Site-Specific Soil Fertility Management
With Emphasis on P, K, and Lime

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Site Specific Management

• What is a site? A field or sections of a field worth managing differently

• Describe, georeference, and account for variation in soil types, soil tests, yields, and other soil or crop measurements

• Use diagnostic tools, information, and equipment that allow for managing field sections in different ways

• Use and manage information better
Precision Agriculture Technologies

• GPS devices, yield monitors
  - Already proved very useful and key tools

• Variable rate technology
  - Proved very useful for P, K and lime

• Aerial/satellite images, electrical conductivity, canopy sensing, precision banded input application
  - We are still learning how to use them effectively and the value for specific nutrients and conditions
Describe and Record Variability

• Reasons for yield variation often are obvious: Leaf diseases, pests, weeds, moisture, N deficiency in corn

• Often reasons are not obvious, such as for P and K fertility

• What is cause or effect? Yield may be high when a measurement is high or low just because others changed at the same time, sometimes not measured
Reasons for Nutrient Variability

- **Organic matter:** natural causes
- **pH:** natural and management causes
- **P and K:** mainly management due to residual effects of fertilizers and manure, long histories of fertilization, removal variation due to yield variation
- The variation patterns differ among nutrients, **but we measure all in the same sample!**
One of the most important steps in soil testing is collecting soil samples. The soil sample is the first part of the soil testing process and the foundation for information derived from laboratory analyses, soil test interpretations, and recommendations. Soil sampling is also the largest and most recommended sampling times and cannot be used with suggested interpretations. Field research calibrations for phosphorus (P), potassium (K), and pH soil tests are based on samples collected in the fall or spring. Recent research suggests that samples taken in late spring or early summer, before around the V6 growth
Most states recommend one sample every 10 to 15 acres.
Sampling by Soil Type & Topography

• Soil formation factors may influence nutrient levels:
  - Mineralogy, chemical properties, and texture of parent materials
  - Topography influences soil profile development, water dynamics, erosion, leaching, and organic matter accumulation

• Soil physical properties may influence yield potential and nutrient removal
Variation Within Soil Map Units

Soil P: 16-86 ppm
Soil K: 111-302 ppm
Soil pH: 5.6-7.0
Soil Nitrate: 2-28 ppm

Soil Ca: 1300-3200 ppm
Soil Mg: 49-456 ppm
Soil OM: 2.6-4.8 %

Mallarino, ISU
Grid Soil Sampling

• More samples are taken compared to sampling by soil type and topography, and should describe nutrient variability better but is more expensive

• Assumes that nutrient differences aren't due only to soil types or topography, or that it is accounted for if it exists

• Ideal as the base for using variable-rate application technology
Systematic Grid-Point Sampling

Small point take 10-12 cores per composite sample

(sampling points overlaid on soil map units)
Unaligned or Random Grid-Point

Could position sampling points to avoid soil map unit borders

(sampling points overlaid on soil map units)
What Is Being Found in Iowa?

• About 20,000 samples from field-scale research to study soil-test P, K, pH, and OM variation and VRT

• Amount and patterns of variability vary across fields and nutrients, and there is very high small-scale variability

• No sampling plan can expected to be best across all fields and nutrients

• Cost-benefit of dense sampling?
Precision of Soil Survey Maps?

Comparison of Detailed and Digital Soil Type Maps

Digitized soil map:
- Colo-Judson B
- Exira C2
- Marshall B2
- Marshall C2

Detailed soil units:
- Ackmore
- Judson - Kennebec
- Marshall
- Marshall ABCD2
- Marshall B3 - Exira
Large Systematic Variability

Mallarino, 1996

SOIL-TEST K (ppm)

DISTANCE (feet)

ACROSS ROWS
FIELD1

ALONG ROWS
FIELD1

ACROSS ROWS
FIELD2

ALONG ROWS
FIELD2
Large-Scale and Small Scale Variation

VARIATION FOR 10-CORE COMPOSITE SAMPLES

FIELD WITH LOW P

FIELD WITH HIGH P

FIELD WITH MANURE

VARIATION FOR SINGLE SOIL CORES

FIELD WITH LOW P

FIELD WITH HIGH P

FIELD WITH MANURE

Mallarino, 1996
Small Scale pH Variation

Mallarino, Bianchini; 2001

Clarion-Webster Soil Association
Sampling Method and Soil-Test P

**0.5-acre point sampling**

Field 1
- Soil-Test P
  - VL
  - L
  - 0 pt
  - H
  - VH

Field 2
- Soil-Test P
  - VL
  - L
  - 0 pt
  - H
  - VH

Field 3
- Soil-Test P
  - VL
  - L
  - 0 pt
  - H
  - VH

**Large point sampling**

**Large cell sampling**

**Soil type sampling**
Grid Cell Size and Interpolation

0.2-acre grid size

2 to 2.5 acre grid size

Large grid size interpolated

Bray-1 P
VL
L
Opt
H
VH

Large grid size interpolated
Management Zones Sampling

• Improve the sampling by soil type method and provide an alternative to a blind and costly grid sampling

• Delineate sampling areas based on many information layers: aerial photos, maps of soil, topography, yield, electrical conductivity, etc.

• Assumes that these factors are the cause or are related to different nutrient availability or crop needs
Management Zones Sampling
Overlay Layers of Information
Identifying Calcareous Field Areas

- Growth patterns
- Nutrient deficiencies

Corn

- Iron chlorosis

Soybean

A. Blackmer & N. Rogovska, ISU
Efficacy Based on Crop Response

- Strip trials, P and K, corn and soybean
- Dense grid sampling 0.3 to 0.5 acres
- Simulated less dense sampling
  - 2.5 acre grid-cell sampling
  - Soil survey map zones
  - Zone sampling based on
    - elevation
    - electrical conductivity (EC)
    - elevation and EC combined
Yield Response & Sampling Method

- Research across 28 crop-years

- Efficacy Index: Capacity of a sampling method to identify field areas with different crop response:
  - Dense 0.3 to 0.5 acre grids: 100
  - 2.5 acre grids: 50
  - Zone sampling: 39
  - Sampling by soil type: 22
Zone Approaches and Average STP

Field 1

STP distribution
2.5-acre Grid

VL 12%
L 63%
Opt 25%

Field 2

STP distribution
2.5-acre Grid

VL 38%
L 38%
Opt 24%

Soil-Test P (ppm)
0
5
10
15
20
25
30

Dominant Soil Series

Elevation & EC Zones

1
2
3
4
Why Isn’t Zone Sampling Better?

• Long histories of fertilization for originally low-testing soils mask soil properties effects on P and K variation

• Within-field yield variation has to be large and consistent over time to clearly influence soil P and K levels

• Results should be better in fields or regions with more contrasting soils and/or shorter fertilization histories
Need Many Cores Even with Grid Sampling

More cores is better, but the gain decreases exponentially

19 ppm Average Soil-Test P (Optimum Class)

Number of Soil Cores

0 5 10 15 20 25 30 35 40 45

Confidence Interval for the Average (+- Soil-Test P, ppm)

0 2 4 6 8 10 12 14

Mallarino, ISU
New Automated Soil Samplers

Taking Many Samples with Many Cores Can be Easy (but costly?)

AutoProbe™, courtesy Jeff Burton, AgRobotics Inc.

Falcon Soil Sampler, courtesy Jerry Romine
Variable-Rate for P, K, and Lime

- More clear justification than for N
- Based on what sampling method?
- Do better sampling and management increase yield enough to pay for the increased costs?
- What about benefits for water quality?
Within-Field STP Variation

Mallarino, Bermudez, Wittry; ISU
Yield Response to P Variation

Yield Increase (%)

0 5 10 15 20 25

Field 1
Field 2
Field 3
Field 4

Mallarino, Bermudez, Wittry; ISU
On-Farm Research: Uniform vs Variable

70 trials over the years, collaboration with coops
Corn and Soybean, P, K, or lime
Dense grid sampling, yield monitors, and GIS
VRT Doesn't Always Increase Yield

• Most farmers are maintaining soil-test values at or above optimum levels
  - Small low-testing areas or do not exist

• Sometimes high small-scale variability
  - How representative are test values?

• Rates for low-testing soils are designed to get maximum yield, so additional P or K applied with VRT to low-testing areas may will not increased yield further
Example 1: Response by Test Class

Fertilization Method
- U = Uniform
- V = Variable

Relative Yield Increase (%)

Very Low
- V

Low
- V

Optimum
- V

High
- V

Very High
- V

Relative Yield Increase (%)
Example 2: Response by Test Class

Corn Yield Increase (bu/acre)

Fertilization Method
- U = Uniform
- V = Variable

Very Low
- U (Uniform)
- V (Variable)

Low
- U (Uniform)
- V (Variable)

Optimum
- U (Uniform)
- V (Variable)

High
- U (Uniform)
- V (Variable)
Fertilizer and Lime Applied

- Difference Variable - Uniform application across all fields and years:
  - $P_2O_5$/acre: -52 to 71 lb, on average -9 lb
  - $K_2O$/acre: -67 to 9 lb, on average -15 lb
  - Lime ECCE ton/acre: -0.5 to -1 ton

- Less product was applied with VRT, but varied greatly across fields according to soil-test values.
VRT Reduces Soil Test Variability

Soil-Test P Variability (SD, ppm)

Field 1
Field 2
Field 3
Field 4
Field 5
Field 6

Control
Variable
Uniform

Mallarino & Bermudez, ISU
Variable Rate P Fertilizer and STP Change

From Bermudez and Mallarino, 2007
Variable Rate Manure P and STP Change

From Mallarino and Wittry, 2010
Better Management with VRT

• Benefits from VRT and grid sampling increases with high soil-test variation and unfavorable price ratios
  - slowly buildup in low-testing field areas to reduce risk of yield loss
  - don't apply to high-testing field areas
  - combine with yield maps/removal
  - reduce soil-test variability

• A good technology used with wrong nutrient recommendations will not work
Soil Fertility Web Site
http://www.agronext.iastate.edu/soilfertility/
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