Mapping of Spatial and Vertical Variation of Soil Mechanical Resistance Using a Linear Pressure Model

Viacheslav Adamchuk
Biological Systems Engineering
University of Nebraska-Lincoln

Mark Morgan
Hartono Sumali
Agricultural and Biological Engineering
Purdue University

July 30, 2001

Reasoning

- There is a need to continuously measure soil mechanical resistance at various depths
- A vertical smooth blade is a simple mechanical system (cantilever beam) that can be pulled through the field
- An array of strain gauges can be used to detect blade’s deflection resulting from variable soil resistance loads

Soil Resistance Measurement

Effect of Soil Compaction
(Tipton Co, Indiana)

Highly Compacted Area (Low Yield)
Normal Soil Conditions (High Yield)

1998

1999

2000
Soil Resistance Measuring Systems

Soil Resistance Parameters

\[
\begin{bmatrix}
-p_1 \\
-p_2
\end{bmatrix} =
\begin{bmatrix}
0.0157 & 0.0062 & 0.0128 & -0.0136 \\
-0.0441 & 0.0054 & -0.0070 & 0.0273
\end{bmatrix}
\begin{bmatrix}
\epsilon_1 \\
\epsilon_2
\end{bmatrix}
\]

- \( p_1 \) = soil resistance 25 cm below surface, MPa
- \( p_2 \) = soil resistance 15 cm below surface, MPa
- \( p \) = average soil resistance, MPa
- \( P_p \) = soil resistance change with depth, MPa/m

\[
p = \frac{1}{3} p_1 + \frac{5}{12} p_2
\]

\[
p_0 = \frac{P_p}{z_2 - z_1}
\]

Laboratory Test

Load 4448 N (1000 lbf)

Field Mapping

25 cm below surface  15 cm below surface
**Tillage Plots Test**

<table>
<thead>
<tr>
<th>Tillage</th>
<th>Moisture</th>
<th>Cone Penetrometer</th>
<th>Soil Resistance Measuring System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot</td>
<td>%</td>
<td>25 cm MPa</td>
<td>15 cm MPa</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test 1 (04/16/01)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chisel</td>
<td>24</td>
<td>1.3</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No-tilt 1</td>
<td>28</td>
<td>1.8</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No-tilt 2</td>
<td>26</td>
<td>1.7</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plow</td>
<td>27</td>
<td>1.0</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test 2 (04/20/01)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chisel</td>
<td>25</td>
<td>1.3</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No-tilt 1</td>
<td>26</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No-tilt 2</td>
<td>26</td>
<td>1.9</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plow</td>
<td>27</td>
<td>1.2</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Conclusions**

- A vertical smooth blade can be used to map spatial and vertical variation of soil resistance
- Mathematical equations were proven through a laboratory test
- A commercial field was mapped to identify specific compaction related field areas
- Tillage plots test was conducted to compare vertical blade and cone penetrometer methods

**Future Work**

- Depth control
- Eliminating plant residues
- Data collection improvement
- Moisture and travel velocity compensation
- Usage of soil resistance maps
- Agroeconomic evaluation

http://bse.unl.edu/adamchuk
E:mail: adamchuk@eng.unl.edu