Project SENSE: Effectiveness of Sensor-Based Nitrogen Management

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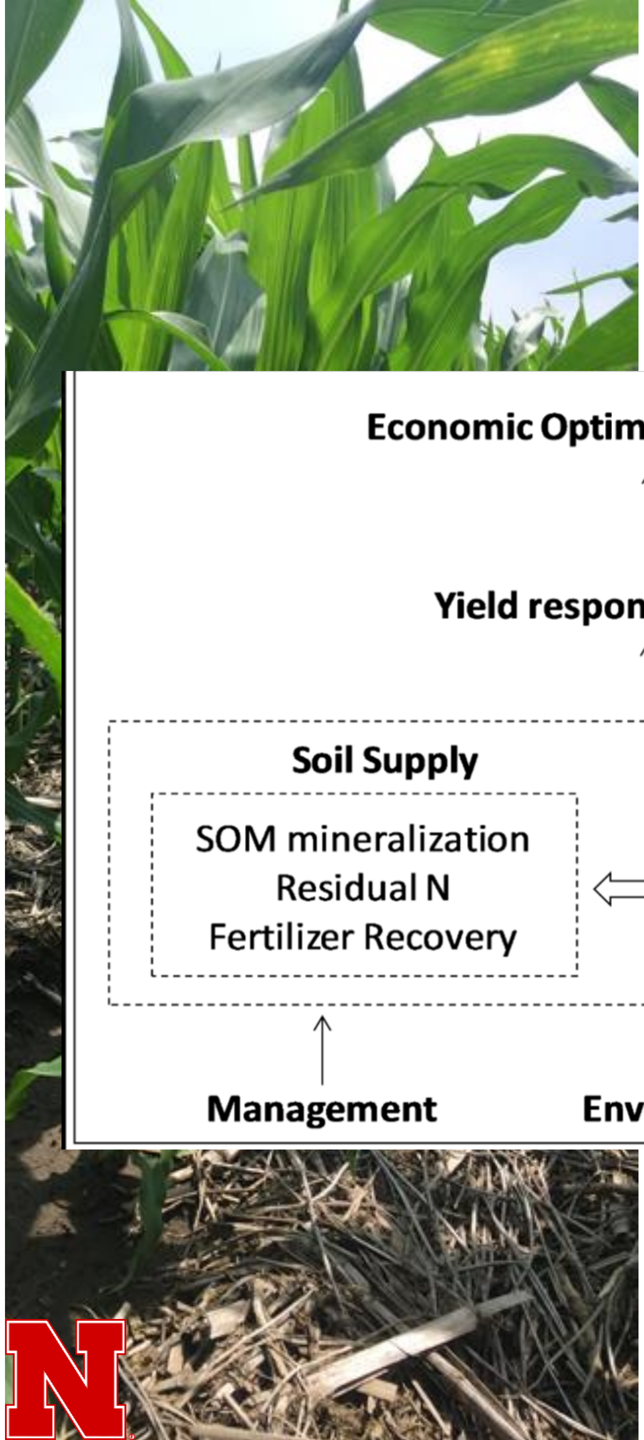
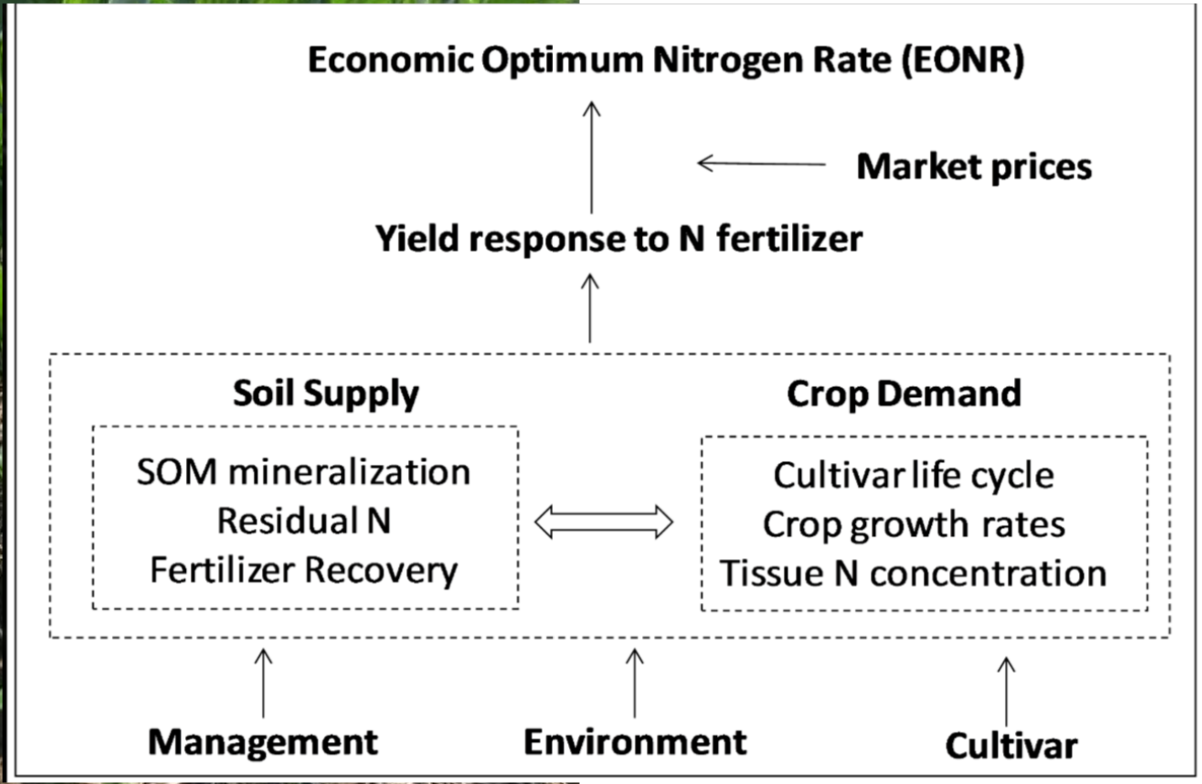
Outline:

- Why In-Season N management?
- SENSE
- Results & Summary

Overview





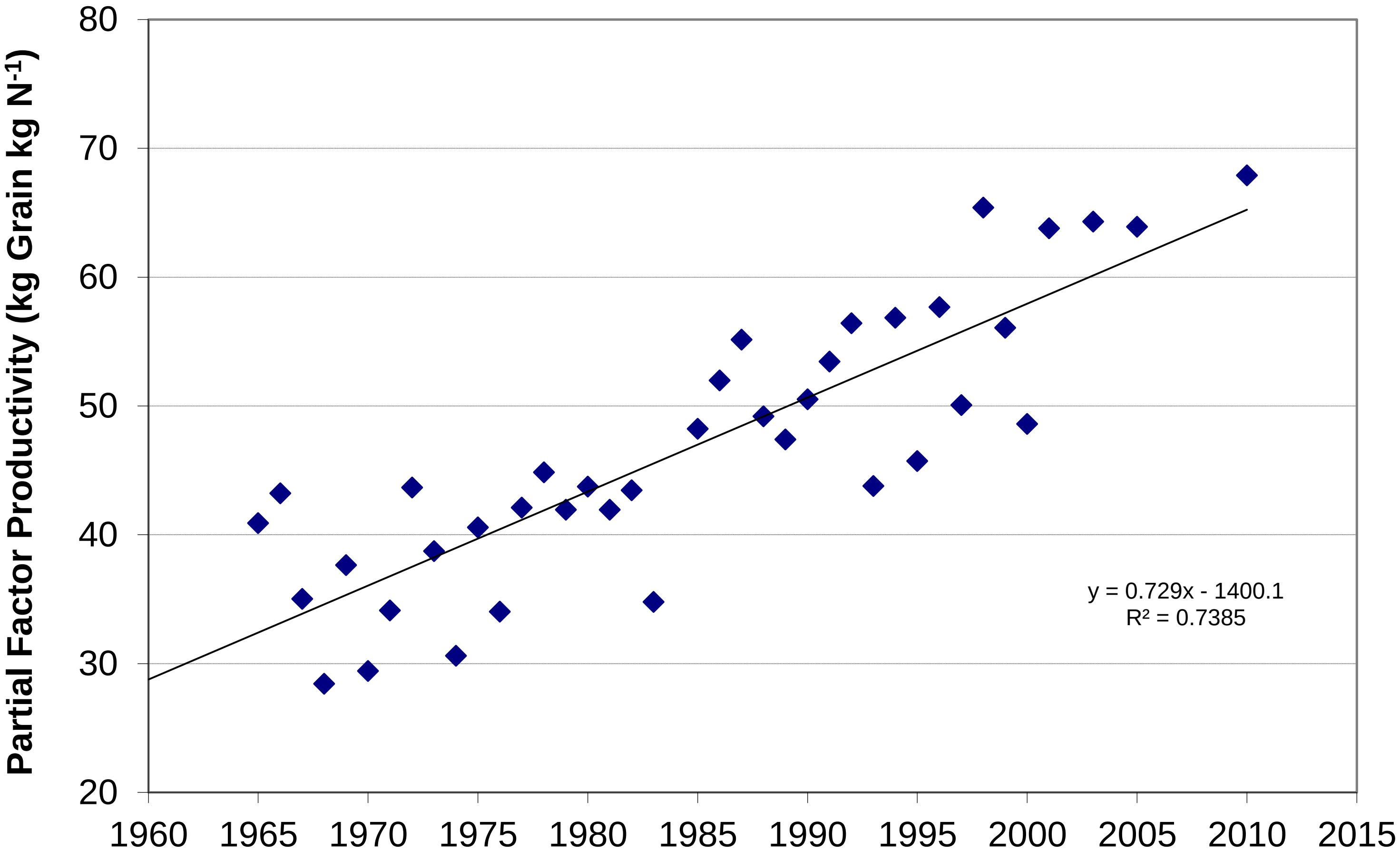
- Nitrogen is the most limiting factor in cereal crop production
- Increases yield a lot!
- Relative quantities, high!
- Beyond crop needs,

  often results in

  environmental implications

NUE for Corn in Nebraska

- Improved genetics
- Improved cultural practices
- Realistic N rates
- Timely N application
- Use of nitrification and urease inhibitors
- Water management



Derived from USDA-NASS ARMS Survey and Nebraska Dept. of Agriculture statistics on nitrogen fertilizer use and corn grain production

Nebraska Nitrate Levels: 2017

The "hotspots" for leaching loss?

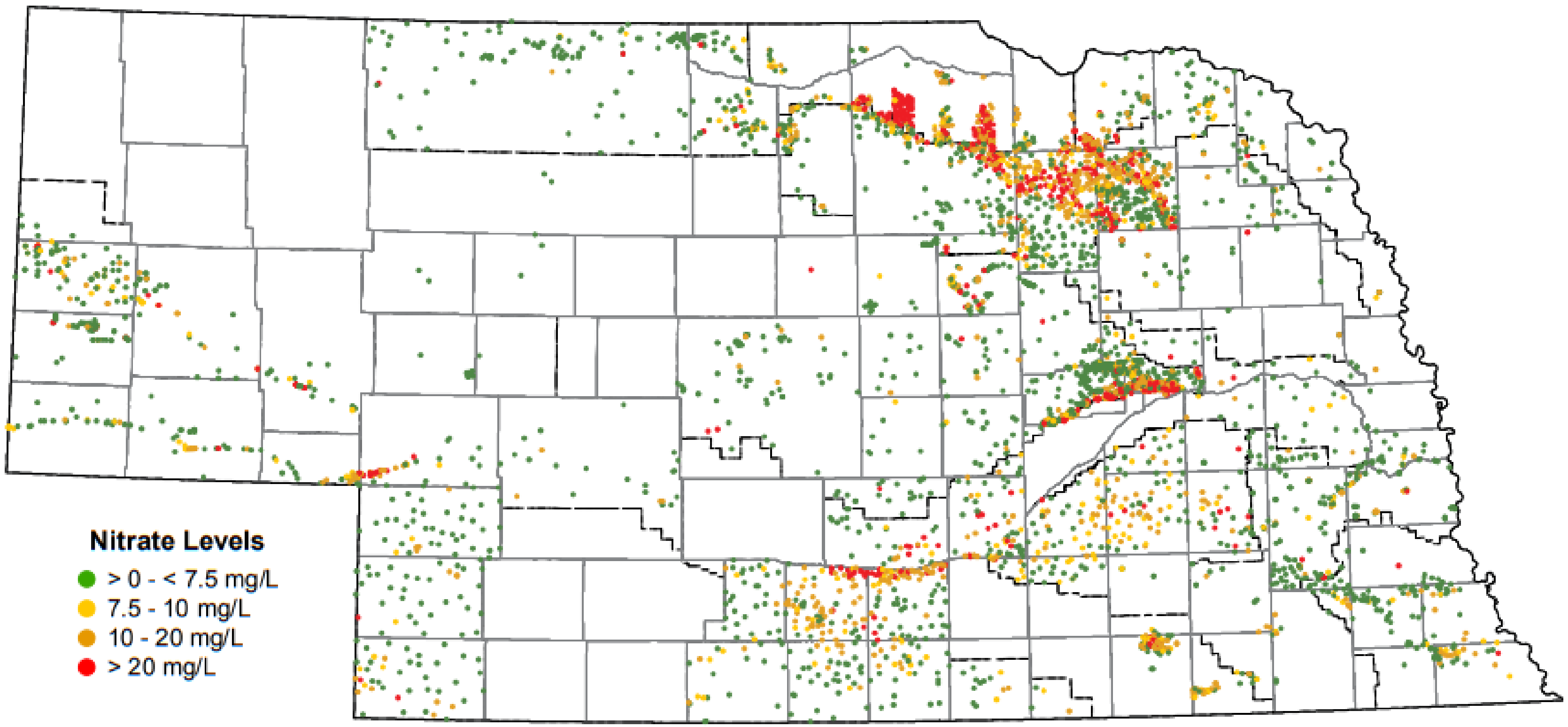
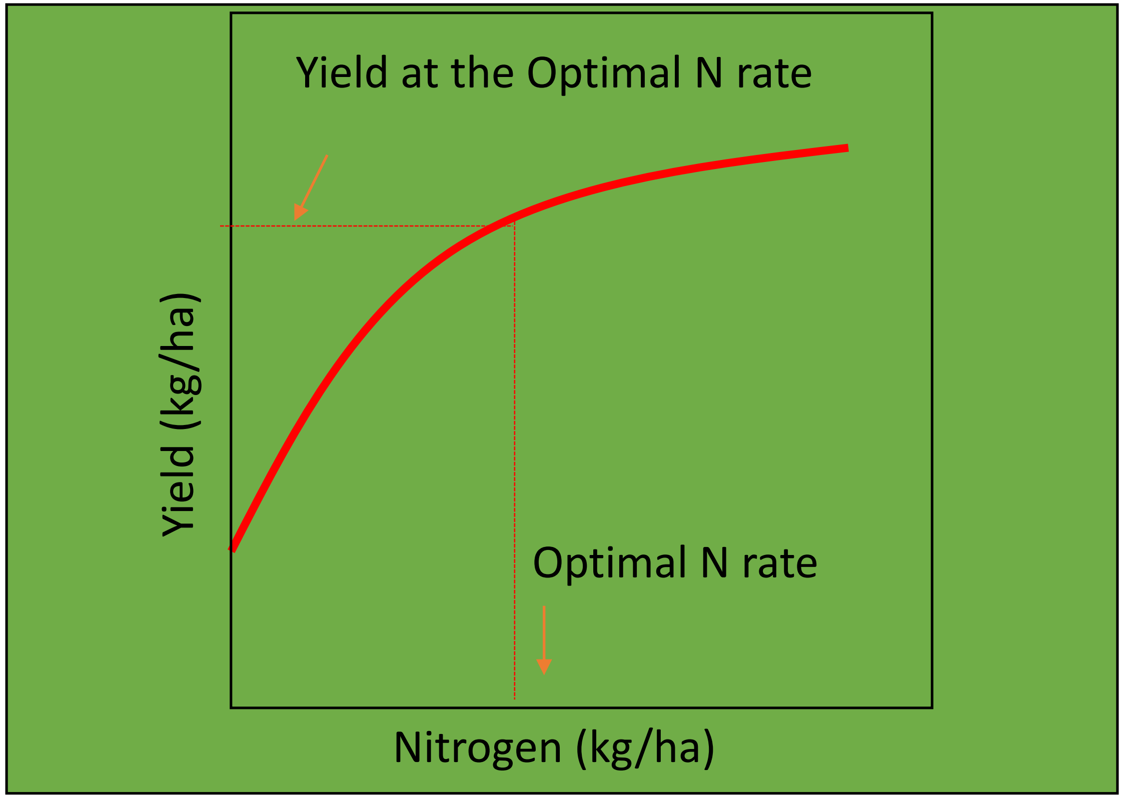


Figure 12. Most recent recorded Nitrate-N concentrations of 4,245 wells sampled in 2017. (Source: Quality-Assessed Agrichemical Database for Nebraska Groundwater, 2018) *Empty areas indicate no data reported, not the absence of nitrate in groundwater.*

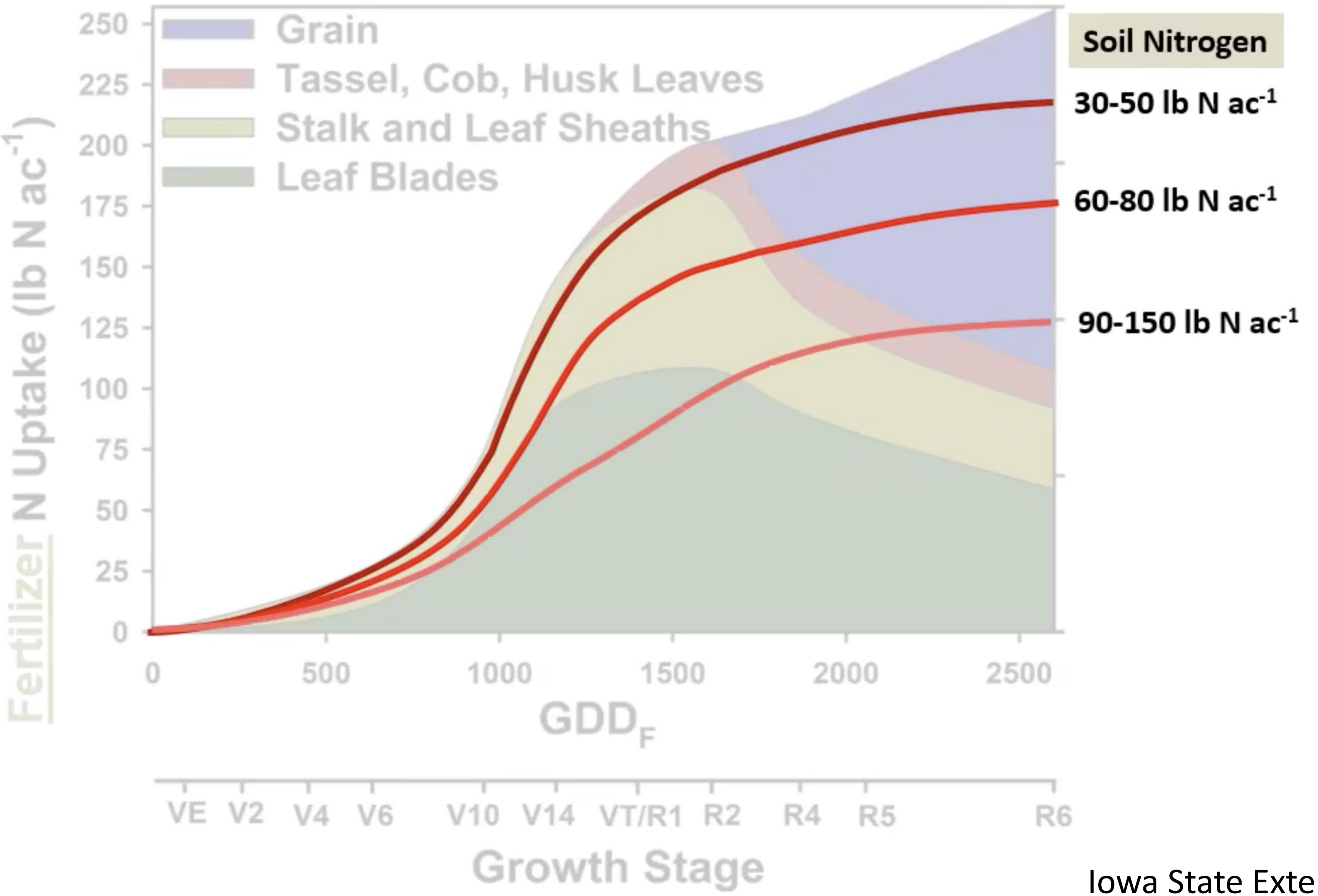
N EXTENSION

Overview

- Optimize the level of inputs within the field
- Increase fertilizer nitrogen use efficiency (NUE)
- Reduce nitrate loss to groundwater

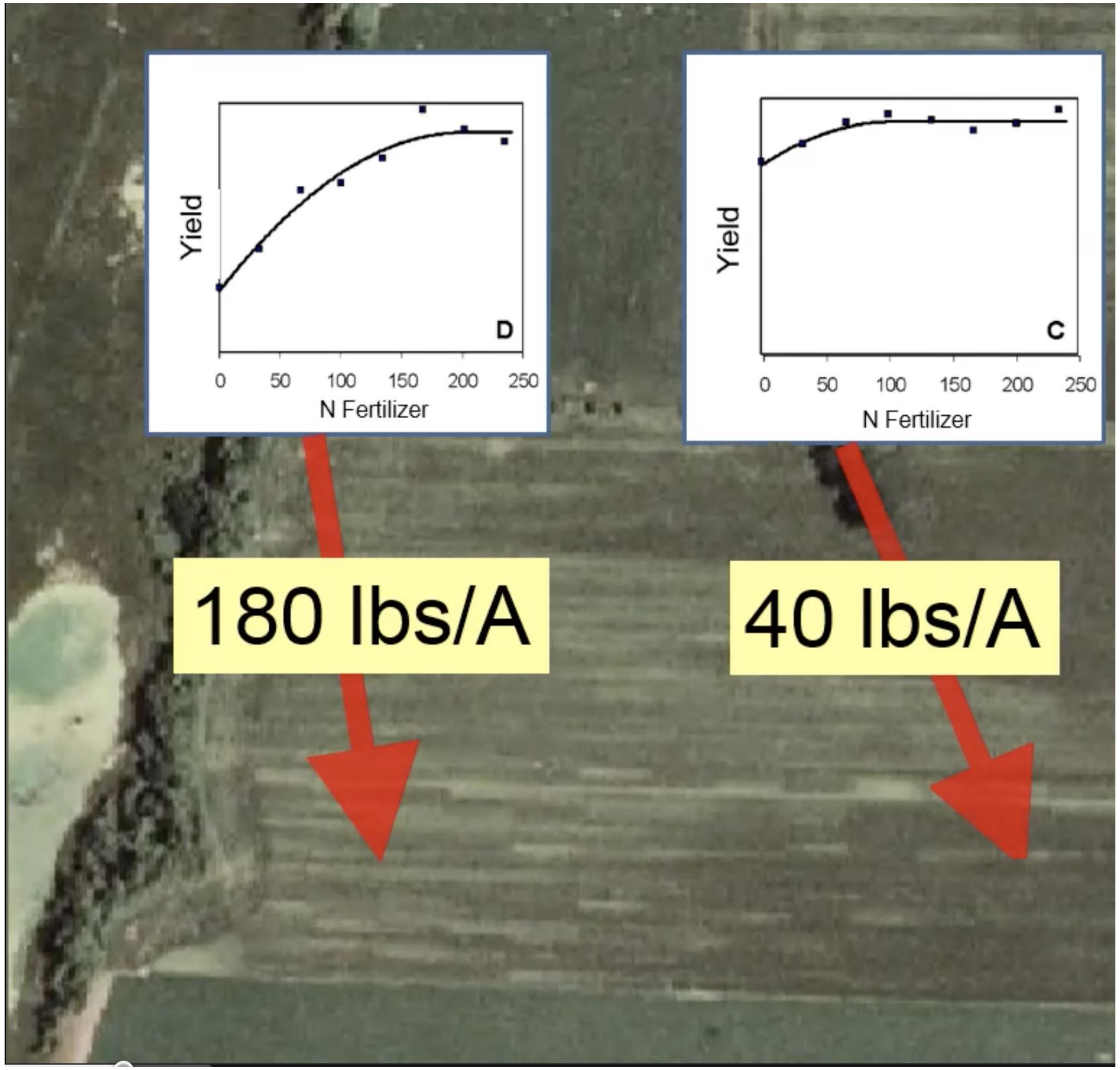


Why In-Season N Management?

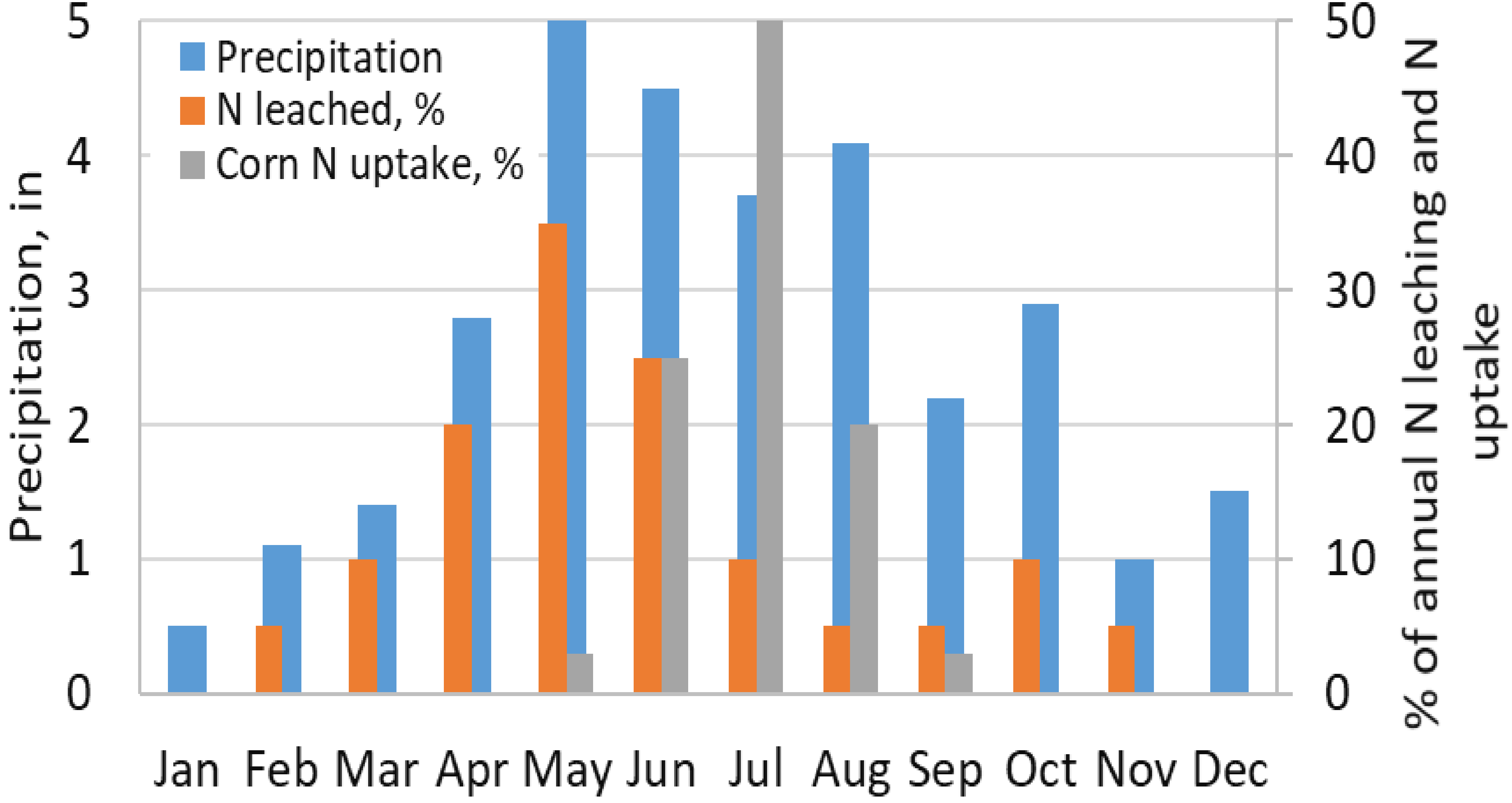


Iowa State Extension

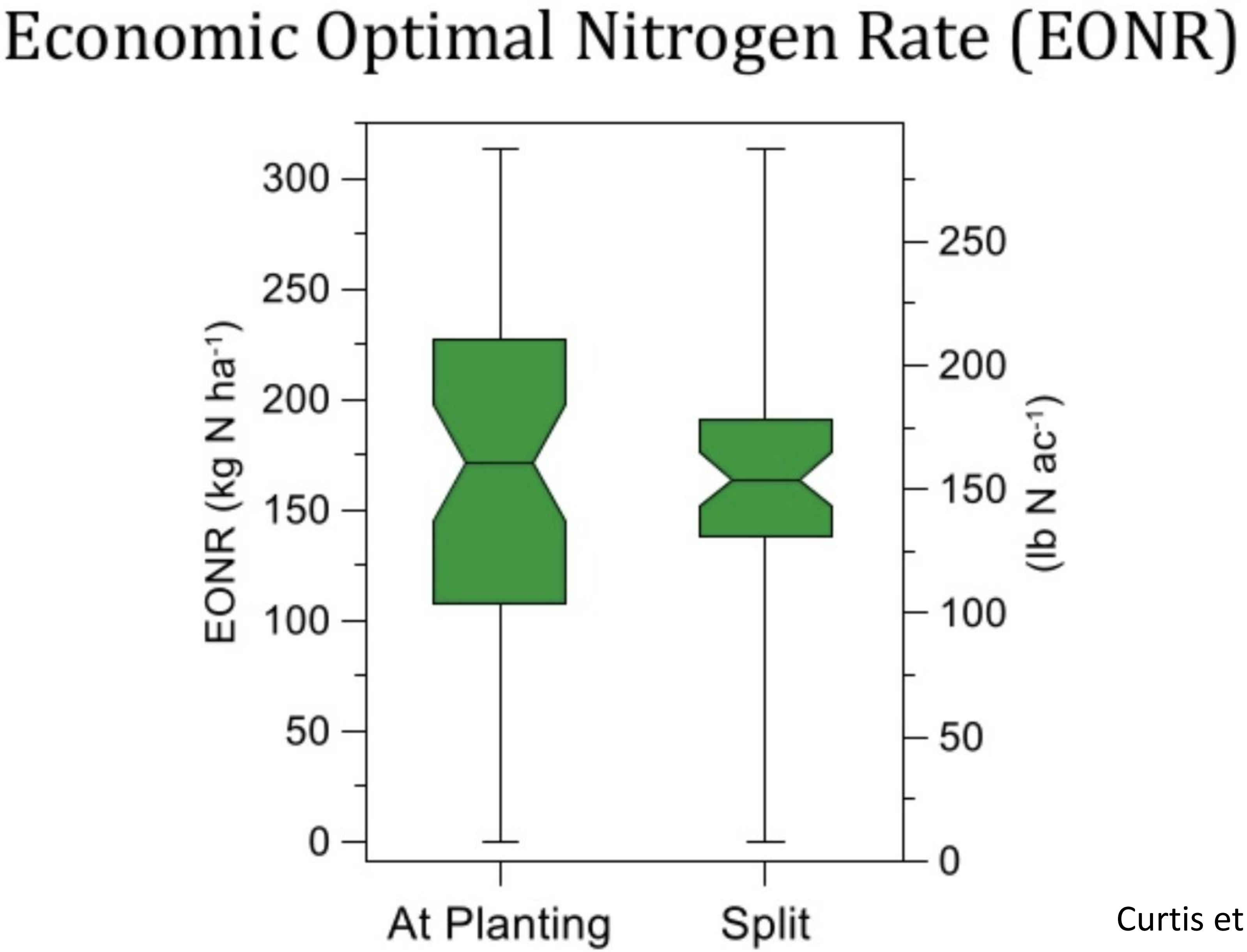
A shot in the dark…?



Monthly estimates for silt loam, York NE



Overview



Curtis et al., 2018

What tool is the best?

Empirical-Based

Proximal Canopy Sensing

Crop Growth Models

Encira

Maize-N

Climate: Nitrogen Advisor

Adapt-N

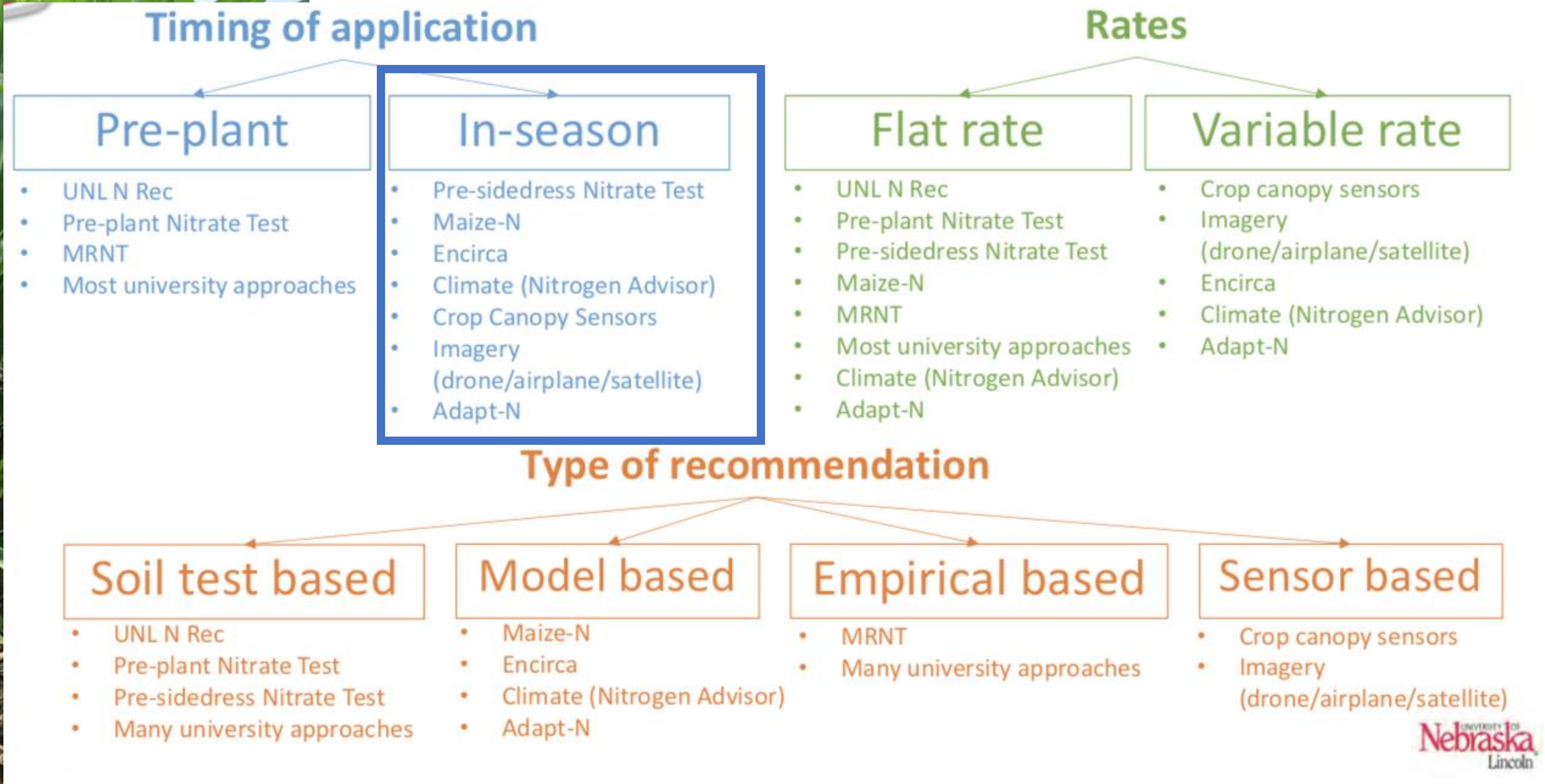
Soil Tests

PPNT Pre-Plant Soil Nitrate Test

PSNT Side-dress Soil Nitrate Test

Curtis et al., 2018

N tools classification



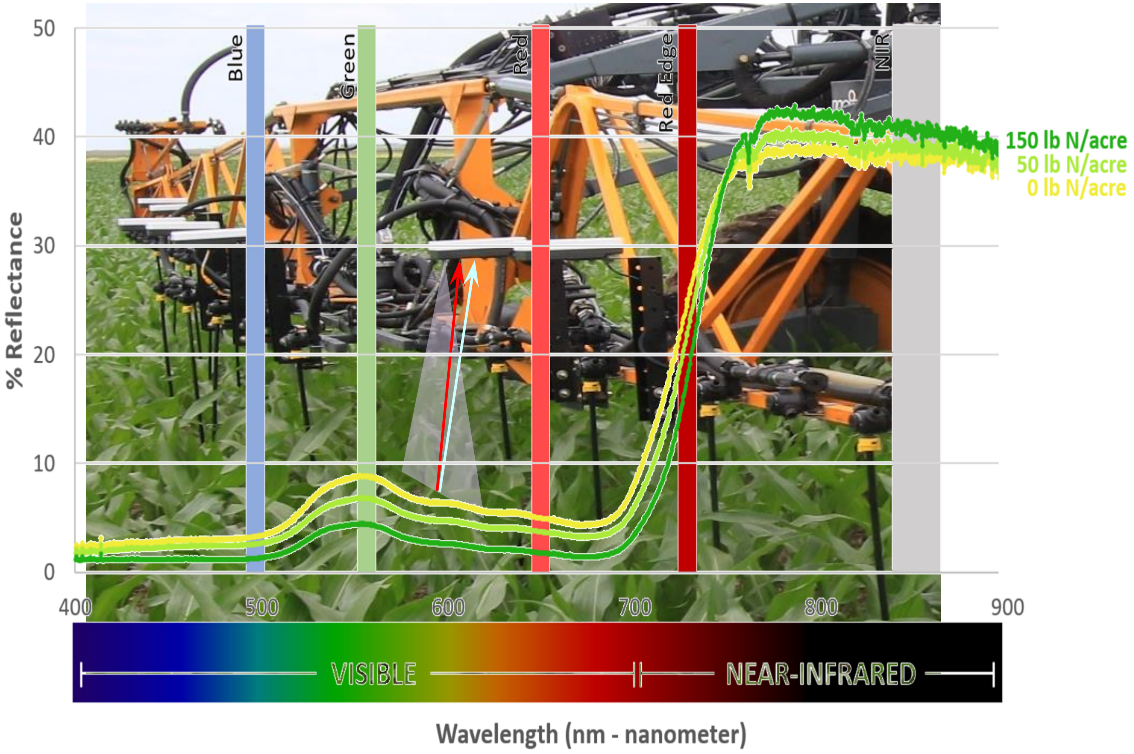
Credit: Laura Thompson

Crop canopy sensing

- Within spatial variability +
- Temporal variability +
- N losses +/-
- Reactive

ACTIVE CROP CANOPY SENSORS

- Light from sensor is modulated (pulsed); only light from system is detected by sensors.
- Light reflectance is measured in 2 or 3 wavebands, depending on sensor, in visible and near-infrared spectra.
- Reflectance from multiple wavebands is combined in a formula, called a vegetation index, to relate to crop stress.



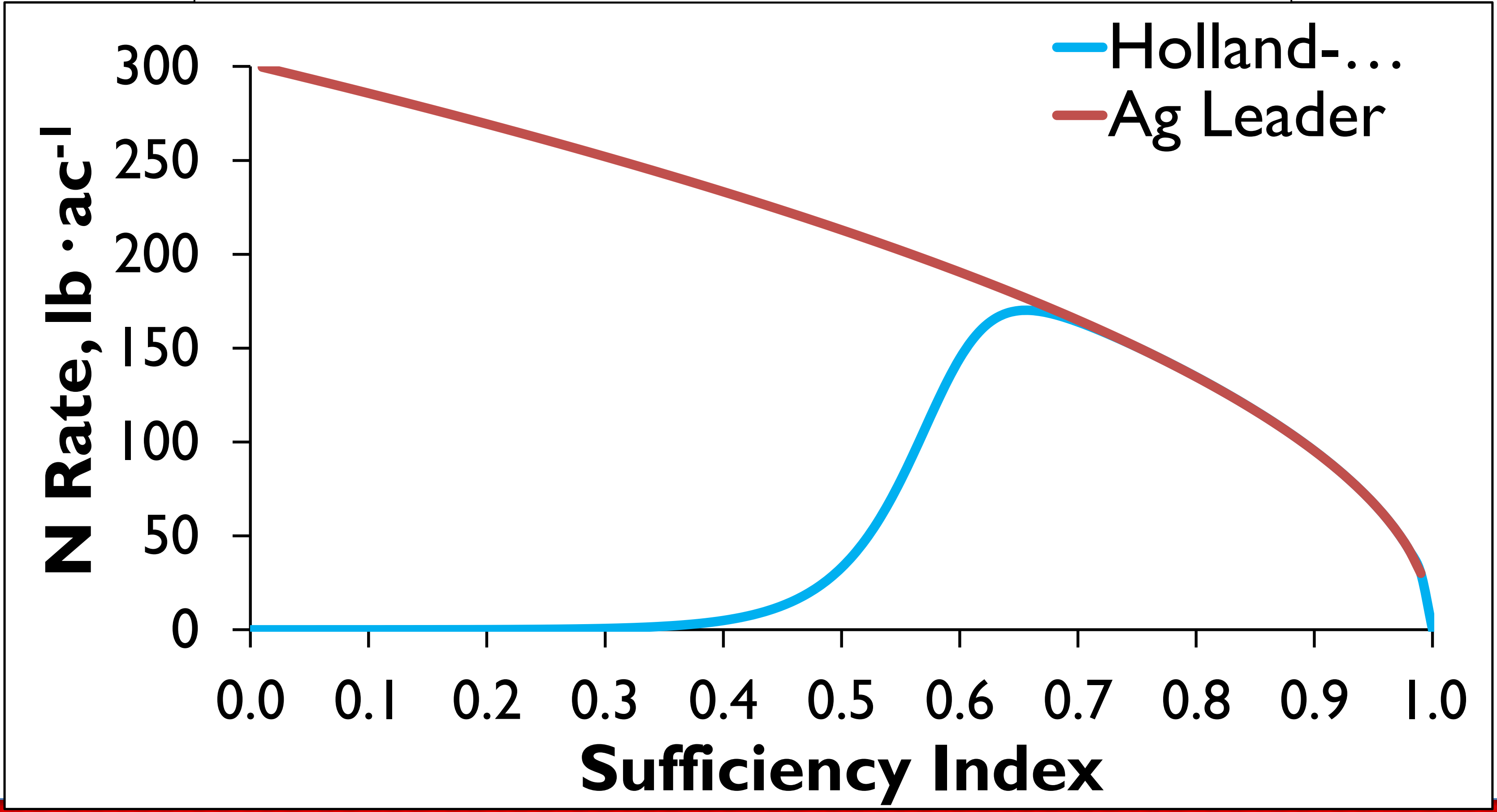
$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \qquad NDRE = \frac{(NIR - RedEdge)}{(NIR + RedEdge)}$$

SUFFICIENCY INDEX (SI)

- Relates the crop to be fertilized to a non-limiting reference

SENSOR ALGORITHM

$$(N_{OPT} - N_{PreFert} - N_{CRD}) \cdot \sqrt{\frac{(1 - SI)}{\Delta SI}}$$



Crop canopy sensing

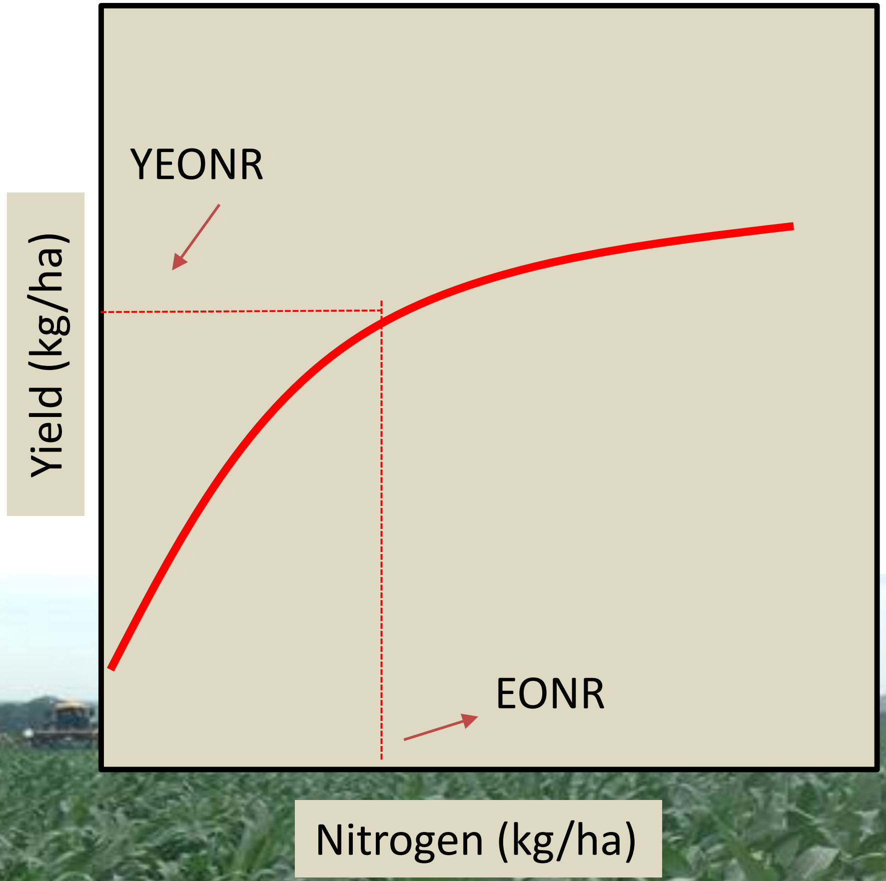
- ***Pre-plant fertilizer nitrogen application***
  - Avoid excessive low N stress prior to the in-season N application.
  - 30-50% of the expected total fertilizer N need ~ 75 lb/ac if in-season N application is targeted for V12-V14.
  - If in-season N < V12, pre-plant fertilizer N rate ~ 25% of the total to be applied.
  - Great opportunity for remote sensing guided in-season N application with manured fields.

Project SENSE - Objectives

Sensors for Efficient N Use and Stewardship of the Environment

- Overall *goal* is to increase fertilizer nitrogen use efficiency (NUE), and reduce nitrate loss to groundwater, through increasing use of in-season nitrogen fertilization.

    - Use a ***reactive approach*** via crop canopy sensors and drone aerial imagery to estimate EONR, adjusting for spatial and temporal variation.



Project SENSE Sites 2015-2019

- A total of 76 field studies were conducted with cooperating growers from 2015 to 2019
- Four sites were removed due to in-season issues based on input from growers at annual meeting

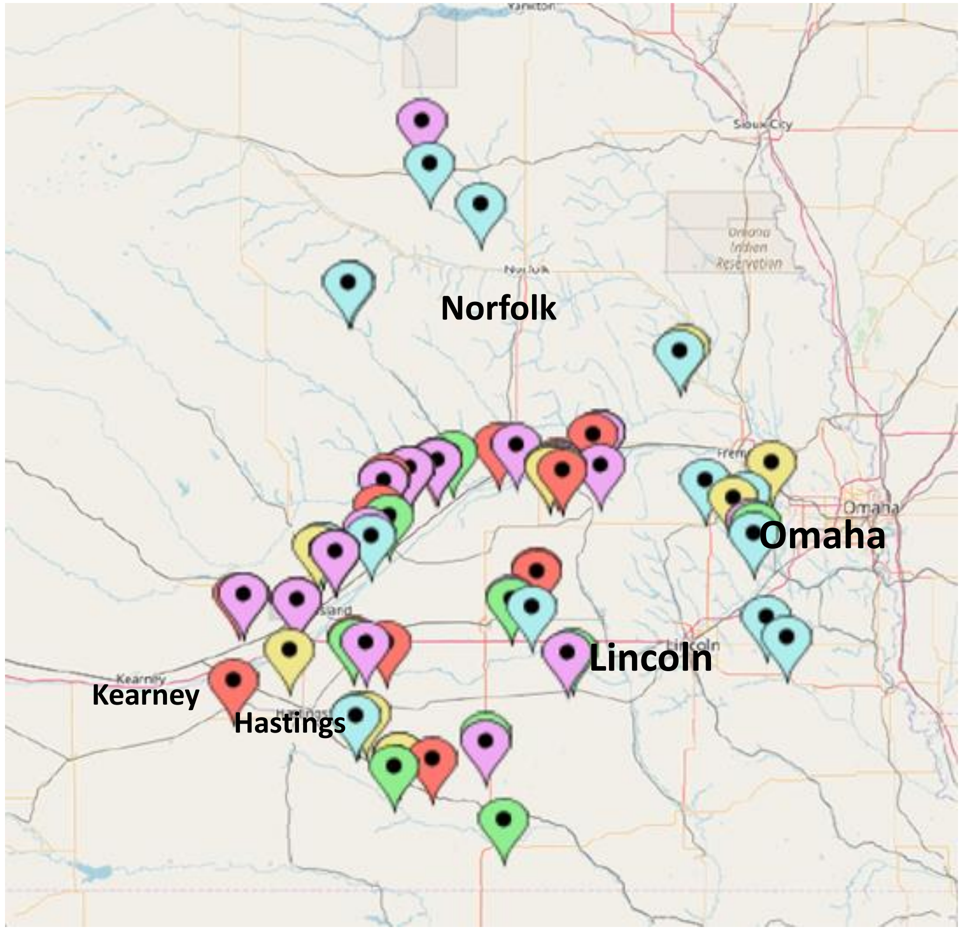
2015 - 17 Irrigated

2016 - 19 Irrigated

2017 - 18 Irrigated

2018 - 5 Irrigated
4 Fertigation

2019 - 3 Irrigated
6 Rainfed
6 Fertigation



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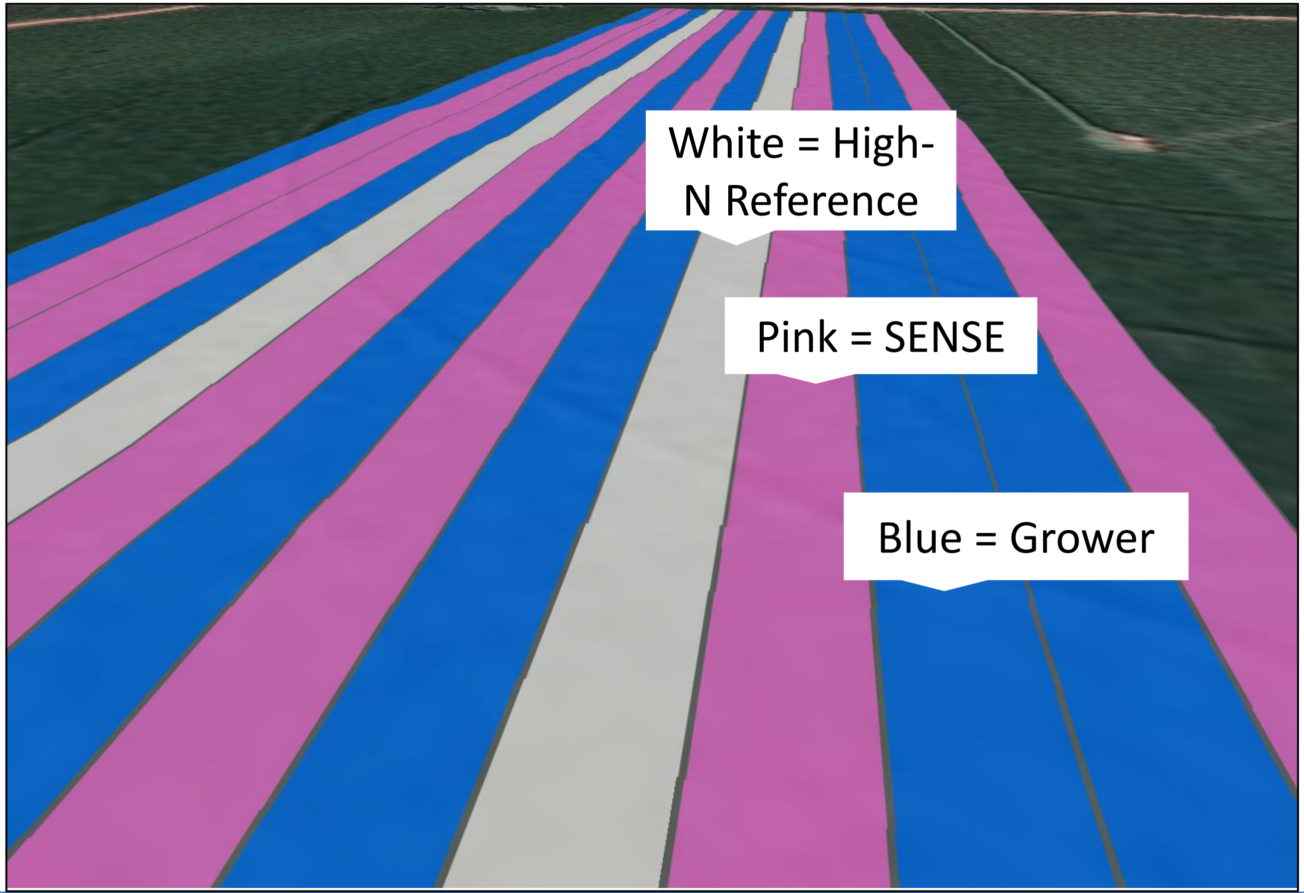
OVERVIEW & RESULTS OF PROJECT SENSE

Experimental Design

- Treatments:
  - Grower’s normal N management (rate & timing)
  - Sensor-based N application (base rate + in-season)
- High-N reference (non-limiting N rate)
- Randomized complete block design
  - 6 replications
- Treatment strip width depended on grower’s equipment
  - 16, 12, and 8 rows
- Total study area: 20-30 acres

Plot Layout

- Randomized, replicated field length strips placed across field to match grower equipment widths



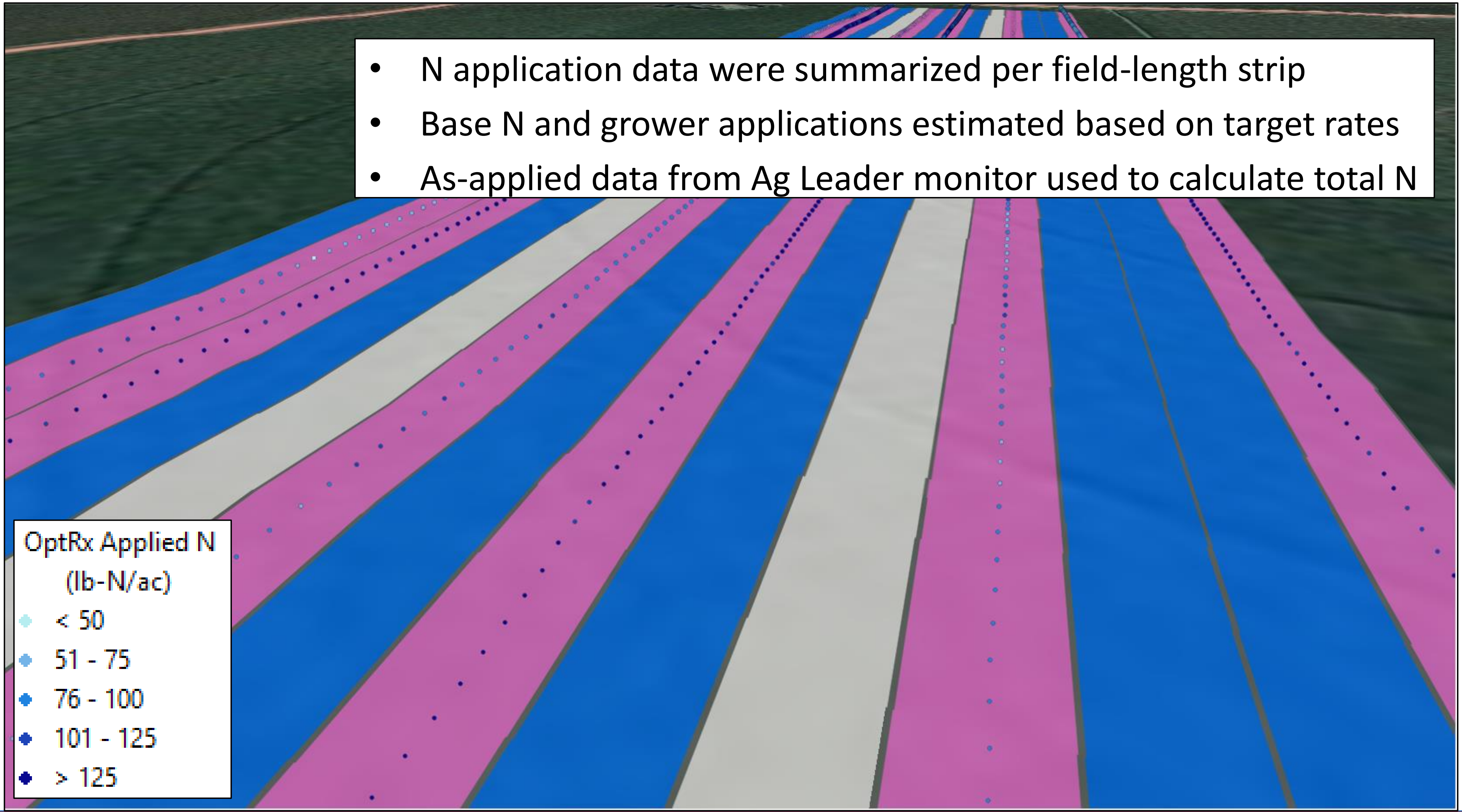
Typical base rate (75 to 100 lb-N/ac) at or before planting

Follow-up application at V8 to V12 with crop canopy sensors

Collect & analyze harvest data

Plot Layout

- N application data were summarized per field-length strip
- Base N and grower applications estimated based on target rates
- As-applied data from Ag Leader monitor used to calculate total N



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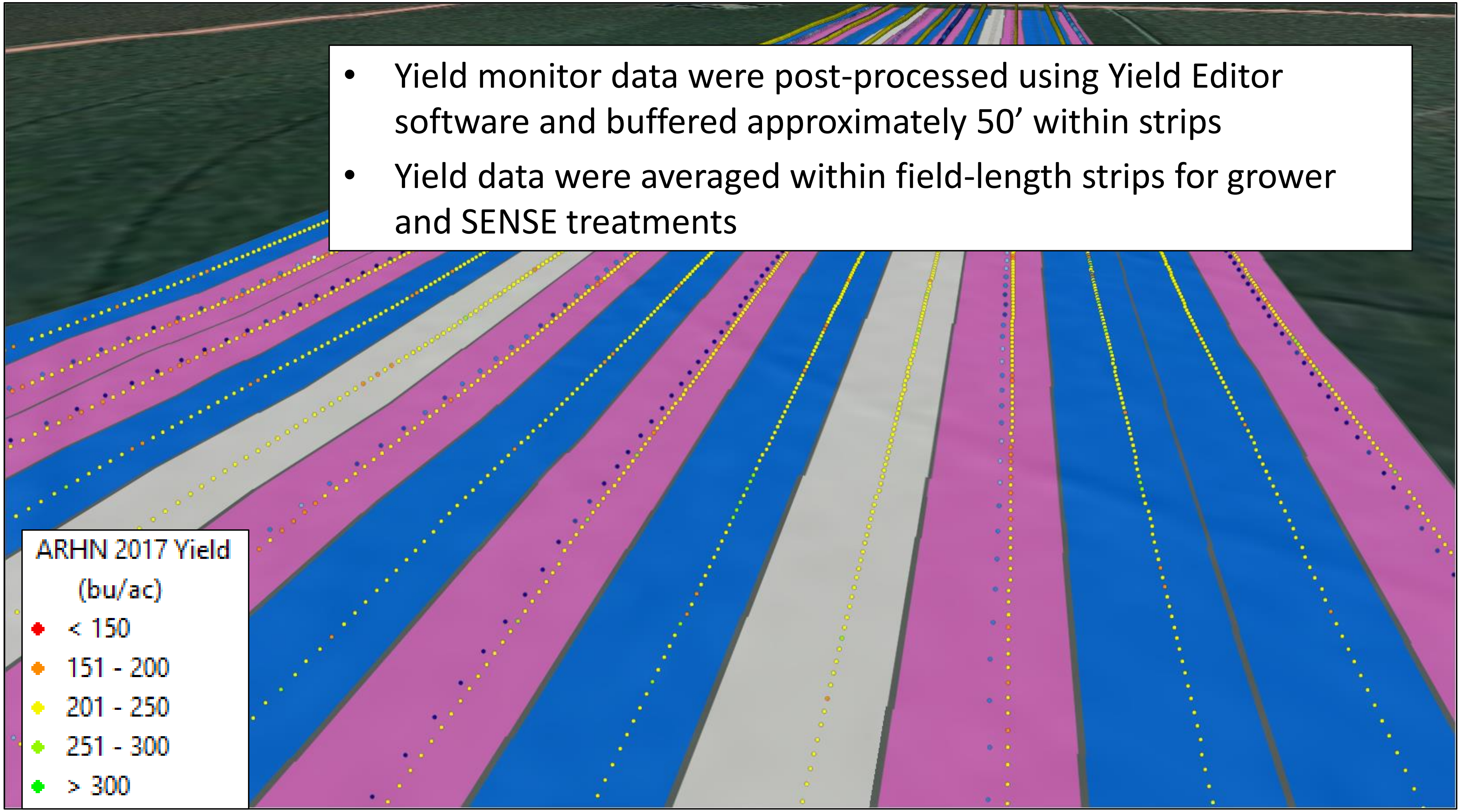
Plot Layout

- Yield monitor data were post-processed using Yield Editor software and buffered approximately 50’ within strips
- Yield data were averaged within field-length strips for grower and SENSE treatments



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Results

- We compared the grower N rates and yields to that of the OptRx™ system:
  - $Difference = Grower - SENSE$
  - SENSE outperformed Grower = **green**
  - Grower outperformed SENSE = **red**
- PFP_N — Pounds Grain per Pound N
- Pounds N per Bushel Grain
- Profit = (Yield * Corn Price) – (N Rate * N Price)

Year	Corn Price	N price
2015	$3.65/bu	$0.65/lb
2016	$3.05/bu	$0.45/lb
2017	$3.15/bu	$0.41/lb
2018	$3.23/bu	$0.35/lb

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Results for All Sites 2015

	Grower N Management	Project SENSE N Management	Difference
Total N Rate (lb/ac)	198 A	153 B	45
Yield (bu/ac)†	235 A	231 B	4.2
PFP_N (lb grain/lb N)	67 B	91 A	-23
Lb N/bu Grain	0.87 A	0.66 B	0.20
Marginal Net Return	$728.06 A	$741.97 B	$13.91

†Yield data from cleaned yield monitor data. Bushels per acre corrected to 15.5% moisture.
*Values with the same letter are not significantly different at a 95% confidence level.

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All Sites Averages by Year

	2015 Difference N=13	2016 Difference N=15	2017 Difference N=18	2018 Difference N=3
Total N Rate (lb/ac)	45	33	15	13
Yield (bu/ac)†	4.2	-2.3	3.5	1.3
PFP_N (lb grain/lb N)	-23	-15	-11	-2
Lb N/bu Grain	0.2	0.2	0.1	0.1
Marginal Net Return	-$13.91	-$21.86	$5.05	-$0.8

†Yield data from cleaned yield monitor data. Bushels per acre corrected to 15.5% moisture.

*Values with the same letter are not significantly different at a 95% confidence level.

N EXTENSION

All Sites Averages by Year

Table 1. Summary of 51 sites in 2015, 2016, 2017, and 2018 comparing sensor-based N management to the grower's traditional method.

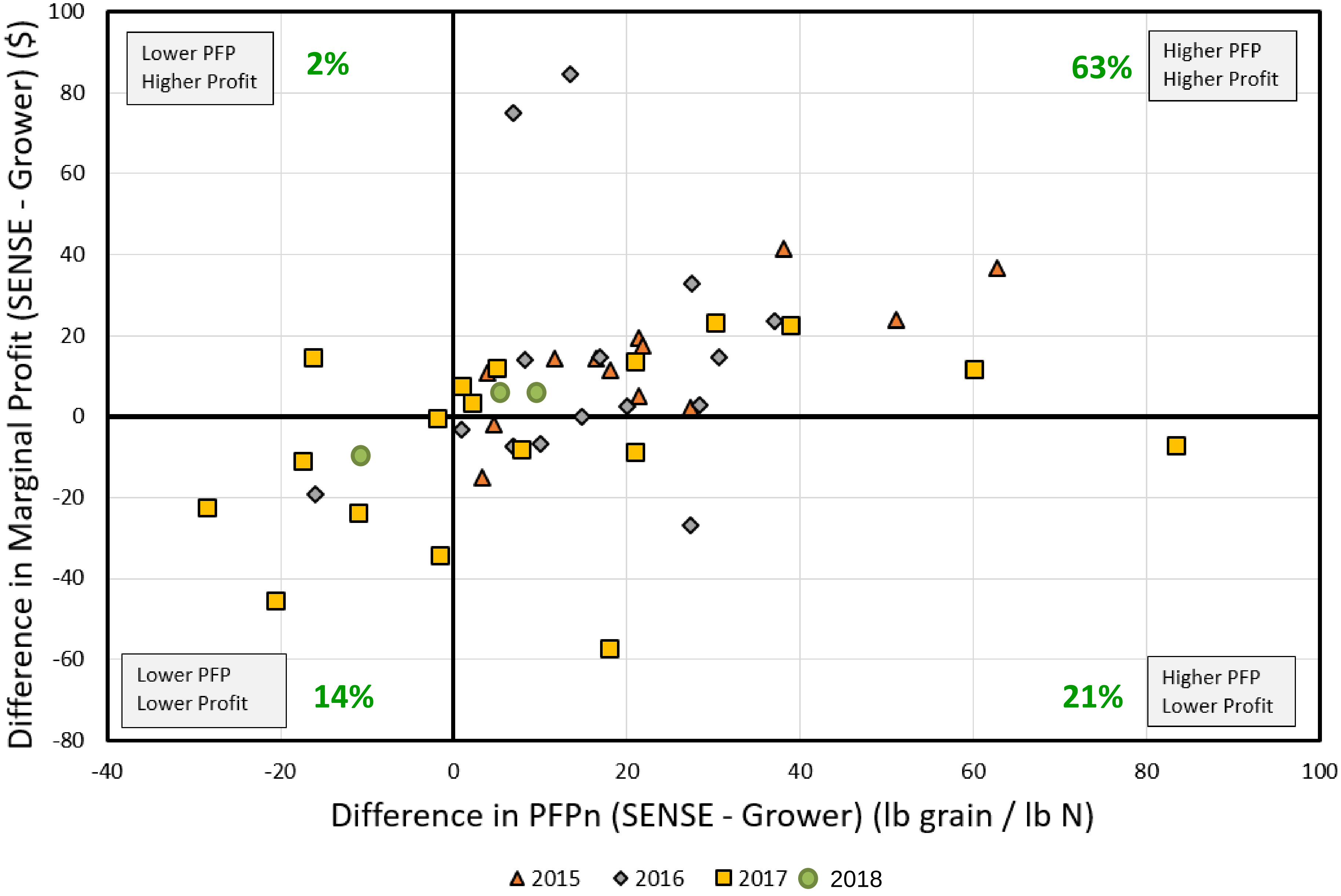
	SENSE	Grower
Total N rate (lb-N/ac)	159.4 B*	188.1 A
Yield (bu/ac)	217.6 B	218.7 A
Partial Factor of Productivity (lb grain/lb-N)	83 A	68 B
Nitrogen Use Efficiency (lb-N/bu grain)	0.75 B	0.91 A
Partial Profitability ($/ac) [@3.65/bu and $0.65/lb-N]	$690.59 A	$675.83 B
Partial Profitability ($/ac) [@3.15/bu and $0.41/lb-N]	$620.06 A	$611.65 B

*Values with the same letter are not significantly different at a 95% confidence interval.

†Yield data from cleaned yield monitor data. Bushels per acre corrected to 15.5% moisture.
*Values with the same letter are not significantly different at a 95% confidence level.

EXTENSION

Comparison of Profitability and NUE by Site: 4 Years



Where do we have the biggest impact?

- Greatest difference in nitrogen rates between SENSE and grower treatments was found in sandy soils
- In these soils, growers applied greater amounts of nitrogen than the SENSE treatments > NUE for SENSE

Differences in nitrogen rate (SENSE-GROWER)

	Dependent variable:		
	I(Gr_Nrate_lbs_ac - (Tgt_Rate_N + Base_N))		
	(1)	(2)	(3)
Nopt _Nrate_lbs_ac	-1.100***	-0.546	-0.763***
	(0.423)	(0.471)	(0.178)
GDD_P_SD_SENSE	0.114***	0.245**	0.025
	(0.040)	(0.097)	(0.037)
refNDRE	3,452.270***		-598.867*
	(1,055.308)	(0.000)	(338.173)
SI	146.534***	363.705***	523.759***
	(21.051)	(35.021)	(72.816)
TWI_SENSE1	-0.0001	-0.00001	-0.654*
	(0.0002)	(0.0001)	(0.338)
Soil_textloamy-sand	18.153***		
	(5.575)		
Soil_textsandy-clay-loam	183.634**	80.695***	117.839***
	(73.693)	(4.035)	(14.220)
Soil_textsandy-loam	-4.973***	32.566	58.429***
	(1.006)	(26.399)	(15.348)
Soil_textsilt-loam	45.960***	79.441***	26.622**
	(15.810)	(5.360)	(11.558)
Soil_textsilty-clay-loam	-2.325	78.650***	38.584**
	(21.488)	(4.448)	(17.037)
Constant	-1,350.124**	-439.259**	-57.004
	(524.129)	(178.800)	(158.272)
Observations	10,256	6,198	20,688
R^2	0.904	0.965	0.811
Adjusted R^2	0.904	0.965	0.811
Residual Std. Error	9.319 (df = 10245)	10.395 (df = 6189)	25.709 (df = 20677)

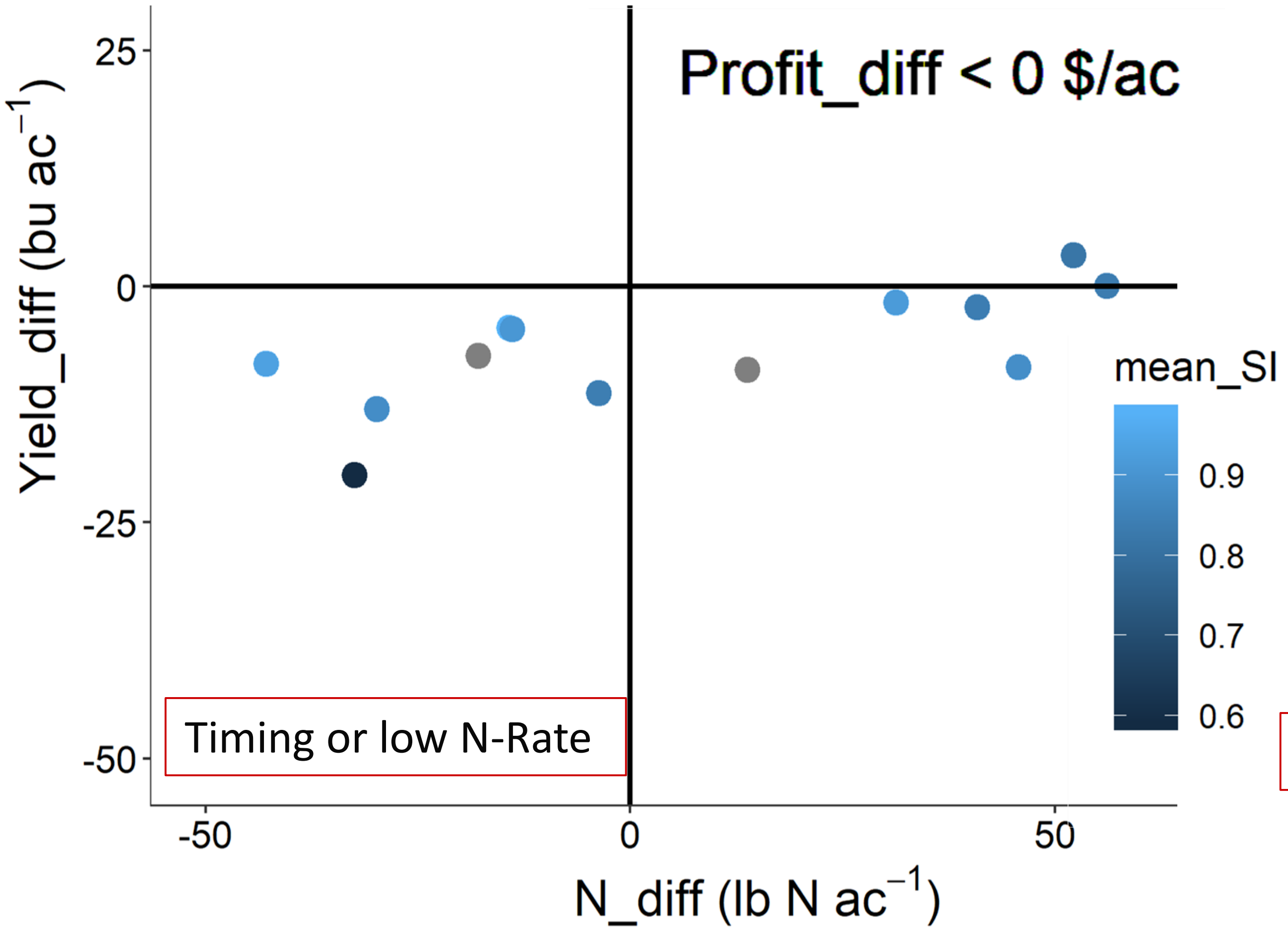
Base N rate

- SENSE treatments performed better with lower Base_N rates

Differences in NUE (SENSE-GROWER)

	Dependent variable:		
	dNUE		
	(1)	(2)	(3)
GDD_P_SD_SENSE	-0.00004	-0.0001	-0.001***
	(0.00004)	(0.0004)	(0.0002)
Soil_textloamy-sand	-0.198***		
	(0.025)		
Soil_textsandy-clay-loam	-0.300***	-0.004	-0.022
	(0.036)	(0.075)	(0.204)
Soil_textsandy-loam	0.076***	0.383***	0.757***
	(0.000)	(0.120)	(0.061)
Soil_textsilt-loam	-0.023***	-0.065	0.211**
	(0.008)	(0.076)	(0.096)
Soil_textsilty-clay			0.056
			(0.070)
Soil_textsilty-clay-loam	-0.566***	-0.189*	-0.050
	[illegible]	[illegible]	[illegible]
Nopt Nrate_lbs_ac	-0.006***	-0.007***	-0.007***
	(0.001)	(0.002)	(0.001)
Base_N	-0.008***	-0.009**	-0.005**
	(0.001)	(0.004)	(0.003)
[illegible]	[illegible]	[illegible]	[illegible]
	(0.179)	(0.898)	(0.445)
Observations	10,252	14,632	20,685
R^2	0.242	0.321	0.454
Adjusted R^2	0.241	0.321	0.454
Residual Std. Error	0.264 (df = 10243)	0.237 (df = 14624)	0.331 (df = 20676)

Nitrogen Difference by Yield Plot

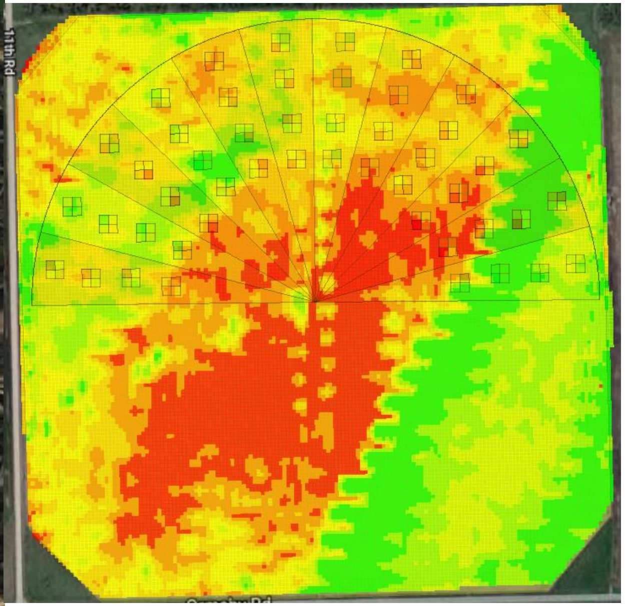


» Low SI indicates plants were too deficient at the time of application

Timing or N_{opt} calculation error

Fertigation Sites

- Drones, aircraft or satellites could be used to determine the amount of N or VR
- 30 to 40 lb/ac N can be applied with as little as 0.25 inch of water.



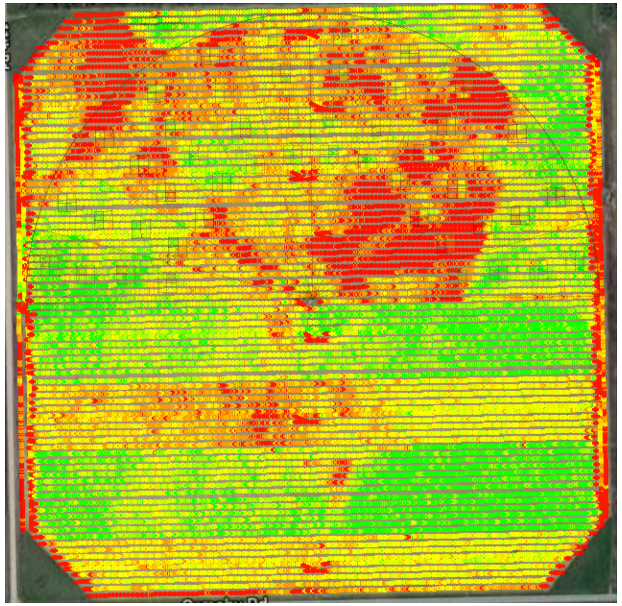


Figure 4. Center pivot system equipped with a variable injection rate fertilizer pump.

Protocol

1. Planting and grower determined base N rate
2. Sidedress application of N with indicator block Rx at ~V5
3. Grower management until ~ V5-V7
4. Gather, process, and analyze weekly imagery
5. Generate and execute fertigation Rx

Steps 4 and 5 are completed until corn reaches R3.

N EXTENSION

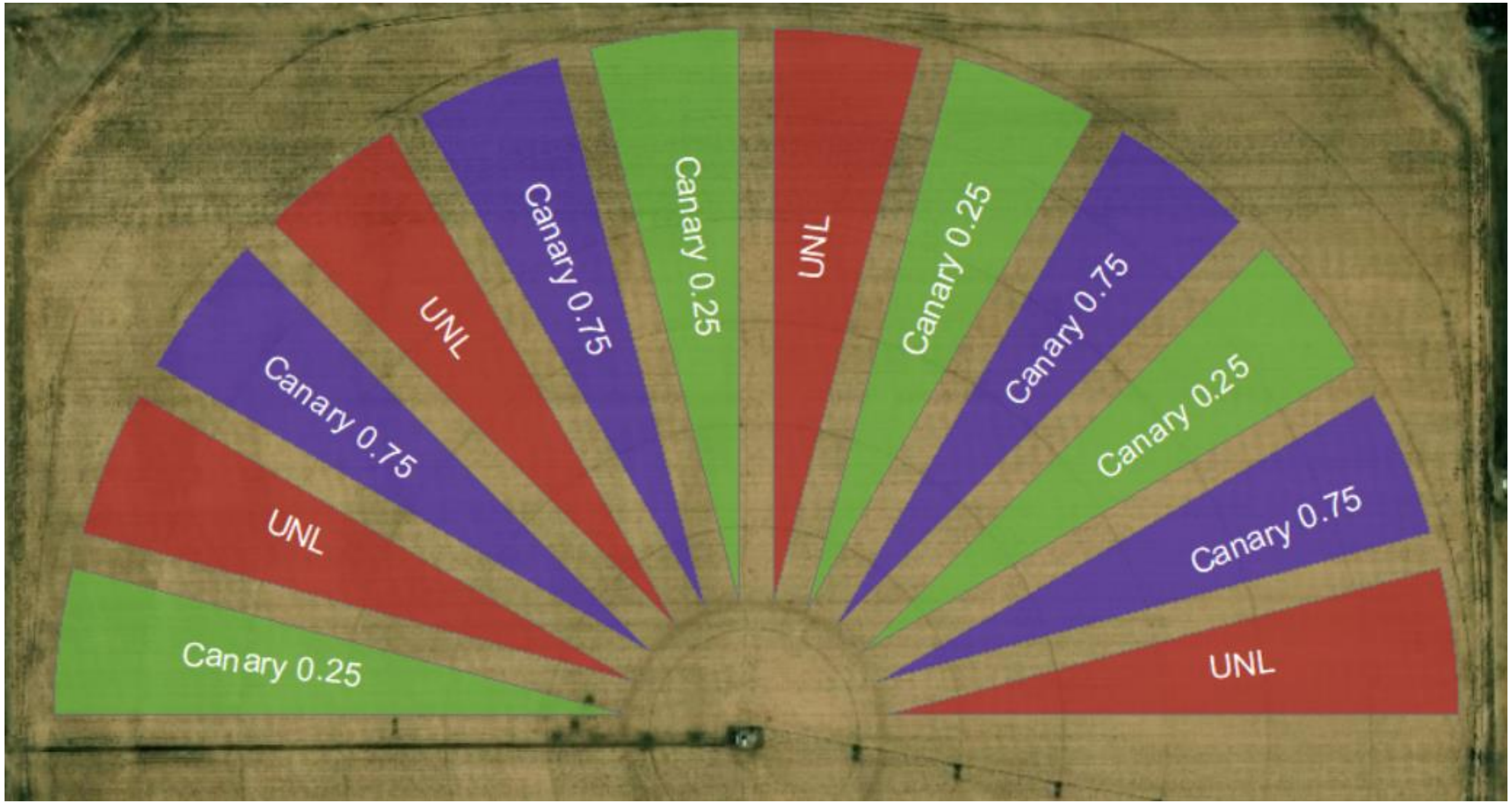
Experimental Design

- 3 Treatments
  - Grower (UNL)
  - Risk Averse (Canary 0.25)
  - Risk Tolerant (Canary 0.75)

- 4 Reps

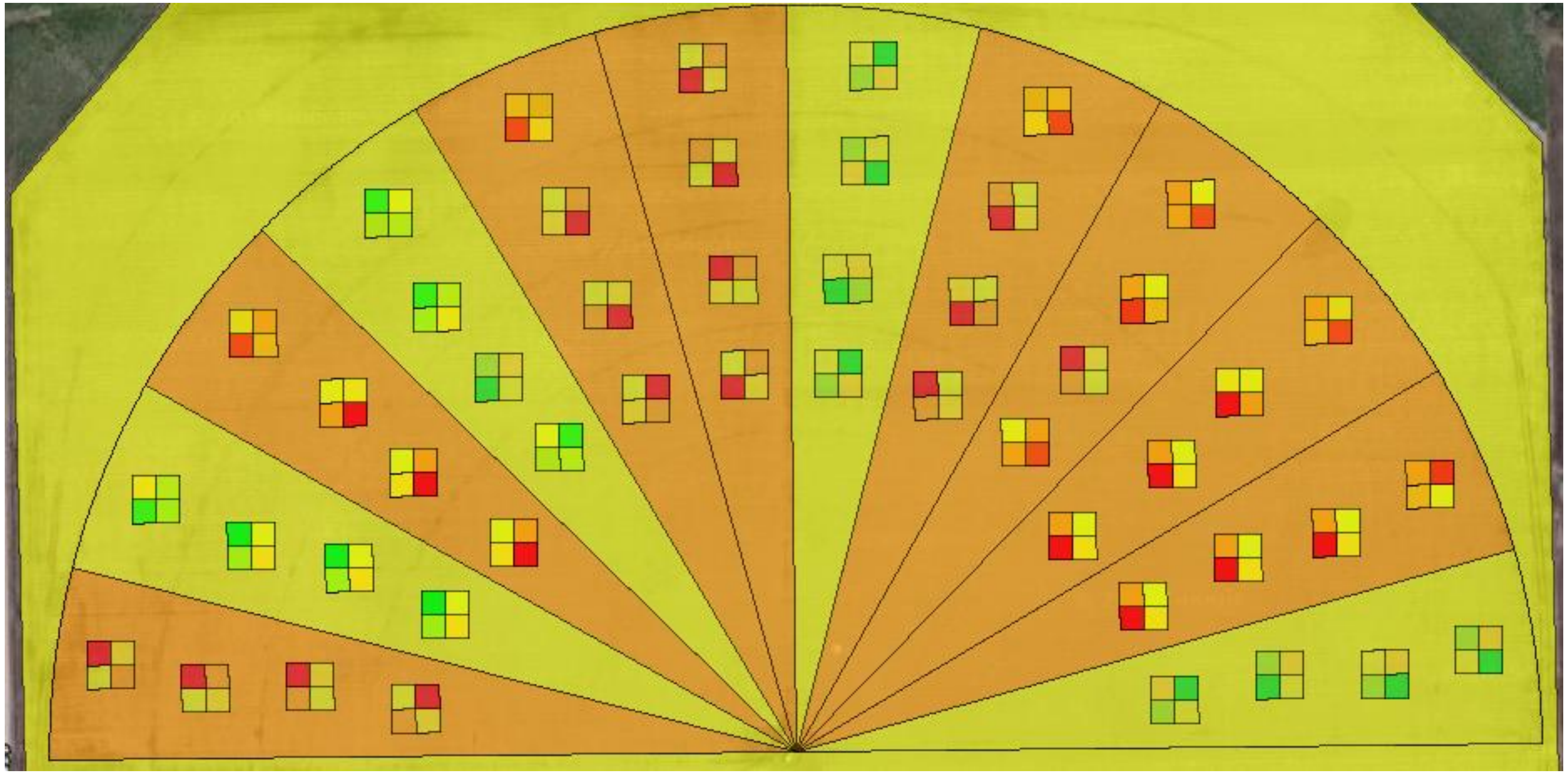
- 12 Total Sectors
  - 15° each
  - Buffered 30 feet around

- 6 Total Sites
  - 2 Central Platte NRD
  - 4 NE Nebraska



Plot Layout for fertigation

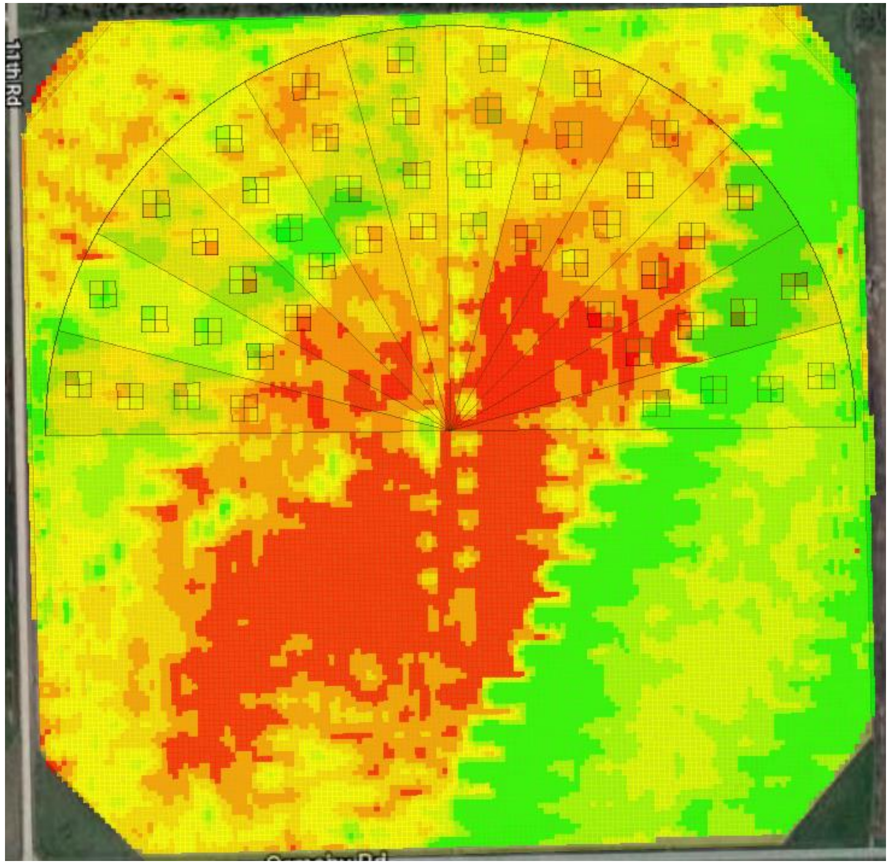
- Sidedress ~V5
  - Establish canary blocks
  - 4 rates per block. Blocks with high-N reference plots (non-limiting N rate) and low-N indicator plots in each sector
- Assess aerial imagery weekly
- Apply if SI < 0.95
  - Rate → 30 lb N/ac
  - 2 week application lockout
- Applications up to R2



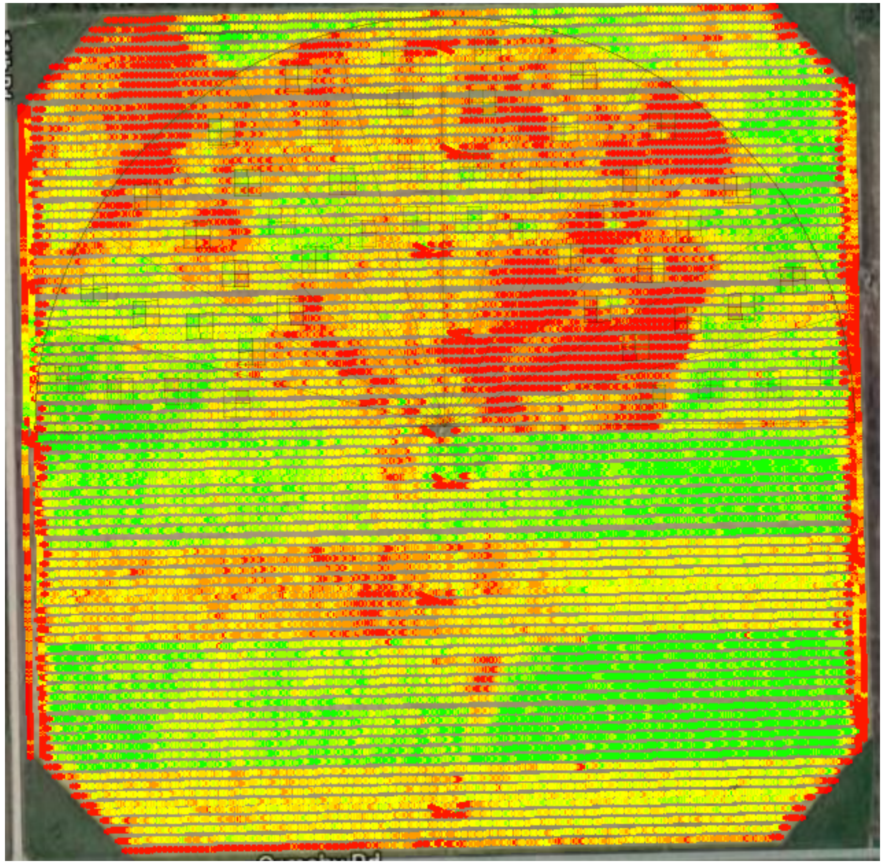
Summary fertigation sites

- An average of 14 $\pm$ 9 lbs N applied with SENSE (2019)
- Yield was no statistically different at any site
- No statistical difference in profitability in most sites, except, 2 at RT.
- Profit tended to be greater for SENSE when using RT approach

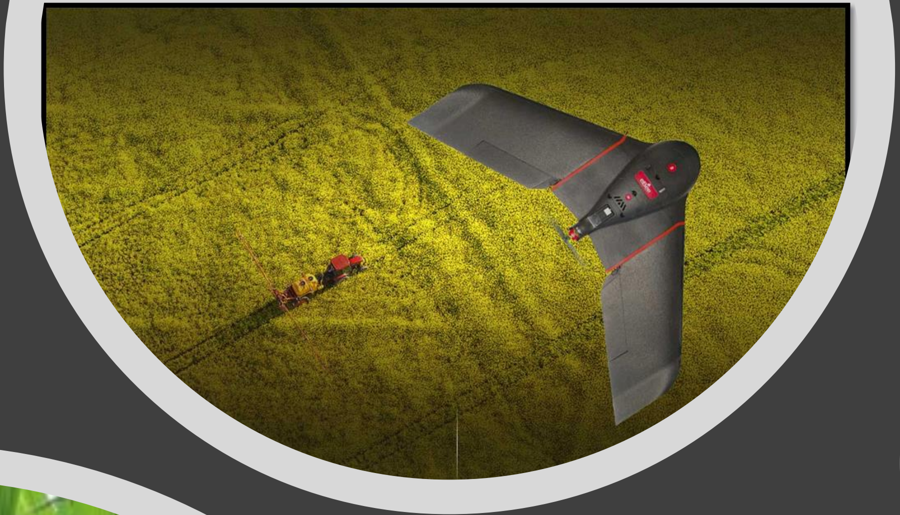
Challenges – Spatial Variability



Soil EC – Deep



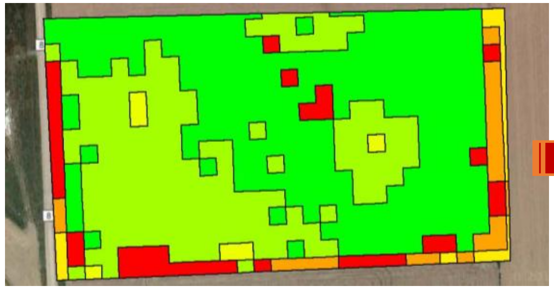
Yield



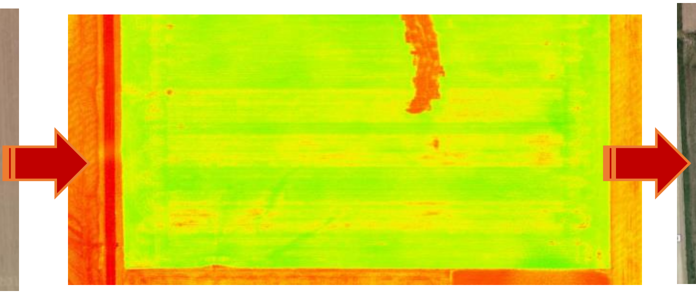
Passive canopy sensing

- Passive sensor: relies on sunlight
- Multiple flights in one season can improve timing of application
- Environmental conditions such as cloud cover and wind can influence data points

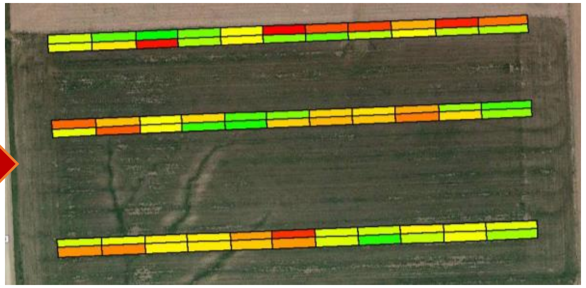
Management Zone Integration



Cluster analysis to create zones



NDRE image from drone flight



Prescription map for trial strips

- Created management zones using soil-based characteristics of elevation, organic matter, soil texture, and hydrology data paired with yield goals for each area from historical yield.

- Drone aerial imagery collected NDRE values and then used in the Holland-Schepers algorithm

Summary rainfed sites

- An average of 28 lbs less N applied with SENSE (2019)
- Yield was only statistically different at one site
- No statistical difference in profitability

- In most cases, the management zone integration with the HS model using drone imagery had similar results to the sensors

Partnerships and Funding Sources

CPNRD
CENTRAL PLATTE
NATURAL RESOURCES DISTRICT

Little Blue
Natural Resources District

LOWERLOUP
NATURAL RESOURCES DISTRICT

LOWER PLATTE NORTH
Natural Resources District

UPPER BIG BLUE NRD
"CONSERVATION IS THE NATURE OF OUR BUSINESS"

Nebraska
CornBoard

USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

A research/educational project of the Nebraska Corn Board, the Central Platte, Little Blue, Lower Loup, Lower Platte North and Upper Big Blue Natural Resources Districts, USDA-NIFA, and the University of Nebraska-Lincoln On-Farm Research Network

N EXTENSION

Want to test your N tool?

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402-472-6449

cropwatch.unl.edu/projectsense