Using the Cornell Soil Health Assessment for Soil Management Planning: Tillage Technologies

Bob Schindelbeck
rrs3@cornell.edu
http://soilhealth.cals.cornell.edu

Cornell University, August 5-8, 2015
Using Tillage to Affect Soil Physical Properties

The Soil Health Management Toolbox

1. Crop Rotation/hybrid choice
2. Growing cover crops
3. Organic/chemical amendments, inoculants
4. Reducing or modifying Tillage

- These four soil management strategies are typically used in combinations with features in another category.
Direct physical manipulation of the soil is fundamental to agriculture—“working the land”
Conventional Tillage Systems
and associated tools

1. Full-width tillage/ conventional tillage
   - Primary Tillage
     • Moldboard plow
     • Chisel
     • Disk plow
     • Rototiller (no secondary tillage)
     • Spader (no secondary tillage)
   - Secondary tillage (to create fine seedbed, incorporate amendments)
     • Harrow
     • Finishing disk-(harrow)
     • Cultipacker/roller

2. Restricted width/Reduced tillage
   • No-till (one pass planting)
   • Zone-tillage (one pass planting)
   • Strip tillage (two pass planting)

Additional tools for reducing tillage:
• Aerway
• Subsoiler/Ripper
• Roller-Crimper
• Creative use of standard tools
Conventional Tillage Features

- time-tested system
- loosen soil
- incorporate surface amendments
- bury crop residue
- control weeds- “end” crop growth
- break up surface crust
- stimulates soil biological processes
- recompact/ level soil for planting
- shape soil surface
- create seedbed for the crop

Tillage really DOES affect the soil physical environment
Conventional tillage systems often use a “clean tillage” approach to burying residue and smoothing the soil surface.

- **moldboard plow**

- **soil surface inversion**

- **disk harrow**

- **spring tooth harrow with rolling basket**

**primary tillage**

**secondary tillage**

**more secondary tillage**
Conventional tillage systems often use a “clean tillage” approach to burying residue and smoothing the soil surface.

<table>
<thead>
<tr>
<th>Moldboard plow</th>
<th>Intensive cropping</th>
<th>Collamer silt loam</th>
</tr>
</thead>
</table>

**Our “HOME” soil**

<table>
<thead>
<tr>
<th>Measured Soil Textural Class: Silt Loam</th>
<th>Sand: 2%</th>
<th>Silt: 83%</th>
<th>Clay: 15%</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
<th>Rating</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available Water Capacity</td>
<td>0.14</td>
<td>35</td>
<td>Rooting, Water Transmission</td>
</tr>
<tr>
<td>Surface Hardness</td>
<td>260</td>
<td>15</td>
<td>Subsurface Pan/Deep Compaction, Deep Rooting, Water and Nutrient Access</td>
</tr>
<tr>
<td>Subsurface Hardness</td>
<td>340</td>
<td>30</td>
<td>Aeration, Infiltration, Rooting, Crusting, Sealing, Erosion, Runoff</td>
</tr>
<tr>
<td>Aggregate Stability</td>
<td>15.7</td>
<td>15</td>
<td>Nutrient and Energy Storage, Ion Exchange, C Sequestration, Water Retention</td>
</tr>
<tr>
<td>Organic Matter</td>
<td>2.5</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>ACE Soil Protein Index</td>
<td>5.1</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Respiration</td>
<td>0.53</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Active Carbon</td>
<td>288</td>
<td>6</td>
<td>Energy Source for Soil Biota</td>
</tr>
<tr>
<td>pH</td>
<td>6.5</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>20.0</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>150.6</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Minor Elements</td>
<td>Mn 131 Fe 1.2 Mn 12.9 Zn 0.3</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

**Overall Quality Score** 50 **Low**
Tillage Features

- time-tested system
- loosen soil
- incorporate surface amendments
- bury crop residue
- control weeds—“end” crop growth
- break up surface crust
- stimulates soil biological processes
- recompact/level soil for planting
- shape soil surface
- create seedbed for the crop

Drawbacks of Tillage

- Time tested system but...
- uses a lot of energy/fossil fuel
- labor cost of equipment operation
- buries crop residue
- can bring up weed seeds
- creates compaction in wet soil
- degrades soil structure
- decomposes organic matter
- increases runoff and erosion
- each field operation prior to planting is a net delay in planting
Reduced intensity full width tillage

Cultural shift away from clean tillage to less aggressive soil management

Chisel plow does not fully invert soil

Chisel shank aggressiveness affects residue retained

Twisted Shank

Straight Point
Reduced intensity secondary tillage tools

- use ground driven, rotating blades or points to perforate the soil surface
- less aggressive than disks or harrows
- often used for liquid manure incorporation

AerWay

GenTill

AerWay

GenTill

Reduced number of passes with disk harrow

Cultivator with undercutting “sweeps” to lift and drop soil
Rototiller use in vegetable production systems can be primary AND secondary tillage in one pass..
(but is this actually reducing tillage?)

- **Highly disturbing**, complete soil mixing
- Little surface residue
- Can cause a hard pan where tines ride
- Intensive effort may benefit small-seeded vegetables
- Bedding (with or w/o plastic) requires multiple passes to “fit” soil for shaping

really affecting the soil physical properties
Tillage intensity continuum

Minimum effort → Maximum effort

- no-till planting
- four pass conventional planting

Photos: Kyle Weber

- single pass planting
- planting into crop residue
- moldboard plow
- offset disk
- springtooth harrow with rolling baskets
- roller crimper with planter
- soybean in killed rye

www.agromaster.com.tr
Tillage Features

- loosen soil
- incorporate surface amendments
- bury crop residue
- control weeds—
  “end” growth of crop
- break up surface clods
- recompact/
  smoothen soil for planting
- shape soil surface
- create seedbed for the crop

Drawbacks of Tillage

- time tested system but..
- uses a lot of energy/fossil fuel
- labor cost of equipment operation
- creates compaction in wet soil
- degrades soil structure
- reduces root health and erosion
- each field operation prior to planting is a net delay in planting

No-till sounds great. Why doesn’t everyone do it?
Tillage Features

- loosen soil
- incorporate surface amendments
- bury crop residue
- control weeds
- “end” growth of crop
- break up surface crust
- recom pact/
- smoothen soil for planting
- shape soil surface
- create seedbed for the crop

Drawbacks of Tillage

- uses a lot of energy/fossil fuel
- labor cost of equipment operation
- creates compaction in wet soil
- damages soil structure
- increases runoff and erosion
- each field operation prior to planting is a net delay in planting

Tillage addiction can be a hard habit to break – for the grower AND the degraded soil!

No-till sounds great. Why doesn’t everyone do it?
Technologies that have lessened the need for clean tillage involve “new” thinking and learning (and testing)

- Evaluation of soil performance
- New understanding of cover cropping options and methods for managing these cover crops
- New understanding of soil organism roles
- New tillage tools that provide targeted de-compaction and surface residue retention
- New planters and transplanters that allow for focused tillage

Which tool will you use (or not use!) for which purpose?
Alternative Tillage Systems
and associated tools

1. **Full-width tillage/ conventional tillage**
   - **Primary Tillage**
     - Moldboard plow
     - Chisel
     - Disk plow
     - Rototiller (no secondary tillage)
     - Spader (no secondary tillage)
   - **Secondary tillage** (to create fine seedbed, incorporate amendments)
     - Harrow
     - Finishing disk-(harrow)
     - Cultipacker/roller
     - Bedding

2. **Restricted width/Reduced tillage**
   - No-till (one pass planting)
   - Zone-tillage (one pass planting)
   - Strip tillage (two pass planting)

**Additional tools for reducing tillage:**
- Aerway
- Subsoiler/Ripper
- Roller-Crimper
- Creative use of standard tools
One Pass No-till Planting Advantages in Time, Money

One Pass Zone-till Planting

Four Pass Conventional Planting

Costs in dollars and time for row crop field operations (2011)¹

<table>
<thead>
<tr>
<th>Tillage/planting system</th>
<th>dollars per Acre</th>
<th>hours per Acre</th>
<th>speed compared to conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone-till (ONE PASS planting)</td>
<td>13</td>
<td>0.12</td>
<td>3.5</td>
</tr>
<tr>
<td>Conventional row crop (moldboard, disk, finish, plant)</td>
<td>46</td>
<td>0.42</td>
<td>1.0</td>
</tr>
</tbody>
</table>

¹ Lazarus, Univ. of Minn Extension
One-pass/ reduced pass planting can TAKE less time and also allow for more timely sowing.

Example: First of the month the soil is friable, workable.

No-till
- Day 1 Field A planted

Reduced tillage systems
- intermediate

Conventional tillage
- Day 1 Field A plowed
- 1/2 inch of rain
- Day 4 Field A disked
- " ” worry, more tillage
- Day 8 Field A planted

- each field operation prior to planting is a net delay in planting
- early planting is essential to attain highest yields
Reduced Tillage Transition—Lessons Learned, or “sounded good but it didn’t work..”

- Conventional tillage “works” and IS the standard..
- “Nothing comes free” - so to replace the heavy work of tillage to prepare a soil the grower must substitute creativity (trade “tweaking” for horsepower)
- Excellent soil management skills/ability to innovate are required for successful adoption of restricted-width tillage systems
- Re-build soil health before trying reduced tillage “cold turkey” (soil is addicted to tillage)
- Degraded soils/ heavy residue conditions may benefit with some tillage

- Simply reducing the number of soil smoothing passes can reduce negative impacts (recreational tillage)
- Lighter soils and dry springs contribute to reduced tillage success
Zone-Till Planter- “almost” no-till

Specialized hardware mounted on planter to allow one-pass planting or following ripped zone strips

Keeton Seed Firmers- Teflon “shoes” that ride in seed groove to set seed

Spiked closing wheels firm seed zone

Footed or Swept-Back Wheels

Closing wheels with a footed design or swept-back spikes aim to firm the seedbed and then release as they move over the soil.
Economic and environmental evaluation suggest focusing disturbance only in the row while moving residues to the interrow area. Rugged equipment is widely available. Planting directly on ripped strips is aided by GPS/ guidance systems.
No-till drill

- heavy seeder capable of seeding cereals (WITH or WITHOUT cover crops) using 7” row spacing in one pass
- rapid method to establish cover and nurse crops without primary tillage - allows for fitting cover crop seeding into narrow time windows
- often available to lease from Conservation District agencies
Reduced Tillage Transition - Lessons Learned (so that you don’t say “sounded good but it didn’t work”)

- Excellent soil management skills/ability to innovate are required for successful adoption of restricted-width tillage systems
- Attend field days, grower twilight meetings to hear local ‘experts’ describe their successes and share locale-specific insights
- Borrow or rent new equipment to find the match for a field or farm
- Set out ‘strip trials’ to test equipment & cover crops on your farm (start small)
- Look for inexpensive new add-on technologies to fine-tune systems

- To identify constraints and guide management decisions, submit soil samples for Cornell Soil Health Assessment

Too wet!
Combining the various management practices that promote soil health can have an additive effect.
### Corn Soil Health Assessment

#### 15 years fall plow
Corn for grain  
Clay loam

#### 15 years No till
Corn for grain  
Clay loam

## Test Results

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
<th>Rating</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available Water Capacity</td>
<td>0.19</td>
<td>55</td>
<td>Rooting, Water Transmission</td>
</tr>
<tr>
<td>Surface Hardness</td>
<td>240</td>
<td>22</td>
<td>Subsurface Pan/Deep Compaction, Deep Rooting, Water and Nutrient Access</td>
</tr>
<tr>
<td>Subsurface Hardness</td>
<td>360</td>
<td>4</td>
<td>Aeration, Infiltration, Rooting, Crushing, Sealing, Erosion, Runoff</td>
</tr>
<tr>
<td>Aggregate Stability</td>
<td>8.3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>ACE Soil Protein Index</td>
<td>4.1</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Respiration</td>
<td>0.20</td>
<td>15</td>
<td>Soil Microbial Abundance and Activity</td>
</tr>
<tr>
<td>Active Carbon</td>
<td>614</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>6.6</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>5.2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>151.9</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Minor Elements</td>
<td>464</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Overall Quality Score</td>
<td>51</td>
<td>Low</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
<th>Rating</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available Water Capacity</td>
<td>0.24</td>
<td>-9</td>
<td>Subsurface Pan/Deep Compaction, Deep Rooting, Water and Nutrient Access</td>
</tr>
<tr>
<td>Surface Hardness</td>
<td>180</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>Subsurface Hardness</td>
<td>380</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Aggregate Stability</td>
<td>59.7</td>
<td>83</td>
<td></td>
</tr>
<tr>
<td>Organic Matter</td>
<td>5.0</td>
<td>-5</td>
<td></td>
</tr>
<tr>
<td>ACE Soil Protein Index</td>
<td>5.1</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Respiration</td>
<td>0.38</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Active Carbon</td>
<td>541</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>6.8</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>4.8</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>160.7</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Minor Elements</td>
<td>108</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Overall Quality Score</td>
<td>67</td>
<td>Medium</td>
<td></td>
</tr>
</tbody>
</table>