TILLAGE IMPACTS ON THE SOIL-CROP SYSTEM

Sjoerd W. Duiker
“Before World War II, we stood arraigned as the most wasteful people in all history. Nowhere else, except in the fabled Garden of Eden, had a people taken such a rich, virgin territory and in a short three centuries ruined large parts of it for all time and semi-destroyed other parts, while busily trying to do away with the rest. We were not husbandmen in the best sense of the word. We were miners.”

The Problem

- Tillage – hoe, disk, moldboard
- One-crop agriculture
  - 1600 - Tobacco in the Chesapeake Region
  - 1793 - Cotton in the South
  - 1837 – Corn in the Midwest
  - 1870 - Wheat in the Plains and Palouse
The Results

In the Chesapeake, after 2-3 years of tobacco and a few years of corn and wheat farmers moved on to the new fields.

It was estimated that the Potomac carried annually 1.7 billion lbs of dissolved nutrients and 470 million lbs of sediment to the Chesapeake Bay, while the James carried 3-4 million cubic yards from north of Richmond and the Roanoke 3-4 million tons from the Piedmont.

From “ Craven, 1925. Soil exhaustion as a factor in the agricultural history of Virginia and Maryland, 1606-1860”. p.28
In the South soil degradation in continuous cotton took its toll – as a result 1000s of miles of gullies ran through the South.

In the Southern Piedmont average soil erosion was estimated at 7 inches.

Unproductive soil reverted back to brush, grassland, or pine plantations as cotton moved west.

Soil Mining in The Midwest

In the Midwest, erosion took its toll and soil organic matter content was mined – the Morrow Plots, IL show that in 50 years up to 46,000 lbs/A of soil carbon was lost from organic matter, releasing 3300 lbs of N, 400 lbs of P, and 400 lbs of S. Soils eroded but effects were noticeable only after many decades or centuries.
Devastation in the Plains

60% of farmers in northern Plains went bankrupt between 1925-31

2.5 million people moved out of Plain States after Dust Bowl years (1930-36).

In the Palouse 10% of land lost all topsoil, and 60% of the land lost ¼-¾ of the topsoil.
Addressing Soil Degradation Today

Soil degradation remains a threat of national proportions
The buffer of virgin land is gone
The demands from the land will increase
The roots of the problem need to be addressed: Shallow or deep tillage combined with ‘one crop agriculture’
The Need of the Hour

✓ Eliminate the tillage conundrum:
  ✓ Limit soil movement to eliminate tillage erosion
  ✓ Mulch cover to control water/wind erosion
  ✓ Mulch to increase infiltration/reduce evaporation

✓ Eliminate ‘one-crop agriculture’:
  ✓ Organic mulch and continuous living root systems to favor soil biological activity and profile modification
  ✓ Diverse crop rotations to help improve soil, manage nutrients, weeds, pests and diseases.
Conservation Agriculture

- Minimal Soil Disturbance (permanent no-tillage)
- Permanent Organic Soil Cover (mulch or living vegetation)
- Diverse Crop Rotations
Soil Erosion
Simulation Study, Corn NE, 10% slope

Soil loss (t/ac)

Moldboard
Chisel
No-till

Residue cover (%)

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Mulch Cover for Erosion Control

Our Challenge: How to Maintain Enough Residue!
Tillage in Rotation Decreases Residue Levels
High Mulch Cover for Increased Infiltration

More than 70% cover results in greatly increased infiltration

Roth et al., 1988. Effect of mulch rates and tillage systems on infiltrability and other physical properties of an Oxisol in Parana, Brazil. Soil Tillage Res 11:81-91
Tillage Effects on Infiltration

Infiltration (inches)

- Plowed, bare
- No-till, bare
- No-till, 40% cover
- No-till, 80% cover

MWPS-45, 2000
## Tillage and Runoff from Watersheds

(runoff in inches)

<table>
<thead>
<tr>
<th>Year</th>
<th>No-Till</th>
<th>Conventional Till</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>0.1</td>
<td>5.5</td>
</tr>
<tr>
<td>1980</td>
<td>0.2</td>
<td>12.5</td>
</tr>
<tr>
<td>1981</td>
<td>0.0</td>
<td>5.6</td>
</tr>
<tr>
<td>1982</td>
<td>0.4</td>
<td>4.4</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>0.2</strong></td>
<td><strong>7.0</strong></td>
</tr>
</tbody>
</table>

**Percent of precipitation**

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<thead>
<tr>
<th></th>
<th>0%</th>
<th>16%</th>
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Coshocton, OH, no till was on 9% slope, conventional till on 6% slope. Average rainfall 42 inches
Tillage Effect on Evaporation

Monthly evaporation (inches)

Conventional till

No-till

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Tillage to Alleviate Cold Soil Syndrome

- Bright residue: High reflectance
- Residue: Low thermal conductivity
- High moisture: * Heat capacity of water 2x that of minerals
  * Thermal conductivity of wet soil 3-5 times that of dry soil
Soil Temperatures Corn Study

Soil temperature (F)

- No-till
- Zone-till
- Strip-till
- Chisel/Disk

2-3 degree difference
Soil Temperatures Corn Study

May 17, 2002

5 degree diff

May 17, 2002

No-till
Zone-till
Strip-till
Chisel/Disk

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Cold soils: corn problem
## Soil temperature and early corn growth

### southern Indiana

<table>
<thead>
<tr>
<th>Tillage system</th>
<th>Temp. (°F)</th>
<th>Height (&quot;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plow</td>
<td>79.3</td>
<td>82b</td>
</tr>
<tr>
<td>Chisel</td>
<td>75.9</td>
<td>76c</td>
</tr>
<tr>
<td>Ridge</td>
<td>77.5</td>
<td>81b</td>
</tr>
<tr>
<td>No-till</td>
<td>74.5</td>
<td>87a</td>
</tr>
</tbody>
</table>

8 wks after planting
Tillage and Organic Matter Stratification

1) Improve water efficiency by reducing runoff and increasing retention in soil

2) Improve nutrient cycling by slowing mineralization and immobilizing nutrients in organic fractions

3) Resist degradative forces of erosion and compaction

4) Improve soil biological activity

5) Enhance long-term productivity of soils.

Franzluebbers, 2002
Tillage Effect on Soil Structure

Aggregate stability (%)

- Long-term NT
- Short-term NT
- Chisel/disk
- Moldboard

Sampling depth:
- 0-2"
- 2-6"
- 6-10"

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Tillage effects on earthworms

Deep burrowing earthworms

No-till  Chisel plow  Moldboard plow

Shallow working spp

Edwards and Lofty, 1982
Longevity of No-Till Affects Microbial Biomass Carbon

Andrade, Colozzi-Filho and Giller, 2003
Tillage History and Microbial Biomass Carbon and Total Carbon

Tillage and Soil Fungi

Frey, Elliott, and Paustian, 1999
Soil profile modification in permanent no-tillage

Kooistra and Boersma, 1994
Better structure improves trafficability

Kooistra and Boersma, 1994
Long-term no-till soil resists compaction.

- 2 yrs old no-till
- Long-term no-till
- Subsoiled this spring
- 1 yr old no-till
Tillage and Soil P Distribution

<table>
<thead>
<tr>
<th>Depth (in)</th>
<th>Soil P Concentration (ppm)</th>
</tr>
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<tbody>
<tr>
<td>36</td>
<td>30</td>
</tr>
<tr>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>24</td>
<td>90</td>
</tr>
<tr>
<td>18</td>
<td>120</td>
</tr>
<tr>
<td>12</td>
<td>150</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>0</td>
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Zone of Interaction with runoff

Tilled
No-till

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Total P loss and Tillage

- Conventional till wheat
- Converted to no-till

Year:
- 1980
- 1985
- 1990
- 1995

Total P mg/L:
- 6
- 4
- 2
- 0
Tillage and Soluble P-loss

Converted to no-till wheat
Are Corn Yields Reduced in Long-Term, Continuous No-Tillage?
Tillage effects on corn yields Landisville, southeast PA

Yield (bu/A)

- No-Till
- ZT to 04
- ST to 04
- CD

NS

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Crop rotation to alleviate cold soil syndrome

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<thead>
<tr>
<th></th>
<th>No-Till</th>
<th>Conv.Till</th>
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<tbody>
<tr>
<td>Continuous Corn</td>
<td>112</td>
<td>125</td>
</tr>
<tr>
<td>Corn-Soybean</td>
<td>129</td>
<td>129</td>
</tr>
<tr>
<td>Corn/Soy/Meadow</td>
<td>127</td>
<td>133</td>
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</tbody>
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20-yr average corn yields (Bu/A) on a poorly drained Hoytville sicl, Ohio
Conclusion

Soil tillage and one crop agriculture devastated U.S. agriculture in the past

Soil tillage
• Reduces or eliminates mulch cover
• This increases erosion and runoff potential, and increases evaporation losses
• Reduces surface organic matter contents and aggregate stability
• Reduces earthworm populations and microbial populations
• Increases soil susceptibility to compaction
• Increases particulate P losses but may decrease soluble P losses

Continued improvement of no-tillage systems is needed - especially the lack of diversity and long fallow periods without living vegetation need to be addressed