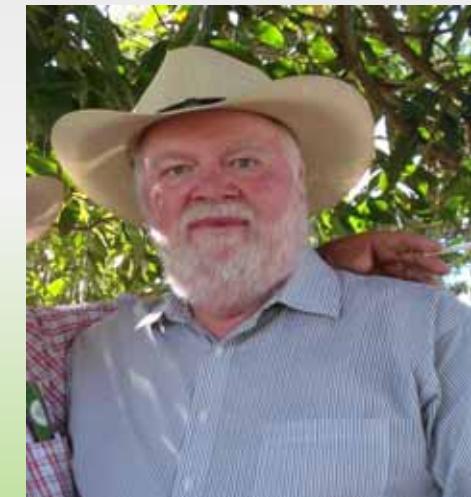


Sensing for In-Season Nitrogen Needs



Jim Schepers
Happily Retired

Taking Sensor Technologies to the Field

Your Goal Today

- Understand the limitations of remote sensing
- Identify situations where sensors are likely to perform well
- Develop a strategy that capitalizes on the capabilities of the technology
- How to test and evaluate the performance of sensors (“***smoke test***”)
- Learn from others and their mistakes

**Welcome - Short Course on Sensors
*and Remote Sensing***

Science may hold the trump card

BUT



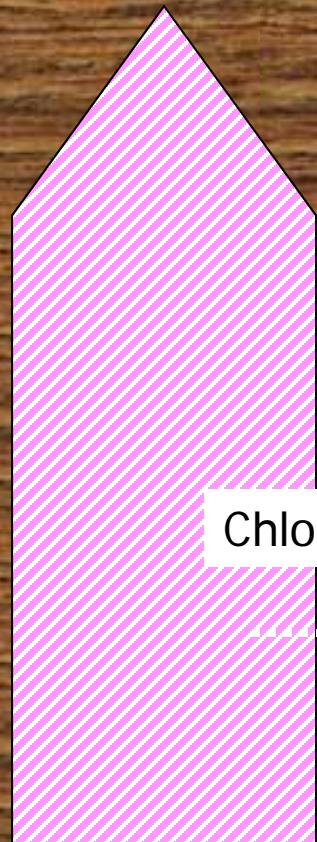
How the game is played determines the winner

Sensors may be able to quantify a situation, but
the patient's symptoms need to be expressed

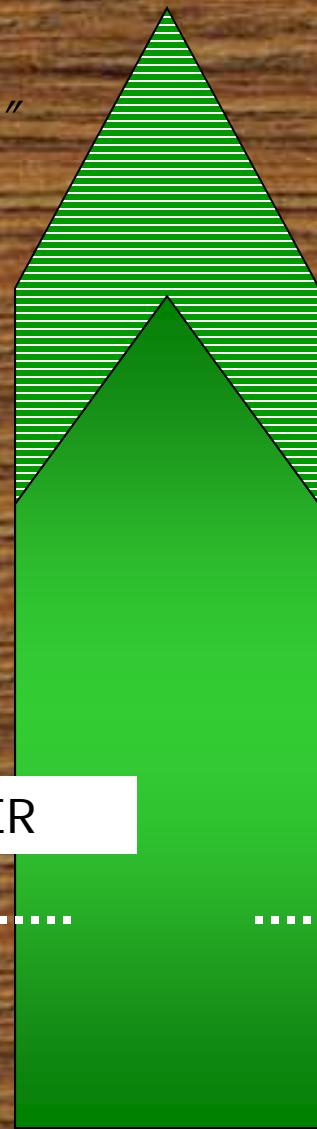
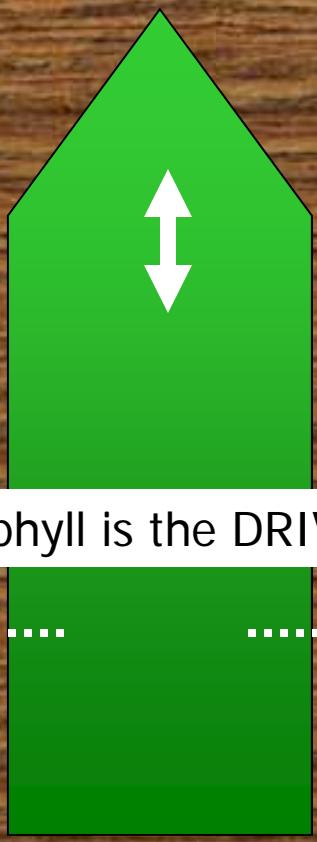
Logic - Linkages

Sensors CAN NOT detect amount of excess N

"Luxury Consumption"



Chlorophyll is the DRIVER



*"Vigor"
Biomass*



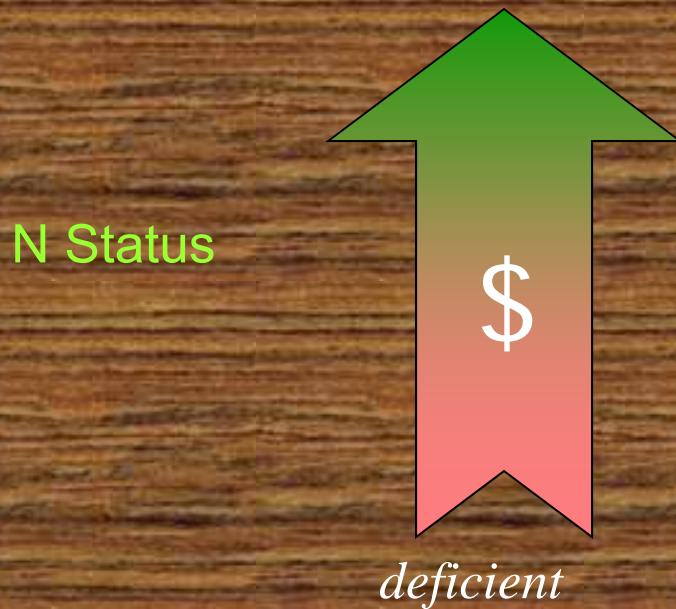
Yield

Photo-synthesis

Chlorophyll

Plant N

The green color in leaves is caused by chlorophyll



What About ?

S
Fe
Zn
Mn
? ? ?

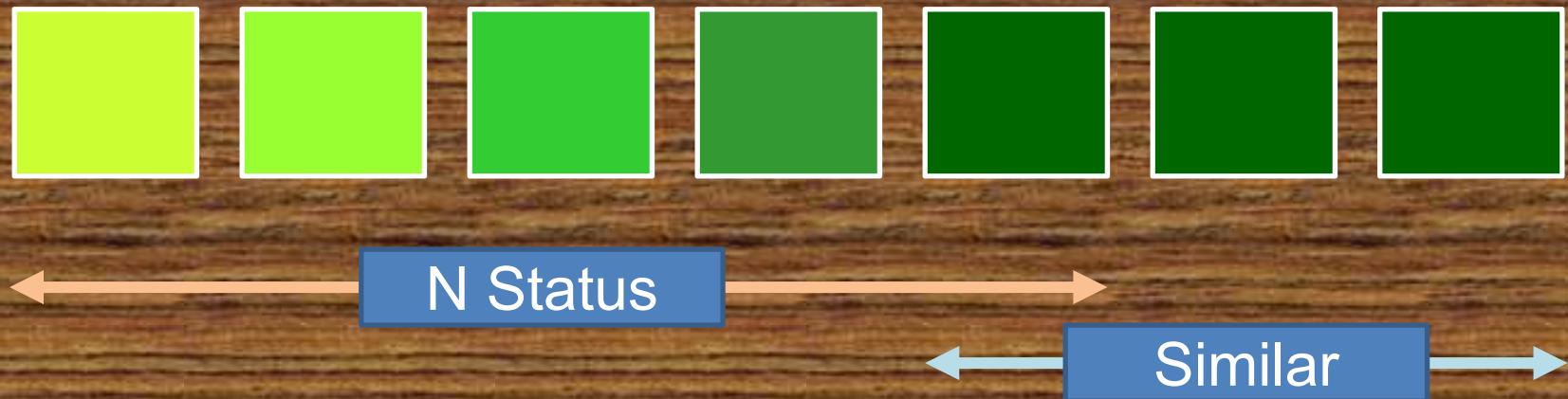
Yellowish colors mean less chlorophyll

Sensors can not detect patterns within leaves !

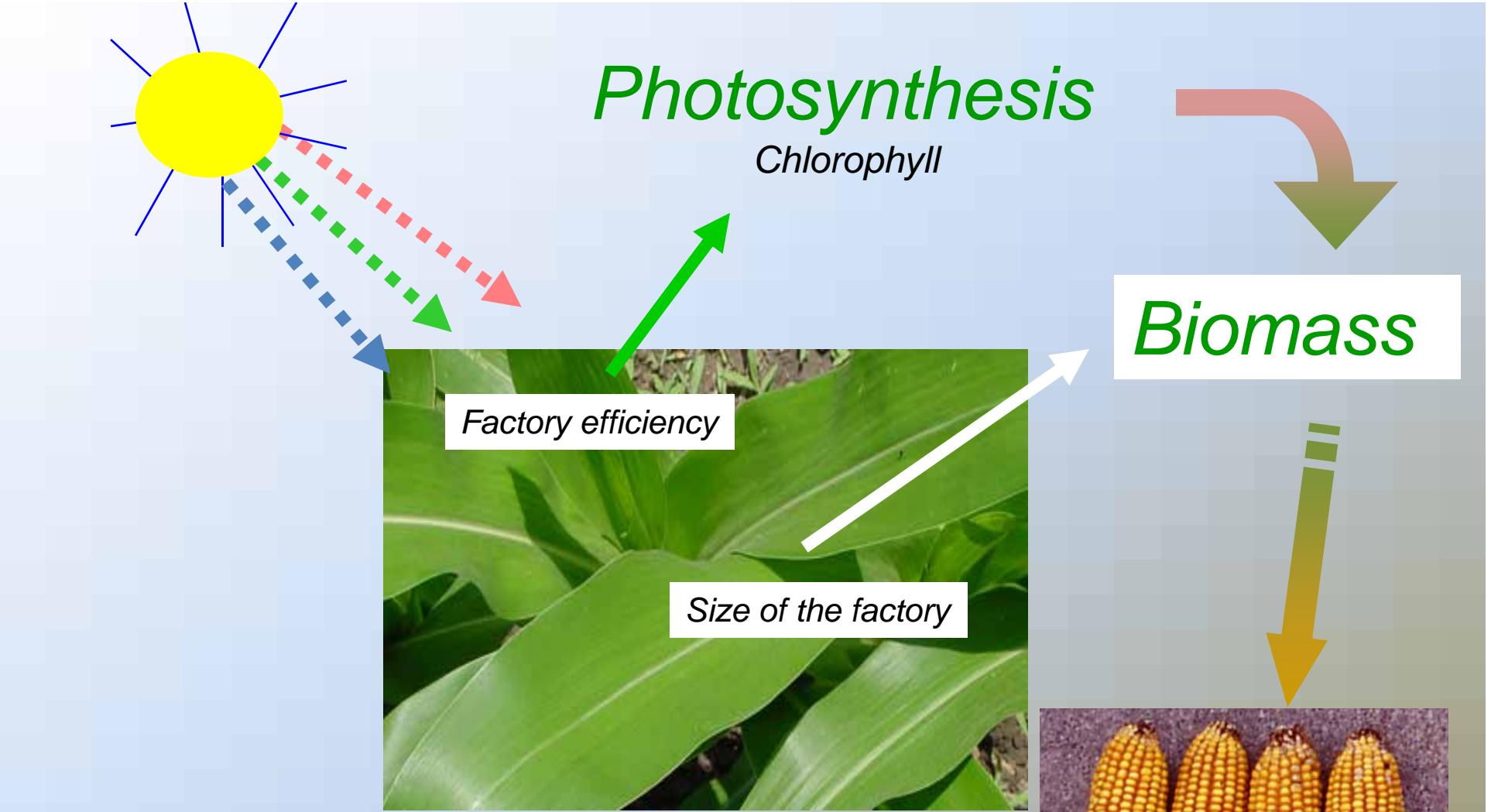
Lesson #1 - - - -

Canopy sensors respond to “*living biomass*” and “*chlorophyll content*”

Treatments / N-rates



**Canopy sensors can not quantify excess N
AND
Soil background reduces sensitivity**



Productivity is proportional to :

Chlorophyll Content *times* Incoming Radiation

Changes rather slowly

Changes by the minute

Producer Comments

- What is the difference between sensors ?
- How do the sensors operate ?
- How are the sensors calibrated ?
- Which vegetation index is appropriate ?
- How does the algorithm work ?
- Can I use my own algorithm ?
- How early can sensors be used ?
- How late can N be applied to rescue yield loss ?
- How much does a sensor system cost ?
- Are the sensor systems compatible with all applicators ?

What are the producer's expectations ?

Bag of fertilizer - - - - -

crop vigor

Jug of Roundup - - - - -

dead weeds

Auto-steer tractor - - - - -

straight rows, less stress

N-Serve - - - - - - - - -

higher yields

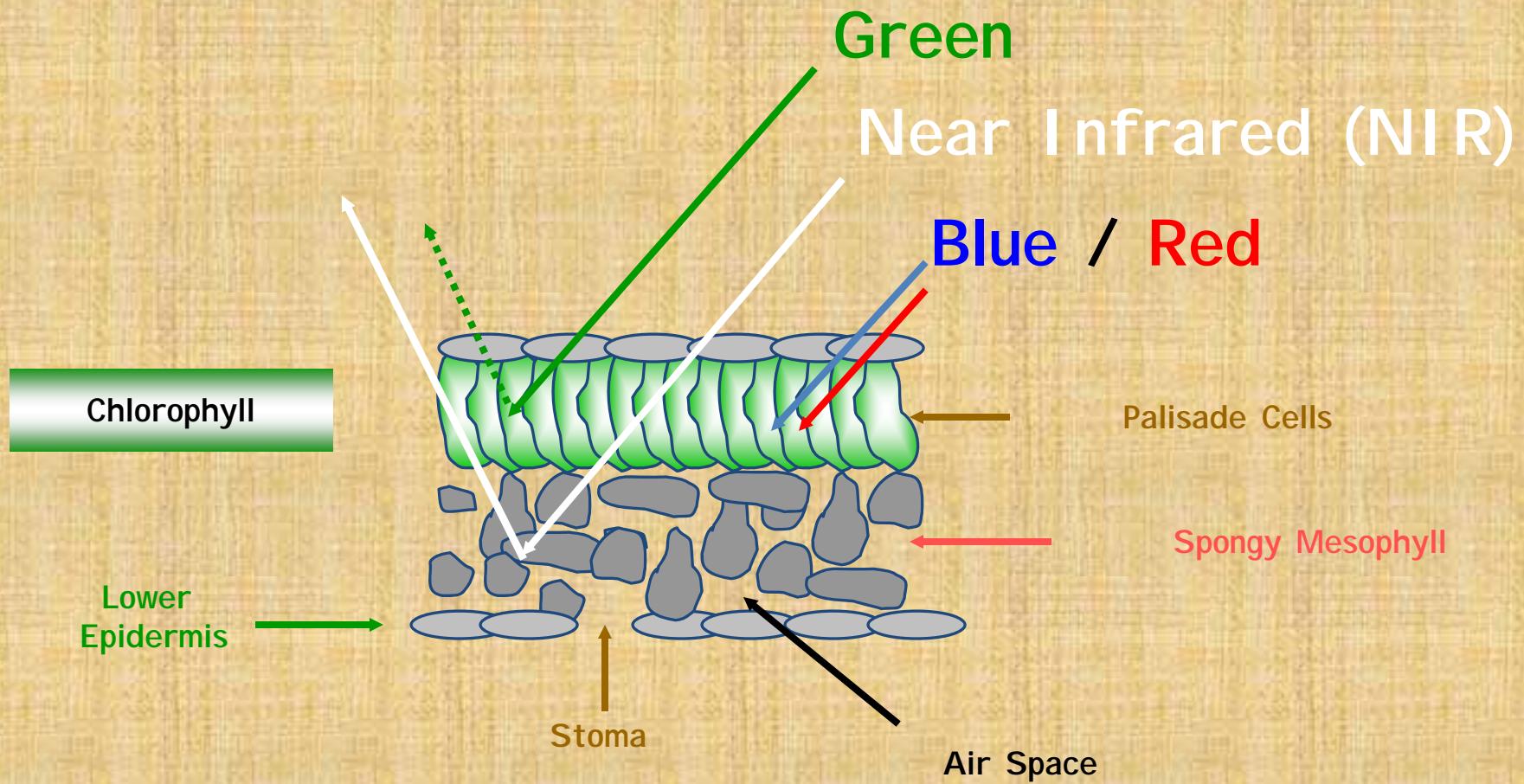
Crop sensors - - - - - - -

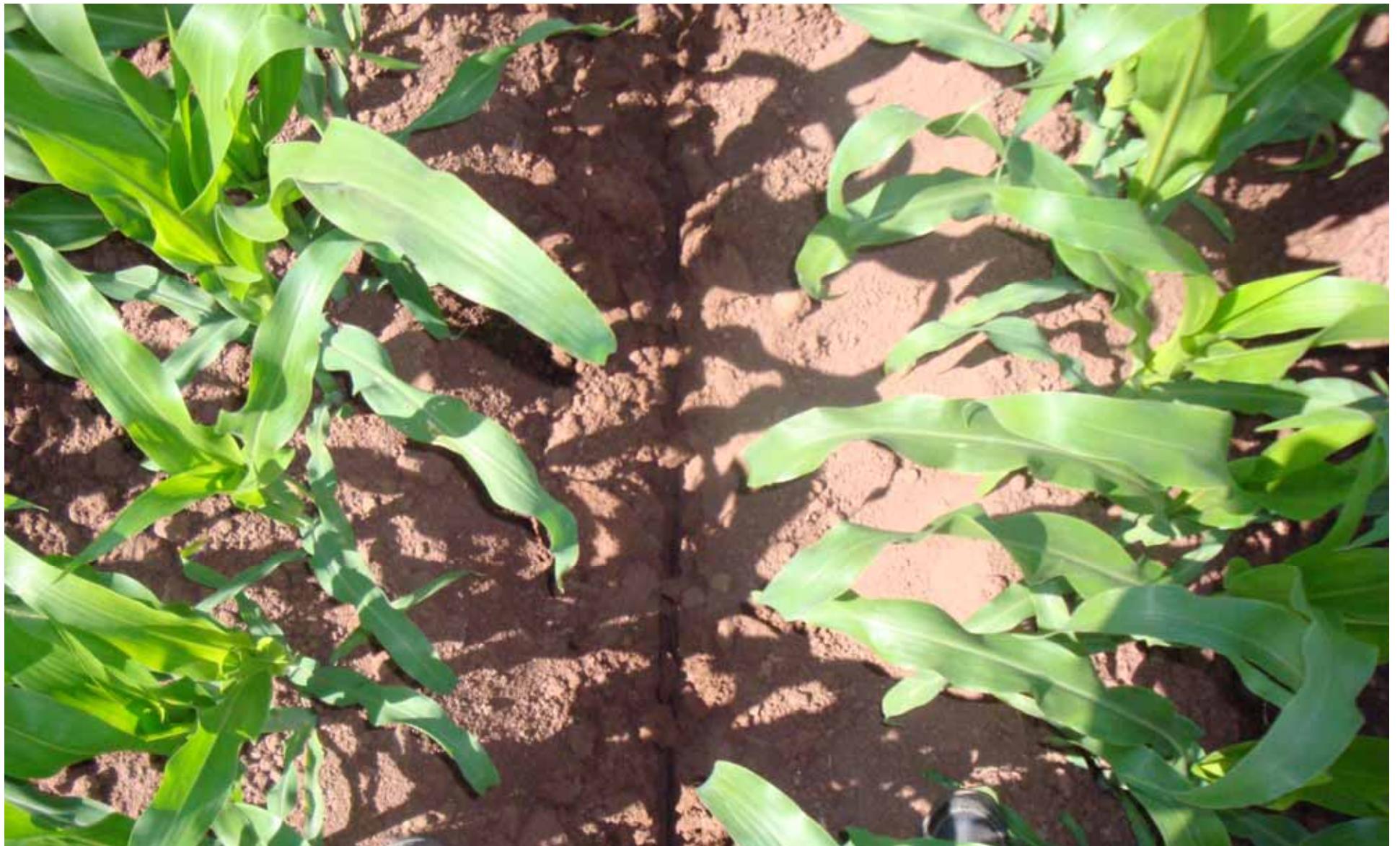
*less N, higher yields,
reduced N losses*

How much management is required ?

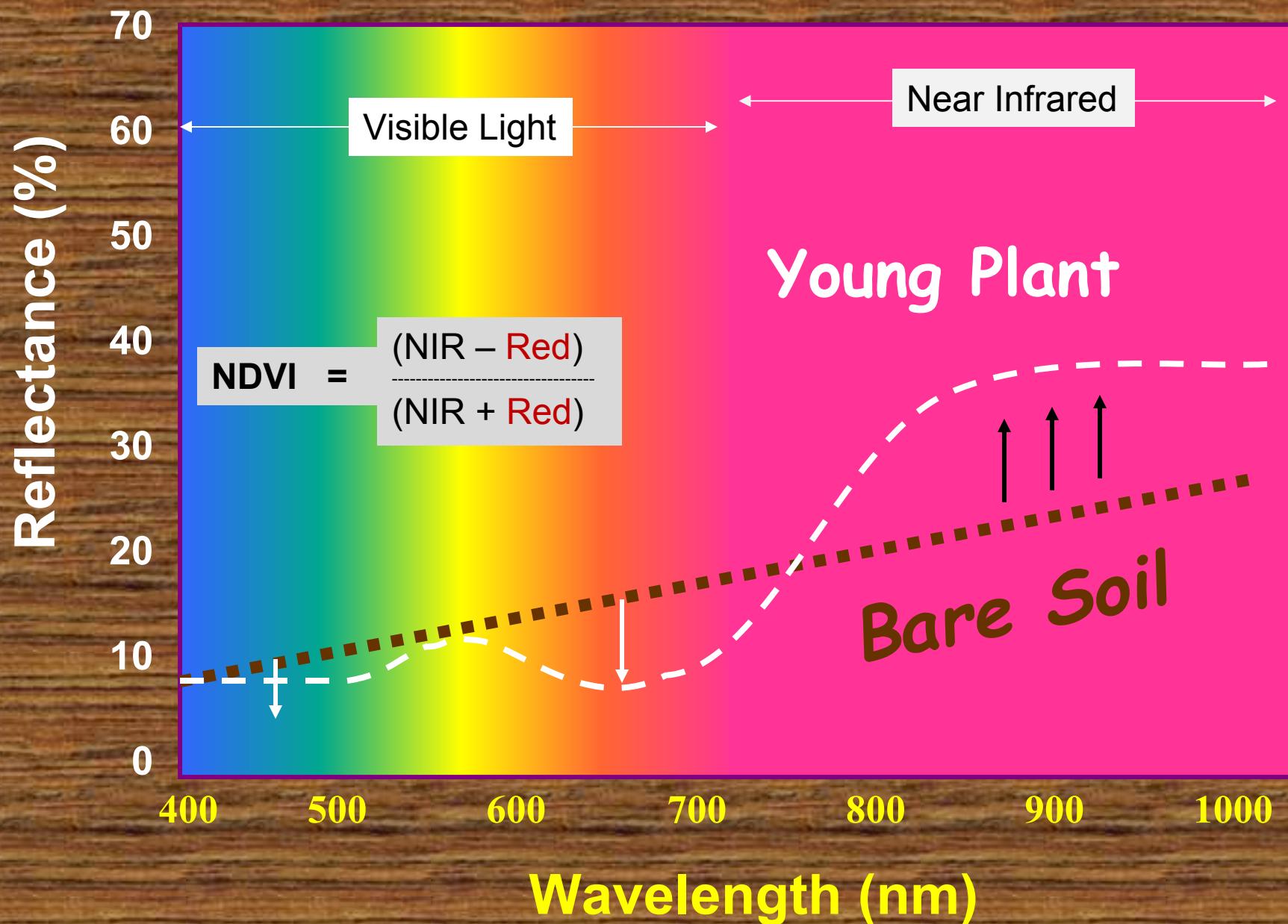
“Nowledge”

Leaf Anatomy & Spectral Interaction



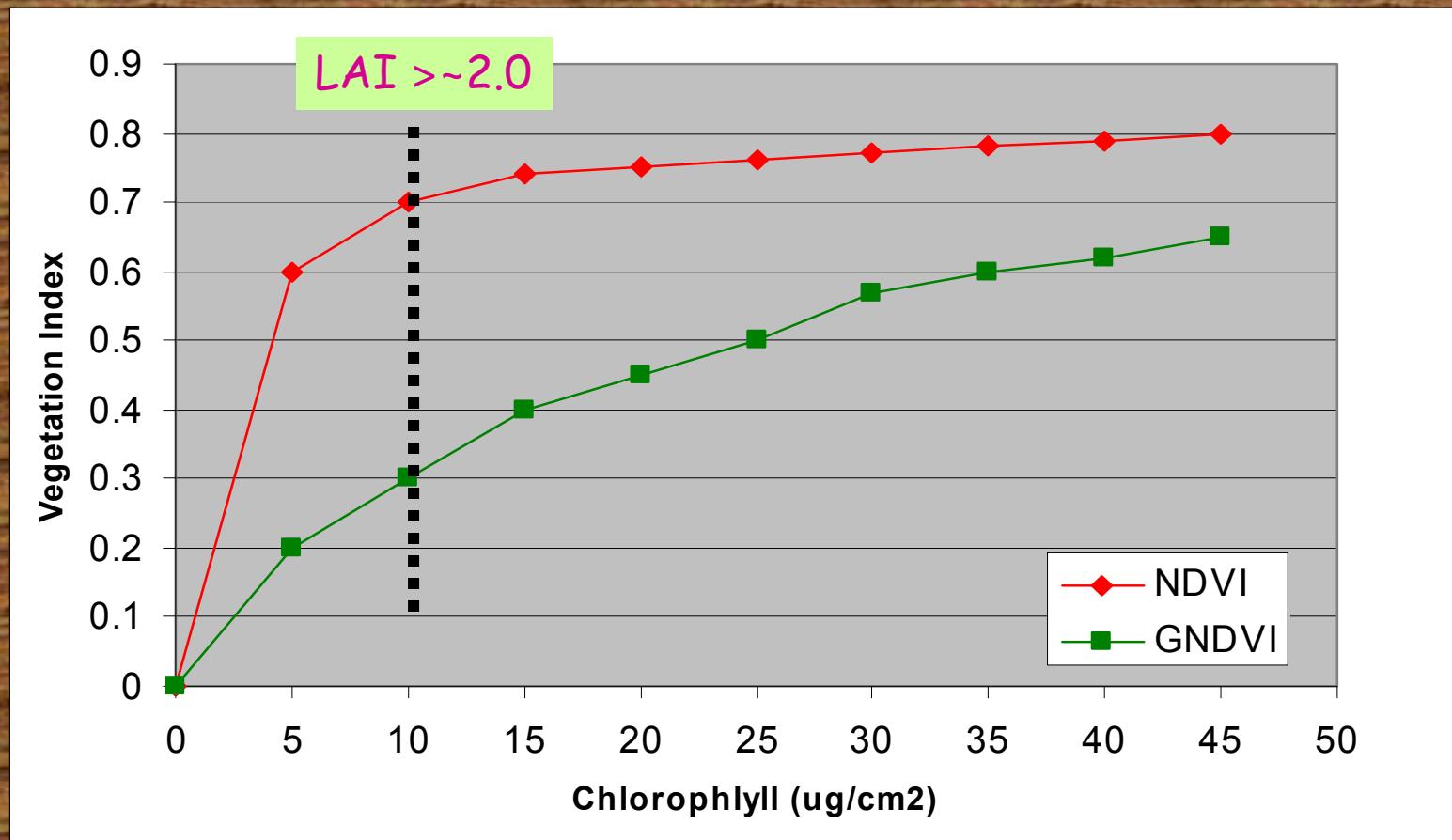


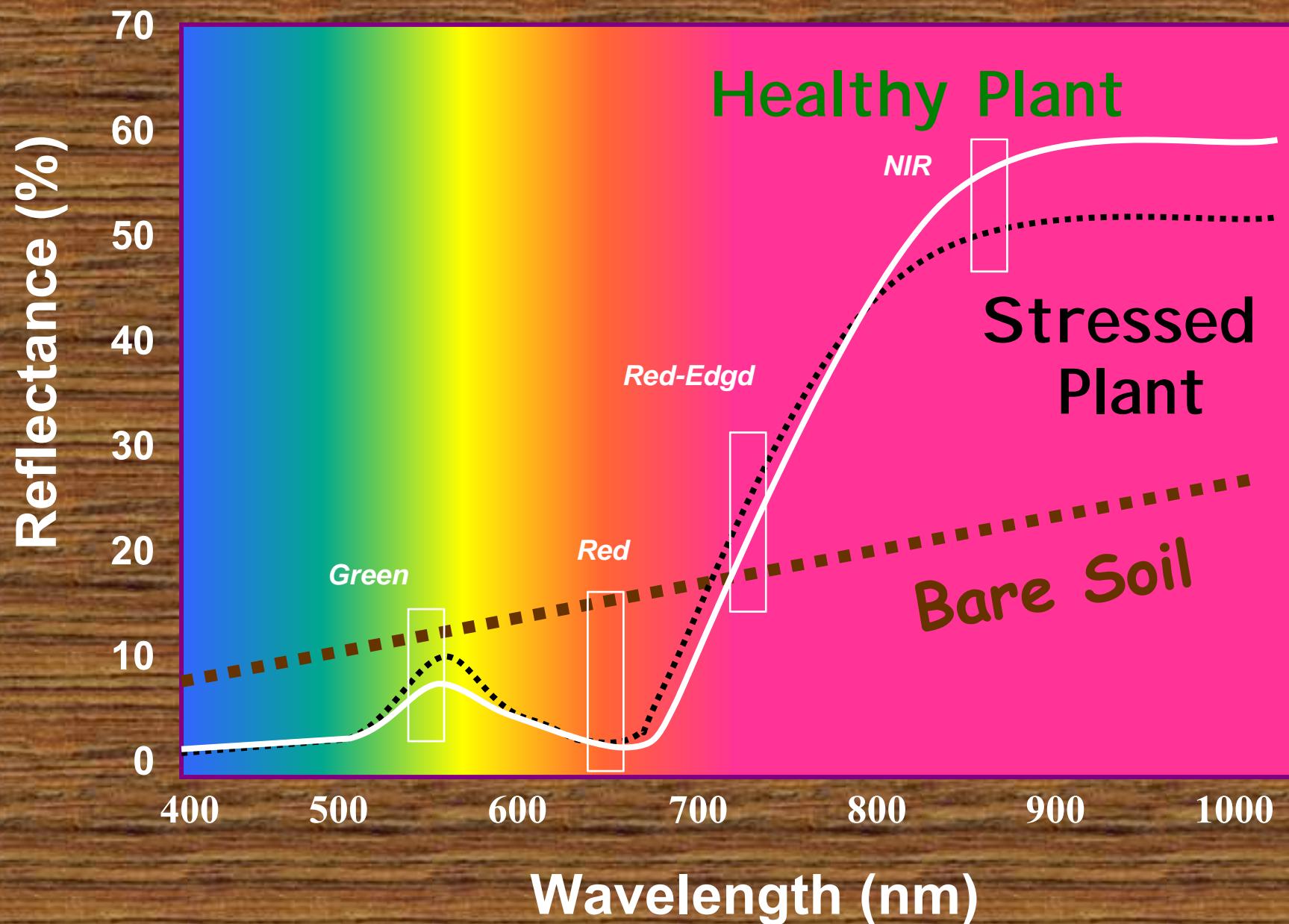
Sensor foot-print includes plants and soil background



Sensitivity of Vegetation Indices To Various Chlorophyll Levels

Adapted From Gitelson et al. (1996)





Common Vegetation Indices

$$\text{NDVI} = \frac{(\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red})}$$

$$\text{NDRE} = \frac{(\text{NIR} - \text{Red Edge})}{(\text{NIR} + \text{Red Edge})}$$

$$\text{Chl Index} = \frac{(\text{NIR})}{(\text{Red Edge})} - 1$$

$$\text{Visible / NIR} = \frac{(\text{Red})}{(\text{NIR})}$$

Normalized Difference Vegetation Index

$$\text{NDVI} = \frac{(\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red})}$$

When red reflectance no longer changes regardless of chlorophyll content (“**saturates**

the distance correction is lost and NDVI becomes unreliable (**influenced by height and plant biomass**)

i.e. When the canopy closes and soil reflectance goes to zero, switch to a sensor that measures green or red-edge reflectance.

Distance from Target

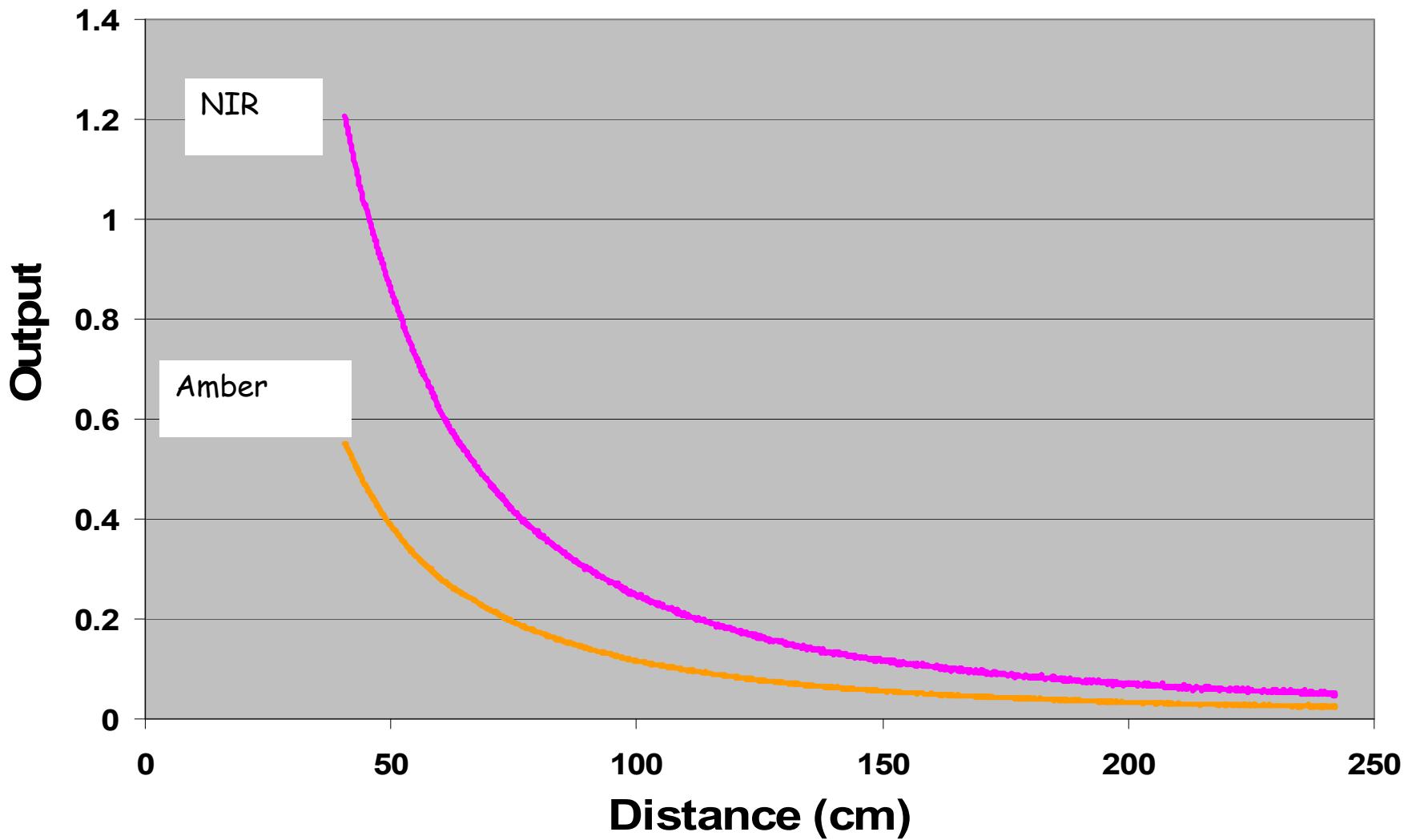


Reflectance

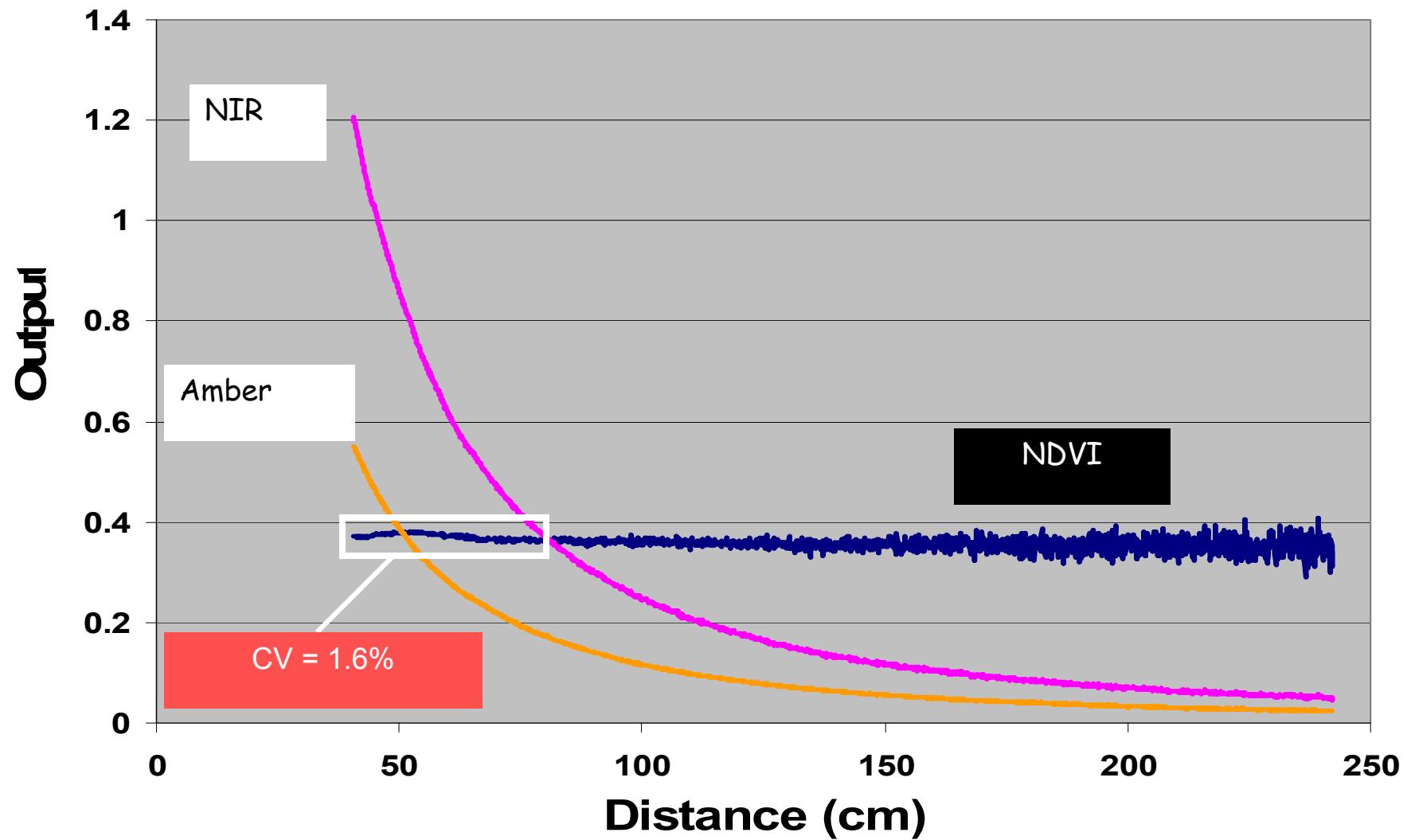
$$\frac{1}{\text{distance}^2}$$

Inverse square of the distance law

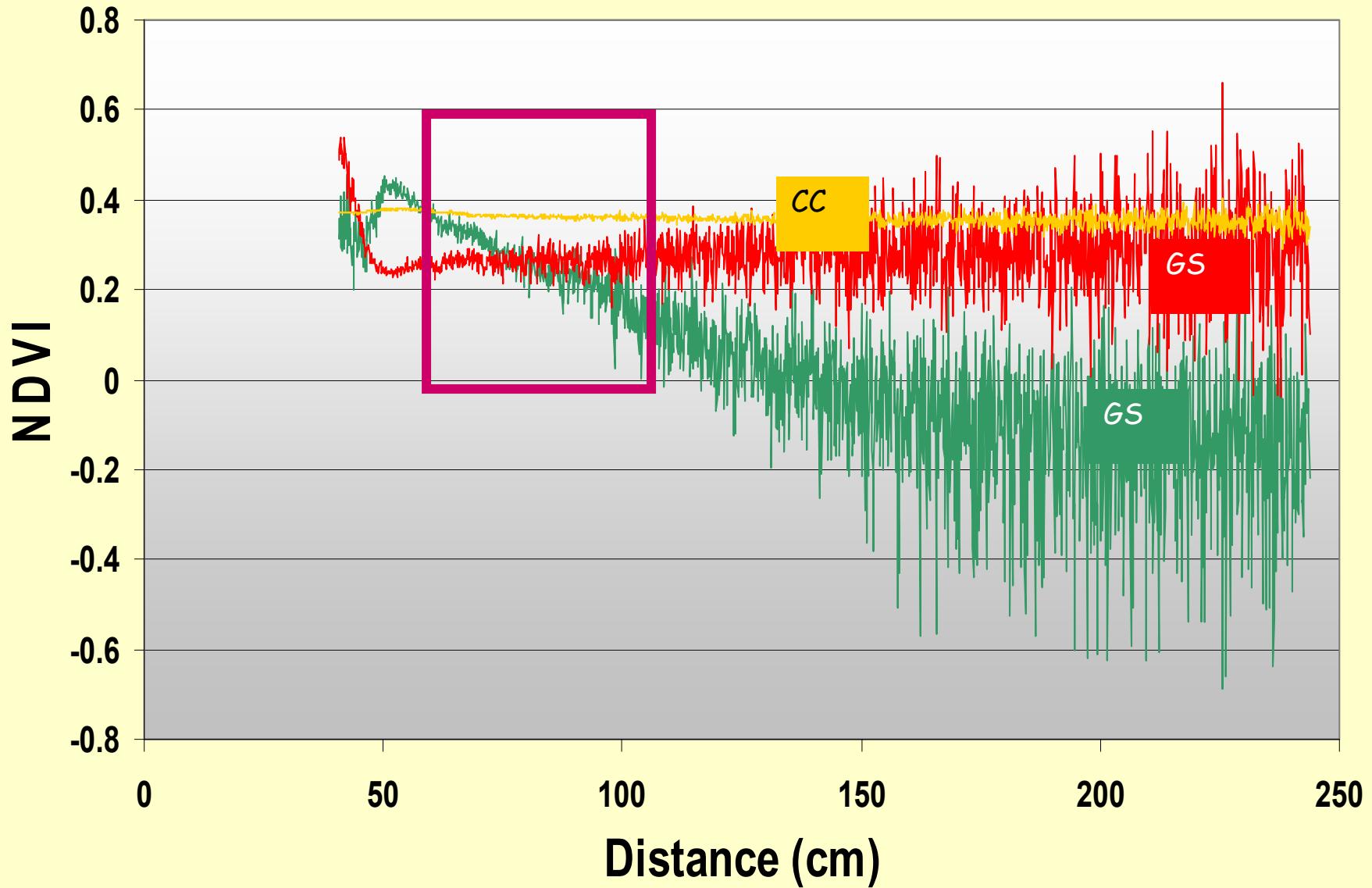
Sensor Distance from Target



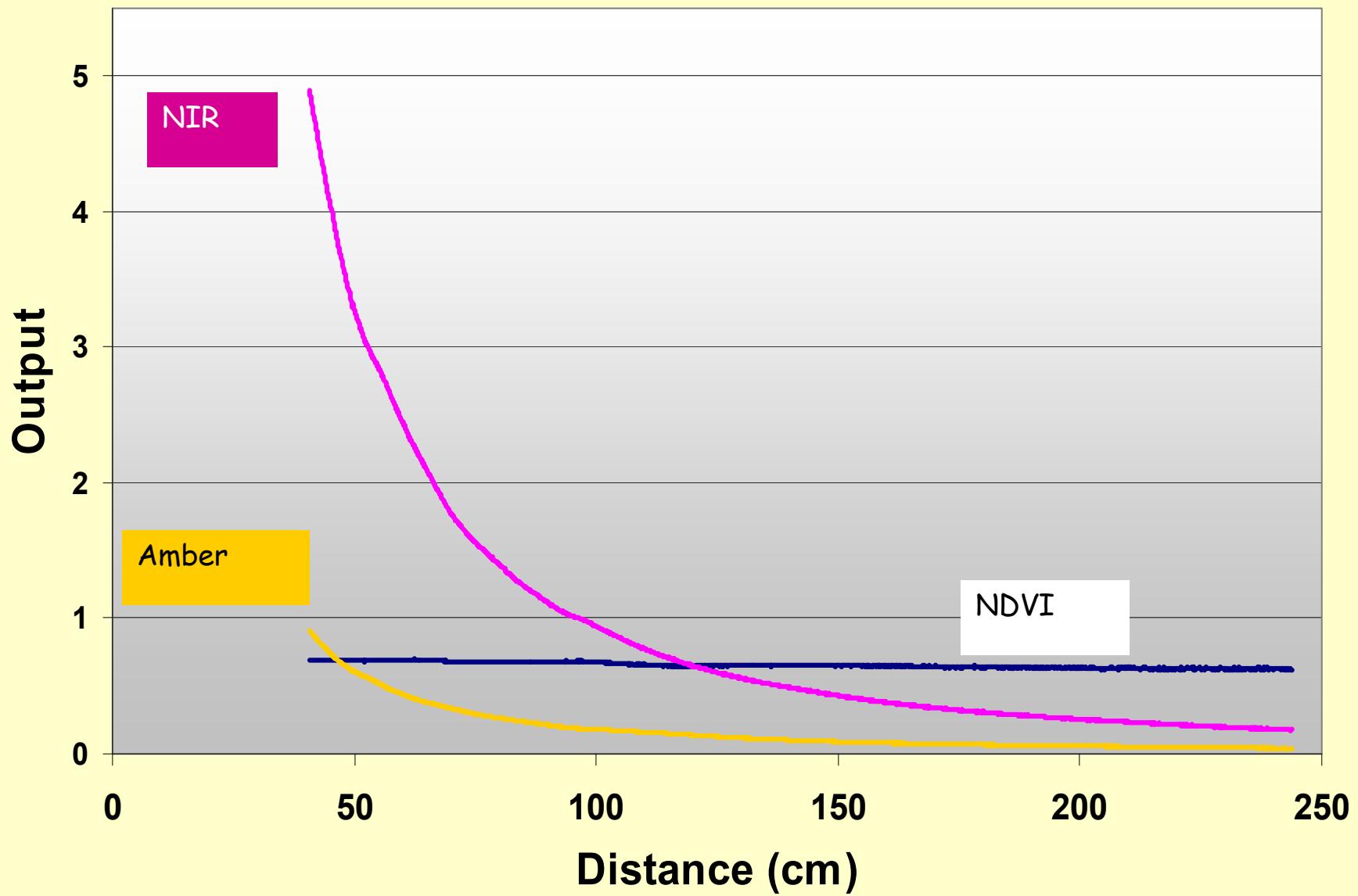
Sensor Distance from Target



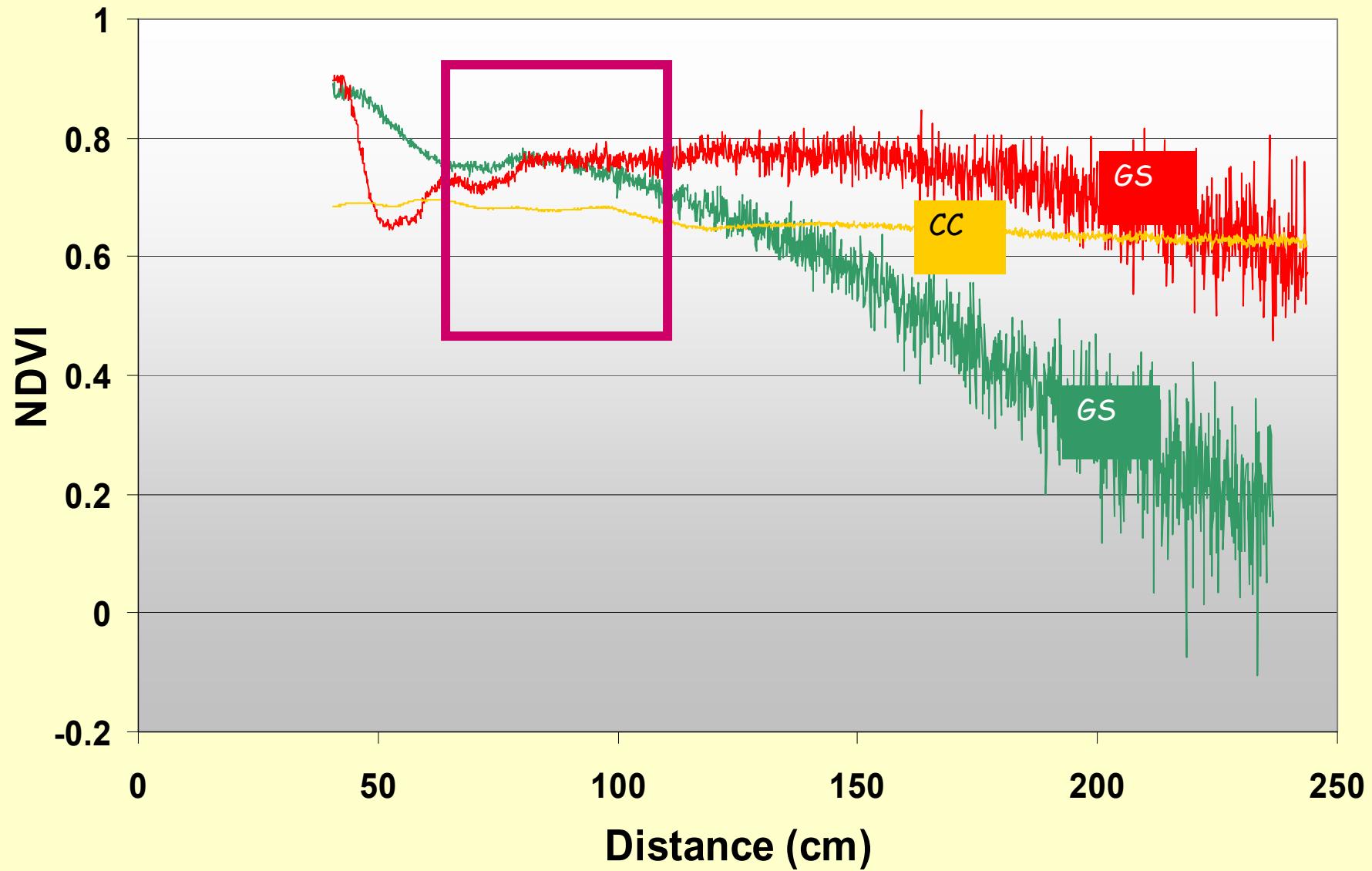
Sensor Distance from Soil



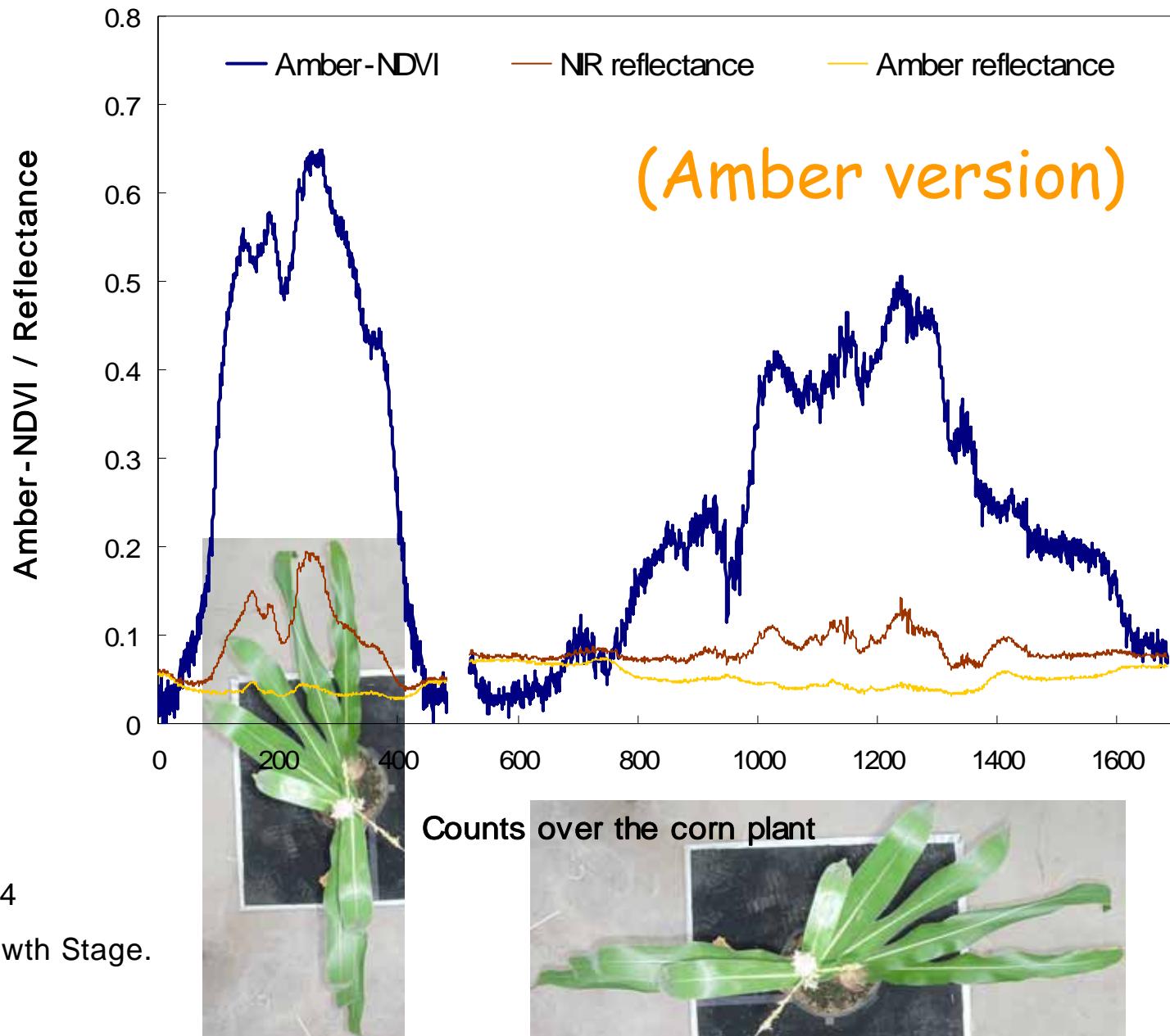
Sensor Distance from Turf



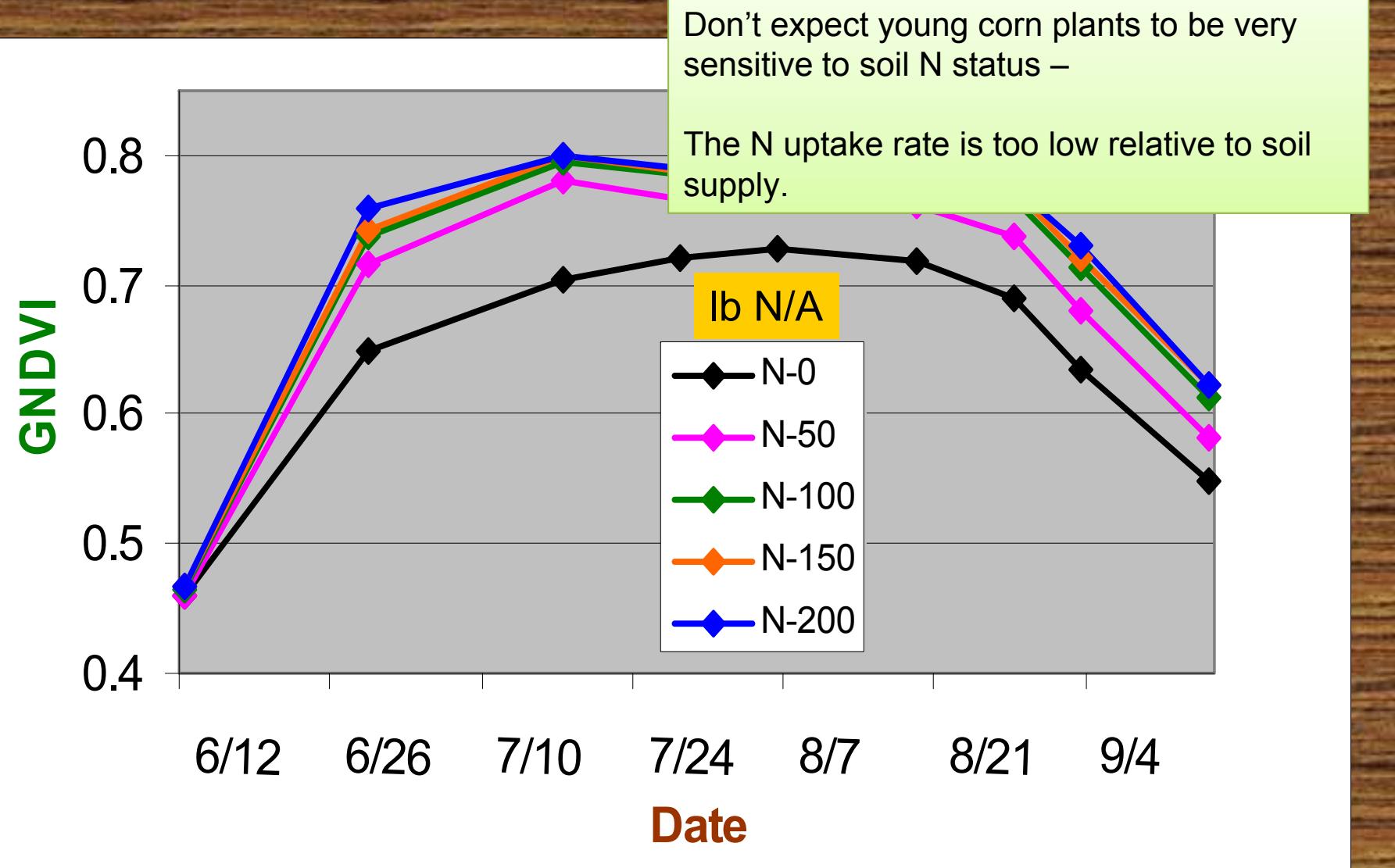
Sensor Distance to Turf



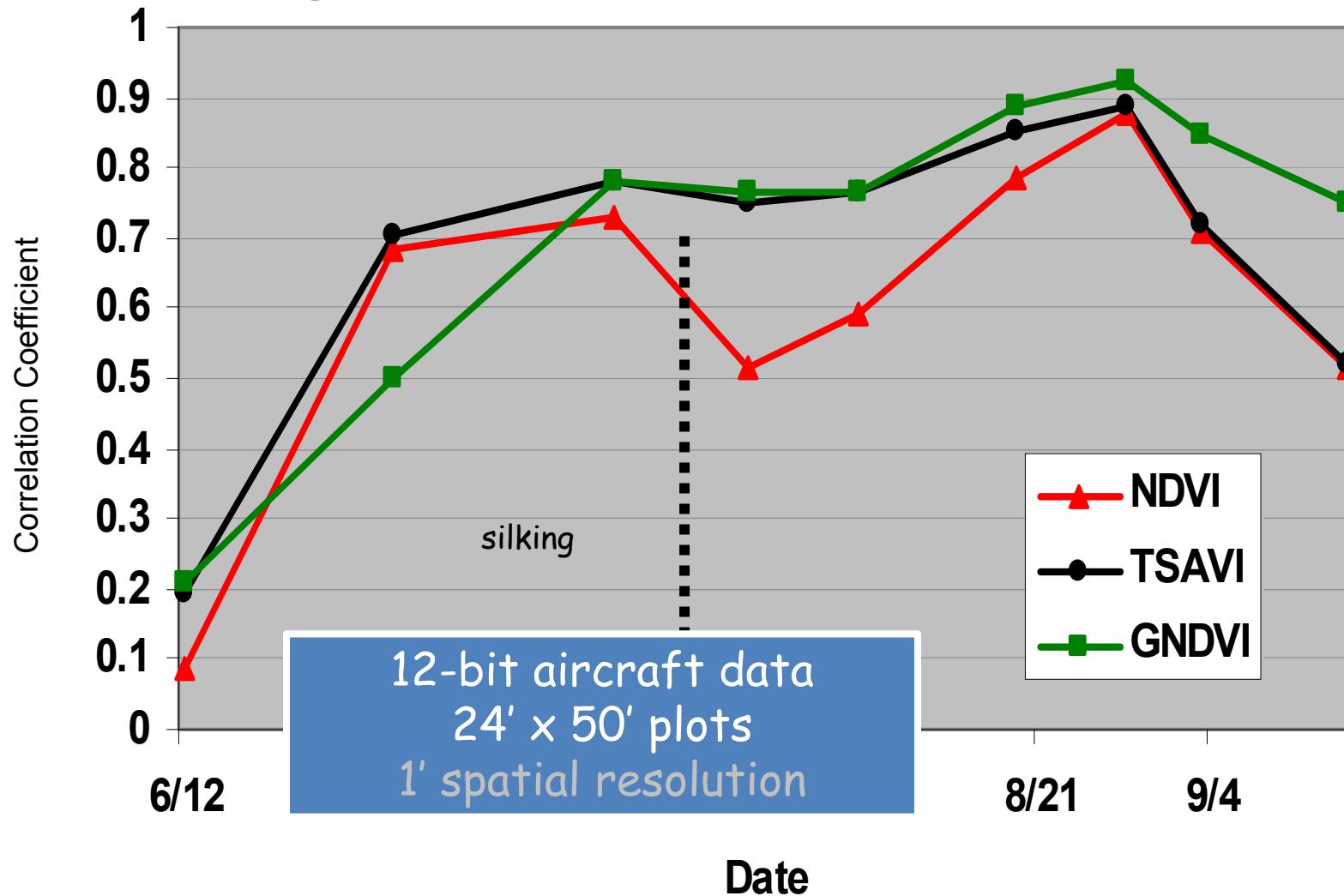
Perpendicular vs. Parallel - Crop Circle



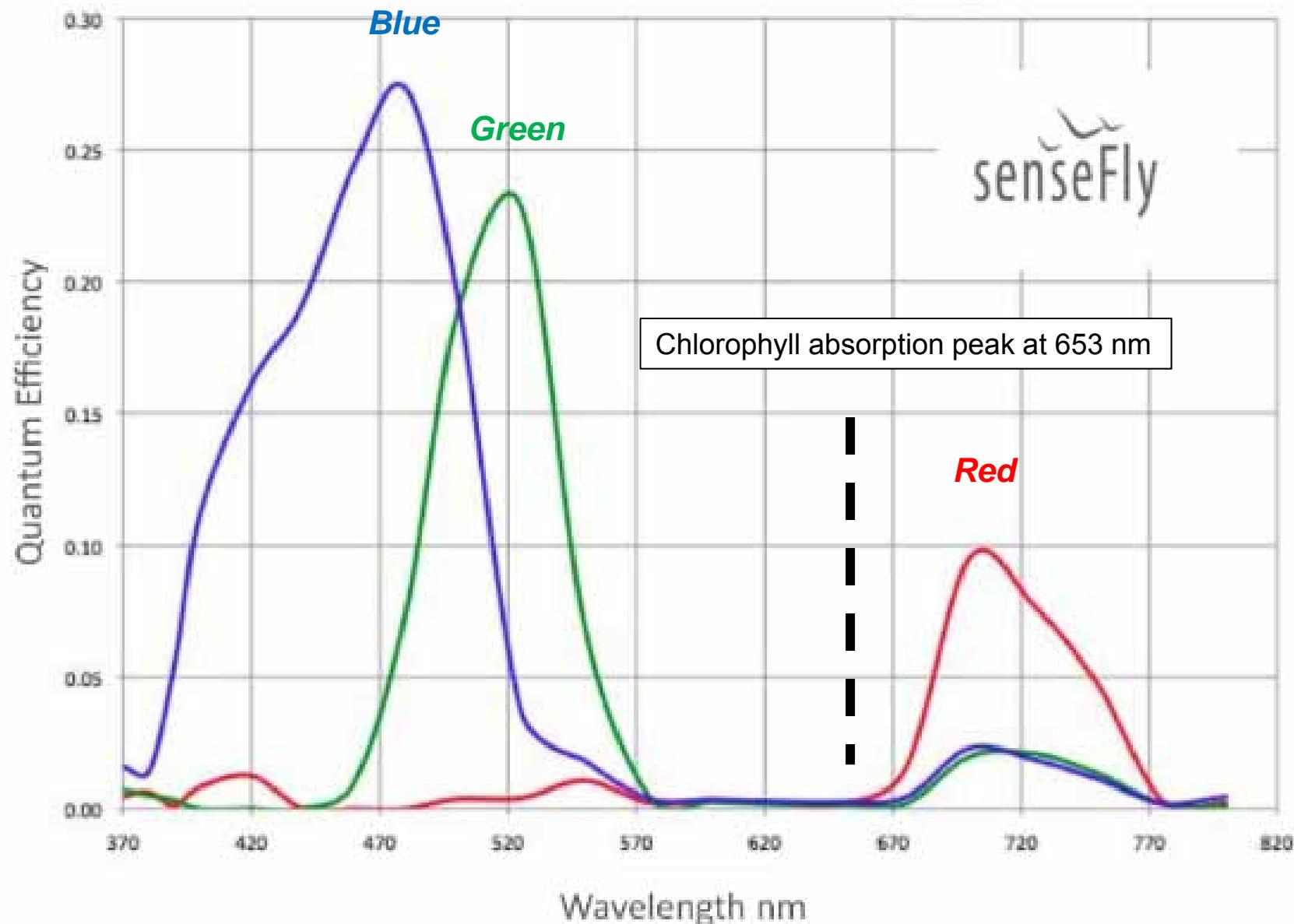
Green NDVI vs N Rate over Time



Vegetation Indices vs Corn Yield



Camera Limitations



In-Season N Management

Crop vigor during the growing season

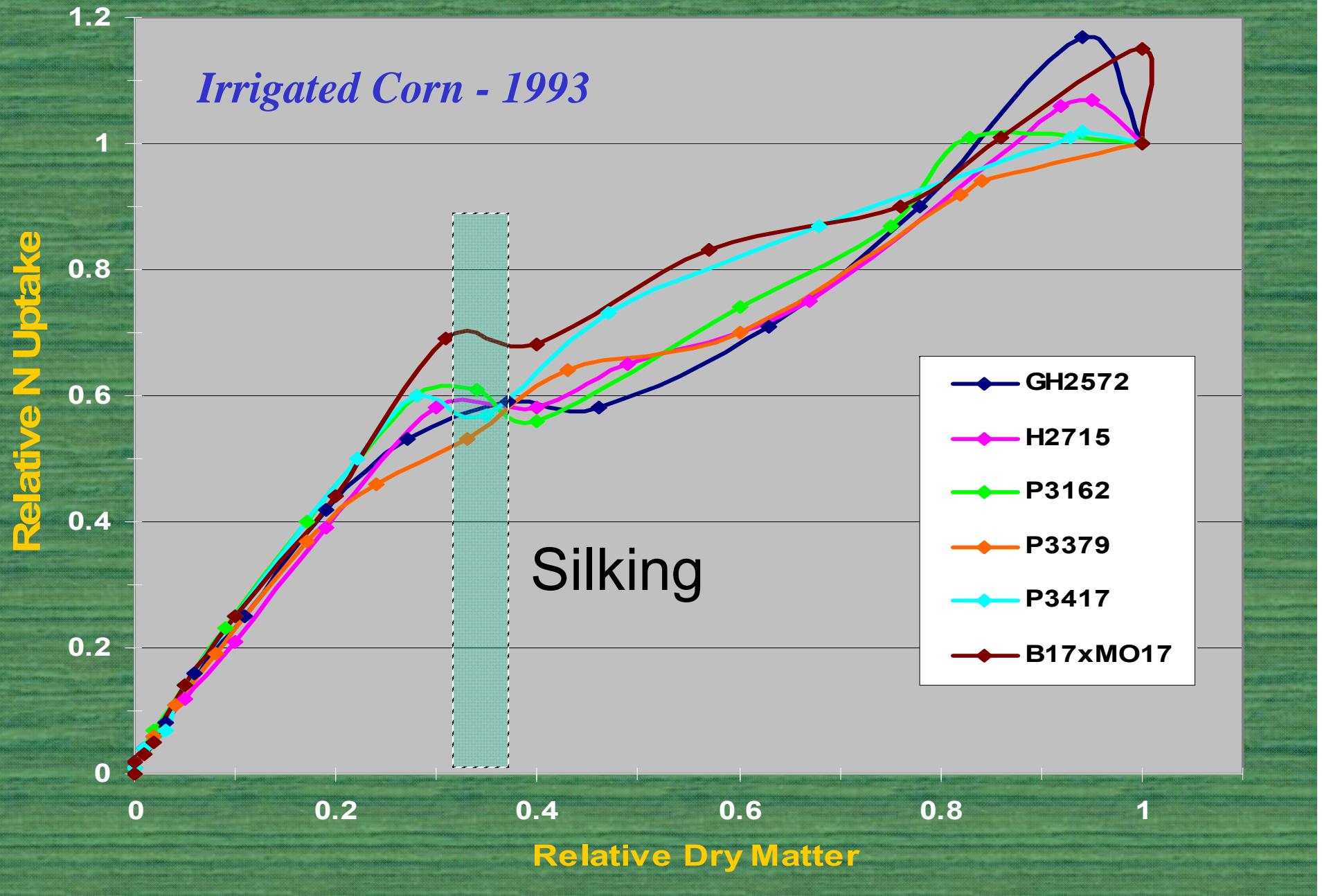
is **proportional** to

yield at harvest



Crop vigor needs to remain high !

Relative Dry Matter vs N Uptake



Keep in Mind

Active crop sensors are a tool to facilitate adaptive management.

- - - BUT - - -

There are some strings attached !

wavebands

preplant
fertilizer

“reference”
procedure

algorithm

Agronomics



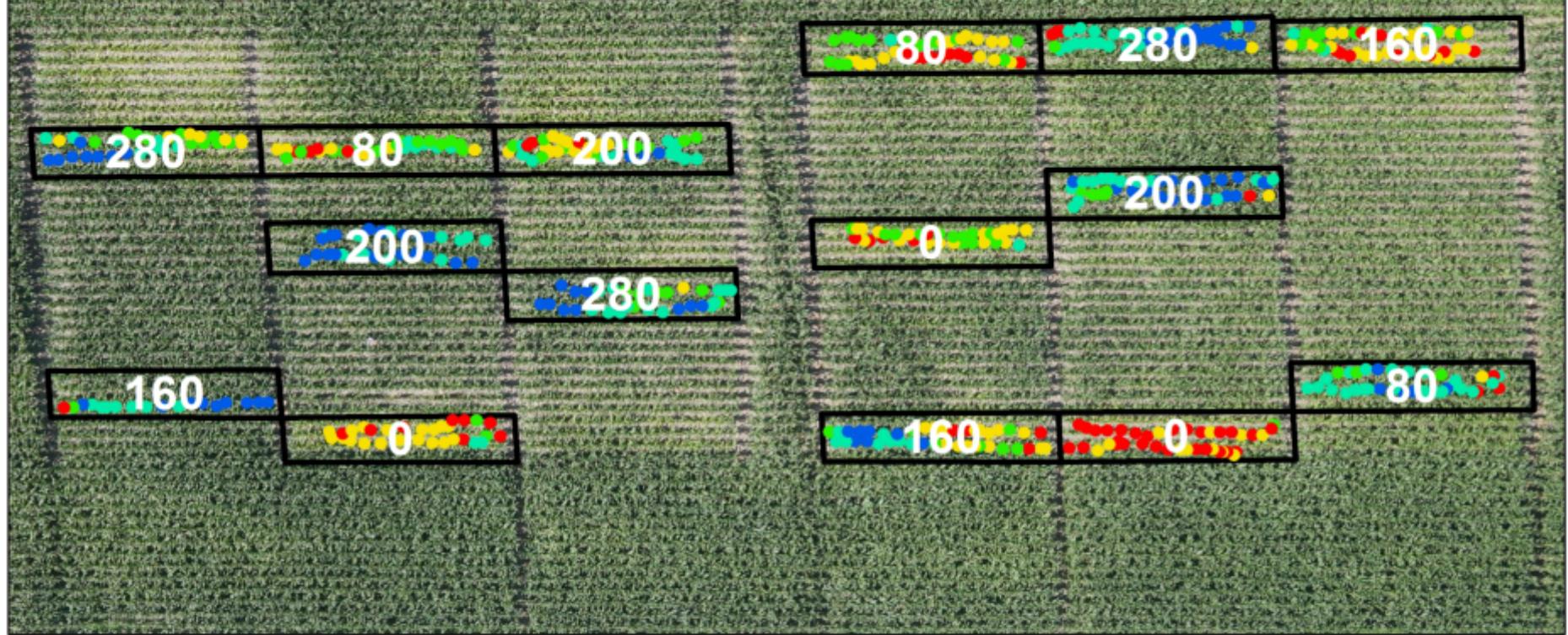
2014 RapidSCAN CS-45U

30

2014 RapidSCAN UAV Maize Sensing



2014 RapidSCAN UAV Maize Sensing



0 12.5 25 50 75 100
Feet

Note:

Labeled nitrogen rates in lbs/acre are within each treatment plot.

Plot length is 45 feet by 10 feet.

UAV-RapidScan Treatment Plots

NDRE

- 0.13 - 0.23
- 0.23 - 0.29
- 0.29 - 0.33
- 0.33 - 0.37
- 0.37 - 0.43





Raptor ACS-225 Mounted to a Fletcher
FU24954 Crop-dusting Aircraft



Cotton
Greece - 2010

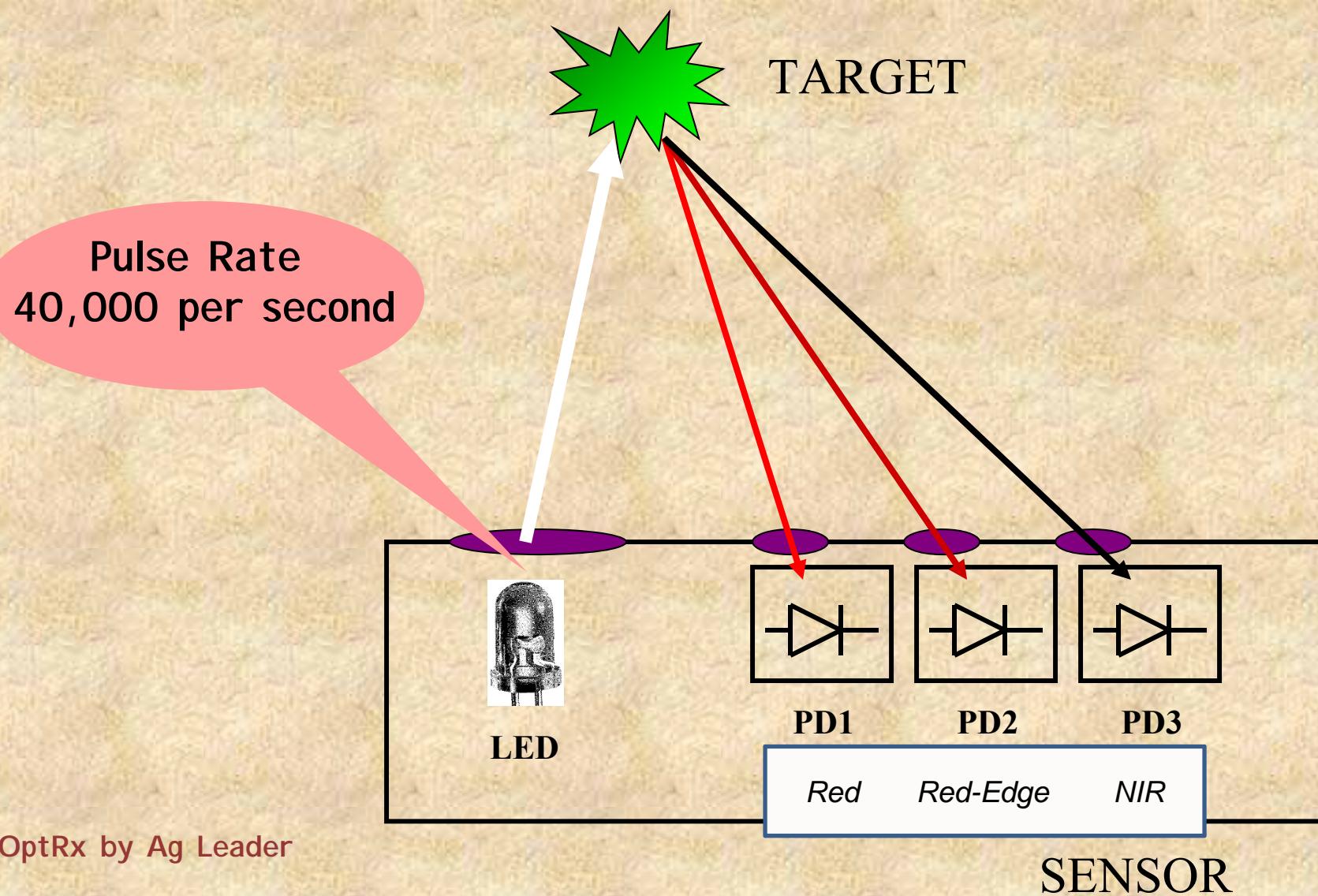
Crop Circle ACS-430

or

AgLeader OptRx

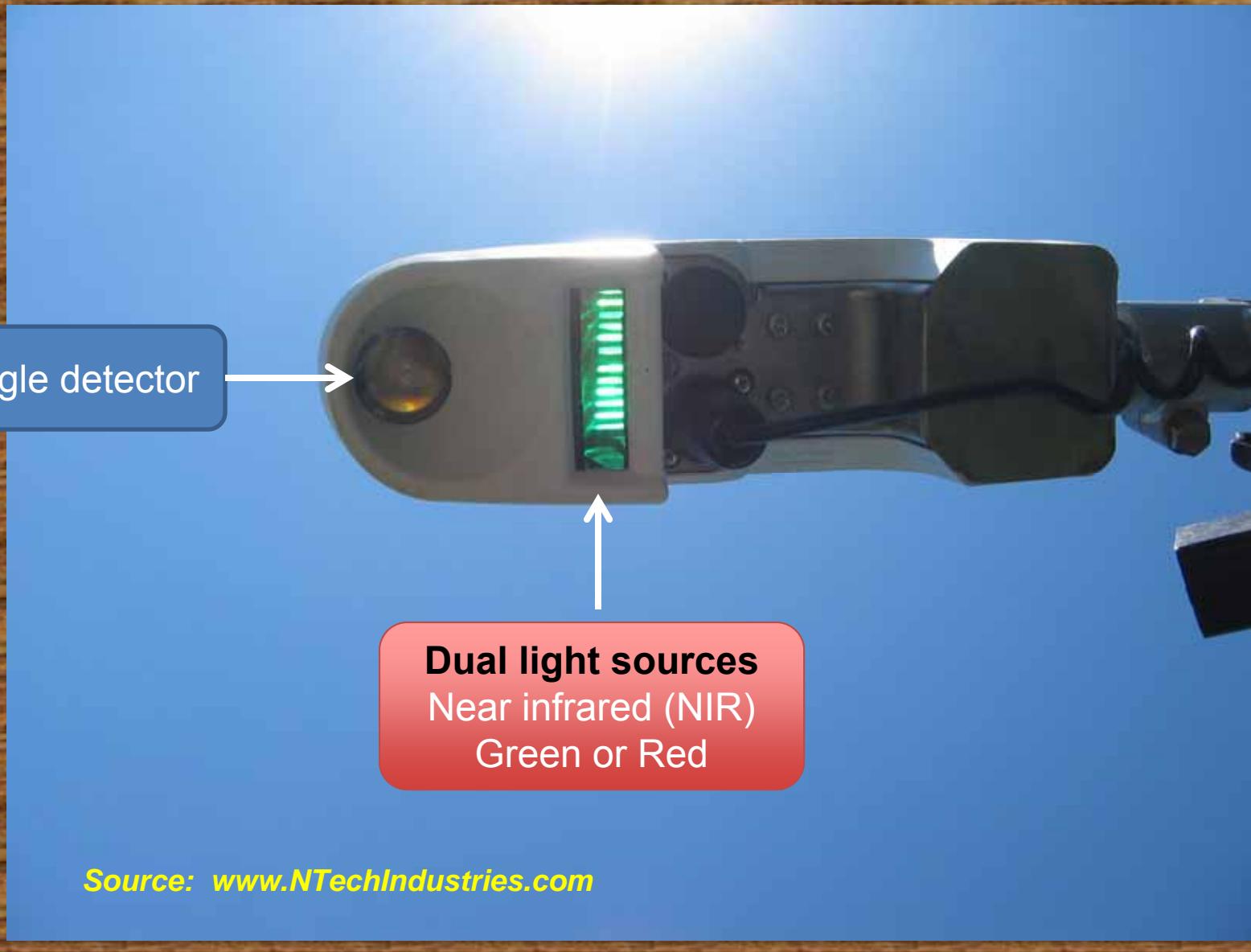


Modulation/Demodulation Using Polychromatic LEDs

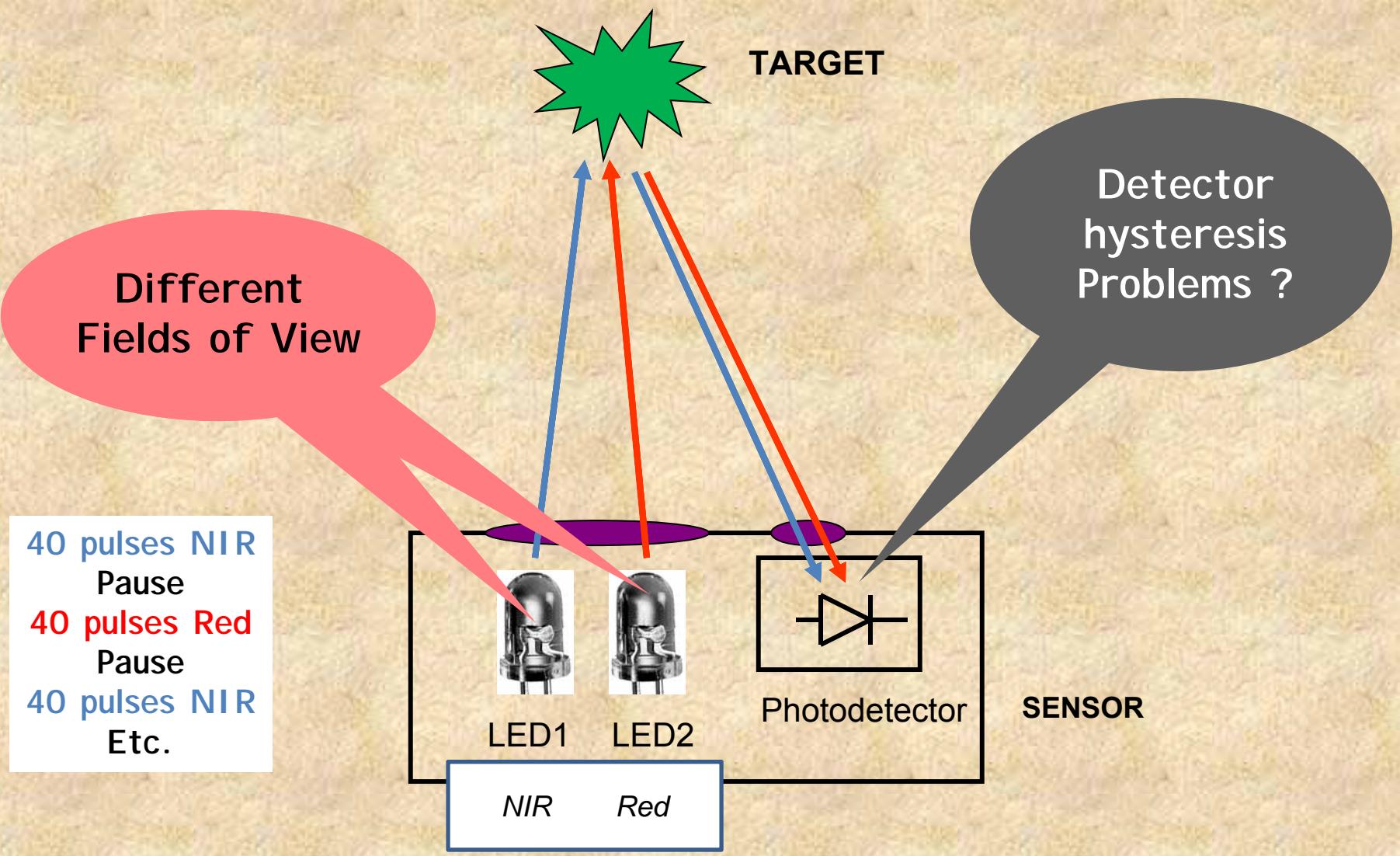




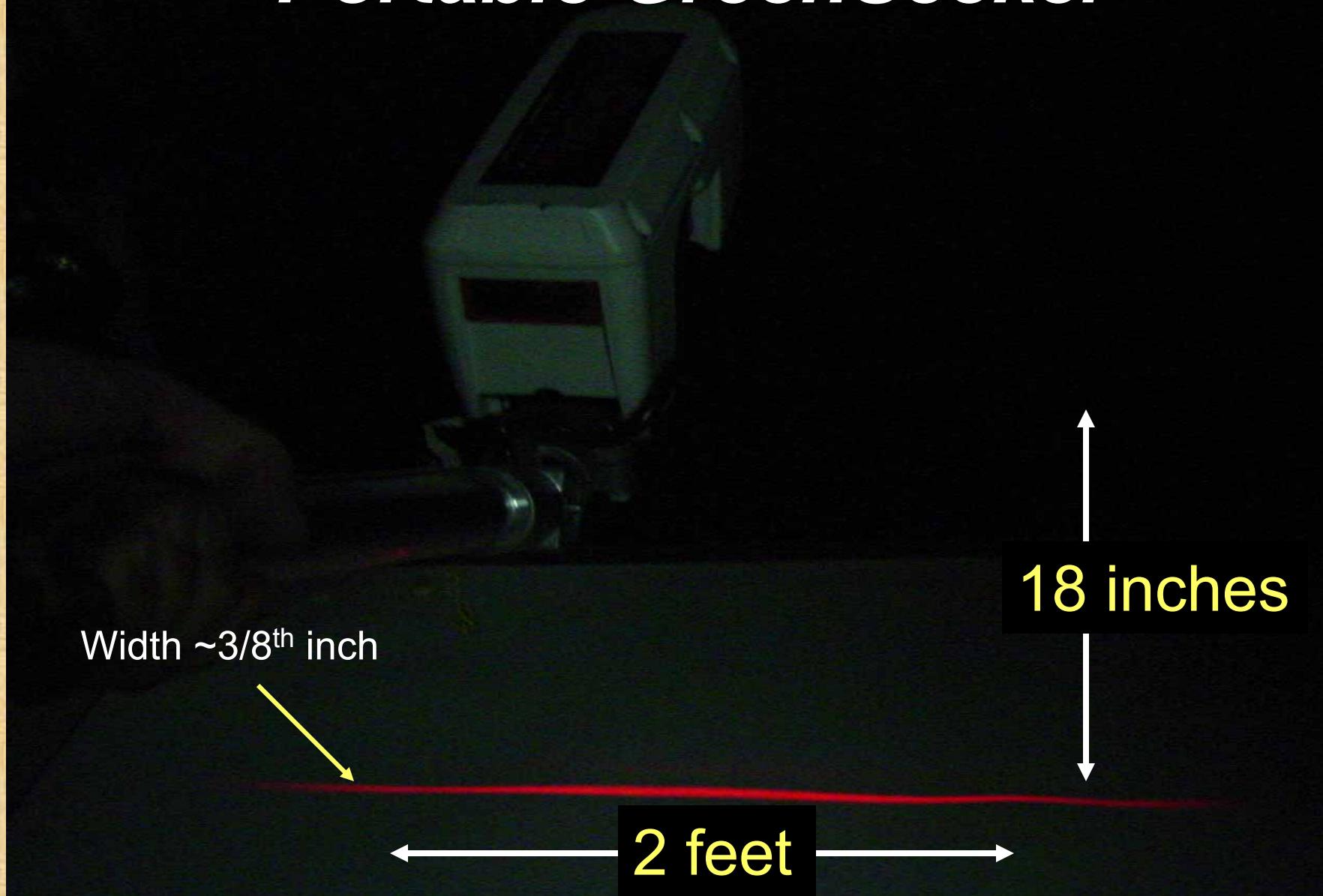
GreenSeeker (Green version)

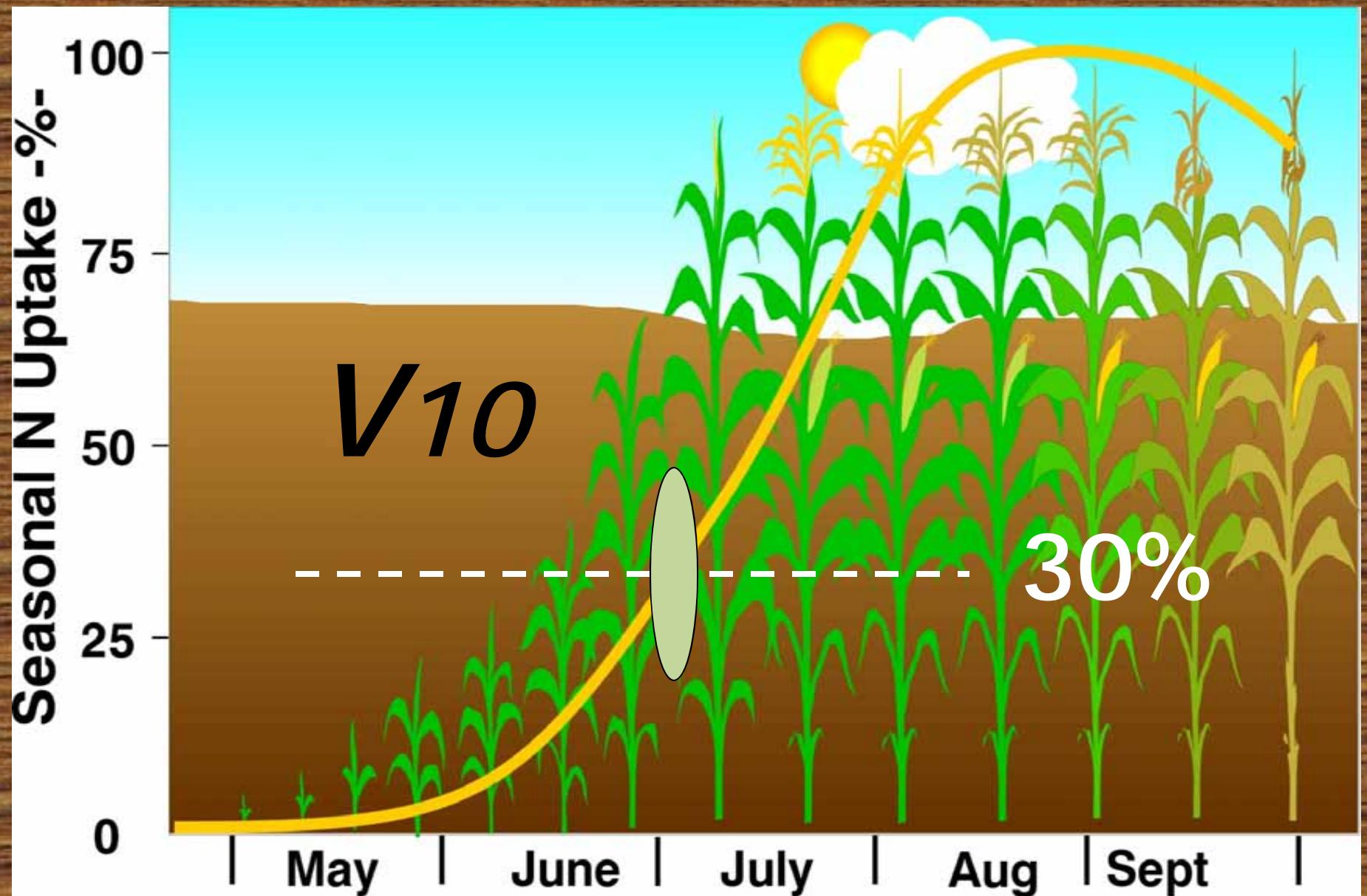


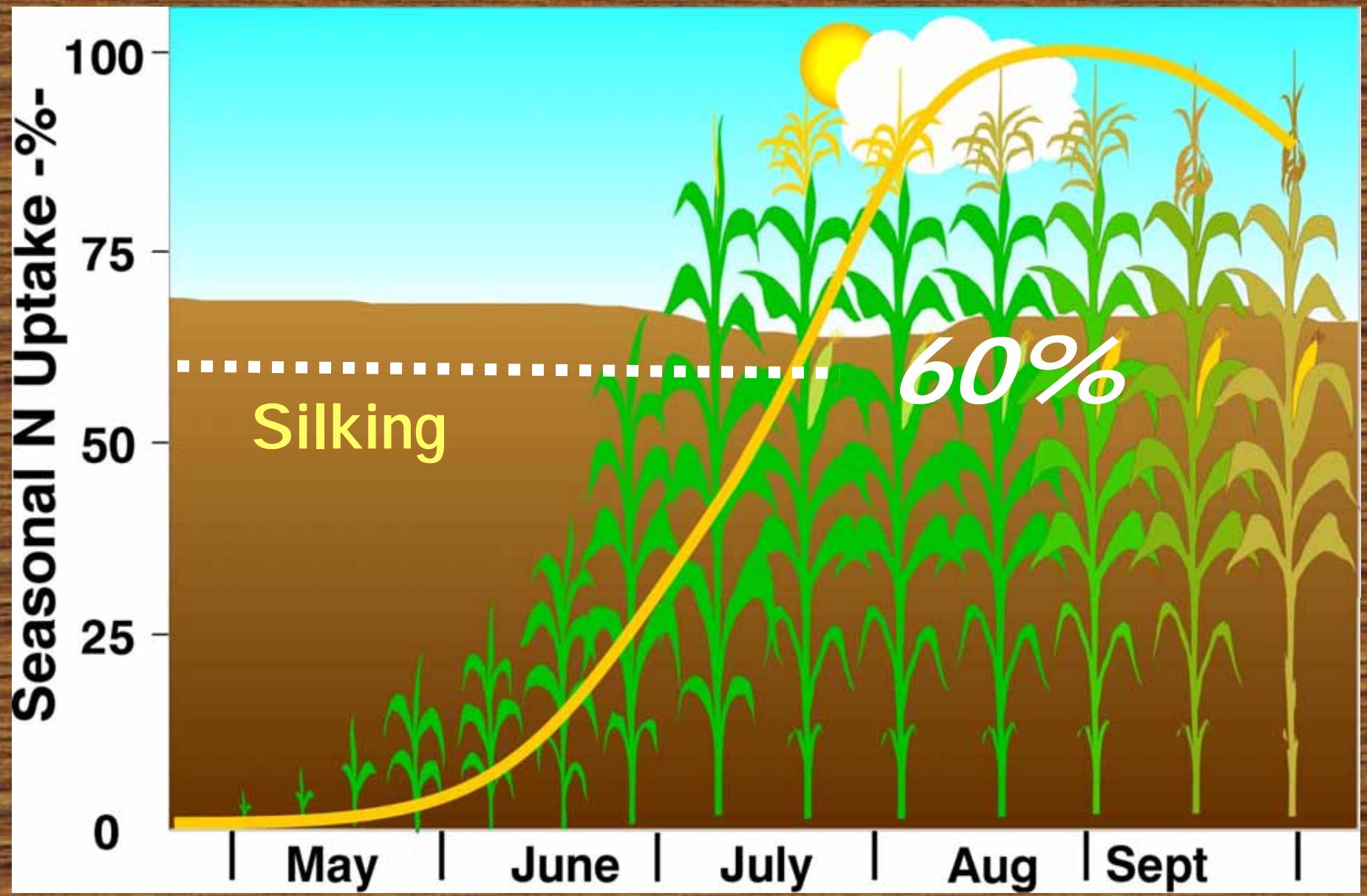
LED Sources - Modulation Techniques



Portable GreenSeeker

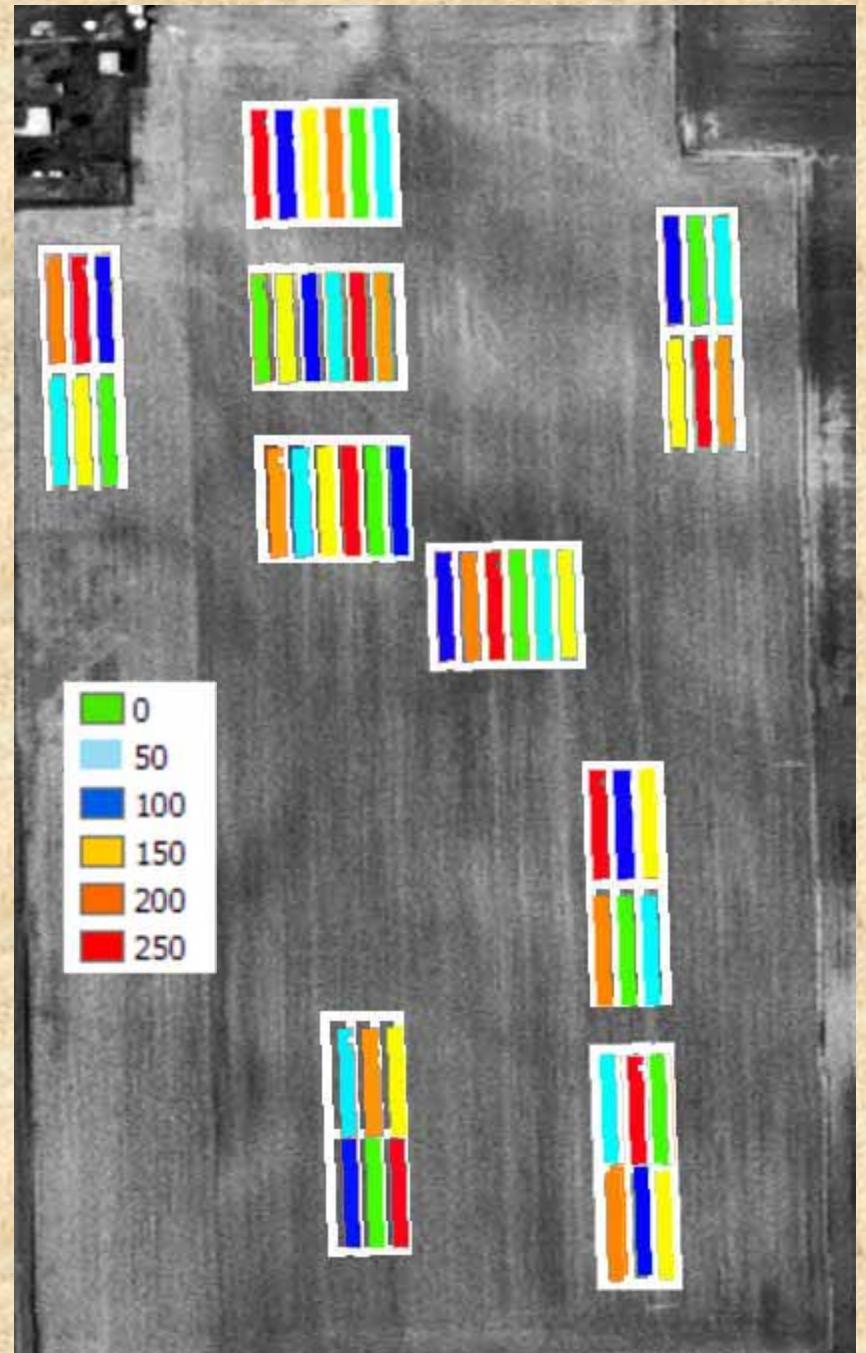






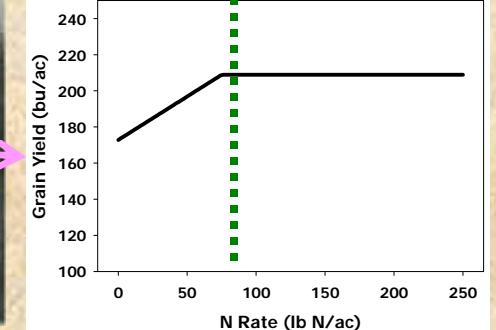
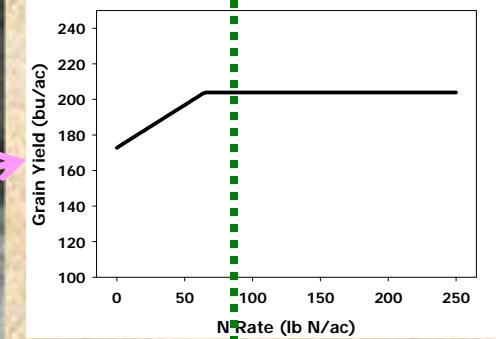
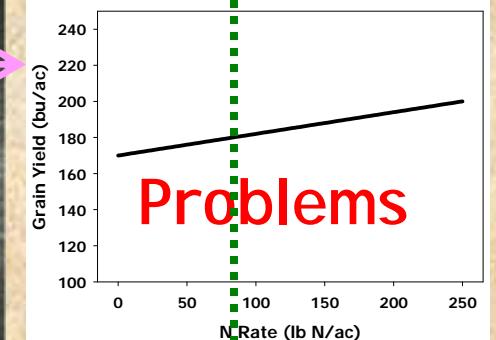
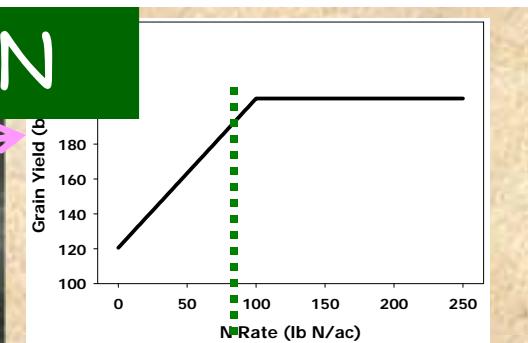
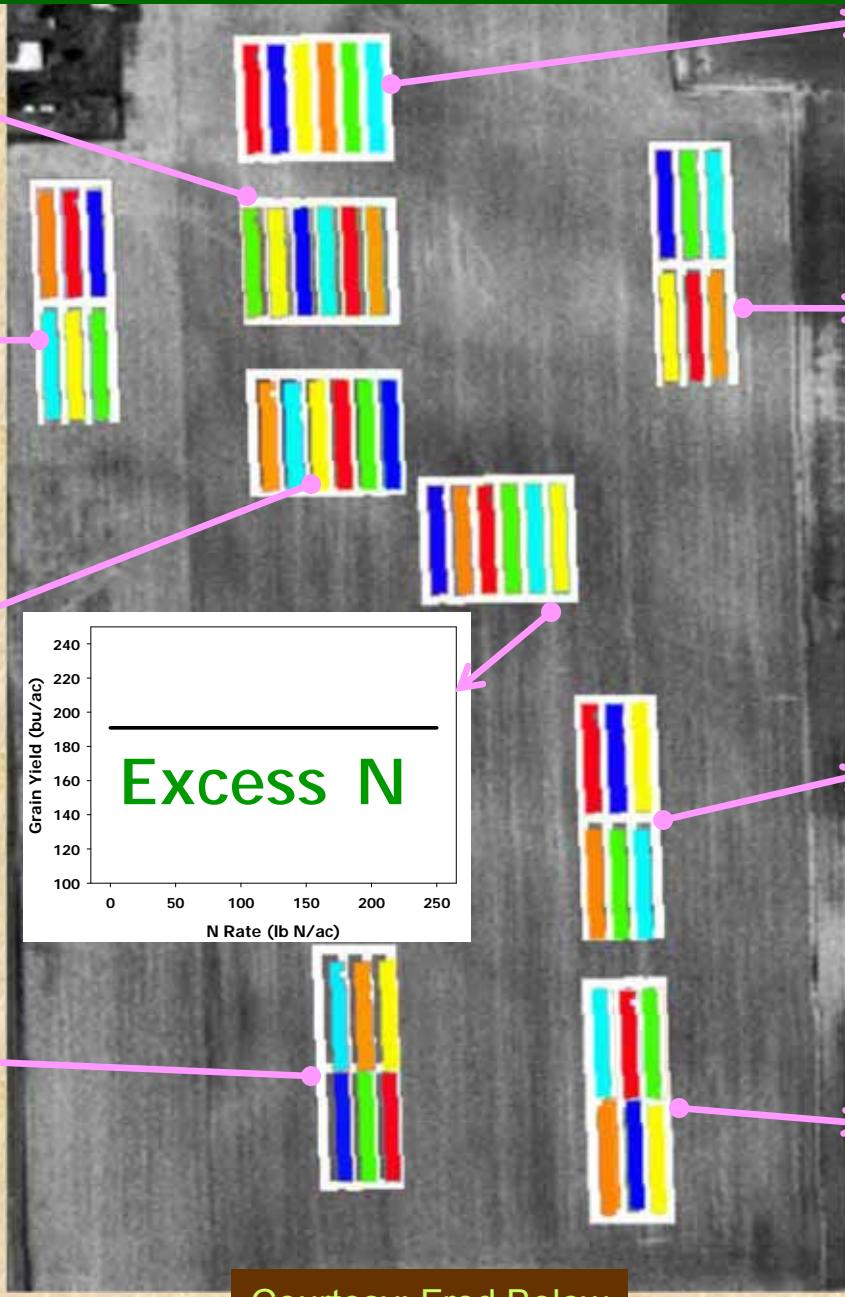
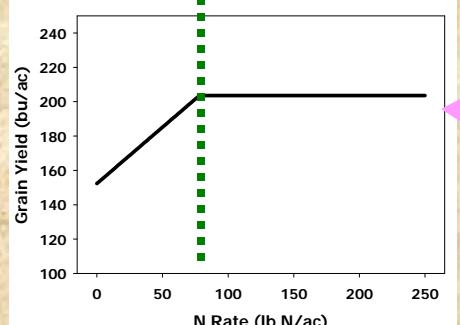
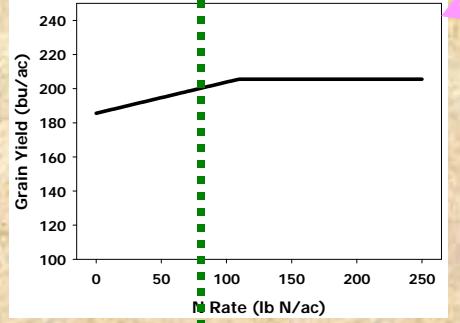
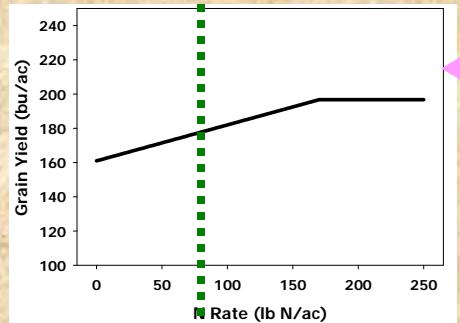
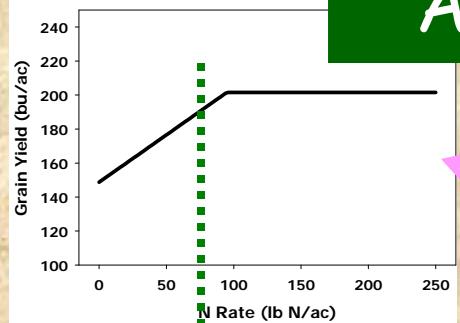
Field Studies

- Six N-Rates per stamp
- Strategically placed stamps within the field by:
soil type and
topography
- Grain yield monitor data



Courtesy: Fred Below

Appropriate Early-Season N



Problems

Excess N

Courtesy: Fred Below

In-Season N Management

100%

200 lb N/A

R6

60%

120 lb N/A

R1

30%

80 lb N/A

R14

15%

40 lb N/A

V12

V10

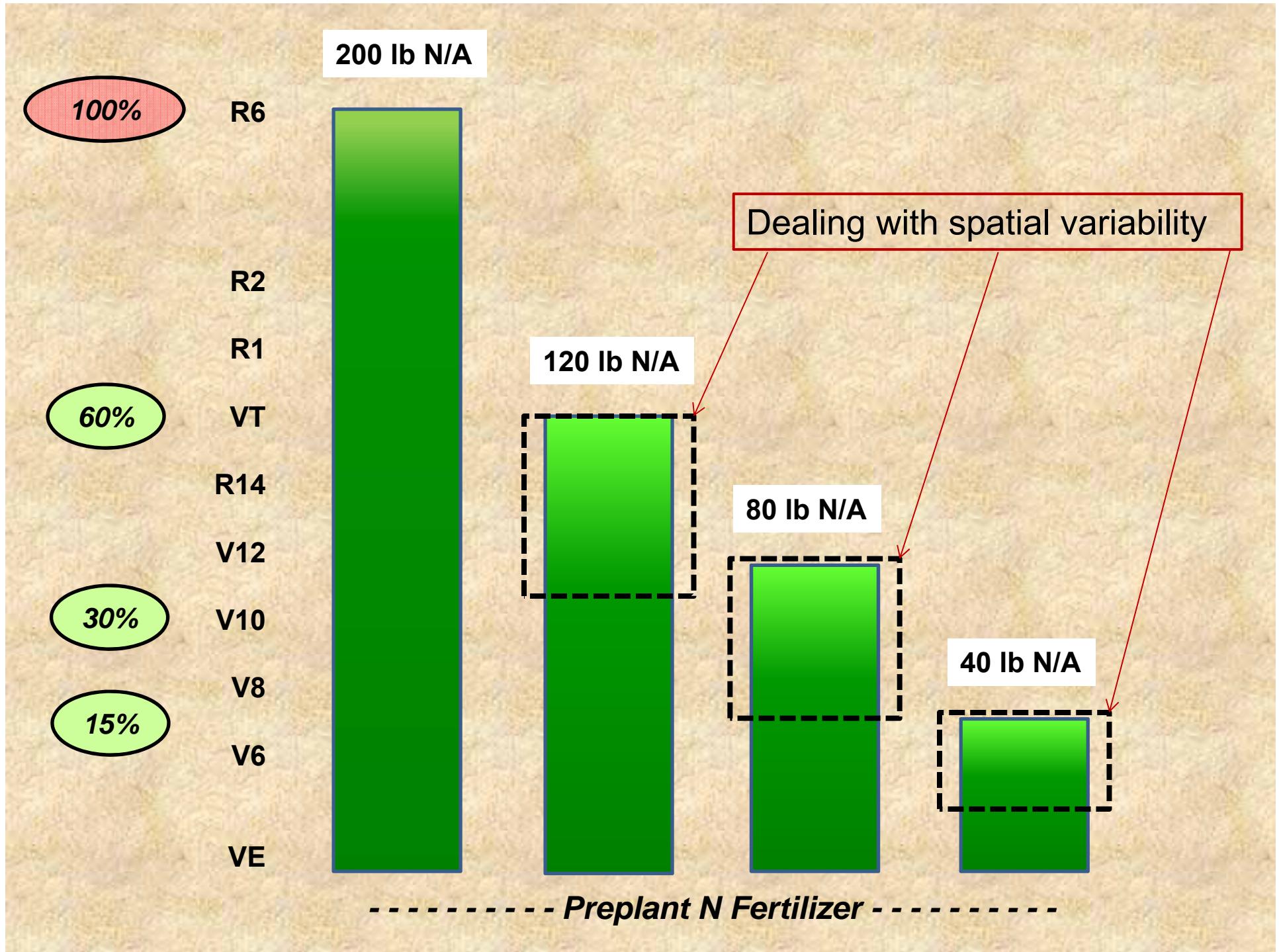
V8

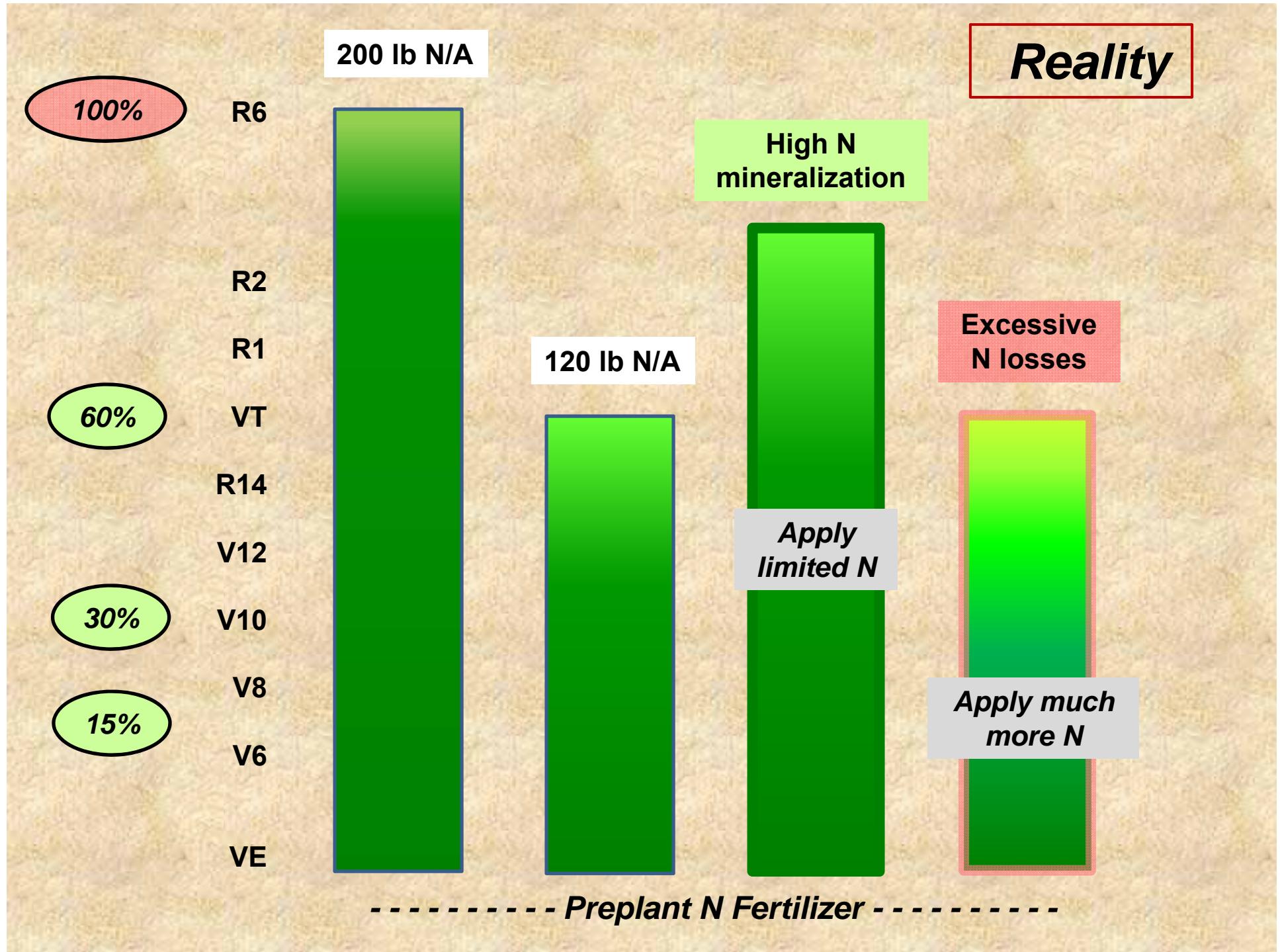
V6

VE

What is the likelihood of sensors being responsive ?

----- Preplant N Fertilizer -----





OptRx

What Reference ?

Soybean Previous Year

Check Plot



100%

200 lb N/A

Sensor Calibration

R6

120 lb N/A

? ? ? ?

60%

80 lb N/A

30%

40 lb N/A

15%

R2

R1

VT

R14

V12

V10

V8

V6

VE

----- Preplant N Fertilizer -----

Converting light reflectance to nitrogen recommendations



Who will do it ?

algorithm



- Based on local calibration information
- Based on bio-chemical principles and processes

“CROP 911” (Nitrogen Rescue)

100%

R6

R2

R1

60%

VT

R14

V12

30%

V10

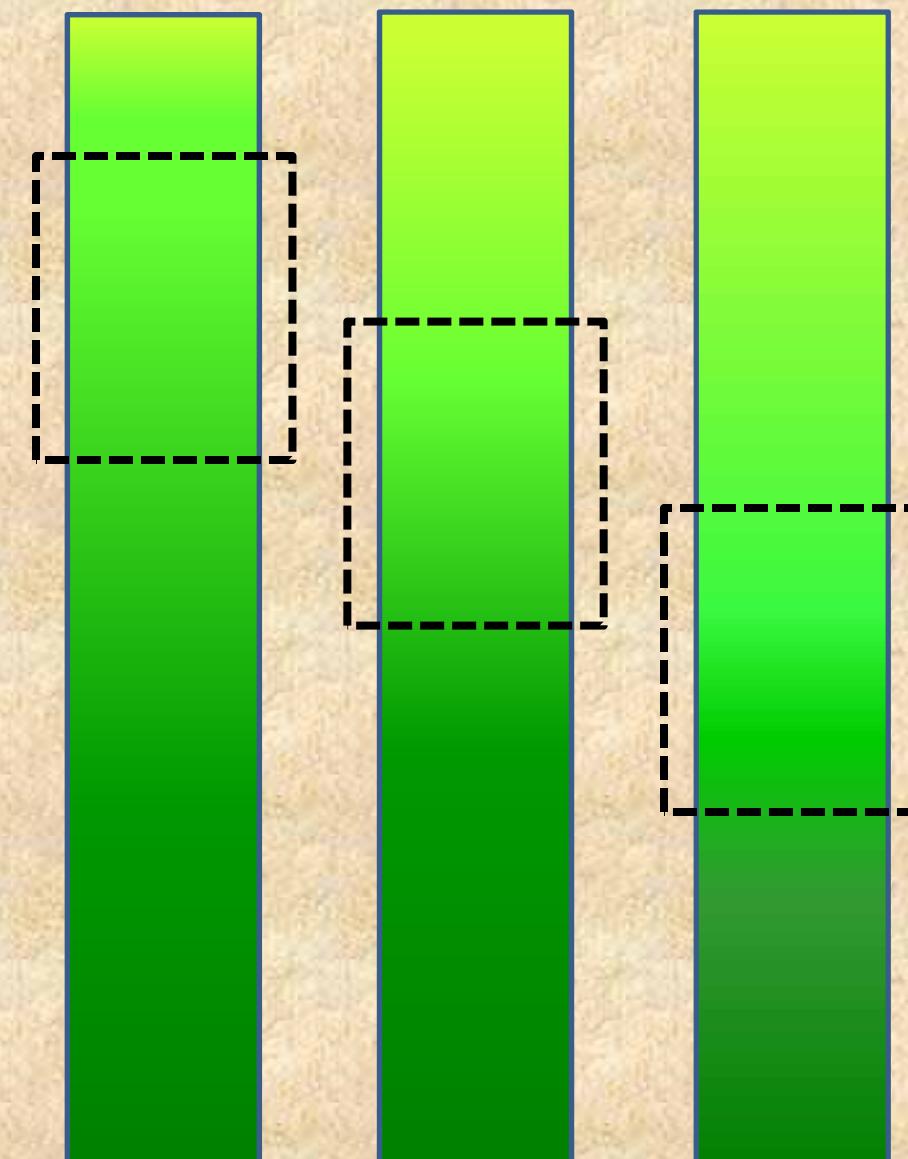
V8

15%

V6

VE

Preplant N Fertilizer



Mexico - White Corn, 2010

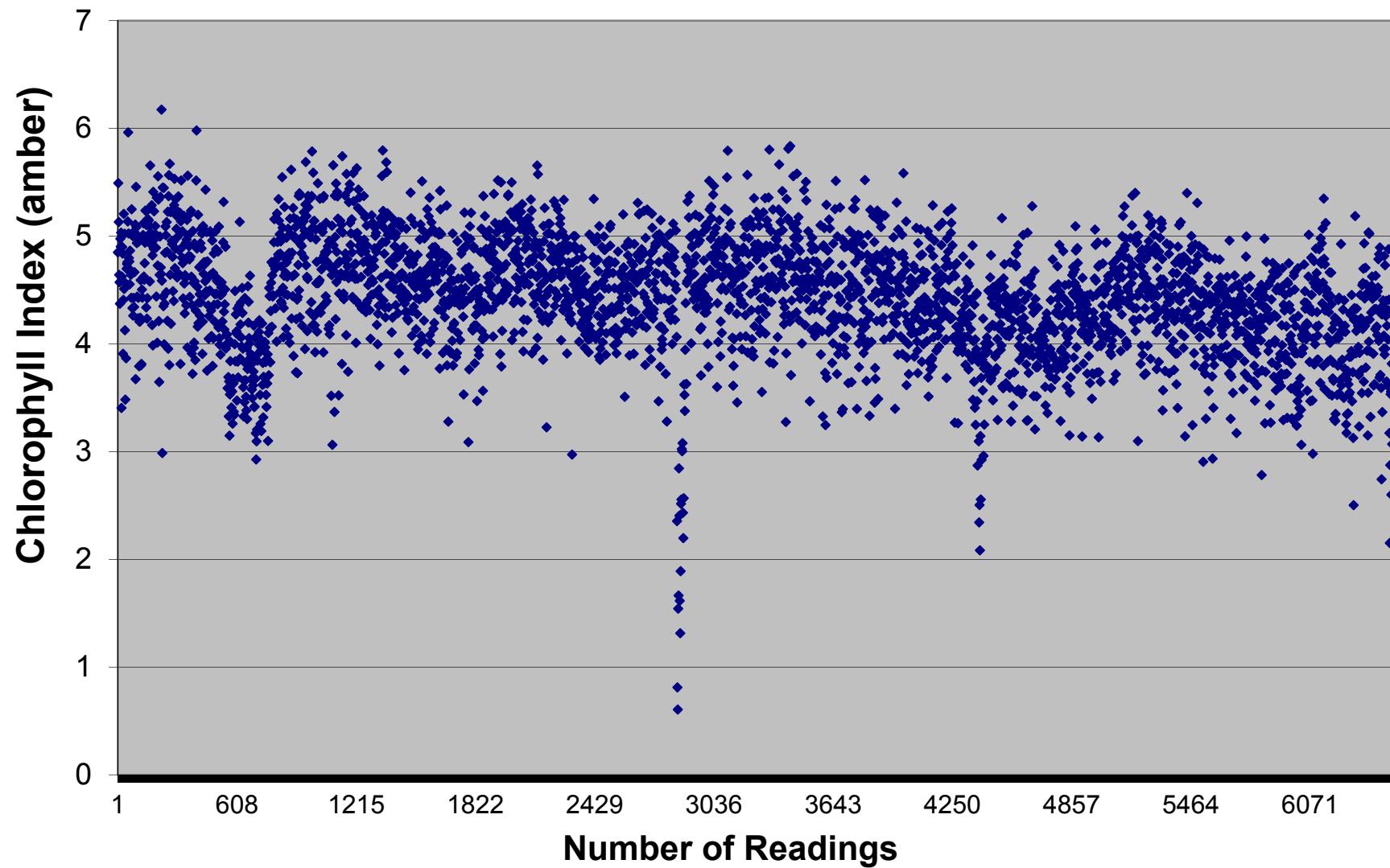
50 lb N/acre preplant



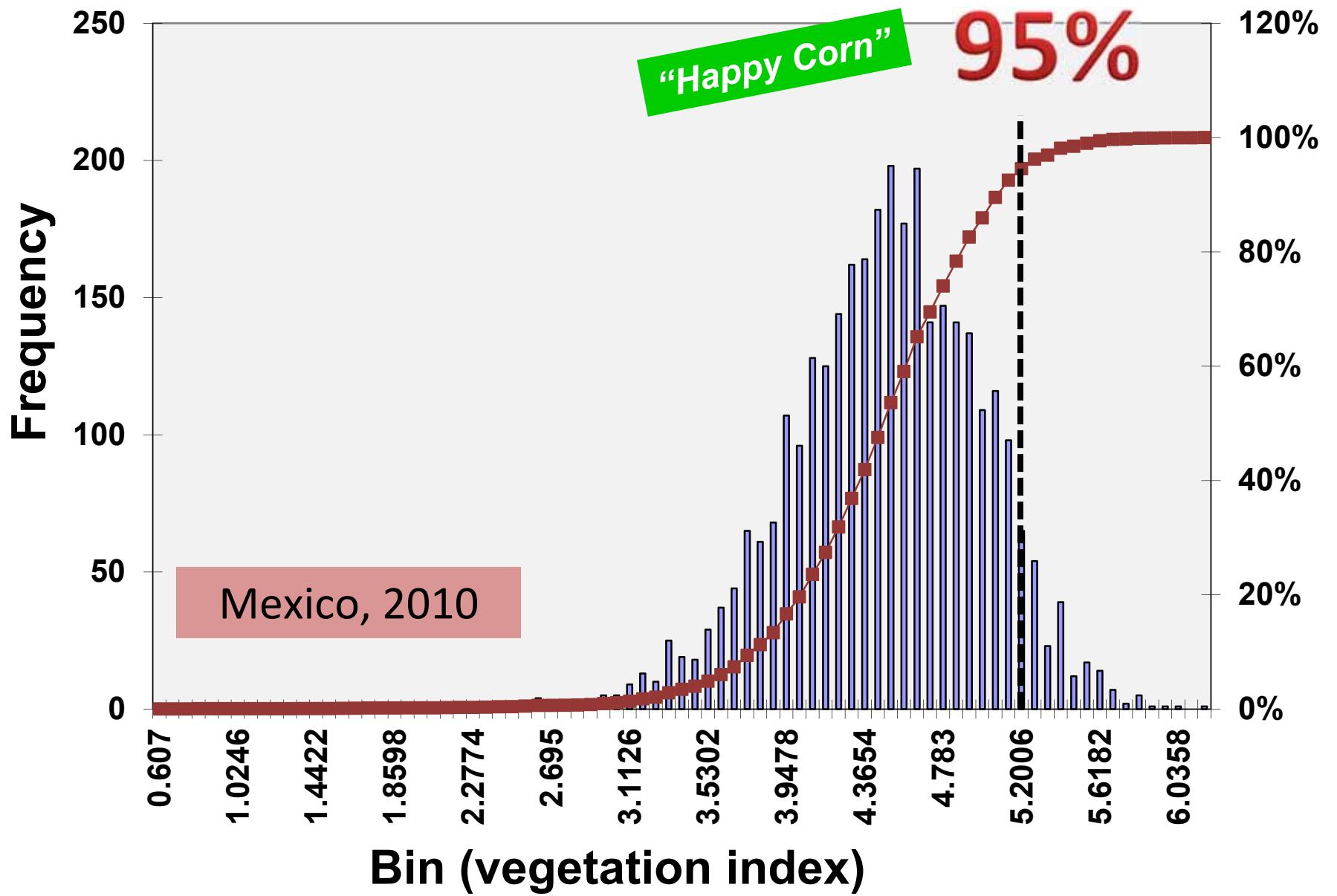
Mexico - White Corn, 2010

Crop Circle ACS-210

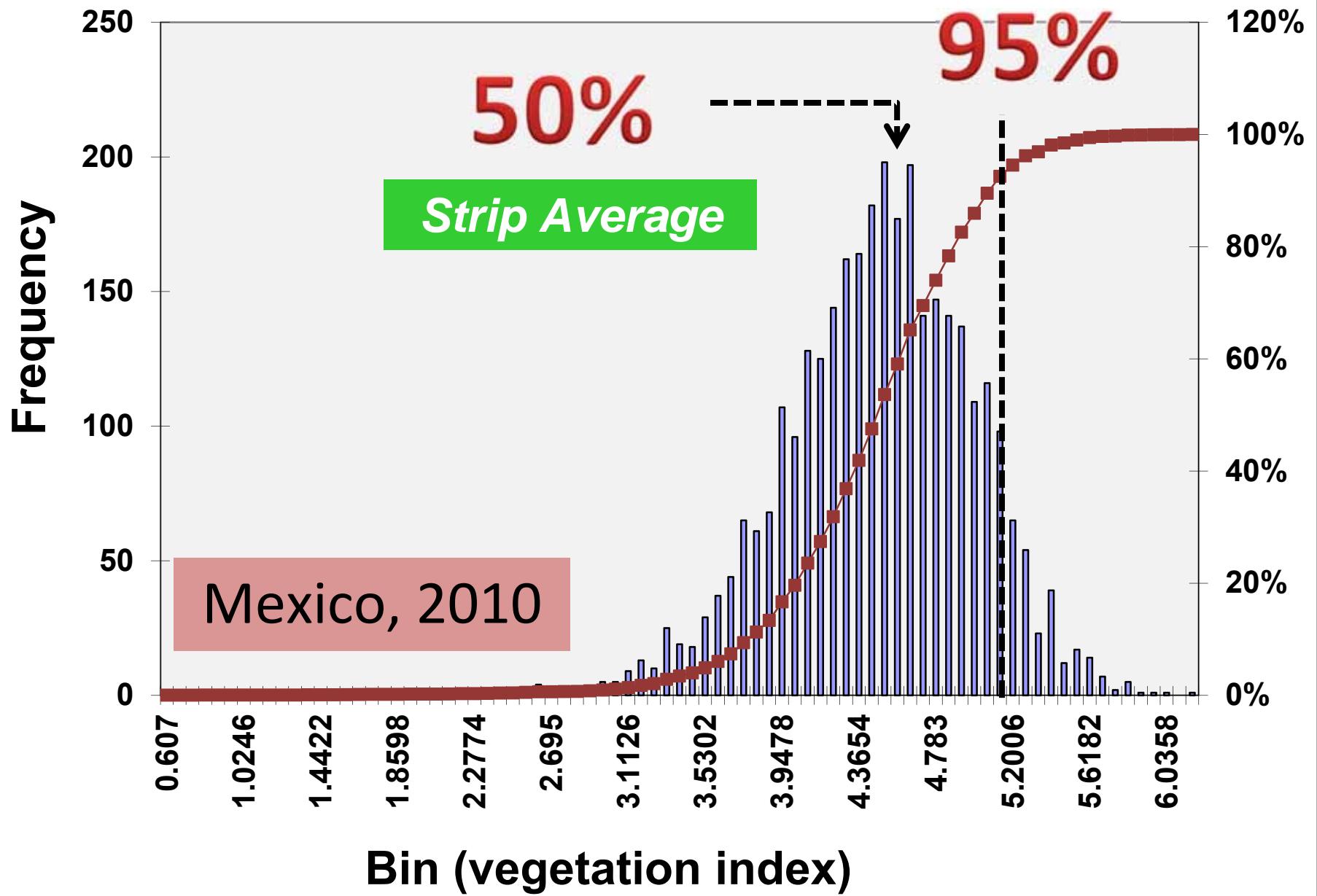
Gustavo Field

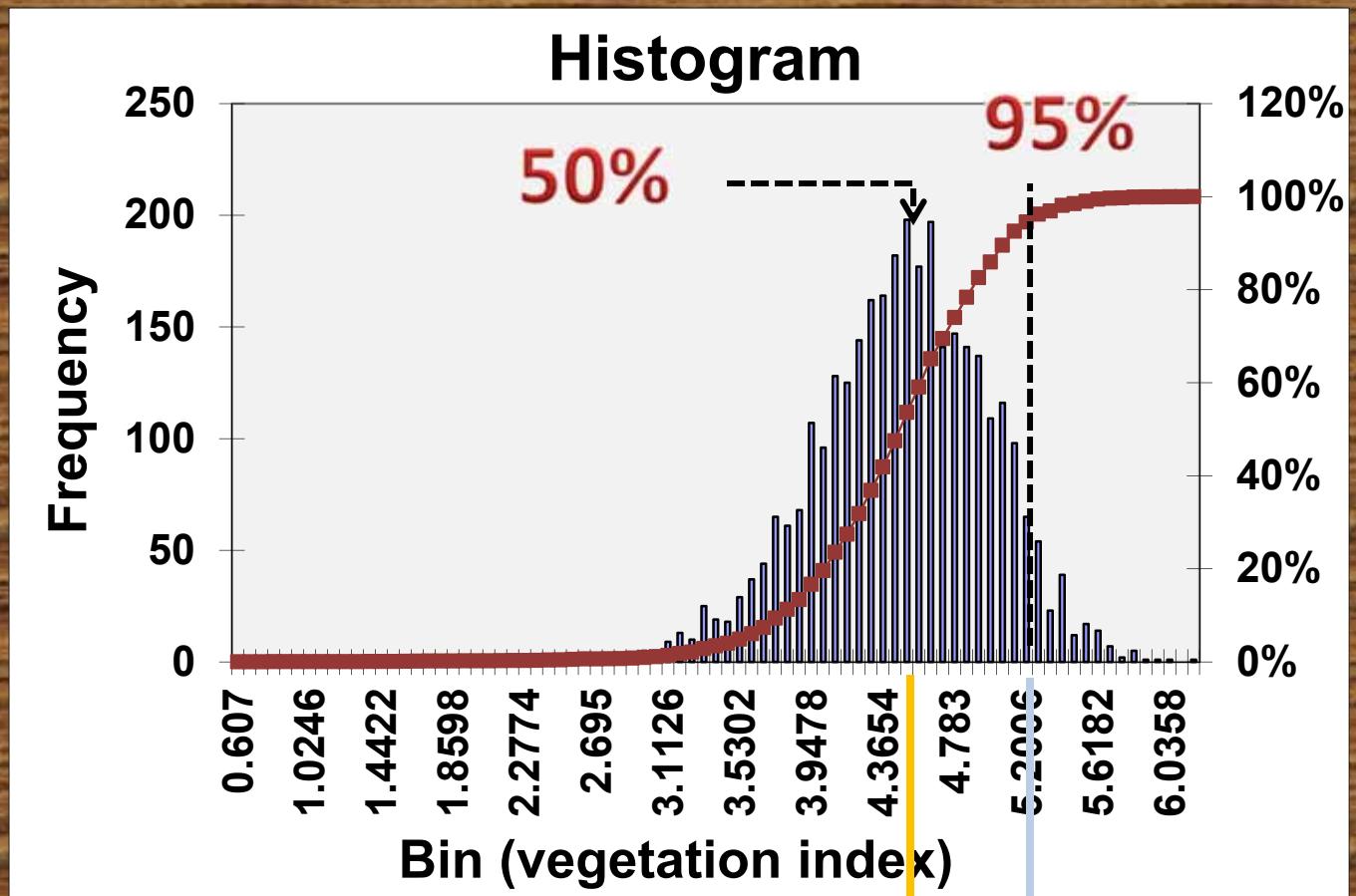


Histogram

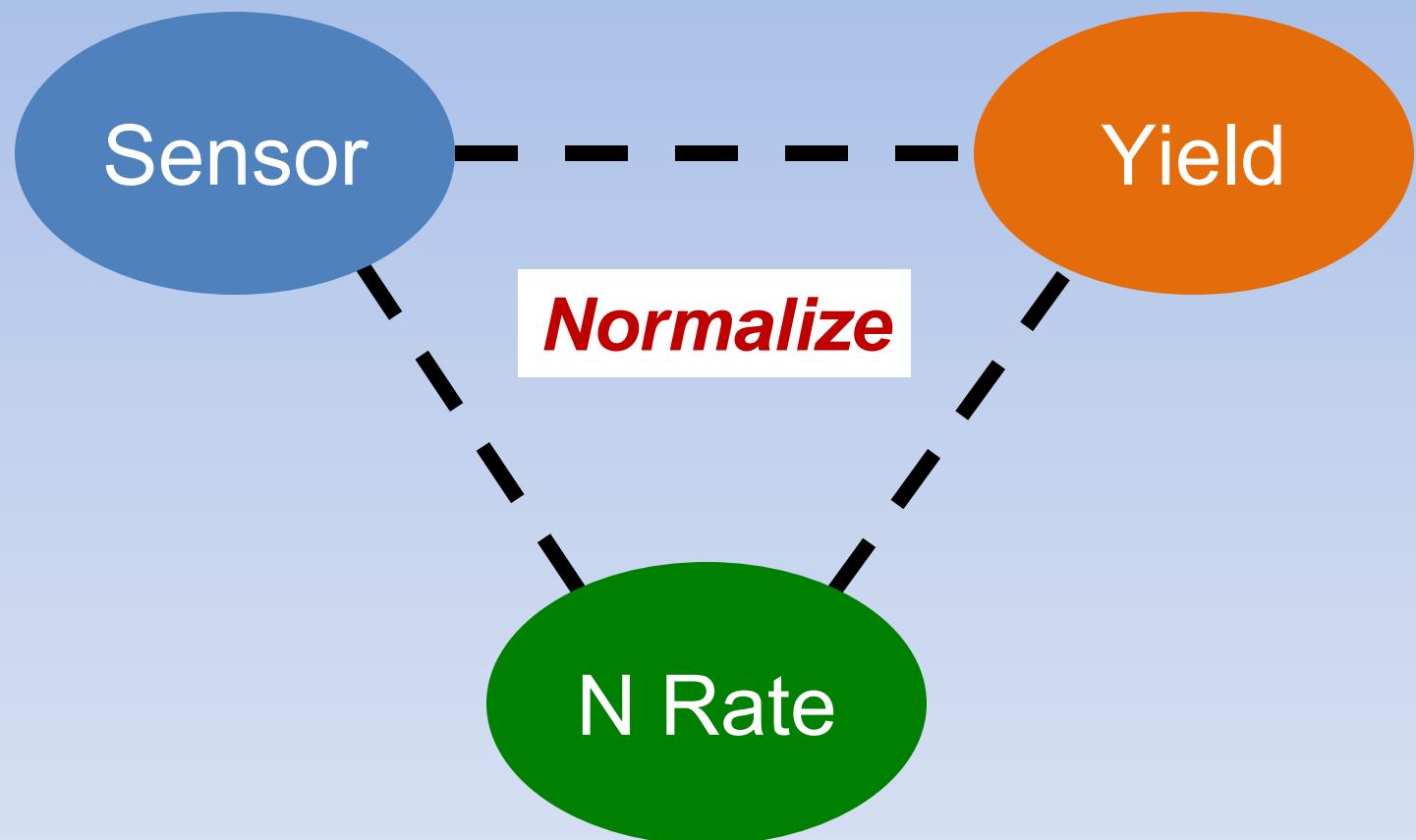


Histogram

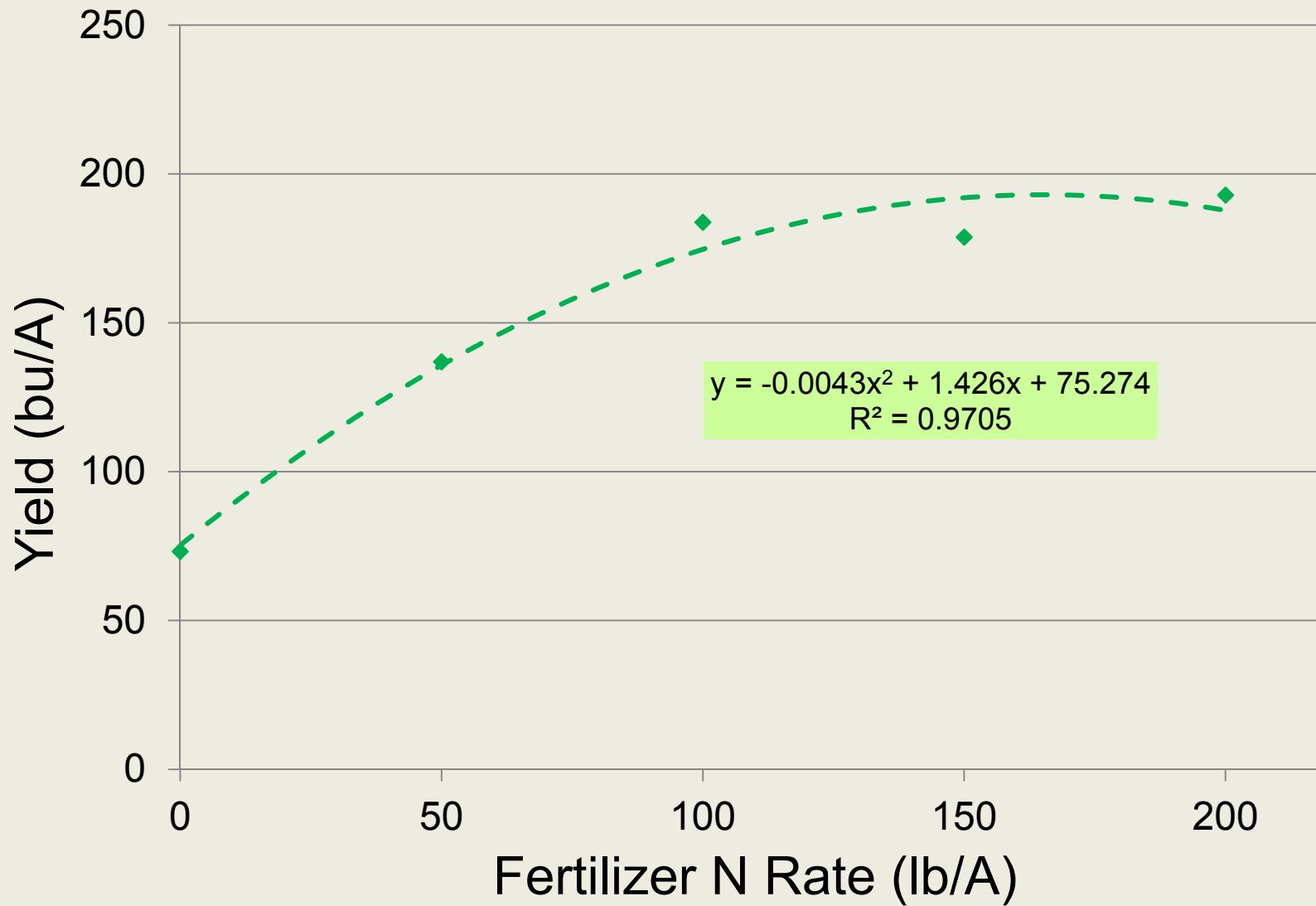




$$SI = \frac{4.47}{5.21} = 0.85$$

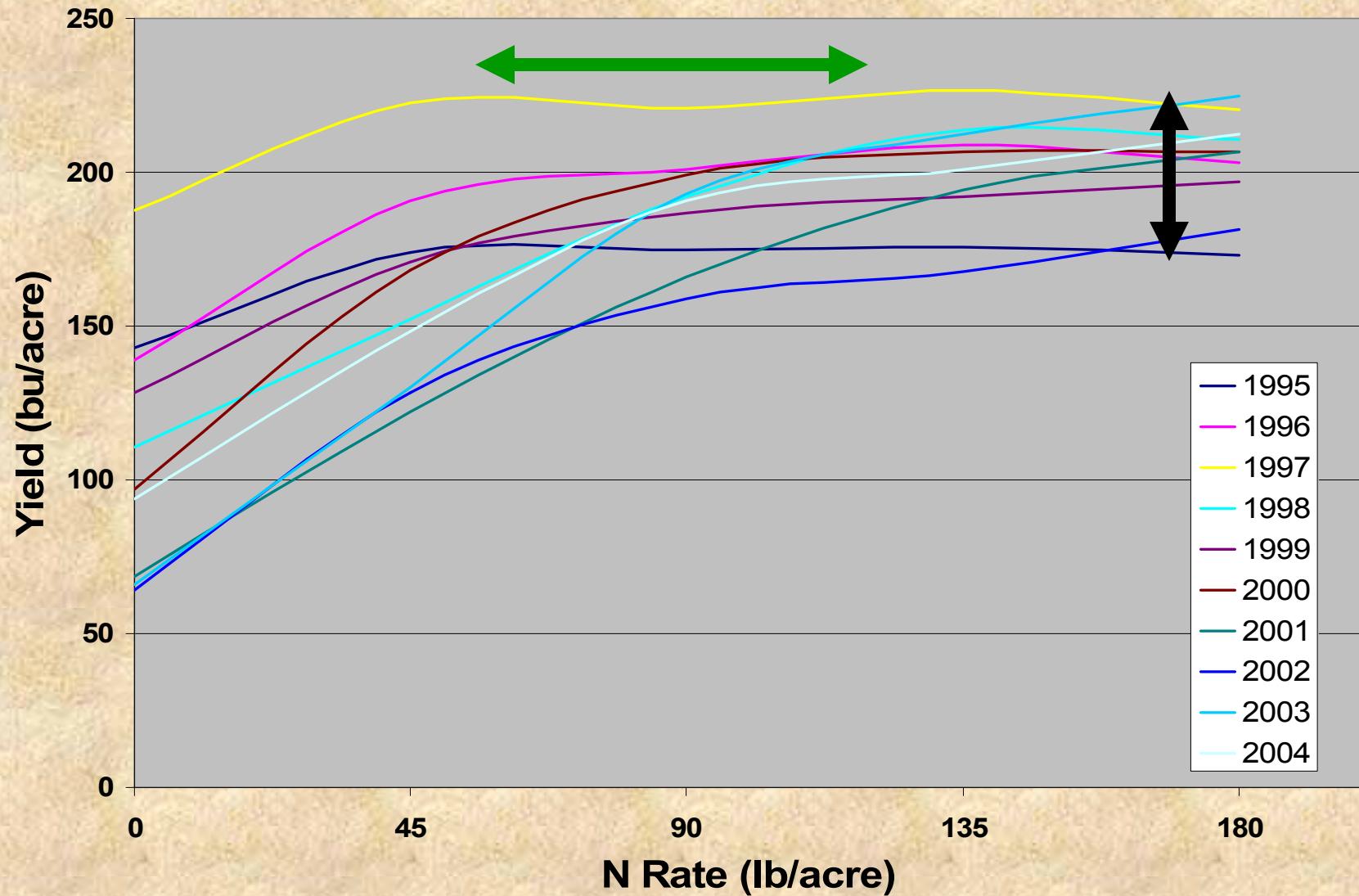


Typical N Response for Corn

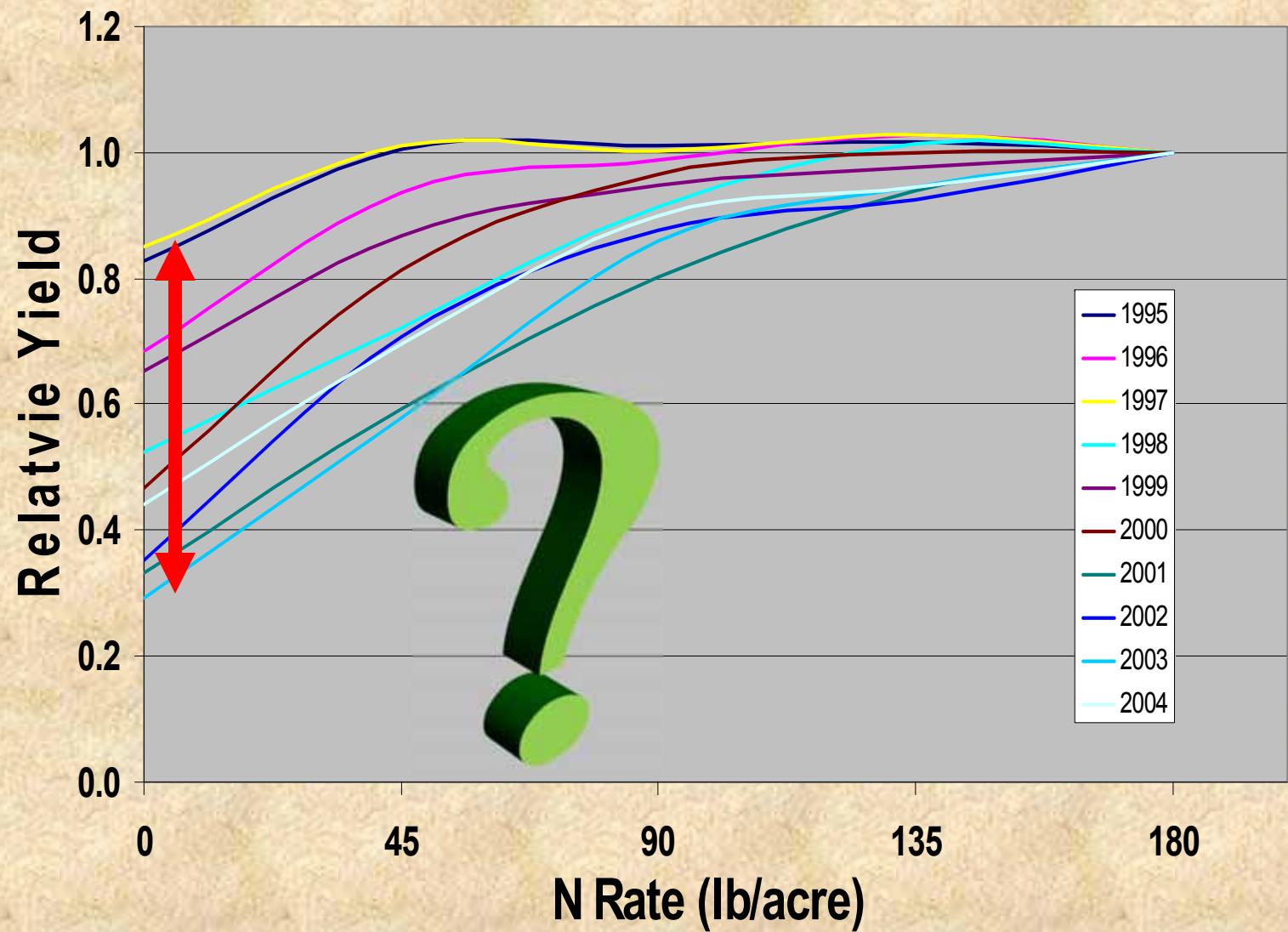


Continuous corn, year 19

MSEA (*continuous corn*)

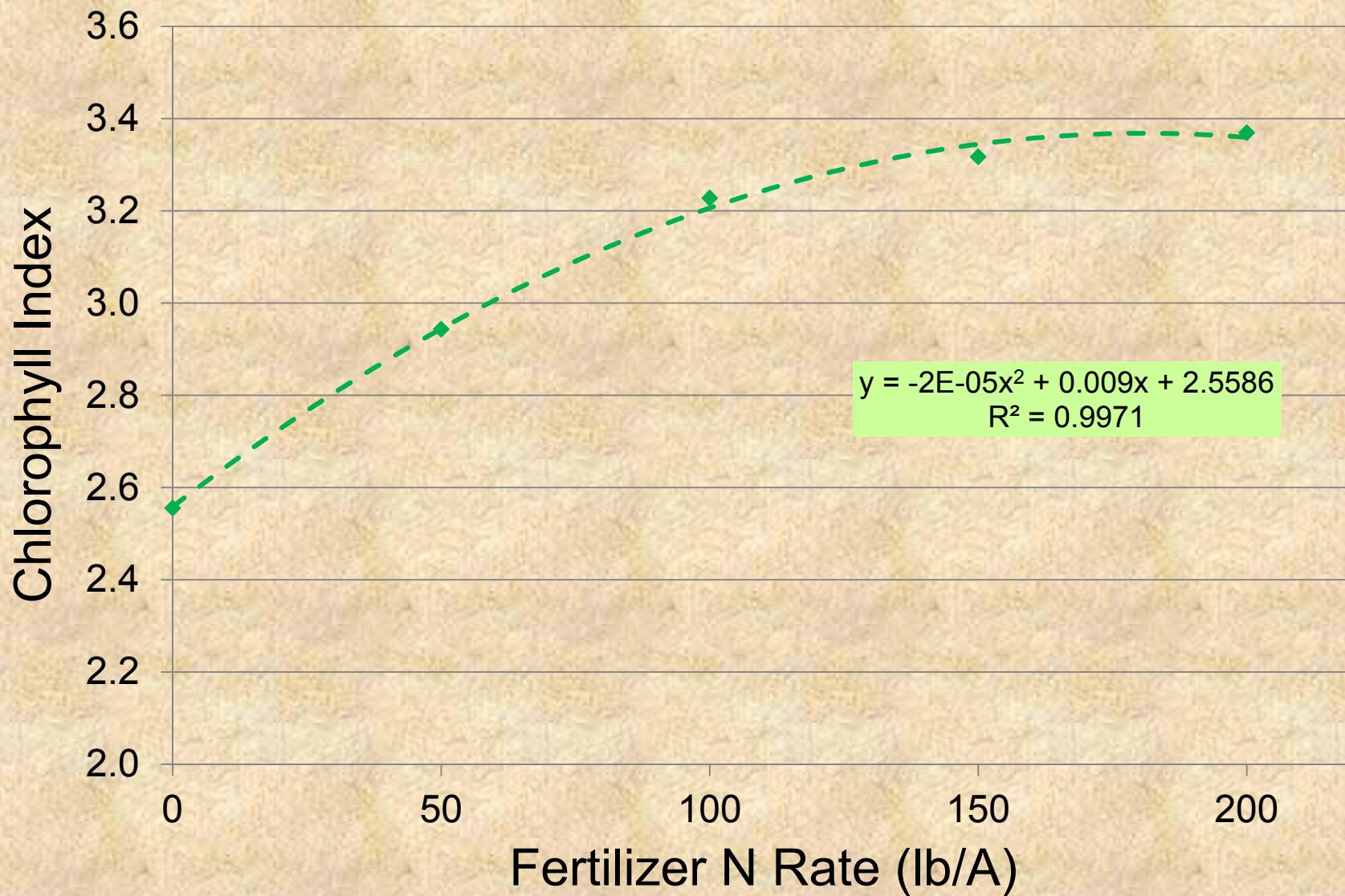


MSEA (*continuous corn*)



Sensor Response to N Rate

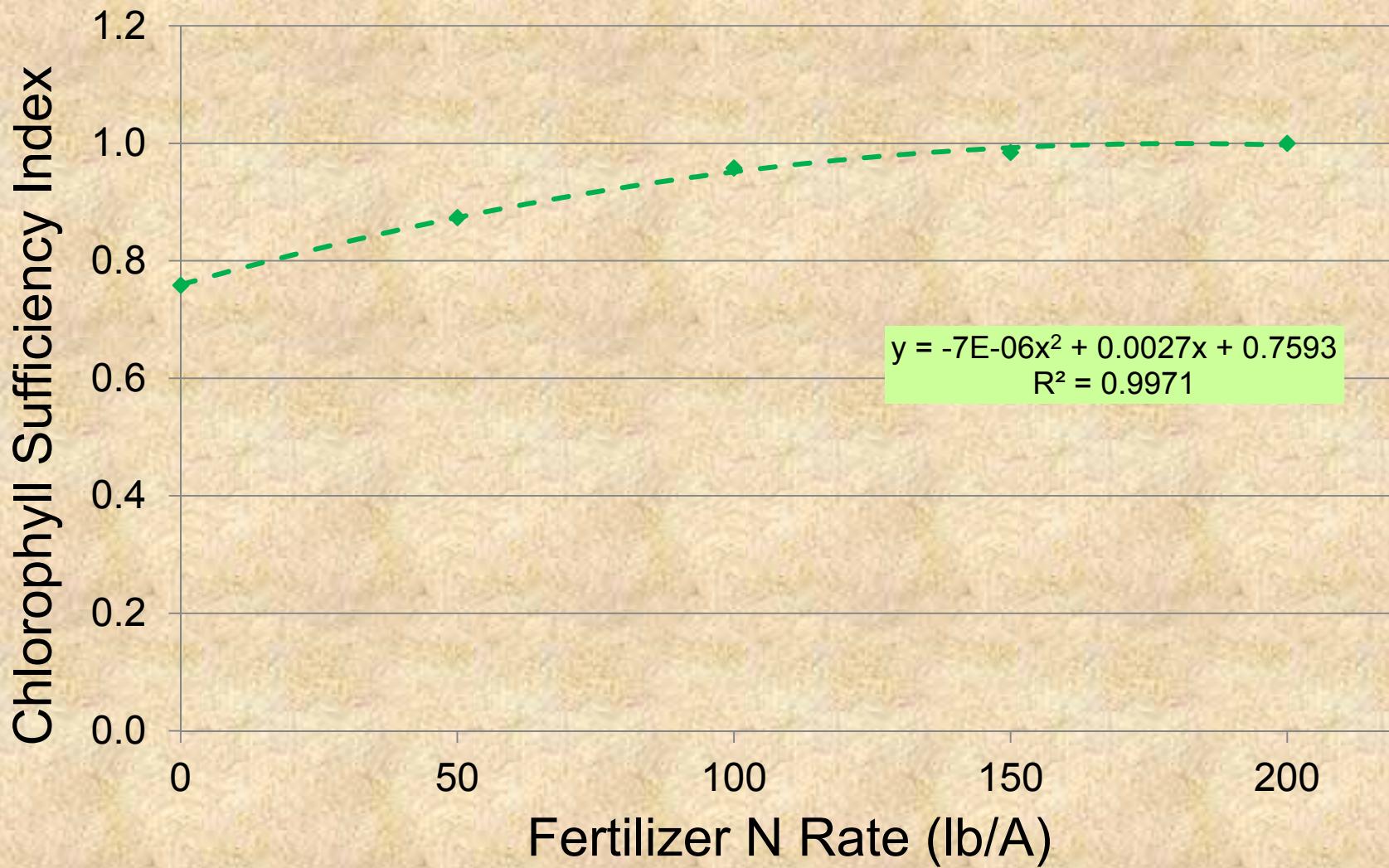
V12



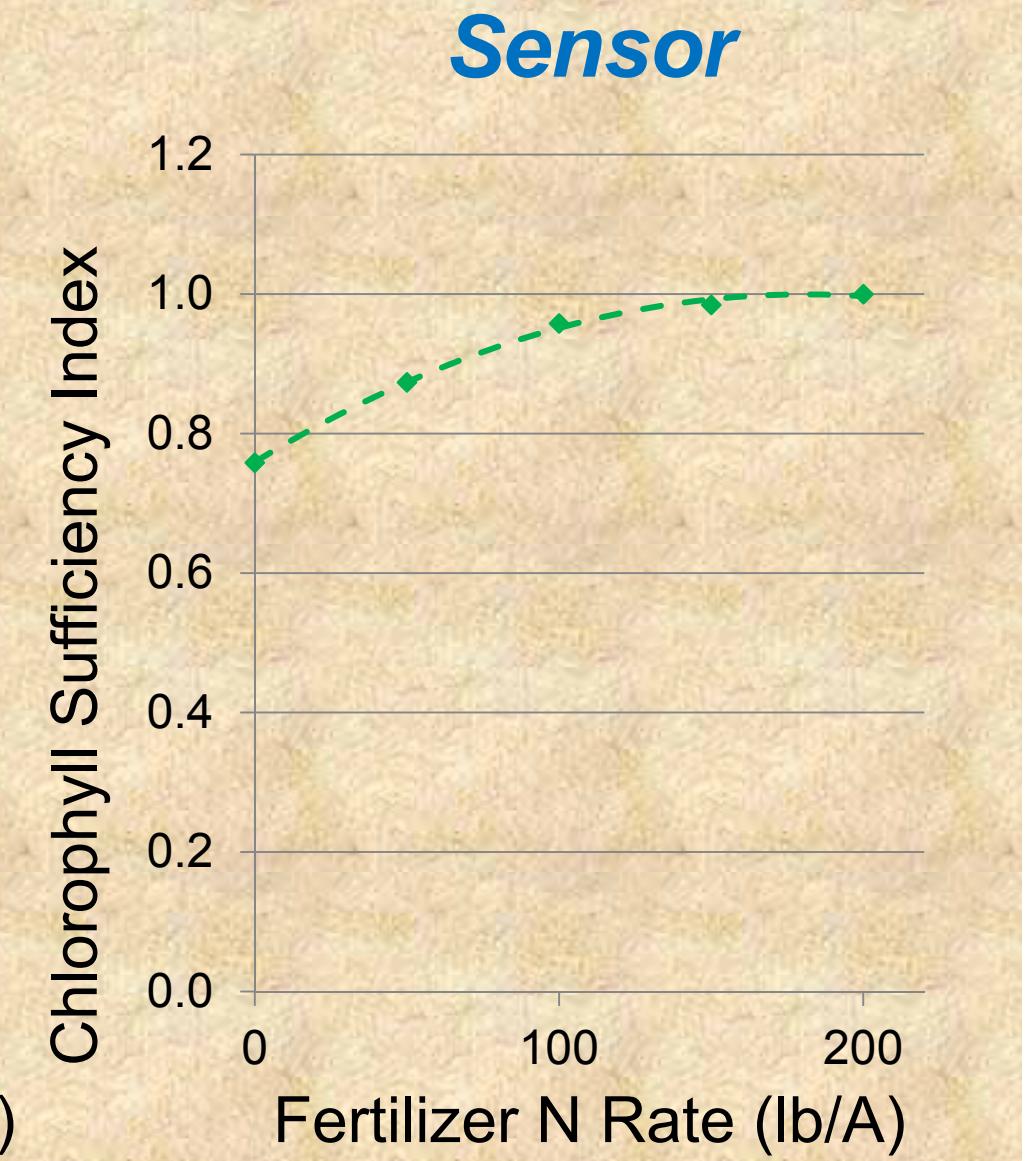
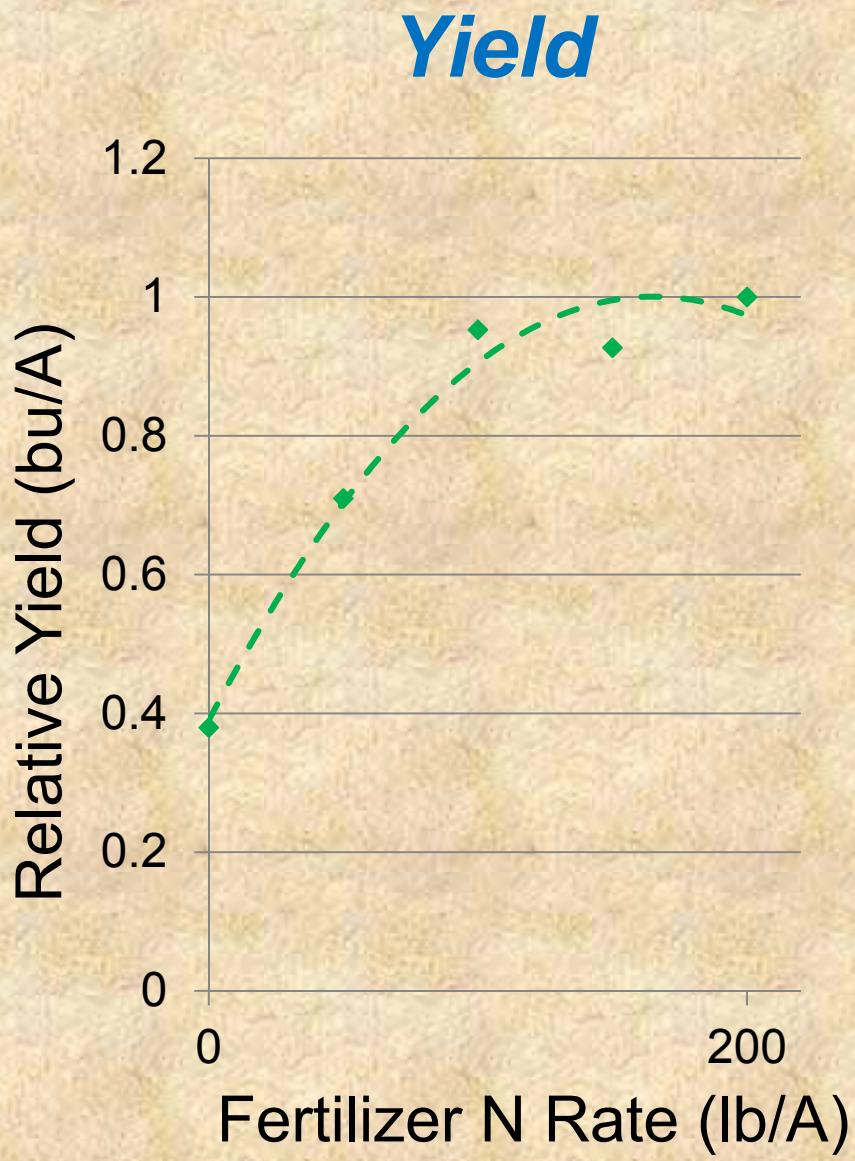
Continuous corn, year 19

Normalized Sensor Response to N Rate

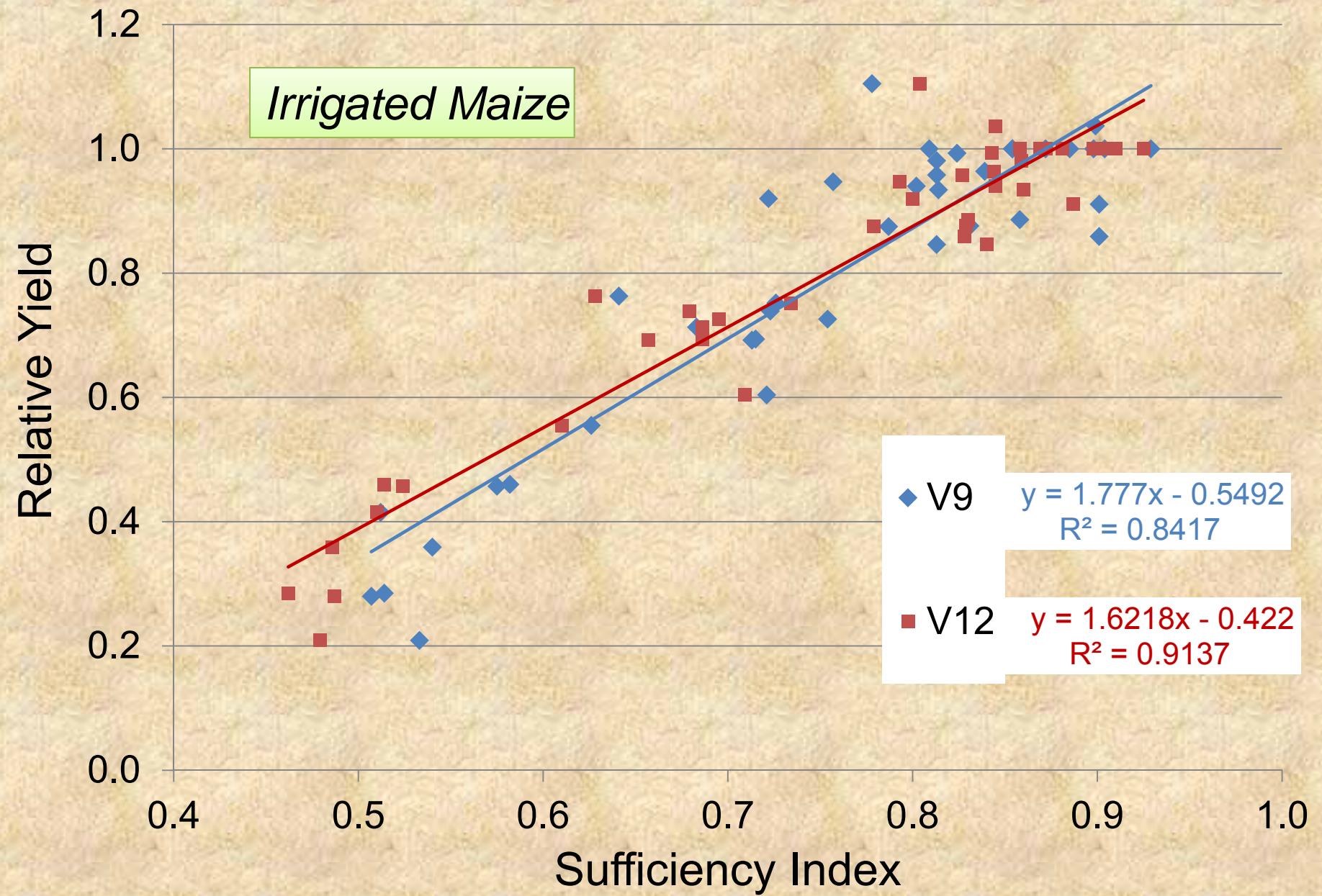
V12



Continuous corn, year 19



Common



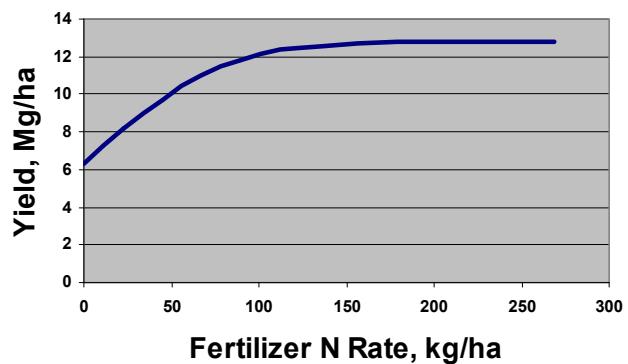
EONR Producer Optimum

N Credits
Preplant N

Field
Reference

Algorithm

Spatial
Soil / Topography



Sufficiency Index

N Accumulation
(based on growth stage)

Back-Off Strategy
SI to start cutback
SI to cut-off

No calibration coefficients

Basic Algorithm

Holland K.H. and J.S. S...

Caution :

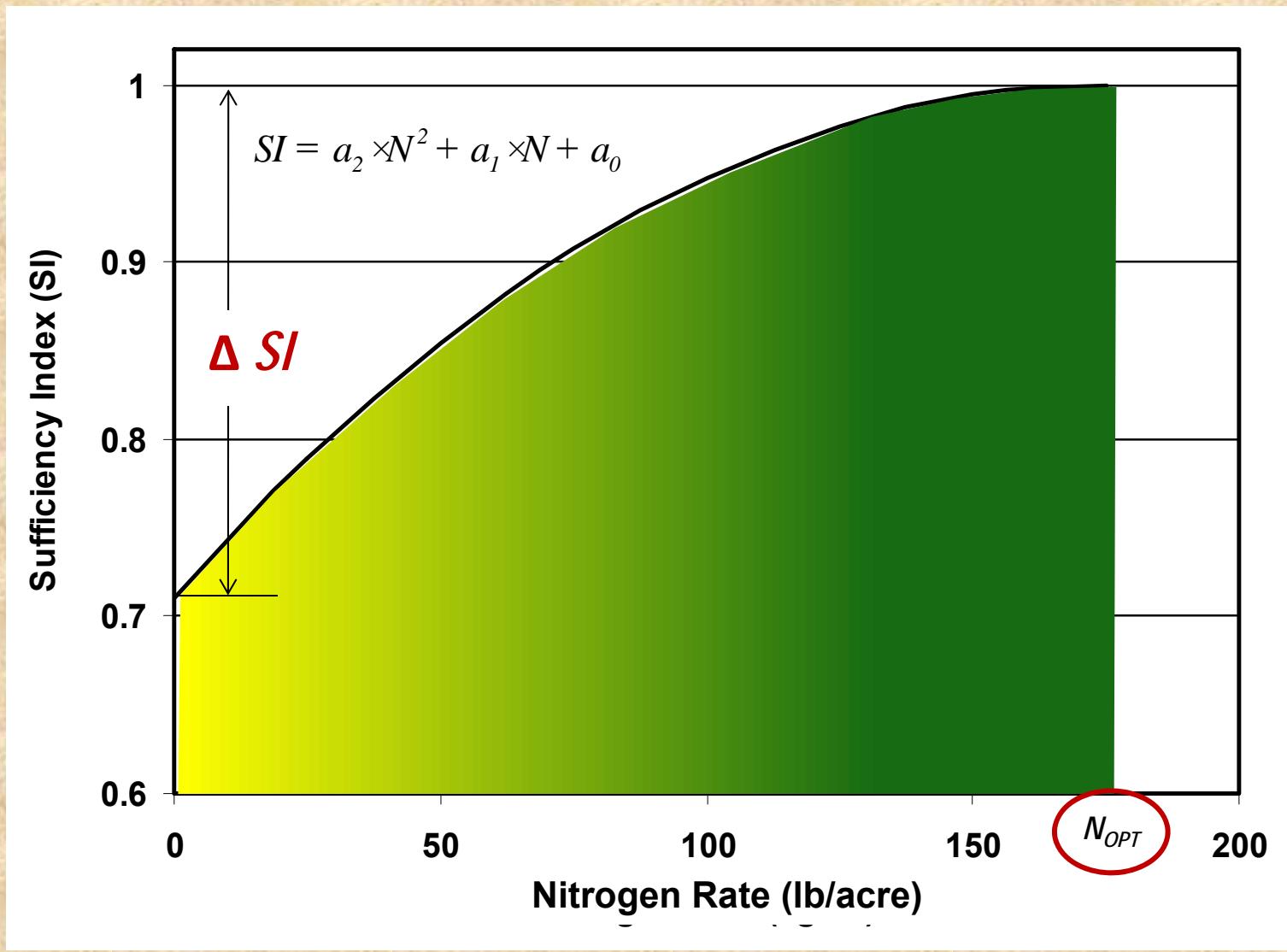
**Mineralization and
Immobilization** are
embedded within SI

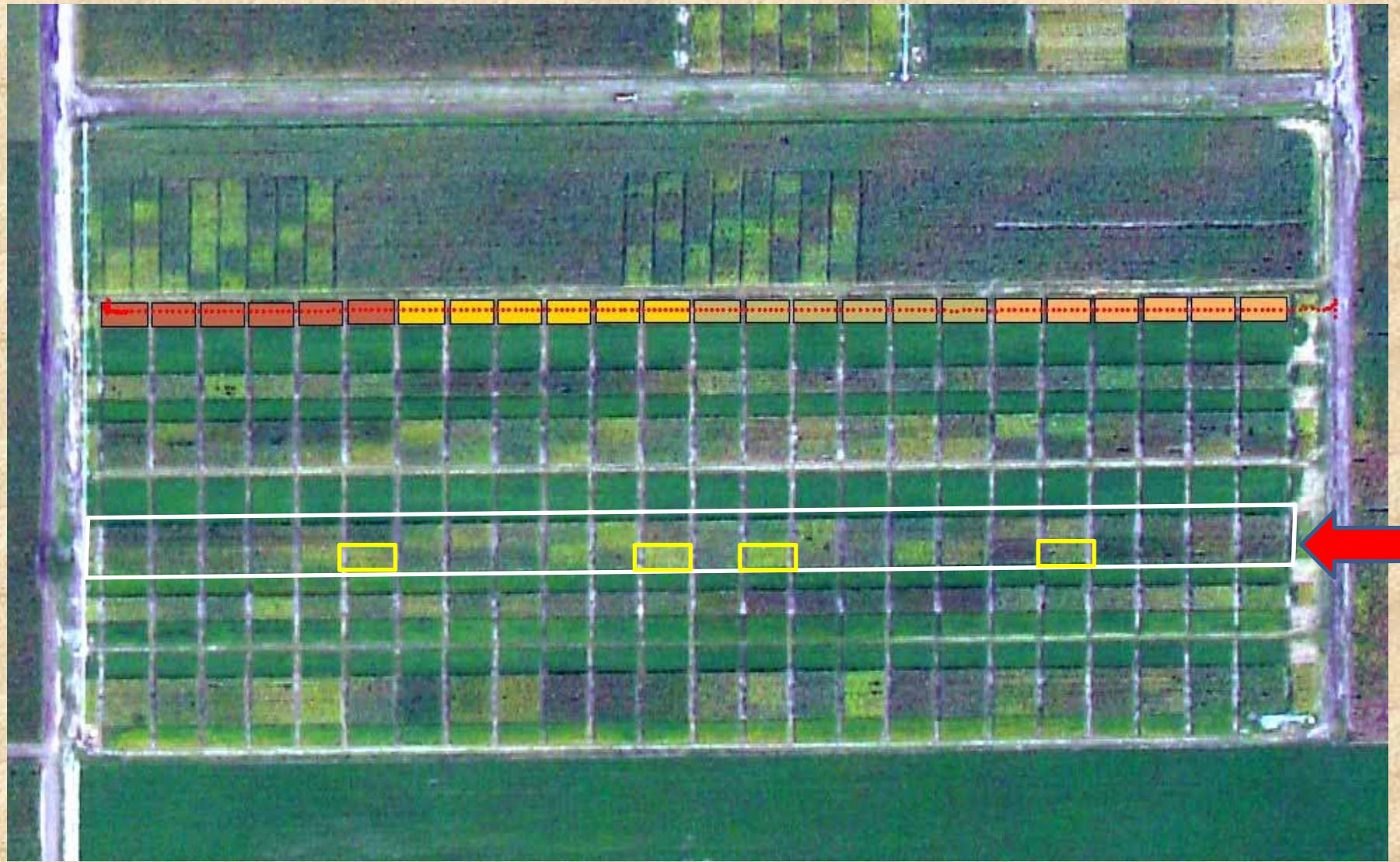
1424.

$$N_{\text{appl}} = (N_{\text{opt}} - N_{\text{cred}}) \sqrt{\frac{(1 - SI)}{\Delta SI}}$$

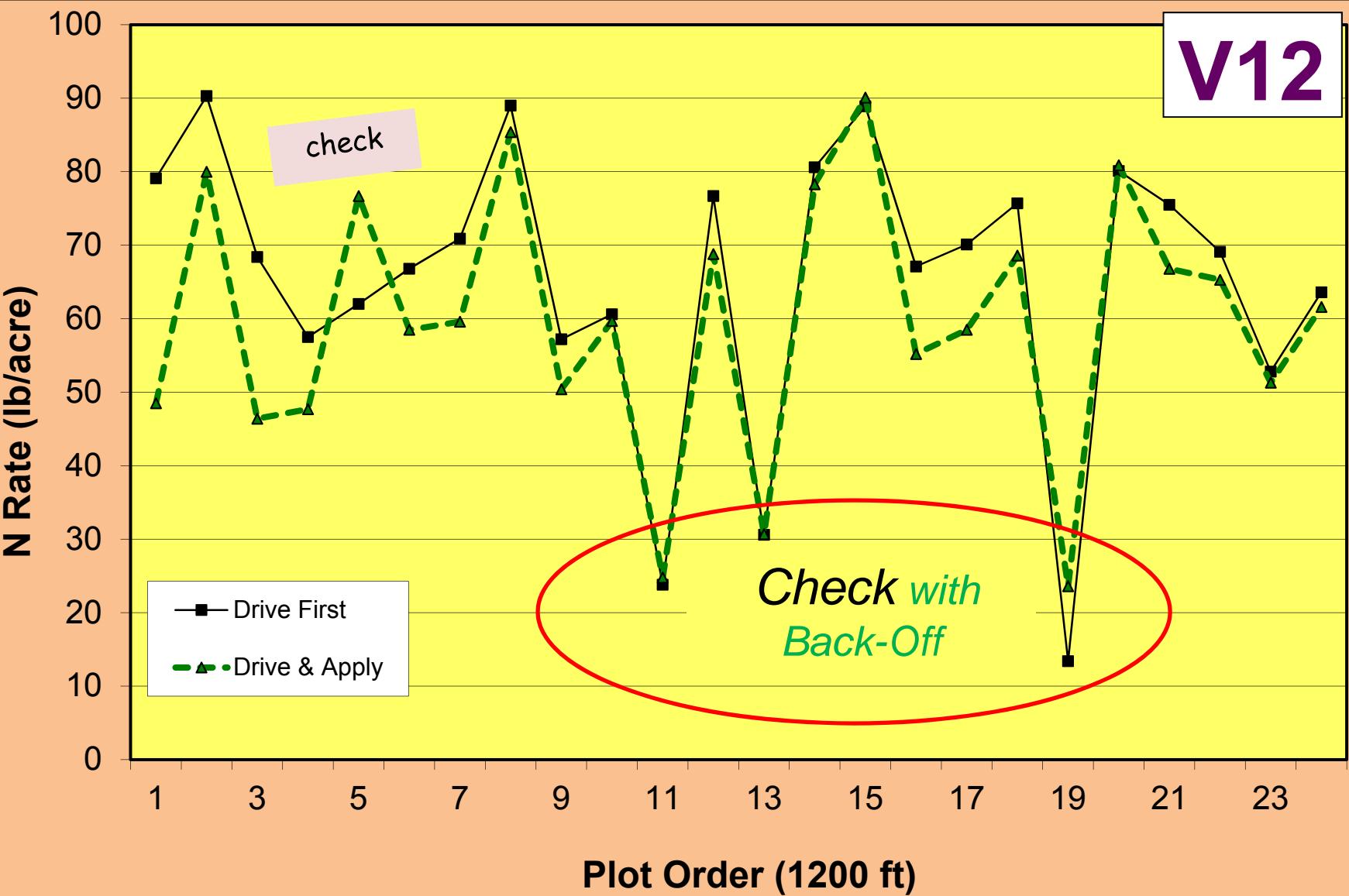
Farmer Rate
or N_{EONR}

General N-Rate Model Example





Virtual Reference Strip (0-200 lb N/acre preplant)



Summary

- In-season N management is a team activity
 - - - You are the captain
 - - - Sensors are just a tool (also applies to remote sensing)
 - - - Spatial variability in soil properties requires flexibility
 - - - Weather is the unpredictable adversary
 - - - The game never ends
 - - - The referee makes the rules, changes the rules, and might not have much empathy
- Some version of in-season management is likely to become your friend because of the occurrence of nitrate in streams, rivers and groundwater.

Thank You

Jim Schepers

402-310-6150

james.schepers@gmail.com