Yield Monitors
Collecting and Utilizing Data

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Lets talk about the hardware....
Yield Monitoring Process

• Yield Data is simply mass divided by the area of removal (lbs/acre) and associated with a Latitude / Longitude Point

Yield Monitoring Hardware

Mass Flow Sensor

DGPS antenna and receiver

Yield monitor console and data card

Grain moisture content sensor

Travel speed sensor

Head position sensor

Harvest Site Location
(Degrees Latitude, Longitude)

Harvest Site Width

Harvest Site Length

Harvest Site Location

Harvest Site Area

Area and Yield Calculations

\[
\text{Yield Site Area (acre)} = \frac{\text{Length (ft) x Width (ft)}}{43,560 (ft^2/acre)}
\]

\[
\text{Harvest Site Yield} = \frac{\text{Grain Volume (bu)}}{\text{Harvest Site Area (acre)}}
\]

Yield Data Table:

<table>
<thead>
<tr>
<th>Harvest Travel distance speed</th>
<th>Harvest Site Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 mph</td>
<td>4.4 feet/sec</td>
</tr>
<tr>
<td>4 mph</td>
<td>5.3 feet/sec</td>
</tr>
<tr>
<td>5 mph</td>
<td>6.3 feet/sec</td>
</tr>
<tr>
<td>6 mph</td>
<td>7.3 feet/sec</td>
</tr>
</tbody>
</table>

*For 1-sec logging interval
Measuring Grain - Volume

• Methods
  – Light (RDS, Loup, Claas, Topcon)
  – Radiation
• Benefits
  – Simple and Cheap
• Problems
  – We sell weight, not volume
  – Test weight becomes a factor
  – MOG becomes a factor
  – Radiation not “acceptable”

Measuring Grain - Mass

• Methods of Measurement
  – Weight (Schrock, et al.,)
  – Torque (Chaplin, et al.,)
  – Flow (force) (Meyer, et al.,)
Measuring Grain – Mass

• Benefits
  – Accurate
  – Measures what we sell
  – Immune to test weight and MOG

• Problems
  – Requires a more intense calibration
  – Requires more mathematics / real-time processing
  – Geometry and dynamics of grain flow
Yield Monitor Calibration - General

• Confirm the accuracy of the moisture tester and weighing device used as a check (weigh wagon, truck scale, grain cart scale, etc.)

• Sample loads for mass flow should be of ample size (3000 lbs) and each should be harvested at a consistent flow rate (bu./hr).

• Samples for moisture sensor calibration should be relatively small, not on a truck load basis

Yield Monitor Calibration

Flow Rates for Calibration

• Full Flow – Drive faster than normal harvest speed (additional 1 - 2 mph), ensure the combine is operating at maximum capacity, note this flow rate (bu./hr)

<table>
<thead>
<tr>
<th>Blank Area</th>
<th>Full Flow</th>
<th>1/4 Full Flow</th>
<th>1/2 Full Flow</th>
<th>3/4 Full Flow</th>
<th>Additional Pass As Needed</th>
<th>Blank Area</th>
</tr>
</thead>
</table>

Additional Pass As Needed
System Differences

- **John Deere, prior to S-series**
  - Advantage – easy to calibrate – 2 points
  - Disadvantage – Only 2 point – not as accurate

- **Ag Leader Type Systems**
  - Advantage – multistep calibration curve is more accurate
  - Disadvantage – more time/loads needed to calibrate
Yield Monitor Calibration

• After calibration procedure error should be approximately 1.5 - 2.5%

• If error exceeds 5.0% then add additional calibration loads or remove loads that are suspect (observe individual load errors)

Producer Implementation of Precision Ag

• Better whole-farm management
  – On-Farm Research
  – Logistics / Machinery Management

• Better whole-field management
  – Making changes from field to field

• Site Specific Management
  – Same process, different scale

• Better management beyond the farm – “Big Data”
Yield Monitor Adoption History

Properties of Yield Data

- Error laden
- Often lacking in meta-data
  - Hybrids (split-planter), weather, etc.
- Temporal density dependent on:
  - Rotation, crop failures, combinability of crops
- **Spatially dense data**
- It is our **best** measurement of what we are trying to manage
Is yield monitor data, big data, small data, or medium data?

YES

Yield Data Transcends Spatial Scales

• Small Data – Site and Time Specific
• Medium Data
  – Site Specific across Time
  – Field Level Data
  – Farm Level Data (Machinery Management)
• Big Data – Large Datasets Aggregated Across Space-Time
  – Regional, National, or Global Scale Across Time
Advantage of Dense Data

Spatially and/or temporally dense data can be scaled up to any scale needed

however.....

Spatially and/or temporally sparse data can’t be scaled down
(or only with a lot of error included)

Yield Data Transcends Temporal Scales

• Single Year Information Value
  – Nutrient removal in current crop
  – Hybrid A vs. Hybrid B

• Multi-Year Information Value
  – Spatial-Temporal Yield Stability
## Hybrid Evaluation

### West School Land Evaluation Strips

<table>
<thead>
<tr>
<th>Difference</th>
<th>3150AG vs. TB055</th>
</tr>
</thead>
<tbody>
<tr>
<td>T3132LL</td>
<td>-0.95</td>
</tr>
<tr>
<td>T3054LL</td>
<td>-13.8</td>
</tr>
<tr>
<td>3111</td>
<td>-19.56</td>
</tr>
<tr>
<td>T3133</td>
<td>-26.6</td>
</tr>
</tbody>
</table>
On-Farm Research Opportunities

- Grain Sorghum in 2012
- No-till summer fallow 2013
- 20 lbs. P2O5 on 8-29 with Case Nutri Placer
- Planted 9-26-2013
- TAM-111 Certified seed
- Ascend blended @ 4oz./cwt seed ($4.08/ac)
- 60 lbs/acre
- Drilled with 30 foot Great Plains HD double disc drill
- Treated strips 180 feet wide
- Untreated strips 180 feet wide
- Harvested with 32’ Stripper Head

Wheat After Cover Crop Study

- Strip plot design
- 3 replications of 4 treatments
- 100ft wide strips
- Ensures at least 1 clean yield monitor pass
Average field capacity difference between 8R and 12R corn head of 3.87 ac hr\(^{-1}\). At $221 \text{ hr}^{-1} \text{ machine cost that’s } $3.44 \text{ ac}^{-1}$.

Site-specific management of inputs

- **Which input?**
  - Has a strong yield – input relationship
  - Data are available to drive the development
  - Opportunity for economic return
  - Ease of implementation
    - Data
    - Software
    - Method, product, and timing of application
What data?

• What data sources would be useful in site-specific nutrient management?
  – What is our recommendation framework
  – What information do we need

Management >>> Site-Specific Management

• How do you determine what seeding rate you're going to use on corn?

• How do you determine how much nitrogen to apply?

• Our decision making process is yield driven, either express or implied

• We are just changing the scale we are making those decisions at.
Normalized Yields from 3 different crops over 6 years

Putting it together:
Determining spatial-temporal yield

Normalized Yield

Standard Deviation (Temporal Stability)
Topdress Nitrogen on Wheat

Yield Stability

Using classifications to adjust spatial yield goal

- Stable High
  \[ \text{SYG} = \text{YG} \times 1.15 \]

- Stable Low
  \[ \text{SYG} = \text{YG} \times 0.95 \]

- Unstable / Average
  \[ \text{SYG} = \text{YG} \times 1.0 \text{ or } 1.05 \]

\[ \text{Nitrogen Rec} = \text{SYG} \times 1.6 - \text{Credits or SYG} \times 0.9 \]

(K-State Recommendation)
Steps to VRA Prescription Development

• Identify decision making approach
  – Equation or Decision based
  – *Example Nitrogen Recommendation Equation*

  **Example**
  • Wheat Nrec =
    (Yield Goal × 2.4)
    – (% SOM × 10)
    – Profile N
    – Other N Adjustments
    + Previous Crop Adjustments
    + Tillage Adjustments
    + Grazing Adjustments

Steps to VRA Prescription Development

• Identify input variables needed AND determine if you have spatial data or NEED spatial data.

• Example
  – Yield goal, soil organic matter and Profile N could be spatial data

  **Example Inputs**
  • Yield Goal (S)
  • SOM (S or U)
  • Profile N (S or U)
  • Other N Adjustments (U)
  • Previous Crop Adjustments (U)
  • Tillage Adjustments (U)
  • Grazing Adjustments (U)
  S = spatial
  U = Uniform field wide
Steps to VRA Prescription Development

Soil Organic Matter

Uniform Inputs
- Profile N = -30 lb/acre
- Previous Crop Adjustments = 0 (soybean)
- Tillage Adjustments = +20 lb/acre for no-till
- Grazing Adjustments = 0 for no grazing
**Steps to VRA Prescription Development**

**Spatial Inputs**

- Yield Goal * 2.4
- SOM * 10

**Uniform Inputs**

- Profile N = -30 lb/acre
- Previous Crop Adjustments = 0 (soybean)
- Tillage Adjustments = +20 lb/acre for no-till
- Grazing Adjustments = 0 for no grazing

---

**Steps to VRA Prescription Development**

Nitrogen Recommendation in lbs N/acre

- 50 lbs N/acre
- 120 lbs N/acre
• Seed and Nitrogen are typically our inputs most directly tied to yield goal

• Nitrogen is fairly straight forward
  \[ N_{\text{rec}} = 1.6 \times \text{YG} - \text{Credits} \]

• Can we develop a seeding rec based on bounds

• If KP remains fairly constant than we can derive seeding rate from yield goal

**Yield Stability**

Using classifications to adjust spatial yield goal

- **Stable High**
  \[ \text{SYG} = \text{YG} \times 1.10 \]

- **Stable Low**
  \[ \text{SYG} = \text{YG} \times 0.95 \]

- **Unstable / Average**
  \[ \text{SYG} = \text{YG} \times 1.0 \text{ or } 1.05 \]

\[
\text{Nitrogen Rec} = \text{SYG} \times 1.6 \text{ - Credits or } \text{SYG} \times 0.9 \\
\text{(K-State Recommendation)}
\]

\[
\text{Seed Rec} = \text{SYG} \times 11688 + 5125 \\
\text{(from our spreadsheet)}
\]
Fertilizer Recommendations

- \( N_{\text{rec}} = (YG*1.6)-(SOM*2.5)\)-Profile N-other adjustments
- \( P_{\text{rec}} = 50 + (YG*0.2)+(STP*-2.5)+(YG*STP*-0.01) \)
- \( K_{\text{rec}} = 73 + (YG*0.21)+(STK*-0.565)+(YG*STK*-0.0016) \)
- \( \text{Lime}_{6.8} = [12,810-(3,180*BpH)+(BpH^2*98)]+\text{Depth (in)} \)

- All are soil test driven – accepted as the most effective methods for fertilizer decisions
- All are yield goal driven (except lime), but phosphorus management is heavily guided by soil test levels

Soil Testing Expense

- Soil Test Cost
  - Lab costs – between $5 and $25
  - Labor “costs” is the limiting factor for soil testing. *Finding time to do it.*

- Fertilizer decisions are often made without the benefit of soil tests.
  - Crop removal/replacement method
  - Standard annual rate method
  - Expected yield without regard to soil test levels
Soil Test Use Plan

• Crop removal & replacement method
  – Crop yield (bu/a) * removal rate (lb/bu) = lb/a

• Soil Testing method
  – Soil test and use recommendation equations
  – Soil test initially, model removal, test periodically to adjust models.

Use yield monitor data to estimate soil test levels?

Phosphorus removal values

<table>
<thead>
<tr>
<th>Crop</th>
<th>Unit</th>
<th>P₂O₅ (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>bushel</td>
<td>0.33</td>
</tr>
<tr>
<td>Grain Sorghum</td>
<td>bushel</td>
<td>0.40</td>
</tr>
<tr>
<td>Wheat</td>
<td>bushel</td>
<td>0.50</td>
</tr>
<tr>
<td>Sunflowers</td>
<td>pound</td>
<td>0.02</td>
</tr>
<tr>
<td>Oats</td>
<td>bushel</td>
<td>0.25</td>
</tr>
<tr>
<td>Soybeans</td>
<td>bushel</td>
<td>0.80</td>
</tr>
</tbody>
</table>
Using yield monitor data to look back...

4 Years of P Removal

\[ \text{P}_2\text{O}_5 \text{ (lbs/ac)} \]

- 15 to 45
- 45 to 65
- 65 to 85
- 85 to 105
- 105 to 130

---

Soil Test P

\[ \text{Mehlich III (ppm)} \]

- 0 to 5
- 5 to 13
- 13 to 25
- 25 to 50
- 50 to 90
Crop Removal – the next step

• Calculate crop removal
• Depending on over/under applications after crop removal, soil test levels will change.
• 18 lbs $P_2O_5$ is required to change STP one ppm.

➤ One cycle of a W-C-F rotation (using field averages)
  ➤ Wheat yield = 60 bu/a, Corn yield = 110 bu/ac
  ➤ STP = 22 ppm, $P_2O_5$ = 30 lb/a
  ➤ Wheat Removal = 60 * .50 = 30 lbs $P_2O_5$ removed
  ➤ Corn Removal = 110 * .33 = 36 lbs $P_2O_5$ removed
  ➤ Total Crop Removal = 30+36 = 66 lbs $P_2O_5$ removed
  ➤ STP change = [30-66]/18 = 2 ppm drop
  ➤ Final STP = 22 – 2 = 20 ppm

➤ Just perform this process at every point in the field

Crop Removal – the next step

➤ Perform crop removal and STP calculations at a site-specific scale for the field

➤ Potential Decision Rules
  ➤ Land ownership/tenancy makes a difference
  ➤ Decisions based on STP
    ➤ IF STP > 30 then apply 0 or very minimal amount (intentional mining)
    ➤ IF STP is >20 and <30 then apply removal rates
    ➤ IF STP is <20 then apply removal + build (build rate?)

➤ VRT apply P to meet management goals
Benchmarks

• Establish benchmarks that get sampled to calibrate models and evaluate fertilizer program progress.

Other Datasets

• Soil EC
• Soil pH
• Soil nutrient sampling (grid, directed zone, etc.)
2/17/2017

On-the-go Sensors


Building relationships from spatially dense data (soil EC)

Water Holding Capacity vs. Shallow Soil EC

\[ y = 0.02130 + 0.06115(\text{SEC}) - (0.000650)(\text{SEC}^2) \]

\[ R^2 = 0.8229 \quad P > F = 0.0001 \]
Airport 2006 - Population x Soil EC Model

Grain Yield (bu ac$^{-1}$) vs. Soil EC (mS m$^{-1}$) and Population (plants ac$^{-1}$).
VRT Seeding Analysis

- Optimal seeding rate derived from yield response curves varied between 12,500 and 35,375 seeds ac\(^{-1}\).
- Use of the producers standard seeding rate of 28,000 seeds ac\(^{-1}\) would result in 67% of the field area seeded under optimal and 33% above optimal.

The Future

- Data Quality
  - Challenges Remain
  - Reprocessing of Old Data
  - Continued Improvements in Hardware
- Data Use
  - More “Turn-Key” Solutions
  - Site-Specific Crop Modeling
Challenges Remain

- Calibration
  - Dealing with real-time data, multiple machines
- Continued proliferation of “second-class” volumetric yield monitoring systems
- Continued hardware development

Site-Specific Crop Modeling

- Crop modeling more accepted in other parts of the world at the field scale
- In the market in some forms
  - AdaptN, Encirca Nitrogen Mgt., Climate Corp, etc.
- What about calibration? Ground truthing?
The Future - Site-Specific Crop Modeling

- Provide probability distributions of potential management strategies
- Yield data is necessary to calibrate and validate the model
- Yield data is necessary to evaluate model results moving forward
Site-specific management questions to consider:

- **Does it make sense agronomically?**
  - Are we addressing a factor that affects yield?
  - Do we adequately understand the input vs. yield response of what we are managing?
  - Are we addressing the issue in an environmentally sound way?
  - Do I have a way to evaluate this method of management?

- **Does it make sense technically?**
  - Can my method of application accurately apply my intentions?
  - Do I have a way to evaluate the results? (as-applied maps)

- **Does it make sense economically?**
  - What are the true costs of implementation? (don’t forget to value your time)
  - What is the probability distribution of years in which this will pay?
  - Is there an easier (cheaper) way to achieve most of the benefit with less cost?
  - Am I collecting enough data in my agronomic and technical evaluations that I can evaluate the economics of the practice?

Questions?

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Other emerging precision ag technologies / opportunities

The future...

- Data quality, reprocessing
- sUAV’s (drones) - ?
- Telematics, mining machinery data
- Crop models?
- What about livestock?
## Estimated Cost of Planting

<table>
<thead>
<tr>
<th></th>
<th>Corn</th>
<th>Soybeans</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planter size, rows</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Row controllers</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base acres</td>
<td>2,800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Downtime during day, hrs</td>
<td>1.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed tender time, minutes</td>
<td>30.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field shape (1=Normal, 2=Bad, 3=Good)*</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Percent of acres</strong></td>
<td>66.7%</td>
<td>33.3%</td>
<td>100.0%</td>
</tr>
<tr>
<td><strong>Planting speed, mph</strong></td>
<td>5.50</td>
<td>5.50</td>
<td>5.50</td>
</tr>
<tr>
<td><strong>Planting days</strong></td>
<td>10.69</td>
<td>6.01</td>
<td>16.70</td>
</tr>
<tr>
<td><strong>Total cost of planting, $/acre</strong></td>
<td>$17.37</td>
<td>$18.53</td>
<td>$17.75</td>
</tr>
<tr>
<td><strong>Benefit of row shutoffs, $/acre</strong></td>
<td>$7.27</td>
<td>$1.92</td>
<td>$5.49</td>
</tr>
<tr>
<td><strong>Total cost of planting, $/year</strong></td>
<td>$32,436</td>
<td>$17,277</td>
<td>$49,712</td>
</tr>
<tr>
<td><strong>Benefit of row shutoffs, $/year</strong></td>
<td>$13,584</td>
<td>$1,789</td>
<td>$15,373</td>
</tr>
<tr>
<td><strong>Total cost of planting, $/tractor hr</strong></td>
<td>$242.67</td>
<td>$229.98</td>
<td>$238.10</td>
</tr>
</tbody>
</table>

* Average angle of incidence = 45, 30, and 75 degrees for normal, bad, and good fields, respectively.
## Spraying costs...

### Costs of spraying under alternative assumptions

<table>
<thead>
<tr>
<th>Avg road speed, mph</th>
<th>Tank fill time, minutes</th>
<th>Tank fill time, minutes</th>
<th>Acres sprayed annually</th>
<th>Total cost/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15.0</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>15.0</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Miles between fields = 3.0

<table>
<thead>
<tr>
<th>Miles between fields</th>
<th>Acres sprayed annually</th>
<th>Total cost/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.0</td>
<td>29,641</td>
<td>$4.40</td>
</tr>
<tr>
<td>28.0</td>
<td>35,379</td>
<td>$3.97</td>
</tr>
<tr>
<td>35.0</td>
<td>29,995</td>
<td>$4.36</td>
</tr>
<tr>
<td>35.0</td>
<td>35,895</td>
<td>$3.93</td>
</tr>
</tbody>
</table>

### Miles between fields = 6.0

<table>
<thead>
<tr>
<th>Miles between fields</th>
<th>Acres sprayed annually</th>
<th>Total cost/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.0</td>
<td>28,015</td>
<td>$4.60</td>
</tr>
<tr>
<td>28.0</td>
<td>33,082</td>
<td>$4.17</td>
</tr>
<tr>
<td>35.0</td>
<td>28,649</td>
<td>$4.52</td>
</tr>
<tr>
<td>35.0</td>
<td>33,966</td>
<td>$4.09</td>
</tr>
</tbody>
</table>

1. All model inputs were held constant except tank fill time, road speed, and sprayer investment (assumed an extra $20K for faster tendering scenarios).
2. Sprayer engine hours are held constant at 500 for all scenarios (if acres are held constant rather than sprayer hours, gain to faster fill rate decreases).
3. Includes an estimate of tendering as well as sprayer ownership and operating costs.
UAV Imagery – Rawlins County 2013
Development of high spatial corn canopy thermal maps using small unmanned aircraft systems for irrigation management

Dr. Ajay Sharda and Dr. Lucas Haag
Biological and Agricultural Engineering
Northwest Research-Extension Center
Kansas State University
CWSI and Soil moisture

CWSI can be used to predict soil moisture

What About Livestock?
What About Livestock?

- Facilities monitoring
- Herd monitoring
- Herd health monitoring
- Grassland assessment and grazing planning