Soil Carbon: Major Player in Maryland’s Greenhouse Gas Balance

Ray Weil
Traditional soil organic matter concepts

- Living organisms; BIOMASS
- Identifiable dead tissue; DETRITUS
- Nonliving, nontissue; HUMUS

HUMIC SUBSTANCES
- Humin (highly condensed, complexed with clays)
- Humic acids (molecular wt. up to 300,000)

NONHUMIC SUBSTANCES
- Soluble organic
- Fulvic acids (molecular wt. 2,000–50,000)

Fig. 12.11 from Brady & Weil, 14th edition, 2007
An often-cited model of “humic acid”
with carbohydrate, hexapeptide, and hydrating water molecules.

But is soil humus really made of humic substances?

New classification of SOM pools and fractions based on recent insights


*Protected on clay surfaces, in aggregates and in ultramicropores.*
Hierarchical and biological nature of physical aggregates greatly influence the biology, physics, and chemistry of the soil.

Iron oxides

From: Weil and Brady. 2016.

Scanning Electron Micrograph of fungal hyphae stabilize a soil aggregate. Courtesy University of Bremen, Germany.
New Concepts of Soil Organic Matter Formation & Stabilization

- **Plant Shoot & Root Litter & Exudates**
- **Microbial Biomass**
- **Humus (stabilized C)**
- **Labile C**

**Char**

**Particulate Organic Matter**

**Dissolved Organic Carbon**

**Protected/stabilized organic matter (Humus)**

- Protected by cold or wet environment
- Protected by sorption to mineral surfaces
- Inaccessible inside microaggregate

**Catabolism**

**Desorption**

**Sorption**

**Enzymes**

**CO$_2$**

**Dissolved Biomolecules, cell fragments**
SOM under diverse rotation versus monoculture.
(a) Greater quantity and quality of residues enhances microbial activity
(b) mega-aggregate formation and stabilization.
(c) enhanced microbial activity
(d) increasing stocks of stable SOC and TN.

Passive C (protected, stabilized SOM)

Oil organic matter in the upper 30 cm of a representative never cultivated prairie soil


Active C (unprotected, labile SOM)

Total soil organic matter

Plant litter/residues

Cultivation ceases or improved agricultural practices are adopted

Changes in soil organic matter fractions due to cultivation and soil management

Conversion of cropland to pasture in temperate Argentina

This page is being updated.

Thank you for your interest in this topic. We are currently updating our website to reflect EPA's priorities under the leadership of President Trump and Administrator Pruitt. If you're looking for an archived version of this page, you can find it on the January 19 snapshot.

Here's what our Public Affairs Office released about these changes.

Other ways to help you find what you are looking for:

This is not the current EPA website. To navigate to the current EPA website, please go to www.epa.gov. This website is historical material reflecting the EPA website as it existed on January 19, 2017. This website is no longer updated and links to external websites and some internal pages may not work. More information »
Below ground (soil) carbon stocks in US Forests

“Total amount of carbon stored in aboveground forest biomass (living and dead) varies far less across diverse forest types than does belowground C, with an average aboveground stock for US forests being 55 Mg C ha\(^{-1}\); this is dwarfed in comparison by how much C is harbored in belowground pools.”

Above and below ground carbon stored in ecosystems
Average Percent Carbon in Master Horizons
Prince William Forest Park

\[ \text{g SOC} / 100 \text{ g soil} \]

Horizon O
Horizon A
Horizon B
Horizon C

Average Grams of Carbon Per Unit Area of Soil For Master Horizons
Prince William Forest Park

\[ \text{g SOC} / \text{m}^2 \]

Horizon O
Horizon A
Horizon B
Horizon C

Carbon concentrations
v. stocks
<table>
<thead>
<tr>
<th>Land Use</th>
<th>acres x 10^6 in Md</th>
<th>ha x 10^6 in Md</th>
<th>SOC in 1 m (Mg/ha)</th>
<th>SOC in Md to 1 m (Mg)</th>
<th>SOC to 1 m in Md (Tg)</th>
<th>MMtCO2e in Md</th>
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</thead>
<tbody>
<tr>
<td>forest</td>
<td>2.4</td>
<td>0.972</td>
<td>80</td>
<td>77760000</td>
<td>78</td>
<td>285</td>
</tr>
<tr>
<td>crops</td>
<td>1.5</td>
<td>0.6075</td>
<td>50</td>
<td>30375000</td>
<td>30</td>
<td>111</td>
</tr>
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<td>turfgrass</td>
<td>1.3</td>
<td>0.5265</td>
<td>80</td>
<td>42120000</td>
<td>42</td>
<td>154</td>
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<tr>
<td>wetlands (non-tidal)</td>
<td>0.23</td>
<td>0.09315</td>
<td>200</td>
<td>18630000</td>
<td>19</td>
<td>68</td>
</tr>
<tr>
<td>total vegetated</td>
<td>5.43</td>
<td>2.19915</td>
<td>168885000</td>
<td>169</td>
<td>619</td>
<td></td>
</tr>
</tbody>
</table>

Annual potential sequestration: 0.3 - 1.0 (sequestration would decline over 20-30 years)

References for land areas:
Cropland: www.mdp.state.md.us/...Farmland/2012_Census_of_Agriculture_Farms_Farmlands.pdf
Turfgrass: http://www.environmentmaryland.org/reports/mde/urban-fertilizers-chesapeake-bay
Forest: http://planning.maryland.gov/PDF/OurWork/LandUse/MDP2010_LU_Summary.pdf

References for C stocks:

- Plant litter / residues
- Animal wastes
- Imported bio-products
- Rhizodeposition
- Root residues
Soil Organic Matter Management: Balancing C inputs with output

Decrease SOM by:
- Erosion
- Intensive tillage
- Whole plant removal
- High temperatures
- Overgrazing
- Dry soil conditions
- High temperature/direct sun
- Fire
- Reliance on inorganic fertilizers
- Excessive mineral N
- Low plant productivity
- Low plant root:shoot

Increase SOM levels by:
- Soil conservation
- Green manures / cover crops
- Return of plant residues
- Controlled grazing
- High soil moisture
- Surface mulch
- Composts & manure
- Appropriate N levels
- High plant productivity
- Year ‘round and perennial vegetation
- High plant root:shoot

Tillage
Soil Organic Carbon Added by NRCS Practices to USA Cropland/Grassland Soils

Synergistic effect on soil health when cover crops and no-till management are combined.

Southern Illinois on a moderately eroded Grantsburg silt loam (fine-silty, mixed, mesic Typic Fragiudalf) 12 y study.

data from Olson et al. (2014)
Our mid-Atlantic project on “Deep Nitrogen”

Triticale, radish and clover after silage corn
Biomass measured 05 Dec, Just before radish died

Cover crop mixes: what you sown is not necessarily what you see
Organic C in 2 Midwest US agricultural soils as influenced by crop residue inputs

Response of net primary production (NPP) of corn to N fertilization (Russell et al., 2009).
Stable soil organic C (fine fraction SOM or FF-C) contains C, H, O as well as N, P and S in approximately constant ratios. The availability of N, P and S is thus needed for the formation of FF-SOM.

No-till increases SOC in surface layers - but what about in deeper soil layers?

Corn root system (Weaver 1929) and sampling depths used in 140 studies of tillage impacts on soil carbon. Scale marks 1 ft. = 30cm.

Most of the data are from top 20 cm... but most of the carbon is deeper.

Studies that look deep suggest that no-till may change the location but not the amount of carbon stored in soils.

From Weil and Brady. 2016.
Cover crops may change that assessment...

Measured in February, 6 months after silage corn harvest, 2 months after radish died. Silt loam soil.

Active carbon in 0-100 cm soil layer

Learning about roots isn’t easy – digging them up and counting them!

Core-break method to determine at root numbers with depth.

Taking soil cores to depth of 2-3 ft

Counting root numbers at the breakage faces.
Investigating roots with fiber optic camera: Mini-rhizotron

Subsoil 16 in (40 cm) deep
Wye, Md – silty clay loam

Subsoil 17 in (42 cm) deep
Groff farm – clay loam
First proof of “bio-drilling” to alleviate subsoil compaction published in 2004

3 May, Rapeseed root

17 July, Soybean root

Roots of corn following rye, radish or no winter cover crop
Subsoil roots: corn v cover

Cornroots = 0.75*Coverroots - 1.47
R^2 = 0.68, p=0.0115
At 16-20 inches depth.

Data of Chen and Weil. unpublished.
Using buried $^{15}\text{N}$ tracer to find out how deep cover crops can reach.
$^{15}$N tracer Placed 2, 4 & 6 feet deep in late August

$^{15}$N in cover crop by 05 Dec.

Cover crops planted 01 Sept.

Means of two sites

AT% N15 to N14

<table>
<thead>
<tr>
<th></th>
<th>4 ft.</th>
<th>6 ft.</th>
<th>2 ft.</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clover</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rye</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuber</td>
<td></td>
<td></td>
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</tbody>
</table>
Conclusions

- Soil carbon is a major player in climate change/GH gases cycles
- Most ecosystems have far more C below than above ground
- Land use & soil management changes typically release or sequester soil C at 0.2 to >1 Mt C y\(^{-1}\).
- The more degraded the soil, the greater its potential for C sequestration
- Maryland soil may be able to sequester 2 to 8 MMtCO2e annually
- Soils also play major role for NO\(_x\) and CH\(_4\).