Soil Quality and Organic Carbon Sequestration with Improved Pasture Management

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Characteristics of Humid Grazing Lands

Generally

- Introduced plant species
- Responsive to management inputs
- High production potential

Legend:
- Green: Warm, humid region: ≥ 750 mm, ≥ 12 °C
- Red: Warm, dry region: < 750 mm, ≥ 12 °C
- Light Blue: Cool, dry region: < 750 mm, < 12 °C
- Blue: Cool, humid region: ≥ 750 mm, < 12 °C
Soil Organic Carbon Sequestration

Processes

- Photosynthesis
- Biochemical transformations
- Harvest
- Respiration
  - Plant
    - Animal
    - Soil microbe
- Soil erosion
- Leaching
Outline

1. Soil organic C under pastures relative to other land uses

2. Pasture management effects on soil organic C
   a. Duration
   b. Forage type
   c. Fertilization
   d. Forage utilization

3. Pasture system effects (CH₄)

4. Soil sampling effects on soil organic C

5. Summary

6. Conclusions
### Pasture SOC: Relative to Other Land Uses

<table>
<thead>
<tr>
<th>Study</th>
<th>Depth (cm)</th>
<th>Forest</th>
<th>Grass</th>
<th>Crop</th>
<th>Significance</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Texas</td>
<td>30</td>
<td>--</td>
<td>88 ± 18</td>
<td>&gt;</td>
<td>57 ± 8</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Laws and Evans (1949),</td>
<td></td>
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<tr>
<td>Potter et al. (1999)</td>
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<tr>
<td>AL-AR-FL-GA-LA-MS-NC-SC-TX-VA</td>
<td>25</td>
<td>31 ± 12</td>
<td>31 ± 16</td>
<td>&gt;</td>
<td>23 ± 15</td>
<td>0.04</td>
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<tr>
<td>McCracken (1959)</td>
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<td></td>
<td></td>
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<tr>
<td>Maryland</td>
<td>15</td>
<td></td>
<td>32 ± 10</td>
<td>&gt;</td>
<td>20 ± 7</td>
<td>0.01</td>
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<tr>
<td>Islam and Weil (2000)</td>
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<tr>
<td>Alabama</td>
<td>25 ± 6</td>
<td>60 ± 21</td>
<td>&gt; 48 ± 26</td>
<td>&gt; 34 ± 8</td>
<td>0.03</td>
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<td>Fesha et al. (2002), Torbert et al. (2004)</td>
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<tr>
<td>Mississippi, Georgia</td>
<td>25 ± 7</td>
<td>47 ± 2</td>
<td>&gt; 38</td>
<td>&gt; 22 ± 6</td>
<td>0.08</td>
<td></td>
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<tr>
<td>Rhoton and Tyler (1990),</td>
<td></td>
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<tr>
<td>Franzluebbers et al. (2000)</td>
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<tr>
<td>Mean</td>
<td>24 ± 6</td>
<td>49.9 a</td>
<td>47.4 a</td>
<td>31.1 b</td>
<td></td>
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</tbody>
</table>

Pasture SOC: Relative to Cropping

Soil Organic Carbon (g · kg⁻¹)

Soil Depth (cm)

Survey of 29 farm locations in AL, GA, SC, NC, VA

Conventional Tillage Cropping

Pasture (24 ± 11 years)

Sequestration of SOC (Mg ha⁻¹ yr⁻¹)

-0.53 **

-0.17 **

0.05 ns

0.74 **

0-20 cm

Management Effects: Duration
Cool- vs Warm- Season Grasses

Soil organic C sequestration rate during 25 years

- 'K-31' Tall fescue: 0.78 Mg ha\(^{-1}\) yr\(^{-1}\)
- 'Coastal' bermudagrass: 0.26 Mg ha\(^{-1}\) yr\(^{-1}\)

Different opportunities for growth during the year.

Management Effects: Duration
Forage Type and Harvest

From a long-term bermudagrass grazing study in Texas (Rouquette)

Maximum Soil Organic C Accumulation (%)

SOC (Mg ha⁻¹ yr⁻¹) 10 yrs 25 yrs 50 yrs
Hayed BG (GA) 0.29 0.21 0.13
Grazed BG (TX) 0.50 0.33 0.19
Grazed TF (GA) 0.91 0.55 0.31

Data from Wright et al. (2004) Soil Biol. Biochem. 36:1809-1816
Management Effects: Duration Forage Type and Harvest

Impact
Saturation to a theoretical threshold is possible (determined by climate, soil type, etc.)
Management Effects: Forage Type
Tall Fescue—Endophyte Association

Specific Mineralization of SOC (mg CO₂-C g⁻¹ SOC)

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>High</th>
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<tbody>
<tr>
<td></td>
<td>98 **</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>43 **</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>23</td>
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<tr>
<td></td>
<td>16</td>
<td>16</td>
</tr>
</tbody>
</table>

Management Effects: Forage Type
Tall Fescue—Endophyte Association

✔ Isolation of endophyte effect within organic carbon fractions

<table>
<thead>
<tr>
<th>Soil pool</th>
<th>E-</th>
<th>E+</th>
</tr>
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<tbody>
<tr>
<td>Whole-soil organic C (Mg ha⁻¹)</td>
<td>29.3</td>
<td>&lt;</td>
</tr>
<tr>
<td>Macroaggregate C (Mg ha⁻¹)</td>
<td>31.1</td>
<td>&lt;&lt;</td>
</tr>
<tr>
<td>Particulate-to-total C (g g⁻¹)</td>
<td>0.42</td>
<td>&gt;</td>
</tr>
<tr>
<td>Microbial biomass-to-total C (mg g⁻¹)</td>
<td>45</td>
<td>&gt;</td>
</tr>
<tr>
<td>Mineralizable-to-total C (mg g⁻¹)</td>
<td>44</td>
<td></td>
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</tbody>
</table>

Management Effects: Fertilization
Inorganic vs Organic Source

Mean yearly change
(Mg · ha⁻¹ · yr⁻¹)

Grazed ‘Coastal’ bermudagrass

Soil Organic Carbon (Mg · ha⁻¹)

Impact Fertilizer sources were equally effective in sequestering soil organic C

Management Effects: Fertilization
Inorganic vs Organic Source

Grazed ‘Jesup’ tall fescue

Impact Fertilizer sources were equally effective independent of forage base

Mean yearly change (Mg · ha⁻¹ · yr⁻¹)

<table>
<thead>
<tr>
<th>Years of Management</th>
<th>0-6 cm soil</th>
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<tbody>
<tr>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>22</td>
</tr>
</tbody>
</table>

Franzluebbers (unpublished data)
Management Effects: Fertilization
Inorganic vs Organic Source

From a compilation of available literature around the world (Conant et al., 2001, Ecol. Appl. 11:343-355), SOC sequestration was compared between inorganic and organic fertilization.

<table>
<thead>
<tr>
<th>Management</th>
<th>Rate of SOC Sequestration (Mg ha⁻¹ yr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inorganic fertilizer</td>
<td>0.29</td>
</tr>
<tr>
<td>Organic fertilizer</td>
<td>0.28</td>
</tr>
</tbody>
</table>
Management Effects: Forage Utilization
Grazed vs Hayed

- Long-term pasture survey (15- to 19-year old fields, 3 each)

Soil Organic Carbon (g · kg⁻¹)

Management Effects: Forage Utilization
Grazed vs Hayed

Grazed ‘Jesup’ tall fescue

Mean yearly change
(Mg · ha⁻¹ · yr⁻¹)

Soil Organic Carbon
(Mg · ha⁻¹)

0.50 Ungrazed / hayed
0.78 Grazed

Impact
Grazing returned carbon to soil to build fertility

Franzluebbers (unpublished data)
Management Effects: Forage Utilization
Grazed vs Ungrazed

Management Effects: Forage Utilization
Animal Behavior

At the end of 5 years of grazing Coastal bermudagrass in the summer

Standing Stock of C (Mg ha⁻¹)

Unpublished data
Pasture System Effects
Methane Emission

ca. 30% of total CH₄ emission in USA is from agriculture (US-EPA, 2007)

Assumptions:

- 0.15 ± 0.08 kg CH₄ head⁻¹ d⁻¹ [Harper et al. (1999) J. Anim. Sci. 77:1392-1401]
- 19 Mha of pasture land in southeastern USA (USDA-NASS, 1997)
- 12 million head of cattle in southeastern USA (USDA-NASS, 1997)

Resulting in:
- 0.62 head ha⁻¹
- 34 kg CH₄ ha⁻¹ yr⁻¹
- 0.37 to 1.20 Mg CO₂-C equivalent ha⁻¹ yr⁻¹

Agriculture’s contribution to greenhouse gas emissions reviewed:
Soil Sampling Effects
Soil Depth Variation

Soil Organic Carbon Sequestration (Mg ha\(^{-1}\) yr\(^{-1}\))
(LSD (P = 0.05) range)

Hayed
Low Grazing Pressure
(High Forage Mass)

High Grazing Pressure
(High Forage Mass)

Unharvested


Linear regression estimates of SOC sequestration sampled at 0, 5, 12 yr of management
Summary

✓ Establishment of perennial grass pastures can sequester soil organic C at rates of 0.25 to 1.25 Mg C ha\(^{-1}\) yr\(^{-1}\)

✓ Soil organic C sequestration rate can be affected by:
  ▪ Forage type
  ▪ Fertilization
  ▪ Forage utilization
  ▪ Animal behavior
  ▪ Soil sampling depth
Conclusions

✓ Sequestration of SOC under grassland management systems is significant
  ▪ Balance needed with ill-defined CH$_4$ and N$_2$O emissions

✓ Rate of SOC sequestration under the wide diversity of pasture conditions in the USA still largely unknown
  ▪ Variations in management, climate, soils, etc.

✓ Greater collaboration is needed to efficiently utilize limited resources and better understand the impacts of diverse conditions on SOC sequestration
  ▪ Among plant, animal, soil, and water science disciplines
  ▪ Long-term field studies need conceptual and financial support
Acknowledgements

Steve Knapp

Robert Martin

USDA

CSREES

U.S. Department of Energy