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Biochar Application to Soils

A Critical Scientific Review of Effects on Soil Properties, Processes and Functions

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1. BACKGROUND AND INTRODUCTION

Biochar is commonly defined as charred organic matter, produced with the intent to deliberately apply to soils to sequester carbon and improve soil properties (based on: Lehmann and Joseph, 2009). The only difference between biochar and charcoal is in its utilitarian intention; charcoal is produced for other reasons (e.g. heating, barbeque, etc.) than biochar. In a physicochemical sense, biochar and charcoal are essentially the same material. It could be argued that biochar is a term that is used for other purposes than scientific, i.e. to re-brand charcoal into something more attractive-sounding to serve a commercial purpose. However, from a soil science perspective it is useful to be able to distinguish between any charcoal material and those charcoal materials where care has been taken to avoid deleterious effects on soils and to promote beneficial ones. As this report makes clear, the wide variety of soil groups and associated properties and processes will require specific charcoal properties for specific soils in order to meet the intention of biochar application. Considering the need to make this distinction, a new term is required and since biochar is the most common term currently used, it was selected for this report. The definition of the concept of biochar used in this report is:

“charcoal (biomass that has been pyrolysed in a zero or low oxygen environment) for which, owing to its inherent properties, scientific consensus exists that application to soil at a specific site is expected to sustainably sequester carbon and concurrently improve soil functions (under current and future management), while avoiding short- and long-term detrimental effects to the wider environment as well as human and animal health.” As a material, biochar is defined as: “charcoal for application to soil”.

The distinction between biochar as a concept and as a material is important. For example, a particular biochar (material) may comply with all the conditions in the concept of biochar when applied to field A, but not when applied to field B. This report investigates the evidence for when, where and how actual biochar application to soil complies with the concept, or not.

The terms ‘charcoal’ and ‘pyrogenic black carbon (BC)’ are also used in this report when appropriate according to their definitions above and in the List of Key Terms. Additionally, BC refers to C-rich residues from fire or heat (including from coal, gas or petrol).

This report aims to review the state-of-the-art regarding the interactions between biochar application to soil and its effects on soil properties, processes and functioning. A number of recent publications have addressed parts of this objective as well (Sohi et al., 2009; Lehmann and Joseph, 2009; Collison et al., 2009). This report sets itself apart by i) addressing the issue from an EU perspective, ii) inclusion of quantitative meta-analyses of selected effects, and iii) a discussion of biochar for the threats to soil as identified by the Thematic Strategy for Soil Protection (COM(2006) 231). In addition, this report is independent, objective and critical.

Biochar is a stable carbon (C) compound created when biomass (feedstock) is heated to temperatures between 300 and 1000°C, under low (preferably zero) oxygen concentrations. The objective of the biochar concept is to abate the enhanced greenhouse effect by sequestering C in soils, while concurrently improving soil quality. The proposed concept through which biochar application to soils would lead to C sequestration is relatively straightforward. Carbondioxide from the atmosphere is fixed in vegetation through photosynthesis. Biochar is subsequently created through pyrolysis of the plant material thereby potentially increasing its recalcitrance with respect to the original plant material. The estimated residence time of biochar-carbon is in the range of hundreds to thousands of years while the residence time of carbon in plant material is in the range of decades. Consequently, this would reduce the CO_2 release back to the atmosphere if the carbon is indeed persistently stored in the soil. The carbon storage potential of biochar is widely hypothesised, although it is still largely unquantified, particularly when also considering the effects on other greenhouse gasses (see Section 1.3), and the secondary effects of large-scale biochar deployment. Concomitant with carbon sequestration, biochar is intended to improve soil properties and soil functioning relevant to agronomic and environmental performance. Hypothesised mechanisms that have been suggested for potential improvement are mainly improved water and nutrient retention (as well as improved soil structure, drainage).

Considering the multi-dimensional and cross-cutting nature of biochar, an imminent need is anticipated for a robust and balanced scientific review to effectively inform policy development on the current state of knowledge with reference to biochar application to soils.

How to read this report?

Chapter 1 introduces the concept of biochar and its origins, including a comparison with European conditions/history.
Chapter 2 reviews the range of physical and chemical properties of biochars that are most relevant to soils.
Chapter 3 focuses on the interactions between biochar application to soil and soil properties, processes and functions.
Chapter 4 outlines how biochar application can be expected to influence threats to soils.
Chapter 5 discusses some key issues regarding biochar that are beyond the scope of this report.
Chapter 6 summarises the main findings of the previous chapters, synthesises between these and identifies the key findings. Suggestions for further reading are inserted where appropriate.

1.4 Biochar and pyrogenic black carbon

A potential analogue for biochar may be found in the charcoal produced by wildfires (or pyrogenic black carbon – BC – as it is often referred to) found naturally in soils across the world, and in some places even makes up a larger proportion of total organic C in the soil than in some Terra Preta soils. Preston and Schmidt (2006) showed an overview of studies on non-forested sites in different parts of the world with BC making up between 1 and 80% of total SOC. For example, BC was found to constitute 10-35% of the total SOC content for five soils from long-term agricultural research sites across the U.S.A. (Skjemstad et al., 2002). Schmidt et al. (1999) studied pyrogenic BC contents of chernozemic soils (Cambisol, Luvisol, Phaeozem, Chernozem and Greyzem) in Germany and found BC to make up 2-45% of total SOC (mean of 14%).

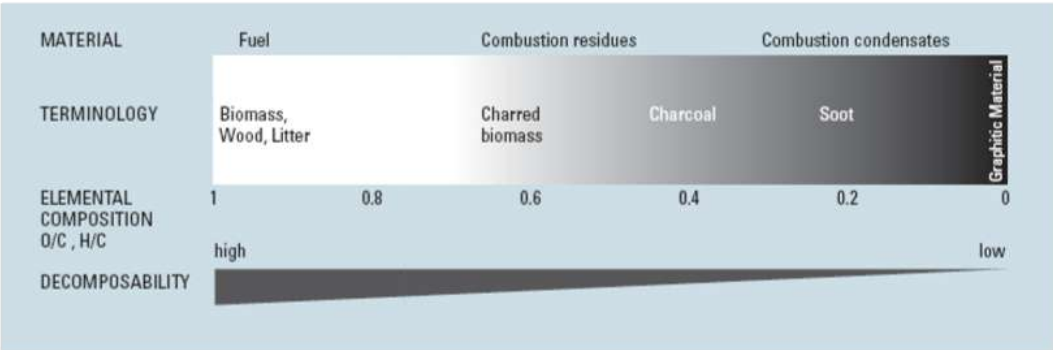

Figure 1.6 Terms and properties of pyrogenic BC (adopted from Preston and Schmidt, 2006)

However, it is important to bear in mind that, while the range of BC materials produced by wildfire overlaps with the range of biochar materials (i.e. the continuum from charred biomass to soot and graphite; Figure 1.6), the composition and properties of biochar can be very different to pyrogenic BC (see Chapter 2). The two main responsible factors are feedstock and pyrolysis conditions. In a wildfire, the feedstock is the aboveground biomass (and sometimes peat and roots) while for biochar any organic feedstock can theoretically be used from wood and straw to chicken manure (Chapter 2). In a pyrolysis oven, the pyrolysis conditions can be selected and controlled, including maximum temperature and duration but also the rate of temperature increase, and inclusion of steam, or e.g. KOH, activation and oxygen conditions.