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

Richard Ferguson, Joe Luck, Laura Thompson, John Parrish, Joel Crowther, Dean Krull, Nathan Mueller, Troy Ingram, Taro Mieno, Keith Glewen, Brian Krienke

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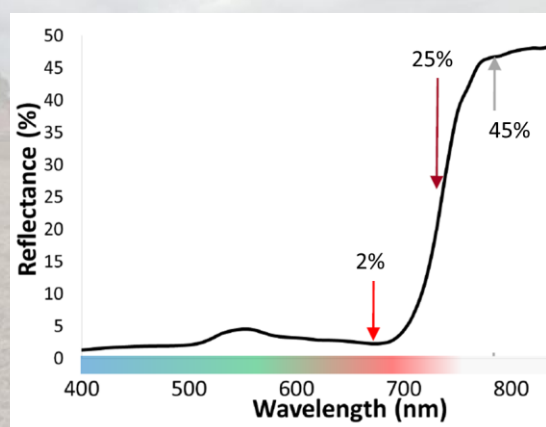
Vegetation Indices:

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

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

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



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Example of NDRE

- Below shows how corn ‘looks’ with different N supply according to NDRE:

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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
  - Determine Economic Optimum N Rate (EONR)
  - Preferred time of application window
  - Determine Sufficiency Index (SI) from reference reflectance data
  - Real-time N application

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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

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

- Holland-Schepers (OptRx system)

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

Trimble Greenseeker®

Ag Leader OptRx™

Topcon (Yara) CropSpec™

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Estimating EONR or ONR

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

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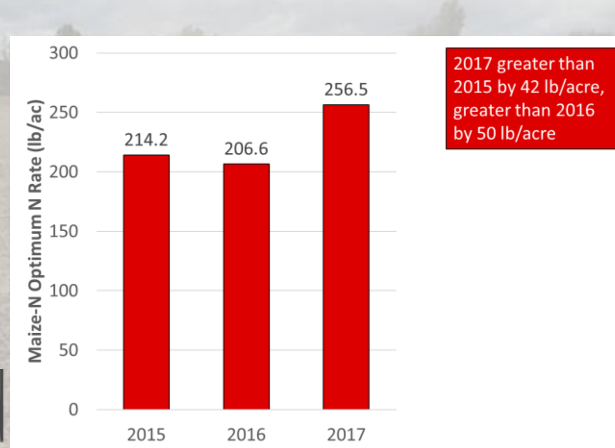

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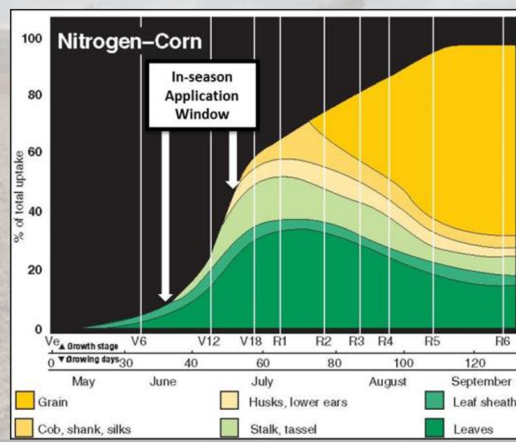
Timing for sensor-based N

- 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:



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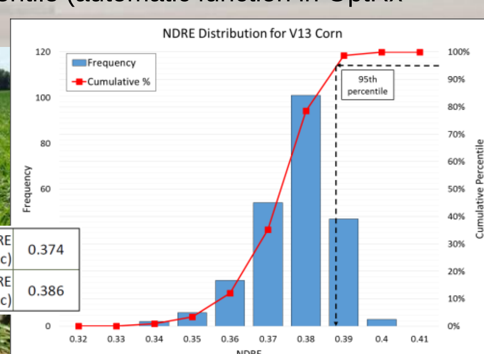
Reference VI

- 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



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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

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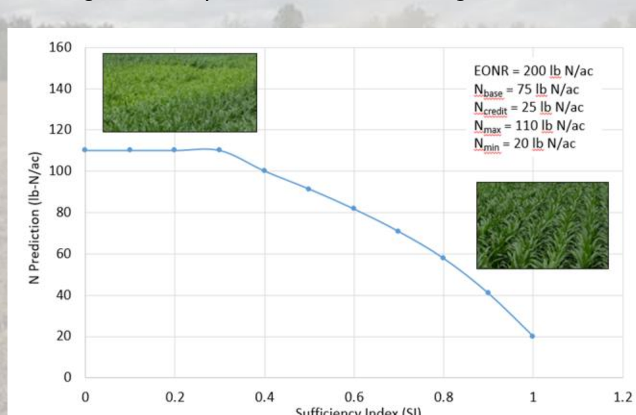
N Application in real-time

- 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):



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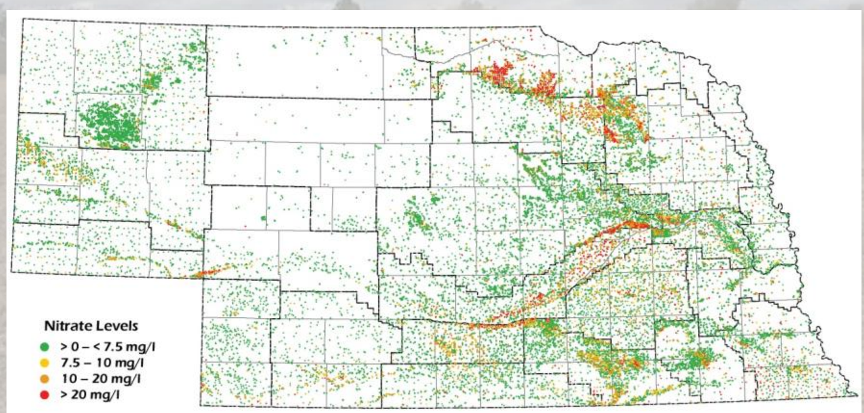
Sensors for Efficient N Use and Stewardship of the Environment

- A three year 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



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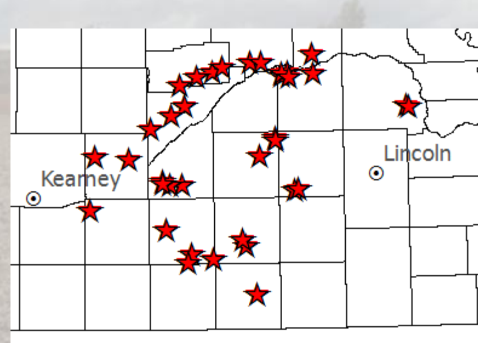
- A responsive approach, using crop canopy sensors, has been proven through research to be an effective way to approach EONR, adjusting for spatial and temporal variation.
- The SENSE project utilized the Ag Leader OptRx system
- A total of 52 field studies were conducted with cooperating growers from 2015 to 2017
- Four sites were removed due to in-season issues based on input from growers at annual meeting



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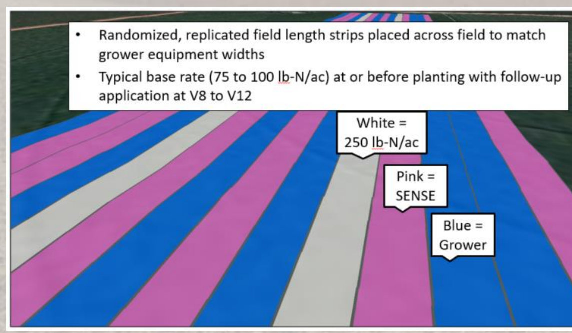
- Three treatments:
    - Grower's normal N management (rate & timing)
    - Sensor-based N application (base rate + in season)
    - High-N reference (non-limiting N rate)
- Randomized complete block design with 6 replications
- Strip width depended on grower's equipment 16, 12, and 8 rows
- Total study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



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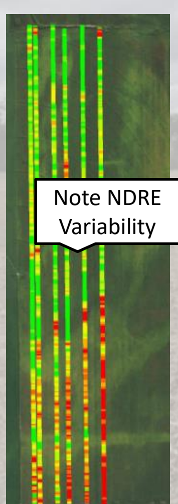
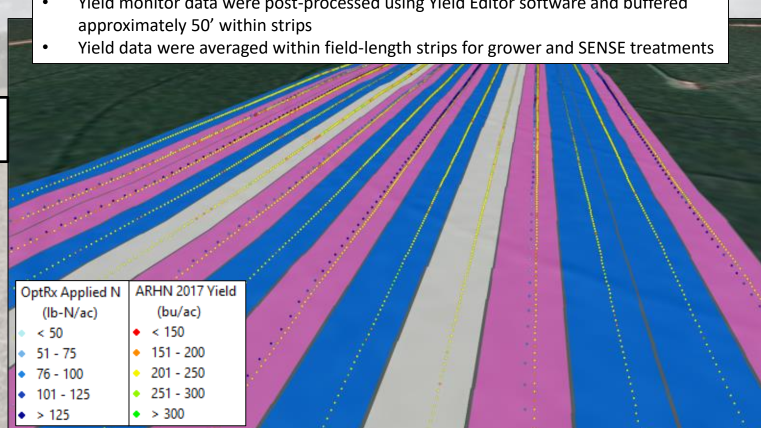
- Data analysis process:
    - N application data were summarized per field-length strip
    - Base N and grower applications estimated based on target rates
    - As-applied data from Ag Leader monitor used to calculate total N
    - Yield monitor data were post-processed using Yield Editor software and buffered approximately 50' within strips
    - Yield data were averaged within field-length strips for grower and SENSE treatments





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- Data analysis process:
  - SENSE outperformed Grower = green
  - Grower outperformed SENSE = red
  - PFP_N = Pounds Grain per Pound N
  - NUE = 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)

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- 2015 Differences (Grower – SENSE) All sites averaged by year:

	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

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- 2016 Differences (Grower – SENSE) All sites averaged by year:

	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

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- 2017 Differences (Grower – SENSE) All sites averaged by year:

	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

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- 2017 Differences (Grower – SENSE) All sites averaged by year:

Summary of Results (all NRD sites)

Three Year Average	SENSE	Grower
Total N rate* (lb-N/ac)	161.1	189.8
Yield* (bu/ac)	218.5	219.9
Partial Factor of Productivity* (lb grain/lb-N)	83	68
Nitrogen Use Efficiency* (lb-N/bu grain)	0.76	0.92
Partial Profitability* ($/ac) [@3.65/bu and $0.65/lb-N]	$692.82	$679.59
Partial Profitability* ($/ac) [@3.05/bu and $0.41/lb-N]	$600.39	$593.15

*values are statistically different at a 95% confidence level.

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We can approach (and drop below) grain removal rates for N (0.65 lb-N/bu)

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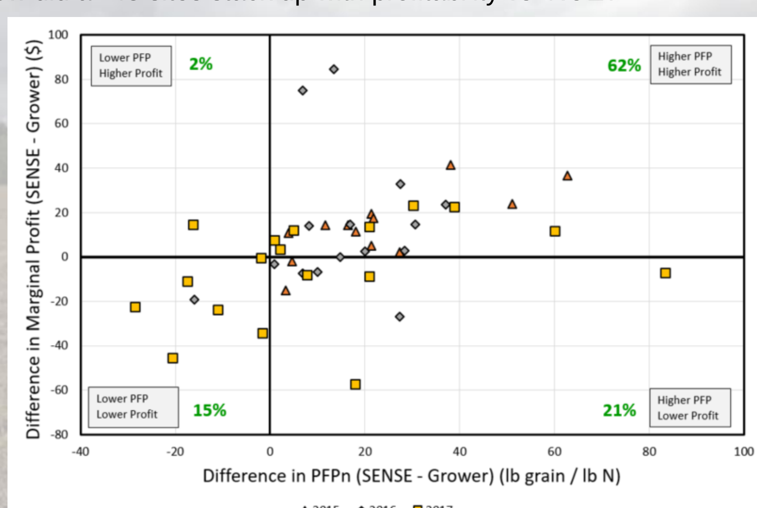
- How did all 48 sites stack up with profitability vs. NUE?



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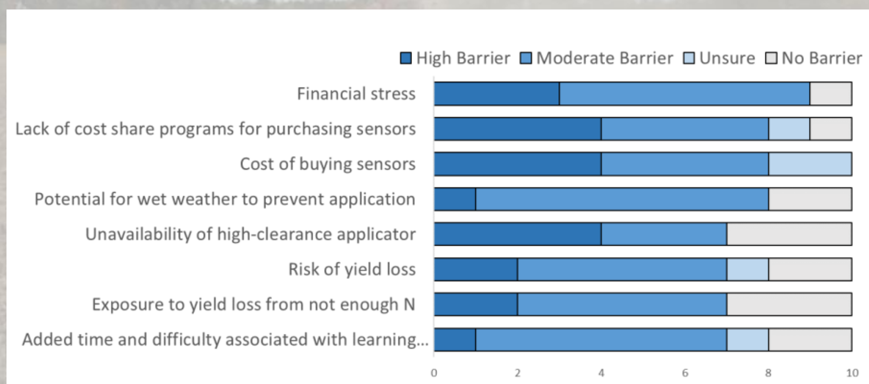
- Project SENSE Grower Meetings:
- Annual meeting with cooperating growers.
- At the final meeting, 50% of respondents indicated that they had reduced N rates or moved to split N application since interacting with Project SENSE.



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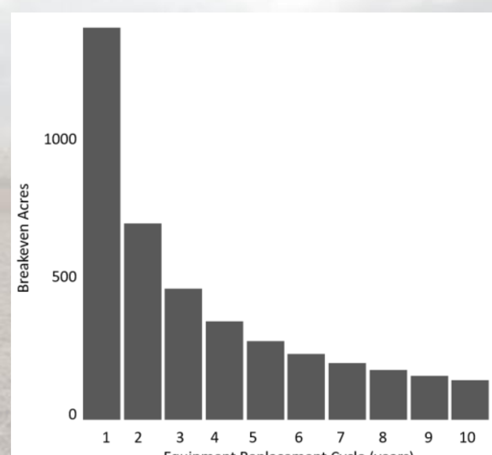
- <u>Considerations for Adoption:</u>
- Utilizing sensors to take advantage of growing season variability with a responsive approach has high potential for reducing N needs
- Terrain, soil texture, and OM variability can affect potential returns
- Reasonable EONR estimates are critical…still requires 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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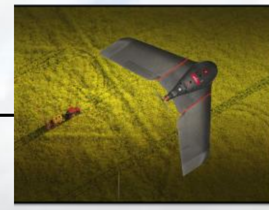
What other options exist?



- Passive sensors for N management
- The same process may be carried out with other sensing platforms to inform a variable rate N applicator just prior to application
- Challenges still exist in terms of data processing time, sun/cloud interactions, etc.
- Image processing, raster-to-polygon transformation required…minimum of 1 day delay is expected

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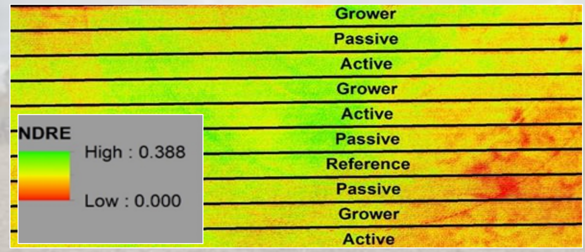

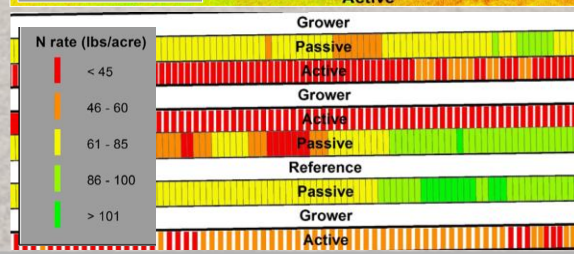

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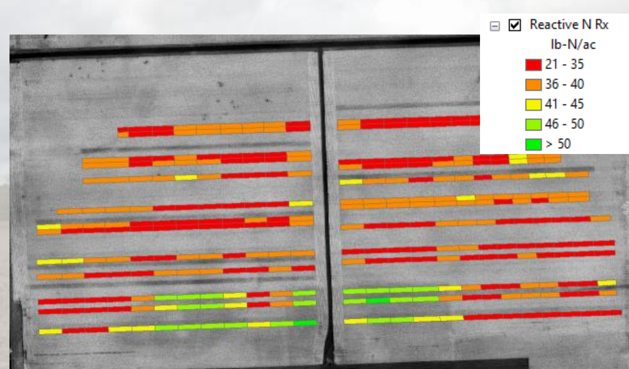
What other options exist?

Further work has demonstrated the benefits of split N and sensor-based N management using passive, aerial-based systems



Treatment	Yield (bu/ac)	Profit ($/ac) [@$3.23/bu]	Total N (lb-N/ac)	N Cost ($/ac)	MNR ($/ac)	NUE (lb-N/bu)
Zero N	168.1 A	$ 542.96	0	$ -	543 A	-
Spring N	217.5 B	$ 702.53	150	$ 44.80	657.7 B	0.69
V5 Split	218.8 B	$ 706.72	150	$ 48.81	657.9 B	0.69
Reactive	224.4 C	$ 724.81	110	$ 34.71	690.1 C	0.49
V12 Split	232.4 D	$ 750.65	150	$ 48.70	701.9 C,D	0.65

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- Supporters of the 2015-2017 project:

Our Cooperating Producers!!!

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jluck2@unl.edu

@joeluck_unl

402-472-1488

cropwatch.unl.edu/projectsense

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