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ABSTRACT

Carbon dioxide (CO_2) is the main greenhouse gas (GHG) and its atmospheric concentration is currently 50% higher th an pre-industrial levels. Biochar, when applied to soils is reported to increase soil carbon sequestration and provide ot her soil productivity benefits such as reduction of bulk density, enhancement of water-holding capacity and nutrient re tention, stabilization of soil organic matter, improvement of microbial activities, and heavy-metal sequestration. Yearl y net emissions of carbon dioxide (CO_2), methane and nitrous oxide could be decreased by a maximum of 1.8 Pg CO_2 -C equivalent (CO_2 -Ce) per year, and total net emissions over the course of a century by 130 Pg CO_2 -Ce, without end angering food security, habitat or soil conservation. The potential threats to the sustainability of biochar systems, at ea ch stage of the biochar life cycle, were reviewed many research papers. We propose that a sustainability framework fo r biochar could be adapted from existing frameworks developed for bioenergy sources. The current state of knowledge is based largely on limited small-scale studies under laboratory and greenhouse conditions. This review paper emphas izes to present the recent research works regarding climate change focusing on the properties of biochar and closely ev aluated the literature concerning biochar's stability.

Keywords: *Greenhouse gas, soil organic matter, life cycle, and bioenergy sources.*

INTRODUCTION

Climate change and global warming have worldwide consequences. The most prominent factor driving these phenomena is the increased atmospheric concentrations of greenhouse gases (GHGs). The World Meteorological Organization (WMO) GHGs Bulletin explains, that globally averaged concentrations of carbon dioxide (CO_2) reached 407.8 parts per million in 2018, up from 405.5 parts per million (ppm) in 2017 [1-3]. As photosynthesis converts CO_2 to organic carbon, increases in plant carbon stocks reduce the atmospheric CO_2 concentrations. The plant biomass does not rapidly decompose, but instead it is stored in wood or increased SOM, it keeps carbon out of the atmosphere [4, 5]. As a strategy for climate change mitigation, a key weakness of improved soil storage of carbon is the susceptibility of soil organic matter (SOM) to decay and re-release of CO_2 to the atmosphere [6, 7]. Carbon dioxide (CO_2) is put into center stage as it is the most abundant, and therefore most significant anthropogenic GHGs despite the fact that there are a number of other common yet more effective GHG's emitted. Recently, CO_2 capturing and utilization (CCU) is studied since CO_2 may be used as a valuable feedstock for industrial processes (Markewitz, Kuckshinrichs et al. 2012) [8]. Production of biochar, in combination with its storage in soils, has been suggested as one possible means of reducing the atmospheric CO_2 concentration [9]. Biochar is one such product that has become quite prominent in recent times.

This review paper presents a key for a sustainable solution of climate change quelling of the current level of knowledge on biochar and its potential role in agroecosystem management in the climate–change–sustainability context.

Biochar of the subject

Biochar is the charred by-product of biomass pyrolysis, the heating of plant-derived material in the absence of oxygen in order to capture combustible gases. The objective of this report was to review and evaluate published studies with regard to what evidence and arguments currently exist that assess the application of biochar to soil to a) sequester carbon and b) produce secondary agronomic benefits. Current studies suggest that there is a global potential for annual sequestration of atmospheric CO_2 at the billion-tonne scale (109 t yr-1) within 30 years [10]. So far, the underlying published evidence ascends

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mainly from small-scale studies that do not currently support generalization to all locations and all types of biochar. Biochar is the solid remains of any organic material that has been heated to at least 350ºC in a zero-oxygen or oxygen-limited environment, which is planned to be mixed with soils [11]. As a fuel or used as an aggregate in construction, it is defined as char, not biochar. There is a very extensive range of potential biochar feed stocks: e.g. wood waste, timber, agricultural residues and wastes (straws, bagasse, manure), leaves, food wastes, paper and sewage sludge, green waste, distillers grain and many others.

Interest in the use of biochar in agriculture has increased exponentially during the past decade. Biochar, when applied to soils is reported to enhance soil carbon sequestration and deliver other soil productivity benefits such as reduction of bulk density, enhancement of water-holding capacity and nutrient holding, maintenance of soil organic matter, upgrading microbial activities, and heavy-metal sequestration. biochar application could augment phosphorus availability in highly weathered tropical soils.

Biochar production and placement have the potential to do one or more of the following:

a. diminish atmospheric greenhouse gas concentrations through CO_2 removal and avoided greenhouse gas emissions (perhaps on a gigatonne carbon abatement scale);
b. improve the structure, properties and 'health' of soils;
c. growth in crop productivity;
d. offer energy (e.g. electricity from syngas, heat from syngas and bio-oil or liquid fuel);
e. safely dispose of certain waste materials with potentially useful recovered by products;
f. absorb pollutants, contaminants and reduce nitrate leaching to water courses;
g. suppress soil emissions of nitrous oxide and methane.

PROPERTIES OF BIOCHAR

Specific surface area

Biochar has a very high specific surface area (SSA) of several hundred m^2g^{-1} to a thousand m^2g^{-1}. The key parameters manipulating SSA are pyrolysis temperature, heating rate, residence time, and presence of active reagents (e.g., steam, CO_2, O_2 etc.).

Contaminants

There are two core potential sources of contamination in biochar: feedstock and the conversion process. Depending on the origin and nature of the pyrolysis feedstock, biochar may contain contaminants such as heavy metals (potential toxic elements, PTEs) and organic compounds. In addition to the contaminants introduced in the feedstock, some contaminants can be molded also in the conversion process. These include polycyclic aromatic hydrocarbons and potentially, in some cases, dioxins.

Heavy metals

Heavy metals present in the feedstock (e.g. sewage sludge, treated wood, etc.) are most likely to remain and concentrate in the biochar. Heavy metals are stable materials and consequently retained (conserved) during the volatilization of associated organic molecules [12]. The majority of metals will, therefore, be present as ash within biochar.

Stability

The stability of biochar is one of its key property, as it determines its potential for long term storage of carbon. Though, despite of its importance, there is no recognised way of determining stability of biochar. The motive for this is the fact that it is very difficult to predict stability of biochar over timescales relevant to carbon sequestration, i.e. centuries to millennia. This difficulty stems from the diversity of processes (biological, chemical and physical) responsible for biochar degradation in the environment and the wide range of properties biochar from different sources possess.

Biochar - A key for a sustainable solution of climate change

Biochar represents pyrolyzed organic matter, similar to wood charcoal, that is used for barbecue. However, in contrast to BBQ charcoal, it can be produced from any organic matter, regardless of its origin, and the production parameters may be exactly controlled. This newly raised attention as biochar may be used in carbon capture and storage strategies if it is used as a soil amendment [13]. In addition, biochar has the capability to positively influence both chemical and physical soil properties. For instance, recent findings suggest that biochar amendment has a deep influence on soil nitrogen cycling in an arable field trial. The porous structure of the char itself is capable of raising the cation exchange capacity as a concern of a high surface area and functional groups at the surface. In addition, pores may rise the soil water retention which is of critical importance on dry and sandy sites [14]. They may also generate a suitable habitat for soil microorganisms.

After incorporation into soil, the labile fraction is oxidized by soil microbes within years and hence no longer acts as a stable carbon pool. It has to be noted here that functions delivered by biochar amendment are subject to temporal changes. Biochar can improve the pore-size distribution of soils, resulting in improved retention of plant-available nitrogen in the soil, increasing plant Nitrogen uptake and fertilizer-use efficiency.

It is useful to consider a biochar-based strategy against more established approaches to increase the organic carbon stored in soil, such as the use of manures and composts. The durability of biochar in the soil is an important component when comparing pyrolysis bioenergy and biochar production with conventional bioenergy strategies, in mitigating climate change [15]. However, it is also vital to assess any indirect reduction in net greenhouse gas emissions from agriculture through the use of biochar. There may be some additional profits arising from the contribution of biochar to facilitating agricultural expansion and improving the socio-economic circumstances of farmers in developing countries.

Climate change mitigation strategies, such as carbon capture and storage (CCS) are essential to secure the future of humanity as carbon emissions due to increased human activities are constantly rising. As provision of energy is the largest anthropogenic source of carbon dioxide from combustion of fossil fuels, biomass utilization is seen as one of various promising strategies to reduce additional emissions. Climate change is a rising hazard for the entire world population. It makes future unreliable, especially in terms of provision of food and the usability of natural resources because a greater number and intensity of extreme weather events is expected as a consequence [16]. Besides the direct physical damage such events may create on local scales, moderate, but persistent changes e.g. in temperature and precipitation, have the ability to change the capacities to produce enough food and consequently cause hunger, social inequalities and conflicts for resources.

In general, any form of organic matter added to the soil degrades subsequent relatively quickly in CO_2 emission. Therefore, adding degradable organic matter into the soil is inefficient in terms of climate change mitigation, with the energy contained being captured and dissipated by soil microbes rather than in power plants where it can offset fossil fuel use.

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