Soil Carbon

John Baker  USDA-ARS, St. Paul MN
“That certain vegetable and animal substances introduced into the soil accelerate vegetation and increase the product of crops is a fact known since the earliest period of agriculture;”

Sir Humphry Davy. 1812. *Agricultural Chemistry*
“Worms are the intestines of the Earth”

Aristotle. ~340 B.C.
“When lands are impoverished, you lay them down to grass, and the longer they lie undisturbed the richer in vegetable matter does the soil become. When broken up, you find a black fertile mould where little trace of organic matter had previously existed...... when cleared and ploughed it yields abundant crops of corn.”

J.F.W. Johnston. 1851. Lectures on the Application of Chemistry and Geology to Agriculture
Benefits of Stable Organic Matter
The cation exchange capacity (CEC) at pH 7 was measured for samples of 347 A horizons and 696 B horizons of New Zealand soils. Multiple regressions were carried out for CEC against organic carbon (C), clay content, and the content of seven groups of clay minerals. The results, significant at $p < 0.001$, were consistent with most of the CEC arising from soil organic matter.

“At low organic carbon contents, the sensitivity of the water retention to changes in organic matter content was highest in sandy soils. Increase in organic matter content led to increase of water retention in sandy soils, and to a decrease in fine-textured soils. At high organic carbon values, all soils showed an increase in water retention. The largest increase was in sandy and silty soils.”

Pesticide Retention

“Measurements of pesticide sorption by soil are among the most sensitive input parameters in pesticide leaching models. Soil organic matter (SOM) is the single most important soil constituent influencing pesticide sorption in soils.”

Manuscript Titles Containing the Phrase

- "soil carbon"
- "soil organic matter"
Soil Organic Carbon

SOC Kg/m²

- < 2
- 2 - 4
- 4 - 8
- 8 - 12
- 12 - 16
- 16 - 20
- 20 - 40
- 40 - 80
- 80 - 120
Loss of SOC in cultivated soil

- Best estimate: 20 to 30% loss of SOC
- SOC loss occurs rapidly: most loss in first 5 yrs

Price and volume reported in metric tons CO₂

Historical Downloads

Related Information

CCX Carbon Market Report - A monthly publication providing information on the carbon market, members and other related news.
Tillage

- Chicago Climate Exchange contracts assume continuous no-till and strip-till store 0.18 tons C/ac/yr in the Midwest
How strong is the evidence?

- Major literature review by West and Post, 2002
  - global extent
  - 67 long term experiments
  - 276 treatment pairs
  - 0.25 tons C/ac/yr

  - 50% only sampled to 8” depth
  - none sampled to more than 12”

What are we missing?
Fig. 9.—Root system of corn on September 2.
What if we dig deeper?

- VandenBygaart et al. (2003) reviewed Canadian data
  - 62 studies
  - NT gains C near surface
  - NT neutral or losing C when sampled >12” deep
- The primary difference between tillage and NT may be the distribution of C.
  
  (Baker et al. 2007. Agric. Ecosys. Environ. 118:1-5)
What about alfalfa?
Some say no..

<table>
<thead>
<tr>
<th>Years of Alfalfa</th>
<th>0-20 cm SOC, g/kg</th>
<th>20-60 cm SOC, g/kg</th>
<th>60-100 cm SOC, g/kg</th>
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<td>2</td>
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<td>13</td>
<td>7.51</td>
<td>5.62</td>
<td>4.77</td>
</tr>
<tr>
<td>19</td>
<td>6.83</td>
<td>6.33</td>
<td>7.95</td>
</tr>
</tbody>
</table>

Some sampling studies say yes..

“..under alfalfa, the C content increased following a sigmoidal shape from 26 g kg⁻¹ in the first season to 30 g kg⁻¹ in the last year.” *

* - only sampled from 5-15 cm

“Cropping systems that contained alfalfa management practices had the highest SOC stocks, whereas the CS system generally had the lowest SOC stocks.”

* - Differences among cropping systems were not significant at individual sites, but were significant when pooled across all sites.

“Estimated C sequestration rate (0–20 cm) following crops to alfalfa conversions averaged 0.57 Mg C ha\(^{-1}\) year\(^{-1}\).....The result ... suggests that the soils studied have great C sequestration potential, and the conversion of crops to alfalfa should be widely used to sequester C and improve soil quality.” * 

* - only sampled 0-20 cm

Hammerly Clay Loam, West Central MN

Depth, cm vs. %C

- Blue line: mean SOC, 2006
- Red line: mean SIC, 2006
- Blue dashed line: mean SOC, 2008
- Red dashed line: mean SIC, 2008
Day of Year

Carbon Exchange Rate

corn
Alfalfa Gas Exchange Data. Wilmar MN. 2005
“In this study, we present data on the effects of a conversion from a cropland (Zea mays L.) to N2-fixing grassland (Medicago sativa L.) on C cycle in an agricultural area of Northern Italy. Net ecosystem production (NEP) and net biome production (NBP) have been followed for 2 years by measuring CO2 fluxes by paired eddy covariance stations .......... An increase in NEP was observed 2 years after conversion from corn to alfalfa (+281 g C m2), however, in terms of NBP, maize was a lower source of C (96 g C m2) than alfalfa (354 g C m2). From the present study, it appears that this type of land conversion is not an effective measure of C sequestration in the short term (1–3 years).”

Concluding thoughts

• As we develop farming systems to mitigate greenhouse gas emissions while maintaining food production, we should focus on a) increasing net primary productivity and b) protecting the soil, not on C credits for SOC sequestration, because potential SOC gains are difficult to verify and the climate benefit is likely small relative to that derived from the direct displacement of fossil fuels with biofuels.