Measuring, Reporting and Verifying Soil Carbon

Katie L. Lewis
Associate Professor
Soil Chemistry and Fertility
Global Carbon Cycle

Biogeochemical cycle by which C is exchanged between the biosphere, geosphere (lithosphere), hydrosphere, and atmosphere.
Global Carbon Cycle

Sources (Gt C/year)
- Ocean release = 90
- Respiration = 60
- Decomposition = 60
- Fossil fuel = 9.3
- Deforestation = 1.0
- TOTAL SOURCES = 220.3

Sinks (Gt C/year)
- Photosynthesis = 120
- Ocean uptake = 92.7
- Soil = 0
- TOTAL SINKS = 212.7

\[ \text{SOURCES} - \text{SINKS} = 7.6 \text{ Gt C} \]

added to atmosphere annually

Source: FAO
Global Carbon Cycle

- **SOURCES – SINKS** = 220.3 – 212.7 = 7.6 Gt C added to atmosphere annually
- Atmospheric pool increases by 4.5 Gt C annually

May 2021: 419.13 ppm
May 2020: 417.31 ppm
Global Carbon Cycle

- Soil is a major C reservoir, but it could have (may be) the potential to be a sink
  - *Sink* is accumulating C (e.g., ocean or atmosphere)
  - *Reservoir (soil)* is not actively accumulating C
    - Photosynthesis (120 Gt C/year) = Respiration (60 Gt C/year) + Decomposition (60 Gt C/year)
- Soil organic C (OC) = 1500 Gt C
  - More C than the atmosphere (800 Gt C) and terrestrial vegetation (500 Gt C) combined

Source: FAO
Soil OC – Cycling

- Dynamic reservoir – constantly changing due to microbial cycling of soil organic matter
  - Pools are not created equally
    - Particulate OC (checking account – quick to change)
    - Mineral-associated OM (saving account – slower to change)

Particulate OC

Physical stabilization of C within aggregates and attachment to minerals

Source: FAO
Soil OC – Managing to Increase Stocks

- Anthropogenic impacts on soil can turn it into either a net sink or net source (lost as gas)

- C Source: greenhouse gases (GHG) including CO\textsubscript{2} and CH\textsubscript{4}
  - CO\textsubscript{2} is most abundant C gas in atmosphere
    - Autotrophic and heterotrophic respiration of CO\textsubscript{2} is second largest terrestrial C flux
  - CH\textsubscript{4} is a 28x more potent GHG than CO\textsubscript{2}
    - Released during decomposition of OM under anaerobic conditions (methanogenesis)

- Sink or SOC storage in soil involves three stages:
  1. Removal of CO\textsubscript{2} from the atmosphere via plant photosynthesis
  2. Transfer of C from CO\textsubscript{2} to plant biomass
  3. Transfer of C from plant biomass to soil where it is stored as SOC in the most labile pool

- Managing to increase SOC stocks requires looking beyond just capturing atmospheric CO\textsubscript{2} – must find ways to retain C in the slow SOC pool
Soil OC – Managing to Increase Stocks

1. Continuous no-till

2. Preservation of crop residues

3. Diversification of crop system

- Soils depleted of SOC have greatest potential to gain C
- Most soils are far from C saturation threshold
- Potential for increased C inputs and management that protects C stocks to maximize C storage
Soil OC – Measuring, Reporting and Verifying

- C cycling and storage is more active in topsoil
- Stabilized C with longer turnover times makes up a greater proportion of SOC found deep in soil
- Soils at deeper depths have greater capacity of storing additional C
- To more accurately determine C stocks, deep cores will be required
- Reporting systems need to ensure that data collected are:
  - Transparent – documentation is sufficient and clear to allow any stakeholder to understand how data was collected
  - Consistent – methodologies differences should not exist
  - Comparable – one country, state, county, or farm to another
  - Accurate – neither over- or underestimated
Soil OC – Additional Thoughts on C Budgeting

- Additionality – potential to penalize early adopters of conservation practices; this cannot happen, early adopters must be credited for C

- Verification – modeling or actual C measurements… balance between the two, possibly paid for C capture rather than C stock increases

- Data collection –
  - Who is responsible?
  - Time required to collect samples/data on that scale
  - Methods to determine OC (e.g. dry combustion vs. loss on ignition OM)
  - Designated labs

- Stability of C – what happens if field is accidentally plowed (e.g. new tractor driver), and farmer has already been paid for the CO$_2$ sequestered?
  - N$_2$O and CH$_4$ are much more stable than CO$_2$ – could be paid for emissions that were never released
Carbon Storage Potential in Texas’ High Plains

Katie Lewis, Associate Professor
Wayne Keeling and Paul DeLaune, Professors
Joseph Burke and Mark McDonald, GRA
Christopher Cobos, Research Associate
Conservation Management - Cotton Systems

Evaluate the impacts of conservation tillage, cover cropping and crop rotations on soil C, cotton yield and economic return.
Helm Farm, Halfway, TX
(Established in 2013)

Pullman clay loam
Sand - 20%, Silt - 50%, and Clay - 30%

Benchmark soil series with extensive distribution on the Texas Southern High Plains
Soil Organic C (Helm Farm, est. 2013)

Soil samples collected prior to planting cotton in 2020 at 4 depths (0-6”, 6-12”, 12-24”, and 24-36”)

Total profile soil organic C (ton acre⁻¹)

<table>
<thead>
<tr>
<th>Depth</th>
<th>CC, CT</th>
<th>C ‘20-W ’21</th>
<th>CC, CC</th>
<th>C ‘20-W ’21</th>
<th>CC, CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6 in</td>
<td>b</td>
<td>a</td>
<td>b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-12 in</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-24 in</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-36 in</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Relative changes in profile soil organic C compared to conventional system (tons acre⁻¹)

<table>
<thead>
<tr>
<th>Depth</th>
<th>C ‘20-W ’21</th>
<th>CC, CC</th>
<th>0.5 BI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 BI</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- 0-6 in
- 6-12 in
- 12-24 in
- 24-36 in
AG-CARES, Lamesa, TX

Amarillo fine sandy loam
[80% sand, 10% silt, & 10% clay]

Long-term Tillage, Est. 1998
Continuous Cotton (CC), Conventional Tillage (CT)
Rye and Mixed Species Cover, No-Tillage (NT)

CC, CT
>25 years

CC, Rye Cover, NT Est. 2014

Cotton-Wheat Rotation, NT Est. 2014
2020 – Wheat
2021 – Cotton

Irrigation
Base
Base + 33% (high)
Base – 33% (low)
Soil Organic C (AG-CARES, est. 2014)

- Total profile soil organic C (ton acre⁻¹):
  - 0-6 in
  - 6-12 in
  - 12-24 in
  - 24-36 in

- Relative changes in profile soil organic C compared to conventional system (tons acre⁻¹):
  - C '20-W '21 +33% BI
  - CC, rye cover +33% BI
  - C '20-W '21 -33% BI
  - CC, rye cover -33% BI
Research plot design at Ag-CARES in Lamesa, TX

Evaluated systems
Continuous cotton systems – (est. 1998)
• Conventional tillage, winter fallow (CT)
• No-tillage, Rye cover (R-NT), 45 lb/acre
• No-tillage, Mixed cover (M-NT), 45 lb/acre
  • Rye (50%)
  • Austrian Winter Pea (33%)
  • Hairy Vetch (10%)
  • Radish (7%)
    • by weight
• Established in November 2014
• NRCS recommended mixture
• Native site with same soil texture (Wellman, TX)
Plot Size (AG-CARES) – 16 rows by 200 ft long

Longterm site

Plot Size (AG-CARES) – 16 rows by 200 ft long
Soil Organic C (AG-CARES, est. 1998)

Cropping System

- Continuous cotton, winter fallow
- No-tillage cotton, mixed species cover
- No-tillage cotton, rye cover
- Native rangeland

Profile (0-40 in) soil organic C (ton Acre⁻¹)

- 0-2 in.
- 2-4 in.
- 4-14 in.
- 14-30 in.
- 30-40 in.

Relative changes in profile soil organic C (0-40 in.) compared to conventional system (tons acre⁻¹)

- No-tillage cotton, mixed species cover
- No-tillage cotton, rye cover
- Native rangeland

Legend:
- b
- a
Summary

Conservation management practices have a variable effect on soil C storage.

Soil texture and irrigation capacity have been identified as major drivers behind differences observed in soil C storage.

C storage is greater using cover crops in sandy soil and greater with rotation in clayey soil.

Potential to sequester 0.14 ton C/acre/year in sandy, semi-arid cotton system using cover crop and no-tillage (23-year system).