

Real-time Sensor Systems for Fertility Management

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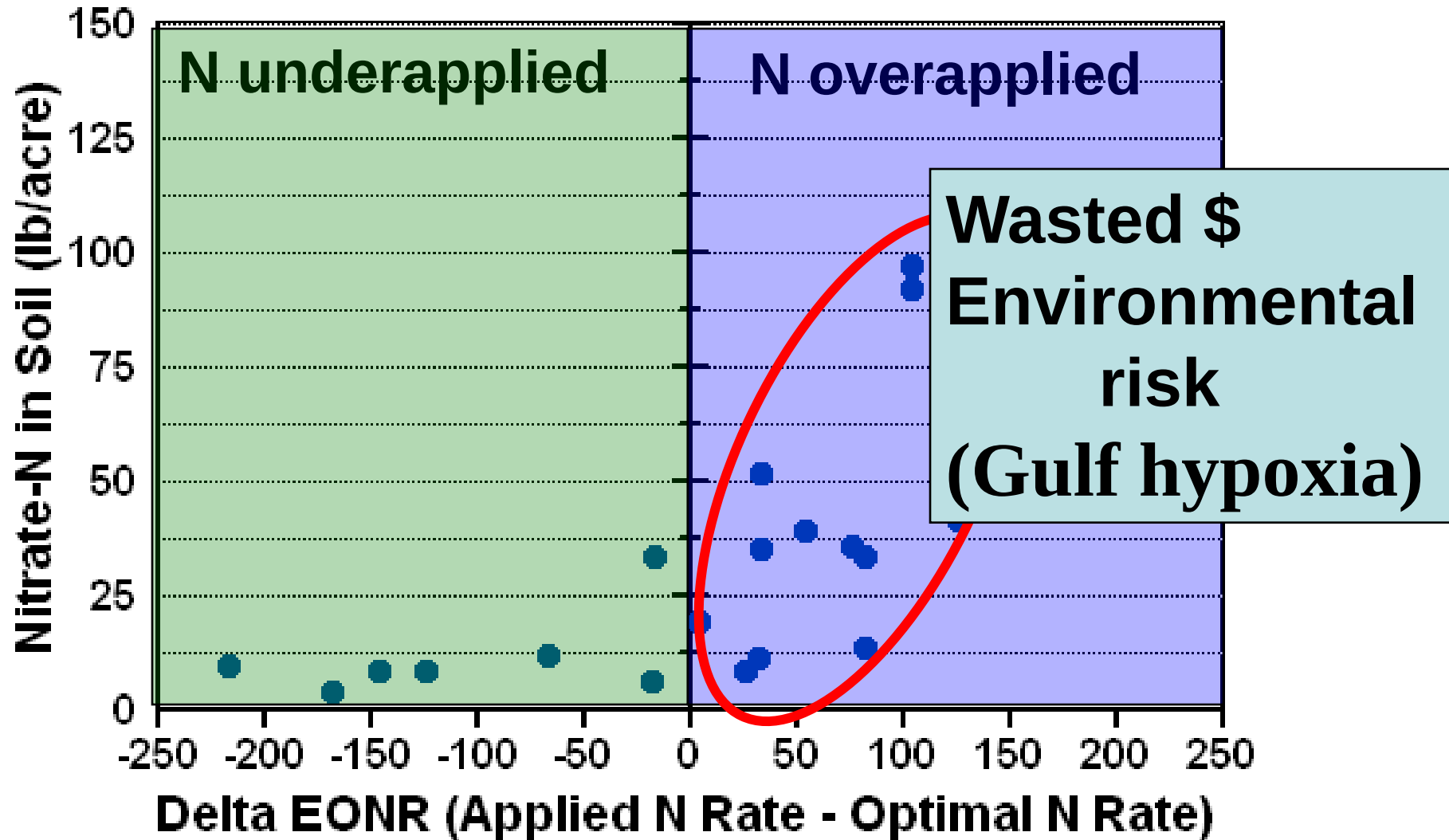
Acknowledgments

Information provided by:

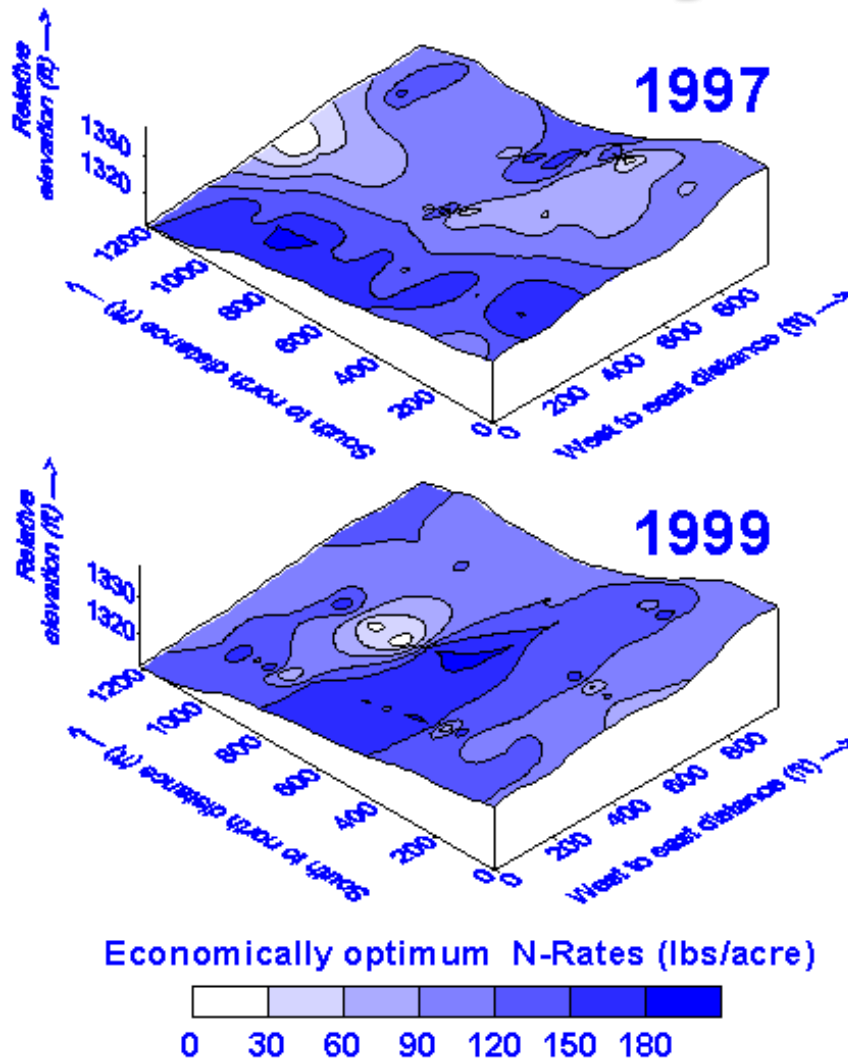
- Christine Morgan, Alex Thomasson, Ruixiu Sui; Texas A&M Univ.
- John Wilkerson, Philip Allen; Univ. of Tenn.
- Newell Kitchen, Ken Sudduth; USDA-ARS (Mo.)
- Peter Scharf; Univ. of Mo.
- Randy Taylor; Ok. St. Univ.
- Leo Espinoza; Univ. of Ark.

**Why not use uniform
application rates for
nutrients?**

Underapplication = lost yield
Overapplication = leftover N in soil



Crop N need is variable: from year to year



Minnesota corn:
the places that
needed the most
and least N were not
the same in the two
years

G. Malzer data from Doerge (2002)
Crop Mgmt. doi. 10.1094/cm-2002-
0905-01-RS

So we need to look at Variable Rate Application (VRA)

Production inputs are applied on an optimum basis for the local conditions.

VRA requires

Knowledge of ***economic*** optimum rates
at chosen management scale

Ability to apply desired rate at desired
scale

Imagery has shown promise as basis for VRA, but many believe that in-field sensing is the future of nutrient management

- The primary benefit of sensor-based measurements is improved accuracy.
- Sensors can increase sampling intensity by orders of magnitude compared to traditional methods. As a result, a significant decrease in overall error can be realized.

Sensor-Based Nutrient Management

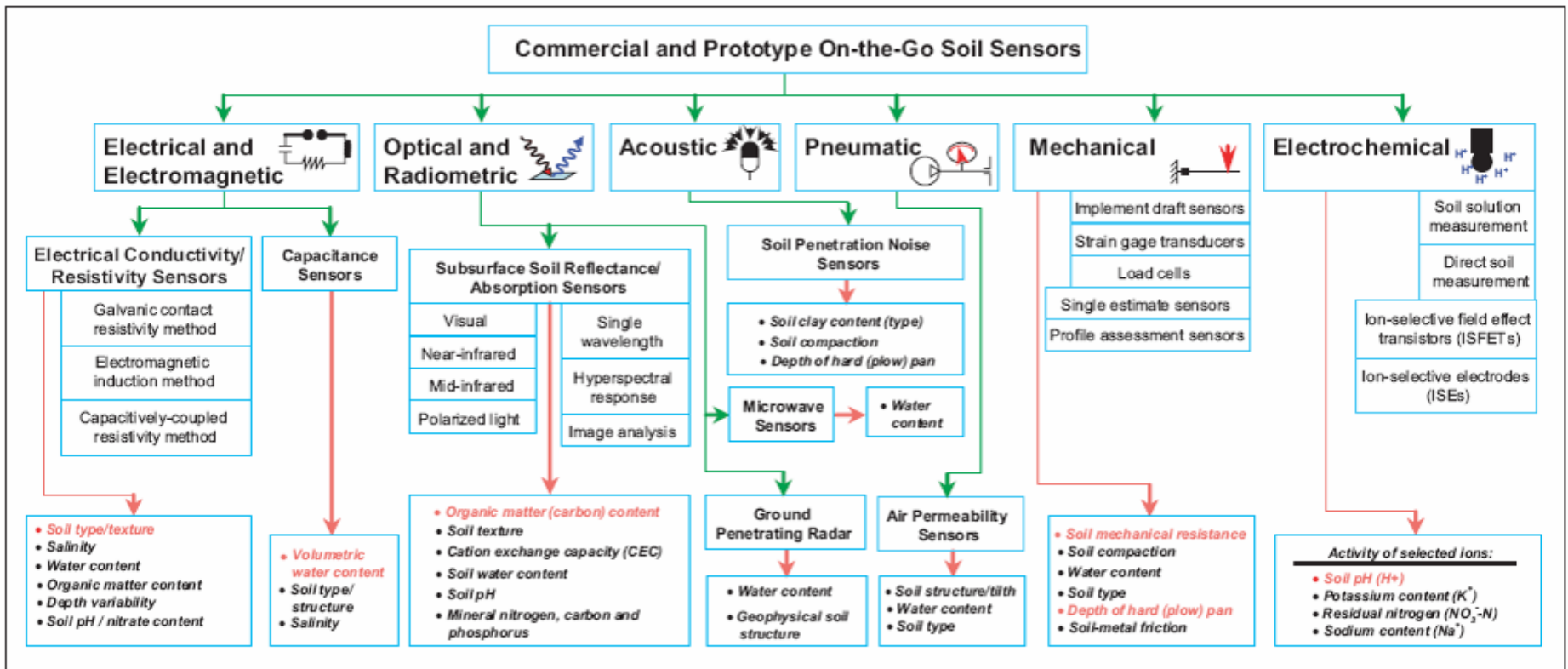
- Monitor (measure) nutrient status in the field
- Apply supplemental nutrients at variable rates to meet crop needs



It Makes *Sense*

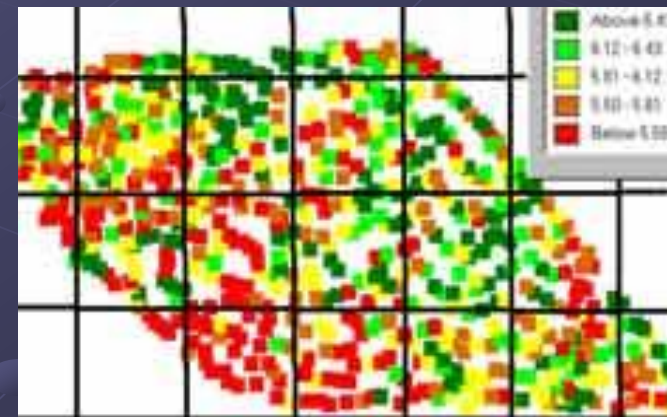
- Soil Sensing
- Plant Sensing



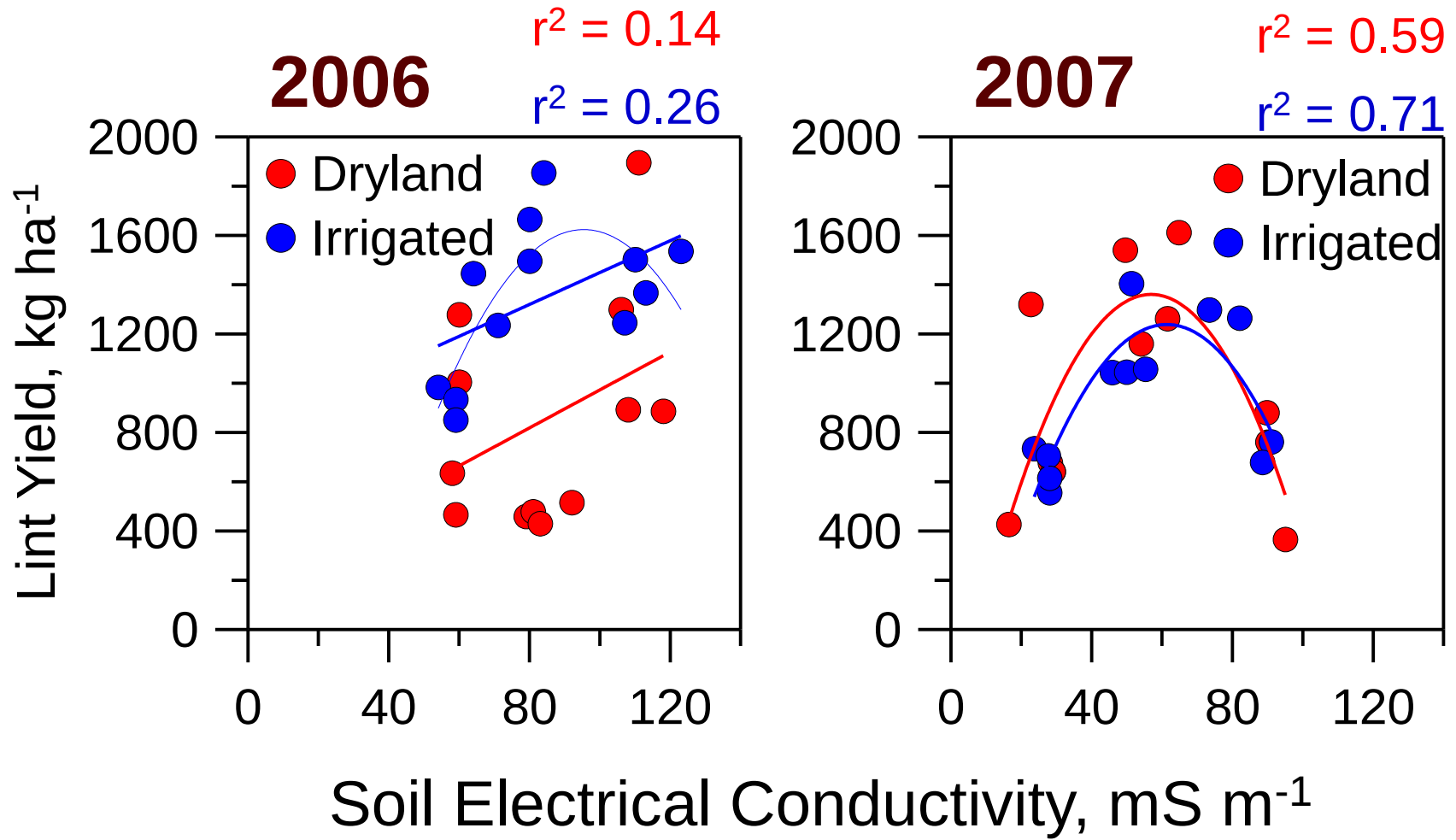


Soil Fertility/Chemistry Sensors

- Sense levels of nutrients important for plant growth to control fertilizer additions
 - Macro-nutrients (Nitrogen, Potassium, Phosphorus), pH (commercially available), trace nutrients
- Sense compounds toxic to plants and/or bad for the environment
- High-throughput, on-the-go sensing is preferred to efficiently obtain data needed to map variations

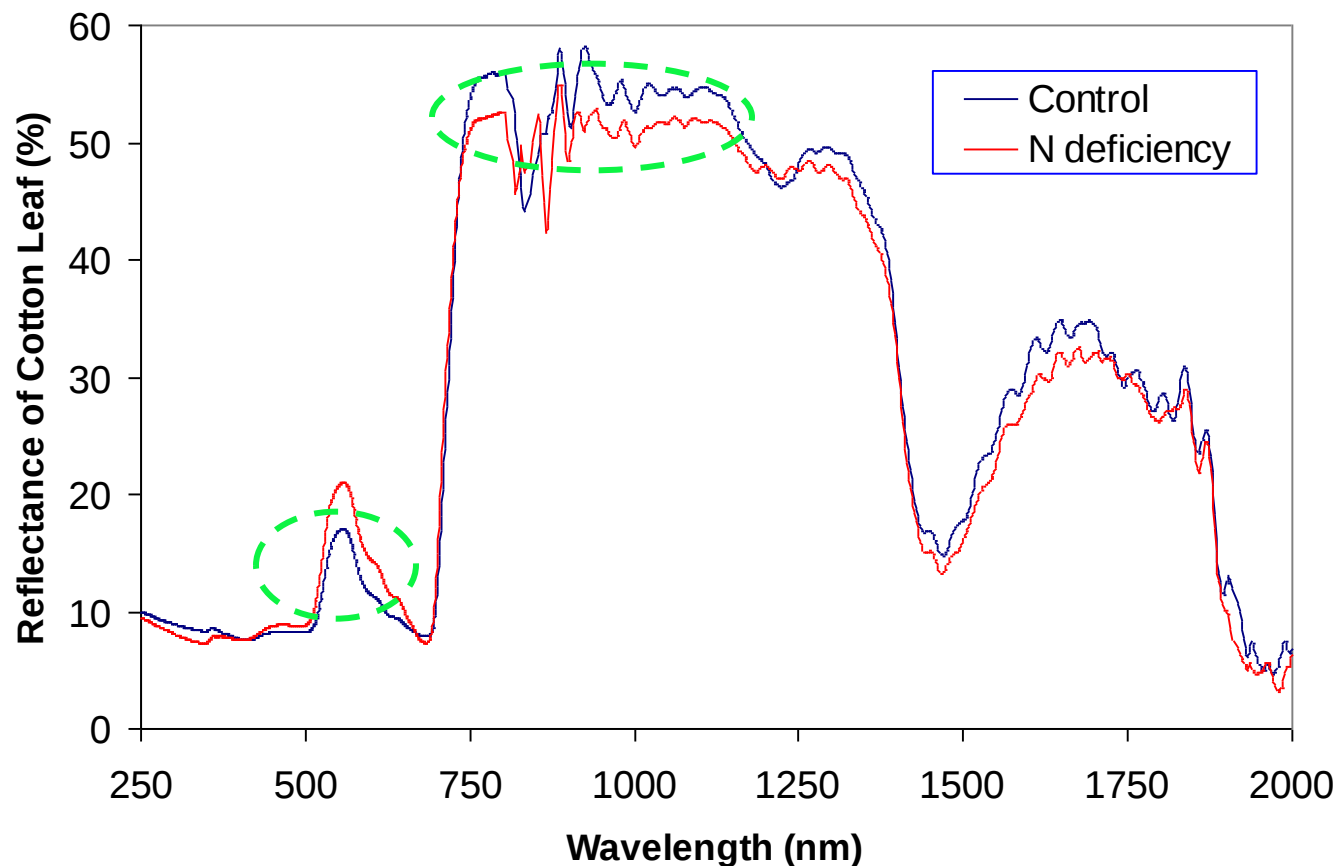


Lint Yield

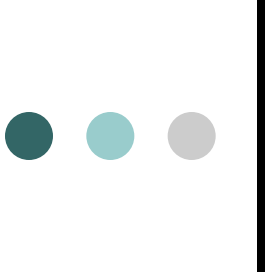




Remote Sensing System for Plant Nitrogen Determination

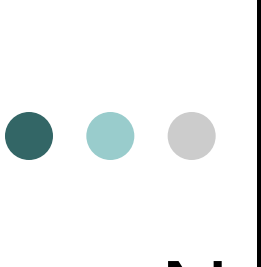


**Spectral reflectance of cotton plant canopy relates
to N status of the plants**



Missouri Reflectance Study

- Six N rate experiments
 - 3 in 2006, 3 in 2007
 - Loamy sand, silt loam, clay each year
- Three commercial sensors (GreenSeeker, Crop Circle, and Cropscan)
- Three stages (early square, mid square, and first bloom)
- Revised protocol for 2008



Sensor vs. optimal N rate

- None of the sensors could predict optimal N rate at first square
- All of the sensors could predict optimal N rate at mid-square and first flower
 - Optimal N rate would have increased profit by \$43/acre relative to typical producer rate of 100 lb N/acre
 - Required comparison to high-N area (may present problem for cotton)



Ground-Based Remote Sensing System for Plant Nitrogen Determination (Real-time management)



- Measure spectral reflectance of plant canopy and plant height
- Diagnose plant N status
- Apply what the plant needs “On-the-go”



Ground-Based Remote Sensing

Active Reflectance Sensors

- **CropCircle**
2 bands (amber @590nm; NIR @880nm)
- **GreenSeeker**
2 bands (red @660nm; NIR @770nm)
- **Experimental Unit**
4 bands (blue, green, red, NIR)



Ground-Based Remote Sensing System for Plant Nitrogen Determination

Multi-Spectral Optical Sensor

- Active optical sensor
- Modulated LED light source
- Measure reflectance
at four wavebands

Four Wavebands

Blue band

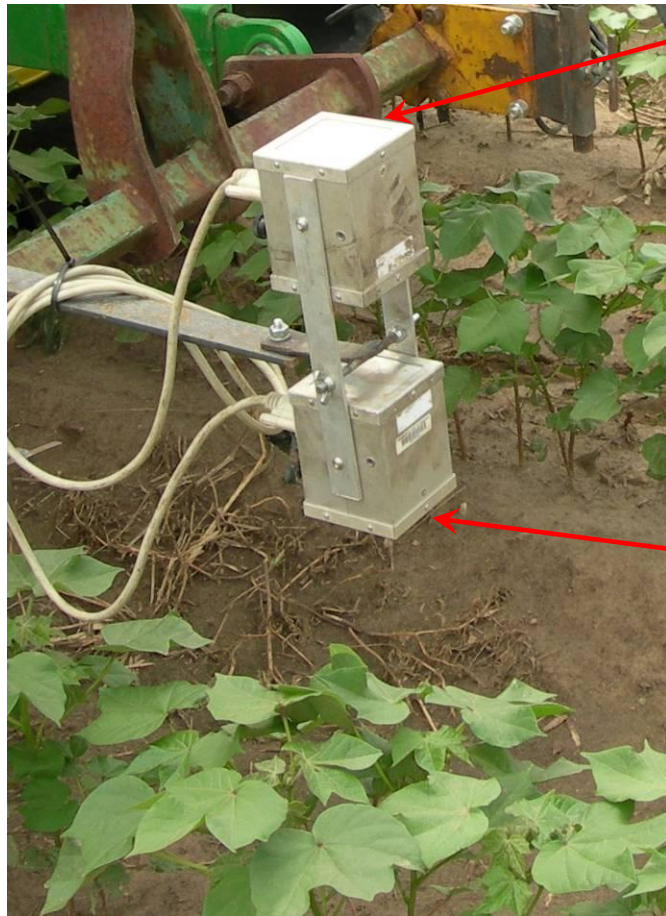
Green band

Red band

NIR band



Cropscan passive sensor uses ambient light (solar)



Multiple sensors
(wavelengths)
pointing up to
measure incoming
radiation

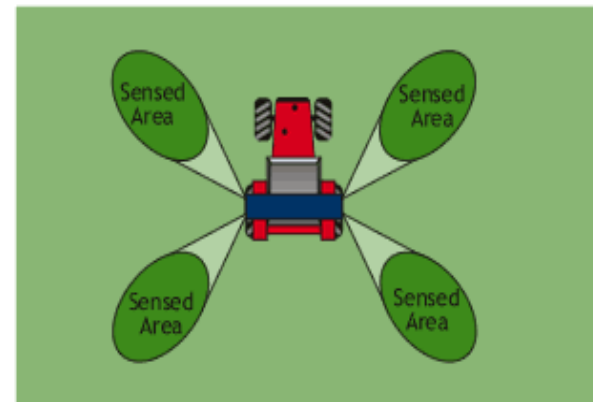
Same sensors
pointing down to
measure reflected
radiation

YARA-N-Sensor (Hydro-N)



Initial system was passive, but an active light system has been developed that provides multiple spectral indices.

Crop Area 'Sensed'



- Reflectance above the row appeared sufficient for corn.
- Do we need another piece of information for cotton?
 - Plant height (may be useful for PGR management)?
 - Between-the-row reflectance?



Ground-Based Remote Sensing System for Plant Nitrogen Determination

Ultrasonic sensor for measuring plant height



Polaroid Ultrasonic Sensor

Frequency: 50 KHz;

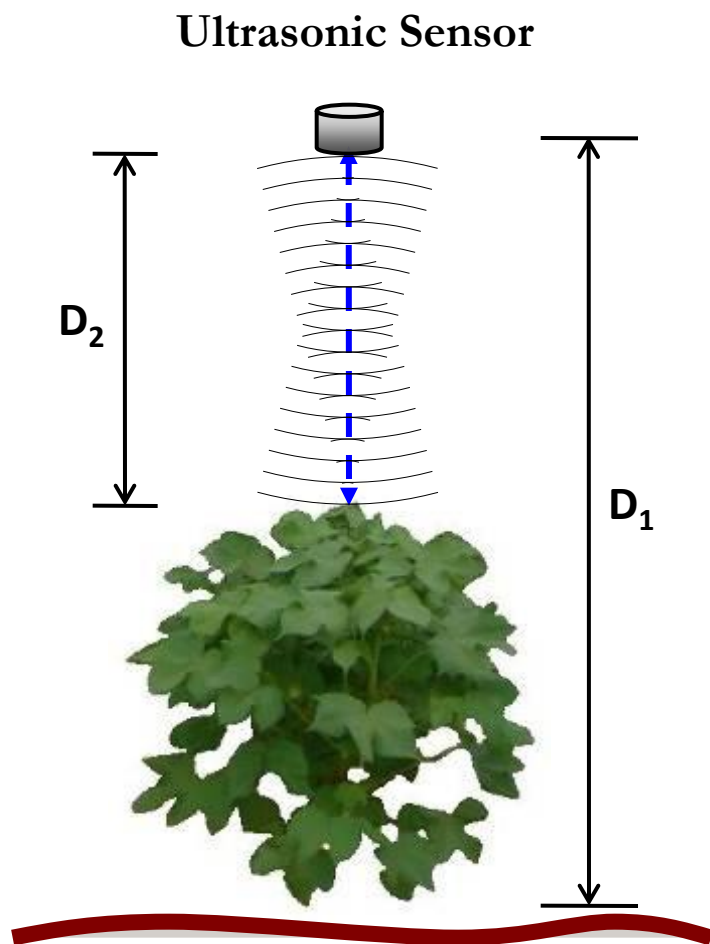
Beam angle: 12°;

Temp: -30 – 70 °C

Univ. of Tenn. has also built ultrasonic sensor



Ground-Based Remote Sensing System for Plant Nitrogen Determination



Sensor transmits ultrasonic pulses toward plant canopy, then waits for the echo to return from the canopy. Distance from the sensor to the canopy (D_2) can be determined based on the speed of sound and the time taken for the ultrasonic pulse to travel the distance from the sensor to the canopy and back to the sensor.

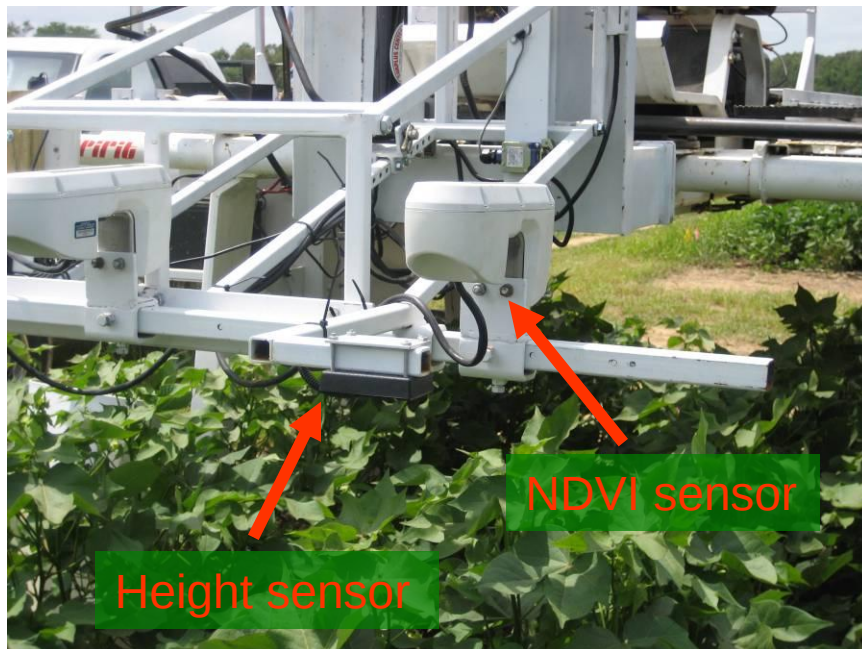
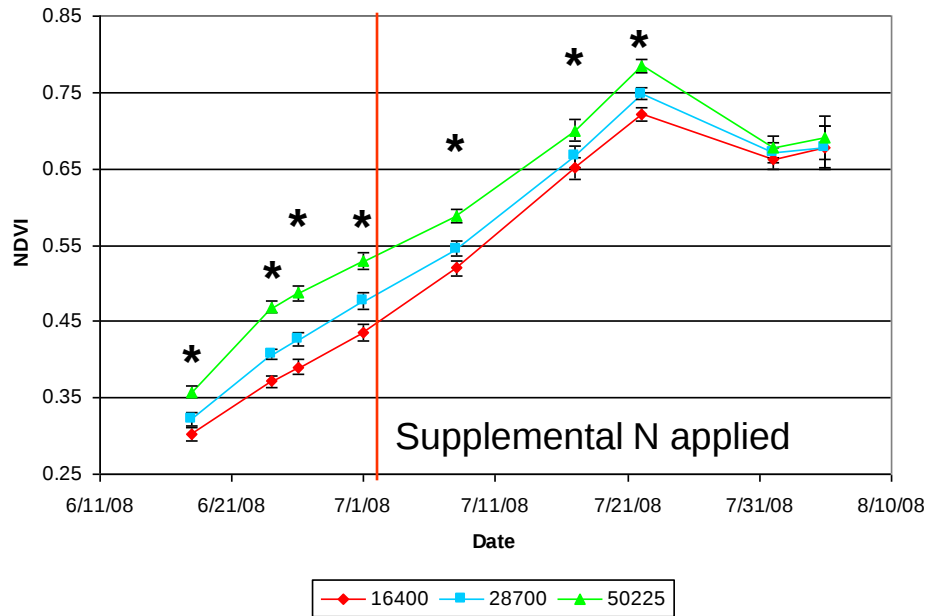
$$\text{Plant Height} = D_1 - D_2$$

D_1 : Known

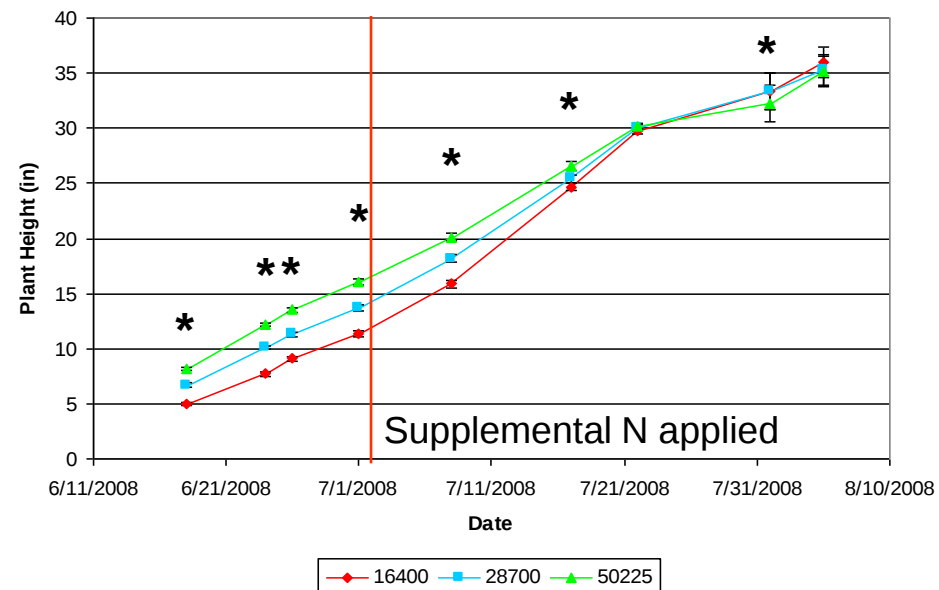
D_2 : Measured

$$D_2 = \frac{1}{2} \text{ Time} * \text{Sound speed}$$

NDVI differed by plant population

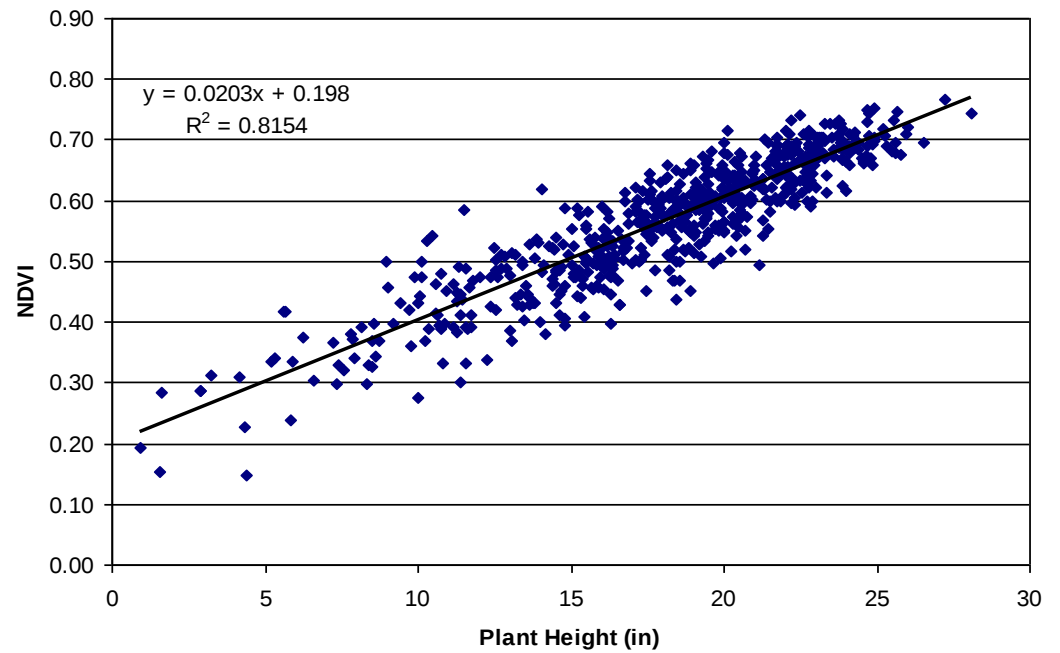


Plant height differed by plant population





Strong relationship between NDVI and plant height (46 days after planting)

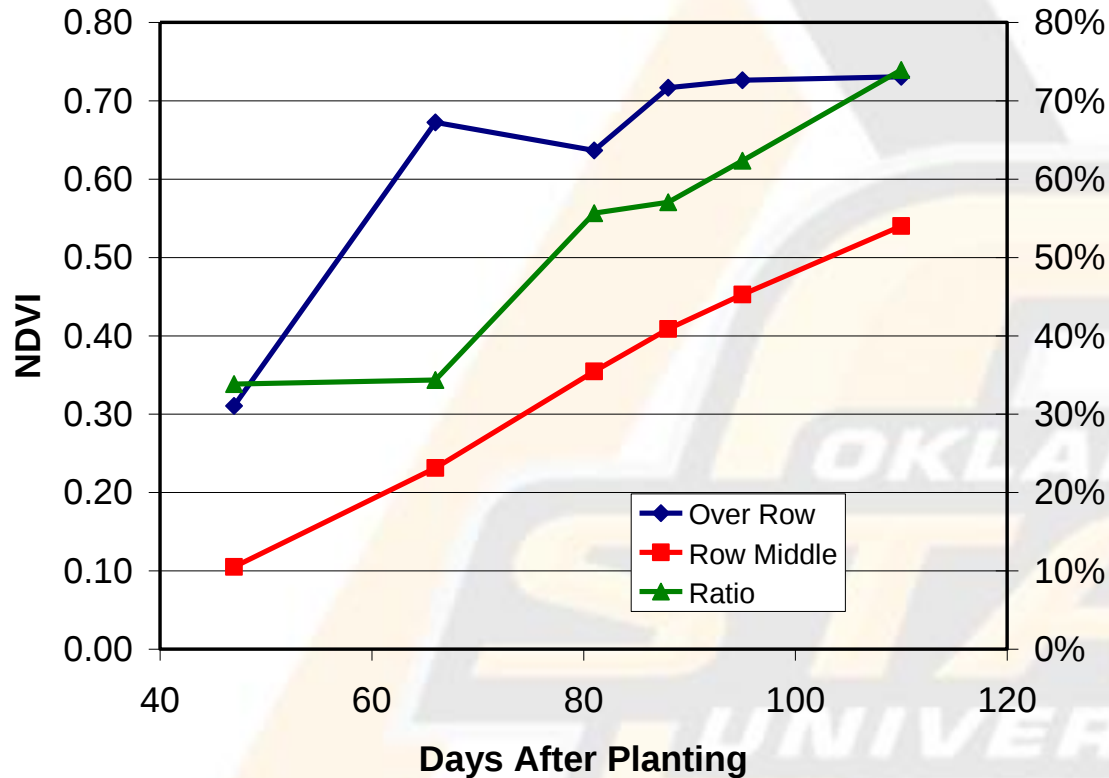


Another Approach for Cotton

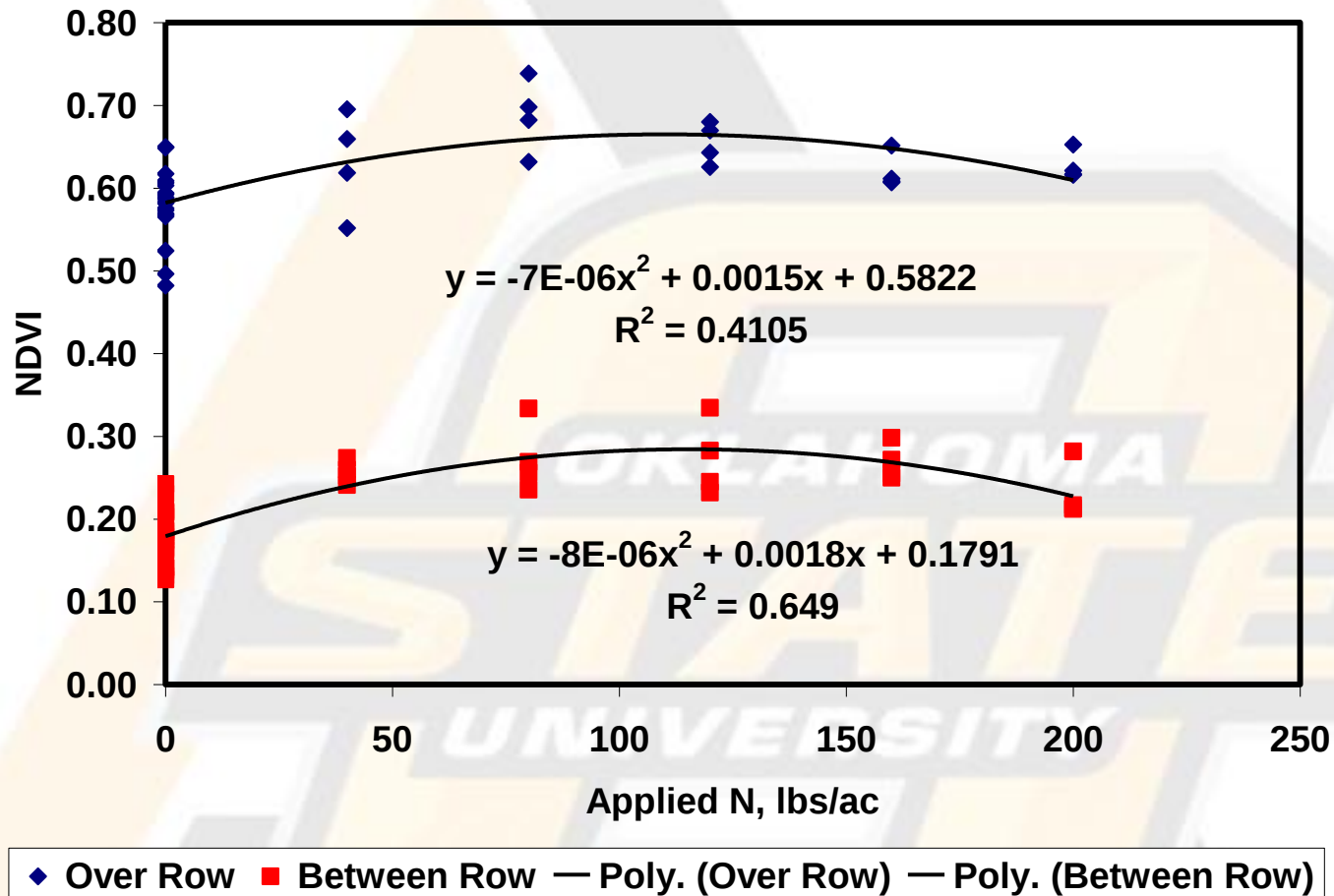
- Measuring NDVI ***directly over the row*** with four sensors and ***between the rows*** with three sensors
- Collected data from research plots and farmers' fields on multiple dates



Estimating Canopy Closure



Sensor Data – July 25



Great deal of on-going work
aimed at developing real-time
nutrient-management system
(especially for nitrogen).

Cotton Incorporated
encouraging communication
among research teams.

On-farm field-scale
nitrogen/sensor demo conducted
in Missouri in 2008.

USDA-NRCS Conservation
Innovation Grant will allow
additional on-farm
demonstrations.

**An effective, reliable, real-time
sensor systems for cotton
nitrogen management should
be available soon.**

**Systems for other nutrients
will follow.**