Many forms of spatial data

- Soil type, texture, elevation, drainage
- Grain yield & moisture
- Aerial imagery
- Satellite imagery
- Optical reflectance
- Soil test nutrients
- Soil test pH
- Electrical conductivity
- Manually mapped spatial features (e.g., wet spots, weeds)
- "As applied" logged rates of fertilizer, seeds, and pesticides
- Planter performance
- Tractor performance

Spatial data “layers” can be...

**Spatially dense**
- Many data points per unit area of land.
- E.g., Grain yield data sets often consist of 300 to 600 data points per acre.

**Spatially sparse**
- Fewer data points per unit area of land.
- E.g., 2.5 ac grid soil sampling results in an average of 0.4 data point per acre.

Non-sampled areas within a field represent spatial “holes” in the dataset with unknown values.

GIS software...

- Fills in the spatial “holes” by mathematically estimating the values in the non-sampled areas based on spatial relationships among the sampled areas.
  - Dense data sets have fewer “holes” per unit land area than do sparse data sets.
  - Thus, less interpolation is required.
  - Thus, the resulting rasterized (smoothed) map is intuitively more believable.

Spatial data density affects the...

- ...accuracy of the subsequent interpolated (rasterized) spatial maps.
- ...accuracy of subsequent management decisions based on the interpolated spatial maps.
- ...yield and dollar consequences of the management decisions based on the interpolated spatial maps.
Raw yield data = Spatially dense

Yield data every second or two

- Yield data collected every 2 seconds at 3.5 mph equals 1 data point every 10 ft of linear travel.
  - Equal to 6,824 data points on 47 ac
  - Equal to 145 data points/ac with a 12-row head.

Interpolated yield data map

Little practical difference between raw & interpolated maps* (*) With respect to spatially dense data

Interpolated yield data map

Soil sampling = Spatially sparse

- One common spatial density for grid soil sampling programs is one per 2.5 acres.
  - A single “sample” might consist of 8 to 12 soil cores pulled from within a ~ 40ft diameter circle and bulked into a single sample for nutrient analysis.
Soil sampling data = Spatially sparse

- 25-ac field, one soil sample per 2.5 acres
- 12 soil samples, each ~ 40ft diameter area

Everything else represents spatial “holes” that must be interpolated with GIS.

That’s a lot of interpolation!

Let me illustrate w/ an example using bare soil imagery & soil test organic matter estimates

- Satellite image of a 30-acre field.
  - Infra-red portion identifies dark & light soils
  - Thus, used as a proxy for soil organic matter
- Both 2.5 acre & half-acre grid soil samples
  - Organic matter values were interpolated to develop smoothed rasterized soil organic matter maps.

Satellite image of bare soil & soil map units

Aerial image vs. 2.5-ac SOM map

Aerial image vs. half-ac SOM map

Let’s consider soil test Bray P1

<table>
<thead>
<tr>
<th>Red</th>
<th>Deficient (less than 15 ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gray</td>
<td>Adequate (15 to 30 ppm)</td>
</tr>
</tbody>
</table>
The spatial lesson here is…

…that GIS software will do what you tell it to do, but does not mean that the resulting rasterized maps are spatially accurate.

Questionable spatial accuracy…

…of rasterized sparse data naturally leads to questionable accuracy of spatial agronomic decisions made on the basis of the rasterized spatial data.

Difference in \(\text{P}_2\text{O}_5\) Spread Maps

Spread map based on 2.5 ac samples

Spread map based on 0.5 ac samples

So, the question is…

- Can you afford to soil sample as intensely as a half-acre spatial density?
  - A 2.5 ac grid sample is admittedly more accurate than traditional whole field sampling.
  - Can you afford NOT to soil sample as intensely as a half-acre spatial density?
  - What is the value of an accurate baseline?
  - Maybe it is a one-time investment, followed by less intensive subsequent soil sampling.

Alternatively…

Supplement 2.5 ac grid sampling by using yield data or imagery to identify spatially "odd" field areas that deserve additional, targeted, soil sampling.
Supplement 2.5 ac grid samples with additional samples targeting low-yielding areas (red).

The key to **consistently** producing high-yielding corn...

...is the ability to accurately identify AND successfully mitigate the **YLFs specific to your farming operation**.

Take advantage of your dense spatial data sets...

...to help you visualize problem areas and then literally navigate to those areas in the field with your handheld “app” to diagnose or verify the causes.

Take advantage of handheld GPS technologies...

...to map, GPS-tag & document problem areas in your fields.

- Crop scouting & mapping “apps”
- Simple note-taking “apps”
- Smartphone cameras
- Use with other GIS information to help diagnose possible causes of problems

Remotely sensed imagery...

...supplements yield maps in identifying and locating problem areas within your fields.

- Can identify problem areas prior to harvest.
- May enable earlier & more accurate crop problem diagnostics and, possibly, in-season mitigation of crop problems (foliar fungicide, late N applic’s).
- Does not, however, diagnose the causes of crop problems by itself.
- Can vary in quality among vendors.
- Digital resolution, spatial accuracy, flight conditions, post-processing of imagery.
Remotely sensed imagery

- Equipment-mounted crop sensors
  - e.g., GreenSeeker®, OptRx®
- Satellite imagery
- Aerial imagery
  - Handheld cameras
  - Professional cameras
  - Drones, UAV?

Aerial NDVI image

31 July 2014 flight, 3+ ft image resolution
Red = poor vegetation; green = better vegetation

2014 Yield Data

Reasonably good correlation between late July NDVI and grain yield

Useful diagnostic aids, but…

…remember, neither yield maps or imagery will diagnose what caused the low yields without more background information or “ground truthing”.

So, what about variable rate crop inputs?
What is the reason we intuitively believe that VR technology will help us?

Because we believe that spatially different areas of a field might require different crop input rates to maximize yield or dollar return to that crop input.

Variable rate P, K, and lime...  
- have tended to be cost-effective because their application rates are strongly correlated with spatial variability in soil test P, K, and pH.  
- In other words, recommended rates for these soil nutrients are based primarily on a single factor.

Variable rate N or seeding rates...  
- tend to be more challenging decisions because yield responses to these inputs are influenced by multiple factors, not simply single soil test variables.  
  - Both inputs: Soil characteristics, rainfall (timing, amount), and possibly genetics.  
  - Nitrogen: Available soil N supply, source of N, timing of N applic., placement of N.

Consequently, it is more difficult to define stable or predictable management “zones” for these variable crop input decisions.

My general opinions
- Be cautious building VR nitrogen prescriptions based on single factors like soil organic matter.  
  - Predicting soil N supply is not that simple.  
- Be cautious with VR nitrogen recommendations from computer models.  
  - Predicting soil N supply is notoriously difficult.  
  - Soil characteristics, biology, moisture, and temperature plus weather forecasting

Let’s focus on fundamentals
Response to plant population is also influenced by a lot of factors, mostly those related to stress on the crop.

One of the most influential factors is likely available soil moisture.

Other than soil moisture…
- …my data has shown very few instances of variability for yield response to population for other kinds of “management zones” within fields (soils, elevation, etc.).
- I also cannot document a consistent relationship between general yield level and optimum plant population.

What one might expect if higher yields required higher populations?

No clear relationship between optimum population & yield from about 140 bu/ac to about 250 bu/ac.

Here’s my opinion on VR seeding:
- Probably no more than two seeding rates necessary within any given field….
  - A lower rate for highly stressed fields / soils.
    - Yields frequently less than ~ 130 bu/ac.
    - Seeding rates ~ 26,000 spa.
  - A higher rate for everything else.
    - Seeding rates ~ 34,000 spa.
Let's focus on fundamentals

Adopt PA technology wisely…

Variable Hybrid Planting?

Challenges ahead for PA

Success requires that…

Precision ag technologies can certainly augment agronomic decision-making, but not without the prerequisite fundamental agronomic knowledge behind whatever it is you are wanting to improve.

Goal: Match hybrid strengths and weaknesses with spatial variability for “growing conditions”.

- Cost/benefit of PA technologies
- Compatibility/reliability of PA technologies
- Rapid cycling of PA technologies
- Customer support for PA technologies
- Data overload, data analysis, data quality
- Data ownership, data privacy
- Agronomic research to support PA decision-making models.

You make the effort to identify Critical YLFs for spatial “zones” in every field.

- Water availability, drainage, rooting depth, diseases, plus a gazillion other YLFs.
- Challenge: Important YLFs tend to vary one year to another because many are influenced by weather patterns.

Hybrid “A”

Hybrid “B”

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Success requires that…

- You make the effort to identify Critical YLFs for spatial “zones” in every field.
- Spatial “zones” for critical YLFs have been accurately identified and are spatially stable year to year.
  - Low and high yielding “zones” tend to occur in different places in a field one year to another.
  - Soil map boundaries can be inaccurate.
  - Multiple year data analysis can be misleading.

- Spatial patterns for critical YLFs have been accurately identified & are stable year to year.
- Hybrid characteristics relevant to critical YLFs are clearly identified.
  - Simple descriptions like “defensive” and “offensive” hybrids are not accurate enough.