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Adelaide

Black Carbon Stocks As Carbon Sinks In Soils Of The U.S.

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Introduction

To explain the role of Black Carbon (BC), the refractory solid residue of combustion (Photo 1) in the carbon cycles of North American ecosystems, it is necessary to acquire information on the contribution of BC to Soil Organic Carbon (SOC) across different climatic regions. BC represents one of the few ways that carbon can be rendered relatively inert. Thus, there is a strong potential for BC to act as a significant C sink from the more rapid bio-atmospheric C cycle to the slower (long term) geological C cycle (Forbes et al., 2006). Recent investigations indicated that up 35% of the total soil organic C in some agricultural soils of the U.S. consisted of BC (Skjemstad et al., 2002).

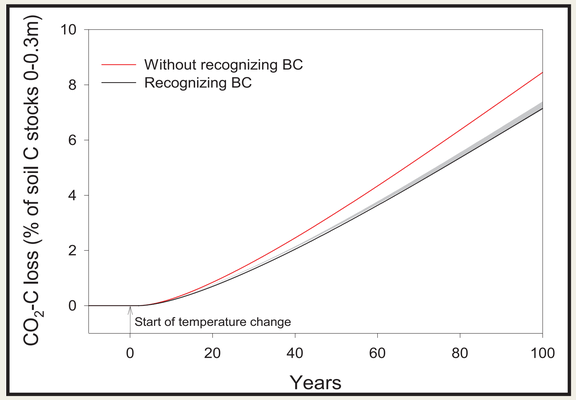

Figure 1: Effect of ignoring black carbon as IOM on SOC losses by mineralization in response to warming by 3°C over 100 years

Source: Lehmann et al., 2008

In spite of these findings, most recent carbon related studies focus merely on non-BC components and therefore neglect to address the long term ecological significance of BC stock changes in the global C cycle. Additionally, most available BC data is largely restricted to topsoils (Murage et al., 2007). If BC forms a larger than currently anticipated pool of SOC, information about pool size must be included in General Circulation Models (GCM) for prediction of climate change (Figure 1).

Photo 1: Vegetation fire residues of various kinds of plant materials contain BC which can be defined as the fire produced carbon fraction

Source: CSIRO

On a regional scale, transformation processes and products, initially driven by climate and geology, define the landscape potential which influences ecosystem characteristics, for instance the capacity to act as a carbon sink or source. Hence, accurate information about the spatial distribution of BC in soils of different ecosystems is important for projections of future climate change (Lehmann et al., 2008).

Objective 1

Quantification of BC Stocks in U.S. Soils Across a Range of Ecosystems And Climates

Hypothesis I

BC stocks of soils in the U.S. will be 20-30% of SOC, meaning soil BC is indeed high enough to affect current non-BC modeled predictions of SOC to climate change.

Hypothesis II

BC stocks will be a function of ecosystem type and climate. Hence, variations in BC stocks across different climates and ecological zones will be significant.

Objective 2

Determination of Subsoil Contribution to Total Soil BC Stocks

Hypothesis III

The proportion of BC as a fraction of total SOC will increase with depth. Therefore, the error excluding subsoil BC from measurements of total soil BC will be siginificant.

Photo 2: Wildfires are the predominant source for BC in soils
Source: CSIRO

Objective 3

Assessment of BC Distribution Throughout Landscapes

Hypothesis IV

Topography and geomorphodynamic processes within a landscape significantly impact the BC contents of soil. Thus, basins will show greater soil BC accumulation relative to associated regions with higher elevation and steeper slope gradients. Dimension and nature of geomorphological denudation and deposition activity will also be influential factors.

Objective 4

Evaluation of Land-use and Land-use Change Impacts on BC Stocks and Distribution

Hypothesis V

Increased mineralization, leaching and erosion due to agricultural activities accelerates SOC losses. Simultaneously, the proportion of BC as a fraction of total SOC in these soils will increase mostly due to the greater recalcitrance of BC.

Samples & Methods

Our project is concerned with establishing a first inventory of BC stocks in surface and subsurface soils across the U.S. using both NSF supported Long Term Ecological Research (LTER) sites as well as a national soil sampling effort by the U.S. Geological Survey. The latter consists of samples from A- and C-Horizons at over 13,000 selected sites distributed at a density of one site per 1,600km^2. In order to refine this lattice, we consider a spiraled continuation from selected sample sites into the 40x40km grid cell.

Table 1: Location and characteristics of LTER sites likely to be included in the study

Site	*Natural Vegetation*	*Major Mangement Comparisons*	*MAT (mm)*	*MAT (°C)*
Bonanza LTER (AK)	Boreal Forest	FM, A	263	-2.9
Cedar Creek (MN)	Prairie/Hardwood Forest	FM, A	801	6.6
Konza LTER (KS)	Tall Grass Prairie	RL, FP, A	834	12.8
Coweeta LTER (GA/TN)	Decidious Forest	FM, FP, A	2140	13.0
Jornada LTER (NM)	Grassland	RL, A, FP	263	24.5
Everglades LTER (FL)	Marsh/Mangroves	FP, A	1450	23.5

FM = forestry management; FP = fire prevention; A = Agriculture; RL =Rangeland, RL;
MAT: mean annual temperature; MAP: mean annual precipitation

To analyze the samples, we are using mid-infrared (MIR) and partial least-squares (PLS) analysis in conjunction with UV-NMR spectroscopic techniques. Since it is difficult to estimate the effects of positive and negative feedbacks within ecosystems while also considering spatial and temporal scales of the processes concerned, we are going to set up a GIS database of BC stocks and related data for the United States that will assist us in modeling said processes and allow us to investigate the nature of BC stocks over a range of climates as well as land-use and landscape features in the United States.

Desired Outcomes

1. Creation of a soil BC inventory in the form of a geospatial data base for the US that facilitates the estimation of the BC content in soils nationwide and assists in interpolating BC distribution

2. Conceptual design of a model for BC production and subsequent accumulation in terrestrial ecosystems as a function of climate, vegetation, land-use, fire frequency/severity, soil type and geomorphological processes

Literature

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