3 topics I’m working on

- Residue removal
  - What’s going on, effects on soil/soil-water
- Compaction
  - Types, Causes, Assessing, Addressing
- New vertical tillage implements
  - Use and benefits?
Abengoa Bioenergy

- Building an ethanol plant in Hugoton, supposed to break ground in 2010
- In 2008, the plan was to:
  - Produce ethanol from both grain and biomass (490,000 tons/year)
- Currently, the plan is to:
  - Only produce from biomass (875,000 tons/year)

Note: 200 bu/ac corn ≈ 5.6 tons/ac residue and we need to leave at LEAST 30% of it out there for conservation compliance
Residue removal experiments

- 2008: Two soil types in Stevens Co
  - Practical removal method vs. no removal
    - Stalk-chop, rake, and bale took off 90% of residue
  - Strip-till, farmer-owned
- 2009: Ottawa, Colby, Hugoton
  - 5 levels of removal
  - NT at experiment fields, ST on farmer
- Objectives for both: Effects on continuous corn yields, soil properties, water dynamics
Residue changes throughout the winter

Residue levels dropped over the winter
- 20-30% for returned plots
- 30-40% for removed plots

Why more loss for harvested? Because raking and baling removed the largest pieces of residue

30% is the bare minimum residue % for conservation compliance

Most people assume 10% loss over winter!!!
Aggregates (soil structure) got smaller during the winter.

No effect of removal on loam.

Significant effect on sandy soil.
Wind erodible fraction:

Increased over winter

Residue removal worse for sandy soil
Soil temp generally warmer for plots w/out residue by $\approx 1^{\circ}\text{C}$, warm up slower when air temp increases.
Plots w/out residue drier for most of this period

Freeze-thaw event in late January: Plots w/out residue froze, plots w/residue didn’t
--This is why wind-erodible fraction increases over winter, structure deteriorates (but can loosen surface compaction, i.e, “mellow”)

Soil Water December 2008 to April 2009 in Bigbow Fine Sandy Loam

- Moisture θ
- Temperature °C
- Soil θ Returned
- Soil θ Removed
- Air Temp °C
Soil Compaction

NE Iowa, Harvest 2009
Top 10 Reasons to Avoid Soil Compaction

- Causes nutrient deficiencies
- Restricts root development
- Reduces soil aeration
- Decreases soil available water
- Reduces infiltration rate
- Increases bulk density
- Increases sediment and nutrient losses
- Increases surface runoff
- Damages soil structure
- Reduces crop productivity
  - Quantity depends on degree of compaction
  - Root restriction
<table>
<thead>
<tr>
<th>Country</th>
<th>Soil texture</th>
<th>Crop</th>
<th>Yield reduction %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>Clayey</td>
<td>Corn</td>
<td>70</td>
</tr>
<tr>
<td>Finland</td>
<td>Mollic gley</td>
<td>Oat, wheat, barley</td>
<td>1-4</td>
</tr>
<tr>
<td>Morocco</td>
<td>Clay loam</td>
<td>Wheat</td>
<td>23</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Sandy</td>
<td>Corn slage</td>
<td>38</td>
</tr>
<tr>
<td>Spain</td>
<td>Loam</td>
<td>Seed cotton</td>
<td>28</td>
</tr>
<tr>
<td>Sweden</td>
<td>Loam</td>
<td>Wheat</td>
<td>11</td>
</tr>
<tr>
<td>USA</td>
<td>Clayey</td>
<td>Corn</td>
<td>24</td>
</tr>
<tr>
<td>USA</td>
<td>Clayey</td>
<td>Sorghum</td>
<td>39</td>
</tr>
<tr>
<td>USA</td>
<td>Clayey</td>
<td>Oat</td>
<td>31</td>
</tr>
<tr>
<td>USA</td>
<td>Silt loam</td>
<td>Barley</td>
<td>14</td>
</tr>
<tr>
<td>USA</td>
<td>Silt loam</td>
<td>Pea</td>
<td>28</td>
</tr>
<tr>
<td>USA</td>
<td>Silt loam</td>
<td>Corn</td>
<td>14</td>
</tr>
<tr>
<td>USA</td>
<td>Clay loam</td>
<td>Corn</td>
<td>30</td>
</tr>
</tbody>
</table>

Ishaq, Ibrahim, and Lal, 2006
Soil Components

- Pore Space
- Minerals
- Organic Matter

Pores contain gases and liquids
Soil structure

- **Arrangement of soil particles into larger units**
- **Good structure** = greater load-bearing capacity, better drainage

<table>
<thead>
<tr>
<th>Structure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granular</td>
<td>Resembles cookie crumbs and is usually less than 0.5 cm in diameter. Commonly found in surface horizons where roots have been growing.</td>
</tr>
<tr>
<td>Blocky</td>
<td>Irregular blocks that are usually 1.5 - 5.0 cm in diameter.</td>
</tr>
<tr>
<td>Prismatic</td>
<td>Vertical columns of soil that might be a number of cm long. Usually found in lower horizons.</td>
</tr>
<tr>
<td>Columnar</td>
<td>Vertical columns of soil that have a salt “cap” at the top. Found in soils of arid climates.</td>
</tr>
<tr>
<td>Platy</td>
<td>Thin, flat plates of soil that lie horizontally. Usually found in compacted soil.</td>
</tr>
<tr>
<td>Single Grained</td>
<td>Soil is broken into individual particles that do not stick together. Always accompanies a loose consistence. Commonly found in sandy soils.</td>
</tr>
</tbody>
</table>

*Source: Soil Science Society of America*
Assessing compaction

- Best tool is a spade or soil probe
- Look at soil structure, plant roots
- Determine exact depth (or location) where problem exists
- Use cone penetrometer if soils are at field capacity
  - 10 points per zone in field (endrows, soil type, etc)
- Make several observations
Penetration resistance

At field capacity, >300 psi is root limiting.
Need to know moisture content, and something
about soil properties to really understand this.
Assessing compaction

At FC

>300 PSI
(or >2000 kPa)

Is root-limiting

cropsoil.psu.edu

The penetrometer simulates root growth. Root growth decreases linearly with increasing resistance, until practically stopping above 300 psi. Remember, however, that roots may still penetrate soil with a resistance greater than 300 psi if natural cracks and pores are present.
Surface crusts may prevent seedling emergence.

May be removed with freeze/thaw and wet/dry cycles.
Penetration Resistance and Soil Depth: Barton County, November 2009

- Average depth of compaction: 3 to 7 inches
- NT since 2004, crops grown include wheat, sorghum, soybean
- Grazing cattle on sorghum stalks

Root limiting = 300 p.s.i at FC
Surface compaction: 0-6”

- Caused by wheel traffic, animals
  - Cattle: 30 to 60 psi, affect upper 2--8” of soil

- Can be controlled by “spreading out” a load, either by using a larger tire or more tires, perhaps “new” tracks

- Tire pressure: 1-2 lbs greater than inflation pressure of the tire

- Usually removed with subsequent tillage operations or, usually by freeze-thaw and wet-dry cycles
  - How well this works depends on the weather, climate, on the cropping system, residue management, soils, etc.
Tillage-induced compaction: Depth of tillage

- Tillage implements that shear the soil, such as moldboard plows, disks, and sweep-type tools
- When continuously operated at the same depth, tillage implements orient soil particles in the same direction
- Potential to cause a tillage pan is greater under wet soil conditions than under dry conditions.
Tillage pan
Sub-surface compaction: >6”

- Deep compaction is related to the maximum axle load, and is not reduced by distributing the weight across more tires or larger tires.
- Annual compaction with 10 ton axle load reduced corn yield by 17% in 3 out of 4 yr in a silt loam.
  - Pennsylvania (Duiker, 2006)
- Subsoil compaction is rare with axle loads under 5 tons and highly likely with loads greater than 10 tons per axle.
Subsurface compaction

- Axle weight is not reduced by distributing the weight between more tires on the same axle or using tires with larger footprints.
- Axle weight is only reduced by adding more axles
- Weight not always distributed evenly between axles
Heavy equipment

- What does a 1050-bu grain cart weigh?
  - Empty: 19,700 lbs
  - Grain: 1050 bushels of grain @ 56 lbs per bushel = 58,800 lbs

- Subtract 8,000 lbs transferred to tractor

- Total: 65,800 lbs

- Axle load = 35 tons (1 axle)

  Tires: 520/85R38 (20.8" x 38")
  7000 lbs at 23 psi, flat plate is 443 in²
  So surface pressure is 25 psi,
  Axle load is 35 tons

Specs: Kinze 1050 Row Crop Wagon
## Approximate axle loads for field equipment

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Axle Load (Tons/axle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure slurry tanker, 4,200 gal.</td>
<td>10-12</td>
</tr>
<tr>
<td>Manure slurry tanker, 7,200 gal.</td>
<td>17-18</td>
</tr>
<tr>
<td>12-row combine, empty</td>
<td>18</td>
</tr>
<tr>
<td>12-row, full with head</td>
<td>24</td>
</tr>
<tr>
<td>720 bu grain cart, full, 1 axle</td>
<td>22</td>
</tr>
<tr>
<td>Grain cart, 1,200 bu., 1 axle</td>
<td>35-40</td>
</tr>
<tr>
<td>Grain cart, 1,200 bu., 2 axles</td>
<td>17-20</td>
</tr>
<tr>
<td>4WD Tractor, 325 HP, front axle</td>
<td>13</td>
</tr>
<tr>
<td>4WD Tractor, 200 HP, front axle</td>
<td>7.5</td>
</tr>
<tr>
<td>MFWD Tractor, 150 HP, rear axle</td>
<td>6.5</td>
</tr>
</tbody>
</table>

If less than 10 tons per axle, compaction is generally restricted to the upper foot or less of soil.

http://www.extension.umn.edu/
The greater the axle load, the deeper compaction will travel in soil.

Higher soil moisture means that soil will be compacted to a greater depth.
Moisture matters

www.extension.iastate.edu

“Ruts that look the worst are actually the best kind to have!”
Tracks or tires?

- Whether the equipment uses tracks or tires, the total axle load is nearly the same.
- Tracks will improve traction and ride-ability, but a 25-ton per axle grain cart will still create subsurface compaction.
- “New” tracks: Configured better, first tracks still basically on 2 axles.
Wheel traffic—Key point

- First pass of a wheel causes 70 to 90% of the total compaction
  
  (Gill, 1967)
Addressing compaction

- Besides prevention...
- Diverse crop rotation is one of the best solutions
  - Including any kind of taproot is beneficial
- Maintaining adequate residue protects surface, builds structure
- Does tillage work or does the benefit last?
Cover crops and roots

Cover Root Channels May Alleviate Soil Compaction Effects on Soybean Crop (Williams and Weil, 2004, SSSAJ)

- Two possible reasons
  1. Forage radish provided low-resistance paths into the subsoil (biodrilling)
  2. Rye provided a mulch that limited evaporation from the soil surface and increased infiltration early in the growing season.
Tillage to address compaction

- Surface smoothing of ruts, rills, etc, use vertical tillage implement
  - Most farmers currently using multiple passes with field cultivator
- Surface (<8”) treat with a chisel plow
- Deep tillage defined as 16 to 20”
Smoothing harvest ruts

- Have to wait until soil is dry again
- One option is to leave it until next fall
- Cost/benefit:
  - Dealing with reduced yield for one year vs.
  - Spending time, energy to deal with it prematurely, possibly causing more damage in the process
When to deal with compaction: When soil is dry enough to shatter again (Stevens Co. Dec 2008)
How long does the benefit last?

- Depends on the producer
  - Traffic on field
  - If they work in wet conditions

Most studies, about 2 years (up to 5)
Subsoiling in conventional tillage: Ohio

- In a plow-based system
  - Primary and secondary tillage, at angles
  - Uncontrolled traffic
- Subsoil one fall
- How long does the benefit last?
- In 2 years, will have trafficked across 75% to 90% of that field (Reeder, 2006)
- Tilled soil is more compactable than well-aggregated soil
Bly (2002) analyzed 169 site years of subsoil tillage data in U.S.

Subsoiling increased crop yield only when a defined restrictive layer was observed

- +18 bu corn
- +7 bu soybeans
- +10 bu wheat

Not economical if there was no compaction

More economical in SE U.S. (low o.m. soil, non shrink-swell clays)
Ottawa, KS study (Keith Janssen)

<table>
<thead>
<tr>
<th>Tillage system and frequency</th>
<th>Corn 6 yr avg</th>
<th>Soybean 6 yr avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-till</td>
<td>98</td>
<td>35.4</td>
</tr>
<tr>
<td>Chisel every year</td>
<td>100</td>
<td>36.6</td>
</tr>
<tr>
<td>Subsoil every year</td>
<td>103</td>
<td>37.0</td>
</tr>
<tr>
<td>Subsoil every other year</td>
<td>99</td>
<td>37.3</td>
</tr>
<tr>
<td>Subsoil every third year</td>
<td>105</td>
<td>37.9</td>
</tr>
</tbody>
</table>

Note: These yields are not statistically different.

Chisel: 5 to 7 inches
Subsoil: 8-14 inches

Averaged across all six years, which included both average and below average moisture years.

Simple math here: If yield isn’t different, Economics aren’t either.
Subsoiling facts

- Subsoiling when it is too wet will only move the compaction zone deeper
- Must wait until very dry (right after harvest?)
  - If this fall is too wet, have to wait for the next dry opportunity
- Cause fracturing
- Only go 1” below the current zone
- Shank spacing = depth of compaction
- Power requirement quadruples as depth is doubled
Vertical tillage
Case, Great Plains, Landoll, Salford, etc.
### Vertical tillage
*(Presley and Hallauer, 2009)*

<table>
<thead>
<tr>
<th>Physical Properties</th>
<th>Depth (in)</th>
<th>VT mean</th>
<th>NT mean</th>
<th>p-value, t-test**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk density (g cm(^{-3}))</td>
<td>0-2</td>
<td>1.13</td>
<td>1.21</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>2-4</td>
<td>1.29</td>
<td>1.30</td>
<td>0.92</td>
</tr>
<tr>
<td>Mean Weight</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>0-2</td>
<td>1.44</td>
<td>1.62</td>
<td>0.04</td>
</tr>
<tr>
<td>Infiltration (mm hr(^{-1}))*</td>
<td>Surface</td>
<td>21.4</td>
<td>44.0</td>
<td>0.04</td>
</tr>
</tbody>
</table>

No emergence, stand, or yield differences in 2009 soybeans. This field had beautiful soil properties to begin with, NT since the 1980’s.
Avoiding compaction

- Stay off wet soil
- Properly inflate tires
- Reduce the load size (<10 tons)
- Consider controlled traffic
- Use a crop rotation
- Increase crop residues
- Increase soil organic matter to improve soil structure
<table>
<thead>
<tr>
<th>Type</th>
<th>Cause</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>Raindrop, traffic, animals</td>
<td>Residue cover, freeze thaw, decrease tire pressure, floaters, duals</td>
</tr>
<tr>
<td>Shallow subsurface</td>
<td>Tillage Planter</td>
<td>Vary tillage depth or eliminate tillage</td>
</tr>
<tr>
<td>&lt; 8”</td>
<td></td>
<td>Don’t work when wet</td>
</tr>
<tr>
<td>Deeper subsurface</td>
<td>Axle load</td>
<td>Reduce axle load to under 10 tons in field (keep heavy equip in endrows)</td>
</tr>
<tr>
<td>8-30”</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>