Project SENSE: Review of 7 Years of Sensor-Based N Management in Irrigated & Rainfed Corn Production

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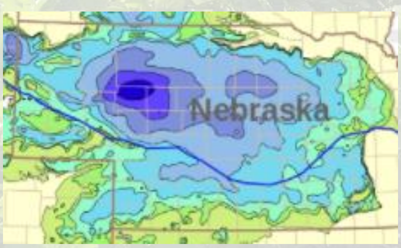
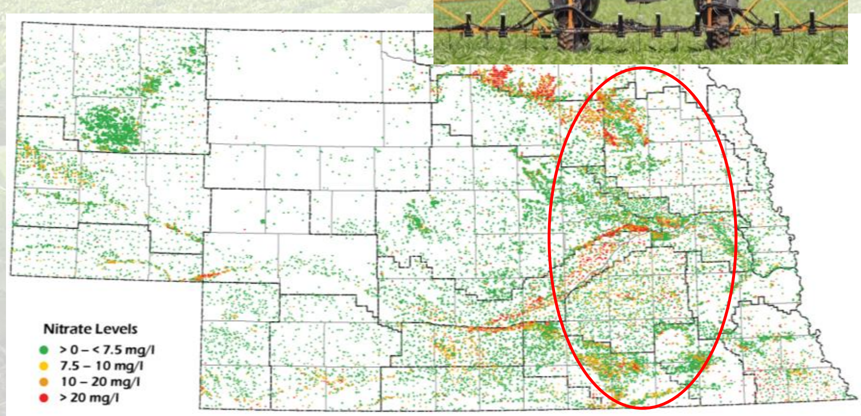
NEBRASKA EXTENSION
DIGITAL AGRICULTURE

Project SENSE

Sensors for Efficient N Use and Stewardship of the Environment

- A project comparing sensor-based N management with current grower practices
  - Overall goal was to increase fertilizer nitrogen use efficiency (NUE), and reduce nitrate loss to groundwater
- Utilize a responsive-approach where sensors assess the Nitrogen stress status of the crop



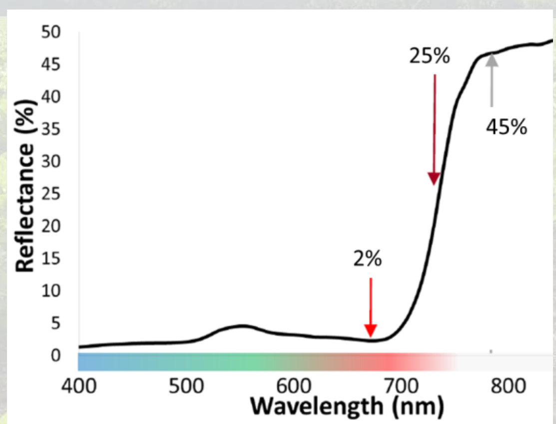


Vegetation Indices:

- Vegetation indices quantify crop reflectance based on reflectance at particular wavelengths

$$NDVI = \frac{NIR_{760} - VIS_{670}}{NIR_{760} + VIS_{670}}$$

$$NDRE = \frac{NIR_{760} - RE_{720}}{NIR_{760} + RE_{720}}$$



Example of NDRE

- Below shows how corn ‘looks’ with different N supply, we can quantify this variability according to NDRE:

Going from VIs to N Recommendations…

- Several steps in the process, for real-time application:
  - Selection of sensor system
    - This typically sets algorithm to be used
  - Establish base N rates around planting (with high N reference strips)
  - Determine Optimum N Rate (Nopt), considering economics!
  - Preferred time of application window (V8-V12)
  - Determine reference NDRE for Sufficiency Index (SI)
  - Proceed with real-time sensing & N application

Active Systems and Algorithm

- Sensor selection will determine VI to be used as well as algorithm
- For corn in NE, two algorithms have been developed:
- Solari

$$N \text{ (lb/ac)} = 317 \cdot \sqrt{0.97 - SI}$$

- Holland-Schepers (OptRx system)

$$N \text{ (lb/ac)} = (N_{OPT} - N_{PreFert} - N_{CRD}) \cdot \sqrt{\frac{(1-SI)}{\Delta SI}}$$

Trimble Greenseeker®

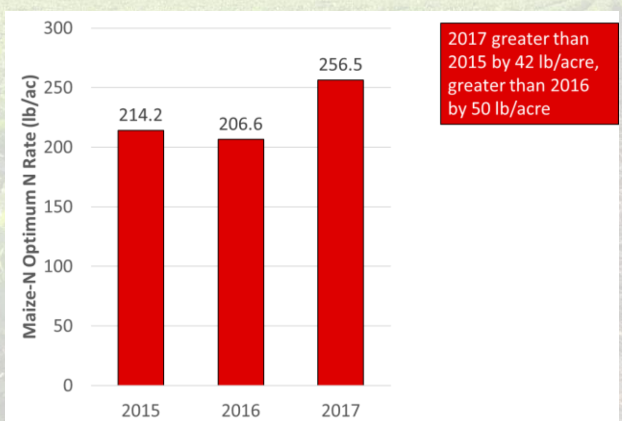
Ag Leader OptRx™

Topcon (Yara) CropSpec™

Estimating Nopt (economic EONR)

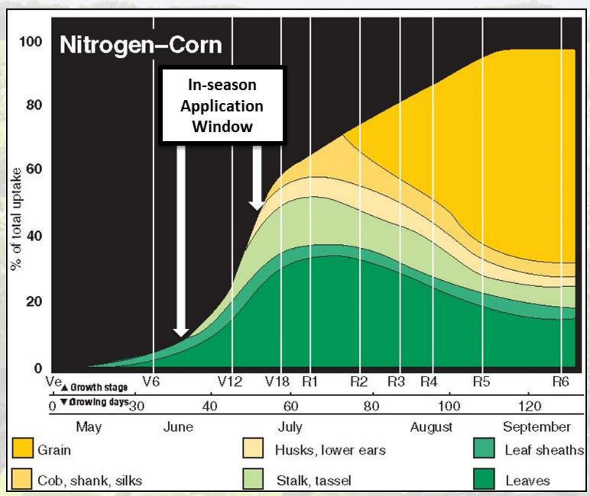
- Several methods exist…
  - N Models (Maize-N, Adapt-N, Encirca, Fieldview, etc.)
  - Field Research
  - N removal

N (lb/ac) = $(N_{OPT} - N_{PreFert} - N_{CRD}) \cdot \sqrt{\frac{(1-SI)}{\Delta SI}}$



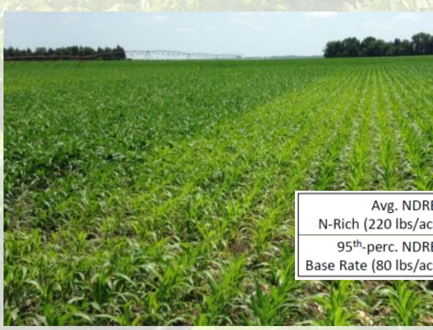
Timing for sensor-based N

- Recommended practice is to apply a base rate of 75-100 lb-N/ac at or near planting
- In-season application would follow, targeting v8 to v12 growth stages
- Why?
- Consider N uptake rate:

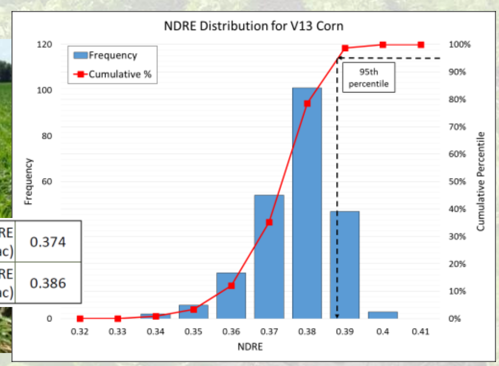


Reference VI

- A reference value for ‘healthy’ (or non-N limited) corn is required for the SI calculation
- Two methods exist for creating a reference VI:
  - High-N reference strip: apply 250 lb-N/ac base rate
  - Virtual reference strip: record NDRE values just prior to N application, select 95th percentile (automatic function in OptRx system)



Avg. NDRE N-Rich (220 lbs/ac)	0.374
95th-perc. NDRE Base Rate (80 lbs/ac)	0.386



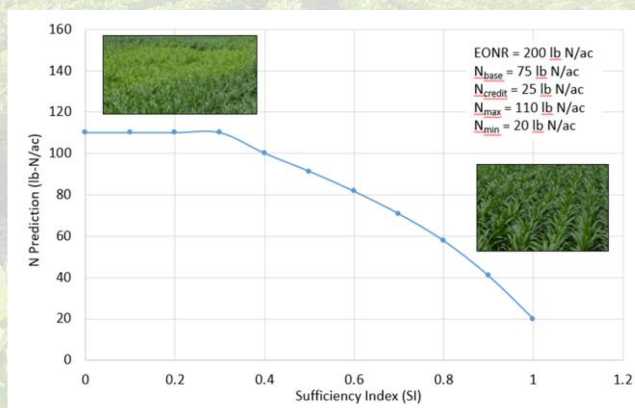
Calculating the Sufficiency Index

- For real-time application, the system will store the reference VI
- The SI values are calculated on-the-go by dividing the ‘target’ (where you’re applying) values by the one reference value

N Application in real-time

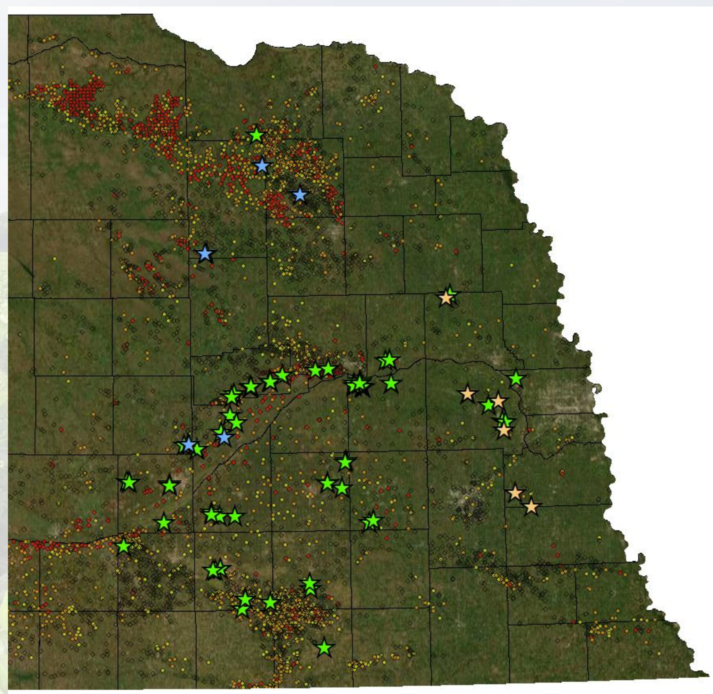
- Once we have the previous information, the system will apply the N algorithm in real-time
- For the Holland-Schepers algorithm, a N response curve might look something like this (note additional settings available to limit N):

N (lb/ac) = $(N_{OPT} - N_{PreFert} - N_{CRD}) \cdot \sqrt{\frac{(1-SI)}{\Delta SI}}$



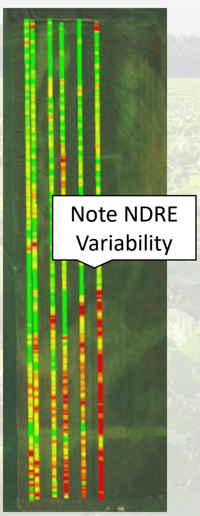
Project SENSE

- We have worked with over 80 growers in their fields with three different types of SENSE projects
- High clearance applicator in irrigated and rainfed fields
- Sensor-based fertigation
- These were some of the best growers out there in terms of NUE!

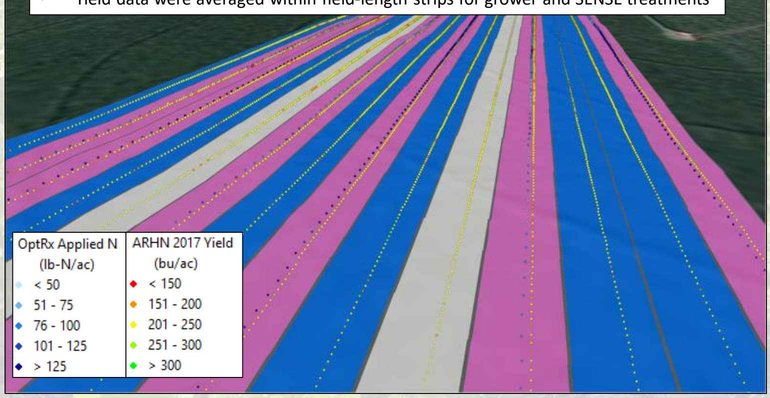


Project SENSE

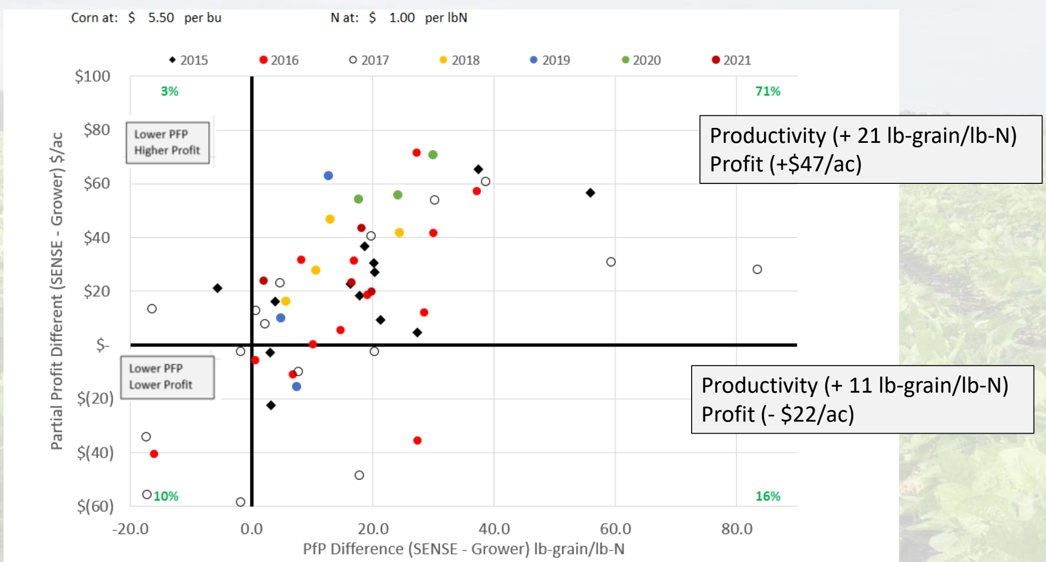
- Data analysis process:



- 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
- 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



Project SENSE



Project SENSE

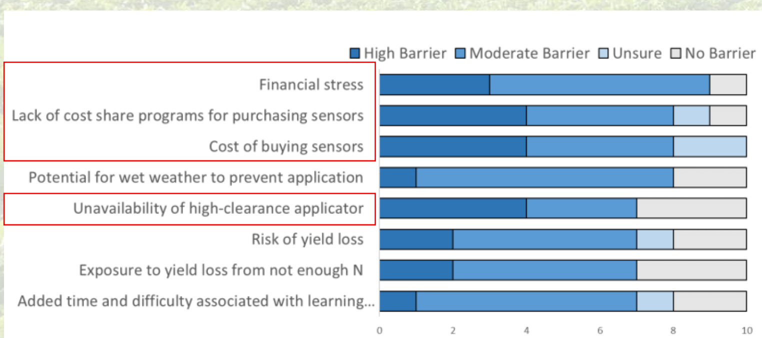
- Average across all years show high potential for this technology!

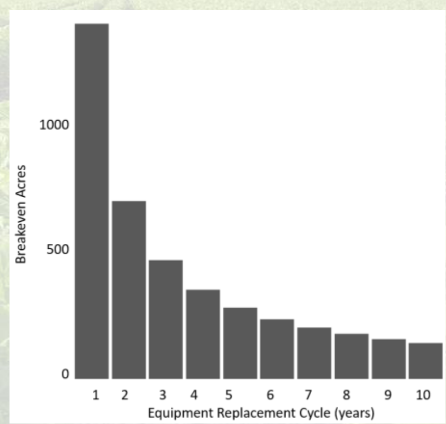
Five Year Average	SENSE	Grower
Total N rate (lb-N/ac)	159.3 B*	190.8 A
Yield (bu/ac)	216.9 B	218.0 A
Nitrogen Use Efficiency (lb-N/bu grain)	0.75 B	0.92 A
Partial Profitability ($/ac) [@3.65/bu and $0.65/lb-N]	$693.17 A	$676.44 B
Partial Profitability ($/ac) [@3.15/bu and $0.41/lb-N]	$622.20 A	$612.82 B

Project SENSE

Sensors for Efficient N Use and Stewardship of the Environment

- 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.





Sub Field Analysis:

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

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)

Sub Field Analysis:

- NUE was greater in the SENSE treatments in sandy soils

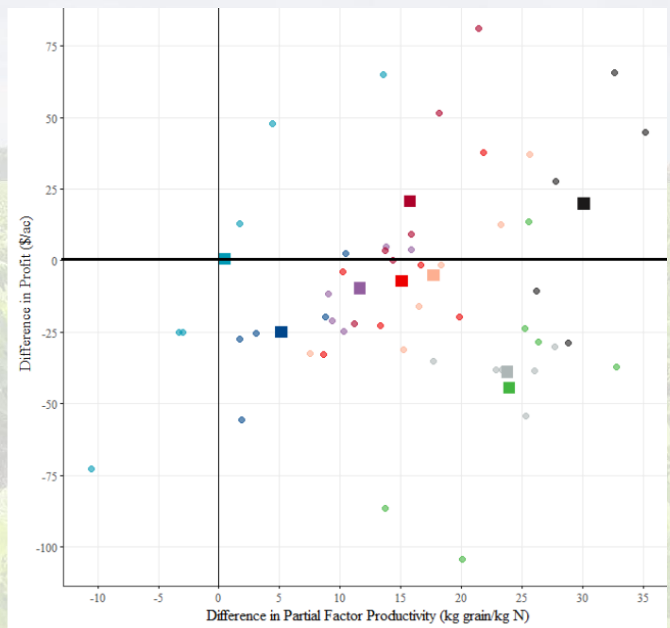
Differences in NUE (SENSE-GROWER)

	Dependent variable:		
	dNUE		
	(1)	(2)	(3)
GDD_P_SD_SENSE	-0.00004	-0.0001	-0.001^{***}
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_textsilty-clay			0.056
			(0.070)
Soil_textsilty-clay-loam	-0.566^{***}	-0.189^{*}	-0.050
	(0.037)	(0.111)	(0.152)
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)
Constant	2.327^{***}	2.663^{***}	3.122^{***}
	(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)

Project SENSE – Rainfed Sites

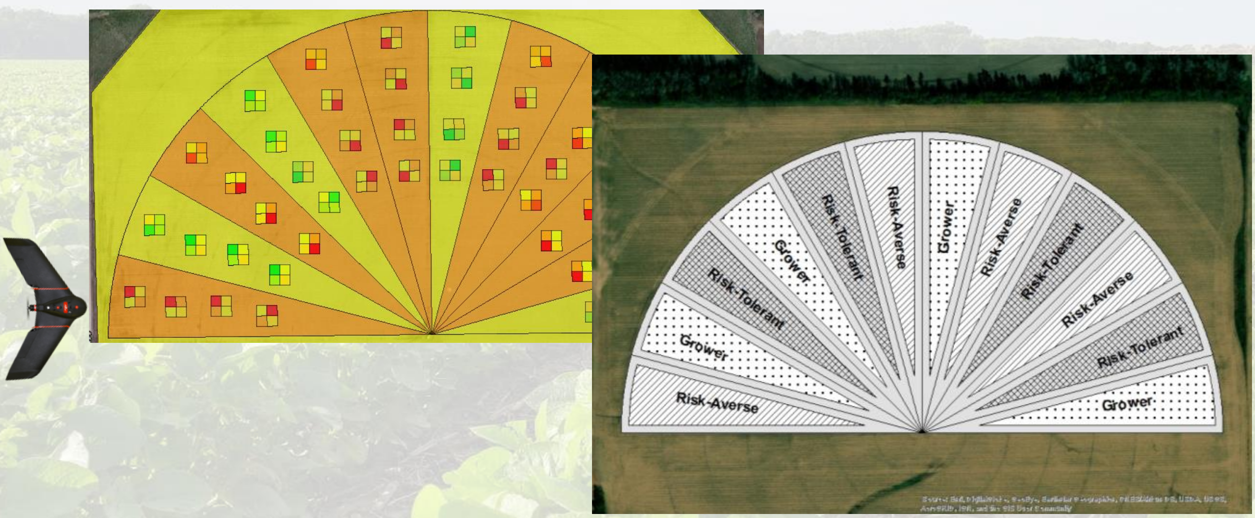
- Project SENSE rainfed sites followed similar field-deployment methods
- Nine sites were deployed in 2019 and 2020
- Average profitability was $2.40/ac less using the in-season approach
- NUE was improved upon at each site; typically from less N applied
- Three grower-cooperators utilized in-season N management approaches

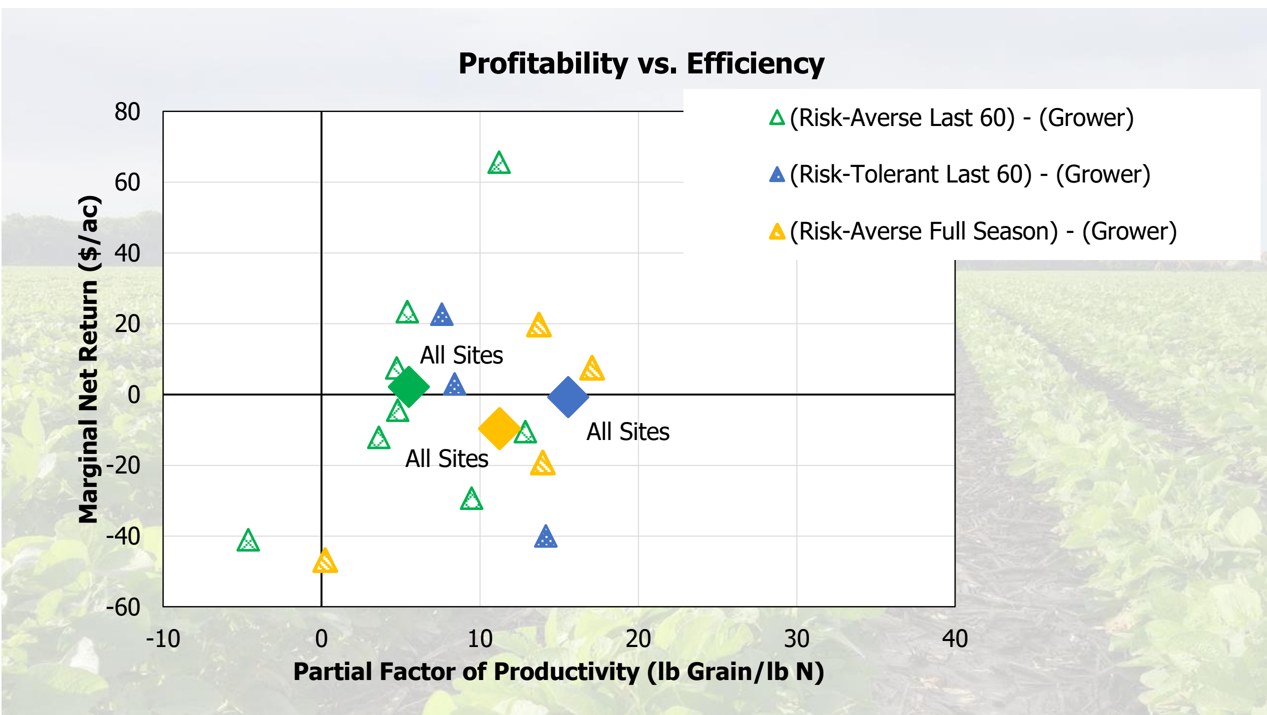
- Future work will include coulter-injected UAN starting in 2022



Sensor-based Fertigation Treatment Layout

(Methodology/Process and Software are patent-pending)





Profitability vs. Efficiency
(Risk-Averse Last 60) - (Grower)
(Risk-Tolerant Last 60) - (Grower)
(Risk-Averse Full Season) - (Grower)
All Sites
All Sites
All Sites
Marginal Net Return ($/ac)
80
60
40
20
0
-20
-40
-60
-10
0
10
20
30
40
Partial Factor of Productivity (lb Grain/lb N)

Thank You!

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cropwatch.unl.edu/on-farm-research

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Special thanks to our grower-cooperators that allow us to work in their fields!