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Successes and Shortcomings of Remote Sensing in Agriculture

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Principal Scientist

Agronomic Modeling

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CERTIFIED CROP ADVISER

Nutrient Management

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CERTIFIED CROP ADVISER

Nutrient Management

AGENDA

- Remote Sensing fundamentals (4 Lessons)
- Successes (and shortcomings) of RS for nutrient management
- What is your role in the future success of remote sensing?

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Family farm (Greenwood, WI)

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Remote Sensing Fundamentals
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Lesson 1

What is your reason for using remote sensing?

If you can't answer this, don't expect to get a lot of value from remote sensing

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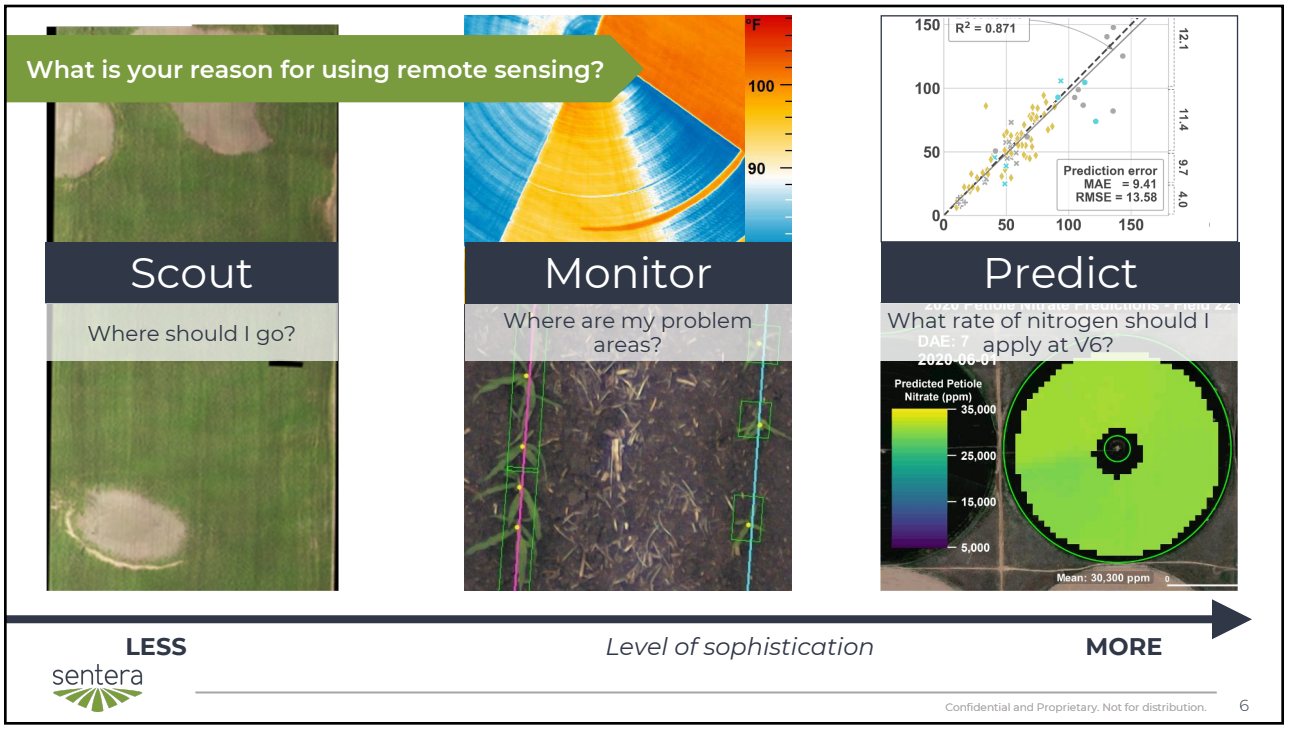
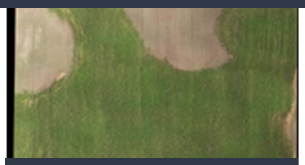


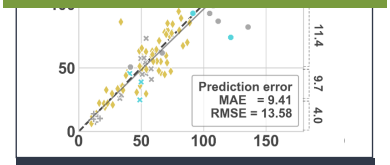
6

More qualitative than quantitative

Reactive

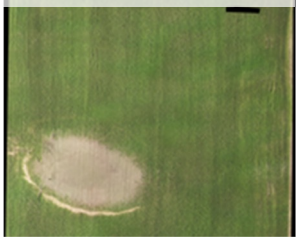
Proactive





Scout

Where should I go?

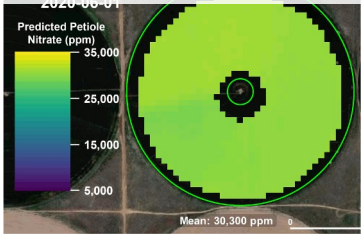


Monitor

Where are my problem areas?

Predict

What rate of nitrogen should I apply at V6?



LESS *Level of sophistication* **MORE**

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More qualitative than quantitative

Reactive

Proactive

Scout

Where should I go?

Monitor

Where are my problem areas?

Predict

What rate of nitrogen should I apply at V6?

Simple RGB

Sentera 6x Thermal

Sentera 6x

Satellites

LESS *Level of sophistication* **MORE**

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Lesson 2

Spectral

vs

Computer Vision

Both are remote sensing technologies, but solve vastly different problems

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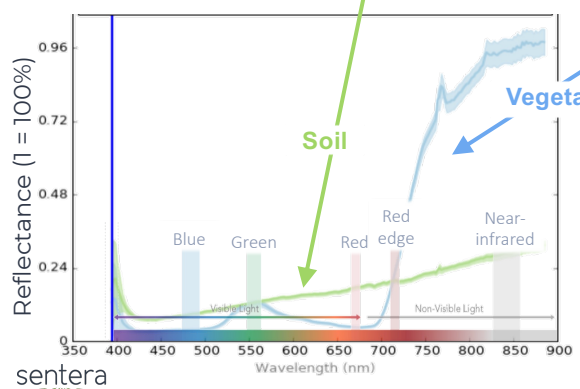
Spectral

Corn plot – 29 June 2019



It's not so much about how images look, it's the data they hold

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Both are remote sensing technologies, but solve vastly different problems

By the time you can use computer vision for nutrient management, it's too little too late

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Lesson 3

Satellite

vs

Drone

A quick review

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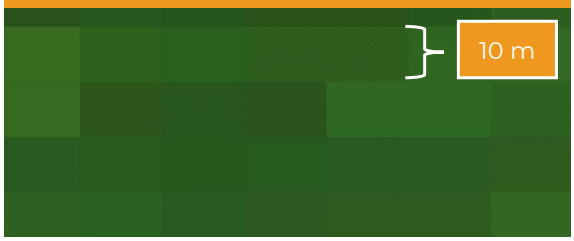
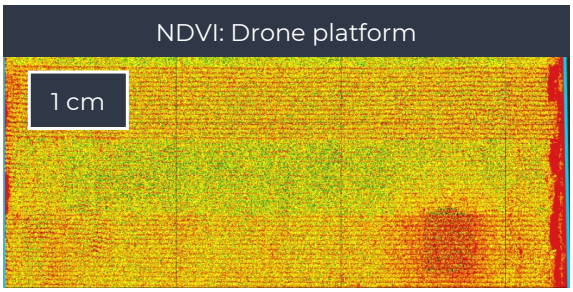
Satellite vs Drone

Not all "Remote Sensing" data are created equal (consider your objectives)

NDVI: Satellite platform



NDVI: Drone platform



Satellite	Specification	Drone
1-20 m	**Spatial Resolution**	<10 cm
Low	**Relative cost (per acre)**	High
Passive	**Timing**	You're in control

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Lesson 4

From data to decisions

It's not just about remote sensing

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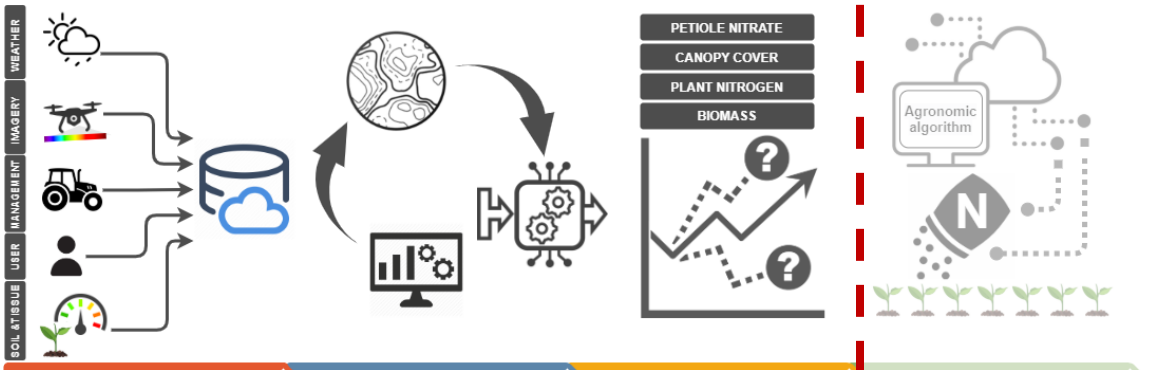
From data to decisions



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What is your objective?

Identify the **problem** and **how it can be solved**

Consider… the **goals** of your agronomy program

Why are you collecting the data you do?

Consider… the **ground-truth data** you routinely collect

*On **all** fields?*

*On **most** fields?*

*On **some** fields?*

Your objective should be focused on **deriving an agronomic insight** from RS data

Your objective is not to own a drone, collect images, or even get a report

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What is your objective?

Identify the **problem** and **how it can be solved**

Do we solve agronomic problems by…

Capturing data?	Summarizing data?	Visualizing data?
No	**Sometimes**	**Sometimes**

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What is your objective?

Identify the **problem** and **how it can be solved**

Different areas of Sentera's business provide value in the agronomic/remote sensing value chain – but they don't solve agronomic problems alone!

FieldCapture
100% aerial coverage throughout the crop lifecycle

FieldInsights
Deep insights into performance to deliver value

FieldAgent
Enterprise platform to view, analyze, and report on insights

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What is your objective?

Identify the **problem** and **how it can be solved**

Consider… the **goals** of your agronomy program

Why are you collecting the data you do?

Can you solve your problem using methods that don't include remote sensing?

If not, I'm sorry to say, but don't expect remote sensing to magically solve your problems

Your objective should be focused on **deriving an agronomic insight** from RS data

Your objective is not to own a drone, collect images, or even get a report

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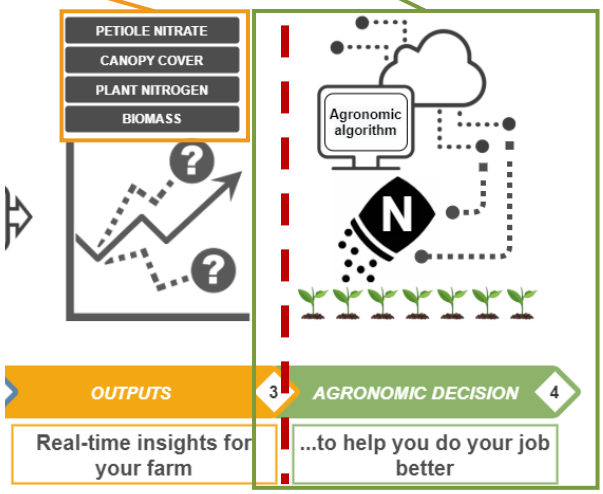
And these are the solutions to your agronomic problems

These are your objectives

You *probably* wouldn't trust me to make your decisions for you

...so you *probably* shouldn't expect remote sensing to either

It's a tool in the toolbox



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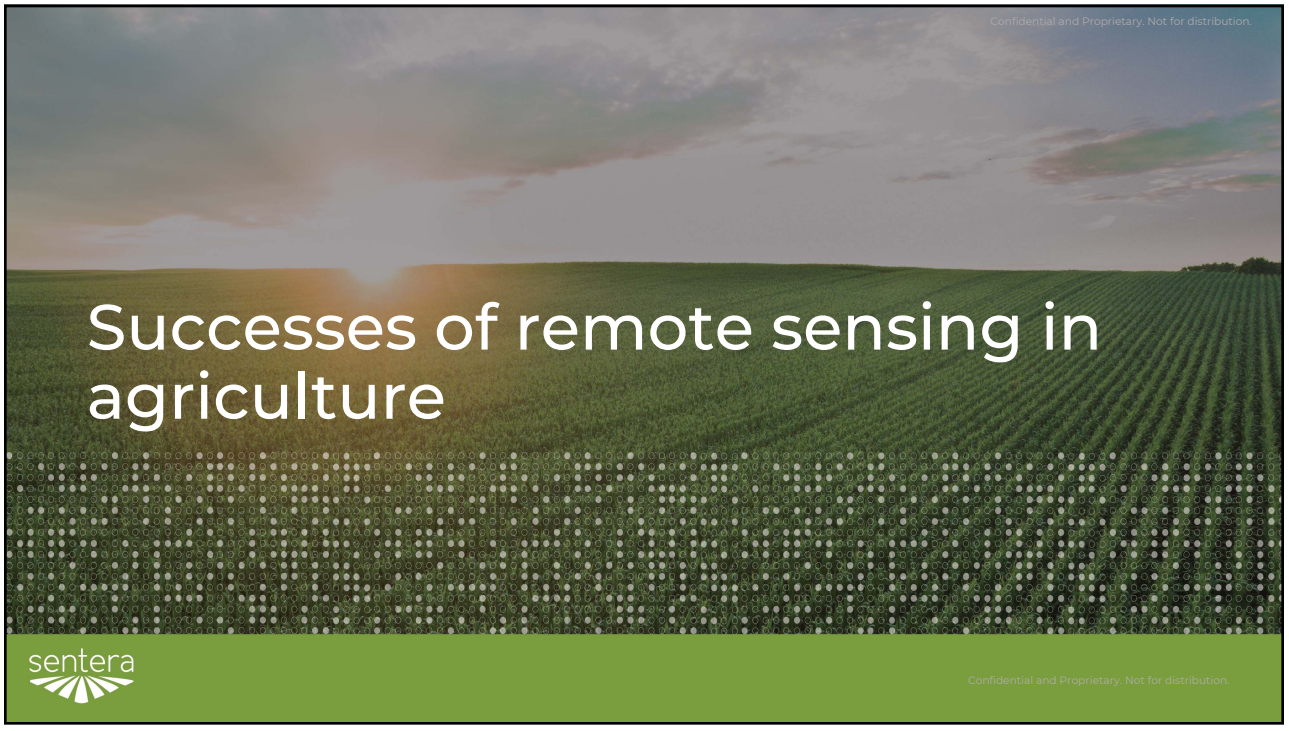

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In-season Petiole Nitrate Prediction (potato)

With satellite-based multispectral imagery

Objective: Predict in-season petiole nitrate concentration

Why: Spatiotemporal quantification of petiole nitrate helps to make more accurate fertigation decisions

Agronomic decision: Rate and timing of weekly N applications

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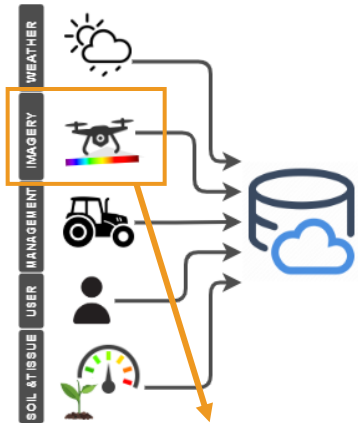
Input data



Remote sensing is just a tool in the toolbox

List of Input Data
Planting date
Cultivar
Daily weather summary
Multispectral satellite imagery (20m)
Nitrogen fertilizer rate and timing (*optional*)
Historical petiole nitrate tissue samples

Response variable

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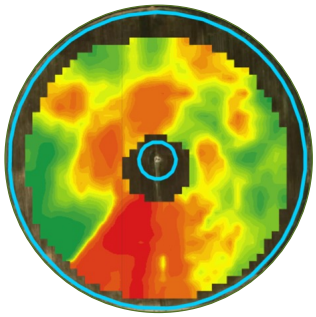
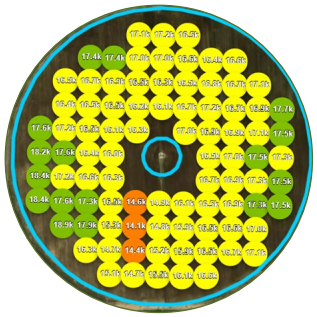
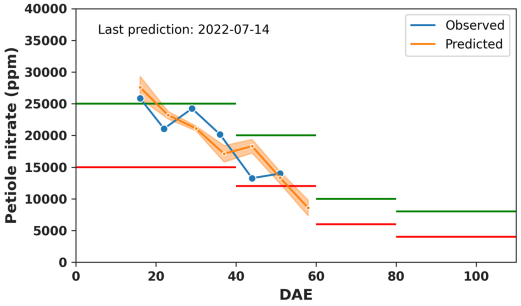
Results: Predicting petiole nitrate



Predicted petiole nitrate raster (20 m)



Predicted petiole nitrate points (1 ac)



Predicted vs. Observed (change over time)

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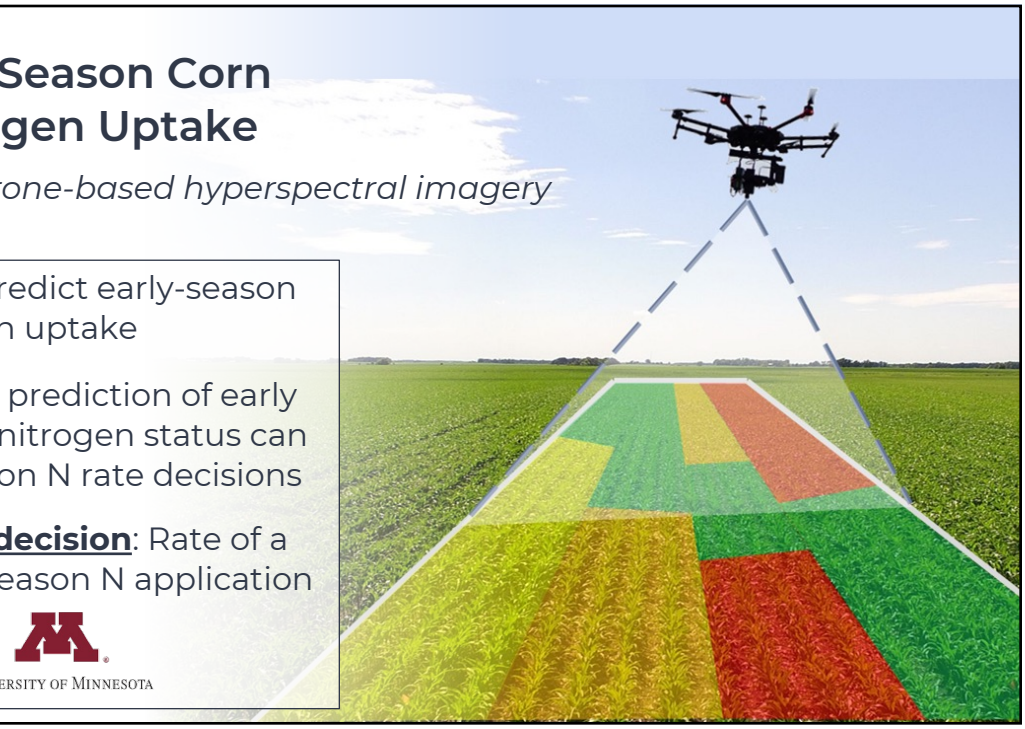
Early Season Corn Nitrogen Uptake

With drone-based hyperspectral imagery

Objective: Predict early-season corn nitrogen uptake

Why: Spatial prediction of early season crop nitrogen status can drive in-season N rate decisions

Agronomic decision: Rate of a planned in-season N application



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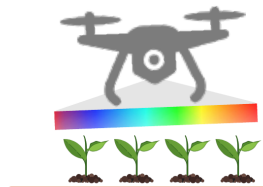
Methodology



CAPTURE 1 PROCESS 2 TRAIN 3 PREDICT 4

HYPERPARAMETER TUNING 3A CROSS-VALIDATION 3B

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Equipment

Drone:

DJI Matrice 600 Pro

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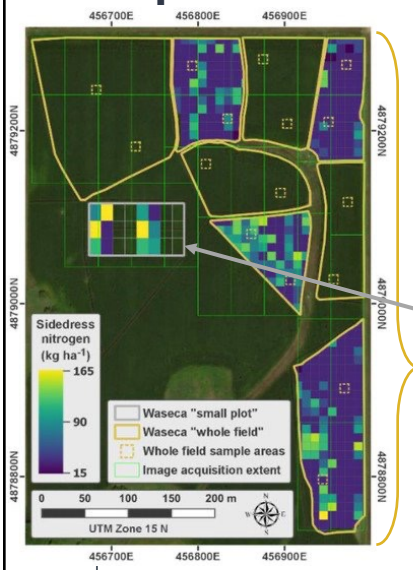
Experimental sites



Site	Altitude	Ground Speed	Ground Swath	Pixel Size	Area Captured	Cropped Plot Size
	m	m s^{-1}	m	cm	ha	m
Wells	40	4.0	23.7	4.0	4.5	6.2 × 1.8
Waseca small-plot [1]	20–25	2.0–2.5	11.8–14.8	2.0–2.5	0.7	1.8 × 1.8
Waseca whole-field	80	8.0	47.4	8.0	11.2	10 × 10

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Experimental Observations

Year	Experiment	Observation *n*	Stage	Sampling Date	Image Date	Image Time	Sample Area	Subsample *n*	Nitrogen Extraction
2018	Wells	143	V10	29 June 2018	28 June 2018	11:49–12:00	1.5 m × 5 m (2 rows)	6	Kjeldahl
2019	Waseca small-plot	24	V6	29 June 2019	29 June 2019	12:21–12:28	1.5 m × 2 m (2 rows)	10	Dry combustion
2019		24	V8	9/10 July 2019 [1]	09 July 2019	11:40–11:46	1.5 m × 2 m (2 rows)	10	Dry combustion
2019		24	V14	23 July 2019	23 July 2019	12:03–12:09	1.5 m × 2 m (2 rows)	6	Dry combustion
2019	Waseca whole-field	16	V8	10 July 2019	08 July 2019	13:06–13:17	5 m × 10 m (6 rows)	6	Dry combustion
2019		16	V14	23 July 2019	23 July 2019	12:32–12:42	5 m × 10 m (6 rows)	6	Dry combustion

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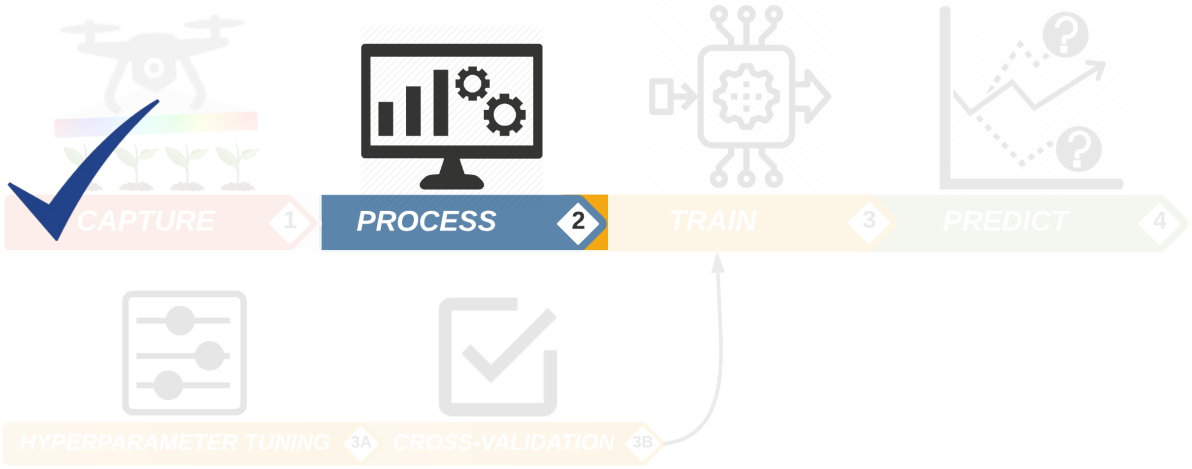
Methodology



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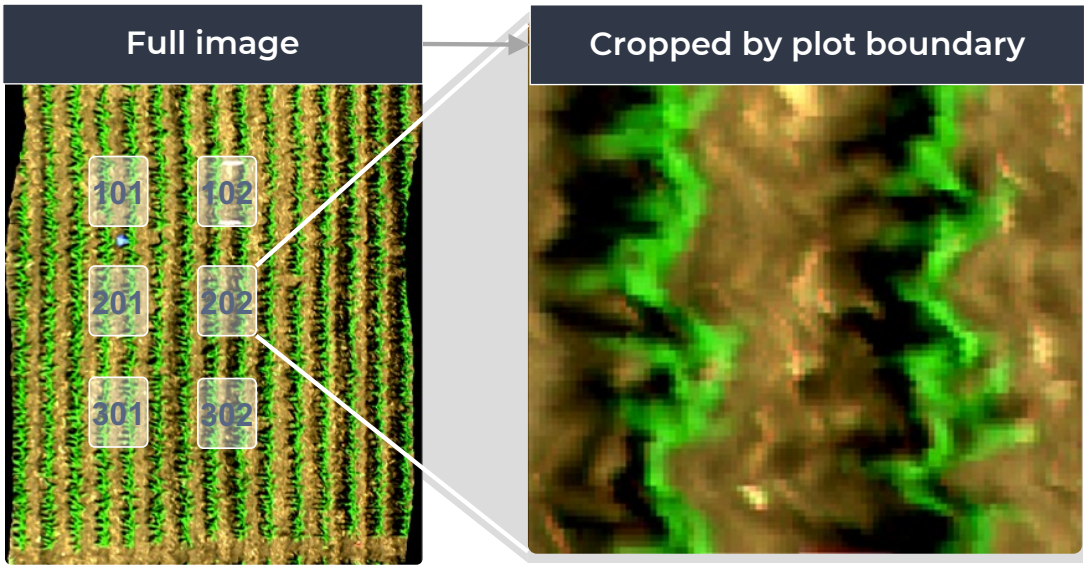

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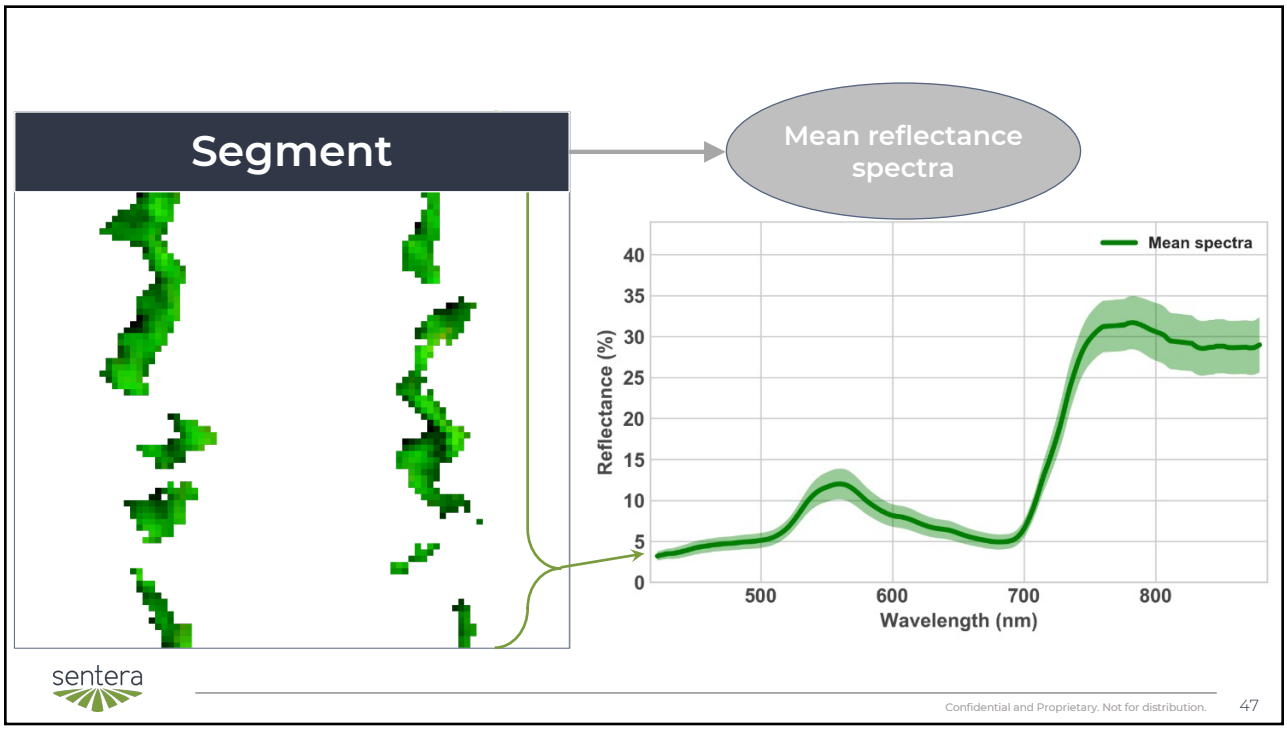
Segment
Mean reflectance spectra
Mean spectra
Reflectance (%)
0
5
10
15
20
25
30
35
40
500
600
700
800
Wavelength (nm)
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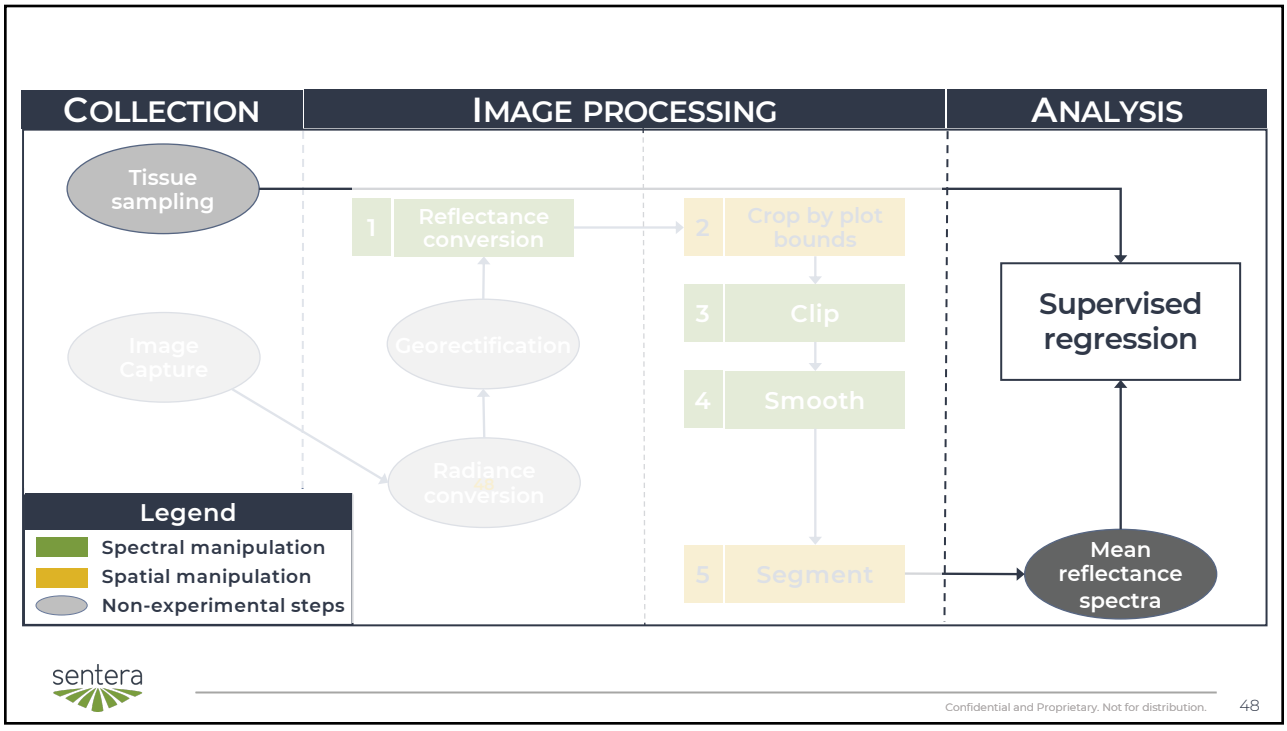
COLLECTION
IMAGE PROCESSING
ANALYSIS
Tissue sampling
Image Capture
1 Reflectance conversion
Georectification
Radiance conversion
2 Crop by plot bounds
3 Clip
4 Smooth
5 Segment
Supervised regression
Mean reflectance spectra
Legend
Spectral manipulation
Spatial manipulation
Non-experimental steps
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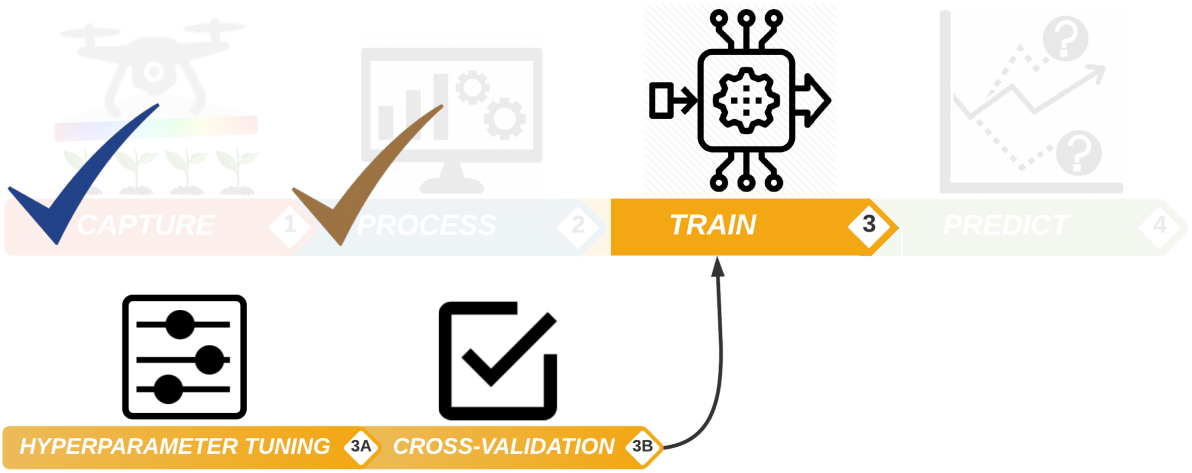
Materials and Methods



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Cross-validation

(how accurate can we expect this model to be in "the real world"?)

Full dataset (*n* = 247)

60% Training set (*n* = 148) | 40% Test set (*n* = 99)

Used for hyperparameter tuning, feature selection, and model training

Reserved to independently assess final model performance

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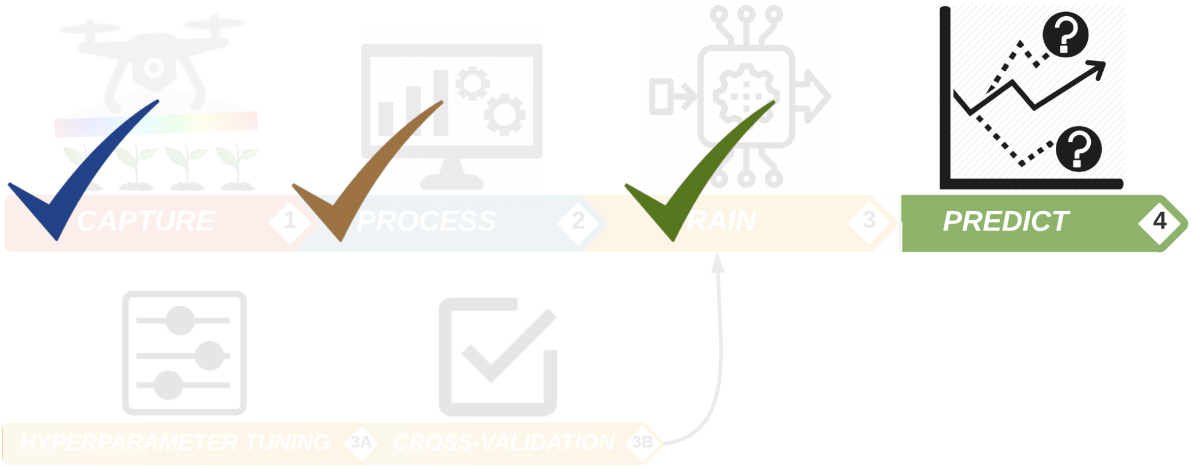
Materials and Methods



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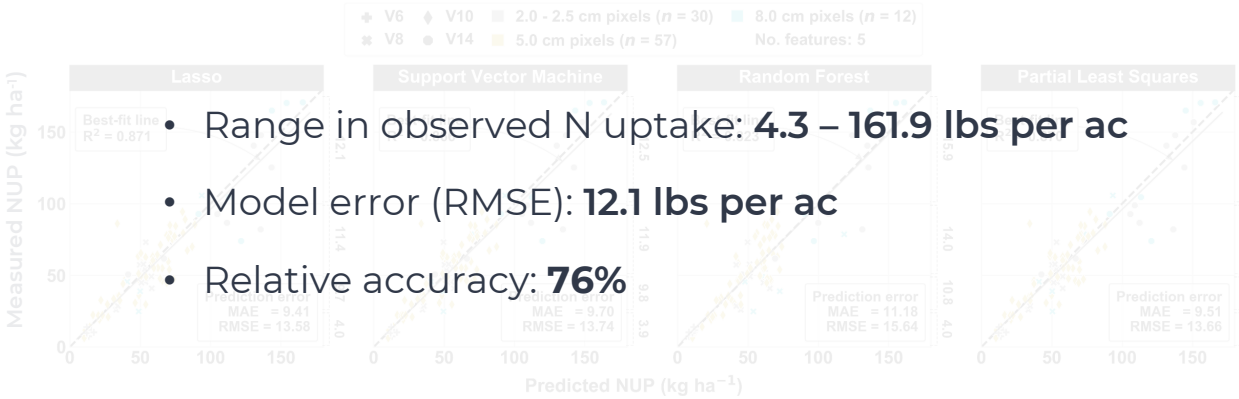
Objective: Predict early-season corn nitrogen uptake (V6 – V14)



- Range in observed N uptake: **4.3 – 161.9 lbs per ac**
- Model error (RMSE): **12.1 lbs per ac**
- Relative accuracy: **76%**

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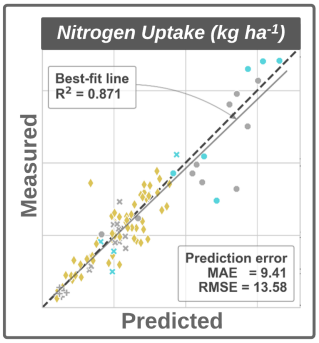
Can hyperspectral imagery predict early-season N uptake?

Yes, with very high accuracy!



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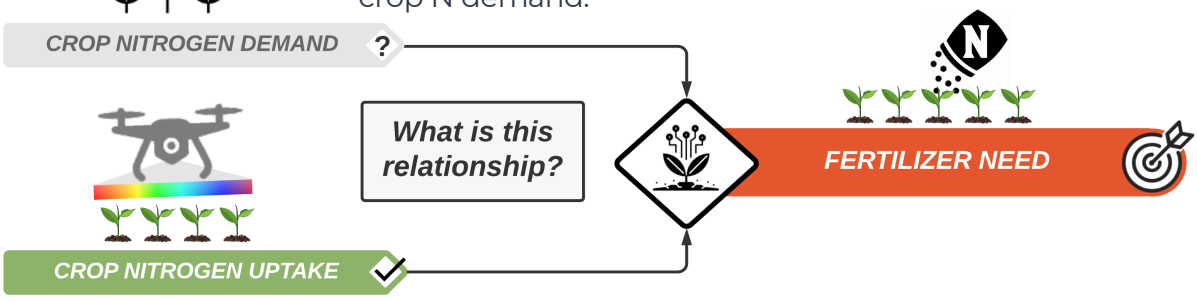
Is hyperspectral imagery useful for making a fertilizer recommendation?

Probably…

- Cost of hyperspectral equipment is still high.
- Image capture and processing turnaround is less than ideal.
- Little is known about early-season N uptake and upcoming crop N demand.



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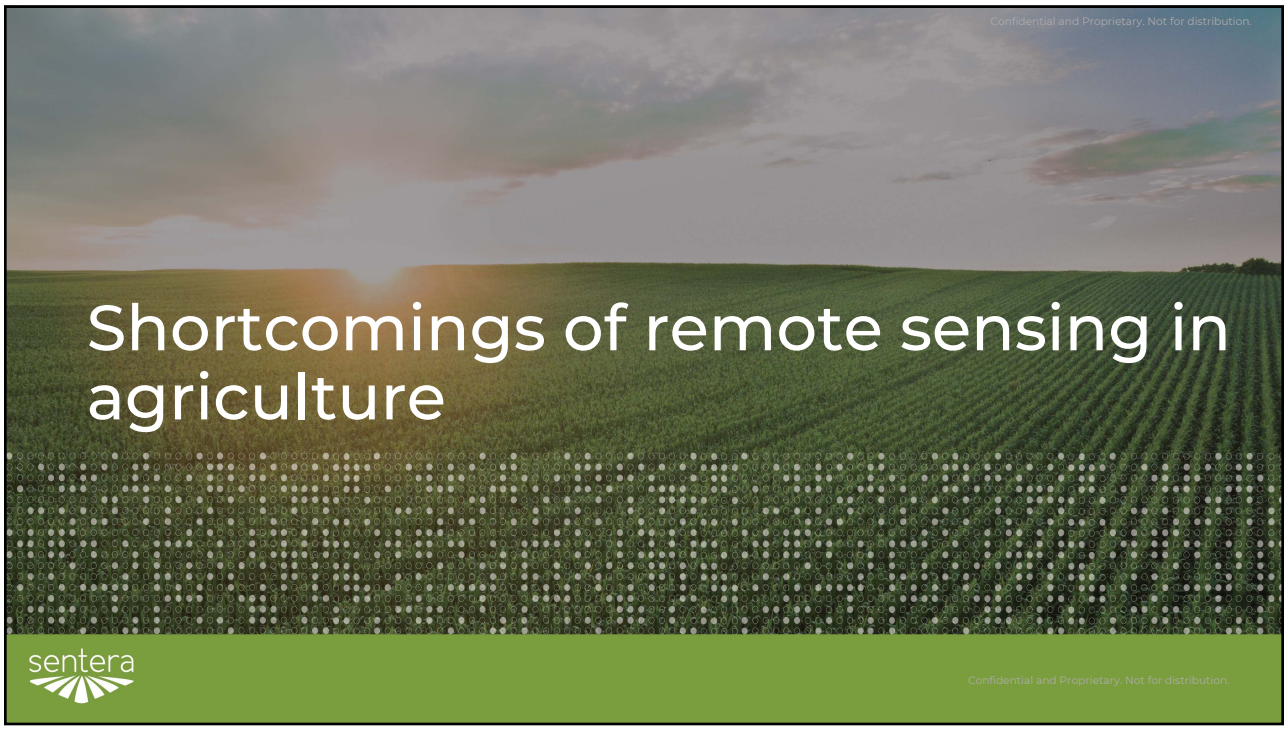
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Shortcomings of remote sensing in agriculture
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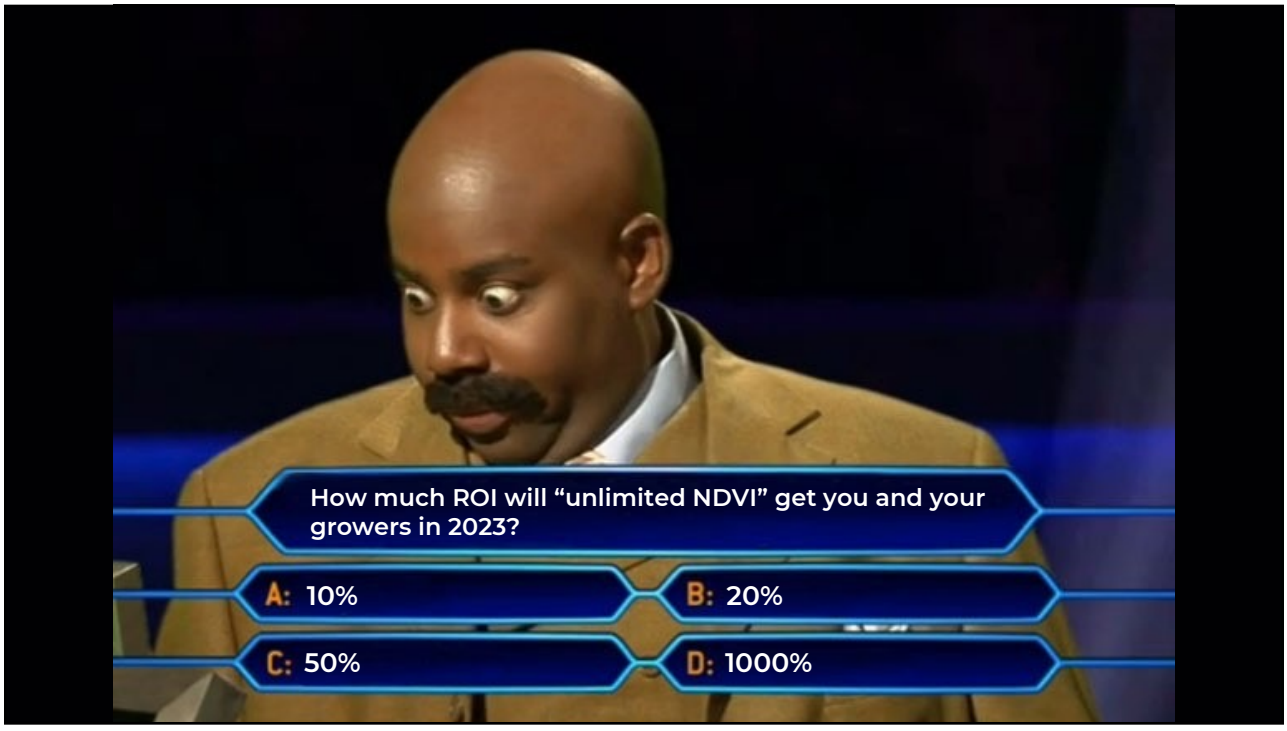
How much ROI will “unlimited NDVI” get you and your growers in 2023?
A: 10%
B: 20%
C: 50%
D: 1000%

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Theme:

Use of remote sensing for agriculture has **over-promised** and **under-delivered**

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NDVI: so what?

Shortcomings of remote sensing in agriculture

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Modified Simple Ratio (MSR)

This index was developed an an improvement over RDVI by combining the Simple Ratio into the formula. The result is increased sensitivity to vegetation biophysical parameters.

$$MSR = \frac{\left(\frac{NIR}{Red}\right) - 1}{\left(\sqrt{\frac{NIR}{Red}}\right) + 1}$$

Reference: Chen, J. "Evaluation of Vegetation Indices and Modified Simple Ratio for Boreal Applications." *Canadian Journal of Remote Sensing* 22 (1996): 229-242.

Non-Linear Index (NLI)

This index assumes that the relationship between many vegetation indices and surface biophysical parameters is non-linear. It linearizes relationships with surface parameters that tend to be non-linear.

$$NLI = \frac{NIR^2 - Red}{NIR^2 + Red}$$

Reference: Goel, N., and W. Qin. "Influences of Canopy Architecture on Relationships Between Various Vegetation Indices and LAI and Fpar: A Computer Simulation." *Remote Sensing Reviews* 10 (1994): 309-347.

Normalized Difference Vegetation Index (NDVI)

This index is a measure of healthy, green vegetation. The combination of its normalized difference formulation and use of the highest absorption and reflectance regions of chlorophyll make it robust over a wide range of conditions. It can, however, saturate in dense vegetation conditions when LAI becomes high.

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

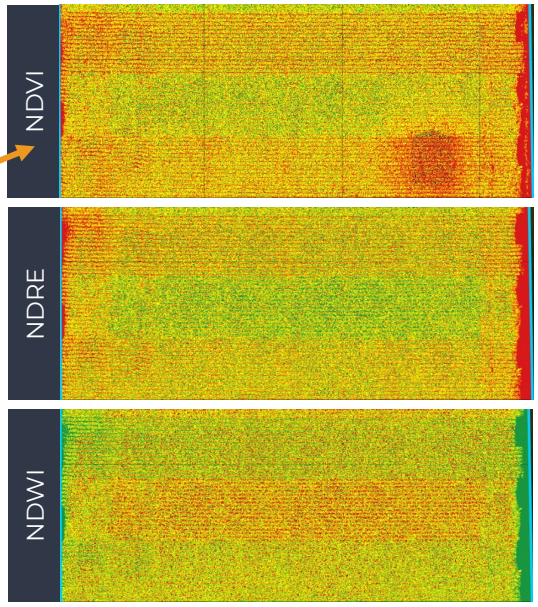
The value of this index ranges from -1 to 1. The common range for green vegetation is 0.2 to 0.8.

Reference: Rouse, J., R. Haas, J. Schell, and D. Deering. *Monitoring Vegetation Systems in the Great Plains with ERTS.* Third ERTS Symposium, NASA (1973): 309-317.

Normalized Pigment Chlorophyll Index (NPCI)

This index assess the cars to chlorophyll ratio at the leaf level.

$$NPCI = \frac{(\rho_{680} - \rho_{430})}{(\rho_{680} + \rho_{430})}$$



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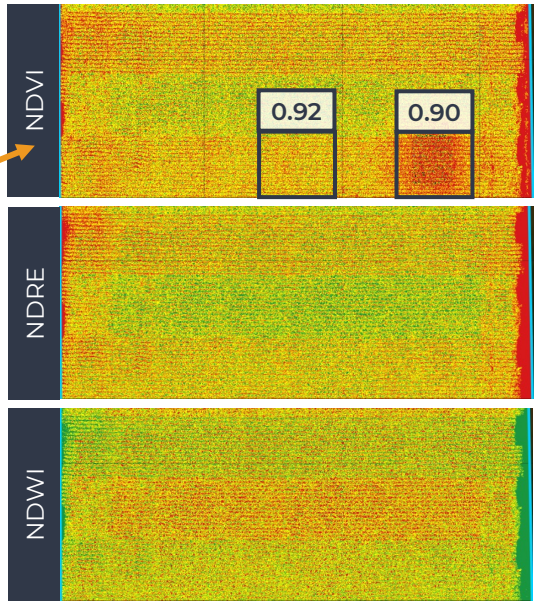

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Fun fact: NDVI is going to be 50 years old next year!

$$MSR = \frac{\left(\frac{NIR}{Red}\right) - 1}{\left(\frac{NIR}{\sqrt{Red}}\right) + 1}$$

Reference: Chen, J. "Evaluation of Vegetation Indices and Modified Simple Ratio for Boreal Applications." *Canadian Journal of Remote Sensing* 22 (1996): 229-242.

Non-Linear Index (NLI)

This index assumes that the relationship between many vegetation indices and surface biophysical parameters is [illegible] linearizes relationships with surface parameters that tend to be non-linear.

Reference: Rouse, J., R. Haas, J. Schell, and D[illegible] ERTS Symposium, NASA (1973): 309-317.

Normalized Difference Vegetation Index (NDVI)

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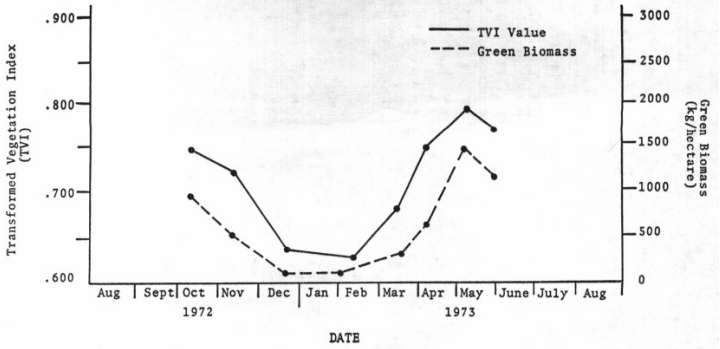
$$NPCI = \frac{(\rho_{680} - \rho_{430})}{(\rho_{680} + \rho_{430})}$$

MONITORING VEGETATION SYSTEMS IN THE GREAT PLAINS WITH ERTS

J. W. Rouse, Jr., R. H. Haas, J. A. Schell and D. W. Deering, *Remote Sensing Center, Texas A&M University, College Station, Texas*

Figure 4. ERTS-1 Transformed Vegetation Index Values Vs. Green Biomass Data

NDVI correlates well with green biomass; but it does not pick up chlorosis very well



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https://ntrs.nasa.gov/citations/19740022614

Accessibility

Shortcomings of remote sensing in agriculture

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Accessibility

Licensing (Part 107) for data capture

Data storage and management

Technical "know-how"

Understanding of data (image) quality

"Garbage in, garbage out!"

Satellites vs Drones

Which sensor do I need?

Image processing (knowledge, software, **time**)

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Expectation of RS to be an "off-the-shelf" product

Remote sensing is more akin to "no-till" in Wisconsin than products like Roundup

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What is your objective?

Identify the **problem** and **how it can be solved**

Consider… the **goals** of your agronomy program

Why are you collecting the data you do?

What do you intend to get out of remote sensing?

Consider… the **ground-truth data** you routinely collect

Are you going to let someone like me tell you what problems you can solve, or are you willing to define the problems (and solutions) yourself?

It's just a tool in the toolbox – remote sensing is better with weather, soils, ground truth data, etc. to go along with it!

Your objective should be focused on **deriving an agronomic insight** from RS data

Your objective is not to own a drone, collect images, or even get a report

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1. Be proactive

(and take responsibility)

Define what your unique problems are, and create your own customized solutions

- Don't expect an "off-the-shelf" solution for every one of your unique problems
- There is too much spatial and temporal variability present for a "one-size-fits-all" product

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2. Build your "data inventory"

(i.e., data management)

Collect your data for the long haul

- If we do a good job, data we collect now will be used for decades into the future
- Your models derived from your data are living and breathing – they can improve with every season

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3. Use other tools

(but don't give up on RS)

Can you solve your problem using methods that don't include remote sensing?

- Remote sensing will help that solution scale
- Start simple, and work up from there

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Your role for the future of RS

1. Be proactive
2. Build your "data inventory"
3. Use other tools

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THANK YOU!
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