Yield Monitoring and Mapping

Yield monitoring and mapping...

- by far the most popular precision agriculture practice
- provides invaluable information on both, scale and location of variability

> average ~ average < average

Yield monitoring and mapping...

- Definition of yield map
- Types of yield maps
- Cycle of Precision Farming
- Methods of Measuring Yield
- process of yield mapping
- calculating instantaneous yields
- eliminating errors in yield map
- transforming multiple years of yield data into decision maps

What is Yield Monitoring?

- Process of measuring and mapping yield in real-time
- Quantifies spatial and temporal variability in soil and crop properties

Yield mapping includes:
- Acquisition
- Analysis, and
- Summarization of crop yield data by location within a field
**Definition of yield map**

A yield map is a spatially referenced, graphical representation of crop yield for a defined area.

Final product is usually a tonal or colored map displaying ranges of yield within a field.

**Yield monitors provide a way to quantify yield variations that producers know exist.**

---

**Types of yield map**

1. Inference maps
2. Prediction maps
3. Interpolation maps, and
4. Aggregation maps.

**Variable rate fertilizer prescription map**

Yield Goal (bu/ac)

- Low: 90
- Avg: 140
- Med: 160
- High: 175

---

**Types of yield map...**

1. **Inference maps**:
   
   Are developed by associating yield estimates with existing map delineations without changing the delineations on a base map.
   
   For example, associating a yield goal with a soil map unit in a county soil survey.

<table>
<thead>
<tr>
<th>Yield Goal (bu/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA Bojac</td>
</tr>
<tr>
<td>104 lb N/acre</td>
</tr>
<tr>
<td>1A</td>
</tr>
<tr>
<td>140</td>
</tr>
<tr>
<td>1B</td>
</tr>
<tr>
<td>160</td>
</tr>
<tr>
<td>25B</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>29B</td>
</tr>
<tr>
<td>175</td>
</tr>
</tbody>
</table>

---

**2. Prediction maps**:

Yield component is not measured but predicted from other spatial data using a prediction function or model.

For example, predicting crop yield as a function of soil/weather properties for a region or field.
3. Interpolation maps:
- Yield measurements are made at specific locations and
- Yield values between data points are estimated using interpolation techniques.
- Measured data are obtained at a much coarser scale than the estimation scale (similar to grid sampling).

4. Aggregation maps:
- Yield maps derived from measured data in which either the original data or some aggregation of the data are mapped.
- Once yield measurements are determined, no estimation, prediction, or interpolation of point yield data is required for mapping because the intensity of data collection is on a very high scale.
- E.g. Site-specific instantaneous (on-the-go) yield monitoring system.

Three major yield measuring approaches
1. Collect and weigh: The most common and widely used method, weighing crop after being threshed, separated and cleaned.
2. Batch type yield monitors: Grain is weighed in grain tank of combine. It holds large volume or batch of grain harvested from large area. Batch type-monitor reports total weight/volume of grain over total area.
3. Instantaneous yield monitors: Measure and record yield on-the-go. When combined with positioning system GPS/DGPS, produce site-specific grain yield maps.

An in-cab batch-type yield monitor
3. Instantaneous method

Instantaneous yield monitors: Measure and record yield on-the-go. When combined with positioning system GPS/DGPS, produce site-specific grain yield maps.

Instantaneous method

Instantaneous yield monitor display location crop yield, area, moisture content, etc all in dynamic mode

- planter and application control
- yield monitoring
- real-time data logging
- automated steering control, and much more

Yield monitor components

Yield monitor components

Ground Speed Sensor:

- Combine speedometer
- Ground speed sensor
  - 10 km/h

An ultrasonic ground speed sensor
An ultrasonic ground speed sensor

10 km/h

In slippery terrain

Yield monitor components

Ground Speed Sensor:
Combine speedometer ≠ Ground speed sensor

An ultrasonic ground speed sensor

Various types (5) of grain flow sensor

1. Impact Force Sensor
2. Plate Displacement Sensor
3. Radiometric Sensor/System
4. Load Cell System
5. Volume Measurement System

Impact Force Sensor:
Grain flow is measured by quantifying the amount of force applied when the grain strikes on a spring-loaded impact plate.

Force is measured by a load cell that converts load into electrical signal. A very light impact on the plate causes a measurable change in the resistance of the electrical current flow. Change in electrical flow is proportional to amount grain flow

Plate Displacement Sensor:

• Similar to impact force sensor.
• Measure displacement of plate and not force.
• Grain flow is measured by quantifying the displacement of the plate when the grain strikes on a spring-loaded impact plate.
Intensity is inversely proportional to grain flow
- It is max. when there is no obstruction (no grain flow)
- It decreases with grain flow

R. Khosla SOCR377 Fall Semester 2015

Simulated Yield Monitor Calibration Curve

Discuss multiple point calibration versus two point calibration

Load Cell System:
The system actually weighs the grain as it passes through combine’s clean grain auger. Grain flow rate is proportional to the load cell electrical impulse.

Volume Measurement System:
- Optical sensor detects the degree to which grain elevator is loaded.
- Measurement of light and dark period is used to estimate grain flow volume
- Must know bulk density [mass/unit volume] to estimate grain yield.

Grain flow (mass) = volume x mass/volume

Yield monitor components
- Grain Flow Sensor
- Grain Moisture Sensor
- Ground Speed Sensor
- Header Position Switch
- Display Console

Various types of Grain Flow Sensor:
- Impact Force Sensor
- Plate Displacement Sensor
- Radiometric Sensor/System
- Load Cell System
- Volume Measurement System

Let’s have a look at Grain Moisture sensor
Moisture sensor

It is a capacitance type sensor, works on the principle of measuring dielectric property of a substance (Grain).

Dielectric constant of:
- Water = 78
- Soil = 4
- Vacuum = 1

Display console:

Operator supplied information:
- Field name
- Load name or number
- Cutting width

Sensed/Calculated information:
- Crop moisture content
- Instantaneous yield
- Average yield
- Area harvested
- Travel speed
- Quality of DGPS signal reception

Data transfer in a yield monitoring and mapping system

Combine Console

USB drive

Laptop/Farm Computer

Yield map and reports

Calculating grain yield on-the-go...

To determine instantaneous crop yield need 3 pieces of information:
1. Grain flow rate (lbs/sec)
2. Combine’s travel speed (ft/sec)
3. Cutting width of header (ft)

Recall:
- 1 mile = 5280 ft
- 1 hr = 3600 sec
- 1 acre = 43560 ft

Calculate instantaneous grain yield of a combine with an 8-row corn header harvesting at a speed of 5 miles per hour. The corn row width is 30” and the grain flow sensor recorded a flow rate of 44 lbs/sec for the previous second.

Recall:
- 1 mile = 5280 ft
- 1 hr = 3600 sec
- 1 acre = 43560 ft
Cleaning yield data

Raw yield map contains several data points with erroneous yield information.

- Out of range
- Outliers
- DGPS problems
- Speed change
- Lag error

Raw yield map needs to be cleaned

Cleaning yield data...

The raw crop yield data need further processing to provide the user with information that is more

- usable
- accurate.

Cleaning yield data...

Table format

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
</tr>
<tr>
<td>C</td>
<td>30</td>
</tr>
<tr>
<td>D</td>
<td>40</td>
</tr>
</tbody>
</table>

STEP 1: Sort

Cleaning yield data...

Loss of differential GPS fix

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
</tr>
<tr>
<td>C</td>
<td>30</td>
</tr>
<tr>
<td>D</td>
<td>40</td>
</tr>
</tbody>
</table>
**STEP 2**

Cleaning yield data...

- **Removing low yield**

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>Yield (bu/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.6</td>
<td>170</td>
</tr>
<tr>
<td>4.7</td>
<td>170</td>
</tr>
<tr>
<td>4.9</td>
<td>165</td>
</tr>
<tr>
<td>5.0</td>
<td>168</td>
</tr>
<tr>
<td>3.6</td>
<td>284</td>
</tr>
</tbody>
</table>

Cleaning yield data...

- **Removing high yield**

**STEP 3**

Cleaning yield data...

Combine speed variation error

For cleaning, remove speed that is + or − 25% of the median

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>Yield (bu/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.6</td>
<td>170</td>
</tr>
<tr>
<td>4.7</td>
<td>170</td>
</tr>
<tr>
<td>4.9</td>
<td>165</td>
</tr>
<tr>
<td>5.0</td>
<td>168</td>
</tr>
<tr>
<td>3.6</td>
<td>284</td>
</tr>
</tbody>
</table>

Area harvested in 1 second
STEP 4

Cleaning yield data...

Mass Flow Delay Errors

The mass flow delay is the time required for the grain to move from the header to the grain flow sensors.

**STEP 4**

The mass flow delay is the time required for the grain to move from the header to the grain flow sensors.

New x = UTM_X - sin(Heading in degrees) x Delay Distance in meters
New y = UTM_Y - cos(Heading in degrees) x Delay Distance in meters

Result of the Cleaning Process

Summary

Original data set: 46,348 data points
Cleaned data set: 40,281 data points
13% of the points were removed

Making Sense of Yield Data

Year 1

<table>
<thead>
<tr>
<th>Year</th>
<th>Yield (bu/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y1</td>
<td>193</td>
</tr>
<tr>
<td>Y2</td>
<td>225</td>
</tr>
<tr>
<td>Y3</td>
<td>180</td>
</tr>
<tr>
<td>Y4</td>
<td>217</td>
</tr>
<tr>
<td>Y5</td>
<td>204</td>
</tr>
<tr>
<td>Y6</td>
<td>252</td>
</tr>
<tr>
<td>Y7</td>
<td>205</td>
</tr>
</tbody>
</table>

Average yield

Y1: 193 bu/ac
Y2: 225 bu/ac
Y3: 180 bu/ac
Y4: 217 bu/ac
Y5: 204 bu/ac
Y6: 252 bu/ac
Y7: 205 bu/ac

Productivity potential of the field

Low

Medium

High

R. Khosla SOCR377 Fall Semester 2015
Clustering the yield data

- Average +/- 10 bu
- Equal parts

Clustering the yield data

Optimal number of zones varies
Black box generates zones
Are all zones significant?

Zones must improve precision management

Traditional way for characterizing spatial pattern

Significant difference in yield
Significant difference in soil fertility
Characterizing spatial variability of soil properties

What is the effect of soil properties on yield?

Management Zones...

1. Bare soil imagery

Management Zones...

2. Field topography

Elevation map

Grain yields are correlated with topography

Slope map

R. Khosla SOCR 377 Fall Semester 2015
3. Farmer’s experience

The three data layers
- Aerial Imagery
- Topography
- Farmer’s experience
are stacked as GIS layers to delineate the zone.

Traits such as dark color, low-lying topography, and historic high yields were designated as a zone of potentially high productivity or high zone.

Management Zones...

Mean grain yield across MZs

- Low
- Medium
- High
In summary

A suite of sensors work together to monitor components of a yield map.

Raw yield data need to be cleaned before processing to improve outcome reliability.

A multi-steps process is used to systematically clean the data.

In summary...

Yield from several years is normalized and integrated into a single map.

The way to integrate the data is not cut and dry and several schools of thought exist.

Clustering algorithms can generate as many zones as requested, but they are not necessarily significant.

Management zones need to generate an improvement in input use efficiency to be useful.