Using active organic matter measurements to predict agronomic performance

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• What is active organic matter and why is it important?

• Two promising measures active organic matter

• Research results
Soil Organic Matter

- Soil Carbon is Soil Organic Matter
  - ~50% of OM is carbon

- OM plays a disproportionate role in soil function
  - 1-6% of mass, but vital for:
    - Soil physical structure: aggregation, infiltration, aeration
    - Chemical: CEC, nutrients available and retained
    - Biological: food supply for soil biology, suppression of diseases

- Soil Carbon is the currency in soil for energy and nutrients
Organic Matter = Inputs - Outputs
(+ lots of biology + soil mineral interactions + time)

**Carbon inputs**
- Crop residues
  - Shoots, roots
- Cover crops
- Organic amendments (Manures, Compost)
- New carbon compounds cycled through decomposition

**Carbon Outputs**
- $\text{CO}_2$ from respiration of plant roots and soil biota
Stabilization vs. Mineralization

• Stabilization = Convert nutrients from an inorganic form to an organic form (a.k.a. Immobilization)
  • Lock up in organic matter, not plant available
  • Process of building OM

• Mineralization = Convert OM from an organic form to an inorganic form (a.k.a. Decomposition)
  • Making nutrients plant available
  • Ex. Protein $\rightarrow$ Nitrate

• Which one does a farmer want?
3 Pools of Organic Matter

**Active**
days – few years
- Recently deposited organic material
- Rapid decomposition and cycling
- 5 – 10% of OM (<1% of soil)

**Slow**
few years – decades
- Intermediate age organic material
- Slow decomposition and cycling
- 10 – 30% of OM

**Passive**
decades – centuries
- Very stable organic material
- Extremely slow decomposition and cycling
- 60 – 80% of OM
How Does Active OM Increase Production Potential?

Active OM + Roots + Soil Food Web = **Nutrient Sponge** (Reservoir)
- Supplies nutrients to crops in times of need
- Locks up nutrients in times of excess
  - Reduces losses

As the soil food web becomes more developed (continuous supply of inputs, little disturbance)
- More complex, diverse, resilient

**Greater nutrient use efficiency**
Benefits of Active OM Tests for Growers

Near-Term
• Establish a baseline of active organic matter for the field(s) of your farm
• Track the trajectory of your soil OM and management impacts trajectory (faster responses than total OM)

Long-Term
• Build predictive models of nutrient supply from OM
• Better on-farm nutrient management
How to Measure Active Organic Matter

Physical Fractionation
- Particulate organic matter ($$$)
  - Size
  - Density

Chemical Fractionation
- Microbial biomass ($$$)
- Dissolved organic carbon ($$)
  - Active carbon ($)
  - Infrared spectroscopy ($)

Biological Process
- Nitrogen mineralization ($$)
- Respiration ($)

Total OM ($) (Grower Test)
Inexpensive Available Soil Organic Matter Tests (<$10)

- Total Organic Matter (Loss on Ignition)

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Active Organic Matter Tests

- Active Carbon (Permanganate oxidizable C [POXC])

- Respiration (Mineralizable C; CO₂ Burst, ex. Solvita)
Active C Procedure

2.5 g soil + 20 ml KMnO₄

Shake for 2 minutes

Settle for 10 minutes

0.5 ml of solution + 49.5 ml H₂O

Read color intensity (on spectrophotometer)
What is Active C?

- Active C related to:
  - Smaller POC fractions
  - Heavier POC fractions

- Active C reflects a more processed pool of available C
  - Smaller C:N
  - Larger portion of MBC
  - Slower turn-over times
Sensitivity of Methods

- Ability of each measure to indicate changes due to experimental factors (e.g., management regimes, different fields, multiple depths)

<table>
<thead>
<tr>
<th></th>
<th>Active C</th>
<th>Particulate Organic C</th>
<th>Microbial Biomass</th>
<th>Total C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of times</td>
<td>42%</td>
<td>32%</td>
<td>9%</td>
<td>29%</td>
</tr>
<tr>
<td>when method was</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>most sensitive</td>
<td></td>
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</tbody>
</table>

Culman et al., 2012, SSSAJ
Respiration Procedure

- 20 g soil + water
- Seal in jar
- Incubate for 24 hours
- Measure concentration of CO₂ in jar
Respiration = Solvita = 24hr CO₂ Burst
• Active C reflects management practices that promote OM building?
• Respiration reflects practices that promote OM mineralization?
Comparison of permanganate oxidizable C and mineralizable C for assessment of organic matter stabilization and mineralization


- Provisionally accepted in SSSAJ
Objectives

1. Determine the relationship between POXC and mineralizable C over a wide range of soil types and management histories

2. Determine important soil ecosystem processes that each of these active organic matter tests reflect

3. Determine the ability of both POXC and mineralizable C to predict crop yields and total aboveground biomass
Study Area

- 13 studies, 76 total sites, $n = 1071$
- Mostly field crops, some tallgrass prairie and forest
<table>
<thead>
<tr>
<th>Active OM Pool</th>
<th>Percent of Total Carbon (%)</th>
<th>Percent of Organic Matter (%)</th>
<th>Percent of Total Soil (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active C</td>
<td>1 – 4</td>
<td>0.5 – 2</td>
<td>0.0002 – 0.0008</td>
</tr>
<tr>
<td>Respiration</td>
<td>1 – 3</td>
<td>0.5 – 1.5</td>
<td>0.0002 – 0.0006</td>
</tr>
<tr>
<td>Microbial biomass C</td>
<td>1 – 4</td>
<td>0.5 – 2</td>
<td>0.0002 – 0.0008</td>
</tr>
</tbody>
</table>

The active fraction is just a small percentage of total soil

*Culman et al., 2012, SSSAJ; Hurisso et al., accepted*
Relationship Between Active C and Respiration

- \( r^2 = 0.15–0.80 \)
Using Regression Residuals to Infer Relative Influence

Positive Residuals = greater than predicted POXC (Active C)
Negative Residuals = greater than predicted Mineralizable C (Respiration)
Management practices disproportionately influencing **POXC**:  
--Conservation Tillage  
--Compost

Management practices influencing **mineralizable C**:  
--Tillage  
--Manure  
--Cover Crops
But which one is better at predicting crop performance??
# AOM Predicting Agronomic Performance

<table>
<thead>
<tr>
<th>Study</th>
<th>1&lt;sup&gt;st&lt;/sup&gt;</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt;</th>
<th>3&lt;sup&gt;rd&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Corn Grain yield</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Russell Ranch, CA</td>
<td>Mineralizable C (0.25)</td>
<td>POXC (0.26)</td>
<td>SOC (0.29)</td>
</tr>
<tr>
<td>LFL, MI</td>
<td>Mineralizable C (0.38)</td>
<td>POXC (0.39)</td>
<td>SOC (0.52)</td>
</tr>
<tr>
<td>Mid-Atlantic, MD, PA</td>
<td>POXC (0.30)</td>
<td>Mineralizable C (0.31)</td>
<td>SOC (0.55)</td>
</tr>
<tr>
<td>KBS-LTER, MI</td>
<td>Mineralizable C (0.08)</td>
<td>SOC (0.39)</td>
<td>POXC (0.47)</td>
</tr>
<tr>
<td></td>
<td>Corn total biomass yield (grain + stover)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Russell Ranch, CA</td>
<td>Mineralizable C (0.19)</td>
<td>POXC (0.20)</td>
<td>SOC (0.20)</td>
</tr>
<tr>
<td>LFL, MI</td>
<td>SOC (0.38)</td>
<td>Mineralizable C (0.73)</td>
<td>POXC (0.45)</td>
</tr>
<tr>
<td>Mid-Atlantic, MD, PA</td>
<td>Mineralizable C (0.09)</td>
<td>POXC (0.13)</td>
<td>SOC (0.12)</td>
</tr>
<tr>
<td></td>
<td>Wheat grain yield</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Russell Ranch, CA</td>
<td>SOC (0.23)</td>
<td>POXC (0.24)</td>
<td>Mineralizable C (0.24)</td>
</tr>
<tr>
<td>Crop-Livestock, GA</td>
<td>POM-C (0.02)</td>
<td>Mineralizable C (0.03)</td>
<td>POXC (0.03)</td>
</tr>
<tr>
<td>KBS-LTER, MI</td>
<td>SOC (0.03)</td>
<td>Mineralizable C (0.11)</td>
<td>POXC (0.11)</td>
</tr>
<tr>
<td></td>
<td>Tomato marketable fruit yield</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Russell Ranch, CA</td>
<td>Mineralizable C (0.15)</td>
<td>POXC (0.25)</td>
<td>SOC (0.16)</td>
</tr>
<tr>
<td>Urban Garden, OH</td>
<td>POXC (0.57)</td>
<td>Mineralizable C (0.84)</td>
<td>SOC (0.84)</td>
</tr>
<tr>
<td>CA-Tomato, CA</td>
<td>MBC (0.27)</td>
<td>POXC (0.43)</td>
<td>Mineralizable C (0.43)</td>
</tr>
<tr>
<td>WORT, IL</td>
<td>POM-C (0.02)</td>
<td>POXC (0.03)</td>
<td>Mineralizable C (0.03)</td>
</tr>
</tbody>
</table>
Mineralizable C was the best predictor of crop productivity = 6 times (out of 14 total)
POXC was the best predictor of crop productivity = 2 times
All other soil C fractions (MBC, POM-C and SOC) = 6 times

POXC and mineralizable C - 1st or 2nd best predictor in 21/28 comparisons

Both of these measurements are capable of predicting agronomic performance relative to other soil C fractions.

But how relevant is it from a management perspective?? Can we use them as tools to inform management?
Conclusions

• POXC (Active C) and Mineralizable C (Respiration) are related but unique soil C fractions
  • Both 1-4% of total soil C

• POXC appears to represent soil OM building
  • Conservation tillage, compost

• Mineralizable C appears to represent OM mineralization
  • Tillage, manure, cover crops
  • Perhaps better predictor of crop performance

• Both are inexpensive and sensitive indicators, but more work is clearly needed
Next Steps

• Determine if POXC, Mineralizable C, Soil Protein, Aggregate Stability, etc are capable of (helping) predict crop response to fertilization

• On-farm fertilizer strip trials across the state

• Results in progress
Thank You

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