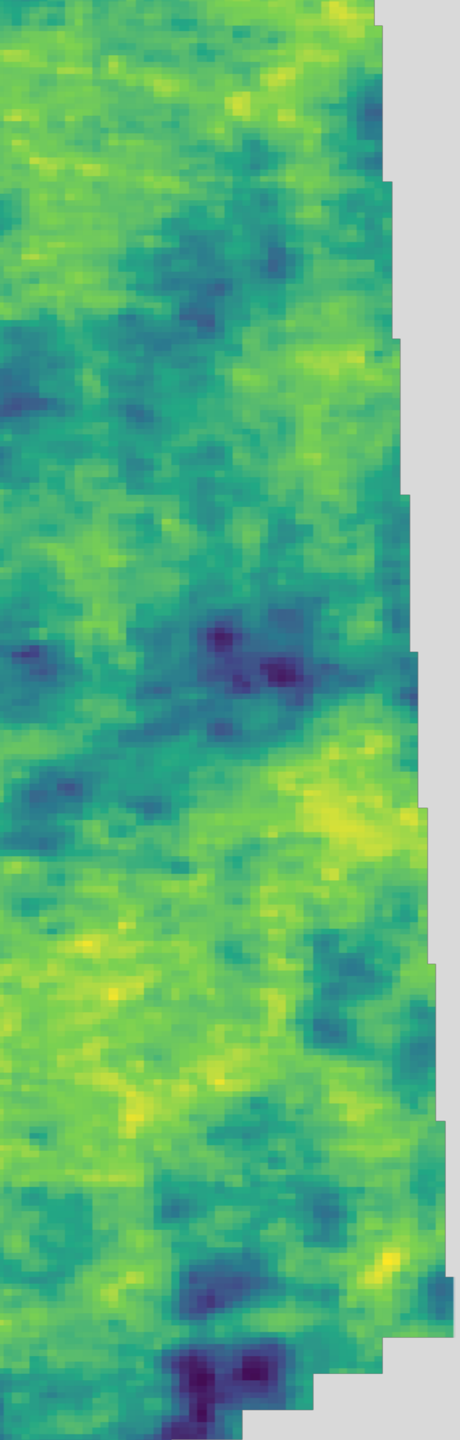

Crop canopy sensors and variable rate fertilizer

Advanced Topics in Precision Ag

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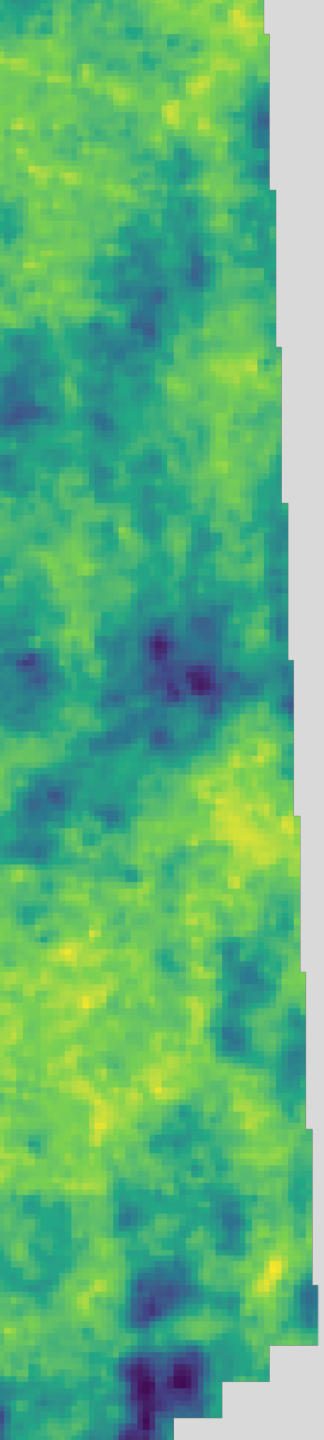
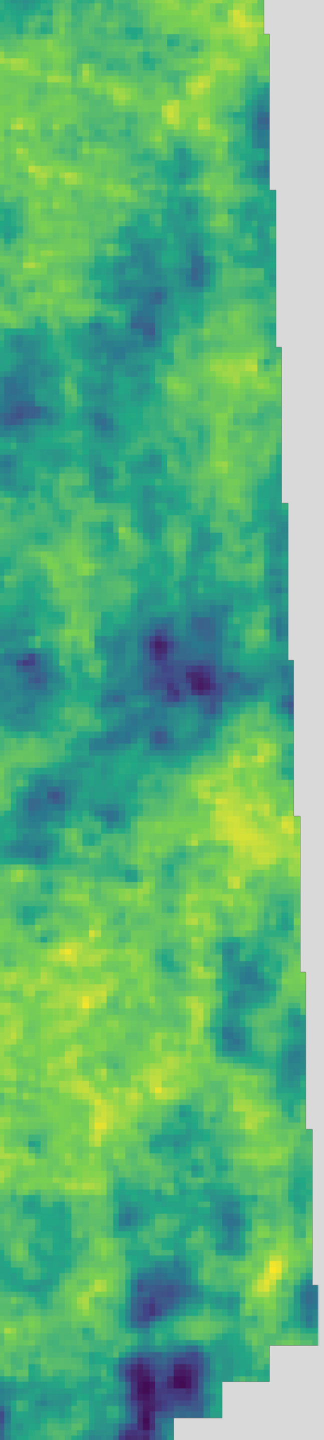
Apr 24th 2023

College of Agricultural & Environmental Sciences
UNIVERSITY OF GEORGIA



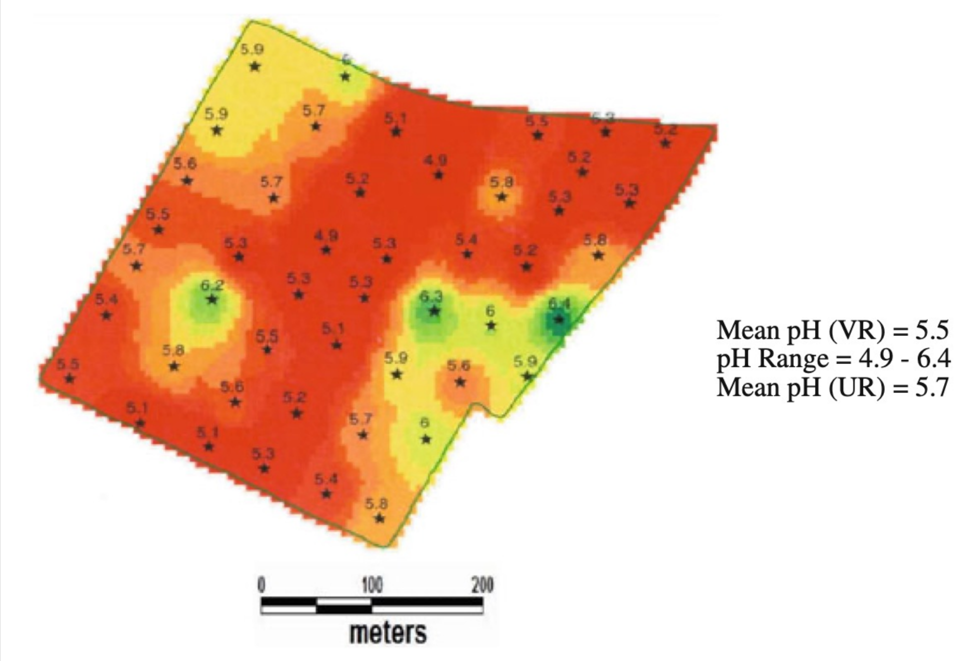
Learning goals for today

1. Review within-field variability
2. Understand variable rate nitrogen components
3. Understand differences among variable rate algorithms
4. Learn the concept of high-N reference and sufficiency index
5. Calculate variable rate nitrogen application
6. Understand how all components come together to perform variable rate N application and effects on N rate and yield

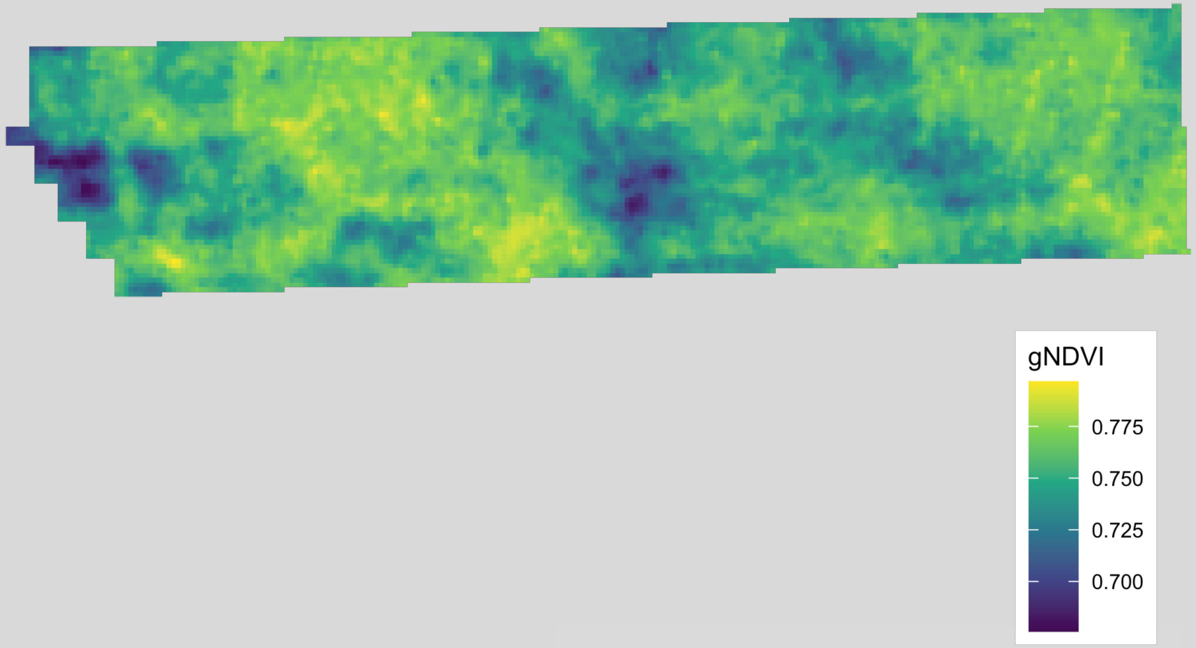


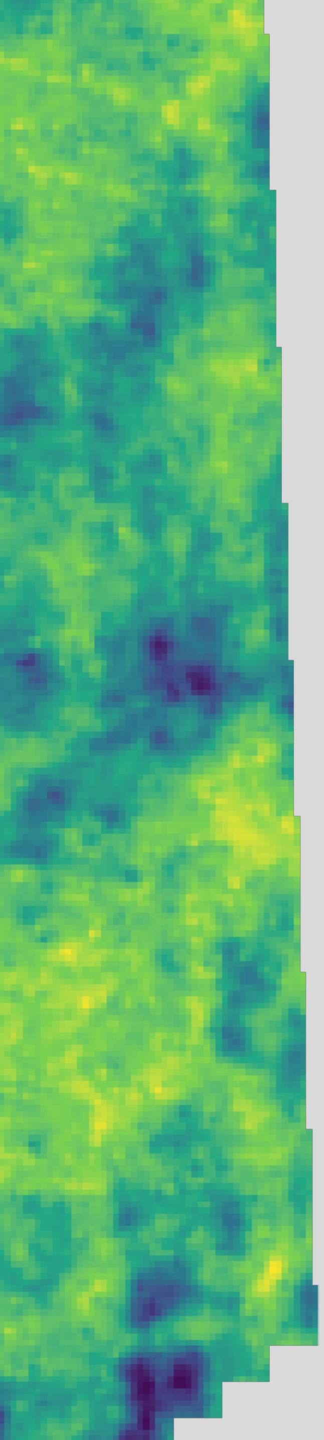
Why variable rate?

Soil pH



Crop vigor





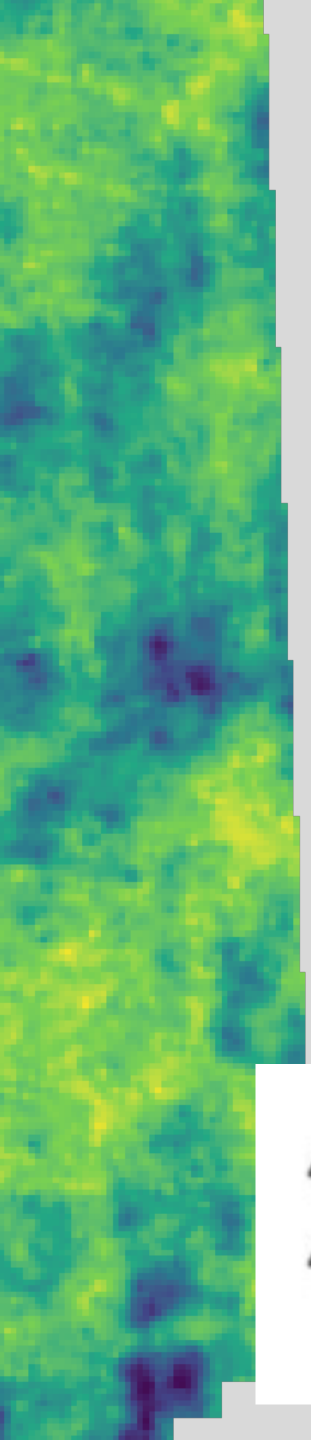
Types of variable rate management stable vs. unstable nutrient

Stable nutrient

- Immobile in the soil
- Soil levels change gradually over time
- Can be corrected/built up with effects lasting more than one growing season
- Examples: ________________

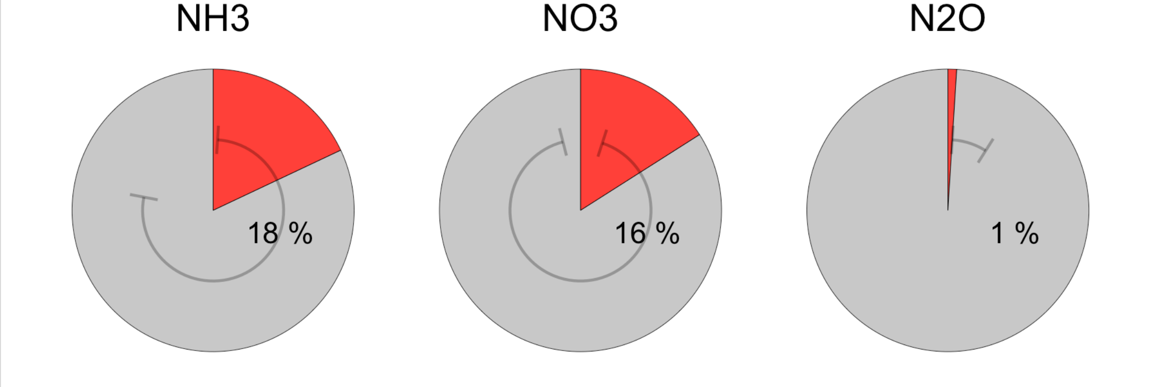
Unstable nutrient

- Very mobile in the soil
- Soil levels can change rapidly due to weather/fertilizer/crop uptake
- Needs to be applied every season (1+ times)
- Examples: ________________



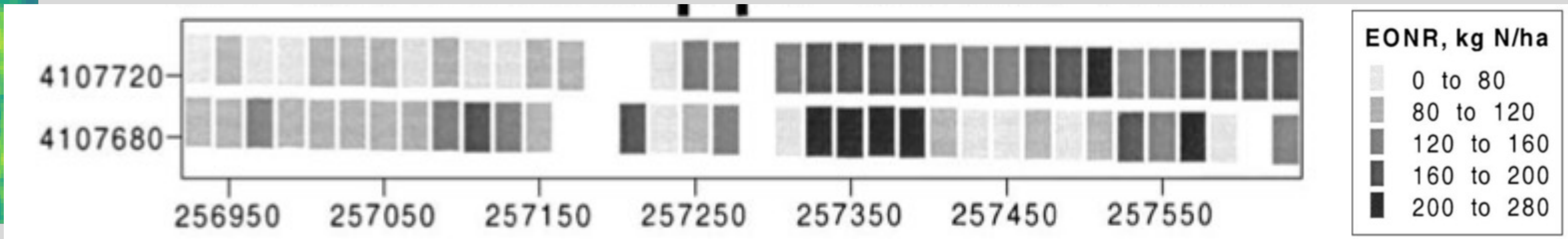
Nitrogen (N)

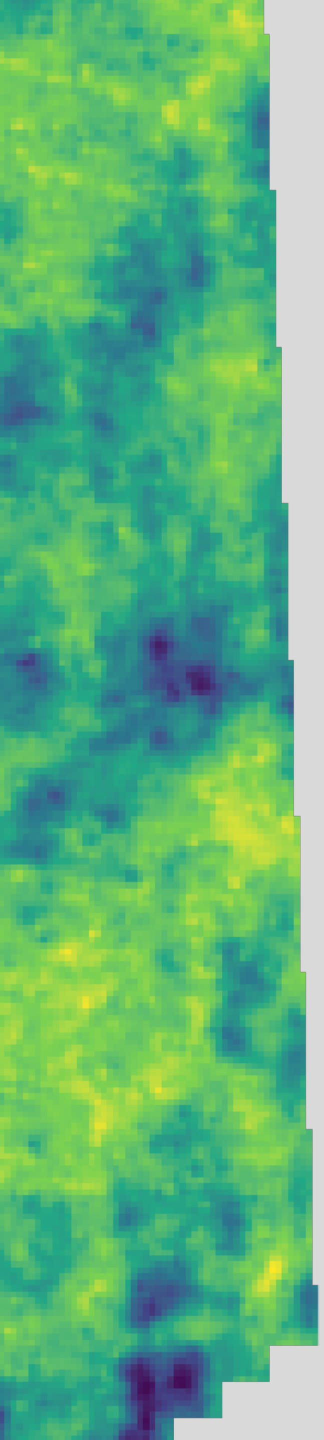
- Unstable: environmental losses



- N is one of most limiting factors on yield for non-legume crops like **corn** and **cotton**

- N needed to maximize $ varies within a field

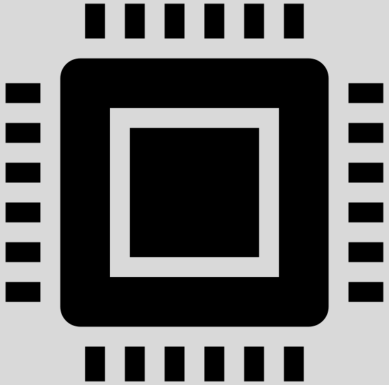




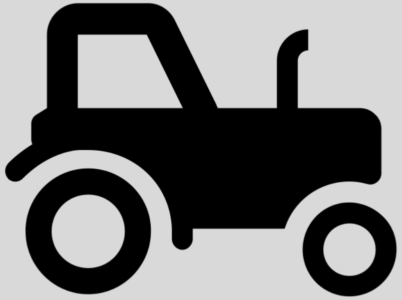
3 variable rate N components

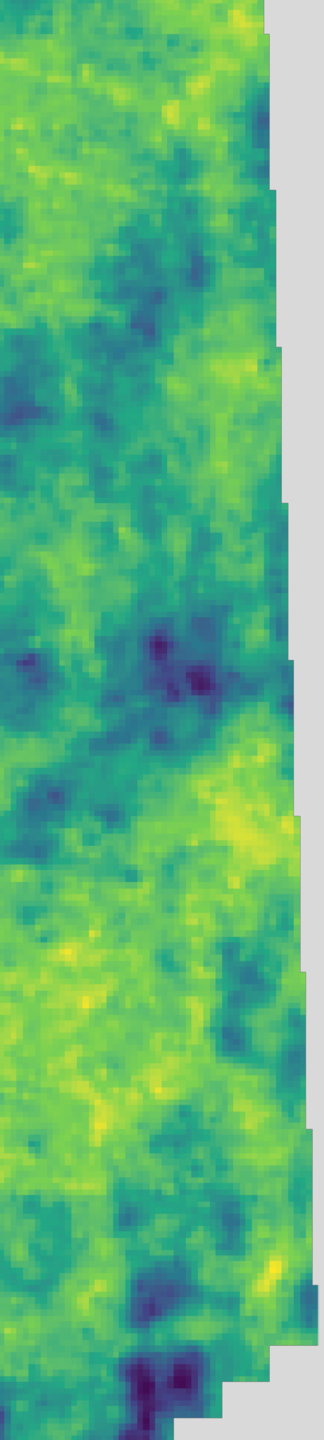
Sensor

Algorithm

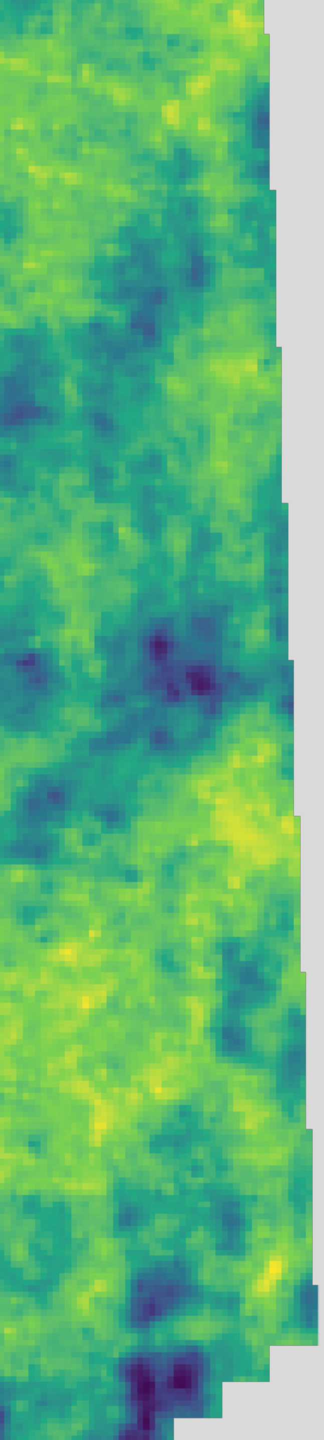


VR equipment





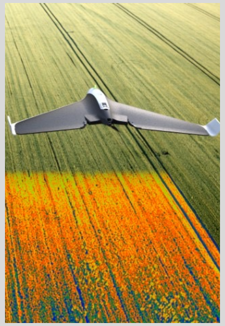
Sensor



Variable rate N components: **Sensor**

Sensor types

- **Active** sensor: emits its own light source
- **Proximal** sensor: close to the target
- **Real-time**: crop sensing and variable rate application done simultaneously
- **Data processing**: automated, little know-how required
- Commercial example: Ag Leader OptRx, Greenseeker

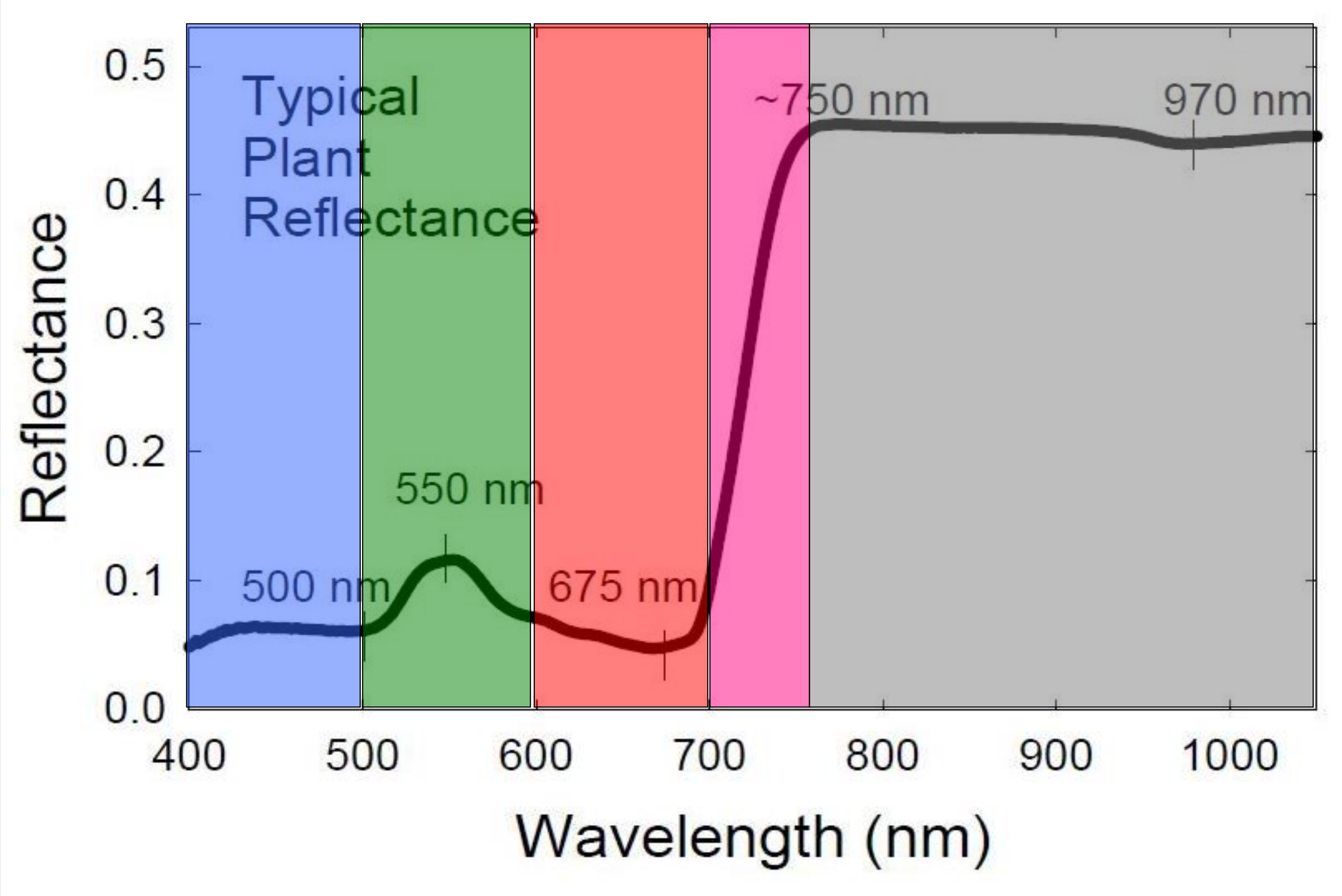


- **Passive** sensor: relies on external light source (sunlight)
- **Remote** sensor: far from the target
- **Sense then treat**: crop sensing and variable rate application done separately
- **Data processing**: intensive, lots of know-how required
- Commercial examples: DJI + MicaSense, eBee + sequoia

- **Passive** sensor: relies on external light source (sunlight)
- **Remote** sensor: very far from the target
- **Sense then treat**: crop sensing and variable rate application done separately
- **Data processing**: intensive, lots of know-how required
- Commercial examples: Planet, Sentinel

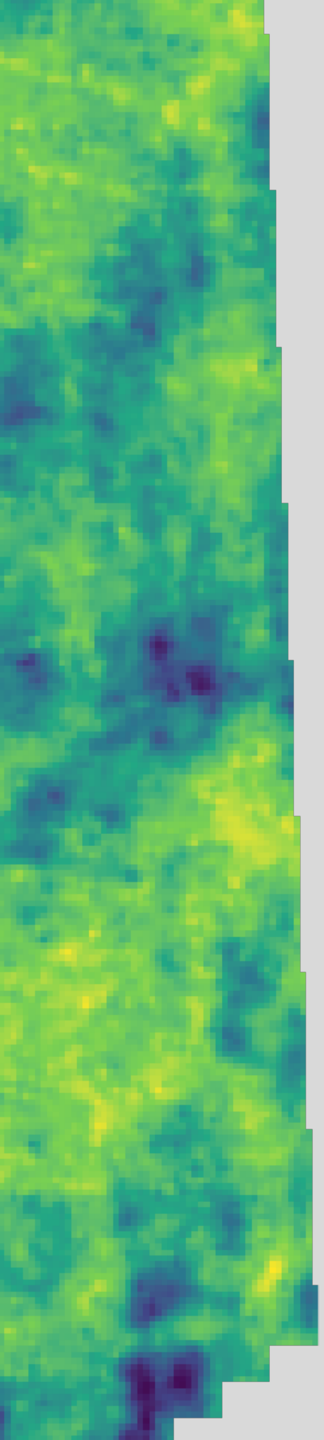
Variable rate N components: **Sensor**

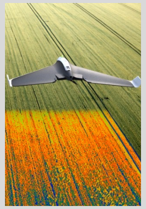
Sensor bands

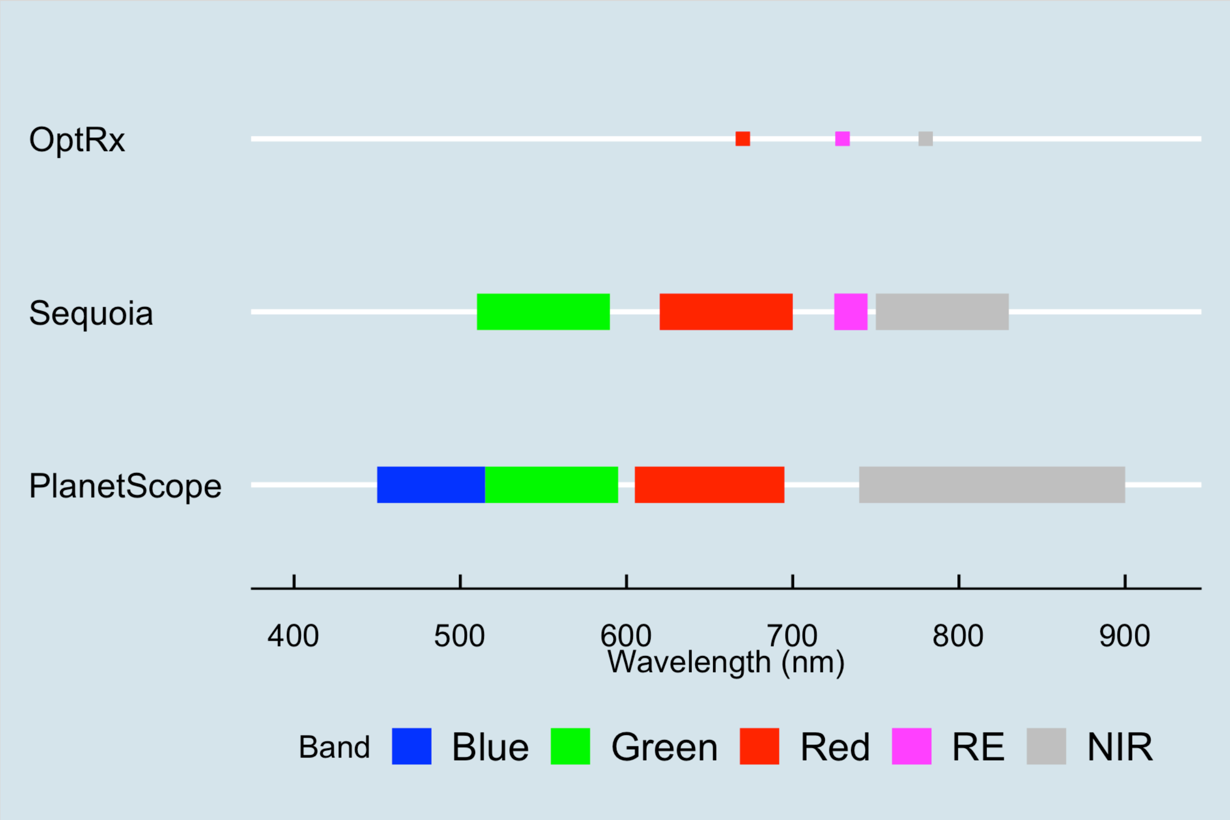


Variable rate N components: **Sensor**

Sensor <u>bands</u>





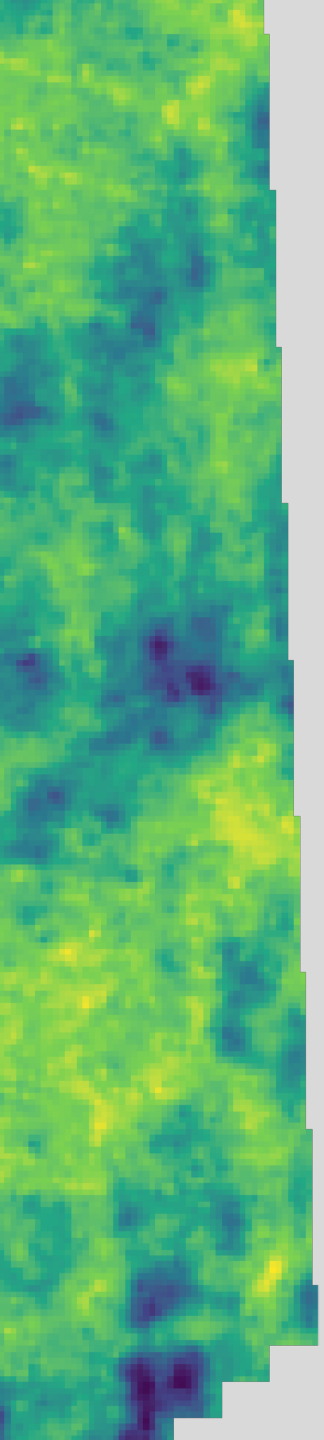


- Different sensors have different bands

- Even the same band will be the average of different wavelengths (look at NIR)

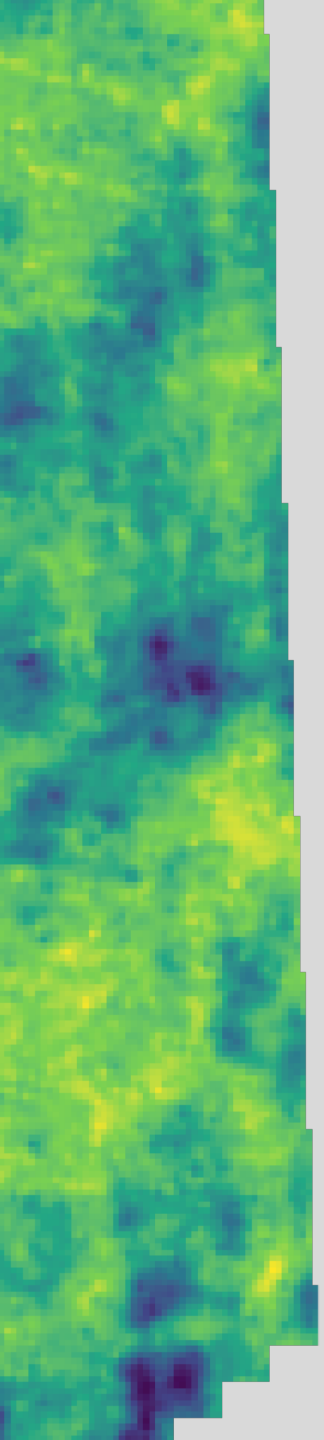
- Bands are not created equally across different sensors

Why are these bands useful in agriculture?

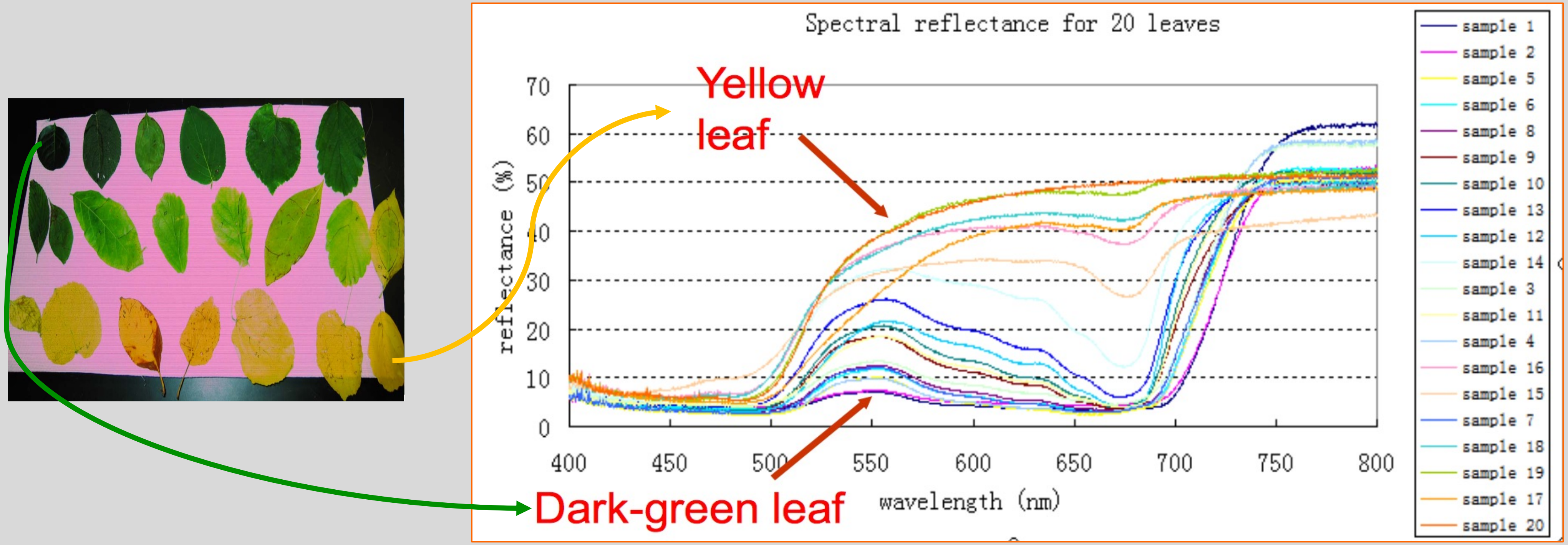


Variable rate N components: **Sensor**
Bands and plant characteristics

Sample #	Chl Content (mg/m2)
1	669
2	565
3	381
4	368
5	347
6	309
7	286
8	269
9	161
10	126
11	156
12	98
13	73
14	25
15	11
16	25
17	5
18	12
19	4
20	4



Variable rate N components: **Sensor** Bands and plant characteristics

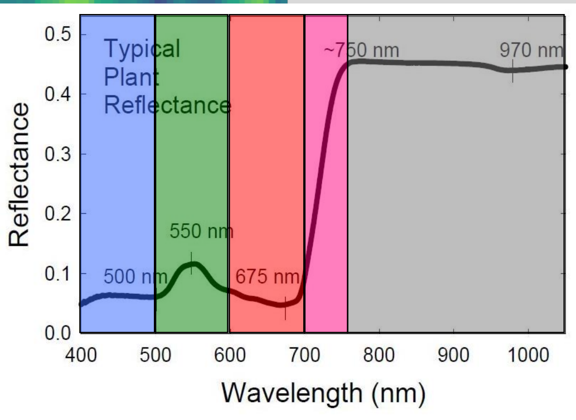


- **Visible** region (400-700 nm): related to leaf pigment
- **NIR** region (800-1200 nm): related to leaf structure/biomass

To assess if a crop is healthy, need to know **both**. How can we combine them?

Variable rate N components: **Sensor**

Sensor vegetation indices



Normalized Difference Vegetation Index (NDVI)

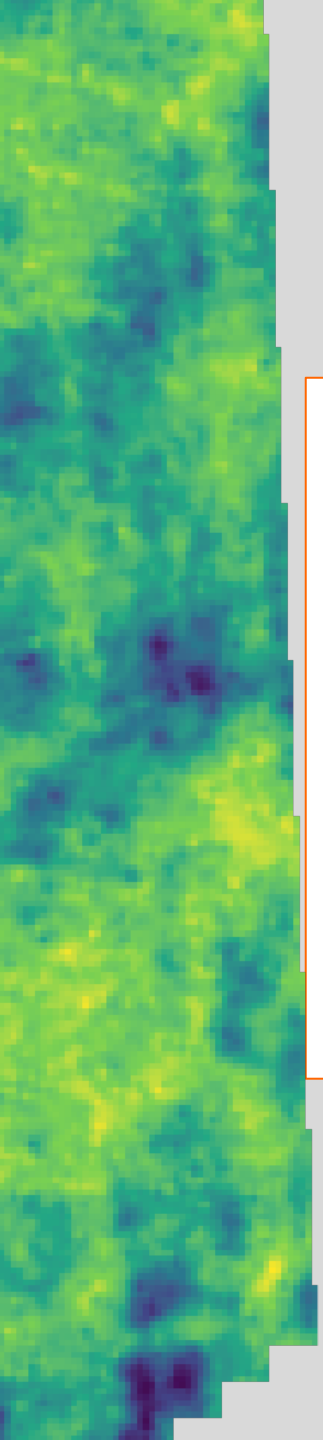
$$\mathrm{NDVI} = \frac{NIR - Red}{NIR + Red}$$

Green Normalized Difference Vegetation Index (GNDVI)

$$\mathrm{GNDVI} = \frac{NIR - Green}{NIR + Green}$$

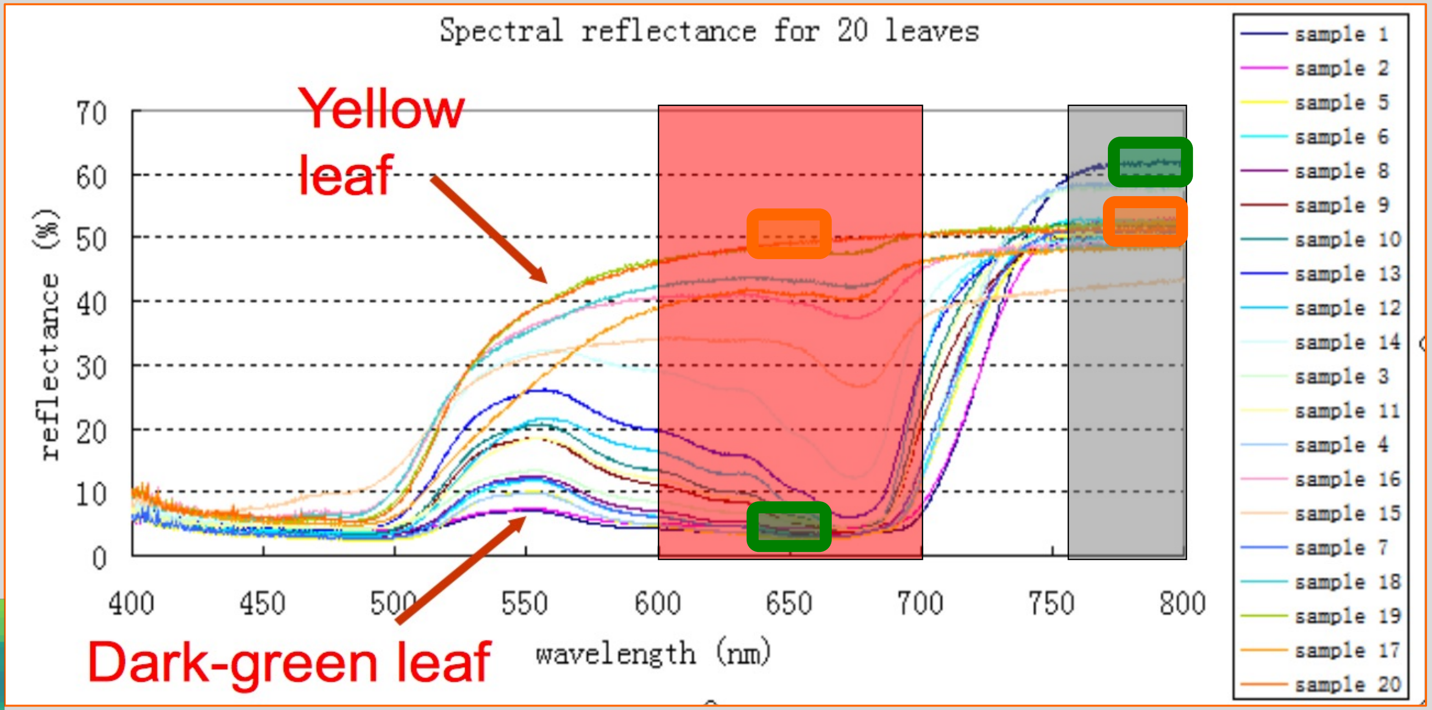
Normalized Difference Red Edge (NDRE)

$$\mathrm{NDRE} = \frac{NIR - RE}{NIR + RE}$$



Variable rate N components: **Sensor**

Sensor vegetation indices

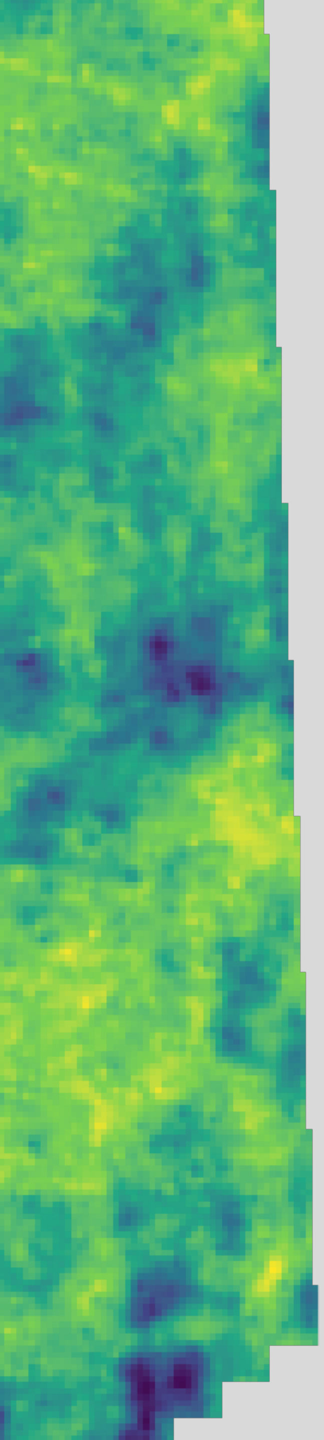


Let's calculate NDVI:

$$\mathrm{NDVI} = \frac{NIR - Red}{NIR + Red}$$

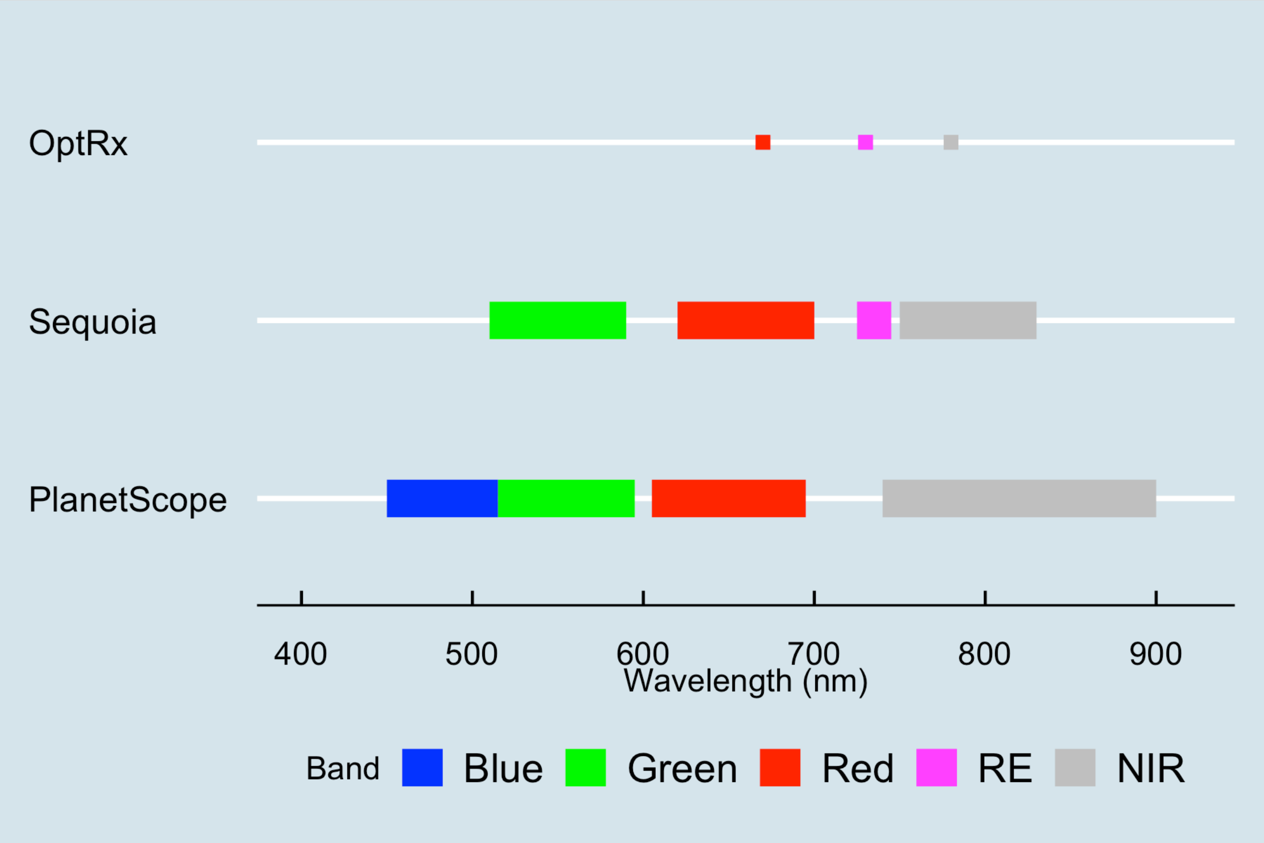
NDVI for dark-green leaf = $\frac{60 - 4}{60 + 4} = \frac{56}{64} =$

NDVI for yellow leaf = $\frac{50 - 45}{50 + 45} = \frac{5}{95} =$



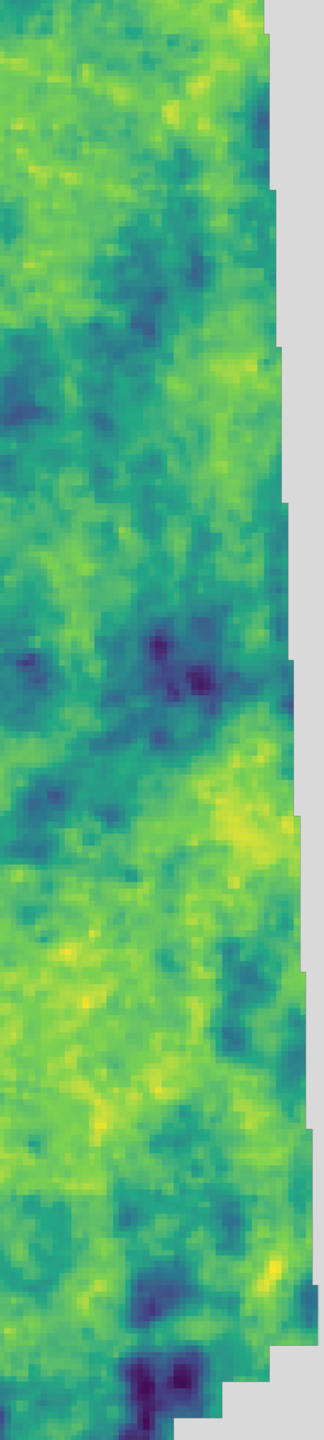
Variable rate N components: **Sensor**

Sensor vegetation indices

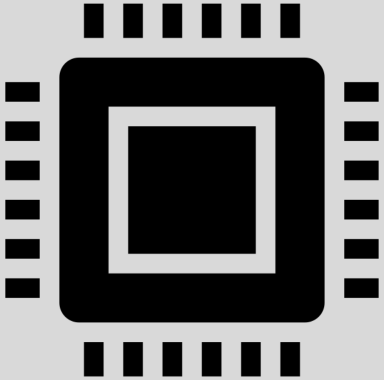


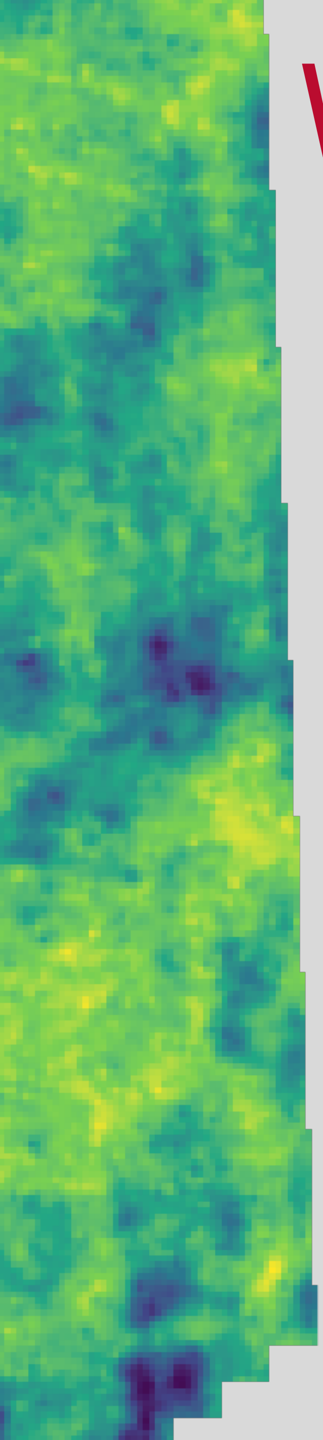
Available bands in a sensor will dictate what vegetation indices can be calculated with that sensor.

Can we calculate all 3 VIs for all the sensors here?



Algorithm





Variable rate nitrogen components: **Algorithm**

2 Algorithm types

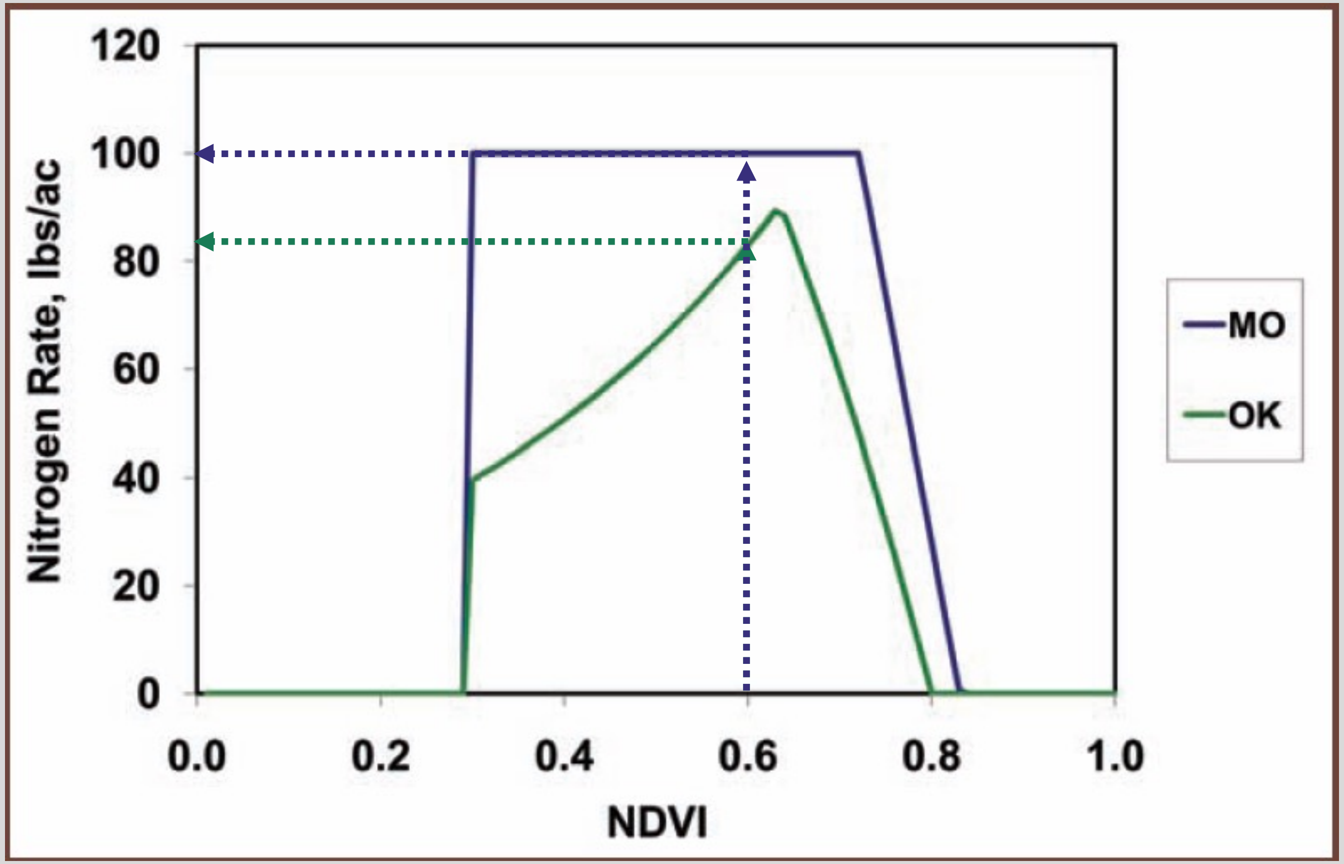
<u>VI-specific</u>

- Built relating **one VI** with N rates
- Normally built with data collected in one specific state
- May not work well in other states/regions

<u>VI non-specific</u>

- Built relating **any normalized VI** with N rates
- Built based on generalized response of yield to N
- More likely to work in other states/regions

Variable rate nitrogen components: **Algorithm**
Algorithm types: 1. VI-specific



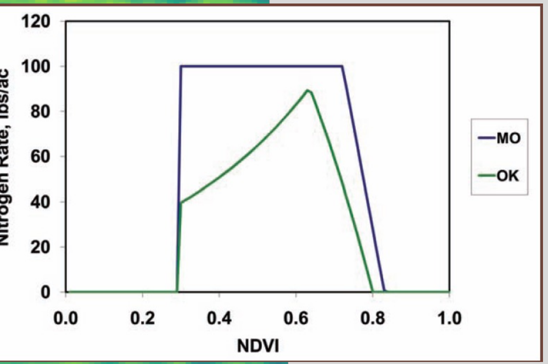
- N rate depends on NDVI

- Missouri and Oklahoma algorithms

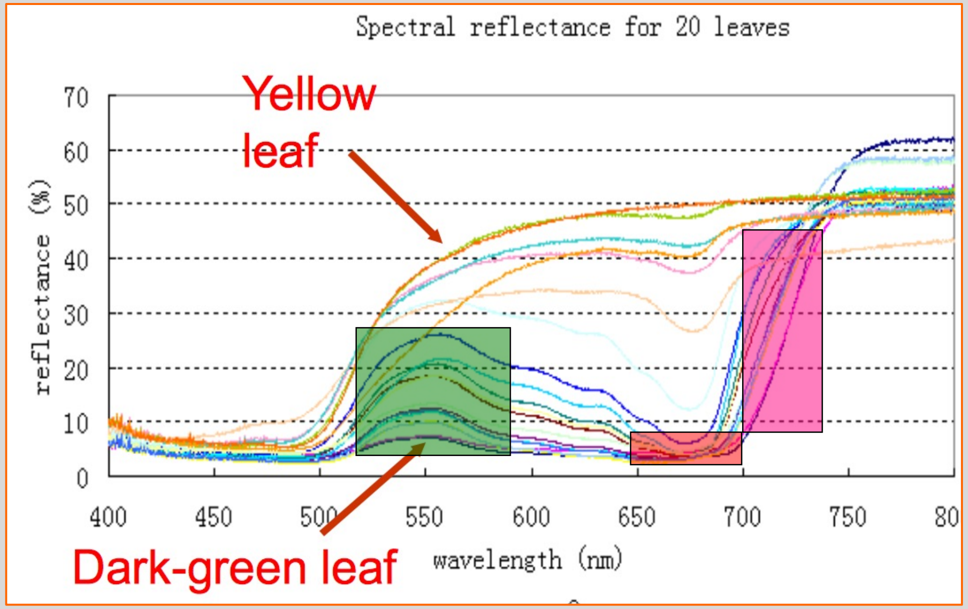
- If NDVI = 0.6,
  OK ~ 83 lbs N/ac
  MO ~100 lbs N/ac

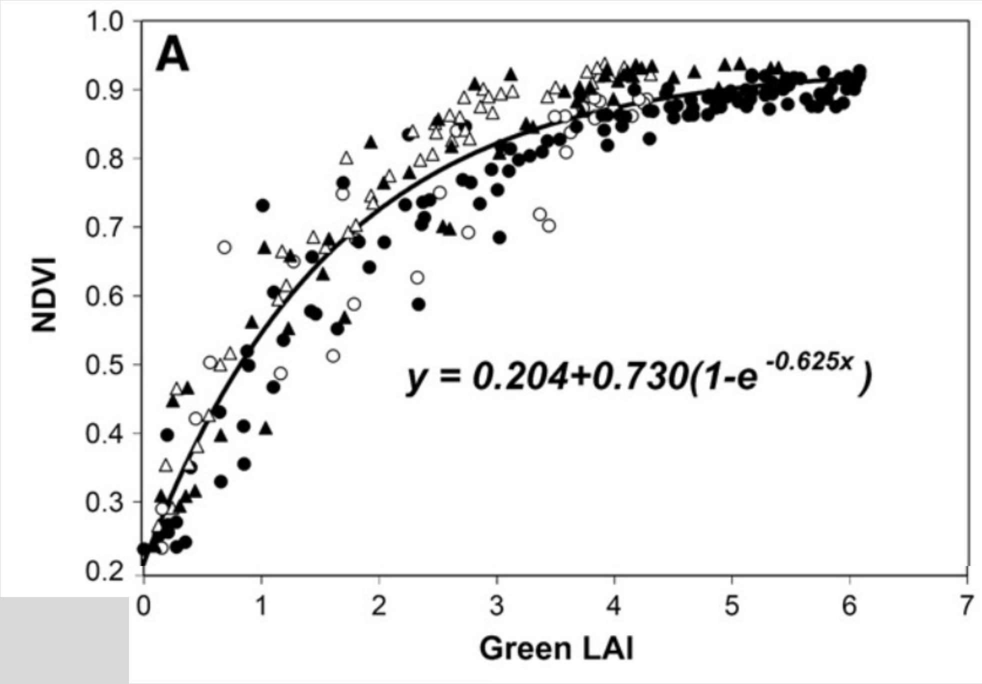
Variable rate nitrogen components: **Algorithm**

<u>Issues</u> with VI-specific algorithm



Simple, but what if ❌ NDVI is not the best VI option



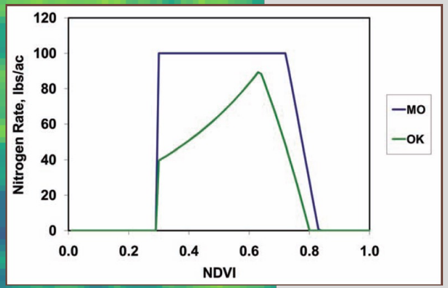


Can we use a different VI?

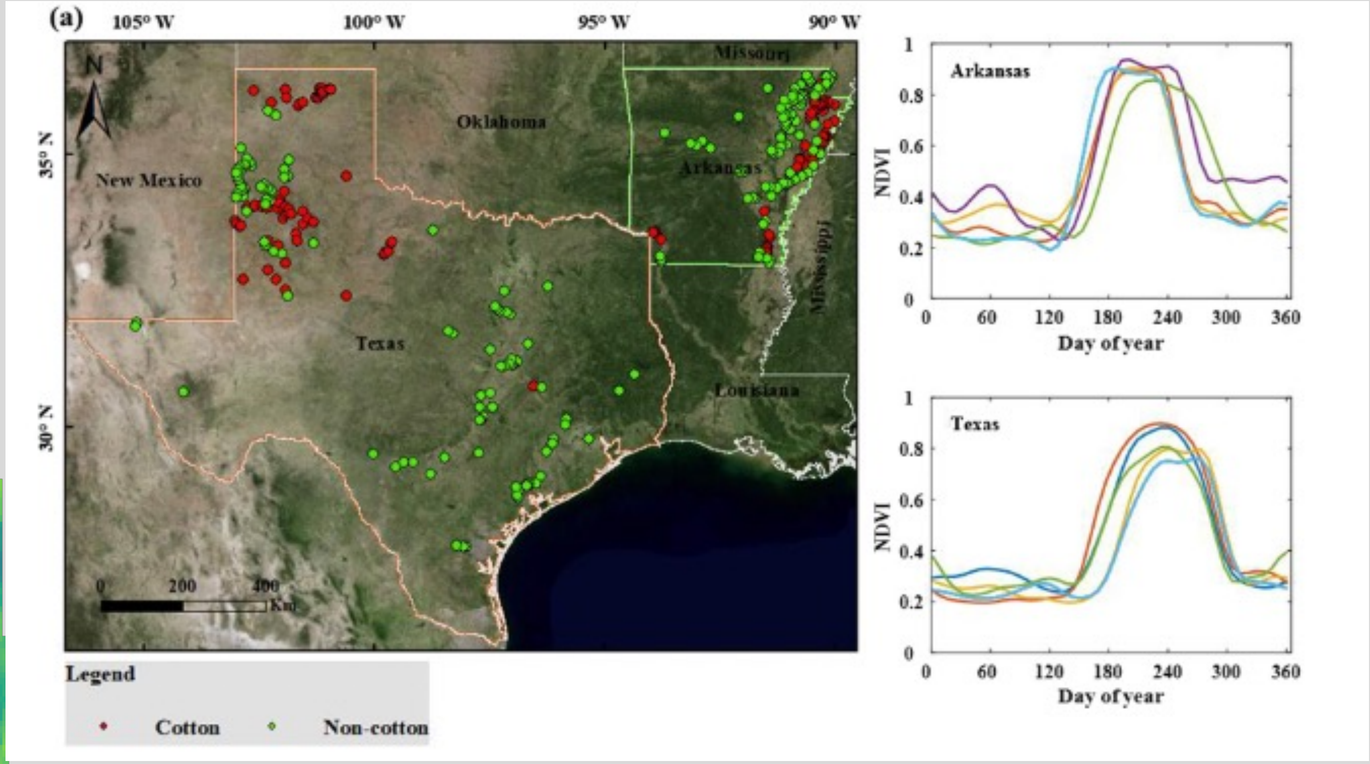
Do we need a different algorithm for other VIs?

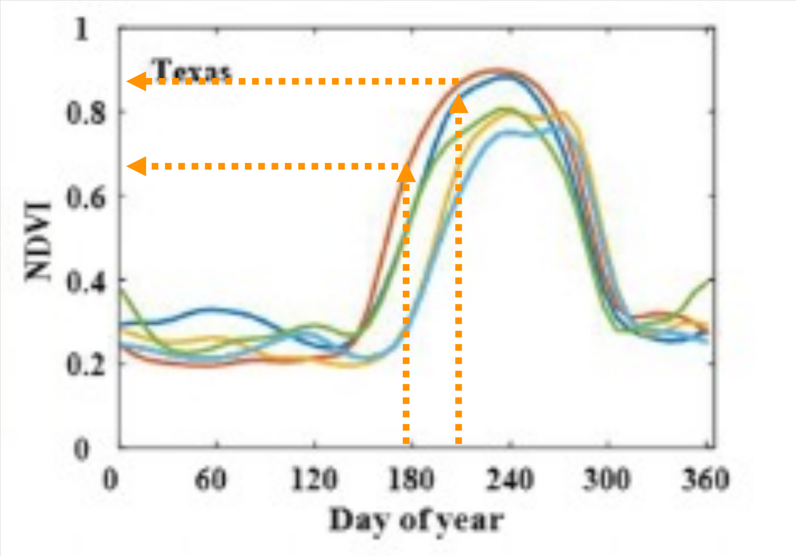
Variable rate nitrogen components: **Algorithm**

Issues with VI-specific algorithm



Simple, but what if ❌ Different growth stages



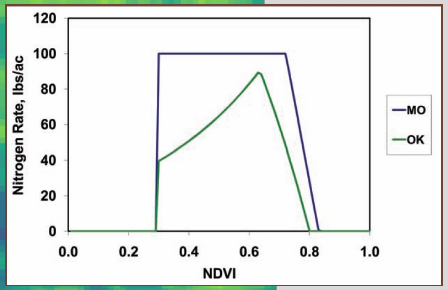


VI changes as crop grows.

Do we need a different algorithm for each growth stage?

Variable rate nitrogen components: **Algorithm**

Issues with VI-specific algorithm



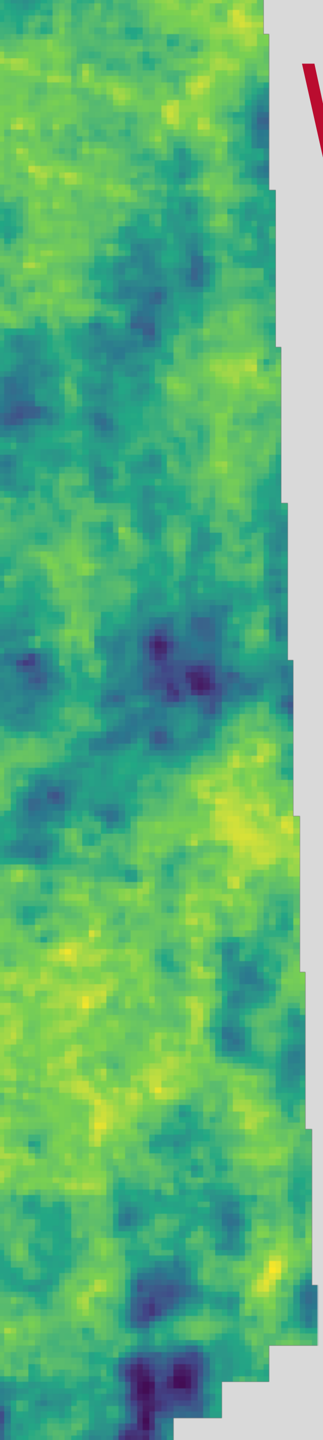
Simple, but what if ❌ Different varieties

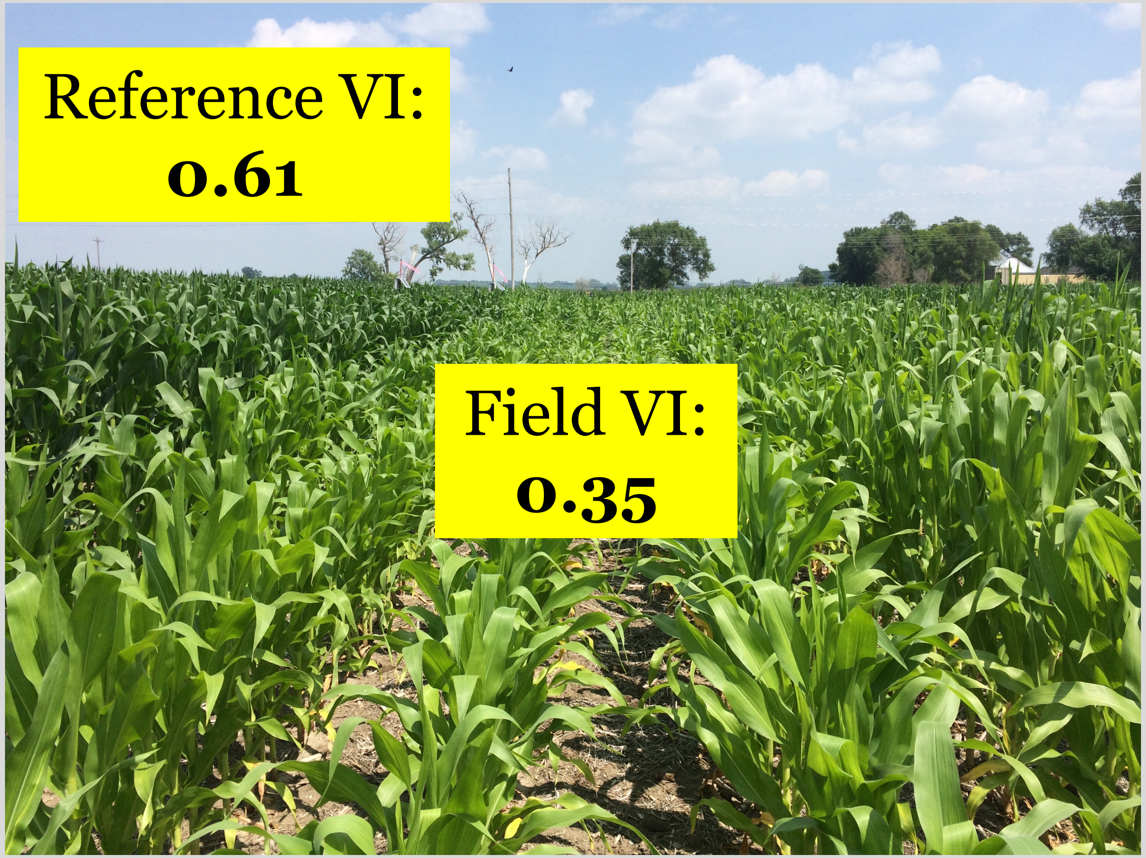
Even at similar N nutrition, different **varieties** will look different to a sensor.

Do we need a different algorithm for each variety?

How to fix these issues and ensure that reflectance differences are only due to N status?

Variable rate nitrogen components: **Algorithm**
Normalizing with an in-field reference





Have a **high-N reference** strip in the field for each genetic and management

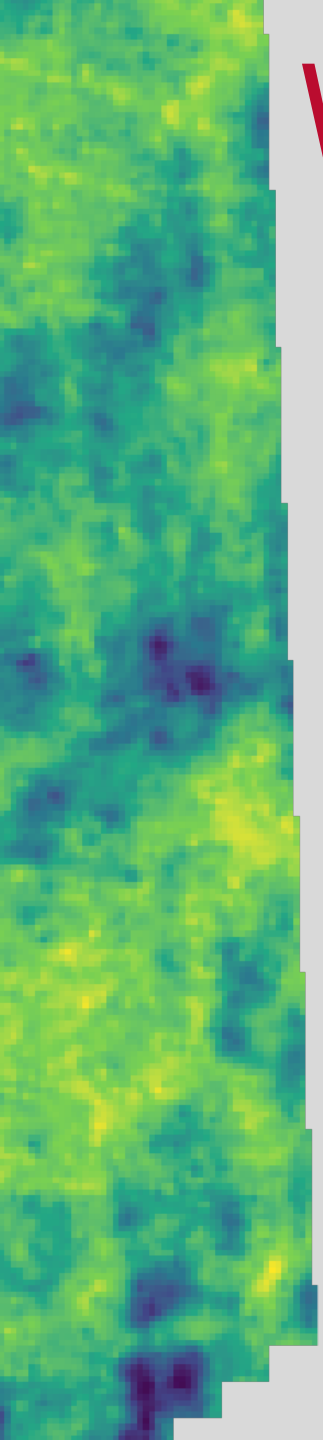
Sufficiency Index (SI)

$$SI = \frac{VI_{field}}{VI_{reference}}$$

For example,

$$SI = \frac{0.35}{0.61} = \mathbf{0.57}$$

By normalizing with a high-N reference, the effects of VI, growth stage, and variety are neutralized



Variable rate nitrogen components: **Algorithm**
Algorithm types: 2. SI-based

Holland-Schepers algorithm

$$N_{app} = (EONR - N_{credits})\ x \sqrt{\frac{(1 - SI)}{\Delta SI}}$$

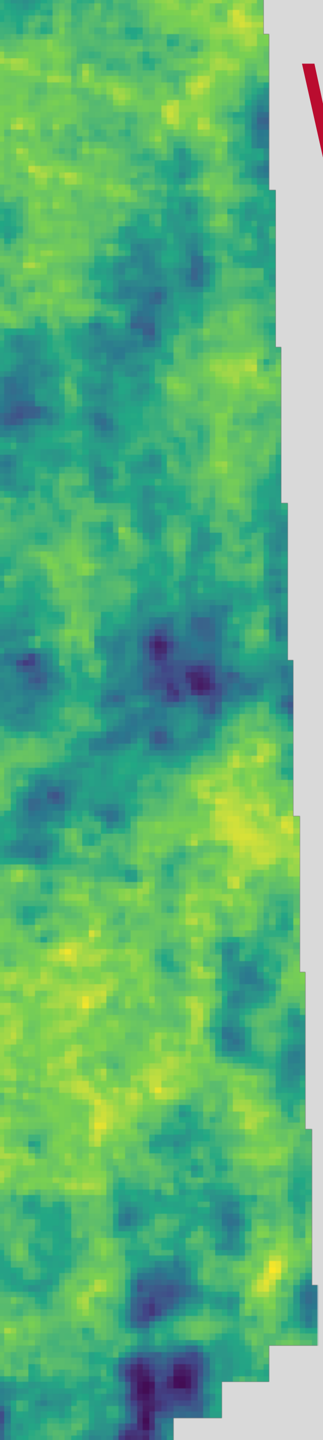
N_{app} = sensor-recommended N rate (lbs/ac)

EONR = economic optimum N rate (lbs/ac)

$N_{credits}$ = pre-applied fert, irrigation water N, legume (lbs/ac)

SI = sufficiency index

ΔSI = 0.3



Variable rate nitrogen components: **Algorithm**
Algorithm types: 2. SI-based

Holland-Schepers algorithm: ΔSI

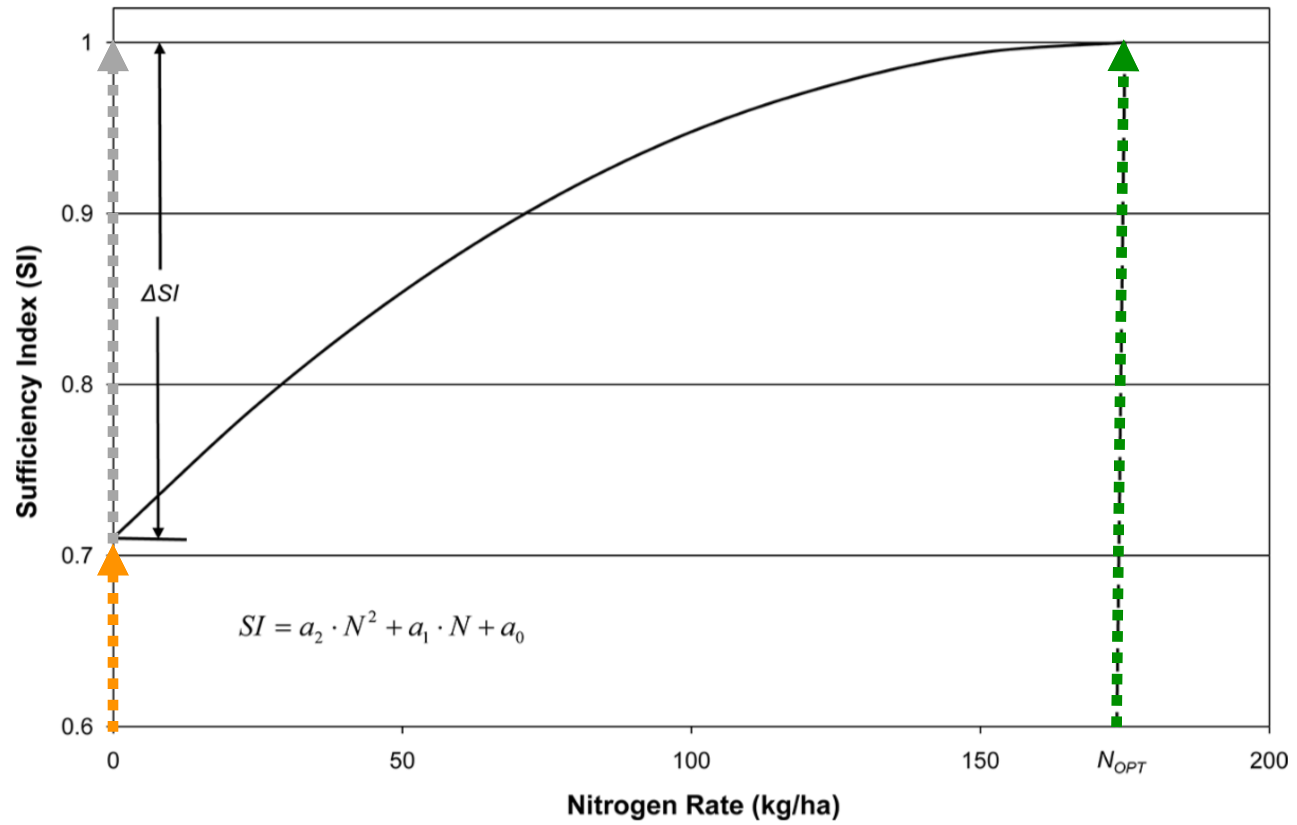
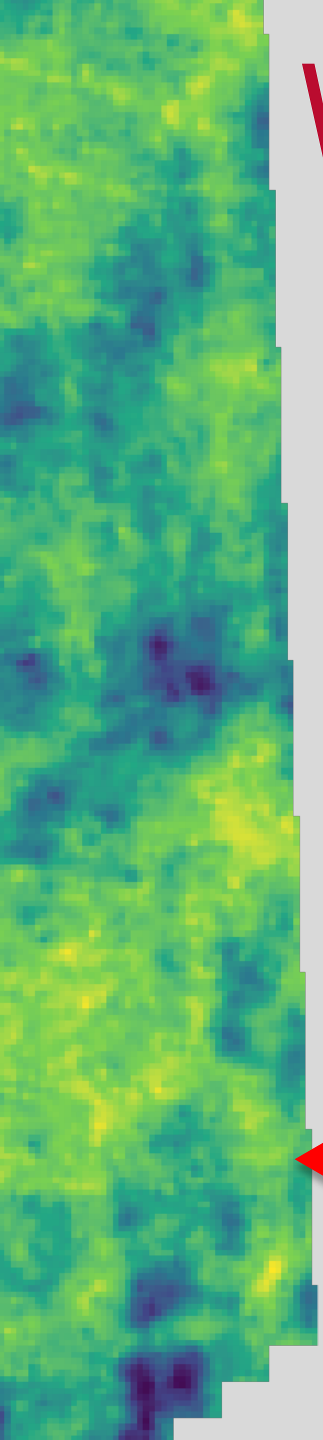


Fig. 1. Nitrogen response curve: sufficiency index (SI) vs. N rate.

ΔSI represents how much potential room there is to catch up between most N-deficient crop (N=0) and N-sufficient crop (N = Noptimum)



Variable rate nitrogen components: **Algorithm**

Algorithm types: 2. SI-based

Holland-Schepers algorithm: **entire workflow**

Reflectance

Reflectance

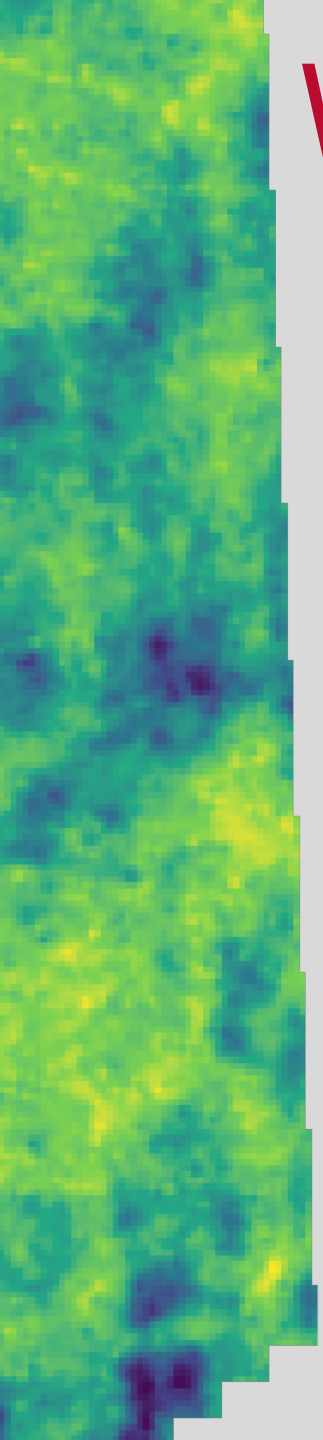
Reflectance

Vegetation Index (VI)

$$SI = \frac{\text{Field VI}}{\text{Reference VI}}$$

Algorithm

Variable Rate N

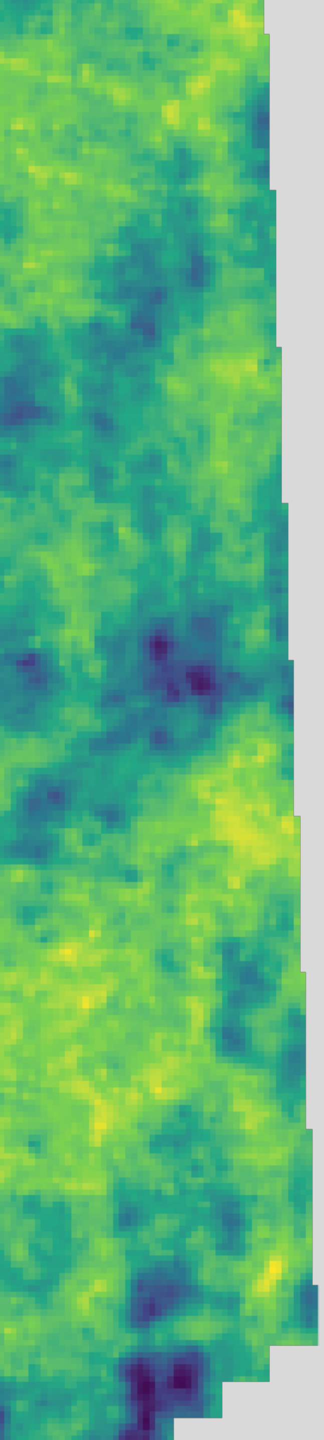


Variable rate nitrogen components: **Algorithm**
Algorithm types: 2. SI-based

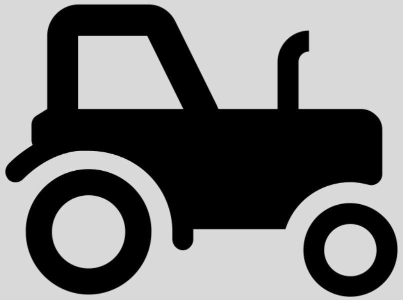
Holland-Schepers algorithm: **your turn**

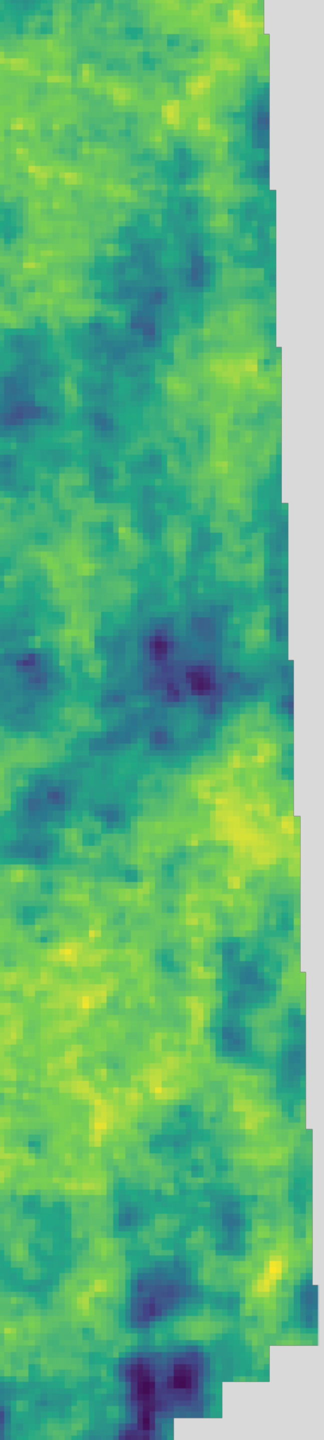
You go out to a field with a crop sensor and measure GNDVI over an area that shows N deficient symptoms (Field VI = 0.5). You then measure GNDVI over an area that has received enough N and looks healthy (Reference VI = 0.6). Assuming an economic optimum N rate (EONR) of 150 lbs N/ac, no N credits, and a ΔSI = 0.3, compute the sensor-recommended N rate (Napp). Tip: don’t forget to calculate SI first!

$$N_{app} = (EONR - N_{credits})\ x \sqrt{\frac{(1 - SI)}{\Delta SI}}$$

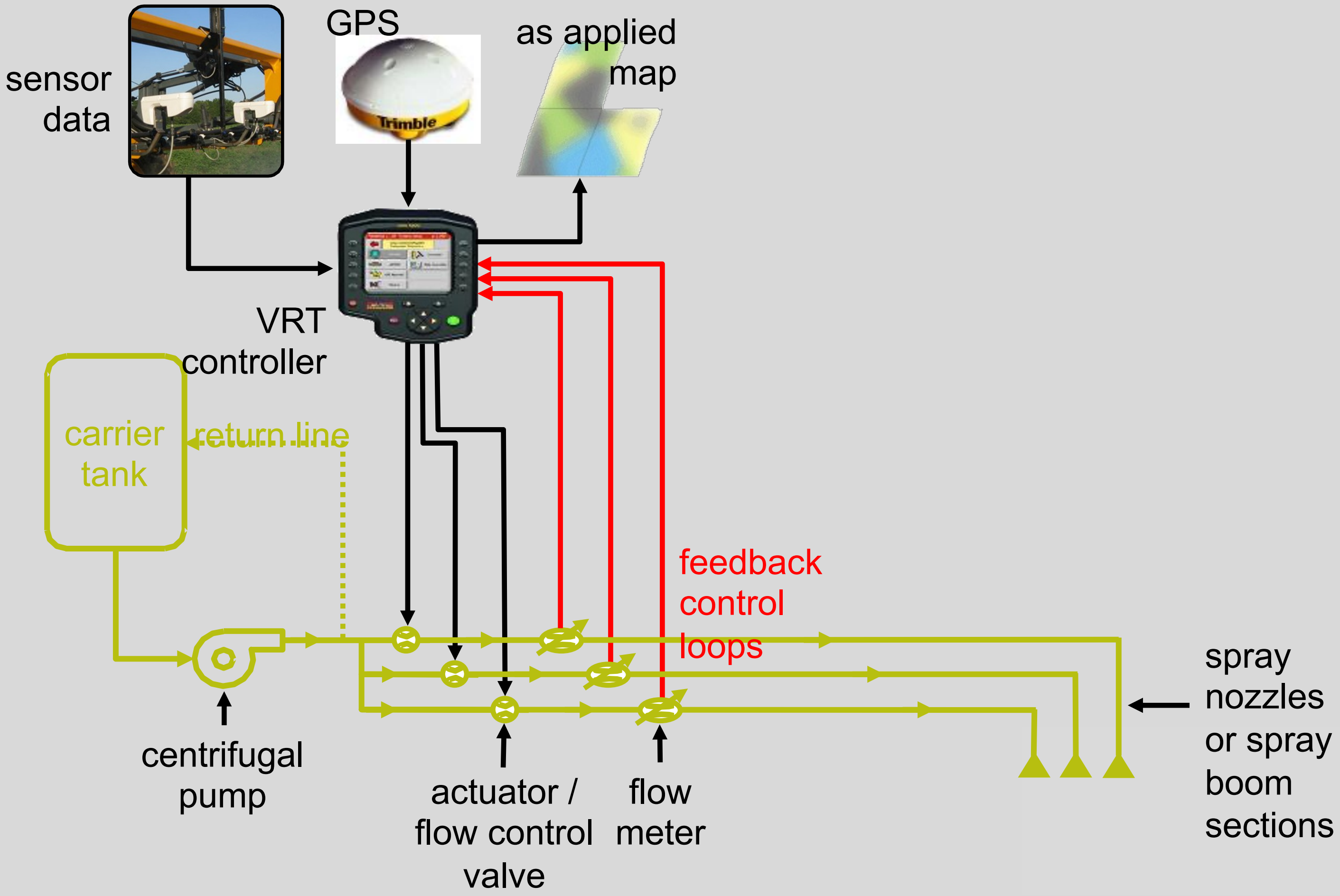


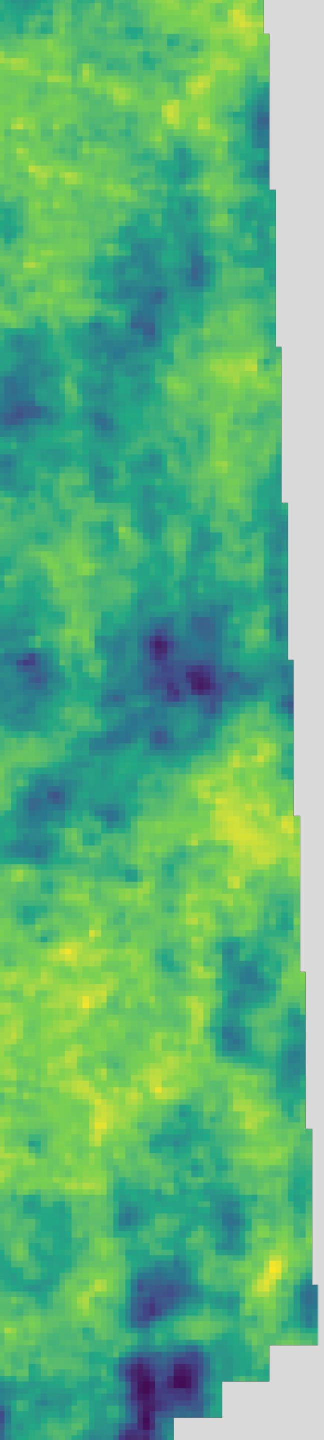
VR Equipment





Variable rate nitrogen components: 3) VR equipment

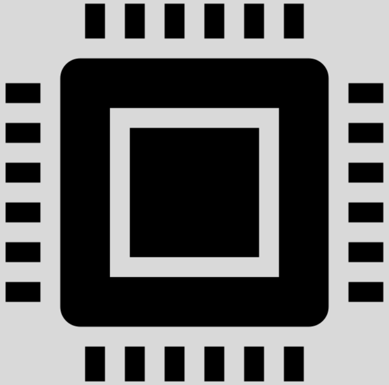




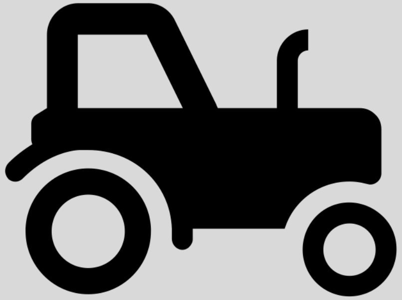
Bringing it all together

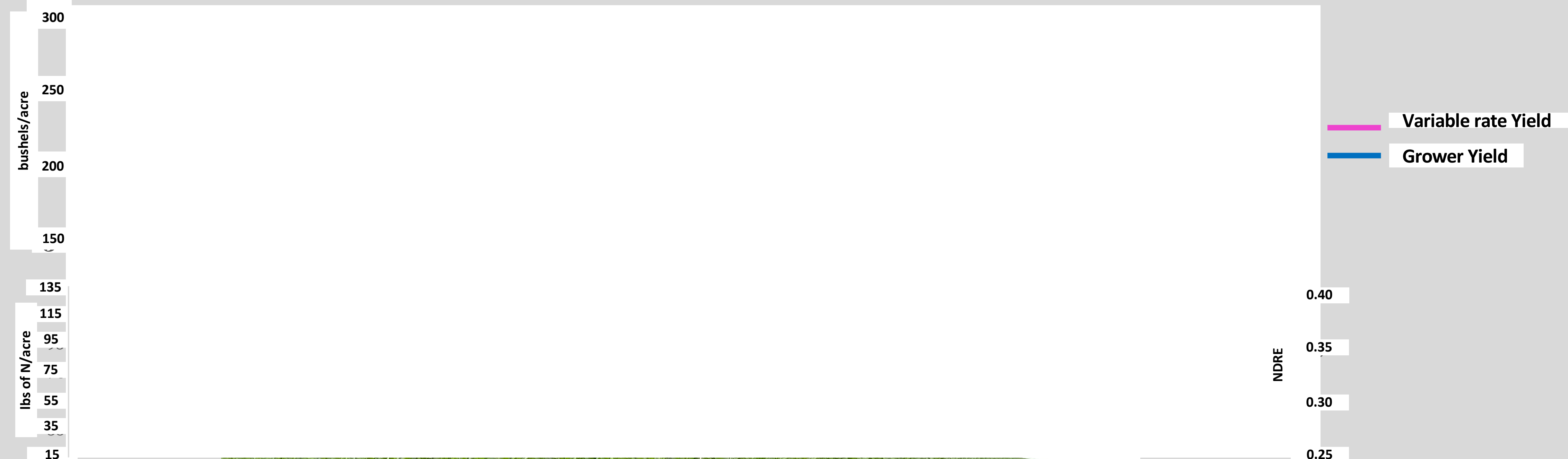
Sensor

Algorithm

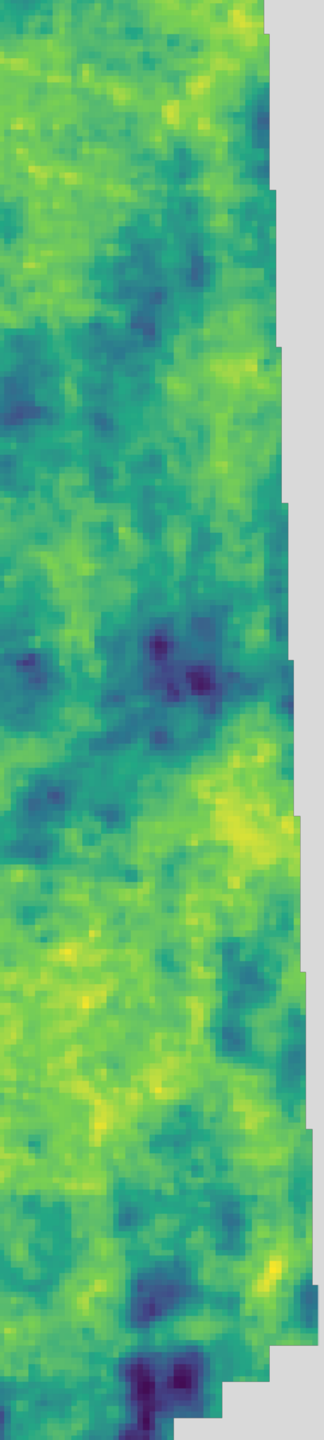


VR equipment



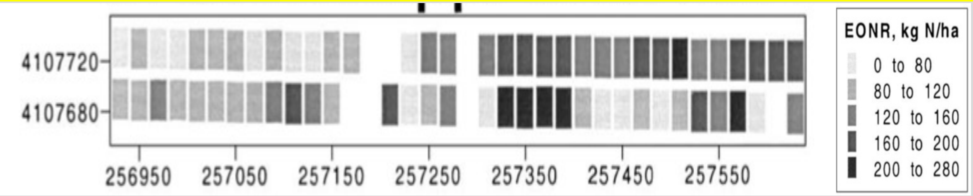


Credit: Laura Thompson, UNL

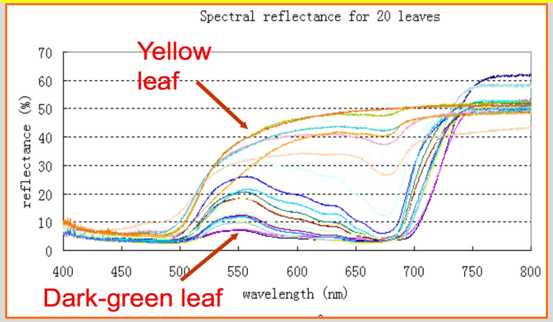


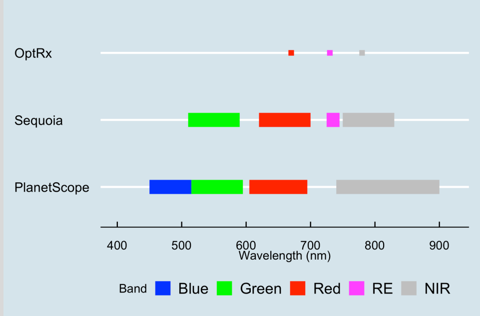
Summary

1. Spatial variability and need for variable rate

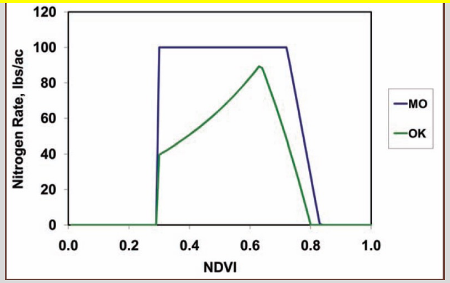


2. VRN components: sensor





3. VRN components: algorithm



$$N_{app} = (EONR - N_{credits})\ x \sqrt{\frac{(1 - SI)}{\Delta SI}}$$

4. High-N reference and sufficiency index

5. Calculate VRN

$$N_{app} = 150 \text{ x } 0.75 = \underline{112} \text{ lbs N/ac}$$

6. VRN in practice and consequences on N and yield