Soil and Production Responses in Integrated Crop–Livestock Systems

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Ecologist

USDA

Watkinsville, Georgia USA
1. **Specialization**, based on considerations of:

- Climate
- Socioeconomics
- Infrastructure
- Markets

Leading to a focus typically on the most profitable system possible without high regard to other factors

Or most traditional system that fits climate/infrastructure domain of region without high regard to other factors
Sustainable Agricultural Systems

2. **Integration**, based on considerations of:
   - Climate
   - Socioeconomics
   - Infrastructure
   - Markets
   - Natural capital
   - Environmental impacts

Leading to diverse agricultural enterprises to balance production and economic gains with minimal negative influence on the environment.

Typically, systems that rely on natural capital rather than purchased capital to maximize resource efficiency.
Agriculture in the Southeastern USA

The 11-state region has the following characteristics compared with totals for the USA:
• 15% of the total land area
• 26% of farms
• 12% of farmland
• 38% of woodland on farms
• 14% of cropland
• 4% of pasture or rangeland

75% of broiler chicken inventory
• 68% of peanut (2.7 Mg ha⁻¹)
• 26% of layer chicken inventory
• 49% of cotton (0.7 Mg ha⁻¹)
• 21% of hog inventory
• 15% of cut forage (4.9 Mg ha⁻¹)
• 16% of cattle inventory
• 11% of wheat (4.2 Mg ha⁻¹)
• 3% of sheep inventory
• 11% of soybean (2.0 Mg ha⁻¹)
• 5% of corn (6.3 Mg ha⁻¹)

The Problem

Production
✓ Farms operating on marginal profit
✓ Economic vulnerability with specialized production
✓ High cost of fuel and nutrients
✓ Pest pressures becoming greater with monocultures
✓ To maintain yields, greater fossil fuel inputs needed

Environment
✓ Nutrient import / export discontinuity
✓ Pollution of water bodies due to poor nutrient cycling
✓ Soil erosion still occurring
A Solution

Integration could be beneficial:
- Agronomically
- Environmentally
- Economically
- Objectives -

✓ Quantify agronomic responses of crops to tillage and cover crop management
✓ Determine soil quality changes following cropping of previous land in pasture
✓ Estimate economics of crop and livestock production
- Experimental design -

**Tillage**

- Conventional tillage
- No tillage

**Cropping System**

- Winter wheat
- Summer grain sorghum

**Cover crop utilization**

- Biomass cut or rolled
- Grazed by cattle
Wheat / pearl millet cropping system

Plot 7 Ungrazed exclosure

No tillage

8 June 2006
Wheat / pearl millet cropping system

Plot 7
Grazed paddock

No tillage

8 June 2006
Corn / rye cropping system

Plot 11 Ungrazed exclosure

Disk tillage

8 June 2006
Watkinsville
Georgia

Integrated
Crop – Livestock
Study

Corn / rye
cropping system

Plot 10
Grazed paddock

No tillage

6 June 2005

[Image of field with corn crops]
Corn / rye cropping system
Plot 10
Ungrazed exclosure
No tillage

6 June 2005
Seasonal conditions

Precipitation and Evapotranspiration

- Cereal rye for grazing
- Sorghum for grain
- Wheat for grain
- Pearl millet for grazing
How did summer grain yield respond to tillage?

<table>
<thead>
<tr>
<th>Year</th>
<th>Tillage System</th>
<th>Pr &gt; t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Disk</td>
<td>No Till</td>
</tr>
<tr>
<td><strong>Sorghum Grain Yield (Mg ha⁻¹)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>1.35</td>
<td>0.76</td>
</tr>
<tr>
<td>2003</td>
<td>3.93</td>
<td>4.24</td>
</tr>
<tr>
<td>2004</td>
<td>0.50</td>
<td>0.90</td>
</tr>
<tr>
<td><strong>Corn Grain Yield (Mg ha⁻¹)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>6.94</td>
<td>7.69</td>
</tr>
<tr>
<td>Mean</td>
<td><strong>3.18</strong></td>
<td><strong>3.40</strong></td>
</tr>
</tbody>
</table>

Overall, no difference in yield between tillage systems.
How did winter grain yield respond to tillage?

<table>
<thead>
<tr>
<th>Year</th>
<th>Tillage System</th>
<th>Pr &gt; t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Disk</td>
<td>No Till</td>
</tr>
<tr>
<td>2003</td>
<td>2.69</td>
<td>2.71</td>
</tr>
<tr>
<td>2004</td>
<td>2.83</td>
<td>2.33</td>
</tr>
<tr>
<td>2005</td>
<td>2.69</td>
<td>2.75</td>
</tr>
<tr>
<td>Mean</td>
<td>2.73</td>
<td>2.60</td>
</tr>
</tbody>
</table>

*Wheat Grain Yield (Mg ha⁻¹)*

Overall, no difference in yield between tillage systems.
How productive and reliable were systems?

Grain Yield (Mg ha\(^{-1}\))
How did winter cover crop respond to tillage?

<table>
<thead>
<tr>
<th>Year</th>
<th>Tillage System</th>
<th>Pr &gt; t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Disk</td>
<td>No Till</td>
</tr>
<tr>
<td>2003</td>
<td>7.21</td>
<td>8.85</td>
</tr>
<tr>
<td>2004</td>
<td>6.67</td>
<td>6.95</td>
</tr>
<tr>
<td>2005</td>
<td>4.21</td>
<td>5.28</td>
</tr>
<tr>
<td>Mean</td>
<td>6.03</td>
<td>7.02</td>
</tr>
</tbody>
</table>

Ungrazed Rye Dry Matter Yield (Mg ha⁻¹)

NT improved cover crop growth compared with DT (16%)
How did summer cover crop respond to tillage?

<table>
<thead>
<tr>
<th>Year</th>
<th>Tillage System</th>
<th>Pr &gt; t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Disk</td>
<td>No Till</td>
</tr>
<tr>
<td>2002</td>
<td>5.28</td>
<td>5.89</td>
</tr>
<tr>
<td>2003</td>
<td>3.64</td>
<td>6.62</td>
</tr>
<tr>
<td>2004</td>
<td>4.36</td>
<td>3.75</td>
</tr>
<tr>
<td>Mean</td>
<td>4.46</td>
<td>5.83</td>
</tr>
</tbody>
</table>

*Numerical data indicates that No Till (NT) improved cover crop growth compared with Disk Tillage (DT) by 31%.*

**Ungrazed Pearl Millet Dry Matter Yield (Mg ha⁻¹)**
**How did summer grain yield respond to cover crop mgmt?**

<table>
<thead>
<tr>
<th>Year</th>
<th>Cover Crop Management</th>
<th>Pr &gt; t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ungrazed</td>
<td>Grazed</td>
</tr>
<tr>
<td><strong>Sorghum Grain Yield (Mg ha⁻¹)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>1.03</td>
<td>1.08</td>
</tr>
<tr>
<td>2003</td>
<td>4.42</td>
<td>3.75</td>
</tr>
<tr>
<td>2004</td>
<td>0.83</td>
<td>0.57</td>
</tr>
<tr>
<td><strong>Corn Grain Yield (Mg ha⁻¹)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>7.53</td>
<td>7.10</td>
</tr>
<tr>
<td>Mean</td>
<td><strong>3.45</strong></td>
<td><strong>3.13</strong></td>
</tr>
</tbody>
</table>

*Overall, no difference in yield between cover crop systems*
How did winter grain yield respond to cover crop mgmt?

<table>
<thead>
<tr>
<th>Year</th>
<th>Cover Crop Management</th>
<th></th>
<th></th>
<th>Pr &gt; t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ungrazed</td>
<td>Grazed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>2.76</td>
<td>2.64</td>
<td></td>
<td>0.46</td>
</tr>
<tr>
<td>2004</td>
<td>2.35</td>
<td>2.81</td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td>2005</td>
<td>2.78</td>
<td>2.67</td>
<td></td>
<td>0.75</td>
</tr>
<tr>
<td>Mean</td>
<td><strong>2.63</strong></td>
<td><strong>2.70</strong></td>
<td></td>
<td>0.60</td>
</tr>
</tbody>
</table>

Overall, no difference in yield between cover crop systems
How did tillage affect livestock responses?

<table>
<thead>
<tr>
<th>Year</th>
<th>Tillage System</th>
<th>Pr &gt; t</th>
<th>Tillage System</th>
<th>Pr &gt; t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Disk</td>
<td></td>
<td>Disk</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No Till</td>
<td></td>
<td>No Till</td>
<td></td>
</tr>
<tr>
<td><strong>Grazing Days (head days ha(^{-1})) – Winter</strong></td>
<td></td>
<td><strong>Summer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>--</td>
<td></td>
<td>518</td>
<td>455</td>
</tr>
<tr>
<td>2003</td>
<td>252</td>
<td>1.0</td>
<td>375</td>
<td>390</td>
</tr>
<tr>
<td>2004</td>
<td>301</td>
<td>0.07</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>2005</td>
<td>228</td>
<td>0.54</td>
<td>250</td>
<td>330</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>260</td>
<td>0.04</td>
<td><strong>386</strong></td>
<td><strong>394</strong></td>
</tr>
</tbody>
</table>

More grazing days with NT than DT in winter (32%), but the same in summer.

More grazing days in summer than in winter (29%)
How did tillage affect livestock responses?

<table>
<thead>
<tr>
<th>Year</th>
<th>Tillage System</th>
<th>Pr &gt; t</th>
<th>Tillage System</th>
<th>Pr &gt; t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Disk</td>
<td>No Till</td>
<td>Daily Gain (kg head⁻¹ d⁻¹) – Winter</td>
<td>Disk</td>
</tr>
<tr>
<td>2002</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1.74</td>
</tr>
<tr>
<td>2003</td>
<td>1.90</td>
<td>2.25</td>
<td>0.17</td>
<td>1.49</td>
</tr>
<tr>
<td>2004</td>
<td>1.81</td>
<td>2.26</td>
<td>0.25</td>
<td>0.60</td>
</tr>
<tr>
<td>2005</td>
<td>0.62</td>
<td>1.36</td>
<td>0.24</td>
<td>2.01</td>
</tr>
<tr>
<td>Mean</td>
<td>1.44</td>
<td>1.96</td>
<td>0.01</td>
<td>1.46</td>
</tr>
</tbody>
</table>

Greater cattle performance with NT than DT in winter (36%), but less difference in summer (13%).

Better performance in winter than in summer (10%)
How did tillage affect livestock responses?

<table>
<thead>
<tr>
<th>Year</th>
<th>Tillage System</th>
<th>Pr &gt; t</th>
<th>Tillage System</th>
<th>Pr &gt; t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Disk</td>
<td>No Till</td>
<td></td>
<td>Disk</td>
</tr>
<tr>
<td>2002</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>452</td>
</tr>
<tr>
<td>2003</td>
<td>239</td>
<td>283</td>
<td>0.17</td>
<td>286</td>
</tr>
<tr>
<td>2004</td>
<td>298</td>
<td>604</td>
<td>0.07</td>
<td>120</td>
</tr>
<tr>
<td>2005</td>
<td>76</td>
<td>163</td>
<td>0.13</td>
<td>250</td>
</tr>
<tr>
<td>Mean</td>
<td>204</td>
<td>350</td>
<td>0.01</td>
<td>277</td>
</tr>
</tbody>
</table>

Greater cattle gain with NT than DT in winter (72%), but less difference in summer (17%).

Greater cattle gain in summer than in winter (8%)
## Summary of production responses to tillage system

<table>
<thead>
<tr>
<th>Response</th>
<th>Sorghum / Rye</th>
<th></th>
<th>Wheat / Pearl Millet</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tillage System</td>
<td>Pr &gt; t</td>
<td>Tillage System</td>
<td>Pr &gt; t</td>
</tr>
<tr>
<td></td>
<td>Disk</td>
<td>No Till</td>
<td></td>
<td>Disk</td>
</tr>
<tr>
<td>Grain</td>
<td>3.18</td>
<td>3.40</td>
<td>0.36</td>
<td>2.73</td>
</tr>
<tr>
<td>Cover</td>
<td>6.03</td>
<td>7.02</td>
<td>0.01</td>
<td>4.46</td>
</tr>
<tr>
<td>Cattle</td>
<td>204</td>
<td>350</td>
<td>0.01</td>
<td>277</td>
</tr>
</tbody>
</table>

**Grain production was unaffected by tillage system.**

**Cover crop growth was enhanced with NT compared with DT in both systems, which led to greater cattle gain on rye.**
Will it pay to integrate cattle with cropping systems?

<table>
<thead>
<tr>
<th>Response (Corn 2005)</th>
<th>Disk Tillage</th>
<th>No Tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ungrazed</td>
<td>Grazed</td>
</tr>
<tr>
<td>← Variable</td>
<td>164</td>
<td>234</td>
</tr>
<tr>
<td>← Fixed</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Crop →</td>
<td>288</td>
<td>333</td>
</tr>
<tr>
<td>Cattle →</td>
<td>0</td>
<td>158</td>
</tr>
<tr>
<td>Return</td>
<td>24</td>
<td>157</td>
</tr>
</tbody>
</table>

$ / acre

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Integrated Crop – Livestock Study

USDA

Watkinsville
Georgia

Grazed
Ungrazed
Grazed
Soil Responses
How has soil changed with tillage?

Conventional tillage

No tillage
At initiation of this study, land was in long-term tall fescue pasture.

Land converted to cropping systems of wheat/pearl millet or sorghum/rye.
Soil Organic Carbon (Mg·ha⁻¹) (0-20 cm)

Years of Management

- No-tillage cropping
- Continuation of pasture
- Conventional-tillage cropping

Continuation of pasture

Integrated Crop – Livestock Study

Watkinsville
Georgia

USDA
Soil microbial biomass C followed a similar pattern as for total organic C. Relatively uniform distribution with depth under CT and maintenance of stratified distribution with NT.
Initially low surface bulk density (BD) with rapidly increasing BD with depth

Moldboard plowing loosened soil initially following tillage

However, after the first year, BD returned to a high level below 12 cm because of switch to shallow disk tillage

Soil Bulk Density (Mg m⁻³)

-10
-20
-30
0
1.0 1.2 1.4 1.6

Initiation

End of 3 years

Conventional tillage
No tillage

***

Watkinsville Georgia
Integrated Crop – Livestock Study
Penetration resistance (PR) was related to antecedent soil water content.

PR was: NT > CT especially when dry

Soil water content averaged:
- CT = 17.1%
- NT = 18.4%
Water infiltration was also related to antecedent soil water content.

At low water content, infiltration was:  
CT > NT  
Likely due to large pores from tillage.

With wet soil, infiltration was:  
NT > CT  
likely due to connected pores.

At average water content, infiltration was:  
NT = CT
Water-stable aggregates became smaller following plow tillage.

Soil under NT maintained aggregate size with time.

Smaller and less stable aggregates would lead to surface degradation (low soil organic C, low water infiltration, crusting).
How has soil changed with cover crop mgmt?

- Mowing in DT system
- Ungrazed
- Grazed
Whether cattle grazed cover crops or not, there was no impact on SMBC under CT.

Under NT, grazing improved SMBC within the surface 6 cm of soil probably due to plant processing through animal digestion.
Whether cattle grazed cover crops or not, there was no impact on bulk density under CT and NT, at least at the end of 2 years of management.
Whether cattle grazed cover crops or not, there was little impact on soil resistance, except at low soil water content.
Water infiltration tended to be lower under grazed than ungrazed condition, especially with high soil water content.

Grazing of cover crop tended to have a relatively minor impact on water infiltration, although more years of grazing might change the magnitude of this effect.
- Implications from study -

- No tillage preserved the stratified nature of soil organic and microbial C following long-term pasture, which helped preserve larger water-stable aggregates and maintain high water infiltration.

- Grazing of cover crops was greatly beneficial to production and had only minor or no detrimental effects on soil properties during 3 years.

- Integration of crops and livestock is possible to improve production and environmental quality.
Watkinsville Georgia

Integrated Crop – Livestock Study

Support

Soils and Soil Biology program of the USDA-NRI, Agr. No. 2001-35107-11126

Georgia Agricultural Commodity Commission for Corn

Steve Knapp  Eric Elsner  Stephanie Steed  Devin Berry  Faye Black, Kim Lyness