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Review

Is current biochar research addressing global soil constraints for sustainable agriculture?

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ABSTRACT

Soil degradation is an increasing threat to the sustainability of agriculture worldwide. Use of biochar from bio-wastes has been proposed as an option for improving soil fertility, degraded land restoration, and mitigating the greenhouse gas emissions associated with agriculture. Over the past 10 years, there have been hundreds of research studies on biochar from which it may be possible to determine appropriate methods for use of biochar to improve sustainable agriculture. To address potential gaps in our understanding of the role of biochar in agriculture, in this paper are reviewed the studies of 798 publications of field-, greenhouse- and laboratory-based biochar amendment soil experiments conducted as of August, 2015. Here we report the findings from a quantitative assessment. The majority of published studies have been performed in developed countries in soils that are less impaired than those found in many developing countries. The majority of the works involves laboratory and greenhouse pot experiments rather than field studies. Most published studies on biochar have used small kiln or lab prepared biochars rather than commercial scale biochars. And, most studies utilize wood and municipal waste feedstocks rather than crop residues though the later are often available in agriculture. Overall, the lack of well-designed long-term field studies using biochar produced in commercial processes, may be limiting our current understanding of biochar's potential to enhance crop production and mitigate climate change. We further recommend greater alliance between researchers and biochar production facilities to foster the uptake of this important technology at a global scale.

Contents

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1. Introduction

Biochar, a product of pyrolysis of residual biomass, may slow carbon turnover in terrestrial ecosystems and thus enhance carbon sequestration in soils (Lehmann et al., 2006; Lehmann, 2007). Application of biochar to soils has been explored as a C-management strategy with the global potential for sustainably mitigating greenhouse gas (GHG) emission from agriculture while treating biowastes for environment management (Woolf et al., 2010). Although public and private sector groups have questioned the practicality of global scaling of biochar production (Ernsting and Smolker, 2009; POST-HP, 2010; Ernsting, 2011; Gurwick et al., 2012), there has been an increasing interest in the potential that biochar has for enhancing C sequestration and improving soil fertility (Spokas et al., 2012), restoring degraded lands (Beesley et al., 2011), and reducing GHG emissions in agriculture (Harter et al., 2014; Troy et al., 2013; Cayuela et al., 2014). These benefits provide the basis for recent calls for a broader, even global upscaling of biochar use in agriculture (Cernansky, 2015).

Increasing soil carbon sequestration could provide additional societal benefits by mitigating greenhouse gas production that contributes to climate change and for increasing food security by improving soil fertility (Lal, 2004; Smith and Gregory, 2013). Furthermore, increasing the amount of stable organic carbon in soils would enhance or restore ecosystem services and benefits (Sohi, 2012; Banwart et al., 2014; Six and Paustian, 2014; Halldórsson et al., 2014). Indeed, loss of soil fertility and crop productivity, as a result of extensive soil degradation across the world, has been increasingly recognized as a global challenge for food security (Lal, 2008; Smith and Gregory, 2013). Soil degradation caused by acidification, salinity, compaction, loss of water holding capacity, and decreased cation exchange capacity as a result of soil organic matter depletion is increasingly constraining global food production (Smith et al., 2015a) while also contributing to accelerated climate change (Smith et al., 2015b). It is thus critical for soil science to address the challenges of soil degradation and sustainable agriculture in the context of a growing human population.

There is a large and growing literature base on the effects of biochar addition to soil conducted over a wide range of laboratory, field, and greenhouse conditions. However, there is no concise assessment of how these studies add to our knowledge of the above mentioned global food and climate issues and if there is sufficient information for policy makers/business developers to adopt biochar production and use in a country or a region with specific soil conditions and feedstocks. In this study, we examine the current status of research on the role of biochar in alleviating soil constraints for world agriculture, and address whether the lack of systematic research is limiting broader adoption of this technology. Sound information from reliable globally organized studies, such as that facilitated by the International Biochar Initiative and international working groups is no doubt critical to assess the efficacy and safety of biochar technology and provide policy makers, practitioners, and the business sector sufficient information and rationale to advocate for its adoption and commercialization. In this critical review, derived from a synthesis and quantitative review of the existing studies on biochar application in agriculture, we present our argument for the urgent need to advance our knowledge and close information gaps that could allow us to assess the economic, climatic, and environmental conditions needed for a sustainable biochar-assisted agriculture.

2. Literature and data processing

A literature search and data collection was conducted via the Web of Science (apps.webofknowledge.com), Elsevier Science Direct (www.sciencedirect.com), Wiley-Blackwell (onlinelibrary.com) and Google Scholar (scholar.google.com``). We searched the literature published up to August, 2015, using the keyword “biochar”. From the papers that were retrieved; we focused on

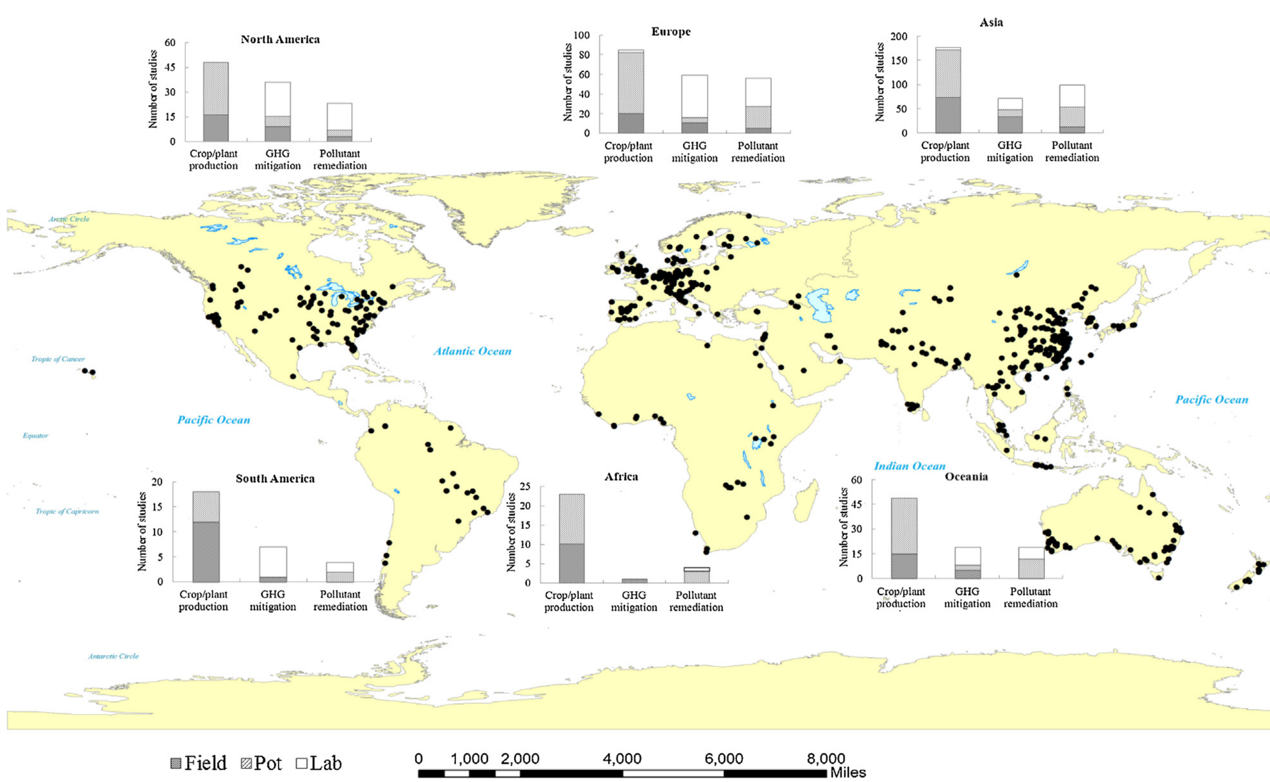

Fig. 1. Global distribution of biochar soil amendment studies (continent allocation in terms of laboratory, greenhouse and field studies).