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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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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).

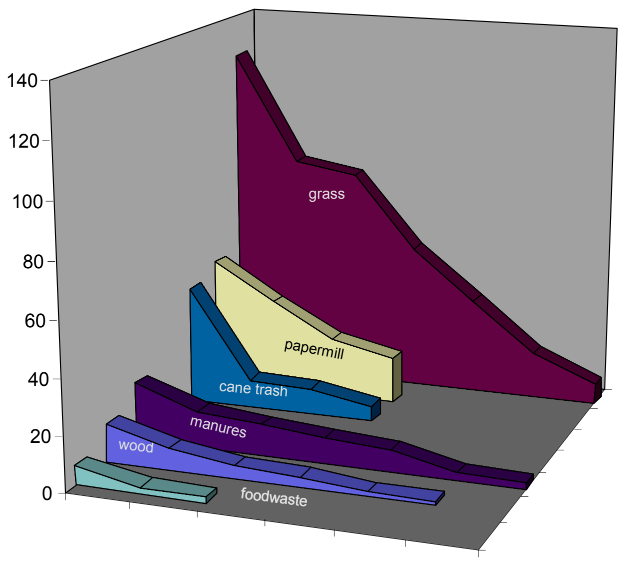

Figure 1. Cation exchange capacity of biochars produced from different materials as m.e./100gC.

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).

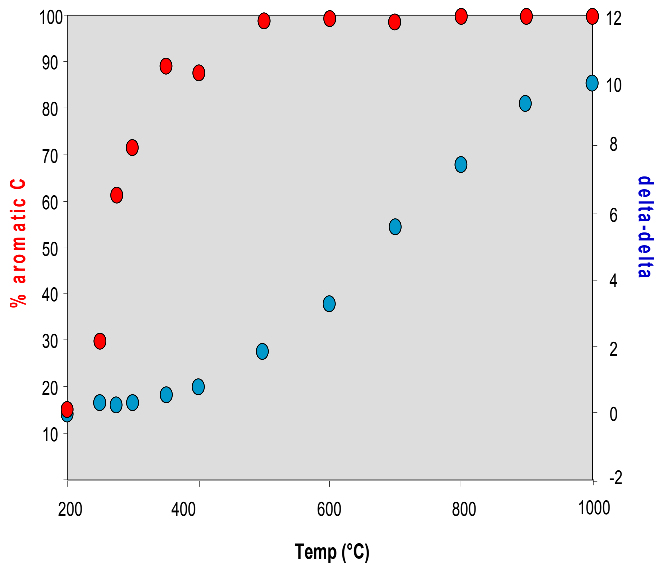

Figure 2. Comparison of %aromatic C and degree of condensation of biochars produced at different temperatures (Anna McBeath, unpubl. data).

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.

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