were assessed. The earthworm mortality (20%) occurred only in the soil with 2.5% of charcoal. Neither statistical differences between mass ratio ($p<0.05$), nor variation of the earthworm masses during the experiment were observed. The coprolite yield was seen in all artificial soil, but slight difference was detected between treatments (variation less than 25%). The average yield for all treatments was 0,47 ± 0.10 g (Table 1).

Table 1. Assessed parameters during the experiment.

Charcoal (%)	corporeal ratio	mortality (%)	Coprolite (g)
0	0.95±0.18	0	0.53
1	0.93±0.33	0	0.33
2.5	1.03±0.20	20	0.54
5	0.98±0.11	0	0.46
Total	0.98±0.03	5±6	0.47±0.10

Conclusions

The artificial soils showed to be an excellent bed for earthworm growth, since any significant mortality was detected and the mass ratio was kept constant during the experiment. Chemical characterization of coprolite using Py-GC-MS is currently being performed.

Acknowledgements

This study was supported by the Embrapa and the Ministry of Agriculture of Brazil.

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[1] Lehmann, J. 2007. *Nature*, *447*, 143.

[2] Glaser, B.; Haumaier, L.; Guggenberger, G.; Zech, W. 2001. *Naturwissenschaften 88*, 37.

Biochar production via Low Temperature Conversion (LTC) technology using Thermocatalytic Loop Type Reactor

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Keywords: *LTC, animal meal, biochar, biofuels*

Introduction

New markets for the use of animal meal (AM) and meat and bone meal (MBM) in the EU are needed. One way to dispose of AM and MBM based on its high NCV of approx. 18 MJ/kg is combustion. As an alternative thermocatalytic conversion (Low Temperature Conversion; LTC), of AM and MBM at 400 °C in pilot scale is applied. Carbohydrates decay to water and carbon in form of graphite under certain conditions. The catalytic system is formed in situ from the trace element spectrum of the materials converted.

Results and Discussion

A vertically installed thermocatalytic loop type reactor (mobile unit) using a moving and heated char-bed (400°C) consisting of already produced solid residue was designed. AM and MBM are continuously fed into the reactor (1). Since decarboxylation of sodium salts from organic acids is a known chemical method to produce hydrocarbons, low temperature conversion of MBM and AM is performed in the presence of alkaline like ash from the incineration of wood. Products of this process are liquid and gaseous biofuels as well as a solid residue, which contains carbon and non-volatile compounds including metal phosphates. This solid LTC-product has a NCV of 12 MJ/kg and could be incinerated. But it deserves further investigation, since it can be used in a more appropriate and sustainable way. The solid LTC-product or biochar is a long-term carbon sink (carbon dioxide capture and storage; CCS). Moreover it is a natural resource of phosphorous (elemental analysis shows up to 9% P) and can therefore be used as a fertilizer for plant nutrition and soil improvement. There are no traceable proteins in the solid residue; consequently there is an already sterilized product available.

Table 1. Solid product's elemental composition and ash content

Elemental analysis	(%)
Carbon	32
Hydrogen	1.4
Nitrogen	5.6
Sulfur	0.2
Ash	58

The relation of the elements (Table 1) C, O and H are similar to black coal.

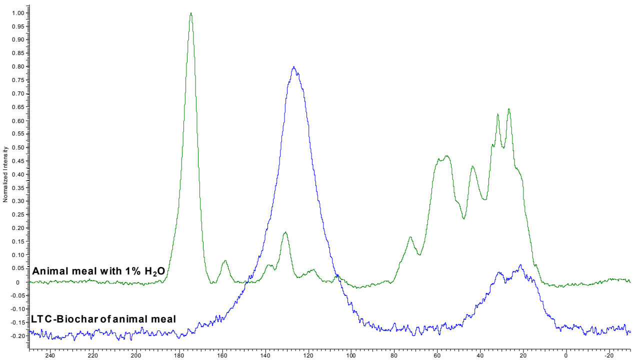

Figure 1. ^{13}C solid-state NMR spectra of both AM (above) and solid LTC-product of AM (below).

^{13}C solid-state NMR spectra show the elimination of peptide groups prevailing in the substrate. Main components of the product are non volatile ring structures such as sp^2-hybridized carbon compounds (Figure 1).

Conclusion

Organic wastes to fuels and renewable raw materials for chemical industry are of ecological and economical interest.

Acknowledgement

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[1] Final report HessenAgentur, LOEWE 146/08-08.

Soil Fertility Project (SFP) - Working with an NGO in Southern India

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Key words: *Biochar, Soil, Fertility*

Objective

This project aims to provide sustainable technologies to rural farmers in Tamil Nadu, Southern India, that will increase the quality and fertility of their soils using primarily agricultural and market waste.

Method

We are working in close collaboration with SCAD (Social Change and Development - www.scad.org.in), a large NGO/charity, which works with over 500,000 rural poor including 20,000 land-owning marginal farmers. SCAD also has technical colleges and an organic farming research facility that provides invaluable knowledge appropriate to the location. We have consulted a number of university faculties in the UK with particular help from Swansea and Bristol.

We believe that biochar, conditioned with fertiliser from anaerobic digestion, would improve the quality and productivity of the local soils whilst, at the same time, reducing the need for inorganic NPK. Feedstock surveys have been carried out to assess the amount of agricultural waste not used for composting, as well as wet vegetable waste from local markets. These surveys indicate that there need be no conflict with traditional agricultural practice, and the use of wet waste would help solve serious pollution problems in the towns.

Funding is already in place, and biochar production will start in December using a continuous updraft gasifier designed and manufactured in Australia by Black is Green Pty. A novel form of continuous and batch biodigester system, to provide nutrients and microbes, is being installed by Biotech a company in the neighboring state of Kerala. SCAD is entering a joint development agreement for the application of these units.

We are aware that the benefits of applying biochar to soil are not fully understood and a major part of the project will be to run extensive field trails in various locations throughout the region using the conditioned biochar. These trials will also be used to compare results with traditional composting techniques. However, we have become aware that scientific studies, however rigorous, are of little value if new practices conflict with the cultural and economic conditions of the villagers involved. This is where our two-year involvement with SCAD, on this project, has been of paramount importance.

History

In December 2007, after showing us his new pyrolysing 'Anila' cooking stove, we introduced Dr Ravi Kumar to SCAD, and subsequently over 100 stoves where manufactured and distributed among women's groups for evaluation. We soon discovered that it was not going to work as planned and we began to look for larger and more controllable pyrolysis units.

Over the next year many designs were tried and, alongside this work, we encouraged SCAD to begin field trials using charcoal from a local rice mill that was freely available at the time. In so doing we discovered that for the previous four years a local banana farmer had been using similarly sourced fine-grained charcoal around his banana seedlings obtaining spectacular results. He claims that yields have increased by up to 30%, the need for watering halved and his use of NPK cut by a third. Neighboring farmers have already started to adopt his practice.

Conclusions

The success of this project will not be achieved by statistics and graphs alone but by the farmers' and villagers perception that conditioned biochar increases the yield and quality of their crops. They will then spread the word.

Maybe, just maybe, some banana farmers in India can't be wrong!

Acknowledgements

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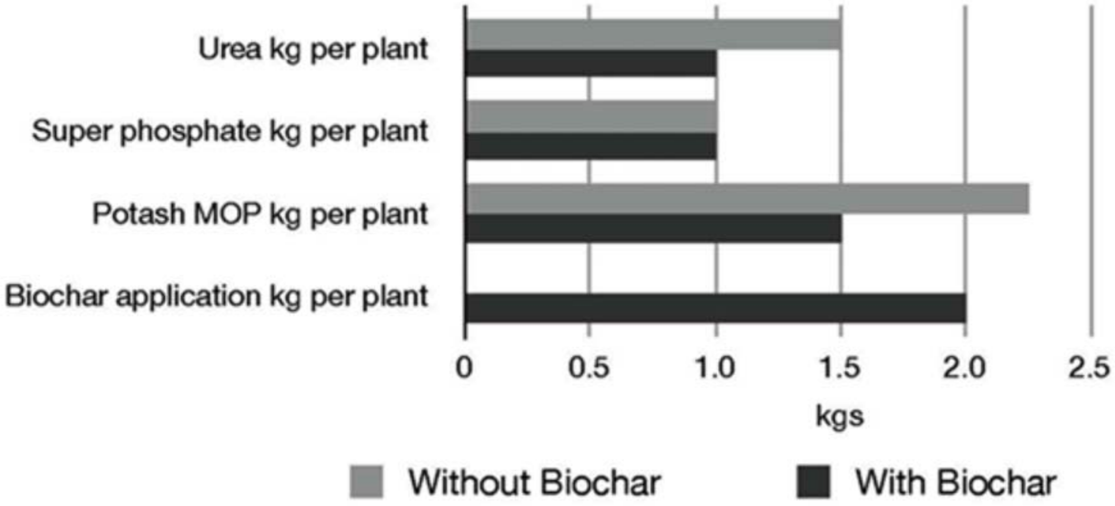
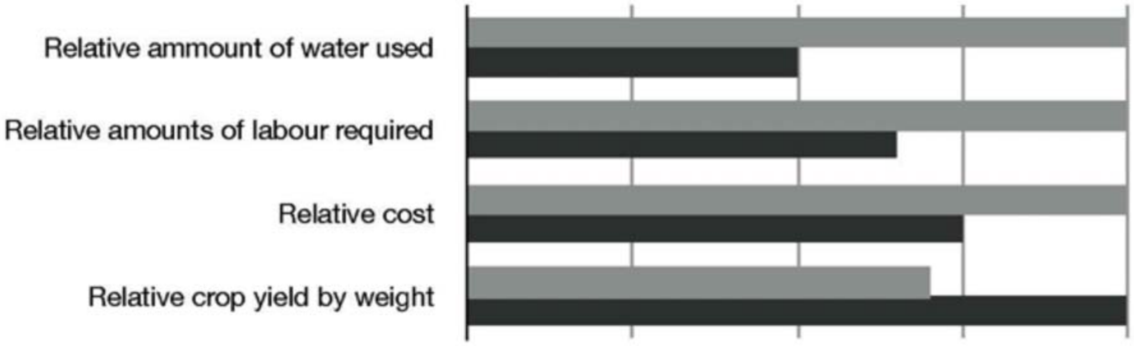
Soil Fertility Project, Bristol, United Kingdom

Farmer’s assessment of his own rice-husk charcoal application on banana plants
Author: Mr Pattu Murugeshan





Nitrogen adsorption on Biochar: a preliminary study

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Key words: *Biochar, Nitrogen, adsorption*

Introduction

Worldwide experiences show that the use of biochar could be a bioenergy source, partially avoiding global warming and positioning itself as a tool for promoting agriculture in unproductive zones. Biochar can improve water retention and nutrients availability in soils. In addition, biochar may be used as soil amendment, enhancing some of the chemical properties and improving their fertility. Also, Biochar could be used as support of nitrogen and phosphorous in controlled release fertilizer.

In this work, a preliminary study of a nitrogen source (NH_4Cl) adsorption on biochar is presented, adsorption kinetics and equilibrium isotherms to understand the effect of biochar on NH_4Cl release processes were studied.

Biochar produced by pyrolysis of *Acacia dealbata* wood and a commercial activated carbon, as blank for comparison purposes, were used in the adsorption experiments. Biochar was characterized by their chemical and physical properties.

Total organic carbon (TOC) and inorganic carbon (CI) were determinated by COT-CVSP analyzer. Total nitrogen (TN) was determined by Kjeldahl digestion (Organic Nitrogen) and, NO_2 and NO_3 by KCl extraction of the sample and selective ion determination. The ash and moisture content were determinate by loss of weight at 550 and 105 ºC during 2 h, respectively.

Specific surface area (S_{BET}) and pore volume (V_p) were determined by 1000 NOVA porosimeter. Finally, the particle size distribution was measured by SALD-3101 particle analyzer.

Results and Discussions

Biochar characterization is show in Table 1.

Table 1. Chemical and physical characterization.

chemical						physical			
CO %	CI %	COT %	NT %	ash %	H_2O %	pH	S_{BET} m^2/g	V_p cm^3/g	PS* mm
87	0.1	87.1	0.2	2.6	5.4	8.4	14.4	0.01	<1

*Particle size

As it show in Table 1 biochar has a high content of total carbon (TC), however, this composition does not depend only on the starting wood, also depends of the pyrolysis conditions employed. Specific surface area and pore volume of biochar used in this experiment are very low compared with activated carbon, up to 380 m^2/g and 0.2 cm^3/g for specific surface area and pore volume respectively [1]. Usually, the adsorption capacity of materials is proportional to surface area and pore volume.

The particle size distribution showed the distribution of the cumulative particle size in the sample of biochar, which was in the range between 1 and 1900 µm. Despite the heterogeneity in the particle size, the largest fraction is between 400 and 800 µm.

Once the biochar was characterized, the NH_4Cl adsorption kinetic was carried out. NH_4^+ adsorption kinetics showed an equilibrium at 2 and 1.5 hours for biochar and activated carbon, respectively. Additionally, after 2 h of treatment a marked desorption was observed in both substrates.

Despite of, the higher specific superficial area and pore volume of activated carbon, there were no significant differences regarding to NH_4Cl adsorption biochar, especially at lower concentrations. However, when higher concentrations of NH_4Cl were used activated carbon presented a 13% more adsorption capacity than biochar. This scare difference suggests that the structure of the activated carbon is mainly microporous, therefore is more difficult to the NH_4^+ molecules penetrate to the inside of the microporous structure.

Once the time to reach the equilibrium of the adsorption was determinated, adsorption isotherms of the NH_4Cl on biochar and activated carbon at various pH values were performed.

From these experiments the adsorption capacities for biochar and activated carbon are show in Table 2, indicating that biochar may act as a NH_4^+ adsorption material, eventually avoiding leaching processes and simultaneously promoting its slow release.

Table 2. Experimental adsorption capacities, q_i,(mg/g) of NH_4Cl on biochar and activated carbon, respectively.

q_i	biochar				activated carbon			
	pH				pH			
	4	6	6.7	8	4	6	6.7	8
q_1	0	0	0	0	0	0	0	0
q_2	16	-	-	-	9	22	13	-
q_3	73	167	192	108	70	153	204	140
q_4	39	300	384	292	170	307	411	260
q_5	357	445	543	362	152	504	610	364
q_6	574	667	541	463	322	412	651	415

As it can be observed in Table 2 the difference in adsorption capacity obtained for biochar and activated carbon is low, considering that biochar specific surface area and pore volume values are smaller than those of activated carbon. The effect of pH was significant for the adsorption process on both materials, showing the highest adsorption capacity at pH values around 6.

Experimental data were adjusted to Freundlich model for biochar and activated carbon (Table 3).

As it can be noted in Table 3 the experimental data were well adjusted to Freundlich model with correlation coefficient (R^2) values up to 99%. Therefore it can be concluded that for both types of materials present heterogeneous adsorption surfaces with sites with different energies.

Table 3. Langmuir and Freundlich parameters

sample	pH	Freundlich		
		k_f	1/n	R^2
Biochar	4	2.10	1.18	0.98
	6	6.99	0.97	0.98
	6.7	16.0	0.79	0.95
	8	4.12	1.04	0.96
activated carbon	4	1.47	1.15	0.97
	6	4.38	1.05	0.97
	6.7	12.8	0.87	0.97
	8	10.9	0.80	0.97

On the other hand, from the parameters calculated in Table 3, it can conclude for activated carbon the higher pH value increase adsorbent affinity (1/n). In the case of biochar a similar effect was observed stopping a pH 6.7. Regard this effect; it can suggest that higher pH values increase the Na^+ cations in the solution sample (due to the addition of NaOH to increase pH value), therefore, Na^+ cations would compete for adsorption sites in the adsorbent, nevertheless, other interaction it does not rule out.

Conclusions

Biochar of *Acacia dealbata* wood presented a lower pore size and specific surface area than activated carbon. Despite of, the high surface area of activated carbon, adsorption of NH_4Cl was not improved, most probably due to the small molecular size of this compound.

The Freundlich equation agrees well with adsorption isotherm of ammonia nitrogen onto biochar and activated carbon with different pHs under the entire concentration ranges studied.

Acknowledgements

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[1] Cheremisinoff, N.P., (1993), Carbon adsorption for pollution control. Prentice Hall (Eds.), Nueva Jersey, pp. 20-24.

Saccharides as raw material for biochar-like production

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Key words: *sugars, microwave, hydrothermal.*

Introduction

Many studies have been inspired by nature to discovery new materials or to obtain others that mimics natural processes. The abundance of saccharides in nature make them attractive to raise the value of a material or its functionality. Commonly the biochar is obtained from the transformation of biomass (carbon source) in coal-like material by thermal decomposition, resulting in the partial depolymerization of cellulose into smaller molecules and/or their repolymerization which could lead to a higher concentration of functional groups. This work was performed comparing three saccharides as precursor of biochar: glucose, cellobiose and α -cellulose. The biochar was produced using a microwave-assisted hydrothermal carbonization method (MAHC), once previous studies have shown that this process was effective in the production the biochar-like material. The MAHC of saccharides was performed at 180°C for 240 min in the presence of a catalyst reagent.[1] The carbonized materials were analyzed by ^{13}C NMR and scanning electron microscopy.

Results and Discussions

^{13}C solid-state NMR spectra confirmed the existence of functional groups (carboxyls, hydroxyls and aromatic groups) in the carbonized material at chemical shifts from 100 to 230 ppm, as well as the presence of oxygen-substituted protonated and non-protonated C=C bonds resonating at 150 ppm.[2]

Scanning electron microscopy micrographs showed the production of carbonized particles with submicron spherical shapes (with about 2.0 μm in diameter) for glucose, cellobiose and cellulose. However, the cellulose showed a tendency of agglomeration, indicating that carbon spheres were not as well formed as seen in the glucose and cellobiose materials. This feature was reinforced by existence of "neck" structures in the cellulose particles.

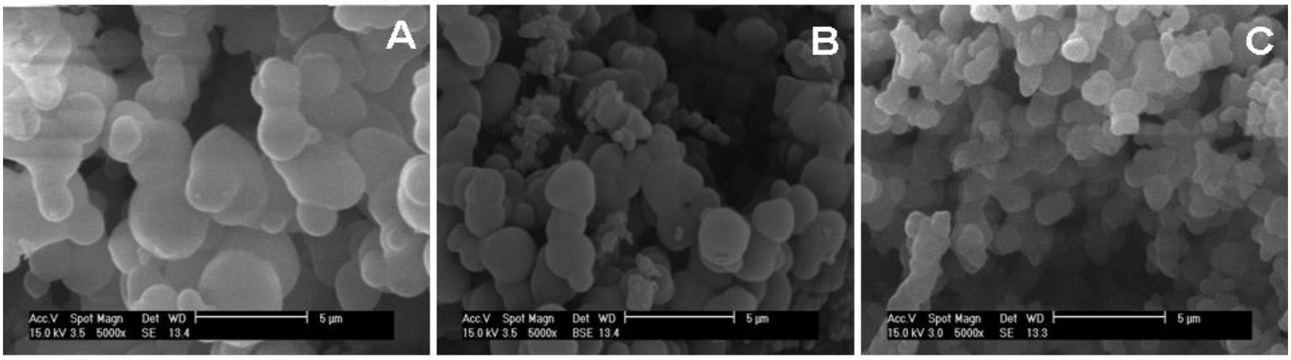

Figure 1. SEM micrographs of microwave-assisted hydrothermally carbonized saccharides (A) glucose; (B) cellobiose (C) and α-cellulose.

Conclusions

In resume, all saccharide sources yielded a chemically similar biochar-like material but with slight morphological differences. Further studies of carbonized materials are being carried on for their chemical structure characterization, properties and functional groups enhancing.

Acknowledgements

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[1] Guiotoku, M.; Rambo, C.R: Hansel, F.A.; Magalhães, W.L.E.; Hotza, D. 2009. *Materials Letters*, *63*, 2707.

[2] Baccile,N.; Laurent, G.;Babonneau, F.; Fayon, F.; Titirici, M.M.; Antonietti, M. 2009. *J. Phys. Chem. 113*, 9644.

3rd International Biochar Conference
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Progressing from Terra Preta de Índios to the Whole World

A comprehensive approach of using agricultural residues to substitute fossil fuels and producing biochar in a 3 MW pyrolysis plant

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Key words: *pilot plant, biochar, agricultural residues*

Introduction

Minimizing carbon dioxide emissions whereas keeping up the high living standard of today is only possible by increasing the efficiency of energy consumption and the change to a mix of renewable fuels.

Huge amounts of unused biomass in terms of agricultural residues like straw, that is a cheap and local feedstock, are often available. But as a reason of the high amount of corrosive ash elements (K, Cl, S, etc.), the residues are not suitable for co-firing in a thermal power plant. Therefore the feedstock is converted by low temperature pyrolysis into pyrolysis gases and biochar. The aim of this process is to hold the corrosive elements back in the char and to produce a high calorific pyrolysis gas that can be co-fired in the power plant.

The pyrolysis pilot plant is located in Dürnrohr/Austria just next to the coal fired power plant. The pilot plant is in operation since 2008. Figure 1 shows the flow sheet of the pyrolysis pilot plant.

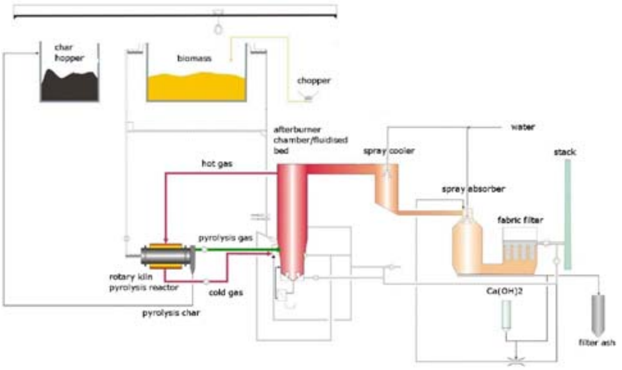

Figure 1. Flow sheet of the pyrolysis pilot plant.

The design fuel power is about 3 MW; the pyrolysis gas capacity is about 1.5 MW. Approximately 0.6 to 0.8 t/h straw, as the primary feedstock can be processed in the rotary kiln. The two most important components are the externally heated rotary kiln pyrolysis reactor, where the thermal decomposition of the biomass takes place, and the fluidized bed combustion chamber. A broad range of different agricultural residues have been under investigation.

Results and Discussions

For the balances, test runs with pyrolysis temperatures of 450, 500, 550 and 600 °C have been performed. An important part is the output of gas, oil and char for the different pyrolysis temperatures. For comparing the four operating points the energy and mass contents of those three fractions were each converted to the reference of the sum of the energy or mass contents of gas, oil and char.

It can be seen that by increasing pyrolysis temperature, the produced amount of pyrolysis gas increases significantly whereas the amount of char slightly goes back and the mass of pyrolysis oil is reduced heavily. This strengthens the already known fact that a higher pyrolysis temperature forces the production of gas at the expense of the formation of pyrolysis oil. The higher temperature causes the decomposition of oil to gas. Slightly less mass of char results in the fact more volatile compounds are used to be stripped due to higher temperatures.

Increasing pyrolysis temperatures cause a raise of energy delivered by pyrolysis gas and char and a drop of the energy delivered by pyrolysis oil. Most of these effects are caused by the different amounts of the products that are produced. A further reason is that due to different pyrolysis temperatures the chemical composition of the products is slightly different. So, at lower temperatures in the rotary kiln reactor there are more polyaromatic compounds with a high boiling point formed that have a high heating value.

In addition to the consideration of the energy and mass fractions of pyrolysis gas, oil and char the distribution of the chemical elements of the feedstock in pyrolysis gas, oil and char is also an important aspect. It is of major significance that the pyrolysis process is operated in a way that prevents the undesired components, which could lead to hot temperature corrosion in the boiler, to enter the gaseous pyrolysis products. Figure 2 shows the distribution of each chemical element in pyrolysis gas, oil and char.

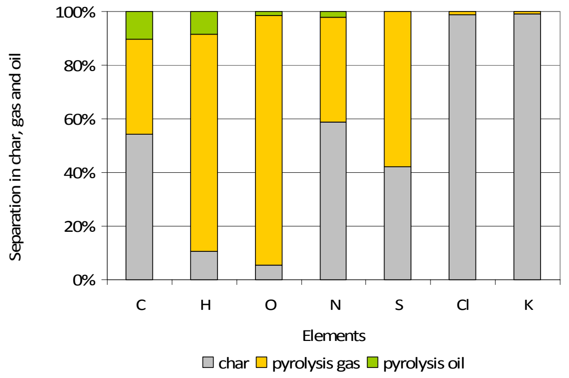

Figure 2. Separation of the chemical elements in the pyrolysis products for indoor stored straw at a pyrolysis temperature of 550 °C.

In the actual pyrolysis pilot plant there is the whole pyrolysis gas burned in the afterburner/fluidized bed. If the process would be used for producing burnable gas for co-firing, the thermal energy for the rotary kiln has to be produced externally. This could happen by firing a part of the produced gas in a separate combustion chamber, by firing straw or another feedstock in a fluidized bed combustion or extraction of hot flue gas from the coal fired power plant.

Some results of this balance concerning the energy of the streams are shown in the following Sankey-diagram (Figure 3).

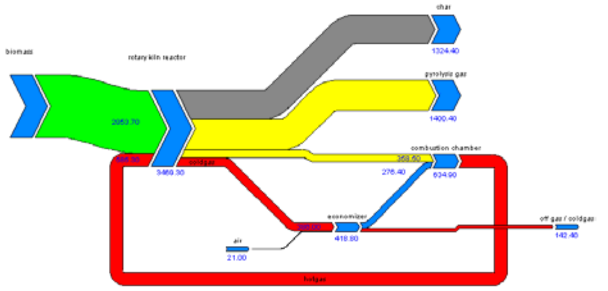

Figure 3. Sankey-diagram for straw pyrolysis for the case of energy supply by pyrolysis gas, energy flows [kW].

Conclusions

The most important reason for the construction and operation of the pilot plant was to gain fundamental information about the start of a pyrolysis plant that produces gaseous pyrolysis products that are suitable for co-firing at coal fired power plants. To keep as much of undesired components, like chlorine, potassium or sodium, back in the pyrolysis char to prevent the boiler from high temperature corrosion requires an intelligent process management of the pyrolysis parameters. This leads one to suspect that there is always a discrepancy between getting as much chemical energy from the feedstock to the gaseous products as possible and keeping the undesired components back in the char. But it has already been proven that the used process technology is proper for producing a gas, whose combustion products do not cause corrosion. It turned out that the operation, handling and control of the pilot plant, especially the pyrolysis reactor, can be done without serious problems with the current state of knowledge. The ruggedly designed rotary kiln reactor is also insusceptible for a contamination of the feedstock with soil or small stones. The pyrolysis char has a very high heating value and is nearly free of any water content. So the pyrolysis char is a very good fuel for combustion systems. The biochar could also be brought back to the fields where the feedstock came from. Biochar is excellently suitable for the improvement of soil. Due to certain reasons the biochar should not be used as fuel but for biosequestration and atmospheric carbon capture and storage. Using the pyrolysis char as reducing agent in the non-ferrous metallurgy is also under investigation. The char could also be used for providing the thermal energy to run the pyrolysis process. The plant efficiency is calculated for the case that the thermal energy that runs the pyrolysis process is provided by combustion of a part of the pyrolysis gas in a separate combustion chamber. The rest of the produced gas can be used in the power plant. In this case and for the pyrolysis of indoor stored straw a net efficiency of 0.48 would be reached. The Dürnrohr power station has an electrical efficiency of 0.42 [1] so if the pyrolysis process would be connected to the power station there would be an electrical efficiency of 0.20 for the generation of electrical energy of straw. This efficiency is significantly higher than the electrical efficiency of smaller biomass fired power stations or CHP.

Acknowledgements

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[1] Böhmer, S., Schindler, I., Szednyj, I., Winter, B., 2003, Stand der Technik bei kalorischen Kraftwerken und Referenzanlagen in Österreich, Wien, Umweltbundesamt GmbH, ISBN 3-85457-682-X.

Biochar from Biorefinery Residuals

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Key words: *Biochar, Miscanthus, Biorefining*

Introduction

The Carbolea Centre at UL is developing biorefinery processes for the production of levulinic acid, furfural, and formic acid from the acid hydrolysis of biomass (*Miscanthus*, sugarcane bagasse, etc.) in a medium pressure and temperature lab-unit reactor system. A bench scale (6 kg/h biomass throughput) fully-integrated continuous reactor was designed and assembled at UL. *Miscanthus* x *giganteus* was subjected to biorefining hydrolysis processes in 3% H_2SO_4. Solid biorefinery residual materials (ca 50% of the biomass) were recovered by filtration of the biorefining digest and subjected to pyrolytic processing at different reactor temperatures and at different hot vapour and solids residence times in order to determine the optimum processing conditions for the production of the biochar, bio-oil, and syngas pyrolysis products. A detailed characterization of the biochars and bio-oils was carried out and the efficacies of the biochars were tested for the promotion of plant growth and for uses as soil amenders. Biochars from *Miscanthus* x *giganteus*, pine, and willow were compared with those of the pyrolysed residuals from the biorefining of *Miscanthus*, and maize (*Zea mays* L) seedlings were grown on soil amended with 1% and 3% biochars.

Results and Discussions

The Scanning Electron Micrographs (SEMs, Figure 1) show that the cell structures in the plants are maintained upon pyrolysis at ambient pressure for 60 min at 600 °C, and with a surface area > 50 m^2g^{-1} (Table 1). At 20 bar the surface area was 1 m^2g^{-1}, the cell structures had collapsed and were clogged with tary residuals.

The data in Table 1 show that, under the same pyrolysis conditions, the surface area of the biochar materials from pyrolysis of the residuals was significantly greater (>300 m^2g^{-1}), and the data also show that the surface areas also increased as the pyrolysis time was increased. Yields of biochar were significantly greater for the pyrolysed residuals than for the original biomass, and the yields were not significantly influenced by the time of pyrolysis. The pyrolysed residuals had slightly increased C contents and lower N contents compared to the *Miscanthus* biochar.

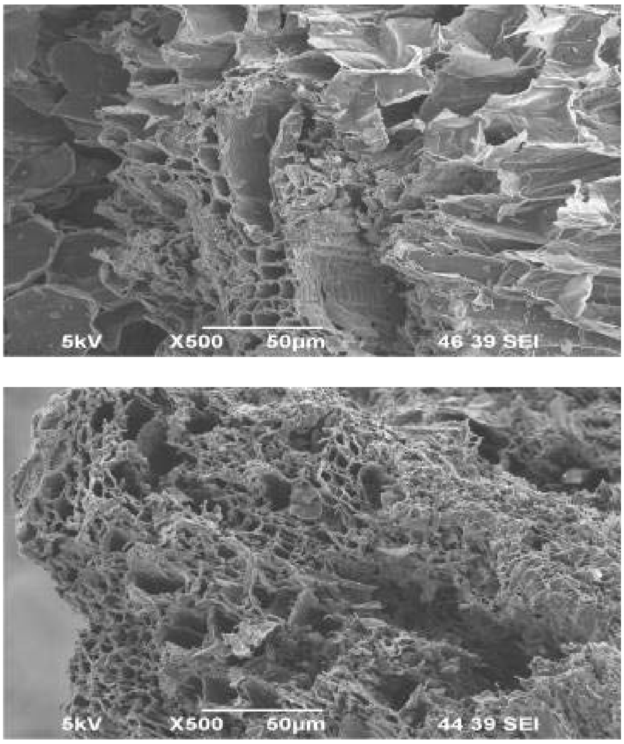

Figure 1. SEM of biochar from *Miscanthus* (top) and willow (botton).

Yields of maize seedlings, after 21 days, were enhanced by 50% when a shallow calcareous soil was amended with 3% of biochar from *Miscanthus*. However, yields from the biochar from the pyrolysed residuals were not significantly influenced by the products from pyrolysis for 10 and 60 min, but were depressed by the product from pyrolysis for 30 min (Figure 2).

Table 1. Yields and properties of biochars from different substrates and reaction conditions

Biochar Source	*Miscanthus*	Hydrolysis residue	Hydrolysis residue	Hydrolysis residue
Pyrolysis time, min	60	60	45	30
Temp (°C)	600	600	600	600
Yield of char (wg%)	19.8 – 20.2	52.41	53.041	53.35
Surface area, m^2g^{-1}	50.9-51.1	310.19	260.89	205.89
HHV, MJ kg^{-1}	31.5-32.5	27.72	27.86	27.88
C, wt.%	85.1	88.39	87.67	87.48
H wt.%	2.40	1.99	2.12	2.15
N wt.%	0.55	0.323	0.379	0.34

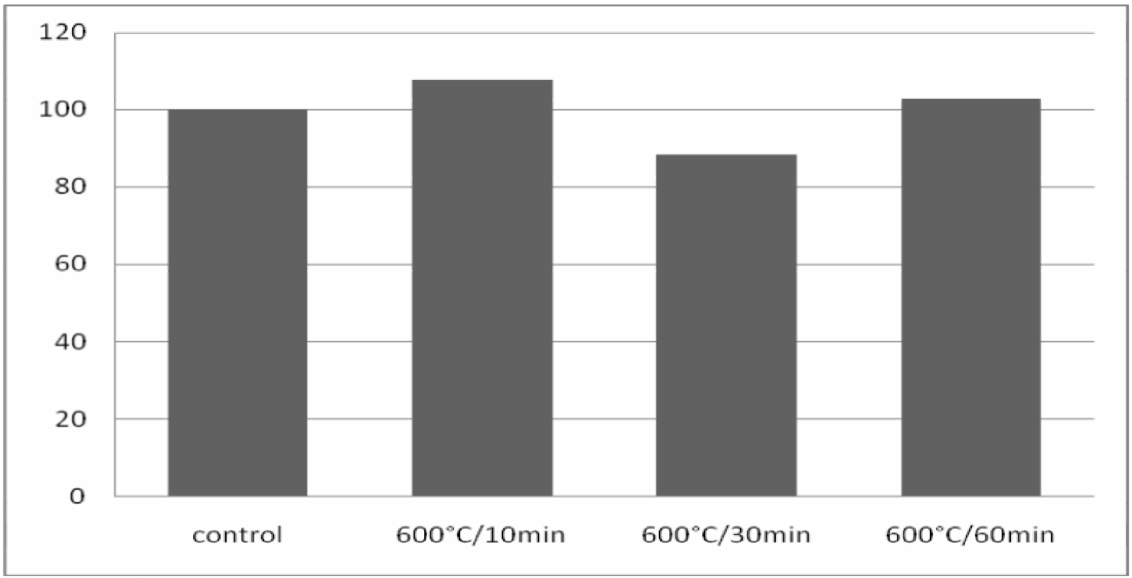

Figure 2. Yields of maize, relative to the control, after 21 days of growth

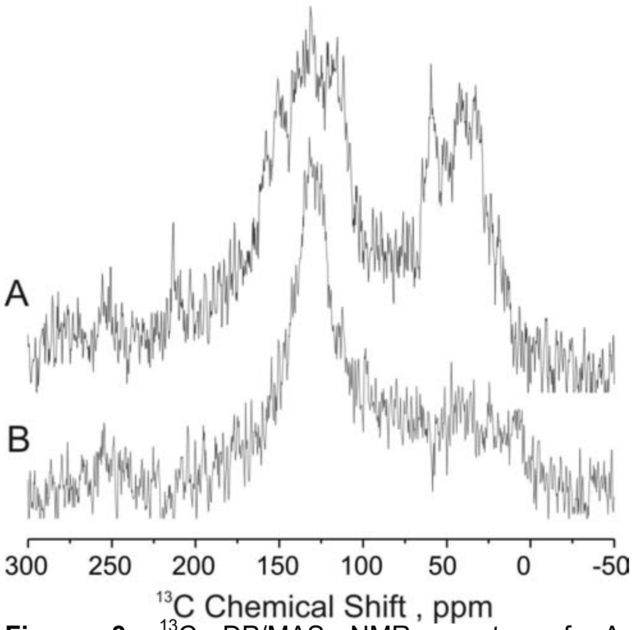

Figure 3. ^{13}C DP/MAS NMR spectra of, A, *Miscanthus* residuals, and B, pyrolysed residuals.

NMR spectrum (Figure 3A) shows that the carbohydrate in the residuals has been degraded/transformed, but the residuals still contain significant lignin and aliphatic hydrocarbon signals.

Conclusions

About 50% of the *Miscanthus* mass is recovered as residual materials in biorefining processes. On pyrolysis, over 50% of the mass of the residuals is retained as biochar. Yields of biochar from pyrolysis of the residuals from the biorefining of *Miscanthus* are significantly greater than those from the parent product, and have higher surface areas and C contents, but slightly lower high heating values (HHV) and N contents. The NMR evidence shows that the residuals from the biorefining process have lost their carbohydrate components (the objective of biorefining is to transform the cellulose and hemicelluloses of plants into platform chemicals).The NMR evidence also indicates that transformed lignin residues, and aliphatic hydrocarbon materials are major components of the residuals, and these are transformed into biochar products (fused aromatic structures)in the pyrolysis process.

Acknowledgements

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Progressing from Terra Preta de Índios to the Whole World

Intermediate pyrolysis for power generation from biomass and the utilization of biochar as a fertlizier

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Key words: *BtVB Process, plant nutrients, Soxhlet*

Abstract

The use of biomass as energetic as well as chemical resource is of high economic and ecologic impact for the future development of Europe. Beside the classical use of wood and straw, agricultural biogenic wastes are of high interest because of low costs and high availability [1]. The use of these material as an energy or chemical resource is challenging because of their special processing demands. Usually those materials have high ash content sometimes with ashes melting at very low temperature. One solution to process these materials is via intermediate pyrolysis/gasification to generate high quality and highly energetic, dust and tar free synthesis gases for direct CHP use. As a by-product biochar of high quality is realised, which contains almost all ash fractions of the biomass used. The process is called Biothermal Valorisation of Biomass (BtVB) [2]. It is a process proven in lab scale and ready for pilot and industrial application. Core technologies are the Pyroformer [3], a gasification unit and a (gas or dual fuel) engine. Within this BtVB process the products of the intermediate pyrolysis pyrolysis char and pyrolysis vapours are treated separately. The described process will offer new options for the usage of the pyrolysis char, acting as a real source for carbon sequestration and in addition closing the fertiliser loop for new biomass growth.

The pyrolysis char, containing all the ash of the biomass is brought back to agricultural sites. This so called black earth is not only a real carbon sequestration (not CO_2 sequestration) as the pyrolysis char consists of non bioconvertable carbon being stable for at least several thousand years. The second big advantage of the BtVB process is the re-fertilisation aspect. In bringing the pyrolysis char including all the minerals, back to the soil, the agricultural sites are re-fertilised, saving not only money but energy and CO_2.

Important is to realise a biochar suitable for this purpose. Intermediate pyrolysis turns biomass in a dry and brittle char without remaining smell. The char is very stable and can be pelletised easily.

To evaluate biochar as a fertilizer first investigations have been made concerning the water solubility of plant required nutrients from biochar to gain water based fertilizers for algae cultivations. Especially for the fast growing biomass microalgae the fertiliser topic is a key point in terms of the economy and of the ecology of the process. Fertilisers and their production are expensive and causes considerable GHG emission [4]. As microalgae have a high fertiliser demand they are expensive and CO_2 intensive to produce [5]. To avoid this dilemma, a cheap and CO_2 neutral way to recycle fertiliser is the extraction of the minerals out of biochar- the residue of biomass pyrolysis- as this char contains all the minerals of the pyrolysed biomass. Studies investigates the water solubility of mineral compounds from Chlorella vulgaris Beijerinck biochar in dependency of the different particle size fractions and different extraction times.

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[1] International Energy Agency, Biofuels for Transport – An international perspective (2004), OECD.

[2] Hornung, A; Apfelbacher, A., Carbon – Negative Power Plant GB 0808740.5.

[3] UK Patent Application, GB 2460156, (2009), A. Hornung, A. Apfelbacher.

[4] IFA, Global Estimates of Gaseous Emissions of NH_3, NO and N_2O from Agricultural Land, Rome 2001.

[5] FAO (1996), Manual on the production and use of live food for aquaculture.

Biochar as a raw material for supercapacitor manufacture

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Key words: *Biochar, Activation, Supercapacitor*

Introduction

World production growth and increasing urbanization have resulted in various effects for society including the production of large amounts of organic industrial and human wastes. These various carbon rich residuals include crop debris, biosolids, food and wood processing waste, etc. Biomasses are considered to be a very important feedstock for fuel manufacture in virtue of especially two facts: they are renewable sources and low cost materials. On the other hand, biomass processing plants and bio-oil refineries generate a lot of biochar, which is, in turn, is considered to be a waste of no economical value. The disposal/utilization of these residues has become an increasing problem and a growing expense for industry and society. To protect our natural resource base for the future, these residues should be converted directly into value-added products or into the precursors of such products [1,2].

This work demonstrates how a char derived from pine processing waste by pyrolysis can be converted by controlled physical activation with CO_2 into a value-added activated carbon suitable for fabrication of the electrodes for supercapacitors.

The activated carbon prepared from the pine processing waste by physical activation with CO_2 at 880 ^{o}C has been characterized by the following methods: BET surface area (liquid N_2, Autosorb 1), iodine number (ASTM D4607), acidity (Boehm titration [3]) measurements; ultimate chemical (Vario MICROcube), thermogravimetric (TA Q500) analyses; and X-ray photoelectron spectroscopy (XPS, Axis 165). Supercapacitor charge/discharge experiments and impedance measurements were performed with a Solartron 1255B frequency response analyzer.

Results and Discussions

The raw biochar had a surface area of 340 m^2/g and contained 83.7 weight % of carbon, 2.71% of hydrogen, 0.27% of nitrogen, and 0.18% of sulphur. The results of TGA presented in Figure 1 revealed the presence of volatiles in the raw material. To remove them, the sample was heated at 1000 ^{o}C, 2h in forming gas (FG, 5% of H_2 balanced with Ar) following by physical activation in dry CO_2. This preliminary heat treatment remarkably increased the surface area of the biochar but decreased the oxygen content and, therefore, acidity of the material.

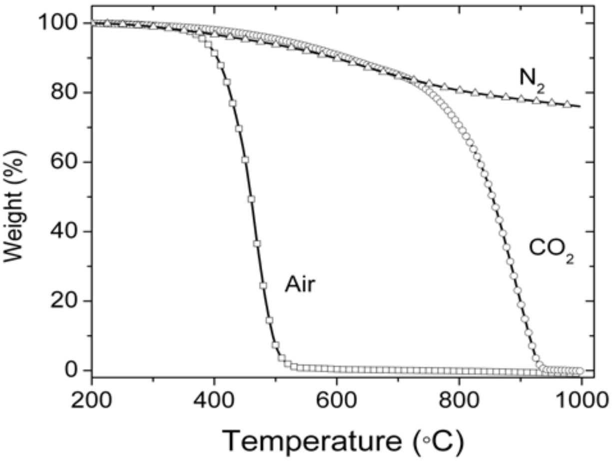

Figure 1. Thermal behavior of as-received raw biochar under different atmospheres; heating rate is 10 ^{o}C/min

The general properties of the activated carbons prepared are presented in Table 1.

Table 1. Some properties of activated carbons prepared at 880 ^{o}C in CO_2

Samp.	Activation time, min	Burn-off, %	Iodine #, mg/g	Acidity, mmol/g
AC-FG*	-	-	380	0.086
AC-1	30	3.8	770	0.275
AC-2	60	5.9	800	0.282
AC-3	120	9.7	870	0.302
AC-4	180	13.8	1050	-
AC-5	300	21.3	1180	0.454
AC-6**	300	39.9	1240	0.396

*Sample prepared in forming gas at 1000 ^{0}C, 2h
**Sample prepared in wet CO_2 (3 vol% of H_2O)

It has been found that for reduced in FG sample the iodine number was almost two times lower than that for BET number (see Tables 1, 2). For CO_2 treated samples both numbers correlated almost 1:1. It has been also found that the surface area of activated carbon increased with treatment time in dry flowing CO_2 (20 cm^3/min) up to 1220 m^2/g for 5h treatment. Carbon's acidity also increased, however, the fabrication of electrodes suitable for supercapacitor was quite challenging due to low wettability of the surface of activated carbon prepared in dry CO_2. To improve wettability one sample (AC-6) was treated at 880 ^oC in wet (3% of H_2O) CO_2.

Table 2. Surface area and pore volume of carbons activated by CO_2 at 880 ^oC

Samp.	S_{BET}, m^2/g	V_{total}, cm^3/g	V_{micro}, cm^3/g	S_{micro}, cm^2/g
AC-FG*	650	0.293	0.255	630
AC-1	800	0.351	0.309	786
AC-2	760	0.329	0.292	744
AC-3	860	0.367	0.332	849
AC-4	990	0.424	0.380	969
AC-5	1220	0.526	0.473	1195
AC-6**	1530	0.718	0.605	1474

*Sample prepared in forming gas at 1000 ^0C, 2h
**Sample prepared in wet CO_2 (3 vol% of H_2O)

The electrodes were prepared from AC-6 carbon using a water-based Teflon suspension (60 wt%) from Dupont as a binder. The geometric area of electrode was 0.32 cm^2 and the thickness was 0.6 mm. The weight of activated carbon in each electrode was 20.0 mg. A plain Ni-foil of a thickness of 25 μm was used as a current collector. To minimize the contact resistance the carbon pellet was attached onto the Ni current collector with a carbon conducting glue and the electrode was finally heated at 200 ^oC, 1h. The test supercapacitor was composed of pair of carbon electrodes separated by a thin (50 μm) Nafion disk. 5 M KOH : LiOH (4:1) aqueous solution was used as an electrolyte. The voltage limits were set between 0 and 1 Volts to avoid the decomposition of aqueous electrolyte. The results of current discharge measurement are presented in Figure 2.

By measuring the slope of V-T curve, the gravimetric specific capacitance of a single electrode C_1 can be calculated through the formula: C_1 (F/g) = 2 x I/slope x m, where I is a current and m is a mass of carbon in one electrode. The specific capacitance measured at 1 mA was found to be as high as of 130 F/g, which is a typical value for electrochemical double layer capacitance of carbonaceous materials [4]. This fairly good performance can be attributed to both a sufficiently high surface area (~1500 m^2/g) and suitable surface functional groups. XPS analysis showed a progressive increase in alcoholic, phenolic, and etheric groups located on the carbon surface as a function of treatment time in CO_2. The oxygen containing functional groups can allow electrolyte to penetrate into small pores more rapidly; they may react reversibly and behave like a "pseudo-capacitor', therefore, the total "apparent" capacitance would increase.

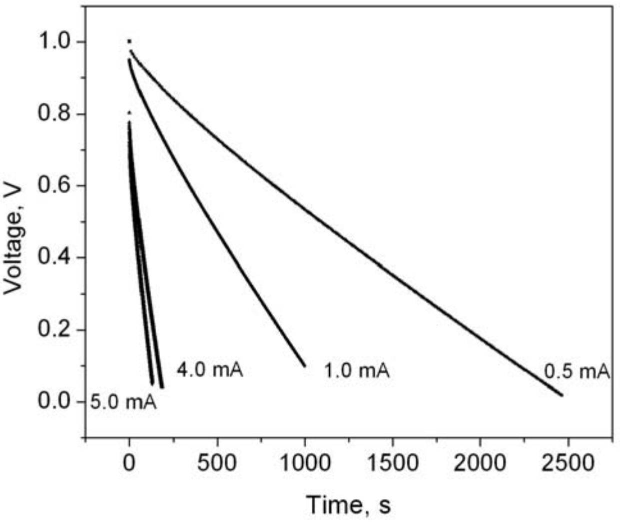

Figure 2. The galvanostatic discharge curves recorded at 0.5-5.0 mA current for a capacitor built from AC-6 in 5 M KOH/LiOH

Conclusions

The activated carbon from pine processing waste prepared in CO_2 exhibits a quite good capacitance characteristic (130 F/g). The surface area and functional groups can be easily tailored by controlling temperature and activation time. This carbon derived from waste can be used as an electrode material for supercapacitor manufacture.

Acknowledgements

The authors are very thankful to Dr. D. Karpusov at the University of Alberta who helped with XPS studies.

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[1] Muchovej, R.M.C.; Pacovsky, R.S. 1997. *In: Agricultural Uses of By-Products and Wastes,* J.F. Rechcigl et al. (Eds.), Amer. Chem. Soc., Washington DC, pp. 1-19.

[2] Mohan, D.; Pittman, C.U.; Steele P.H. 2006. Energy & Fuels, 20, 848-889.

[3] Boehm, H. P. 1966. Adv. Catal., 16, 179-274.

[4] Pandolfo, A.G.; Hollenkamp, A.F. 2006. J. Power Sources, 157, 11-27.

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Project to establish a dedicated feedstock plantation for production of high quality Biochar

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Key words: *Gliricidia, Pyrolisis, Biochar*

Gliricidia Facts

Gliricidia is an introduced plant species brought to the country by Christian Missionaries over 400 years ago. Subsequently it was used extensively as a shade provider when plantation crops such as Tea, Coffee and Cocoa were grown as commercial crops. Later still it was planted as live stakes for Trailing crops as Vanilla and Pepper. It is extensively planted in Coconut estates as an avenue crop due to it's Nitrogen Fixing capacity providing N rich biomass as a green mulch. The most wide spread use is seen in villages through out the country as live fence boundary markers.

Gliricidia is a semi deciduous multi purpose plant with a medium canopy, growing equally well from seeds as well as cuttings and has adapted into most climatic zones in the country. It is rarely if ever affected by diseases and requires little fertilizer.

It is recommended that at the time of planting the cutting, the top cut end be treated with a ball of wet clay covered and tied in place with a piece of polythene material. This will not only prevent the cutting from drying out, but also retains available moisture and encourages shoot burst from the top of the cutting

However it does not tolerate “wet feet“ for too long a period and does well on well drained soils. Elevation is the sole restriction to be noted in gliricidia cultivation, not doing well enough for the purpose under consideration above 1500 meters above sea level.

An annual well spread rainfall regime ranging from 900 mm to 1800 mm is considered most suitable. However drought periods extending beyond 6 – 8 months can retard growth.

Gliricidia is known to grow well in tropical and sub – tropical countries spread from Costa Rica in the west to Indonesia in the east.

The Sri Lanka Coconut Research Institute was tasked by the government to conduct detailed research on the plant as a fuel wood source for Gasifier power plants and after a 20 year study Gliricidia was gazetted as the fourth plantation crop after Tea, Rubber & Coconut. Details on planting, care & maintenance, Harvesting, and processing as fuel wood for gasifiers, has been well recorded.

The value of gliricidia as a feedstock for power generation by gasification is due to it's short rotation coppicing ability and the relatively low smoke & soot released during gasification. The long, straight branching habit can be induced by the close spacing of plants as recommended, which encourages the plant to compete for sunlight and thereby growing straight and long rather than spreading sideways and therefore is admirably suited for harvesting, cutting into sticks to feed gasifiers or hand\ mechanical chipping for pyrolisis.

All outspread branches are cut off at 1.0 to 1.5 meters above ground at harvest, which encourages uniform re - growth. The cutting height allows harvesting by machete or motorized saw, standing upright on the ground without any climbing aid, thereby saving on time. The harvested branches are left in the field for the short period required for the leaf to fall. The green colored immature end of the branch is lopped off and along with a portion of the leaf is applied at the tree base as thatching and mulch to provide nutrients and also reduce the bulk which needs to be transported to the chip processing point. When harvesting, care should be taken not to cause any splitting of the tree end of the cut, as such damage could reduce the economic life span of the tree itself.

At the time of harvest the moisture of the cutting is around 50% During the period that the cuttings are kept in the field to allow leaf fall (7 – 12 days) the moisture will come down to 35%. After chipping to size and packing in 50 KG net bags and kept to air dry in the shade for another two weeks, the moisture will come down to 25%. The chips are ready for pyrolising when moisture reduces to 20%.

The potential of gliricidia as a feedstock for pyrolisis into biochar for agriculture applications is yet to be recognized in the country and is the reason for this abstract.

Biotic and abiotic oxidation of compost formulated with charcoal and enriched with silicate powdered rocks

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Key words: *carbon, nitrogen, composting process*

Introduction

Charcoal has a chemical structure highly aromatic and can be oxidized by biotic and abiotic processes, forming functional groups with net negative charges on the surface of its particles.

The aim of the present work is to evaluate the biotic and abiotic oxidation of compost formulated with charcoal to wich was added silicon powdered rocks, rich in oxidizing agents such as nickel.

Results and Discussions

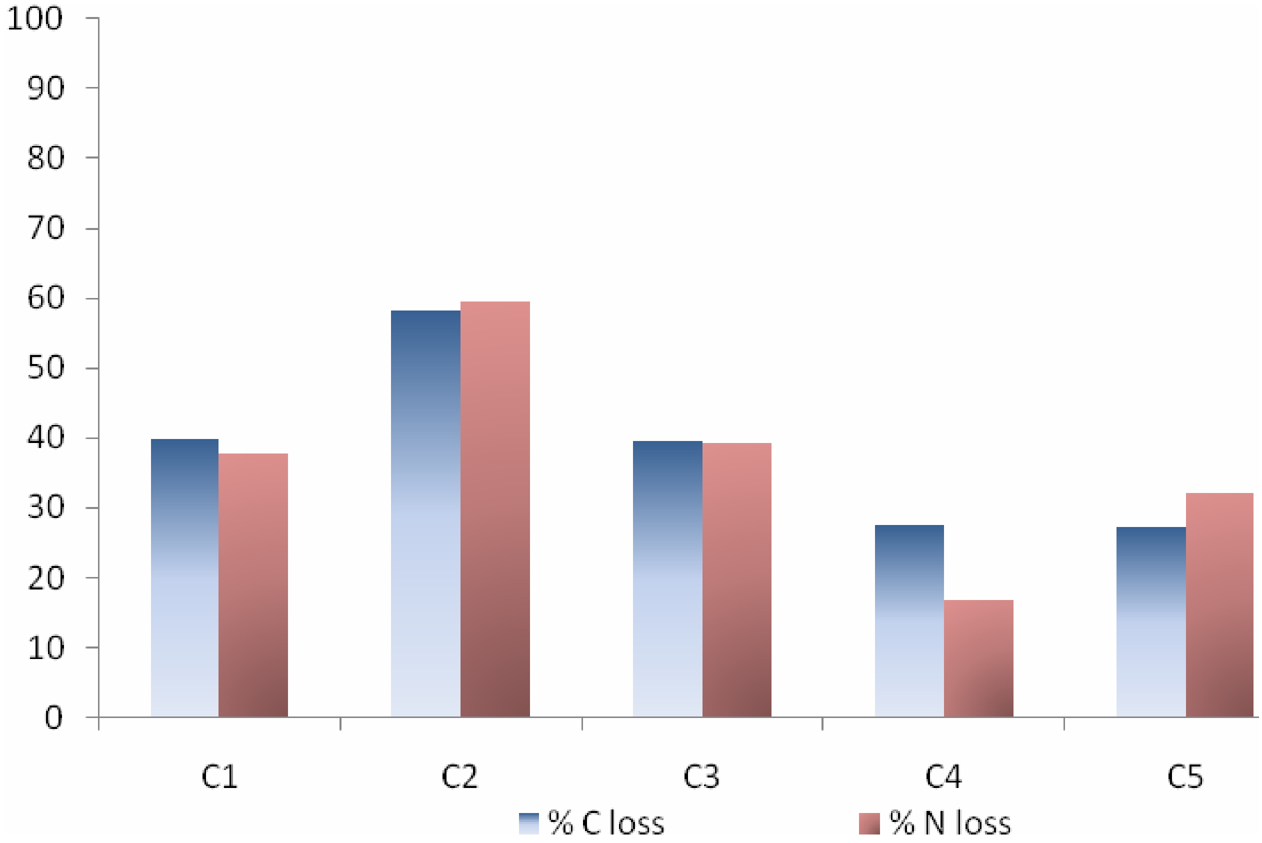

Figure 1. Losses of C and N of composted charcoal, filter cake and castor oil plant (C1), and powdered silicate rocks added at 0 (C2), 30 (C3), 60 (C4) and 90 (C5) days after the start of the composting process.

Table 1. Elemental composition, atomic ratio and oxidation rate (ω) compost obtained from different materials and mineral enrichments.

Compost	C	N	H	O	Atomic ratio			ω
	dag kg^{-1}				C:N	H:C	O:C	
C1	48,24	2,12	3,33	46,31	19,54	0,01	1,28	1,85
C2	36,26	1,73	2,46	59,54	17,91	0,01	2,19	3,22
C3	47,39	2,02	3,95	46,64	20,12	0,01	1,31	1,88
C4	48,00	2,34	3,27	46,39	17,56	0,01	1,29	1,86
C5	49,23	1,95	3,04	45,78	21,63	0,01	1,24	1,80
Average	45,82	2,03	3,21	48,93	19,35	0,01	1,46	2,12
Error	±5,39	±0,22	±0,54	±5,94	±1,67	±0,00	±0,41	±0,61

Conclusions

a) Enrichment of compost with powder of silicate rocks at the beginning of composting process (C2) has enabled most significant losses of C and N, the order of 58 and 59% respectively. In this same treatment, there was greater development of quantitative negative charges on the materials composted, inferred to rate of oxidation, in the order of 74% higher than the control (C1).

b) The lowest losses of C and N were of the treatment C4, with 27 and 16%, respectively.

c) The addition of powders of silicate rocks 30 days after the beginning of composting process did not favor the oxidation of materials composted, since the differences in their rates of oxidation compared to control (C1) did not exceed 3%.

Acknowledgements

The authors are very thankful to Dr. D. Karpusov at the University of Alberta who helped with XPS studies.

Chemical functionalisation of actived charcoal - Reproducing the *Terra Preta de Índios* organic matter model

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Key words: *Soil amendment, Biochar, ^{13}C Solid state NMR*

Introduction

Terras Pretas de Índios are anthropogenic soils found in the Amazon which have high carbon content, high fertility and high resilience. These characteristics are due to the pyrogenic character of their organic matter.

Based on several investigations of the organic matter from *Terra Preta de Ìndios*, an efficient model of organic material has been proposed, that can provide agriculture sustainability and carbon sequestration. This model involves a compound of polycondensed aromatic structures with carboxylic functionality.

Charred materials have condensed aromatic groups that guarantee their recalcitrance in the environment (half-life ranging from centuries to millennia), being so an efficient material for carbon sequestration. Its application in the soil is followed by biological and chemical transformations through which carboxyl groups are directly connected to the recalcitrant aromatic structures. After those transformations, the final compound attributes high fertility to the soil. This is what makes *Terra Preta de Indios* soils so fertile, differentiating them from other soils in the Amazon.

However, this transformation process may take decades to occur in nature. That is why, through chemical functionalisation of charcoal, we are seeking to obtain, in a short period of time, compounds similar to the ones found in the *Terra Preta de Indios*, which sequestrate carbon in a recalcitrant and reactive form.

To promote the oxidation of peripheral aromatic units to carboxylic groups, activated charcoal was subjected to chemical treatments with different concentrations of NaOCl (0.05; 0.1 and 0.2 M). Then, the obtained mixture was filtered and acidified to pH ~ 1. The humic acid like fraction precipitated and the fulvic acid like fraction remained in solution. Thereupon, the humic acids were recovered by centrifugation and dialysed; and the fulvic acids were purified with resin XAD-7 and Ambertile IR-120. Afterwards, both fractions were freeze dried.

Variable-amplitude cross-polarization (VACP) Solid-state ^{13}C NMR experiments were carried out using a 500 MHz Varian spectrometer at ^{13}C and ^{1}H frequencies (125 and 500 MHz, respectively). Magic-angle spinning (MAS) at 15 kHz was employed. Typical cross-polarisation times of 1 ms, acquisition times of 13 ms, and recycle delays of 500 ms were used. High-power Two-Pulse Phase-Modulation (TPPM) proton decoupling of 70 kHz was applied.

Results and Discussions

The dark colour intensity of the filtered, measured by UV-Vis spectroscopy, showed a linear relationship with the NaOCl concentration (data not showed), indicating that the oxidant excess is still not reached.

The ^{13}C NMR spectra of the obtained products (Figure 1) are characterised by a featureless aryl peak in the region of 130 ppm and a carboxyl peak at 169 ppm. This up field shift (smaller chemical shift value than regular carboxyl groups ~ 175 ppm) indicates carboxyl groups attached directly to the aromatic backbone.

The aryl peak of humic acids presented a smaller chemical shift value (128 ppm) than the one of fulvic acids (132 ppm), indicating that the former presents a more polycondensed aromatic structure. On the other hand, the fulvic acids presented a higher content of carboxyl groups than the humic acids.

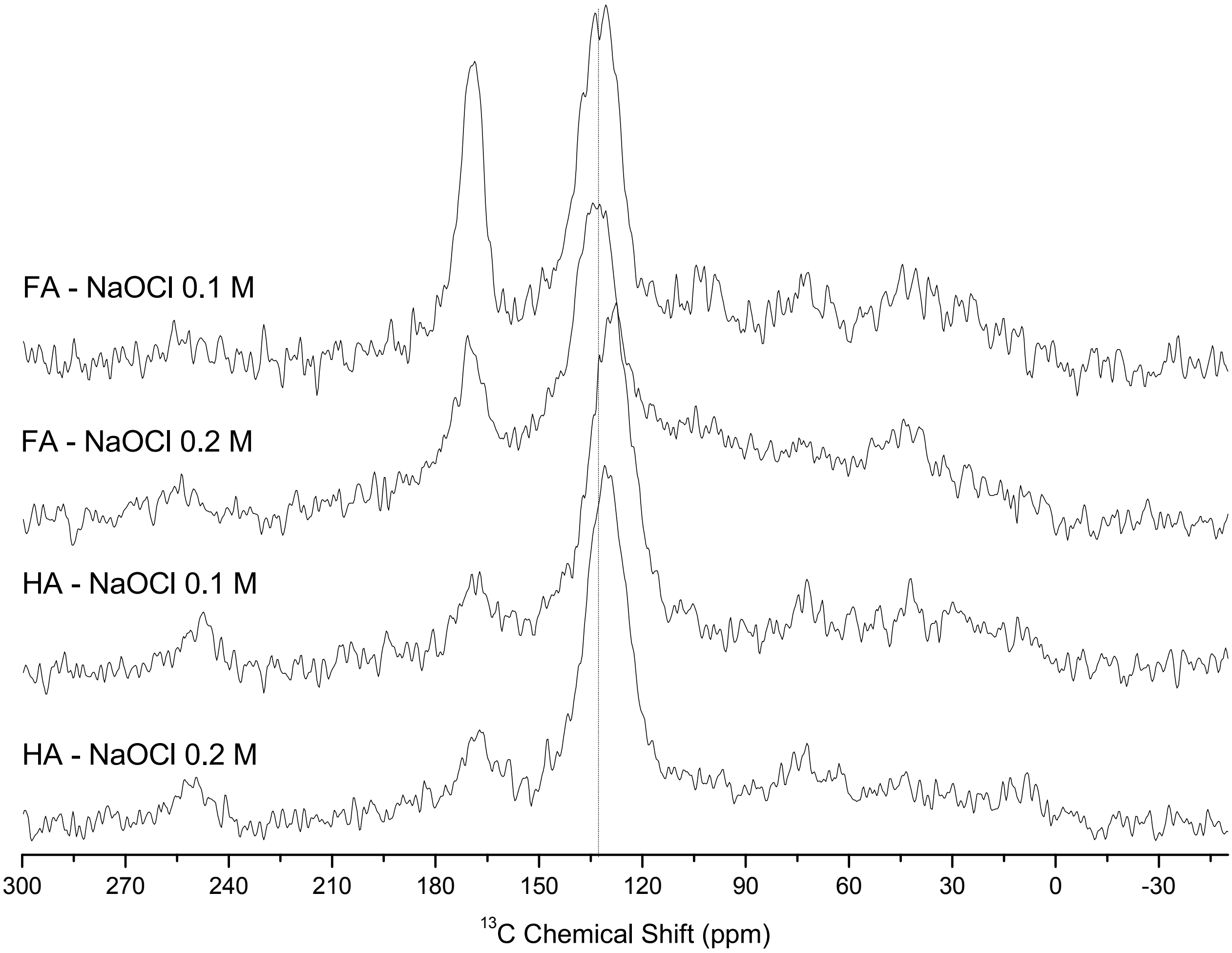

Figure 1. Solid State ^{13}C NMR of the obtained products. FA – Fulvic Acids; HA – Humic Acids.

Conclusions

According to the obtained results, the functionalisation was effective, producing the expected compounds. The reaction yield was proportional to the oxidant agent concentration, indicating that the oxidant excess is still not reached. The fulvic acids were soluble at any pH value probably due to higher concentration of carboxylic moieties and also due to its lower aromatic ring condensation.

Acknowledgements

We acknowledge the support of CAPES and CNPq (Brazil).

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[1] Novotny, E.H.; Hayes, M.H.B.; Madari, B.E.; Bonagamba, T.J.; Deazevedo, E.R.; Desouza, A.A.; Song, G..; Nogueira, C.M; Mangrich, A.S. 2009. Lessons from the Terra Preta de Índios of the Amazon Region for the Utilisation of Charcoal for Soil Amendment. *J. Braz. Chem. Soc.*, 20, 1003-1010.

Influence of biochar production conditions on its structure, properties and stability

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Key words: *Biochar, pyrolysis, stability*

Introduction

The main objective of this work has been to relate the biochar production process and operating conditions to the yield, and the resulting structure and properties of biochar that determine its long-term stability. Such knowledge is very important from the point of view of designing a biochar production system with optimal energy balance that would produce high yields of biochar of suitable quality.

To achieve this, we used our lab-scale pyrolysis facilities to produce biochar from sugarcane bagasse under closely defined, controlled and monitored conditions. Initial tests were performed in a batch system on a scale of approximately 100g (see Fig. 1), before scaling up to a continuous pyrolysis unit capable of producing up to 2kg of biochar per hour. In our experiments we varied operating conditions including the temperature, residence time and the heating rate. Biochar samples obtained in these experiments were then characterised. The biochar from the lab-scale pyrolysis units and its properties were compared with biochar produced from the same starting material in an industrial slow pyrolysis unit (Pacific Pyrolysis).

Results and Discussions

To assess the impact of production conditions on the stability of biochar we subjected the different biochar samples to a series of tests that are a part of a biochar characterisation toolkit, under development at the UK Biochar Research Centre. These tests consist of different aging and degradation procedures that aim to simulate natural processes occurring in soils, i.e. processes to which biochar would be exposed during its long-term storage in the environment. The results provided information on the expected short-term release of labile carbon from biochar in soil, and the presence of labile nutrients within the biochar matrix. Even though this information does not yet provide us with a quantitative predictive capability for long-term biochar stability, it allows us to do comparative analysis of the stability of biochar produced under different conditions. This then allows us to assess which combinations of feedstock and operating conditions are best suited for production of biochar with different proportions of stable carbon.

Figure 1. Batch lab-scale pyrolysis unit for biochar production at the UKBRC pyrolysis lab.

Conclusions

The information on stability of biochar is very important for the assessment of the climate change mitigation potential of biochar, as it has not yet been clearly defined what proportion of biochar actually remains "permanently" sequestered and how much is quickly released back to the atmosphere, potentially altering patterns of short-term biological activity in soil. Our results show how and to what degree the selection of operating conditions influences the yield and stability of biochar.

C-13 and P-31 NMR Analyses of swine bones biochar

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Key words: *Pyrolysis, biochar, ^{31}P Solid state NMR*

Introduction

The intensive livestock production results in massive amounts of residues, such as bones. Nowadays, due to sanitary questions, e.g. Bovine Spongiform Encephalopathy, these residues are banned as feed for animals. In this way, a potential destination for this material is pyrolysis, seeking biofuels and biochar production. Due to the chemical composition of the feedstock the obtained biochar will be rich in phosphorus and calcium, important plant nutrients. Additionally, the thermal treatment of the bones will result in a sterile agricultural input.

Despite the fact that the major mineral phase of bone was found, by X-ray diffraction, to be similar to hydroxyapatite, the exact chemical and structural nature of the solid phase(s) of calcium phosphate in bone is still unclear, but the contribution of brushite-like (monoacid orthophosphate) to the bone composition is important and depends on of the animal species and age [1]. The bone composition is an important parameter since the solubility of brushite-like orthophosphate is 1 to 3 order of magnitude greater than of hydroxyapatite in the pH range of 5-6.5.

The X-ray diffraction technique failures to uniquely identify the mineral phase(s) of bone, and probably it will fail to characterise bones biochar, in part from the fact that the mineral crystallites are very small and the resulting X-ray diffraction patterns are too poorly defined to permit a unique solution to the structural analysis. On the other hand, the solid state ^{31}P NMR technique is prone to characterise this kind of material [2], especially when associated with chemiometric tools.

Experimental procedures

In this communication we present the NMR characterisation of three swine bones biochars, labelled as Bones 1, Bones 2 and Bones 3. The bones biochars were obtained at different carbonisation temperature and time. The pyrolysis parameters are displayed in Table 1.

Table 1. Pyrolisys parameters of swine bones biochars samples.

Bones	Physical conditions
1	930 °C 10 min
2	300 °C 45 min 500 °C 7 min
3	300 °C 25 min 500 °C 10 min

The NMR spectra were acquired using a 500 MHz VARIAN spectrometer. The T3NB HXY of 4-mm probe was used to implement the solid state NMR experiments as CP-MAS, DP-MAS and others (not presented in this communication), to detect ^{13}C and ^{31}P nuclei from the pyrolysed samples. The rotors were spun using dry air at 15 kHz for ^{13}C and 10 kHz for ^{31}P. All experiments were carried out at room temperature.

Results and Discussions

The measurements of CP-MAS NMR solid state experiments detecting ^{13}C nuclei and ^{31}P are detailed in Figure 1 and Figure 2, respectively.

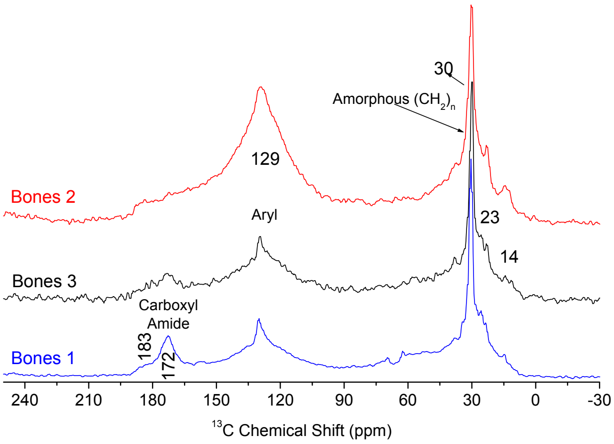

Figure 1. ^{13}C NMR spectra of swine bones biochars, using the CP-MAS NMR solid state.

From Figure 1 is possible to infer that swine bones biochars produced at higher temperature or residence time results in a decrease of carboxyl/amide functionalities and also an increase and broadness of the aromatic signal in the ^{13}C NMR spectra, indicating greater carbonisation. Also in the spinning side band intensity analysis (Figure 2), it is possible to infer that there could be two crystallographic structures with different symmetry. The sample bones 1, submitted to shorter carbonisation time, presents the highest contribution of the ^{31}P compounds with lower symmetry (higher intensity of the spinning side band – Figure 2). This sample also showed itself more efficient at the ^{1}H-^{31}P cross polarisation (data not showed), indicating a stronger ^{1}H-^{31}P dipolar coupling, probably due to a shorter ^{1}H-^{31}P distance.

Solid state ^{31}P NMR spectroscopy joint to the Principal Component and Multivariate Curve Resolution analyses (Figure 3) indicated that the studied biochars were a binary mixture, and had a component that cross-polarises easer and showed a that presents a lower symmetry, probably associated with brushite-like crystallites. The content of brushite-like orthophosphate decreased with the carbonisation degree. Its estimated proportion varied from 100% until 20% (Insert in Figure 3).

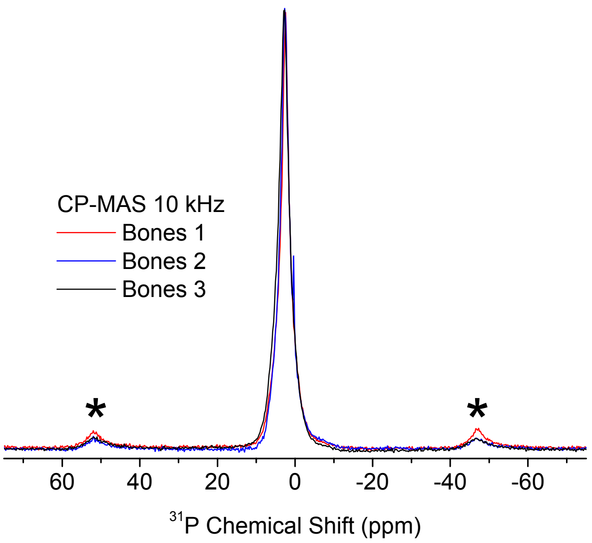

Figure 2. ^{31}P NMR spectra of swine bones biochars using the CP-MAS NMR solid state
* Spinning side bands

Conclusions

The analysis shows that swine bones could be converted in a promising phosphorus fertiliser by its carbonisation. The adjustment of the pyrolysis temperature or of the residence time could produce fertilisers with different solubility and P release rates.

Acknowledgements

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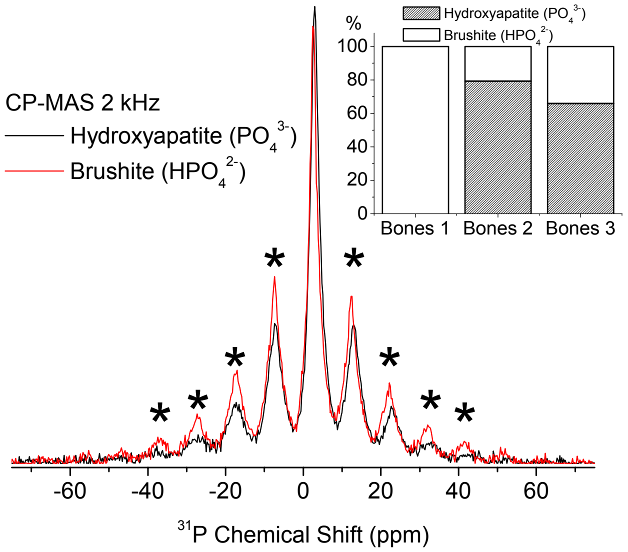

Figure 3. Multivariate Curve Resolution analysis about ^{31}P nuclei from the CP-MAS experimental data
* Spinning side bands

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[1] Wu, Y.; Ackerman, J. L.; Strawich, E. S.; Rey, C.; Kim, H.-M.; Glimcher, M. J., 2003. *Calcif. Tissue Int.*, *72*, 610-626.
[2] Kaflak-Hachulska, A.; Samoson, A.; Kolodziejski, W., 2003. *Calcif. Tissue Int.*, *73*, 476-486.
[3] Curtis, M. D.; Shiu, K.; Butler, W. M.; Huffmann, J. C. 2001. *In: The Rhizosphere: Biochemistry and Organic Substances at the Soil-Plant Interface,* R. Pinton et al. (Eds.), Marcel Dekker, New York, pp. 141-157.

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Progressing from Terra Preta de Índios to the Whole World

The Million Tons Bamboo Biochar Project

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Key words: *Bamboo Biochar, Carbon Sequestration*

Introduction

Bamboo and rattan are integral to the lives of up to 1.5 billion people, roughly a quarter of the present world population. For many of them, life is a constant struggle against poverty and deprivation. With its unique growing capacity and its remarkable versatility, bamboo can provide a sustainable way out of poverty for these communities. Moreover, bamboo is increasingly recognized today on the international scene as an efficient strategy for environmental conservation, rehabilitation of degraded land and long-term carbon sequestration. This is being taken forward by INBAR[1], an intergovernmental organization dedicated to improving the social, economic, and environmental benefits of bamboo and rattan through a global network of partners from the government, private, and not-for-profit sectors in over 50 countries.

Bamboo Charcoal as Biochar

One of INBAR's main achievements over the past 10 years is the establishment of commercially viable community-based bamboo charcoal production units in several countries such as India, the Philippines, Mozambique, Ghana and Ethiopia using simple, inexpensive batch drum kilns and throughput modified thermal gasifier. Building on this success, INBAR, along with the European Union and partners, announced in 2009 the launch of a Bamboo Firewood and Charcoal Programme in Ethiopia and Ghana. This project is the first concerted effort to focus on bamboo firewood and charcoal as a mainstream alternative to timber charcoal in the region.

Besides its use as alternative cooking fuel, INBAR now plans to explore the use of bamboo charcoal as biochar for agricultural soil amendment and carbon sequestration. By improving the soil fertility, biochar could significantly help the target rural communities fight soil degradation and hunger, still one of the main issues in countries such as Ethiopia, whose Global Hunger Index was ranked « Extremely Alarming » in 2009.

At the same time, with its potential to be a long-term carbon sink, biochar could represent an effective solution to reduce the levels of CO_2 in the atmosphere and thus mitigate climate change on a global scale. Bamboo is a rapidly growing woody plant that can produce up to 100 tons or more of biomass/ha annually. The carbon needed during this process comes mainly from atmospheric CO_2, making biomass in itself able to sequester a considerable amount of carbon. However, this sink is organic and subject to degradation, while a long-term carbon sequestration method is required to mitigate effectively climate change.

A Million Tons Bamboo Biochar per Year

It is therefore proposed to undertake large-scale intensive production of bamboo biomass and convert it into charcoal which is inorganic and can be stored and its stocks verified easily. Conversion efficiencies of 40% can be achieved relatively inexpensively (higher efficiencies need higher initial investment) and in a carbon-neutral way, ensuring a net sequestration of carbon by application of biochar in the soil.

Starting from converted oil drums used as charcoal kilns, modified thermal gasifiers have been developed that can continuously produce 100kg of charcoal per hour or around 2.5 tons in 24h. Based on such units, it has been proposed to set up a million tons/year charcoal project, with the bamboo grown and harvested by poor rural communities, thereby generating rural employment and income, and reducing poverty, while sequestering carbon at the same time. Importantly, this will actually contribute to reduction of atmospheric carbon.

A million tons of charcoal would need 2.5 million tons of biomass a year. This would need 25,000 ha to be grown with bamboo intensively. There would be not only substantial rural employment generation, but this would result in greening on a mass-scale, with considerable environmental benefits. Bamboo is known to enhance the quality of soil, increase water capture and recharge, reduce soil erosion etc., all impacts that would durably and on a large scale generate other economic and non-economic benefits to the communities and their environment. Alternatively, nearly 1200 MW of renewable power could be produced from this biomass, and generate in addition a substantial amount of carbon credits.

Conclusion and Upcoming Work

Complementing the above is a strong integrated programme to take forward biochar in participation with the community. A project of CIBART[2] with INBAR on Bamboo Livelihoods Business Enterprise Project for Primitive Tribal Groups of South Gujarat in India has established partnerships with government, rural communities, social enterprises and the private sector to integrate into rural livelihoods development the production from well-maintained and sustainable bamboo resources of bamboo charcoal for domestic fuel, and of bamboo biochar for agriculture purposes and carbon sequestration.

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[1] International Network for Bamboo and Rattan (INBAR)

[2] Centre for Indian Bamboo Resource and Technology (CIBART)

Development of Carbonator^{TM} to Pyrolyze 20 ton/day Palm Oil Empty Fruit Bunch into Biochar

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Key words: *Empty Fruit Bunch, Biochar, Pyrolysis*

Introduction

Biochar can be produced by thermal processing of biomass mainly pyrolysis and gasification. The type of thermal process used to produce the biochar determine the biochar output. Slow pyrolysis produces higher amount of biochar than fast pyrolysis and gasification for the same biomass input. Most research and development works have been focusing on fast pyrolysis and gasification to maximize the oil and syngas output for energy. Slow pyrolysis is limited to production of low grade activated carbon and pretreatment before gasification.

However among the three processes, the slow pyrolysis process is probably the easiest to scale up due to its low temperature and the output is largely biochar. Recent finding of the potential of biochar for environmental management will increase demand for it. Therefore, it is important for us to develop a pyrolysis unit capable of producing large amount of biochar using green technologies. Furthermore, the country has a vast amount of biomass waste which can contribute to green house gas emission if left to decay.

In Malaysia we produce more than 180 million tons of Palm Oil Empty Fruit Bunch (EFB) every year. EFB comes from the biomass bunch that hold together the fruitlets. When the fruitlets are removed for oil extraction, the empty bunch becomes a waste. In this work, we tried to convert 20 ton/day EFB into biochar at 400^{o}C. Since the process was energy intensive, we planned the energy recovery and recycle to keep the processing cost low. The schematic of the pilot plant is shown in Figure 1. The plant comprises of three pairs of oven and rotating drum. For the startup the oven was heated using hot air generated from a diesel burner. When fully operational, the heat was supplied by hot gas generated by recycle gas burner where gas produced by the pyrolysis process was combusted. The completed plant is shown in Figure 2.

The Palm Oil Fruit Bunch and EFB is shown in Figure 3. The EFB was fed to each of the three drums without shredding at different time. The process took about 4 hours to complete including drying and pyrolysis. The second drum operated after drying in the first drum completed and the third drum start when the drying in the second drum completed. In this mode of operation, the energy generated from the drum under pyrolysis by syngas combustion was used in the other drums. Excess energy was purged through the chimney.

Results and Discussions

The Plant construction was completed in 6 months. Early test where each drum was operated separately showed the EFB was fully transformed and biochar produced was in the form of carbon powder with average diameter of 2 mm. About 20 weight percent of the EFB was converted into biochar. 70 percent of the EFB was evaporated as water and the rest was as gas. The amount of oil was very small. Each drum took in 1.4 ton of EFB. This show the output was well within lab analysis of EFB [1]. The gas from the process was immediately combusted and there was no visible smoke observed at the chimney outlet.

The second stage of the development was to operate the plant for 24 hours with heat recycles where the heat produced by syngas combustion generated from one of the drums was sent to other drums. The maximum temperature recorded at the syngas burner was 1100^{o}C. This was above the temperature required therefore the gas was diluted with atmospheric air before recycled into the ovens and also purged through the chimney. The biochar powder was analysed.. The field study of the biochar as soil amendment is currently ongoing in the Universiti Putra Malaysia Soil

Science Department. Previously the researchers have used biochar from rice husk in a plot trial [2].

The analysis of the biochar is shown in Table 1. The carbon content was a lot higher than rice husk which has only 10% carbon [2]. The CEC value was also higher than rice husk. The normal soil in Malaysia has CEC value of about 15 Cmol$^{(+)}$/kg. Potassium content was significant although nitrogen was low due to the thermal treatment. The carbon content indicates that the biochar from EFB is good for carbon sequestration. Although plot trial is still ongoing, the potassium content suggests that the EFB biochar will have positive effect to plants.

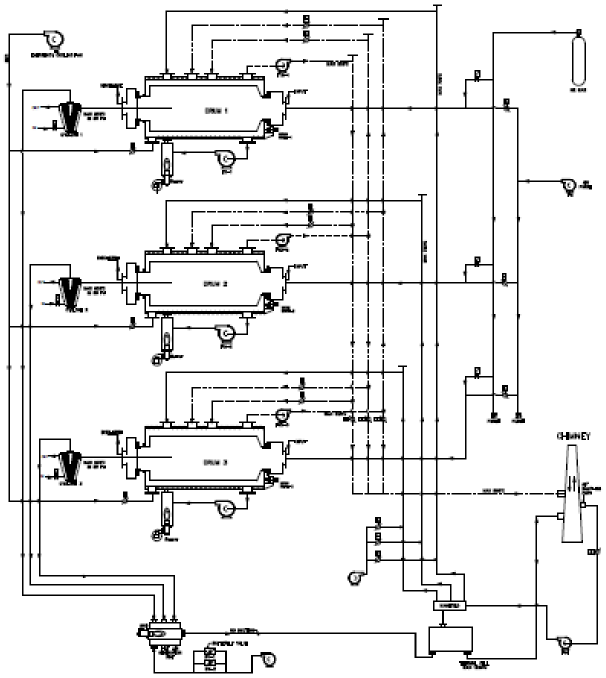
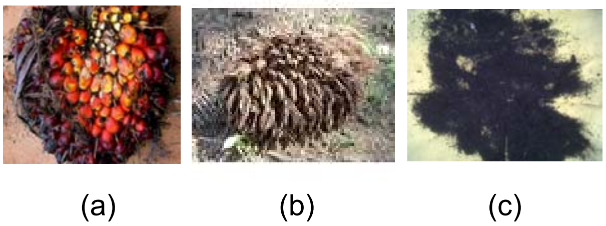


Figure 1. Schematic of the EFB biochar plant show the three rotating drums, syngas burner and heat cycles.

Figure 2. The EFB biochar plant



(a) (b) (c)

Figure 3. a) Palm Oil fruit bunch b) Empty fruit bunch (EFB) (c) EFB biochar

Table 1. Analysis of the biochar

C	45	%
N	0.32	%
P	626	µg/g
K	14200	µg/g
Ca	379	µg/g
Mg	290	µg/g
Mn	442	µg/g
BET Surface Area	12.7	m^2/g
CEC	42.85	Cmol$^{(+)}$/kg
pH	9.66	

Conclusions

We have successfully developed, build and operate a carbonator plant capable of processing 20 ton/day oil palm empty fruit bunch into biochar. The plant has run for twenty four hours without failure. The gas generated from the pyrolysis was successfully combusted and recycled to supply heat to the carbonator. The emission was negligible in the sense that no visible smoke was released. The biochar from the process has high carbon content, potassium and CEC value most likely to be suitable for carbon sequestration via soil amendment.

Acknowledgements

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[1] Rozita Omar, A. Idris, K. Khalid, R. Yunus and W. A. K. G. Wan Azlina, 2007, *Characterization of Empty Fruit Bunch (EFB)*, World Engineering Congress, Penang, Malaysia

[2] Rosenani A.B., Ahmad S.H., Nurul Adila Shaharin, Eliza Tajudin and Tan Wei Loon, 2010, *Biochar as a Soil Amendment to Improve Crop Yield and Soil C Sequestration*, Food Security Conference, Kuala Lumpur Malaysia.

Biochar Use in the Poultry Industry

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Key words: *manure, carbonization, nitrogen*

Introduction

There is growing concern about the large amounts of manure nutrients being generated by large animal feeding operations and the potential hazard for water recourses and air quality. In many cases there is insufficient land available for spreading the manure at agronomic rates and the growing concentration and size of animal feeding operations increased the accumulation of excess nutrients. Biochar might reduce some of the problems associated with large scale poultry production. Potential applications for biochar in poultry production systems include the carbonization of the poultry litter (PL) or composting PL with biochar.

During the pyrolysis process important plant nutrients concentrate in biochar (*1*). This might facilitate a more efficient nutrient recovery by reducing the costs associated with land application and transportation. But depending on pyrolysis temperature, some nutrients susceptible to volatilization such as nitrogen (N) are partially lost during the process. At pyrolysis temperatures of 400 °C and 500 °C, 69 and 76% of the original feedstock N was lost respectively (*1*). Formation of heterocyclic N and aromatization increases the recalcitrance of the carbonized material (*2*), and has implications on N availability (*3*).

Therefore we compared the fertilization efficiency of carbonized chicken litter with that of un-carbonized chicken litter and mineral fertilizer. The experiment was established in a greenhouse using pots with a volume of 4 liters. First 1200g of soil (Cecil sandy loam, clayey, kaolinitic thermic Typic Kanhapludult; Chromi-Alumic Acrisol, near Watkinsville, Georgia) was filled on the bottom of the pot and the remaining 2400g was mixed with the fertilizers. The organic amendments PL and carbonized PL (PLc) were applied at the rates of 1.5, 3.0 and 6.0 Mg ha^{-1}. By coincidence the N content of PL (35.2 g kg^{-1}) was very close to that of PLc (35.0 g kg^{-1}) and the corresponding N applications were 52.5, 105 and 210 kg ha^{-1} for the 3 application rates respectively. The concentrations of other elements such as P, K, Ca and Mg were approximately twice as high in PLc as PL. The 3 application rates and the nutrient concentrations allowed comparing the N supply of the different fertilizers. For the mineral fertilized controls we mixed ammonium nitrate (NH_4NO_3), potassium chlorate (KCl), calcium phosphate ($CaHPO_4$) and magnesium sulfate ($MgSO_4$) in a ratio to match the nutrient contents of PL and PLc (MF and MFc, respectively). One unfertilized control was established additionally (C). All treatments were arranged in a randomized complete block design with 4 replicates. Five plants of ryegrass were established in each pot and harvested regularly (4 harvests) to assess the biomass production and nutrient uptake.

Results and Discussions

Total biomass production increased with increasing levels of fertilization except for PLc where a doubling and quadruplicating of the amount of fertilized N did not result in higher productivity. The cumulative N uptake from plants fertilized with PLc was significantly lower than that from plants fertilized with PL. While the N uptake of PLc fertilized plants remained close to the control (unfertilized plants) the uptake of PL fertilized plants lay inbetween MF and the control (Figure 1).

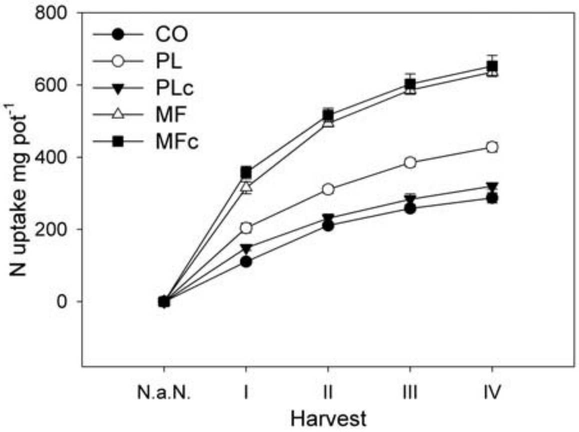

Figure 1. Cumulative nitrogen uptake by ryegrass over 4 harvests at the highest N fertilization level (210 kg ha^{-1}). CO = control, PL = poultry litter, PLc = carbonized poultry litter, MF = mineral fertilization based on PL, MFc = mineral fertilization based on PLc. Means and standard errors, n = 4.

Composting of PL is an alternative way to reduce potential pathogens; weed seeds and odor. However N is also lost during composting through ammonia (NH_3) volatilization. Ogunwande et al. (*4*) found a cumulative N loss to vary between 71 and 88% during composting of PL. This reduces the fertilizer potential and economic value of the product while causing environmental pollution (*5*). Activated carbon was successfully used to adsorb NH_3 (*6*). A cheaper option would be biochar and Iyobe et al. (*7*) showed that woody charcoal produced at 500°C had a higher capacity for NH_3 adsorption than the activated C. The recalcitrance of biochar, its pore space and moisture adsorption may provide ideal properties to be used as bulking agent in manure composting operations.

Adding 20% pine chip biochar to PL reduced NH_3 emissions significantly during composting and reduced N losses by up to 52%, without compromising the speed of decomposition. PL mass loss during composting was not altered due to biochar additions, peak CO_2 and temperatures increased (*8*).

Conclusions

The limited supply of fossil fuels as well as climate change and environmental impacts makes it imperative to increase N fertilizer use efficiency and improve nutrient cycling. Weather combusted, pyrolysed or composted, N rich materials loose a significant proportion of N during these treatments. However, the reduced bulk density and higher mineral concentration (mainly P and K) of ash or biochar may facilitate transportation to areas where fertilizer is needed.

Increasing the carbon content of agricultural soils would be negligible, if PLc is applied at agronomic rates (based on the phosphorus (P) demand of crops) due to the high P content of PLc. Using biochar produced from N poor materials as bulking agent for manure composting operations may reduce N losses and improve N cycling.

Acknowledgements

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[1] J. W. Gaskin, C. Steiner, K. Harris, K. C. Das, B. Bibens, *Transactions of the ASABE* 51, 2061 (2008).

[2] G. Almendros, H. Knicker, F. J. González-Vila, *Organic Geochemistry* 34, 1559 (2003).

[3] H. Knicker, J. O. Skjemstad, *Australian Journal of Soil Research* 38, 113 (2000).

[4] G. A. Ogunwande, J. A. Osunade, K. O. Adekalu, L. A. O. Ogunjimi, *Bioresource Technology* 99, 7495 (2008).

[5] M. Kithome, J. W. Paul, A. A. Bomke, *Journal of Environmental Quality* 28, 194 (1999).

[6] C. C. Rodrigues, D. D. M. Jr., S. W. d. Nobrega, M. G. Barboza, *Bioresource Technology* 98, 886 (2007).

[7] T. Iyobe, T. Asada, K. Kawata, K. Oikawa, *Journal of Health Science* 50, 148 (2004).

[8] C. Steiner, K. C. Das, N. Melear, D. Lakely, *Journal of Environmental Quality*, (2010).

Produção de Biochar a partir de Ossos de Suínos

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A carne suína é a fonte de proteína animal mais importante no mundo, sendo o Brasil o quarto maior produtor em termos absolutos, resultados obtidos pelo abate de 36.819.000 cabeças em 2008. Sabendo que o peso médio de animais abatidos é de 110 kg, e que 12 % deste valor corresponde a ossos, é possível estimar a quantidade de ossos produzidos anualmente no Brasil é de 486.010.800 kg. Vale ressaltar na composição química dos ossos de suínos, estão presentes, aproximadamente, cerca de 18% de P e 27,68 % de Ca, permitindo inferir que a cadeia de suínos pode contribuir com 203.152.514 kg de P_2O_5 e com 134.527.789 kg de Ca por ano.

No entanto, o destino final para estes resíduos da agroindústria ao longo do tempo vem sendo a produção de farinha de osso para alimentação animal, em razão do alto teor de nutrientes, fator que, também, lhe confere excelência como fertilizante. Porém, no futuro próximo o consumo deste tipo de matéria prima poderá ser restringido das formulações de rações devido às restrições sanitárias, a exemplo de países europeus onde esta prática já é proibida.

A proposta deste trabalho é dar um novo destino à utilização dos ossos de suínos, através da inovação tecnológica do biochar, tratando agora este resíduo como fertilizante de liberação lenta e não mais como ração. O processo de produção do biochar pelo processo de carbonização no equipamento preconizado pelo trabalho não gera gases tóxicos ou de efeito estufa (GEE). Desta forma, este trabalho mostra a possibilidade de manter estes mesmos teores nutricionais de P e Ca, entre outros nutrientes, somado ao fato de preservar o C no processo de produção, fator que, possivelmente, conferirá melhor ajuste do fornecimento dos nutrientes, o que permitirá melhor demanda às plantas nos diferentes estádios de desenvolvimento, além do diferencial da maior economia de demanda de energia durante o processo de produção, somado a não emissão de GEE.

Portanto, esta demanda de pesquisa visa alcançar a hipótese da International Biochar Initiative - 2010 que traz a idéia de otimizar a geração de energia e/ou químicos através de métodos modernos de pirólise e reciclagem de resíduos ou subprodutos e transformá-los em fertilizantes ou condicionadores do solo. Fator que confere ao biochar a responsabilidade de ser uma alternativa para mitigação e adaptação das alterações climáticas globais e, talvez, poder gerar outra renda ao produtor através dos mercados voluntários de carbono.

O experimento foi conduzido em novembro de 2009 no município de Concórdia em parceria entre as Embrapas: Suínos e Aves (CNPSA), Solos (CNPS) e Arroz e Feijão (CNPAF). Os experimentos foram desenvolvidos nas instalações da empresa Perozin Indústria Metalurgica Limitada, onde se encontra o protótipo do carbonizador para transformação de ossos em biochar, o qual foi adaptado do incinerador de animais produzido por esta mesma empresa em parceria com a Embrapa.

O carbonizador é desenvolvido em estrutura metálica com revestimento interno de material refratário, possuindo duas câmaras de queima. A primeira câmara serve para a queima primária e a segunda para a queima dos resíduos voláteis e particulados, gerados na primeira câmara. As câmaras possuem queimadores com capacidade para geração de calor de 60.000 a 200.000 Kcal/h, utilizando como combustível o gás liquefeito de petróleo (GLP). A temperatura no interior de ambas as câmaras é regulável e superior à 800ºC, atendendo a Resolução CONAMA Nº 316/2002.

Os parâmetros operacionais do processo de incineração como capacidade, tempo de carbonização, temperatura das câmaras de combustão, qualidade dos resíduos sólidos foram otimizados e padronizados com base em resultados neste prévio estudo científico. Para se chegar a estes valores de temperatura e tempo de exposição para pirólise dos ossos de suínos foram realizados testes preliminares.

Durante estes testes foi possível notar que em alguns casos a temperatura subia rapidamente, passando dos 700ºC, o que possibilita inferir que existia a combustão da própria matéria premia, fato que possibilita ter noção de que o material já se encontrava como carvão e, assim quando se atingia esta situação o equipamento era desligado e a tampa era aberta a fim de terminar o processo em condições ambientais.

Assim, com base neste testes, foi possível estabelecer parâmetros para o experimento que constou dos seguintes modelos de simulação de tempos e temperaturas para carbonização: a) exposição dos ossos de suínos a 930ºC por 10 minutos (rápida); b) exposição a 300ºC por 45 minutos mais 500ºC por 7 minutos (lenta); c) exposição a 300ºC por 25 minutos mais 500ºC por 10 minutos (intermediária).

Humanure-based Biochar

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Biochar, when used as a soil amendment, can increase soil organic matter, ease water pollution and erosion, as well as sequester carbon from the atmosphere. By using humanure as the base for biochar, additional benefits can be achieved. These include the diversion of a potentially harmful substance from entering waterways, the conservation of water, and the creation of a carbon-rich soil amendment. The objectives were to, 1) make biochar with humanure as biological material base, 2) to test the sterility of the biochar through comparing average bacterial colonies found in the biochar and in the raw compost samples, and 3) to test for heavy metal concentration levels in the final biochar product. Partially composted humanure was collected from the two Clivus Multrum composting toilets in the Ecodorm on the Warren Wilson College campus, and dried for three weeks. Samples of the dried compost were taken and half were pyrolyzed to make biochar, and the other half were kept as raw compost samples. The samples of biochar and raw compost were then taken to the Warren Wilson biology lab, where one gram of each were diluted in 100 ml of sterilized water and then diluted to different concentrations, and plated on one of three agar-based growing mediums. A total of 12 samples of biochar and 28 samples of raw compost were plated. In total, the average number of bacteria colonies found from the biochar samples was 4.7 x 103 colonies/gram and the average number of bacteria colonies found from the raw compost sample was 3 x 1010 colonies/gram. The raw compost was found to contain approximately 6 x 106 times as many bacteria colonies than the biochar. In addition to the sterility tests, a heavy metal analysis was done on the final biochar sample. A sample of the humanure-based biochar was sent to the North Carolina Department of Agriculture and Consumer Services where it was tested for heavy metal concentrations of the nine heavy metals under regulation by the United States Environmental Protection Agency for biosolids. All nine of the required heavy metal concentrations found in the humanure biochar were below the ceiling concentrations for EPA standards. The results suggest that 1) the humanure-based biochar is more sterile than raw compost, 2) pyrolysis can be used to recycle humanure, and 3) the humanure-based biochar has the potential to be used as a soil amendment.

Affordable Biochar Furnace Producing Heat Energy and Biochar for the Small Farm and Nursery with Inoculation System

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The author, C.J. du Plessis, holds 8 patents on process and equipment to produce activated carbon from agricultural wastes. I have owned and operated activated carbon producing factories in South Africa, Mexico and the United States. I currently own and operate a butterfly farm and nursery with my wife in New York State. (See article by D.Yarrow at www.RainbowsEndBiochar.com).

I got interested in producing heat energy for nurseries utilizing wood chips as a heat source and at the same time producing high-grade biochar. The research and development to produce this unit was done in the farm workshop. A prototype was built and tested, normal R & D procedures were followed, concentration was on feedstock, particle size range distribution, moisture content and flow properties. Flow obstacles of wood chips were overcome and a continuous flow process was developed. The unit was specifically built and designed to be affordable, supply heat energy and produce a high-grade biochar from a readily available waste product on the northeast and northwest coasts of the US. These goals have been achieved.

The second phase was to produce an active biochar activated with biology! For this a vermicompost and garden compost extract was developed and used to impregnate the biochar produced by the unit. \Test work and verification were done by an outside laboratory, Soilfoodweb, internationally known as the people for biology identification. The produced active biochar is currently being used in the greenhouses of Rainbow’s End Butterfly Farm & Nursery for plant growth evaluation.

This is not a presentation of what “could” be done. This is a presentation of what has been done. As we say in South Africa, “talk is cheap…money buys the whiskey”. Presentation will consist of power point and video clips.

For references, please consult our homepage www.RainbowsEndBiochar.com or contact me at katnip827@gmail.com or (845) 832-6749.

Bamboo Charcoal and Biochar

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There are 1500 woody bamboo species and 27 mil ha bamboo forest around the world. Bamboo is a widely distributed sustainable natural resource in Asia, America and Africa and has more than 2000 uses in the world. Bamboo is playing more and more important role in the changing world to environment, livelihood and economy. One of the important uses of bamboo is bamboo charcoal. Bamboo charcoal specific area can be up to 300-500 m^2/g compared to less than 30 m^2/g of most wood charcoal. Because of its outstanding absorption capacity, bamboo charcoal is used as deodorants and many other uses.

Bamboo charcoal has a good market in Japan and China due to a felling ban in natural forests and the good character of bamboo charcoal. In addition to bamboo charcoal being used for fuel, there are several other uses:

Agriculture: As a carrier of organic manure and micro-organism in the soil, bamboo charcoal can improve the vigour of the soil, so people use it as a good soil enhancer. Bamboo charcoal is a kind of biochar, it contributes also to carbon sequestration besides as fertilizer.

Chemicals: Bamboo charcoal can be used as the raw materials of bamboo active carbon.

Medicine and health care: Pillows and mats made of bamboo charcoal can soothe the nerves, relax backaches, and control snoring. Bamboo charcoal also has the functions of deodorization, dehumidifier and fungicide.

Environment protection: Bamboo charcoal can be used as a water clarifier, shield off electromagnetic waves and absorber of poisonous gases.

Other fields: Bamboo charcoal can be made into many kinds of compound materials in the material industry. It also can be made into handicrafts, feed additives and high capacity rechargeable storage batteries, textile added with bamboo charcoal etc.

Annually over 100,000 tons bamboo charcoal is been produced. These bamboo charcoal is used as above mentioned purposes and can sequestrate and store almost 400,000 CO_2 annually. The annual production of bamboo charcoal is increasing very fast, hence bamboo charcoal is playing a more and more role to mitigate climate change as well other benefits on economy.

We are implementing an EC bamboo biomass energy project -- Bamboo as sustainable biomass energy: A suitable alternative for firewood and charcoal production in Africa.

Preliminary Evaluation of Biochar Production for Oil Palm Trunks by Using a Batch Reactor

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During oil palm crop renovation around 80 tones /ha of dry biomass are produced, thus oil palm is one of the species that adds more organic matter into the soil where it is grown. In Colombia, there are more than 60.000 hectares of oil palm that are going to be replanted during the next 5 years. Additionally, the bud rot disease has destroyed more than 25.000 ha of oil palm plantations in the western zone in Colombia and right now, this disease is been spreading out in other regions. Carbonization of oil palm trunks has been seen as a method to produce biochar not only to be used at the same field where the next generation of oil palm will be grown up, but also as a way of sanitary control to kill the inoculums of the bud rot disease.

At this moment, there is not a commercial method of carbonization of those huge materials in open field areas. However, the use of batch reactors has been seen as a starting point to deal with the oil palm trunks. The main goal in this paper is to show the methodology that has been used to improve the carbonization process. Records of internal and external temperature of the reactor during the carbonization process, biochar and biomass characterization, yield of biochar, and ways of operation among others issues, will be shown in this paper. A discussion about of using this methodology as a CDM project will be also addressed.

Lessons Learned from a Successful Small-Scale Biochar Production Operation

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Since late 2009, approximately 2.5 m^3 (>=1ton) of biochar have been produced weekly from sawmill waste. All biochar produced has been sold locally. Community support has enabled funding and fabrication of an increasingly more advanced production facility. Construction has begun on a retort capable of producing 5 m^3 of biochar per batch as well as bio-oil and heat.

Many obstacles have been presented in the growing of this business. Public education, local consumer demand, product consistency, and farming economics have proven to be critical points of interest.

Potential clients are often initially skeptical of the merits of biochar. Although peer-reviewed scientific journal articles and informative websites are referenced, the greatest impact often comes from examples of successful applications in local soils. Many samples of biochar were donated to achieve this goal. Free workshops and lectures offering education on the biochar paradigm and how it may fit local needs both increased public awareness and sales. The initial availability of biochar and resulting usage also seemed crucial in aiding to increase demand by way of satisfied clients telling others of their success.

Biochar product consistency, in particular particle size, is of great concern to most clients. Achieving high levels of adsorbancy and cation exchange capacity (CEC) is ubiquitously desirable yet the desirable particle size consistency may vary depending on specific needs. In this business' local area heavy clay soils benefit from gravel size and finer particles (<=12mm), Orchid growers demand clean particles in the range of 12mm and for blending with fertilizers particle size of 6mm and less has been desired. Achieving these specific sizes required fabrication of specialized grinding machinery.

Initial applications of biochar can be overwhelmingly costly to farmers. Grant funded research into composting biochar as a means of increasing CEC, nutrient value and thus plant growth response has been under way and analysis of product characteristics and plant growth trials will be compiled in June of 2010. Plant growth trials are showing positive results and have sparked much excitement. Biochar inoculated with microorganisms and liquid organic fertilizer shows promise as a novel method of achieving a similar goal in a shorter period of time. After many conversations with local farmers, blending biochar with organic material based fertilizers has come up as an economic way to apply both fertilizer and biochar. Wholesale and retail distribution of such a product is expected to begin by June.

Formation, Structure and Stability of Biochar-Mineral Complexes

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Biochar-mineral complexes (BMC's) have been developed to combine the unique properties of biochar, torrefied high mineral ash biomass, clay and minerals. The reaction of the clay and specific minerals with the heat treated biomass results in carbon-rich phases with relatively high stability, cation exchange capacity and ability to release nutrients when they are needed by plants. The addition of BMC into soils improves both the utilization efficiency of specific nutrients (especially P) in the mixture and also soil microbial growth. This subsequently provides plants access to nutrients through a symbiotic microbial pathway.

In this study, two BMCs were synthesized and applied in an agronomic field trial in Western Australia, where wheat was grown as a crop. The structure was characterized using both SEM and TEM. Elemental composition was analyzed by energy X-ray dispersive spectrometry (EDS) facilities attached to both the SEM and TEM. Solid state ^{13}C NMR was applied to characterize the carbon structure within the BMCs. Thermal Gravity – Mass Spectrometry (TG-MS) was employed to provide data regarding chemical structure and stability. Water extractions from the soil, both with and without BMC, were analyzed by Liquid Chromatography - Organic Carbon Detection (LC-OCD) to indicate the change of dissolved organic carbon (DOC) in the soil and evaluate its bioavailability so to assess its retention in the soil. After the field trials, some BMC particles were isolated from the soil and observed using SEM to identify microbial activity.

Electron microscopy showed that interfacial reactions occurred between biochar and the mineral phases. EDS analysis showed that P, Ca, Mn, Mg, Fe, Al/Si rich phases were present at the interface between the mineral and the biochar. This suggests that cations have a major contribution to the formation of BMC's. Phosphate precipitation, especially at these interfaces, was also observed. Solid state ^{13}C NMR showed that aromatic carbon was the dominant organic phases in BMC. However, there was also a relatively high percentage of labile carbon present. TG-MS showed that organic phase decomposition commenced at temperatures above 300°C, which implies that the labile carbon in the BMC was more stable than that in biochar alone. LC-OCD analysis showed the decrease of DOC in the water extractions from the soil with BMC. In other words, DOC was greater for the BMC, which indicated more DOC was retained by the BMC. For the aged BMC's, fungi hyphae were observed using SEM, suggesting the BMC promoted microbial activity.

Biochar, the Oldest Technique but Newest Hope

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Biochar is the oldest techniques but newest hope of the planet. Biochar is defined simply as charcoal that is used for agricultural purposes. It is created using a pyrolysis process, heating biomass in a low oxygen environment. Once the pyrolysis reaction has begun, it is self-sustaining, requiring no outside energy input. Byproducts of the process include syngas (H_2 + CO), minor quantities of methane (CH_4), tars, organic acids and excess heat.Evidence shows native peoples in the Amazon used the substance centuries ago to enrich their soil to feed a thriving civilization. New grassroots efforts are aimed at showing biochar is not ancient history. Research shows that the stability of biochar in soil greatly exceeds that of un-charred organic matter, sequestering carbon in stable soil carbon pools for centuries to millennia. Bioenergy coproduction with biochar can displace fossil fuel use. Because biochar retains nitrogen, emissions of nitrous oxide (a potent greenhouse gas) maybe reduced. Turning waste biomass into biochar also reduces methane (another potent greenhouse gas) generated by the natural decomposition of the waste. Biochar systems are integrated systems with multiple, cascading benefits It is very much necessary to broadcast the techniques all over the woirld to save our planet.

Continuous Production of Biochar Through Direct Contact, Aerobic Pyrolysis

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A process and apparatus for the production of charcoal through direct contact aerobic pyrolysis is described in which a biomass input is pyrolysed in a reaction chamber that is open to atmospheric air. Energy released in the pyrolysis of biomass supplies the heat necessary to cause the pyrolysis of incoming material. There are a number of issues with this method including reduced control over reaction temperature and a need for input biomass to have moisture content below 20%. These issues can be addressed by drying input material and by adjusting reactor conditions such as air flow rates and stirring rates. Using direct contact, aerobic pyrolysis, char can be produced across a range of conditions, specifically between 500-700 ˚C so that the adsorption of a product biochar can be maximized while other properties can be modified through production temperature to produce a biochar that is well suited to a particular application.

Hydrothermal Carbonization of Residues from Anaerobic Digestion

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Fermentation residues from anaerobic digestion are an abundant source of biomass. High concentrations of minerals and water, however, are limiting their use to a few applications. Therefore, the aim of this study was to investigate the feasibility of HTC for converting these wastes to biochar. For comparison purposes, also the microcrystalline cellulose Avicel PH-101 (Fluka) was tested.

The experiments were carried out in a 1 L stirred batch reactor (Parr, USA) using distilled water as process medium. The fermentation residue (TS = 96.9 g/kg; Total-N = 7.9 g/kg; NH_4-N = 735 mg/kg, C in % of TS = 45.4) was obtained from a laboratory digester using maize silage as a sole substrate. Avicel (C in % TS = 43.7) was processed at temperatures of 190, 230 and 270°C whereas the fermentation residue was only treated at 230°C. All experiments were started at pH 5 (after addition of citric acid) and operated with a retention time of 4 h. The reactor's initial TS concentration of Avicel and fermentation residue was 97 g/L and 73 g/L, respectively.

The particulate carbon produced from Avicel at 190, 230 and 270°C was 13.7, 14.2 and 16.0 g corresponding to a C efficiency of 64.7%, 67.2% and 75.6% and a C content of the biochar of 49.9%, 67.7% and 73.1%, respectively. Treated at 230°C, the fermentation residue yielded 8.1 g of particulate C. This corresponds to a C efficiency of 61.2% and a C content of the biochar of 53.6%. When comparing the final liquor pH values from processing Avicel (pH 2.7-3.2) and fermentation residue (pH 6.4) it can be assumed that the HTC of fermentation residue was affected by the puffer capacity deriving from its minerals. In respect to the HTC liquid phase, it appears noticeable that acetate is the dominant volatile fatty acid (VFA) of both carbonized Avicel (0.59-1.77 g/L; 90-97% of total-VFA) and carbonized fermentation residue (1.33 g/L; 81% of total-VFA).

As shown by the experimental results, the HTC of fermentation residues from anaerobic digestion is feasible but could be disturbed by their relative high concentrations of minerals. As acetate is an ideal substrate for anaerobic digestion, recycling the HTC liquor back to the original digester could be a promising option. Topics for future research concerning the HTC of fermentation residues should include the optimal process design and optimal process control as well as a suitable pre- and post-treatment strategy.

Multi-Functional Porous Carbon Beads

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The conversion of organic wastes into porous lightweight charcoals which are multi-functional produced physically with no chemicals and then carcbonised upto 400 ºC chemically and physically inert and stable diverse uses in horticulture water purification etc

Caracterização do Carvão Vegetal e Cinzas por Diferentes Métodos

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Amazonian soils are highly weathered with high levels of aluminum and low levels of calcium and phosphorus, which are the main factors limiting the productivity. The charcoal and ashes, when incorporated into the soil increase the availability of nutrients to plants. This work consists of the chemical characterization of charcoal and ash from the combustion of wood in the Amazon type furnace hot ass. The samples were subjected to four different methods: Methodology for analysis of soil, the levels of available phosphorus and exchangeable potassium were extracted by Mehlich 1, exchangeable calcium and magnesium extracted by KCl 1 mol L^{-1}; methodology for analysis of plant tissue, the levels of phosphorus, calcium, potassium and total magnesium were extracted by perchloric digestion; methodology for analysis of calcium carbonate, the Ca and Mg were extracted by the method quelatométrico EDTA; methodology for analysis of fertilizer, phosphorus, calcium, potassium and total magnesium were extracted by perchloric digestion. The chemical characterization of charcoal showed low levels of elements in all the methods analyzed. Chemical characterization of ash had low levels of nutrients to the methodology used for soil analysis, the methodology for analysis of organic fertilizer had higher levels of calcium, potassium, magnesium and phosphorus. This indicates that charcoal is more suitable as a soil conditioner and ash may be used as fertilizer.

Biochar Production Strategies and its Potentials for Utilization in Agriculture

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The application of biochar (biocoal, agrichar, or biomass-derived black carbon (C)) to soil is proposed as a fresh approach to ascertain a significant, long term, sink for atmospheric CO_2 in terrestrial ecosystem. Apart from optimistic effects of both reducing emissions and increasing the sequestration of green house gases, the production of biochar and its application to soil will convey immediate benefits through improved soil fertility and increased crop yields. conversion of biomass C to biochar C leads to sequestration of about 50% of the initial C compare to the low amount retained after burning (say 3%) and biological decomposition (<10 - 20% after 5 -10 years), consequently yielding more stable soil C than burning or direct land application of biomass. This great efficiency of C conversion of biomass to biochar, is highly dependent on the type of feedstock, but is not significantly affected by pyrolysis temperature range of between 350 ºC - 600 ºC. Existing slash-and-burn system cause considerable degradation of soil and release of green house gases. Opportunities now exist for conversion to slash-and- char (biochar) system. Global analysis shows that up to 12% of total anthropogenic carbon emissions by various land changes can be off-set annually in soil just by a switch from culture of slash-and-burn to slash-and-char. Agricultural and forestry wastes e.g. mill residues, forest residues, field crop residues, and urban wastes can be converted to biochar resulting in clean environment and reducing the pressure on landfills. Biofuels production using modern biomass can produce biochar by-products through pyrolysis resulting in sequestration of 30.6 kg carbon for each Gj of energy produced. Published projections of the use of renewable fuels in the 21st century, biochar sequestration could amount to 5.5-9.5 Pg C / yr if this demand was met through pyrolysis which would exceeds current emission from fossil fuels (5.4 Pg C/ yr). Biochar soil management system can deliver tradable C emissions reductions; and C sequestered, is easily accountable and provable.

Exergy Analysis of Woody Plant Biomass Torrefaction

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Many studies have analyzed high temperature pyrolysis of woody-plant biomass, with emphasis on the production of bio-oil or syngas. Here we investigate the exergy efficiency and losses of the lower temperature torrefaction (230-290°C). We model a low-temperature processing system optimized for maximum biochar output, in addition to the energy and exergy losses in the process in transportation, chopping, heating and aromatic destruction. Thermodynamic process modeling was carried out using ASPEN-plus.

Using this same analysis we investigate the radius of carbon neutrality for a biochar operation where the biochar is derived from waste feedstock from a plantation perennial bioenergy crop, such as coconut or oil palms. For this study we use the test case of coconut palm as the energy crop and model processing the coconut husk and other waste byproducts in a low-temperature torrefaction process (230-290°C) to create the biochar. The processing facility is modeled to be in the center of the bioenergy crop plantation, with the biochar then re-distributed and buried equally throughout the plantation land area.

Using this model system we compare an approximate radius of carbon neutrality for the biochar system where biochar is spread throughout plantation, and a radius of carbon neutrality where 50% of the biochar is combusted at the charring location, and 50% is spread throughout the plantation. For each scenario we show analyze the system considering the energy from the primary energy crop (copra oil) and excluding it. In this way we hope to shed light on the potential of bioenergy plantation crops such as coconut or oil palms and biochar systems to create completely accounted carbon neutral or carbon negative systems.

Albedo modification of the plantation soil due to addition of the biochar is likely, and we estimate its possible impact. Here, we do not consider additional indirect carbon uptake due to increased activity of soil microbes and increased standing biomass, but we will include it in future analyses in order to quantify a complete carbon impact for the system. Enhanced nutrient retention due to biochar as it relates to the avoided artificial fertilizer and associated carbon intensity of these fertilizers is also not considered, but could constitute significant additional avoided CO_2 released in the full-cycle processing and should be studied in the future.

Soil Biofumigation - An Adaptation and Mitigation Strategy for the New Green Economy and a Safe Solution for the Global Warming. Toward a New Biochar and Terra Preta. Case Study in Brazil and Egypt

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The phase-out of methyl bromide for soil fumigation under the Montreal Protocol indicates to the world that chemical pesticides that harm and damage the world environment will no longer be useful for our sustainable agriculture. This wise phase-out is a major and an important turning point for plant pathologists all over the world, and especially those whom working in organic farming sector. Moreover, the issue for the food and feed safety and the recent regulations for the organic production. This led and stimulated a massive and shuttle research efforts to find a safe and eco-friendly means instead of this toxic soil fumigant. This proper and safe approach is the biofumigation. Organic farming scientists considered the new technology could be developed and adopted by farmers in both developing and developed countries as well. We have to notice that Brazil is the world's largest producer of plant charcoal (38.5% of the production).

Renewable energy accounts for 50% of its total energetic matrix, contrasting with the world average of 14%; Alcohol from sugarcane, the main feedstock in Brazil's renewable energy matrix, generates a fantastic quantity of residues appropriate for biochar production. The emergent biofuels (biodiesel) industries will potentially produce tons of residues.

So, one of the objectives of my presentation to produce a both a compost that is enriched with biofumigant and use in the same time as Biochar and Terra Preta.

The reduction of GHG emissions from farming activities is a challenge for agriculture as, globally, the sector is also called upon to increase production in order to keep pace with growing global food and energy demand. Agriculture should continue to contribute to the global food balance while increasing its overall environmental performance, including reducing its impact on the atmosphere and the climate. Unlike other businesses, agriculture is a biological process inherently linked to GHG emissions and removals from natural systems (plants, animals, soils, agricultural by-products). When evaluating the possibilities of curbing emissions, account has to be taken of the limits that these natural processes set for the reduction potential. Further challenges for the adoption of biofumigation to produce a Biochar and Terra Preta will be discussed during the presentation.

Energy Revolution Through Biomass Gasifiers: A Case Study From India

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India, being an agrarian country, is rich in biomass resources and millions of tons of biomass is being generated in the form of dry wastes like agro residues, fuelwood, twigs etc and wet wastes like cattle dung, organic effluents night soil, sugarcane bagasse, banana stem, rice husk etc in rural areas where poor people live and where other sources of energy have not yet reached. On a conservative estimate, about 30 million tones of solid waste and 4400 m^3 of liquid of liquid waste are generated every year in urban as well as in rural areas from household and other commercial activities. Therefore, biomass holds considerable promise as an eco-friendly source for generation of power for decentralized applications. Nearly 46% of the total energy consumption in India is now estimated to be met from various biomass resources such as agricultural residues, animal dung, forest waste and firewood. To tap this large potential a National Program on Biomass Power / Cogeneration has been launched by the Government of India, envisaging bio-mass based power generation, biomass / bagasse-based cogeneration, biomass resource assessment, through a number of projects including the installation of gasifiers. Greater focus has been laid on the promotion of village electrification projects, as well as on industrial applications. The producer gas is burnt directly for thermal applications (it can even be used for replacing diesel oil engines for mechanical and electrical applications for water pumping). So far, India has installed nearly 1700 gasifiers systems in more than dozen States with an aggregate capacity of around 35 MW. The biomass gasifiers are boon to the Indian rural population where country’s developmental activities could not reach for the want of energy resources. Such energy development is particularly important in minimizing drudgery of Indian rural women, who otherwise spend a lot of time and energy in collecting fuel wood. In fact, it can be said that a quiet energy revolution is being brought about, particularly in villages un-reached and unreachable by conventional electricity through the grid. What is of significance is that locally available biomass material like pruning and residues from energy plantations in the area, weeds, paddy husk etc are used as fuels in the gasifiers.

The Design and Analysis of Activated Biochar Material for Control of Elemental Mercury Emissions from Industrial Facilities into the Global Atmospheric Pool

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Mercury in the environment has been one of planet earth's largest environmental issues over the past decade. The emental mercury is emitted from various industrial sources of the planet into the atmospheric environment's global pool. Once in the atmospheric environment, the elemental mercury mixes globally within the atmosphere's pool. Then deposits uniformly to the planet's surface. it is the aquatic systems of planet earth that are the most sensitive to the elemental mercury deposition. The mercury deposition essentially methylates the various water systems of planet earth. The Saskatchewan Research Council with the University of Saskatchewan' s Chemical Engineering Department and SaskPower have been working for many years with programs on the activation of biochar aerosol material for in-stack elemental mercury capture and removal prior to emission of the flue gas into the atmospheric environment.

Preliminary programs have been conducted with various coal burning Power Plants within the province of Saskatchewan Canada to use several biochar companies material to design an injected biochar aerosol that will effectively capture and remove elemental mercury within an operational industrial flue gas stream setting. We used the Emission Control Research Facility (ECRF) of SaskPower to conduct these programs. At the ECRF with an input Powdered Activated Carbon (PAC) feed rate of 1.0 lbs/M/Macf the elemental mercury removal rate for the same flow rate of activated biochar aerosols was 90% from the flue gas stream compared to a corresponding 75% elemental mercury removal rate for the same flow rate for a coal carbon based activated carbon based aerosol particle. We also conducted research on varying the levels of activation for a specific type of biochar aerosol injected into a similar flue gas stream for effective elemental mercury capture efficiencies. Specifically with the same biochar precursor source material we compared a reference level of activation with an optimum level of activation for its elemental mercury capture characteristics within a flue gas stream. The results showed that for the same biochar precursor material it was the optimum level of microporosity with a BETA surface area of 538 m^2/g on the injected aerosol surface that effectively removed 92% of the elemental mercury in the flue gas stream vs. the reference level of microporosity with a BETA surface area of 482 m^2/g on the aerosol surface that removed 78% of the input elemental mercury.

We have shown that biochar material if prepared in an appropriate manner can be an effective capture agent for industrial in-stack elemental mercury atoms. Indeed, biochar produced aerosols for elemental mercury sequestration are quite superior to coal carbon aerosols specifically designed for flue gas stream mercury removal. The full details of this project results and it implications for global atmospheric emissions of elemental mercury to the environment will be presented.

The Making and Uses of Biocarb, a treated Biochar

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The making of biochar from trees and shrubs (ebano and mesquite) growing in the northeastern arid region of Mexico using traditional methods is presented. The layout of a plant to process biomass into biochar where excess thermal energy is used for distilling essential oils and essential holophytes (acqueous fraction of distillate) and progress in the construction of a continuous pyrolisis reactor and a sui generis biochar mill are also presented. Preliminary results from a pilot scale reactor using local biomass from various sources, will be given.

We have coined the term BIOCARB to designate a biologically treated biochar. The details are the subject of a patent we are applying for. Results of ongoing tests of BIOCARB on various states of MEXICO will be presented, along with preliminary studies of economic feasibility.

Caracterización de Biochar obtenido de Diversos Feedstocks en las condiciones Hiper Áridas del Valle de Lluta, Arica, Chile

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El Valle de Lluta, ubicado en el extremo norte de Chile, se caracteriza por tener un clima desértico costero hiper árido (sin precipitaciones) de temperaturas benignas para el crecimiento vegetal durante todo el año, y por ser una cuenca afectada por sales (Conductividad Eléctrica del agua superior a 2 mS/cm), y en particular por un relativamente elevado contenido de boro (promedio superior a 15 mg/L) que en estas concentraciones resulta fitotóxico y restringe significativamente la variabilidad de especies presentes. Pese a estas condiciones relativamente adversas al crecimiento vegetal, este Valle cuenta con la presencia de una densa cubierta vegetal en las zonas no cultivadas, con muchas malezas halófilas extremas que se adaptan perfectamente al crecimiento en estas condiciones y generan una importante cantidad de biomasa anualmente. Junto con esta biomasa, la actividad agrícola, basada principalmente en ecotipos de maíz, alfalfa y cebolla tolerantes a las concentra ciones de boro, y la actividad ganadera asociada a la disponibilidad de forrajes, genera a su vez una importante cantidad de residuos vegetales y animales en cada ciclo de producción anual. Con el objetivo de estudiar la utilidad de la biomasa disponible en este Valle para fines de producción de Biochar y su uso como enmienda agrícola y método de secuestramiento de C, se efectuó un trabajo de recolección de muestras y elaboración controlada de Biochar con cada uno de los materiales disponibles. Se reportan los valores encontrados para cada feedstock evaluado en cuanto a: Contenido de Humedad inicial (% m/m), Rendimiento a la conversión en Biochar (entre 35 y 50% m/m); y características del Biochar tales como: Contenido de Cenizas (% m/m), Salinidad inducida en solución con C.E. entre 9.5 y 27.0 mS/cm, pH en solución en un rango de 9.5 a 11.5, Contenido de C (promedio de 50% m/m), Capacidad de Intercambio Catiónico (CIC). Se analizan las probables consecuencias de estas características para el uso de estos Feedstocks como fuente de Biochar para uso agrícola y secuestramiento de C.

Los autores agradecen el financiamiento otorgado por la Fundación para la Innovación Agraria (FIA) Proyecto Código PYT-2009-0072, así como al Convenio de Desempeño UTA – MINEDUC.

Making Biochar on a Medium Scale Economically and Safely, While Minimizing Pollution

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As an organic farmer using biochar for several years, and now as a cofounder of New England Biochar, I have studied the effects of using biochar on the farm as well as the challenges associated with its production. My company has developed a very clean low tech system that can produce excellent biochar while simultaneously harvesting the extra process energy as gas, heat, or electricity. All of this is done while producing so little smoke that one cannot tell that the machine is running until one is close enough to sense the heat. Our units can be stationary or mobile. They integrate very nicely into small businesses like compost producers, saw mills, greenhouse operations, or any number of other situations that can make use of the available energy. Our process can work on diverse feedstocks with wide ranging moisture contents. We have shown that making biochar can be profitable and we believe that distributed production represents the greatest hope for the world to see the best from biochar both environmentally and economically. While we are happy to promote our own technology we believe in encouraging as many others as we can to create or improve biochar technology. The field of opportunity is huge and we see no need to fear competition but instead we look forward to recommending the right technology for each given situation. Lastly, we believe it is very important to educate the next generation in the hope that biochar creation and use will be ruled using the wisdom necessary to keep us on the right track.

Integrated biochar systems
Sustainability, certification and legislation
Commercializing biochar and large scale dissemination
Emissions trading and climate change policy

The TLUD cookstove system with low-cost Biochar production aggregating to large volume

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Key words: *Biochar-production, TLUD, cookstoves*

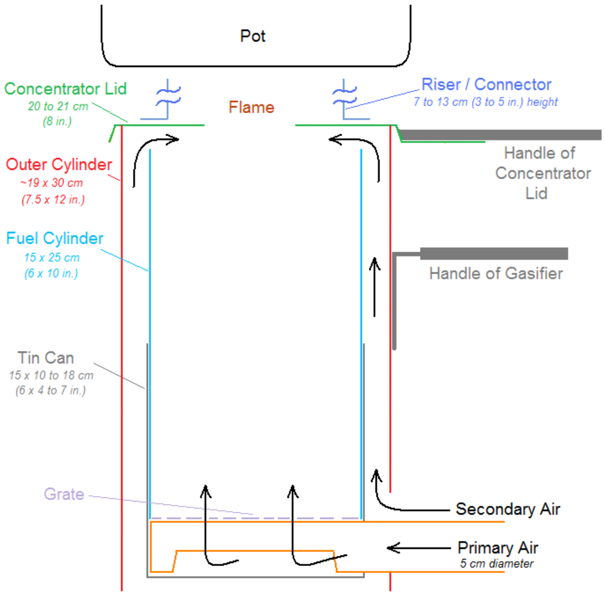
Making Biochar in Households

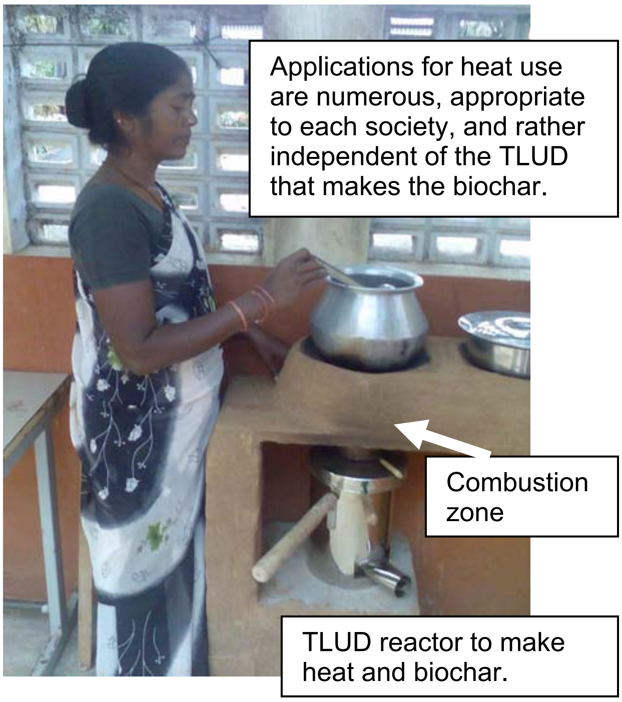
While preparing a meal in rural Africa, Asia or Latin America, the cook almost effortlessly transforms low value biomass into quality biochar because her stove is a fuel-efficient Top-Lit UpDraft (TLUD) pyrolytic gasifier. The collected biochar can be easily crushed and applied to the land when convenient.

By prior arrangement, a “biochar assessor” from the area could document the placement of the biochar onto the field either during dispersal or by soil sampling even years later, justifying payment for carbon credits. Alternatively, weekly or monthly biochar production could be purchased (or traded for fuel) by a centralized entity that manages the full project.

TLUD Technology

Gasifiers are devices in which dry biomass is transformed into combustible gases in processes distinctly and controllably separate in time and location from the eventual combustion of the gases. Within the TLUD type of gasifiers, flaming pyrolysis in the pyrolysis zone at the top of a column of chunky dry biomass is starved of oxygen, resulting in pyrolytic gases (“smoke”) moving upward to where fresh secondary air enters, resulting in clean combustion of the gases.





Applications for heat use are numerous, appropriate to each society, and rather independent of the TLUD that makes the biochar.

Combustion zone

TLUD reactor to make heat and biochar.

- •TLUDs can utilize a wide range of biomass fuel types that should be in chip or chunk sizes, including briquettes, pellets and seeds.
- •TLUDs are “gas burners” that produce their own supply of gas on demand via pyrolysis of biomass, creating charcoal as an optional by-product to be easily collected.
- •TLUDs can provide continuous heat when using two fuel containers.
- •TLUDs consistently have significantly lower emissions of CO and particulates than do most other biomass cookstoves. In the least developed societies, indoor air pollution (IAP) is the fourth worst cause of poor health and avoidable deaths of women and small children. (WHO study, 2004), adding to TLUD appeal.

Biochar Yields

Depending on cooking styles and biomass supply, each household produces between half and one kilogram of biochar each day, accumulating 180 to 400 kg of biochar per year, easily equal to one ton of CO_2 _removed_ from the atmosphere. The biochar is sufficient to apply 1kg/m^2 to a 20 x 20 meter agricultural plot. Additional dry biomass wastes could be pyrolyzed in larger TLUDs. The poorer the soil, the greater the favorable impact on the family's crops in all subsequent years.

The biochar benefits can be directly multiplied by the number of participating households. Annually a village of 100 households could create 30 tons of biochar, improve 3 hectares of cropland, and earn their share of 100 carbon-credit-tons. At least three hundred million households that burn solid fuels (mainly wood) in developing societies are candidates for this system. A multitude of small, locally sensitive, decentralized projects combine to create large volumes of biochar. This vision by UBI and others is totally realistic.

Realities

-- TLUD biochar-making cookstoves of several designs have been constructed, tested, and found to have extremely low emissions, generating interest by health-focused allies to participate in dissemination efforts of improved cookstoves.

-- TLUD stove production costs and fuel flexibilities are advantageous for the target communities.

-- Tested TLUD biochar is average to superior in adsorption and other characteristics, depending on the specific device and how it is operated.

-- Pilot projects of TLUD stoves (without a focus on biochar) are starting in Costa Rica, Mongolia, Thailand, India, Nepal, and six African countries. These will gather important data on stove acceptance, fuel issues, and environmental impact (less deforestation).

-- TLUD technology can be sized larger and smaller to suit the needs of the heat users and to increase the production of biochar by increased usage for diverse tasks, including water heating, room heating, and small industrial needs.

Challenges

-- Without the trial sites for the stoves, there is currently no TLUD biochar production for field testing.

-- Without incentives for saving biochar, most of the produced char will be consumed in char-burning stoves.

-- Carbon credit funding for cookstoves has not reached the TLUD or biochar level.

Conclusions

All indications are that the TLUD technology and cookstoves can accomplish or at least significantly contribute to **NINE WINS.**

1. Families **use low-value biomass,** save money, cut fewer trees, reducing deforestation.
2. Society accomplishes **less CO_2 entering the atmosphere** (via charcoal co-product).
3. Kyoto/CDM **"carbon credit" is generated** by this charcoal and reforestation.
4. Impoverished **families receive improved cookstoves** to motivate A & B.
5. **Reduced Indoor Air Pollution** yields better health for biomass users.
6. **Verifiable permanent sequestration** of carbon via scattered burial.
7. **Soil characteristics improve**; crops are better (w/ improved food & health).
8. Appropriate sustainable technology **creates employment** & capacity building.
9. De-centralized implementation allows **maximum localized adaptations** and minimal transportation costs.

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www.bioenergylists.org/

andersontludconstruction	(dimensions)
Mclaughlintoucan	(dimensions)
Andersontludcopm	(emissions data)
Tludhandbookdraft-1	(background & links)
content/pyrolysis-temperatur	(large TLUD)

http://terrapreta.bioenergylists.org/content/all-biochars-are-not-created-equal-and-how-tell-them-apart
(characteristics of TLUD biochar)

www.hedon.info/Micro-GasificationWhatItIsAndWhyItWorks

The use of private law instruments as a new trend of international environmental law: the case of biofuel promotion

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Key words: *Contracts, certification schemes, international environmental law effectiveness*

Abstract

The purpose of this work is to demonstrate how private law instruments, such as contracts and certification schemes used in the context of biofuel promotion may contribute to more effective compliance to International Environmental Law. In order to understand the role of private law instruments in the protection of the environment some traditional regulatory instruments used in International Environmental Law are analysed as to point out their weak effectiveness and in order to explain the need for new regulatory instruments. Afterwards, some examples in which private law instruments are being used to guarantee environmental protection and how they may be able to "overtake" these traditional regulatory difficulties is also analysed.

Traditionally, regulatory instruments used by International Environmental Law were based on command and control measures, economic incentive systems and information-based systems. These regulatory instruments are frequentelly seen as not effective for many different reasons. Basically, because their goals aren't always implemented worldwide, for instance the United States of America opted in not following the kyoto protocol. The lack of effectiveness can also be explained because they can not be directly applied to private parties. Therefore, it is possible to see an increasing use of regulatory instruments that motivate environmentally favourable behaviour rather than just instruments that regulate or sanctionate them.

As market based instruments, private law instruments such as contracts and certification schemes have already been to some extent used before as an instrument for International Environmental Law compliance. For example, in the domain of biodiversity conservation, biodiversity prospecting contracts are used in order to establish rules for researches and commercial use of natural resources. These biodiversity contracts are signed normally between a host country rich in biodiversity and in general a pharmaceutical company and they have been considered as an effective way of assuring equitable benefit sharing among all parties directly envolved in the contract and even parties indirectely envolved such as traditional communities that share their traditional knowdlege for these researches. These contracts enforce compliance towards the obligations set out by the Convention on Biological Diversity as they guarantee that private companies which explore natural resources are more directly "regulated".

As well, we can see Contract law being used in the Climate Regime, these contracts are known as carbon contracts or Emission Reduction Purchase Agreement. They are agreed among private companies with the main objective of assisting companies in buying or selling carbon offsets in the Carbon Market. So, these contracts assure private companies more legal certainty and stimulate more investment in emission reduction projects.

In the Biofuel promotion context, the production of biomass for biofuels may have both negative and positive effects to the environnement. Since there isn't yet an internationally recognized and harmonized regulatory system for their production, what we see is the increasing number of international private contracts and private voluntary certification schemes being designed with the promise of guaranteeing environmental protection as well as social and economical development. These contracts establish the sustainable use of the environment as a mandatory condition to continue their economic activities. The nature of these contracts vary considerabily but normally they consist in investment agreements, such as joint ventures and concessions.

However, these contractual relations should be carefully analysed in order to see if these private contracts may be considered as "an instrument for international cooperation" in the sense that the partnership between the companies result gains for all parties envolved, from the local biomass producer until to the

multinational company that invested in the development of biofuel. So if well agreed, private investment contracts can also be used to insert rules that obligate environmental protection and other sustainability goals. The surveillance of these “promised” sustainable commitments turns out to be complex and quite difficult since these contracts have many privacy principles that can not be easily trusspased.

Considering the humankind interets envolved it is important to also establish effective tools capable of ensuring more transparency in order to maximize the contribution of an investment contract towards environmental friendlly actions. Therefore, considering the necessity of contract and commitment surveillance, certification schemes appear to have an increasing importance to assure environmental protection. There are many different kinds of certification iniciatives being negotiated at national, international, and European Community level. These certifications schemes establish sustainable critereas that must be considered in order to prove that a certain biofuel is environmentally safe. However, these iniciatives are quite descoordinated and not at all harmonized, specially in what concerns developed and developing countries point of view.

Just to illustrate this scenario, the European Union Directive on Renewable Energy promotion was adopted in 23 april 2009, and sets out in article 17 some sustainable critereas that must be fullfield so that only biofuels can count for European Members national targets. These critereas are applied for all biofuels, whether they are produced within European Union or imported from outside the EU.

The European commission encourages industry, governments and NGOs to set up voluntary certification schemes. So, these certificates must guarantee that all the biofuels sold under the label are sustainable. All schemes have to have an independent auditors which will inspect and report the whole production chain, from the farmer to the trader and the fuel supplier. Briefly, there are two kinds of criteras set out by the directive, one concerning the biofuel capacity of GHG savings and another criteria is realted to land use, so it explains which types of land can not be used to produce biofuels.

However, even if this sustainable critereas seem to be a good solution to the surveillance problem earlier mentioned, it must be pointed out that the proliferation of different technical criterias of sustainability are creating more difficulties especially with regard to the legitimacy of their elaboration and to the possiblity of creating commercial trade discrimination barriers. These certification schemes will be more effective if they are internationally harmonized and recognized, but in order to achieve that harmonisation it is necessary to have a broad participation of diferent stakeholders in the elaboration of these critereas.

In conclusion, what we see is that the use of contracts can contribute to the construction of a hybrid regulatory system, formulated by both public and private regulatory instruments and that this hybrid system may ensure a more effective protection of the environnement since its norms are directly applied by private sectors. Therefore, even if the use of hybrid public-private regulation in International Environmental Law is still in an early stage it is already possible to conclude that private law will have an important role to prevent future environmental damages.

Potential for Biochar in Stann Creek and Toledo Districts of Belize

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Key words: *waste management, energy, soil fertility*

Introduction

The design of an effective biochar system for a given location is dependent on many environmental and economic factors; from a biochar engineering perspective, the goals of the potential biochar users are critical to determining what kind of biochar system should be implemented.

The Stann Creek and Toledo districts in the south of Belize consist of large protected land areas, commercial farms for citrus, banana and shrimp exports, native communities practicing traditional milpa (slash and burn) agriculture, coastal areas and cayes (islands) frequented by tourists, Mayan archeological sites, and tropical rainforest. Climate and soil quality vary significantly across the region though many areas have very weathered soils prone to low fertility, inconsistent rainfall, and erosion. As a soil amendment and as an energy production platform, biochar has the potential to address some of these issues.

Three scenarios are considered for potential biochar implementation: a nearly self-contained ecosystem on a small caye, a relatively large commercial farm growing citrus for export and a milpa-style farm primarily used for sustenance.

Among the factors for consideration were soil and environment information available from previous land surveys, goals of the national governing bodies such as the Ministry of Agriculture and Fisheries, the Department of Forestry, and the Protected Areas Conservation Trust (PACT), cultural and policy emphases on diversity and sustainable eco-tourism, and local development goals regarding import/export balance, affordable energy, education and capacity building, environmental conservation and sustainable revenue sources.

Results and Discussions

The first scenario considered Small Mulligan Caye, also known as Frigate Caye or Big Bird Caye, just 45 minutes by boat off the coast of Placencia town. The very small island has a dock and two small buildings, a manager's shack and a gazebo bar, and is used for camping and as a staging area for line fishing and diving trips. Waste management and energy are two of the main challenges for the island. Typically, food/compostable waste is tossed into the sea to feed the fish, and paper products such as toilet paper and food packaging are burned, but most garbage has to be transported back to the mainland. Energy comes from a solar/battery system, a propane stove, a charcoal grill, and if necessary, a diesel generator. A small biochar cook stove (i.e. low temperature gasifier) could be used here to replace the propane that must be shipped in for cooking with heat provided by the pyrolysis of paper products, garden wastes, and driftwood. The biochars produced could then be added to the garden soils, which were brought in one bucket at a time from the mainland to grow vegetables, fruit trees, palms, and sugarcane on top of the infertile sand.

The second scenario considered a large (~100 ha) citrus farm in the Stann Creek district used to grow juicing oranges and grapefruits for one of the Citrus Products of Belize Limited (CPBL) processing plants that makes juice concentrate for export to the U.S. and other countries. While the soils in this region are well-drained and are good for supporting tree root growth, the low pH (4-5) and high demand for fertilizers are constant challenges [1]. A relatively high ash biochar applied to the built-up area around the base of the trees would provide some of the necessary liming capacity to raise the pH, some phosphorus and potassium, as well develop nutrient holding capacity over time such that less fertilizer would be needed. Biochars could be produced at the juice processing plants utilizing the fruit rinds, seeds, tree cuttings, etc. The energy co-product could be used within the plant and to dry the biomass prior to pyrolysis. Previous research has shown that citrus byproducts can be used as feeds for ruminants [2], as well as feasible feedstocks for producing chars [3].

The final scenario considered a small (5-10 ha) family/community farm practicing milpa agriculture for home consumption. The farm is situated on the side of a hill and produces maize, beans, squashes, tomatoes, peppers and other vegetables, trees such as palm, almond, mango and papaya, annatto (used as a food coloring and flavoring) and other spices, and a couple cacao trees. The low soil fertility of the region requires that fields must be cleared and burned every year during the dry season, then allowed to lie fallow after harvest for 7-10 years before they can be used again [4]. Such land-clearing is very time consuming, requires a large amount of land per capita, emits a lot of air pollution, and increases the risks of soil erosion. Production and application of biochar during the clearing process in mobile, efficient pyrolyzers could mitigate several of these challenges, most importantly by helping to build up and maintain soil fertility such that fields could be used for more than one growing season and less land would need to be put into production. The need for less land would be especially important in regions immediately adjacent to protected lands, where illegal use of the forests for timber, fuel and crop land remain a serious concern [5]. As with the first scenario, a small biochar-producing high-efficiency cook stove could also lower the demand for expensive propane.

Conclusions

Three scenarios were used to demonstrate the potential for biochar implementation in the Stann Creek and Toledo districts of Belize on small and large scales. The needs in these scenarios for waste management, renewable energy and soil fertility improvements, combined with strong cultural emphasis and government policies focused on ecological sustainability, make Belize an especially promising location to develop biochar research programs.

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[1] King, R. B.; Baillie, I. C.; Dunsmore, J. R.; Grimble, R. J.; Johnson, M. S.; Williams, J. B.; Wright, A. C. S. 1989. *Land Resource Assessment of Stann Creek District, Belize*; Overseas Development Natural Resources Institute: Chatham, UK.

[2] Bampidis, V.A.; Robinson, P.H. 2006. *Animal Feed Science and Technology, 128,* 175.

[3] Marquez-Montesinos, F.; Cordero, T.; Rodríguez-Mirasol, J.; Rodríguez, J. J. 2002. *Fuel, 81*, 423.

[4] King, R. B.; Baillie, I. C.; Bissett, P. G.; Grimble, R. J.; Johnson, M. S.; Silva, G. L. 1986. *Land Resource Survey of Toledo District, Belize*; Land Resources Development Centre: Surbiton, UK.

[5] *Ministry of Natural Resources, Local Government and the Environment Forest Department Strategic Plan 2005-2010*, The Government of Belize: Belmopan, Belize. 2005.

Economic research into biocharisation of urban solid waste in China

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Key words: *Trash*, *Biochar technology, Feasibility*

Introduction

With the development of economy, China is producing a huge amount of trash everyday; most of them are urban solid wastes (USW). Today the USW treatments are mainly landfill, incineration, composting, etc. Some of them have fatal weaknesses and are meeting more and more dramatic oppositions from the publics.

This research applies biochar technology to USW treatment in order to avoid the weaknesses and contribute to the mitigation of global climate change.

This research includes 4 aspects:

1. Present situation of USW treatment in China;
2. Laboratory test of USW biocharisation;
3. Assessment of hazardous materials from biocharisation process and its countermeasures; and
4. Contrastive mass production test of USW biocharisation and activated carbonization and the feasibility of USW biocharisation.

Results and Discussions

Biochar can be made from USW, the elemental composition of USW biochar is shown in table 1.

Table 1. The elemental composition of USW biochar

Items	Value
Biochar yield (%)	49.8
Total N (%)	3.030
Total P (%)	3.299
Total K (%)	0.831
pH (water/carbon = 2.5/1)	9.86
Electric conductivity (water/carbon = 20/1, mS/cm)	5.0

Hazardous materials detected in the pyrolysis process are far below the national standards;

The cost of producing biochar using a special-typed pyrolysis system is between \$50~60 (excluding the cost of feedstock), it is economical feasible. See table 2.

Table 2. Daily costs and returns of USW biochar production using the special-typed facility

Items	Q'ty	Unit	Price or Costs (US\$)	Value or Costs (US\$)
Returns				**1,173.00**
Biochar[1] (yield:20%)	4	ton	293.25	1173.00
Bio-oil[2]	0	gallon		0.00
Subsidy from governments[3]	20	ton	8.82	176.40
Costs				52.44
Facility depreciation[4]				5.44
Overhead[5]				10.85
Labor(3 shifts, 1 worker/shift)	3	day	10.29	30.87
Electricity consumption	24	hr	0.22	5.28
Daily profit				**1,120.57**
Annual profit				**403,403.40**

Notes: The explanations of items with superscripts will be provided in the text.

The feasibility of USW biochar is just because of the low cost of the special-typed pyrolysis facility which is easy to be questioned by many people (in case of doubt, please contact me).

Conclusions

The test results revealed the great feasibility of USW biocharisation in China technologically and economically even though there are not subsidies from governments.

Ensuring sustainability of biochar: Learning from the experience of bioenergy

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Key words: *sustainability assessment; criteria and indicators*

Introduction

Biochar has the potential to make a major contribution to climate change mitigation and enhancement of land productivity, but to achieve this potential, biochar must avoid criticisms such as have been levelled at the bioenergy industry. The bioenergy industry is expanding rapidly around the globe, largely in response to climate change and energy security policies that promote its adoption. Bioenergy has potential to contribute significantly to mitigation of GHG emissions, and deliver positive environmental, social and economic outcomes. However, bioenergy, especially biofuels, have been criticised for delivering questionable greenhouse benefits, reducing soil fertility, causing deforestation, threatening biodiversity and increasing poverty through inflating food prices and displacing vulnerable communities. Recently, some have challenged the sustainability of biochar on similar grounds, raising concerns about production methods and potential negative environmental and social consequences.

In order for biochar to fulfil its considerable promise the industry should learn from the experiences of bioenergy. The biochar industry should take pre-emptive action to encourage and demonstrate sustainability as the adoption of biochar becomes more widespread.

Discussion

In recent years the bioenergy industry has undertaken major efforts to address sustainability challenges, through collaborative processes to define sustainability, identify measures for its assessment, and develop institutional mechanisms to promote adoption of sustainable systems. Many of these measures are applicable to biochar.

The development of a scientifically robust and socially accepted sustainability framework for biochar requires:

- engagement of a broad range of stakeholders, working to achieve consensus;
- a scientifically-based conceptual framework for sustainability assessment; and
- institutional mechanisms involving regulation and incentives, at domestic and international level, to ensure the widespread adoption of agreed sustainability assessment and assurance measures.

A framework for sustainability assessment should comprise:

- agreed principles of sustainable biochar systems, encompassing environmental, social and economic goals;
- articulated criteria that describe the elements of sustainability; and
- identified indicators for monitoring and assessment of trends in sustainability.

A system of criteria and indicators could form the basis of sustainability guidelines or standards for biochar, which could be applied within a domestic or international certification scheme.

The challenges in devising such a scheme include

- identifying indicators that are practical, cost-effective, outcome-based, and sensitive to change in significant processes of the coupled human-environment system;
- identifying indicators that are relevant across a range of environments and production systems;
- minimising transaction costs, to encourage participation, while maintaining sufficient rigour to ensure credibility;
- ensuring that small-scale producers are covered but not disadvantaged; and

- maintaining compliance with World Trade Organisation requirements on technical barriers to trade.

Sustainability should be clearly defined then assessed and assured at each stage of the value chain, and for the system as a whole. The following elements should be considered in assessing biochar systems:

- Impacts of biomass supply: e.g.
  - soil health, including nutrient levels, organic matter, structural stability, erosion;
  - depletion of plant and soil carbon stocks (rate of harvest compared with rate of growth, and off-site impacts due to indirect land use change);
  - impact on water resources;
  - on-farm and off-site biodiversity impacts;
  - local and regional social impacts.
- Impacts of biochar production: e.g.
  - emissions of pollutants and nutrients to air and water;
  - efficiency of utilisation of syngas and process heat to displace fossil energy sources.
- Impacts of biochar application: e.g.
  - nutrient value of biochar;
  - contaminant content of biochar;
  - impacts on soil health, leaching of nutrients, breakdown of pesticides.
- Whole system assessment: e.g.
  - life cycle climate change impact;
  - ecosystem function and resilience;
  - community impacts including incomes and health.

The issue of indirect land use change has been a particular challenge to the bioenergy industry, because of difficulties in attribution and quantification. Some have proposed adjusting the calculated mitigation value of bioenergy products based on estimated emissions due to land use change, but there is much debate over appropriate methodology and data. Additionally, many believe that the biomass producer, who often has limited choice of crop and control over the ultimate fate of his product, should not be penalised for deforestation outside his control; rather, indirect land use change should be managed and assessed at a regional scale.

Actions can be taken at a project scale to reduce the risk of indirect land use change, for example: utilization of waste biomass sources, intensification of production on existing agricultural land through, for example, agroforestry and intercropping; rehabilitation and utilisation of degraded land; and increased efficiency of energy utilisation.

Ideally, what is required is policy that promotes sustainable land use, whether the product is used for food, feed, fuel or biochar. Sustainable land use policies could also address the potential contaminant risk (such as where biochar is produced from contaminated feedstocks), ensuring that the product is fit for land application. Sustainable land use policies combined with effective regulation of biochar production facilities, and incentives for efficient utilisation of energy, could provide a strong framework for development of a sustainable biochar industry.

However, until such policies are implemented universally, the biochar industry needs to focus on development and promotion of guidelines that address the various elements of sustainability of biochar, as well as the whole system impact. Compliance with such guidelines could be verified by third parties, as a basis for certification of “sustainable biochar” products. Governments can play a role through policies that favour or discourage particular biomass sources, or support certified products. Ensuring sustainability will become a greater challenge as the biochar industry expands: the industry needs to be prepared to deal with issues and perceptions as they arise.

Conclusions

Ideally, sustainable biochar systems should be ensured through a policy framework that integrates sustainable land use, renewable energy and climate change goals, with effective industry regulation. Until such integrated policy is implemented universally, the biochar industry needs to manage sustainability from within, developing and promoting sustainability guidelines. Guidelines need to consider biomass sourcing, biochar production, and biochar utilisation, as well as management of whole system impacts.

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Socioeconomic barriers to implementing biochar projects at commercial scale

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Key words: *Biochar, Barriers, Commercial Scale*

Introduction

In the short time since the first international biochar conference at Terrigal in 2007, biochar has progressed from relative obscurity to international prominence, with its potential for tackling climate change and declining soil fertility achieving widespread recognition and acceptance. Despite this, there is still an extraordinary lack of commercial scale biochar production facilities anywhere in the world.

This creates a significant barrier for the development, demonstration and deployment of biochar products. To reach its full potential, biochar needs to be available for research and demonstration projects in large (kilotonne) quantities rather than the comparatively small (tonnes) quantities typically available for use by research projects to date. This generally limits research efforts to small scale (pots and plots) trials. At a rate of 20 t/ha, establishing a 50 ha field trial would require 1,000 tonnes of biochar.

Transfield Services has been working with Pacific Pyrolysis (formerly BEST Energies Australia) to realize project opportunities based on the slow pyrolysis technology they have developed. Despite strong interest from many parties and investigation of numerous prospective opportunities - well over 20 at last count – getting such projects to financial close and practical implementation has proved to be a surprisingly elusive goal.

In the course of pursuing these opportunities a range of barriers have been encountered. These have been social and economic in nature, rather than technical. They also have a tendency to form self-reinforcing loops which can be difficult to break.

Results and Discussions

The main barriers we have encountered are:

1. Security of feedstock supply

For a commercial-scale production plant to make a return on the capital invested, it must have a reliable supply of feedstock of suitable quality available at an acceptable price. A Pacific Pyrolysis plant requires ~16,000 dry tonnes p.a. (i.e. 2 tonnes per hour).

Typical feedstocks we have looked at are relatively homogeneous woody waste streams with manageable levels of contamination, e.g. municipal green waste, or construction wood waste. However, our experience has been that high expectations around the potential future value of such waste streams often leads to reluctance for the parties controlling them to enter long-term supply agreements at commercially viable prices.

We have developed several stratagems to mitigate this risk. These include constructing business models that allow the feedstock supplier to share in any future upside benefit received by the project as a whole (e.g. increased revenue from energy produced); and modularizing the plant so that if a feedstock supply becomes unviable it is relatively easy to relocate the plant.

2. Technology risk

We are finding that there are numerous groups keen to participate in biochar projects once the prototype plant has had all the teething problems resolved and the technology is proven to be reliable and profitable at commercial scale. This is often called the "Fast Follower" strategy.

Prototype projects encounter several other risks, such as uncertainty about how planning and regulatory agencies will treat such projects.

The problem is exacerbated by the extremely poor track record of AWTs (Alternative Waste Treatment) technologies, which makes investors and project partners extremely sensitive to technology risk.

The solution to this challenge is to structure the first project as a technology demonstration, with improvement of the technology and production of biochar to support research as explicit objectives, rather than success or failure being judged solely by strictly commercial criteria from the outset.

3. Project scale

A challenge for these projects is that their scale – with total capex around the A$10M mark - is awkward for financing. Unfortunately, being not too big and not too small is not just right! It means that relatively inelastic project costs like development permit applications, contract drafting etc, amount to a significant percentage of the total project cost. For the same reason, the transaction costs associated with financing such modest sums makes them unattractive to many financial institutions.

Our solution has included looking for project opportunities that are repeatable and allow standardization of as much of the business model as possible; finding and working with a financial institution that sees the long term value in the biochar industry; and looking for ways to finance portfolios of projects rather than financing each project individually.

4. Piecemeal Government support

One of the purposes of Government funding support for emerging technologies is to help companies like Pacific Pyrolysis address the preceding two challenges and get through the risks and uncertainties of the commercial prototype stage of technology development.

Unfortunately, this objective frequently gets obscured by procedural issues, resulting in funding programs with such long timelines, application & reporting complexities and strict eligibility constraints that they fail to achieve their primary objective. The only solution to this problem is to lobby Governments to simplify these funding programs and focus on outcomes rather than process.

5. Maximizing value from outputs

The main outputs from a Pacific Pyrolysis plant that have commercial value are energy (gas or electricity), biochar, and carbon emission offsets. In Australia (and many other countries) wholesale energy is a relatively low-priced commodity, biochar does not yet have a market presence (so is difficult to value) and the market for carbon emission offsets is voluntary; and very much in its infancy. Maximizing the value from these outputs, a prerequisite for commercial viability, is therefore a challenge. For the energy outputs the key to doing this is to find ways to supply the output directly to the end user at a retail tariff, rather than wholesale to a distributor.

Maximizing the value of biochar as a product requires market development, and a crucial aspect of this is producing enough biochar to support large scale research and demonstration trials, a key objective for us. It is very important to ensure that the quality of the feed material can be controlled, as this is the input to a production process and will (of course) influence the quality of the product – biochar. It is tempting to use “waste” materials that are readily available at low cost, but this strategy brings with it the risk of a contaminated product of no value, and with a damaged reputation in the market.

In the Australian state of New South Wales, as with many other jurisdictions, it is illegal to apply a product that was once classified as waste to land without an exemption from the EPA. We are currently working t obtain such an exemption for biochar.

Finally, maximizing the value of carbon offsets from biochar will require recognition and validation of methodologies for quantifying such offsets, preferably within the framework of national or international schemes for regulating and pricing carbon emissions.

Conclusions

Numerous challenges have been encountered in our efforts to build a commercial scale biochar production plant. We have now developed strategies to address these challenges and are confident that there are numerous viable opportunities for biochar production at a commercial scale.

The key to unlocking these opportunities is to build and operate a full-scale prototype production plant, which will resolve the technology risk, demonstrate the viability of the business model and produce sufficient biochar to drive the next generation of large scale research and demonstration of the agronomic and carbon sequestration benefits of biochar.

Acknowledgements

In our journey to realize commercial scale biochar production we have spoken and worked with many people. They have invariably been enthusiastic about the potential that biochar has to offer. Their interest has buoyed us through the many highs and lows, while their ideas and suggestions have all contributed to the progress we report here. We acknowledge their fellowship and support with real gratitude.

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Seeding Biochar in Costa Rica: Profile of an Integrated Development Program

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Key words: *BMC, Moisture Content, TLUD*

Introduction

At the earliest stages, commercial adoption of biochar as a soil amendment will rely upon robust plant yield data from field trials and reliable cost information from producers. Philanthropic-funded, NGO-managed programs offer a viable path for generating such cost/benefit scenarios. Integrating biochar production and field trials into a single program offers the prospect of interaction and optimization of outcomes. But implementation of such programs may not be easy or obvious, and if not carefully managed, things can go astray. Ours is a cautionary tale.

Costa Rica is an ideal setting for biochar development. In addition to its reputation for environmental stewardship—aspiring to be the world's first carbon neutral nation—Costa Rica hosts strong institutions in sustainable agriculture and renewable energy. Its tropical climate and varied geography support diverse, productive agricultural and agroforestry enterprises. The Osa Peninsula, project focus area, has acidic nutrient-poor soils on sites degraded from timber extraction and pasturing; the sort of setting where biochar's benefits can be most profound. The Osa distinguishes itself by being one of the most biodiverse places on the planet, affording a unique opportunity to assess biochar's potential for habitat restoration as well.

While first season results from agronomic studies were compromised by delays and quality issues, the strongest plant yield results were from "biochar mineral complex" (BMC), a heat-reacted blend of wood biochar, clay, chicken litter, and mineral nutrients. Wood biochar activated with phosphoric acid and amended with calcium carbonate also performed well. Straight biochar did little better than controls in the first year.

Results and Discussions

The Costa Rica Biochar Project was conceived in three broad phases: 1) implement biochar production equipment; 2) conduct plant field trials; and 3) develop economic analyses. Targeted feedstocks were the heaps of mill scrap from area *Gmelina arborea* plantations, and the growing mounds of waste from local African oil palm processing. A "dream team" was assembled involving Costa Rica institutions: the *Clean Production Center* (CPC, part of an international network of such centers supported by the United Nations Environment Program) and *Centro Agronómico Tropical de Investigación y Enseňaza* (CATIE—regional leaders in sustainable agriculture); to be guided by consultants from IBI, administered by the forest conservation NGO *Forest Trends*.

Given the qualifications of participants and the expertise of project consultants, it was widely assumed that the first task, developing biochar production equipment, would be relatively routine. Sadly, this was not to be the case. The question of liability insurance for the kiln's designers arose, resulting in several weeks delay and a level of remove between the CPC and IBI consultants. And the CPC proved to be less a technical resource than a stable of consultants and subcontractors. The resulting disconnect between design, engineering, fabrication, authority and responsibility led to delays and ultimately fabrication of a defective kiln.

High prevailing moisture content in the *Gmelina* scrap was another complicating factor; equilibrium moisture percentage of seasoned wood in the humid tropics during the rainy season hangs in mid to high 20's—high enough to compromise kiln performance Overcoming this would require a pre-drying oven, which could be powered by waste heat from the kiln exhaust stack. The oil palm waste, a fibrous low-density material, also proved challenging to pyrolyze in the retort kiln design, and so a separate kiln design would be needed for this unique material.

In August of 2009 IBI consultant Dr. Stephen Joseph came to Costa Rica to advise on the project and assist in the commissioning of the kiln. Although some biochar was produced, defects were such that its further operation would result in rapid deterioration and mechanical failure. The CPC and their subcontractors were given a fix-it list to bring the kiln up to snuff. The promise of repairs dragged on for the months, but none were implemented.

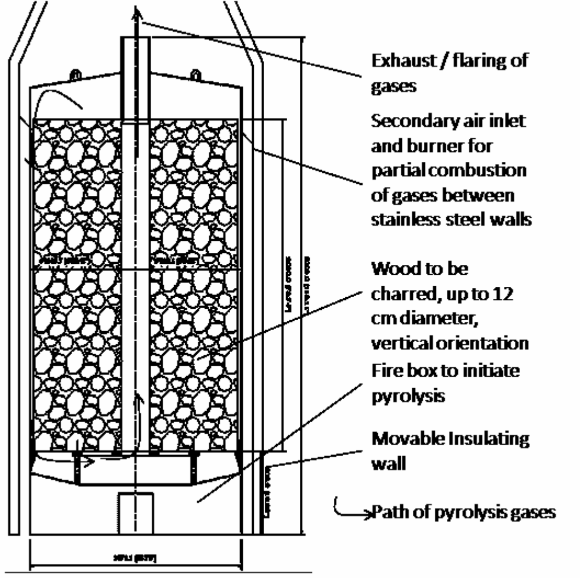

Figure 1. Retort kiln design by Nikolaus Foidl.

Meanwhile, Joseph advised aspiring Osa biochar start-up BCR on building a simple biochar mineral complex (BMC) reactor, wherein a slurry of biochar, clay, chicken litter, and mineral nutrients are continuously blended while being heated to torrifaction temperatures (~220C). CATIE investigators were somewhat belatedly provided with a selection of biochar products for scaled back field trials, including *Gmelina* biochar, acid-activated biochar, and BMC.

When the project was renewed for the 2010 season, BCR was awarded the contract to complete kiln development, including a TLUD sawdust gasifier to prime the main kiln (Figure 1), and a drying oven for feedstock; all under the guidance of IBI consultant/biomass engineer Nikolaus Foidl.

The new project team overcame the legacy of delays and defects from the prior season, and various other technical challenges, to achieve clean, controlled kiln performance with the new and refurbished hardware. Pending approval of bridge funding, the retort kiln, TLUD, a new and improved BMC reactor, and an oil palm waste pyrolyzing kiln will all be assembled under one roof by end of the year—an unprecedented collection of biochar hardware assets for pilot-scale production of a spectrum of biochar based soil amendments in this part of the world; enabling expanded and comprehensive field trials.

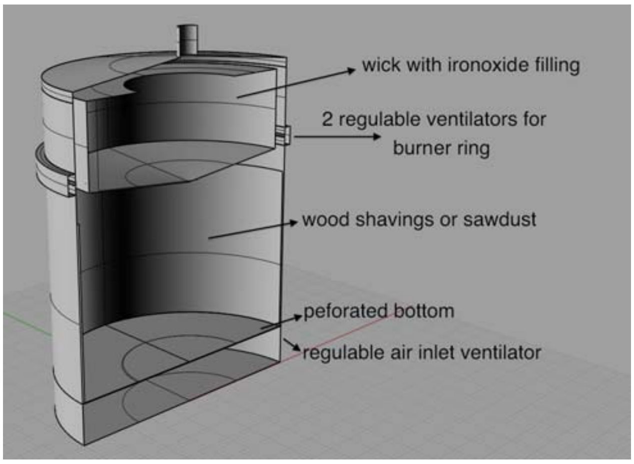

Figure 2. TLUD to prime the main kiln; at 1M dia. and 200kW+ output, maybe the world's biggest.)

Conclusions

Perhaps the most important conclusion from our work is that developing biochar production hardware—of sufficient capacity to serve for meaningful field trials; capable of producing a controlled uniform product; while generating only minimal emissions; and safe to operate by unskilled labor—is not a trivial undertaking.

The stage is now set for a complete collection of biochar hardware assets under one roof, enabling production of a spectrum of biochar products and derivatives, facilitating comprehensive field trials.

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CHAB Camp: Hands-on Development of "Combined Heat And Biochar" Devices

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Key words: *CHAB, Biochar-production, Workshop*

Introduction

Society has hundreds of reasonably priced devices that use wood and other biomass as fuel, deliver useable heat, and generate ash. It is proposed that a selection of devices be developed to similarly consume biomass and provide useable heat, while also creating a solid charcoal residue to be used as biochar.

Distributed biochar production by CHAB (Combined Heat And Biochar) devices in affluent and impoverished societies worldwide can make an important contribution to the diverse biochar objectives. Distributed small-scale biochar production is an integral component for spawning the biochar industry, affording individuals in both affluent and impoverished societies the opportunity to interact with biochar on a personal level. This interaction derived from the use of CHAB devices will create an understanding of and appreciation for biochar otherwise unavailable to industry and society.

A weeklong hands-on workshop (not a children's camp) to study and develop CHAB devices was held at the New England Small Farm Institute (NESFI), Belchertown, in western Massachusetts from August 9th-13th, 2010. The two co-authors were the principal organizers of this event. The three criteria for the CHAB devices developed and tested were that they must:

1) generate wood gas, the product of the thermal treatment of biomass, and utilize it in a productive manner,

2) provide for the recovery of biochar, and

3) produce acceptably low emissions for untreated discharge at the intended application or via flues to the outside environment.

Activities and Discussion

The goal of the CHAB Camp was to establish a core set of knowledge about wood gas (pyrolytic gases) generation and utilization, build awareness of the range of CHAB devices and explore their configurations with hands-on tasks and usage. Examples of CHAB devices include cookstoves that use the TLUD (Top-lit Updraft) technology, where biomass is converted to biochar and the wood gas is combusted to provide heat for cooking. Another CHAB configuration is the retort, where biomass is heated in the complete absence of air to create biochar and wood gas, and the wood gas is subsequently combusted for useable heat. An Adam Retort was operated during the camp week. Suitable heat applications for CHAB devices include greenhouse heaters, home furnaces, saunas, and combination cooking/water heaters. Cooking and heat recovery for residential space heat and hot water are the most likely heat applications. Although mentioned and discussed, large and expensive industrial applications for biochar production were beyond the scope of CHAB Camp activities.

In a series of morning study groups, the fundamentals of biomass pyrolysis, biochar characterization, carbonization conditions (those that promote higher performing biochars) and heat capture and transfer were reviewed. Afternoons and evenings were devoted to the design, fabrication and testing of existing and prototype CHAB devices.

Because of their prominence as cookstoves that can be operated for the simultaneous production of a quality biochar and cooking heat, the Top-Lit UpDraft (TLUD) pyrolytic gasifiers received considerable attention. The participation of Dr. Thomas B. Reed (innovator of TLUDs in 1985) provided an extremely valuable resource in both morning lectures and afternoon development sessions. The sequentially separated two stages (pyrolysis and char-gasification) of TLUD devices permit the biochar removal when the pyrolysis front reaches the bottom of the fuel stack and before excessive char-gasification occurs.

CHAB performances, both in terms of heat recovery and biochar properties, were measured and evaluated. The highlights of the actual units developed and their performance are reported for the first time at the IBI

Conference in Brazil, including a short video segment.

Conclusions

CHAB Camp is occurring when this expanded abstract is submitted. Fifteen people (including chemical engineers, international development practitioners, graphic designer, MBA candidate, masonry stove builder, and organic farmers) are attending, with larger numbers at the two demonstration events on Tuesday evening and Friday. Many participants are active “Stovers” (advocates and developers of improved cookstoves for Developing Societies) who shared experiences and collaborated to create stove solutions. This aspect is similar to “Stove Camp” held each summer in Oregon, USA, except that the only stoves being discussed at CHAB Camp are the ones that can produce biochar, namely TLUDs and retorts. Two persons who attended both camps this year noted the high value of both events.

The networking aspect of CHAB should not be overlooked. As people come together across disciplines, ideas are created and discoveries made through reframing arguments and explanations for a new and different set of ears and eyes. Relationships are forged that have far reaching value, as new initiatives are born and ideas hatched.

It is anticipated that CHAB Camp will become an annual event, allowing continued evolution of simple, inexpensive and accessible CHAB devices. Persons interested in organizing CHAB Camps in other locations are encouraged to contact the authors.

Reference Link for Further Info

The New England Small Farm Insititute (NESFI) is the central contact point for CHAB Camp information: www.smallfarm.org

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The potential of pyrolysis to create sustainable land management opportunities in the Hunter Valley

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Key words: *Carbon Valley, Pyrolysis*

Abstract

With the first commercial production module of the Crucible Carbon Pyrolysis technology being built for demonstration on the site of the Vales Point coal-fired power station, the creation of a new way of managing biomass in the region has begun.

This is a step towards the “Carbon Valley 2050” vision of the Hunter Valley as an emerging region of climate friendly innovation.

Can land owners incorporate into their business models this prospective opportunity to provide renewable energy resources as well as biochar for agriculture and rehabilitation of mined land?

What are the systems necessary to enable farmers to participate in this new opportunity? While coal may be king in the Hunter Valley most of the land remains under pasture and is utilised predominately for cattle grazing.

This research project will study and measure:

1. The biomass resources available on one 10,000 acre farm combining livestock grazing and horticulture
2. The performance of different biomass accumulation techniques.
3. The quality of energy and char products that might be produced by pyrolysis.
4. Application of the biochar in a commercial horticultural crop on the same farm and the performance impacts on the soil and the crop.
5. The carbon balance for the system as a whole, including net abatement and sequestration.

Farmers need to understand the biomass/bioenergy potential under their management. This study will assess the business opportunities and logistical challenges in the Hunter Valley environment and will demonstrate in practice the most promising solutions.

Industrial agriculture so often thinks little of bringing onto the farm huge volumes of inputs – both inorganic and organic. This research will examine how to better utilise the biomass within one farm in the hope of reducing inputs and creating a more cyclical micro-economy.

There is a need to re-imagine the land’s potential productivity if we are to maximize the value from bio-energy and carbon capture and storage in soils. This is an opportunity for farmers, land owners and rural industries to make a vital contribution to the transition away from the fossil fuel economy.

Opportunities for biochar in the sugarcane industry

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Key words: *sugarcane, renewable energy, slow pyrolysis*

Introduction

Globally, the requirements of food and energy are increasing. The sugarcane industry is well positioned to meet these rising demands, in that it can offer both food and energy production (in the form of fuels , both first and second generation), and stationary power from crop residues such as lignin wastes, bagasse and trash. It has the capacity to meet these demands without increasing the quantity of greenhouse gases in the atmosphere. Climate mitigation can be achieved through both displacement of fossil fuels, as well as the conversion of labile organic carbon into very stable organic carbon (biochar) that is used as a soil amendment.

Historically, sugarcane cogeneration systems were designed with low efficiency boilers, aimed primarily at disposing of the bagasse waste stream. This limited opportunities to sell excess electricity to the grid. Large-scale modern renewable electricity production from cogeneration projects can grid-input around 0.44MWh per t bagasse [1]. As sugarcane regions are updating milling and processing of wastes, significant opportunities exist to implement new technologies that diversify income from this industry.

The introduction of green cane harvesting presents challenges and opportunities for the management of trash, which was previously burnt in-field. Trash can impact some agronomic practices such as irrigation, while the higher biomass volumes transported to mills adds cost, and results in greater biomass residues for disposal. Trash may also pose technical difficulties if used in cogeneration due to high concentration of K (0.64%w/w).

This presentation details the opportunities for implementing slow pyrolysis for the production of renewable energy and biochar from sugarcane residues.

Results and Discussions

To provide alternative management of residues, we investigated the use of Pacific Pyrolysis technology using a highest heating temperature of 550^0 C with mean residence time of 40 minutes and a heating rate of 5^0 C/min. It was shown that trash yielded 34% by weight biochar while bagasse yielded 31% biochar. Both feedstock's generated 1.33MW/t, which at 37% engine efficiency, would generate 0.5MWh of electricity- equivalent to modern co-generation systems.

The resulting biochars were analysed (Table1) for a range of chemical properties. Trash biochar had high levels of total K, while levels of this mineral were lower in the bagasse biochar.

Table 1. Properties of sugarcane biochar

Sample ID	**Trash biochar**	**Bagasse biochar**	**Millmud biochar**
EC dS/m	4.8	0.18	0.50
pH (CaCl$_2$)	9.6	8.4	9.2
Bray P mg/kg	250	67	400
NH4$^+$-N mg/kg	0.73	2.2	8.7
NO$_3$-N mg/kg	<0.20	<0.20	<0.20
N%	1.2	1.1	1.4
CaCO$_3$- eq%	4.6	1.1	7.2
K %	2	0.25	0.35
P %	0.25	0.22	3.4
Carbon %	68	65	24
Molar H/C	0.45	0.43	na
Exchangeable Cations cmol(+)/kg			
Al	<0.03	<0.03	<0.03
Ca	6.4	2.1	11
K	27	0.94	1
Mg	5.3	0.25	8.3
Na	0.9	0.25	1.2

In combustion systems like traditional co-generation facilities, alkali compounds such as K foul heat transfer surfaces, participate in slag formation in grate-fired units and contribute to the formation of fluidized bed agglomerates [2].

The concentrations of K in bagasse feedstock were not significant; however, concentrations in the cane trash would certainly contribute to fouling. These fouling problems are overcome through the use of slow pyrolysis. In addition, K, an important sugarcane nutrient, is recycled with an almost 100% efficiency back into the biochar for soil application.Ultimate analysis of the biochars revealed they had molar H/C ratio's of 0.45 for trash biochar and 0.43 for bagasse biochar. Parent feedstock had ratios of 1.50 and 1.45 (data not shown), indicating disproportionate loss of H and therefore conjugated aromatic structures, conferring long residence times in the soil.

The CEC of the biochar from trash was 40 cmol(+)/kg, while the bagasse biochar was lower at 3.5cmol(+)/kg.

Many of the biochar trials undertaken have used values of 10t/ha application rate. Applications of this rate would be equivalent to increasing soil carbon from a hypothetical value of 2.0% to close to 2.5% carbon, assuming a bulk density of $1.5 g/cm^3$. The application would be equivalent to 200kg application of K, and a minor addition of P. pH of soil would be expected to increase with an equivalent addition of 460kg agricultural lime. The effects on soil fertility including CEC however can not be fully predicted and field assessments are necessary.

It has been estimated that over 2.5MT of unutilised biomass exists in the Australian sugarcane industry every year (Bernard Milford pers comm.). This waste biomass could generate around 140MW/hr of electricity if processed via slow pyrolysis, and close to 855,000 t biochar production annually. Putting numbers into perspective, this would equate to ca. 350,000 t avoided CO_2 emissions though offsetting fossil fuels, and around 2 MT CO_2 equivalents locked up in soil.

Conclusions

The global sugar industry is well positioned to implement large-scale slow pyrolysis for the production of energy and biochar from bagasse, cane leaf (trash) and other waste streams (including mill mud, fermentation residues and 2nd generation biofuel residues). The technology will help meet rising demands for food and fuel, and has the potential to offer climate mitigation through the stabilization of carbon into biochar.

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[1] Balasankari, P. K.; Mathias, A. J. 2009 Renewable Energy World International, 12, 4.

[2] Turn, S. Q.; Kinoshita, C. M.; Ishimura, D. M. 1997 Biomass and Bioenergy, 12, 241- 252.

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Progressing from Terra Preta de Índios to the Whole World

The Development of a Systems Approach to the Integration of Pyrolysis of Agricultural and Tree Crop Residues into Broad Scale Agriculture in Western Australia

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Key words: *Integration, Biochar, Systems Approach*

Introduction

Over the past nine years a systems approach has been developed to use pyrolysis of agricultural and tree crop residues to produce biochar and energy in regional nodes in Western Australia.

The potential to integrate the use of residues derived from the distillation of Mallee Eucalypt biomass for energy production to reduce the cost of eucalyptus oil production was the initial stimulus for the research project. Professor Ogawa, who was the chief scientist of the Kansai Power Corporation (who had contracted the Oil Mallee Company Pty. Ltd. to establish a one thousand hectare planting of Mallee Eucalypts on farmland to offset carbon dioxide emissions), introduced Western Australian scientists involved in the project to the concept of incorporation of charcoal into soils to increase crop productivity.

A series of standard pot trials was carried out to determine if biochar derived from Mallee Eucalypt residue could increase wheat (a major Western Australian crop) productivity.

These trials were followed by a number of attempts to assess the effect of biochar in the field. The basic design and methods used to implement these trials has been reported [1]. Essentially they involved placing different levels of biochar in bands below the crop rows in each treatment.

The principle problem with the implementation of these trials (apart from the occurrence of a series of droughts) was the difficulty of producing biochar in the quantities required and the unavailability of machinery capable of incorporating the biochar levels in one process. Consequently it was necessary to make a series of "passes" over each plot to incorporate the biochar. This caused a cultivation effect and it was impossible to accurately place the specified quantity of biochar consistently below the crop rows throughout the length of the plots.

In 2009 a different method of incorporating biochar was used. A randomized block design (five replications and fourteen treatments) using 2mx2m plots was established over a recently seeded area that had been fertilized at half the standard rate and which had just commenced germinating. Spades were used to lift and place the soil immediately below the germinating crop approximately 30 cm to one side of the row. Varying levels of biochar, equivalent to rates of 1.75, 3.5,5, and 7 tonnes per hectare, in unpelleted and pelleted form with and without the addition of mycorrizal spores was placed in the furrow. Following the addition of the biochar the soil containing the germinating seedlings was returned to the furrow. This procedure ensured that the biochar was concentrated below the wheat seedlings without a severe "cultivation effect".

One of the major constraints to biomass utilization using has been the absence of a low cost method of pyrolysis which did not require large production units that inevitably involve transport of biomass over large distances.

Rainbow Bee Eater Pty. Ltd. has been given access to a pyrolysis technology invented and patented by the Crucible Group in Newcastle New South Wales which resolves these problems. The technology is efficient, modular and low cost. This allows the size of the pyrolysis unit to be adjusted to the density of the biomass.

Importantly it allows the integration of the Rainbow Bee Eater System into existing agricultural and tree crop enterprises at the sub regional scale capitalizing on existing biomass materials handling processes, the innovation of farmers and access to large quantities of biomass which are not currently utilized.

This enabled realistic modeling of the Rainbow Bee Eater System to be carried out to determine the sensitivity of the commercially viability of the system to different factors.

Results and Discussions

Biochar and wheat productivity.

- Pot trials consistently demonstrated a significant response (> 30%) to biochar but at biochar levels which if translated to the field were significantly in excess of what would be practically and commercially viable.
- Field trials using machine delivery of biochar in bands have demonstrated statistically significant increases in wheat productivity of between 10-18 % but the results have been inconsistent and the experiment which gave a yield increase of 18% had some irrigation because of drought conditions [1].
- In the “hand placed “ biochar trial wheat yields were increased by between 20% and 29% when the biochar was not pelleted. Pelleted biochar that had been inoculated with mycorrizal spores increased wheat yield by 37% at a rate of biochar application equivalent to 3.5 tonnes per hectare but pelleted biochar without inoculation did not significantly increase wheat yield (Figure 1).

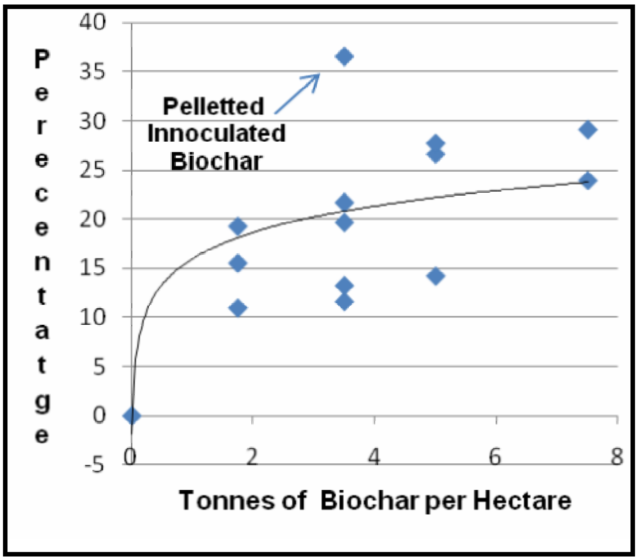

Figure1. Percentage Increase In wheat Productivity.

2. The value of Incorporation of Biochar into Soil.

Details of the efficiency and costs of production of the Crucible Carbon Groups pyrolyser are confidential. Once the initial cost to develop the technology is covered, acceptable commercial returns are expected at forecast longer term prices for biochar and the renewable electricity that is generated as a co-product with the biochar.

Table 1 shows a farmer’s internal rate of return from incorporating biochar at a price of $250/tonne, assuming conservative and realistic costs, at 10%, 20% and 30% increases in crop productivity.

Table 1. Returns from incorporation of biochar.

	Internal Rate of Return No Value for Carbon Sink (%)	**Internal Rate of Return Carbon Price$20 /CO2 T.**
Increase in Wheat Productivity(%)		
10	**4**	**9**
20	**15**	**46**
30	**26**	**183**

Conclusions

Further work is required to confirm the response of wheat crops to biochar on a range of soil types. These preliminary results suggest that biochar applied, at rates that are practical and commercial, in a concentrated form below the wheat crop row can significantly increase wheat productivity over large areas. Further work is required to confirm the response of wheat crops to biochar on a range of soil types.

Acknowledgements

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[1] Blackwall, P.; Shea, S.; Store, P.; Kerkmans, M.; Stanley, I. 2007. In: Improving wheat production with deep banded Oil Mallee charcoal in WA. International Agrichar Initiative (IAI) 2007 Conference, April 27 – May 2, 2007, Terrigal, Australia; http:///www.iaiconference.org

3rd International Biochar Conference
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Progressing from Terra Preta de Índios to the Whole World

Toward diffusing “Cool Vegetables” – reconstructing rural socio-economic systems in Japan based on an eco-branding strategy with biochar cultivated vegetables

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Key words: *biochar cultivated vegetables, eco-branding strategy, Cool Vegetables*

Introduction

Reducing GHG on a global scale is needed and carbon sequestration with biochar has the potential to continuously sequester carbon if it is part of a sustainable, regional socio-economic system. Of particular importance is the redevelopment of agriculture to incorporate biochar, especially marginalized rural areas. Our project focuses on applying biochar to agricultural land and proposes a social scheme based on an eco-branding strategy with biochar-cultivated vegetables named “Cool Vegetables” in a rural area of Japan (Kameoka City, Kyoto Prefecture).

The “Carbon Minus Project” (Figure 1) was launched by a partnership between the Kameoka City Government, Ritsumeikan University, and a local farming cooperative in 2008.

The socio-economic system proposed in this social scheme can be sustainable and feasible when local communities have the capacity to cover biochar production and application costs. The scheme includes a system to trade emission-offset credits, but the returns from trading are expected to be unable to cover whole these costs. Therefore, eco-branding of biochar-cultivated vegetables supplements income is expected to complete this scheme.

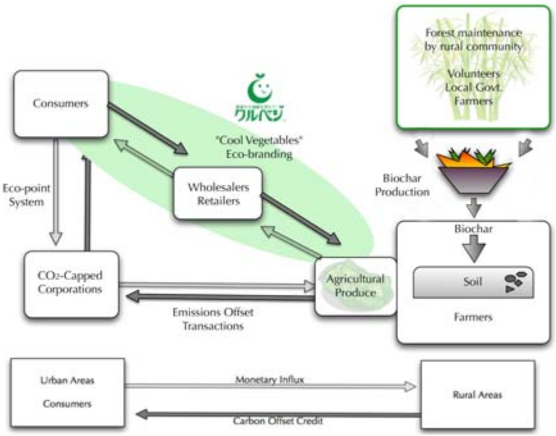

Figure 1. “Carbon Minus Project” Scheme

However, little is known as to how “Cool Vegetables” branded products will be accepted by the public. This paper reports the results from a marketing pre-survey conducted to gauge the public response to the “Cool Vegetables” brand.

Results and Discussion

(1) *Outlining the experimental sale of “Cool Vegetables” (CV) and the marketing pre-survey*

The conditions of the experimental sale of “Cool Vegetables” as an eco-friendly agriculture brand are summarized in Tables 1, 2, and 3. ”Cool” cabbageswere sold to a supermarket chain, processed into deli salads, marked with a “Cool Vegetables” brand sticker, and sold to consumers.

Table 1. Cultivation details

Site	0.2 ha; Hozu Town, Kameoka City
Period	Aug. 2009□Jan. 2010
Agricultural product	Cabbages
Sequestered carbon by Biochar	1.1t/10a
Charged material into agricultural field	Mix of compost(Cow manure, rice husks) and biochar
Biochar material	Bamboo and food residue
Biochar carbon content	About 80%

Table 2. Sale details

Number of sites	69 outlets
Sales period	Jan.15, 2010□Jan.31, 2010
Promotion at the store	Self-talker, price cards with logo and video display

Table 3. Survey details

Allocated number	**750**
collected number	**78**
Rate of collection	**10.4 %**
Question items	**Q1. When did you first learn about CV?** **Q2. Why did you purchase CV?** **Q3. What environmental issues are you interested in?** **Q4. What are you doing to prevent global warming?** **Q5. How open are you to the idea of paying for products that mitigate climate change?**

(2) *Results of the marketing pre-survey*

1) Consumer attitudes and price

Half of the respondents answered that they would purchase global warming preventing “Cool Vegetables” if they were priced equally with other agricultural products. About 15 % of the respondents answered that they would purchase ”Cool Vegetables” even if they were sold at a premium (Table 4).

Table 4. Consumer motivation for purchasing “CV”

Motivation of purchasing “Cool Vegetables”	Number of times	%
Purchase if this prevents global warming and leads to saving	29	38.2
Purchase if this prevents global warming and the same price	36	47.4
Purchase if this is at higher price but prevents global warming	11	14.5
Total	76	100.0

2) Consumers’ environmental consciousness level and reason for purchase

Consumers’ general level of environmental consciousness was assessed and compared against the reasons for purchasing “Cool Vegetables” (Table 5). Environmentally conscious consumers purchased “CV” for such reasons.

Table 5. Relationship between reason of purchasing and environmental conscious levels

			Reasons of purchasing “Cool Vegetables”					Total
			Wish product	Looked tasty	New product	Looked eco-friendly	Contribution to preventing GW	
Environmental conscious levels	1	Num	1	1	1	0	0	3
		%	33.3%	33.3%	33.3%	0%	0%	100%
	2	Num	0	3	0	0	0	3
		%	0%	100%	0%	0%	0%	100%
	3	Num	0	6	1	0	0	7
		%	0%	85.7%	14.3%	0%	0%	100%
	4	Num	1	6	0	4	0	11
		%	9.1%	54.5%	0%	36.4%	0%	100%
	5	Num	1	30	1	4	7	43
		%	2.3%	69.8%	2.3%	9.3%	16.3%	100%
Total		Num	3	46	3	8	7	67
		%	4.5	68.7	4.5	11.9	10.4	100.0

3) Positive response and consumers with children

Of those consumers willing to pay a premium for “Cool Vegetables,” 31% had children (Table 6). The ratio of the respondents who answered that they would purchase “Cool Vegetables” if it leads to savings exceeded 40% of the whole sample.

Table 6. Positive response with or without a child

			Positive attitude of purchasing “Cool Vegetables”			Total
			Purchase if this prevents global warming and leads to saving	Purchase if this prevents global warming and the same price	Purchase if this is at higher price but prevents global warming	
With or without a child	without	NUM	26	22	6	54
		%	48.1%	40.7%	11.1%	100.0%
	with	NUM	3	8	5	16
		%	18.8%	50.0%	31.3%	100.0%
Total		NUM	29	30	11	70
		%	41.4%	42.9%	15.7%	100.0%

4) Eco-brand imagery and eco-consumers

On encountering the “Cool Vegetables” eco-brand, what kinds of images are conjured in environmentally conscious consumers’ minds? In examining the constituents of their eco-brand imagery, the ratio of responses for “river or marine conservation,” “chemical-free vegetables,” and “additive-free food” were high, as shown in Table 7.

Table 7. Constituents of eco-brand imagery of eco-consumers

	Constituent of the eco-brand image	Interest to global warming	Interest to eco-friendliness	, Ž
River or marine conservation	26.7	100.0%	26.7%	n=10
Chemical-free vegetables	23.9	75.6%	31.6%	n=22
Additive-free food	19.9	68.6%	29.0%	n=24
Energy saving	18.3	81.1%	22.6%	n=22
Organic vegetables	16.7	61.1%	27.3%	n=23
Domestic food	14.0	54.3%	25.8%	n=21
Local production for local consumption	13.4	58.1%	23.1%	n=19

Conclusions

The results of this marketing pre-survey indicate that “Cool Vegetables” brings additional value to produce and may be a viable eco-brand. Coop Kobe, where this survey was conducted, sells many environmentally-friendly products and attracts consumers with a high environmental consciousness. This may explain why respondents might have showed higher consciousness toward “Cool Vegetables” than “common” consumers. Further inquiry is needed at stores frequented by typical consumers to verify this conclusion.

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Biomass availability, energy consumption and biochar production in rural households of Western Kenya

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Key words: *biomass, productivity, cooking, pyrolysis, energy, biochar*

Introduction

Biomass is one of the most important resources in smallholder farms in Africa. It provides rural households with ecosystems services such as soil organic matter, nutrient recycling to crops, fuel, building materials and animal feed. Inefficient policy interventions, unfair pricing structure, weak institutional structure, and lack of strong research priority and implementation [1] contribute to the continued use of biomass and the existing pressure on land resources. In order to reconcile the need to increase food production, energy needs, and environmental conservation, technology innovations must be identified that are able to mitigate these problems while making sure that existing natural resources are protected. An alternative to conventional cook stoves based on biomass burning is the pyrolysis of biomass residues while cooking, which can provide both cooking energy and biochar as a soil amendment [2, 3]. Our goal was to determine whether on-farm biomass production was capable of supplying sufficient fuel energy to sustain household cooking energy needs as well as of producing sufficient biochar by way of pyrolysis as a soil amendment.

Materials and Methods

For purposes of this study, we measured the biomass of vegetation identified by farmers as sources of fuel for pyrolysis. Total aboveground biomass was measured for four major biomass classes; woody biomass, maize residues (cobs and stover), collard green stalks and banana pseudo stems. Based on total aboveground biomass calculations, available biomass energy was calculated for each farm. The quantity of energy currently used for cooking was assessed through daily cooking tests in a subsample of 20 households. Fuelwood and wood char residue measurements were made in each household during daily cooking activities with traditional stoves. For the pyrolysis stove, fuelwood, biomass, wood char residues and biochar were measured. Energy consumption per capita serves as a baseline to compare the current energy consumption of the household and the consumption when a pyrolysis stove is introduced.

Results and Discussions

Biomass availability for bioenergy across conversion ages

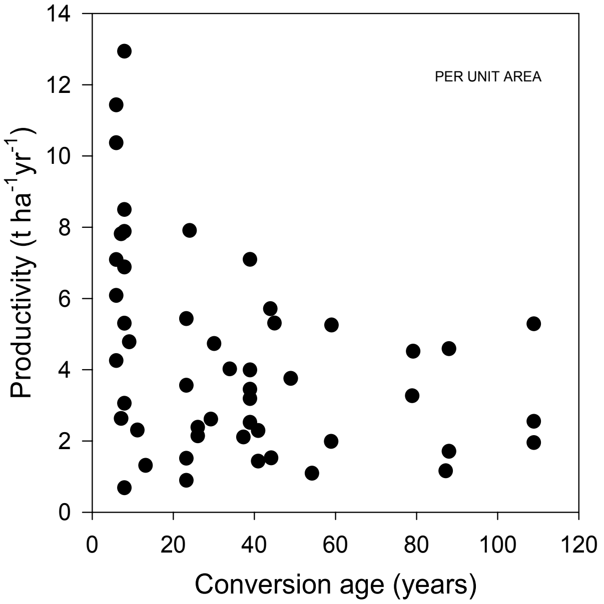

Figure 1. Total aboveground biomass productivity for all farms with increasing age of conversion on a hectare basis (N=50).

Biomass availability for pyrolysis varied widely from 0.7 to 12.4 t ha^{-1} yr^{-1} with an average of 4.3 t ha^{-1} yr^{-1} (Figure 1), across all 50 studied farms. Recently converted farms with high soil fertility presented the highest variability (CV=83%), which was a result of the wide range of farm size and feedstock types in the farm. Smaller farms allocated more land to the production of food crops, while larger farms distributed land among a greater diversity of plants and therefore bioenergy feedstocks. Biomass variability was two times lower for old conversion farms with low soil fertility (CV=37%). The reduction in variability is a direct consequence of the soil quality, coupled with farm size and feedstock type. A lower soil fertility led to lower biomass productivity and variability.

Household energy requirement and biomass available for pyrolysis

While most of the farms currently have some form of wood production, the total wood energy available in the farms is not sufficient to meet the current cooking energy needs. However, total biomass productivity usable in pyrolytic cook stoves including crop residues, shrub and tree litter can provide 18.2 GJ capita^{-1} yr^{-1} of energy for cooking needs, which is well above the average cooking energy consumption of 10.5 GJ capita^{-1} yr^{-1} (Table 1).

Table 1. Total mean available energy for pyrolysis on per capita basis for each conversion category.

Conversion	Energy Available for Pyrolysis (GJ capita^{-1} yr^{-1})	Energy Consumed (GJ capita^{-1} yr^{-1})
Recent <20	22.7a	13.0a
Intermediate 21-49	18.7ab	11.4a
Old >50	10.1b	8.4a

In our study, a household using a traditional three-stone stove or a chepkube stove consumes 7.1 and 9.7 GJ capita^{-1} yr^{-1}, respectively (Table 2). A traditional cook stove studied in Mexico was shown to consume 19.7 GJ capita^{-1} yr^{-1}, with significant reductions found for improved cook stoves with 6.5 capita^{-1} yr^{-1} [4].

Table 2. Total biomass energy used per capita and total production of biochar per hectare (±SE).

Stove type	N	Total Energy Used (GJ capita^{-1} yr^{-1})	Total Biochar Produced (ton ha^{-1} yr^{-1})
Three Stone	9	7.11ab ± 1.16	-
Chepkube	10	9.65a ± 1.10	-
Pyrolysis	19	6.69b ± 0.80	0.46 ± 0.07

In comparison, the households in our study would consume 6.7 GJ capita^{-1} yr^{-1} with the studied pyrolysis stove. Therefore the introduction of the studied pyrolysis stove may lead to a reduction of 27% overall wood energy used. As a result, the introduction of a pyrolysis stove to a smallholder farming system, similar to gasification stoves or other improved cook stoves, could lead to gains in energy efficiency [4, 5], bearing in mind that significant improvements in stove designs can be expected in the near future. In addition to improved energy efficiencies, the studied pyrolysis stove would produce annually 0.46 t ha^{-1} of biochar (Table 2).

Conclusions

Our study was able to demonstrate the capacity of on-farm biomass production to meet the energy needs of households in western Kenya, if pyrolysis cook stoves are used instead of combustion cook stoves. If biomass is harvested and used sustainably; households are able to use different combinations of biomass to meet cooking energy need through pyrolysis due to the wider feedstock types that can be utilized. In addition, the production of biochar and its use as a soil conditioner could increase on-farm crop productivity, leading to an overall increase in food production for the household. A system that combines the production of biochar and bioenergy may be able to reduce off-farm biomass gathering, improve energy security, and produce sufficient biochar to improve soil productivity in resource-poor farms in Africa.

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[1] Lal R.; Singh B. 1998. Effects of soil degradation on crop productivity in East Africa. J Sustain Agr., 13(1):15.

[2] Whitman T.; Lehmann J. Biochar—One way forward for soil carbon in offset mechanisms in africa? Environ Sci & Policy.11;12(7):1024.

[3] Lehmann J. 2007. Bio-energy in the black. Front Ecol Environ.,5(7):381.

[4] Berrueta V.; Edwards R.; Masera O. 2008. Energy performance of wood-burning cookstoves in Michoacan, Mexico. Renewable Energy.,33(5):859.

[5] Johnson M.;Edwards, R.;Ghilardi, A.; Berrueta V.; Gillen D.;Frenk C.; Masera O. Quantification of carbon savings from improved biomass cookstove projects. Environ Sci Technol.,43(7):2456.

Agro-economic valuation of biochar using field-derived data

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Key words: *yield, benefit cost analysis, market development*

Introduction

Although there has been a significant interest in biochar recently, the implementation of the technology on a broad scale is still lacking. Scientific data on the agronomic benefits of biochar allows an economic evaluation to be developed. This is an industry enabling analysis to justify economic models of potential pyrolysis projects.

Results of this analysis will be used to assist in the market development process for biochar by quantifying the costs and benefits involved with the use of biochar as a soil amendment by land managers.

A number of replicated long-term field trials were established in a subtropical environment on the far north coast of NSW (29°S, 153°E), Australia. Trials are on an acidic red Ferrosol with low nutrient availability.

A cereal- legume rotation was established in 2007 to test the impact of two contrasting biochars: poultry litter biochar and papermill biochar amendments, compared with standard farmer practice, lime and compost application. Fertiliser included annual application of urea (400kg/ha), single superphosphate (300kg/ha) and muriate of potash (140kg/ha) before the summer crop. Both biochars were applied at 10t/ha, lime at 3t/ha and compost at 25t (wet)/ ha. The site was sown with sweet corn in the 2007/2008 summer, followed by fababean as the winter legume. This rotation was continued until Feb 2010.

Results and Discussions

Chemical analysis of the biochars revealed significant differences in their nutrient content and liming capacity (Table 1). Both biochars influenced soil chemistry resulting in a reduction in soil acidity, and an increase in soil N, P, CEC and C. These changes in soil chemistry were sustained over the experimental period, reflected by the sustained improvement in yield in the biochar treated plots.

Table 1: Basic chemical characterization of biochars used in field trial

	Poultry litter biochar	**Papermill biochar**
N (%)	2.2	0.44
P (%)	2.4	0.11
K (%)	2.1	0.047
$CaCO_3$ (%)	14	7.50

An enterprise budget for sweet corn in northern NSW was specifically developed for this analysis, whilst an existing budget for fababeans in northern NSW (NSW DPI, 2009) was used in the analysis.

Two types of economic analyses were conducted;

1. Partial or marginal analysis
2. Benefit cost analysis (BCA)

The first of these analyses, the partial or marginal analysis, examined the elements of the enterprise budget which changed as a result of the change in the activity with all other elements remaining the same. Partial budgeting was used to assess the net benefits from investment in the biochar soil amendment allowing for comparison of alternative treatments.

In the net benefit analysis, we assumed a value of poultry litter biochar of A$300 per t, and a cost of spreading of $25 per t. It was shown that over the 3 crops described in Table 2, the net value of production was increased by $5731 per ha compared to the standard farmer practice. This resulted in an incremental net benefit increase of $2480/ha. This value was even greater in the papermill biochar treatment.

Table 2: Impact of amendments on crop yield

All treatments with farmer practice fertiliser	**Corn 07/08** weight of cobs (t/ha)	**Fababean 2008** dry bean (t/ha)	**Corn 08/09** weight of cobs (t/ha)
Farmer practice	20.5	2.1	19.4
Poultry Biochar (10t/ha)	23.7	3.9	23.3
Papermill Biochar (10t/ha)	25.7	3.9	27.3
Lime (3t/ha)	22.3	4.6	24.9
Compost (25t/ha)	19.9	4.4	23.0

The field site at Wollongbar (Photograph 1) provides the basis for long-term evaluation of biochar (and other organic amendments) in sub-tropical cropping. It must be stressed that these economic valuations will vary significantly between regions and the value of the crop produced, and should therefore only be used as a guide. The presentation will also describe other methods for valuing the biochar, such as valuing the direct nutrient addition from the biochar, and evaluation of benefits such as increased biological N_2 fixation and the economic and greenhouse gas emission benefit associated with this.

Photograph 1: Fababean crop in 2008

Conclusions

This study has clearly demonstrated that biochar derived from poultry litter and biochar derived from papermill wastes has an impact on yield and amendment at 10t/ha provides significant economic gains when analysed over several cropping cycles.

Acknowledgements

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[1] NSW DPI (2009), *Farm Enterprise Budget Series.* Budget for fababeans available at http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/175992/fababeans.pdf

Biochar – Sustainability, Certification and Legislation

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Key words: *biochar-soil matching; monitoring; soil data*

Introduction

Biochar can be produced with a wide variety of physical and chemical characteristics, depending on the feedstock and operational conditions. Much progress has been achieved and substantial research is still ongoing on the way such factors determine the properties of the resulting biochar. Soil is also highly heterogeneous in nature and its properties can vary widely both in space and time. It is recognized that the effects of biochar on soils, as well as on the wider ecosystem/ecotope and socio-economic landscape may be positive, negative or not yet fully quantified [1]; see Table 1. This paper conceptually discusses how biochar properties may be matched to soil (and wider ecotope) properties as well as relevant socio-economic conditions, as part of a biochar certification procedure.

Results and Discussions

Sustainability

For biochar to be considered as a sustainable policy option, it is essential to extend R&D to cover all soil functions comprehensively and at several spatio-temporal scales. In addition, R&D needs to be representative of the natural and socio-economic conditions of any site (physical area) under consideration for policy development. Beyond representation of current conditions, true sustainability should be shown by preliminary modelling of expected changes in natural (i.e. climate change), land use (incl. soil/crop management) and socio-economic conditions of any site under consideration, for the same period as the expected functional lifetime of biochar in the different soils of that site.

Table 1 Potential interactions and effects of biochar on soil and the wider ecotope/system, for which a comprehensive evidence base is not available; adapted from [1]

Long-term effects of modern biochars in soils under modern arable management
C Negativity
Effects on N cycle
Biochar Loading Capacity (BLC)
Environmental behaviour mobility and fate
Distribution and availability of contaminants (e.g. heavy metals, PAHs) within biochar
Effect on soil organic matter dynamics
Pore size and connectivity
Soil water retention/availability
Soil compaction
Priming effects
Effects on soil megafauna
Hydrophobicity
Enhanced decomposition of biochar due to agricultural management
Soil Albedo

Certification/legislation

Certification should extend beyond a technical description of the biochar material, i.e. it should include the natural and social context that biochar would be applied in (Figure 1).

We should aim to get to a point where biochar certification reads (in simple term): This biochar:

- has properties A, B, C
- is appropriate for ecotopes with properties D, E, F
- to grow crops G, H, I
- at biochar application rates of J t ha^{-1} yr^{-1} every K years to L t ha^{-1} yr^{-1} every M years,
- up to a maximum biochar loading capacity of N gBiochar kgSoil^{-1}.
- Etc.

In addition, socio-economic impact assessments should be performed, as part of the certification procedure, for scenarios of possible combinations of the above-mentioned factors.

In many cases, it is expected that too few relevant primary soil data (i.e. measured directly, not inferred), will be available at the required spatial resolution. Therefore, in these cases, requirements for soil testing will have to be described as part of the certification procedure. The methodological design of soil testing should be informed by the range of potential biochar properties for a specific site.

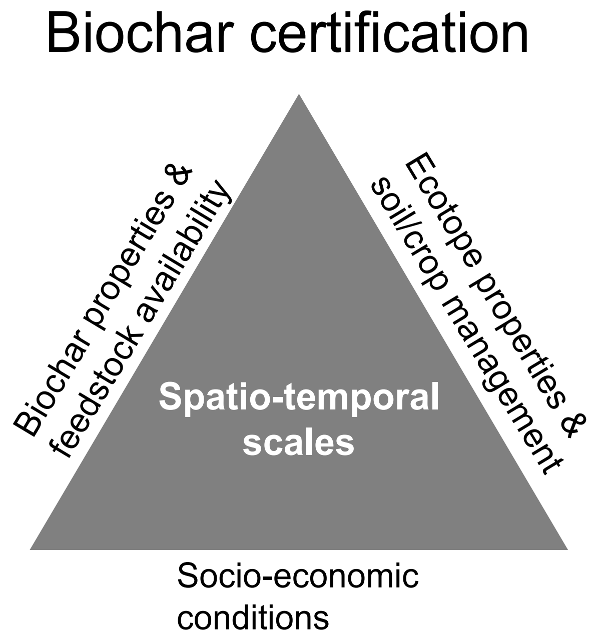

Figure 1. Conceptual diagram of factors that require integration ('critical matching') into a biochar certification procedure

Conclusions

Biochar certification should extend beyond characterizing biochar properties (the production process and subsequent biochar properties) to include suitable ecotope factors (e.g. soil physicochemical properties, geomorphology, hydrology and climate) as well as land management (crop type/rotation and soil management). Therefore, the definition of biochar certification should include the 'critical matching' of biochar properties to combinations of ecotope factors and land management options.

In a sense, the greatest strength of the biochar concept is also its greatest weakness.

Its relatively long mean residence times in soils (100s of years) make it a potential instrument of sequestering carbon (climate change mitigation). At the same time, it may improve one or more soil functions while avoiding deleterious effects (if managed appropriately and carefully, i.e. critical matching is achieved). However, that same long mean residence time sets biochar apart from more conventional soil amendments (i.e. fertilizers, lime, 'fresh' organic matter) that are considered as transient in the soil, with functional lifetimes of 1-10s of years. The functional lifetime of biochar in soils essentially moves biochar from the soil management box to the geoengineering box. While biochar may be considered as 'soft geoengineering' (i.e. ecosystem manipulation) in contrast to 'hard geoengineering' (e.g. putting mirrors in space to reflect sunlight away from the Earth), it can be considered 'hard' in terms of reverse-engineering. That is, it can be very difficult, or it takes a long time, to remove the biochar from the soils again if at any time that might become desirable.

Therefore, biochar deserves a sophisticated certification procedure, where biochar properties are matched to ecotope and socio-economic conditions at appropriate spatial scales, as well as modelled at temporal scales similar to the expected functional life time of biochar in soils at a particular site.

Acknowledgements

We would like to thank Simon Jeffery, Marijn van der Velde, Ana Catarina Bastos and Iason Diafas for their scientific support.

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[1] Verheijen, F.G.A., Jeffery, S., Bastos, A.C., van der Velde, M., and Diafas, I. (2010). Biochar Application to Soils - A Critical Scientific Review of Effects on Soil Properties, Processes and Functions. EUR 24099 EN, Office for the Official Publications of the European Communities, Luxembourg, 149pp. http://eusoils.jrc.ec.europa.eu/esdb_archive/eusoils_docs/other/EUR24099.pdf

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Progressing from Terra Preta de Índios to the Whole World

A comparison of variable economic costs associated with several proposed biochar application methods

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Keywords: *Biochar, Application Method(s), Economics*

Introduction

Biochar is the carbon-rich product obtained when biomass is heated in a closed container with little or no available air through a process called pyrolysis [1]. Biochar can be used to improve agriculture in several ways, and its stability in soil and nutrient-retention properties make it an ideal soil amendment to increase crop yields [2]. In addition to the known agronomic benefits [3,4,5,6], biochar application to soil, in combination with sustainable biomass production, can be carbon-negative and therefore used to actively remove carbon dioxide from the atmosphere on a millennial timeframe [7].

The ability of biochar to store carbon and improve soil fertility will not only depend on its physical and chemical properties [8,9], but also on the technical and economic limitations of handling biochar at quantity in an agronomic setting. Despite building interest among scientists and policy-makers over the potential benefits of biochar, little is known about the physical act of applying biochar to soil [10]. We believe this is a critical area for investigation since a more complete understanding of various constraints of application will help enable an adequate assessment of the overall feasibility of biochar.

This article examines the problem of biochar application to soil. Specifically, we look at two methods of application—broadcast-and-disk and trench-and-fill—and provide cost estimates for each under varying rates of saturation. We draw on data from experimental work at Flux Farm and elsewhere [11], regional custom rates [12], implement specifications, and calculated estimates. Our calculations cover variable costs only—those costs that are dependent on the rates of application—and therefore ignore capital costs associated with the machinery needed for application. We also disregard the cost of biochar itself since projecting a market value at present remains speculative [13].

Results and Discussions

Our findings show that the broadcast process is generally cheaper, however we consider a trench-and-fill method to be more suitable for storing high quantities of biochar in soil. For broadcast application, we found that at saturation rates of 2.5, 5, 10, 25, and 50 tons per acre, a respective cost per acre is $29, $44, $72, $158, and $300 (Table 1). Our examination of the trench-and-fill process revealed that cost depended on several variables, including saturation rate, trench depth, and operator efficiency. We found that at saturation rates of 5, 10, 25, 50, and 75 tons per acre, with trenches 2 feet deep, and at trenching and application rates of 15 feet per minute, a respective cost per acre of applied biochar is $34, $85, $171, $341, and $512 (Table 2). In both methods, we found results that suggest biochar application could constitute a considerable cost, many times greater than typical agricultural processes.

Although our findings offer only a basic guide to calculating the cost of application, the intent of this paper is to serve as a launching pad for the much-needed additional research into the costs and other potential constraints of biochar application to agricultural soils.

Table 1. Broadcast-and-disk application results

Biochar saturation rate		Time	Application Costs			Subtotal	Disking	Total
Tons/acre ***S***	**ft^3/acre** ***28.3L/ft^3***	**Total (hr)** **t_b**	**Labor** **L_b**	**Fuel** **f_b**	**Maint.** **m_b**	**Application** **A_b**	**Disking** **D**	**Cost** **C_b**
2.5	228	0.4	$5	$7	$2	$14	$15	$29
5	456	0.9	$10	$15	$3	$29	$15	$44
10	912	1.7	$20	$30	$7	$57	$15	$72
25	2280	4.3	$51	$74	$17	$143	$15	$158
50	4559	8.5	$102	$149	$34	$285	$15	$300

Table 2. Trench-and-fill application results

SATURATION				TRENCHING						APPLICATION						
Saturation Rate		**Trench Size**		**Time**		**Costs**			**Subtotal**	**Time**		**Costs**			**Subtotal**	**TOTAL**
Tons/ac s_t	ft^3/acre *28.3L/ft^3*	Depth (ft) d	Rows/ac n	Rate (ft/m) r_t	Total (hr) t_{tr}	Labor l *$12*	Fuel f *$18*	Maint. m *$4*	Cost c_t	Rate (ft/m) r_a	Total (hr) t_a	labor l *$12*	Fuel f *$17.42*	Maint. m *$3.97*	Cost A_t	Cost C_t
5	456	1	4	12	1.3	$15	$23	$5	$43	12	1.3	$15	$22	$5	$42	$85
				15	1.0	$12	$18	$4	$34	15	1.0	$12	$18	$4	$34	$68
				20	0.8	$9	$14	$3	$26	20	0.8	$9	$13	$3	$25	$51
5	456	2	2	12	0.6	$8	$11	$3	$22	12	0.6	$8	$11	$3	$21	$43
				15	0.5	$6	$9	$2	$17	15	0.5	$6	$9	$2	$17	$34
				20	0.4	$5	$7	$2	$13	20	0.4	$5	$7	$2	$13	$26
12.5	1140	1	11	12	3.2	$38	$57	$13	$108	12	3.2	$38	$55	$13	$106	$213
				15	2.5	$30	$46	$10	$86	15	2.5	$30	$44	$10	$85	$171
				20	1.9	$23	$34	$8	$65	20	1.9	$23	$33	$8	$63	$128
12.5	1140	2	5	12	1.6	$19	$28	$6	$54	12	1.6	$19	$28	$6	$53	$107
				15	1.3	$15	$23	$5	$43	15	1.3	$15	$22	$5	$42	$85
				20	0.9	$11	$17	$4	$32	20	0.9	$11	$17	$4	$32	$64
25	2280	1	22	12	6.3	$76	$114	$25	$215	12	6.3	$76	$110	$25	$211	$343
				15	5.1	$61	$91	$20	$172	15	5.1	$61	$88	$20	$169	$274
				20	3.8	$46	$68	$15	$129	20	3.8	$46	$66	$15	$127	$206
25	2280	2	11	12	3.2	$38	$57	$13	$108	12	3.2	$38	$55	$13	$106	$213
				15	2.5	$30	$46	$10	$86	15	2.5	$30	$44	$10	$85	$171
				20	1.9	$23	$34	$8	$65	20	1.9	$23	$33	$8	$63	$128
50	4559	1	43	12	12.7	$152	$228	$51	$431	12	12.7	$152	$221	$50	$423	$853
				15	10.1	$122	$182	$41	$344	15	10.1	$122	$176	$40	$338	$683
				20	7.6	$91	$137	$30	$258	20	7.6	$91	$132	$30	$254	$512
50	4559	2	22	12	6.3	$76	$114	$25	$215	12	6.3	$76	$110	$25	$211	$427
				15	5.1	$61	$91	$20	$172	15	5.1	$61	$88	$20	$169	$341
				20	3.8	$46	$68	$15	$129	20	3.8	$46	$66	$15	$127	$256
75	6839	1	65	12	19.0	$228	$342	$76	$646	12	19.0	$228	$331	$75	$634	$1280
				15	15.2	$182	$274	$61	$517	15	15.2	$182	$265	$60	$507	$1024
				20	11.4	$137	$205	$46	$388	20	11.4	$137	$199	$45	$381	$768
75	6839	2	33	12	9.5	$114	$171	$38	$323	12	9.5	$114	$165	$38	$317	$640
				15	7.6	$91	$137	$30	$258	15	7.6	$91	$132	$30	$254	$512
				20	5.7	$68	$103	$23	$194	20	5.7	$68	$99	$23	$190	$384

Conclusions

We find it crucial that future research efforts focus more on application and associated costs of various application processes. The estimates provided in this analysis offer only a preliminary idea of expected costs of application for only two of many possible proposed and emerging methods. Confirmation of these results will only come through on-the-ground testing. In addition, more testing of the effects of various application rates on the soil needs to occur. There is still uncertainty regarding the benefits of various saturation rates, and it is also unknown what potential negative impacts various application methods can have on different types of soils for different types of crops. As part of this testing, special attention needs to be paid to the enduring effects of biochar in soil. Understanding how long the economic or agronomic benefits from biochar can continue to accrue may help justify the potentially high cost of application we observe in this paper.

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[1] Lehmann J. et al. 2006. *Mitigation and Adaptation Strategies for Global Change*, 11: 403–427.

[2] Sohi S, et al. 2009. Biochar's roles in soil and climate change: A review of research needs. *CSIRO Land and Water Science Report*. White Paper. http://www.csiro.au/files/files/poei.pdf. Accessed on May 4, 2010.

[3] Warnock DD. et al. 2007. *Plant Soil*, 300:9–20.

[4] Rondon MA. et al. 2007. *Biol Fertil Soils*, 43:699–708.

[5] Gaunt J, and Cowie A. 2009. Biochar, greenhouse gas accounting and emissions trading. *In Biochar for Environmental Management: Science and Technology*; Lehmann J, Joseph S, Eds.: Earthscan: London, 317-340.

[6] Gaskin JW. et al. 2007. Potential for pyrolysis char to affect soil moisture and nutrient retention status of a loamy sand soil. In: *Proceedings of the Georgia Water Resources Conference*. Institute of Ecology, University of Georgia, Athens Georgia.

[7] Lehmann J. et al. 2009. Stability of biochar in soil. In *Biochar for Environmental Management: Science and Technology*; Lehmann J, Joseph S, Eds.: London, Earthscan, 183-206.

[8] Lehmann J. 2007. *Front. Ecol. Environ.*, 5: 381-387.

[9] Novak JM. et al. 2009. *Annals of Environmental Science*, 3:195-206.

[10] Blackwell P. et al. 2009. Biochar Application To Soil. In: Lehmann J, Joseph S, eds., *Biochar For Environmental Management.* London: Earthscan, 206-226.

[11] Husk B, and Major J. 2009. Preliminary Evaluation of Biochar in a Commercial Farming Operation in Canada. BlueLeaf Inc., Quebec, Canada. White Paper. http://www.dynamotive.com/assets/resources/BlueLeaf-Biochar-FT0809.pdf. Accessed on May 4, 2010.

[12] CSU Agricultural Extension, "Custom Rates for Colorado Farms and Ranches in 2009." http://www.coopext.colostate.edu/ABM/custrates09.pdf. Accessed on May 4, 2010.

[13] Roberts KG. et al. 2010. *Environ. Sci. Technol.*, 44 (2), 827-833.

Developing Biomass Engineering Technology and Application for Low Carbon Agriculture in China

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Key words: *Biochar, biomass engineering, low carbon agriculture*

Introduction

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 GHGs emission from agriculture.Totally, 0.7 Gt of crop straw is produced in croplands annually in China.

Biomass engineering technology

At Sanli Biomass Engineering Corporation, great efforts have been dedicated for the last 5 years to developing new and high technology for waste biomass conversion from crop straw to new energy and biochar as well as biogases with totally 15 techniques and devices patented The large production system can treat per hour 1 metric tons of straw and produce biogas of 800 cubic metre 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 30kg of straw and producing 10 cubic meter 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 bi-ammonium phosphate at 10%).

Field experiments in agriculture

A networking field experiments at 8 sites has been established of 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 gases emission with biochar application are monitored using closed chamber systems. In an experiment in Yixiang, Jiangsu, under biochar application at 10 t/ha and 40 t/ha, rice grain yield was increased by 12% and 10% without N fertilization and by 11% and 8% with N fertilization respectively compared to no biochar amendment. A significant yield increase at 8.8% was observed under biochar application at 10t/ha compared to N fertilization at 300kg N/ha. Application of biochar at 10 t/ha and 40 t/ha in rice season increased grain weight by 5% and 18%, and wheat yield by 60% and 230% compared to no biochar amendment. N_2O emission was greatly reduced while CH_4 emission increased significantly under biochar application in the rice season. Moreover, biochar application at 10t/ha may offset a normal N fertilization at 300 kg/ha for a normal rice yield. Therefore, application of biochar from straw may be expected to enhance soil C, increase crop productivity and reduce N use in croplands.

Figure 1. A large scale treatment system

Results and Discussions

Thus, a national demonstration project on biochar application in agriculture is suggested. Total C balancing is being to assess with biochar conversion and application in croplands. Some policy briefing is being addressed for extending biochar application in agriculture for low carbon technology in China.

Conclusions

An effective biomass engineering system is available for biochar production with crop straw. Biochar application may enhance soil C, increase crop yield as well as reducing GHGs emission in agriculture of China.

The Effect of Biochar Amendments on *Andropogon gerardii* (Big Bluestem) Seedling Growth First

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More than 90% of tallgrass prairie in North America has been lost since European colonization with substantial accompanying reductions in biodiversity and ecosystem services. Effective weed management is essential to successful prairie restoration efforts, particularly during the early stages of plant establishment. High levels of soil nitrogen appear to favor weedy species over native prairie species and may facilitate the invasion of restoration sites by non-native plant species. Several studies support the hypothesis that weed growth can be reduced in restored sites by adding organic carbon to limit soil N availability. Biochar, a carbon-rich product obtained from burned biomass has proven to benefit crop productivity and improve degraded soils, but has yet to be considered in prairie restoration. This study examines the response of big bluestem (*Androgen gerrardii*), a key tallgrass prairie species, to biochar amendments. A greenhouse experiment was conducted using two soil types (silt clay loam and a sandy loam) mixed with biochar at six rates: 0, 1, 2, 4, 8 and 16%, with and without nitrogen (10 g N/ m^2) in a complete randomized block design. Percent germination and early growth (height, number of tillers, biomass) were recorded and the experiment was replicated. Initial results suggest that early establishment was strongly affected by soil type and biochar concentration. This research demonstrates native prairie response to biochar, specifically during early development and also Investigates the potential of biochar to be used as a management tool to restore tallgrass prairie.

Innovative Building Capacity Program

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Keywords: Biochar, sustainable technology, building capacity, Egyp.

Purpose – the paper aims to assure building capacity quality in the term of biochar sustainable technology. The building capacity program has become vital for the process of achieving sustainable development priorities in Egypt. The program be appropriate to all biochar professionals, policy analysts, policy makers, users, producers, investors, and students. The planned participants are graduates of engineering, agriculture technology, and applied science.

Design/methodology/approach – this paper presents the structure of building capacity program, and assesses its outcome. The focus of the program is to guarantee that the participants have an adequate knowledge about related biochar sustainable technology disciplines. Integrated biochar systems, biochar quantification in the environment, climate change mitigation, sustainability, certification, and legislation, commercializing biochar, emissions trading and climate change policy are introduced.

The researcher has developed a program assessment package using micro and macro analysis to assess the program performance toward the achievement of superiority criteria. Data collected from the implementation has been analyzed and results indicate that pre- and postcourse assessments provide valuable information about cadet knowledge. Moreover, the results can be used to continue improving effectiveness of training.

Findings – The outcome of this innovative biochar sustainable training program is guarantee that the participants have an adequate knowledge in these disciplines. The graduates possess professional biochar knowledge. They will be capable of doing their best in biochar different fields. The results indicate that pre- and postcourse assessments with micro and macro analysis provide valuable information about cadet knowledge.

The researchers are encouraged to test the proposed building capacity program in Arab and Nile basin countries. The paper concludes that the capacity building program for biochar sustainable technology has a good human resource impact. After training, biochar sustainable technology professionals can propose and campaign practical solutions to sustainable development problems.

Biochar Offset Protocol Initiative

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In order to position biochar to access the carbon offset markets, there is a need for approved greenhouse gas (GHG) emission reduction quantification protocols to be developed that meet the needs of such projects. Each protocol for biochar projects would need to reflect the range of platforms and meet the requirements for each of the applicable offset systems.

Of particular interest in the North American context, are two opportunities for industry-led GHG protocol development: the Voluntary Carbon Standard (VCS) and the Alberta Offset Standard (AOS) Protocols for these systems would need to meet the ISO 14064 pt II standard. Under this approach, and with due consideration to the variance in carbon market standards, a protocol under the VCS and AOS could be leveraged into other carbon markets – across North America and globally.

As protocol documents reside in the public domain, and given the considerable associated costs, there is a natural hesitancy for project developers to undertake this work on their own. Further, when left to do this work on their own, project developers can limit the scopes of the protocol to those configurations contemplated by that particular project developer. This serves as a means of hindering others in applying the protocol for related projects.

Carbon Consulting and Blue Source are leading an effort that will follow a different approach; technically more challenging, but ultimately of far greater value as a public domain effort. We will deliver a design for Protocol Development that is not tied to specific projects but which meet the needs of foreseeable pyrolysis projects. This design will identify appropriate structures that will enable the protocol to be robust across the number of project types anticipated.

In developing this protocol in the public domain, we are soliciting input from the biochar community and offering primers and presentations on the science and policy implications behind biochar. Our goal is simple: to open up carbon markets to biochar and pyrolysis technologies. Information can be found at www.biocharprotocol.org.This presentation will address:

- Basics of GHG Protocols and Available Markets
- GHG Emission Reduction Mechanisms and Available Science

The BlackCarbon Project: Pyrolysis/Stirling Engine Co-generation at micro scale (250-500 kW)

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BlackCarbon has commissioned and financed a pilot plant that combines ScrewPyrolysis and StirlingEngine technology to create a cost-effective, robust and resource efficient multifunctional biomass energy unit. The unit is the first of its kind anywhere in the world to combine these technologies.

It has now run for 1000 hours and has produced 25.000 kW of electricity and 20 tonnes of Biochar. A small number of technical questions need to be resolved before the unit can enter into commercial use. These will be dealt with over the next 3 months.

The expected annual production of BioChar is 20 kg/h for 7.500 hrs, equal to 150 tonnes of Biochar per annum.

The test runs have confirmed this performance.

Quality of Char:

The main concern has been whether the char would meet the strict standards in Denmark with regard to heavy metal and PAH content. Early lab tests and recent tests of an actual char batch from the unit have confirmed that the char easily meets the standard.

Energy economics:

The expected Turn-Key delivery cost of a 350 kW unit is 250.000 €.

If the feedstock (dry (15%) wood chip) is valued at 50 € per tonne the annual cost is: 37.500 €

Annual Capital costs (i=8 and n=10) 37.500 €

Maintenance and personnel costs 60.000 €

Overhead 25 % 15.000 €

Total annual costs 150.000 €

Value of electricity at a feed-in-tariff of 20 €-cent 52.500 €

Value of heat at 10 €-cent per kWt 91.500 €

Production Cost of Bio-char 6.000 €

Production cost per tonne of Bio-char 40 €

Production cost per tonne of CO_2 equivalents in char 11 €

Challenges:

- In order to reach stable hour-on-hour energy output and high quality Bio-char production the unit has to achieve a fine calibration of feed-stock input, residence time, and re-use of exhaust heat. Presently, the use of exhaust gas to heat the pyrolysis screw is not delivering enough heat to make the entire unit fully exothermic. If we force more wood-chip through the screw, the char contains too much tar.
- The syn-gas contains a lot of tar - at the tar sometimes combines with char-dust, which clogs up the gas pipe leading from the screw to the combustion chamber. Right now it is still necessary to “burn-out” the pipe every 24 hours.
- Other feed stocks: We need to ascertain whether other feed stocks than wood chip can be used: straw, corn stover, rice husks, olive pits.
- Safe cooling of biochar - we have experienced reignition of biochar- even when it has been stored at ambient temperature for a number of days.
- Agricultural use of bio-char-the rules in Denmark are quite strict - especially on land which is certified organic. The rules specifically state that biomass waste with a residual energy content (ie. biochar) need aspecial permit.

Treatment of greywater and wastewater with char coal

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Char coal has been used for millennia to clean liquids and air from certain elements or compounds. Recently, biochar as a soil improver and simultaneously a carbon sink has been acknowledged. To balance the high carbon content of biochar, its application as a soil improver may need an additional nitrogen application. One way to obtain a favorable carbon/nitrogen ratio of the biochar would be to expose the biochar to household effluents rich in nitrogen.Here we present results on different qualities of char coal exposed to grey water, nitrogen solution, human urine, and wastewater, respectively. Nitrogen sorption and transformation were studied in laboratory and field in order to evaluate the potential of char coal as a means for treating greywater and wastewater in robust treatment plants based on principles of nutrient cycling.

Charvester development for a sustainable biomass production

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In recent years, the usage of biomass for heating purposes of houses has increased in Sweden as a means to replace burning of fossil fuels. However, this will lead to decreased content of soil organic matter, being important for maintaining soil fertility. A sustainable approach would be to insulate the houses better so less heating will be needed and use excess biomass for biochar production and apply to productive soils. Technology used for gathering branches and straw for biomass could be used also for gathering biomass to pyrolysis, while suitable equipment for pyrolysis needs to be developed.

The current state of the Swedish ’Charvester’ project is described. The goal of this project is to create a prototype for a mobile pyrolyser autonomously moving using the pyrolysis heat for movement as well as internal energy needs for biomass processing, as chipping and drying. Possibly, a surplus fraction of the pyrolysis gases/liquids will be converted into biodiesel or other products in the synthetic industry. The produced char will be optimized for biological virtues, length of heating time, and pyrolysis temperature. As improving biological virtues may increase machinery size and process time, an optimization will be found, using specific surface area (BET analyses) and micrography methods as proxys for biological virtue.

Mycorrhizal inoculated biochar as an active filter of dairy wastewater in constructed wetlands

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Phosphorus is one of the principal nutrient pollutants that causes eutrophication and consequent population decline of plant and animal populations in aquatic ecosystems. Constructed Wetland treatment of dairy wastewater, a major point source of P pollutant, is currently being researched as a viable mitigation of fresh water eutrophication. However because wetland plants have relatively low P requirements, they often do not remove it to satisfactory standards. Therefore, research is needed of how different substrates might enhance P uptake and retention in constructed wetlands. The addition of biochar, or pyrolysized biomass, to soil has proven to greatly increase P retention. Biochar acts as a “sponge,” providing micro habitat, and subsequent increased microbial populations, including mycorrhizal fungi, in the soil. Based on mycorrhizal fungi’s positive correlation with P uptake, mycorrhizal colonies are believed to be key in the biochar’s nutrient retention.

The purpose of this study is to conduct a column experiment to test the efficacy of mycorrhizal inoculated biochar as a substrate for phosphorus removal in constructed wetlands.

Intellectual Merit:

The main objective of this proposal is to quantify the ability of biochar inoculated with mycorrhizal fungi to uptake and retain phosphorus. The project is unique in several aspects. First, activated charcoal has long been touted as an effective filter of water. Our experiment will expand on this already proven, time tested effectiveness of activated charcoal to physically filter water, by adding a biological component. Our hope is to prove that by actively inoculating with mycorrhizae, the filtering effects of biochar, a material almost identical to activated charcoal, will be compounded beyond physical filtration by the biological plant-fungal mutualistic community. Second, in a time of ever inflating fertilizer prices, farmers need methods for recycling nutrients within their agroecosystem. Our proposed study could potentially provide evidence that biochar is an effective way to mine and retain nutrients from farm wastewater, which could then be returned as a microbial inoculated, nutrient rich soil amendment. And lastly, once in the soil, biochar not only continues to retain nutrients, but also acts as a carbon sink, resisting degradation for thousands of years. To summarize the goal of our experiment is to produce an integreated on farm design that 1) cleans polluted water, reducing eutrophication issues, 2) recycles nutrients within an agroecosystem, reducing necessary external fertilizer inputs, and 3) sequesters carbon, mitigating global warming.

Biochar Engineering Corporation: current technical and economic performance

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Biochar Engineering Corporation (BEC) manufactures a mobile biochar production unit. The intent of this equipment is to provide the following technical advantages to the user:

- Mobility for field and front country use
- Scalable throughput by number of machines
- Standard parts in standard sizes
- Continuous operation
- Automated operation
- Biochar production
- Forest by product mitigation
- Thermal heat production and utilization
- Fully off grid operation or grid connected operation per project needs

This unit has a cost of operation that may include; wood product inputs, energy inputs, water inputs, personnel, and capital costs. Potential revenues from the system include; thermal heat utilization, biochar sales, waste mitigation and carbon values. The following work will cover the details of technical and economic characteristics, successes, challenges, and needed next steps.

De Terra Preta a biochar: controversia de una resurreccion

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Se analiza la controversia sobre la reproduccion contemporanea de Terra Preta de Indio.

Se definen los distintos enfoques sobre las diversas incertidumbres acerca del rol asignado a las practicas y tecnologias bajo el nombre de "biochar". Se procura identificar las agendas de distintos actores involucrados en el debate.En particular se analiza la forma en que intervienen en el debate conceptos clave como geoingenieria, practicas tradicionales/ancestrales y mercado de carbono.

Linking invasive tree species management with biomass energy and biochar production to help small holder farmers restore soil fertility

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The Limpopo Province is the poorest region in South Africa. Effective strategies for poverty alleviation have done little to empower the majority of small, rural farmers. We propose a systems dynamics approach that combines invasive tree species management with integrated biochar systems to increase soil fertility, water and air quality, carbon sequestration, and the efficiency of resource use by small farmers. By incorporating biochar stoves with culturally sensitive designs, small holder farming systems can benefit from reduced emissions, less input dependency, and shared stewardship of fragile environments under agro-ecological principles to minimize impact and restore biodiversity. The biochar system discussed engages the root causes of poverty while at the same time being a cost effective strategy for helping to mitigate global climate change. Conservation through utilization in South Africa's northern province can prove to be a holistic answer to endemic malnourishment and rampant poverty.

A rational pricing mechanism for the creation of a world carbon neutral energy economy, and some implications

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The cycle governing carbon is in disequilibrium. Carbon is the element essential for the energy for life on earth. It is characterized by the short term carbon cycle. Photosynthesis converts solar energy to chemical energy which is then stored in green plants. Because it removes carbon from the atmosphere it is a carbon negative process (C-). Respiration/oxidation/combustion is the means by which this energy is released to non-herbaceous life. Because these processes emit carbon into the atmosphere they are carbon positive processes (C+). Together, photosynthesis and oxidation create a carbon neutral (C=) equilibrium. When we superimpose fossil fuel combustion which is C+ the carbon cycle is no longer in equilibrium, resulting in increased atmospheric concentration of CO_2, and creating a significant environmental challenge.

Consumers of energy, acting in their own perceived self interest consume fossil fuel energy. The commodity market for carbon, the largest commodity market in the world has the perverse characteristic that energy consumers acting in their own perceived self interest are creating the most daunting problem facing mankind. This is a classic example of the tragedy of the commons.

Substituting a C= source for fossil fuels would decrease atmospheric CO_2, but could have serious negative repercussions for economic activity. Alternatively complementing C+ fossil fuel combustion with a C- process could balance the carbon equation. Economically, because C- is used to complement the C+ process it has many profound and virtuous repercussions.

The ability to mandate C= consumption with public policy could effectively mitigate fossil fuel consumption. It would create a market constraint that drives the largest commodity market in the world toward protection of the commons. It has the virtuous characteristic that consumers of energy, still acting in their own perceived self interest would develop solutions, growing a C- energy sector and creating trillions in new wealth and millions of jobs. Because low cost producers of C- are likely to be emerging economies, well managed, this sector could become a powerful equalizer of global wealth, resulting in immediate economic and financial benefits, and significant long term positive changes in agricultural, health, and social welfare.

Hands-On Biochar Education in Two Schools in the Pacific Northwest

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Report on biochar education programs at an elementary school in Oregon and a secondary school in Washington state. These multidisciplinary programs not only explore cultural and technical issues in the production and use of biochar, but they are building infrastructure at each school to process waste and grow food. Presentation of an article to be published in Green Teacher magazine.

3rd International Biochar Conference

IBI 2010

Progressing from Terra Preta de Índios to the Whole World

Characterization of fresh and aged biochars
Biochar quantification in the environment

Contribution to the characterization of biochars for the prediction of their carbon longevity

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Key words: *Stability, Oxidation, Respirometry*

Introduction

The stability of biochar in soils determines how long biochar will contribute to (i) the mitigation of greenhouse gas emissions, and (ii) improved soil functions [1]. Knowledge of size of the labile fraction of biochars under the different biogeochemical soil conditions to which these are applied may be sufficient to determine the stable fraction of biochar needed for trading carbon offsets.

The objective of this study was to estimate the size of the labile component of different biochars produced from three plant residues (pine, poplar and willow) at two temperatures (400 and 550ºC) through different methodologies.

Biochars were characterized by their elemental composition (C, H, O, N, S), TGA (volatiles, fixed C, ashes), pH-H_2O, and BET. The fraction of total C in biochars oxidable with potassium dichromate (OC_{dichro}) and potassium permanganate (OC_{per}) was also determined. Platinum filament coil probe pyrolysis-GC/MS was performed on both feedstocks and biochars.

Biochars were mixed with two acid soils of contrasting chemical properties (Umbrisol, Podzol), and inert sand at different doses (7.5 and 15 t ha^{-1}) and incubated under biotic and abiotic conditions to assess their short-term degradability in the different substrates. Here, however, only the results from soil incubations are reported. Basal respiration of biochar-soil mixtures (10 g total) was measured with a Micro-Oxymax Respirometer (Columbus Instruments, Columbus, OH).

Results and Discussion

All the biochars had a pH value above neutrality, except the biochar produced from pine at 400ºC (Table 1). As expected, high temperature biochars (PI-550, PO-550, WI-550) had a smaller fraction of volatiles and a greater surface area (Table 1) than their corresponding low temperature biochars (PI-400, PO-400, WI-400),. The fraction of volatiles was greatest for WI-400 and smallest from PI-550. For PI-400 and WI-400, the rate of temperature change showed a peak at 400ºC (Fig. 1), which suggests that some volatiles produced during pyrolysis remained within the pores. On the other hand, analytical pyrolysis-GC/MS has confirmed that trapped aromatics (benzene and toluene) are present in PO-550 and WI-550 (TGA peaks around T 650ºC; Fig. 1).

Table 1. Main physical and chemical properties of the biochars studied

Sample	Feedstock		Biochar											
	C	N	pH	mass recovery	C	N	H	O	Ash	Atomic ratios		S_{BET}	OC_{dichro}	OC_{per}
	%	%		%	%	%	%	%	%	H:C	O:C	m^2g^{-1}	%*	%*
PI-400	48.7	0.2	5.7	34.9	76.7	0.6	4.6	15.6	2.6	0.7	0.2	1	24.5	4.1
PO-400	47.9	0.5	7.2	29.7	75.5	1.0	4.2	15.2	4.0	0.7	0.2	3	29.4	3.9
WI-400	47.6	0.9	7.5	37.8	66.2	1.5	3.5	9.8	5.7	0.6	0.3	3	50.7	4.6
PI-550	48.7	0.2	5.2	28.4	84.7	0.6	3.5	8.1	3.1	0.5	0.1	368	11.6	0.9
PO-550	47.9	0.5	8.8	26.9	75.8	1.1	3.6	8.9	6.5	0.6	0.1	55	21.1	1.8
WI-550	47.6	0.9	8.6	28.8	79.1	1.7	3.5	10.6	5.2	0.5	0.1	149	21.9	0.5

* expressed as fraction of total C in biochar

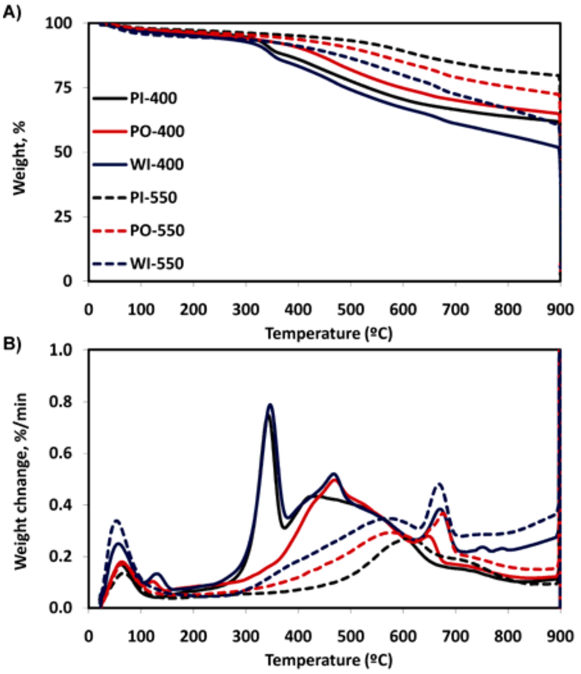

Figure 1. TGA spectra of the samples studied. A), weight, B) rate of change in weight.

In relation to the oxidability of C with the different oxidant reagents used, OC_{per} values were <5% in all biochars, whereas OC_{dichro} values ranged between 11 and 50% (Table 1), although with both reagents, high temperature biochars showed lower values of oxidizable C than the corresponding low temperature biochars.

Biochar-amended soils showed differences in basal respiration (Fig. 2). In general, as the temperature of pyrolysis increased, (i) the amount of CO_2 evolved from substrates decreased, and (ii) the response of the different biochars to decomposition became more uniform and thus more predictable. However, unexpectedly, the biochar produced from pine wood at 400ºC had a CO_2 evolution pattern similar to the high-temperature biochars (Fig. 2). Several factors could have affected the pattern of the PI-400 biochar: (i) the acidic nature of the biochar, which resulted in a low liming ability, and (ii) the presence of compounds potentially toxic to soil microflora. In this sense, analytical pyrolysis-GC/MS found traces of retene-like compounds in this sample.

There was generally a good correlation between OC_{dichro} content and volatile C (r > 850); the cumulative CO_2 evolved from soil mixtures correlated well with both OC_{dichro} contents (r > 0.850) and volatile C (r > 0.700). However, these determinations could not predict the pattern observed for the PI-400 biochar.

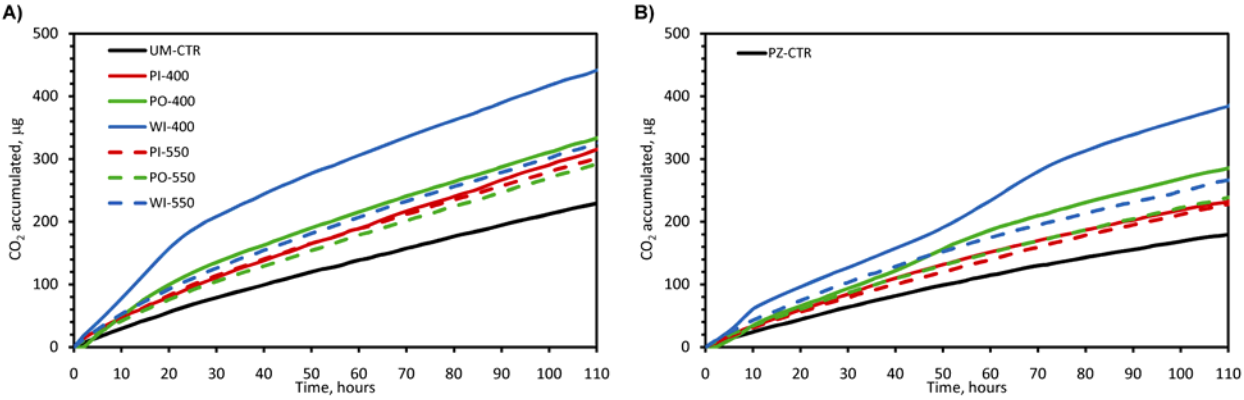

Figure 2. Cumulative CO_2 evolution from A) Umbrisol and B) Podzol mixtures with the different biochars;(dose: 15 t ha^{-1}).

Conclusions

The results obtained to date indicate that the nature of the feedstock and process conditions had a strong influence on the short-term lability of biochars. The labile fraction in biochar estimated using three tests (dichromate, permanganate, TGA analysis) correlated well between them. These tests also showed a good relationship with the CO_2 evolved from incubations. However, they were not able to predict the different pattern of the PI-400 biochar, which was probably caused by factors not related to C degradability.

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

Chemical composition and carbon stocks of organic matter in subtropical Leptosol under pasture affected by fire

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Key words: *physical fractions, recalcitrance, organo-mineral interaction*

Introduction

In the pastures of the *Campos de Cima da Serra*, South Brazil, burning of vegetation residues at the end of the winter season is a common and ancient practice, which aims to accelerate the pasture re-growth. The goal of the present study was to evaluate the effect of periodic fire on carbon stocks, soil organic matter (SOM) distribution in physical compartments and its composition in profiles of a Leptosol (1200 m.a.s.l, 28°36´S, 49°58'W) under pasture submitted to periodic burning. The SOM of the same soil under native forest was also analyzed for comparison purpose. Soil samples (triplicates) were collected in three layers (0-5 cm, 5-10 cm, 10-15 cm) of a native pasture that was biennially burned and last affected by fire 240 days ago and grazed by 0.5 animal ha^{-1} (1NB), native pasture without burning in the last 23 years and grazed by 2 animals ha^{-1} (23NB), and Araucaria forest (AF). Carbon (TOC) and nitrogen contents were determined by dry combustion and carbon stocks were calculated. Physical fractionation was performed by the densimetric method using politungstate solution ($\rho = 2$ g cm^{-3}) resulting in free light fraction (FLF), occluded light fraction (OLF) and heavy fraction (HF). SOM in physical fractions was investigated by thermo-gravimetric analyses (TGA) between 40 and 800°C under synthetic air and a chemical recalcitrance index was calculated: $\Delta m_{(3°)} / \Delta m_{(2°)}$.

Results and Discussions

The periodic burning of vegetation (1NB) increased the C stocks in the subsurface. In comparison to the site not fire-affected in the last 23 years (Table 1). The 1NB site presented a greater proportion of C in the OLF in the 0-5 cm layer. This result can be related to the occurrence of a more recalcitrant SOM originated during the fire that concentrates in this fraction and is more resistant to decomposition than other residues. In opposite, the 1NB site presented a greater C proportion in the HF in subsurface layer, what can be a consequence of the wider root system usually found in fire affected soils. In both depths, the OLF from 1NB showed a greater value for the TGA index (Table 2), evidencing the occurrence of a more recalcitrant SOM produced by periodic burning, that remained protected in this fraction.

Table1. Carbon stocks and C/N ratio in soil layers of a Leptosol.

Site	**TOC,** Mg ha^{-1}			
	0-5 cm	5-10 cm	10-15 cm	0-15 cm
1NB	33.1 ± 2.9^{a}	32.8 ± 1.1	32.0 ± 3.1	97.8 ± 6.9
23 NB	31.2 ± 3.3	28.0 ± 1.2	26.2 ± 1.1	85.4 ± 4.0
AF	52.0 ± 5.1	43.7 ± 4.4	41.7 ± 2.0	137.4 ± 10.6
	C/N			
1NB	14.9 ± 0.6	15.5 ± 0.8	15.7 ± 2.3	15.4 ± 0.7
23 NB	14.6 ± 2.0	13.1 ± 1.0	15.1 ±1.8	14.2 ± 1.1
AF	15.2 ± 0.3	14.9 ± 0.6	14.1 ± 1.2	14.8 ± 0.5

Table 2. Proportion of soil carbon in the physical fractions and TGA index in soil layers of a Leptosol. N.d.: not determined.

Site		**0-5 cm**			**5-10 cm**	
	FLF	OLF	HF	FLF	OLF	HF
			$C_{fraction}$/TOC			
1NB	2.0 ± 0.0	25.6 ± 3.6	72.4 ± 3.6	0.8 ± 0.2	13.6 ± 0.2	85.6 ± 0.2
23 NB	4.6 ±0.2	15.1 ± 1.9	80.3 ± 2.0	3.2 ± 0.9	19.3 ± 1.5	77.5 ± 2.3
AF	20.8 ±1.6	26.3 ± 2.0	52.9 ± 3.4	2.0 ± 0.4	24.0 ± 4.9	74.0 ± 5.2
			$\Delta m_{(3°)}$ / $\Delta m_{(2°)}$			
1NB	0.76	1.33	1.29	n.d	1.40	1.36
23 NB	0.99	0.65	1.24	n.d.	0.61	1.30
AF	0.73	1.54	1.31	n.d.	1.24	1.75

Conclusions

Periodic burning of subtropical pastures after the winter promotes the carbon sequestration until 15 cm soil depth. The more recalcitrant SOM produced during fire remains protected in the occluded light fraction.

Acknowledgements

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Carbon stocks and organic matter composition in subtropical Oxisols after 8 and 41 years of ceasing fire

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Key words: *Pasture management, chemical recalcitrance, physical fractions*

Introduction

At the highland soils, located at the northeastern part of Rio Grande do Sul State, South Brazil, cattle raising is one of the main economic activities. Burning of vegetation at the end of winter has been replaced in the last years by other management strategies like lower grazing intensity and frequency, introduction of new forage species, grassland cutting and soil liming and fertilization. The present work aimed to investigate the effect of pasture management on the quality and stocks of soil organic matter (SOM) of a Red Oxisol. Soil samples (0-5cm) were collected (three replicates) from: non-managed native pasture without burning in the last 41 years and grazed with 1.2 animal ha^{-1} (NP), native pasture without burning in the last 8 years and grazing of 0.5 animal ha^{-1} (BP), native pasture without burning in the last 41 years, grazed with 1.2 animal ha^{-1} and ameliorated by liming and fertilization in the last 17 years (AP) and native forest (NF). Physical fractionation was performed by the densimetric method (politungstate solution, $\rho = 2\ g\ cm^{-3}$) resulting in free light fraction (FLF), occluded light fraction (OLF) and heavy fraction (HF). Carbon and nitrogen contents were determined by dry combustion and carbon stocks were calculated. SOM in physical fractions was investigated by thermo-gravimetric analyses (TGA) between 40 and 800°C under synthetic air and a chemical recalcitrance index was calculated: $\Delta m_{(3°)} / \Delta m_{(2°)}$. From the FTIR spectra, relative intensities of the main absorptions were obtained.

Results and Discussions

Soil C stock was greater in the ameliorated pasture (38 Mg ha^{-1}) than in the BP environment (27 Mg ha^{-1}), whilst an intermediate value was found in NP (30 Mg ha^{-1}). This result is related to the higher forage production in the ameliorated pasture in comparison to the non-managed pastures. Therefore, the greater input of vegetal residues (above and below ground) in the former environment promoted C sequestration in spite of its higher grazing intensity, when compared to the more recently burned pasture.

The same behaviour was followed by C stocks in the physical fractions. The increase in C stocks in the ameliorated pasture in comparison to BP occurred in all three fractions, and the obtained values were 7.0 Mg ha^{-1} for FLF, 4.7 Mg ha^{-1} for OLF and 26.1 Mg ha^{-1} for the heavy fraction. C stocks shown by BP were the smallest ones: 2.2; 3.1 and 21.4 Mg ha^{-1}, for FLF, OLF and HF, respectively. Both light fractions of the BP environment showed high C/N values (28 and 19), indicating the occurrence of a different forage (FLF) and of a more recalcitrant OLF in this environment in comparison to NP and AP. These results were corroborated by the FTIR data, where the lowest intensities of N-H bands were found for OLF and FLF of BP. Additionally, these two fractions showed the smallest relative intensity of the 1630 cm^{-1} band and greatest of the 2920 cm^{-1} band in comparison to their respective counterparts of the other environments. The opposite occurred with the HF. It follows that the forage species developed under BP were more aliphatic and less aromatic than in the other environments. The BP heavy fraction, due to the lower residue input, was enriched in aromatic structures. TGA data confirmed partially these findings.

Conclusions

Fertilizing and Liming of subtropical pastures in South Brazil highlands proved to be an appropriate management strategy to improve soil C sequestration. Ceasing fire, without any subsequent pasture amelioration, deplete C stocks and increase SOM recalcitrance in the heavy fraction.

Acknowledgements

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Solid-state ^{13}C NMR studies of activated carbons prepared from biomass using different chemical agents

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Key words: *NMR, activated carbons, biomass*

Introduction

Activated carbons are largely employed in several chemical and physical processes nowadays, including water treatment, catalysis, gas storage and others [1]. The surface properties of the porous carbons are determinant for most of such applications. Oxygenated functional groups present at the edges of the aromatic lamellae are known to influence decisively the surface chemistry of these materials [2]. In this work, solid-state ^{13}C nuclear magnetic resonance (NMR) spectroscopy was used for the analysis of a series of activated carbons prepared from a lignocellulosic precursor, using different chemical activating agents.

The lignocellulosic precursor chosen for the preparation of the activated carbons was the testa of *Mesua ferrea* oil seed, which is found extensively in North East India and is used in the production of biodiesel. The precursor, after water washing and drying, was cut into small pieces and carbonized at 450^{O}C for 30 min under N_2 flow. From this resulting char, activated carbons were prepared by chemical activation with KOH, NaOH, $CaCl_2$ or H_3PO_4, using an impregnation procedure. The activation heat-treatments were carried out at different final temperatures (in the range 500-950^{O}C) under N_2 flow. Some samples were prepared by carbonization of the precursor without any activating agent, for comparison. The products were initially washed repeatedly with hot distilled water. Some selected samples were also washed by refluxing with 25% HNO_3 for 2h at the water boiling point and then filtered and washed again with hot distilled water for several times. Finally, all samples were washed with methanol and then dried at 110^{O}C for 48h.

Solid-state NMR spectra were recorded at room temperature using two NMR spectrometers. Experiments with ^{1}H-^{13}C cross-polarization (CP) were conducted in a Varian INOVA 400 spectrometer at a frequency of 100.5 MHz (magnetic field of 9.4 T), whereas single pulse excitation (SPE) experiments were performed using a Chemagnetics-Varian 200 spectrometer at 51.4 MHz (4.7 T). The chemical shifts were externally referred to tetramethylsilane (TMS). All experiments were conducted with magic angle spinning (MAS). Recycle delays varied in the range 1-10 s, being adjusted to avoid saturation problems.

Results and Discussions

The ^{13}C SPE-MAS NMR spectra of a set of activated carbons are shown in Fig. 1, compared to the spectrum corresponding to the precursor charred at 850°C. All spectra are dominated by a broad and intense band associated with aromatic carbons. Weak aliphatic contributions can be observed in some spectra, especially for the non-activated char.

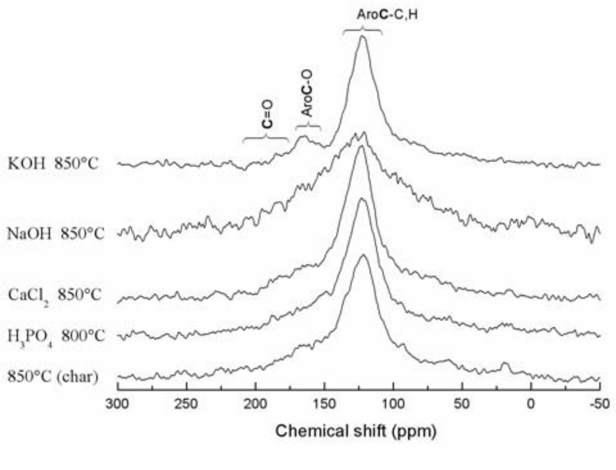

Figure 1. ^{13}C SPE-MAS NMR spectra of the charred precursor and a set of activated carbons prepared with different chemical agents.

The presence of resonances due to oxygenated functional groups is observed in the range 160-210 ppm. These groups are especially visible for the KOH-activated sample.

A strong intensity in this chemical shift range is also observed in the spectrum corresponding to the NaOH-activated sample, but the excessive broadening of the resonances precludes a precise assignment in this case. This finding is likely to be associated with the dipolar coupling between the ^{13}C nuclei and the quadrupolar and abundant ^{23}Na nuclei in the neighborhood [3].

The ^{13}C SPE-MAS NMR spectra of the activated carbons prepared with H_3PO_4 as the activating agent at different temperatures are shown in Fig. 2. The spectrum corresponding to the non-activated char, also shown in Fig. 2 for comparison, shows the presence of a sizeable aliphatic contribution around 25 ppm. All activated samples are predominantly aromatic.

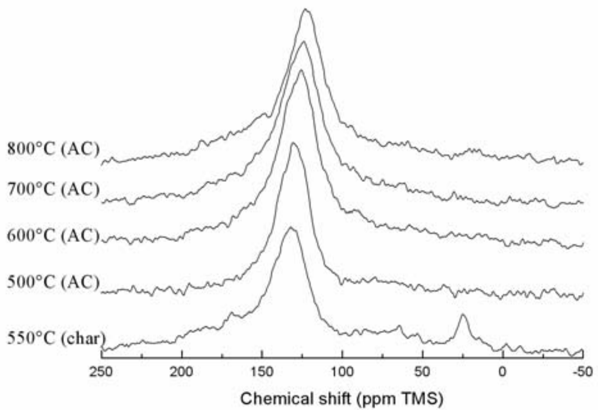

Figure 2. ^{13}C SPE-MAS NMR of the charred precursor and the activated carbons (AC) prepared at different activation temperatures using H_3PO_4 as the activating agent.

The chemical shift of the strong aromatic peak decreases with the increase in the activation temperature, as a consequence of the increase in the diamagnetic susceptibility of the graphene-like planes [4]. It is interesting to mention that this trend is also observed for the chemical shifts of the main resonance found in the ^{31}P NMR spectra (not shown), which indicates the proximity of the phosphorous species and the aromatic planes in the $H_3PO_4^-$ activated carbons.

Conclusions

Solid-state ^{13}C NMR was used to study a series of activated carbons prepared from different chemical activating agents. The predominantly aromatic nature of all activated materials was clearly established. Oxygenated functional groups were detected especially for the alkali-activated carbons. For samples prepared at different temperatures, the chemical shift of the aromatic resonance showed a trend of reduction with the increase in the activation temperature, caused by the increase in the diamagnetic susceptibility of the graphene-like planes in the activated carbons.

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[1] Marsh, H.; Rodriguez-Reinoso F. 2005. *Activated Carbon*. Elsevier, Amsterdam.

[2] Leon y Leon, C. A.; Radovic, L. R. 1994. *In: Chemistry and physics of carbon*, vol. 24, P. A. Thrower (editor), Marcel Dekker, New York, pp. 213-310.

[3] Duer, M. J. 2004. *Introduction to Solid-State NMR Spectroscopy*. Blackwell, Oxford.

[4] Freitas, J. C. C.; Emmerich, F. G.; Cernicchiaro, G. R. C.; Sampaio, L. C.; Bonagamba, T. J. 2001. *Solid State Nucl. Magn. Reson. 20*, 61-73.

Development of a Biochar Classification System Based on Plant Growth Effects

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Key words: *Biochar, Plant growth stimulation, NMR classification*

Introduction

Our investigations focus on the characterisation and classification of biochars based on their compositions and influences on plant growth. Biochars from Miscanthus x *giganteus* chips, pine and willow were pyrolysed in a lab-scale pyrolyser (1 dm^3). The more extensive studies have focused on miscanthus. Biochar products from pyrolysis at: (a) 400°C for 10 min; (b) 500°C for 30 min; and (c) 600 °C for 60 min have been used as amendments (1% and 5% w/w) to a shallow calcareous Irish brown earth loam soil (20% clay, pH 7.5), and maize (*Zea mays* L) seeds were planted in pots for plant growth experiments variously carried out in a growth chamber and in a greenhouse. At the end of the growing periods (21 and 28 days), plants were cut at the soil level, weighed, and oven dried at 60°C. Surface area measurements, heating values, and C, H, and N contents were determined for each biochar sample. Biochar morphologies were observed using Scanning Electron Microscopy (SEM). Volatile materials associated with the biochars were determined according to the standard procedure CEN/TS 15148:2005. Solid state CPMAS ^{13}C NMR was a major procedure for the characterisation of the biochars produced.

Results and Discussions

After 15 days, maize seedlings had not emerged in the control pots in the greenhouse experiment whereas stems were 10 cm in height and with three leaves per stem in pots amended with the 5 wt.% miscanthus biochar. Seedling emergence was observed after 20 days for the control. The best growth was observed for the miscanthus biochar-amended pots (Figure 1 and Table 1), and in these cases the results for the 1% amendments matched those for 5%.

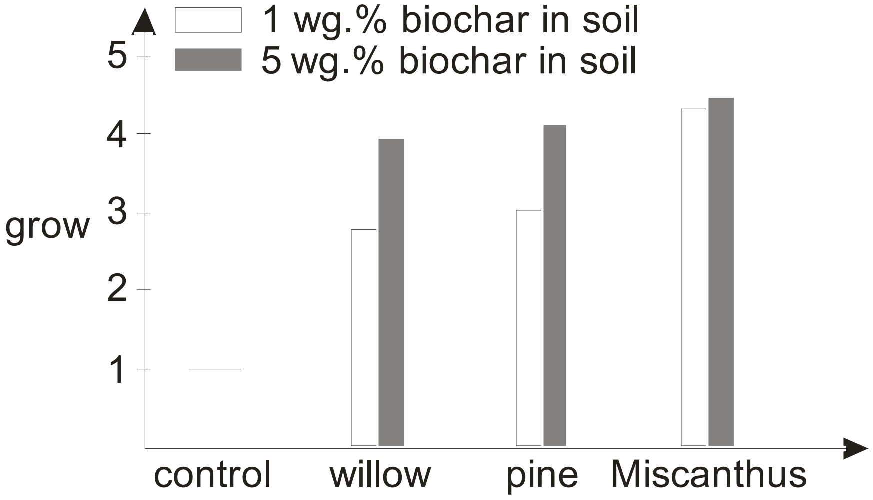

Figure 1. Growth of plants (relative to the control) after 21 days in soil amended with 1 and 5 wt.% biochar from miscanthus, willow, and pine prepared under the same conditions.

Table 1. Yields and properties of biochars from different substrates and reaction conditions

Biochar source	Control (no biochar)	Willow	Pine	Miscanthus
Yield after 21 days (as growth % of control)	100	393	402	437
Yield after 28 days (as growth % of control)	100	128	135	153

Biochars from willow and pine also gave similar growth response at the 5% level, though the response to these was less at the 1% amendment level (Figure 1). The difference in growth in the control and char-amended soils became less with time, as can be inferred from the data in Table 1. The greenhouse experiments have shown that biochar has the best effects during germination and in the first stages of growth. The experimentation has shown that biochar prepared at 600 °C for 60 min gave the best growth results, and that prepared at 400 °C for 10 min suppressed plant growth. The latter had a significantly lower surface area. The NMR spectra (Figure 2) for the biochar samples differed greatly from that for the parent miscanthus The distinctive evidence for lignin and carbohydrate components in miscanthus was absent from the spectra for the biochars formed at 600 °C.

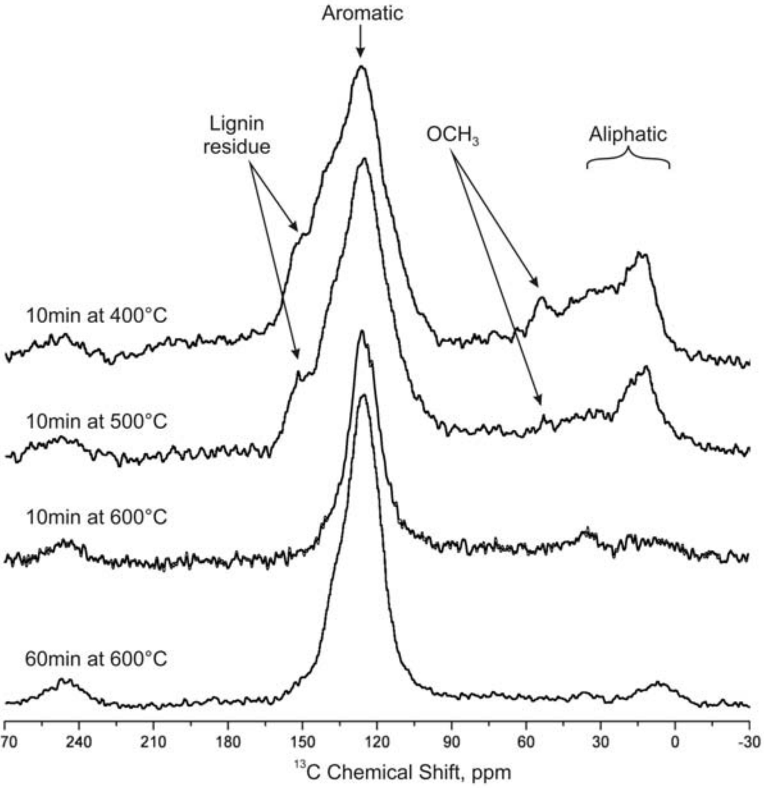

Figure 2. DPMAS ^{13}C NMR spectra of different miscanthus biochars.

However, there is evidence for some lignin-derived residuals in the products formed at 400 °C and at 500 °C. The product formed at 600 °C for 60 min clearly shows a resonance at 127 ppm that is characteristic of fused aromatic structures characteristic of chars.

Conclusions

Our results have shown that the temperature and time of pyrolysis have major influences on the extents to which biochar amendments to soil influence seed germination, and plant growth, at least in the early stages. It would seem that the stimulation of seed germination is hormonal/chemical from sorbates on the biochar surfaces. Further research by our team members has shown prolific fungal associations (possibly VAM fungi), with the plant roots associated with the biochar, and also extensive bacterial proliferations in the biochar enriched areas in the soil. Symbiotic relationships between fungi and plants may give rise to long term stimulation of the plant growth. It is clear that, depending on the procedures used for the preparations of biochars, the products can stimulate or inhibit plant growth. It is therefore very important to develop a biochar preparation and testing protocol that that will allow classification of biochar products in terms of their properties for uses in agriculture. Surface area is an important criterion, and that property, combined with NMR data provide the best evidence we have at this time to indicate that a particular biochar can benefit plant growth.

It is very important also to develop criteria that will indicate that marketable biochars do not pose a threat to human health.

Acknowledgements

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Carbon and nitrogen dynamics of grass-derived pyrogenic organic material during 2.3 years of incubation in soil

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Key words: *Aryl C, Degradation,* ^{13}C *and* ^{15}N *NMR*

Introduction

Incomplete combustion of vegetation results in pyrogenic organic material (PyOM) which occurs ubiquitously in soils and sediments. To understand the C sequestration potential of PyOM in environmental systems knowledge is required about the respective degradation and humification mechanisms and the stability of the different chemical PyOM structures. The present study focuses on the microbial recalcitrance of PyOM on molecular scale. Therefore, microcosms incubation experiments were performed using PyOM produced from highly isotopically enriched ^{13}C and ^{15}N rye grass (*Lolium perenne*) at 350°C under oxic conditions for one (1M) and four minutes (4M). Solid-state CPMAS ^{13}C and ^{15}N NMR studies were accomplished to obtain insights into the involved humification mechanisms at different stages the PyOM degradation.

Results and Discussions

In total up to 38% of the bulk PyOM C was mineralised during the 28 months of incubation. The O/N-alkyl C and alkyl C residues, which survived the charring process, were effectively decomposed. At the end of the incubation up to 73% and 57% of the initial O/N-alkyl C and alkyl C amount were mineralised or converted to other C groups, respectively. The total aryl C group recovery of the PyOM decreased significantly during the 28 months of incubation ($P \leq 0.001$). After 20 months of incubation between 26% and 40% of the initial aryl C amount was lost. For this group, relative short half time periods in the range of 3.0 and 3.8 years were obtained. The observed loss of aromatic C structures may be attributed to two simultaneous processes, the mineralisation to CO_2 and the conversion to other C groups by partial oxidation. The presence of a readily decomposable co-substrate showed no significant changes in the degradation pattern of the different PyOM, possibly because decomposable sources were already available in the starting PyOM.

Most of the organic bound N of the fresh PyOM was assignable to heterocyclic aromatic compounds such as pyrrole and indole-like structures with contributions of 62% and 72% for PyOM 1M and PyOM 4M, respectively. The other part of the ^{15}N NMR signal intensity was assignable to amide-like structures. No major alteration of the amide and heterocyclic N contribution was detected for the PyOM 1M incubates. For the more charred PyOM 4M, the relative heterocyclic N contribution decreased. After the 28 months of incubation no significant difference in the chemical N composition of PyOM 4M related to the PyOM 1M treatments could be observed ($P=0.472$). Further, we detect a continuous degrease of the total amounts for the amide and heterocyclic N compounds. After 20 months, only 49% to 59% of the heterocyclic N compounds were recovered. The respective amide N recoveries were larger with 59% to 87%.

Conclusions

It can be concluded, that PyOM may not be as highly refractory as it is commonly assumed. During the efficient degradation not only a considerable PyOM amount is mineralised, but also the chemical structure of the remaining PyOM is strongly modified. This includes the formation of O-containing functional groups and the loss of aromatic C and N containing heterocyclic domains by mineralisation and conversion to other C and N groups.

Acknowledgements

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Biochar effect on the humification dynamics of chicken manure compost

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Key words: *IF-TR*, *RMN ^{13}C*, *Termodegradation.*

Introduction

Agricultural use of biochar would have positive effects on yield and physico-chemical properties of soil (1;2), however, on the dynamics humification during composting process are still unknown.

With the refinement of spectroscopic techniques such as Fourier transform infrared (IF-TR), nuclear magnetic resonance (NMR) of ^{13}C, beyond the methods termodegradativos, much has been advanced in the analysis of changes in the molecular structures of organic fractions during the composting process, which allows inferences about maturity and stability of the compounds (3).

The objective of this study was to evaluate the humification dynamics and the maturation degree of of the composting process of chicken manure with biochar, by employing the technique of thermogravimetry and analyzing the spectral signatures of humic substances in IF-TR e NMR ^{13}C.

The piles of compost were prepared using chicken manure and charcoal, obtained by pyrolysis of Eucalyptus grandis in an oven with ambient atmospheric pressure and temperatures ranging from 300 ° - 450 °C.

Subsamples of waste were collected at 0, 60, 120 and 210 days after the start of the composting process. At each sampling time, samples were extracted humic acids (HA) according to the recommended methodology by the International Humic Substances Society (4).

Thermograms were obtained using the analyzer SDT-2960 *simultaneous* DSC-TGA (TA *instruments*), determining the thermogravimetric index (ITG) (5).

The spectra of IF-RT were obtained using a spectrophotometer Perkin Elmer, Spectrum 1000. After obtaining the spectra were determined, the hydrophobicity indices (HI) and condensation (CI) (6).

We obtained ^{13}C NMR spectra of the solid-state cross-polarization and magic angle rotation seconds. The intensity of the signals and the proportional contribution of each type of carbon were determined by integrating the spectral regions, the index of aromaticity was calculated by the relationship between the intensity of absorption in the region of the aromatic C region of aliphatic C (3).

Results and Discussion

The ITG calculated increases with the composting process (Tabela 1) showing a gradient of resistance to thermal degradation of samples from the beginning of composting, less ITG, until the stabilized compound, higher ITG. It is observed the highest values after 210 days of composting, which can be related to the higher proportion of highly condensed aromatic groups derived from the charcoal, because the HA of pyrogenic origin have a higher resistance to thermal oxidation, due to the occurrence of nuclei aromatic hydrocarbons in the same (5).

Table 1. Thermogravimetric index (ITG), hydrophobicity (HI), condensation (CI) and aromaticity of organic waste during the composting process.

Índex	Composting time (days)			
	0	60	120	210
ITG	1,11 c	1,24 b	1,21 b	1,39 a
IH	0,49 a	0,37 b	0,25 c	0,23 c
IC	0,44 c	0,64 b	0,84 a	0,81 a
IA	16,4 b	23,53 a	17,50 b	21,06 a

*Means followed the same letter in the row did not differ for the time of composting, by Tukey test, P <0.05.

In general, changes in the spectra of IF-RT obtained from composted organic wastes indicate that the constituents of the more easily degradable organic matter, have been chemically or biologically oxidized with increasing time of composting, as can be seen through the hydrophobicity indices (HI) and condensate (JI), which are presented in Table 1.

Significant differences were observed for the values of HI obtained at different times of composting, and the highest rates observed for the first days of composting for all mixtures evaluated, with a reduction to the maturation phase of the compound. Thus, according to the results observed, it can be deduced that the degradation is occurring more aliphatic compounds, the lower the HI, is the lowest concentration of C-aliphatic (7).

Regarding the CI, there were higher at the end of the composting process, it can be inferred that the organic matter has more humified structures.

The ^{13}C NMR indicated a small increase in the content of aromatic groups and a reduction in the content of aliphatic groups during the composting process. The aromaticity index obtained in the composting of chicken manure with coal showed little significant increments after 210 days (Table 1), indicating that some aliphatic components were degraded during the composting process and, consequently, there was an enrichment of aromatic structures, but the more aliphatic character of humic acids was more pronounced.

Conclusion

Thermogravimetry showed an increased resistance to thermal degradation of humic materials with advancing humification. The rates of condensation and hydrophobicity showed a greater degradation of labile compounds and an increase in the degree of humification. The ^{13}C NMR indicated a small increase in the content of aromatic groups and a reduction in the content of aliphatic groups during the composting process.

Acknowledgements

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[1] Chan, K.Y. et al. 2007. *Aus. J. Soil Res.* 45, 629-634.

[2] Steiner, C. et al. 2007. *Plant Soil.* 291, 275-290.

[3] Ait Baddi, G. et al. 2004. *Bio. Tech.* 93, 285-290.

[4] Swift, R.S. 1996. In: Sparks, D.L. et al.;. (Eds.). *Methods of soil analysis*. Madison, p. 1011-1020.

[5] Benites, V.M. et al. 2005. *Geoderma.* 127, 104-113.

[6] Dias, B.O. et al. 2009. *Rev. Bras. Ci. Solo.* 33, 885-894.

[7] Capriel, P. et al. 1995. *Soi. Bio. Bioc.* 27, 1453-1458.

The Redox Characteristics of Biochar and Hydrochar

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Key words: *redox properties, cyclic voltammetry*

Introduction

Biochar is proving itself to be a valuable additive to soils to improve fertility and ultimately crop yields for human consumption or energy production. Considerable effort has been expended in trying to understand the mechanism through which biochar improves soil fertility, although at this time conclusive evidence is not available.

One possible mode of action is through the electrochemical characteristics of the biochar relative to the soil. Certainly the soil and groundwater composition contribute to the chemistry of the environment. However, the potential (Eh) and acidity (pH) of the terrestrial environment will also contribute to the nature of the species present; i.e., oxidation state, and hence their bio-availability. An important point to note is that these Eh and pH conditions (and hence speciation) are changeable and in most cases react to changes in the local environment.

Biochar, like many carbon-based materials (e.g., coal, activated carbon, carbon black, etc.), can exhibit redox and charge storage capabilities depending on its intrinsic physico-chemical properties. Redox activity (Faradaic processes) originates from charge transfer associated with functional groups on the carbon surface or from ionic intercalation into the char structure. Alternatively, charge can be stored at the char-electrolyte interface within the double layer (non-Faradaic processes).

Results and Discussions

In this paper we report on our efforts to characterize the electrochemical behaviour of a number of char samples prepared either conventionally by pyrolysis of an organic matter precursor, or hydrothermally from a waste wood precursor.

Electrochemical characterization was achieved initially by cyclic voltammetry (CV) on a composite electrode of char and graphite (1:10 by weight) in a buffered pH 7 electrolyte, an example of which is shown in Figure 1.

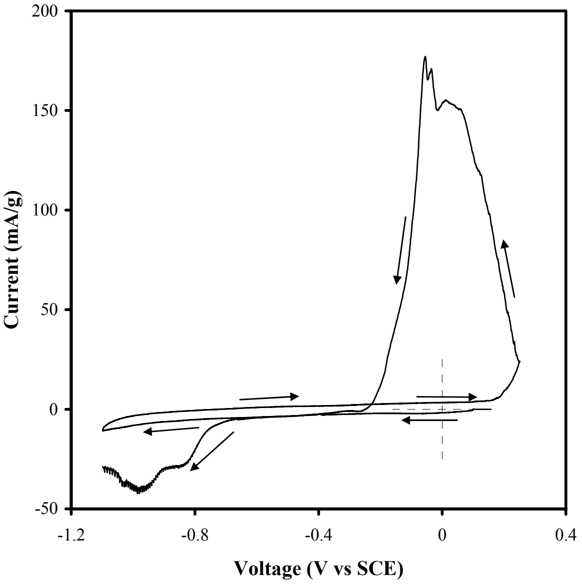

Figure 1. Typical CV of biochar (0.05 mV/s).

Starting at ~0.15 V the first cathodic scan liberates very little cathodic charge. That which is measured is associated with non-Faradaic discharge of the double layer at the char-electrolyte interface. Upon sweep reversal similar non-Faradaic phenomena occur until the upper voltage limit is reached. However, upon sweep reversal again it is clear that the char undergoes an activated oxidation process that liberates considerable charge. What is surprising is that it happens at lower voltages impliying the higher voltage anodic treatment has changed the char-electrolyte interface to make more charge available. This may be associated with either chemical changes to the char surface, or more likely physical changes to the interface through pore opening, for example. At even lower voltages after the second cathodic scan the surface is more redox active with a greater cathodic current flowing. Most biochar and hydrochar samples we have examined exhibited similar behaviour, the difference being the magnitude of the activated anodic current.

We have also conducted a series of electrochemical impedance spectroscopy (EIS) experiments, coupled with step potential electrochemical spectroscopy (SPECS) on similar char electrodes to characterize the charge storage mechanisms. The electrochemical protocol applied is shown schematically in Figure 2, with EIS spectra collected at the end of each step, while selected data is shown in Figures 3(a) and (b).

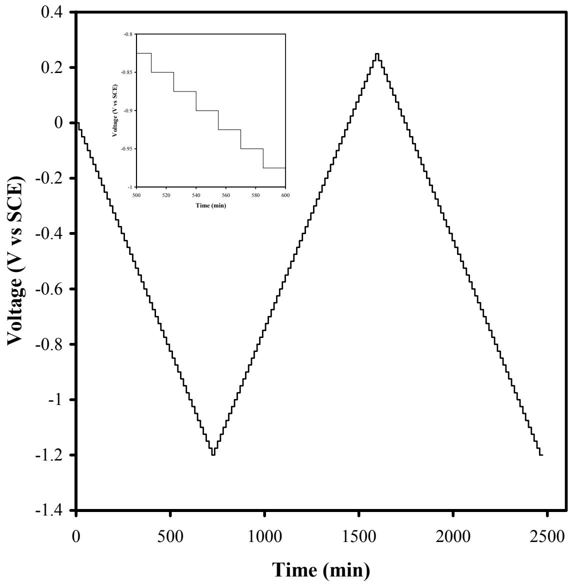

Figure 2. Electrochemical protocol for the EIS experiments.

In this case there was considerable variation in the EIS data depending on the applied voltage. It shows a range of different phenomena occurring, including the effects of electronic conduction, charge storage in the double layer, and mass transport of species within pores, all as a function of state of charge.

Coupled with this we have also conducted a range of SEM, XPS and gas adsorption measurements on the char samples both before and after electrochemical cycling. Based on these experiments, the electrochemical activity of the chars will be discussed.

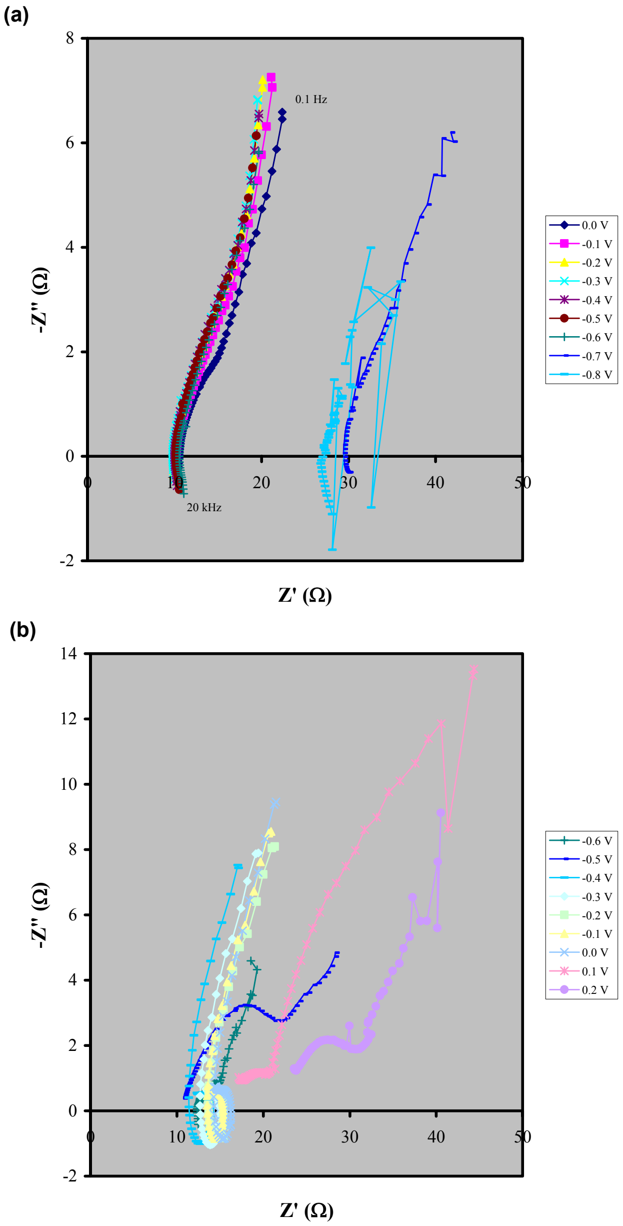

Figure 3. EIS data during (a) the first cathodic and (b) anodic sweep.

Acknowledgements

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Characterisation for commercialisation: What the consumer needs to know

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Key words: *characterization; industry standard; consumer confidence*

Introduction

Some businesses around the globe are currently marketing biochars without any quality control measures; either for sourcing of feedstock or product. To maintain the credibility of this fledgling industry, the development of a simple classification system for biochars and biochar composites that meets the needs of both consumers and producers is urgently required.

Results and Discussions

Previous publications (Lehmann and Joseph 2009, ANBZ 2009) and discussions at meetings and conferences have resulted in a number of approaches to the classification and testing of biochars. Some scientists have emphasised tests to determine the recalcitrance of the biochars, in response to an interest in long-term C sequestration potential, while others have focused on specific surface properties, as these may have important implications in the retention of nutrients in soils. However, these properties while crucial for a scientific understanding of biochar, do little to build consumer confidence in the product.

This paper takes a different approach in that we are asking the following questions from the consumer's perspective.

Are there tests or guidelines that can determine?

1. If and when a specific biochar will improve the yield of a specific crop (s) for a specific soil(s).
2. If a biochar will result in detrimental impacts when applied to soil, such as inhibited germination, phytotoxicity, or reduction in earthworm population.
3. The long term effect of biochar(s) in the target soil.
4. Are there contaminants in the biochar that will impact either human health, soil health or impose trade barriers or restrictions on agricultural produce
5. If the feedstock has been sourced sustainably.

Table 1: Ecotoxicological assessment of biochar

Required analysis	**Recommended method**	**Minimum criteria to be termed biochar (or notes)**
Earthworm avoidance	Toxicity testing conducted using (OECD) earthworm avoidance method (OECD, 1984) as described in (4) *Biochar is applied into OECD standard soil at a rate of 1% w/w, with 10 replicates.*	Biometrical analysis against controls should show no biometrically significant earthworm avoidance to the biochar treatment.
Germination inhibition assay	Germination inhibition is tested against three test species using OECD standard soil (OECD 2004). [5]	Biometrical analysis against controls should show no biometrically significant decrease in plant germination.

It is proposed that a minimum set of information be provided when the biochar is sold. This includes ;

1. A statement of plant available nutrients (Lehmann and Joseph, 2009; Yao et al, 2010),
2. Recommendation of how to transport, store apply
3. Recommended application rates for different types of crops and/or different types of soil,
4. Indication of water holding capacity and,
5. For some applications, the ability to sorb toxic substances.
6. Results of ecotoxicity tests and if from waste compliance with local heavy metal content.

A range of possible simple tests to determine biochars effectiveness in different soils will be illustrated during the presentation. These test are based on a range of chemical, biological and physical factors that have influenced crop production in over 200 field plots in Australia, The tests also reflect the changes that occur during the growth and fallow periods over a 5-20 year period. They include simulated biogeochemical weathering (Yao et al., 2010), dissolution tests and changes in soil redox following biochar addition.

It will be recommended that ecotoxicological assessments need to be undertaken (Table 1). These tests will not guarantee the biochar has a positive influence on crop performance; however, they will assess any potential harm a poorly-produced biochar may impart in soil. Details of other simple tests that can be carried out in at the point of manufacture to determine quality and consistency will be discussed.

Current guidelines for similar products should be met such as those laid out in Table 2 for compost (EPA, 2010). Within the Australian context It is anticipated biochar should meet Grade A standards for application above 10t/ha. Grade B standard of heavy metal contamination may be adequate for lower application rates, or for non-food soil amendment.

Conclusions

The consumer is asking whether biochar will work and what are the risks associated with its application. Guidelines for safety of production and emissions from production are outside the scope of this paper and are subject to individual countries' legislation.

The biochar industry would be wise to adopt guidelines developed by the biofuels industry for sustainable sourcing of biomass (*Version Zero, Standard for Sustainable Biofuels, 2008*).

Table 2. Metal Contaminants Guidelines

Contaminant acceptance threshold NSW EPA230800d (EPA compost guidelines 2009)		
Contaminant	*Grade A mg/kg total*	*Grade B mg/kg total*
As	*20*	*20*
Cd	*3*	*5*
Cr	*100*	*250*
Cu	*100*	*375*
Pb	*150*	*150*
Hg	*1*	*4*
Ni	*60*	*125*
S	*5*	*8*
Zn	*200*	*700*

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[1] ANBZ (2009) *Guidelines for Characterising, Classifying and the Safe Use of Biochar*

[2] Lehmann J, Joseph S (ed) (2009) Biochar for Environmental Management. Earthscan Publications Ltd, Sterling, VA.

[3] *Roundtable of Sustainable Biofuels* (2008) Version Zero, Standard for Sustainable Biofuels, An initiative of the EPFL Energy Centre.

[4] Van Zwieten, L., Rust, J., Kingston, T., Merrington, G. and Morris, S (2004) *Sci. Tot. Environm.* 329, 29-41.

[5] Van Zwieten L., Kimber S., Morris, S., Chan, YK., Downie, A., Rust, J., Joseph, S., and Cowie, A. (2010) *Plant and Soil* 327: 235-246.

[6] Yao F.X., M. Camps Arbestain, S. Virgel, F. Blanco, J. Arostegui, J.A. Maciá-Agulló, F. Macías (2010) Simulated geochemical weathering of a mineral ash-rich biochar in a modified Soxhlet reactor. *Chemosphere* 80:724-732.

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Chemical alterations occurring during biomass charring and their impact on char recalcitrance

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Key words: *model chars, chemical structure, (bio)degradation*

Introduction

The application of biochar to soil is proposed as a novel approach to establish a significant, long-term C sink and to improve soil fertility. Beside the production of volatiles, charring transforms labile organic components into recalcitrant dark colored and highly aromatic structures. Bearing in mind that they are chemically and physically distinct from soil organic matter (SOM) formed during fire-free humification, a good understanding of the chemistry of biochars is crucial to ensure its sustainable use as soil amendment. Therefore, in this presentation, recent and previous [1][2] studies elucidating the chemical alterations during controlled charring of plant residues and their typical biomacromolecules (casein, cellulose, lignin, tannins) are presented. Subsequently, the chemical features of the model chars were related to its chemical recalcitrance as determined by chemical oxidation with acid potassium dichromate [3]. Additionally, the biodegradability [4] as well as the recalcitrance of plant chars in soils are elucidated.

Results and Discussions

After charring at 350°C for 4 min, casein showed a C-loss (34%) that was lower than for cellulose (76%) , but in the range determined for condensed tannins (spruce) (33%) and only slightly smaller than for lignin (23%). Although the C-losses increased, this pattern remained comparable after augmentation of the temperature to 450°C. Since no major differences were observed between C and N-losses, it can be assumed that N is an integral part of the BC derived from peptide-like materials. The comparably low organic N losses further demonstrate that during charring N has a tendency to be incorporated into structures, which are highly resistant to heating. Similar C and N losses were also observed after charring of grass residues, although the higher temperature reduced the C- and N-recovery by a factor of two. However, wood sawdust depicted a lower heat resistance than the grass residues.

NMR-spectroscopic studies revealed high thermal recalcitrance of the lignin backbone and considerable contributions of furans and anhydrosugars from thermally altered cellulose (Figure 1). Black nitrogen (BN) occurs mostly in pyrrole-type structures. Accordingly, it was calculated that in non-woody biochars, such compounds may consume up to 17% and sometimes even up to 60% of their organic C. Bearing in mind the high frequency of vegetation fires and the relative high biological recalcitrance of biochars, those numbers imply a considerable relevance of such structures for pedogenetic and also diagenetic processes leading to organic matter stabilization and maturation.

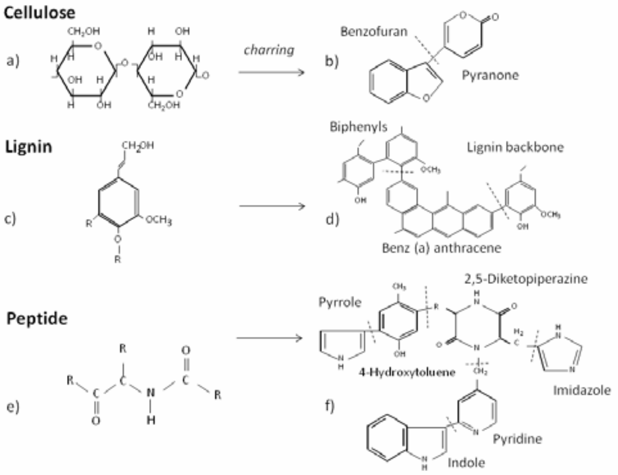

Figure 1. Biopolymers (a,c,e) and their possible charring products (b,d,f) as evidenced by solid-state NMR spectroscopy [1].

Enhancing the temperature during the charring of casein to 450°C decreased the C and N recovery to 30% and 23%, respectively. Comparably the C, O and H recovery were also reduced in the cellulose char, but to a considerably higher extent. The changes went along with a further augmentation of the relative contribution of aromatic C. Increased C, H and O losses were also observed for charring of lignin at higher temperature, although they were smaller than those observed for casein and cellulose. The higher temperature considerably altered the chemistry of the lignin char.

Subjecting the produced chars to chemical oxidation with acid potassium dichromate clearly demonstrated that the resistance of the casein chars against heat is not necessarily related to chemical recalcitrance. For the char produced at 350°C, only 13% of the C and N remained in the oxidation residues, whereas for that produced at 450°C this value increased to 80%. In contrast, both cellulose chars showed high chemical resistance with a C-survival of more than 80%. Comparatively, the C and N recalcitrance in the grass chars increased with temperature, whereas, the burned wood residues (350°C) suffered an almost complete oxidation. The chars from condensed tannins, on the other hand showed a high chemical resistance independently from the production temperature.

In summary, this study shows that the thermal and chemical recalcitrance of plant chars is highly variable and is related to its chemical structure. The latter depends on the source and the respective charring conditions. Biotic degradation studies of grass chars confirmed such a relationship for biodegradation.

However, one has to consider that recalcitrance of plant chars in soils depends not only upon its chemistry but also on the environment in which it is accumulating. Comparable to the humification of fire-unaffected SOM, different mechanisms including O_2-deficiency, unfavorable conditions for microorganisms or interaction with the mineral phase, seem to be involved in pyrogenic organic matter (PyOM) stabilization. According to this concept, the efficiency of the single pathway varies with the respective soil conditions, resulting in a specific PyOM pattern which is typical for a certain soil. Such a scenario could explain the varying abundance and recalcitrance of PyOM in fire-affected soils. In turn, the respective PyOM pattern, which can have been generated over decades and millennia, determines typical soil properties and thus PyOM can be seen to be actively involved in the pedogenic process, leading to soil classes such as Terra preta soils in the Amazon region, and possibly also to Chernozems in Central Europe or other Black soils all over the world.

Conclusions

More and more reports evidence the degradability of PyOM in soils. Its chemical nature which largely depends on its source and forming conditions determines its stability. Some of its structural components certainly delay its biochemical decay relative to microbially easily available plant residues and several of those may even have an exceptionally high biochemical resistance. However, its final survival seems to be determined by comparable mechanisms that are active with respect to the fire-unaffected SOM, allowing some fractions to survive for millennia while others are quickly degraded. From this point of view, the consideration of charcoal addition to soils as a means of C-sequestration needs a reevaluation, bearing in mind the C-loss during its production. On the other hand, comparable to fire-unaffected and humified (stabilized) SOM with residence times of several thousands years, PyOM can also be involved in pedogenic processes. The latter is expressed in the observation that human activity of Neolithic and earlier times contributed to the formation of soils with typical features. Thus, using fire and charcoal application as an agricultural practice, one has to account for the possibility that such an approach has formerly and will in future alter soil environments and properties not only on a short but also on a long term scale.

Acknowledgements

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[1] Knicker, H.; Hilscher, A.; González-Vila, F.J.; Almendros, G. 2008. *Org. Geochem. 39*, 935.

[2] Knicker, H.- 2010. “Black nitrogen” – An important fraction determining the recalcitrance of biochars. *Org. Geochem. in press.*

[3] Knicker, H.; Müller, P.; Hilscher, A. 2007. *Geoderma* 142, 178-196.

[4] Hilscher, A.; Heister, K.; Siewert, C.; Knicker, H. 2009. *Org. Geochem. 40*, 332.

Characterization of organic matter's quality evaluated through ^{13}C NMR of the Serra do Sudeste's soils in Rio Grande do Sul

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Keywords: density physical fractionation, native grassland

Introduction

Due to the absence of significant research work on the characterization of soil organic matter (SOM) in the region of Serra do Sudeste do Rio Grande do Sul, the purpose of this work is to evaluate qualitatively the physical fractions of a Lithic Leptosol (RL), Haplic Planosol (SX) and Haplic Vertisol (VX) under a native grassland in Torrinhas, 2nd District of Pinheiro Machado, RS.

The soil sampling was performed on the soil's layer from 0.000 to 0.025 m and part of the undisturbed samples were used for the density physical fractionation of the SOM [1], in which a solution 2.0 Mg m^{-3} of sodium polytungstate was used. The energy dispersion per ultrasound was of 357 J mL^{-1} for RL, 374 J mL^{-1} for the SX and 461 J mL^{-1} for VX.

The samples of the free light fraction (FLF) and occluded light fraction (OLF) were treated with aqueous solution of HF 10%, to perform the analysis on the ^{13}C nuclear magnetic resonance (NMR).

Results and Discussion

The spectra were similar for the different soil types analyzed (Figure 1). In the region between 25-35 ppm, the C alkyl signal is from methylene, derived from long chain aliphatic. In the region of C O-alkyl (60-110 ppm), one can observe two distinct peaks; the one at 72-75 ppm is assigned to cellulose and the other at 105 ppm, derived from hemicellulose and other carbohydrates. The signal between 160-230 ppm corresponds, in part, to the carboxyl groups of organic acids [2].

In the analyzes of different soil types, there was a predominance of substituted C alkyl groups (C O-alkyl/C di-O-alkyl + C N-alkyl/C methoxyl), whose proportion varied from 36% to 37%, followed by C alkyl groups (26% to 36%). The aromatic structures (C aryl + C phenyl) contributed approximately with 13% of the composition of the samples, the carboxyl groups with 8% and carbonyl groups with 6% (Table 1).

Considering that the substituted C alkyl groups indicate the presence of polysaccharides and proteins structures in the SOM and that these compounds are easily decomposed by microorganisms; it can be inferred that the presence of these structures in the OFL indicates the process of physical protection of SOM by occlusion in the interior of stable aggregates.

Analyzing the chemical composition of FLF of the SOM, the proportions of substituted C alkyl, varied from 37% to 51% for RL and VX, respectively. For C alkyl, these ratios ranged 26-32% for VX and RL, respectively. Possibly the greatest abundance of substituted C alkyl in the FLF of VX can be explained by the differences in chemical composition (recalcitrance) of crop residues and its relationship with the environment where the decomposition occurs.

With respect to the aromatic structures (C aryl + C phenyl), the highest percentage was found in RL (17%). These higher proportions found in the substituted C alkyl groups, in relation to the aromatic structures; show that carbohydrates are the main organic constituents of the soil, although they have low molecular recalcitrance. This fact, associated with the aromatic compounds that correspond to smaller proportions, is an indication that the colloidal and the physical protection of SOM are overlapping the magnitude of protection by recalcitrance [3].

In OFL, similar proportion was observed among the functional groups of carbon in comparison to FLF. However, in the average of the different types of soils studied, there was a decreased of 3%, in FLF compared to OFL, for the substituted C alkyl groups and for the C alkyl. These variations indicate an increase in the degree of decomposition of OFL [4].

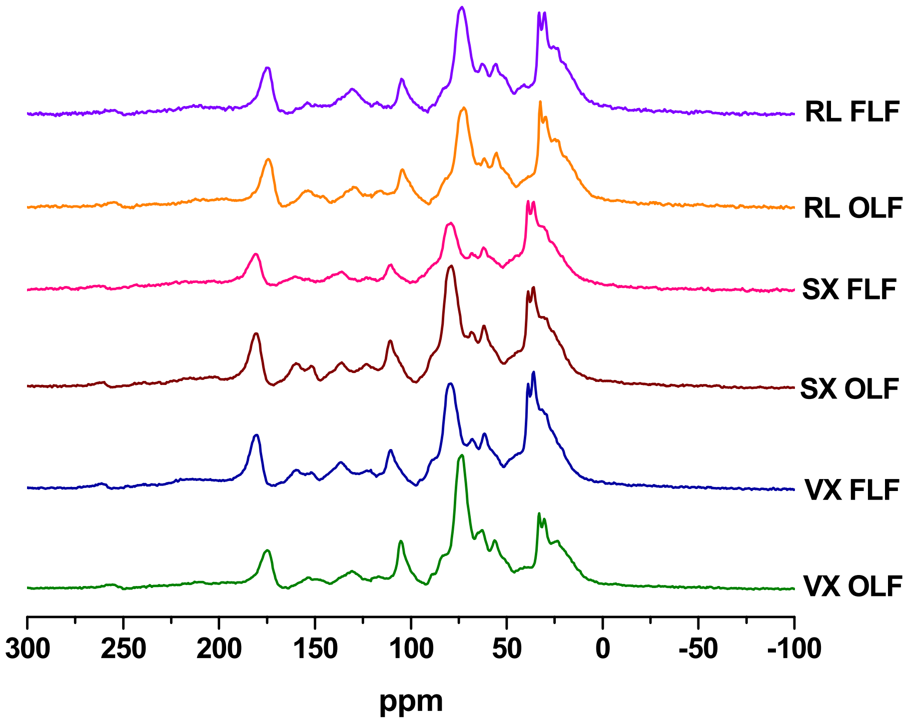

Figure 1. ^{13}C NMR spectroscopy of free light fraction (FLF) and occluded light fraction (OLF) of organic matter in a Lithic Leptosol (RL), Haplic Planosol (SX) and Haplic Vertisol (VX), under native grassland in the layer of 0.000 to 0.025 m.

Table 1. Percentage distribution of the C's functional groups determined by ^{13}C NMR spectroscopy in the free light fraction (FLF) and occluded light fraction (OLF) of organic matter in a Lithic Leptosol (RL), Haplic Planosol (SX) and Haplic Vertisol (VX), under native grassland in the layer of 0.000 to 0.025 m.

Soils *	Distribution of types of C / chemical shifts (ppm)						
	C alkyl	C N-alkyl C Methoxyl	C O-alkyl C di-O-alkyl	C-aryl	C phenolic	C carboxyl	C carbonyl
	0 – 45	45 – 60	60 - 110	110 - 140	140 - 160	160 - 185	185 - 230
				FLF			
RL	32	10	27	13	4	8	6
SX	30	10	33	8	5	8	5
VX	26	9	42	7	3	7	6
				OFL			
RL	36	10	27	8	4	8	7
SX	33	9	29	9	5	9	6
VX	27	15	32	8	4	8	6

*RL – Lithic Leptosol; SX – Haplic Planosol and VX – Haplic Vertisol.

Conclusions

The occluded light fraction has a higher proportion of more recalcitrant compounds in relation to the free light fraction, suggesting a more advanced stage of humification, regardless of the soil's type.

In the fractions analyzed there is no evidence of charred material, due to the absence of fires in this study area.

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[1] Conceição, P.C.; Boeni, M.; Dieckow, J.; Bayer, C.; Mielniczuk, J. 2008. Rev. Bras. Ci. Solo, 32,541-549.

[2] Kögel-Knabner, I. 2002. Soil Biol. Bioch., 34,139-162.

[3] Diekow, J. Estoque e qualidade da matéria orgânica do solo em função de sistemas de culturas e adubação nitrogenada no sistema plantio direto. 2003. 164f. Tese (Doutorado) – Universidade Federal do Rio Grande do Sul, Porto Alegre.

[4] Baldock, J.A. et al. 1992. Biogeochemistry, Netherlands, 16,1- 42.

3rd International Biochar Conference
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Progressing from Terra Preta de Índios to the Whole World

The effect of cover crops on the humification of organic material in a built soil after coal mining

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Key - words: *laser induced fluorescence, recovery of degraded area*

Introduction

While the coal is being mined, layers of soil are removed which need to be replaced, and afterward vegetated, seeking the recovery of mined areas. This study evaluated the rate of humification of organic matter (OM) of rebuilt soil, after the coal mining, under different cover crops, using indices obtained through fluorescence spectroscopy analyzes. The experiment has been conduced since 2003 in an area of built soil of the Riograndense Mining Company (CRM) in partnership with the Federal University of Pelotas (UFPEL). In Sept/2009, samples from 0.00 to 0.03 m soil's layers were taken in four treatments: T1-grass limpograss (*Hemarthria altissima* (Poir.) Stapf & CE Hubbard); T2-Pensacola (*Paspalum notatum* Flüggé); T3-Bermuda grass (*Cynodon dactilon* (L.) Pers.) T4-Brachiaria (*Brachiaria brizantha* (Hochst.) Stapf). Samples were also collected in an area adjacent to this experiment; with built soil without ground vegetation cover (T8) and in a natural soil with native vegetation (T9). The laser-induced fluorescence spectroscopy (LIF) is relatively easy to implement and is usually non-invasive, and it is very useful for environmental applications [1]. The soil samples, passed through a sieve of 9.52 mm, were ground; and soil pellets were obtained by pressing them at 8 tons. The fluorescence analysis was performed by using in a portable LIF system. It was used four measurements per sample and the data was used to calculate the humification index (HLIF) [2].

Results and Discussions

The areas under the curves, normalized by the carbon content, provide the HLIF (Table 1), which can be directly related to the humification degree of OM. The LIF spectra of the soil samples indicate that the greatest HLIF was presented by the uncovered built soil (Table 1). This may have occurred due to mining processes, which involve the mixing of surface horizons, the soil disaggregation and the decrease of plant biomass; reducing the physical protection of more labile soil organic matter and accelerating the process of decomposition.

Table 1. Area under the curve of fluorescence (ACF) weighted by the content of organic carbon as the humification degree (HLIF) of the organic matter of a built soil after the mining of coal.

Treatments	HLIF
T1 - Limpograss	5120
T2 - Pensacola	5075
T3 - Tifton	7579
T4 - Brachiaria	6274
T8 - Bare soil	8905
T9 - Natural soil	3845

The natural soil had the lowest humification degree. This is probably due to higher input of plant's residues over this ground and the non-revolving of the same, resulting in a slower decomposition of the organic matter [3]. A lower rate of humification of a natural soil in comparison to a soil under cultivation was also detected by this same author. Favoretto & Gonçalves et al [4] found a lower humification degree for soil under no-tillage than for soil under conventional tillage, using the technique of LIF, and they justified the incident by the major input of organic residues existing in the surface layer of soil under no-tillage. The soil built under the cover crop showed an intermediary humification index, between T8 and T9. Among the cover crops evaluated, the Tifton and Brachiaria were those that resulted in a more recalcitrant soil OM. The most humified OM is rich in functional groups with unsaturated bonds. Thus, when samples are illuminated with near ultraviolet or blue lights, it excites preferentially the most recalcitrant structures, which concentration increases in the humification process [1]. The Limpograss' and Pensacola's hedges were the ones that showed the lowest HLIF (Table 1). According Pulrolnik et al. [5], when the plant's components are more lignified and aromatic, it decomposes more slowly, favoring the maintenance of organic substances in soil. Milori et al [6], obtained positive correlations as they compared methods, already described in literature, to obtain the humification degree with the technique of LIF in intact soil, index of Zsolnay et al. [7] for humic acid solution (r = 0.85), index of Kalbitz et al. [8] (r = 0.76) and index of Milori et al. [9] (r = 0.77), showing that the technique used in this work has great potential for application.

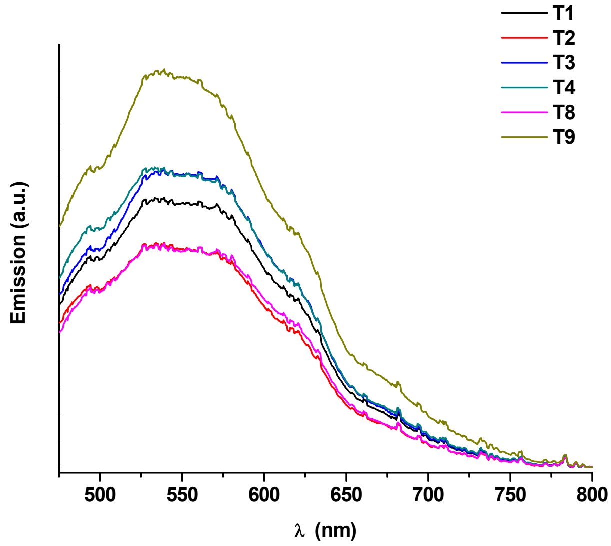

Figure 1. Fluorescence emission of the organic matter from a built soil after the coal mining under different vegetation cover.

Conclusions

The data indicate a higher rate of organic matter humification for soil under Tifton and Brachiaria.

The soil under Pensacola and Limpograss had the lowest indices of organic matter humification, indicating greater potential to recovery of built soils. The covering of the soil with plant species resulted in an intermediate humification degree, higher than the one in natural soil and lower than the one in uncovered built soil, indicating the recovery process of degraded soil.

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---

[1] Abreu JR., C.H.; Neto, L.M.; Milori, D.M.B.P.; Simões, M.L.; da Silva, W.T.L. In: Melo, V. De F.; Alleoni, L.R.F. *Química e mineralogia do solo*. Parte II – Aplicações. Viçosa - MG, 2009.

[2] Milori, D.M.B.P.; Galeti, H.V.A.; Martin-Neto, L.; Dieckow, J.; Gonzálezpérez, M.; Bayer, C.; Salton, J. 2006. *Soil Sci. Soc. Am. J.*, 70, 57-63.

[3] Rosa, C. M. *Matéria orgânica em Planossolo Háplico sob sistemas de manejo no cultivo do arroz irrigado no Sul do Brasil*. Tese (Doutorado em Solos). Programa de Pós-Graduação em Agronomia. UFPEL. Pelotas-RS, 2010.

[4] Favoretto, C.M.; Gonçalves, D.; Milori, D.M.B.P.; Rosa, J.A; Leite, W.C.; Brinatti, A.M.; Saab, S.C. 2008. *Química Nova*, 31,1994-1996.

[5] Pulronik, K; Barros, N. F; Silva, I. R; Novais, R. F; Brandani, C. B. 2009. *R. Bras. Ci. Solo*, 33, 1125-1136.

[6] Milori, D. M. B. P; et al. 2004. *Índice de Humificação Obtido Através da Fluorescência Induzida por Laser*. Boletim de Pesquisa e Desenvolvimento. Embrapa. São Carlos/SP.

[7] Zsolnay, A.; Baigar, E.; Jimenez, M.; Steinweg, B.; Saccomandi, F. 1999. *Chemosphere*, v. 38, p. 45-50.

[8] Kalbitz, K.; Geyer, W.; Geyer, S. 1999. *Biogeochemistry*, v. 47, p. 219-238.

[9] Milori, D. M. B. P.; Bayer, C.; Bagnato, V. S.; Mielniczuk, J.; Martinneto,.L. 2002. *Soil Sci.*, 167, p. 739-749.

Variability of biochar properties - implication for usage and sourcing of materials

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Key words: *feedstock, pyrolysis conditions*

Introduction

The term 'biochar' is used as a general term to describe the charred product resulting from pyrolysis. However, the physico-chemical characteristics of biochar vary widely depending on feedstock and pyrolysis conditions.

As part of two national biochar projects in Australia (GRDC, DAFF funded), our work has created an inventory of biophysical and chemical characteristics of more than 70 different biochars derived from a wide range of feedstocks and produced under various pyrolysis conditions.

Results and Discussions

Using multivariate analysis, we explored the impact of feedstock and pyrolysis conditions on the over-all characteristics of biochar.

Analysis demonstrated considerable variability in the physico-chemical characteristics of biochar products, and indicated that feedstock (e.g. manure, wood, food-waste) was the primary determinant, with pyrolysis conditions (HTT, heating rate) having a more subtle impact.

With regard to nutrient content (N, P, K) associated parameters (cation exchange capacity, pH, water-holding capacity) wood-derived biochars demonstrated surprising variability, while manure-derived biochars were relatively similar to one another. It might be expected that wood-waste derived from oil mallee, or from oak, in a similar form (e.g. sawdust vs. cuttings) would be relatively homogenous, yet variability in nutrient composition was evident.

Manures are inherently heterogeneous materials depend on animal production and the type of bedding material used. Although nutrient content was rich and relatively consistent, the heavy metal content of the manure-based biochars proved highly variable. Further work is required to assess the bioavailability of the heavy metals.

Conclusions

Our work demonstrates that the physiochemical properties of biochar varied primarily as a result of feedstock, with pyrolysis conditions having a smaller secondary influence.

The biochar inventory demonstrates wide variability in the physico-chemical properties of biochars, and provides a unique resource to address how biochars of contrasting properties interact with the soil environment.

Characterizing the physico-chemical nature of biochar is fundamental to interpreting research results and in working towards developing guidelines for biochar application to benefit agricultural production.

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Selective extraction of the characteristic humic fraction from *Terras Pretas de Índios*

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Key words: *Pyrolysis, Biochar, ^{13}C Solid state NMR*

Introduction

The *Terra Preta de Índios* soils, found in the Amazon basin differ markedly from adjacent soils, because of their higher fertility and greater carbon content. This high fertility and the great capacity of these soils to maintain it, despite their intensive and degradative use (resilience), can be explained by its high levels of organic matter with a strong pyrogenic character.

In this way, these soils provide us an excellent model that helps pursue the goal of improving soil fertility and promoting soil carbon sequestration. In spite of the big efforts to reproduce these soils, there are no analytical methods to check the success of these attempts.

Studies employing Nuclear Magnetic Resonance (NMR) and Multivariate Curve Resolution (MCR) showed that humic acids from *Terra Preta de Índios* can be satisfactorily modelled as a binary mixture [1].

One of the components of this mixture is similar to regular humic acids from tropical soils. It presents signals of the following chemical groups: alky, N-alkyl, methoxyl, carbohydrates, aryl, O-aryl, aliphatic carboxyl and amide. These chemical groups indicate the presence of plant material (fat acids, proteinaceous material, lignin and cellulose) in different humification stages.

The second component is characterised by condensed aromatic structures with high charge density due to carboxylic groups linked directly to the aromatic core, i.e., pyrogenic carbon (biochar) partially oxidised. This structure, recalcitrant and reactive, is what explains the high fertility and resilience of these special soils.

Taking this in account, it is proposed a modification of the classical extraction method of the International Humic Substances Society seeking to extract selectively the recalcitrant and reactive fraction of the soil organic matter that differentiates *Terras Pretas de Índios* from regular soils. This modification consists in extracting exhaustively the humic fractions in a sequence of base (0.1 M NaOH) adjusted to pH 7, to pH 10.6, and at pH 12.6. The afterwards obtained samples is analysed by solid state ^{13}C Nuclear Magnetic Resonance.

Variable-amplitude cross-polarization (VACP) Solid-state ^{13}C NMR experiments were carried out using a 500 MHz Varian spectrometer at ^{13}C and ^{1}H frequencies of 125 and 500 MHz, respectively. Magic-angle spinning (MAS) at 15 kHz was employed. Typical cross-polarisation times of 1 ms, acquisition times of 13 ms, and recycle delays of 500 ms were used. High-power Two-Pulse Phase-Modulation (TPPM) proton decoupling of 70 kHz was applied in all experiments.

Results and Discussions

The experimental NMR spectra of humic acids, extracted by aqueous NaOH solutions at pH 7 and 10.6, were very similar to the second component spectra, estimated by mathematical method (MCR). These spectra are characterised by a featureless aryl peak centred at 129 ppm, typical of a polycondensed aromatic structure and by a carboxyl peak with a clear up field shift (168 ppm), attributable to carboxyl groups that are attached directly to the aromatic backbone.

The fact that the simulated spectrum from MCR method represents a real component of the soil organic matter from *Terra Preta de Índios,* corroborates the results, obtained by the MCR analysis, in the characterisation and quantification of the distinctive humic fraction from *Terras Pretas de Índios* [1].

These results confirm the precision and accuracy of the MCR, as well as the suitability of the proposed extraction method.

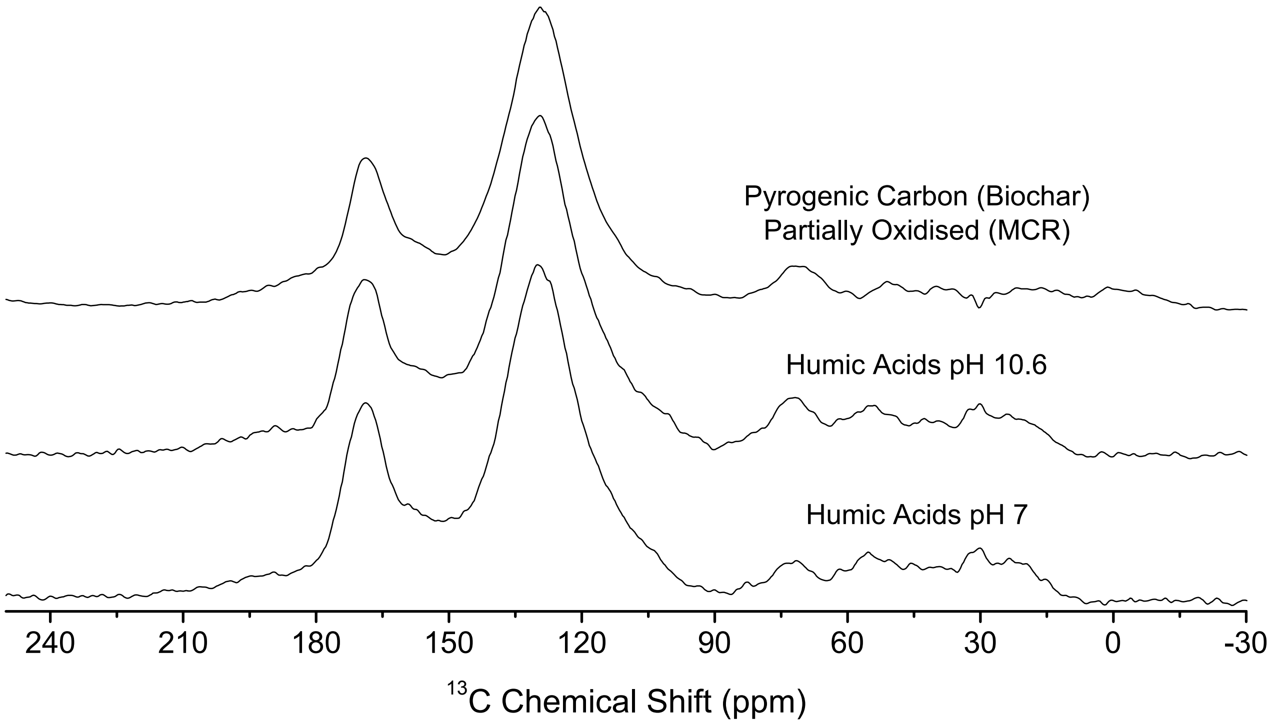

Figure 1. Solid State ^{13}C NMR of the characteristic humic fraction from *Terra Preta de Índios* and the simulated spectra obtained by MCR.

Conclusions

The aqueous NaOH solutions, adjusted at pH 7 and at pH 10.6, selectively extracted the distinctive humic fraction of *Terra Preta de Índios* soils, *i.e.*, polycondensed and functionalised aromatic structures. In this way, this approach can be used as a rapid and simple method to evaluate the proposals to reproduce the *Terra Preta de Índios* soils.

Acknowledgements

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[1] Novotny, E.H.; Hayes, M.H.B.; Madari, B.E.; Bonagamba, T.J.; Deazevedo, E.R.; Desouza, A.A.; Song, G..; Nogueira, C.M; Mangrich, A.S. 2009. Lessons from the Terra Preta de Índios of the Amazon Region for the Utilisation of Charcoal for Soil Amendment. *J. Braz. Chem. Soc.*, 20, 1003-1010.

DRUV-VIS analyses in the biochar preparation process

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Key words: *Biochar, DRUV-VIS, Kubelka-Munk remission function*

Introduction

Diffuse reflectance is an excellent analytical tool for condensed materials in the mid-IR, NIR and UV-VIS spectral ranges. It can be used for analysis of intractable (not soluble) solid samples. The reflectance spectra can be converted to the Kubelka–Munk remission function defined by, $f(KM) = (1-R)^2/2R = k/s$, where R is the reflectance, k is the absorption coefficient, and s is the scattering coefficient. Assuming that the scattering coefficient varies only slightly as a function of wavelength over the range of interest, the shapes of the Kubelka-Munk remission function and the actual absorption spectrum in that wavelength range should be identical. In order to increase the resolution of the spectral curves, we applied the second derivative mode of the Kubelka-Munk function using the OriginPro, version 7.5, software. Towards the development of cheap and more at hand analytical alternatives in the production of "biochar", this work has been carried out to characterize the synthesized biochars by DRUV-VIS. Through the pyrolysis at low temperatures, 300 °C, velocity of heating of 10 °C min^{-1} and period of heating of 60 min, biochar was prepared from the raw products, castor oil cake, *Eucalyptus* saw dust and *Pinus* saw dust. The DRUV-VIS spectra were obtained at room temperature in the region of 190-900 nm, at intervals of 0.5 nm, with a Shimadzu UV-2401PC spectrophotometer equipped with a Model 240-52454-01 integration sphere. The reflectance spectra were converted to the Kubelka–Munk remission function, and to the second derivative mode [1, 2]. For validation of the method the sample were analyzed also by NMR spectroscopy. Solid-state ^{13}C NMR experiments were carried out using a Varian VNMRS 500 MHz spectrometer at ^{13}C and ^{1}H frequencies of 125.7 and 500.0 Hz, respectively. The technique used was variable amplitude cross-polarization (VACP).

Results and Discussions

The ^{13}C NMR spectra of the raw material samples are shown in the top of figure 1, and only the castor oil cake sample presents typical absorption of aliphatic (0 – 48 ppm), aromatic (110 – 150 ppm) and carboxylic structures (160 – 180 ppm).

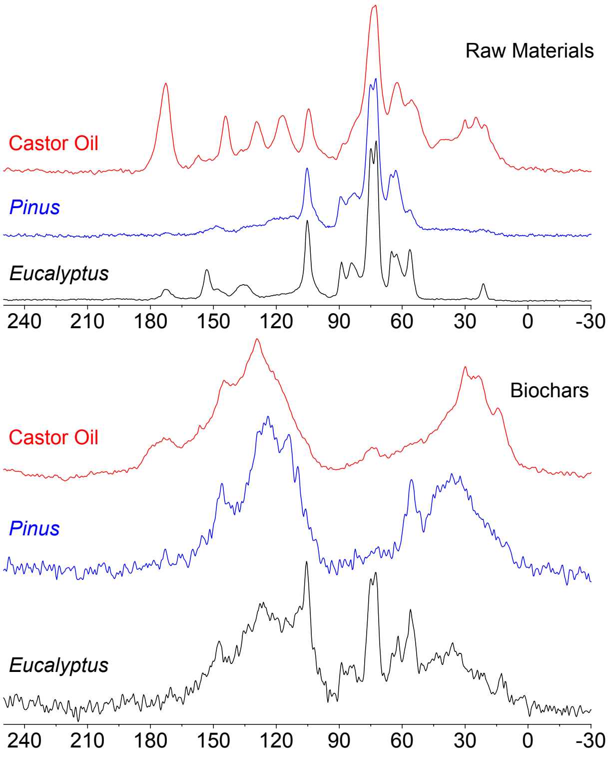

Figure 1. ^{13}C NMR spectra of the raw materials, castor oil cake, *Pinus* and *Eucalyptus* saw dust (top), and of the samples in the same order submitted to treatment of pyrolysis as described in the text (bottom).

The three raw materials present intense absorption between 50 and 100 ppm typical of carbohydrates, methoxyl and N-alkyl structures. When submitted to the pyrolysis treatment the biomass samples develop aromatic and aliphatic structures but only the castor oil cake maintains some carboxylic groups. The saw dusts preserve some of the metoxyl groups (~50 ppm) after the pyrolysis experiments.

Figure 2 shows the reflectance, the absorbance after the K-M treatment and the second derivative K-M mode spectra of the three studied samples after the pyrolysis treatment.

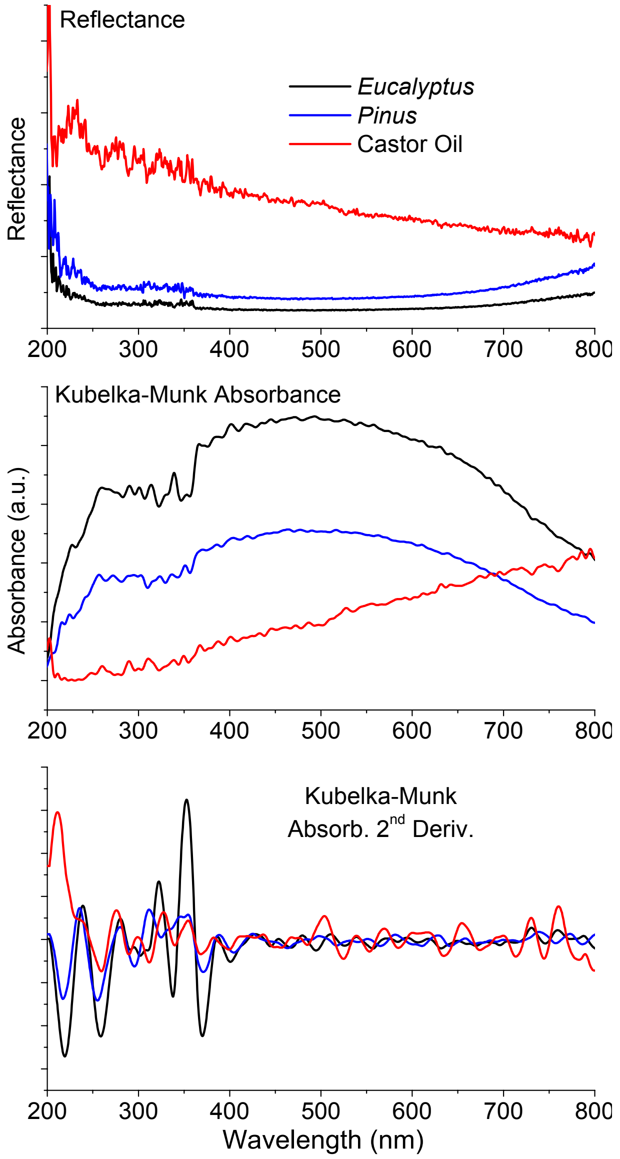

Figure 2. Reflectance spectra of the *Pinus* saw dust, PN4, *Eucalyptus* saw dust, E4, and castor oil cake, P4, after the pyrolysis treatment (top), Kubelka-Munk absorbance (center), and K-M second derivative mode (boton).

Like for the ^{13}C NMR analysis results the two materials coming from *Pinus* and *Eucalyptus* saw dust present similar results that are different from the castor oil cake material. Although one can note the difference among the three samples by reflectance or K-M absorbance, only through the K-M second derivative mode spectra it is possible to see more clear differences among the three samples. The maximum in the absorption spectra corresponds to the minimum in the second-derivative mode spectra. The biochars from the *Eucalyptus* saw dust shows four major peaks at 215, 260, 340, and 370 nm while the *Pinus* biochar shows similar spectrum. The biochar obtained from the castor oil cake presents a very different spectrum with the band at 260 and 370 nm well specific. Like saw by NMR analysis the two biochar from tree biomass are similar and well different from the castor oil cake biochar.

Conclusions

By DRUV-VIS spectroscopy and working with the Kubelka-Munk remission function we characterize the similarities of the biochar obtained by the pyrolysis of *Pinus* and *Eucalyptus* saw dust, and differences from the biochar obtained from castor oil cake.

Acknowledgements

The authors are grateful to CNPq and CAPES for research fellowship, FINEP for the financial support and to the UFPR/CD for the infrastructural work conditions.

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[1] Sherman, D. M.; Waite, D. 1985. *Am. Mineral.*, 70, 1262-1269.

[2] Nicolini, K. P.; Fukamachi, C.R.B.; Wypych, F.;Mangrich, A. S. 2009. *J. Coll . Int. Sc.*, 338, 474–479.

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Effect of land use on organic matter's quality evaluated by ^{13}C NMR

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Key words: *density fractionation, agrosilvopastoral system, eucalyptus*

Introduction

On the western border of Rio Grande do Sul, there are extensive areas on sandy desertification process. One of the strategies for sustainable use of sandy soils of this region, the Pampa Biome, is the implementation of agrosilvopastoral systems and/or the afforestation with eucalyptus.

In this context, it was aimed to evaluate the effect of these systems on the quality's changes of the organic matter's (OM) physical fractions of an Ultisol, in the city of Alegrete-RS. The installation of the experiment occurred in 2002. From the installation time until now, there has not been any type of fire event. However, prior the installation there is no knowledge about fires occurring in these areas. The soil sampling, in the layer of 0.000 to 0.025 m, was performed in 2007 in: an area under homogenous eucalyptus forest (FH); an agrosilvopastoral system (AS); and in a native grassland (NG), that was used as a reference area. The soil of the area is a Typic Eutrophic Ultisol. The particle size distribution, in the layer from 0.00 to 0.26 m, was 900 g kg^{-1} sand, 30 g kg^{-1} silt and 70 g kg^{-1} clay.

It was performed density physical fractionation of OM [1], using a solution of sodium polytungstate of 2.0 Mg m^{-3}. The energy dispersion by ultrasound was 250 J mL^{-1}.

The samples of free light fraction (FLF) and occluded light fraction (OLF) were treated with an aqueous solution of 10% of HF, to perform the ^{13}C nuclear magnetic resonance (NMR) analysis.

Results and Discussions

The ^{13}C NMR spectra of the FLF's and OLF's samples showed themselves similar on the different systems evaluated (Figure 1). In the region between 25-35 ppm, the signal of C alkyl is a methylene, derived from long chain aliphatics. In the region of C O-alkyl (60-110 ppm), one can observe two distinct peaks. The peak at 72-75 ppm is assigned to cellulose and at 105 ppm is derived from hemicellulose and other carbohydrates. The signal's strength between 160-230 ppm corresponds, in part, to the carboxyl groups of organic acids [2].

The different soil's treatment showed a predominance of substituted C alkyl groups (C O-alkyl/C di-O-alkyl + C N-alkyl/C methoxyl), whose proportion varied from 41% to 50%; followed by C alkyl group (27% to 34%). The aromatic structures (C aryl + C-phenyl) contributed approximately with 11% of the composition of the samples, the carboxyl groups with 8% and carbonyl with 6%.

The high percentages of substituted C alkyl groups in the examined systems indicated the abundance of proteins and polysaccharides-like structures present in OM. Considering that these components are easily decomposed, because they are preferentially attacked by microorganisms, the OM can be considered of low decomposition degree [3].

Analyzing the chemical composition of the OM on the FLF, the proportions of C O-alkyl/C di-O-alkyl + C N-alkyl/C-methoxyl ranged from 42% to 50% for the AS and FH. For C alkyl, these ratios ranged 27-34% for the FH and the AS respectively. Possibly the greatest abundance of substituted C alkyl in the FLF of FH could be explained by the differences in chemical composition (recalcitrance) of crop residue and through its relationship with the environment, where the decomposition occurs. With respect to aromatic structures (C-aryl + C-phenyl), the chemical composition of the two systems were similar, approximately 10%.

These higher proportions observed in C O-alkyl/C di-O-alkyl + C N-alkyl/C methoxyl in comparison to the aromatic structures, demonstrate that carbohydrates are the soil main organic constituents, even thought they have low molecular recalcitrance. This fact associated with the aromatic compounds, that corresponds to a smaller proportions, is an indication that the colloidal and the physical protection of the OM, are overlapping the magnitude of recalcitrance's protection [4].

In the OLF, there was a similar proportion of C's functional groups found in comparison to those found in FLF. However, on average the systems presented a decrease of 4% in FLF in relation to the one in OLF, for the grouping of substituted C alkyl, showing decreases of aliphatic structures, such as polysaccharides and carbohydrates, from FLF to the OLF, agreeing with [5].

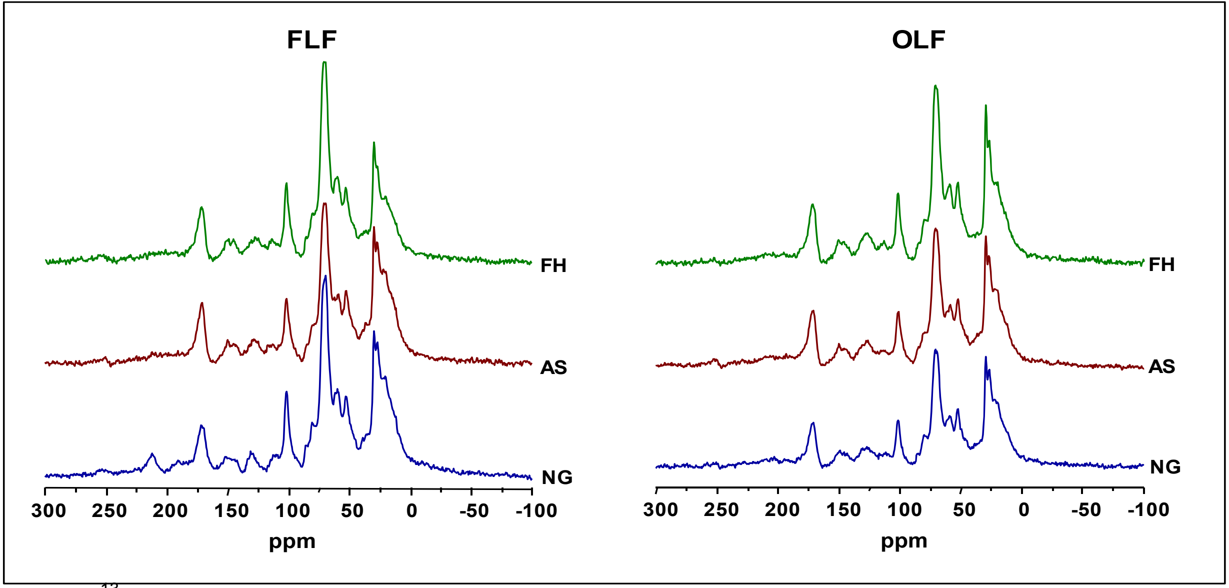

Figure 1. ^{13}C NMR spectroscopy of the free light fraction (FLF) and the occluded light fraction (OLF) of organic matter of an Ultisol under different use systems in the layer of 0.000 to 0.025 m. FH = Forest homogeneous eucalyptus; AS = Agrosilvopastoral System between rows and NG = native grassland.

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Table 1. Percentage distribution of functional groups of C determined through ^{13}C NMR spectroscopy in the free light fraction (FLF) and occluded light fraction (OLF) of the organic matter of an Ultisol under different use systems, in the layer of 0.000 to 0.025 m.

	Distribution of C types / chemical shifts (ppm)						
	C-alkyl	C N-alkyl C-Methoxyl	C-O-alkyl C-di-O-alkyl	C-aromatic	C-phenolic	C-carboxyl	C-carbonyl
Systems*	0 - 45	45 - 60	60 - 110	110 - 140	140 - 160	160 - 185	185 - 230
				FLF			
FH	27	13	37	7	4	7	5
AS	34	11	31	7	4	8	5
NG	32	12	34	5	4	7	6
				OLF			
FH	31	12	32	8	4	8	5
AS	32	11	30	8	5	8	6
NG	33	9	32	8	4	8	6

*FH - Forest homogeneous eucalyptus; AS – System agrosilvopastoral between rows e NG - native grassland.

Conclusion

This work allows us to infer that: i) there is a tendency of increasing proportion of C O-alkyl like structures in homogeneous eucalyptus forest, compared to the agrosilvopastoral system and the native grassland and ii) the absence of significant differences in the C types distribution in the free light fraction and occluded light fraction, for all systems, suggests relatively low capacity for physical protection of the organic matter in this soil.

The analyzed fractions do not show evidence of charred material.

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[1] Conceição, P.C. et al. 2008. *Rev. Bras. Ci. Solo*, 32, 541.

[2] Kögel-Knabner, I. 2002. *Soil Biol. Bioch.*, 34,139.

[3] Dick, D.P. et al. 2008. *Rev. Bras. Ci. Solo*, 32,2289.

[4] Diekow, J. *Estoque e qualidade da matéria orgânica do solo em função de sistemas de culturas e adubação nitrogenada no sistema plantio direto.* 2003. 164f. Tese – UFRGS, Porto Alegre.

[5] Kölbl, A.; Kögel-Knabner, I. 2004. *J. Plant Nutr. Soil Sci.*, 167, 45.

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Analyzing a Simple Biochar Production Process and the Cultivation and Assessment of "Cool" Cabbages in Kameoka City, Japan

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Key words: *Simple biochar production process, biochar cultivated vegetables, Cool Vegetables*

Introduction

Reducing GHG on a global scale is needed and carbon sequestration with biochar has the potential to continuously sequester carbon if it is part of a sustainable, regional socio-economic system. Of particular importance is the redevelopment of agriculture to incorporate biochar, especially in marginalized rural areas. Our project focuses on applying biochar to agricultural land and proposes a social scheme based on an eco-branding strategy with biochar-cultivated vegetables named "Cool Vegetables" in a rural area of Japan (Kameoka City, Kyoto Prefecture).

The "Carbon Minus Project" (Figure 1) was launched by a partnership between the Kameoka City Government, Ritsumeikan University, and a local farming cooperative in 2008.

The socio-economic system proposed in this social scheme can function best when biochar is produced efficiently and cheaply. Adopting a modified-pit process enables the producer to convey equipment easily to the biomass site, helping reduce carbon emissions and supporting carbon minus LCA. We utilized bamboo from overgrown stands, which are abundant in Japan, as feedstock.

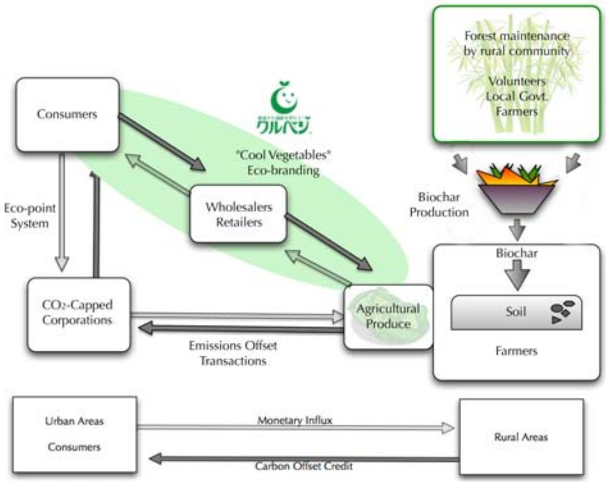

Figure 1. "Carbon Minus Project" Scheme

Biochar produced from this process was then used in a series of experiments to investigate the growth effects of biochar on agricultural products (cabbages).

This paper presents data from these two processes.

Results and Discussion

(1) Examining charring and economic efficiency in the simple carbonization process

Bamboo was carbonized in round, steel, open kilns by MOKI Manufacturing Co. Ltd. as shown in Photos 1 and 2. We are calling this process a "modified pit method."

Table 1 shows the capacity of carbonization. Over the course of a five day period, 3391kg of bamboo (1798kg of dry weight) was charred and doused with water to produce 1318kg of biochar (423.7kg dry weight). Moisture content was measured twice and averaged 67.84% due to dousing. Carbonized ratio (wet/wet) was 38.86% and (dry/dry) was 23.53%.

Photo 1. Carbonization of bamboo

Photo 2. Biochar produced

Table 1. Capacity of carbonization

Date of experiment (2009)	Jul.9	Jul.16		Aug.17		Jan.31		May.11		Total	Ave
Number of batchs	1st-2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd		
Input of biomass (kg)[A]	818.0	291.7	447.5	140.0	334.1	206.8	334.2	395.2	423.3	3391	
Biochar yield (kg) [B]	410.2	113.5	141.6	88.1	118.5	74.9	65.8	140.5	164.4	1318	
Non-carbonized matter	exist	exist	exist	exist	exist	exist	exist	exist	exist		
Moisture content of biomass(%)											46.98
Moisture content of biochar (%)											67.84
Dried biochar yield (kg)[C]	131.9	36.5	45.5	28.3	38.1	24.1	21.2	45.2	52.9	424	
Charring ratio (including moisture) (%) [B/A]	50.15	38.91	31.64	62.93	35.47	36.22	19.69	35.55	38.84		43.82
Dried biochar yield/Input of biomass (%) [C/A]	16.13	12.51	10.18	20.24	11.41	11.65	6.33	11.43	12.49		14.00
Ratio of carbon(%)	81.53	86.87									
Carbonizing time (minute)	398	108	167	58	115	85	325	258	193	1707	

Table 2. Costs for producing the biochar

Item	Unit price (JPN)	Unit	Quantity					Total	Total cost
			Jul.9	Jul.16	Aug.17	Jan.31	May.11		
Material for biochar	0	kg	818	739	474	541	819	3391	¥0
Carbonization instrument	¥1,627	piece/day	1	1	1	1	1	5	¥8,133
Labor cost 1	¥1,000	hour	8.1	6.1	4.4	8.3	9.0	36	¥36,000
Labor cost 2	¥1,000	hour	8.1	6.1	4.4	8.3	9.0	36	¥36,000
Chain saw	¥700	piece/day	1	1	1	1	1	5	¥3,500
Fuels, gloves and tools etc.	¥4,000	day	1	1	1	1	1	5	¥20,000
								Total	¥103,633

The ratio of carbon was measured from three biochar samples each of July 9th and July 18th and averaged 84%. These results indicate highly efficient charring because normal carbon ratios for bamboo charcoal range from 79% to 82% [1].

From an economic standpoint, the initial cost for producing biochar doused with water was 79 yen ($0.91US) per kg and 245 yen ($2.83US) per kg as a dry product (see Table 2 for breakdown of costs). Comparatively, inquiry into the cost of producing commercially available bamboo charcoal for gardening found an average price of 443 yen ($5.12US) per kg. Our biochar costs were equivalent or less than commercially available sources, but feedstock conveyance costs were not considered in these calculations.

(2) Examining the growth effects of biochar with varying treatments on cabbage

“Cool” cabbages were cultivated under three variables--- biochar application rate, presence of compost, and presence of chemical fertilizer-- over a range of treatments. The experimental treatments are shown in Table 3. Photo 3 gives a visual of the cabbages measured.

From these experiments, statistical analysis was performed on: (1) The difference between T-1:CM-4,-5,-6 (no biochar vs. biochar and chemical fertilizer). No significant difference was found between T-1 and CM-4,-5,-6 (P(0.05); (2) The difference between CM-1:CM-2,3 (no biochar vs biochar with no chemical fertilizer).

Table 3. Experimental treatments

Plot	CM−6	CM−5	CM−4	CM−3	CM−2	CM−1	T−1
Biochar	○	○	○	○	○	×	×
volume/0.1ha	4.3M3	2.1M3	1.0M3	4.3M3	2.1M3	0.0M3	0.0M3
carbon weight (ton−C/0.1ha)	3.0t	1.5t	0.8t	3.0t	1.5t	0.0t	0.0t
Compost 5 M^3/0.1ha	○	○	○	○	○	○	○
Chemical Fertilizer 120kg/0.1ha	○	○	○	×	×	×	○

Photo 3. Measured cabbages (L to R: CM=6 to T=1)

Table 4. Measured result

Section number	Above-ground part (kg)		height(cm)	diameter(cm)	circumference (cm)
	Total weight	Edible part			
CM=1	1.75±0.07	0.79±0.05	12.5±0.41	15.8±0.40	50.6±1.12
CM=3	2.29±0.10	1.21±0.07	14.6±0.37	18.0±0.35	57.9±1.07
P-number	0.11	0.04＊	0.25	0.28	0.27

There was significant difference between CM-1 and CM-3 ($P \leq 0.05$) in the edible portion (Table 4); (3) No significant difference was found between CM-2:CM-5 and CM-3:CM-6 (biochar without chemical fertilizer vs. biochar with chemical fertilizer) ($P \leq 0.05$).

In addition, empirical analysis showed that the amount of lateral root and root hair growth was greater for biochar-cultivated cabbages.

Further experimentation taking into account more technical (feedstock and biochar production characteristics) and environmental factors (regional characteristics in climate and soil) is recommended.

Conclusions

The results of these experiments suggest that biochar production from a simple method is economically viable and among the cases of cabbages with varying treatments, no highly significant differences were found.

Acknowledgements

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[1] Ikejima, Y. 1999. *Takezumi & Tikusakueki no Tsukurikata to Tsukaikata. (Production Methods and Use of Bamboo Charcoal and Bamboo Wood Vinegar)* Tokyo: Nobunkyou, p.141.

Production and characterization of different feedstocks

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Key words: *pyrolysis, biomass, heating value*

Introduction

The diminishing stockpile of fossil fuels and the accompanying negative effects of their usage in terms of producing green house gases and shift in climate has also regenerate the interest in renewable energy sources [1, 2]. Biochar is a product of pyrolysis, which is carbon rich, with high heating value and relatively pollution free solid biofuel. The aim of this work is to produce and characterize biochar from different feed stocks (corn stover, switchgrass, miscanthus, big bluestem, and prairie cord grass) by conventional pyrolysis. The pyrolysis was carried out in a reactor (mild steel 20 cm long, diameter of 10 cm) placed in an Isotemp programmable muffle furnace. Before heating, nitrogen was flushed in to the reactor for 10 min to remove air from the system. The heating rate was varied from 20-40°C/min. The temperature was maintained from 300 to 600˚C. Corn stover was taken to evaluate the operating conditions, as consequence 4 mm particle size and 40°C/min has given the highest yield of biooil. The calorific value of the samples was measured by 1341 Plain Jacket Bomb Calorimeter. The elemental analysis of biomass and biochar was done according to ASTM D 1762-84 (2007). The physical characteristics such as particle density and porosity were measured according to ASTM D6683 (2001), geometrical mean diameter was determined according to ASAE S319.3 (2003). Fourier Transform Infrared Spectroscopic analysis of all the samples was obtained using ATR –FTIR Nicolet 380. The spectrum was obtained by using 64 scans with a resolution of 4 cm^{-1}. The FTIR spectra were recorded in the transmission mode between 4000 and 500 cm^{-1} for all the samples. All the experiments were carried out in triplicates and the data collected was analyzed using SAS 9.2.

Results and Discussion

Figure 1 shows that the yield of biochar was maximum at a heating rate of 20°C /min and 300 °C with a particle size of 6 mm. Table1 shows the physical and chemical characteristics of different biomass and their carbonized residues (char). Geometrical mean diameter of the biomass has decreased significantly when converted into char irrespective of the feedstocks. As a result of the pyrolysis process, the carbon content of char increased when compared to the original biomass. The highest percent increase of 49.7% was observed for prairie cord grass. The heating value of the char was higher than that of the raw biomass especially for prairie cord grass (36.6 %). The porosity of biochars was higher than that of respective biomass samples, with an obvious notice of 6% increase for prairie cord grass and a possible reason might be needle shape biomass and biochar.

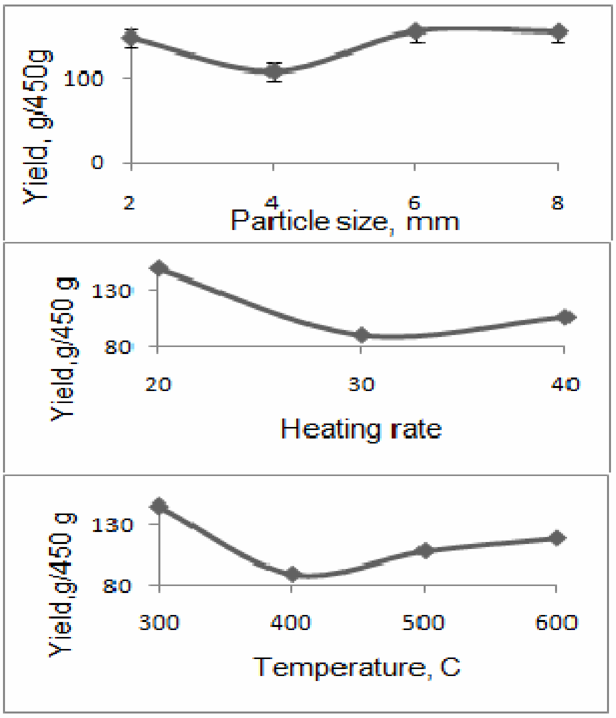

Figure1: Biochar (corn stover) yield as a function of particle size, heating rate, and temperature.

Table 1. Physical and chemical properties of biomass and biochar

	True density (kg/m^3)	Porosity (%)	GMD (mm)	C (%)	N (%)	LHV (MJ/kg)	Moisture (%)	Ash-total (%)
Cornstover	108.9	0.090	0.69^{a}	43.7	0.62	10.2	5.35	5.6
Char$_{CS(300C)}$	101.1	0.092	0.35^{ef}	35.5	1.67	11.4	TBR	TBR
Char$_{CS(500C)}$	100.6	0.092	0.32^{gf}	41.2	1.43	11.9	5.38	36.6
Switchgrass	109.9	0.092	0.64^{b}	46.8	0.60	15.6	7.40	5.3
Char$_{SG(300C)}$	80.6	0.089	0.44^{c}	50.3	1.72	16.5	TBR	TBR
Char$_{SG(500C)}$	97.1	0.093	0.36^{ef}	61.1	1.74	18.3	8.03	10.4
PrairieCGrass	139.1	0.089	0.35^{ef}	47.6	0.35	15.1	6.85	5.0
Char$_{PCG(300C)}$	75.2	0.091	0.36^{ef}	59.4	1.40	19.7	TBR	TBR
Char$_{PCG(500C)}$	104.0	0.095	0.30^{g}	71.3	1.66	20.7	1.64	11.4
Big Bluestem	130.3	0.089	0.40^{d}	47.0	0.70	13.9	6.51	10.4
Char$_{BB(300C)}$	79.9	0.089	0.39^{de}	45.9	1.73	11.0	TBR	TBR
Char$_{BB(500C)}$	100.6	0.092	0.35^{f}	59.0	1.39	14.4	1.88	21.0
Miscanthus	101.2	0.092	0.61^{b}	45.7	0.46	13.9	6.50	6.9
Char$_{miscan(300C)}$	80.2	0.089	0.39^{de}	45.6	1.02	14.9	TBR	TBR
Char$_{miscan(500C)}$	96.3	0.093	0.35^{ef}	56.0	1.03	14.7	4.91	24.6

GMD indicates Geometrical Mean Diameter TBR-To Be Reported

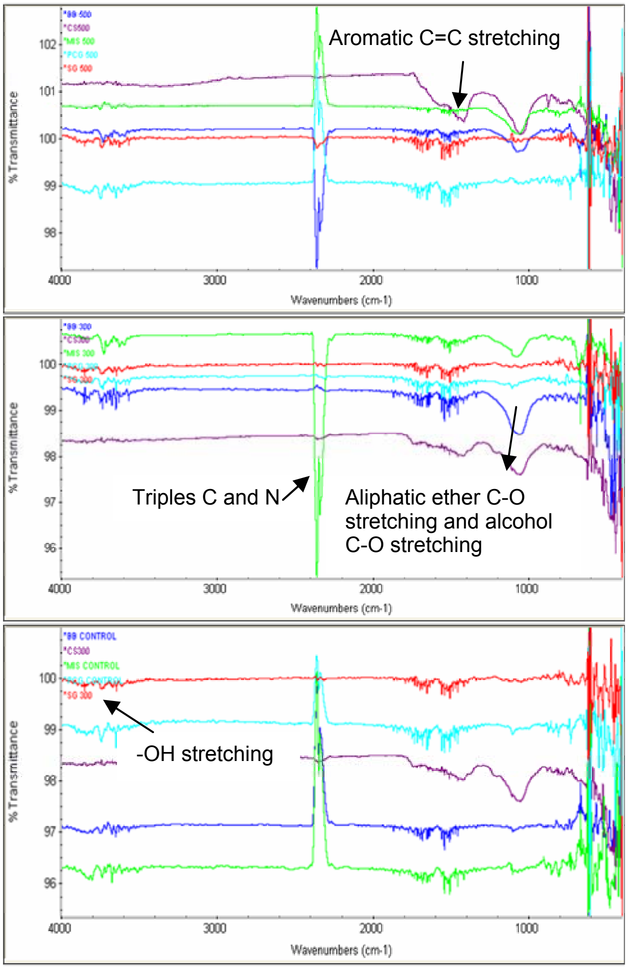

Figure 2. ATR-FTIR images of biomass and biochar.

The peaks were observed between 3600 and 4000 (-OH stretching), 2000 to 2400 (triple C and N), 900 to 1100 (aliphatic ether C-O and alcohol C-O stretching) and 1100 to 1600 cm^{-1} (aromatic C=C stretching).

Conclusions

The results have shown that the physical and chemical characteristics of biochar significantly differed with varying feedstocks and pyrolysis conditions such as heating rate and temperatures.

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[1] Bridgwater, A. V. 1995. The technical and economic feasibility of biomass gasification for power generation. Fuel 74(5), 31.

[2] Lehmann, J.; Gaunt, J.; Rondon, M. 2006. Biochar sequestration in terrestrial Ecosystems-A Review. Mitig. Adapt.Strat. Global Change 11(2), 40.

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Py-GC-MS characterisation of fresh and aged biochars produced from green waste, paper mill sludge and chicken manure

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Key words: *Biochar, pyrolysis-GC MS*

Introduction

A biochar's interaction with a soil is known to be complex as the biochar reacts with organic matter, microbes and minerals within a short period of time after being applied to soil to form an outer organomineral layer [1]. This aging process aids development of the soil structure and increases the capacity of the soil to retain nutrients and recent research has indicated that aged biochars are much more effective in increasing nutrient uptake [2]. The initial composition of the biochar is also important as different biochars placed in the same soil at the same time appear to react at different rates and form different structures. Previous work has been carried out to characterise these structures using a range of techniques [2]. This paper reports the Py-GC-MS results of biochars, prepared by slow pyrolysis of green waste (GW), chicken manure (CM) and paper mill sludge (PMS), in the fresh and aged (applied at a rate of 10 t/ha to a ferrosol soil in NE NSW where sweet corn was grown for 9 months) states at two pyrolysis analysis temperatures; 340°C and 520°C.

Results and Discussions

The data for the pyrolysis of fresh and aged chars at the two pyrolysis analysis temperatures are shown in Figures 1 and 2. The chromatograms are of varying complexity and the products of pyrolysis are difficult to identify, but can be classed, generally, as aliphatic or aromatic. Of the fresh chars, the Py-GC-MS chromatograms of the GW char were found to be the least complex containing mostly aliphatic long chain hydrocarbons as the pyrolysis products. The CM char behaved similarly, but contained more nitrogen containing pyrolysis products indicating a greater nitrogen content of the original char. The PMS char produced the most complex chromatogram containing aromatic pyrolysis products, in addition to the nitrogen containing and aliphatic hydrocarbons. The Py-GC-MS chromatograms of the aged biochars were all found to be more chemically complex than their fresh counterparts. The order of complexity, however, remained the same with the PMS char containing the greatest variety of hydrocarbons from aliphatic to aromatic. The CM char contained significant proportions of the initially observed aliphatic and nitrogen containing long chain hydrocarbons, but also contained aromatic material. The GW char was the most similar to its fresh counterpart, but had also evolved in the soil to produce some aromatic content. A noticeable feature of all the aged biochars was the increase in the proportion of more volatile hydrocarbons observed at the 340°C analysis temperature.

Previous investigations of these biochars have found that the greatest increase in dry biomass yield was achieved by the PMS and least by the GW char. This trend correlates with the increasing chemical complexity.

Conclusions

A correlation between the effectiveness of the biochar and the complexity of the Py-GC-MS chromatogram was observed. The increased complexity in the chromatogram was accompanied by an increase in the aromatic content suggesting that aromaticity is also an important factor in biochar activity.

Acknowledgements

VenEarth LLC for funding the research.

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[1] Joseph S., Camps-Arbestain M, Lin Y, Munroe P, Chia CH, Hook J, Van Zwieten L, Kimber S, Cowie A, Singh BP, Lehmann J, Foidl N, Smernik RJ, Amonette JE (2010) An investigation into the reactions of biochar in soil, *Australian Journal of Soil Research* (in press).

[2] Amonette JE, Joseph S (2009) Physical properties of biochar. In 'Biochar for environmental management. Science and technology.' (Eds J Lehmann and S Joseph) pp. 13-323. (Earthscan: London).

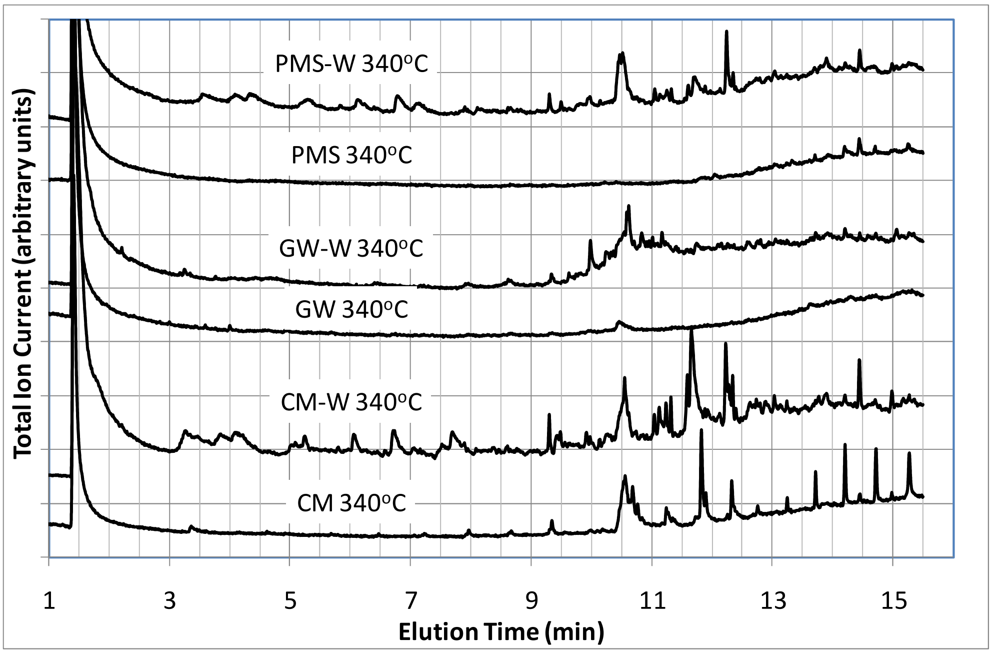

Figure 1. Py-GC-MS data collected for the pyrolysis of biochars at a pyrolysis analysis temperature of 340°C.

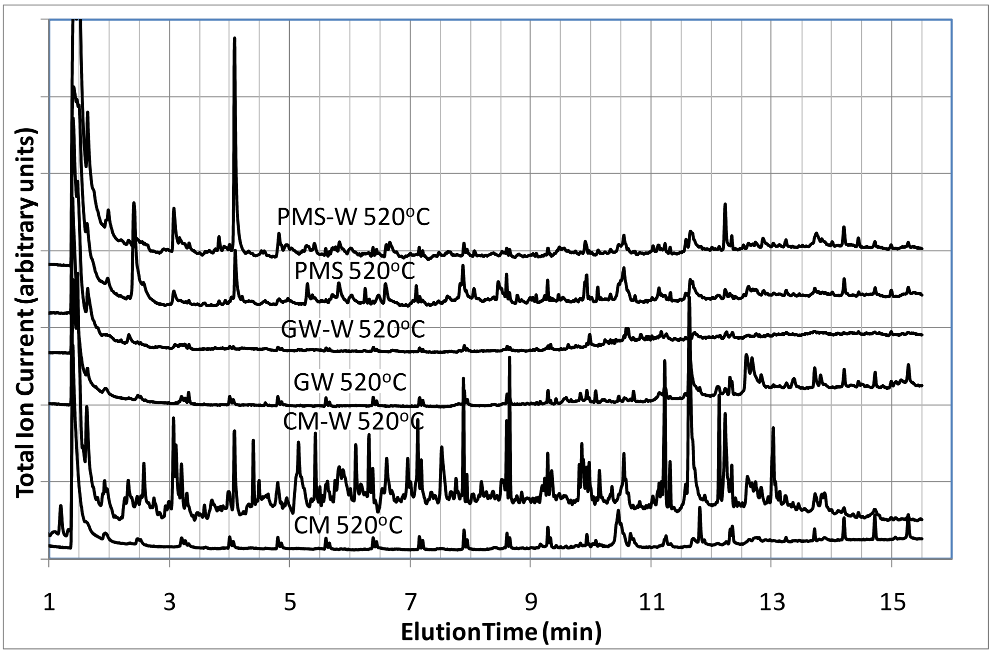

Figure 2. Py-GC-MS data collected for the pyrolysis of biochars at a pyrolysis analysis temperature of 520°C.

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Chemical-physical characterization and bioassay on poplar and conifer biochar

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Key words: *Biochar, Charcoal, Characterization*

Introduction

Biochar produced from different types of biomass may greatly differ in its chemical and physical properties; moreover the process parameters and typology of biomass conversion technology influence the biochar final quality and characteristics [1].

In 2009 two different types of charcoal obtained from an Italian innovative gasification system (fixed-bed, down-draft, open core, small size) using two different kind of biomass (poplar and conifer woods) were analyzed for the following chemical and physical properties: pH, salinity, total and available nutrients, organic carbon content, humidity, ash, compacted bulk density, particle size distribution. Soil improvers and fertilizers standard methods were used and at least six replicates for chemical parameters were done to estimate coefficient of variation.

Moreover a bioassay was carried out using lettuce (*Lactuca sativa L.*) as a test plant [2]; conifer charcoal was tested for potential toxicity at different mixing rates with a reference sandy soil to obtain a growth index.

The different treatments were calculated to simulate field application and are listed in the Table 1.

Table 1. Bioassay treatments

Treatments (g fresh charcoal * kg^{-1} reference sandy soil)	Corresponding field application of fresh charcoal at 6% humidity (Mg ha^{-1})
0	0
5	23
10	45
15	68
20	90

The test was performed in growing room, with light and fixed temperature (22°C), using 250 ml pots with three seed plants/pot. Four replicates for each treatment were carried out, with a randomized design.

After 21 days aboveground biomass was cut and weighed, both fresh and dried at 105°C for 48 h,.

Dried production was analyzed by analysis of variance (ANOVA) and mean separation was done using Duncan test (P=95%).

Results and Discussions

Dry matter growth index obtained from bioassay is shown in Figure 1. Only corresponding fresh biochar field applications between 23 and 68 Mg ha^{-1} are significantly different and better than control.

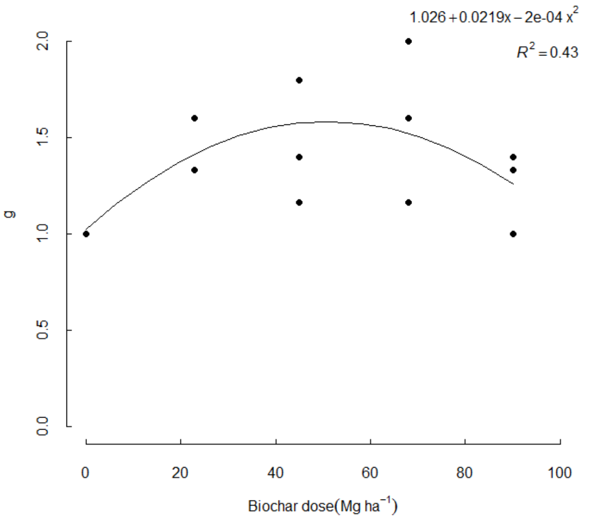

Figure 1. Conifer charcoal bioassay: lettuce dry matter production index (control index = 1).

Characterization data of conifer and poplar charcoal are shown in Table 2 (mean values).

Poplar charcoal has higher compacted bulk density (fresh matter) and humidity than conifer charcoal, because it was moistened during storage to prevent fire risk and to facilitate mechanical field application.

The pH value is higher in conifer than in poplar charcoal; however both are alkaline (> 9,0). The application of charcoal increases the pH of acid soils, but this effect is probably due to ash content [1]. As ash content (loss on ignition 600°C) is higher in poplar than in conifer charcoal, application of poplar charcoal may have more effect on soil acidity decrease.

Salinity is slightly higher in poplar charcoal, due to high water soluble nutrients content in fresh matter, especially for potassium and phosphorous. Even so salinity values are not toxic to plants when charcoal is used as soil improver.

Total organic carbon content has been determined both by dichromate oxidation-titration techniques (oxidation with heating time and temperature 10 min and 150°C respectively) and by dry combustion (elementary analysis using a correction for carbonates). Values range from 53 % for poplar charcoal to 70% for conifer charcoal (Dumas method), in line with the major bibliographical data [3].

C/N ratio is very high in conifer charcoal, due to higher carbon content and lower nitrogen value.

Poplar charcoal shows the highest values in total nitrogen, phosphorus and potassium content. As to available bases (exchangeable cations), the different values for potassium (lower in conifer charcoal) and calcium (lower in poplar charcoal), are related to feedstock and charring conditions.

Particle size distribution shows that conifer charcoal is coarse and it has an homogenous division between 1, 2 and 5 mm.

Both have particle size near 100% < 5 mm.

Table 2. Conifer and poplar charcoal characterization (mean values – coefficient of variation always < 0,5)

Parameter	Conifer biochar	Poplar biochar	Reference method
Compacted bulk density (g l^{-1} fm)	196	421	UNI-EN 13037:2002
Humidity (%)	6,0	50,5	UNI-EN 13040:2008
pH (H_2O)	10,3	9,6	UNI-EN 13037:2002
Salinity (mS m^{-1})	28	39	UNI-EN 13038:2002
Nitrate $_{\text{(N water soluble)}}$ (mg l^{-1} fm)	< 1,0	< 1,0	UNI-EN 13652:2001
Ammonium $_{\text{(N water soluble)}}$ (mg l^{-1} fm)	32,2	35,9	UNI-EN 13652:2001
Potassium $_{\text{(K water soluble)}}$ (mg l^{-1} fm)	245,0	510,0	UNI-EN 13652:2001
Phosphorus $_{\text{(P water soluble)}}$ (mg l^{-1} fm)	2,9	99,7	UNI-EN 13652:2001
Organic Carbon (% dm)	63,8	58,0	DM* 21/12/00 Add. 6 (Springer-Klee)
Organic Carbon (% dm)	69,5	53,0	DM* 13/09/99 met. VII.1 (Dumas)
C/N (Dumas method)	173,8	37,9	DM* 13/09/99 met. VII.1 (Dumas)
Nitrogen $_{\text{(N Total)}}$ (% dm)	0,4	1,4	UNI-EN 13654-2:2001 (Dumas)
Phosphorus $_{\text{(P Total)}}$ (% dm)	< 0,1	0,4	UNI-EN 13650:2002 (aqua regia)
Potassium $_{\text{(K Total)}}$ (% dm)	0,4	1,0	UNI-EN 13650:2002 (aqua regia)
Ash $_{\text{(loss on ignition at 600°C)}}$ (% dm)	8,0	22,0	UNI-EN 13039:2002 (loss on ignition)
$Ca^{2+}_{\text{(exchang.-BaCl2)}}$ (mg kg^{-1} dm)	4972	1580	DM* 13/09/99 met. XIII.5
$Mg^{2+}_{\text{(exchang.-BaCl2)}}$ (mg kg^{-1} dm)	586	522	DM* 13/09/99 met. XIII.5
$K^{+}_{\text{(exchang.-BaCl2)}}$ (mg kg^{-1} dm)	2957	5207	DM* 13/09/99 met. XIII.5
$Na^{+}_{\text{(exchang.-BaCl2)}}$ (mg kg^{-1} dm)	200	446	DM* 13/09/99 met. XIII.5
Particle size < 1,00 mm (%)	29	56	UNI-EN 15428:2008
Particle size < 2,00 mm (%)	60	77	UNI-EN 15428:2008
Particle size < 5,00 mm (%)	97	96	UNI-EN 15428:2008
Particle size < 10,00 mm (%)	100	100	UNI-EN 15428:2008

* Ministerial Decrees for official methods

Conclusions

Biochar produced from different types of biomass varies in its properties, as much as charring conditions.

A databank for different kinds of biochar is useful and desirable.

Moreover, as to assess the agronomic values of the different biochars, we need to define parameters, standard harmonized methods and bioassays, in order to allow different data comparison.

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[1] Glaser, B. et al. 2002 *Bio Fertil Soil*, *35*, 219-230.

[2] Lombardy Region (Italy) 2003. *Bioassay: effect of complex materials on the growth of superior plants,* D.G.R. 7/12764 16/04/03, Encl. B.

[3] Lehmann, J.et al. 2006 *Mitigation and Adaptation Strategies for Global Change*, 11, 403-427.

Nanoscale characterization of biochars-mineral complex

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Amazonian Dark Earths (Terra Preta – or TP) are unique soils that exhibit outstanding fertility by promoting and sustaining plant growth. Prior studies of TP, where the focus has been characterization of microstructure, have revealed that they are composed of microagglomerates formed by the interaction of a variety of organic matters, clay particles and other minerals. These microagglomerates comprise regions of amorphous carbon surrounded by mineral phases that are rich in aluminum, silicon, iron, calcium and phosphorus. Examination of aged biochar particles, following field trials in soils, reveals similar structures compared to TP.

Inspired by these findings, biochar-mineral complexes (BMC) have been produced to mimic the properties of TP. BMC is produced by combining wood biochar, clay, sawdust, chicken manure and several other mineral compounds followed by torrefaction at low temperatures (180-220°C) in an oxidizing environment. BMCs perform well during field trials due to the unique properties of their interfaces and surfaces. It has been found that BMC's increase plant uptake of nutrients through increases in microbial activity, cation exchange capacity and acid neutralising capacity. It also appears that BMC's have high redox potential promoting the breakdown of organic matter and reducing the energy required for cations to migrate through the cell walls of the roots. Initial investigations indicate that the BMC's change the microbial and microfauna population resulting in greater resistance to disease. It is also relatively inexpensive to manufacture BMC's due to their low torrefaction temperature.

BMC particles from both before, and after, field trials were examined using a range of analytical tools including scanning transmission electron microscopy (STEM) coupled with electron energy loss spectroscopy (EELS), transmission electron microscopy (TEM), and scanning electron microscopy (SEM). Characterization of such materials on a nanoscale provides information about the interactions that take place at the interface between the organic and inorganic phases in the BMC. This provides a basis to understand and predict the reactions that will take place at the micro and macroscopic level, especially between organic and mineral phases. Experimental results shows that the BMC's exhibit a similar nanostructure compared to TP. STEM and TEM examination reveals a complex aggregation of phases and nanopores, together with evidence of the interfacial reactions.

This presentation details the findings of various techniques used in the characterization of BMC's. Moreover, the possible mechanisms underpinning the formation of BMC will be described, together with comparisons between aged biochars and BMC's.

Liquid phase characterization of biochar derived from Lluta valley vegetable, as a function of the sequential aqueous leachate

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The biochar is in its raw material, one of the determinants of its quality as a modifying agent to the soil properties that may eventually be added. In the Region XV in northern Chile, there are alluvial valleys embedded in the macro region of the Atacama Desert, one of the world's driest, with no precipitation, all stocked with low flows of surface water and salt, mostly endorheic basin with high rates of evaporation. Saline soils and saline water Lluta Valley, inserted in the arid zone, allows the development of different plant species native and cultivated, all adapted to these conditions and are mostly subject to burning or combustion process to facilitate cultivation of plants of economic interest on the one hand or as a waste management plant after harvest. Being so these species, an alternative raw material for the production of biochar. The treated material via pyrolysis, with a production of elemental carbon, also makes a product to some extent mineralized, ie some fraction of their original inorganic chemicals but transformed, being labile to reaction with water. To verify this lability Batch experiments were conducted in a ratio of 1:10 (biochar: distilled water), generating solubilization and hydrolysis by an electrolyte solution, the latter characterized by a significant degree of salinity, measured by electrical conductivity (EC) and a basic pH, with significant presence of alkali cations. The biochar subjected to a sequential leachate reacts with a significant change in the slope of the EC from first to second trial and therefore tends to decrease gradually in value of EC and in the degree of its subsequent negative slope in leachates. However, sequential leaching generates a slight change in pH value, but there is no significant change, remaining constant as the basic character of the solution. The nature of the original plant, developed physiological saline substrates, directly affects the quality of saline input char.

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Influence of pyrolysis temperature on production and agronomic properties of wastewater sludge biochar

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It is an important challenge to manage wastewater sludge in an environmentally and economically acceptable way. The wastewater treatment industry has a concern to minimize the quantity and transportation costs of its waste management. A possible option for effective management of wastewater sludge is through pyrolytic conversion to biochar. The aim of this work is to investigate the influence of pyrolysis temperature on production of wastewater sludge biochar and evaluate the properties required for agronomic applications. Wastewater sludge collected from an urban wastewater treatment plant was pyrolysed in a laboratory scale reactor. It was found that by increasing the pyrolysis temperature (over the range from 300 °C to 700 °C) the yield of biochar decreased. Biochar produced at low temperature was acidic whereas at high temperature it was alkaline in nature. The concentration of nitrogen was found to decrease while micronutrients increased with increasing temperature. Concentrations of trace metals present in wastewater sludge varied with temperature and were found to be primarily enriched in the biochar.

The IBI's efforts for defining and characterizing biochar

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Biochar technology has the potential to be a tool for climate change mitigation and for increasing food security. However, the nascent biochar industry must be correctly implemented in order to realize its full benefits, and to date no widely accepted guidelines exist for sustainable biochar systems or safe, effective biochar products. In September 2009, the IBI formed a workgroup to define and characterize biochar. Currently, the workgroup comprises 57 researchers and industry members. Workgroup participants have provided input on a definition for biochar and a basic system for characterizing the material, remotely using IBI's Basecamp website and surveys. IBI has also produced a Pyrolysis Plant Design and Test Guideline which has been reviewed by IBI's Technical Advisory Committee (Production). This document is designed to support the safe and efficient design and testing of pyrolysis plants. Progress made to date will be presented, including IBI efforts to fund this work, and to develop an overarching vision for a biochar certification system including feedstock and overall system sustainability on a cradle-to-cradle basis, pyrolysis unit safety, and safety and effectiveness of the biochar material for application to soil.

Simple method of carbon sequestration analysis in the farm soil added with charcoal

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In order to establish sequestration mechanism of carbon in soil scattered with charcoal, simple analysis method of charcoal carbon amount in the soil was studied quantitatively. Total carbon and inorganic carbon amount was measured with combustion method using SHIMADZU SSM-5000A, organic carbon amount was decided by the Tyurin method. Charcoal carbon amount was estimated by subtracting the inorganic carbon and the organic carbon from the total carbon in the soil. In the sample where bamboo charcoal carbonized at 680 °C was mixed with farm soil with 1.0, 3.0, 5.0 and 15.0 wt%, the charcoal carbon amount was estimated with an error of about some %. It was found that the charcoal carbon amount in the soil was easily and efficiently estimated using this method.

Biochar-Ion Interactions: An Investigation of Biochar charge and its effect on ion retention

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The method of measuring exchangeable cations as an approximation for cation exchange capacity was examined using cow manure (CM) and green waste (GW) biochar. Both biochars were pre-treated by shaking with water over a range of times. Leachates were analysed, and the pre-treated biochars were then treated with two solutions (0.1M $BaCl_2$ or 0.1M CsCl) to measure ion adsorption. Pre-treatment water shaking significantly increased monovalent cation and anion adsorption in the GW biochar. Ion adsorption for the CM biochar was not affected by pre-treatment water shaking. The CM biochar did not adsorb the anion at all. Adsorption of moisture was postulated as the cause of the change in surface structure of the GW biochar, enhancing its ability to retain ions. Compulsive exchange of cations to determine the ability of a substrate to retain positively charged ions on its surface may require the use of multivalent solutions to fully neutralise the different forms of charge and varying charge densities that make up some substrates. The relative moisture content of a substrate may also influence the strength and sign of surface charge sites, thereby influencing its Characterization. The pre-treatment of biochars through shaking in water over differing times has manipulated the GW biochar particle-ion structure, thereby changing the potential for the biochar particle to adsorb ions.

Biochar amendments to soils

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Bio fuel and the world dream

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Key words: *Food security; communities, agriculturalist*

Introduction

Although the discovery of bio fuel from sugar cane, vegetables and others are part of the great achievement in the history of mankind as well as the superiority in talents of the modern society for the ability to be able to discover a clean, affordable and sufficient source of energy from ordinary plants that had long being in existence for thousands and even millions of years undiscovered in mans environment, but it should be understood that there are great numbers of challenges that will be coming the way of this great discovery and if it remains unresolved the dream of replacing the petroleum as a source of energy will ever remain unachieved.

Results and Discussions

Figure 1. Showing Jatropha plant in Ghana which has rich oil content.

Figure 2. Showing an advert of how bio fuel works in an African television.

Figure 3. Showing a local farm in Eikeihof outside Johannesburg, South Africa.

Some of the challenges are as under listed:

1. Food security; many communities, agriculturalist, economies and researchers predicted or forecasted that if the use of bio fuel takes off or starts on a commercial quantity as expected many farmlands used for food crops will give way for bio fuel producing plants, because of the value of the products [bio fuel] in the market there by creating vacuum in the food security of the entire world that will be hard to be fill.
2. Social conflicts; many grazing fields for animals will be leased or sold out for the cultivation of bio fuel plants, hence the situation will lead to communal clashes in sharing of alternative lands between peasant farmers and cattle rearers especially in Africa and Asia.
3. Create room for more research; when on the 23rd February 2008 a passenger plane belonging to virgin Atlantic was on a test drive using the bio fuel was flown from London [united kingdom] to Amsterdam [Netherlands] successfully and promised that the aviation industry will start the use of the bio fuel on commercial quantity in ten years time .Many people felt that the time period to begin the use of this bio fuel by the aviation industry is too short because experts said that there could be some hidden disadvantages that will take years to be understood especially at the phase of the on going global climate change caused by man.
4. Deforestation and desertification; many natural shelter belt plants capable of preventing desert encroachments in the Sahelian

environments especially in the Sahelian parts of Africa will give way to bio fuel producing plants like sugar canes, vegetables etc there by given advantage to the deserts advancement.

5. Unemployment; many employees working in the petroleum industries will lose their jobs as a result of the bio fuel replacing or competing with the petroleum products in the energy market.

6. Climate change; when natural vegetations like grazing fields and forests are altered by man through or by replacing them with bio fuel plants, the situation tends to create micro climatic changes which will latter lead to or affects the entire global climate change processes.

7. Traditional knowledge; many communities depending on local plants within their environment for medicinal cultural, ritual and spiritual purposes will suffer from the coming of bio fuel as many of such plants will be disappearing over time by giving way to bio fuel plants.

8. Indigenous issues; many governments especially in Africa, the Americas and Asia will use their powers in giving indigenous lands for bio fuel farming, because of the profits involved in the bio fuel production, hence creating more problems for the indigenous people who are already suffering from the impacts of colonialism in there territories.

In view of the above the issue of bio fuel becomes or assumes the shape of a vicious cycle.

Conclusions

The more the farmland for bio fuel- the more the production of bio fuel -the more the problem it causes.

Therefore in order to make this new discovery of the 21st century to be a clean, affordable and alternative source of energy in the energy market as well as a environmental friendly source of energy.

All the above listed points are needed to be taken into consideration, otherwise the dream and the future of the bio fuel will ever remain unachieved.

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[1] http://www.irinnews.org/Report.aspx?ReportId=86044

[2] http://bio-fuel-watch.blogspot.com/2009/06/biofuelwatch-code-of-conduct-urged-for.html.

[3] http://www.un.org/News/Press/docs/2007/hr4923.doc.htm

[4] UNITED NATIONS Conference on Environment and Development (1992) Report Vol. 1 Agenda 21, IUCN Publication Washington Dc. USA.

The position of new human activities in Africa, the North and South Pole regions on global climate change

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Key words: *Climate, Africa, Antarctica*

Introduction

As a result of the rapid increase in the petroleum exploration, Industrial, deforestation and other human activities going on within or around the Arctic and Antarctica ice caps near or in the temperate region countries like Canada, Greenland, Russia, U.S.A (Alaska), Iceland, Finland, Argentina, Tasmania and New Zealand among many others plus the increase in deforestation activities in Tropical world countries like the Amazon of Brazil, The Tropical Rain forest of Nigeria, Zaire (Democratic Republic of Congo), Cote d voire, Indonesia etc. in addition to the Sahara and the Kalahari deserts encouragement as a result of human factors plus the uncontrolled disposals of broken Refrigerators, Air conditioners and propellants containing chlorofluorocarbon substances capable of destroying the Ozone layer in African refuse dumps (B.Abubkar,2006) are collectively becoming a threat to the world climate.

Results and Discussions

Figure 1. Showing some important arctic exploration routes.

Figure 2. Showing recent deforestation activities in Africa.

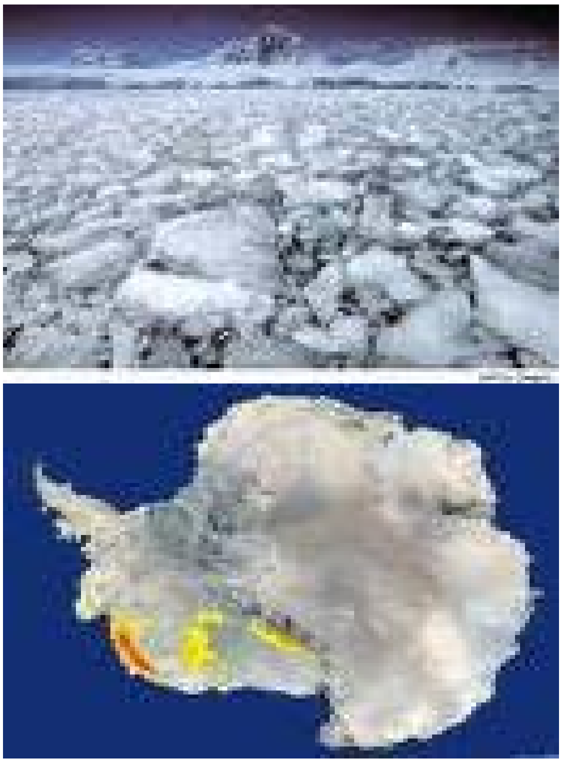

Figure 3. Showing the melting Antarctica ice.

This explains why the volume of the Ocean keeps on rising, global temperature keeps ascending and the global climate is becoming abnormal since the beginning of the above mentioned activities in the above mentioned locations. In view of the above the issue of bio fuel becomes or assumes the shape of a vicious cycle.

Conclusions

It was in view of the above that this research was conducted and came up with the under listed suggestions/recommendations:

1. The temperature region countries like Canada, Russia, U.S.A, Argentina etc. should come up with polices restricting certain industries with the possibilities of causing environmental hazards from operating near the Ice Caps of the Arctic or Antarctica even in areas which the Ice was frozen thousands of years ago as the case with Greenland.
2. The research and exploration activities going on around or on the Arctic and the Antarctica regions should be carried out with utmost care and concern to the global climate.
3. The deforestation activities going on without control in most of the Tropical World Countries should be monitored by the United Nation’s Specialized Agencies on forest and other related international organization in such a way that goals could be achieved without necessarily causing problems to the world climate.
4. The International Maritime Organization (IMO) should check and control the Ocean Pollutions caused as a result of the degreasing activities of the “QUAY APRONS” currently going on at the various African Sea Ports in order to protect the Ocean pollution with chemicals that can make the World’s ice to be melting.
5. The International Meteorological Organization should open its offices within each region of the six continents in order to have a closer monitoring of human activities that can influence the world’s climate.
6. Organizing seminars, Conferences and Workshops on a regular basis by the United Nations and other related organizations can help in the areas of public enlightenment and the education of the rural populace who are also great contributors to the situation.
7. The UN should use its capacity to discourage the importation of fairly used refrigerators, Air-conditioners and propellants to Africa and at the same time assist in the subsidy of the newer ones coming to Africa, so that the average African can afford buying them

I believe that if the above listed suggestions/recommendations are adopted and implemented it will help in reducing these challenges threatening the entire world.

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[1] Abubakar, B. 2009, a Paper presented at the Nineteenth UN/IAF Workshop
Friday 9 October 2009 and Saturday 10 October 2009 08:00-18:00“Integrated Space Technologies and Space-based Information for Analysis and Prediction of Climate Change” in Dejeon Republic of Korea.http://www.iafastro.com/index.html?title=2009_UN-IAF_Workshop

[2] Babagana, A. 1997, Water Availability, Supply and its Associated Problems in Rural Communities of Borno State. A. Case Study of Nganzai Local Government Area of Borno State, Nigeria 10-19. (Unpublished)

[3] Daily Trust Newspaper, a April15 2008 P 41 Climate Change can Hinder MDGs, Published by Media Trust Limited Abuja.

[4] UNITED NATIONS Conference on Environment and Development (1992) Report Vol. 1 Agenda 21, IUCN Publication Washington Dc. USA.

[5] http://www.google.com.ng/search?hl=en&client=firefox-a&hs=RXi&rls=org.mozilla%3Aen-US%3Aofficial&channel=s&q=PHOTO+OF++THE+MELTING+ANTARCTIC&btnG=Search&aq=f&aqi=&aql=&oq=&gs_rfai=

[6] http://www.google.com.ng/imgres?imgurl=http://photos.mongabay.com/07/0607vma2002_yanga1_rd.jpg&imgrefurl=http://news.mongabay.com/2007/0611china.html&h=252&w=336&sz=72&tbnid=TcubHlYlbpfvZM:&tbnh=89&tbnw=119&prev=/images%3Fq%3DPHOTO%2BOF%2BDEFORESTATION%2BIN%2BAFRICAN%2BFOREST&hl=en&usg=__x7xpVnDoDrcLI92hwpS_Lg6HBXY=&sa=X&ei=hm5YTN-9A4uOjAeOoqToCQ&ved=0CCgQ9QewAw

[7] http://www.google.com.ng/imgres?imgurl=http://media-2.web.britannica.com/eb-media/57/5857-004-02E2CDAC.gif&imgrefurl=http://www.britannica.com/EBchecked/topic-art/419365/433/Routes-of-major-Arctic-explorations&h=558&w=550&sz=51&tbnid=WJRVWQpFnmqY4M:&tbnh=226&tbnw=223&prev=/images%3Fq%3DPHOTO%2BOF%2BEXPLORATION%2BIN%2BTHE%2BARCTIC&hl=en&usg=__YPfC5oq863eT69qn1O9dVzcKtVA=&sa=X&ei=WG5YTIT5Jti4jAf3luXUCQ&ved=0CCIQ9QEwAg

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Establishing release dynamics for plant nutrients from biochar

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Key words: *Biochar, Nutrient Release*

Introduction

To understand the value of biochar products to direct supply of crop nutrients, and to distinguish these from indirect effects on plant nutrition, the dynamics and mechanisms of nutrient release need to be described.

In this study the magnitude and dynamics of phosphorus, magnesium and potassium released in water were studied for a hardwood charcoal, with different levels of prior physical disruption (crushing).

The charcoal was created at 500°C from sycamore wood in a traditional charcoal kiln[1]. Total elemental composition of both sycamore and charcoal was determined by ICP-OES analysis.

The sample was manually ground and sieved into a size range of 150–600 μm. Three sub-samples (approx. 10.0g) were weighed into 500mL LDPE bottles. Deionized water was added to give a solid-to-liquid ratio of 1:20 by mass. The bottles were then shaken using an orbital shaker at 160 min^{-1} for 4 h along with one LDPE bottle containing only deionized water as a control.

The contents of each bottle were subsequently filtered to recover charcoal, including loosened particles >11 μm (pre-weighed Whatman No. 1). The filtrate was filtered again at 0.45 μm and analyzed for total P, K and Mg by ICP-OES.

Solid residues >11 μm were dried on the filters overnight at 105°C, cooled to room temperature in a desiccator and weighed. The samples were then subjected to the same water extraction procedure five more times.

The volume of water added in each cycle was adjusted accordingly to maintain the same solid-to-liquid ratio. After the sixth extraction, the samples were dried overnight and sieved using a 150 μm mesh, and for each sample the weight of the particles <150 μm was recorded to establish the extent of physical breakdown during the treatments.

Results and Discussions

Phosphorus concentration in charcoal was low (119 mg kg^{-1}), but approx. four times greater than in sycamore wood, reflecting the ratio of feedstock mass to charcoal yield in charcoal manufacture. In contrast, the magnesium and potassium contents of charcoal were 1889 mg kg^{-1} and 3309 mg kg^{-1} respectively. The latter were only twice the feedstock concentrations of 856 mg kg^{-1} and 1651 mg kg^{-1} which may suggest a decrease in chemical extractability.

Phosphorus released in water did not change greatly between extraction cycles, the first few extractions yielding only slightly greater amounts than the last extractions. However, one-fifth of total extractable-P was released in the first cycle, suggesting that P is conserved and rendered more water-available by pyrolysis. Phosphorus released from the first extraction was 0.027 mg g^{-1}, which at a charcoal application rate of 20 t ha^{-1} would equate to only 0.54 kg ha^{-1} P. However, it would appear that this could be sustained over time.

The washing, shaking and/or handling of the charcoal samples both created fine particles and led to some losses through the filter paper. In addition, some charcoal was unable to be retrieved from the interior of the bottle following each extraction. An average of 16 % mass was lost from each sample, and an average of 3% of each sample was recovered as particle sizes <150 μm. The concentration of P in later extractions could be explained by the generation of smaller particles with a higher release potential. The P concentrations could also reflect P that was sorbed to the <11 μm particles that passed through the filter.

The release of Mg decreased linearly from one extraction to the next. This, and the fact that the proportion released in the first cycle was smaller than P, 5–10 %, indicates that the availability of this element is low in pyrolysed material compared to P. Mg released from the first extraction was 0.176 mg g^{-1} charcoal, which at a charcoal application rate of 20 t ha^{-1} would equate to 3.52 kg ha^{-1} Mg.

The proportion of K released in the first extraction was higher than for Mg, but declined exponentially in subsequent cycles. This indicates that although the water-available portion of K is small it is released very quickly, suggesting a different location within the char structure from P and Mg. The release of potassium does not appear to have been affected by the erosion of the particles since the correlation between the particle size and the release of potassium remained almost the same throughout the extractions (data not shown). K released from the first extraction was 2.47 mg g^{-1} charcoal, which at a charcoal application rate of 20 t ha^{-1} would equate to 49 kg ha^{-1} K.

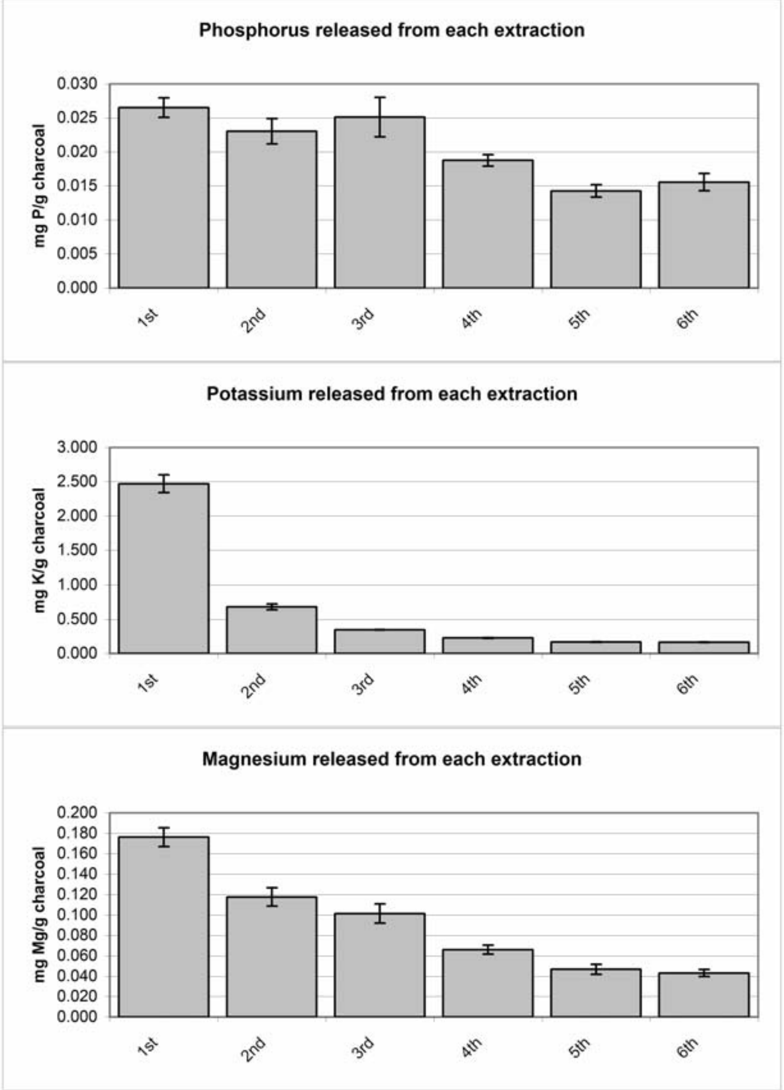

Figure 1. Release of phosphorus, potassium, and magnesium from each extraction

Conclusions

Although sycamore charcoal applied at a rate of 20 t ha^{-1} would be relevant to the K requirement for many crops, in general it is unlikely to meet a great proportion of P or Mg requirement.

Most of the K release from the charcoal occurred during the first extraction, whereas the difference between the earlier extractions of P and the later extractions was less pronounced. In addition, the release of Mg and P did not follow a similar trend. This indicates that these three elements either adsorb differently to the charcoal, or perhaps one or more of the elements are contained within the charcoal in particulate form.

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We would like to thank Peter Anderson and Tanya Peshkur for their laboratory support as well as Colin Cunningham for his help with the design of the experiment. We would like to thank Jason Cook for supplying the charcoal.

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[1] Charcoal produced by Dalkeith Char.

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Factors affecting stability of biochar and effect of biochar on stability of soil organic matter

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Key words: *Biochar stability, laboratory incubation, Radiocarbon labeling*

Introduction

The stability of biochar is of importance both in terms of the ability for biochar to act as a measure for climate change mitigation and for the ability of biochar to provide sustained improvement of soil fertility. The high resistance to degradation of a fraction of biochar is demonstrated by the high ^{14}C age of charcoal particles [1,2]. Furthermore, incubation [3,4] and chronosequence [5] experiments have shown that it is degraded slowly compared with other types of natural organic materials.

However several aspects of biochar degradation are still inadequately studied. The effect of the degree of thermal alteration i.e. the temperature under which the biochar has been produced has mainly been investigated a lower temperatures than those relevant for commercial biochar production, and hardly anything is known about how biochar interacts with the mineral soil and how this affects the stabilization. Recently, an experiment from Sweden indicated the biochar increases the degradation of plant litter [6]. If biochar increases decomposition of other types of organic matter, the release of carbon dioxide from the soil organic matter (SOM) may offset the carbon sequestered in the biochar.

We conducted several incubation experiments using ^{14}C labelled biochar to investigate these issues. In the first experiment, ^{14}C labelled biochar was produced at different temperatures in the range from 400°C to 600°C, and incubated in different soils at the same water potential. In a second experiment we investigated the effect of biochar on the stability of other types of organic matter. To investigate the effect of biochar on the degradation of SOM, a soil that had been incubated 40 years ago with ^{14}C labelled barley straw was incubated with different amounts of biochar. To investigate the effect of biochar on litter decomposition, ^{14}C labelled plant material was incubated with and without biochar.

Results and Discussions

The results of the first experiment showed that the stability of biochar is increasing with the production temperature. When the production temperature increases from 400°C to 500°C, the fraction of added C which is evolved as CO_2 is reduced considerably (Figure 1). When the production temperature is increased from 500°C to 600°C a larger fraction of the added C is evolved in the beginning of the experiment. However, the content at carbonates is also greater in the biochar produced at 600°C. Therefore, the increased CO_2 evolution early in the experiment is likely to come from carbonates contained in the biochar [7]. After the carbonates have disappeared, the CO_2 evolution is lower from the biochar produced at 600°C than at 500°C.

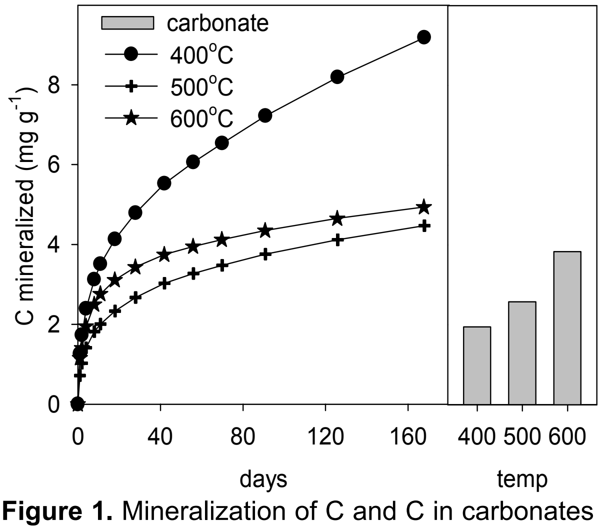

Figure 1. Mineralization of C and C in carbonates of biochars produced at 400°C, 500°C and 600°C.

The interpretation that most of the CO_2 evolution early in the experiment stems from carbonates is supported by the fact that the soils with low pH are releasing CO_2 faster in the beginning than the soils with a high pH. Apart from the effect of pH, the soil type seemed to have little effect on the CO_2 evolution. This indicates that interactions with the soil matrix do not affect the stabilization of biochar within the duration of the experiment.

Although the amount of carbonates in biochar would depend very much on the way it is produced, the initial burst of CO_2 evolution often observed in mineralization experiments of biochar may in fact come from carbonates. This means that the fraction of biochar which is easily degraded may be due to carbonates and biochar may be more stable than expected from the results.

In the second experiment the ^{14}C labeled SOM in the soil labeled 40 years ago mineralized more slowly the more biochar that was added (Figure 2).

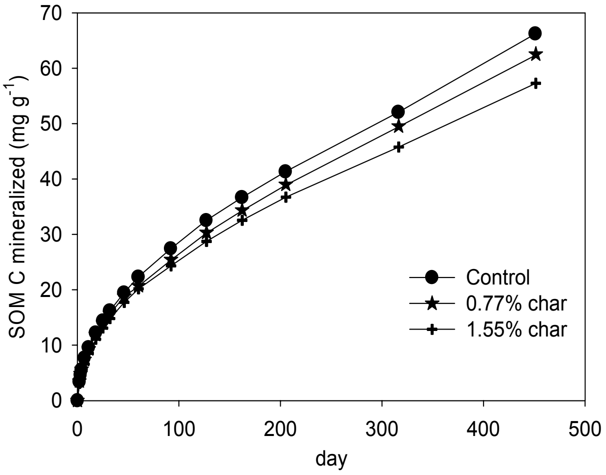

Figure 2. Mineralization of SOM C from a control soil and soils amended with different amounts of biochar

The effect of biochar on the mineralization of litter was very small. Without biochar 48%±0.2% of the litter C was mineralized and with addition of 0.15% biochar, 45%±1.6% was mineralized.

The reason for the decreased release of CO_2 from SOM and litter upon addition of biochar can be manifold. First, the addition of biochar may change water availability by absorption. Secondly, microorganisms degrading biochar may immobilize N and impose N limitation on SOM decomposition. The slow decomposition of biochar and the fact that N was added to the soil means that this is not considered the primary reason for the decreased decomposition. Addition of biochar increases the pH of the soil. However, this would most often increase decomposition of SOM.

Therefore, the reduction of water availability may be one of the primary reasons for the reduced CO_2 evolution resulting from addition of biochar. Unfortunately this reduction of water availability does not correspond with what would happen under field conditions and therefore it is problematic to conclude that biochar reduces the decomposition of SOM and litter. We can however conclude that there was no indication that biochar addition decreased the stability of litter and SOM.

Conclusions

We can conclude that the production temperature of biochar affected the stability of biochar strongly producing more and more stable biochar the higher the temperature. However, the CO_2 evolution right after the addition of the biochar also depends on the carbonate content which increases with production temperature.

The fact that the CO_2 evolution early in the experiment may come from carbonates may also be true in other experiments and the fraction of biochar which is easily degraded may be smaller than expected.

The pH of the soils also affected the CO_2 evolution from carbonates, but apart from this the soil type seemed to have little effect on the CO_2 evolution.

Biochar did not seem to increase the mineralization of SOM. On the contrary less CO_2 was evolved from the incubations with large biochar additions. Although this may be explained by decreased water availability after biochar additions which would not happen under field conditions, it must be concluded that there was no evidence of decreased stability of litter and SOM after biochar addition.

Acknowledgements

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1 Carcaillet, C. 1998. J. Ecol., 86, 384-396.
2 Titiz, B.; Sanford, R. L. 2007. Biotropica, 39, 673-682.
3 Bruun, S.; Jensen, E. S.; Jensen, L. S. 2008. Org. Geochem., 39, 839-845.
4 Kuzyakov, Y.; Subbotina, I.; Chen, H. Q.; Bogomolova, I.; Xu, X. L. 2009. Soil Biology & Biochemistry, 41, 210-219.
5 Nguyen, B. T.; Lehmann, J.; Kinyangi, J.; Smernik, R.; Riha, S. J.; Engelhard, M. H. 2009. Biogeochem., 92, 163-176.
6 Wardle, D. A.; Nilsson, M. C.; Zackrisson, O. 2008. Science, 320, 629.
7 Bertrand, I.; Delfosse, O.; Mary, B. 2007. Soil Biology & Biochemistry, 39, 276-288.

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Preliminary study of Biochar application in subarctic soils

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Key words: *nutrients, pyrolysis, enhancer*

Introduction

Alaska is in a region where productivity is limited by the cold climate, short growing season, and young nutrient-limited soils. These factors contribute to heavy dependence on synthetic fertilizers. However, with the rising cost of fossil fuels, and the absence of fertilizer producers in the state, commercial soil additives can quickly become cost prohibitive. Biochar has the potential to benefit both producers and consumers by lowering production costs, and increasing food quality, while simultaneously answering food security issues.

This research is focused on nutrient retention in soils after biochar applications in two consecutive years. Data analyzed will demonstrate if the use of biochar as a soil amendment in Alaska is a viable practice for farmers in the state.

Biochar will be attained using a simple pyrolisys/gasification system created in a 208 liter steel drum using biomass from black spruce (*Picea marianna*). Once the biochar has been created, its physical and chemical properties (available nutrients) will be analyzed using a scanning electron microscope (SEM) and extracted by Mehlich III double acid method then measured by ICP- mass spectroscope respectively.

Barley (*Hordeum vulgare*) will be grown under four replicates of each of four treatments, including 1) control (no soil additive), 2) commercial fertilizer 3) biochar addition 4) biochar and fertilizer. Soil samples will be collected every two weeks during the growing season and analyzed for pH (water 1:1), electrical conductivity (saturated paste), N, P, K and micronutrients (Mehlich III), exchangeable bases and cation exchange capacity (extracted by NH_4 Ac then stem distillation), total carbon and nitrogen (LICO CNS analyzer). According to laboratory methods Michaelson et al (1997). The statistical analysis will be analyzed using ANOVA.

Results and Discussion

The soil type used for biochar is a Bohica silt loam, classified as Coarse-loamy, mixed, superactive, Typic Haplocryepts according to Soil Taxonomy (Soil Survey Staff 2010) and Fluvic Cambisols according to WRB (IUSS Working Group WRB 2006). The parent material is loess over alluvium or fluvial deposits reworked by wind (NRCS 2008).

It is expected that biochar application will enhance soil nutrient holding capacity and increase crop yields. Biochar may improve soil structure by increasing organic matter content while retaining water and nutrients.

Table 1. Typical soil profile and chemical soil characteristics

Horizon	Depth cm	Texture	CEC cmol/kg	pH
Oi	0 to 5	Slightly decomposed plant material	peat	5.0-5.6
A	5 to 10	Silt loam	20 - 30	5.1-7.3
Bw	10 to 45	Silt loam	15 - 25	5.6-7.3
C	45 to 182	Stratified very fine sand to loamy fine sand	10 - 25	5.6-7.3

Conclusions

Biochar has been used in small and large scale operations around the globe. Australia, Kenya, India, Brazil, Colombia and other countries have adopted biochar as a soil enhancer using different type of biomass successfully. (www.IBI.org). Since soils in Alaska are weakly developed, this project will promote the use of a sustainable economical practice that is environmentally sound. The emerging biochar production technology promises the possibility of local, state, and regional benefits.

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[1] Warnock, D.D, Lehmann, J., Kuyper T.W., Rilling, M.C (2007). Micorrhizal responses to biochar in soil - concepts and mechanisms. *Plant and Soil* 300:9-20

[2] Husk,B., Major, J (2009). *Commercial scale agricultural biochar field trial in Quebec, Canada, over two years: Effects of biochar on soil fertility, biology, crop productivity and quality*.

[3] Major, J.,(2009). *Biochar application to Colombia savanna Oxisol: fate and effect on soil fertility, crop production, nutrient leaching and soil hydrology*. Department of Crop and Soil Sciences. Cornell University, Ithaca NY USA, p.841.

[4] Lehmann, J., Joseph, S. (2009). *Biochar for Environmental Management: Science and Technology*. Earthscan, London, UK.

[5] Michaelson .G,J., Ping. C.L., and Mitchell, G.A, (1997). *Methods of Soil and Plant Analysis*. Palmer, Alaska: Experiment School of Agriculture and Natural Resources Management, University of Alaska.

[6] USDA-NRCS 2007 *Alaska Web Soil Survey* available at: http://soildatamart.nrcs.usda.gov/Report.aspx?Survey=AK657&UseState=AK. Last accessed on April 6th 2010.

[7] Buol, S.W., Southard, R. J., Graham, R.C., and McDaniel, P.A., (2003). *Soil Genesis and Classification*, Fifth Ed. Blackwall Publishing, Ames, Iowa.

[8] IUSS Working Group WRB (2006). World Reference Base for Soil Resources 2006, *World Soil Rewsources Reports* No. 103, FAO, Rome.

[9] Soil Survey Staff (2010) *Keys to Soil Taxonomy Eleventh Edition*. US Department of Agriculture Natural resources Conservation Service, Washington D.C.

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A Meta-Analysis of Plant Biomass Response to Biochar

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Key words: *Biochar, soil, plant response*

Introduction

Estimates of biochar's potential magnitude as a strategy for mitigating climate change must be based in part on its economic costs and benefits [1], which include improvement of crop yields [2, 3]. A meta-analysis of experimental results was undertaken to determine (a) average plant response to biochar (BC) at varying concentrations in soil; (b) if there are BC concentrations beyond which plants show declining or negative response; (c) whether biomass charring temperature (as a proxy for aromaticity, conjugation, and thus recalcitrance [4]) influences biomass response.

Data on plant growth, char properties, and soil properties were extracted from 19 studies examining first-year effects of BC [5-23], and analyzed via multiple regression. Constituent studies contained 96 "experiments", defined here as a set of treatments in which only BC addition amount varies. Plant biomass response was calculated as the percentage increase or decrease of a BC treatment from its zero-BC control. Subsets of the data were taken to examine response in fertilized versus non-fertilized experiments and tropical versus temperate environments. For all subsets, three application ranges were examined: 0-10 t ha^{-1}, 10-40 t ha^{-1}, and 40+ t ha^{-1}.

Gaps in reported data precluded a model specification with all soil and char variables. Thus, models took the form $BM = \beta_1 BC + \beta_2 F + \beta_3 pH_s + \beta_4 HTT + \varepsilon$, where BM is plant biomass response (as a percentage change from control), BC is biochar application rate in tons/hectare, F is presence or absence of fertilization (categorical; 0 or 1), pH_s is initial soil pH, and HTT is BC production temperature. Where too few studies reported HTT to run the model with at least half of observations (tropical studies above 10 t/ha), a proxy HTT was derived by regressing BC pH on HTT for observations reporting both, and using the fitted value for those studies missing HTT data.

Results and Discussion

Positive, significant ($p<.05$) β values for BC were predicted up to 10 t ha^{-1} for all sub-sets except unfertilized treatments (Figure 1). Above 10 t ha^{-1}, BM approached zero.

Across all studies, HTT was statistically significant ($p<.05$) and positively correlated to BM in the 0-10 t ha^{-1} range. Also in the 0-10 t ha^{-1} range, pH_s was negatively correlated to BM and significant in the fertilized subset. F was significant only in the tropical subset.

In addition, change in pH was a very strong predictor of biomass response in acid soils, while neutral and alkaline soils showed little change in pH on BC addition (Figure 2). A similar relationship was observed for cation exchange capacity (not shown).

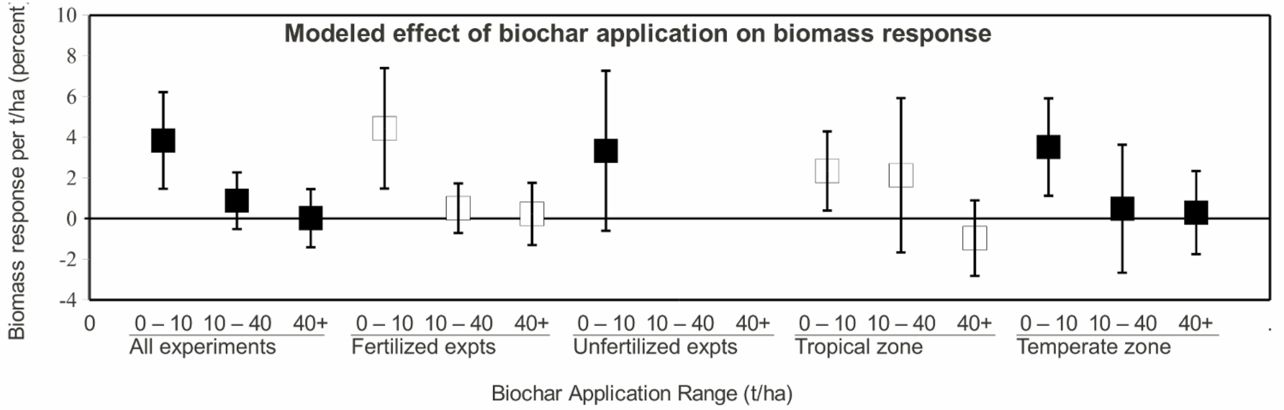

Figure 1. Average plant response to BC across application ranges, and experiment sub-sets.

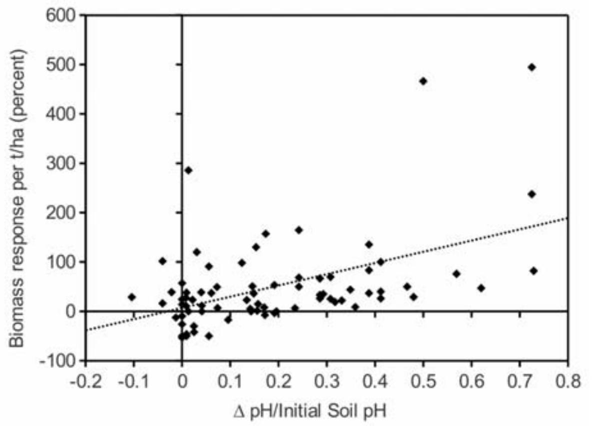

Figure 2. Biomass response to change in soil pH on addition of biochar.

Conclusions

Caution is warranted in interpreting these results due to gaps in data, few observations, and the lack of sufficient studies on multi-year effects of BC. Despite these limitations however, modeled average biomass response to moderate amounts of BC is large and significant. While biomass response diminishes at higher application ranges, it is not immediately possible to draw conclusions regarding accumulation of stable biochar in soil over many years and applications, due to the chemical alteration undergone by BC over time [24], which is not reflected here.

These results also re-confirm that pyrolysis processes and soil properties are very important determinants of biomass response to BC. As noted elsewhere [2], the greatest agronomic opportunities from biochar production may be in acidic and low-CEC soils, while positive correlation between plant response and HTT suggests that agronomic and C sequestration goals may be synergistic in many cases.

Generalized estimates of plant response to BC across broad climatic, soil and management conditions are important for estimating BC's potential as a climate change mitigation strategy. As such, these results provide estimates which may be useful in modeling the economic costs and benefits of biochar vis a vis other climate change mitigation options. However, further studies are required to better understand biomass response in a more specific range of contexts, to higher BC application rates, or to longer-term accumulation of BC in soil.

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[1] McCarl, B.A.M. Peacocke, C., Chrisman, R., Kung, C., Sands, R.D. 2009. In: Lehmann, J., & Joseph, S. 2009. *Biochar for environmental management*. London: Earthscan.

[2] Glaser, B., Lehmann, J., & Zech, W. 2002. *Biol Fert Soils.* 35 4, 219.

[3] Blackwell P, Riethmuller G and Collins M 2009. In: Lehmann, J., & Joseph, S. 2009. *Biochar for environmental management*. London: Earthscan.

[4] Nguyen BT, Lehmann J, Hockaday WC, Joseph S, & Masiello C. 2010. *Environ Sci Technol.* Published online April 2010.

[5] Noguera, D; Rondon, M., Laossi, K. R., Hoyos, V., Lavelle, P., Cruz, . C. M. H., Barot, S., Noguera, D. *Soil Biol Biochem, 42,* 7, 1017-1027.

[6] Asai, H., Samson, B. K., Stephan, H. M., Songyikhangsuthor, K., Homma, K., Kiyono, Y., et al. 2009. *Field Crops Res.* 111 1, 81.

[7] Biochar Fund, 2009. http://biocharfund.org.

[8] Chan, K., Van Zwieten, L., Meszaros, I., Downie, A., Joseph, S. 2007. *Aus J Soil Res.* 45 8, 629-634.

[9] Chan, K., Van Zwieten, L., Meszaros, I., Downie, A., Joseph, S. 2008. *Aus J Soil Res.* 46 5, 437-444.

[10] Gaskin, J.W. Speir, R.A., Harris, K., Das, K. C., Lee, R.D., Morris, L.A., and Fisher, D.S. 2010. *Agron J. 102 2, 623 - 633*

[11] Hossain MK, Strezov V, Chan KY, & Nelson PF. 2010. *Chemosphere.* 78 9, 1167-71.

[12] Husk, B., Major, J. 2009. Unpublished.

[13] Lehmann, J., Pereira da Silva Jr., J., Steiner, C., Nehls, T., Zech, W., & Glaser, B. 2003. *Plant Soil.* 249 2, 343-357.

[14] Major J, Rondon M, Molina D, Riha SJ, & Lehmann J. 2010 *Plant Soil.* Published online 10 March 2010.

[15] Masulili A, Utomo WH, Syechfani MS. 2010. *J Agr Sci.* 21, 39 – 47.

[16] Rodríguez, L., Salazar, P., Preston, T.R. 2009. *Livestock Research for Rural Development* 217.

[17] Rondon, M., Lehmann, J., Ramâirez, J., & Hurtado, M. 2007. *Biol Fert Soil*. 43 6, 699-708.

[18] Steiner, C., Teixeira, W., Lehmann, J., Nehls, T., Macãedo, J., Blum, W., et al. 2007. *Plant Soil.* 291 1-2.

[19] Tagoe SO, Horiuchi T & Matsui T. 2008. *Afr J Agr Res*. 311, 759 – 774.

[20] Uddin SMM, Murayama S, Ishimine Y, Tsuzuki E & Harada J. 1995. *Jpn J of Crop Sci.* 644, 747-753.

[21] Van Zwieten L., Kimber S., Morris S., Rust J., et al. 2010. *Plant Soil.* 327 1, 235-246.

[22] Yamato, M., Okimori, Y., Wibowo, I. F., Anshori, S., Ogawa, M. 2006. *Soil Sci Plant Nutr.* 52 4, 489-495.

[23] Pichler, B. 2010. MSc Thesis. Dept of Geog, U Zurich.

[24] Cheng, C. H., Lehmann, J., & Engelhard, M. H. (2008). *Geochim Cosmochim Ac.* 72 (6), 1598-1610.

Using charcoal as a soil amendment in poly-bagged nurseries of rubber (*Hevea brasiliensis* (Muell.) Arg.) in Sri Lanka

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Key words: *Charcoal, Hevea brasiliensis, Growth*

Introduction

Rubber is being grown in Sri Lanka over an extent of 122,000 ha on rolling to undulating terrains that receive monsoon rains. Inherently less fertile soils in these landscapes are degrading due to cultivation of rubber as a mono-crop for more than 125 years and poor adoption of soil management practices. Decrease in soil organic carbon reserves and top soil erosion could be identified as major causes of soil degradation in these lands. In order to increase the land productivity, arresting further degradation and improving soil fertility status is essential.

Various organic soil amendments have been recommended for land application to enhance soil fertility [1], but their residence time is so short under hot and humid climatic conditions in tropical environments [2], that constant application is required to achieve sustainable fertility improvement. Although the land application of biochar (BC) could be a viable and sustainable technology to arrest further degradation of these soils [3], agronomic effectiveness of this technology in rubber plantations is yet to be evaluated. The objective of this study was to determine the response of rubber plants to charcoal application, using poly-bagged plants under nursery conditions.

Methodology

Commercially available timber mill charcoal was ground to pass through 2-mm sieve, mixed with soil (Typic hapludult) at a rate of 1% (w/w) and filled into polyethylene bags (15×45 cm lay flat dimensions). Five treatments, (1) soil only, (2) soil+recommended rates of NPKMg fertilizer, (3) soil+charcoal only, (4) soil+charcoal+50% recommended rates of NPKMg fertilizer, (5) soil+50% recommended rates of NPKMg fertilizer, and were arranged according to a completely randomized design under field conditions. There were 20 single plant poly-bags per treatment. Growth and nutrient uptake of plants were measured at two important growth stages (pollarding of the successfully bud-grafted seedling plant and when the new scion is 3 month old: i.e., 4 and 8 months after planting, respectively). Soil properties were measured at the beginning and end of the experiment.

Results and Discussions

The used charcoal had a pH of 9.55 and a CEC of 15.9 cmol(+) kg^{-1}. Organic matter content was 824 g kg^{-1} and total N content was 2.6 g kg^{-1}. The mineral content of it was 17.6% and were rich in exchangeable K, Mg and Ca, 2662, 407 and 5181 mg kg^{-1}, respectively.

Growth of the seedling and scion plants had been significantly retarded in charcoal applied treatments compared to those in soil + NPKMg applied treatments (Table 1). Compared to plants in the recommended fertilizer treatment dry matter contents of the seedling and scion plants in the 1% charcoal only treatment decreased by 43 and 36%, respectively.

Table 1. Growth and leaf nutrient contents

Treatment	Seedling dry matter	Scion dry matter	Leaf N	Leaf P	Leaf K	Leaf Mn
	g plant^{-1}	g plant^{-1}	%	%	%	μg g^{-1}
soil only	15.7 ^{c}	11.8 ^{b}	1.96 ^{b}	0.15 ^{b}	0.70 ^{c}	112 ^{ab}
soil+recomnd fertilizer	28.7 ^{a}	15.8 ^{ab}	2.98 ^{a}	0.25 ^{a}	1.07 ^{b}	171 ^{a}
soil+1% charcoal only	16.4 ^{c}	10.1 ^{b}	2.32 ^{ab}	0.24 ^{a}	1.31 ^{a}	36 ^{c}
soil+1% charcoal + 50% recomnd. fertilizer	24.3 ^{b}	14.8 ^{ab}	2.48 ^{b}	0.24 ^{a}	1.33 ^{a}	101 ^{b}
soil+50% recomnd. fertilizer	28.7 ^{a}	18.3 ^{a}	2.78 ^{a}	0.19 ^{ab}	1.04 ^{b}	119 ^{ab}

* Values followed by the same letter in a column are not significantly different at $p<0.05$.

However, addition of 50% of the recommended fertilizer together with 1% charcoal improved the growth but not up to the level of the two fertilizer only treatments.

Charcoal added plants showed nutrient deficiency symptoms similar to N and Mn. Leaf analysis data confirmed that N and Mn contents in the plants were significantly low in the charcoal added treatments (Table 1). Low N status in charcoal treated plants could be attributed to the high C/N ratio of the charcoal used [4]. Readily decomposable forms of organic C present in charcoal [5] could increase demand for soil available N by microorganisms resulting the N deficiency. Increase in microbial growth due to improvements in the habitable space may be another reason for reduction in N availability in soils amended with charcoal. In our study, application of charcoal with 50% of the current fertilizer recommendation did not improve the leaf N levels compared to that in the charcoal only treatment. This suggests that N fertilizer applied was not enough to improve leaf N status when charcoal is applied at a rate of 1%.

Generally, Mn availability is not a problem in rubber growing soils in Sri Lanka due to low pH in these soils, even though the Mn concentrations are low [6]. Application of high alkaline charcoal (pH=9.55) increased the soil pH by 1.4 units immediately after charcoal addition and the soil pH was still 0.5 units higher than pH in charcoal treated soils at the end of the 8 month experiment period. Therefore, low availability in Mn after charcoal addition could expected to be due to the increase of the pH.

Interestingly, application of charcoal has improved P nutrition, in addition to K and Mg nutrition, of the plant compared to those in the soil only treatment (Table 1). K and Mg improvements could be due to the high K and Mg contents in the used charcoal. The liming effect of the charcoal which increased soil pH and completely removed exchangeable Al observed in BC amended soils even at the lowest rate (10 Mg ha^{-1}) of BC application [7]. In addition to the increases in soil pH towards neutral values, BC could influence mycorrhizal abundance and/or functioning resulting an increase in bio-available P in soils amended with biochar [8].

Conclusions

Beneficial effects of land application of BC could be realized in rubber plantations only if its agronomic effectiveness is ascertained. Results of this preliminary study using poly-bagged nursery plants of rubber revealed that application of 1% (w/w) timber mill charcoal, commercially available in Sri Lanka, has negative impact on the growth of the rubber plant. However, these effects could be attributed, at least in part, to the availability of plant nutrients, such as N and Mn, which could easily be altered by judicious application of chemical fertilizers. Therefore, further investigations on different rates and types of charcoal with different N and Mn rates are needed in order to realize the benefits of land application of BC in rubber plantations.

Acknowledgements

Technical support extended by Ms C. K. Maheepala and Mr S. Gayantha during sample analyses and statistical analysis done by Dr. Wasana Wijesooriya are gratefully acknowledged.

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[1] Yogaratnam, N.; Silva, F. P. W. 1987. *Bull. Rubb. Res. Inst. Sri Lanka. 24*:17-20.

[2] Tiessen, H.; Cuevas, E.; Chacon, P. 1994. *Nature. 371*:783–785.

[3] Lehmann, J.; Rondon, M. 2006. *In: Biological approaches to sustainable soil systems.* Uphoff N. et al. (Eds.), CRC Press, Florida. pp 517–30.

[4] Lehmann, J.; de Silva, J. P. Jr.; Steiner, C.; Nehls, T.; Zech W.; Glaser, B. 2003. *Plant Soil 249*:343–357.

[5] Deenik, J. L.; McClellan, T.; Uehara, G.; Antal, M.J. Jr.; Campbell, S. 2010. *Soil Sci. Soc. Am. J. 74*:1259–1270.

[6] Kalpage, F. S. C. P.; Silva, C. G. 1968. *Q. J. Rubb. Res. Inst. Ceylon 44*:8-15.

[7] Chan, K. Y.; Van Zwieten L.; Meszaros I.; Downie A.; Joseph, S. 2007. *Aus. J. Soil Res. 45*:629–634.

[8] Warnock, D. D.; Lehmann, J.; Kuyper, T. W.; Rillig M. C.; 2007. *Plant Soil. 300*:9–20.

Soil microbial respiration and nitrogen mineralization in a biochar-amended soil from Quebec, Canada

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Key words: *soil microbial respiration, nitrogen mineralization, temperate soil*

Introduction

The impact of biochar on soil microbial communities is poorly understood. Although biochar is not an important substrate for microbial metabolism or growth, there is evidence that biochar-amended soils support greater overall cell biomass, respiration and nitrogen cycling processes. This may be due to physical protection of microorganisms within biochar pores or retention of substrates essential for microbial growth on biochar surfaces. The objective of this study was to evaluate the response of soil microbial communities under controlled conditions in a biochar-amended soil from Quebec, Canada. The experiment was a completely randomized design with two soil types (surface soil, subsurface soil) and one biochar amendment. Soil of the St. Bernard series (pH 6.0) was cultivated for corn production in the previous two years. The surface soil (5-30 cm) was a sandy-loam with 11.6 g organic C kg^{-1}, while the subsurface soil (> 40 cm) was a sandy clay loam with about 4.0 g organic C kg^{-1}. Wood based biochar made through pyrolysis (Pyrovac) was added at rates of 0, 10, 20 and 30 g biochar kg^{-1} soil, which was equivalent to field application rates of 20, 40 and 60 tonnes ha^{-1}. Experimental units were 90 cm^3 plastic cups containing 75g soil mixed with biochar, moistened to 50% water-filled pore space, placed in covered 1 L Mason jars and incubated at 25^{o}C. Soil respiration was measured weekly and mineral nitrogen (NH_4-N and NO_3-N) concentrations were evaluated after 0, 1, 2, 4, 8, 12, 16 and 20 weeks of incubation following protocol described at Whalen *et al.*[1].

Results and Discussions

Soil respiration and N mineralization were greater in topsoil than subsoil, regardless of biochar amendment. After 8 weeks of incubation, there was significantly more soil respiration in soils amended with 40 tons and 60 tons of biochar than without biochar (Figure 1 and 2).

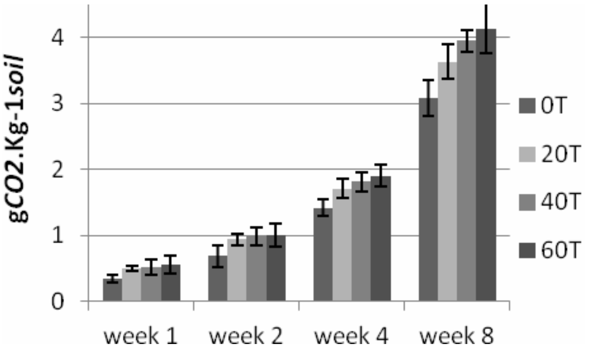

Figure 1. Respiration (gCO_2. Kg $^{-1}$ soil) detected in the topsoil treated with different amounts of biochar.

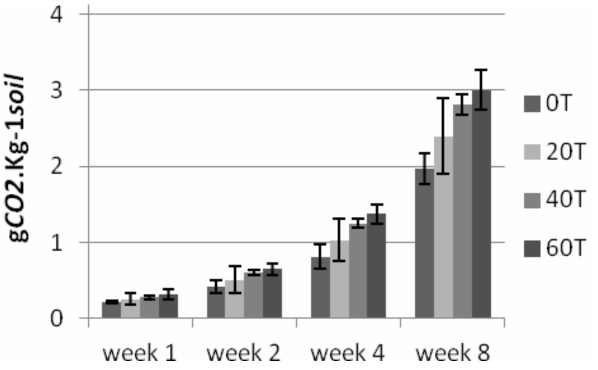

Figure 2. Respiration (gCO_2. Kg^{-1} soil) detected in the subsoil treated with different amounts of biochar.

The nitrogen mineralization was not affected by biochar amendment in both types of soils (Figure 3 and 4).

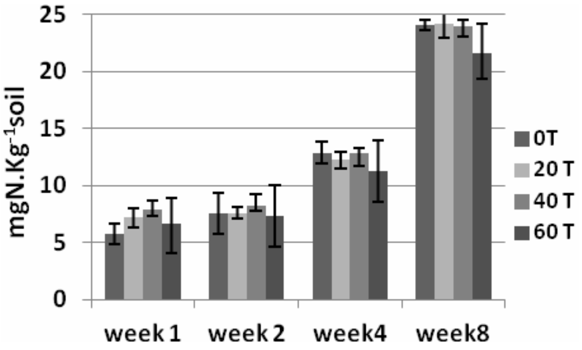

Figure 3. Nitrogen mineralization (mgN.Kg^{-1}soil) in topsoil treated with different amounts of biochar.

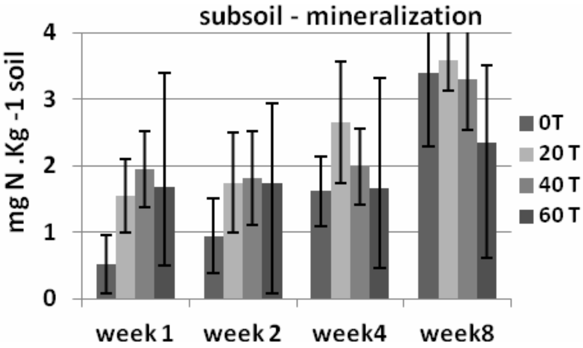

Figure 4. Nitrogen mineralization (mgN.Kg^{-1}soil) in subsoil treated with different amounts of biochar.

Conclusions

These results suggest that biochar provides a favorable habitat for microbial communities involved in decomposition while maintaining nitrogen forms required for crops. The incubation will be continued for another 12 weeks to verify the trends observed. Field trials are underway with corn, soybean and switchgrass to evaluate nitrogen availability to crops grown in temperate agroecosystems of Quebec, Canada.

Acknowledgements

Funding for this project was from a Strategic Project Grant awarded by the Natural Sciences and Engineering Research Council of Canada. Thanks to Helene Lalande for technical assistance.

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[1] Whalen J. K.; Bottomley P J.; Myrolda 2000 *Soil Biology & Biochemistry 32*, 1345-1352.

Soil characteristics of a half century old Terra Preta in Sweden

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Key words: Swedish t*erra preta, Water holding capacity, Charcoal*

Introduction

Sweden has a long history of char production. For more than thousand years, char has been used for iron production in Sweden and during World War II; wood was gasified and used to run vehicles. At some places, it was noted that char improved plant growth.

Here we present an investigation of a unique Swedish terra preta. The area is a piece of farmland situated outside Uppsala, which inhabited charcoal kilns for about a decade seventy years ago[1]. Due to residues from the kilns an area of 520 m^2 holds high concentrations of charcoal. Interestingly, adjacent to the terra preta there is an area without coal but otherwise with the same soil and with the same history of cultivation. Here we present comparing analyses of crop yield and physical soil characteristics such as density, organic content and water holding capacity from both areas. The common soil is a clay soil with a high content of organic matter and the soil is highly fertile also in its original state.

Results and Discussions

Sampling.

Two samples from the terra preta (TP1 and TP2) and two samples from the area without coal (original soil, OS1 and OS2) were taken. TP1 was close to the site were the kilns had been. Furthermore, one sample was prepared by mixing an OS-sample with charcoal (TP ref) and one by stirring an OS-sample similar to the TP ref case (OS ref).

Bulk density of dried soil.2

Samples from the terra preta area had bulk densities of 0.9 (TP1) and 1.0 (TP2) while the corresponding values from the non carbon area were 1.8 (OS1) and 1.5 (OS2). Thus, the terra preta had about 40% lower bulk density.

Soil grain size distribution.2,3

Samples heated at 600 °C were sieved and the different fractions were weighted. The result in figure 1 shows that the charcoal containing samples have a higher content of coarse grains and that the samples with the highest content of charcoal also have most coarse grains. The explanation is that the heat from the kilns sintered clay into larger particles.

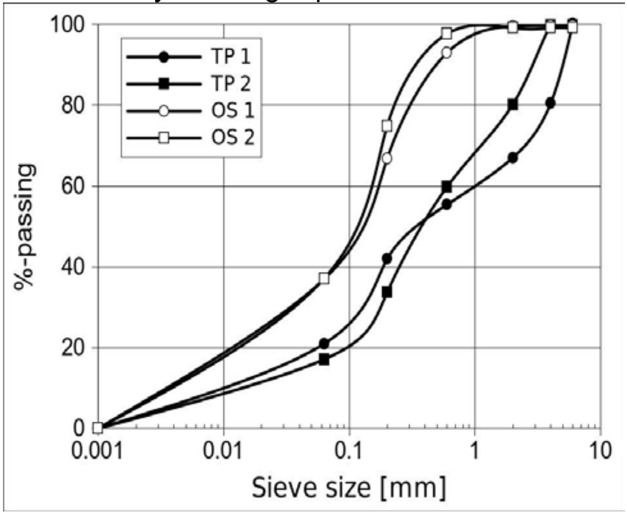

Figure 1. Soil grain size distribution.

Content of organically derived carbon matter[2]

Dried samples were weighted before and after being heated at 550 °C. Samples from the terra preta area had weight losses of 37(TP1) and 31% (TP2) while the corresponding values from the non carbon area were 9 (OS1) and 10% (OS2). Thus, the terra preta had about 25 percent units more combustible matter, which should approximately equal the content of organically derived carbon matter.

Water quota[2]

The proportions of natural water (moisture present at the sampling) were calculated. Samples from the terra preta area had quotas of 65 (TP1) and 42 (TP2) while the corresponding values from the non carbon area were 20 (OS1) and 22 (OS2).Thus, the water quotas in the terra preta were in average about 150% higher.

Water retention.

This analysis describes the capacity of a soil to hold water and the amount of the water that is accessible to plants (Fig 2).

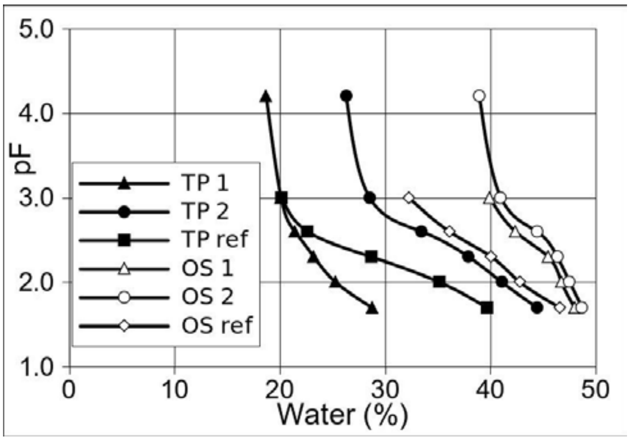

Figure 2. Water retention. Percent water left in the soil at different pressures (pF is the negative logarithmic value of drainage suction pressure expressed as cm water column). The analysis was performed at University of Copenhagen, Faculty of Life Sciences, Denmark, by Dr Carsten Pedersen.

The numbers in Table 1 was calculated using data from Figure 2. The accessible water in TP2 was about 100% higher than the values for OS, but the value for TP1, that had the highest content of combustible matter, was similar to the OS values. The reason is probable the higher content of coarse grains in TP1 (as can be seen in figure 1), that evens out the water retaining properties of the charcoal.

Table 1. Accessible water

Sample	Accessible water %
TP1	8.6
TP2	15.9
OS1	8.1
OS2	7.7
TPR*	19.5
OSR*	14.3

* TPR: terra preta reference. OSR: original soil reference.

Crop yield.

At the time of investigation, a mixture of oats and barley was grown. Plant samples of 17 one-meter long strings were taken from arbitrary selected positions at crop maturation.

The samples were dried and the total amount of above ground plant material was weighted. The crop yield analysis showed that there was no difference between the terra preta and the adjacent original area (at the 90% significance level). It should be noted however, that the variation within each group was large. It is also possible that the concomitant sintered clay evened out the positive effect that charcoal could have, via increased water retaining capacity, on crop yield.

A more elaborated crop sampling procedure is required in order to determine if there is a substantial and significant difference between the TP and OS areas with regard to crop yield.

Table 2. Crop yield statistics

	TP	OS
Crop yield mean value[a]	154	148
Standard deviation[a]	33	21
Variance coefficient[b]	21	14

[a] g.[b].%.

Conclusions

The charcoal containing soil had lower density and higher water quota. The water accessibility for plants was elevated in the *terra preta* area but not where the highest concentration of charcoal was found. This was probably due to increased content of more coarse soil particles originating from sintering processes of the clay soil. The crop yield analysis did not show a significant difference between the *terra preta* and the adjacent original area.

Acknowledgements

Research grants from MISTRA (Stiftelsen för miljöstrategisk forskning) and the EU North Sea Interregional project “Biochar - Climate saving soils” are acknowledged.

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[1] Karlsson, B. 2009. *Kolmilorna vid Länna (The charcoal kilns at Länna). Roslagsexpressen*, (3):8-9. (In Swedish).

[2] KGI. *Quaternaria, Kompendium i jordartsanalys-laboratorieanvisningar (Compendium in soil analysis – laboratory instructions).* Department of Quarternary Geology, Stockholm University, Stockholm, 2000. (In Swedish).

[3] Wiklander, L. 1976. *Marklära (Soil science).* Swedish high school of agricultural sciences. (In Swedish).

3rd International Biochar Conference
IBI 2010
Progressing from Terra Preta de Índios to the Whole World

Does biochar lower the energy required for plants to take up nutrients by changing the redox potential and the concentration gradients of nutrients in the rhizosphere

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Key words: *Biochar, Redox potential, rhizosphere*

Abstract

The energy required for plants to take in nutrients is given by the equation:

$$(1)\quad \Delta\mu = RT\ln Ci/Co + z\Delta E$$

The first term is the concentration gradient (Ci is the concentration inside the cell and Co is outside the cell) and the second term is the electrical potential difference. [2]

Biochar and biochar mineral complexes produced at low temperatures are semi-conductors. [1] They can have a high radical content [3] and have Eh and pH values that may differ to that of the soil to which it is applied. The pH of the biochar will depend on the balance of the alkalinity of the ashes relative to the acidity of the organic fraction, whereas Eh will depend on the electron density of the final product. An Eh gradient is expected to exist across a biochar transversal section, as a result of the different exposure to O_2.s. When placed in soils, the bulk and the local pH and Eh will change accordingly in response to the new conditions.

Root hairs penetrate the pores and attach to the surfaces of biochars and biochar mineral complexes. [4] These roots can exude acids that may promote the dissolution of the ash-fraction of the biochar; increasing nutrient availability. Abiotic and biotic oxidation of biochar has been reported [2], thus reflecting the electron transfers occurring at the biochar-soil interfaces.

To determine the extent to which these processes occur, a series of detailed measurements have been carried out to determine the redox potential (i) of different biochars, (ii) across a section within a high mineral-ash biochar and (iii) of soil and biochar with and without plants. The results to date indicate that high mineral-ash chars and biochar-mineral complexes do alter the local Eh and pH and reduce the energy required for nutrient uptake in the roots.

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[1] Bourke, J., Manley-Harris, M., Fushimi, C.,Dowaki, K., Nunoura,T. and Antal,M. J. (2007) 'Do all carbonized charcoals have the same chemical structure? 2. A model of the chemical structure of carbonized charcoal', Industrial Engineering and Chemical Research,vol 46, pp5954–5967.

[2] Chesworth (2008) Encyclopedia of soil science, (Springer: Netherlands) Cheng C-H, Lehmann J, Thies JE, Burton SD, Engelhard MH (2006) Oxidation of black carbon by biotic and abiotic processes. Organic Geochemistry 37(11), 1477-1488.

[3] Emmerich, FG, Rettori C, Luengo CA. 1991. ESR in heat treated carbons from the endocarp of babassu coconut. Carbon 29, 305-311.

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

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Progressing from Terra Preta de Índios to the Whole World

Agronomic and environmental implications of biochar sourcing, production and application

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Key words: *Feedstocks, Adsorptive Capacity, Aromaticity*

Introduction

It is widely accepted that biochars produced from different feedstocks and under different conditions have different physical, chemical and biological properties. However, while most studies focus on proximate and ultimate analyses of biochars, agronomic-specific (e.g. pH, cation exchange capacity, water holding capacity, adsorptive capacity and specific surface area) data need to be considered when aiming to understand the effects of biochars on soil properties and on plant growth. Similarly, when aiming to use biochar as a means for effective C sequestration, its stability and longevity cannot only be determined by its C content. More sophisticated analyses, that characterize the C structure and changes over time, are necessary. Finally, erosion of biochar away from its source of application and deposition in rivers and estuaries needs to be taken into consideration when biochar is applied to large parts of the land.

Results and Discussions

As part of our GRDC and DAFF-funded biochar projects, we have analysed over 70 biochars, derived from different feedstocks and/or produced under different temperature regimes and pyrolysis conditions. We found that while temperature controlled the ratios of fixed to volatile C, most agronomic properties varied according to feedstock and pyrolysis condition played a minor role. Even within one type of feedstock (e.g. woodwaste) there were large variations in the data, indicating that it is not only the broad feedstock groups that control biochar qualities and that a generalization across broad categories is not possible. With regard to agronomic properties, we found that biochars produced from crop residues had the highest water-holding capacity, nutrient adsorption/desorption capacity and cation exchange capacity (Figure 1).

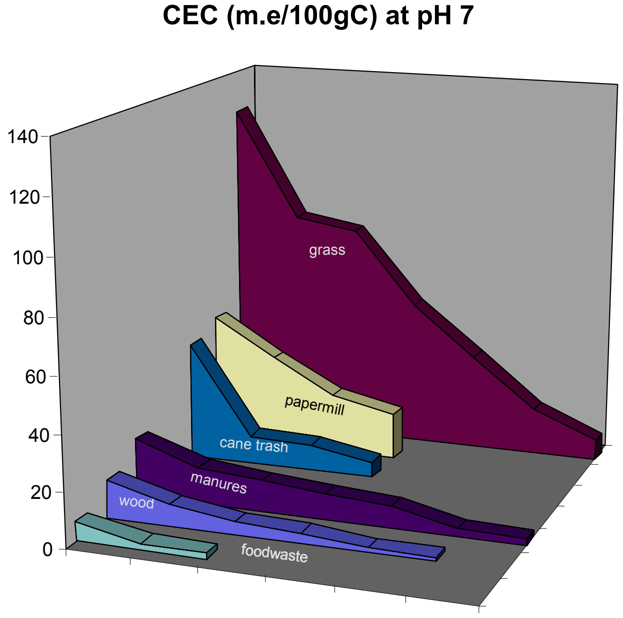

Figure 1. Cation exchange capacity of biochars produced from different materials as m.e./100gC.

Specific surface area/microporosity played a particular role in determining the water holding capacity of different biochars. However, we also found that while water-holding capacity increased in soils with increased biochar application, nutrient poor soils (acidic sand, calcareous sand) showed the greatest response compared to a ferrosol or vertisol, indicating the importance of assessing the interaction of biochars and different soil types.

With regard to the stability of biochars, published data from incubation experiments are non-conclusive with regard to agreeing on a mean residence time; however, most studies concur that biochars derived from high lignin sources are stable over centennial timescales. Due to the (perceived or real) longevity of biochar combined with relatively short funding cycles, it is impractical to assess mean turnover time through long-term field or pot experiments. ^{13}C-NMR spectroscopy provides a means to study the structure of biochars by determining the relative proportion of aryl (aromatic) structures. Unfortunately, this type of measure is only sensitive in the lower temperature range and most biochars show pure aromatic structures above 450°C. An extended NMR technique, using ^{13}C-labelled benzene, has been successfully used to gain greater information of the degree of condensation of biochars and these data are sensitive in the temperature range between 450 and 1000°C (Figure. 2).

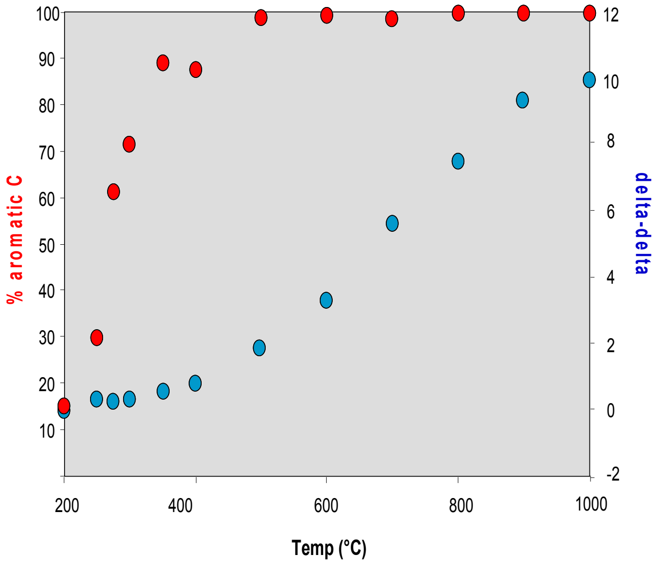

Figure 2. Comparison of %aromatic C and degree of condensation of biochars produced at different temperatures (Anna McBeath, unpubl. data).

Finally, the high stability of biochars and its particulate nature means that it has the potential to be transported analogous to sediment particles. Especially in the case of surface application of biochars, there is potential for erosion through wind and water. This scenario does not differ from the transport and erosion of natural produced chars from wildfires. However, one has to consider the ultimate areas of deposition and its implication for the associated ecosystem as well as C accounting. Krull et al. (unpubl. data) found that the charcoal content in surface sediment of several estuaries off the east coast of Australia had on average a magnitude greater charcoal content compared to the soils of the catchment area. It can be assumed that deposition of charcoal in estuarine sediments does not impart the same decomposition processes compared with soil. Hence, the mean residence time is likely to be longer. At this point in time, no studies are focused to assess the effect of charcoal deposition in estuaries from a C sequestration or ecosystem health perspective.

Conclusions

Our work shows that the variability of biochars and biochar interaction with soils is greater than anticipated. We also attempt to determine the processes that drive some of the agronomic properties (e.g. microporosity and water holding capacity) and what analytical tools exist to assess the stability of biochars.

Acknowledgements

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Biochar properties and environmental behavior

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Key words: *Crop growth, Nutrient leaching, Pyrolysis*

Introduction

Biochar properties vary significantly with the type of feedstock used under different production conditions [1]. It is less clear what effect those differences have on environmental behavior of biochars, such as persistence in soil, nutrient retention, water retention, or nitrous oxide emissions from soil. In a series of experiments, we tested the effects of both the pyrolysis temperature and feedstock type on a range of effects including plant growth and nutrient uptake. We attempted to characterize the biochars using spectroscopic techniques as well as by less expensive and more rapid tests to predict environmental behavior.

Results and Discussions

Between 300°C and 600°C, environmental behavior largely improved with greater charring temperature. Stability against microbial mineralization generally increased at higher temperature, even though this increase was more pronounced for the more labile biochars made from maize stalks than those made from oak wood. Nitrous oxide emissions were larger than the unamended control for high-N containing feedstocks such as poultry manure, pyrolysed at 300°C. However, increasing the pyrolysis temperature to 600°C decreased N availability in the biochar, and nitrous oxide emissions almost completely disappeared. Similar effects of pyrolysis temperature on N leaching were observed with the same set of biochars. The ability of soil to retain plant available soil water more than doubled with 7% added maize biochar pyrolysed at 600°C, but hardly increased when maize stalks were charred at 300°C. Biochar produced from food waste significant decreased maize growth in a greenhouse experiment when pyrolysed at 300°C. This negative effect largely disappeared when food waste was pyrolysed at 600°C. Detrimental effects of biochars were largely a result of Na contents, and apparent only at high application rates of 2-7% (Figure 1).

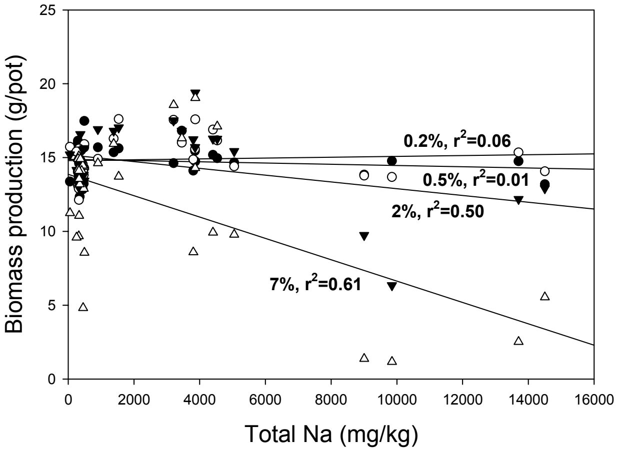

Figure 1. Relationship between total Na and biomass production in a greenhouse experiment after additions of biochars with greatly varying properties to a loamy soil from Upstate New York.

Conclusions

These results indicate that environmental behavior of biochars may be significantly influenced by production conditions, even in situations where feedstock properties can not be varied.

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[1] Lehmann, J. 2007. Frontiers in Ecol. Env. 5: 381-387.

The effect of biochar soil-carbon stabilization in a highly SOM-depleted soil

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Key words: *Eucalyptus charcoal, Maize, delta-^{13}C*

Introduction

Biochar may be an important strategy to store stable carbon in soils, but the impact on the dynamics of other carbon entering soil has not been established. Important issues are still open about how biochar modified the soil organic matter stability and recalcitrance. This study aimed to follow the inputs and dynamics of organic C added into an amended soil profile by maize, and $^{13}C/^{12}C$ isotopic ratio monitored monthly during a cropping cycle. The hypothesis was that the presence of biochar would accelerate the accumulation of plant-derived organic matter in soil initially low in carbon. Plots of 3.5m x 6m size were established in five randomized block design with four treatments: biochar and maize; biochar fallow (no maize); unamended fallow; and unamended maize. Charcoal fines from Brazil were used as biochar and a soil highly depleted in organic matter due to long term bare fallow management (Woburn Experimental Farm, Rothamsted Research, UK). The fines were applied at 30 Mg per ha (dry mass), equivalent of 20.5 Mg C per ha and 153 Kg N per ha incorporated to 15 cm. Soil samples were taken monthly from 0 to 25 cm depth from April to October 2009.

Results and Discussions

After 141 days total soil C with biochar was in average 2.7 times higher (10.4 mg C/g) than plots without biochar. There was no difference in soil ammonium concentration in all plots, but fallow plots with and without biochar displayed higher nitrate than plots with maize. No differences were found at pH, $CaCO_3$, total N and inorganic C. Plots with biochar had biomass average (33.66 t ha^{-1}) 17% higher than plots unamended (28.76 t ha^{-1}). As for the isotopic ratio in the whole soil sample at 0 to 25 cm (Figure 1), plots unamended maize showed the higher Delta ^{13}C average (-26.57‰) during the maize cycle. Plots with biochar and maize show δ ^{13}C average of -28.38‰ and plots amended fallow of -28.01‰. Plots unamended fallow show a intermediary value (-27.47‰). At the subsoil, from 25 to 50 cm, the differences between δ ^{13}C averages were smaller but again the highest value was found at plots unamended maize (-27.87‰) and lowest value at plots amended fallow (-28.31‰). Plots unamended fallow show δ ^{13}C average of -27.91‰.

These results indicate that biochar presence could be distinguished from MO from C4 plants. Data from δ ^{13}C of organic fractions are been processed to ascertain the origins of the additional carbon in amended plots.

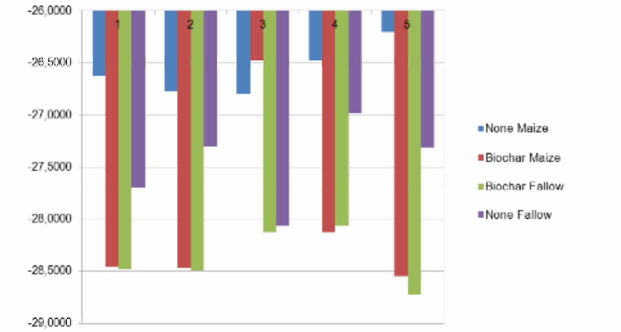

Figure 1. Isotopic ratio variation (δ C^{13}) in soil at 0 to 25 cm depth during the first maize cycle (2009).

Conclusions

In Brazil, up to 1 Mt of charcoal fines arises as a by-product of charcoal production from sustainable plantation forest. This material appears to impacts on the dynamics of carbon cycling in the soil, and this may be used or manipulated for commercial agronomic gain, as well as carbon sequestration.

Acknowledgements

This study was supported by Rothamsted Research, UK and Embrapa and the Ministry of Agriculture of Brazil.

Effect of Biochar (oil palm chaff Charcoal) application on some agronomic characters of cocoyam (*Xanthosoma* spp.) - *A pilot project to improve marginal soils through biochar application*

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Key words: *Biochar, Cocoyam*

Introduction

Cocoyam (*Xanthosoma spp*), commonly called 'makabo', is an important staple food stuff in Cameroon. It is a crop that grows on a wide variety of soil with high economic importance, as its leaves, comels and combs are converted to a variety of local dishes.[1,2,3,5]

The crop strives well in the savanna and forest region of Cameroon. It cultivation techniques and periods of planting vary among these areas.[4,6]

The objective of this study was to investigate the potential of biochar (oil palm chaff charcoal) application on some agronomic characters of cocoyam (*Xanthosoma spp)*

An on farm trial was made during the farming season of the South West Region of Cameroon to investigate the potential of biochar (oil palm charcoal) application on some agronomic characters of cocoyam (*Xanthosoma spp*). The experiment use only one level of biochar 0.5 kg/mount/stand at planting. Character studied included number of functional leaves, comb size, plant vigor, and size of basal leaves.

Results

Functional leaves: From the physical counts of the leaves it shows that there were more 4-6 functional leaves on the experiment compare to 2-3 leaves on the control.

Comb size: Combs were larger 1-2 kgs compare to 0.5-1kg on the control plot.

Plant vigor*:* Plants on the experimental plot were growing very luxuriantly even in the dry season (more vegetative growth) compare to the control where only the innermost leaf was surviving.

Size of basal leaves: Leaves where very large in surface area compare to very small leave size in the control plot.

Discussions

Application of biochar to cocoyam (*Xanthosoma* spp) shows that cocoyam responds well to biochar application with the result of promoting more vegetative growth which is an indicator (more functional leaves, vigorous plant, larger basal leaves and larger combs) for higher crop yields.

Conclusions

The results of this study showed that biochar (oil palm chaff charcoal) had significant effects on some agronomic characters studied e.g. functional leaves, comb size, plant vigor and size of basal leaves.

From the foregoing it can be concluded that biochar (oil palm chaff charcoal) be applied to increase yield. However, more work need to be carried out on other crops, different time of planting and different levels of biochar.

Acknowledgements

Thanks to all the biochar promoters and supporters who contributed in one way or the other for the success of this work.

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[1] Mbanaso et al. In: *Cocoyam Programme of the National Root Crop Research Institute*, Umudike, Nigeria

[2] Onwueme, I.C. (1978). *The tropical tuber crops*. John Wiley and Sons, New York, USA, p 234

[3] Purseglove, J.W.(1972). *Tropical crops, Monocotyledons.* I. London, Longman, p 333

[4] Raemaekers, R. (2001). *Crop production in tropical Africa*. Directorate General for International Co-operation, Belgium, p 1539.

[5] Reyes,C,G. (2006). *Studies on cocoyam* (Xanthosoma *spp.) in Nicaragua, with emphasis on Dasheen mosaic virus.* Doctoral thesis, Swedish University of Agricultural Sciences, Uppsala.

[6] www.cocoyam.org

Method to evaluate the long-term soil improving effect of biochar

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Key words: *15-N, Long-term effect*

Introduction

In Belgium soil fertility is threatened by declining organic carbon content. This is caused by increasing plowing depth, less plowing in of crop residues and the strict manure decree. Reverting the trend of decreasing carbon contents requires innovative and sustainable solutions. Biochar could provide a possible answer to this challenge. Evidence exists that addition of biochar to the soil results in higher crop yields, but this has only been proven for a small number of soil/crop combinations and mainly in tropical soils. More research is needed in temperate regions such as Belgium in order to assess potential advantages of biochar for European agriculture. Moreover, most of the pot trials designed to assess the soil improving effect of biochar and the resulting crop response do not allow distinguishing between short- and long-term effects. It can be expected that there is a short term effect of biochar caused by the nutrients present in biochar and by its labile carbon fraction, which could cause the observed nitrogen immobilization on the short term [1] due to a high C/N ratio.

The objective of our study is twofold:

1. To study the effect of two biochar types on the N-cycle in short- and long-term;
2. To develop a protocol to test if a given biochar type works as a soil improver in the long-term.

In this abstract, an overview is given of the material and methods to reach this objective.

The two biochartypes used are produced during pyrolysis (horizontal screw reactor) of silage maize at 350°C and 550°C. These temperatures are chosen in order to study a biochar type with a high and one with a low labile carbon fraction. Residence time was 30 minutes.

The size of the labile carbon fraction will be determined by means of incubating biochar with quartz sand with and without microbial inoculation, while measuring headspace CO_2 by means of gas chromatography (GC-TCD). In this way, biotic and abiotic carbon mineralization can be distinguished.

The presence of a labile carbon fraction in fresh biochar can cause biotic N immobilization, through which a different effect from biochar in the short- and the long-term can be expected. To determine if biochar causes biotic and/or abiotic nitrogen immobilization and/or delayed mineralization, a ^{15}N tracing experiment is conducted. Pool specific N transformation rates will be simulated [2, 3]. To obtain insight in the effect of biochar on the N-cycle in the long-term, the same experiments will be repeated after incubation of the same soil and biochar under field circumstances during one year. It is expected that in the short-term, both biotic and abiotic nitrogen immobilization will occur, while in the longer term, the labile carbon fraction will be mineralized and only abiotic immobilization occurs. If the effect of biochar on the N-cycle differs in the short- and the long-term because of the presence of a labile carbon fraction, this fraction should be removed before the soil improving effect of biochar in the long term can be assessed correctly. Therefore, it is tested whether this fraction can be reduced in a fast way without changing the structural biochar characteristics.

A second condition to test the long-term effect of biochar in the soil is removing its accompanying nutrients to avoid that an improved crop response due to biochar addition is caused by the presence of nutrients (fertilizer effect). A leaching method is therefore tested to reduce the nutrient content of biochar.

When the labile carbon fraction and the nutrient content of biochar is reduced, the biological recalcitrant carbon fraction remains and its long-term soil improving effect can be studied when mixing the modified biochar with soil in a pot-experiment.

Acknowledgements

This work is financially supported by the Interreg IVB North Sea project biochar: climate saving soils.

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[1] Ryckaert, B. 2009. Biochar, koolstofsekwestratie gecombineerd met een bodemverbeterende werking. Masterproef voorgedragen tot het behalen van de graad van Bio-ingenieur in de Landbouwkunde, UGent, Faculteit Bio-ingenieurswetenschappen, Labmet. 105p.

[2] Müller, C.; Rütting, T.; Kattge J.; Laughlin, R.J.; Stevens, R.J. 2007. *Soil Biol. Biochem. 39*:715-726.

[3] Huygens, D.; Rütting, T.; Boeckx, P.; Van Cleemput, O.; Godoy, R.; Müller, C. 2007. *SoilBiol. Biochem. 39*:2448-2458.

The effect of biochar on the transpiration rate response of upland rice to water deficit

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Key words: *Oryza sativa, FTSW, charcoal*

Introduction

Upland rice in the Brazilian cerrado (savanna) experiences multiple abiotic stresses. One of the main risk factors contributing to the heterogeneity of plantations is variable water availability. In this region upland rice growers are mostly small and family based holdings, associated with low inputs and effectively shallow fertile soil layers that enhance drought effects. Biochar might be a promising alternative to diminish this uncertainty in upland rice production. The pore size distribution in biochar added to the soil may have a direct impact on soil pore structure at the macroscale, suggesting that in the longer term the effect of biochar on available moisture would be positive in sandy soils ordinarily dominated by much larger pores than present in biochar. The objective of this study was to evaluate the effect of eucalypt (*Eucaliptus sp.*) charcoal fines, a byproduct of charcoal production, on the transpiration rate of upland rice (*Oryza sativa* cv. Curinga) as a function of water deficit, a measure that expresses the response of plants to drought stress. Two greenhouse experiments, at different dates, were installed. The experimental design was completely randomized with subdivided "plots", the main factor being the presence or not of water deficit and the sub-factor charcoal amendments (doses) added to the basic substrate (sand) (T1: 0%, T2: 6%, T3: 12% e T4: 24% charcoal). The charcoal was ground to pass a 2 mm sieve. To describe water deficit the water transpiration from soil (FTSW) and transpiration rate (TR) were calculated. The daily TR was normalised using control (no water deficit) data to receive the normalised transpiration rate (NTR). The NTR and FTSW values were combined using a non linear model (equation 1) to get the response curve.

$$NTR = \frac{1}{\left(1 + a * \exp(-b * FTSW\right)} \qquad \text{eq. 1}$$

Being *a* and *b* model empirical parameters.

Results and Discussions

The empirical *a* and *b* parameters determined in equation (1) for the 4 treatments are showed In Table 1.

Table 1. Empirical a and b model parameters for treatments T1, T2, T3 and T4, for cultivar BRSMG Curinga.

Treatments	a	b
T1	1.54*	6.35*
T2	1.85*	7.87*
T3	3.31*	12.38*
T4	3.87*	12.77*

* = significant to 5% of probability level.

The adjusted model (equation 1) for treatments T1, T2, T3 and T4 are presented in Figure 1 a, b, c and d. Basically, increasing the biochar levels has an effect on the BRSMG Curinga transpiration response curve. This effect is related with the available soil water. Many studies have been related that at the highest potential the volumetric water content was double that of soil without biochar added [1,2]. In this study it was observed that the increase of biochar levels was responsible for an increase of available soil water as illustrated by Figure 2.

Conclusions

The biochar had a positive effect on plant transpiration.

The increase in the proportion of biochar occurred greater availability of water in different treatments.

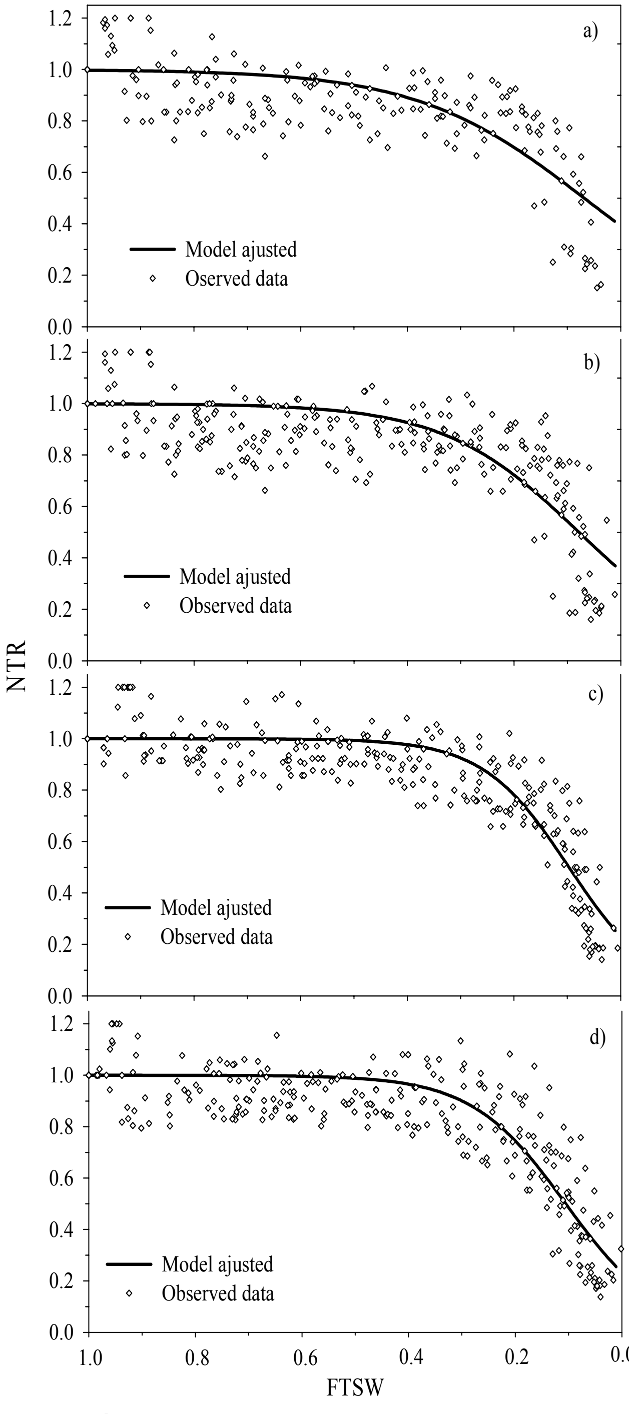

Figure 1. Relationship between the normalized transpiration rate (NTR) and the fraction of transpirable soil water (FTSW) for treatments a) T1 (0% of biochar), b) T2 (6% of biochar), c) T3 (12% of biochar) and d) T4 (24% of biochar) for BRSMGCuringa cultivar.

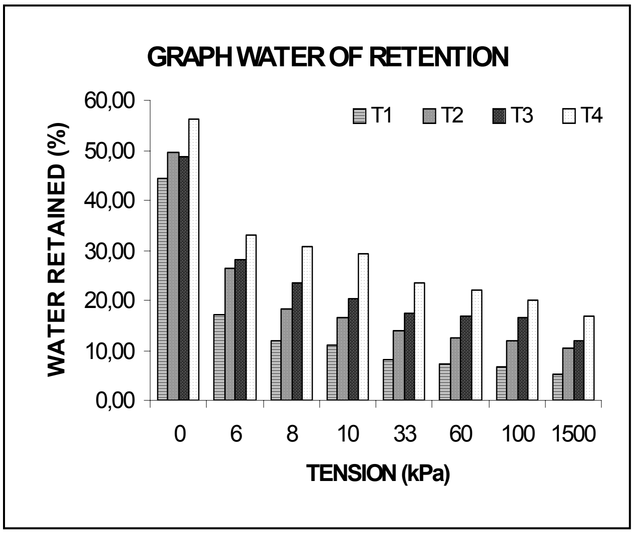

Figure 2. Graph water retention in treatments a) T1 (0% of biochar), b) T2 (6% of biochar), c) T3 (12% of biochar) and d) T4 (24% of biochar).

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[1] Gaskin, J. W., Speir, A., Morris, L. M., Ogden, L., Harris, K., Lee, D., and Das, K. C. Potential for pyrolysis char to affect soil moisture and nutrient status of loamy sand soil. In *"Georgia Water Resources Conference"*, University of Georgia, 2007.

[2] Sohi, S. P., Krull, E., E. Lopez-Capel, E., and Bol, R. A Review of Biochar and Its Use and Function in Soil, in *Advances in Agronomy*, Vol. 105 Chapter 2, P 48- 76, 2010.

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A Demonstration of Biochar Farming at the North Carolina Farm Center

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Key words: *Crops*, *Growth*, *Indicators*

Background

Farmers around the world are strongly motivated to use biochar because of its potential to improve soils, increase water retention and accelerate crop productivity. Yet, there are very few models suggesting how a biochar farming system may work. A first step towards understanding how farmers and agricultural operations may be better equipped to capture the benefits of biochar is to demonstrate the workings of a more comprehensive biochar farming enterprise within the context of a working farm.

The NC Farm Center is developing a comprehensive biochar farming management approach by utilizing on-farm agricultural residues for feedstocks to produce and apply biochar on-site. The idea is to gain more knowledge of what a working biochar farming operation looks like, including cost-benefits of mobile biochar production and indicators of improving soil quality and increasing agricultural productivity. The Center's biochar project is supported by a 2009 three-year USDA/NRCS Conservation Innovation grant and located on its farm in southeastern North Carolina.

Discussion

The project evaluates the impacts of biochar added to soil for cultivating traditional rotational row crops in North Carolina- winter wheat, soybeans, cotton and corn. Crop yield, plant tissue and mass density growth indicators are developed to examine general productivity characteristics associated with biochar. While field trails are important to gather information about changes in soil quality that positively affect increases in crop yields, other data is recorded to assess biochar's affects to retain moisture in light of the Farm Center's marginal sandy soil types. Applications of the farm's biochar use levels of 2.25, 4.5 and 6.75 tons per acre on two different field trial sites over the course of three years. Biochar is evaluated as a standalone soil amendment and as a blended amendment mix with poultry litter and swine manure compost. The Farm Center has signed a Cooperative Agreement with the USDA/ARS Coastal Soil Center to add a more scientific approach to analyzing soil moisture relationships to biochar.

The mobile Pyrolysis unit-BEC1000 is used on the farm to produce biochar, and care is taken to apply the best sustainable biomass harvesting techniques by incorporating conservation wildlife corridors as the source of much of the pinewood feedstocks.

Preliminary Results

Early findings point to a positive growth affect by adding biochar. Winter wheat planted in no till fashion at the mid-point of maturation, when measured by average plant density (g/0.5m2) indicated a 36% higher mass rate with biochar compared to the control plots.

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Soil biochar application: first experiences in North Italy with gasification plants product

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Key words: *Biochar, Soil, Gasification*

Introduction

Soil biochar application is often reported as a technique able to increase agricultural productivity, but variability in charcoal characteristics (depending mainly on feedstock type and process conditions) is generally high and moreover it is not clear yet under what kind of soil and climatic conditions, besides plant species, high or low yields can be expected [1].

The knowledge is even more limited for temperate climates; in fact, most researches derive from tropical and savannah lands [2].

In order to better understand the soil dynamics and the growing effects of the biochar amendment, in the year 2009, c/o the Minoprio Foundation (Vertemate con Minoprio – Como – North Italy), some field and laboratory activities were carried out with the aim to investigate the fine-grained, highly porous charcoal co-produced from gasification process in a fixed-bed, down-draft, open core, innovative gasifiers of small size (300 kW electric power unit).

Biochar was obtained from two different kind of fuel biomass, poplar wood from short rotation forestry and conifer wood from forest management.

The materials, produced in two different plants, showed different moisture content, since the poplar charcoal was originally wet to prevent fire hazards. This treatment has ensured an easer soil application especially with relation to the dust lack.

Poplar charcoal showed higher conductivity and ash content; conifer charcoal had higher pH, contained more than 10% more of total organic carbon and its particle size distribution was wider than poplar charcoal.

Undisturbed native topsoil (silty-loam, acid, organic matter normal content) was mixed with the two different types of biochar at the same dose per hectare (130 Mg dry matter) and it was sown with maize (*Zea mais* L.). The experimental plant consisted of three treatments (control, poplar and conifer biochar) in triplicate replication each, therefore nine randomized plots; a 10 by 4 meter unit size was used.

At corn silage maturity crop productivity was measured by recording fresh and dry matter data; moreover soil samples (0-30 cm) were analyzed in laboratory with the aim to investigate the main physical, chemical and biochemical [3] parameters, the latter able to assess the microbial biomass and understand its vitality.

Dried production and laboratory results were evaluated by analysis of variance (ANOVA) and mean separation was done using Duncan test (P=95%).

Results and Discussions

The corn productivity increased in the plot conditioned with biochar, especially with the one from conifer, but only in absolute value and not statistically.

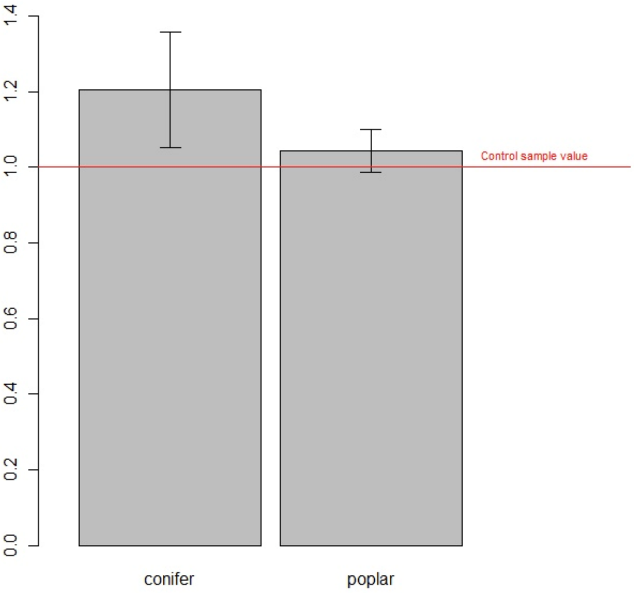

Figure 1. Corn production index

The laboratory tests showed a moderate reduction of acidity in the carbon-soil, a high improvement in organic carbon (total carbon analysis with C/N analyzer), soil exchange capacity (CEC) and soil macro porosity (mainly with conifer biochar) (Table 1).

The biochemical data, recorded after only five months of biochar application, did not score a sudden change of the soil microbial life, but certainly they showed an alteration of the system and a gradual change is expected.

Table 1. Main laboratory results*

Parameter	Control		Conifer		Poplar	
pH (H_2O)	6,4	a	6,9	ab	7,3	b
pH ($CaCl_2$)	5,7	a	6,3	ab	6,6	b
TOC (g kg^{-1})	16,6	a	55,7	b	40,6	b
OC$_{(C/N\ Analyzer)}$ (g kg^{-1})	14	a	59	b	39	b
OC$_{(Walkley\text{-}Black)}$ (g kg^{-1})	14	a	16	a	17	a
N$_{(C/N\ Analyzer)}$ (g kg^{-1})	1,5	a	1,5	a	1,8	b
C/N$_{(C/N\ Analyzer)}$	9,7	a	38,4	c	21,1	b
C.E.C. $_{(BaCl2)}$ (cmol$_c$ kg^{-1})	15,6	a	17,0	b	16,6	ab
Ca$_{(Exchangeable)}$ (cmol$_c$ kg^{-1})	4,1	a	4,7	ab	6,0	b
Mg$_{(Exchangeable)}$ (cmol$_c$ kg^{-1})	0,6	a	0,5	a	0,7	a
K$_{(Exchangeable)}$ (cmol$_c$ kg^{-1})	0,4	a	0,6	ab	0,8	b
Na$_{(Exchangeable)}$ (cmol$_c$ kg^{-1})	<0,1	a	0,1	ab	0,1	b
Basic cation saturation ratio (%)	32	a	34	a	46	b
Mg/K ratio	1,4	b	0,9	a	1,0	ab
ESP$_{(Exchangeable\ Sodium\ Percentage)}$ (%)	0,1	a	0,5	ab	0,9	b
P$_2$O$_{5(Assimilable\ –\ Olsen\ method)}$ (mg kg^{-1})	210,0	a	213,0	a	232,0	a
Salinity$_{(1:5)}$ (mS cm^{-1})	<0,1	a	<0,1	a	0,1	b
Microbial biomass carbon[a] (ppm C)	83,4	a	77,2	a	81,0	a
Basal respiration[b] (ppm C-CO$_2$)	6,3	a	8,9	a	9,8	a
Cumulative respiration[c](ppmC-CO$_2$)	246,0	a	287,0	a	284,0	a
Metabolic quotient[d] (% h)	0,3	a	0,5	a	0,6	a
Mineralization quotient[e] (%)	1,5	b	0,5	a	0,8	a
Dry bulk density (g l^{-1})	1,3	a	1,1	a	1,1	a
Water retention at 1,5 pF (%)	36,2	a	44,0	a	42,7	a
Capillary porosity (%)	45,8	a	46,8	a	48,1	a
Macro porosity (%)	4,0	a	11,3	b	4,2	a

*For each line the values marked by the same letter are not statistically different.

[a] Microbial biomass carbon estimates the content of microbial biomass in the soil.

[b] Basal respiration describes the activity in standard laboratory conditions.

[c] Cumulative respiration estimates the mineralization speed of the labile fraction of organic matter.

[d] Metabolic quotient (b)/a) ratio) considers the metabolic efficiency of active microorganisms.

[e] Mineralization quotient (c)/TOC ratio) gives information about organic matter labile fraction mineralization by microorganisms activity.

Conclusions

The soil application of biochar resulting from gasification process for bioenergy production is an interesting agricultural practice, thanks to the characteristics of the contained organic matter.

The charcoal production in small size gasifiers for electric micro generation enables to solve both problems of product availability and practice profitability. In fact, the diffusion of biochar soil application requires a good supply with moderate costs.

The aim is to improve global fertility and crop productivity also by restoring degraded land after intensive agriculture and helping the farmer profitability, without forgetting C sequestration from the atmosphere.

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[1] Lehmann, J.; Rondon, M. 2006. *Bio-char soil management on highly weathered soils in the humid tropics,* in N. Uphoff (ed) *Biological Approaches to Sustainable Soil Systems*, CRC Press, Boca Raton, FL, 517-530

[2] Blackwell, P.; Riethmuller, G.; Collins, M. 2009. *Biochar Application to Soil*, in *Biochar for Environmental Management – Science and Technology*, Earthscan, London, UK, 207-226

[3] Bloem, J.; Hopkins, D.W.; Benedetti, A. 2006. *Microbiological Methods for Assessing Soil Quality*, CABI Publishing, Wallingford, UK

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Biochar Super Gardens

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Key words: *Super Gardens*, *Biochar*

Introduction

Micro-scale agriculture, i.e. gardening, is a central activity of billions rural households in developing countries whose daily food supply depends for the most part on their own production. The rampant poverty and malnutrition experienced by these communities is dramatic evidence that despite their effort and hard work, most of them fall short of covering the needs of their whole family. National and international organizations and authorities usually address these issues on a large scale by following a top-down approach and conducting large and ambitious development programs with little if no impact on the individual farmers.

It seems however obvious that a bottom-up approach is unavoidable in order to reduce in the long run the poverty of rural households and communities and to increase their self-sustainability while protecting their environment and natural resources. In this paper, we present Biochar Super-Gardens (BSGs), a new concept developed by Pro-Natura International and JTS Seeds and already successfully implemented in several developing countries all over the world.

Biochar Super Gardens

JTS Seeds, a social business focused on GMO-free agronomical research since the mid-nineties, has developed the innovative, ecological and highly productive Improved Tropical Garden (ITG). Initially conceived for African drylands, this enriched garden combines the most efficient agricultural strategies from seed selection to irrigation and pest control in order to reach the highest productivity while selecting exclusively green practices harmless to the environment and ensuring the long-term sustainability of the garden.

Pro-Natura, on the other hand, is an NGO which has developed an innovative pyrolyzer using renewable biomass for the production of *green charcoal*, which can be used as domestic fuel in place of charcoal or as biochar. The efficiency of Pro-Natura's biochar has already been confirmed by several field trials in Africa showing a significant increase of the yields of crops grown on soil amended with biochar in combination with organic fertiliser, compared to crops grown on a normal soil.

The BSG project results from a partnership between JTS Seeds and Pro-Natura, aiming at combining their experience and expertise to develop ITGs on soils amended with Pro-Natura's biochar. With its remarkable capacity to retain water and nutrients and improve the overall soil quality, biochar fits indeed perfectly with the other agricultural practices developed in ITGs. Adding biochar fosters the action of fertilizers as well as the water retention capacity of the soil, which leads to a yield increase as well as a reduction of the costs of water and other inputs, since their required quantity is significantly reduced compared to traditional gardens.

The resulting garden, called BSG, has the potential to yield vegetables sufficient for 10 people all year long on a surface area of 60 m^2 in a developing country, with minimum cost, work and training. Indeed, BSGs only require low-tech material affordable by the target communities, and maintaining them only requires about two hours work per day. This leaves plenty of time for other activities such as education of the children or generation of additional income, which are usually sacrificed on the behalf of food production. The initial setup of BSGs is also facilitated by its distribution in form of a kit that includes all the required material for its setup. This kit, sold at low price, is complemented by training and support provided directly to rural communities by experienced trainers.

BSGs have already been successfully implemented in Senegal, Niger, Algeria and Egypt, and similar projects are planned in Morocco, Mali, Brazil and Haiti in the near future. The demand and potential for development are tremendous, since the cost and work for the setup and maintenance of these gardens are completely and very quickly compensated by the benefits obtained by the farmers, who become self-sustaining after only a few months. The first results confirm the expectations and show a remarkable yield increase compared to a traditional gardens.

Besides facilitating the development and dissemination of BSGs, Pro-Natura is also concerned with the evaluation of the amount of carbon stored in the soil in the form of biochar, whose accuracy and reliability are key prerequisites to any official acceptance of biochar as valid methodology for GHG emission reduction (as carbon sink). A global monitoring strategy of BSGs is therefore being developed by Pro-Natura, which consists in maintaining an up-to-date database of all operational BSGs with static information (location, target community, etc.) as well as dynamic data (crops currently in cultivation, yield results, etc.) regularly updated by the owner of the BSG or an intermediary entity (NGO, co-operative etc.) in close relation with the farmers maintaining the BSG. Part of the collected data is made available in the public domain on a website showing a dynamic map of the implemented BSGs all over the world and their related information and pictures.

Conclusion

In the future, Pro-Natura aims at developing further this dual approach: promoting the implementation of new BSGs in developing countries on the one hand, and monitoring the network of existing BSGs on the other hand, in order to keep track in a transparent way of the global impact of biochar in the world and see its evolution. We believe that partnerships with other key actors in the biochar community supporting this approach could eventually lead to a new consideration of the biochar strategy by the decision makers in the climate change authorities, and thus eventually open new opportunities for the development of projects in developing countries.

Figure 1. Installation of a Biochar Super Garden (1).

Figure 2. Installation of a Biochar Super Garden (2).

Figure 3. Biochar Super Garden in Niger.

Effect of different level of charcoal powder in the vegetative growing of feijão Caupi

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Key words: *biochar, Oxisol, cowpea*

Introduction

The biochar, principal component of the organic matter in the Amazon Dark earth is formed by organic compost with high resistence to the decomposition [1], In addition it has a functional group able to retain water and adsorb organic substances, decreasing nutrient loose by leaching contributing to the increase of CEC and soil structure by interaction with soil mineral matrix [2,3]. Aiming to evaluate the effect of different level of charcoal powder (0, 100, 200 e 300 T ha^{-1}) plus 3,0 T ha^{-1} and 0 T ha^{-1} of pure chicken manure, was carried out a trial following a completely randomized design in the factorial (4x2), totalizing eight treatment and five replication. The soil was Distrofic Yellow Oxisol and before the treatment application the soil received 2 t ha^{-1} of dolomitic lime. The species was Cow pea (*Vigna unguiculata L.*).

Results and Discussions

The table 1 is showing that treatment 8 (300 T ha^{-1} of charcoal powder in the presence of chicken manure was who showed the higher dry matter stem production (6,18g), with six time high then control plot. The slower value of pH$_{(H2O)}$ was observed in the control plot (5,5) and the higher value was determined in the treatment 7 that received 200 T ha^{-1} of charcoal powder plus 3 T ha^{-1} of pure chicken manure, with pH$_{(H20)}$ value of 6,2. The exchangeable aluminium in all treatment presented level considered low, with exception for treatment 8 that stayed on superior limit of the line considered average. The exchangeable bases potassium, calcium and magnesium showed values below the average.

Table 1. Average values of the soil chimistry atributes determined after the experiment harvested.

Treat.	Level (t ha^{-1})		pH		Ca^{++}		Mg^{++}	K^{+}	Al^{+++}		Fe	Zn	Mn
	Charcoal	Chicken manure	H_2O				cmolc kg^{-1}					mg kg^{-1}	
T1	0	0	5,5	b	0,54	c	0,35	0,11	0,18	b	392,6	4,64	3,8
T2	100	0	6	ab	0,96	ab	0,53	0,33	0,17	b	384,4	5,66	6,84
T3	200	0	6,1	ab	0,99	ab	0,42	0,37	0,09	b	350,2	5,3	5,82
T4	300	0	5,9	ab	0,74	c	0,57	0,39	0,33	ab	384,8	5,02	5,66
T5	0	3	5,8	b	0,9	c	0,4	0,2	0,24	b	360,4	4,84	4,88
T6	100	3	5,8	ab	0,9	c	0,45	0,36	0,23	b	381	5,06	6,06
T7	200	3	6,2	a	1,24	bc	0,6	0,35	0,27	ab	390,8	5,6	6,82
T8	300	3	5,7	ab	0,78	c	0,46	0,29	0,99	ab	382,4	3,88	4,66

*Average following by the same letter in the colum no differ by Tukey test (5%) of probability.

The results showed that treatment 8 (300 T há$^{-1}$ of the charcoal powder with chicken manure) was who presented the higher stem dry matter production (6,18g), equivalent six time the control plot. Considering the cost and benefit rate in term of improve the plant growing and soil chemistry properties the treatment three can be considered the treatment in who showed the best response to addition charcoal powder.

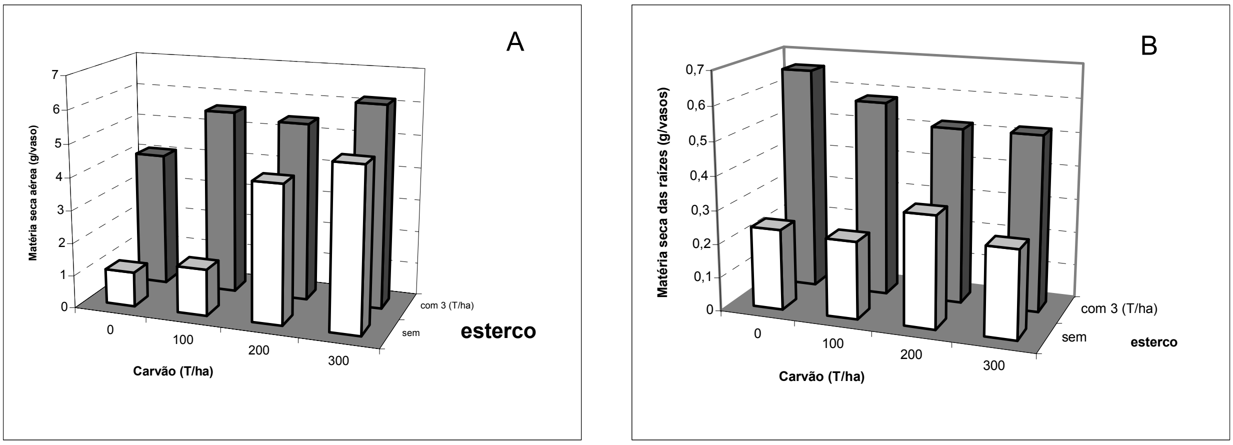

Figure 1. Stem dry matter production (A), and root dry matter (B) of cow pea as a function of different level of charcoal powder (0; 100; 200 e 300 T/ha) with and no chicken manure applied (0 e 3 T ha^{-1}).

Conclusions

The treatment eight (300 t ha^{-1} of charcoal powder and 3 t $há^{-1}$ of chicken manure) allowed the higher stem dry matter production;

The root dry matter production was lower in the treatment that received the higher level of charcoal powder.

Acknowledgements

The autor wish to thanks to the logistic and financial sponsor of the INPA – FAPEAM.

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[1] Glaser, B.; Haumaier, L.; Guggenberger, G.; Zech, W. 1998. Black carbon in soils: the use of benzenecarboxylic acids as specific markers. Organic Geochemestry, 29: 811-819.

[2] Glaser, B.; Lehmann, J.; Zech, W. 2002. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal – a review. Biol. Fert. Soils, 35: 219-230.

[3] Steiner, C.; Teixeira W.G.; Zech, W. 2004. Slash and Char: An Alternative To Slash and Burn Praticed In The Amazon Basin. In: Glaser, B.; Woods, W. (Eds). Amazonian Dark Earths: Exploration in Space and Time. Springer – Verlag, Berlin, pp.183-193.

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Influence of Rice Husk Biochar Application on Nitrogen Use Efficiency by Wheat Plants Grown on Mediterranean Soils

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Key words: *Biochar, Nitrogen, Rice Husk*

Introduction

Agricultural soils in south Mediterranean Sea (e.g., Egypt) are classified as drylands which defined by high aridity index, high rates of organic matter depletion and accelerating soil salinity problems [1]. In Egypt, although, there is about 30–35 million ton of agricultural wastes are generated annually, only 20 % are used in organic fertilizer and fodder production [2] and the rest of waste amount is needed to précised management. Biochar, as one of stable sources of organic carbon, is considered as one of the option for agricultural waste management and recycling as soil amendment. Therefore, using stable soil conditioners such as rice husk biocher was considered as an attempt for (1) controlling fertilizer nitrogen loss and thereafter increasing the bioavailability of N to grown crops and (2) testing its role in reducing vulnerable effects of salinity on plant growth. In the current study, rice husk biochar (RHB) was produced by slow pyrolysis method [3]. Greenhouse experiments were carried out to study the effect of rice husk (RH) and rice husk biochar (RHB) application by rate of 30 ton ha^{-1} to alluvial soil samples collected from agricultural experiment station in the Northwestern Nile Delta, Egypt (see Table 1) for some RH, RHB and soil properties), and the seeds of wheat plants (Sakha 104 local cultivar) were emerged after adding third of N, all of P_2O_5 and K_2O by rates 60, 70 and 120 in the form of ammonium sulfate, single super phosphate and potassium sulfate, respectively. Then, two thirds of N was applied after 45 and 65 day of plant emergence.

Table 1. some characteristics of rice husk (RH), rice husk biochar (RHB) and soil used in the study

	OC, %	**Total N, %**	**TP, %**	**TK, %**	**TFe, mg/kg**	**TMn, mg/kg**	**TZn, mg/kg**	**TCu, mg/kg**
RH	27.9	1.19	0.4	0.62	233.4	78.6	41.6	16
RHB	36.6	0.52	0.54	88	248.2	90.6	50	17.6

	EC, dS/m	pH	OC, %	min.N, mg/kg	DTPA-extractable Micronutrients, mg/kg			
					Fe	Mn	Zn	Cu
Soil	6.23	7.81	2.9	104.6	3.17	2.93	2.58	0.14

The plants were irrigated by fresh water (S0) till 40 day of planting then irrigated by two levels of saline water had sodium chloride salinity equivalent 5 (S1) and 10 (S2) dSm^{-1} of electrical conductivity. At harvest, total weight of plants and grain weight were recorded, plant height, and number of spikes were measured. After oven drying of plants, N, Na and K in grains and straw were determined using ICAP Thermo model 6000 Series. Top 20-cm soil samples were withdrawn using soil tub to extract and distillate the remaining available nitrogen by 2.0 M KCl solution [4, 5]. Statistical analysis for all measured parameters was done using Costat software.

Results and Discussions

The results in Table (2) showed that grain and straw yield were highly affected by the application of both RH and RHB in all salinity treatments. Under non saline conditions (S0), RH addition increased grain and straw yield by about 60 and 33.3% whereas RHB application increased it about 10.4 and 2.5%, respectively. RH addition also increased the yield of grain (by 23.5 and 13.7%) and straw (by 17.1 and

3.9%) under the two salinity levels (S1 and S2) of irrigation water, respectively. RHB application only increased grain yield by about 17.3% and decreased straw yield by 3.3% in the pots irrigated with S1 water comparing with RHB-non treated pots. In S2-irrigated soils, RHB addition led to decrease both grain and straw yield by 2.9 and 4.74%, respectively. These findings are agreed with the results obtained by Zwieten et al. (2009) when applied papermill biochar in wheat plants grown in calcareous soils under greenhouse conditions [6]. It is observed that application of RHB increased the plant height and decreased the number of spikes per plant in all salinity treatments comparing with RH. Sodium percent in wheat straw in RHB treatments was greater than RH and non amended soil samples under all irrigation salinity levels (Table 2). These results reflect the higher content of Na in RHB and RH, and subsequent corresponded higher Na uptake, comparing to non amended soils. RHB was more beneficial in potassium uptake only under fresh irrigation water conditions where K content in grain increased about 35% more than in plants grown on non amended soil.

Table 2. Effect of RH and RHB application on the yield components and contents of Na, K and N in grains and straw of wheat plants irrigated with different saline water

Treatment	Grain yield (ton/ha)	Straw yield (ton/ha)	Plant height, cm	Spike No/pot	Na in straw, %	Na in grains, %	K in straw, %	K in grains, %	N in Grains, %	N in Straw, %
S0	2.99	8.45	82.67	34.67	0.21	0.07	1.93	0.45	1.14	1.17
S0 + RH	4.79	11.27	84.67	42.33	0.27	0.12	2.43	0.48	1.24	1.38
S0 + RHB	3.30	8.66	85.67	32.33	0.33	0.07	2.60	0.45	1.16	1.40
S1	3.67	8.65	74.33	38.33	0.56	0.13	2.67	0.47	1.14	1.42
S1 + RH	4.79	10.13	80.00	37.33	0.62	0.10	2.77	0.46	1.26	1.49
S1 + RHB	4.30	8.36	81.33	35.33	1.06	0.11	2.27	0.44	1.13	1.28
S2	3.83	8.66	78.00	34.67	1.30	0.12	1.80	0.46	1.23	1.16
S2 + RH	4.36	8.99	78.67	38.33	1.33	0.16	2.43	0.53	1.37	1.44
S2 + RHB	3.72	8.25	81.00	31.00	1.34	0.14	1.90	0.45	1.20	1.19

Nitrogen content in both wheat grain and straw slightly changed as a result of application RH and RHB. The highest N percents in grains and straw were obtained fro plant grown on RH-amended with all salinity levels of irrigation water. Whereas RHB application did not has significant effect on N content (Table 2). After plant harvest, the results of available mineral nitrogen (NH_4^+ + NO_3^-) in soil in the top 20-cm soil showed that RHB application saved more N in soil comparing to RH- and non-amended soils (Fig. 1) where about 35.3, 45.2 and 50.4% of mineral N in soils irrigated by S0, S1 and S2 water salinity, respectively, were remained in soil more than those occurred in corresponded non-amended soils. In contrast, concentrations of N in RH- amended soil were less than those in non-amended one with all corresponded salinity levels of water (Fig. 1) by about 15, 2.5 and 8.5%. These results indicate that studies of RHB application should be extended to the next growth seasons to explain its role in mineral fertilizer nitrogen conservation to the followed crops and its subsequent impact on crop production economies and further studies are needed to explore the role of different biochar sources as soil amendment for saline soils in arid areas.

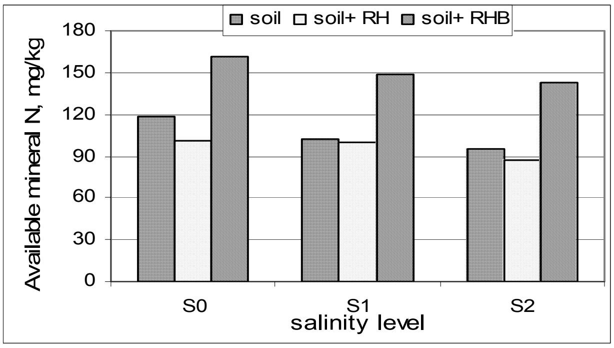

Figure 1. Soil mineral available N (NH_4^+ + NO_3^-) as a results of RH and RHB application to wheat grown on soil irrigated with different saline water.

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[1] FAO. 2001. General Treands in Carbon Sequestration in Soils. In *Soil Carbon Sequestration for Improved Land Management*. pp: 1:69. FAO, Rome.

[2] Ministry of Environmental Affaires. 2009. Waste Management in Egypt. Annual report. Cairo, Egypt.

[3] Masulili, A. et al. 2010. *J. Agri. Aci.* Vol 2 (1): 39-47.

[4] Keeney, D.R. and D.W. Nelson. 1982. Nitrogen – Inorganic forms. In A.L. Page (ed.) *Methods of soil analysis*. Am. Soc. Agron. Mad. Wis. USA.

[5] Bremner, T.M. and C.S. Mulvaney. 1982. Nitrogen – total. In A.L. Page (ed.) *Methods of soil analysis*. Am. Soc. Agron. Mad. Wis. USA.

[6] Zwieten, L.V.et al. 2009. *Plant Soil.* Vol 327 (1-2): 235-246.

The potential use of pyrolysis charcoal (bio-char) for Ultisol soil bio-ameliorant

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Key words: *bio-char, oil palm, bio-ameliorant*

Introduction

A series of research was carried out with the objective to meet the challenge and determine the direction and strategy required for overcoming highly weathered Ultisol soil that impact to low productivity. Selected ameliorating materials, i.e. bio-char, compost, and peat were examined their physical characteristics to determine the best combination of them as bio-ameliorant carrier materials for aggregate stability bacteria. It is postulated that the oil palm nutshell originating bio-char has a comparable properties as microbial carrier materials and acid soil ameliorant for maize as alternative to the other two said materials.

Results and Discussions

The bio-char originated from oil palm nutshells is shown in Figure 1 indicating a porous microstructure as reported earlier by others [1,2].

Figure 1. Microstructure of bio-char from oil palm nutshells.

Table 1. physico-chemical characteristics of bio-char, compost, and peat.

Type of materials	*Type of analysis*								
	N (%)	P (%)	K (%)	C-org (%)	*CEC* (meq/100g)	BD (g/cc)	PD (g/cc)	Total Pore Space	WHC (%)
Bio-char	1.32	0.07	0.8	25.62	4.58	0.8	1.85	63.3	25.3
Compost	1.38	1.08	0.19	22.38	60.8	0.42	1.45	71.2	9.7
Peat	1.10	0.08	0.18	33.51	103.5	0.25	1.45	82.4	10.1

Table 2. Vegetative growth of maize Bisma var. 8 weeks after planting.

Treatments	*Parameter**	
	Height (cm)	*Number of leaf*
Full rate of NPK fertilizer dosages	129.9 b	10.4 a
Full rate of NPK fertilizer dosages+25% bio-ameliorant (2.1 g/tree)	132.4 b	10.5 a
Full rate of NPK fertilizer dosages+ 50% bio-ameliorant (4.2 g/tree)	149.8 a	10.2 a
50% of NPK fertilizer dosages+ 50% bio-ameliorant (4.2 g/tree)	138.9 ab	9.9 a
Blank	49.4 c	4.9 b
Coefficient of Variability (%)	4.2	4.0

*Figures in the same column followed by similar letter (s) are not significantly different according to Duncan Multiple Range Test (P>0,05).

Bio-char was found to be the most suitable carrier material as it has highest total pore spaces and available water content (Table 1). Microbial population obtained from the granular forms of bio-ameliorant was 107 CFU/gram of the sample until 12 months life time periods. Best vegetative growth performance of maize Bisma var. in Ultisol soil of Experiment Station (KP) Taman Bogo, Lampung, Indonesia was shown by the application of 100% standard dosage of NPK conventional fertilizers in combination with the addition of 4.2 g/tree of bio-ameliorant (Table 2).

Conclusions

Bio-char, compost, and peats exhibited best comparable performances as microbial media and soil ameliorant. This finding would lead to the formulation of most effective soil ameliorant consisting bio-char, organic materials, and basic mineral components.

Acknowledgements

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[1] Saito, M. & Marumoto. T. (2002). Inoculation with arbuscular mycorrhizal fungi: The status quo in Japan and the future prospects. *Plant and Soil*. 244, 273–279.

[2] Lehmann, J. (2007). Bio-char for mitigating climate change: carbon sequestration in the black. *Forum Geookol*. 18(2): 15-17.

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Biochar: a review

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Key words: *Climate change mitigation value and potential, Soil fertility, Crop yield*

Climate change mitigation

In the context of this abstract, carbon sequestration is the primary driver for considering the application of biochar to soil. Policy makers charged with meeting greenhouse gas emission targets and addressing public concern over increasingly evident climate change may recognize the potential for biochar-based strategies. The land-owner or farmer is likely to have a more practical or financial perspective. A particular combination of feedstock, pyrolysis technology, energy conversion and byproduct usage can comprise a biochar-based system. Alternative systems have different greenhouse gas balances. Additionally, economically and politically conceivable systems for different regions of the world must be considered. The future price of carbon and the inclusion of biochar in carbon-trading schemes is a key factor as well the likely additional benefits of biochar to agricultural production. These factors are critical since they dictate whether relevant practices are adopted on a large scale through their effect on the decision making of individual farmers. From a global and policy perspective the potentially negative impacts of biomass use on climate forcing must be considered. These include the effects of soot and trace gases that are emitted into the atmosphere during combustion. Airborne transport and deposition of soot has been implicated in the acceleration of polar ice melt, but conversely in facilitating cloud formation and ‘global dimming’ (McConnell et al., 2007; Ramanathan et al., 2008). Currently biomass burning accounts for 10% of global CH_4 emissions and 1% of N_2O (Crutzen et al., 1990). Although current charcoal production activity could account for a component of these emissions (Woolf, 2008), a general shift to pyrolysis-based systems would decrease, if not eliminate, them. However, the net result with great expansion of alternative bioenergy systems have not been assessed. As is apparent in the loam soil, the addition of biochar can dramatically darken the colour of soil, especially in soils that are low in organic matter. A relationship between soil colour and low temperature fire occurrence has been demonstrated (Ketterings et al., 2000). Oguntunde (2008) found soil at charcoal manufacturing sites to have 8% greater hue, and 20% higher value and chroma. Since dark soils absorb more solar energy they may, depending on water content and plant cover, display higher soil temperatures (Krull et al., 2004). This will affect rate processes, enhancing the cycling of nutrients and potentially extending the growing season in seasonal climates. In Japan it is a traditional farming practice to apply charcoal to accelerate snow melt. Anecdotal evidence suggests more rapid crop establishment in temperate soils enriched in char, but to date no quantitative relationships between biochar application rate and these parameters have been reported. The study of Oguntunde (2008) showed a one-third reduction in soil albedo in soils enriched in char. On a large spatial scale, the application of biochar could affect the albedo of the Earth’s surface. Increasing surface albedo has been proposed as a possible mitigation measure for climate forcing (Crutzen, 2006). The frequency with which potentially toxic compounds materialize in biochar and their concentration is inadequately researched. Two classes of compounds are of generic concern, since they can potentially from in the pyrolysis of any feedstock: polycyclic aromatic hydrocarbons (PAH) and dioxins.

Soil fertility

Expectation of increased soil fertility benefits arise from studies of the *Terra Preta* that contains high proportions of black carbon (Haumaier et al., 1995; Glaser et al., 2002; Lehmann et al., 2003; Lehmann and Rondon, 2006). The evident fertility of the *Terra Preta* is generally attributed to high soil organic matter content – organic matter assists in the retention of water, soil solution and cations – and the retentive capacity of aged biochar itself for nutrients and water. The black carbon present in *Terra Preta* is thought to originate from partially-combusted biomass residues derived from a range of anthropogenic activities, including kitchen fires and field burning. A particularly striking characteristic is a stronger relationship between soil carbon content and soil CEC in these soils relative to adjacent land, indicating that biochar comprises a greater proportion of soil carbon (Liang et al., 2006). Since CEC is indicative of the capacity to retain key nutrient cations in the soil in plant-available form and minimize leaching losses, this is cited as a key factor where differences in crop productivity are observed. High rates of biochar addition in the tropical environment have been associated with increased plant uptake of P, K, Ca, Zn and Cu (Lehmann and Rondon., 2006). In contrast to mainstream chemical fertilizer, biochar also contains bioavailable elements such as selenium that have potential to assist in enhancing crop growth. There has been much speculation concerning the potential effects of biochar on microbial activity in soil, which in the context of *Terra Preta* has been reviewed in detail by Steiner et al. (2003). Assuming that plant inputs and hence microbial substrate remain unchanged, enhanced microbial activity alone would diminish soil organic matter. However, this is contrary to the observation in *Terra Preta*, where soil organic matter is generally higher than in similar surrounding soil (Liang, 2006). However, a change in the balance of microbial activity between different functional groups could benefit crop nutrition, specifically enhancement of mycorrhizal fungi (Ishii et al., 1994), and this could feed back into higher net primary productivity and carbon input. There is relatively extensive literature documenting stimulation of indigenous arbuscular mycorrhizal fungi by biochar, and this has been reflected in plant growth e.g. Rondon (2007), Nishio (1996). This literature has been reviewed in some detail by Warnock (2007), who proposed four mechanistic explanations, of which a combined nutrient, water and CEC effect was considered most probable.

Crop yield

The majority of currently published studies assessing the effect of biochar on crop yield is generally small scale, almost all short term, and sometimes conducted in pots where environmental fluctuation is removed. These limitations are compounded by a lack of methodological consistency in nutrient management and pH control, biochar type and origin. Studies in a wide range of climates, soils and crops have been conducted. It is not therefore possible at this stage to draw any quantitative conclusion, certainly not to project or compare the impact of a particular one-time addition of biochar on long-term crop yield. Nonetheless, evidence suggests that at least for some crop and soil combinations, moderate additions of biochar are usually beneficial, and in very few cases negative. Glaser (2001) reviewed a number of early studies conducted during the 1980s and 1990s. These tended to show marked impacts of low charcoal additions (0.5 t ha^{-1}) on various plant species. Higher rates seemed to inhibit plant growth. In later experiments, combination of higher biochar application rates alongside NPK fertilizer increased crop yield on tropical Amazonian soils (Steiner et al., 2007) and semi-arid soils in Australia (Ogawa, 2006). Due to the year to year variation in climate and its impact on short-term dynamics, results from a number of field experiments recently set up are, whilst generating data, not yet published. The nature and mechanistic basis for interactions between crop, soil type, biochar feedstock, and production method and application rate will have to be understood to gain predictive capacity for the performance of biochar in soil, and open the possibility for large scale deployment.

Priorities and future challenges

Based on the results of this review, the following research priorities have been identified:

1) Determine a predictive relationship for properties and qualities of biochar and its manufacture such that it can be optimized for use in soil.
2) Examine how the possibility of adverse impacts on the soil and atmosphere can be eliminated with certainty.
3) Model the impact of alternate bioenergy systems on the carbon cycle at the global scale, and in the context of national targets, in order to support policy decisions and devise suitable market instruments.

Since the underlying context for biochar-based strategies is that of global climate change, research needs to provide answers that are applicable under diverse combinations of climate, agriculture and energy production systems. This requires a fundamental, mechanistic understanding of how biochar provides its unique functional characteristics, probably embodied in models, and would include its interactions with other living and nonliving components of soil.

Globally coordinated research activity across a range of countries and climates is necessary if the global applicability of knowledge gained is to be rigorously assessed.

The effect of charcoal amendment on soil physical properties related to water retention in the Brazilian savanna (Cerrado)

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Key words: *upland rice, chemical fertilizer, SWRC*

Introduction

Charcoal amendments to soil had been proposed as alternative to paralell climate change mitigation (C sequestration) and soil quality improvement by increasing soil organic matter levels and nutrient availability. The objective of this work was to evaluate the effect of different doses of fine of charcoal in combination with mineral fertilizer on the physical properties of soils related to water retention.

Were evaluated the effects of different doses of fine of charcoal (0,2,4,8,16,32 Mg ha^{-1}) in combination with mineral fertilizer (NPK, 0,100,200,300,400 kg ha^{-1}). Three experiments were conducted in the Brazilian savanna (Cerrado) in 3 different soil types (sandy Haplic Ferralsol (EXP I) under soybeans, sandy Dystric Cambisol (EXP II) and clayey Rhodic Ferralsol (EXP III)) under upland rice. Charcoal was incorporated to the soil in 2006, 2008 e 2009, respectively. EXP I was evaluated in the 1st and 3rd year after aplication and EXPs II and III in the 1st year after application of charcoal. The undisturbed soil samples were collected in 0-10 cm of depth, and the soil retention curves were built using van Genuchten's parameters[1] with SWRC software[2].

Results and Discussions

In the sandy soils charcoal, in general, increased water retention, agreeing with Sohi[3]. However, in EXP I (Fig. 1), in the 1st year, when charcoal was combined with NPK, especially the 8 and 16 Mg ha^{-1} doses, water retention was decreased compared to no combination. In EXP II (sandy Cambisol) (Fig. 2) the 32 Mg ha^{-1} charcoal dose in combination with 200 kg ha^{-1} NPK had highest water retention. In EXP III (clayey Ferralsol) (Fig. 3) the highest water retention was observed at 16 Mg ha^{-1}. Charcoal increased significantly the microporosity in EXP I but did not have effect on this parameter in the other experiments (Fig. 4). This was due higher sandy quantity on soil, wich has originally higher macroporosity than microporosity.

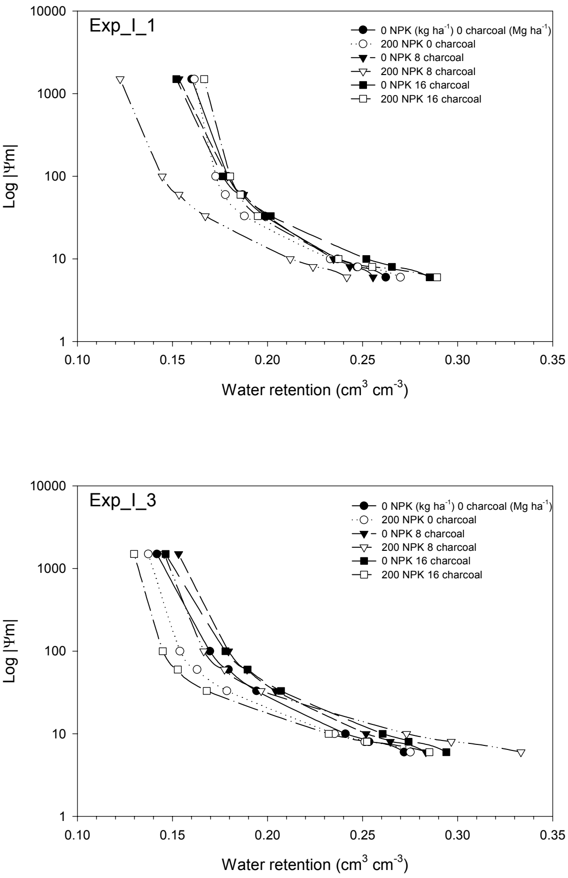

Figure 1. Effects of charcoal and chemical fertilizer on soil water retention curves in the 1st (Exp_I_1) and 3rd (Exp_I_3) year after application. Nova Xavantina, MT, 2010.

In EXP III (Fig. 3) charcoal modified macroporosity in a positive manner (Fig. 5). Besides the above described results charcoal did not show effect on other examined parameters like available water, total porosity, soil density, gravitational water, S index based on variance analysis, may be, because charcoal undergoes changes through time and these avaliations was done just after 1 and 3 years, and the charcoal had no time to have these modifications.

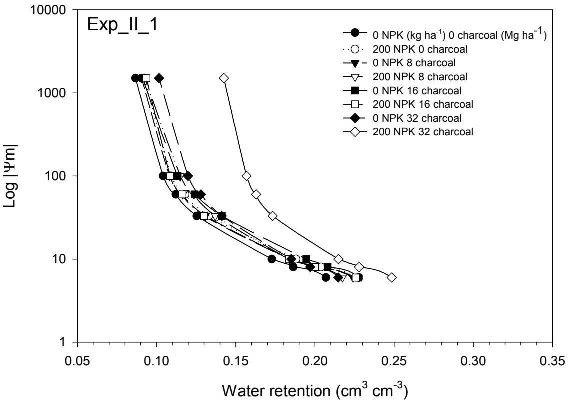

Figure 2. Effects of charcoal and chemical fertilizer on soil water retention curves in the 1st year after application. Nova Xavantina, MT, 2010.

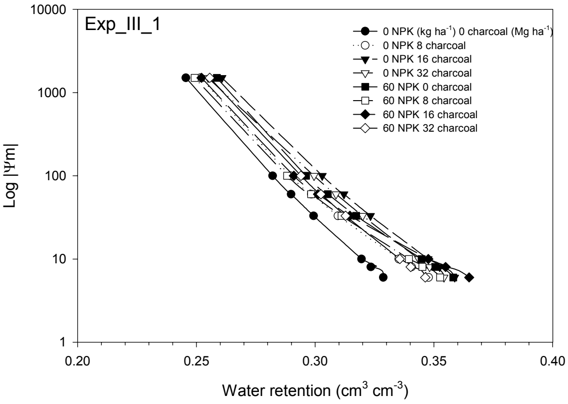

Figure 3. Effects of charcoal and chemical fertilizer on soil water retention curves in the 1st year after application. Santo Antônio de Goiás, GO, 2010.

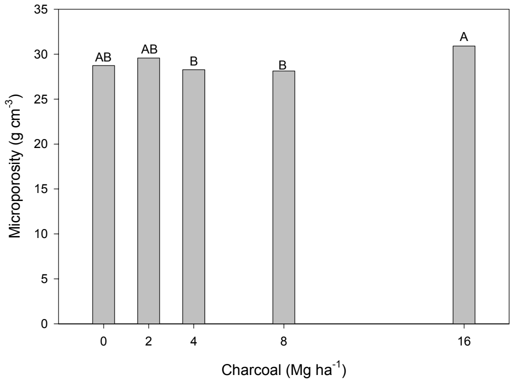

Figure 4. Effects of charcoal amendment on soil microporosity. Nova Xavantina, MT, 2010.

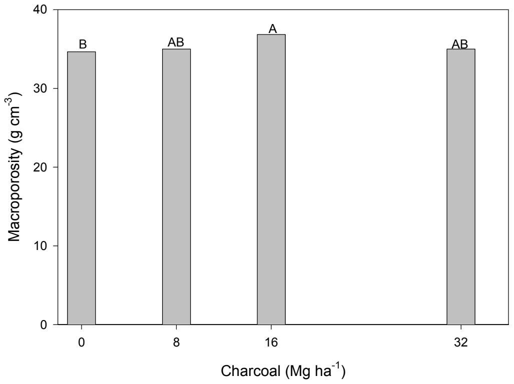

Figure 5. Effects of charcoal amendment on soil macroporosity. Santo Antônio de Goiás, GO, 2010.

Conclusions

Observing the water retention curves, differences between soils with and without charcoal amendment can be seen that, with time, may evolve in a manner that differences might be detected, in favor of charcoal addition.

Acknowledgements

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[1] Van Genuchten, M.T., A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Science Society of America Journal, 1980. 44: p. 892-898.

[2] Dourado-Neto, D., et al., Software to model soil water retention curves (SWRC, version 2.00). Scientia Agricola, 2000. 57(1).

[3] Sohi, S., et al., Charcoal's roles in soil and climate change: A review of research needs. Vol. Report 05/09. 2009: CSIRO Land and Water Science. 64

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Influence of biochar on soil fertility, carbon storage and biomass in sub-tropical pasture: Results from a 3 year field study

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Key words: *soil C, agricultural emissions, productivity*

Introduction

Prior to land clearing in northern NSW, Australia in the late 1800s, the highly fertile and naturally acidic red ferrosols supported tropical rainforests. Upon replacing these tropical rainforests with dairy pastures, soil productivity declined not only as a result of a decrease in organic matter and nutrient removal in forage but also because of an increase in acidity exacerbated by the frequent application of high rates of N fertiliser. As a consequence, it is a common requirement to apply lime to these soils in order to ameliorate the acidification associated with high N use and to sustain pasture productivity [1].

The use of N fertiliser to drive crop and pasture growth has been identified as a significant source of N_20 emissions from soils. Urea is the main form of N fertiliser applied to annual ryegrass pastures in a subtropical environment. The direct carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions from urea application to soils are estimated to be 3 t CO_2–e t^{-1} urea [2]. with additional emissions arising during fertiliser manufacture and transport [3].

The application of lime to offset the acidifying effects of urea also results in greenhouse gas emissions, as CO_2 is released from the soil during the chemical dissolution of lime. Using the IPCC default value of 12% for lime applying 1 t lime to soil has the potential to directly emit 0.44 t CO_2-e yr^{-1} [2].

The subtropical dairy production system is thus characterised by a high demand for manufactured fertilisers and soil additives, and a corresponding level of both direct and indirect GHG emissions. New technologies for this system will need to demonstrate not only the capacity to improve productivity and fertiliser use efficiency but also reduce net GHG emissions.

A field site was established in 2006 to assess the benefits of biochar on pasture productivity, soil fertility and soil carbon storage. Twelve soil amendments were formed by crossing 3 factors: 2 rates of fertiliser (nil and 276 units of N: 22P: 50K kg/ha/y, N applied to ryegrass only) by 2 rates of lime (nil and 5t/ha single application) by 3 biochar amendments (nil, beef feedlot manure biochar (FM) at 10t/ha and greenwaste (GW) biochar at 10t/ha single application). The experimental area was then direct-drilled to forage peanut (*Arachis pintoi*) and oversown in autumn in 2007 and 2008 with annual ryegrass (*Lolium multiflorum*).

Results and Discussions

Compared to nil amendments total ryegrass yield was increased 96% by applying NPK fertiliser, 14% by FM biochar application and 7% by liming. Addition of FM biochar with lime and fertiliser achieved the highest total yield of 16787 kg DM/ha which was 877 kg DM/ha above the nil biochar. The GW biochar did not significantly influence yield. Without fertiliser the FM biochar generally increased uptake N, P, K, Ca, Mg and Na compared to the GW and nil biochar.

In fertilised and limed plots, adding FM biochar significantly reduced the acidification rate at 3 years following trial establishment. Without lime, the FM biochar also gave significant increases in plant available P in fertilised and unfertilised plots at 3 years, and there was no effect of fertiliser application on available P at the rates applied (Table 1). It is clear the biochar amendment played a significant role in altering plant available P in this ferrosol.

There was no significant difference in either the soil microbial biomass, or soil enzyme activity following biochar amendment although significant differences occurred between seasons.

Soil (in the 0-75 mm profile) initially contained 4.7% C which increased to between 5.1- 5.4% following amendment with biochar. Over the 3 years, there was no significant accumulation in C in the controls without biochar, despite application of fertiliser and lime. The GW biochar with farmer-practice fertiliser rates in the absence of lime resulted in the greatest accumulation of total soil C with 6.5% C found 3 years following the establishment of the trial (Table 1). In all treatments, the presence of GW biochar resulted in significant C accumulation.

Likewise, the FM biochar provided significant increases in combination with some other amendments, but this accumulation of soil C was not as great as with GW biochar. The positive priming effect previously reported [4, 5] was not observed in this field study.

Table 1: C and P content in field plots 6 months and 3 years following trial establishment

Biochar	NPK	Lime	Bray P mg/kg 3yrs	C% 6 mths	C% 3 yrs
nil	nil	nil	6.9	4.7	4.8
FM	nil	nil	13.0	5.1	5.5
GW	nil	nil	6.7	5.2	5.9
nil	nil	+	6.6	4.6	4.7
FM	nil	+	10.1	5.2	5.5
GW	nil	+	6.4	5.3	6.0
nil	+	nil	8.3	4.8	5.1
FM	+	nil	16.0	5.2	5.7
GW	+	nil	11.0	5.4	6.5
nil	+	+	11.3	4.7	4.9
FM	+	+	11.7	5.1	5.5
GW	+	+	14.3	5.1	5.7
l.s.d. (p=0.05)			4.1	0.4	0.4

Increases in soil carbon storage were estimated to enable an offset against GHG emissions of 16 and 38 t CO$_2$-e for the FM and GW biochar, respectively. These systems typically include application of N at rates of (600 kg urea y^{-1}), with an initial application of 5 t ha^{-1} lime. This would equate to around 1.8t CO$_2$-e emissions ha^{-1} y^{-1} from urea and a total of 2.2t CO2-e emission from liming using published estimates [2]. Over the 3 year cropping cycle described here, the increase in C storage in the pasture soil offset emissions associated with N and lime application.

Conclusions

Although the reason for increased soil C in our study was not fully explored, it is likely that increased biomass production with the FM biochar amendment resulted in greater soil deposition of C. Yield could not explain increased soil C with GW biochar amendment. In this case, the soil C increase may have been due to the stabilization of otherwise decomposable SOC by sorption to mineral and organic soil surfaces, occlusion within aggregates, and deposition in pores [6] which are inaccessible to microbial decomposers [7]. Work is continuing to identify the fractions of soil C that are responsible for this significant increase.

Acknowledgements

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[1] Fulkerson, W. J.; Slack, K.; Moore, K.; Rolfe, C. 1993 Australian Journal of Soil Research, 44, 1947.

[2] De Klein, C. et al. 2006 N$_2$O Emissions from Managed Soils, and CO$_2$ Emissions from Lime and Urea Application. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf (cited 03/03/2010)

[3] Wood, S.; Cowie, A. 2004 A review of greenhouse gas emission factors for fertiliser production. http://www.ieabioenergy-task38.org/publications/GHG_Emission_Fertilizer%20Production_July2004.pdf (cited 08/03/10)

[4] Wardle, D. A.; Nilsson, M-C.; Zackrisson, O. 2008 Science, 320, 629.

[5] Novak, J. M.; Busscher, W. J.; Watts, D. W.; Laird, S. A.; Ahmndna, M. A.; Niandou, M. A. S. 2010 Geoderma, 154, 281.

[6] Downie, A,; Munroe, P.; Crosky, A. 2009 Characteristics of biochar-physical and structural properties. In Biochar for environment management: science and technology. Earthscan, pp 13-29.

[7] Jastrow, J. D.; Amonette, J. E.; Bailey, V. L. 2007 Climatic Change, 80, 5.

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Rice husk biochar improves productivity of sandy soils in Central Coastal Vietnam

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Key words: *Rice husk, sands, soil moisture*

Introduction

Central coastal Vietnam has more than 500,000 ha of sandy soils and a tropical monsoon climate characterized by 8-9 months of hot dry season. Most farmers use irrigation during the dry season to grow field and tree crops. The sands are very low in organic carbon and so have low water and nutrient holding capacities. Farmers in this region use animal manures and NPK fertilizers for soil improvement and are also amongst the poorest in Vietnam. Vietnam produces more than 20 M tonnes pa of rice which provides an organic waste resource of 3-4 M tonnes pa of rice husk. Rice husk stoves which produce a biochar byproduct have been used in Vietnam for many years. The biochar from these stoves is approximately 30% carbon. This research is evaluating this rice husk biochar (RHB) as an amendment for infertile sandy soils to improve crop productivity and farmer incomes.

A field trial was established in Binh Dinh in 2009 to evaluate the effect of rice husk biochar on peanut yields and nutrient use efficiency. The soil is an arenosol with more than 85% sand. The treatments were T1= nil NPK + nil manure, T2= NPK + nil manure, T3= nil NPK + manure, T4= NPK + manure, each applied with and without rice husk biochar giving a total of eight treatments. Fertilizer was applied as NPK (30N, 60P205, 90K20 kg/ha); manure at 5 t/ha and biochar at 20 t/ha. The manure and biochar were incorporated into the soil prior to planting. Lime (500 kg/ha) was applied to all plots. Treatments applied to 2x5 m plots and replicated 3 times in a random complete block design. The plots were irrigated using hand held hose every 2-3 days. Soil moisture was measured in each plot every 7-8 days at 0.1, 0.2 and 0.3 m depth during each crop production period using a portable soil capacitance probe. Soil was sampled at the end of each crop to assess soil organic matter (SOM) content (Walkely Black) and soil nutrients. Plant biomass and pod yield were assessed at harvest. Biomass was analyzed for nitrogen (N), phosphorous (P) and potassium (K) and nutrient uptake assessed from plant concentration and biomass amount.

Results and Discussions

This paper reports the effects of treatments on production, crop nutrient uptake soil moisture and SOM (Table 1). Peanut yields increased significantly ($p<0.05$) from 0.99 ton/ha in response to additions of NPK, manure and RHB with 2 ton/ha achieved when RHB, NPK and manure were combined. A similar response was observed in above ground plant dry matter assessed prior to harvesting with 1.47 ton/ha harvested from nil input plots, increasing to 2.59 tons/ha from soils amended with RHB + NPK + manure. Increases in crop production from adding biochars to soil have been observed in many studies however, this study is one of only a few to have demonstrated gains in production in response to soil amended with RHB.

The differences in crop uptake of N were relatively small between treatments, as would be expected with a legume that balances its N content by supplementing soil N with atmospheric N. A significant increase in crop uptake of N was observed for the RHB + NPK + manure treatment. This increase corresponded to a dry matter biomass response of a similar magnitude rather than an increase in plant concentration. Treatment responses to crop uptake of P and K were much more obvious especially when biochar and NPK were combined with each other (P=15.1 kg/ha; K=38.8 kg/ha) and biochar and NPK were combined with manure (P=15.5 kg/ha; K=42.3 kg/ha). The apparent improvement in crop uptake of fertiliser, P and K in particular, appears to have been the primary factor driving increased crop production in response to amending this low fertility sandy soil with RH biochar.

No differences in the status of soil macro nutrients were observed post-harvest which indicates most nutrients added to the soil as fertiliser, manure or RHB were either leached or taken up by the crop. Evidence indicates that, to varying degrees, biochars slow nutrient leaching and improve soil nutrient retention by sorption and by holding water containing dissolved nutrients within their porous structure (Major et al. 2009). It is possible that both these processes were operating in the RHB amended soils sufficiently to extend the duration that nutrients were available for plant uptake. This provides a feasible explanation for gains in yield and biomass.

A repeated measures analysis of soil moisture indicated that there was a trend toward increasing soil moisture to 20cm depth in plots amended with manure and RHB over the 12 week period. A comparison of predicted mid-point (i.e. 6 week) soil moisture values (Table 1) indicated that only the nil input and RHB + NPK + manure treatments came close to being significantly different. The trend toward increasing soil moisture coincided with significant increases ($p<0.05$) in soil organic matter in manure and biochar amended soil. This indicates that a secondary benefit from amending sandy soil with RHB may be increased SOM which would lead to further improvements in soil water and nutrient retention over time. This will be explored further in future work.

Table 1. Production, crop nutrient uptake and soil responses to rice husk biochar, NPK and manure treatments.

Treatments			**Production**		**Crop nutrient uptake**			**Soil**	
Rice husk biochar	**NPK**	**Manure**	**Pod yield (ton/ha)**	**Biomass^{++} (ton/ha)**	**N (kg/ha)**	**P_20_5 (kg/ha)**	**K_20 (kg/ha)**	**SOM^{+} (%)**	**Moist* (mm)**
-	-	-	0.99	1.47	21.9	6.3	5.6	0.25	13.5
-	✓	-	1.53	1.80	20.1	10.6	22.4	0.33	14.6
-	-	✓	1.58	1.60	19.5	9.5	15.6	0.55	14.0
	✓	✓	1.60	1.96	19.0	11.2	27.2	0.58	15.1
✓	-	-	1.66	1.90	22.9	10.7	13.8	0.63	14.1
✓	✓	-	1.88	2.12	22.8	15.1	38.8	0.70	14.8
✓	-	✓	1.66	1.97	16.1	9.6	19.2	0.69	14.8
✓	✓	✓	2.00	2.59	30.6	15.5	42.3	0.84	15.5
LSD			0.30	0.23	7.7	4.1	10.8	0.11	2.2

$^{++}$ Biomass assessed as aboveground dry matter

$^{+}$ Walkley and Black soil organic matter

* Predicted mid-point soil water content to 20cm depth estimated from a repeated measures analysis.

Conclusions

Rice husk biochar appears to be an effective soil amendment for increasing the production of peanuts grown in infertile sandy soils through improving efficiencies in crop fertiliser uptake. Greatest yield improvement was found in the biochar plus NPK plus manure treatment. Other benefits such as increased soil organic matter, leading to improved soil water retention, may also result from amending sandy soils with rice husk biochar.

Acknowledgements

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[1] Major et al. 2009. In Lehman J, Joseph S. eds. Biochar for Environmental Management. Earthscan, London.

Effect of Feedstock and Pyrolysis Temperature on the Retention Capacity of Biochars to Sorb Steroid Hormones and Veterinary Antibiotics

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Key words: *Partition coefficient (K_f), Estradiol, Estrone and Sulfamethoxazole*

Introduction

Veterinary antibiotics are administered to animals in order to prevent, treat diseases and also as growth promoters. Their usage in New Zealand amounts to about 60 tonnes per year. After administration up to 80% is excreted in urine and faeces. Additionally, steroid hormones are naturally excreted by dairy cows, and given the land-application of effluent is a common practice in many parts of NZ, there is a concern among regulatory bodies that these contaminants may end up in the receiving environment through soil leaching and may also impact terrestrial organisms. Biochar can contain 60-80% as black carbon, and due to its high surface area, it has been used an effective soil remediation tool [1]. Biochars are often made from different feed stocks and under different heat treatment conditions and these variations may make biochars heterogeneous and therefore may have different contact times with soil components thereby affecting its retention capacity.

Objective

To determine the retention ability of a farm soil amended with biochar obtained from 3 different feed stocks and pyrolytic temperatures (only for Green waste) for an estrogenic steroid hormone (E2), its primary metabolite (E1) and a veterinary antibiotic, sulfamethoxazole (SMO).

Materials

Matawhero silt loam (0-5 cm) was collected from Gisbourne, NZ. Biochars used in this study were produced from green waste (GW) feedstock at 3 different pyrolytic temperatures 350 °C, 450 °C and 550 °C by slow-pyrolysis technique and corncob (CC) by flash carbonization technique, and pine sawdust (PSD) by steam gasification at > 600°C.

Biochar characterization

A range of techniques (Scanning Electron Microscope, X-Ray Diffraction, Fourier Transform Infrared Spectroscopy, ICPMS, 13c-solid-state NMR and EDAX) were used to characterise the biochars [1].

Sorption Experiment

Duplicate air-dried soil samples (2g) amended with above mentioned biochars (1.0% by wt.) were weighed into glass centrifuge tubes. An aliquot of 30 ml of E2 and SMO with 6 concentrations (0.5, 0.75, 1, 2.5, 3.75 and 5 mg/l) in 0.005M CaCl2 were added to the tubes, wrapped in aluminium foil, and shaken for 8-12 hrs to equilibrate in the dark (23°C ± 2). After centrifugation (1750g x 5 min), for SMO: 0.5 ml of supernatant was measured directly by HPLC. For E2/E1, 10 ml of supernatant was extracted with 5 ml of DCM, and the residual soils were extracted with 5 ml dichloromethane. Aliquot (1ml) of extract was evaporated to dryness under N_2, and the residue was reconstituted in 1 ml of 70% methanol + 30% water. Analysis was done by High Performance Liquid Chromatography and UV detector (201 nm for E2 [1]; 275nm for SMO) using a C_{18} column.

Results

All sorption isotherms were highly non-linear for both E2 and E1 in soil amended with the biochars. For SMO, amendment with GW biochars gave linear isotherms whereas for CC and PSD biochar, it was highly nonlinear. Overall, the K_f values for SMO, E2 and E1 in GW amended biochars were similar to soil alone (Table 2), showing the non sorptive nature of GW biochars. When compared to biochars made from different feedstock, E2 and SMO sorption was maximum in the treatment PSD BC + soil,15 folds greater than the control and 8 fold greater than other biochar amendments for E2. For SMO there was 125 fold increase (PSD) and 15 fold increase (CC) in the sorptive capacity when compared to the control. The higher sorption by PSD derived biochar can be attributed to the level of carbon present and the high BET surface area [1].

Conclusions

The biochar characterization results show that there was not a marked change on the biochar properties due to the different heat treatment except the C content (Table 1). The results from batch sorption studies showed that when same feedstock was used the variations in the pyrolytic temperature had no effect on the sorption characteristics. The soil amended with PSD biochar showed a marked affinity for both SMO, E2 and E1 as compared to other two biochars (CC and GW), presumably due to the higher SSA and C content of PSD biochar as well as due to the presence of abundance of polar functional groups (e.g. – OH) as observed from characterization data [1].

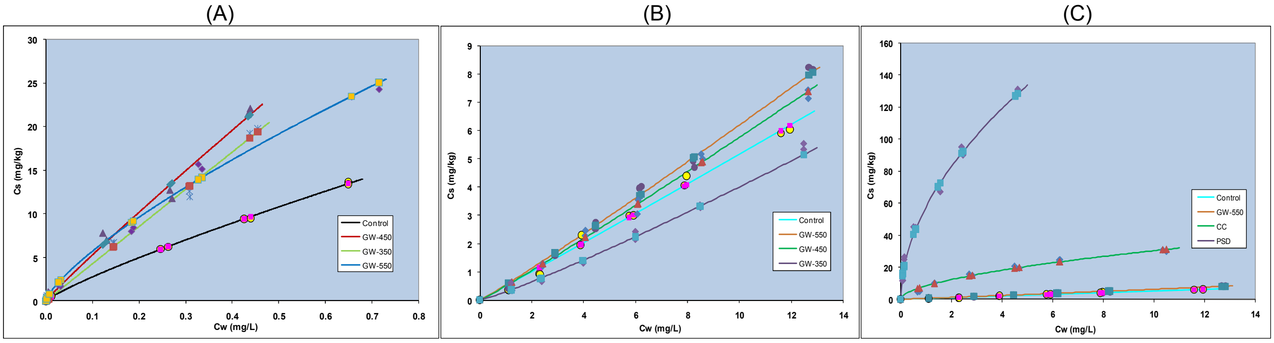

Figure 1. Batch sorption isotherms for E2 (A), SMO (B&C).

Table 1: Chemical properties of Green waste biochar used in sorption studies; *specific surface area was measured by BET nitrogen adsorption; # measured by ICPMS;** experiments in progress.

Biochar	Total C (%)	Total N (%)	Total H	Exchangeable cations# cmol(+)/kg Ca	Mg	K	Na	CEC cmol(+)/kg	Ash (%)	SSA* (m^2/g)
GW-550°C	79.8	0.35	2.83	0.51	0.19	0.77	0.24	1.71	1.61	153
GW-450 °C	71.8	0.31	3.28	0.37	0.13	0.37	0.17	1.04	1.51	**
GW-350 °C	65.2	0.23	4.26	0.21	0.08	0.10	0.05	0.43	1.04	**

Table 2. Summary of sorption parameter Kf derived from the multiple-concentration isotherms in Matawhero soil amended with biochars and in soil alone. Kf in mg $^{1-N}$ L ^{N} kg $^{-1}$

Treatment	SMO	E2	E1
		K_f	
GW +soil	0.45	28.3	63.4
CC +soil	5.95	32.8	34.9
PSD +soil	46.85	262	89.9
Control	0.35	18.4	22.0

Treatment	SMO	E2 [1]	E1
		K_f	
GW-550 °C +soil	0.45	28.3	63.4
GW-450 °C +soil	0.33	29.8	41.1
GW-350 °C +soil	0.33	26.4	43.6
Control	0.35	18.4	22.0

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[1] Sarmah, K. S.; Srinivasan, P.; Smernik, J. R.; Manley-Harris, M.; Antal, J.M; Downie, A; Van Zweiten, 2010. *J. AJSR* 48(6) in press. “*Retention capacity of biochar-amended New Zealand dairy farm soil for an estrogenic steroid hormone and its primary metabolite*”

Microbial Ecology of Biochar-Amended Soil

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Key words: *microbial community composition, soil biota, soil enzyme activities, exoenzymes*

Introduction

Soil biota are critical for soil function; thus, understanding how biochar added to soil may affect soil ecology is important for ensuring that soil quality is maintained. The size distribution of pores in properly prepared biochar provides a habitat for many microorganisms, where they are protected from predation and desiccation and where their diverse carbon (C), energy and mineral nutrient needs are met. We examined soil microbial biomass C; basal respiration; the metabolic quotient (qCO_2); C, nitrogen and phosphorus exoenzyme locations and activities; microbial community composition; and, the identity of dominant fungi colonizing biochar in a NY soil amended with 0, 1, 12 or 30 t biochar ha^{-1}.

Results and Discussion

Results echo those obtained in studies on the terra preta soils of the Brazilian Amazon. Biochar-amended soils had higher microbial biomass C, but lower basal respiration, which resulted in lower values for qCO_2. These results indicate a substantial increase in microbial carbon use efficiency, the existence of an alternative soil sink for CO_2 (such as the carbonate cycle), or some combination of these. Biochar-amended soils had higher activities of aminopeptidase and phosphatase, relative to β-D-glucosidase or β-D-cellobiase, which indicates a low demand for C substrate relative to cellular needs for N or P. The opposite was true for unamended soils, where C mineralizing enzymes were most active. These results suggest that the changes observed in qCO_2 in biochar-amended soils may be linked to increased microbial C use efficiency. Alternatively, the functioning of C-mineralizing enzymes may be impaired by how they become adsorbed to the biochar.

Biological molecules adsorb strongly to biochar. This compromises recoveries of target molecules in many of the assays commonly used to measure microbial characteristics of soils. In enzyme assays that depended on recovering fluorescent products formed when the substrates, MUF-P and MUF-G, were cleaved by their target enzymes, adsorption of liberated fluorophores increased with increasing levels of biochar added to soils. A unique approach was used to derive the kinetic coefficients needed to measure enzyme activities in biochar-amended soils. Adsorption isotherms were derived for each rate of biochar applied. These were fitted to the Freundlich Equation, which was then used to model the kinetics of each of four enzymes tested. and using the resulting modeled values derived to do so was developed (Jin et al., submitted). All other assays based on soil extractions needed to be similarly examined and modeled so that more robust data could be derived. The bacterial and fungal community compositions s were affected strongly by adding biochar to the NY soil. Community divergence increased with increasing rates of biochar applied. Sequenced fungal internal transcribed spacer (ITS) amplicons indicated a shift from septate fungi in the *Basidiomycetes* and *Ascomycetes* to coenocytic fungi in the *Zygomycetes* and *Glomeromycota* (arbuscular mycorrhizal fungi, AMF).

Enhanced germination of AMF spores in contact with biochar has been observed in other studies. Here, we suggest that the adsorption of essential nutrients on biochar allows these fungi to colonize, produce exoenzymes and meet their mineral nutrient needs. The recalcitrance of biochar suggests that the septate fungi may not be able to meet their C needs from biochar and thus are not encouraged to colonize.

Conclusions

Overall, our data suggest that profound changes in soil microbial communities are occurring in biochar-amended soils that apparently lead to tighter cycling and reduced system loss of both nutrients and carbon (as CO_2). Biochar clearly influences the diversity of microbes colonizing its surface, their activities and their abundance, with a net result of the conservation of resources within the soil system.

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Biochar for soil management: effect on soil available N and soil water storage

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Key words: *Soil ammonium-N, soil nitrate-N, soil moisture*

Introduction

Soil management practices for improving soil moisture storage and nutrients are needed to increase food production in smallholder agriculture. In a field studies at Soil Research Institute, Kumasi Ghana, (6°40′N, 1°40′W), a control treatment, five inorganic fertilizer combinations ($P_{30}K_{60}$, N_{60} $P_{30}K_{60}$, $N_{120}P_{30}K_{60}$, $N_{180}P_{30}K_{60}$ and $N_{240}P_{30}K_{60}$) and four biochar rates + inorganic fertilizer (2 t ha^{-1} Biochar + N_{60} $P_{30}K_{60}$, 4 t ha^{-1} Biochar + N_{60} $P_{30}K_{60}$, 6 t ha^{-1} Biochar + N_{60} $P_{30}K_{60}$ and 8 t ha^{-1} Biochar + N_{60} $P_{30}K_{60}$) were assessed for their effect on soil moisture storage, soil available nitrogen and crop yield. The test crop was okra. The experimental design was Randomized Complete Block Design with three (3) replicates. Extractable nitrate and extractable ammonium was analysed using colorimetric method (Anderson and Ingram 1993, ICRAF, 1995).

Results and Discussions

Biochar amendments increased soil moisture relative to sole inorganic fertilizer application by 14%. Biochar + inorganic fertilizer at 0-15 cm soil depth increased available nitrate concentration by 85% but decreased ammonium-N concentration by 71% relative to sole inorganic fertilizer. Inorganic fertilizer ($P_{30}K_{60}$) resulted in more than 100% increase in okra fresh fruit yield relative to the control.

Addition of 60 kg N ha^{-1} to P_{30} K_{60} caused 23% decline in okra fresh fruit yield but showed 60% more okra fresh fruit yield compared to the control. Inorganic N rate 120,180, 240 kg N ha^{-1} combined with $P_{30}K_{60}$ caused an average okra fresh fruit yield decline of 74%. Biochar + inorganic fertilizer on the other hand, showed superior okra fresh fruit yield. The added benefit of biochar amendment to okra fresh fruit yield ranged from 8.6% to 43%.

Conclusions

Biochar combined with inorganic fertilizer has tremendous potential to address food insecurity through soil moisture improvement and soil N availability.

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[1] Anderson, J.M; Ingram, J.S.L. 1993. Tropical Soil Biology and Fertility: A handbook of methods. CAB International, Wallingford, UK.

[2] ICRAF, 1995. Laboratory Methods for Soil and Plant Analysis. Version 1.1. Nairobi.

Effect of biochar amendment on rice yield, soil respiration and greenhouse gas emissions from heavy metal polluted and non-polluted paddy from Tai Lake plain, China

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Recently, an urgent need for use of biochar from crop straw material as an option to mitigate climate change and improve food productivity has been raised world wide. In this study, a field trial was carried out in 2009 to compare the mutual effect of biochar application on rice yield and GHGs emission from heavy metal polluted and non polluted rice paddy from the Tai Lake plain, Jiangsu province, China. Two plots of rice fields were chosen for study. One was polluted due to with downwind emission from a metal smelter factory and the other was non-polluted in 1km distance in upwind direction. The biochar amendment was made by pyrolysis of wheat straw produced in SanLi biomass engineering company, China. it was applied at rate of 0, 10 and 40t/ha with and without nitrogen addition respectively. Yield, soil properties was determined after rice harvest and greenhouse gases emissions were monitored using closed chamber devices at 1wk interval during growing season of rice (Oryza sativa L., cv. Wuyunjing 7).

Soil pH (H_2O), soil microbial biomass carbon and total N increased and soil bulk density decreased under biochar application in both polluted and non-polluted plots without N addition, especially at higher application rate. Rice yield reached 9.5t/ha and 10.2t/ha respectively under biochar application alone, which was respectively no significantly smaller and significantly higher than that under N addition alone of the non-polluted paddy and no significant difference of polluted paddy.

The figure of GHGs emission from the rice paddy under biochar application was very complex. In non-polluted plot, no significant changes in of N_2O emission but increase in CH_4 emission was observed without N addition. Both CH_4 and CO_2 emission was significantly increased with N addition in the non-polluted plot. However, there was indeed a much significantly decrease in N_2O emission factor, showing an offsetting potential of using biochar for reducing N emission from N fertilization in agriculture. It is also very interesting that a small increase in CH_4 emission but a big decrease in total soil CO_2 emission during the whole rice growing season was observed both with and without N addition in polluted plot. There was a significant ($p<0.01$) correlation of soil respired CO_2 emission with available Cd and Pb content in the polluted plot, demonstrating that biochar amendment increased soil microbal biomass and decreased soil respiration through decreasing available Cd and Pb in polluted soil.

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

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Increasing levels of greenhouse gases in the atmosphere have lead to the search for new technologies to mitigate climate change. The use of biochar, which includes all kinds of carbonized biomass types, is believed to sequester carbon (C) into soils. However the addition of biochar to soils may also change physico-chemical soil properties, microbial activity, nutrient dynamics and consequently soil productivity. Due to the excessive historic addition of manure and mineral fertilizers, Flemish soils are prone to nutrient losses, and especially nitrogen (N) leaching, with detrimental effects on the environment. We hypothesize that addition of biochar may prevent N leaching from these soils.

An incubation experiment was conducted over 98 days into two silty loamy soils, with different management histories, to which four different types of biochar were added. Biochar, prepared from either poultry litter or pine chips and combusted/pyrolized at both 400 °C and 500 °C, was added at a rate of 20 $Mg.ha^{-1}$. Every two weeks pH, mineral N (NO_3^-, NH_4^+) and plant available phosphorus (PPP) was determined. Initially and after 14, 56 and 98 incubation days cation exchange capacity (CEC) and additional soil microbial parameters, such as phospholipid fatty acid analysis (PLFA) for the microbial community structure, microbial biomass (by the fumigation-extraction method) and enzyme activities were measured.

Due to the biochar amendments nutrient cycles in these loamy soils were affected. Depending on the charring temperature and the biomass feedstock, N dynamics differed significantly among the treatments. Higher charring temperatures slowed the rate of N mineralization down. In pine wood biochar amended soils even an immobilization of N was observed. PPP increased in poultry litter amended soils, however charring temperature increase the amount of PPP. Also microbial community structure, biomass and activity were affected by the different biochar amendments. These changes were linked to the changed nutrient dynamics.

We conclude that the addition of biochar to Flemish loamy soils has a tremendous effect on soil nutrient dynamics. Especially N leaching and the accompanied environmental harm may be prevented by adding specific biochar types to these soils.

The effect of biochar on corn, soybean and switchgrass on high and low fertility soil in Southern Quebec, Canada

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Addition of biochar to tropical soils has resulted in increased nutrient availability and soil organic matter leading to increased crop yields [1]. However, little research has been conducted on the impact of biochar soil amendments in temperate climates. The aim of this 2-year field experiment is to investigate the effects of biochar on the growth of three crops (switchgrass, corn and soybean) grown on two contrasting soil types (a high quality loamy soil and a low fertility sandy soil) in Southern Quebec, Canada. Biochar was added in the spring prior to secondary tillage and seeding at rates of 0, 20 and 40 t ha^{-1} and was incorporated into the soil through secondary tillage. Time to seedling emergence, time to flowering, leaf area index and accumulated biomass were recorded at the mid-vegetative stage, at flowering and halfway through seed-filling. In the case of soybean the nodulation process was observed through indicators such as the number and weight of nodules. At harvest total crop residue (stems and leaves), seed number, 100-seed weight, seeds per reproductive structure (cob or pod) and seed yield were all measured. Detailed results will be presented on the effects of biochar soil amendment on the three crops. This research will provide insight into the effects of biochar soil amendment in a temperate climate and investigate its prospects to be used commercially in Southern Quebec.

Effect of Biochar on wheat yield, soil respiration and nitrous oxide fluxes

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The idea that agricultural soils have great potentials for storing Carbon and sequester atmospheric CO_2 is attracting increasing interest in the scientific community and society. Agricultural intensification occurred over the last 50 years in developed countries led to a substantial depletion of Carbon stored in the organic fraction of agricultural soils and soils which are depleted in organic Carbon represents a potential large sink for atmospheric C-sequestration. The pyrolisis conversion of agricultural residues into biochar and its incorporation in agricultural soil, avoids CO_2 emissions providing a safe long-term soil carbon sequestration. Furthermore, biochar application to soil seems to increase nutrient stocks in the rooting zone, to reduce nutrient leaching and to improve crop yields. This paper reports the results of an experiment of biochar application in Central-Italy on a durum wheat (Triticum durum L.) crop. The present study was carried out. A randomized block experiment with three treatments and four replicates was made, involving a C (control), B3 (30 t biochar ha^{-1}) and B6 (60 t biochar ha^{-1}). Each experimental plot had an area of 25 m^2. The addition of large amounts of biochar caused detectable changes in the optical properties of the soil surface.

Based on results from two subsequent years of biochar application, an increase crop yield and dry matter production was observed. The time lag between sowing and plant emergence was significantly reduced in the treated plots. The increased soil temperature, the improved soil water retention, the increased CEC are some of the soil modifications induced by biochar which might have stimulated plant growth. CO_2 and N_2O fluxes were also measured during and between fertilization events. Preliminary data seems to indicate that biochar application slightly increases soil CO_2 emissions and partially reduced N_2O production.

Influence of different types of biochars on the water retention of two soils (an Alfisol and an Andisol)

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The use of biochar as a means to ameliorate the physical properties of soils and, particularly, the soil water retention capacity, has emerged after identifying its unique characteristics (e.g., high porosity). The objective of this study was to investigate to what extent the addition of biochars produced from different feedstocks and at different temperatures affects the water retention curve of two soils. Four biochar types – produced from corn stover (CS) and Miscanthus spp. (MS) pyrolysed at 25 °C min^{-1} to 350 and 550 °C (MS350, MS550, CS350, CS550) – were incorporated into two distinct soils, an Alfisol and an Andisol, at the following application rates: 0, 2.5, 5.0, and 10.0 t ha^{-1}. Soils were previously dried and sieved through 2 mm. Moisture contents of the mixtures at different matric potentials (-15, -1, -0.3, -0.1, -0.08, -0.06, -0.04, and -0.02 bar) are being measured to represent the soil water retention curve. The results obtained at -0.1 bar indicate that, compared to the controls – which had a soil water content of 0.50 and 0.70 (wt/wt) for the Alfisol and the Andisol, respectively – all the biochar-amended soils increased the amount of water retained, as expected. When adding 2.5, 5 and 10 t ha^{-1} of MS350 biochar to the Alfisol, the moisture content increased 4-12 % the original value. This range changed to 2-10, 4-8, and 2-6 % when the MS550, CS350 and CS550 biochars were added to the same soil. The addition of 2.5, 5 and 10 t ha^{-1} of MS350 biochar to the Andisol increased the soil moisture 3-9 % of the original value. This range changed to 1-6, 3-7, and 3-6 % with the addition of MS550, CS350 and CS550 biochars, respectively. A greater water retention was generally observed in the 350-biochars compared to the 550-biochars, but this was only significant ($P<0.05$) for the MS biochar added to the Alfisol. No significant differences ($P<0.05$) in water retention were observed between the MS a nd CS biochars, except for the biochars produced at 350 °C and applied to the Alfisol. Application rate also showed a significant effect ($P<0.05$) on soil water retention for both biochar types in either soils, this effect being more evidenced at the highest application rate. The results obtained to date suggest that the addition of biochar to soils can have a positive effect on the water availability of these two soils.

Agricultural and environmental benefits from Biochar use in ACP countries: The BEBI project

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The BEBI project aims to reduce the pressure of ACP population on their forested area and, in the meantime, to increase soil fertility of croplands and reduce health risks related to cooking activities in Togo, Sierra Leon and Ghana. In particular, the project is focused on the objective of using crop residues more efficiently by adopting a pyrolisis process in innovative, low cost, and no polluting biochar producing stoves. Partners will test different feedstocks with different types of stoves and choose the best one to be distributed among local users for households cooking. Furthermore, the biochar produced as a residue of the pyrolisis will be used as an amendment in soil. These two activities are supposed to reduce desertification and unmanaged deforestation, improve soil fertility, increase agricultural yields, reduce the health risks related to charring and cooking activities, contribute to GHG mitigation and reduce poverty. The cooperation between three local NGOs and the stove producers will help to adapt the stoves to the cooking traditional methods and local people needs. The cooperation between the local and the European academic partners will enable to study the impact of biochar on soil quality, microbial communities, soil nutrients, water balance, agricultural yields, and the relation between feedstock quality, energy outputs and biochar productivity. The BEBI partners will assess also the improvement of indoor quality air due to the use of the innovative stoves. If the new stoves and biochar will be accepted by the local people a small medium enterprise will be set up to produce locally the stoves in order to boost a local sustainable development. Due to the biochar carbon sink potential a voluntary carbon trade scheme will be launched at the end of the project. The BEBI project will allow to analyse the acceptability, usability and suitability of the stoves and biochar production and use from both environmental and socio-economical point of view. Furthermore, it will improve the local partners' competence level and support their process to become poles of attractions on these technologies.

The development of a toolkit for rapid assessment and prediction of biochar stability and agronomic utility

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Before the potential for pyrolysis–biochar systems can be realised, the production and sequestration processes must be correctly specified, designed and tested. It is important that biochar produced from different feedstock under different processes has no detrimental effects on the environment. The beneficial agronomic benefits of biochar additions to soils, as well as short and long-term stability of biochar in soils may need to be maximised before biochar-enhanced soil management can be widely adopted. If biochar is to be effectively used for carbon sequestration on a large-scale, its long-term stability (i.e. centuries to millennia) needs to be proven. In addition, biochar contains a small fraction of labile carbon (which is not eligible for carbon credit under current schemes) which may impact soil processes in the short term, perhaps compounded by available mineral nutrients in the added material. The effect of biochar additions on pre-existing soil carbon (priming) also needs to be assessed.

The objective of this work has been to define a toolkit for rapid screening of short-listed biochar products for these characteristics. Quantification of the labile carbon fraction in biochar was assessed using controlled incubations of biochar in sterilised sand. Long-term stability was tested by subjecting biochar to a novel oxidative ageing technique. Soil-specific priming for the loss of pre-existing soil carbon (and its magnitude) was determined using natural abundance isotope tracing and reference soils from a single site with contrasting organic matter status. The nutrient value of biochar was determined using a procedure to extract mineral ions determined to be imminently crop-available, whilst the soil structural value of biochar products was evaluated using an approach that assessed the effects of biochar on abiotic and biotic soil aggregation processes.

Application of activated carbons prepared from biochar for soil amendment and crop yield improvement

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The largest energy input into crop production is generally nitrogen fertilizer. Activated biochar has a porous structure and its surface chemistry can be tailored for particular applications. Activated biochar captures positively charged ions like NH_4^+, K^+, Ca^{2+}, and Mg^{2+} which are retained on the carbon surface and not lost through volatilization or leaching. The binding of NH_4^+ to carbon surface is of particular interest because it reduces rate of nitrification (NH_4^+ to NO_3^-) and hence the loss of N_2O and N_2 via denitrification. Then it can sequester nutrients and hold water that might otherwise be leached through the soil profile. Activated biochar is able to bind nitrogen so that less is lost to leaching and denitrification, leading to a reduced requirement for nitrogen fertilizer application, as well as reduced ground water contamination and reduced greenhouse gas emissions (via nitrous oxide from the soil).

Activated biochar is commercially produced from lignocellulosic materials (such as agricultural wastes or forest residues), especially because of low inorganic materials content. Physical (using steam or CO_2) and chemical (using H_3PO_4 or KOH) activation methods are used to develop the porosity of biochar.

Pyrolysis of biomass produces biochar with yield of 20-30 wt %. For this study, the biochar was produced from whitewood (Spruce) using fast pyrolysis (provided by Dynamotive Corporation). This biochar was used for production of activated biochars using physical (steam) and chemical (KOH) activation. Two correlations were developed for BET surface area and activation yield of processes as a function of operating conditions. Using these correlations, the optimum operating conditions were calculated. The BET surface area and activation yield of optimum steam-activated biochar are, respectively, 643 m^2/g and 56.9 wt %, and those for KOH-activated biochar are, respectively, 783 m^2/g and 75.3 wt %.

In this study, performances of biochar (precursor), two optimum activated biochars, and treated-activated biochars (prepared by acid-treatment and nitrogen-modification) for NH_4^+ adsorption are investigated. Long-term performance of the best activated biochar will be determined by field test. Different techniques used to characterize the porous characteristics and chemical structure of original and activated biochars are as follows: Nitrogen adsorption isotherm, Boehm titration, Fourier transform infrared spectroscopy, Elemental analysis.

Effect of corn stover biochar on the growth and water relations of a bean crop

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The study was conducted in the experimental field of the Faculty of Agricultural Sciences, University of Tarapacá, Arica, Chile. The objective was to analyze the effect of biochar concentration on growth and water relations of bean cv Magnum F1. The experiment was conducted in 3 L pots in a sandy substrate with biochar corn. Irrigation was performed with a nutrient solution of Hoagland (1952) and was applied every other day when the humidity was reduced to 30% of field capacity. Before sowing, the substrate was washed three times with distilled water. The experiment considered the following treatments: 0%, 3%, 5% and 10% char. The parameters measured in plants of 20 days are for height, stem diameter, fresh and dry weight, relative water content (RWC), water potential, osmotic potential, turgor potential and stomatal conductance. The results indicate that growth factors pres entan little difference between treatments, however, the dry weight can be seen further development in plants controls without char. The CRA is very similar between treatments. The water potential tends to diminish in direct relation to increased concentration of biochar, however, these variations are rare and occur in a range of - 0.2 MPa and - 0.55 MPa. These results indicate that 10% of biochar in the substrate is more available water for the plant which could be explained by assuming that the char can act as a water retainer and maintain, therefore, a more stable saturated environment between each irrigation. This effect of biochar on the water potential, may be reflected in cell turgor (turgor potential) which also increases in direct relation to increased concentration of biochar which resulted in treatment with 10% of this char a turgor m ayor that the control without char. Stomatal conductance is a little variable factor between biochar concentrations tested, demonstrating that plants are not subject to water stress in any of the treatments the effect of char.

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Charcoal Powder and Sawdust on Nutrient Availabity in a degraded Amazonian Oxisol

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The use of charcoal as a soil amendment is being touted as a potentially effective technique for nutrient management in tropical soils. The objective of this study was investigate the effect of charcoal, sawdust and organic compost on the chemical properties of a representative, low fertility Amazonian soil in an attempt to reproduce the fertility of Dark Earth soils. The effect of treatment 13 (120 Mg ha^{-1} of charcoal powder and no sawdust) increased pH five units higher then control plot in the soil sample showed at 0-10 cm depth. Additionally the treatment 4 (120 Mg ha^{-1} of sawdust and no charcoal) presented the lower value of potential acidity ($H^+ + Al^{3+}$).

The "Sewchar" Concept – A Strategy for the Sustainable Treatment of Human Waste and Sewage Sludge?

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Biochar strategies evolve extra (socio) economic and environmental benefits when waste materials are used as feedstocks, that up to now have to be discharged into cost-intensive and non-sustainable treatment processes. In contrast to directly plant derived feedstocks, such as biomass from dedicated bioenergy crops or agricultural and silvicultural residues, carbonaceous materials from the wastewater sector do not face any relevant competitions by alternative utilization routes. In many developing countries human excreta are hardly treated at all and, thus, cause substantial harm to human beings and the environment. On the other hand, due to the risks of organic contaminants the reuse of sewage sludges from conventional wastewater treatment plants as soil amendments is a matter of debate in industrialized countries. Thermochemical conversion processes used in biochar production principally allow for both, the removal of pathogens and the degradation of xenobiotics. By this way, biochars from human waste and sewage sludges, so-called "sewchars", could offer benefits not only for climate change mitigation and soil amelioration but also for health and environmental protection.

In order to develop environmentally sound and economically viable sewchar strategies our long-term research program addresses aspects of conversion technology, the physico-chemical characteristics of the conversion products and the effect of these products on soil properties and plant growth under specific site conditions. Our ongoing work encompasses concepts based on i) low temperature conversion (LTC), a process for dried feedstocks related to low temperature pyrolysis and ii) hydrothermal carbonization (HTC), that enables the conversion of carbonaceous materials with high moisture contents. The HTC technology is still in its infancy and investigations of HTC products are scarce. To increase the knowledge particularly in this field we are currently comparing LTC sewchars of an activated sewage sludge with the solid and liquid conversion products of a primary sludge that has been hydrothermally treated at different time/temperature regimes (h/°C: 4/180 – 4/200 – 8/200). Our initial analyses address the inorganic and organic composition of the conversion products and their impacts on germination of cress as well as on the plant mineral nutrition and growth of tomato and wheat in mixtures with inert quartz sand and soil material of a chernozem. In addition to the effects of sewchar additions on relevant soil parameters, such as CEC, WHC and plant available nutrient contents, influences of the different thermochemical treatment processes on the recalcitrance of the carbonaceous fraction will be discussed.

Nitrogen Use Efficiency of Maize after Biochar Additions to a Temperate Soil

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Abstract: Biochar additions to tropical soils have been shown to reduce nitrogen leaching through increased adsorption capacity and greater fertilizer use efficiency. Few studies exist documenting this trend in temperate agricultural soils. To what extent the application rate of biochar affects fertilizer use efficiency is also not known. Biochar derived from maize stover produced under slow pyrolysis was applied to a maize cropping system in central New York at rates of 0, 3, 12, and 30 t ha^{-1} in 2007. Nitrogen was applied at 12.35 kg N ha^{-1} at planting and at 107.61 kg N ha^{-1} six weeks after planting. The secondary N application was applied in treatments consisting of 100, 90, 70, and 50% of 107.61 kg N ha^{-1}. Labeled isotopic 15N was applied for the 2009 season at 1 kg 15N ha^{-1} for the treatment combinations of 0 and 12 t ha^{-1} of biochar and 100 and 50% secondary N application. Free-draining lysimeters were installed 0.6m below the soil surface in these same treatments for the 2009 growing season to collect the leachate. With a constant fertilization rate of 90% secondary N, biochar application rate did not significantly affect maize grain yield. At the 50% secondary N application rate and 0 and 12 t ha^{-1} biochar there were no significant differences in maize yield or N leaching between treatments. With 100% secondary N application biochar additions significantly increased grain yields and significantly decreased N losses via leaching. Mechanisms for these differences are being evaluated through stable isotope tracing.

Investigation of potting mixes containing biochar and biochar mineral complexes for the horticultural industry

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There is a significant potential market for biochar as a component of potting mixes. The use of biochar has, for some time, been recommended in a variety of horticultural applications including as a substrate for potting mix (Santiago and Santiago, 1989). A range of potting mixes containing biochar and biochar mineral complexes were formulated for horticultural applications. The physical and chemical properties of the mixes were tested and compared with the Australian Standard for Potting Mixes (AS 3743). Detailed structural characterization of the mixes were also performed to investigate the extent of interfacial reactions between the constituent phases. Germination, toxicity and pot trials were then undertaken. Results describing the structure and composition of these materials will be described, together with preliminary results of pot trials.

Santiago, A. and Santiago, L. (1989) 'Charcoal chips as a practical substrate for container horticulture in the humid tropics', Acta Horticulturae, vol238, pp141-147

The Quantitative Differentiation Between the Presence of Carbon Basal (Humus) and Biochar Carbon In Soil Aggregates

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The need for suitable land for agricultural cultivation, has stimulated the search for technologies that allow the recovery and improvement of soils, such as those found in northern Chile, characterized as arid soils with low organic matter content, as well high concentrations of salts.

In this type of soil, bind the difficulties imposed by the climate typical of these latitudes, which impacts heavily on water management and water retention due to high temperatures and low humidity, which cause a high evaporation of substrate fluid in the growing areas.

The application of biochar as a soil amendment, has shown beneficial effects, because it has a more condensed chemical structure, which is very reactive toward many chemical agents, such is its almost no interaction with alkaline solvents used for solubilization of humus.

The main objective of this work is to differentiate quantitatively between the two main sources of organic carbon corresponding to the basal soil organic carbon (OC) or "humus", and the integrated biochar in soil through solid-liquid extraction alkaline solution.

To achieve this goal, we used the different chemical properties of humus and char, particularly in their chemical reactivity against alkaline solutions, subjecting soil samples from two locations in the XV region of Chile, with humus and char, using different systems extraction. The extracted organic carbon was quantified by wet oxidation with a mixture of dichromate and sulfuric acid (Walkley & Black amended), by measuring the reduced chromium molecular absorption spectroscopy UV-VIS, 600 nm, thus confirming the quantitative difference between carbon from organic soil and biochar.

The results show that the method of extraction of organic carbon is the most effective treatment solution where 1 N sodium hydroxide and sodium hexametaphosphate 4% w / v, improving the efficiency of extraction by application of heat in a system reflux, where the extraction of CO is about 80%, for soils without biochar, and about 100% in soil treated with biochar artificially in a 1:1 ratio.

The study of phosphorus fixation was performed in an alluvial soil and Lluta Aridisol Valley, in the Atacama desert in northern Chile, using as raw material for the preparation of biochar and RC, vegetable salt grass (Distichlis spicata), a very common and widespread weed in the soil of the valley. These are incorporated in increasing proportions to the ground, mixed and stirred in 1:20 with KH_2PO_4 solution containing 100 mg P / mL to reach equilibrium. The results show a gradual increase of pH according to the presence of char and RC on the ground, and the phosphate binding capacity generated by the RC can be up to three times the fixation of phosphate generated by the char.

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Effect of biochar amendment on carbonate chemical processes in soil

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Soil in-organic carbon is an important C pool in semi-arid and arid zone. In arable soil, intensive input of irrigation water and fertilizer make the transformation process of soil calcite quicker. Biochar, with high CEC, nutrients in mineral form, micro-pores, active reacting groups, and special macro-molecules, will be affect the carbonate processes when be added to soil. With 2 hypothesises, 1) high CEC meaning strong absorbance for cations will have impact on fractionation of Ca^{2+} and Mg^{2+} between free ion (in solution) and absorbed ion (exchangeable), and 2) biochar, with slow decomposition and absorbing to CO_2, will result in decrease of CO_2 pressure in soil, and change the balance of solubility and precipitation of Ca^{2+} and Mg^{2+}, a laboratory experiment was conducted. Different proportion of biochar (made from wheat straw) and wheat straw was added to soil and incubated at 25, 50-60% WHC, and free air exchange with atmosphere. In situ soil CO_2 concentration and pH was measured periodically. Water soluble and exchangeable Ca^{2+} and Mg^{2+} was also measured by chemical method. Primary result showed that, 1) Biochar alone did not decomposed in soil, 2) Biochar reduced in situ soil CO_2 concentration in straw-amended soil up 40%, 3) Biochar amendment to soil increased both the water soluble Ca^{2+} and Mg^{2+} and its ratio to exchangeable Ca^{2+} and Mg^{2+}, 4) Biochar amendment to soil increased the saturation degree of Ca^{2+} and would changed chemical behavior greatly. The current result gave more clue to explore on soil carbonate chemistry under biochar amendment.

Caracterização dos Macronutrientes e a Dinâmica dos Resíduos de Lâmina de Madeira em Terra Preta Nova

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A Terra Preta Arqueológica possui alta fertilidade devido ao acúmulo de material orgânico depositado nas aldeias indígenas na pré-história, como prática cultural daqueles povos. Na tentativa de replicar estes solos, procurando-se alternativas para minimizar a incineração e acumulação em locais inadequados de resíduos de madeira das serrarias de Tailândia- PA, tida como um dos maiores pólos madeireiro do país, foi implantado o Projeto Terra Preta Nova. Experimento de longa duração, conta com 17 tratamentos resultantes da combinação de Carvão, Resíduos de pó de serra, Resíduos de lâmina triturada, Resíduos de ossos e Sangue + gordura. Os resultados preliminares, após seis anos, indicam uma relação positiva no incremento dos macronutrientes principalmente P, Ca, Mg e K.

Field trials in Québec, Canada: report on 2 years of biochar effect on crop productivity, and multiple biochar material testing

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We will report on a 2-year old commercial-scale biochar trial, as well as show preliminary results for a new experiment established in 2010. A biochar field trial was established on a farm in Québec, Canada in May 2008 on a clay loam soil. Biochar from fast pyrolysis was applied using farm machinery at approximately 3.9 t/ha. Biochar was applied in a single, 1,000 m^2 swath and compared to an adjacent, unamended control swath, thus this is not a standard replicated experiment. Soybean was grown in 2008 and mixed forage species in 2009, and a large dataset was gathered including monthly data on soil physical parameters, soil chemical fertility, soil micro- and macrofauna, crop morphology, quality and yield. Yield increases in soybean averaged 19% over the control, and forage biomass was doubled by biochar application, compared to the control. In soybean, yield improvements arose from greater plant population density, as opposed to greater seed production per plant. Yield differences cannot clearly be attributed to chemical soil fertility differences among treatments. Surface soil infiltration was greater when biochar had been applied, but no differences were found in soil temperature, moisture content, and resistance to penetration. The number of nodules per soybean plant was not affected by the biochar treatment, but root colonization by ectomycorrhizae in the forage crop was greater when biochar was applied. Earthworm density was generally greater with biochar, and data on fungal and microbial grazers, and microbial and fungal biomass seem to support the hypothesis that biochar can serve as a refuge for soil microbes. Total soil carbon, soil respiration and potential organic matter mineralization were not measurably different in the biochar-amended plot. This is the first report on results from commercial scale biochar field trials in Canada.

In April 2010, two additional replicated and randomized field experiments were established on a nearby farm. The goal of these experiments is to assess the impact of three different biochar materials and the effect of soaking biochar in dairy manure prior to soil application, on crop production and soil fertility in the field, and to study the form and availability of phosphorus (P) in soil, under the various treatments. Phosphorus management in agricultural soil is seen as key for reducing eutrophication problems in this watershed, and biochar is a potential tool for decreasing P export from soil into surface water.

Potential of Biochar as a source of Amendment in degraded Lateritic soils of tropical forest plantations in Kerala, India

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Soils of Kerala in general are lateritic in nature and the fertility of the soil is mainly decided by its organic carbon content. Most of the initial forest plantations of the State were established on organic rich virgin soil immediately after deforestation and hence they were high yielders. But in due course, along with the growth of plantations over rotations soil became sterile due to the loss of their life imparting component ie organic carbon through run off and faster decomposition. In the context of current issues of global warming and soil degradation, it was finally realized that increasing the soil carbon level was the only solution for the sustainable development of plantations and environmental safety. But the question before us is the production of enough organic amendments to meet the current demand in forestry sector. Selective application of organic amendments based on soil carbon stock offer judicious management of available resources. Considering the proven benefits of Biochar, a study is being under taken to produce biochar from various sources such as forest weeds, wastes from municipal and industrial sector etc. and to evaluate the quality of biochar thus produced with respect to nutrient composition. Dalbergia latifolia, a premium-quality timber species internationally known as "Indian Rosewood" is being used as a test crop to study the growth response to biochar. Attempts to raise plantations of rosewood by Forest Department and progressive farmers have shown difficulty in initial establishments and slow growth, especially in degraded, acidic soils of the Western Ghats. Even though the application of organic manures was found to increase the growth rate of rose wood in experimental fields, their availability for establishing large scale plantations is a real problem usually encountered. Considering these factors a study is being under taken to evaluate the potential of biochar as a source of amendment for degraded lateritic soils of forest plantations in Kerala so that the use of other organic manures can be minimized.

Empirical Model for Soybean Productivity (Y) having as Independent Variables NPK (X1) and Biochar Doses (X2)

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Biochar has stable components and electrically charged functional groups. This makes its use in agriculture promising for C sequestration and for soil fertility management. In the studied field experiment in the Brazilian savanna biochar (charcoal) was added to the soil in 5 different doses (0, 2, 4, 8, 16 Mg/ha) and combined with 5 doses of NPK (0, 100, 200, 300, 400 kg/ha) in 4 repetitions in a field experiment (random block design, sandy Haplic Ferralsol). Soybean productivity (Y, kg/ha) was modeled as function of biochar (X2) and NPK (X1). The quality of the model was evaluated by variance analysis. The linear model for the variable was considered significant by the F test, however, the explained variation was only 57.5%. This was increased to 65.6% when quadratic behavior was tested for X1 (NPK) that was expected because of the general response curve to essential nutrients (Roat-Malone, 2006). When quadratic contribution was applied to X2 (Biochar) there was only a little increase in the explained variance (66.5%). This could be neglected since its coefficient was smaller than the respective standard deviation, however, it would make sense to use it since the response (Y) will certainly not be linear to ever increasing X2 (at high doses). This curvature can orient future studies that search for the optimal range of application of this variable. The graphical analysis of the residuals of the linear model suggested a behavior of third order for NPK. Testing it the explained variance by the model increased significantly to 74.7%, the standard error diminished and the statistical significance of the model increased. However this value can be still considered low compared to other experimental models, we considered it satisfactory due to the high variability of the repetitions that makes modeling difficult. The proposed model is the following: Y = 2885.7(37.1) – 84.5(76.3) X1 + 98.8(48.4) X1*X1 – 19.8(8.0) X1*X1*X1 + 22.7(9.1) X2 – 0.4(0.6) X2*X2.The experimental intervals, X1 (0 through 400 kg/ha) and X2 (0 through 16 Mg/ha), were used in this equation to make the response surface analysis. The optimal range for NPK was between 200 and 300 kg/ha. For the biochar there was no optimal region obtained for maximum. Following the response surface in the direction of the maximum inclination repeating the steps of modeling and dislocation when necessary, the optimal region for the investigated phenomenon can be reached.

Effects of the application of biochars with different physicochemical properties on soil functions of two temperate soils

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Biochar can improve soil fertility and biomass production. However, biochar derived from different processes and different raw materials differ with respect to their physicochemical properties, which leads to diverse effects on soil functions after application. Moreover, the prerequisite for an amendment of biochar to soils is the exclusion of negative effects on soil functions and the environment. Therefore this study investigates effects of biochars made by flash pyrolysis from spruce wood (PC), gasification from beech wood (GC) and conventional charcoal produced from beech wood (CC) on functions of two temperate soils in a field trial. The physical and chemical properties differed strongly between the studied biochars. CC and GC exhibited clearly higher pH values (CC: 8,4; GC: 10,6; PC: 4,2), ash and nutrient contents, specific surface areas (CC: 122 m^2g^{-1}; GC: 191 m^2g^{-1}; PC: <0,4 m^2g^{-1}) and micro porosities (CC: 450 m^2g^{-1}; GC: 449 m^2g^{-1}; PC: 262 m^2g^{-1}) than PC. The degree of condensation increased in the order PC (H/C = 0.58) < CC (H/C = 0.45) < GC (H/C = 0.20) and the degree of oxidation decreased in the order PC (O/C = 0.13) > CC (O/C = 0.05) > GC (O/C = 0.04). The different physicochemical properties of the biochars are reflected in the first results of the field trail. While the overall effect of the added biochars (1.5% weight) on soil functions was only small, significant differences between soils mixed with different biochars were nevertheless detected. Applied PC significantly decreased the soil pH and also reduced the actual soil water content, whereas the application of CC and GC significantly increased soil water contents. Concentrations of inorganic and organic pollutants in the biochars did not exceed German environmental standards (precaution values). Our results indicate that negative side-effects of biochar application to soils might outweigh potential merits such as carbon sequestration. Properties of different biochars and their effects on soil functions such as fertility must be considered and regulated prior to the widespread use of biochar as a soil conditioner.

Biochar and plant-root interactions

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Soil amended with biochar may provide benefits to soil fertility and crop production. The improvements may be due to increased soil aeration, moisture retention and nutrient availability, and the mechanisms behind these are likely to vary with soil and plant type, as well as biochar type and rate of application. In general, biochar studies relate higher crop yields with larger root systems, but further quantification of plant roots, other than root biomass, is required: for example in terms of root growth (rate, turnover), root architecture (length, diameter, density), root health (disease resistance), and subsequent impacts on the rhizosphere (the zone of soil that is directly affected by roots) and microbial communities. Our hypothesis is that changes in root dynamics following biochar application will affect moisture and nutrient uptake, soil biogeochemical cycling, and soil carbon dynamics. To test this, the effects of sustainably-sourced charcoal (as a proxy for biochar) on cereal roots and the rhizosphere were studied. Results indicate that root proliferation was more pronounced in char-amended soil and addition of char altered root architecture (total root length, root density). Furthermore, changes in ‘bulk soil’ vs. ‘rhizosphere soil’ pH were greater in char-amended soil compared to the control. The implications for biochar will be discussed.

Aplicação de “Biochar” de Eucalipto em Solos Degradados: Atividade do solo e índices físicos

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A elevação das emissões de gases de efeito estufa (GEE) na atmosfera tornou-se um grave problema ambiental e econômico na atualidade, face as suas implicações no aumento da temperatura média do Planeta. Essa elevação é causada, principalmente, pelas emissões de CO_2 (Dióxido de Carbono) via queima de combustíveis fósseis e mudanças no uso e cobertura da terra (desmatamento e queimadas, por exemplo), as quais ocasionam alterações importantes nos estoques naturais de carbono. Isto por que, depois do vapor d’água que causa de 36 a 70% do efeito natural (não incluindo nuvens), o CO_2 é o GEE que mais contribui para o efeito estufa (entre 9 a 26%) (COLE et al., 1995; IPCC, 2007).
Dentre as novas tecnologias desenvolvidas, uma que se encontra em destaque é o “biochar” (biomassa + carvão, em inglês), por se tratar de uma tecnologia potencialmente eficaz no que diz respeito a seqüestro de carbono, além de ser apontado como de grande auxilio na fertilização agricultura, já que aumentaria a quantidade de carbono no solo possibilitando do desenvolvimento microbiano. O “biochar” é produzido por pirólise, que é basicamente a queima de matéria orgânica em ambientes com pouco ou zero de oxigênio No entanto, pensar no uso de “biochar” somente para a questão do aquecimento global esconde sua potencialidade na recuperação de solos e também na remoção via pirólise de produtos químicos indesejáveis como resíduos. Neste contexto, iniciou-se um trabalho de trabalho de pesquisa tendo como objetivo viabilizar a utilização de resíduos orgânicos na forma de “biochar” por meio de pirólise em solos degradados. Os parâmetros em estudo são: os índices físicos e a atividade dos solos incorporados com “biochar” de eucalipto em diferentes texturas e dosagens.

A Simple Method for assessing the potential of Biochar to increase Crop Productivity

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This paper describes a simple procedure to provide an estimation of the potential of biochar to increase productivity of different crops in different soil types, biochar made from different feedstocks and with different microbial additives.
The procedure does not substitute for controlled field trials. However, given the large number of permutations of soils, climate, crops and microbial additives it is impossible to test all potential biochar treatments in the field.
This procedure has the potential to allow the design of strategic and focused field trials.

Biochar como condicionante de substrato para produção de mudas de carvoeiro (*Tachigali paniculata* Aubl.)

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O avanço da fronteira agrícola no Brasil Central tem provocado problemas de degradação ambiental, com perda da biodiversidade e redução dos teores de matéria orgânica dos solos, exigindo ações de recomposição de áreas degradadas (RAD). A produção de mudas destinadas à RAD requer técnicas adequadas para obtenção de plantas sadias e aptas às condições adversas de campo. Uma das formas de produção de mudas vigorosas é o uso de condicionantes de substratos com base em compostos vegetais ricos em carbono. Apesar de estudos apontarem que solos antropomórficos da Amazônia (Terra Preta de Índio) apresentam alta produtividade agrícola sem adubação devido à alta CTC resultante da ação do carvão vegetal das antigas fogueiras dos índios, até o momento, no Brasil Central pouco se sabe sobre os efeitos do carvão vegetal pirogênico (Biochar) na produção de mudas de espécies nativas. O objetivo deste estudo foi testar a eficiência do Biochar como condicionante de substrato para a germinação de sementes e desenvolvimento de mudas de carvoeiro (*Tachigali paniculata* Aubl.), espécie de grande importância para RAD. O experimento foi realizado no Viveiro da Universidade do Estado de Mato Grosso, Campus de Nova Xavantina. Foram testadas quatro concentrações de Biochar em pó e um controle: 5%, 12,5%, 25% e 50% e 0% do volume total do substrato base. Foram plantadas 60 sementes em cada tratamento e no controle. A semeadura foi diretamente em sacos de polietileno de 10×20 cm em casa de vegetação. A cada 30 dias, durante sete meses, foram tomadas as medidas do diâmetro do coleto, altura total e número de folhas. No final do experimento foi determinada também a biomassa seca da raiz e da parte aérea. Adicionalmente, foi testada a relação entre concentração de Biochar e umidade do substrato através de reflectômetro por domínio de tempo (TDR). Os tratamentos foram comparados pelo teste Kruskal-Wallis, regressão linear e teste qui-quadrado com correção de Yates. Os valores de altura total, o número de folhas, diâmetro do coleto, biomassa radicular e parte aérea mostraram-se positivamente correlacionados com as concentrações de Biochar (regressão linear simples, $r^2>0,9$; $p<0,01$). Todos esses parâmetros foram significativamente maiores no tratamento com a maior concentração de Biochar (50%) (ANOVA, $p<0,01$), indicando eficácia do produto para a produção de mudas em viveiro. Não foram verificadas diferenças significativas no teor de umidade do substrato entre os tratamentos, indicando não haver influência do Biochar nestes parâmetros. O Biochar pode ser recomendado como condicionante do substrato para a produção de mudas de *T. paniculata* em viveiro na concentração de 50%, assegurando melhor desempenho da espécie na recomposição de áreas degradadas ou mesmo outras finalidades.

Palavras-chave: Terra Preta de Índio, recuperação de áreas degradadas, carvão pirogênico, produção de mudas.

Effect of Charcoal And Nitrogen on Soil Arthropods Associated to Common Beans and Upland Rice

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Incorporating carbon in the form of carbonized biomass into the soil is an agricultural practice known thousands of years ago by Amazonian Indians. Nowadays it is being rescued and evaluated as an alternative to dealing with global warming. Nevertheless, the effect of modern charcoal application on soil biota must be evaluated. The effects of carbon and nitrogen fertilization on population of soil arthropods were assessed in common beans (Phaseolus vulgaris L) and rice (Oryza sativa L). The study was conducted at Embrapa Rice and Beans, Santo Antônio de Goiás, GO, from August, 26 to September, 11 2009 for common beans and from January, 07 to February 12 2010 for upland rice. The treatments were: 1. Charcoal (32 Mg / ha) + nitrogen (90 Mg / ha); 2. Charcoal (32 Mg / ha) + nitrogen (0 Mg / ha); 3. Charcoal (0 Mg / ha) + nitrogen (90 Mg / ha); 4. Charcoal (0 Mg / ha) + nitrogen (0 Mg / ha). For comparison, the same evaluations were made in plots at four sites in native cerrado forest. The experimental design was a randomized complete block with four replications. Plots were 4m wide and 10m long. Evaluations were performed weekly, using pitfall traps per plot installed between plants, standing for 72 hours. The containers with the arthropods were removed, labeled and taken to the laboratory for sorting and identification of species. All arthropods collected were sorted and packed in bottles containing 70% alcohol or pinned and stored in entomological boxes for later identification of species. The data were processed in and submitted to analysis of variance. Means were compared by LSD test ($\alpha= 0.05$). For beans, 85 morphospecies were collected, predominating ants, beetles and spiders. The total number of ant and spiders species were greater under native forest than in the crop, regardless of treatment ($P <0.05$). The number of beetles was higher in treatments receiving nitrogen, regardless of charcoal. In rice, 42 mo rphospecies were collected, mainly ants and collembolans. The collembolans predominated in cultivated environment ($P <0.05$) in plots with nitrogen. The total number of ants was significantly higher in the native forest. In the cultivated environment, arthropod populations were higher in plots treated with charcoal. Although the treatments had not provided significant changes in the populations of most species sampled, further analysis of species richness and abundance should be correlated with environmental variables for further inferences.

The enhance of soil cation exchange capacity by using charcoal in an Typic clayey Acrothoxl in the Central Amazon – Brazil

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The cation exchange capacity (CEC) of a soil is a key factor to keep soil productive capacity and and to hold the cations added by fertility management in tropical soils. In the clayey oxisols in the Central Amazon the CEC is originally low and is basically due the organic matter charges. The CEC is reduced as consequence of organic matter degradation by inadequate land use systems. The objective of this study was to evaluate the application of different charcoal levels in the CEC in the clayey yellow latossol cultivated with banana. The experiment was carried out at the Research Station of Embrapa Amazônia Ocidental in Manaus – AM. The soil was classified as an clayey Typic Acrothox. The experiment was done using a design with completely randomized blocks with in a confounded factorial (3x3) scheme with 27 treatments. The factors tested were charcoal levels (0, ~13 and ~26T ha^{-1}), phosphorus (167, 334 e 668 kg P_2O_5 ha^{-1}) and nitrogen (0, 90e 180 kg N ha^{-1}). The source of charcoal used were fine residues produced by canonization of local trees (~700 g C kg^{-1}), super phosphate simple (20% de P_2O_5) and urea (42% de N). Soil samples were collected in triplicate at each treatment in the depth of 0 - 10 cm. The CEC was determinate using an indirect methods, in which the exchangeable bases were added to the exchange acidity extracted from soils samples. The results shows significance effects ($p < 0.05$ - Tukey Test) between the level 0 (without charcoal application) and level (13336 and 26672 L ha^{-1}) and those levels do not shows differences between them. Those results shows the potential to use charcoal as soil conditioner to enhance CEC and soil fertility quality in the Oxisols. Another results about the possible influences of the enhance of CEC in the banana nutrition and production will be presented.

Black C contribution to nutrient retention and carbon sequestration in laboratory incubations

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Biochar is a high surface-area, variable-charge organic material that may improve nutrient retention and soil C sequestration but its general beneficial properties have yet to be quantified in many soil types. Biochar has the potential to increase soil water-holding capacity, cation exchange capacity (CEC) and surface sorption capacity which decrease the leaching losses of nitrate and ammonium, and reduce the emission of N_2O. Despite these properties, the magnitude of soil benefits will depend on the size, quantity, and individual characteristics of both the biochar and the amended soil. In order to determine the relative contribution of biochar to: 1) nutrient retention and 2) soil C stabilization versus losses through soil respiration, we established a relatively long-term (3 years) laboratory experiment. We added two sizes (>250 and <250 µm) of C3-derived biochar to two C4-soils (sandy, silty-clay loam) with and without fertilizer addition, and measured over time C and N losses trough respiration and leaching, respectively. At occasional destructive harvests, the contribution of char to soil organic matter fractions, separated by size and density, is quantified, and the potential for biochar to contribute to long term soil C stabilization assessed. Stable C isotope mixing model is applied to partition SOC versus biochar C in the measured C pools. Data from this experiment will be reported and results discussed in the context of the potential for biochar to promote soil organic carbon sequestration.

Biochar in rice-based systems: Impact on paddy soil and yield

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To study the effect of biochar input paddy soil, biochar was added to cultivated field of Qianyanzhou ecological station, Southern China. We used 30 plots (3m×3m), in which we fertilized three plot replicates per treatment with control, biochar, straw, inorganic fertilizer, biochar plus inorganic fertilizer and biochar plus straw. The biochar and straw were used as two levels (3000kg ha^{-1} a^{-1} and 6000kg ha^{-1} a^{-1}). After one growing season, soil carbon increased in the plot with straw and biochar, and pH of soil increased slightly with biochar and straw. The plot with biochar plus inorganic fertilizer got highest yield. The yield of plot with biochar was higher than that of control plot. Overall, our result shows that biochar can enhance the soil carbon content, the use of biochar can decrease the use of inorganic fertilizer.

Influência da incorporação de carvão nos atributos químicos e físicos do solo num plantio de *Eucalyptus benthamii*

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A utilização de subprodutos florestais nos solos surge como alternativa para a minimização de custos, proporcionar altos rendimentos à produção e benefícios ao meio ambiente. O carvão pode melhorar a qualidade do solo, gerando aumentos significativos na produtividade e resolvendo o problema da destinação final desse produto. O objetivo desse trabalho foi verificar as mudanças iniciais ocorridas nos atributos do solo quarenta dias após a incorporação de finos de carvão, num plantio de *Eucalyptus benthamii*. O experimento sob delineamento em blocos ao acaso está instalado na Universidade Estadual do Centro-Oeste (UNICENTRO) em Irati – PR, Brasil. No preparo do solo foi realizada a limpeza da área, controle de formiga, calagem (2,5 t ha^{-1}) e incorporação de finos de carvão. O plantio foi manual num espaçamento 3 x 2 m. Quarenta dias após a incorporação de finos de carvão foram coletadas amostras de solo de 0-20 cm nos seguintes tratamentos: T1 = testemunha; T2 = 10 t ha^{-1} de carvão; T3 = 20 t ha^{-1} de carvão; T4 = 40 t ha^{-1} de carvão; T5 = 200g/muda de NPK 4-14-8; T6 = 10 t ha^{-1} de carvão + 200g/muda de NPK 4-14-8; T7 = 20 t ha^{-1} de carvão + 200g/muda de NPK 4-14-8; T8 = 40 t ha^{-1} de carvão + 200g/muda de NPK 4-14-8. Foram realizadas as análises químicas de pH, matéria orgânica, K^+, Na^+, Ca^{2+},Mg^{2+}, P, Al^{+3}, H^++ Al^{+3} e determinação da saturação por bases; e as análises físicas de granulometria, densidade real e aparente, umidade e porosidade. Para os atributos matéria orgânica, teor de Mg^{2+}, granulometria, densidades real e aparente e porosidade não foram observadas diferenças estatísticas entre os tratamentos a um nível de 95% de probabilidade. Foram observadas diferenças estatísticas entre os tratamentos que receberam carvão e os que não receberam (testemunha e T5), quanto ao pH, teores de K^+, Ca^{2+} e Al^{+3}, V% e umidade. A adição de carvão aumentou o pH, os teores de K^+ e Ca^{2+}, a saturação por bases e a umidade, e diminuiu o teor de Al^{3+}. Esses resultados sugerem que a aplicação e incorporação de finos de carvão ao solo promovem a melhoria de alguns atributos químicos e físicos, podendo favorecer a produção florestal.

Biochar properties and its influence on plant growth and GHG

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Properties of biochar pyrolyzed under various temperatures, plant growth and GHG mitigation effects were investigated. Results showed that biochar recovery rates decreased with rising temperature: $y = -0.0446T + 59.614$, $R^2 = 0.8927$. Similar water soluble P contents were found in biochar pyrolyzed under 250 as under 350, and under 400 as 450, respectively. Water soluble P in biochar under 400 and 450 was significantly 67% higher than those under between 250 and 350, however when temperature was 500, water soluble P was significantly lower than those under 400 and 450, but still higher than those under 250 to 350. pH increased with rising temperature, but water absorb capacity decreased with rising temperature. Maize height was significantly shorter at high biochar amendment treatment 144 g kg^{-1} dry soil□than low (7.2 g kg^{-1} dry soil) and zero biochar amendments on day 13 after sowing, along with experiment going on, the impeding effect disappeared. However no stimulation effects of biochar on maize growth were found till now.

Composting of food waste containing biochar as biological medium and carbon sequestration by using the compost for the field

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Composting factory in a suburban area of Tokyo deals 100 tons of food industry waste a day added with charcoal. Undesired materials such as plastic, steel and aluminum materials are separated from food garbage with a separator. Then, charcoal of several % and returned compost are mixed to the garbage, and the mixture is thrown into the top of a fermentation tank. The temperature of the mixture increases to 60-70°C, because aerobic microorganisms proliferate on the surface of the charcoal. After 2 weeks, the first fermented compost is pull out of the tank. After two months the matured compost is prepared. Finaly, the compost contains ca. 10 wt% of biochar. Biochar and the compost were used for the field; 2 kg/m^2 of biochar 2 kg/m^2 of the compost for 5 a, 2 kg/m^2 of the compost for 5 a and no use of biochar and the compost: Yield of the spinach was 1.9 kg/m^2, 1.6 kg/m^2 and 1.3 kg/m^2, respectively. The total carbon, the total nitrogen and the carbon sequestration amount in the field was measured. Green house gases of CO_2, CH_4 and N_2O emitted from the field were also measured.

Salt grass biochar and combustion residue as factors in the fixation of P in a saline soil

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The "hot" or combustion "in situ" of plant residues from harvesting and pruning, as well as weed is considered one of the most traditional and universal exerted on the ground in the field of agriculture. This process contributes to the overall increase and local air pollution as it generates among other greenhouse gases like CO_2, particulate matter such as coal and other substances that can be regarded as harmful, so it is necessary to explore alternatives that minimize this problem, but at the same time means a contribution to the benefit of farming. In this perspective appears pyrolytic production of biochar with plant debris, replacing the combustion product properties in aqueous media involve a basic pH and release of alkali cations. In this scenario, we propose that the residue of combustion (RC), da do the chemical process of collection, including roasting, and given the nature of the plant material, when incorporated into soil, in the same proportions that biochar, generated in its interaction with water, chemical changes and physical-chemical processes in the soil more firmly in favor of phosphate by the mechanism of precipitation reaction with calcium in an alkaline medium

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Bacterial diversity in Biochar and Amazonian Dark Earth soil by pyrosequencing and T-RFLP

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Key words: *Central Amazon, Richness, Operational Taxonomic Units*

Introduction

Soils called Amazonian Dark Earth (ADE) exhibit approximately three times more organic matter, nitrogen and phosphorus and 70 times more Biochar (BC) content when compared to their adjacent infertile soils (ADJ), without past history of anthropogenic activities by the Amazonian pre-Colombian native. The aim of this work was to study the structure and diversity of the bacterial communities in ADE, BC and ADJ using the T-RFLP (Terminal Restriction Length Polymorphism) and pyrosequencing technique. The soils were collected in the archaeological site Hatahara located in the Central Amazon, in the city of Iranduba-AM.

Results and Discussions

Bacterial fingerprints of the most dominant populations present in ADE and ADJ soil and BC were obtained by T-RFLP analysis. The principal component analysis (PCA) based on T-RFs of Bacterial communities indicated that the community structures were distinctly separated along the first and second axes from the graphic (Figure 1).

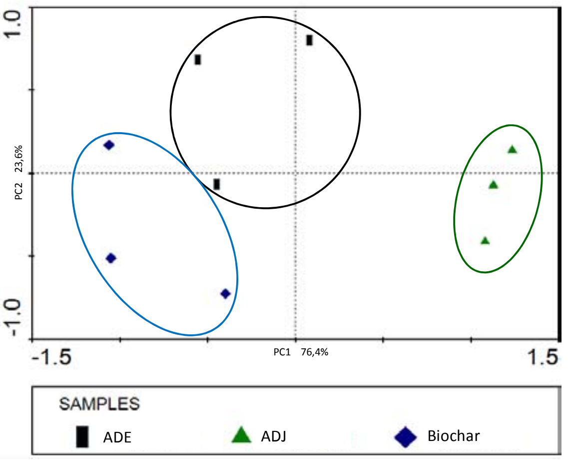

Figure 1. Principal components analysis (PCA) of bacterial communities using the software CANOCO v4.5.

Therefore, the T-RFLP technique in combination with the PCA ordination analysis is an important tool to reveal changes in the composition of microbial communities, and can contribute to further phylogenetic studies for the characterization of the soil microbial community structures. We observed higher richness on ADE soil (100) followed by Bichar (56.3) and the lower diversity was noted on ADJ (42.6). The pyrosequencing data indicate that the BC can host species of *Bacteria* in numbers not much lower than the ADE. Richness of bacterial Operational Taxonomic Units (OTU) was higher in ADE (1425) followed by lower richness in BC (1368) and ADJ (933). The most abundant bacterial phyla in ADE, ADJ soils and BC were *Proteobacteria* 49% ADE, 61% ADJ and 54% BC; *Acidobacteria* 32% ADE, 17% ADJ and 15% BC; *Actinobacteria* 5% ADE, 6% ADJ and 18% BC. The pyrosequencing data indicate that the BC can host species of *Bacteria* in numbers not much lower than the ADE; however, the latter had significantly greater OTU richness (Figure 2).

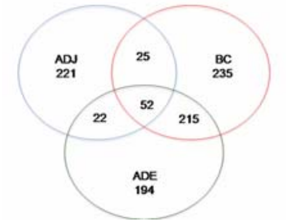

Figure 2. Venn diagram of the operational taxonomic units (OTUs) based on the sequencing by pyrosequencing.

Conclusions

Differences were noted in the bacterial community composition in ADE, ADJ soil and BC, and a higher bacterial diversity present in anthrosols was revealed by T-RFLP and pyrosequencing technique. The high fertility in the ADE associated with a higher soil bacterial diversity, even when under intensive cultivation by the native population.

Acknowledgements

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A survey of the microbial communities from Amazonian anthrosols and their black carbon for sustainable agriculture and biotechnology

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Key words: *Microbial diversity, slash-and-burn agriculture, land use systems, Amazonian Dark Earth, Terra Preta de Índio, black carbon*

Abstract

The processes of land conversion and agricultural intensification are a significant cause of biodiversity loss, with consequent negative effects both on the environment and the sustainability of food production. The anthrosols associated with pre-Colombian settlements in the Amazonian region are examples of how anthropogenic activities may sustain the native populations against harsh tropical environments for human establishment, even without a previous intentionality of anthropic soil formation. In a case study (Model I – Slash-and-Burn) the community structures detected by automated ribosomal intergenic spacer analysis (ARISA) revealed that soil archaeal, bacterial and fungal communities are heterogeneous and each capable of responding differently to environmental characteristics. ARISA data evidenced considerable difference in structure existed between microbial communities in forest and agricultural soils. Richness of archaeal operational taxonomic unit (OTU) was higher in primary forest soil (51.08) followed by lower OTU richness in pasture soil (42.33), secondary forest soil (42.16) and crops (40.25), consecutively. For soil bacterial communities the OTU richness in primary forest (23.08) was found similar to that of secondary forest (25.83). In this study, the fungal OTU richness was higher in primary forest soil (123.5) followed by lower OTU richness in secondary forest soil (73.92), pasture (71.0) and crops (58.0), respectively. In a second approach (Model II – Bacterial Diversity in Anthropogenic Soil), the bacterial community structures revealed by terminal restriction fragment length polymorphism (T-RFLP) differed among an Amazonian Dark Earth (ADE), black carbon (BC) and its adjacent non-anthropogenic oxisoil. The bacterial 16S rRNA gene (OTU) richness estimated by pyrosequencing was higher in ADE than BC.

The most abundant abundant bacterial phyla in ADE soils and BC were respectively, Proteobacteria – 24% ADE, 15% BC; Acidobacteria – 10% ADE, 21% BC; Actinobacteria – 7% ADE, 12% BC; Verrucomicrobia, 8% ADE; 9% BC; Firmicutes – 3% ADE, 8% BC. Overall, unclassified bacteria corresponded to 36% ADE, and 26% BC. Finally, in a third study (Model III – Functional Diversity in Anthropogenic Soil), bacterial aromatic hydrocarbons degraders communities from ADE and BC were examined by targeting the α-ARHD gene, with codes for alpha subunit of dioxygenases. Based on 123 ADE and 156 BC bacterial α-ARHD sequences, the richness estimates by Jackknife (34; 40), Chao1 (30.5; 36) and ACE (31.6; 38.4). The rarefaction curve approaches to a maximum for both libraries. Heterogeneity measures values were calculated using Shannon-Wiener Function and Simpson index (2.87; 3.05 and 0.07; 0.05, respectively). The richness estimates and heterogeneity measures indicated greater diversity in the BC library. Venn diagram showed twenty-four unique OTUs from BC, suggesting that specific microbial processes may be occurring in this environment. Considering the microbial complexity in highly fertile soils (ADE), we employed high throughput sequencing (pyrosequencing) to assess functional bacterial diversity. Regardless of current land uses, our data suggest that soil microbial community structures may be strongly influenced by the historical soil management and that anthrosols in Amazonia, of anthropogenic origins, in addition to their capacity of enhancing crop yields, may also improve microbial diversity, with the support of the black carbon, which may sustain a particular and unique habitat for the microbes.

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Presence of Lipid Compounds in Soil of Amazon Archaeological Sites

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Key words: *biomarkers, chromatography, mass spectrometry*

Introduction

Amazon archaeological soils have been largely studied in many chemical parameters, but lipid analysis have not been explored in their whole potential in these soils.[1]

Lipids, as biomarkers, provide a diagnostic mean for answering specific questions related to soil organic matter engendered by various overlying vegetation changes or anthropogenic activity.[2]

The aim of present study was to evaluate the presence of lipid biomarker in two Amazon archaeological soils: Terra Preta do Indio (TPI) and Terra Mulata (TM).

Top soils (5g) were extracted and sonicated with a solvent mixture and then fractionated by four separated solvent systems using a silica gel:alumina column (F1 – hexane, F2 – dichloromethane, F3 ethyl acetate:methanol, 3:1; F4 ethyl acetate:acetic acid 3:1). Lipids were analysed using GC-MS system.

Results and Discussions

Four classes of lipid components were detected, n-alkanes, n-alcohols, steroids, and n-alkanoic acids in both soils. n- Alkane typified by a monomodal distribution maximized at C_{29} in TPI soil and C_{31} in TM soils. The range of n-alkanes were different with a higher range in the TPI soil (Fig. 1).

Distribution of alcohols compounds, n-alcohols ranging from C_{14} – C_{34} with a maximum at C_{28} and steroids, were similar in both soil, but steroids were the major compounds in TPI and n-alcohols in case of TM (Fig. 1).

n-Alkanoic acid distributions obtained for most of soil samples exhibit a bimodal distribution of components with distinct relative abundance. TPI shows a range of C_{16} to C_{34} carbon atoms with a higher maximum at C_{16} and a lower maximum at C_{30}. In contrast, TM depicted a range of C_{16} to C_{32} carbon atom with a higher maximum at C_{16} and a lower maximum at C_{24} (Fig. 1).

An extra class of compounds were detected in the TM soil, the ω-hydroxyalkanoic acids.

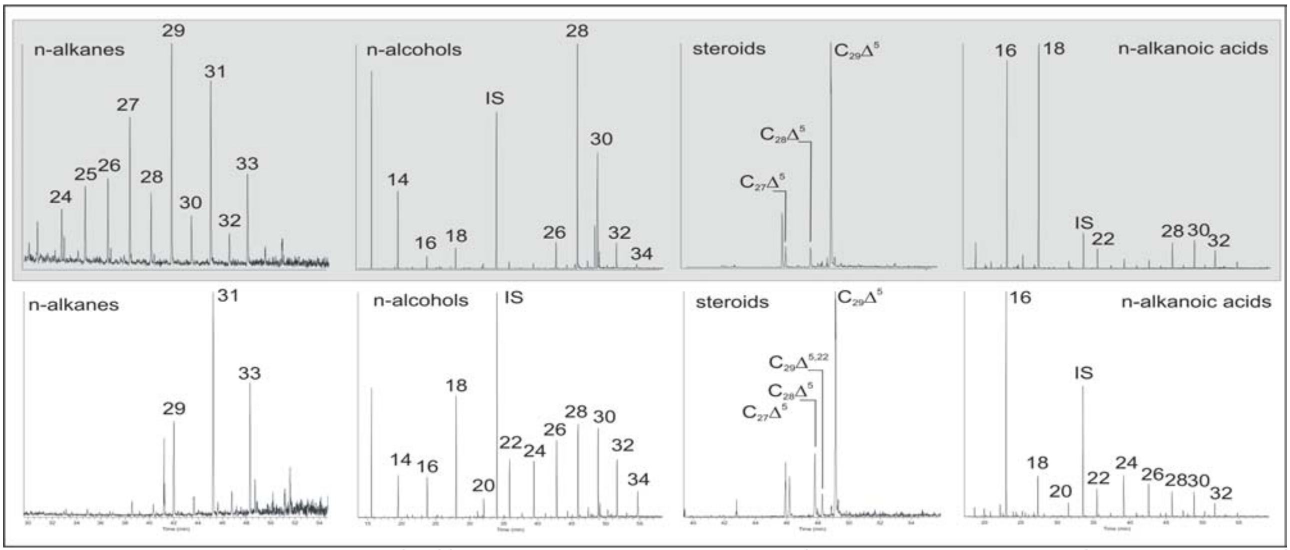

Figure 1. Partial total ion current (TIC) showing the major classes of lipid compounds identified in the soils of Amazon Archaeological Sites. "Upper" Terra Preta do Indio (TPI) and "below" Terra Mulata (TM). Numbers refer to the number of carbon atoms in the lipids compounds.

Conclusions

Both archaeological soils showed a good preservation of at least four different classes of organic compounds. Therefore others studies identifying the source of this compounds will be carry on in theses soils samples in the future.

Acknowledgements

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[1] Glaser, B.; Haumaier, L.; Guggenberger, G.; Zech, W. 2001. *Naturwissenschaften 88*, 37.

[2] Bull, I. D.; Simpson, I. A.; Dockrill, S. J.; Evershed, R. P. 1999. *Organ. Geochem. 30*, 535

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Las Terras Preta dos Indios de La Pedrera (Amazonia Colombiana)

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Key words: *Amazonia, Cultivos Terras Pretas*

Introducción

El programa de investigación 2008-2012: *Las Pretas de La Pedrera a Araracuara (Amazonia Colombiana): Implicaciones arqueológicas, etnográficas, edáficas, agroforestales y florísticas*. Tiene como objetivo estudiar el origen, distribución, los usos y la importancia cultural histórica y actual de las Terras Pretas de la región del Medio y Bajo río Caquetá (Amazonia Colombiana). Entre sus objetivos específicos esta: **1.** Conocer las concepciones sobre los orígenes y los sistemas clasificatorios para las TP por parte de los actuales indígenas de la región. **2.** Determinar la diversidad, el manejo y el cultivo de los tubérculos en las TP utilizadas por la comunidades actuales. **3.** Determinar las características microbioticas, mineralógicas y químicas de las TP para conocer la génesis de las TP. **4.** Realizar el levantamiento florísticos en las TP y áreas adyacentes para determinar su diversidad. **5.** Registrar y mapear las TP de la región del Medio y Bajo río Caquetá. **6.** Determinar la temporalidad de introducción de la agricultura en la región de estudio y los procesos de domesticación de especies como *B. gasipaes* (chontaduro) y otras especies amazónicas.

La Amazonia con sus 6 millones de Km^2, posee el 70 % de sus suelos con una baja fertilidad. Sin embargo allí, se existen unos suelos que son conocidos como Terra Preta do Indio o Suelos Antropogénicos, caracterizados por su alta fertilidad, por sus coloraciones oscuras, por estar asociados a grupos humanos precolombinos y por encontrarse distribuidos en gran parte de la cuenca Amazónica. Estos suelos conocidos desde el siglo XIX y estudiados con intensidad desde la década de los años 70 del siglo XX, son hoy objeto de estudio de interés mundial.

En Colombia las TP han sido registradas y estudiadas principalmente en la región del bajo y Medio río Caquetá, en el río Guayabero y en el Trapecio Amazónico Colombiano.

Resultados y Discusión

En el 2008 iniciamos las investigaciones en TP, en la región de La Pedrera, localizando hasta ese momento tres sitios: la pista aérea, el internado y Pto. Cordoba y en el 2009 localizamos dos yacimientos TP en el resguardo de Curare (Mapa 1). Los resultados hasta el momento obtenidos evidencian una ocupación humana asociada a TP, con una antigüedad de 6500 años AP, lo que indican la existencia de TP muy antiguos en esta región. Algunas de las características de las TP de La región de La Pedrera son: **1.** Se encuentran asociadas a raudales (cachoeiras); **2.** Su forma es semieliptica, con extensiones promedio de tres hectáreas; **3.** Sus colores varían de 10 YR 2/1, 10YR 2/2; 10 YR 3/2; **4.** Los espesores de estos suelos están entre los 70 cm y 120 cm; **5.** Uno de los usos de estos espacios fue el agrícola. Los restos cerámicos de los yacimientos, establecen la existencia de dos tipos de cultura asociadas a las TP. Una portadora de cerámica con desgrasante de cauxí (espículas de agua dulce), con decoración de motivos geométricos y figuras antropomorfas y otra cultura que se caracteriza por la presencia de una cerámica con caraipe (agregado vegetal) predominando los motivos antropo-zoomorfos. Esta ocupación con este tipo de cerámica es la de mayor antigüedad en el región, 6500 AP. Igualmente los estudios paleobotánicos (semillas y fitolitos arqueológicos) indican una alta selección de los géneros *Astrocaryum*, *Mauritia*, *Euterpe*, *Oenocarpus* y *Bactris* (Palmae) y de cultivares como el maíz (Zea mays), yuca (*Manihot esculenta*) y *Cucurbita* sp.

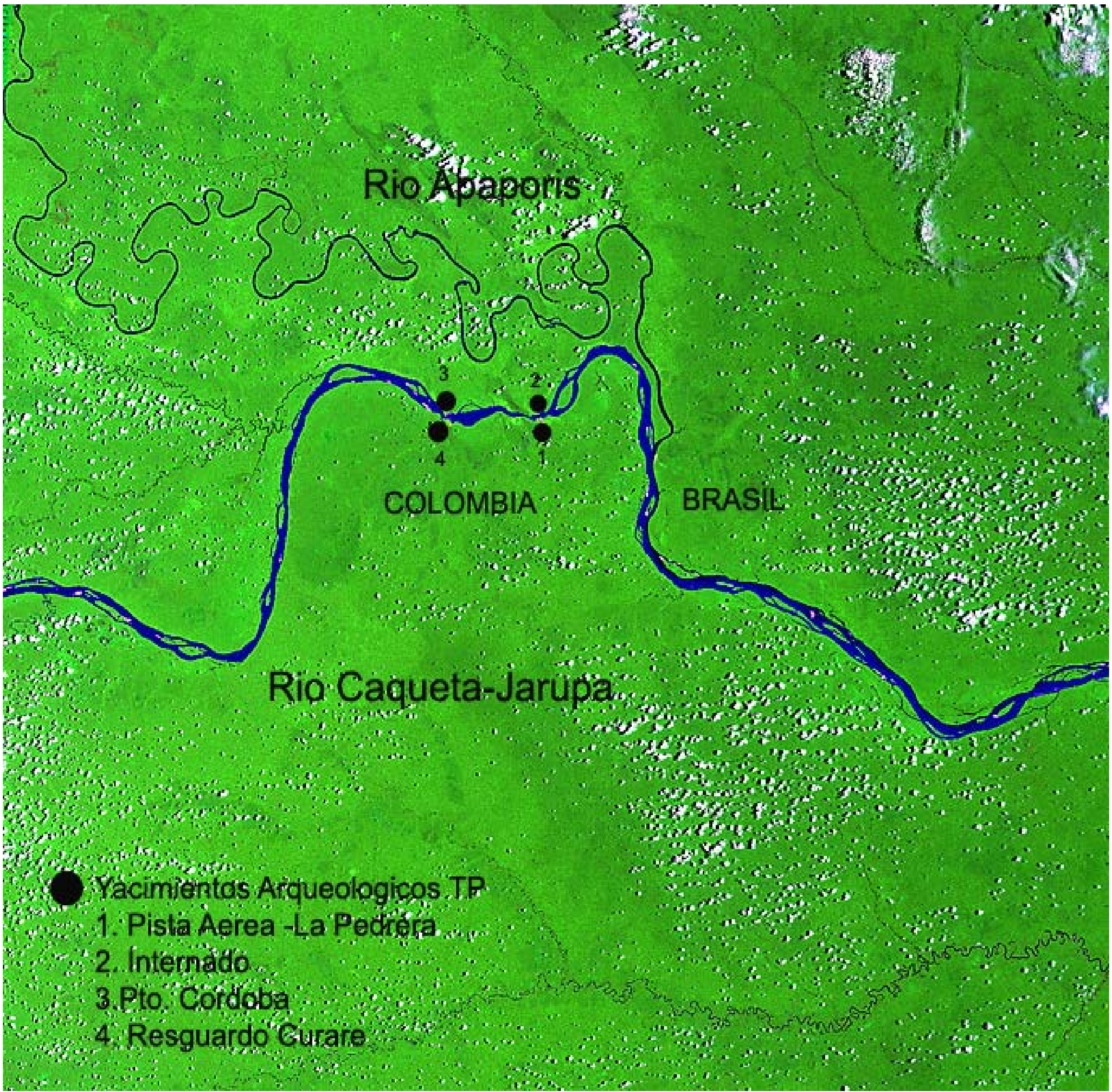

Figure 1. Yacimientos asociados a TP en el Caquetá-Jarupa (Amazonia Colombiana).

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Evolution of “Biochar” and “Terra Preta” publications

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Key words: *indexed articles, research advances, number of citations*

Introduction

Biochar has been related to chemical, physical and biologic benefits to soils, as well as to improvements in crop production. The addition of biochar to soil is also related to increased sorption of many pollutants and the decrease soil greenhouse gases emissions [1]. This work evaluates the evolution of publications registered in Thompson’s ISI Web of Science indexed for “biochar” or “bio-char” and those indexed for “terra preta” (until July 26th 2010).

Results and Discussions

There are 103 articles and 7 reviews indexed for “biochar” or “bio-char” between the years 2000 and 2010. Documents indexed for “terra preta” totalized 29 articles and 4 reviews, which were published between 1984 and 2010. The last five years represent 90 % of the indexed articles for “biochar” or “bio-char” and 66 % of those indexed for “terra preta” (Figure 1).

Articles were divided according to words in the title, objectives and key words in 12 classes (Figure 2). For “biochar” or “bio-char” the subjected areas with major number of articles, according to this classification, were: i) effects on soil and/or in crop production, ii) description characteristics and/or properties, iii) production methods, iv) relations of biochar use and greenhouse gases emissions and v) biochar interactions with pesticides and/or pollutants in soils. The subject is recent in the international literature. For instance, the first two articles related to effects of biochar on soil or crop production were published only in 2006. In 2007 the first articles involving biochar effects in soil microorganisms and immobilization of heavy metals in biochar were available. Just in 2008 and 2009 papers accosting greenhouse gases emissions and pesticides or pollutants behavior in soils began to be published.

For “terra preta” the most important areas were i) effects on soil and/or in crop production, ii) effects on soil microorganisms and iii) description of characteristics and/or properties of “terra preta”. The first articles about effects of “terra preta” in soil or crop production were published in 2003. In 2007 was published the first article on the relationship between “terra preta” and soil microorganisms.

Until July 26th 2010 there were 35 articles indexed for “biochar” or “bio-char”, which represents an increase of 16.6 % in comparison to the same period in 2009. For “terra preta” the number of indexed articles in Thompson’s ISI Web of Science have remained almost constant since 2007. The number of biochar articles published in 2008 enhanced significantly (283 %) compared to 2007 and 176 % in 2009 compared to 2008 (Figure 1). Interestingly, three papers published in 2007 and 2008 , have received, until July 26th 2010, more than 44 citations each [2, 3, 4].

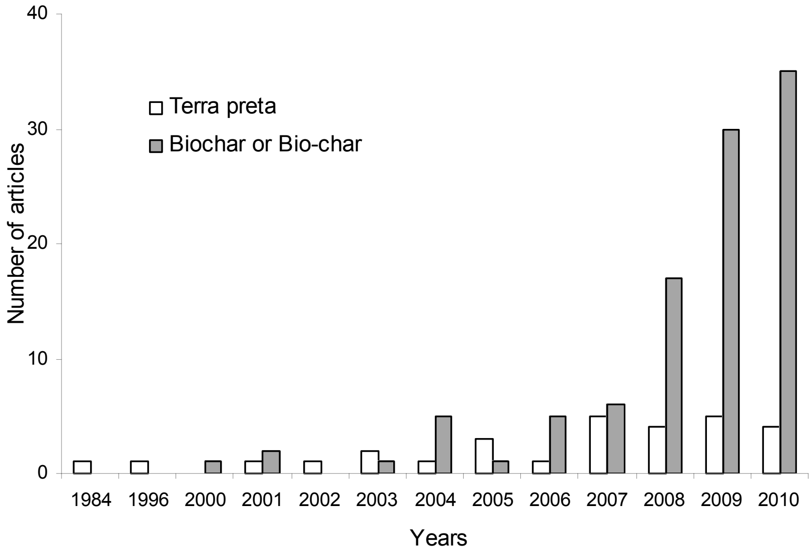
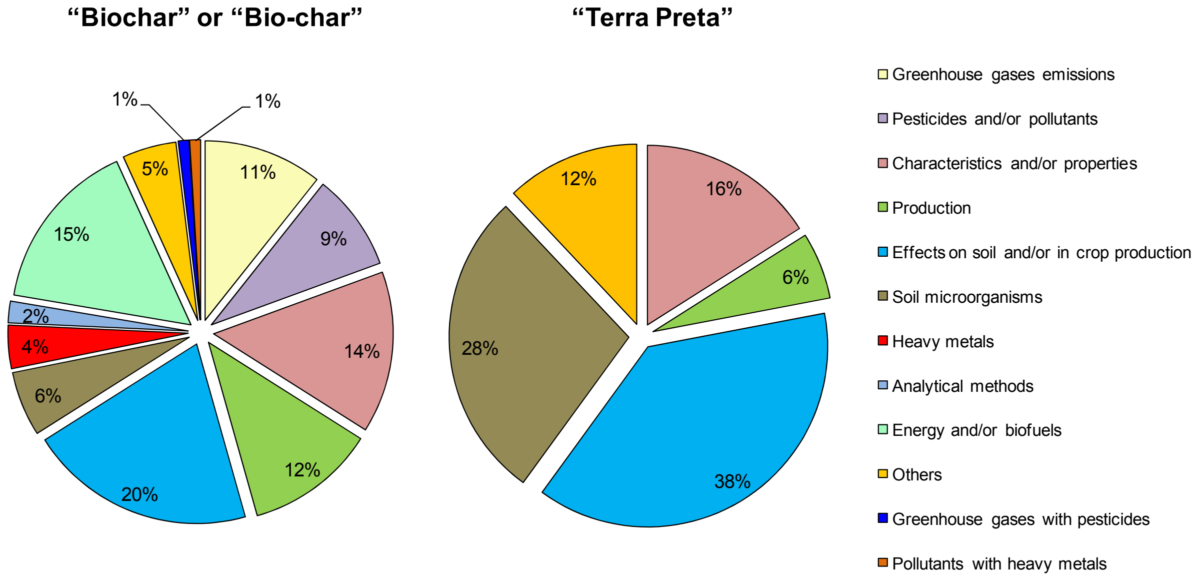


Figure 1. **E**volution of publications indexed for “terra preta” and for “biochar” or “bio-char” in Thompson’s ISI Web of Science.


“Biochar” or “Bio-char”

“Terra Preta”

Figure 2. Subjected areas of indexed articles in Thompson’s ISI Web of Science for “terra preta” and for “biochar” or “bio-char”.

Conclusions

The researches on biochar have been significantly increased in the last five years, while the number of published articles indexed for “terra preta” demonstrates only a small increase. Papers about heavy metals, soil microorganisms, greenhouse gases emissions and pesticides and pollutants behavior in soils with addition of biochar began to be published in the last four years. Two of these subjects are in the group of the most important areas in number of published articles indexed in Thompson’s ISI Web of Science.

Acknowledgements

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[1] Verheijen, F.; Jeffery, S.; Bastos, A. C.; van der Velde, M.; Diafas, I. 2010. Biochar application to soils. JRC Scientific and Technical Reports. European Communities, 2010.

[2] Lehmann, J. 2007. *Frontiers in Ecology and the Environment*. 5, 381.

[3] Mohan, D.; Pittman, C.U.; Bricka, M. et al. 2007. *J. colloid interface sci*. 310, 57.

[4] Demirbas, A. 2008. *Energy convers. manag*. 49, 2106.

The Terras Pretas de Índios investigation by Raman spectroscopy and a sustainable agriculture

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Key words: *Terra Preta de Índio, Raman spectroscopy, amorphous carbon*

Introduction

The Terras Pretas de Índios da Amazonia (TPI's or Indian Black Earths) are extremely fertile soils found in northern Brazil in contrast with surrounding soils. The origin may be anthropogenic, probably from the Pre-Colombian civilizations.

The presence of charcoal in this material is very expressive (containing 70 times more black carbon than the adjacent soils [1]) and the Raman spectroscopy is a widely used technique to characterize carbonaceous materials, from the more organized structures (graphene, nanotubes) to the most random (amorphous carbon, a mixture of carbon atoms with sp, sp^2 and sp^3 hybridization). Thus, we used Raman spectroscopy to classify the forms of carbon found in three samples of TPI's.

The origin of our TPI's can be found in the Table 1.

Table 1. Origin of TPI's

Soil sample	Origin*
TP1	Serra Baixa (costa do Açutuba), Iranduba
TP2	Balbina, Presidente Figueiredo
TP3	Costa do Laranjal, Maracapuru

* Regions near Manaus (AM)

Results and Discussions

The disorder-induced mode (D band ≈ 1350 cm^{-1}) and the tangential stretching mode ≈ 1580 cm^{-1}) are present in the spectra obtained with a 632.8 nm laser. The peaks are very broad and it is characteristic of amorphous carbon materials. The frequencies of these bands vary with the amount of sp^2 and sp^3 hybridizations, the presence of polycyclic and distorted chains [2].

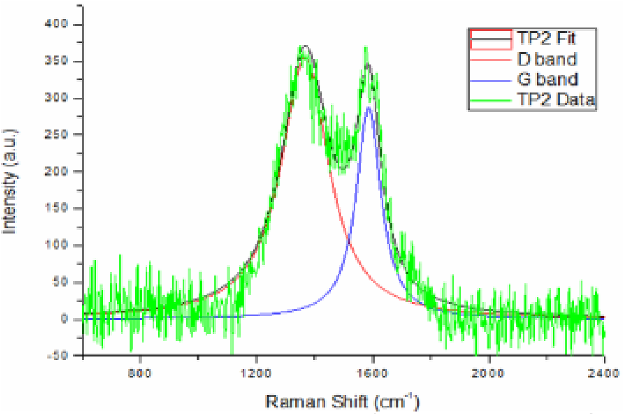

Figure 1. Typical spectrum of a TPI sample. Our spectra were obtained with a 632.8nm laser.

Our results indicate that the TPI's are in different stage of amorphization, and it is possible to distinguish three different phases for the three TPI samples we have analyzed. These phases seem to be related with each kind of TPI is the most productive.

Conclusions

Raman spectra show different phases for different TPIs, being able to distinguish them. The variety of structures of carbon present in the TPIs, in addition to field observations and the analysis made conventionally seems to indicate the relative productivity of the TPIs. To identify the structural disposition of carbon in TPIs it is important to give a direction in the attempts of producing synthetic Terra Preta, and might be fundamental to the development of sustainable practices in agriculture.

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[1] Glaser, B. 2007. *Phil. Trans. R. Soc. B 362*, 187-196.

[2] Ferrari, A. C.; Robertson, J. 2000. *Phys. Rev. B 61, 20.*

“Amazonian Dark Earths: Foundation Investigations” to be Presented at the Meeting of the 3rd International Biochar Conference

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Key words: *Amazonian Dark Earths*

Introduction

Against a backdrop of highly weathered, infertile soils, patches of very productive soils are found throughout lowland Amazonia. Although the anthropogenic origins of these soils, termed Amazonian Dark Earths (ADE), were recognized in the mid-19th century, debate continued over this scenario well into the 20th century. Until recently, not much scientific attention was given to their significance for our understanding of the past, their present use, or future applications. The early years of ADE research and reports are discussed in this paper.

Results and Discussions

Amazonian Dark Earths (ADE) are anthropogenic soils called *terra preta do índio* and *terra mulata*, respectively, in Brazil. They were created by indigenous people hundreds, even thousands of years ago. *Terra preta* proper is a black soil, associated with long-enduring Indian village sites and is filled with ceramics, animal and fish bones, and other cultural debris. Brownish colored *terra mulata*, on the other hand, is much more extensive, generally surrounds the black midden soils, contains few artifacts, and apparently is the result of semi-intensive cultivation over long periods. Both forms are much more fertile than the surrounding highly weathered soils and they have generally sustained this fertility to the present. This fertility probably is because of high carbon content, which retains nutrients, and an associated high and persistent microbial activity.

It has only been since about 1980 that these soils have received intensive scholarly attention. Recent research has been multidisciplinary and international, especially by soil scientists, archaeologists, and geographers from the Brazil, Germany, the United States, and Colombia. The topic is now of major scientific interest, of relevance both to prehistory and to agricultural development and global climate change today; hence the value of this historical survey.

Other than a 17th century Jesuit priest’s observations all known entries are dated since 1874. Hartt, Smith, Brown and Lidstone, Orton, Derby, and Steere in the 1870s all noticed the *terra preta* and referred to its distinctive properties and association with prior settlements. Friedrich Katzer in the late 19th century conducted pioneering analytical work on these soils and suggested that because of their fertility the dark earths were cultivated in ancient times when the region was more or less densely populated. In the early 1920s Curt Nimuendajú directed excavations and surveys of dark earth sites within the lower Tapajós region and adjacent Amazon bluffs. Like Katzer, Nimuendajú believed that the dark earths had developed from Indian habitation activities associated with permanent settlements and that the resultant fertile soils were then used for crop production In the 1940s and 1950s various observers reported and described dark earth soils. However, rather than analytical research, attention was more focused on possible natural origins of the soil, in contrast to the earlier belief that the soil was of human origin.

In 1966 Dutch soil scientist Wim Sombroek based on his earlier dissertation published his classic *Amazon Soils*, which includes descriptions and lab analyses of dark earths on the Belterra Plateau. He made a distinction between black *terra preta* proper derived from village middens and brownish *terra mulata*, a term he introduced to the literature, which be believed "obtained its specific properties from long-lasting cultivation." He was the first to suggest this as far as we know. And he mapped the distribution of dark earths along the bluffs of the lower Rio Tapajós. In 1966 he questioned whether it was "economically justifiable," in his words, to create and cultivate such soil today. However more recently he promoted the idea of developing new dark earth as carbon stores and sinks for intensive cultivation, what he called "*Terra Preta Nova*". Sombroek, “The

Godfather of Amazonian Dark Earths", ushered in the modern period of investigations of these distinctive soils and all four of the recent *Amazonian Dark Earths* books are dedicated to Sombroek, who tragically passed away in 2003 [1-4].

Conclusions

The early period of publications about Amazonian Dark Earths, involving discovery and initial descriptions, included perceptive reporting by observers such as Hartt, Herbert Smith, Katzer, Nimuendajú, and a few others. In many respects their observations about the anthropogenic origins and importance of these soils were ignored or misinterpreted until they were resurrected by Sombroek in the 1960s. It has now been archaeologically demonstrated that large, planned, and persistent pre-European settlements associated with anthropogenic dark earths were present throughout Amazonia. The topic of Amazonian Dark Earths is finally receiving the focused interdisciplinary, international scientific attention it deserves. In just a relatively short period the results have been stupendous and have taken us on avenues unseen before. We see no reason that this trend should or will abate.

Acknowledgements

We thank all of those many colleagues who have contributed to the development of this knowledge through their kind sharing of information and work in the field and laboratory. And, as always, our dear friend, Wim Sombroek, is especially acknowledged.

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[1] Teixeira, W. G.; Kern, D. C.; Madari, B. E. Lima, H. N.; Woods, W. I. (Eds.). 2009. *As Terras Pretas de Índio da Amazônia: Sua Caracterização e Uso deste Conhecimento na Criação de Novas Áreas.* Embrapa Amazônia Ocidental, Manaus. 421 p.

[2] Woods, W. I.; Teixeira, W. G.; Lehmann, J.; Steiner, C.; WinklerPrins, A.; Rebellato, L. (Eds.). 2009. *Amazonian Dark Earths: Wim Sombroek's Vision*. Springer, Berlin. 502 p.

[3] Glaser, B.; Woods, W. I. (Eds.). 2004. *Amazonian Dark Earths: Explorations in Space and Time*. Springer-Verlag, Berlin. 216 p.

[4] Lehmann, J.; Kern, D. C.; Glaser, B.; Woods, W. I. (Eds.). 2003. *Amazonian Dark Earths: Origin, Properties and Management*. Kluwer Academic Publishers, Dordrecht. 505 p.

Physical, Chemical and Mineralogical Characteristics of Soils with Anthropics Horizons (Terra Preta de Índio) in the Floodplains of Solimões River in the Central Amazon-Brazil

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In the Amazon has many reports about the occurrence of antropic horizons formed in pre-Colombian Indian settlements, they are called Terra Preta de Índio (TPI) and are normally found in the uplands. TPIs show dark color and high carbon stocks, high levels of calcium, magnesium and phosphorus. The borders of he Solimões river that are annually flooded are called “varzeas” and has few report about the occurrence of TPI in those areas. The objective of this work was to characterize morphologically physically and chemically eight soil profile with buried antropic soil horizons in the floodplains of the Solimões River in the Brazil in the Central Amazon. The results showed that silt fraction predominate in whole horizons and profiles. The chemical characterization (total and available mineral elements) shows that P, Zn, Cu, Ba and Sr were good indicator of antropic horizons in the rich floodplain in the Central Amazon. The original high levels of Ca an Mg and low level of C do not permit to use them as indicators of antropic activities in the floodplain environment. The presence of archeological ceramics and high level of P indicate that the buried antropic horizon were in the surface in the past. The mineralogical composition of antropic and non antropic horizons were very similar (ilite and muscovite) indicating the same mineral matrix. The wide of the buried horizon may be interpreted that large populations lived in those site in the past. The Fluvents enriched by the rich sediments from the Andean mountains in the Solimões rivers are naturally very fertile for agriculture activities. The natural high level of P, Ca, Mg are above the critical levels for response to the fertilization to corn and manioc cultivation. This fact may be a strong indicator that the enrichment of the soil in the TPIs was not for agricultural purposes, at least in the floodplains. In the Solimões River occur the phenomena called “terras caídas” that is a natural erosion process that collapse the border of many rivers in the Amazon and destroy the archeological sites. Moreover, the frequent flooding cover by new sediments the old antropic A horizons that became covered and difficult to localize, with more soil surveys in the floodplains probably more paleosols will be found and may prove that large populations lived in those areas in the past.

Terra Preta and Terramare: Similarities and Differences

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The occurrence of banked and ditched villages of the Middle and Recent Bronze ages (c. 650–1150 BC) in Northern Italy (Po plain) is known to the archaeologists since a century. Those sites are called Terramare adopting the same terminology that was used in the past to identity the organic rich earth “terra marna” of mounds quarried as fertiliser by the local farmers. About two hundreds Terramare sites have been found so far and are considered the archaeological remains of a complex society whose subsistence was based on agriculture, pastoralism, handicraft and long-distance trade. Settlements consisted of fortified villages surrounded by an embankment and a ditch. The socio-economic system of the Terramaras was based on a cooperative organisation and a complex territorial association of villages; the estimated number of people in the Terramara area around the 14th–13th century BC was about 150,000. At the end of the Late Bronze Age (ca. 1200 BC) this civilisation vanished, possibly through a combination of climatic, ecological and socio/economic causes. Every Terramare site is characterised by the occurrence of potent organic soil horizons (up to 3-4 meters depth) that were created by the inhabitants by mixing organic and inorganic residues and different types of waste. Charcoal, likely originating from wood fires, is an important component of the Terramare layer and is supposed to have played a crucial role in organic matter and nutrient protection, over millennial time scales and the extraordinary fertility of this type of soil is witnessed by the exploitation that was made for long periods by the farmer of the 18th and 19th century. This paper illustrates the most recent findings of Terramare research that link archaeology, soil science and agronomy. The fertility of the Terramare soils is also discussed in the light of new measurements made very recently. The hypothesis is raised of a stringent parallelism between the origin of the Terra Preta of Indios and Terramare, suggesting that soil fertility was in both cases an inadvertent result of landfilling activities involving organic waste, charcoal and ash from woodfirers.

Chemical Characterization and Mineralogy of Three Anthropics Soils (Indian Dark Earth) of Central Amazon

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The aim of present study was to evaluate chemical attributes and mineral composition of the clay and the sand fractions from three soils with anthropic horizons locally called Terra Preta de Índio (TPI) and around soil. Samples were collected and analyzed chemically and mineralogically by X-ray diffraction (XRD). The TPI has moderate acidity and around soil has high acidity. The contents of changeable Al too is high in the around soil. Available and changeable nutrients show high contents, especially phosphorus and calcium, as well as, the contents of total organic carbon. The chemical fractionation of humic substances showed that the TPI, the highly humified fraction (humic acids) and higher for the more mobile fractions (fulvic acids). The mineralogical analysis shows that clay fraction of TPI isn't different of around soil. The kaolinite is the predominant mineral in the clay fraction, but was found in less amount the minerals goethite, gibbsite and anatase. The sand fraction has the quartz with predominant mineral.

Key words: site, XRD, goethite.

Climate change mitigation value and potential

3rd International Biochar Conference
IBI 2010
Progressing from Terra Preta de Índios to the Whole World

Biodiversity and Sustainable Management of Natural Resources: - A Case Study in the Hohoe Municipality, Ghana

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Key words: *Biodiversity*

Introduction

The biological diversity of our environment is crucial to sustaining human livelihoods: that is why people strive to preserve it. Its preservation requires conservation of the relevant habitats and ecosystems. Many of the world’s important ecosystems and those most worth protecting are in the developing countries - where because of the prevailing poverty they are often subjected to a high level of competing landuse pressure.

This is why sustainable management of natural resources is so important for the conservation of biological diversity. But in many developing countries, low priority is given to assuring effective conservation of biological resources resulting in a corresponding insufficient level of capacities. Thus involvement of local communities in conservation activities becomes essential to ensure long-term conservation.

This paper reports on conservation activities involving local communities in the Hohoe Municipality in the Volta Region of Ghana that are making significant contributions to the development of ecotourism in the area. Information for the paper was collected through visits to these ecotourism sites and from interviews with opinion leaders and farmers in the rural communities and review of various reports of public and private sector organizations.

Results and Discussions

Like most other areas in Ghana food production systems in the Hohoe Municipality, are under threat and, with them the accompanying local knowledge, culture and skill of the food producers due to loss of agricultural biodiversity

For example half of the breeds of many domestic animals have been lost .More than eighty (80) percent of crop varieties have disappeared from the fields of the local farmers

There are many causes of this decline but the major ones are (i) rapid explosion of population (ii) rapid expansion of housing and green revolution agriculture and (iii) intensive timber lumbering for plywood production, some production systems using genetically modified species.

In spite of this decline in agricultural biodiversity the Hohoe Municipality has many ecotourism sites. These are the Wli, Aflabo, Tagbo and Tsatsadu falls. Other ecotourism sites are the mountains Afadjato and the Tafi Atome Monkey Sanctuary.

The Hohoe Municipality involves the local communities as much as possible in the management of these ecotourism sites to ensure that they are kept well while the ecological and cultural resources in their environment are conserved.

At these sites, indigenous knowledge involving taboos and the institution of local laws have helped to conserve biodiversity. For example the forefathers of the current villagers at Liati Wote considered the Tagbo River sacred and some of the belief is still conserved. For instance no fishing is allowed in the river as the spirits of their ancestors are thought to live in it. Washing on Fridays is also prohibited because on this day, the spirit of the river and its children bath. Also dogs are taboo in the village, because inhabitants believe they can see the spirits and scare them off with their barking.

Another example is the Tafi Monkey Sanctuary (a sacred grove) which is a traditional conservation area backed by statutory enforcement in co-operation with local communities. These monkeys are found in a remnant patch of forests, which has survived fire and human disturbance around the village. These monkeys are regarded as gods and as such the natives do not kill them. They are protected by tradition.

However, in the late 1980s these beliefs were almost abandoned when Christianity became the main religion and the villagers lost reverence for the animals. Thus in 1993 to protect the monkeys and the forest they live in,a sanctuary was created in 1993 by a coalition of villagers, public institutions and NGOs

To ensure that biodiversity in the Hohoe Municipality is conserved, the GNAFF in Affiliation with Majestic Agribusiness Center in Hohoe have initiated the following long term strategies in partnership with CTA, The Netherlands:

- Sensitization of stakeholders on environmental protection and degradation;
- Organization on priority information themes (PIT) to identify potential problems, set priorities, analyze decision making and development of community action plan;
- Supporting local communities with pilot micro-enterprises and other income generating activities including agriculture;
- Holding environmental awareness days on land degradation and forest conservation;
- Establishment of woodlots in the communities;
- Supporting the use of appropriate and safe agrochemicals to conserve biodiversity;
- Sensitization of communities on gender issues in biodiversity conservation.

Conclusions

Community-based ecotourism is on the rise in Ghana as the country positions itself to become the prime destination for visitors to Africa.

Ecotourism contributes to the management and protection of some national parks, 'wilderness areas' and wildlife; creates jobs for community members and allows them to directly participate in determining how the generated income will be reinvested. For the ecotourism, it allows you to enjoy the fauna and flora in their natural environment with minimal damage to the environment.

There are other sacred groves and ecosystems protected by local people that are widespread not only in the Hohoe Municipality but also in the rest of the Volta Region. These can further be developed for ecotourism in the local communities to enhance rural development

The GNAFF will contribute to this effort by packaging information on biodiversity in local content for dissemination through film shows, drama, print media, television and radio. In this way biodiversity will be conserved for generations to come.

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Effects of the use of biochar in soil nitrous oxide emissions

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Key words: *biochar, nitrous oxide soil emissions*

Introduction

It is estimated that 80% of nitrous oxide (N_2O) emissions caused by human actions are from agriculture [1].

The global warming potential of N_2O is about 296 times that of CO_2, considering a period of 100 years [2].

This study was carried out to evaluate the biochar application effects in N_2O soil emissions.

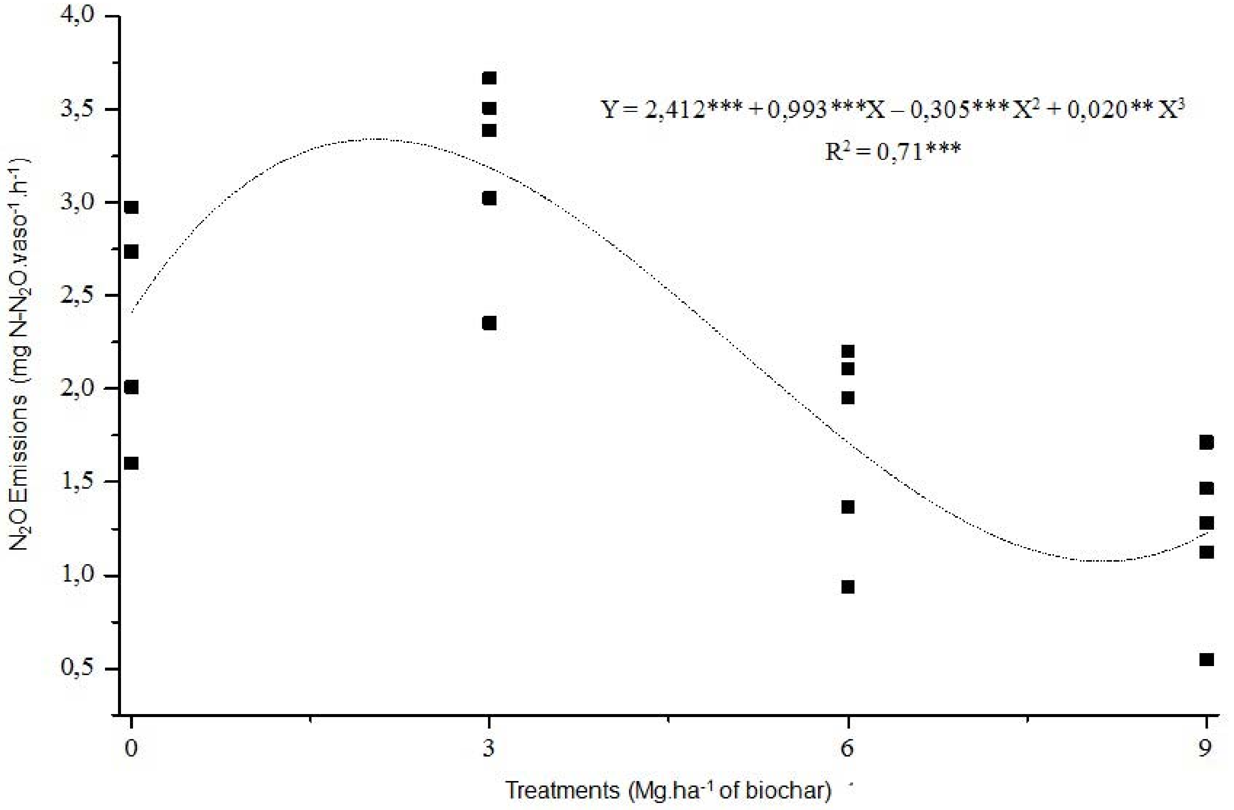
For this experiment, soil samples from Planossolo Háplico, commercial powdered charcoal, as biochar and urea, as the nitrogen source (100 Kg of $N.ha^{-1}$), were used. Four treatments were performed: zero (Control), 3, 6 and 9 $Mg.ha^{-1}$ of biochar.

Results and Discussions

From the data analysis, there was a significant difference between treatments and the cubic regression was significant.

The treatments with 6 $Mg.ha^{-1}$ and 9 $Mg.ha^{-1}$ equivalents showed a mitigating effect on the N_2O soil emissions, with values 29 and 49% lower than control, respectively.

Treatment with a 3 $Mg.ha^{-1}$ dose equivalent had an increase of 32% in emissions (Figure 1), indicating a possible positive effect on the factors that stimulate denitrification, such as increasing water retention, which implies a condition that increases the denitrification process.



** Significant at 1%, *** Significant at 0.1%

Figure 1. N_2O soil emissions found for the different treatments.

Conclusions

The use of biochar may be a potential alternative to mitigate N_2O soil emissions.

By analyzing the regression equation obtained, this study indicates that with doses above about 5 $Mg.ha^{-1}$ of biochar, the mitigating effect of N_2O soil emissions is obtained under the tested conditions.

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[1] Beauchamp, E.G. Nitrous oxide emission from agricultural soils. *Canadian Journal of Soil Science*, V. 77, p.113-123, 1997.

[2] Albritton, D., Derwent, R., Isaksen, I., Lal, M. E Wuebbles, D. Radioactive forcing of climate change. In: Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., Van Der Linden, P.J. & Xiaosu, D. *Climate change . The science of climate change.* Cambridge University Press, New York, p.118-131. 1996.

Nepal's REDD process & Opportunities and challenges for carbon financing in community forestry in Nepal

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Key words: *Co-benefits, Community forestry, Carbon sequestration, FCPF, Multistakeholder mechanism, REDD, Readiness to REDD, Readiness Plan Idea Note*

Introduction

April 2008 marked the beginning of Nepal's initiatives on Reduced Emissions from Deforestation and Forest Degradation (REDD). The process began by way of submitting Readiness Plan Idea Note (RPIN) [1] to the Forest Carbon Partnership Facility (FCPF) that was drawn by the multistakeholder forum under the overall coordination and leadership of the Ministry of Forests and Soil Conservation. Subsequent approval of RPIN by the FCPF provided Nepal with funds to support for Readiness Preparation Proposal (RPP) [2]. Lately the country has submitted the RPP to the FCPF which is currently in the review phase. It is apparent that the country will be receiving support to implement RPP with an objective of being ready for REDD by 2012 [3].

The work draws mainly from the author's own experience enriched by available literature and the interview with the relevant REDD practiceners.

Results and Discussions

REDD process in Nepal's community forestry is characterized by both opportunities and challenges.

Opportunities include:

-Over 15 thousand patches of Community forests in the hills of Nepal have already demonstrated that they are capable of sequestrating forest carbon (one study shows that the average sequestration rate is 1.8 ton/ha/year) [4]. There already exists a federation of these communities which is keen to support these communities in REDD related process.

-The community forests are characterized by several co-benefits like biodiversity conservation, watershed conservation environmental maintenance, and poverty alleviation.

-Holistic multistakeholder and multisectoral mechanisms are already in place from the apex level to the grassroots. The former mechanism consists of government (e.g. Ministry of forests), civil society organizations (e.g., Federation of Community Forest User Groups, FECOFUN), Nepal Federation of Indigenous Nationalities, NEFIN) and Private/research Sector (e.g. Forest Action), Likewise, The later would consist of as many as 9 key relevant government entities (such as national planning commission, ministry of finance, ministry of land reform and ministry of forests, ministry of forests) that are responsible for holistically dealing to address the drivers of deforestation.

-REDD cell has been established within the ministry of forests to forge multistakeholder and multisectoral process towards readiness.

-Readiness Preparation Proposal (RPP) drawn from a multistakeholder process is already in place and there are large scale awareness among all stakeholders particularly about the potential of carbon trade and a need for equitable benefit distribution.

-Support is forthcoming both from the FCPF (who is going to pledge for US $3.5 million) and other bilateral donors within the country.

Challenges include:

-Proving, additionality, permanence and leakage is very difficult both in technical and financial sense. Small patches of community forests are of course capable of sequestrating carbon but it is very hard for them to comply with the international demands and standards owing to their small size, scattered location and lack of prior experience in carbon transaction.

-Widespread poverty in the rural areas means that communities might lose interest in the future owing to the reason that REDD is a time consuming and difficult process. Lack of good governance might add up to the problem

-While a workable institution and appropriate tenurial arrangement exists for the hills of Nepal, this is largely lacking in the low land (Terai) and high altitude thus posing a real problem in conserving the forest resource base in these regions of the country.

-The current fluid political situation of country means that the government and the civil society find difficult to launch a new and demanding programmed like REDD

-While Nepal's community forestry can produce a number of co-benefits including bio-diversity conservation, watershed conservation and poverty alleviation, the proposed REDD instrument have a parochial view towards the payment. It provides for payment merely to carbon thus not doing justice to their overall environmental and social contribution. As the situation stands today REDD payment do not cover the full costs involved [5]. Only a system of paying to their overall contribution to their environmental services and the 'indigenous knowledge system' might encourage these people continued interests towards playing meaningful role in the future.

Conclusions

Nepal has been intending to be ready for REDD when the tenure of the Kyoto Protocol (KP) would end in 2012. While opportunities exist, those are accompanied by a number of challenges. However, if succeeded, Nepal's participatory community forestry model may provide an enduring way to conserve the forest resource base thus lending to a viable REDD options not only within its border but across the globe. Nepal thus should proceed towards more holistic REDD process with active cooperation of the local and international community.

Acknowledgements

I need to thank many individuals including relevant personnel from Federation of Community Forest User Groups, Nepal and the ICIMOD staff engaged in REDD piloting who shared their views on the topic at hand. Likewise, I thank to IBI who invited me to participate at the important and timely conference related to climate change.

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[1] GON Ministry of Forests and Soil Conservation, 2008. Readiness Plan Idea Note (R-PIN) Nepal, Proposal submitted to World Bank by Ministry of Forests and Soil Conservation

[2] GON Ministry of Forests and Soil Conservation, 2010. Nepal's Readiness preparation Proposal, REDD 2010-2013

[3] FCPF, June 2010, Review of R-PP of Nepal, Reviewers: Jayant Sathaye + 4 reviewers (Date of review:10 June 2010)

[4] Banskota, K., Karky B.S. and Skutch, M. 2007. Reducing Emissions through Community Forest Management in the Himalayas, Nepal, ICIMOD

[5] "Science for Environment Policy": 2010. European Commission DG Environment News Alert Service, edited by SCU, The University of the West of England, Bristol

Climate change mitigation value and potential

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Key words: *Biochar, Climate Change*

Executive Summary

Our NGO is currently looking for $910,000.00 funding to assist the people along the largest manmade Volta Lake in Ghana to improve upon their Soil fertility problems with Biochar Technology. The degradation of the area is due to the result of the worldwide climate change and construction of the Hydro Electric dam. The Lake has a surface area of 8,480 km² and 5,200 km of shoreline. Prior to the construction of the Ghana Akosombo Hydro Electric Dam in the 1960's agricultural activity was at the height of its peak but the after effects of the dam and worldwide climate change etc on the micro environment has resulted in the lost of vast arable land and displacement of people. The environment of the Upper Manya Krobo District (UMKD) of Eastern Region of Ghana which have population of 89,646 people and covers a total land area of 885 square kilometers used to be the evergreen rain forest type until the construction of the Akosombo Dam and climate change effect have change the soil acidity level of major part of the district and these have affected most trees, shrubs and low ground cover plants. The district has large deposit of seasoned refused dumps for a compost manure and dead woods for charcoal production which we are currently using as an experiment in cultivation of pepper (vegetable) without the use of chemical fertilizer, and it looks promising and the pepper leaves looks healthier, though we are yet to document the yield when the time is due for harvesting.

Project Description

NRO pilot Biochar projects are located in UMKD notable at Akotoe, Anyaboni-Bisa, Akateng, Asesewa environs. NRO believe introduction of Organic farming with incorporation of BIOCHAR (TERRA PRETA) system will solve problems associated with the dam construction, climate change and chemical fertilizers. This compelled NRO to send proposal to the district authority for funding to support the NGO to advocate the Biochar techonology, but lack of funds on the part of the district Administration makes it impossible to receive any help from them. And we believe our presence in these IBI 2010 conference would help us source for funds to build the capacity of our staff and district Agric Extension Officers who would intend educate and impact the Biochar technology to the rural farmers in our part of the world. This promising technology would enhance crop production particularly vegetables, mango production and agro forestry practices in general. This intervention would eventually protect the ecosystem.

Goals and Objectives

Our plan of action is to go into serious Biochar Out-grower scheme in the selected sub district within the Upper Manya Krobo District (UMKD) and make it a showcase in West Africa for others to learn from. These would go a long way to prevent the use of chemical fertilizers and promote all year round organic farming to improve farmers crop yield to increase income of farmers and reduce poverty. These would stop rampant destruction of the vegetation to earn a living by the rural folks. The project intends to embark on all year round farming through the use of sustainable irrigation systems to reduce the farmers unemployment during the dry season, which have been identified as the major period when environmental degradation particularly charcoal burning for fuel occurs.

Procedures and Methods

The organization is critically soliciting for funds for capacity building using Farmer School Approach, Workshops, Demonstrations, Fora and Advertisement to encourage farmers to cultivation vast Organic Vegetables which would be intercrop with mangoes etc as agro forestry with Biochar system, Stakeholders will include, the UMKD Assembly (the local Authority), Ministry of Food and Agriculture (MoFA), etc.

Budget

Our Budget is to raise the necessary funds and machineries to service about 640 acres of lands at Akotoe, Anyaboni-Bisa, Akateng, Asesewa environs, to introduce Biochar technology to the larger farming communities in the district through the out-grower scheme. The total cost of the first phase of the project would demand an amount of $910,000.00. And it would involve over 300 peasant farmer in our area of operations in Ghana.

Monitoring and Evaluation System

The Nubians Renewal Organization field staff and the District Directorate of Agriculture Extension Officers would be use to supervise farmers and submit monthly reports to donors and NRO office on time.

Timelines of the Project

Schedule for this project which would be in three phases of five years each would takes 15 years as total project duration. So, the first phase would end in 2015.

Sustainability Plan

In Ghana the farmers enjoyed theoretical education from the Ministry of Food and Agriculture (MoFA) staff called Agric Extension Officers (AEO), due to these opportunities NRO intends working hand in hand with the Agric Extension Officer in our operation area to build their capacity so that they can continue the process when the project phases ends.

Impact of biochar and nitrogen management on nitrous oxide emissions in aerobic rice cropping system

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Key words: *greenhouse gas, agronomic efficiency, Brazilian savannas*

Introduction

The increase in nitrogen prices and demand for sustainable production gave importance to studies about strategies that increase nitrogen use efficiency. Besides contributing to carbon (C) sequestration, some studies have suggested that biochar can be used as amendment in soil to improve the uptake by plants of NPK fertilizer, consequently increasing plant growth and grain yield, as well as to reduce nitrous oxide (N_2O) emissions from agricultural fields [1].

The average yield achieved by aerobic rice based cropping systems in Brazilian savannas has been around 1.8 ton ha^{-1}. The high climatic variability is the main cause for that low grain production. Hence, two long term experiments were implemented aiming to test the effect of charcoal on nitrogen use efficiency and N_2O emissions in aerobic rice production systems under two different areas in Brazilian savannas (Figure 2 and 3).

One was implemented on a sandy Haplic Cambisol, in summer 2008/2009, testing two doses of N (0 and 110 kg ha^{-1}) and four doses of charcoal (0, 8, 16, 32 Mg ha^{-1}) from Cerrado (legalized), whose composition was 49.06% of C and 0.66% of N. Another was implemented on a clayey Haplic Ferralsol, in summer 2009/2010, testing four doses of N (0, 30, 60 and 90 kg ha^{-1}) in combination with four doses of charcoal (0, 8, 16, 32 Mg ha^{-1}) from eucalyptus (*Eucalyptus* sp.), whose composition was 75.89% of C and 0.78% of N.

The charcoal was incorporated to 15 cm in the soil right before sowing rice. The variety of aerobic rice (*Oryza sativa*) used was 'Primavera'. Fifty per cent of the N fertilizer (urea) was applied at sowing and 50% at 45-35 days after sowing. In both experiments, each plot of $40m^2$ had a static chamber used to collect the N_2O fluxes afterwards analyzed in a gas chromatography, during all the rice cycle. The fluxes were log transformed and the total emissions were calculated by interpolation of the mean fluxes and interpolation over the time [2]. Both experiments are still ongoing. The results presented here are from the first year of evaluation.

Results and Discussions

For both areas, the highest N_2O fluxes were observed for the treatments with the highest doses of N and charcoal, around the 2nd day after sowing, meaning 13,459 $\mu g\ m^{-2}\ dia^{-1}$ in sandy soil (treatment 110/32) and 616 $\mu g\ m^{-2}\ dia^{-1}$ in clayey soil (treatment 90/32). Moreover, in sandy soil the fluxes were almost 4 times higher than in clayey soil. Pay attention at the scale in axis Y in Figure 1. Also, the average of temperature in the soil at layer 0-10 cm was higher in the area of sandy soil (30ºC) than in the area of clayey soil (25ºC). Consequently, the highest total emissions were 1.2 kg ha^{-1} in sandy soil (treatment 110/32) and 0.134 kg ha^{-1} in clayey soil (treatment 90/32). Besides the doses 0 of N and 0 of biochar, the lowest total emission was observed for the treatments 110/16 in sandy soil, 0.657 kg ha^{-1}, and for the treatment 30/16 in clayey soil, 0.081 kg ha^{-1}. However, in clayey soil there was no statistical difference ($p \leq 5\%$) between emissions. The average rice yield was 2,600 kg ha^{-1} in clayey soil and 759 kg ha^{-1} in sandy soil, where the rice plants faced periods of drought during the end of the cycle. The agronomic efficiency (AE) [3] in clayey soil was higher for the treatment 30/32 and lower for the treatment 90/0. In the sandy soil the AE showed unexpected behavior, meaning that the charcoal effect on the rice yield was much greater than the N itself, probably due the hydric stress. The highest emission factor (F) in clayey soil was 0.09% for treatment 90/32 and in the sandy soil 1.1% for the treatment 110/32. The recognized F by IPCC [4] is 1% of N applied.

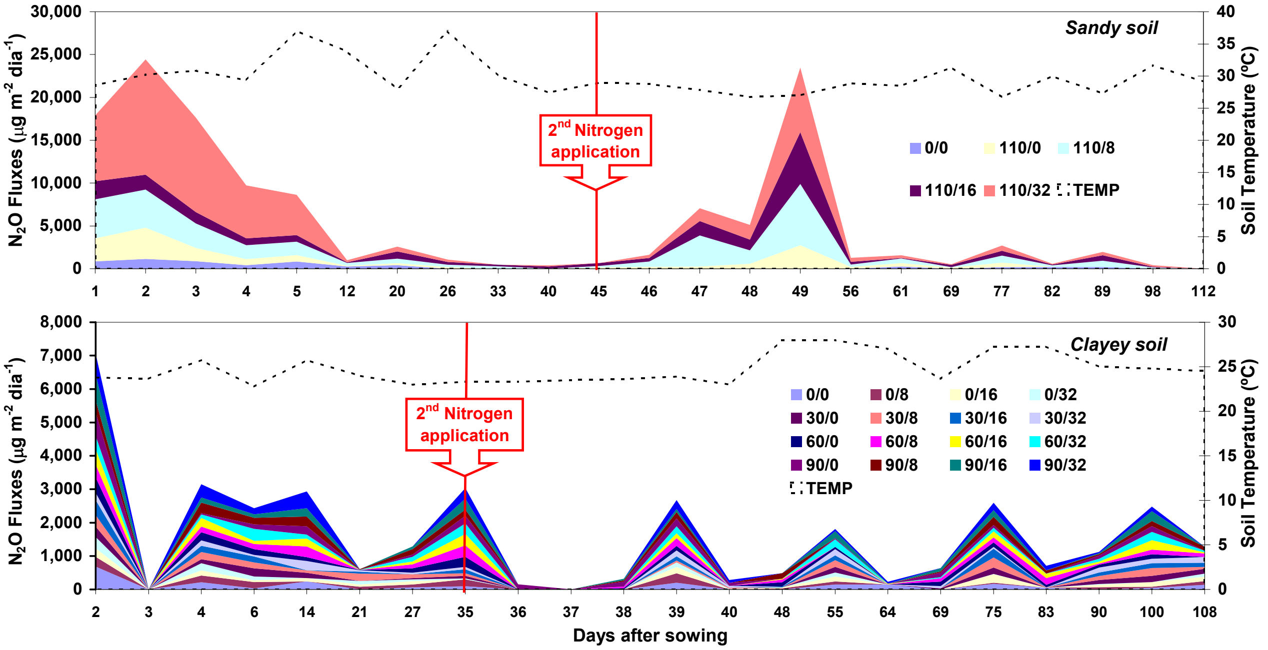

Figure 1. Nitrous oxide fluxes and soil temperature at layer 0 to 10 cm observed during all the cycle of aerobic rice cropping system (112-108 days after sowing) cultivated under sandy Haplic Cambisol and clayey Haplic Ferralsol in Brazilian savannas.

Conclusions

In summary, in clayey Ferralsol, charcoal had positive effect on rice yield, no effect on N_2O emission, increasing AE and decreasing F. In sandy Cambisol, charcoal had positive effect on rice yield, but it caused higher N_2O emission, resulting in greater F.

Therefore, the pros and contras of charcoal application to soil has to be carefully considered since its overall effect, yield, AE, F, N_2O emission, can be positive, however, depending on environmental characteristics acting on water-soil-plant-atmosphere system, contras may weight more in the balance.

Hence, long term assessment, considering specificity of local conditions, must be done before recommendation of biochar as a soil amendment in agricultural systems.

Acknowledgements

Special thanks to owners from Estrela do Sul Farm and students from State University of Mato Grosso (Unemat) who have been helping in executing this study.

Figure 2. Biochar incorporated in clayey Haplic Ferralsol at Capivara Farm (16°29'17" S and 49°17'57" W) (Photo by Holger Meinke, February, 2010).

Figure 3. Biochar incorporated in sandy Haplic Cambisol at Estrela do Sul Farm (14°34'50" S and 52°24'01" W) (Photo by Beata E. Madari, February, 2009).

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[1] Fowles, M. 2007. *Biomass and Bioenergy*, *31*, pp. 426-432.

[2] Velthof, G. L. 1997. *Nitrous oxide emissions from intensively managed grasslands.* (PhD Thesis). Wageningen University.

[3] Fageria, N. K.; Slaton, N.A.; Baligar, V.C. 2003. *Advances in Agronomy*, 80, pp. 63-152.

[4] IPCC. 2006. *Guidelines for National Greenhouse Gas Inventories, 4*, 54.

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Is biochar carbon negative? Quantifying the climate change mitigation benefits of biochar

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Key words: *greenhouse gas balance; life cycle assessment*

Introduction

It is commonly claimed that biochar is a “carbon negative” technology. This claim needs to be justified through scientifically-rigorous assessment. Simplistically, “carbon negative” implies that the system removes more greenhouse gas (GHG) from the atmosphere than it releases. The appropriate metric for assessing carbon negativity is not so readily defined. Simple input/output ratios do not adequately reflect the mitigation benefit of a biochar system. Rather, it is necessary to document the whole life cycle GHG balance of biochar production and utilisation, and compare this with conventional practice.

Results and Discussion

The appropriate methodology for assessment of mitigation benefits of biochar is illustrated through a desk-top study in which the GHG balance of various biochar feedstocks applied to different cropping systems (biochar case) is compared with current practices (reference case) (Figure 1).

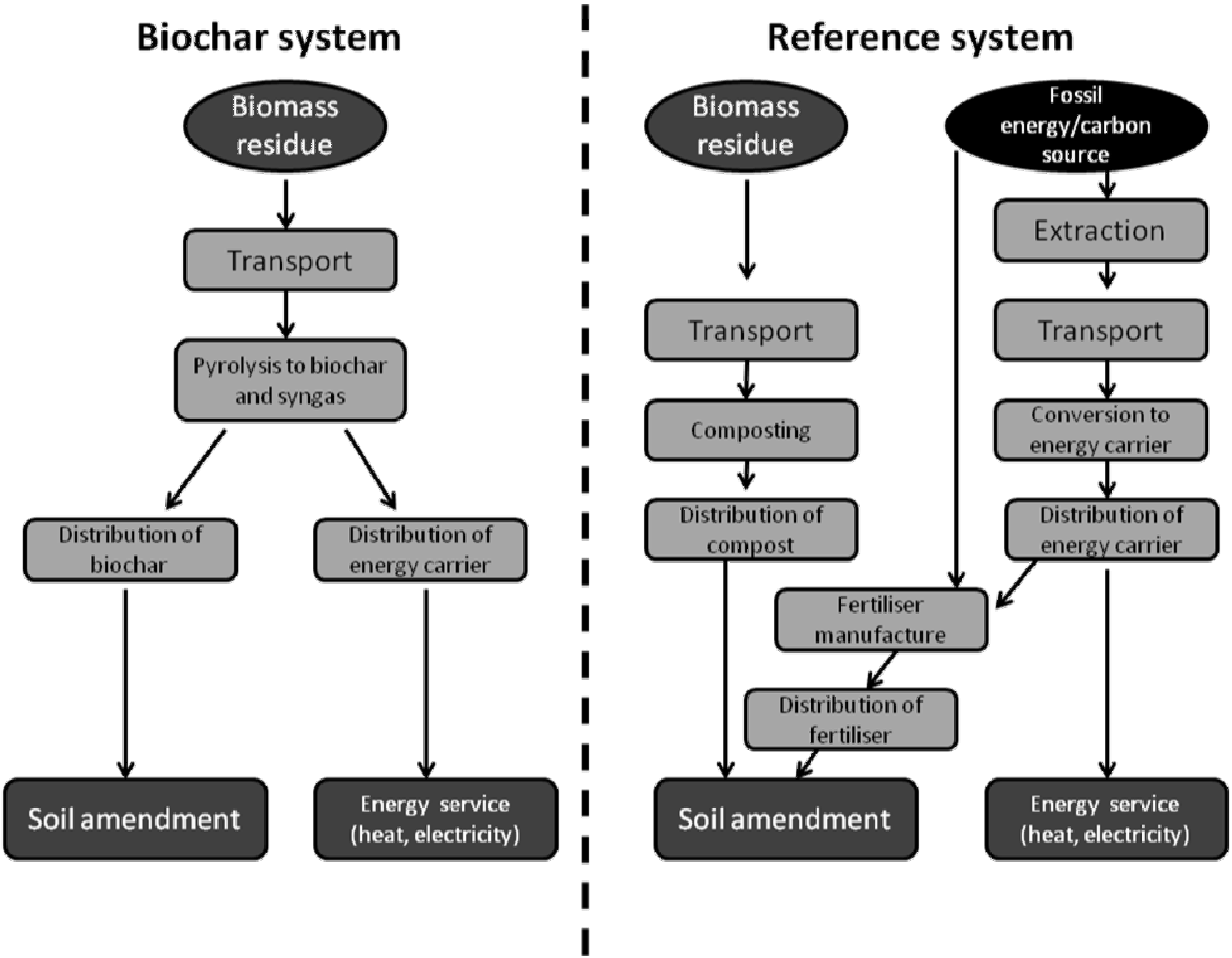

Figure 1. Life cycle stages of a biochar system and corresponding reference system

The emissions reduction benefit of biochar systems is calculated as the difference in net emissions between the biochar and reference cases.

For both the biochar and references cases the assessment should include:

- direct and indirect carbon stock change in biomass and soil;
- emissions of nitrous oxide and methane;
- crop yield, fertiliser and irrigation requirement;
- fossil energy use in plant construction, transport , processing, application of soil amendment, cultivation of crop, manufacture of fertiliser; and
- renewable energy generated.

Other elements that may be significant are timing of emissions and sequestration, and impact on radiative forcing of change in albedo.

It is important that the same “services” are delivered by the biochar and references cases. That is, they must produce equivalent energy output, generate soil amendment for the same land area, and utilise the same quantity of biomass.

In this example, the estimated net emissions reduction summed over 100 years for different biochar scenarios ranged from 1.7 to 3.1 t CO_2-e per t (dry) feedstock, equivalent to 1.3 - 2.0 times the CO_2-e of the feedstock.

The main factors determining emissions reduction were, in order of significance:

- emissions of methane and/or nitrous oxide avoided by diverting biomass from its conventional use;
- biochar yield and carbon turnover rate in soil;
- net energy exported and the energy source it displaces, determining displaced fossil fuel emissions; and
- nitrous oxide emissions from soil.

The result is highly sensitive to the assumptions in relation to these factors.

There is high uncertainty in many components of the analysis, particularly:

- emissions associated with landfilling of biomass in the reference case (the extent of decomposition and the proportion of carbon released as methane)
- the impact on nitrous oxide emissions
- the turnover rate of biochar under field conditions
- the longevity of the impact on crop yield and fertiliser requirement.

These aspects require further investigation to improve estimates of mitigation benefit.

In this example, the greatest GHG mitigation is obtained for the cases that utilise waste material that would otherwise be landfilled, and where biochar is applied to a horticultural crop with high fertiliser requirements. The benefit is lower for cases that divert biomass from its current beneficial use as fertiliser.

Conclusions

The net climate change benefit of biochar should be determined by comparison with the appropriate reference system, representing the conventional use of the biomass, and conventional energy source. A whole system, life cycle perspective is required, that includes indirect (upstream and downstream) emissions as well as direct emissions and sequestration. The desk-top analyses undertaken to illustrate the methodology demonstrate that use of biomass to produce biochar for utilisation as a soil amendment can lead to net negative emissions. Thus, it can be considered a “carbon negative” system. In fact, the magnitude of the net life cycle abatement can exceed the amount of GHG sequestered in the biomass, in situations where avoided emissions are substantial. The major contributions to mitigation vary depending on feedstock, target crop, and characteristics of the situation-specific reference system. The result is highly sensitive to the assumptions, and also to the reference system. Further research is needed to provide accurate data for estimation of mitigation benefit. Aspects of particular uncertainty are the turnover rate of biochar carbon under field conditions, and the impact of biochar on nitrous oxide emissions from soil. Care should be taken in generalising outcomes of life cycle GHG balance studies.

Acknowledgements

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Microbial utilisation of organic carbon as affected by biochar application

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Key words: *Biochar, Organic acids, 13-C PLFA*

Introduction

Biochar has become an area of intensive research for soil biogeochemists in recent years. Little is known about its rates of degradation and the mechanisms behind this. Recent interest has had two main objectives: a) its indirect or direct effects on soil quality; and b) its potential for terrestrial carbon sequestration. Much research has been carried out to investigate processes by which chars may remain stable, and whether their presence may affect the degradation of recalcitrant indigenous carbon pools such as humic-carbon [1].

Organic acids such as citrate may be exuded by plant roots through a multitude of mechanisms in response to a number of well-defined environmental stresses (e.g. Al, P and Fe stress) [2]. Sorption of organic acids to the soil solid phase, and mineralisation by the soil's microbial biomass greatly affect the efficacy of these compounds in most rhizosphere processes. Charcoal in soil is known to be sorbent in soil systems, has the potential to reduce the efficacy of exudate-derived organic acids by binding them to its surface. In addition, these organic acids are routinely turned over by the soil microbial community at extremely high rates ($t_{1/2}$ 2-3 h). The potential sorption of organic acids to charcoal may affect the microbial community, reducing the availability of this carbon source, and possibly favouring K-strategists who grow at a slower rate and prefer a stable environment, but degrade more recalcitrant carbon – as discussed in [1].

Possible implications of this may be that biochar application may lead to a shift in the microbial community from one mainly utilising low molecular weight organic carbon (LMWOC) to one more suited to degrading recalcitrant portions of the soil carbon stock.

A counter-argument to this is presented by [3]. In a study investigating effect of glucose on black carbon, it was found that biochar enhanced glucose mineralisation. However, it should be noted that glucose does not bind strongly to solids, whereas significant sorption is observed by organic acids [2].

Outline and Hypotheses

We plan to investigate the effect of biochar on the microbial uptake and degradation of the organic acid citrate in a mesocosm experiment, with the overarching hypothesis: Biochar sorbs compounds, making them less available to the soil microbial community. Our secondary hypotheses are:

a. Bound compounds will be utilised more readily by fungi as these microbes are generally more capable of degrading recalcitrant material
b. Soils containing more fungi will take up the compounds much faster than those which are dominated by bacteria
c. Soils which have had greater exposure to charcoal will contain microbial communities which are more readily able to assimilate organic compounds which may be bound to biochar.

This experiment will be conducted in conjunction with another mesocosm experiment by Thomas Kuhn, which investigates the bioavailability of labile compounds in biochars through ^{13}C-labelling, quantitative and isotopic analyses of microbial respired CO_2, and compound-specific isotope analyses (CSIA) of microbial phospholipid fatty acids (PLFAs)

Proposed methods

An initial study will be carried out using [U]^{14}C-citrate to quantify the capacity of the biochar used in this study to sorb citrate by fitting a sorption curve to the Langmuir isotherm [4]. Soils from long-term biochar field trials are being sought, and will be used in a destructively-sampled incubation experiment to investigate the effect of biochar on the microbial uptake and degradation of [U]^{13}C-citrate.

Treatments will be:

- Soil only (control)
- Field soil and biochar (aged)
- Soil + new biochar
- Field soil and aged biochar + new biochar

Gas will be captured and analysed for CO_2 concentration and $^{13}CO_2$ release. In addition we plan to use CSIA to allow us to investigate uptake of the ^{13}C label and incorporation into microbial biomass by different groups of microbes. This will involve the extraction of the PLFA biomarkers and analysis by gas chromatography – combustion – isotope ratio mass spectrometry (GC-C-IRMS) to determine how much ^{13}C has been incorporated into each group of microbes. This technique will enable us to elucidate much more specific results than if just the $^{13}CO_2$ data were used, or if just microbial community structure were analysed by either PLFAs or DNA-based analyses.

Outcomes

This work should enable us to delve into microbial degradation of organic compounds to a level of much finer detail than that offered by either bulk isotope studies, or by general community profiling techniques. It will enable us to identify which microbial groups are utilising labelled substrates, and should react much quicker to these additions than the time taken for actual shifts in community structure to be observed, hence affording us a more accurate picture of rapid changes in the rhizosphere. In the context of this experiment, we hope to be able to demonstrate a more rapid utilisation of the ^{13}C tracer by the microbial community that has been previously exposed to biochar.

Acknowledgements

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[1] Wardle, D.A.; Nilsson, M-C.; Zackrisson, O. *Science*, *320*, 629.

[2] Jones, D.L. *Plant Soil*, *205*, *25*.

[3] Hamer, U.; Marschner, B.; Brodowski, S.; Amelung, W. *Org. Geochem.*, *35*, *823*.

[4] Langmuir, I. *J. Am. Chem. Soc.*, *40*, *1361*.

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Biochar's Role in Global Carbon Management

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Key words: *Biochar, Carbon, Sequestration*

Introduction

There is a growing scientific consensus that excess atmospheric CO_2 already emitted from fossil sources would take over 1,000 years to return to preindustrial levels, and more will be added before we can bring emissions to zero. Thus, human intervention will be required to remove several hundred petagrams (Pg) of carbon from the atmosphere [1].

Results and Discussions

The CO_2 concentration in the atmosphere is known to have fluctuated between 180ppm and 280ppm over at least the last 650,000 years, based on ice core data [2]. The current atmospheric CO_2 concentration is almost 400ppm, and is projected to reach a minimum of 450ppm, and very likely 500ppm, or higher, with continued emissions.

The figure 350ppm, popularized as a safe maximum figure, is not precise. It was simply a round number cited in response to arguments about whether we could safely go to 450, 550, or 650ppm, or beyond. Modeling now suggests that a safe level will more likely be closer to 300ppm, which is still significantly higher than the consistent interglacial maximum of 280ppm seen repeatedly over the past 650,000 years.

Each 1ppm of atmospheric CO_2 corresponds to approximately 2.1Pg (1Pg=1Gt) of carbon in the atmosphere. However, the carbonic acid concentration in the oceans is in equilibrium with the CO_2 concentration in the atmosphere, so as atmospheric CO_2 has increased, the oceans have absorbed a large fraction of that carbon. The acid level in the oceans will very likely become the most serious limiting factor, as calcium-shelled organisms that support life in the oceans appear to already be at serious risk, even at current acidity levels.

There is now a strong scientific consensus that the rate of natural carbon removal from the atmosphere is very limited, and that it would take at least 1,000 years, and likely much longer, for the existing atmospheric CO_2 concentration to drop back to around 300ppm. The heating that would result from existing CO_2 levels being maintained over such a prolonged period would drive warming of greater than 2°C.

To reduce the atmospheric CO_2 concentration from 400ppm down to 300ppm would appear to require removing about 300Gt of carbon. This does not include future overshoot, so the net carbon removal required to stabilize the atmosphere could easily be in the range of 600Gt before we bring emissions down to zero.

Many assume that producing biomass energy with CCS (carbon capture and storage) will be the way to remove large amounts of net carbon from the atmosphere. However, CCS remains largely technically unproven, and the sheer volume of suitable geologic formations required for the total amount of CO_2 in question could severely limit its potential.

Other proposals include synthetic trees, or adding large amounts of limestone (calcium carbonate) to the oceans. The energy required for these solutions would mean that one would have to create a vast amount of extra solar, wind or nuclear capacity to support them, or burn even more fossil carbon in an attempt to remove incrementally more than emitted [3].

Afforestation and changes in agricultural and rangeland practices may be the most cost effective way to remove net carbon from the atmosphere. However, such approaches can only correct the portion of the atmospheric imbalance caused by the corresponding carbon emitting agricultural and forestry practices since the dawn of humanity. The majority of excess atmospheric carbon is due to fossil emissions, therefore only a fraction of the total excess can be reversed by corrective land use practices.

The carbon sequestration efficacy of biochar, while not yet fully quantified, is reasonably certain. The biochar cycle can remove and sequester 40-50% of the total carbon in the biomass used to make the biochar, *for on the order of 1,000 years* [4].

Conservative estimates indicate that biochar produced from a sustainable fraction of existing agricultural waste could remove and retire about 1Pg/yr of carbon, while energy co-production could replace up to another 1Pg/yr of fossil emissions [5].

If forestry residues, particularly one-time surplus materials from pine beetle kill and other epidemics, and plantations were included, those numbers could be significantly larger.

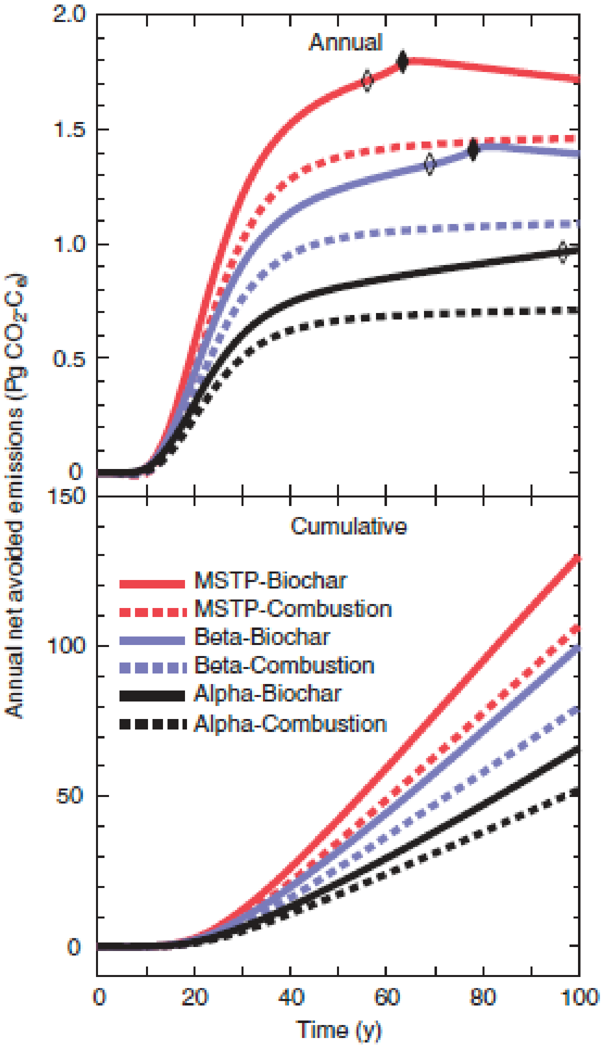

Figure 1. Avoided emissions attributed to biochar production or biomass combustion over 100 yrs relative to current biomass use. Results shown for 3 scenarios—biochar represented by solid lines and biomass combustion by dashed lines. Top panel shows annual avoided emissions; the bottom panel, cumulative avoided emissions. Diamonds indicate transition periods when top 15 cm of soil is biochar-saturated, requiring alternative disposal options [5].

The total benefit from biochar also includes increased biomass production and the potential to expand biomass production into now barren and degraded lands. This allows biochar to bootstrap increased total biomass production, increasing total food production and potentially reduce destructive pressure on intact forestland [6]. Moreover, the economic benefits of biochar accrue from soil fertility in advance of economic drivers for carbon management.

If N_2O emissions are considered, the CO_2 equivalent could make biochar economics even more attractive, even at low carbon prices. Ammonia reduction in agriculture and reduced need for fertilizers also contribute to both the climate carbon balance and the economics [7].

Biochar represents the only truly stable carbon retirement method currently available. If CCS does prove to work, CO_2 emissions from biomass energy coupled with biochar could also be sequestered via CCS, and total annual carbon retirement potentially almost doubled.

The global capacity to retire atmospheric carbon through biochar will depend on biomass allocation among competing uses. Near term, burning biomass to replace coal appears to maximize avoided emissions, but once the energy mix begins to shift to de-carbonized sources, biochar production will offer a uniquely valuable way to remove and retire atmospheric carbon, while also producing about half as much energy from the biomass. The goal of an 80% reduction in emissions by 2050 implies that the energy mix will be de-carbonized within 50 years. Producing a combination of biochar and energy offers true carbon retirement, which will be essential as we remove net carbon from the atmosphere to restore the climate over coming centuries.

Conclusions

It may appear to be more attractive to use biomass as a substitute for coal now, while we are still burning coal, however, once we begin to rapidly de-carbonize the economy, continuing to burn biomass will not be the best use of that carbon, and committing to long-term biomass co-firing projects now would be a mistake.

Acknowledgements

We are deeply grateful to Jim Amonette for his foundational work on biochar and climate.

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[1] The Royal Society. 2009. *Geoengineering the Climate*, ix.

[2] Siegenthaler, H. et al. 2005. *Stable Carbon Cycle-Climate Relationship During the Late Pleistocene*, 3.

[3] MacCracken, M. et al. 2010. Asilomar Climate Intervention Conference.

[4] Lehmann, J. 2008. Live conversation. UNFCCC COP-14, Poznan, Poland.

[5] Woolf, D. et al. 2009. Sustainable Biochar to Mitigate Global Climate Change. *In: Nature Communications. 3*,5.

[6] Goodall, C. 2009. Exceptional Results from Biochar Experiment in Cameroon. Accessed online: http://www.carboncommentary.com/2009/10/01/761

[7] Singh, B. et al. 2010. Influence of Biochars on N_2O Emission & N-Leaching from 2 Contrasting Soils. *Am. Soc. of Agronomy.*

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The UBI concept: significant, timely climate change mitigation from thinly distributed feedstock in sustainable rural development using low tech biochar production

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Key words: *Climate Change Mitigation, Thinly Distributed Feedstock, Low Tech Production.*

Introduction

In his keynote address for the ‘09 Asia Pacific Region Biochar Conference, Professor Lehmann indicated that he felt that the greatest potential for global warming mitigation through the sequestration of biochar lay in the utilization of distributed feedstocks. UBI (the Ulaanbaatar Biochar Initiative) is a program dedicated to testing the concept that these feedstocks can actually be utilized to significantly contribute to global warming mitigation. It is a program focused on significant climate change mitigation within the time limits set by the physics of climate change through initiating a geometric growth in sequestered biochar utilizing thinly distributed feedstock and low tech production available to 3rd world smallholders in sustainable rural development.

The UBI Concept

UBI utilizes two drivers. The first is the well known soil enhancement qualities of sequestered biochar resulting in increased plant growth which generally maximizes at 10 to 20 tons/ha of sequestered biochar and, of course, the self interest of smallholders in enhancing crop production at less cost.

The second driver comes from the same self interest through income augmentation through carbon credits from sequestering additional biochar on crop land (up to as much as an additional 90 t/ha without damaging growth) and pasture as well as on other land where it is not disruptive to do so. As envisioned in UBI, carbon credits earned by an individual small scale producer would be marketed through their local marketing organization. This marketing organization would also assure the sustainable production of the biochar and verify the quantity and quality of the biochar as well as its having been properly mixed into the soil for sequestration purposes. The local marketing organization and intermediary organizations would aggregate the individual members’ production credits for not-for-profit brokering on the open market, insuring an equitable share passed back down to the individual producers. To date such a straight forward post sequestering marketing and pass-back of profit for primary work done does not seem to be the norm in the carbon trading markets. It will be one of the objectives of UBI to work with interested rural development and/or environmental organizations to facilitate the development of such market access in the current markets as well as getting a significant place for representatives at the table in up-coming conferences where the rules for future carbon trading &/or energy taxes are made.

The program itself relies on dedicated NGOs informing the smallholders of these possibilities and promoting them in such a way as to generate a geometric growth in the production and sequestration of biochar by them.

This geometric growth is to be initiated by demonstrating the concept in select pilot communities in given cultural and biological environments and then, once buy-in is achieved, using these communities in a communities-mentoring-communities program, starting a chain reaction.

As the program develops and proves itself, more and larger NGOs & INGOs will need to be involved, followed by GOs, RGOs and IGOs to handle the rapid growth and massive nature of a geometric increase. This kind of growth is necessitated by the narrow time window with which we are dealing to achieve meaningful climate change mitigation.

Program Developments

A Not-for-Profit NGO, UB International (also UBI) [1] has been incorporated in Hawaii to serve as an umbrella organization to coordinate the establishment of local sib-projects. These local sib-projects instantiate the UBI concept adapted to the local cultural and environmental environments.

The Mongolian Biochar Initiative (MoBI) [2] is the initial sib-project set up under the UBI umbrella. It began as a consortium of 3 local

NGOs involved in local urban and rural community development working with the precursor of UB International and a research group of the Mongolian State University of Agriculture. These have been joined by an additional local NGO and a second research group from the Mongolian University of Science and Technology (Forestry). Initial funding was to have been from the accepted Mongolia program of IBI Nine Country Program [3] but, unfortunately, funding for the entire 9CP has been put on indefinite hold due to the current economic situation. Startup funding for the last 2 years has been coming from the Australian Embassy's ADAP program.

A second sib-project, the Thai Biochar Initiative (ThBI) [4] has been set up and another, the Hawaii Biochar Initiative (HaBI) is in the process of organizing and exploring the adaptability of the UBI concept in developed country urban and rural smallholder context.

We invite contact by others interested in developing sib-projects for appropriate cultural and ecological situations around the world as well as interested volunteers and those with appropriate training, especially in the other needed areas beyond biochar production and use. Additional information on UBI type projects can be found in 'Using Low-Tech Biochar to Mitigate Climate Change"[5].

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[1] http://www.biochar-international.org/regional/ubi

[2] http://www.biochar-international.org/regional/mongolia

[3] http://www.biochar-international.org/9country

[4] http://www.biochar-international.org/regional/thailand

[5] Frogner, K. J.; Taylor, P. Ltd. Draft Edition. *In: The Biochar Refolution: Transforming Agriculture & Environment,* P. Taylor (Ed.) www.biochar-books.com, pp. 287-298.

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Initial Life Cycle Analysis for Pyrolysis Biochar Systems in the UK

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Key words: *Carbon Abatement, Soil Organic Carbon, Biomass*

Introduction

A life cycle assessment (LCA) was undertaken of slow pyrolysis biochar systems (PBS) in the UK context. Configurations using small, medium and large scale pyrolysis units and distributed or centralized process chains were analysed for eleven likely UK feedstocks, including: short rotation coppice, miscanthus, short rotation forestry, straws, forestry, and forestry residues. Biochar was assumed to be incorporated into mainstream UK arable farmlands. Carbon abatement (CA) and electricity production were monitored. Results were compared to equivalent biomass combustion, fast pyrolysis and gasification.

The LCA technique was attributional rather than consequential [1]; meaning that only those effects directly attributed to actions within the system were included. Land use change emissions or market effects due to re-allocation of resources were not included, with the exception of energy export form pyrolysis offsetting fossil fuel emissions. Data on UK specific logistics and feedstocks were taken from well established research efforts [2,3], pyrolysis data from comprehensive literature survey [4], and biochar stability and biochar-soil interactions from literature survey and expert elicitations [5].

Results and Discussions

Pyrolysis biochar systems appear to offer greater carbon abatement than other bioenergy systems available at present. Carbon abatement of 0.71–1.24 tCO_2e per oven dry tonne (odt) of feedstock processed was found. Expressed in terms of delivered energy PBS abates 1.4–1.8 tCO_2e/MWh, which compares to average carbon emissions of 0.05–0.30 tCO_2e/MWh for other bioenergy systems. Assuming that biomass is replanted after harvesting, PBS can therefore be said to deliver carbon negative energy. Expressed in terms of land-use, PBS appears to abate approximately 5.4–21.5 tCO_2e/ha compared with typical bioenergy carbon abatement of 1–7 tCO_2e/ha. Although larger scale PBS with more centralised supply chains delivered higher net carbon abatement and more useful energy, smaller and more distributed systems appear to be also very much worth pursuing.

Table 1. Carbon abatement efficiencies and electricity production for small, medium and large scale pyrolysis biochar systems.

	Small	Medium	Large
Carbon Abatement			
tCO_2e/odt feedstock	0.71	1.12	1.12
tCO_2e/MWh electricity	2.38	1.61	1.40
tCO_2e/ha	12.46	11.2	6.65
tCO_2e/t char	2.15	3.38	3.39
Total tCO_2e/yr per facility	1068	16802	84248
Electricity Production			
Electrical efficiency (%)	6	15	16
MWh/odt feedstock	0.3	0.7	0.8
MWh/ha	5.25	6.96	4.76
Total MWh/yr per facility	450	10447	60366

Three feedstock availability scenarios were created – low, medium and high – for UK by 2020. From these, total carbon abatement of 3.6–11.1 $MtCO_2e$ per year could be achieved [6].

The largest contribution to PBS carbon abatement (40–50%) is from the feedstock carbon stabilised in biochar. The next largest contribution (25–40%) arises from the more uncertain effects of biochar upon the build-up of soil organic carbon levels. Change in soil organic carbon levels was found to be a key sensitivity. Electricity production off-setting emissions from fossil fuels accounts for 10-25% of carbon abatement. The LCA suggests that provided 43% of the carbon in biochar remains stable, PBS will out-perform direct combustion of biomass at 33% efficiency in terms of carbon abatement, even if there is no beneficial effect upon soil organic carbon levels from biochar application.

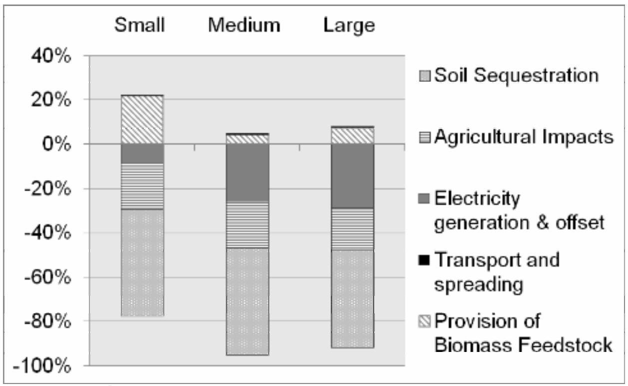

Figure 1. Percentage contribution to net carbon abatement by life cycle stage; for small, medium and large scale pyrolysis biochar systems.

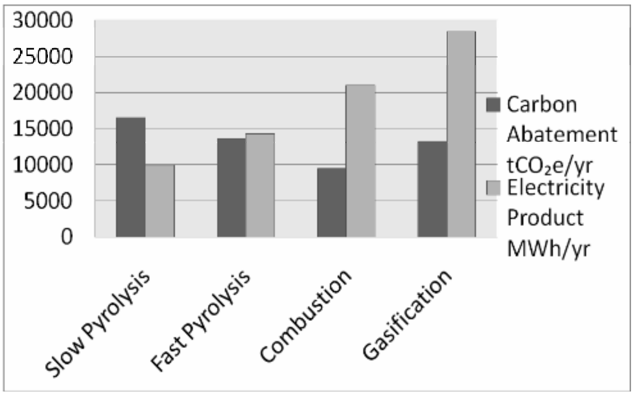

Figure 2. Carbon abatement and electricity produced from different ways of processing 20,000 tonnes of biomass.

The most important factor in determining overall carbon abatement was the amount of stable carbon in biochar entering the soil. Increased biochar yields whilst maintaining stable carbon content increased net carbon abatement, and biochar losses during transport or field application reduced net CA. The carbon stability factor of 0.68 was used, meaning that 68% of the carbon in the fresh biochar was assumed to remain after 100 years. Reduced carbon stability had a major effect upon net CA. This study assumed that biochar additions led to crop NPP increase of 10%, and increase in soil organic carbon levels by 21% (after 100 years). This soil organic carbon increase constituted a major (25–40%) contribution to net CA, but is perhaps the least well understood element of the biochar lifecycle. Improved conversion efficiency of biomass products to electricity or the use of low grade heat to offset fossil fuel use further benefited increased net carbon abatement. Transport distances and fertiliser offsets were found to be negligible in terms of carbon reductions.

Whilst PBS delivers energy in the form of syngas and bio-oils, the amount of energy delivered per unit of biomass processed was at least 50% lower than for other bioenergy systems, presenting a choice as to whether to use biomass for energy production or greater carbon abatement. In the UK low carbon electricity is rewarded where as carbon abatement is not, incentivising other uses of biomass than biochar. Even without incentives, electricity is a more marketable product than biochar at present. Until the agronomic effects of biochar can be predicted accurately, it may be difficult to market, and therefore justify any biochar production which does not offer substantial electricity production, at least in non-agricultural economies. Fast pyrolysis may present such a middle ground of biochar and energy production.

Conclusions

Pyrolysis biochar systems as assessed in UK conditions appear to offer greater carbon abatement than other bioenergy systems available at present. Carbon abatement of 0.71–1.24 $tCO_2e\ odt^{-1}$ of feedstock processed was found. Biochar carbon stability is a key determinate of how much carbon can be abated, and biochar effect on soil organic carbon stocks is potentially a very important uncertainty in biochar systems.

Biochar systems produce less electricity than other advanced bioenergy systems, which makes biochar less appealing to investors when electricity has a higher market value than carbon abatement. The agronomic benefits of biochar could help to add value, but are not yet predictable enough to be marketed.

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[1] Brander M, Tipper R, Hutchison C, Davis G. Consequential and Attributional Approaches to LCA: a Guide to Policy Makers with Specific Reference to Greenhouse Gas LCA of Biofuels. Edinburgh, Ecometrica; 2008.

[2] Mortimer ND, Evans A, Shaw VL, Hunter AJ. Life Cycle and Techno-Economic Assessment of 1 the North East Biomass to Liquids Project. York, North Energy Associates Limited; 2009.

[3] Thornley P, Upham P, Tomei J. Sustainability Constraints on UK Bioenergy Development. Energy Policy 2009; 37(12):5623-35.

[4] Brownsort P. Biomass Pyrolysis Processes: Review of Scope, Control and Variability. Working Paper 5, Edinburgh, UKBRC. 2009

[5] Hammond J, Shackley S, Sohi S, Brownsort P. Predicted Life Cycle Carbon Abatement for Pyrolysis Biochar Systems in the UK. Forthcoming.

[6] Shackley S, Sohi S, (eds). An assessment of the benefits and issues associated with the application of biochar to soil. Edinburgh, UKBRC, Defra; 2010.

Nature's Smorgasbord – Plant nutrient selection by microbial activation and it's role in the soil carbon regime

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Key words: Geomite Biomineral, Agriculture

Introduction

A long term study of soil-plant interaction suggests that plants obtain the range of nutrient cations they require by manufacturing and releasing highly specific root exudate compounds whose purpose is to activate targeted species of soil micro-organisms which then solubilise 'insoluble' minerals within the soil base for absorption by the plant. The same process is used to obtain antibiotic medication from appropriate microbial sp when plants are threatened by disease organisms. It has been given the working title 'Nature's Smorgasbord.

Results and Discussions

The process operates continuously throughout the life cycle, and in doing so creates an exponential growth of soil microbiota in the rootzone. The growth in turn promotes that of a range of macrobiota, notably earthworms. The breakdown products of this demographic release nitrogen and act to physically cement soil textural particles in the creation of aggregates, and in so doing, strongly modify soil structure to faciltate ongoing plant development. The ultimate decay product is carbon, and it is possible that 30-40% of atmospheric carbon dioxide absorbed by the plant foliage is sequestered as soil carbon in this way, the remainder being applied to creation of actual plant tissue.

The process continues without hindrance in the wild state, and is nature's way of developing soil structure and sequestering carbon for the shelter and energy needs of succeeding microbe generations. The soil microbial demographic is measured in tonnes per hectare where the process is allowed to continue unchecked.

Although root exudation has been common knowledge for a century or more, it's extent and purpose is only now being fully apparent. Within recent years, RNA research conducted by the Max Planck Institute has identified 110 000 different compounds in root exudation from a sample wild tobacco plant.

When soluble chemical fertilizers are applied to crops however, the plants accept them as required, without need to activate target micro-organisms. When this occurs, the development of the soil microbe demographic is aborted, structure development is halted, and carbon sequestration does not take place.

The traditional farming practice of turning land to pasture for 3-4 years between crop cycles exploited the increase in fertility without being aware of it's cause. By contrast, land which was caused to fallow under minimal growth, or that which was consistently over-grazed, was found to decrease in structure and fertility. These characteristics are identical with those of land which is subject to chemical fertillization over an extended period and include reduced drought tolerance, reduced water absorption and increase of fungal and bacterial pathogens.

An assessment of the Morrow plot, the oldest monitored soil in the US, has shown a 10 tonne/hectare loss in soil organic carbon in a fifty year period following the introduction of chemical fertilization. This occurred despite annual return of all crop debris to the soil.

Reference: Journal of Environmental Quality Kahn, Mulvaney et al various.

It is suggested that this result is optimistic in wider world terms due to the fact that the 'null' period, that in which the activity of soil microbiota slows or ceases, is the result of low temperature in the Morrow case. In the world's arid soils it is the product of heat and dehydration. The consequences are quite important because carbon oxidation from cold soils is minimal whereas that from hot, dry soils is extremely high to catastrophic and organic carbon loss may even double that observed in the Morrow example. It is the opinion of the author that CO_2 released to atmosphere as a consequence of world scale chemical fertilization has been grossly understated.

Conclusions

The foregoing discussion suggests that the properties of biochar may best be realized by practising farmers if chemical fertilization is either progressively decreased, or eliminated entirely from the maintenance program in order to maximize development and function of soil biota.

Application by spreader to established pasture at onset of the growing season is perhaps the most economic approach, and attention should be given to maintenance of pasture height in order to maximize microbiota activity on the soil surface. Only very light grazing should be practised in the early stages so as to maximize root growth. Under these conditions biochar is rapidly absorbed into the A horizon, and more deeply by earthworm action. Seeding with earthworm varieties is recommended, particularly where populations have been decimated by chemical practice.

Direct seeding using modern equipment requires a pelleted product.

The World's Tropical Rainforests as source of high potency Biochar

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Key words: *rainforest bamboo mineralization*

Introduction

Tropical rainforests are characterised by the high rate of extraction of mineral cations from depth and their deposition on the forest floor in biomass, where the process is augmented by composting which is activated and supplemented by animal excretion. Nowhere is this more effective than in volcanic regions, where the mineral source constitutes that upon which all life on earth has developed. The rapidity with which these processes operate in the world's tropical rainforests generates a vast untapped nutrient resource in the form of runoff which presently flows to the oceans.

Correctly trapped and converted to transportable form, this can be a major component of future world agriculture.

Results and Discussions

A means of trapping, harvesting and concentrating nutrient from this source in the form of biochar and augmenting it for increased potency is described, using bamboo as a trap crop.

The procedure mimics the way in which farm crops extract applied fertilizer nutrient and export it in the form of produce, and will involve the establishment of bamboo forestry plantations along the lower slopes of rainforest where, during the four year maturation period the culms become charged with nutrient extracted from runoff and constitute an excellent biochar feedstock.

By implementing a system of village level agroforestry programs based on this concept, endangered rainforests would be conferred with economic value far beyond the transitory cash returns derived from logging of their timber, and the way opened for a true partnership between world agriculture and rainforest village communities which will benefit both. Village latrines located above the plantations offer further sources of enrichment while the bamboo root mass functions as an effective filter against stream pollution.

A permanent root system which facilitates nutrient take-up and holds future benefiits viv a vis carbon credits, culm by culm harvest which preserves canopy, rapid four year maturation cycle, and carbon dioxide absorption almost three times greater than that of other forest species, make bamboo a preferred feedstock. Location of highly CO_2 absorbent plantations at base of valley slopes, where atmospheric CO_2 concentrations are highest, is advantageous. Bamboo also secretes within it's culm tissue 5% silica in fine crystalline state.

Pyrolysis of mature biomass from such plantations will yield biochar of high silica and fullerene content. The latter being molecular-sized structures of crystalline carbon which resemble those of zeolites in the capacity to act as molecular sponges which store cations, microbes and water. Biochar possessing these structures is of greatly enhanced value to agriculture, and such value may be further augmented by including seaweed and fish waste in the pyrolysis.

In the kiln seaweed halogens react with silica to form insoluble halides and are retained in the resulting biochar. Likewise, dried fish waste releases valuable nutrient cations, in particular phosphorus, to the mix. Phosphorus is normally lost as the pentoxide in traditional charcoal production because of inadequate kiln sealing but this does not occur with modern biochar plant.

Concerns over future supplies of phosphorus for world agriculture appear to be poorly founded in the light of the growing awareness that superphosphate is a wasteful means of application and much more is either fixed or leached from agricultural soils than had previously been supposed. Estimations of phosphorus actually available to crop plants are now as low as 5%, and experience with biomineral fertilization in South Australia has achieved credible response from as little as 2% applied in a form which is insoluble and converted only in answer to plant demand as outlined in the abstract titled Nature's Smorgasbord. There are in addition, strong indications that appropriate mineral/microbial balance in the rhizone promotes a synergy which greatly increases the efficiency of metabolic utilization of phosphorus, and that high application rates may no longer be necessary.

A first season response of wheat crop under biomineral management resulted in harvest levels of only 10% less than those under diammonium phosphate, and experience has shown that the first-use crop depression is corrected in the second season. It is of interest to note that protein content of wheat was increased by 20% under biomineral fertilization, confirmed by University of Adelaide analysis. These results were obtained using biomineral fertilizer with a carbon agent much inferor to biochar, which at the time was unavailable.

A project with the goal of establishing proof-of-concept for biochar production on the lines discussed is proposed for the Indonesian archipelago, which constitutes a sustainable nutrient source for the Australasian region. In Mexico, Dr Mario de la Pena of Project Ihuita Siyonami is assessing a similar program in the southern provinces and hopes to extend to Central America. The aim of these programs is to integrate village communities with world agriculture so as to protect rainforest and create sustainable village income streams.

Conclusions

Biochar technology offers the means to harness the vast untapped nutrient resource of tropical rainforests for world agriculture in partnership with village communities. In doing so it will endow rainforest with powerful economic leverage against destructive logging practice.

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Will Biochar Help Mitigate the Global Agricultural Bubble?

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Key words: *Food security, Climate change, Energy security*

Introduction

An unprecedented series of global imperatives are currently challenging the health and stability of agroecosystems and are a threat to long-term global food security. Population growth and diet changes associated with economic growth are rapidly increasing the demand for food, fuel, and fiber. Given the finite global land base and the fact that the most productive lands are already being used for agriculture, we must increase yields on existing agricultural lands to meet future demand for food, fuel, and fiber. As crop yield increase, however, agricultural systems become less robust and increasingly dependent on inputs of energy from fossil fuels and other non-renewable resources.

Results and Discussions

As we pass through peak global oil production, the price of fossil fuels and nitrogen fertilizer, which is heavily dependent of fossil fuel, are anticipated to increase sharply. As we approach peak global rock phosphate production, the price of phosphorous fertilizer will become prohibitive for marginal farmers. While only 18% of agricultural lands are irrigated 40% of global food production comes from irrigated land. Ground water in many irrigated areas, notably the Punjab in India and north-east China, is being rapidly depleted. Soil degradation through erosion, nutrient depletion, oxidation of soil organic matter, and salinization are reducing the productivity of agricultural lands. Increasing demand for biofuels threatens to divert agricultural production capacity from food to biomass and from the world's poor to the wealthy. Global climate change (GCC) caused by emissions of greenhouse gasses (GGE) from both industry and agriculture is anticipated to increase the severity and frequency of both droughts and floods, to which agricultural production is vulnerable.

These trends give every indication of an emerging agricultural bubble. The consequences of this bubble bursting will be starvation for the 2 billion people on the planet who are already threatened with food shortages and rapidly growing global poverty and political instability.

Biochar is not the solution to these problems. However, global deployment of a pyrolysis-biochar industry is uniquely positioned to help mitigate many of these problems and perhaps help prevent a disastrous bursting of the agricultural bubble. Biochar is a means of recycling nutrients and increasing both nutrient and water use efficiency and thereby increasing the fundamental capacity of soils to sustain food production. Furthermore, the pyrolysis-biochar platform is simultaneously a system for producing renewable fuels that will help reduce dependence on fossil fuels and a means of reducing net global GGE. Although the potential of the pyrolysis-biochar platform to simultaneously address many of the largest challenges facing our planet is very large, it is imperative that we proceed with caution and due diligence in developing a pyrolysis-biochar industry. Dust inhalation and fire are serious safety hazards associated with the handling of biochar. Emissions of black carbon during production or application biochar could reduce the efficacy of biochar in mitigating GCC. The presence of toxic compounds such as heavy metals and/or PAHs in biochar could temporarily or even permanently contaminate agricultural soils. Growth of a dedicated biomass production industry to feed a pyrolysis industry could threaten natural ecosystems, displace endogenous people from the land, and exacerbate regional poverty and food shortages.

Conclusions

The world appears headed towards an agricultural bubble that threatens global food security. Development of a global pyrolysis-biochar industry is not the solution, but may help mitigate the severity of food security, energy security, and GCC challenges facing humanity. However, a substantial amount of research is needed to ensure the safe and effective development of a pyrolysis-biochar industry and to develop policies that incentivize the equitable and environmentally sustainable development of the industry.

Climate Change Mitigation Value and Potential

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Key words: *Biochar, Climate Change and Soil*

Introduction

There are increasing calls to mirror and enhance this process by the concerted use of 'biochar', a form of charcoal produced with the simultaneous production and capture of bio-energy which is then applied to the soil. A measure of the need and interest for a concerted effort in this area has been the evolution of an organised consortium, known as the International Biochar Initiative (IBI) (<www.biochar-international.org>).

The inspiration for the supplementation of soil with charcoal stems from observations made in the ancient agricultural management practices that created terra preta, deep black soils. These soils, found throughout the Brazilian Amazon, are characterised by high levels of soil fertility compared with soils where no organic C addition occurred (Harder, 2006; Marris, 2006; Lehmann, 2007a; Renner, 2007). The evident value of the terra preta led to the suggestion that investment into biochar and application to agricultural soil may be both economically viable and beneficial. Rising fossil fuel prices, the need to raise yields in light of the global food crisis, and the emergence of a significant global market for trading carbon appear to promise added economic incentives in the future.

At the same time the need to protect soils under an increasingly uncertain climate makes the apparent ability of biochar to increase the capacity for soil to absorb and store water vitally important. It also appears that adding biochar to soil may be one of the only ways by which the fundamental capacity of soils to store and sequester organic matter could be increased.

There are a number of detailed reviews describing charcoal formation (Knicker, 2007) and associated C dynamics (Preston et al., 2006; Czimczik et al., 2007), including its role in the global carbon cycle (Schmidt et al., 2000). Forthcoming is a compendium of review articles ("Biochar for Environmental Management: Science and Technology"), which will place existing studies in the context of pyrolysis bioenergy (Lehmann and Joseph, 2009b).

Current studies are in many cases conceptually or geographically limited, and are often constrained by limited experimental data. In particular, mechanistic descriptions of the characteristics of biochar and its function in the soil and experimentation relevant to wide-scale applications of biochar are currently limited. In this report we examine existing published research within a framework constrained by a policy context. Thereby, we aim to identify gaps where new research should be focused in a way that will enable biochar to engage with climate change mitigation and to maintain soil productivity.

Results

The summary of guidelines can be found in the Table 1.

Crop Name	Results
Tomato	0.5 Mgha^{-1} char increased biomass 140%
carrot	0.5 Mgha^{-1} char increased biomass 102%
Maize on volcanic soil	0.5 Mgha $^{-1}$ char increased yield 131%
„	5 Mgha^{-1} char decreased yield to 53%
„	5 Mgha^{-1} char decreased yield to 19%
Onion on clay loam soil	0.5 Mgha^{-1} wood charcoal increased biomass by 240%
„	0.5 Mgha^{-1} bark charcoal increased biomass 224%
„	0.5 Mgha^{-1} activated charcoal increased biomass 200%
Maize	91% yield higher and biomass yield 40% higher on charcoal site than control
Maize, garden peas and Squash in area of low soil fertility	Water Hyacinth charcoal plus urine and manure increased maize and garden peas yields but not squash
Beans	Beans yield increased by 50% and Manure production by 43% over the control at 90 and 60gkg^{-1} biochar respectively

Conclusions

Based on the results of this review, the following research priorities have been identified:

1) Determine a predictive relationship for properties and qualities of biochar and its manufacture such that it can be optimized for use in soil.

2) Examine how the possibility of adverse impacts on the soil and atmosphere can be eliminated with certainty.

3) Model the impact of alternate bioenergy systems on the carbon cycle at the global scale, and in the context of national targets, in order to support policy decisions and devise suitable market instruments.

Since the underlying context for biochar-based strategies is that of global climate change, research needs to provide answers that are applicable under diverse combinations of climate, agriculture and energy production systems. This requires a fundamental, mechanistic understanding of how biochar provides its unique functional characteristics, probably embodied in models, and would include its interactions with other living and nonliving components of soil.

Field Trial in Western Kenya

In Picture one and two Salim Mayeki Shaban determining the height of Crops in the Biochar Test Plots.In Picture three and four Mayende observing squash and maize in his biochar test plot

Rob Lavoie helping my staff and community prepare biochar test plots in Musamba Village in Mumias District in Western Kenya

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Biochar carbon sequestration in tropical land use systems

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Key words: *Slash-and-Char, Oil Palm, Timber Plantations*

Introduction

Issues of permanence, leakage, land tenure and additionality are the greatest obstacles for land use and forestry (LULUCF and REDD) projects. Furthermore, the "permanence" and vulnerability of these sinks is likely to change in a warming climate. Therefore C sequestered by LULUCF projects is generally considered only temporarily sequestered.

Biochar C sequestration is fundamentally different to other forms of bio-sequestration. Carbonization of biomass increases the half-live time by order of magnitudes and can be considered a manipulation of the C cycle. While fire accelerates the C cycle the formation of biochar decelerates the C cycle. Therefore issues of permanence, land tenure, leakage, and additionality are less significant for biochar projects.

Tropical land use systems provide unique conditions for biochar C sequestration. The humid tropics produce more biomass than anywhere else and the abundance of "waste" biomass is huge. Decomposition of labile SOC is fast and in strongly weathered tropical soils, SOC plays a major role in soil productivity. Therefore both, the conditions to produce biochar as well as the benefits of soil biochar applications are greatest in the humid tropics. We estimate the carbon sequestration potential and implications for the global carbon trade in different land use systems.

Results and Discussions

Slash-and-Burn

The burning of fallow biomass is a cheap and easy practice for land clearing. Increasing pressure on land by a growing human population, market factors, and changes in agricultural practices, has led to land use intensification, and a decrease in the length of possible fallow periods. This shortening of the fallow period and/or lengthening of the cropping period is leading to a loss of crop productivity and sustainable livelihoods for small farmers. Failing to adjust land management techniques to these changing agricultural practices has led to soil degradation and to an increased need for agrochemicals such as fertilizers and pesticides. To overcome these limitations of low SOC soils with low nutrient availability and low nutrient-retention capacity will require alternatives to slash-and-burn and alternative fertilization methods [1,2]. Slash-and-char is inspired by recreation of Terra Preta. The goal of slash-and-char is the purposeful creation of biochar through efficient mechanisms of carbonization and incorporation of this material into the soil for sustained and enhanced fertility and crop productivity.

Given the application of biochar to the soil surface and an expectation for minimal mineralization of the biochar the SOC levels can be increased rapidly. Multiple repetitions of the cropping – fallow – carbonization cycle would allow for a build-up of SOC, potentially to levels found in Terra Preta (Figure 1).

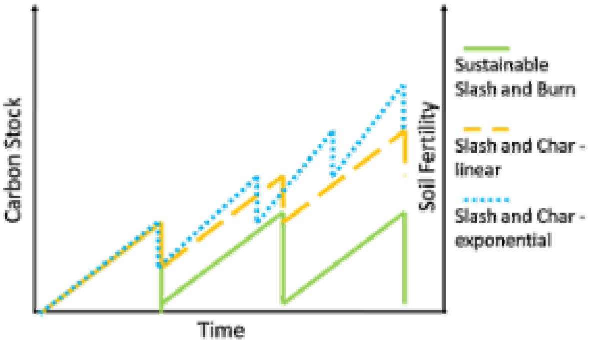

Figure 1. Sustainable slash-and-burn agriculture (green line) maintains carbon stocks and soil fertility over several cropping-fallow cycles. Slash-and-char would capture up to 50% of the C stored in the fallow vegetation and transfer the C into recalcitrant SOC pools. Assuming a faster regeneration of biomass (blue line) the gains in SOC could increase exponential.

The carbon sequestration potential depends on carbon accumulation in fallow based cropping systems. A potential C sequestration of 7.7 Mg of CO_2 ha^{-1} yr^{-1} was estimated in Indonesia if slash-and-burn is replaced by slash-and-char. However, monitoring, reporting, verification and implementation costs might pose significant obstacles in a rural small holder community. Ex-ante credits, such as those issued by the Plan Vivo System can provide the necessary capital.

Oil Palm Plantations

Depending on the replaced vegetation and soil conditions (low carbon soil or tropical peatlands) oil palm plantations can either be a sink or a source of greenhouse gases. The mills typically process 60 Mg of full fruit bunch (FFB) per hour. The available amount of biomass is 13.2, 8.1 and 3.3 Mg h^{-1} with a moisture content of 65%, 42% and 7% for EFB, fiber and shells respectively.

Table 1. Main biomass streams in oil palm plantations and potential for biochar carbon sequestration at the mill and in the field.

Biomass	Biomass Mg ha^{-1} yr^{-1}	Biochar – C[1] Mg ha^{-1} yr^{-1}	CO_2 Mg ha^{-1} yr^{-1}
At the mill			
EFB 8% of FFB	1.55	0.33	1.21
Fiber 8 % of FFB	1.63	0.34	1.25
Shell 5.5% FFB	1.10	0.23	0.84
Total at the mill	**4.28**	**0.9**	**3.30**
In the field			
Fronds[3]	11.4	2.39	8.77
Trunks[4]	3.02	0.63	2.31
Fronds and rachis[4]	0.58	0.12	0.44
Total in the field	**15.00**	**3.14**	**11.52**
Total (mill + field)	**19.28**	**4.04**	**14.82**

* Biomass data from [3] and [4]. Biochar-Carbon assuming a conversion efficiency of 30% and a mean carbon content of 70. 2The dry weight of fronds from annual pruning, 3every 25 years at renovation (75.5 and 14.4 Mg ha^{-1} 25 yrs^{-1})

Timber Plantations

The visited plantation in Indonesia covers 12,000 ha of which 9,000 ha are planted with *Acacia mangium* and *Paraserienthes falcataria*. The trees are harvested after 8 years and 1,000 ha are harvested annually. The plantation is thinned after 2 and 4 years. Logs and branches with a diameter of less than 7 cm remain in the field and serve to reduce the impact of heavy machinery during harvesting operations. Assuming a conservative carbonization efficiency of only 20% the annual biochar production from waste biomass (after harvesting) could be 5,640 Mg (0.7 Mg ha^{-1} yr^{1}), taking half of the available biomass (*5*), which represents 17,000 Mg CO_2 (2.1 Mg ha^{-1} yr^{-1}). This does not include biomass from thinning operation after 2 and 4 years.

Natural Forest Management

A significant amount of waste biomass is produced during logging operations. Reducing the impact on the remaining trees is crucial in order to allow a fast re-generation of the forest and C stocks. However, successful implementation of biochar C sequestration might create an incentive to increase waste biomass generation and fire is not an integral part of forest management in the humid tropics. It is uncertain if harvesting and removal of waste biomass and killed trees for biochar production would cause further damage. As long as the forest is not disturbed too much, re-growth is relatively fast and decomposing wood might play an important ecological role in forest regeneration.

According to [5] 63.5% of the wood waste generated at pulp mills is used to generate power the rest is deposited in landfills. This waste (mainly bark) could be used for biochar production and thus saving the costs for landfill disposal. Integrating biochar into existing compost (potting soils, soil amendments etc.) production might promise a business independent of C credits or not and would increase the value (mainly due to its stability) for land restoration purposes.

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The arrangements made by the GTZ offices in Jakarta, Sumarinda and Palembang facilitated the work in Indonesia. I want to express my gratitude to the management of an oil palm plantation and a logging company. At all locations the staff and operational managers were very hospitable, skilled and willing to share their knowledge.

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[1] E. C. M. Fernandes, P. P. Motavalli, C. Castilla, L. Mukurumbira, *Geoderma* **79**, 49 (Sep, 1997).

[2] S. M. Ross, *Progress in Physical Geography* **17**, 265 (Sep, 1993).

[3] S. Yusoff, *Journal of Cleaner Production* **14**, 87 (2006).

[4] D. Sheil *et al.*, "The impacts and opportunities of oil palm in Southeast Asia: What do we know and what do we need to know?" (Bogor, Indonesia, 2009).

[5] Y. Okimori, M. Ogawa, F. Takahashi, *Mitigation and Adaptation Strategies for Global Change* **8**, 261 (2003).

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CHAB micro-gasification for $1GtCO_2$/yr mitigation-sequestration: A quantitative analysis for practical decentralized low-cost results before 2020

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Key words: *Micro-gasification, Sequestration,* $1GtCO_2$*/yr*

Introduction

Removal from the atmosphere of one gigaton of carbon dioxide per year ($1GtCO_2$/yr, equivalent to 273 MtC/yr) is the goal of the Virgin Earth Challenge. This can be accomplished by the production and deployment into the soil of 300 megatons of biochar (allowing for a 10% mobile/volatile fraction). Through quantitative analyses based on socio-economic, cultural, demographic, climatic and biomass variables, and our detailed knowledge of existing low-cost micro-gasification devices and their resultant biochars, we show the possible accomplishment of that goal within ten years, including sustainable sources of necessary feedstocks.

Combined Heat And Biochar (CHAB) systems use diverse renewable biomass fuels to produce thermal energy and biochar. Our focus is on the small and micro-size CHAB units for distinctly cleaner-burning cooking stoves (third world uses) or to replace high value, carbon-positive fossil energy consumed for heating of residences, small businesses, and industrial process heat (affluent world uses). Expenditures for the heat-creating units can be justified in economic and health/environmental terms, with the production of biochar providing additional incentives to make decisions for change.

Methods

Three low cost ranges of technology each contribute substantially to the target of 300 Mt of biochar production,

1. Micro-gasification that produces biochar is mainly a 21st Century development. The TLUD (Top-Lit UpDraft) pyrolytic gasifier cookstoves bring biochar production to residential living and cottage industry in developing countries. Financial and social advantages accrue from clean emissions/health benefits, fuel efficiency with fuel diversity, environmental protection, employment generation, and low production costs ($0 to $1000).
2. For affluent nations, fully automated AVUD–technology biomass furnaces of 150 – 300 K Btu/hr (40 – 90 kW) are designed, tested, and ready for pilot projects for medium-sized buildings or agro-industrial processes. Smaller units for residences are possible, including replacement of thousands of manually tended smoky outdoor wood boilers that do not produce biochar. At $5000 to $25,000 per project, 5- to 10-year ROI, job creation and improved energy security, the necessary investments are attractive, with biochar as a natural co-product.
3. Units costing from $25 K to $500 K will provide powerful heat in cold climates and potentially electricity (CHP&B) for schools, public buildings and industry, mitigating fossil fuel as well as making biochar. In these, the major costs are for the heat application peripherals (boilers, gensets, etc.), not for the heat-generation/biochar-maker units.

To substantiate fuel supply and pre-processing options, data are presented, including an innovative low-cost “Biomass Conversion Facility” to process 100 tons per day into usable biomass fuel.

Discussion and Conclusions

1. Biochar production becomes economically feasible when the value of heat production covers most of the costs.
2. Except in expensive mega-utilities, heat requirements are typically in small quantities and dispersed locations, favoring the use of micro installations.
3. Micro-installations can be relatively inexpensive, widely distributed (with minimal transportation costs), and number in multi-millions.
4. $1GtCO_2$/yr of biochar results from the accumulation of biochar from so many decentralized micro-gasification users.

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Influence of biochars on flux of N_2O and CO_2 from amended ferrosol

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Key words: *greenhouse gas flux, nitrogen, mechanism*

Introduction

Nitrous oxide (N_2O) is a potent greenhouse gas with global warming potential 298 times greater than the equivalent mass of CO_2 in the atmosphere. Anthropogenic sources of N_2O contributed 3 GT CO_2e, around 8 % of global emissions in 2004 with agriculture being responsible for 42 % of this total [1].

N_2O is formed in soil through three key biological mechanisms, nitrification, nitrifier denitrification and denitrification. Denitrification is often discussed as the main pathway for N_2O production [2], occurring primarily in moist soils. The key processes controlling production of N_2O are however not well understood [3]. The factors that significantly influence emissions of N_2O from farmed soil can include; N application rate, the form of N that has been applied, crop type, soil organic C content, pH and redox, water content and gas diffusivity.

N enters soil primarily through the application of fertilizers, biological N_2 fixation, addition of organic material and the excreta of animals. Independent of the source of N, IPCC (1997) assign a value 1.25 % conversion of soil nitrogen to N_2O, although values greater than this have been recorded in some agricultural systems. For example, up to 21 % of applied N in a sugarcane crop in northern NSW, Australia, was converted into N_2O [4], equivalent to 45.9 kg N_2O-N/ha/ annum.

Recently, biochar application to soil has been suggested as a means of reducing N_2O emissions [5,6], although data supporting these observations are still limited.

Results and Discussions

In an attempt to better understand the influence of biochars on processes which lead to emissions of N_2O, we tested a range of contrasting biochars under conditions where emissions would be expected. Soil microcosms containing acidic red ferrosol were amended with biochars derived from the slow pyrolysis of greenwaste (GW), poultry litter waste (PL), papermill waste (PS) and biosolids (BS), as well as the un-pyrolysed GW feedstock. These amendments were applied at rates of 1 and 5% w/w. Following stabilisation of emissions and ageing of the biochar in soil, the microcosms were amended with 165 kg N/ha (as solubilised urea). At field capacity moisture contents, this did not result in significant emissions of N_2O. Upon stabilisation of emissions, the microcosms were flooded. During this phase, significant emissions occurred from all treatments with the control soil releasing the greatest amount at 3165 mg N_2O-N m^2. The percentage of N lost to N_2O during the incubation (totaling 134 days) is described in Table 1.

Table 1: Total N lost as N_2O during the 134 day incubation.

Treatment	Amendment rate	% N lost as volatilized N_2O
Control		15.2
GW feedstock	1%	9.0
GW feedstock	5%	3.9
GW 350 °C	1%	9.0
GW 350 °C	5%	8.7
GW 550 °C	1%	7.5
GW 550 °C	5%	5.6
BS	1%	4.8
BS	5%	2.5
PS	1%	4.5
PS	5%	5.2
PL	1%	6.7
PL	5%	4.0

Across the entire incubation, the control lost 15.2% of the applied N as N_2O. This is significantly greater than the 1.25% default value, but not as great as some of the “worst case” scenarios [4].

All of the amendments resulted in statistically significant reduction in N_2O flux, with the greatest reduction resulting from application of biochar from biosolids. Mechanisms for reduced emissions following amendment with greenwaste feedstock were possibly due to increased C:N ratio and altering microbial availability of N. Both amendments with the un-pyrolysed feedstock resulted in greater metabolic activity measured by CO_2 emissions (Figure 1).

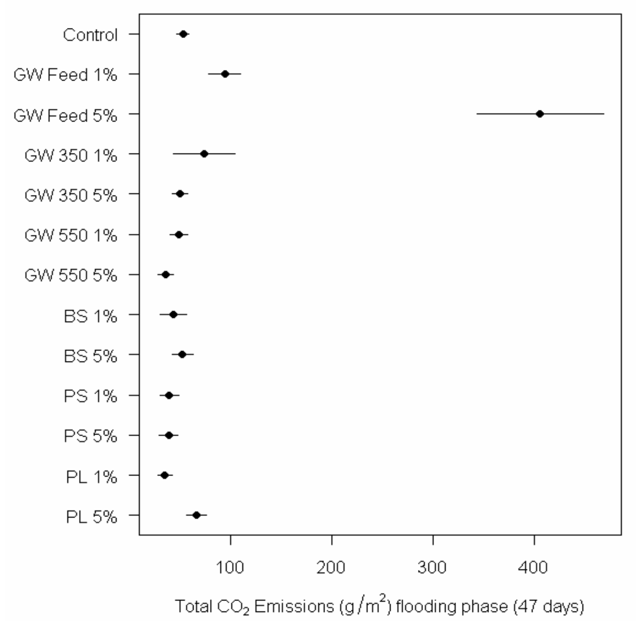

Figure 1. Soil CO_2 emissions during the flooding phase of incubation.

The greenwaste feedstocks also resulted in significantly lower nitrate-N concentrations in the soils throughout the incubation, probably due to the metabolic demand for N.

The reduction in emissions from the biochar amendments however could not be explained by changes in metabolic activity. Likewise, differences in mineral N in the soil throughout the incubation could not explain reductions in N_2O emission, and they remained similar to controls. The amendments with PL, BS and PS biochars however all resulted in significantly higher pH's in soils (Table 2).

It was hypothesised that the biochars which influenced soil pH, drove denitrification through to dinitrogen during the flooding phase, although a range of mechanisms for reduction in N_2O emissions were likely to have occurred simultaneously.

Table 2. Soil pH following incubation

Treatment	Amendment rate	pH
Control		4.2
GW feedstock	1%	4.3
GW feedstock	5%	4.3
GW 350 °C	1%	4.3
GW 350 °C	5%	4.4
GW 550 °C	1%	4.2
GW 550 °C	5%	4.5
BS	1%	4.9
BS	5%	6.2
PS	1%	6.1
PS	5%	6.8
PL	1%	4.8
PL	5%	5.9

Conclusions

Organic amendments were capable of altering the emission of N_2O during a 134 day incubation. It was likely that different mechanisms were responsible for reduced N_2O flux. Further studies are required to understand mechanisms involved.

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[1] Denman, K. L. et al. 2007 Couplings Between Changes in the Climate System and Biogeochemistry. In: Solomon S, et al. (Eds.), 'Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change'. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[2] Opdyke, M. R.; Ostrom, N.E.; Ostrom, P. H. 2009 Global Geochem.Cycles 23

[3] Hernandez-Ramirez, G.; Brouder, S. M.; Smith, D. R.; Van Scoyoc, G. E.; Michalski, G. 2009 Soil Sci. Soc. Am. J. 73, 1182-1191.

[4] Denmead, O. T.; Macdonald, B.; Naylor, T.; Wand, W.; Salter, B.; White, I.; Wilson, S.; Griffith, D.; Moody, P. 2008 Proc. Aust. Soc. Sugar Technol. 30, 105-114.

[5] Van Zwieten, L.; Bhupinderpal-Singh; Joseph, S.; Kimber, S.; Cowie, A.; Chan, Y. 2009 In Biochar for Environmental Management. Earthscan pp227-249.

[6] Singh, B-P.; Hatton, B. J.; Singh, B.; Cowie, A. L.; Kathuria, A. (2010) JEQ 39, 1224-1235.

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Climate change impact of introducing a biochar cook stove to Western Kenyan farm households: a system dynamics model

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Key words: *Carbon, Mitigation, Pyrolysis*

Introduction

Improved cook stove projects in developing countries have been promoted for decades driven by the desires to improve health by decreasing indoor air pollution from cooking, to limit forest degradation and deforestation while decreasing the burden on those who collect the biomass fuels and, more recently, to mitigate climate change.

While methodologies for quantifying the carbon (C) savings of improved cook stoves have been developed and extensive research has been done on improved cook stoves in Mexico [1], this research was limited to direct stove impacts, while the current study examines a more complex stove system. Cook stoves that produce biochar as well as cooking energy are a relatively recently developed technology, and have yet to be rigorously investigated for their climate change mitigation potential [2]. These cook stoves add another layer of complexity to the climate impacts of the system due to (i) the effects of biochar applied to soil on crop yields, (ii) the stabilization of the relatively labile C from fresh biomass as biochar, and (iii) possible changes in the sources of biomass that can be used as fuel.

This study uses system dynamics modelling to (i) investigate the climate change impact of biochar-producing cook stoves and improved combustion cook stoves in comparison to conventional cook stoves, (ii) assess the relative sensitivity of the stoves to key parameters, and (iii) quantify the effects of different climate change impact accounting decisions.

Methods

The modelled system is a rural farm household in the highlands of western Kenya. The region is characterised by common use of traditional 3-stone biomass cook stoves and declining biomass fuel availability. Farm households primarily grow maize, but some also grow sukuma-wiki or banana trees, among other minor crops. The region is also marked by declines in maize yields over the time since the farms were converted from primary forest. This decline has been shown to be mitigated by the application of biochar to soils, increasing yields [3].

We employed the system dynamics modelling approach to determine the GHG impact of the introduction of improved biomass cook stoves using either pyrolysis or combustion technology to a western Kenyan farm household. Our model consists of four interlinked modules: on-farm production, soil carbon, cook stove fuel use and emissions, and GHG impact.

The model was run (i) to predict the GHG impact deviation from the 3-stone stove baseline. (ii) to explore the sensitivity of this value to six key parameters, and (iii) to evaluate the impact of two policy decisions.

Results and Discussions

Simulated reductions in GHG impact range between means of 2.58-4.74 tCO_2e/ household/ year for the prototype pyrolytic stove, 3.33-5.80 for the idealized pyrolytic stove, and 2.56-4.63 tCO_2e/household/year for the improved combustion stove. These numbers are similar to those calculated by Johnson et al. [1] for Kyoto emissions from improved cook stoves in Mexico – a 95% confidence interval of 2.3-3.9tCO_2e/household/year. This rate of emissions reductions could allow stove projects to access carbon financing if the monitoring costs were similar to those discussed in Johnson et al. [1]. However, if the values of biomass stabilization as biochar and changes in SOC stocks are ignored and only reductions in gaseous emissions were counted, this would reduce the annual emission reductions by 16-36% for the idealized biochar cook stove, and 29-57% for the prototype biochar cook stove, thus decreasing the economic viability of the project for biochar-producing cook stoves.

The magnitude of the GHG reductions is most sensitive to the fraction of non-renewable biomass (fNRB) of the off-farm biomass fuel sources and the baseline fuel wood use. The impact of changing this value depends on how much reductions depend on stove emissions as compared to biochar production.

If there is no change in maize stover gathering (25%), non-biochar soil carbon increases over time, resulting in a negative deviation from baseline. If gathering is increased, there is an initial depletion, but increased yields due to biochar result more stover being returned to the soil, increasing non-biochar soil carbon.

Conclusions

Our modelling shows that even the prototype biochar stove is likely comparable to other improved cook stoves in terms of reducing GHG impact, but has the fascinating additional dynamics of biochar production and the associated crop yield increases, which could have important effects on food security in developing regions such as the one considered in this study. While this aspect of biochar cook stoves would be considered an advantage for its users, it is an additional challenge for those hoping to account for its GHG reductions.

Acknowledgements

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[1] Johnson, M. et al. 2009. Environ. Sci. Technol., 43, 2456.

[2] Whitman, T. and Lehmann J. 2009, Environ. Sci. Pol., 12, 1024.

[3] Kimetu, J.M. et al. 2008. Ecosyst., 11, 726.

Fighting Global Warming by increasing Soil's Organic Matter

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Climate change is a serious challenge to humanity and sustainable development which can be curbed to a large extent by increasing the soil's organic content. Field experiments were conducted at three experimental stations in Southwestern Nigeria viz: International Institute of Tropical Agriculture, Ibadan; Institute Agricultural Research and Training, Ikenne and University of Agriculture, Abeokuta) to monitor the impact of phosphate rock addition with and without legume biomass on Soil's organic matter. The fertilizer treatments consisted of four rates of Ogun phosphate rock (0, 30, 60 and 90 kg P ha^{-1}) and triple super-phosphate at 40 kg P ha^{-1}. Legume treatment consisted of mucuna and cowpea. The experiment was laid out in randomized complete block design with three replicates. Soil samples were collected and analysed for organic carbon. The data collected was subjected to statistical analysis. There was significant increase in organic carbon with addition of Ogun Phosphate rock in all the three sites Plots receiving 90kg P ha^{-1} of Ogun phosphate rock significantly increased Organic carbon content by 13% over control plots while an increase of 8.6% was observed on plots treated with mineral P fertilizer at Ikenne but no significant effect was observed at Ibadan and Abeokuta during the first field trial. Effect of Legume incorporation with Ogun Phosphate rock on soil organic matter was significant in all the three sites at 1% probability level. A significant increase of 30% in organic matter was observed with plots treated with mucuna biomass and phosphate rock at 90 kg P ha^{-1} during the first field trial at Ibadan (1.70%) over plots receiving only mucuna biomass (1.19%). Incorporation of phosphate rock into the soil proves a viable means of maintaining fertility of the soil and reducing atmospheric carbon through carbon sequestration.

Keywords: Phosphate rock, soil organic matter, carbon sequestration

Graphitic Carbon Yield in Biochar

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The word "charcoal" covers a continuum of materials of continuing interest, but covers a wide spectrum of properties. Biomass is composed C, H and O in which the carbon has aliphatic and aromatic bonds. Charcoal is characterized by having graphitic bonds and can be viewed as an amorphous graphite at 450 ºC which becomes more crystalline with further treatment.

The carbon-oxygen bond is almost impossible to break under thermo-chemical conditions found in charcoal production. Therefore, the fundamental formula for woody biomass, normalized for carbon:

$CH_{1.4}O_{0.6}$

indicates that there are only 0.4 carbons, or 40% of the biomass on a molar basis, which are not already bonded to oxygen, and therefore available to become true graphitic carbon in charcoal. This translates to about 21% yield on a bone-dry ash-free weight basis.

Perspective on the various charcoals can be further understood on a triangular diagram with C, H and O as the vertices. Biomass, torrefied wood and the various charcoals lie on a line in which progressively more CH_2O volatiles ("tars") are removed at higher and higher temperatures, according to

$CH_{1.4}O_{0.6} - x\ CH_2O \implies C_{(1-x)}H_{(1.4-2x)}O_{(0.6-x)}$

where x varies from 0.3 to 0.6 as successive CH_2O are removed. A number of charcoals are described in these terms. Freshly formed charcoal is highly absorbent and can re-absorb these tars, depending on their method of removal or combustion. This adds another variable to the charcoal making process.

The charring process can also be viewed as the continuous removal of the principle components as processing proceeds to higher and higher temperatures. The principle components of biomass are the cellulose, hemicellulose and lignin, (typically ~50%, ~25% and ~25% for most biomass). Their progressive decomposition with temperature are shown by their thermogravimetric traces. Hemicellulose decomposes most easily in the range 270-310 ºC. Cellulose decomposes in the narrow range 330-350 ºC. Lignin decomposes over a broad range from 280 to 400 ºC. The decomposition of biomass is endothermic up to ~300 ºC, but becomes exothermic to the endpoint at ~425 ºC, at which all of the carbon is graphitic. Heating beyond that point requires further heating.

Biochar (charcoals for soil amendment and CO_2 mitigation) focuses new interest on the properties and yields of different production methods and we must be able to evaluate the various charcoals on the basis of: Yield; energy content; volatile content; graphitic carbon content; porosity; pH; growth enhancement and permanence in the soil.

Biochar: Delivering a Gigaton Offset

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Growing plants draw down CO_2 from the atmosphere to produce biomass containing carbon. When plants die the carbon contained in biomass is released back to the atmosphere as CO_2 as the biomass decomposes. Created through a process called pyrolysis, biochar locks in and stabilizes this C that would otherwise be released back into the atmosphere as CO_2. As such, the production of biochar represents an exciting and important opportunity to remove CO_2 from the atmosphere.

During pyrolysis, biomass is heated in an oxygen-deprived environment, causing thermal decomposition of the plant matter to produce biochar. Beyond the benefits of capturing carbon, pyrolysis by-products can be used to deliver energy products like heat and electricity. Further, biochar can be returned to the soil, where it continues to store this carbon while improving soil quality. By using biochar in their fields, farmers can increase agricultural production without increasing cropped area and reduce use of inputs such as fertilizers and water.

We believe that this gigaton offset opportunity will be delivered through a relatively small number of "platforms". Each platform represents a distinct configuration of feedstock, pyrolysis technology, biochar and energy products. Revenue streams may be derived from tipping fees or cost savings associated with the feedstock processing (e.g. diverting material from landfill), biochar sales as an agricultural or horticultural product, sale of energy products and revenues from Carbon Offsets.

These platforms will be extremely diverse in nature and each will pose particular challenges both to project operators and protocol development. This presentation will identify key platforms and present a preliminary assessment of the offset potential of ach platform, the likely scale of the offset potential for each platform and an analysis of challenges that face the developers of each platform.

Identifying Challenges and Advantages of Biochar Production in Climate Change and Agriculture School Advocacy Programme for Young Farmers in Lagos

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Background

The school advocacy programme is an initiative of the Ministry to get young people practically engaged in Agriculture, protecting the environment using environment friendly ways in waste management, sustainable use of our natural resources and provide adequate agricultural trainings for young farmers which are vehicles of change for larger society, improving their awareness on mitigation of the impact of climate change in different schools, in Lagos Surveillance report found out that most of the youth under the programme are not aware of the importance of biochar use in mitigating the impact of climate change in the state.

Objectives: To assess the knowledge of youths on biochar production, in mitigating the impact of climate change and integrate biochar training into the climate change school advocacy programme for young farmers in the state.

Methods: 300 youths were trained from 6 educational districts on biochar production a carbon rich product from biomass, such as wood, manure or leaves, and other waste generated in the school communities littering the environment with high Global warming potential (GWP). Each groups produced biochar in the environment used to sequester carbon and serve as renewable energy production and serves as a valuable soil enhancer, thereby discouraging rainforest destruction, restore depleted soils, and put the Earth back in the black.

Agriculture and environment trainer provided youths sound, reality based information that increases their awareness about biochar. Agricultural fields, demonstration plots, posters and handbills with information on biochar and climate change were produced and distributed to youths.

Sessions encouraged youths to recognize the importance of biochar in mitigating the impact of climate change protecting the environment for food security and the future of the states' environment.

Result: According to the study, youth were interested in innovative approaches and technologies in mitigating and adapting to climate change. Only about 35 percent of the young men and 39 percent of the young women understands the concept of climate change. It was also determined the relationship between agriculture and climate change, methods and technologies for combating and mitigating climate change, by using biochar for carbon sequestration in a stable soil carbon pool and reducing green house gas emission GHG.

Conclusion: Integrating biochar production technologies into the school advocacy programme will help in combating climate change, ensure sustainable environment and favourable soil environment that is safe and friendly for plants environment and soil living organisms. Since youths are the future of tomorrow there is the need to train them on the importance of biochar in reduction of emission from waste and carbon sequestration while combating different environmental problems and climate change.

Greenhouse gas Mitigation by Different Types of Biochar

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In this study untreated soils were compared with three different types of biochar in terms of emission of carbon dioxide (CO_2) and nitrous oxide (N_2O). Untreated soils were sand (C = 1.3%), Terra Preta (C = 4.4%) and peat (C = 13.2%). Thermal conversion of poplar and pine wood yielded biochar from hydrothermal carbonization (HTC) (C = 56.9%), from fluidized bed gasification (C = 75.4%) and from pyrolysis (C = 79.9%). Biochar substrates were mixed with the carbon-poor sand for simulating real conditions after application of biochar to farmland. Emission rates of CO_2 and N_2O were measured from the rewetted substrates by gas chromatography after incubation in 125 ml glass vessels in an atmosphere of air for 72 hours.

The carbon content of the soils showed a clear relationship to the CO_2 emission, ranging between 0.6 mg CO_2-C kg^{-1} h^{-1} for pure sand and 17.5 mg CO_2-C kg^{-1} h^{-1} for peat. The C emission rate of the biochars ranged between 1.0 and 8.3 mg CO_2-C kg^{-1} h^{-1} and did not correspond with their total C contents. Since the CO_2 emission rates of the biochars under study were higher than that of the pure sand their carbon stability might be questioned. Long-term incubations are running to get more information about the carbon stability of these biochars.

Although considerable contents of total N and extractable ($CaCl_2$) nitrogen were found in the biochars under study, enhanced N_2O release could not be observed within our 72 h incubation experiment. N_2O emission rates in the three biochar/sand mixtures decreased from 31.6 µg N_2O-N kg^{-1} h^{-1} (sand) to 12.1 µg N_2O-N kg^{-1} h^{-1} (sand/pyrolysis biochar), 3.5 µg N_2O-N kg^{-1} h^{-1} (sand/gasifier biochar) and 0.6 µg N_2O-N kg^{-1} h^{-1} (sand/HTC biochar).

Since N_2O has a global warming potential 298 times higher than that of

CO_2, this positive effect of biochars may play an important role in mitigating CO_2 equivalents, which has to be taken into account for a balance of greenhouse gases emitted after biochar is applied to soil.

The use of biochar in soils opens the question of possible ecotoxicological side effects. First bioassays with invertebrates had shown that the contact with extracts from HTC biochar did not affect the reproduction of the nematode *Caenorhabditis elegans*.

A role for biochar in waste water processing in the petroleum sector

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The use of biochar as a carbon sink can be very expensive if insufficient biomass residues are available and the full cost of biochar production must include the costs associated with growth and harvest of the biomass feedstocks. Therefore, the large-scale use of biochar to mitigate climate change would benefit from technologies that either reduce the production cost or that open up new, value-added markets for biochar.

In this study, we examine the potential of creating a biochar that could be used as an activated carbon to clean up wastewater in the petroleum sector, such as water produced from Canada's oil sands operations or in natural gas recovery. Like the mitigation of fossil fuel carbon emissions, the processing of contaminated water from Canada's petroleum sector is a major environmental and regulatory challenge for the industry.

Initial studies used a synthetic aqueous solution of 100 to 1000 ppm (w/w) naphthenic acids to simulate water from the tailings ponds of Canada's oil sands mining operations. Previous studies (Deriszadeh et al. 2009) had identified naphthenic acids as the primary substrate leading to the microbial production of methane (a potent greenhouse gas) in the tailings ponds.

Activated carbon biochar made from various biomass feedstocks were compared with activated carbon made from coal and petroleum coke (petcoke). The paper will describe the performance of various types of activated carbon in cleaning up water produced in Canada's petrochemical sector.

The results from these 'proof of concept' studies will be used to inform a theoretical model that estimates the potential economic - environmental costs and benefits for a biochar application that addresses both the water and greenhouse gas challenges associated with Canada's petroleum sector.

Can biochar resolve the current soil and environmental problems in China?

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China annually has more than 3000 millions tons of biomass production, mainly from swine farms and crop residues. Currently, a small portion of the waste biomasses are used for rural fuel, manure, marsh gas production. Most the biomass is not effectively utilized. A significant amount of crop straw, more than 20% of the total, is burned in field, which creates serious environmental problems. Chinese government is encouraging to developing new approaches to effectively use these "waste". In next 20 years, about 4000 marsh gas facilities will be established in swine farms. More than 40 millions rural families will use marsh gas as fuel. A significant amount of plant biomass will be used for producing biogas through pyrolysis, which may produce a large quantity of biochar.

China has less than 1220 millions hectares of arable land. Of the cropland, around 80% are of low soil quality. The fertile crop land, 20% of the total, is nibbled by economic development. To meet the food requirement of the increasing population, it is essential to enhance soil fertility and the use efficiencies of nutrient and water. Current researches show that biochar has significantly positive impacts on soil fertility, enhancing soil pH, CEC, nutrient retention, and water-holding capacity, but reducing ion leaching. Adding appropriate biochar into soil usually results in a significant increase of crop yield. There is thus a big potential to improve soil quality with biochar in China. At present, a series of field experiments of biochar amendment to soil among main agronomic zones across China are being discussed. Accordingly, a network on biochar application to improve soil fertility is under construction, leading by China Agricultural University and including main local agricultural research and extension organizations. In the network, same method will be used among different sites and results in soil physical, chemical, and biological processes will be co-shared to make most clear conclusion.

Estimation of Carbon: A Modeling Approach for Acacia Woodlands in Meatu, Tanzania

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Acacia as woody trees and shrubs are wide spread in the savannah of tropical and sub-tropical Africa and worldwide [3]. In Tanzania. Acacia tortilis, Acacia nilotica and Acacia. polyacantha are dominant species in woodlands, particularly in Meatu district [5] and they are increasing, leading to increase in biomass and may influence carbon (C) storage.

At present methods, for estimation of biomass and C stored in terrestrial plant ecosystem has gained importance since the Kyoto protocol gained force in 2005 [1] as the demand for C credits has been escalating in international markets. In addition, these estimates are required to satisfy the requirements of United National Framework Conference on Climate Change (UNFCCC). Countries have to report frequently the state of their forest resources and emerging mechanisms [7] such as Reducing Emissions from Deforestation in Developing countries (REDD).Carbon stock is derived from above-ground biomass (in dry weight) assuming that, 0.5 of the biomass is C [2,6]. Therefore, precise estimate of biomass in the tropical forests is crucial for quantification of C.

The accurate approach to estimate C stock in above-ground biomass is using developed allometric equations [7]. Allometry is a technique, which involve relationships between tree above-ground biomass and tree stem diameter or height and between below-ground biomass and above-ground biomass [7].

This study was undertaken to develop specie-specific and tree components allometric models in above-ground biomass of Acacia species for estimation of C stocks.

Mitigating Climate Change through Alternative Energy Sources

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Climate change has emerged as one of the greatest threats to sustainable development and it is causing a colossal gun shoot wound in the emerging economies characteristically to the Sub-Saharan Africa.

Throughout the Earth's history, there have been warm and cold cycles. Carbon-dioxide CO_2 emissions have been proven to be a result of anthropogenic (human) activity, a fact which has been significantly proven with hard evidence.

On the other hand it is believed and perceived that climate change is a result of Greenhouses gases (GHGs) for over the last 4 decades which has led to global warming but there are other greater inducers of climate change. GHGs occur due to the long-term industrially and agriculturally atmospheric gas generation and emissions such as carbon-dioxide (CO_2), chlorofluorocarbons (CFCs), ammonia (NH_2) and nitrous-oxides (N_2O). The above are known to absorb torrential radiations on the earth. Climate change has tremendously affected the availability of fresh waters, food production, and transmission of vector borne diseases like Malaria.

Africa's electricity consumption remains low, about 8% of global electricity consumption. Majority of the African population do not have access to electricity. In the year 2000, only 22.6% of the population in sub-Sahara Africa had access to electricity, compared with Asia – 40.8%, Latin America – 86.6% and Middle East – 91.1%. On the supply side, Africa's energy profile show low production and huge untapped potential and this is the potential which is needed. The continent has one of the highest average annual solar radiations; 95% of the daily global sunshine above 6.5kWh/m^2 falls on Africa during winter. African energy situation is characterized by high rate of demand driven mainly by demographic factors, while supply is lagging behind. About 11.3% of the electricity generated in Africa is wasted compared with world's average of 9.2%.

Therefore, in order to achieve supply of alternative energy sources there is need to use of informal market instrument, Priority investment on renewable energy, Removal of import tariff and other trade barriers, Policy formulation, Involvement of Private Sector, Training of African personnel, Awareness creation, Elaborate regional perspective in renewable energy development and Creation of special agency responsible for renewable energy and energy efficiency.

Biochar Stability in Soil Depends on Feedstock Source and Pyrolysis Temperature

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The stability of biochar is the major determinant of its value in long-term C sequestration in soil. However, little research has been undertaken to quantify the stability of biochar applied to soil and its effect on 'native' soil C. In order to precisely quantify the magnitude and rate at which biochar C is decomposed in soil and released as CO_2, we have initiated a long-term incubation experiment using a novel method based on measuring the inherent differences in ^{13}C signature between biochar and soil. Briefly, biochars from a range of C3-biomass sources (bluegum wood and leaves, paper sludge, poultry manure on rice hull, and cow manure) produced at different temperatures (400ºC or 550ºC) and activation level (activated or non-activated), were applied to a clay-rich soil (Vertisol) from a C4-pasture (Astrebla spp.) field. Soil-respired CO_2-C and microbial-C and their associated $\delta^{13}C$ values have been measured over 2.3 years to date, and are continuing. Results show decomposition of biochar C varied depending on biomass source and pyrolysis temperature and only 0.3% to 6.0% of the applied biochar C was decomposed in the first 2.3 years of incubation. Biochar application enhanced decomposition of 'native' soil C; this priming effect on soil C was higher in soil amended with leaf or poultry manure biochars than wood biochars. Microbial biomass C was not affected by the biochar treatments, except for the low-temperature poultry manure biochar treatment which significantly increased microbial biomass C as compared to the control. Our estimates of mean turnover time of biochar-C, determined by fitting the two-pool kinetic model to the cumulative CO_2-C evolved under ideal conditions in the laboratory, ranged from ~100 to ~2000 years between biochar types. The low-temperature (400ºC) manure biochars decomposed substantially more quickly than the high-temperature (550ºC) biochars.

The Potential for the Implementation of an Effective Mechanism for Improving Mountain Communities Knowledge of Adaptation to Climate Change

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Mountain territories not only are some kind of "barometre" of global climate changes, but their reaction have a significant impact on the further strengthening of these processes. Consequences of climate change exacerbated by anthropogenic impacts on the environment. Such problems arise because of lack of knowledge and environmental education. As we know progresivnye initiatives promoted at the schooling level. Meanwhile, environmental problems are mainly related to the activities of adults. But adult education - a more complex process, methods of environmental education of adults do not exist. To help address these issues Ecoforum implements the educational program. Ecoforum organizes round tables, trainings in the villages. Brochure "Environmental security of family and environment conservation" is published. It is the first in a series of books about the adaptability of the family to climate change (organic farming and rational grazing, the shift to new activities - sustainable tourism, national crafts, a knowledge of climate change consequences mitigation at the household level - ways of cleaning water, saving water and energy resources, rational wastes management). The peculiarity of this program - almost without a costs (which is important for developing countries) and has the maximum available coverage. Educational programs became national winners of two international Awards on Sustainable Development - Energy Globe.

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Progressing from Terra Preta de Índios to the Whole World

The production of biochar and by-products

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Introduction

Biomass is heated in the absence of air or oxygen to decompose or devolatilise the biomass into solid char, liquid as bio-oil, tar or pyroligneous liquor and gas. Three products are always produced. Product yields depend on biomass, vapour and solids residence time, and temperature. There are several modes of pyrolysis.

Fast pyrolysis produces up to 75wt.% liquid with some byproduct char and gas. A wide variety of reactors have been developed including fluid beds and circulating fluid beds.

Intermediate pyrolysis produces approximately equal proportions of solid, aqueous liquid, organic liquid and gas. It is a slower method typically carried out in auger or screw reactors or rotary kilns that are particularly suitable for heterogeneous wastes in terms of composition and/or size.

Slow pyrolysis maximises the production of charcoal. It is carried out in continuous or batch reactors.

Torrefaction is low temperature slow pyrolysis to enhance properties including water, heating value and friability.

Table 1. Types of pyrolysis, conditions and typical product distribution

Mode	Conditions *Wt % products*	*Liquid*	*Char*	*Gas*
Fast	~ 500ºC; very short hot vapour residence time (RT) ~1 s; short solids RT	**75%**	12%	13%
Intermediate	~ 500ºC; short HVRT ~10-30 s; moderate solids RT	50% in 2 phases	25%	25%
Slow	~ 400ºC; long HVRT; very long solids RT	30%	**35%**	35%
Torrefaction	~ 300ºC; long HVRT; long solids RT	Vapours	**80%** solid	20% vapours
Gasification	~ 800-900ºC; short HVRT; short solids RT	1-5%	0% (all burned)	**95-99%**

Results and Discussions

Charcoal yields are shown in Figure 1. Products that are not charcoal, i.e. gases, liquids and vapours, must be managed effectively through safe disposal or recovery of valuable products.

Fast pyrolysis

Fast pyrolysis aims to maximise liquids. This is achieved with very high heating rates usually requiring very small particle sizes of generally <3mm in size and < 10% moisture. Total liquid yields are up to 75 wt.% on dry biomass feed. The charcoal forms about 10-15 wt.% of the products. It retains all the alkali metals. It is often used to provide process heat for which about 50-75 wt.% of the char is required. Some processes consume all the char and some use part of the charcoal for process heat. Char is captured in enclosed vessels and can be handled in enclosed vessels.

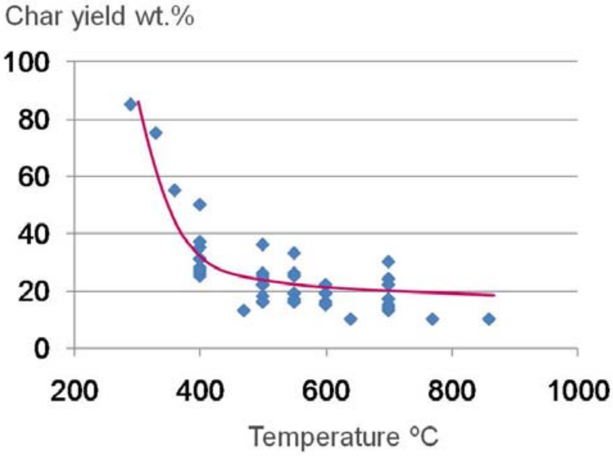

Figure 1. Charcoal yields vs temperature

Fast pyrolysis char is pyrophoric i.e. it spontaneously ignites when fresh; it has a small particle size – from maximum 3 mm from fluid beds down to fine dust; and may be used within the process for heat or exported.

Intermediate pyrolysis

Intermediate pyrolysis processes include rotary kiln, screw, auger, moving bed and fixed bed reactors. Intermediate pyrolysis can process more difficult materials with handling and/or feeding and/or transport problems. The charcoal forms about 25 wt.% of the products. It retains all the alkali metals. Due to the mechanical and abrasive action of the reactor, the charcoal will tend to be small particle size. The liquid is 2 phases – aqueous and organic.

Slow pyrolysis

Processes include batch kilns and retorts and continuous retorts e.g. Lambiotte and Lurgi. Feed size and shape is important. Heating can be direct (air addition) or indirect. Charcoal is mostly lump with smaller particles and some dust. Gases, vapours and liquids are seldom collected or processed. Exceptions include Usine Lambiotte inn France (now shut down) and proFagus (Chemviron/Degussa) in Germany (still operating).

Table 2 summarises the performance and economics of the Usine Lambiotte plant in France during 2000/2001. This shows the significance of the chemicals recovery to the viability of the operation and the management of all the outputs.

Table 2. Economics of Usine Lambiotte slow pyrolysis operation showing significance of chemicals recovery.

	t/year	€/t	k€/y	%
Charcoal	25,000	*100	2,500	31.5
Total pyroligneous liquid	40,000			
Water	30,000			
Organics	10,000			
Acids and alcohols	3,830	452	1,732	
Oils	310	1,258	390	
Fine chemicals	56	49,732	2,785	35.1
Fuel	5,804	90	522	
Total organics	10,000	543	5,429	68.5
Total income			7,929	

Torrefaction

This is very low temperature pyrolysis. It enhances the properties of the biomass by removing water, reducing hemicellulose, Improving heating value, Improving the friability of the product for subsequent processing e.g. Grinding. Vapours can either be burned to provide some process heat or waste disposal; or collected to yield potentially valuable chemicals, but some disposal will always be needed.

The role of torrefied biomass for carbon sequestration is not well understood: questions arise concerning unknown life and effect in soil.

Questions

What is the maximum level of volatiles in charcoal compatible with acceptable health and safety and bio-toxicity levels? This will tend to maximise charcoal yields.

What is the minimum pyrolysis temperature to give a relatively permanent carbon sequestration effect? This will also tend to maximise charcoal yields.

What is the best method of applying charcoal to land?

What chemicals can be economically recovered from co-products?

What is the optimum waste disposal solution?

Conclusions and Recommendations

Conclusions

- Pyrolysis is very flexible in the process and products.
- Chemicals can be produced from the liquids with considerable economic potential.
- Non-products are wastes and must be effectively disposed of.

Recommendations for char production

- Technologies needs to be improved to increase char quality and char yield.
- Technologies need to satisfy emissions and health and safety requirements.
- Technologies need to be optimised for valuable products and disposal of wastes.