# Proceedings of the 4th Annual Nitrogen: Minnesota's Grand Challenge & Compelling Opportunity Conference


Thank you to all of our Supporters!

# Opportunities and Challenges Associated with Integration of Variable Rate Nitrogen and Irrigation Applications

# How can we manage variability?

- The primary goal of precision agriculture is to increase the efficiency of inputs.
- To accomplish this we must determine in-field variability that affects crop growth.
- Only by accurately assessing in-field variability can we accurately use variable rate tools to increase input efficiency.

# Origins of spatial variability

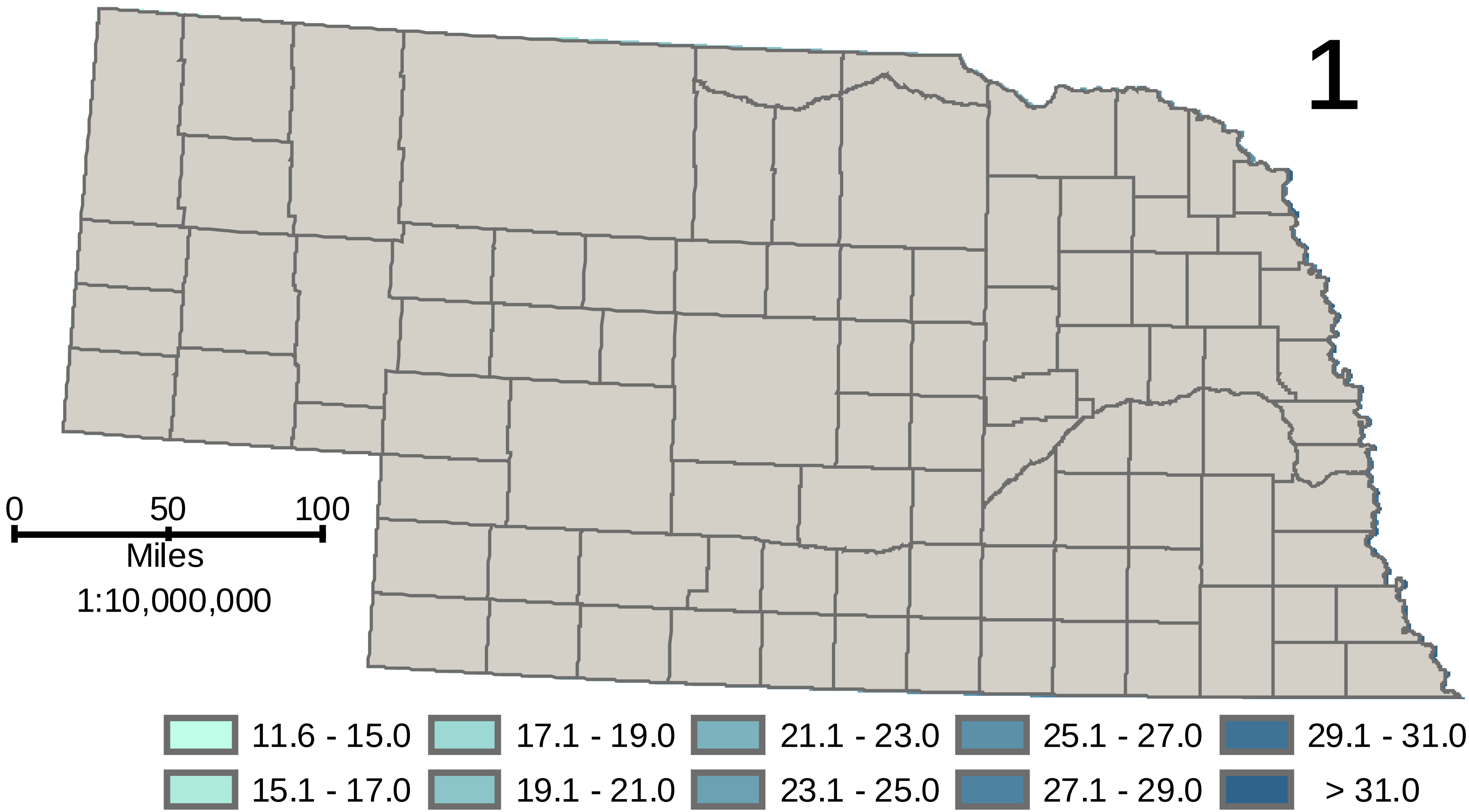
- Natural:
  **Soil = *f* (c, o, r, p, t)** H. Jenny (1941)
  - c: climate
  - o: organisms (plants, microbes, insects, animals)
  - r: relief (topography)
  - p: parent material
  - t: time
- Management induced (humans):
  - Land use (cropping systems, field boundaries)
  - Old roads, farmsteads, etc.
  - Earth movement (land leveling, terraces)
  - Tillage & traffic
  - Planting patterns (e.g., in row crops)
  - Fertilizer application, other amendments (lime, manure)
  - Irrigation & salinity
  - Crop nutrient removal (yield and crop residue management)

IANR

# Origins of spatial variability

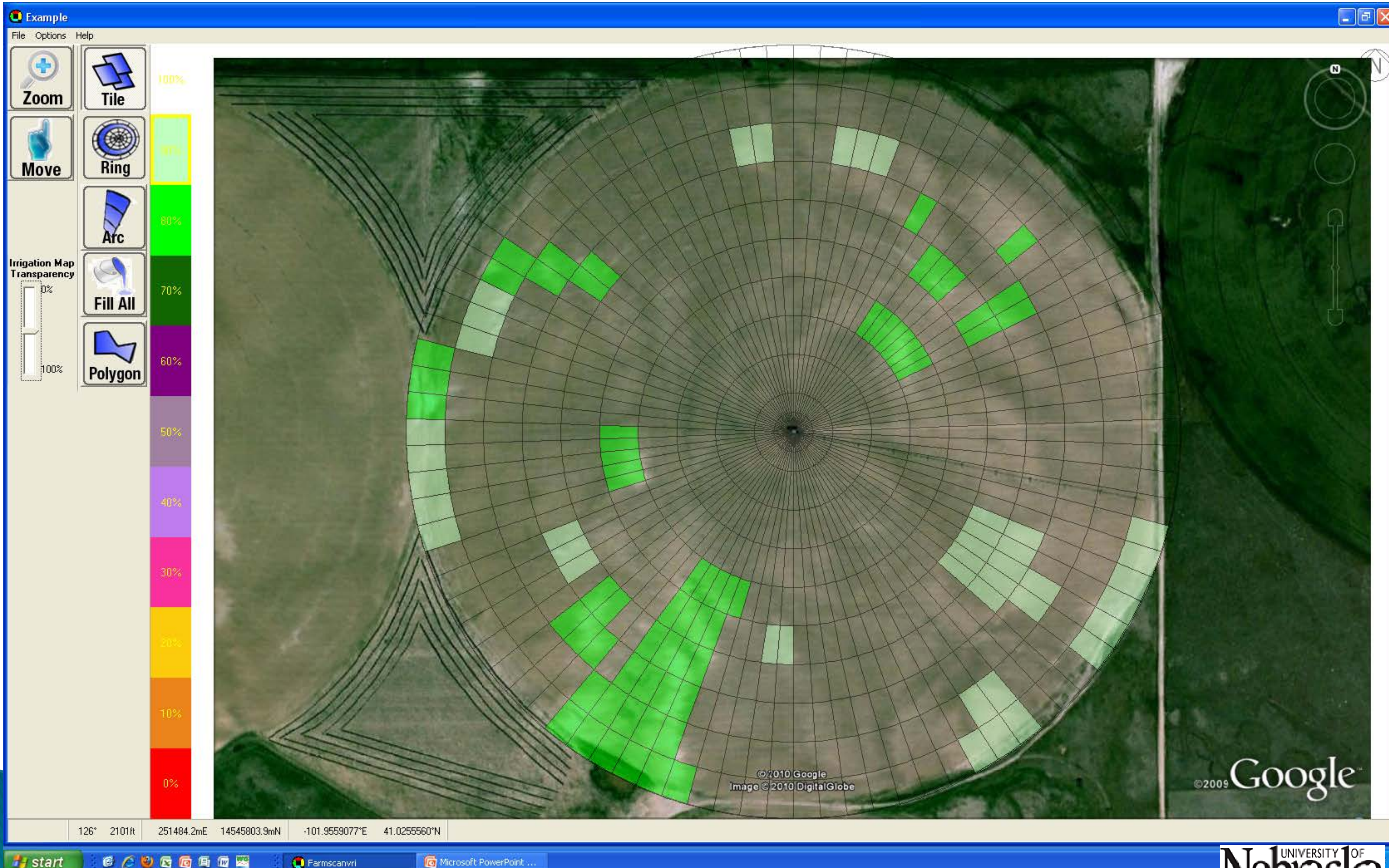
- Some factors cause soil variability over large distances (watershed, regional & global scales):
  - Climate
  - Natural vegetation & associated fauna
  - Topography
  - Parent material
- Some factors cause soil variability over shorter distances (point to field scales):
  - Topography
  - Parent material
  - Management
- Some factors cause soil variability at microscopic scales
  - Anything affecting solute and air dynamics in soil,including microbial activities, chemical processes on clay minerals, processes in the rhizosphere of plants, etc.

# Nebraska: Annual Precipitation (in)



# Nebraska Irrigated Cropland: 3.46m ha

# Variable Rate Irrigation:

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Installing soil moisture sensors, SCAL


Deere Field Connect soil moisture sensor

Collecting soil moisture sensor data

VRI system – SCAL

Collecting canopy stress data (spectral, thermal, acoustic sensors)

VRI system – BWL

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# Questions:

- If variable rate irrigation is implemented, what are the interactions with nitrogen supply?
- Can we develop recommendations for combined spatial and temporal management of water and nitrogen supply?
- How can sensors monitoring soil and plant water and N status be used most effectively?

# Crop Canopy Sensors


# What are crop canopy sensors?

- Crop canopy sensors are devices that simply record light reflectance.
- Because they do not directly contact the plant they are referred to as a “proximal sensor”.
- The data recorded is similar to information recorded from remote aerial platforms (satellites, airplanes).

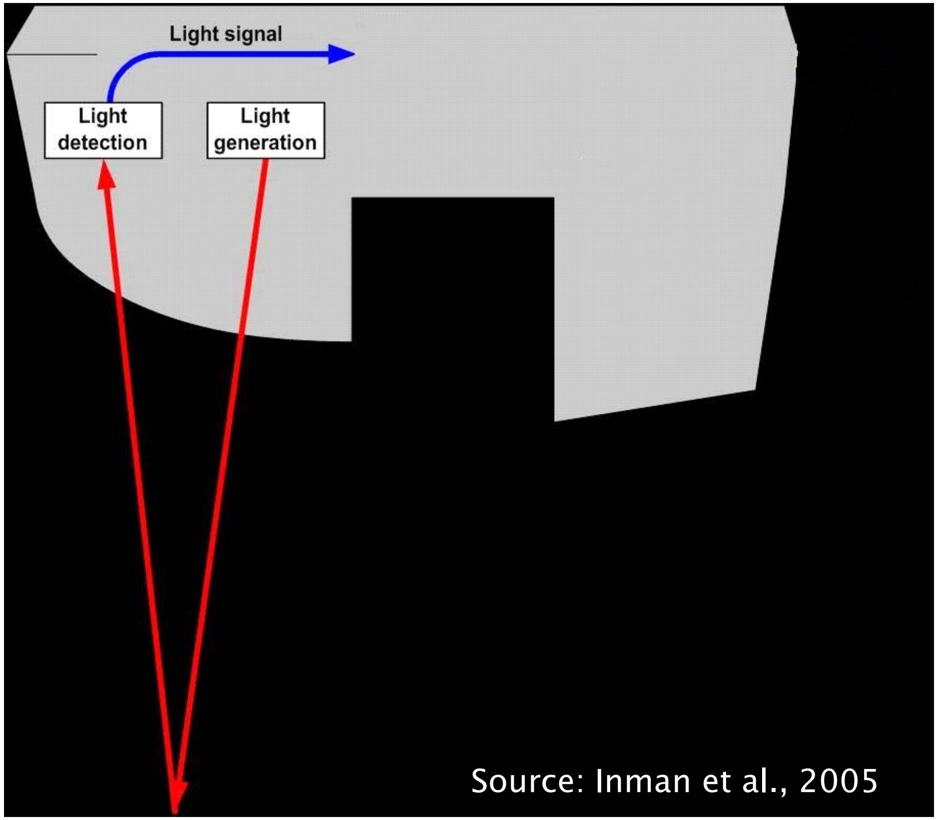
# Sensor Operation:

Emitted light:

-Visible Light (VIS)
-Near Infra-Red (NIR)

-Reflected
-Transmitted
-Absorbed

Plant characteristics affect each of these.

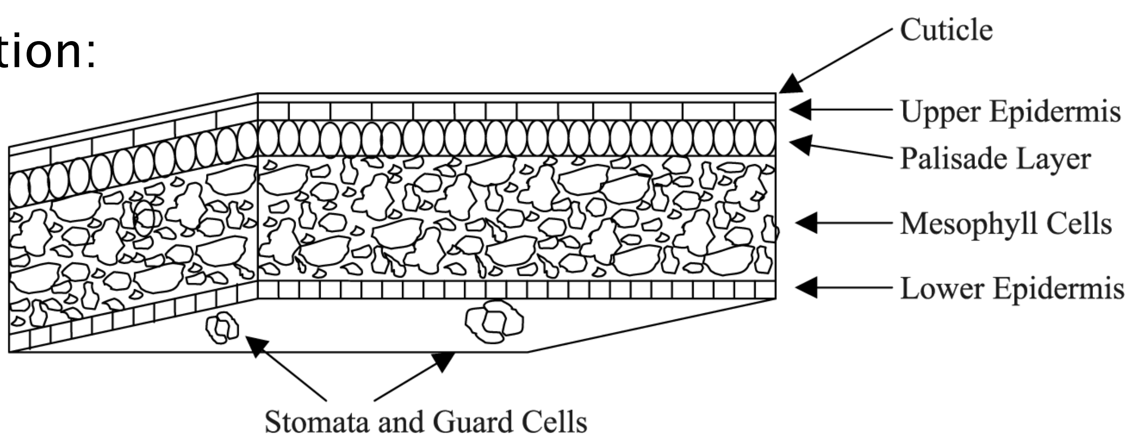



Source: Inman et al., 2005

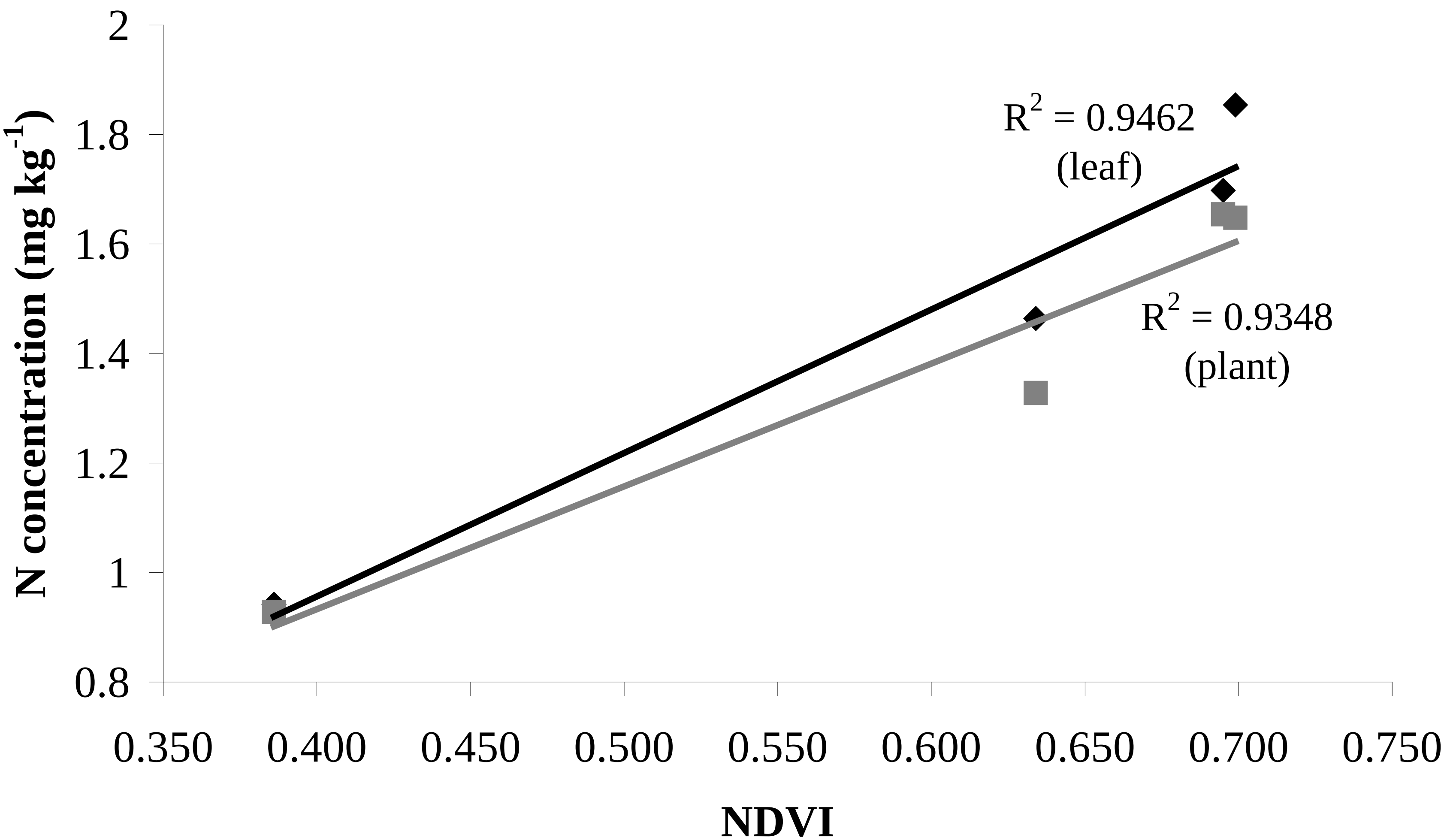
# Reflected Light:

- VIS reflectance is dependant on the chlorophyll contained in the palisade layer.
- NIR reflectance depends on the structure of the mesophyll cells.

Leaf Cross Section:
Source: Inman et al., 2005



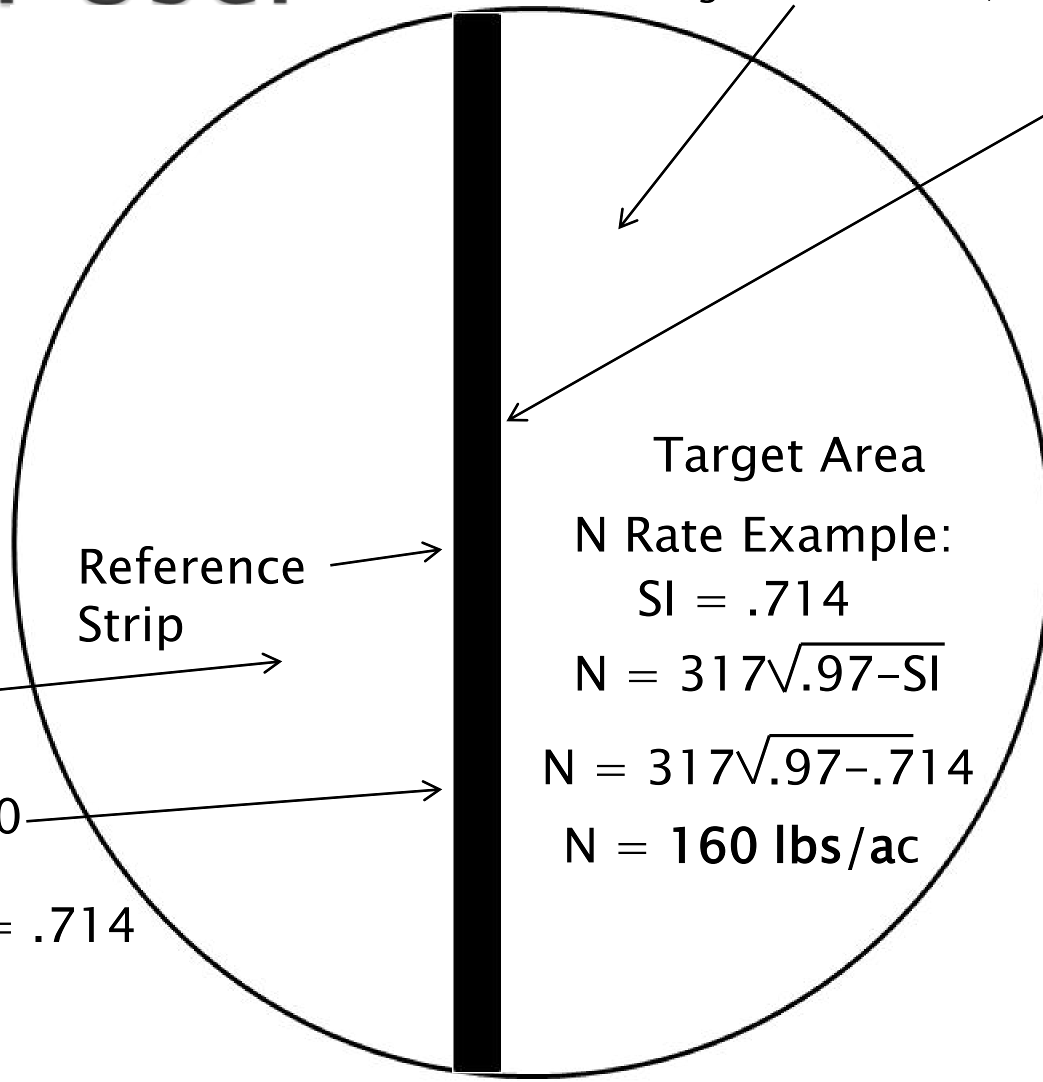
# Crop Circle NDVI vs whole plant and leaf N concentration



# Sensor Use:

Sufficiency Index (SI):
Target Reflectance / Reference Reflectance

N Algorithm:
$317\sqrt{.97-SI}$




N Rate Example:
SI = .714

$N = 317\sqrt{.97-SI}$

$N = 317\sqrt{.97-.714}$

N = **160 lbs/ac**

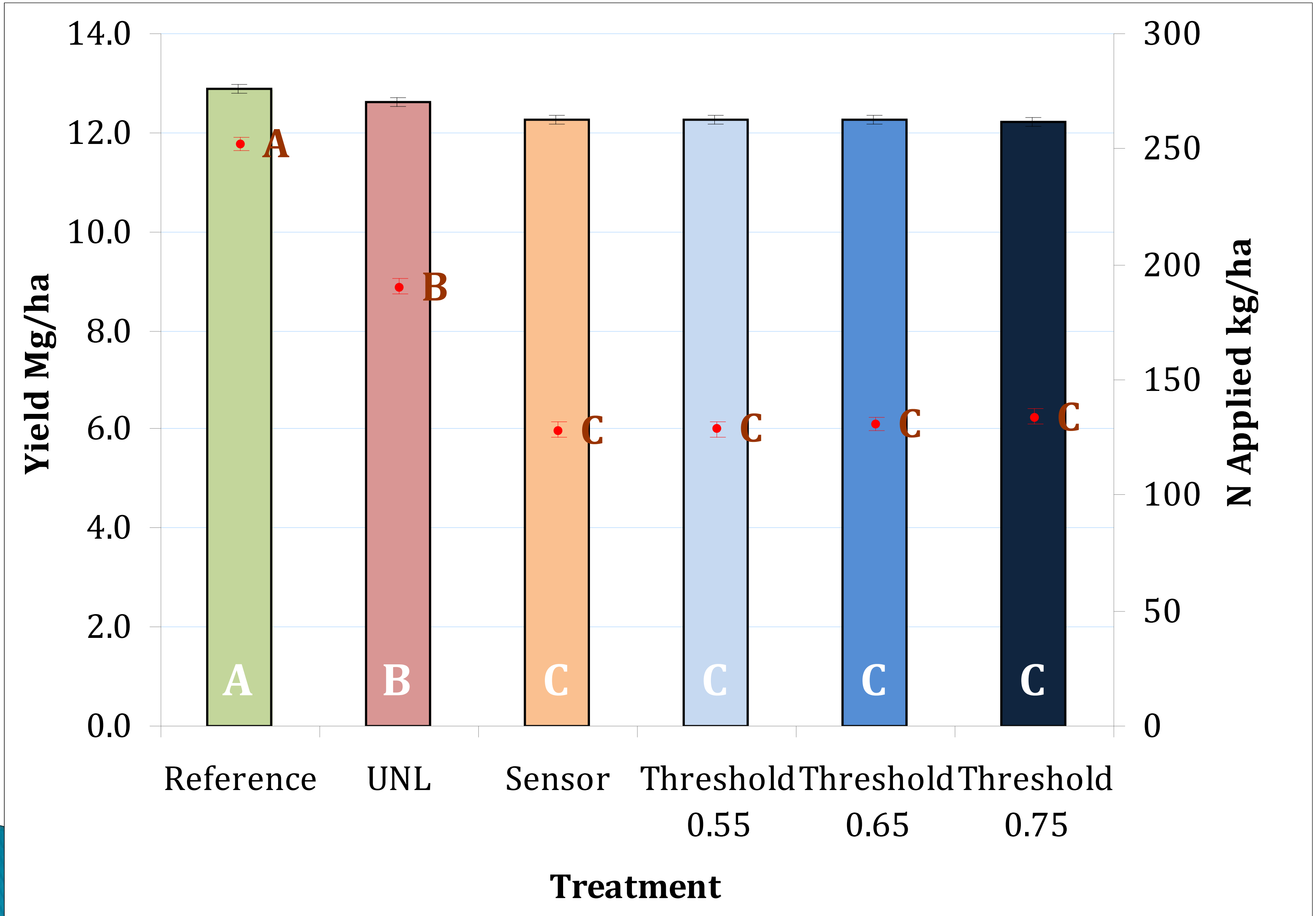
SI Example:

Target = .607

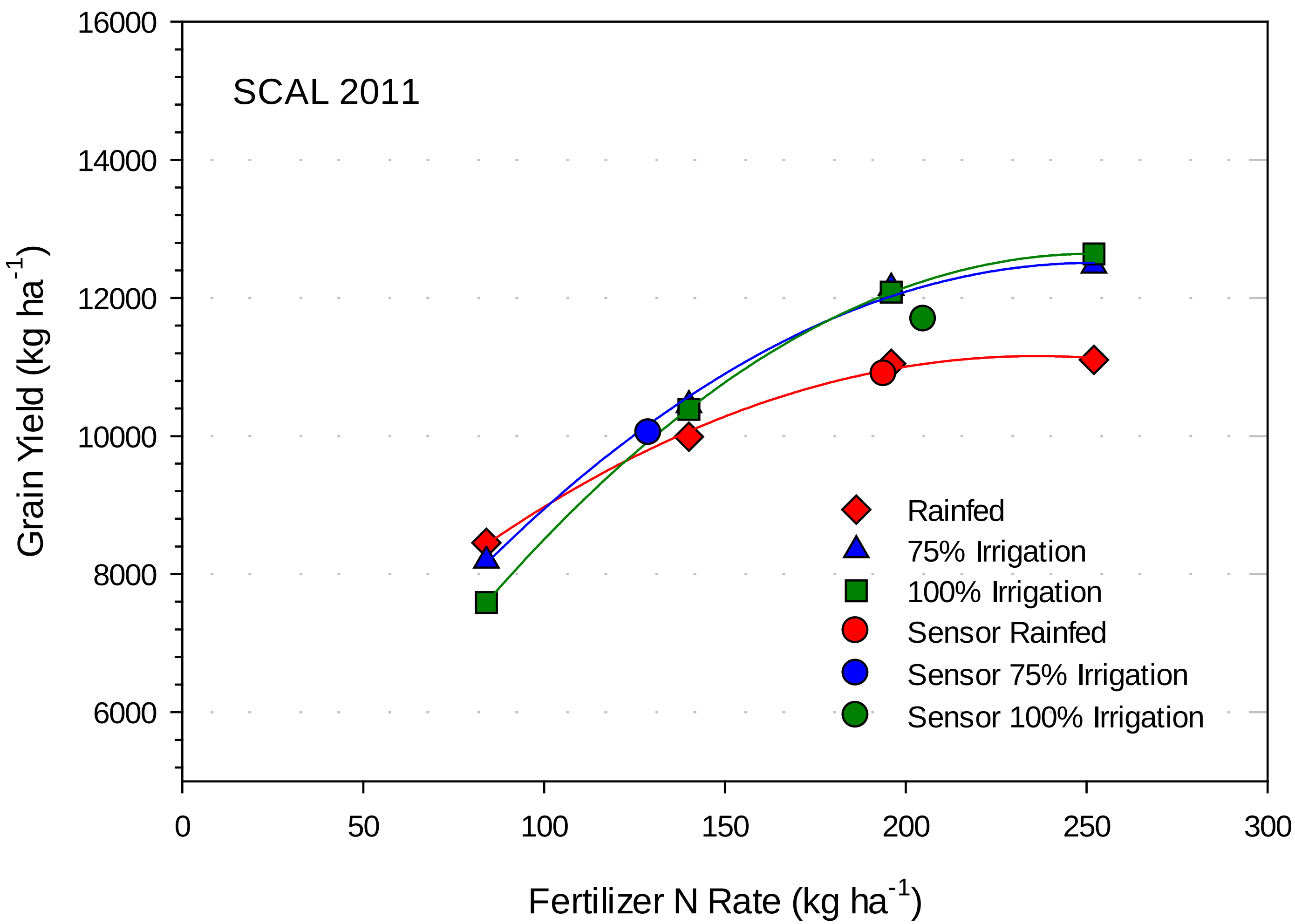
Reference = .850

SI = .607/.850 = .714

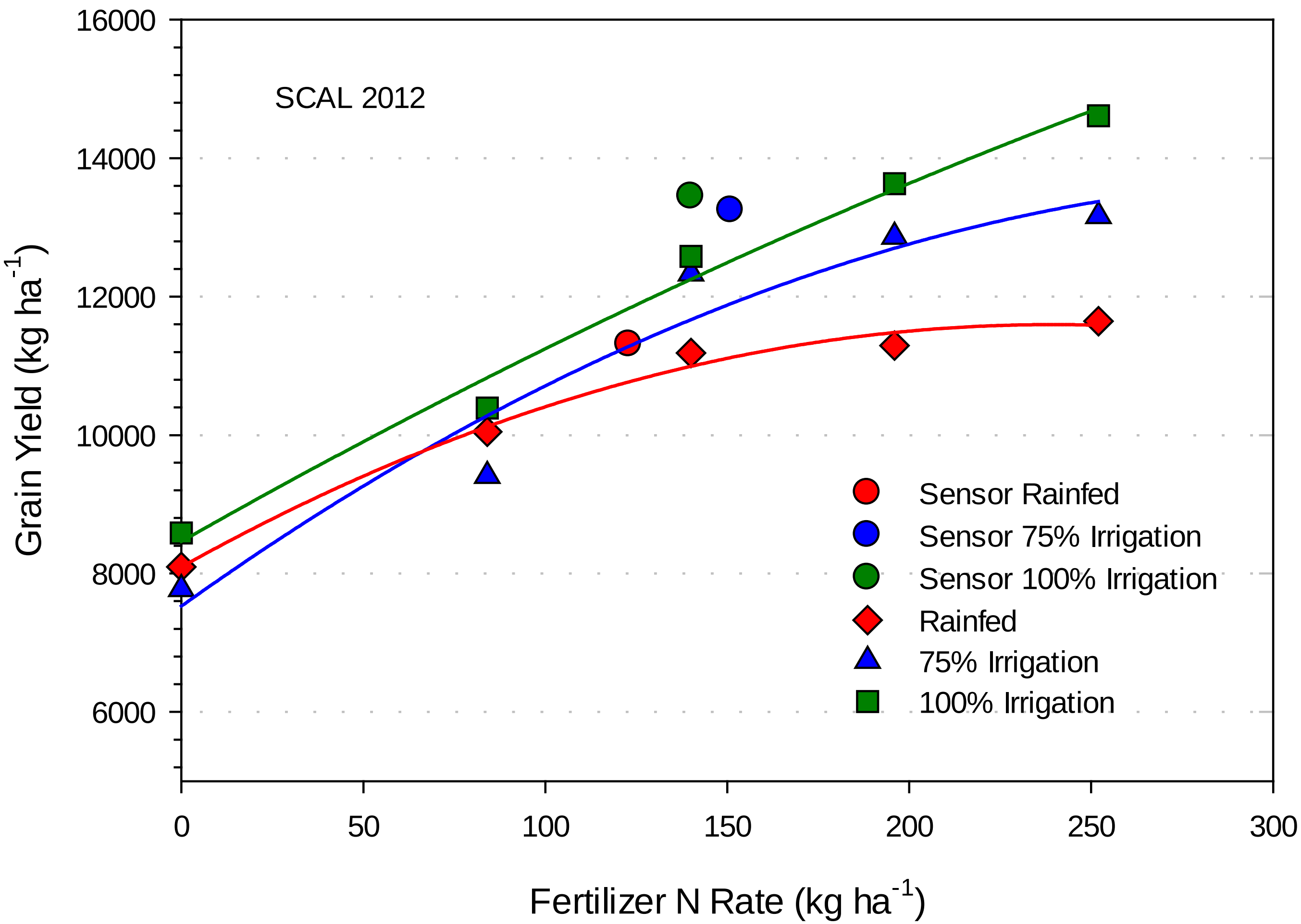
# Hunnicutt Site – Hamilton Co., 2010



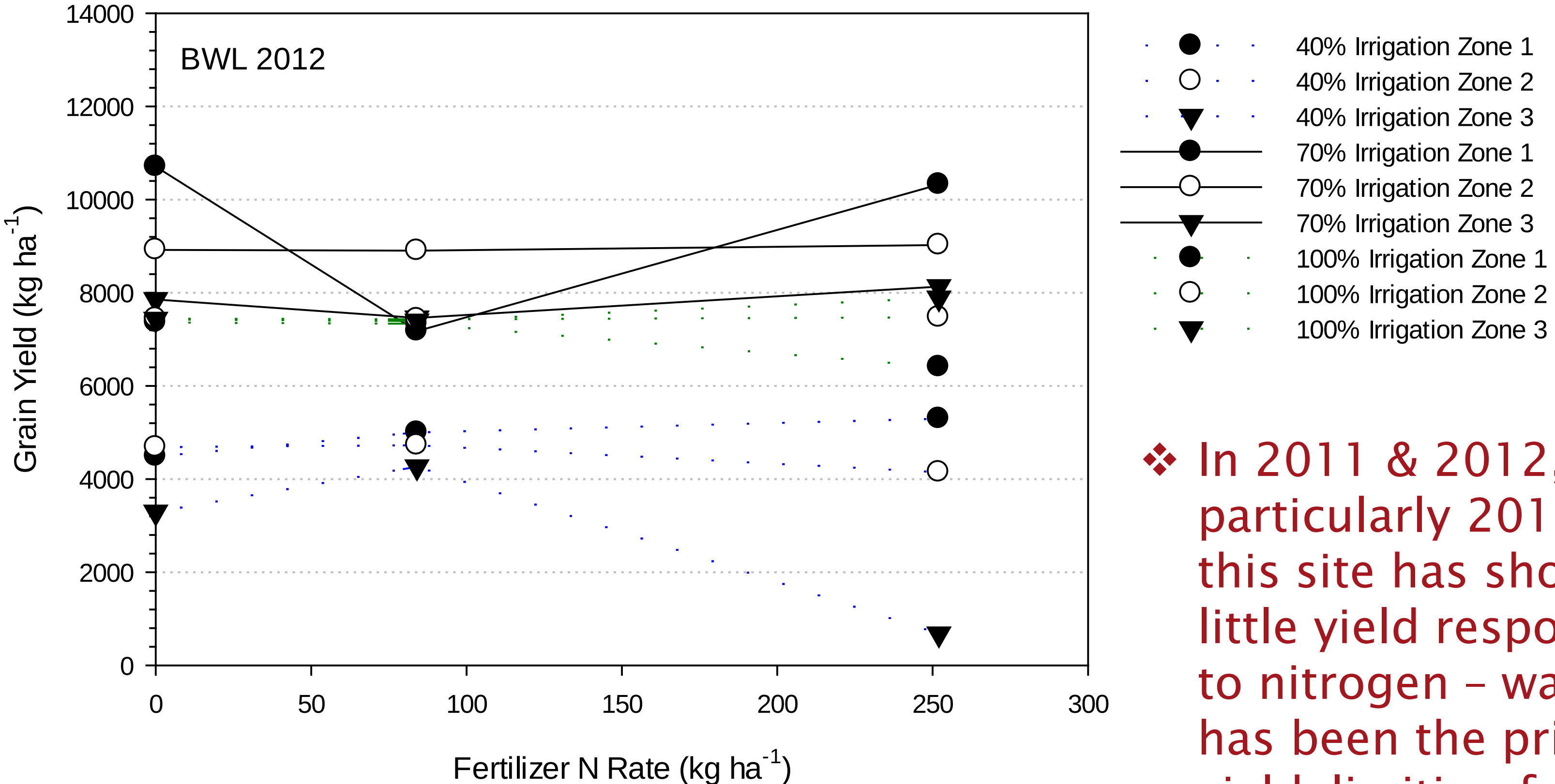
# Grain Yield – Site 1 (SCAL), 2011



# Grain Yield – Site 1 (SCAL), 2012

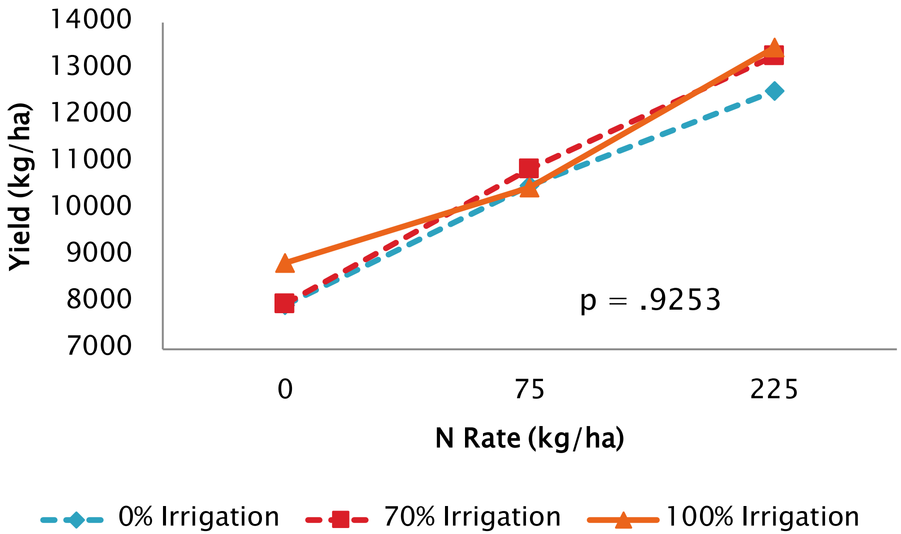


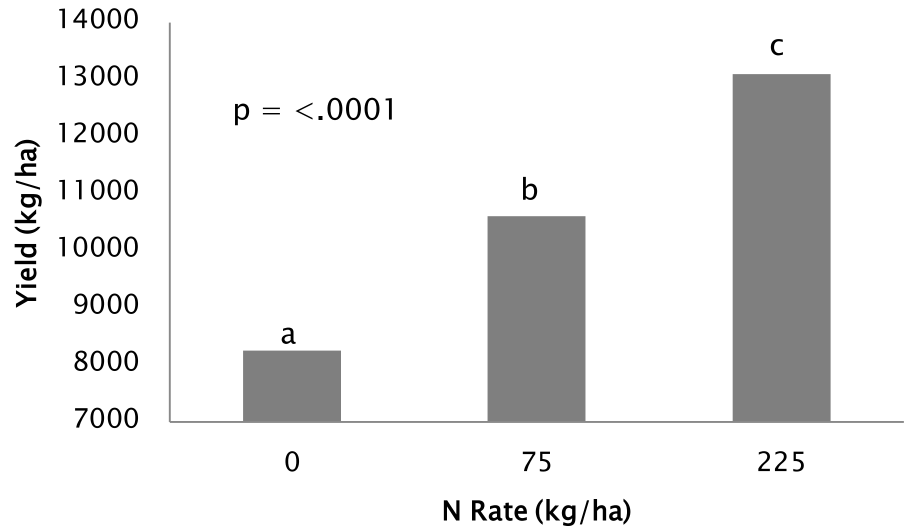
# Grain Yield – (BWL), 2012

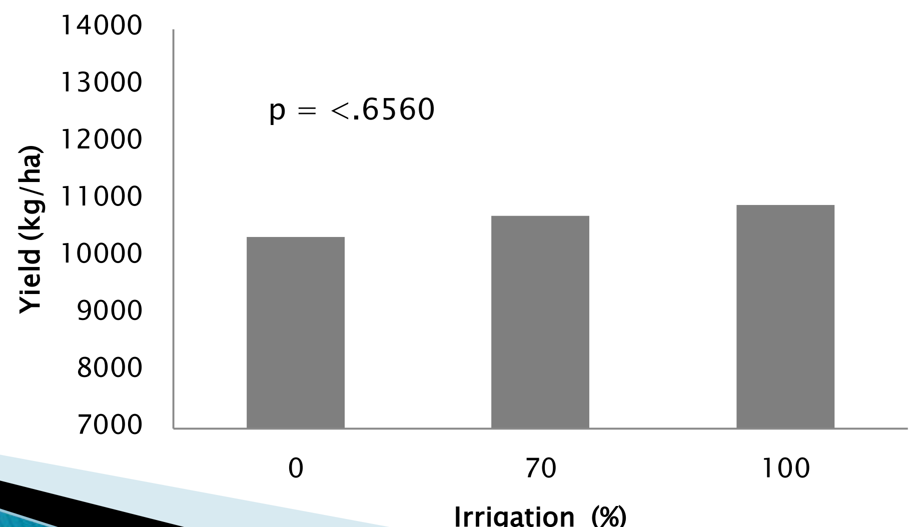



- In 2011 & 2012, but particularly 2012, this site has shown little yield response to nitrogen – water has been the primary yield-limiting factor.

# Grain Yield – Site 2 (BWL), 2013

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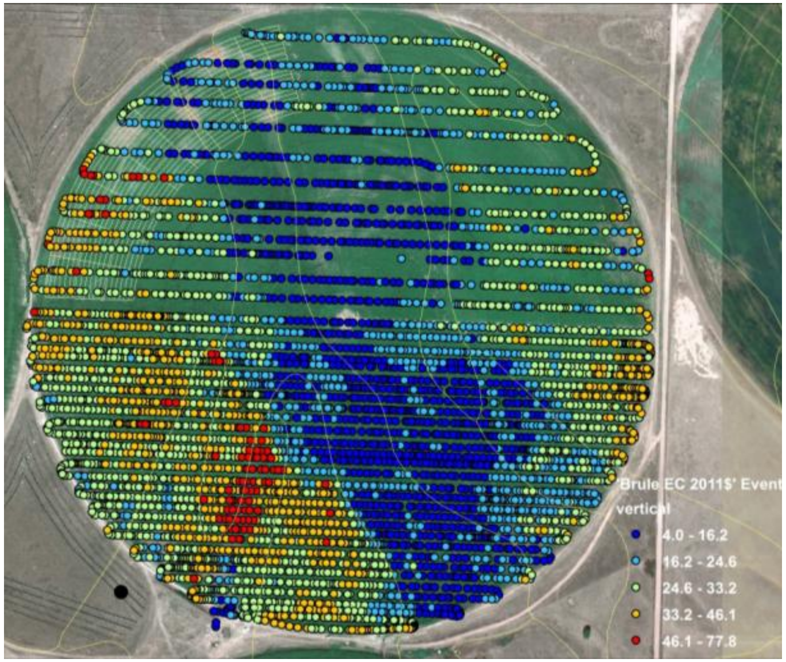
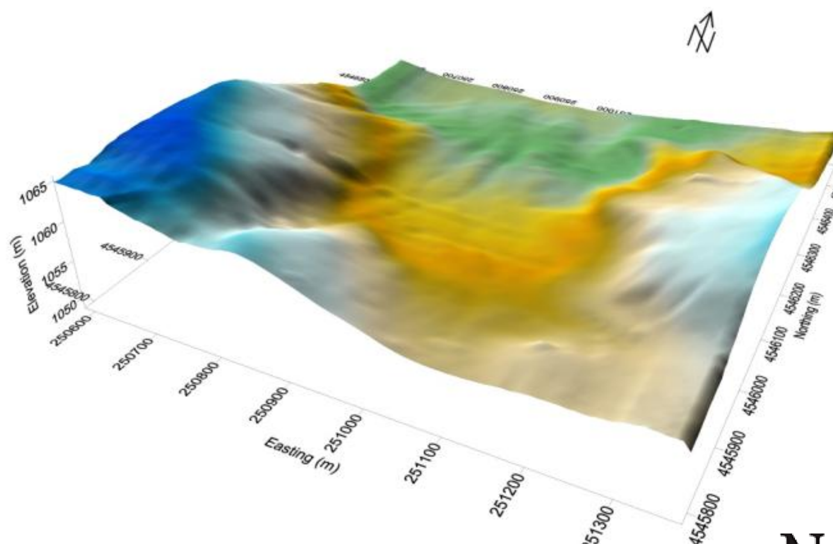
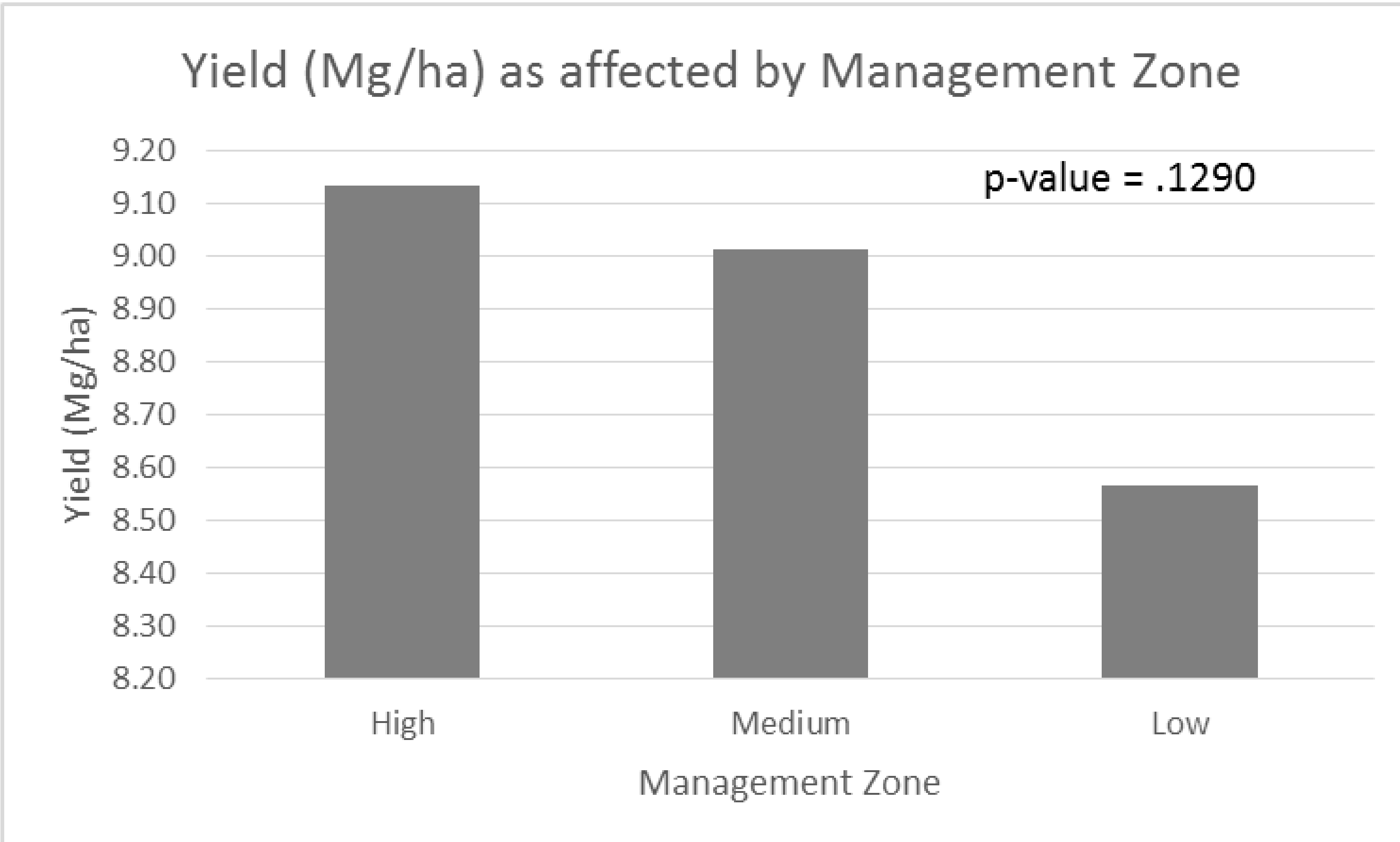
# UNL Water Field Lab (Brule NE):



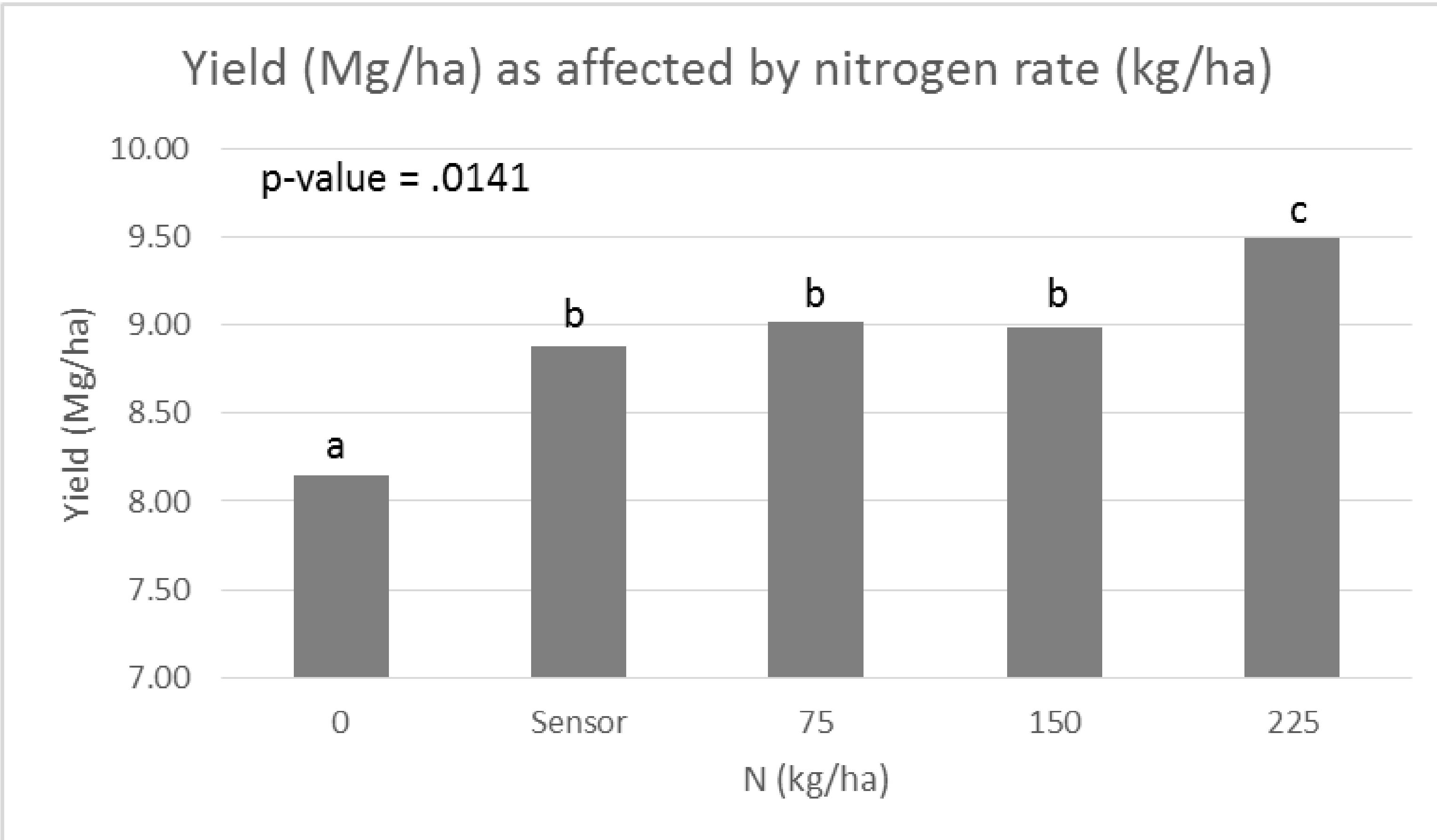

# Soil Apparent Electrical Conductivity and Topography



# MZ Results (2014):



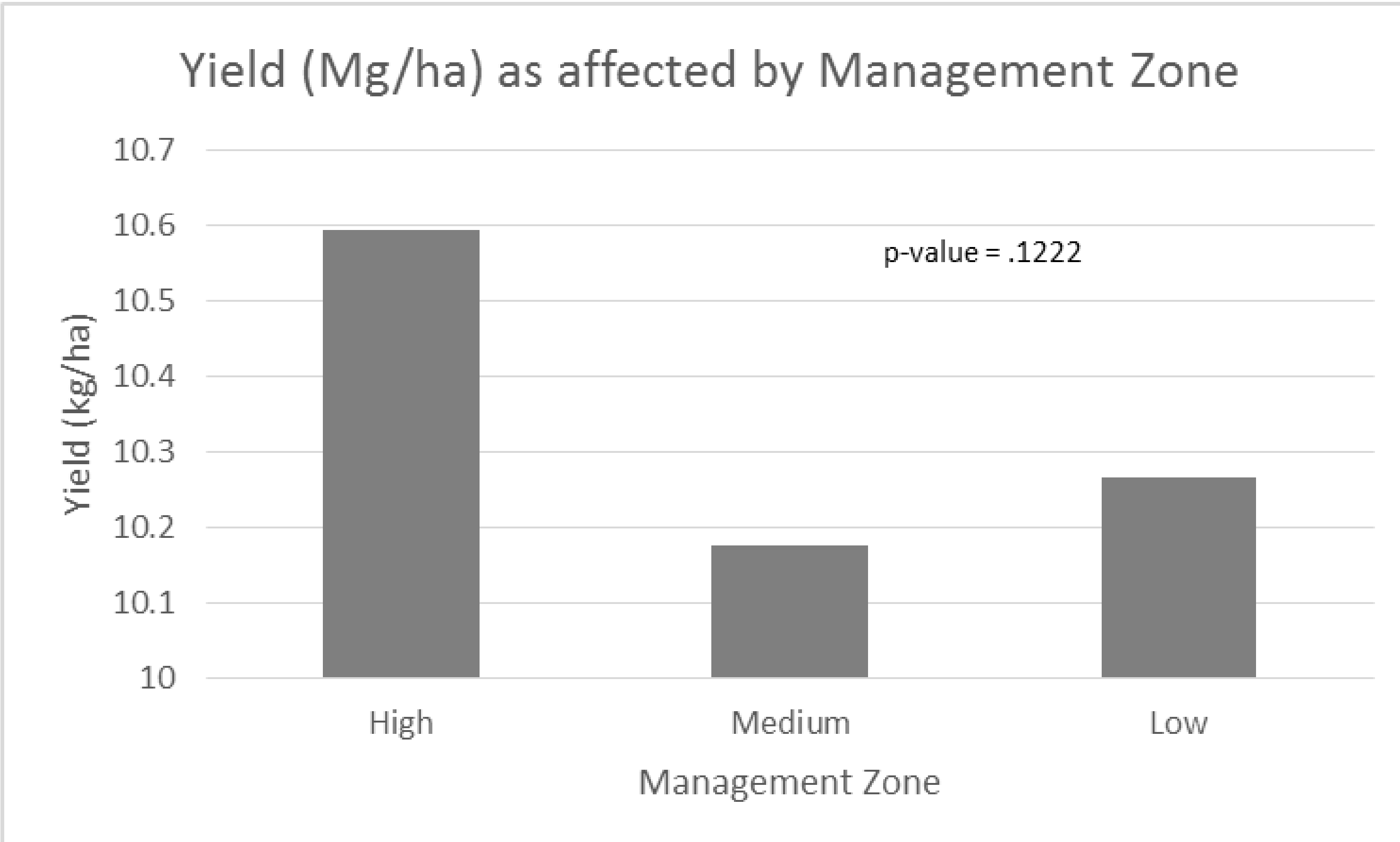
# N Results (2014):



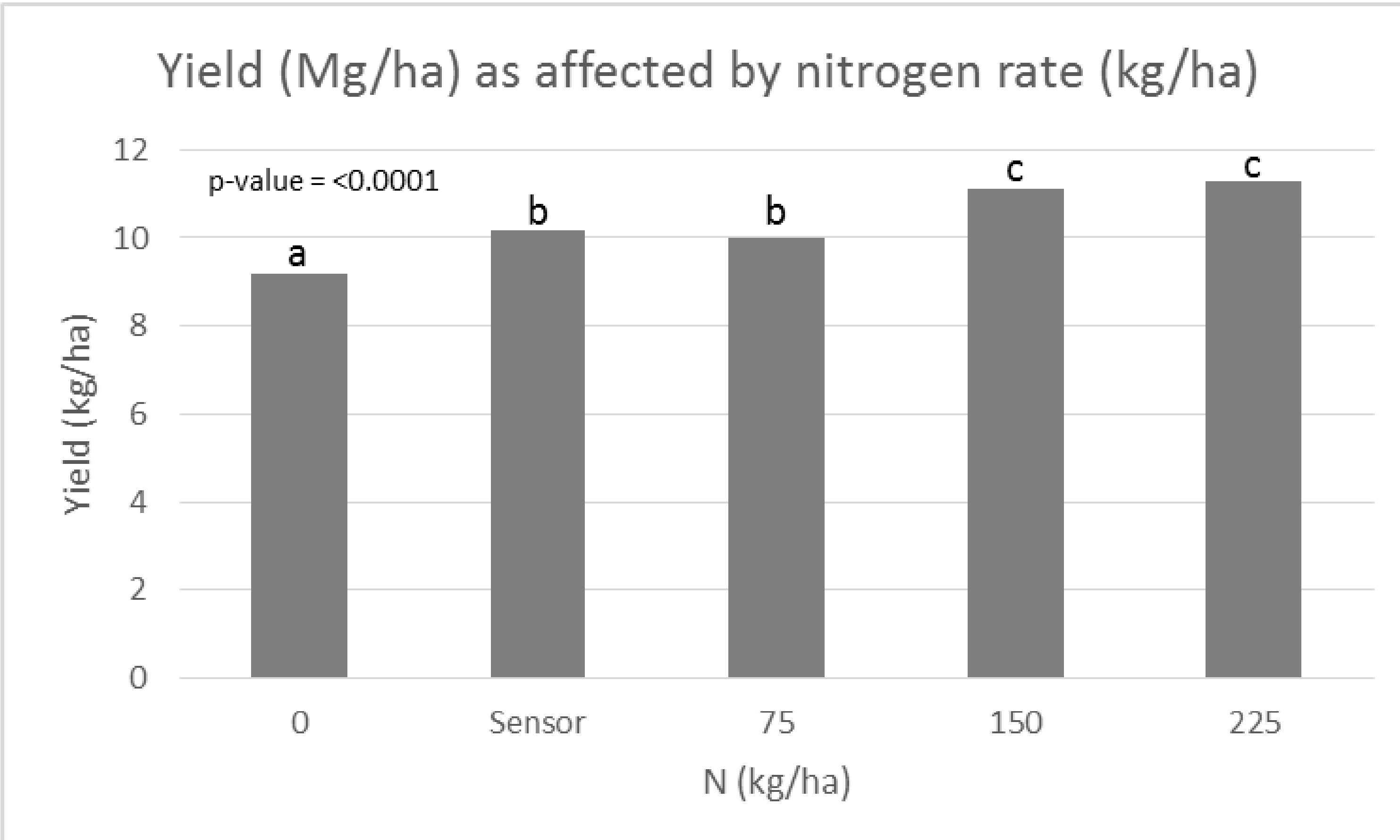
# MZ x N Results (2014):

| Nitrogen (kg/ha) | Management Zone | Yield (Mg/ha) |
|---|---|---|
| 0 | High | 8.55 |
| 0 | Medium | 8.25 |
| 0 | Low | 7.64 |
| Sensor | High | 9.11 |
| Sensor | Medium | 9.39 |
| Sensor | Low | 8.15 |
| 75 | High | 9.10 |
| 75 | Medium | 9.41 |
| 75 | Low | 8.53 |
| 150 | High | 8.99 |
| 150 | Medium | 8.82 |
| 150 | Low | 9.15 |
| 225 | High | 9.93 |
| 225 | Medium | 9.20 |
| 225 | Low | 9.36 |
| p-value = .7249 | | |

# MZ Results (2015):



# N Results (2015):



# MZ x N Results (2015)

| Nitrogen (kg/ha) | Management Zone | Yield (Mg/ha) |
|---|---|---|
| 0 | Low | 9.16 |
| 0 | Medium | 8.79 |
| 0 | High | 9.63 |
| Sensor | Low | 10.56 |
| Sensor | Medium | 9.96 |
| Sensor | High | 9.97 |
| 75 | Low | 9.82 |
| 75 | Medium | 10.09 |
| 75 | High | 10.08 |
| 150 | Low | 10.80 |
| 150 | Medium | 11.02 |
| 150 | High | 11.47 |
| 225 | Low | 11.00 |
| 225 | Medium | 11.02 |
| 225 | High | 11.78 |

p-value = .5325

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# Results (2016): EC Based

**Zone**

| Zone | Grain Yield (Mg/ha) |
|---|---|
| High ECa Zone | 7.5a |
| Low ECa Zone | 8.3b |

p-value = 0.0237 (different letters indication significant differences at alpha = 0.05

**Nitrogen x Zone**

| Zone | N Treatment | Avg N Applied (kg/ha) | Grain Yield (Mg/ha) |
|---|---|---|---|
| High ECa Zone | Uniform | 180 | 7.6 |
| Low ECa Zone | Uniform | 180 | 8.2 |
| High ECa Zone | Sensor Based | 140 | 7.3 |
| Low ECa Zone | Sensor Based | 147.5 | 8.4 |

No Significant Differences

**Nitrogen**

| N Treatment | Avg N Applied (kg/ha) | Grain Yield (Mg/ha) |
|---|---|---|
| Uniform | 180 | 7.8 |
| Sensor Based | 144 | 7.8 |

No Significant Differences

# Implications:

- There were significant interactions between water and N supply, even on a site with little landscape variation.
- If both site-specific water and N management are possible, it may be important to consider these interactions for rates and timing of each input.
- Predicting available soil water and N supply is highly complex; using sensors to measure soil water status, and evaluate the crop canopy for both water and N status is important for accurate characterization of water and N management.

# Conclusions:

- Applying management zones are variable rate N to highly variable fields is challenging and can change year to year.

- There is no easy or adequate way to account for vertical variability.

- Crop canopy sensors show promise, and may currently be the best way to account for extreme variability.

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# Questions?