Organic Benefits and Challenges in the Face of Climate Change

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Outline of Presentation

• Global C budget
• Organic agriculture
• Wisconsin Integrated Cropping Systems Trial
• Impact of organic production systems on soil carbon
• Relevancy for semi-arid climates
• Conclusions
Agriculture, carbon & the climate

Source of C emissions

- Combustion of Fossil Fuels
- Land Use Change

CO₂ & climate change

- Change in temperature & rainfall
- Extreme weather: drought, flood, storms
- Food & resource insecurity

Moberg et al. 2005

http://www.prism.gatech.edu/
Agriculture, the global C budget, and climate change

**CO₂ mitigation via agriculture**
- Agricultural land as a C sink
- Reverse historic losses of SOC

**Attractive mitigation option**
- Immediately implementable
- Cost-effective

**Policy & rural economy**
- Cap & Trade – Chicago Climate Exchange (CCX)
- Ecosystem service subsidies
Organic Agriculture

• Regulations set by the US National Organic Program
• Requires three year transition period
• Set of specific production practices – more than not spraying pesticides and not using synthetic fertilizer
Organic Regulations Re: Soil Building

• Section 205.203(a): Select and implement tillage and cultivation practices that maintain or improve the physical, chemical, and biological condition of soil and minimize soil erosion

• Section 205.203(b): Manage crop nutrients and soil fertility through rotations, cover crops, and the application of plant and animal materials
How can agriculture influence climate change, particularly with respect to CO2 and global C budget? How do our production practices (and particularly organic production practices) specifically influence SOC?
The Wisconsin Integrated Cropping Systems Trial

Arlington, WI
The Wisconsin Integrated Cropping Systems Trial (WICST)

- UW Ag. Research Station
  - Arlington, WI
  - Lakeland, WI
- 0.7 -acre plots – field scale equipment
- Silt loams
- In dairy rotation 1850 - 1989
- WICST established 1989 - 1990
- RCB with 4 blocks
WICST Cropping Systems

Grain

Corn

Soybean

Cropping Systems

Forage

Corn

alfalfa

alfalfa

Corn

alfalfa

Oats/alfalfa

Rotational Grazing

Perenniality
Arlington soils: Mollisols

Formed in deep loess (>1) deposits over calcareous glacial till
Vegetation dominated by tall grass prairie and oak savannah communities

– Highly productive
  • High SOC

Photo courtesy of University of Nebraska
Historic loss of SOC
c. 1850 - present

Wisconsin

Grace et al. 2006
• 14% SOC lost
• Sampled 0 - 10 cm

Arlington, WI

Collins et al. 1999
• 18% SOC lost
• Sampled 0 - 20 cm

Globally: 30 - 50% of SOC lost (Lal 2008; Ogel et al. 2005)
WICST SOC trends

Change in Soil Carbon Over 20 years (Mg ha\textsuperscript{-1})

Bars represent ±1 standard error; Pr>|t|, † p<0.1, * p<0.05, ** p<0.01
## Soil C inputs on WICST

<table>
<thead>
<tr>
<th>Group</th>
<th>System</th>
<th>Description</th>
<th>Estimated Annual C Input</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Above Ground</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(kg ha⁻¹)</td>
</tr>
<tr>
<td>Grain</td>
<td>CS1</td>
<td>continuous corn</td>
<td>3800</td>
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<tr>
<td></td>
<td>CS2</td>
<td>corn-soybean</td>
<td>2940</td>
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<tr>
<td></td>
<td>CS3</td>
<td>organic grain</td>
<td>2240</td>
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<tr>
<td>Forage</td>
<td>CS4</td>
<td>conventional forage</td>
<td>3050</td>
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<tr>
<td></td>
<td>CS5</td>
<td>organic forage</td>
<td>3220</td>
</tr>
<tr>
<td></td>
<td>CS6</td>
<td>pasture</td>
<td>1590</td>
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</table>
# WICST SOC trends

## General SOC (g kg\(^{-1}\)) trends

<table>
<thead>
<tr>
<th></th>
<th>Δ g kg(^{-1})</th>
<th>Sign.</th>
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<tbody>
<tr>
<td>NT vs. Tilled</td>
<td>2.8</td>
<td>†</td>
</tr>
<tr>
<td>Forage vs. Grain</td>
<td>3.2</td>
<td>*</td>
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</table>

## SOC (g kg\(^{-1}\)) correlations

<table>
<thead>
<tr>
<th>Tillage</th>
<th>Manure</th>
<th>Aboveground</th>
<th>Belowground</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>r</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.10*</td>
<td>0.13**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.05</td>
<td></td>
<td>0.11**</td>
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</tbody>
</table>

Pr>|t|, ns=not significant, † p<0.1, * p<0.05, ** p<0.01
Organic Agriculture and Tillage

- Organic farmers cannot use herbicides
- Rely heavily on tillage and cultivation for weed management
Phases of Cover-Crop Based No-Till

1. Cover crops seeded the previous fall

2. Cover crops killed in June

3. Grain or seed crop no-till drilled into killed cover crop

4. Grain or seed crop is combined

Images courtesy of Kathleen Delate at Iowa State Univ., and Dale Mutch at Michigan State Univ.
Soybean – end of July
Microbial biomass C-Fall 2011

IA-Marsden

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<th>Variant</th>
<th>Value</th>
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<tbody>
<tr>
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<tr>
<td>NTR2</td>
<td>171a</td>
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<tr>
<td>CTR1</td>
<td>134a</td>
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<tr>
<td>CTR2</td>
<td>133a</td>
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PA-Rodale Inst.

<table>
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<tr>
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<tr>
<td>CTR1</td>
<td>114a</td>
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<tr>
<td>CTR2</td>
<td>121a</td>
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</tbody>
</table>
Conclusions & Implications

• SOC: loss is rapid (140 yr), accretion is slow (~3000 yrs)

• WICST: best management ≠ SOC sequestration

• Below ground C allocation crucial to sequestration
  – Quantity & quality

• SOC stabilization:
  – \( f \) (C input > C oxidation) + sufficient time
Conclusions & Implications

**Agricultural**

- NT, manure, forage crops – beneficial
- Perennial grasses in crop rotations
  - Grass ley
- Perennial functionality
  - Cover crops, intercropping
- Pasture systems – important part of agricultural landscape

- **Organic Agriculture** trends toward greater use of: manure, forage crops, perennial crops, cover cropping, and intercropping
- Overall reduction of tillage and inputs across systems is beneficial
WICST Life Cycle Analysis

• Embedded emissions: accumulated emissions emitted over the entire production process

• Data from the GaBi databases
  – Seed
  – Diesel
  – Fertilizer
  – Pesticides
  – Grain drying
  – Supplemental heifer feed while on pasture

• $N_2O$, $CH_4$, $CO_2$ computed and converted to $CO_2$ eq in kg/ha/yr
Embedded components at ARL (kg CO$_2$ eq/ha/yr), 1993-2008
Differences of Arid Climates and the Southwest

• Lack of rainfall
• Higher average mean temperatures
• Fallowing practices
How does the WICST data relate to desert southwest?

• Nebraska – compared three winter wheat/fallow management systems
  – no-till management resulted in greatest conservation of soil organic matter and posed the least threat to atmospheric quality relative to loss of greenhouse gases such as CO2 (Doran, Elliot, and Paustian)
How does this relate to desert southwest?

- Pacific Northwest (Inland Empire) – small grain/fallow systems - summer fallow lost SOM over time without additions of manure
- Most SOM loss was due to high biological oxidation and absence of C inputs
- Issue with fallow – not continually inputting C into the soil
- Tillage – converting plowing into mulch (non-inversion) tillage conserved N and C
  - No-till systems are perhaps the only tillage systems with a chance to maintain SOM at a steady state
Cover Crop Options for NM

- Cowpea-- well acclimated to the desert’s drought and high temperature environment
- Can produce about 2 tons of biomass per acre in 75 days in central Arizona
- Has a favorable C:N ratio and breaks down rapidly
- Iron Clay - common variety
- 20 to 30-inch row spacing at a 35 to 40-pound/acre seeding rate
Cover crop options for desert regions

• Pearl millet - grows 4 feet to 5 feet high and produces 2 to 3 tons of biomass in 60 days
  – planted in June and flowers later in the month
  – has a deep root system that grows well with low nitrogen and water inputs
  – when used in vegetable cropping systems, pearl millet can use residual nitrogen and reduce nitrate leaching
  – recommended planting rate is 5 to 10 pounds per acre

• Other warm-season cover crops with a potential good fit in desert vegetable systems include: lablab; sesbania; sunnhemp; velvet bean; German (foxtail) millet; and Japanese millet
Cover Crop Research in Arizona

• Summer cover crops cowpea and sudangrass can increase yields in soils planted in winter vegetables and spring cantaloupe

• Cowpea planted in July and cut and incorporated into the soil in September; cowpea cut and left on the soil surface as a mulch during the same time frame; sudangrass planted in July and cut in September for soil incorporation; plus a bare ground control plot.

• Incorporated cowpea cover crop improved conventional and organic fall lettuce and spring cantaloupe yields

• Sudangrass cover crop slightly reduced fall lettuce yields, but improved the spring cantaloupe yield
Cover-crop based no-till techniques in NM?
Methods

• Planted cover crops in September
• Cover crops grew through September and October
  — Lablab bean, cowpea, sorghum sudangrass
• Terminated at first killing frost
• Chile transplanted into cover crops in following April
Sorghum sudan before frost
Cowpeas
Killed cover crops

Cowpea and Sorghum Sudangrass
Yield of cold-sensitive cover crops, 2006

* treatment means designated with a similar letter are nonsignificant at the 5% level

Department of Plant & Environmental Sciences
Take-home messages

• Organic production integrates production practices that benefit soil organic carbon
  – Diverse crop rotations – deep rooted crops
  – Compost and manure additions
  – Cover cropping
  – No-Till – cover crop based no-till?

• Maintaining and building soil organic carbon in desert southwest is challenging

• Production strategies that integrate the above approaches will provide best results with respect to building SOC and soil health