Project SENSE: A Summary of 3 Years of On-Farm Research and Demonstration on Crop Canopy Sensors for In-Season N Management

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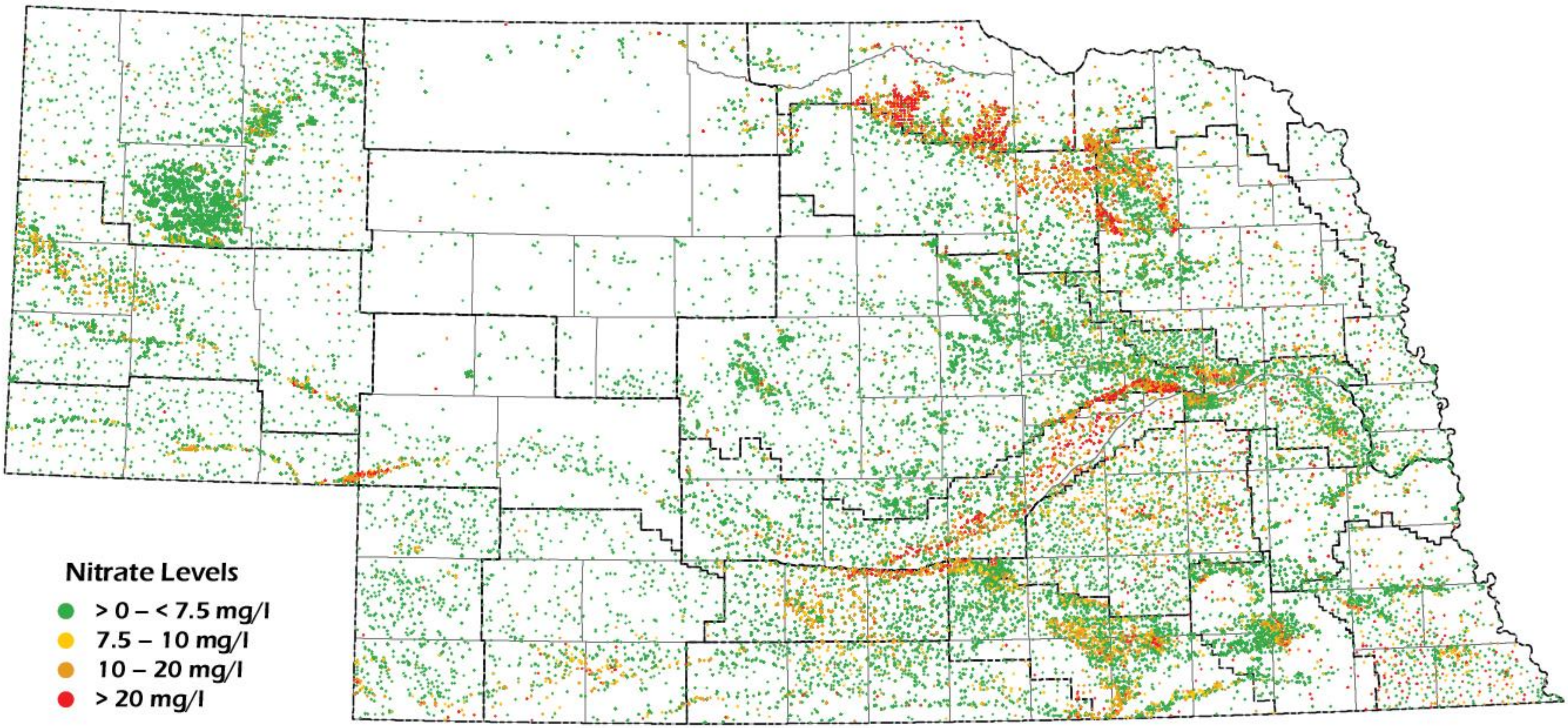
EXTENSION

Nebraska Nitrate Levels: 2013



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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

Our Cooperating Producers!!!

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

Project SENSE

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.

A *reactive* approach, using crop canopy sensors, has been proven through research to be an effective way to approach EONR, adjusting for spatial and temporal variation.

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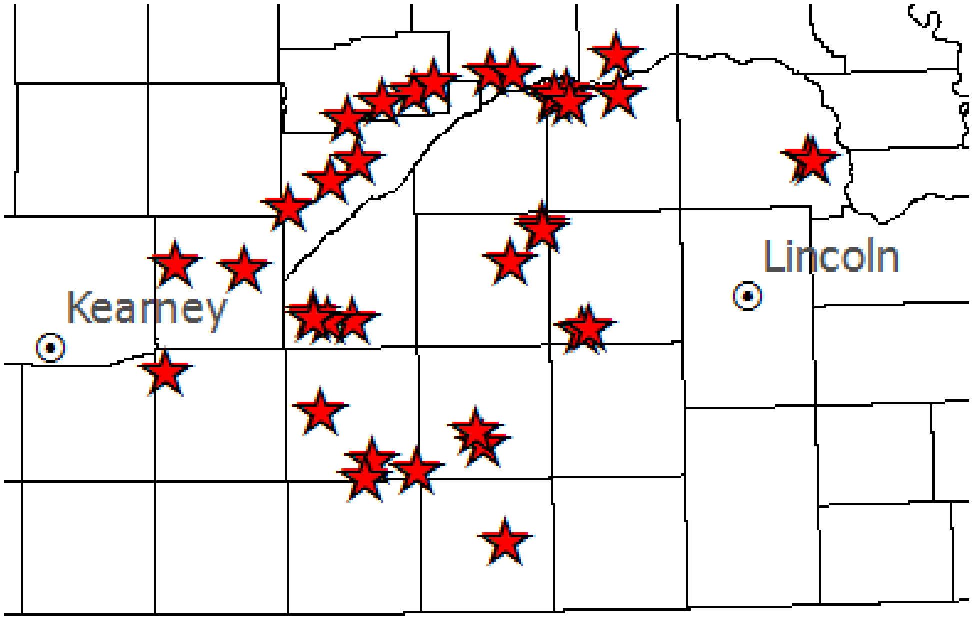
Project SENSE Sites 2015-2017

- A total of 52 field studies were conducted with cooperating growers from 2015 to 2017
- Four sites were removed due to in-season issues based on input from growers at annual meeting



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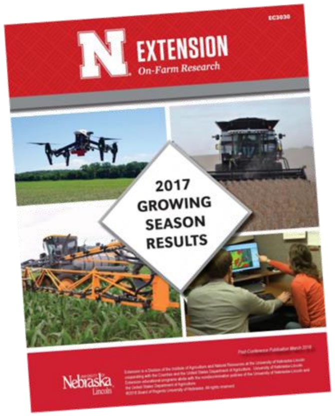
Nebraska On-Farm Research Network

2017 Growing Season



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2016 Growing Season

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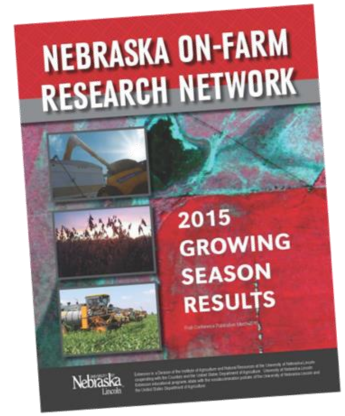
2015 Growing Season



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On-Farm Research

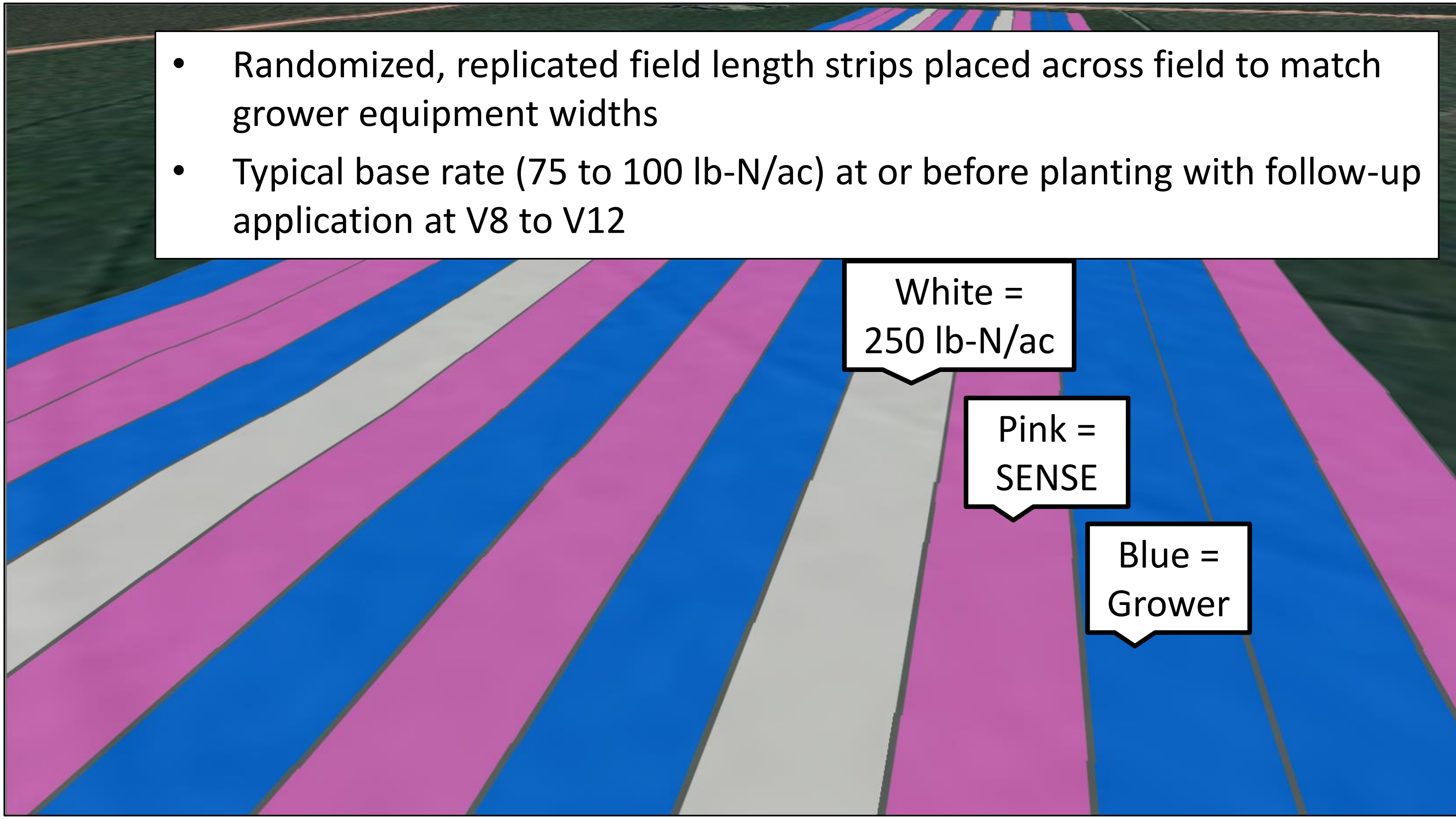
RESEARCH & ANALYSIS METHODS

Experimental Design

- Two 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 with follow-up application at V8 to V12



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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.

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

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

Sufficiency Index (SI)

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

Virtual Reference

- Generating a Reference NDRE
  - 5-minute process; system records NDRE across field
  - A range of crop conditions is okay…ensure that healthy crop is recorded
- Set up is now done and ready to apply sensor-based treatment in real time!

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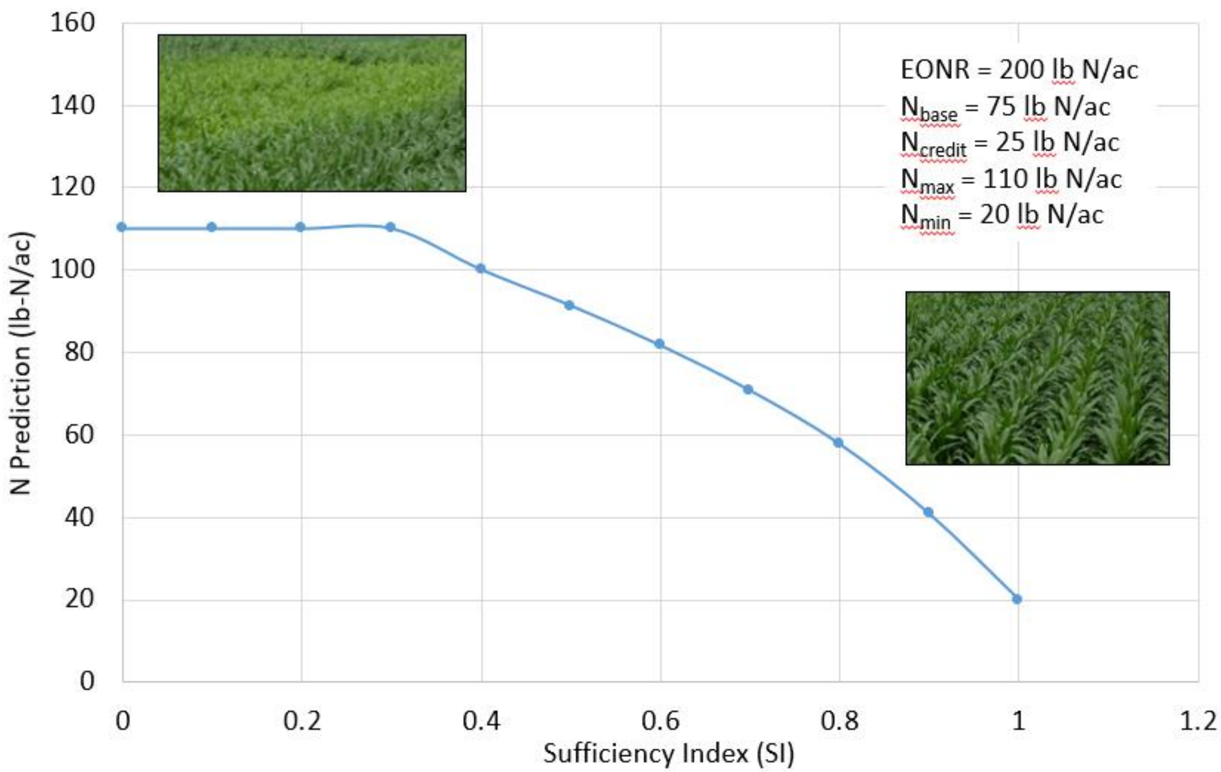
Sensor Algorithm

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



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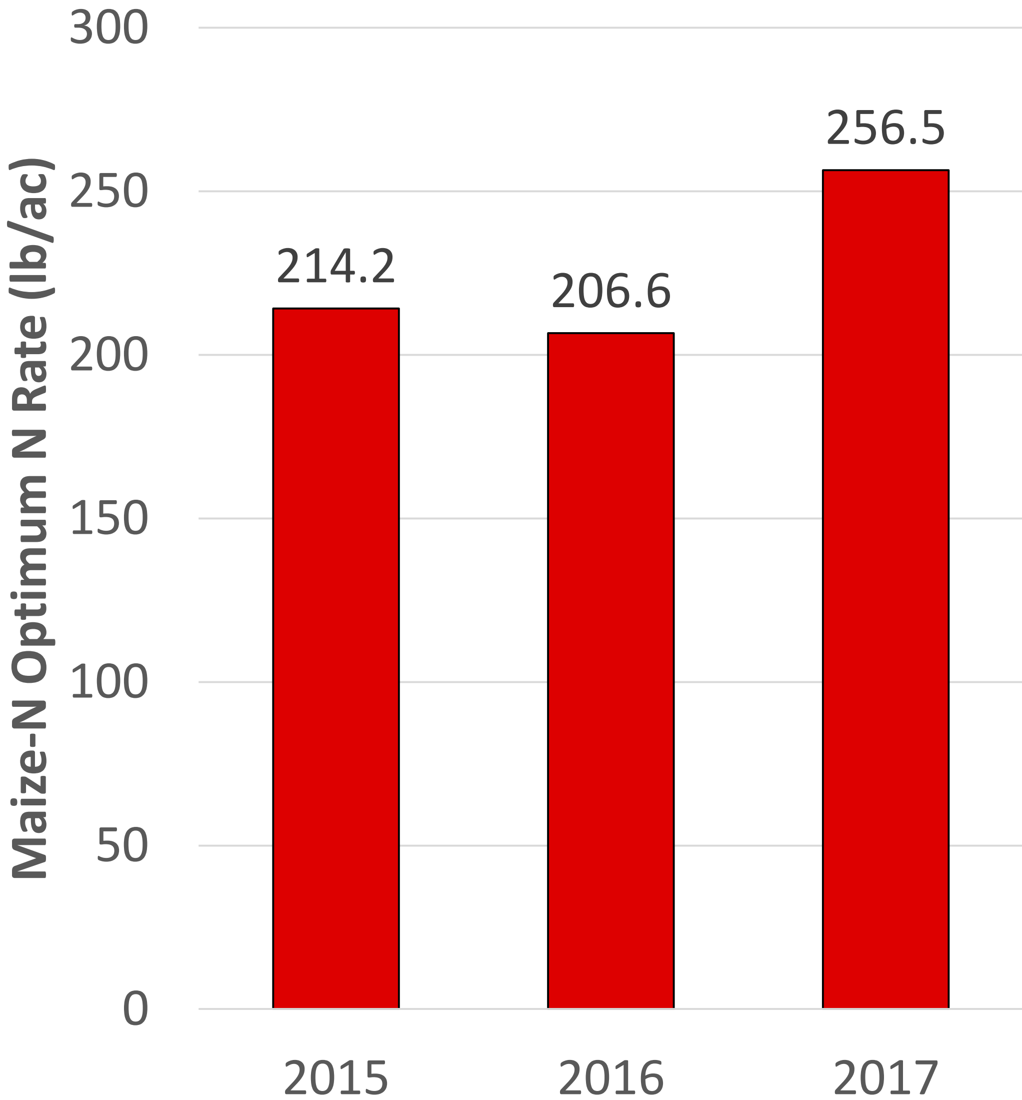
Comparison of Calculated ONR Over Years



2017 greater than 2015 by 42 lb/acre, greater than 2016 by 50 lb/acre

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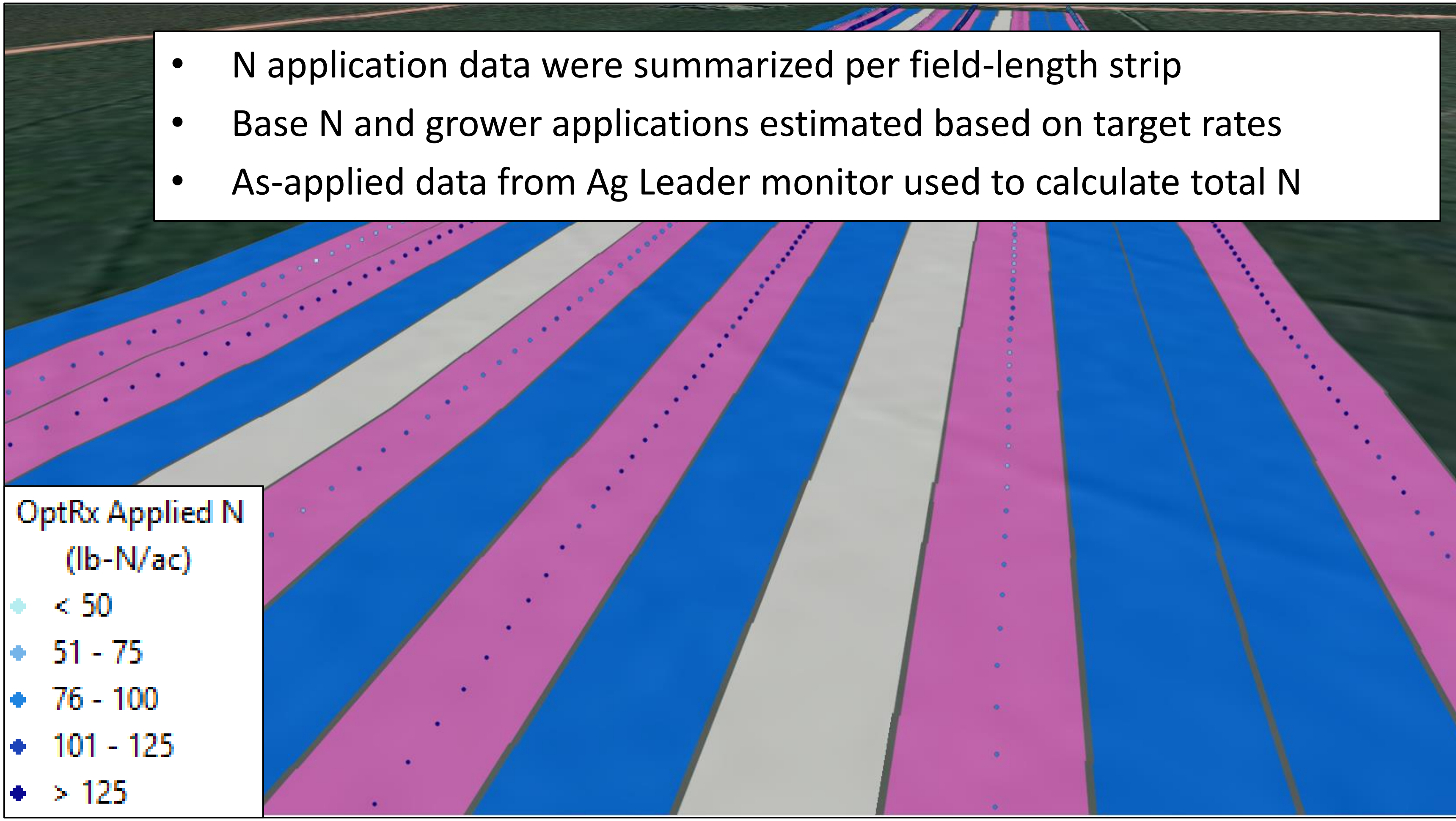
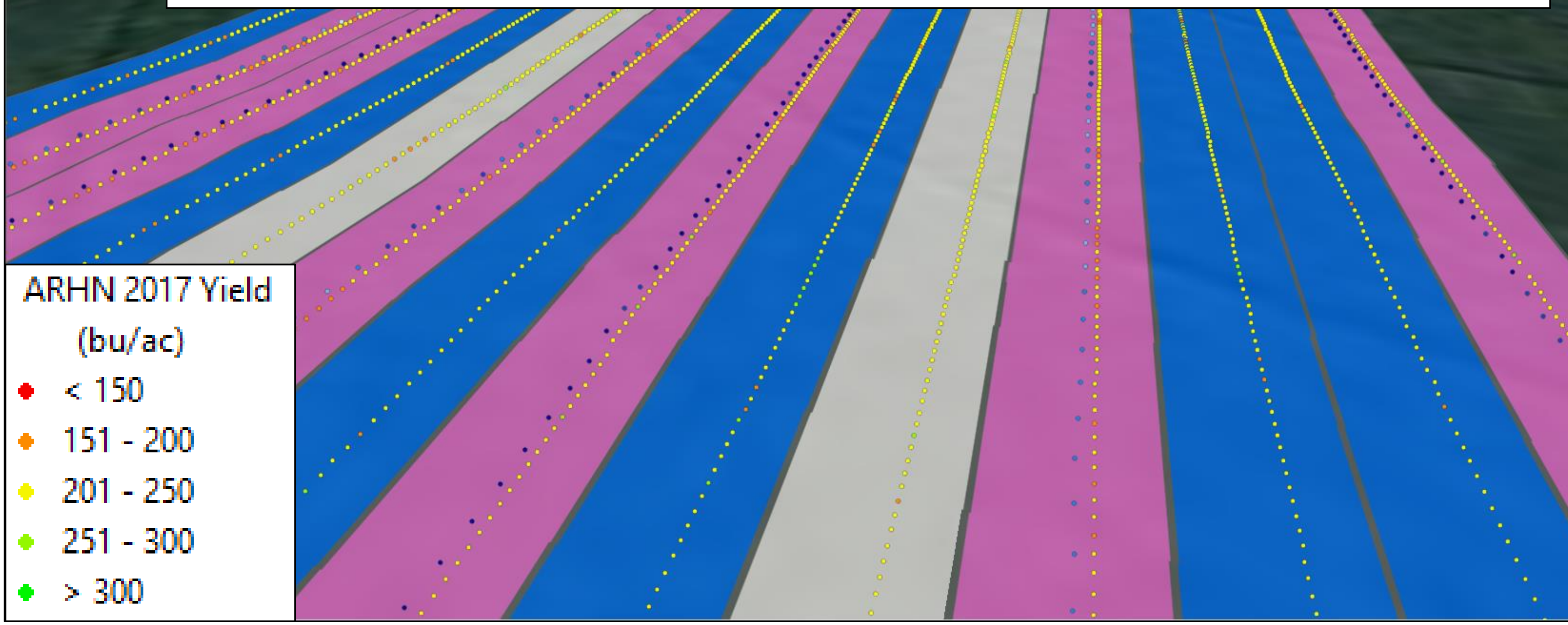
Plot Layout

- 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



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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YEAR AVERAGES

Results

- We compared the grower N rates and yields to that of the OptRx[TM] 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

- Differences were statistically analyzed using PROC GLIMMIX in SAS 9.4 (SAS Institute, Cary, NC)

N EXTENSION

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.

N EXTENSION

Results for All Sites 2016

	Grower N Management	Project SENSE N Management	Difference
Total N Rate (lb/ac)	186 A	153 B	33
Yield (bu/ac)†	192 A	194 B	-2.3
PFP_N (lb grain/lb N)	60 B	75 A	-15
Lb N/bu Grain	1.08 A	0.84 B	0.24
Marginal Net Return	$502.13 A	$523.99 B	$21.86

†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

Results for All Sites 2017

	Grower N Management	Project SENSE N Management	Difference
Total N Rate (lb/ac)	188 A	173 B	15
Yield (bu/ac)†	234 A	231 B	3.5
PFP_N (lb grain/lb N)	75 B	85 A	-11
Lb N/bu Grain	0.81 A	0.75 B	0.06
Marginal Net Return	$661.43 A	$656.38 B	$5.05

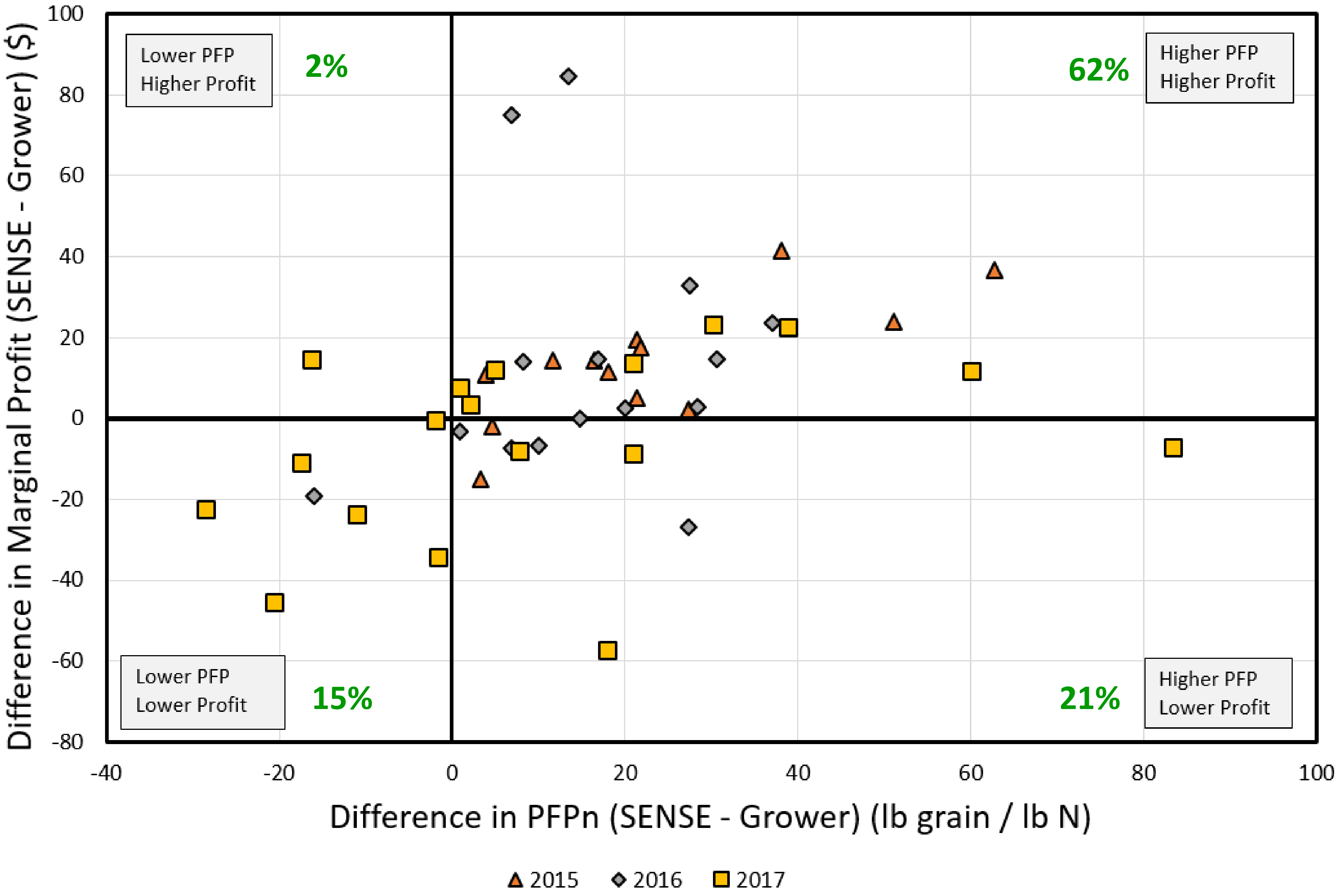
†Yield data from cleaned yield monitor data. Bushels per acre corrected to 15.5% moisture.
*Values with the same letter are not significantly different at a 95% confidence level.

N EXTENSION

All Sites Averages by Year

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

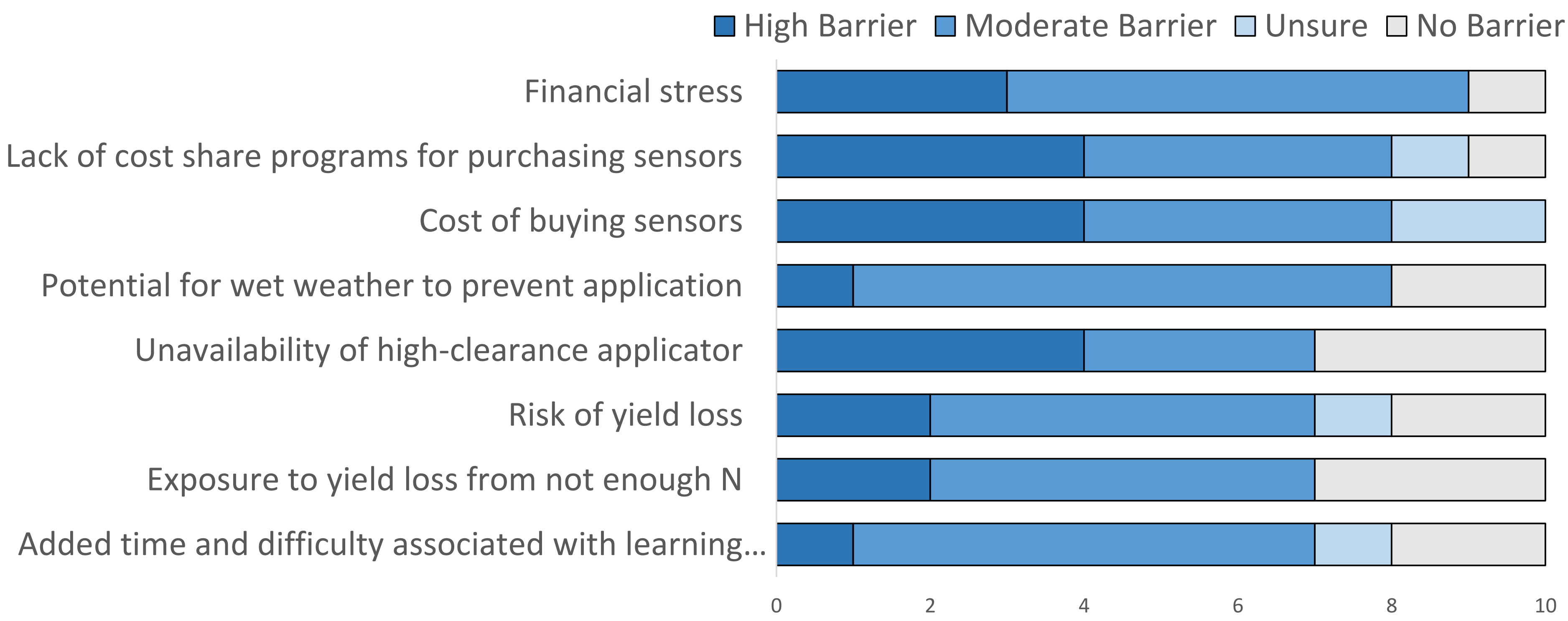
N EXTENSION


Lower PFP
Higher Profit
2%
62%
Higher PFP
Higher Profit
Lower PFP
Lower Profit
15%
21%
Higher PFP
Lower Profit
Difference in Marginal Profit (SENSE - Grower) ($)
100
80
60
40
20
0
-20
-40
-60
-80
-40
-20
0
20
40
60
80
100
Difference in PFPn (SENSE - Grower) (lb grain / lb N)
2015
2016
2017

Results/Evaluation Responses

Project SENSE Grower Meetings:

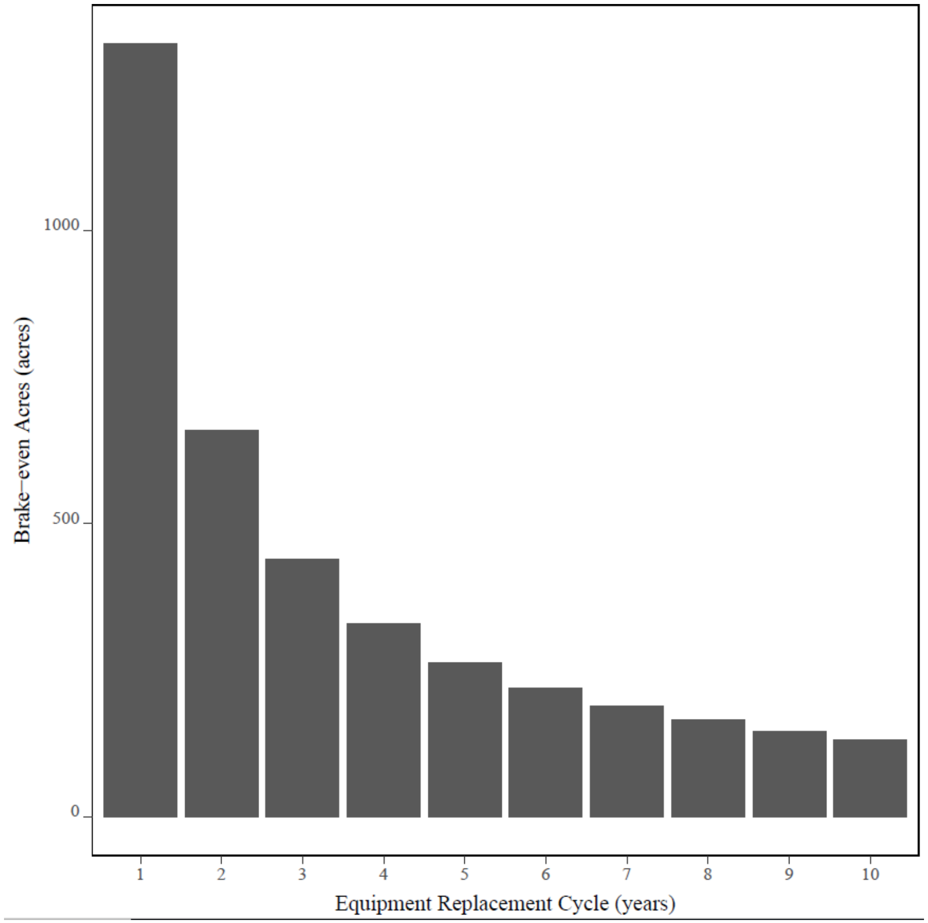
- Annual meeting with cooperating growers.
- At the final meeting, 50% of respondents indicated that they had reduced N rates or moved to split N application since interacting with Project SENSE.



Future Efforts and Thoughts

Considerations for Adoption:

- Utilizing sensors to take advantage of growing season variability with a responsive approach has high potential for reducing N needs
- Reasonable EONR estimates are critical…still requires input
- Consider NUE metrics that you are currently operating at…how much more efficient can you operate economically?
- Breakeven acres could be very low if you're currently operating specific equipment for in-season N management



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Comparison of Active and Passive Sensors to Inform In-Season N Fertilization

- Determine what correlation exists between the active and passive sensors in terms of producing vegetative indices
- Can a passive sensor prescribe N rates similarly or better than an active sensor
- Determine the profitability of using sensor based systems compared to a growers standard practice

EXTENSION

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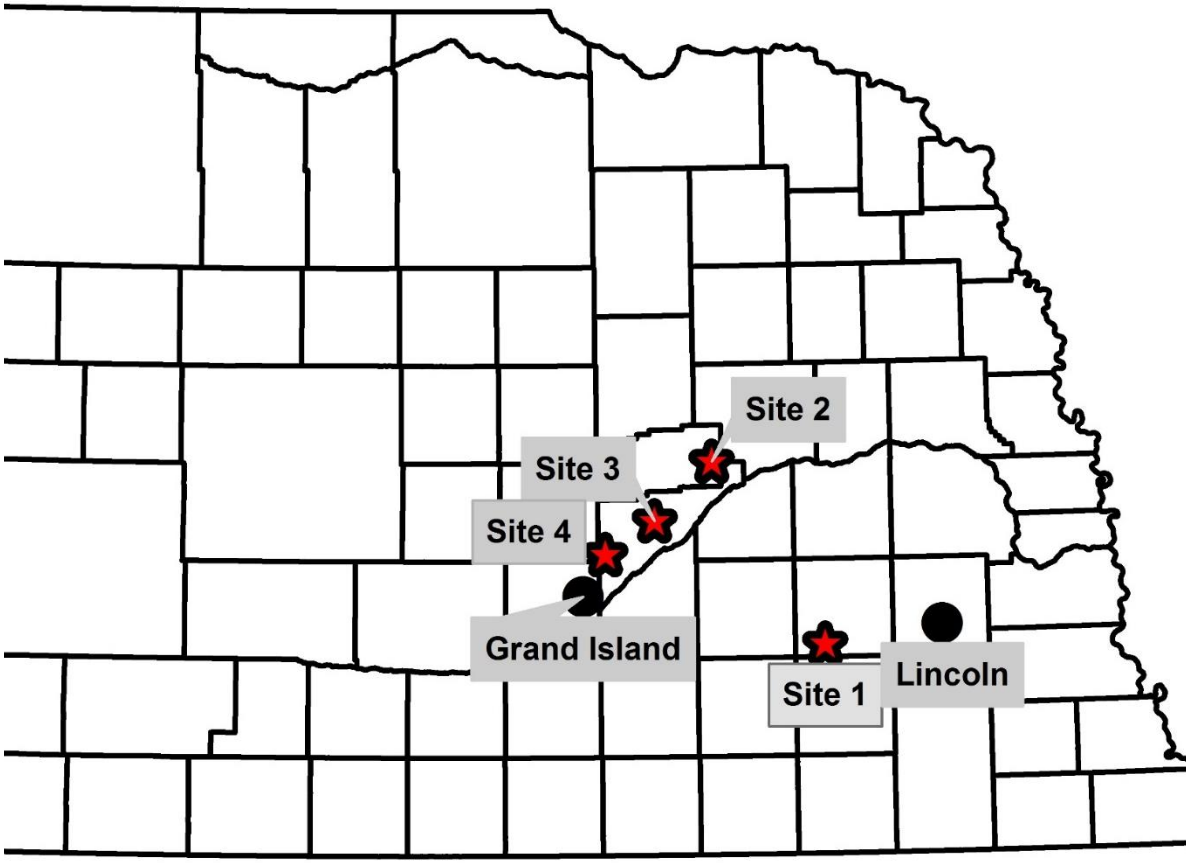
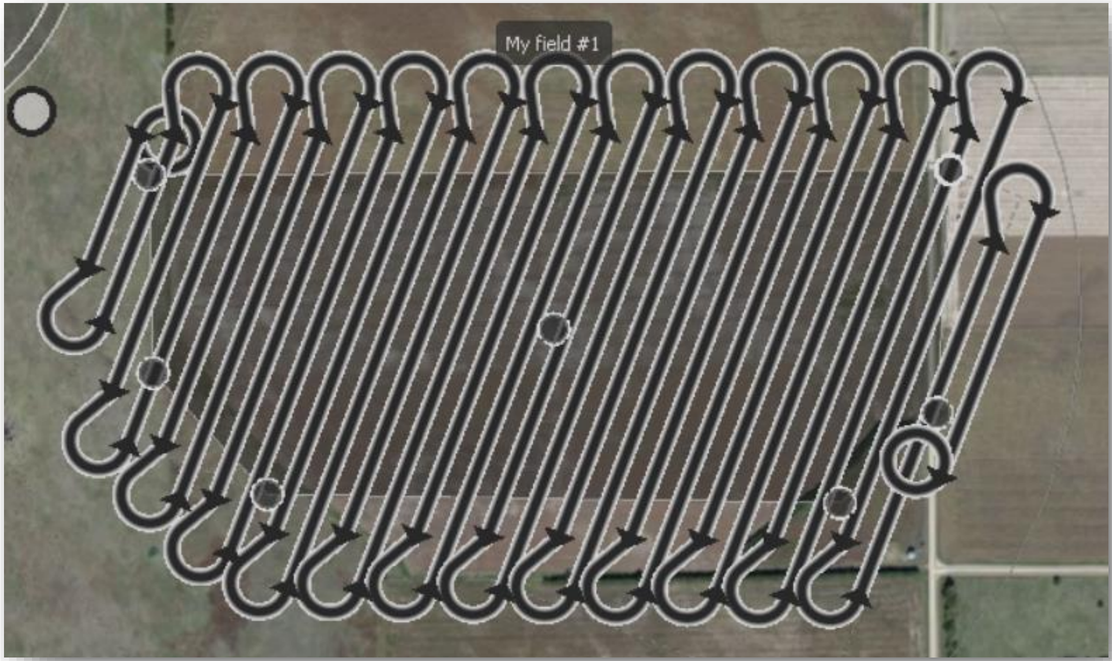
Locations

- 4 Locations
- 3 center pivot irrigated
- 1 subsurface drip

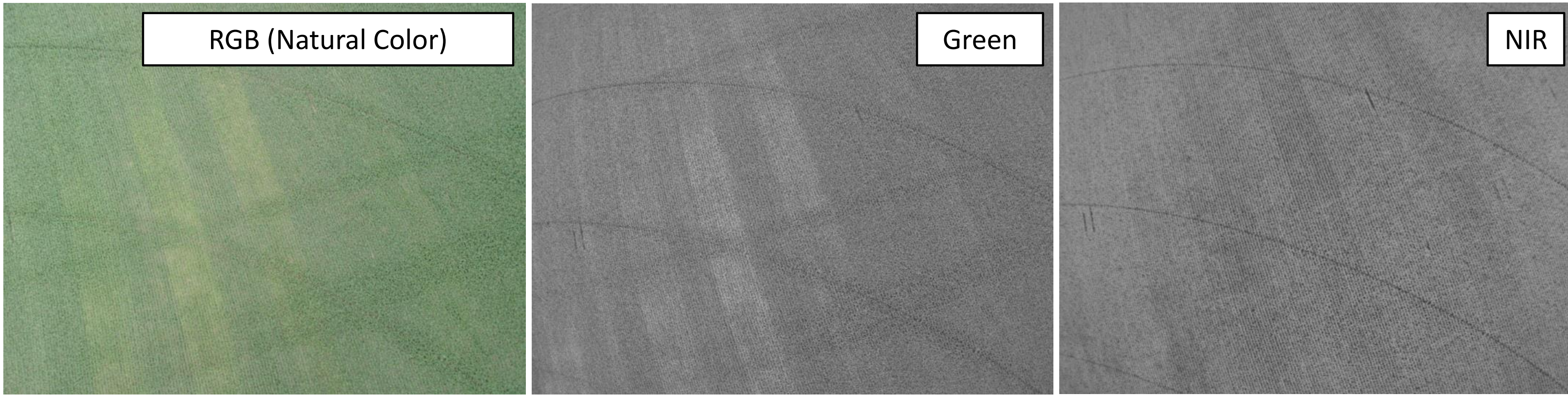


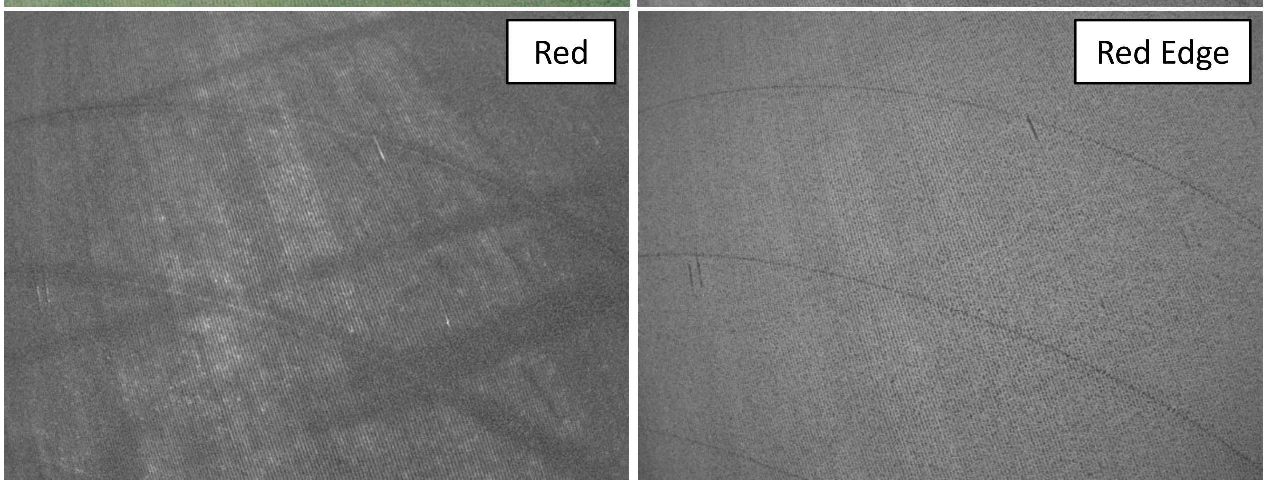
Fixed-Wing SenseFly eBee SQ for Mapping

- Fully autonomous
- User sets ground resolution and desired overlap
- Software plans mapping route



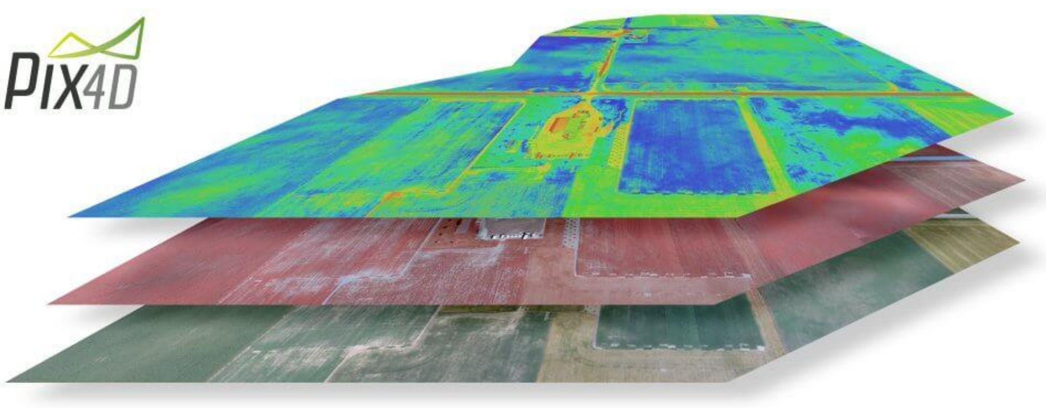
70 acres, 356 waypoints
5 images per waypoint

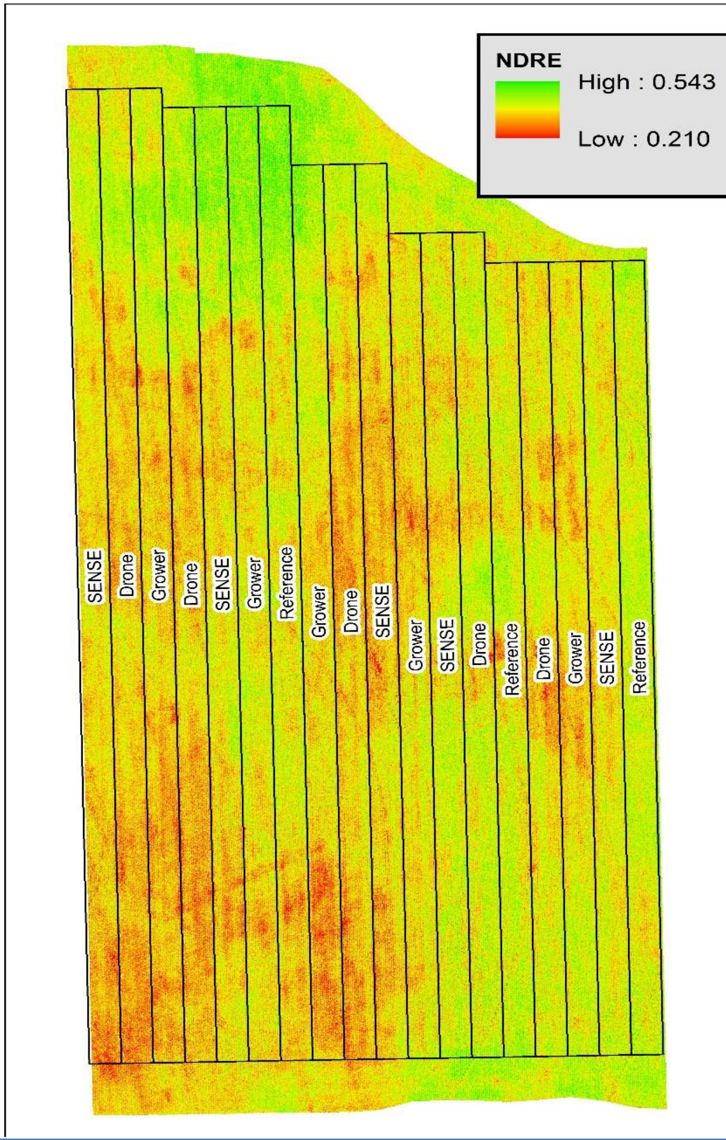

RGB (Natural Color)
Green
NIR


Red
Red Edge

Processing Passive Sensor Data

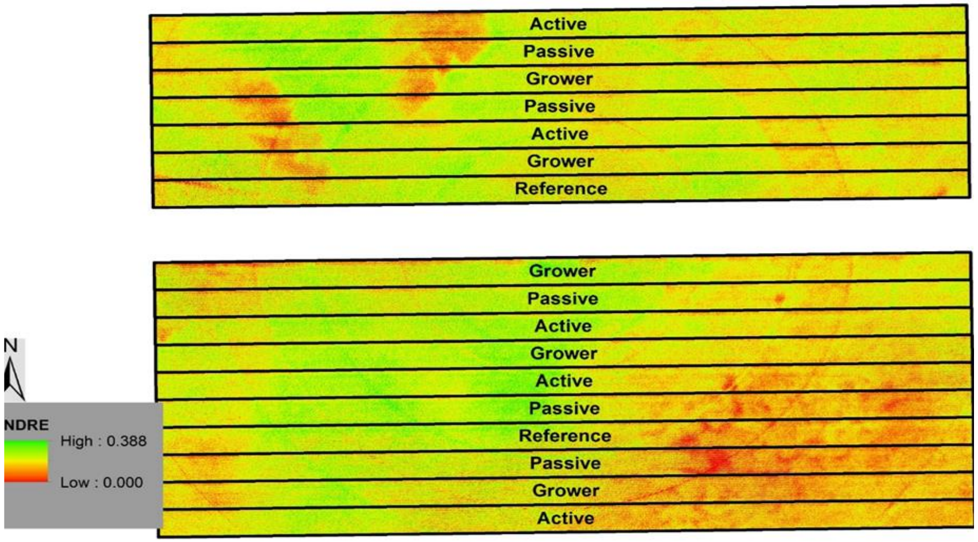
- Images are geotagged and stitched together with image processing software
- Vegetation indices can then be calculated

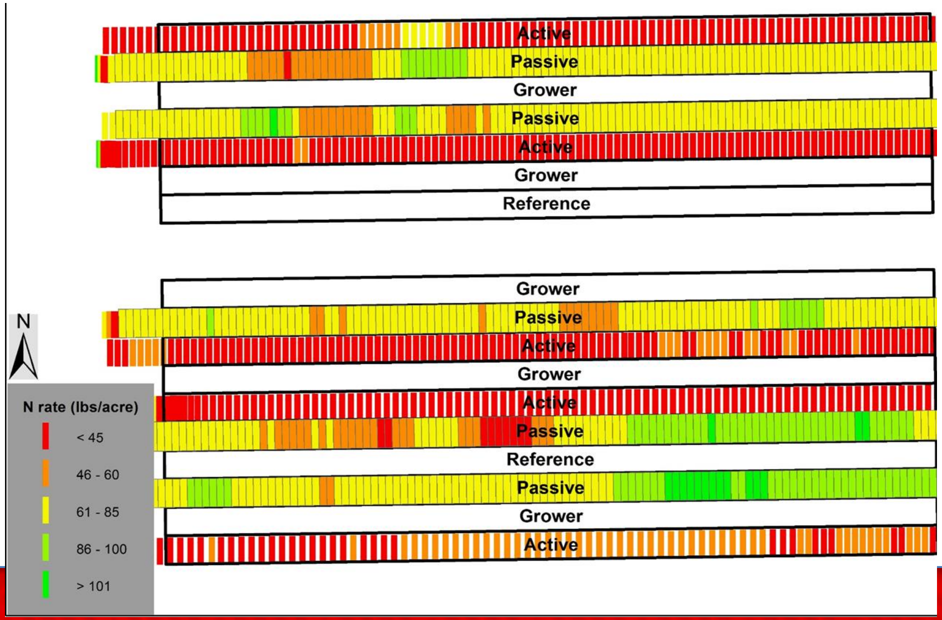




Processing Passive Sensor Data

- Transform raster to polygon to create a prescription map
- Long process with many applications used





- Resolution of image affects how many pixels are used
- 8 hour turn around

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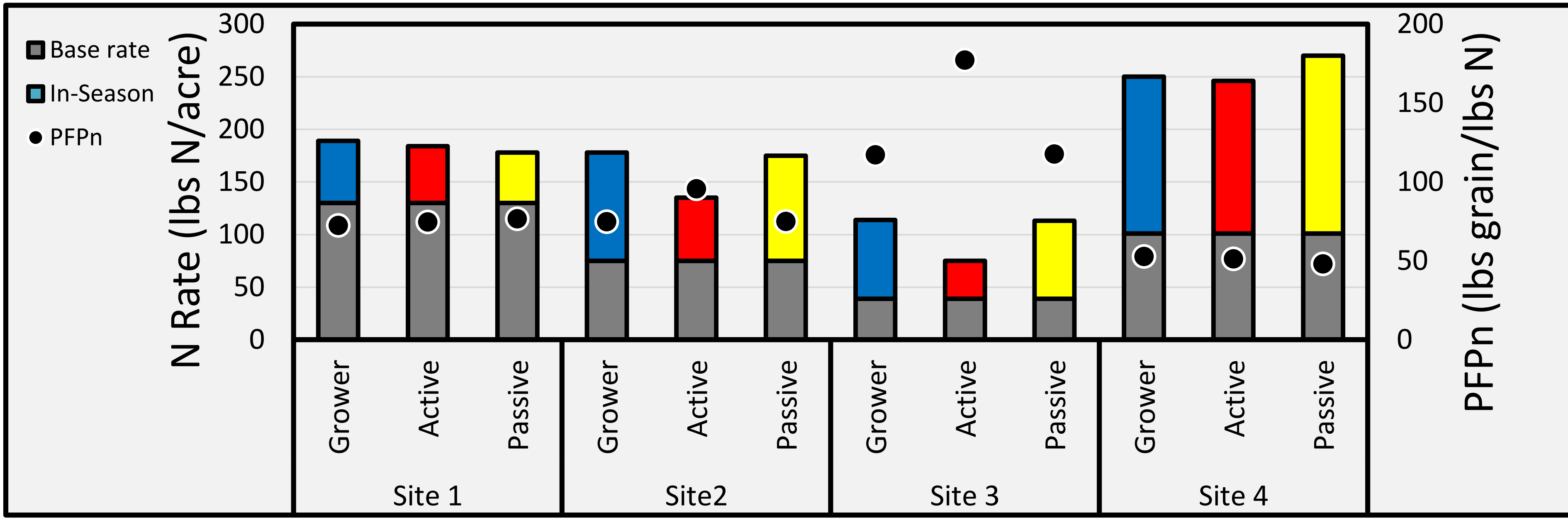
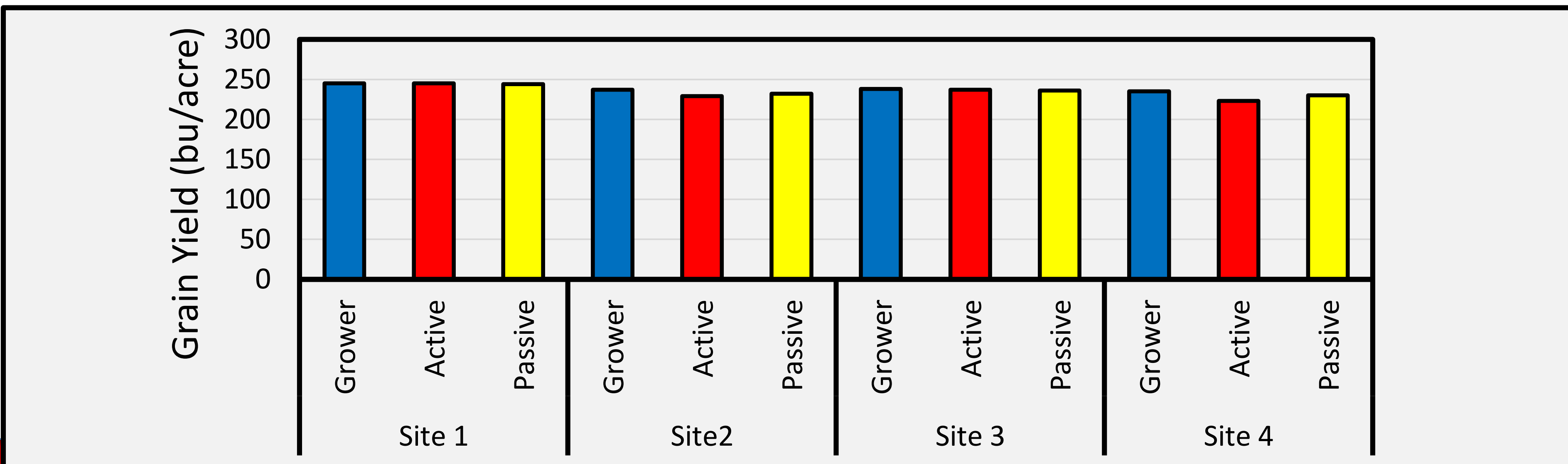
Results


Base rate
In-Season
PFPn
N Rate (lbs N/acre)
PFPn (lbs grain/lbs N)
300
250
200
150
100
50
0
200
150
100
50
0
Grower
Active
Passive
Site 1
Site2
Site 3
Site 4


Grain Yield (bu/acre)
300
250
200
150
100
50
0
Grower
Active
Passive
Site 1
Site2
Site 3
Site 4

The Future

- *For Project SENSE, 2018 will be a transition year, with increased focus on use of drone-based crop canopy sensing to inform need for fertigation.*
- *Eventual integration of sensors to inform variable rate fertigation as well as irrigation.*
- *Potential for regulations to restrict significant N application to the growing season in areas at greatest risk for N leaching, or areas with highest groundwater nitrate concentrations.*