Is Deep Zone Tillage Agronomically Viable in Minnesota?

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Abstract
Deep zone tillage is a strategy used to alleviate compaction problems, including plow pans, and to improve internal drainage. Midwestern soils do not typically form a defined plow pan under normal production practices. Despite lack of scientific evidence for yield benefits associated with deep tillage, it is still used in Minnesota as a low cost alternative to tile drainage. To evaluate the soil and economic impact of deep zone tillage on crop yield when a restrictive layer is lacking, a 20-acre field was deep zone tilled to a 20-inch depth, every other 12 rows at 30-inch spacing. After zone tilling, the entire field was ridge tilled. Ridge tillage confines wheel traffic to the same rows, reducing the percent of the field trafficked. All crop and soil measurements were collected in the depressional and upland areas of the field to distinguish if zone till is of benefit in different landscape areas. Crop yields were measured for two seasons following zone tilling a ridge-tilled field. Zone till failed to increase corn and soybean yields. A restrictive layer was not observed in this field and as a result, potential economic losses occurred due to deep zone tillage.

Introduction
The size and mass of farm machinery used in row crop production has increased dramatically over the past half century, subsequently increasing the risk and the depth of soil compaction. Soil compaction increases penetrometer resistance and soil bulk density, which can impede water and air movement, and limit root proliferation, thereby reducing crop growth and yield. One strategy for ameliorating compaction below a ‘normal’ depth of tillage (8 to 12 inches) is subsoil tillage or subsoiling. The goal of this very aggressive tillage operation is to break up compacted layers in the soil profile to a depth of 16 to 20 inches and help with water infiltration and root growth. Zone tillage is a specific form of deep tillage designed to only disturb the soil in a narrow band directly below the crop row. The soil and residue in the inter-row are undisturbed providing surface cover and protecting the soil against erosion.

Research has been conducted for decades on the efficacy of deep plowing and other forms of subsoil tillage to ameliorate subsoil compaction (3,5,8,9,11,15). The results are mixed, even in areas with defined plow pans such as in the southeastern United States (12). It is difficult to accurately predict subsoil tillage affects on crop yield because of multiple factors, such as the intensity and depth of compaction, soil water content, subsequent traffic, variable weather conditions, the crop grown, and tillage methods (10).

Bly (2) analyzed 169 site years of subsoil tillage data in the United States and reported that subsoil tillage consistently resulted in increased crop yield only when a defined restrictive layer was observed. He reported average yield increases of 18, 7, and 10 bu/acre for corn, soybeans, and wheat, respectively, when a distinct root restrictive soil layer was present. In contrast, there was no yield advantage to using deep tillage when this layer was not present. Restrictive layers were mainly identified in the southern and coastal states such as Mississippi and North and South Carolina. Soils that did not exhibit a restricted
layer sufficient to inhibit root growth were typically from areas of the northern Corn Belt, e.g. Minnesota, Nebraska, North Dakota, and Wisconsin.

Despite the lack of consistent yield results in the Midwestern states (1,2,3,4,5,15) there is still considerable interest in subsoil tillage among producers and within the implement industry. Tillage, including deep tillage is used to improve soil drainage and infiltration, especially in poorly drained soils (1) and thus is viewed as a low-cost alternative to tile drainage.

The goal of this on-farm study was to determine if the effects of a single application of a deep zone tillage event improved corn and soybean yields at two landscape positions (upland and depression) characterized as somewhat and very poorly drained respectively. In addition, the goal was to assess related soil parameters in response to tillage.

### Evaluating the Impact of Deep Zone Tillage on Crop Yield

#### Site history

A field experiment was initiated in fall of 2002 with soil and crop response monitored in 2003 and 2004 in a producer’s field near Elrosa, MN. The field had been in a corn soybean rotation and had been ridge tilled for 16 years. A ridge till field was used to confine wheel traffic throughout the field and to assure the deep tilled zone would be directly under the crop grown.

#### Soil characterization

The field had two primary soils a Normania loam (Fine-loamy, mixed, superactive, mesic Aquic Hapludolls) on the upper portion of the landscape (upland position) and a Flom loam (Fine-loamy, mixed, superactive, frigid Typic Endoaquolls) on the depression portion of the landscape (depression position). The Normania soil series consists of very deep, somewhat poorly drained soils formed in glacial till with moderate permeability (9). The Flom soil series consists of very deep, very poorly drained soil with moderately slow permeability. The Ap horizon had an organic matter content of 4.8%.

#### Experimental design and treatments

The experimental field had two tillages: ridge tillage with zone tillage and ridge tillage without zone tillage, which alternated every other twelve rows across a 20-acre field to provide eight replications. The field was approximately divided into thirds with the northern third in a depression area and the southern third in an upland area (Fig. 1). At least four samples were collected for each of the two tillage treatments and landscape positions. The zone tilled rows were tilled in the fall of 2002 with a Brillion Farm Equipment (Brillion, WI) four-row tillage implement with 20-inch straight shanks, a 2-inch tip and 30-inch spacing (Fig. 2). After zone tillage, the ridges were re-ridged across the entire field. A Proc mixed model (SAS version 9.1, SAS Institute Inc. Cary, NC) with tillage and distance across the field, and position treated as fixed effects within each depression or upland position. Tillage treatments were alternated across the field but not randomized, therefore no random effects were included in the model.
**Parameters measured.** One time soil temperatures were measured at 2 inches below the row three weeks prior to planting in 2003. Soil temperatures were not collected in 2004. Corn was planted 3 May 2003 and soybean on 4 May 2004. Plant counts were taken from 20-ft row length in corn and 10-ft in beans, after plant emergence at three locations for each plot.

In 2003, soil samples were collected and split into 0 to 6-inch and 6 to 12-inch increments after corn emergence and to a depth of 0 to 6 inches in 2004. Microbial biomass and soluble carbon were estimated from these subsamples using the extraction and fumigation method (14) as an indicator of soil microbial activity (6,13). Soil biota provides important services such as nutrient cycling, decomposition, and improved soil tilth. Depth of tillage is one of several management practices that can impact soil biota. In general, as tillage depth and intensity increase soil biota decrease (6,13).

Penetrometer resistance was chosen as a nondestructive, fast, low-cost indicator of soil compaction. Penetrometer resistance and soil moisture were collected three weeks after planting. Penetrometer readings were taken to a depth of 20 inches at 0.5-inch increments in 2003, and to a depth of 24 inches at 0.4-inch increments in 2004. Penetrometer measurements were taken directly in the row (site of tillage), 7.5 inches from the row, and 15 inches from the row at three locations within each plot.
Corn test weight, grain moisture, and yield were collected 17 October 2003 and soybean yield was measured at harvest on 9 October 2004. During harvest, yield was taken from the middle eight rows of the 12-row plots. The combine and yield mapping program was calibrated using a weigh wagon prior to harvest. The length of the plots was 500 feet.

**Soil Data**

We did not detect any difference in soil temperatures measured directly in the row at a 2-inch depth in 2003 due to landscape position or tillage treatment (*data not shown*). In the upland position, soil soluble C averaged 430 and 355 µg C per g soil at 0 to 6 in 2003 and 2004, respectively (Table 1). Tillage treatment did not statistically effect soil soluble C at the 6 to 12-inch depth in 2003 (*data not shown*). Similarly, there was little variability in microbial biomass C in the upland position due to tillage. In the depression area during 2003 but not in 2004 a distance by tillage interaction was observed, which suggests that a trend for soluble C may be different for each tillage system in the surface 6 inches. There were no apparent difference in microbial biomass C in the depression area, averaging 1.43 µg C per g soil for both years and depths (6 to 12-inch soil depth *data not shown*). Depth of tillage has been indicated (6) as one of the major drivers of microbial biomass within locations, however, it was not observed in this field after one pass of zone tillage.

Table 1. Soil biology indicators, soluble C, and microbial biomass C across the field at soil depths of 0 to 6 inches in two landscape positions: Upland position (UP) and in a Depression area (DA) of the field, both had ridge tilled (RT) only or ridge tilled after deep zone tillage (RT with ZT).

<table>
<thead>
<tr>
<th></th>
<th>2003</th>
<th>2004</th>
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<tbody>
<tr>
<td></td>
<td>UP</td>
<td>DA</td>
<td>UP</td>
<td>DA</td>
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<tr>
<td><strong>Soil soluble C</strong> (µg C per g soil)</td>
<td></td>
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<td></td>
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<tr>
<td><strong>Microbial biomass C</strong> (µg C per g soil)</td>
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<tr>
<td><strong>Tillage</strong></td>
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</tr>
<tr>
<td>RT</td>
<td>410</td>
<td>690</td>
<td>330</td>
<td>570</td>
</tr>
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<td>710</td>
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<td>670</td>
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<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Distance (D)</td>
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<td>0.01</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>D*T</td>
<td>NS</td>
<td>0.03</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

* NS= Probability of significant exceeds 5%.

The impact of zone tillage on penetrometer resistance was observable in the row in 2003 below 12 inches and to a lesser extent between the rows (Fig. 3a). By 2004, penetrometer resistance as affected by deep zone tillage was no longer discernable (Fig. 3b).
Fig. 3. Penetrometer resistance by depth, treatment and placement in the row (shank centered on row during 2002 tillage) for 2003 (A) and 2004 (B). Penetrometer measurements were taken directly in the row, 7.5 inches from the row, and 15 inches from the row at three locations within each plot.
Crop Response

Corn. Corn plant population averaged 30,140 plants per acre; there were no differences in stand between the upland and the depression area of the field. Corn grain yields averaged 29 bu/acre more in the upland site compared to the depression site, which was attributed to better internal soil drainage. There was no difference in grain moisture attributed to landscape position (Table 2). There was no evidence that zone tillage changed corn yield or grain moisture at harvest.

Table 2. Average grain moisture and corn yield at harvest in 2003 measured at two field sites with contrasting landscape positions – an Upland position and a Depression area of the field – which were either ridge tilled only (RT) or ridge tilled after deep zone tillage (RT w/ZT).

<table>
<thead>
<tr>
<th>Tillage</th>
<th>UP</th>
<th>DA</th>
<th>Moisture (%)</th>
</tr>
</thead>
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<tr>
<td>RT</td>
<td>183</td>
<td>156</td>
<td>22.5</td>
</tr>
<tr>
<td>RT w/ZT</td>
<td>185</td>
<td>155</td>
<td>21.5</td>
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</table>

<table>
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<tr>
<th>Probability</th>
<th>Tillage (T)</th>
<th>Distance(D)</th>
<th>D*T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

x Yield was corrected to 15% moisture.

y NS = Probability of significant exceeds 5%.

Soybean. Soybean yields were nearly double in the drier area of the field compared to the lower, wetter, poorly drained soil (Table 3). Ponded water in the poorly drained soil likely reduced yields. There was no evidence to support a yield increase provided by zone tillage. Distance was significant which indicated there was a linear trend in soybean yields across the field, since the strips were alternating and not randomized the estimates of tillage impacts are biased by position across the field. Meaning the impact of tillage could be confounded by position. Grain moisture varied less than 1% with the ridge tillage plus zone tillage in the upland position the driest.

Table 3. Average soybean grain moisture and yield at harvest in 2004 measured at two field sites with contrasting landscape positions – an Upland position and in a Depression area of the field – which were either ridge tilled only (RT) or ridge tilled after deep zone tillage (RT w/ZT).

<table>
<thead>
<tr>
<th>Tillage</th>
<th>UP</th>
<th>DA</th>
<th>Moisture (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT</td>
<td>32.1</td>
<td>14.2</td>
<td>11.3</td>
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<tr>
<td>RT w/ZT</td>
<td>32.8</td>
<td>17.4</td>
<td>10.6</td>
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<table>
<thead>
<tr>
<th>Probability</th>
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<th>Distance(D)</th>
<th>D*T</th>
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<tbody>
<tr>
<td>Probability</td>
<td>NS</td>
<td>NS</td>
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</table>

x Yield was adjusted to 13% moisture.

Soil Profile

Three 4-ft soil pits were dug across tillage treatments in 2003. Visual inspection of the root profile revealed evidence of where the shank passed under the row (Fig. 4a). It was also clear that roots extended to the same depth regardless of zone tillage treatment (Fig. 4b). In addition, there is no appearance of a distinct plow pan visible. This is consistent with the penetrometer observations (Fig. 3a and 3b).
Economic Analysis

The producer spent extra time, fuel, and money to zone till his field. While there was a substantial yield increase due to landscape position there was no yield increase due to zone tillaging (Tables 2 and 3) which is consistent with Bly’s data (2). For this study, there was no evidence to suggest zone tillage as an economical way to increase crop yield. In 2002, the University of Minnesota Custom Rate Survey cited that the average cost to zone till was $17.50 an acre (7). The price has increased substantially for 2009 at $22.25 an acre. Assuming the value of corn is $3.00/bu and soybeans are $7.00/bu, a producer would either need to increase his corn yields by 5.8 bu/acre or his soybean yield by 2.5 bu/acre to cover the cost of the zone tillage.

Discussion

This on-farm study did not provide evidence that subsoil zone tillage in soil without a restrictive layer improves yield. In the absence of yield increase there would be no economic incentive to zone till. These results are consistent with other studies, which reported few yield benefits to subsoil tillage in soils relatively high in organic matter, such as those found in Minnesota and lacking distinct root restriction (2,3,4,5,15). In the coastal plains soils of southeastern United States, there is a higher probability for increased yields in response to deep subsoil tillage, when deep tillage penetrates root restricting plow pans (12). Digging soil pits provided clear evidence of comparable rooting depths with and without zone tillage (Fig. 4), which was consistent with the penetrometer resistance patterns observed (Fig. 3b).

The results of the study together with other published research find minimal yield or economic return on subsoil tillage. Prior to investing the time and money in subsoil tillage at the very least a visual or penetrometer check for defined root impedance would be recommended.

Acknowledgments

The authors wish to thank Dr. Gyles Randall for his constructive comments, Dr. David Archer for statistical advice and to the entire Illies family for their hard work and interest. This research and outreach effort was supported by funds from the Crop Production Research Foundation, the University of Minnesota Extension, and the USDA-ARS in Morris, MN.

Literature Cited