Soil Health and Soil Carbon

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SOIL HEALTH: continued capacity of soil as a vital living system whereby plant and animal growth and environmental quality is sustained; a holistic approach in which plant, animal, and human health is promoted.
Soil functions

Soils deliver ecosystem services that enable life on Earth.

- Provision of food, fibre and fuel
- Cultural heritage
- Provision of construction materials
- Foundation for human infrastructure
- Source of pharmaceuticals and genetic resources
- Water purification and soil contaminant reduction
- Climate regulation
- Nutrient cycling
- Habitat for organisms
- Flood regulation
Soil degradation and its impact on other systems (hydrosphere, atmosphere, biosphere)

• Erosion
• Decline in organic matter
• Contamination (local and diffuse)
• Paving
• Compaction
• Loss of biodiversity
• Salinization
• Floods and landslides
Soil degradation in the Pampean Region of Argentina

Nutrient losses after 80 years of continuous agriculture

Pergamino series - Typic Argiudoll

Source: Andriulo, Galantini y Abrego (1996)
Feeding the World

- 854 million people are chronically or acutely malnourished (14% of the global population)

- > 2 billion people suffer from hidden hunger (micronutrients)

(Sanchez and Swaminathan, 2005)
Increased Soil Health

- Higher soil organic carbon
- Better soil structure
- Greater microbial activity

- Greater resilience
  - Water
  - Nutrients

- Greater yield stability
- Lower risks to farmer
Keys to Future Agricultural Systems

• Focus on Soil Health

• Intensify Systems:
  – Fertilizer, water and energy management
    • Efficiency not inputs
  – Crop rotations

• Diversify Systems:
  – Crop rotation and management
No-Tillage Cropping Systems
Conservation Agriculture

- Restores soil carbon
- Conserves moisture
- Saves fuel
- Saves labor
- Lowers machinery costs
- Reduces erosion
- Improved soil fertility
- Controls weed
- Planting on the best date
- Improves wildlife habitat
Management Strategies for C Sequestration

Develop Management Programs that:

**Enhance C Inputs**
- Crop Management
- Crop Selection
- Crop Rotations

**Reduce C losses**
- Tillage
- Fallow Management
Soil organic C (Mg ha\(^{-1}\))

- 0 - 0.05 m
- 0.05 - 0.15 m
- 0.15 - 0.30 m
- 0 - 0.30 m

\[ \Delta = 0.63 \text{ Mg ha}^{-1} \text{ year}^{-1} \]

\[ \Delta = 0.32 \text{ Mg ha}^{-1} \text{ year}^{-1} \]
Soil organic C (g kg⁻¹)

Depth (cm)

A

NT 1992
NT HM 2007
NT HF 2007
CT 1992
CT HM 2007
CT HF 2007
Change in soil C after 25 years

The graph shows the change in SOC (soil organic carbon) stock (Mg ha$^{-1}$) with depth (cm). The x-axis represents depth in cm, ranging from -20 to 20. The y-axis represents SOC stock in Mg ha$^{-1}$. The bars are color-coded, with NT (no-till) represented in brown and CT (conventional till) represented in green. The error bars indicate the variability in the data.
Change in Soil N after 25 years

SON Stock (Mg ha$^{-1}$)

Depth (cm)

0-5

0-15

0-30

0-60

NT

CT

-1 0 1 2 3 4
### Soil C sequestration rates for 15 years (Mg C/ha/y)

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Fertilizer N Tilled</th>
<th>Fertilizer N No-till</th>
<th>Manure N Tilled</th>
<th>Manure N No-till</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>0.161</td>
<td>0.351</td>
<td>0.393</td>
<td>1.182</td>
</tr>
<tr>
<td>0-15</td>
<td>0.254</td>
<td>0.497</td>
<td>0.792</td>
<td>1.402</td>
</tr>
<tr>
<td>0-30</td>
<td>0.336</td>
<td>0.717</td>
<td>0.839</td>
<td>1.387</td>
</tr>
<tr>
<td>0-60</td>
<td>0.146</td>
<td>1.325</td>
<td>0.733</td>
<td>1.141</td>
</tr>
</tbody>
</table>

Nicoloso et al., 2008
Intense and diverse cropping system

- Wheat
- Oats
- Soybean
- Corn

Crop Residues

- Continuous C Flux
- Active Pool
- Slow Pool
- Passive Pool
- Soil carbon pool

- Organic compounds
- Bulk Density; SOC and N pools
- MBC e MBN; humic compounds
- C; ΔpH; CTC; P e K

Physical, chemical and biological properties
## Capítulo 2 – Resultados e discussão

**Oxisol**

<table>
<thead>
<tr>
<th>Source</th>
<th>CT R0</th>
<th>CT R1</th>
<th>CT R2</th>
<th>NT R0</th>
<th>NT R1</th>
<th>NT R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean</td>
<td>2.36</td>
<td>2.87</td>
<td>2.53</td>
<td>2.57</td>
<td>2.57</td>
<td>2.80</td>
</tr>
<tr>
<td>Wheat</td>
<td>1.23</td>
<td>1.73</td>
<td>1.43</td>
<td>1.34</td>
<td>2.00</td>
<td>1.58</td>
</tr>
<tr>
<td>Oat</td>
<td>-</td>
<td>2.21</td>
<td>2.12</td>
<td>-</td>
<td>2.63</td>
<td>2.46</td>
</tr>
<tr>
<td>Corn</td>
<td>-</td>
<td>-</td>
<td>3.84</td>
<td>-</td>
<td>-</td>
<td>4.68</td>
</tr>
<tr>
<td>Oat+Vetch</td>
<td>-</td>
<td>-</td>
<td>2.61</td>
<td>-</td>
<td>-</td>
<td>2.94</td>
</tr>
<tr>
<td>Radish</td>
<td>-</td>
<td>-</td>
<td>1.51</td>
<td>-</td>
<td>-</td>
<td>1.51</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>3.59</td>
<td>4.84</td>
<td>5.31</td>
<td>3.91</td>
<td>4.88</td>
<td>6.05</td>
</tr>
</tbody>
</table>

1 Means with different letters between nitrogen sources within corn or total C inputs are significantly different (Tukey test, P<0.05). R0: soybean/wheat; R1: soybean/wheat/soybean/oat; R2: soybean/oat/soybean/oat+vetch/corn/radish/wheat.
Influence of tillage on soil C

Tribune, KS

Spearville, KS

Wallace, KS

Asmus 1996
Water stable aggregates between 10 and 22 yrs of management

Mika et al.
Change in macroaggregate (>2000 um) over time

SFWSA (%) vs Year

PG
NT
CT

2004 2006 2008 2010
### Ecosystem SOC sequestration rate (0-5 cm)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total C (Mg ha⁻¹)</th>
<th>2004</th>
<th>2006</th>
<th>2008</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>y = 0.37x - 74; r² = 0.98</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NT</td>
<td>y = 0.78x - 16; r² = 0.94</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RP</td>
<td>y = 0.89x - 18; r² = 0.98</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Mfombep 2013)
Macroaggregates

\[ P < 0.0001 \]
\[ r^2 = 0.834 \]
Soil Organic Carbon
Microbial Activity
Soil Structure
Gaseous Emissions
Environmental Services
Soil Biodiversity
Nutrient Cycling
Water Erosion & Availability
Plant Growth Yield
Sustainability

Soil Structure
Soil Organic Carbon
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Water Erosion & Availability
Plant Growth Yield
Less tillage promotes fungal activity

Fonte: Juca Sá
Bars of the same color for a given PLFA biomarker are not different (p<0.10). Lines are ± 1 standard error.

White and Rice, 2007
Daily Precipitation & Soil Temperature (5cm)
2016.04 - 2017.03
Inherent soil health differences vs differences due to management.

Use of “baseline conditions” to assess response of soil health to subsequent soil management decisions.

From Karlen et al. 2008

Fig. 2. Conceptualization of dynamic soil quality trends from time zero ($T_0$). Adapted from Seybold et al., 1998.
Dynamic Soil Monitoring System

• Quantify changes in soil health and carbon at the resolution of individual agricultural management units for diverse environmental conditions and cropping systems.

• Evaluate the relative contributions of management factors, environmental conditions, and cropping systems for changes in soil health and SOC.
Prairie Soil Carbon Balance (PSCB) project in Canada

Geo-reference microsites

- Microsites reduces spatial variability
- Simple and inexpensive
- Used to improve models
- Used to adopt new technology

Ellert et al. (2001)
Remote Sensing and Soil Health / Carbon

- Remote sensing cannot be used to measure soil C directly unless soil is bare.

- Remote sensing useful for assessing:
  - Vegetation
    - Type
    - Cover
    - Productivity
  - Water, soil temperature
  - Tillage intensity?
Other uses

• Crop Health
  – Pests
  – Nutrient (Nitrogen)
  – Water stress
• Yield
• Document management practices
• Rotations
• Ecosystem Services
## Value of soil C

Table 1. Plant nutrients supplied by soil organic matter (SOM).

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Value</th>
<th>Supplied by SOM</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$ kg^{-1}$</td>
<td>$ lb^{-1}$</td>
<td>$ kg ha^{-1}$</td>
</tr>
<tr>
<td>Nitrogen (N)</td>
<td>0.5</td>
<td>1.1</td>
<td>11-300</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>1.5</td>
<td>3.3</td>
<td>15-36</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>0.4</td>
<td>0.9</td>
<td>7-40</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2.4</strong></td>
<td><strong>5.3</strong></td>
<td><strong>31-220</strong></td>
</tr>
</tbody>
</table>
Summary

As we improve soil health and carbon

- How do we assess?
  - Monitoring!!

- Soil Health may be more valuable than soil Carbon

- How do we value that?

- Dynamic system: what is next?
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