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Recarbonization of the Soil

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Summary

The terrestrial biosphere and, in particular, soils currently contain less carbon (C) than their potential capacity due to land use and land use changes. To provide ecosystem services to an ever increasing population and to mitigate and adapt to climate change, the cycling of soil organic carbon (SOC) must be managed. The recarbonization of the soil, in particular, can be achieved by SOC sequestration implying an additional net transfer of C from the atmosphere to the soil via biomass. Through enhancing the SOC pool the capacity of soil to produce food, feed, fiber and fuel can be restored for the sustainable development of human society.

Keywords: Soil organic carbon; Carbon sequestration; Ecosystem services

Global Soil Forum

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Introduction

The finite global soil resource provides ecosystem services such as the production of food, feed, fiber and fuel. However more food must be produced as the human population is expected to rise to 10 billion by 2100 but already more than 1 billion people lack sufficient dietary energy availability, and at least 2 billion people suffer micronutrient deficiencies (Barrett 2010; United Nations Population Division 2011). However, food security can be improved by increasing the soil organic carbon (SOC) concentration in the root zone as this increase is associated with gains in agronomic productivity. For example, strong and positive impact of SOC concentration on increase in agronomic yield of wheat (*Triticum* spp.), barley (*Hordeum vulgare* L.), maize (*Zea mays* L.), rice (*Oryza sativa* L.), and other food crops have been reported for a wide range of ecoregions (Lal 2010).

Anthropogenic carbon dioxide (CO_2) emissions are increasing annually at a rate of 9 Pg (1 Pg = 10^{15}g) carbon (C) (U.S. DOE 2008). However, the terrestrial biosphere contributes to mitigating increases in atmospheric CO_2 by taking up about 3 Pg C yr^{-1}. The SOC pool, in particular, accumulates about 0.1 Pg C yr^{-1} (Lorenz and Lal 2012). Historically, about 650 Pg C may have been lost from the terrestrial biosphere by anthropogenic land use (Ruddiman 2003, 2005: Houghton 2010). For example, most agricultural soils contain 30 to 75% less C than their potential capacity as determined by soil, climate, terrain, drainage, land use, and soil and crop management practices (Lal and Follett 2009). Thus, SOC-accreting soil and land use management practices must be implemented for the recarbonization of the soil. This can be achieved by SOC sequestration which implies an additional net transfer of C from the atmosphere into the soil.

Carbon Sequestration

An additional net transfer of C via biomass into soil can be achieved by phyto-engineering, i.e., the breeding and cultivating of plants for SOC sequestration. Strategies include improving the carboxylation efficiency of the enzyme Rubisco which catalyzes the first major step of C fixation during photosynthesis (Spreitzer and Salvucci 2002). Another approach includes increasing the proportion of C_4 plants in warmer climates as plants using the C_4 photosynthetic pathway are more efficient in converting solar radiation into biomass under these conditions than those using the C_3 photosynthetic pathway (Zhu et al. 2010). As the overall efficiency of C_3 plants may be higher at lower temperatures (Jansson et al. 2010), the C_3/C_4 species mixture needs to be optimized for SOC sequestration in colder climates.

As plant roots and associated microorganisms are the major soil C input (Lorenz and Lal 2005), breeding of plants with deeper and bushy root ecosystems and their cultivation may contribute to SOC sequestration (Kell 2011). Further, replacing annual crops with perennial crop relatives may contribute to the recarbonization of the soil by an additional net transfer of C from the atmosphere into soil (Glover et al. 2010). However, it must be evaluated whether (i) production of plants with deeper and bushy root ecosystems will be at the expense of aboveground biomass yields and (ii) whether soil resources (e.g., nutrients, water) are sufficient to support the cultivation of perennial crop relatives.

Engineering towards recarbonized soils can also be achieved through the construction of reclaimed mine soils and urban soils with high C contents in the stabilized SOC fraction (Macías and Arbestain 2010). The soil addition of black C compounds (e.g., char, charcoal, biochar) may also contribute to a net transfer of C from the atmosphere but C sequestration strategies based on adding recalcitrant material to soil must be re-evaluated (Schmidt et al. 2011).

Research Needs

Recarbonization of the soil may have unintended effects on other ecosystem services aside C sequestration that must be studied by long-term experiments at the field scale. For example, additional soil C input may prime soil biota and result in increased fluxes of nitrate and nitrous oxide. Further, downstream aquatic ecosystems may be affected by higher dissolved and particulate C inputs. A recarbonized soil may have a higher risk of soil C loss by disturbances such as tillage and fire. Also, the supply of nitrogen, sulfur and phosphorus may limit SOC level not just C input (Kirkby et al. 2010).

Global Soil Forum

Soils are back on the global agenda as without fertile soils the will be no food security. However, there is a lack of translation of soil research to decision makers. Thus, the Global Soil Forum (GSF) was announced during a workshop at IASS in May 2011 which brought together fifteen leading soil scientists and policy makers from around the world. The GSF is an independent body that acts on the basis of transdisciplinary principles. Its creation is a response to the need of identifying workable and progressive soil management practices, policies and institutions. The GSF provides credible information to policy makers and practitioners on global soil protection and management issues and it will contribute to global soil policy processes.

The GSF feeds research findings into consultative processes with decision makers in governments, civil society and business in order to jointly design action plans at local, regional and global scales and contributes to their implementation in cooperation with stakeholders. From 2012, GSF is to host the annual Global Soil Week, an international multi-stakeholder conference on soils. The conference will present cutting-edge research and create an enabling environment to foster the exchange between the various stakeholders. It envisages specialized sessions to facilitate the interaction between scientists and practitioners. Further, GSF publishes policy papers targeted at specific clients for the maximum impact. The GSF will attract leading scientists to work on innovative and cutting edge research on soils and will serve as an incubator for global research consortia. GSF organizes public lectures and hosts international workshops on soil-related concerns and soil management attracting scientific excellence and key policy stakeholders.

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