NDVI for Variable Rate N Management in Corn

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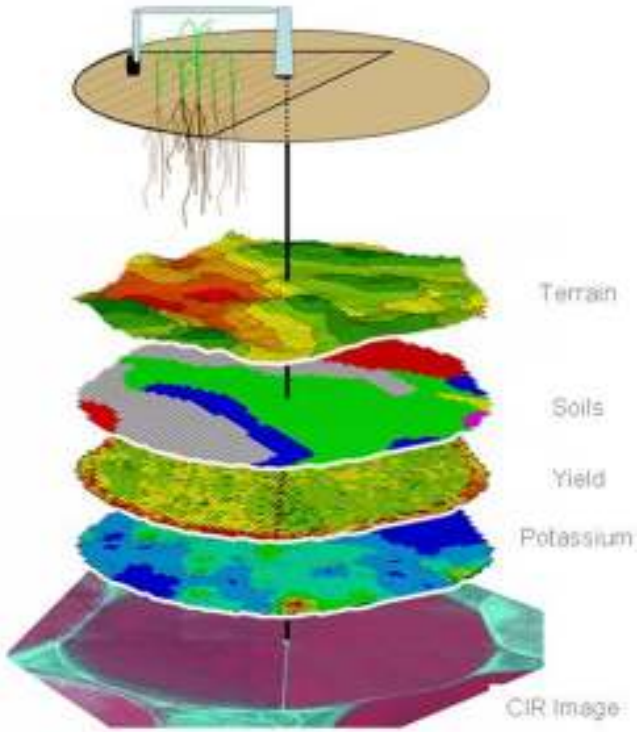
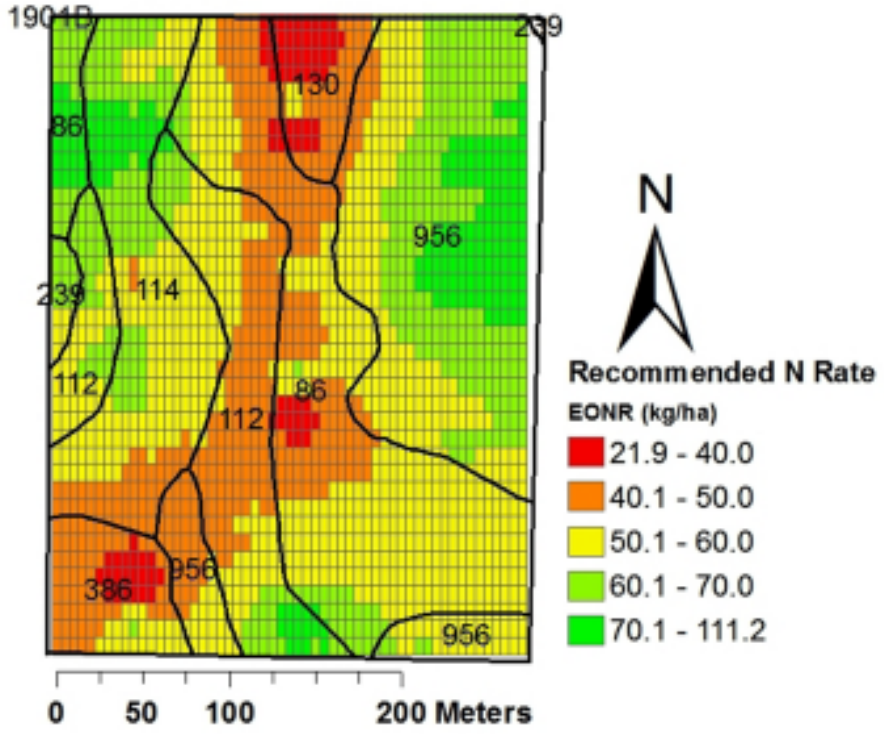
What is Precision Agriculture?

- A management practice applied at the right rate, right time and right place
  - Customized field management
  - Nutrients
  - Drainage or Irrigation
  - Pests and Weeds
  - Tillage and Seeding Operations



Benefits of Precision Agriculture

- Increased profitability
- Increased efficiency of inputs
- Reduced environmental pollution

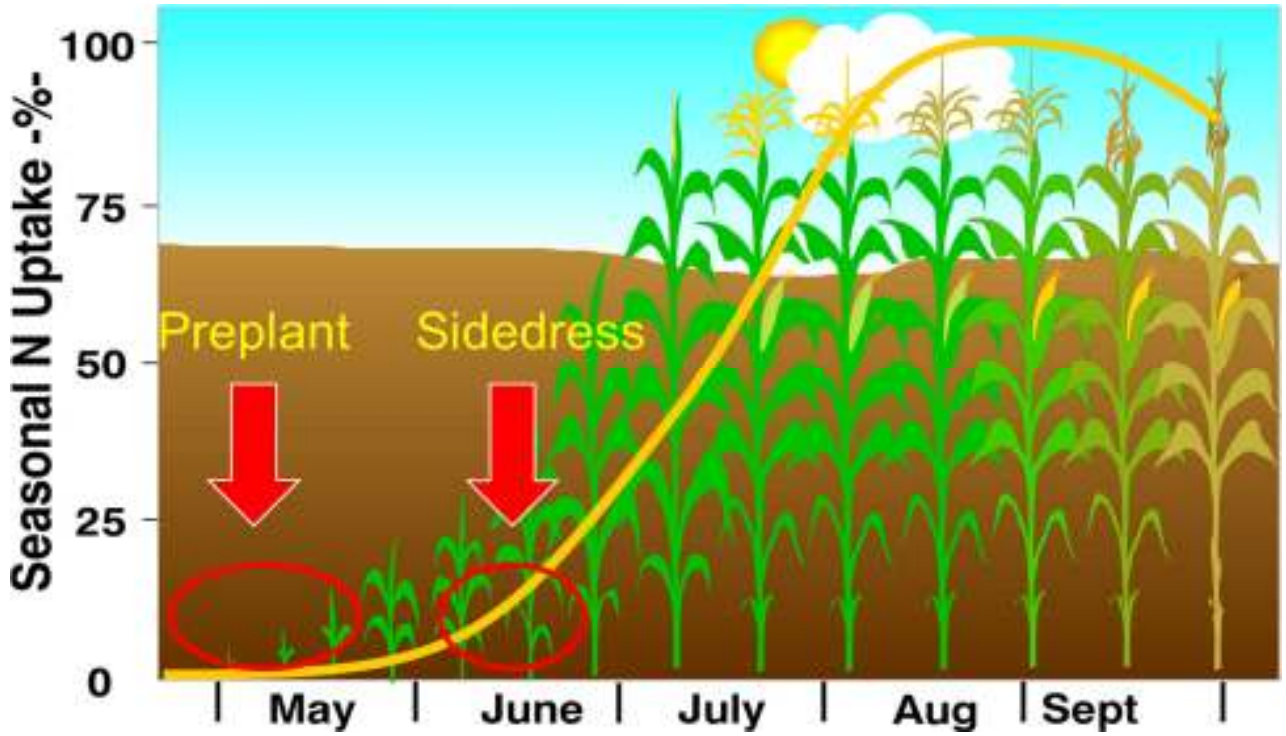


Conventional Agriculture

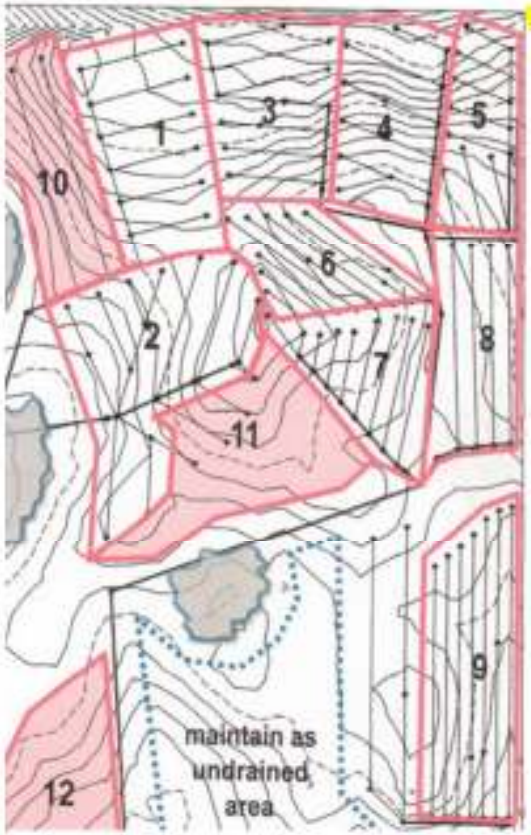
- Most nitrogen fertilizer in Minnesota is fall applied
- Uniform management based on
  - Average or best field conditions
- Uniform management ignores spatial and temporal variability in crop growth, soil or landscape features and denitrification or leaching losses of N
- It leads to overuse of farm inputs

Variable Rate Side-Dress Nitrogen (VRN)

- Match side-dress N fertilizer application to crop growth patterns
- Use remote or proximal sensing to detect N deficiency in leaves



Study Area Agricultural Ecology Research Farm, Waseca



Site 2 is used for VRN rate estimation

Sites 1, 4, 6, 8 are uniform N
Sites 3, 5, 7, 9 are VRN

Methods

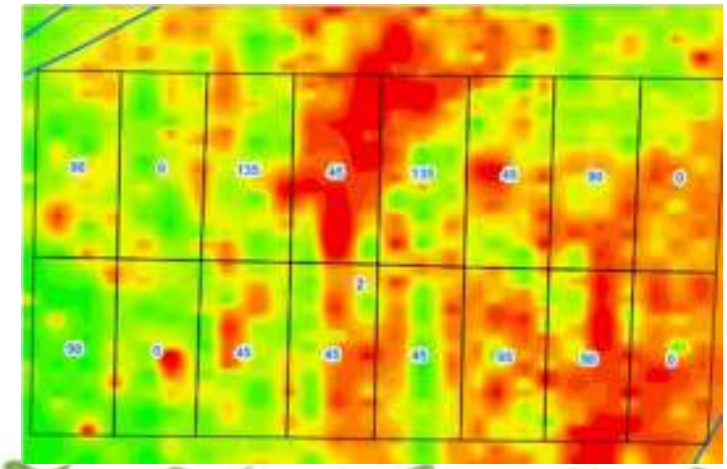
- Conventional Treatment: EONR (135 lb/ac N in 2016 and 180 lb/ac N in 2017)
  - Corn after soybean in 2016
  - Corn after corn in 2017

- VRN Treatment: 30% of EONR (PP) + VRN Side-dressed based on NDVI with CropCircle ®

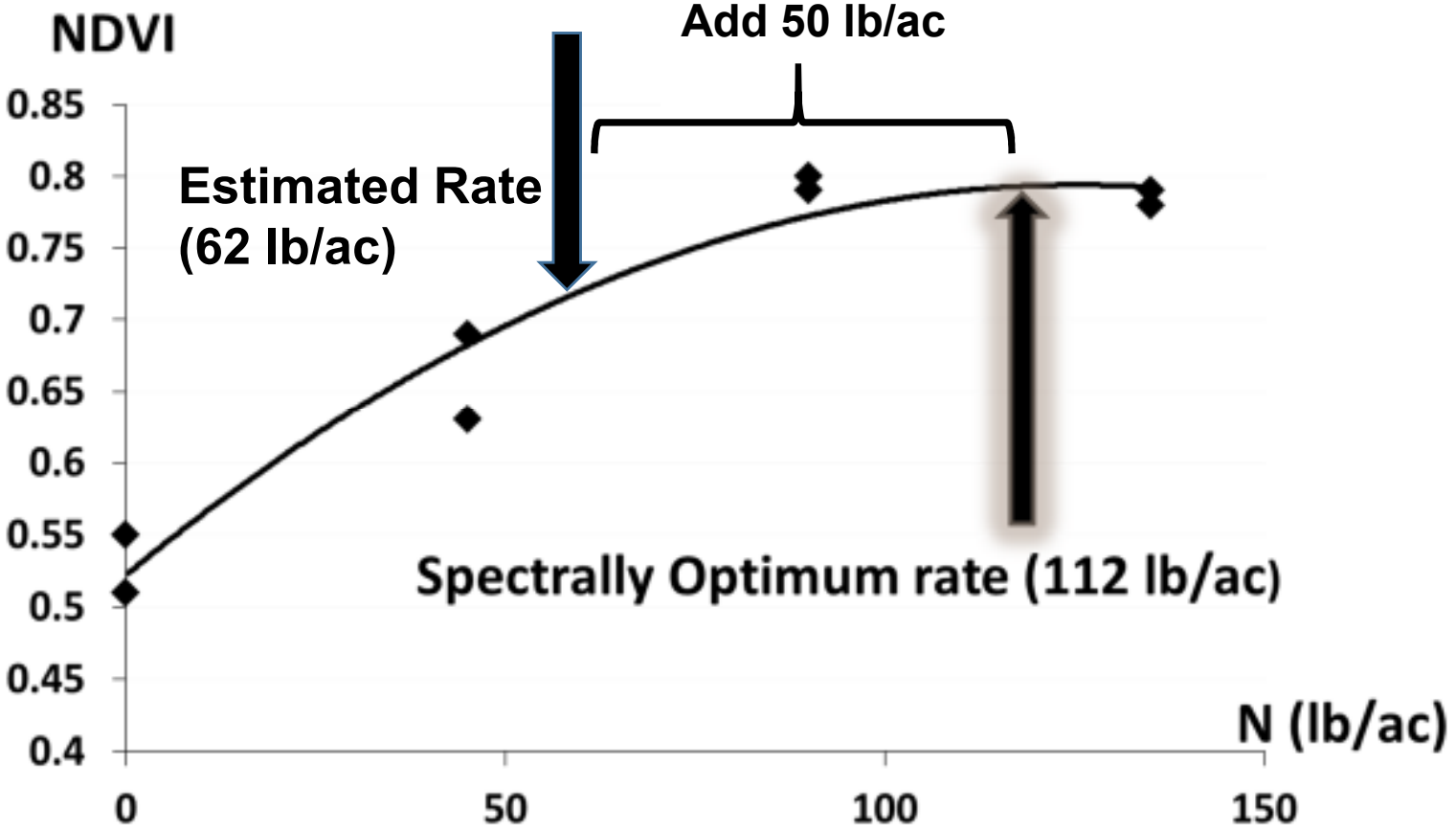
Variable Rate N Fertilizer Recommendations Based on CropCircle® NDVI

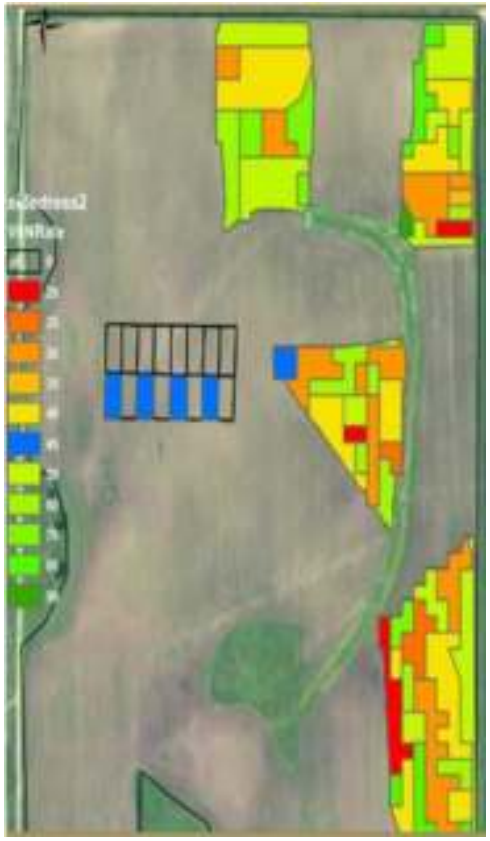
- Three N Response Zones (2016)
  - Zone 1: high N response (lower OM, lower NDVI)
  - Zone 2: low N response (higher OM, higher NDVI)
  - Zone 3: Average of 1 and 2

NDVI = (NIR-R)/(NIR+R)



EONR Fertilizer Rate based on NDVI (2016)





VRN Fertilizer Side-Dressing at V6-V7

Raven Controller

Toolbar

Results

VRN subfields in green received 20-30% less N than uniform subfields, with no significant impact on yield (2017)

Subfields	Yield (bu/ac)
1	194
3	199
4	204
5	204
6	198
7	203
8	212
9	198

120 lb N/ac

Control

Economics of VRN Fertilizer Management

- Urea fertilizer and market price of $0.35/lb N
- $5/ac cost for variable rate prescription and application

VRN Sub-fields	2016 ROI (Per acre)	2017 ROI (Per acre)
3	$13.5	$15.75
5	$13.5	$15.75
7	$11.5	$12.5
9	$16	$19

Comparison Between NDVI and Other VI

Reflectance	Absolute Correlation with N Rate		
	V6	V10	R2
NDVI	0.47	0.37	0.10
Green NDVI	0.47	0.57	0.70
GDVI	0.59	0.65	0.68

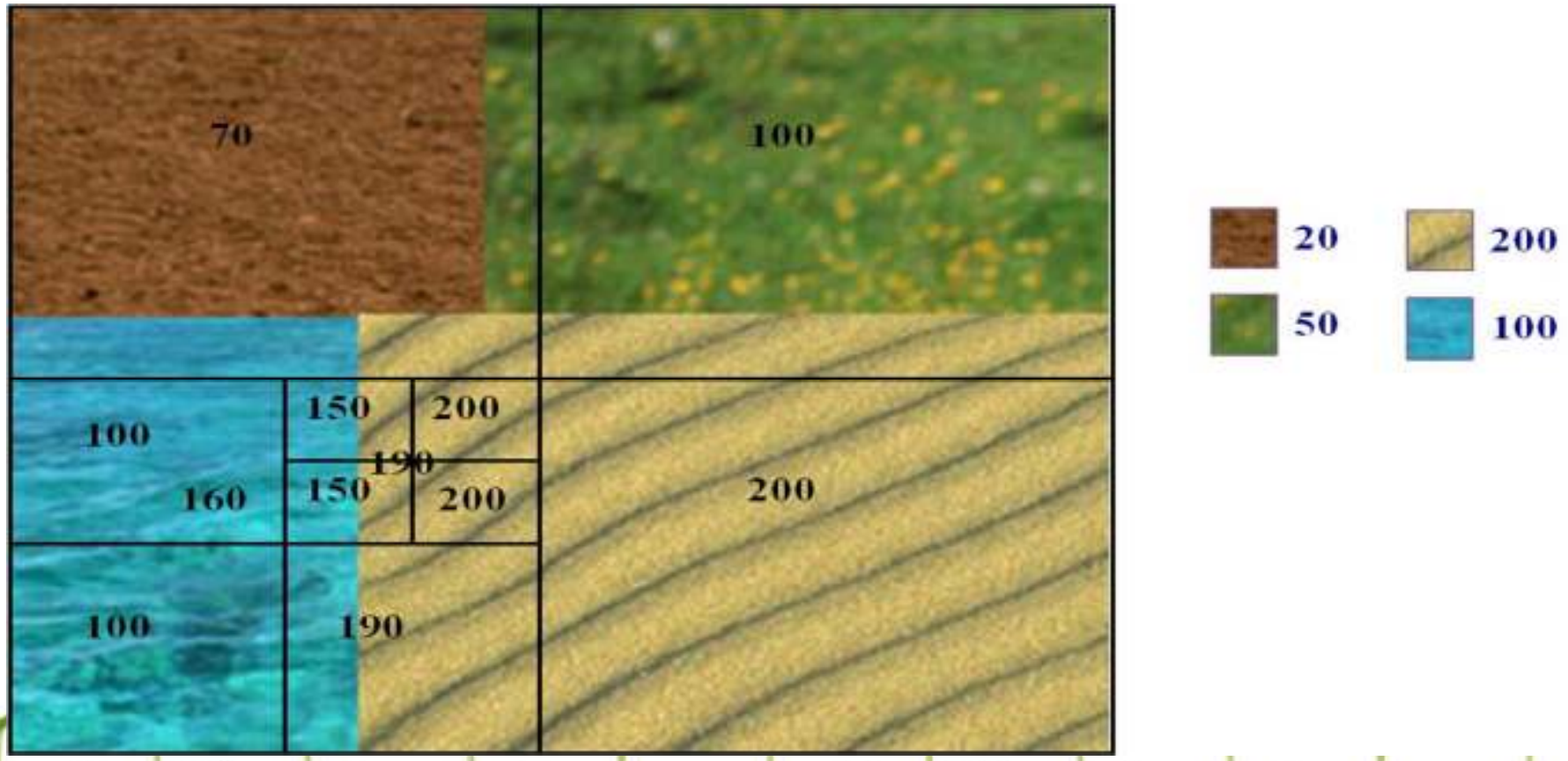
NDVI = (NIR-R)/(NIR+R)
Green NDVI = (NIR-G)/(NIR+G)
GDVI = (NIR-G)

Comparison Between Satellites and Cameras (all can estimate NDVI)

Satellite/Sensor	spatial resolution (ft)	spectral resolution (no. of bands)	pixels per ac
IKONOS 2	2.69 (P), 13.1 (M)	4	6019, 254
QuickBird	2.0 (P), 13.1 (M)	4	10890, 254
RapidEye	16.4 (M)	4+red-edge	162
GeoEye	5.4 (M)	4	1494
WorldView-3	4.1 (M), 12.1 (SWIR)	8 (M), 8 (SWIR)	2591, 298
Landsat 8	98.4	4 (M), 4 (SWIR)	4.5
Sentinel 2	33-66 (M), 66-197 (SWIR)	8 (M), 4 (SWIR)	18, 2.5
AISA Eagle	3.3 (H)	63	4000
Tetracam MCA6	0.22 (M)	5+red-edge	900000

M – Multispectral, SWIR – Short Wave IR, H - Hyperspectral

Increased Homogeneity of Pixels



Limitations to Satellite Remote Sensing

- Coarse spatial resolution and infrequent repeat coverage for older satellite platforms
- Difficulty obtaining images when needed
- Interference from clouds
- Changes in irradiance on multiple passes
- Slow turn-around time due to image processing for calibration, corrections, and geo-rectification

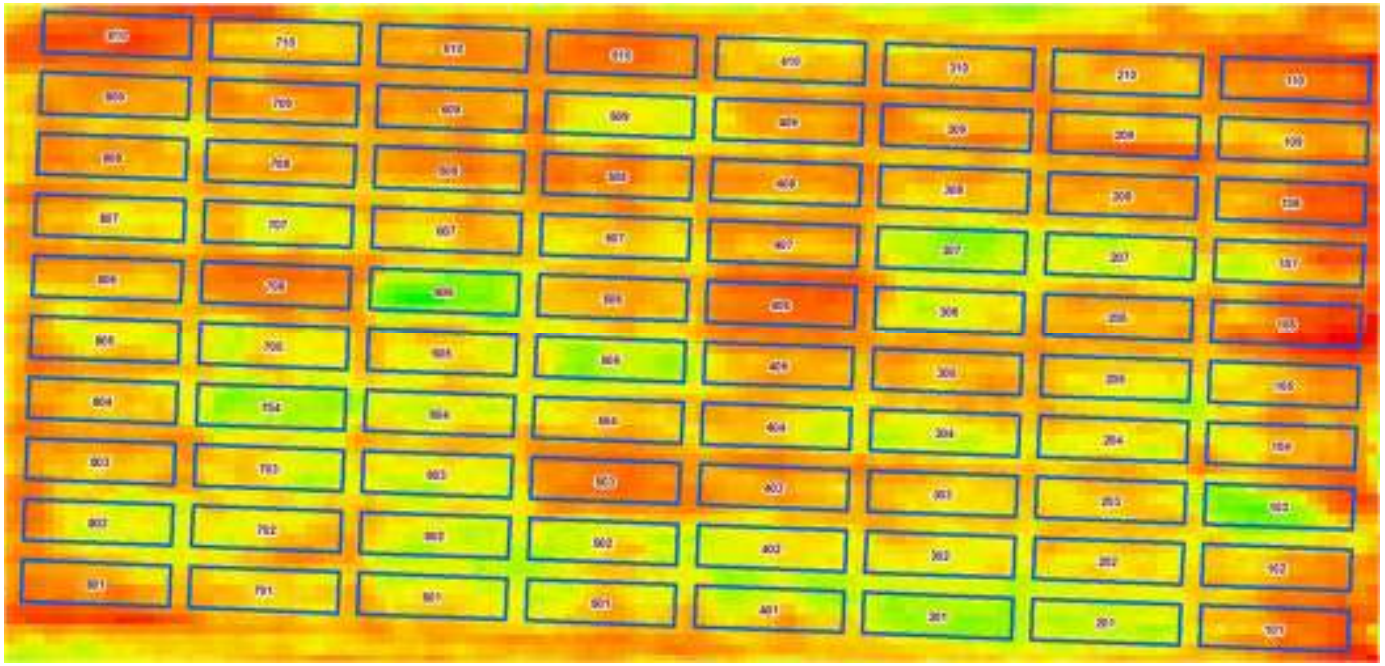
The Mini Satellite Revolution

- Flocks of miniature (nano) satellites have been launched by Planet ®
- These Dove (radar) and SkySats (MSS) have the capacity to cover the entire earth daily at sub-meter resolution
- Future launches may include mini satellite flocks that provide HS imaging at high spatial resolution and low S/N ratio

Challenges For VRN Implementation

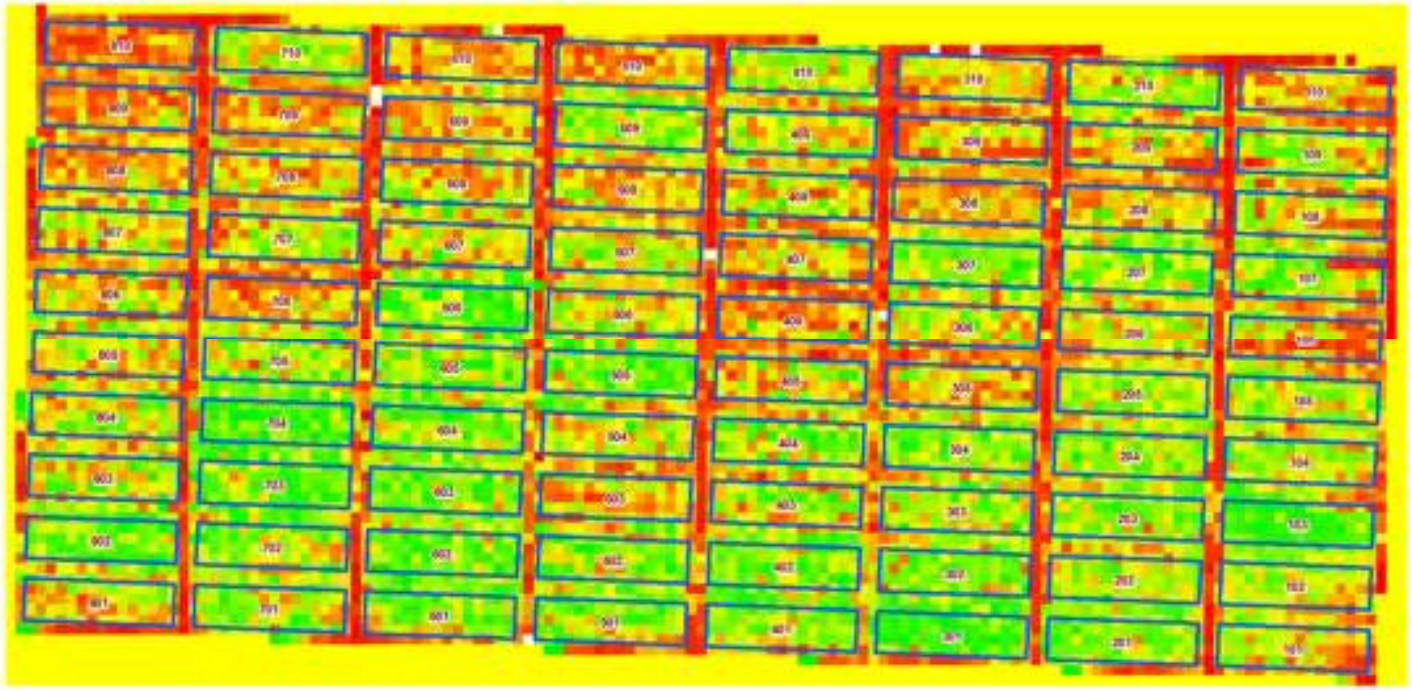
- How much N to apply pre-plant?
  - 30-60 lb N/ac is generally appropriate
  - Applying more than 90 lb N/ac is excessive
- How should N response zones be identified?
  - A combination of soil organic matter and historical crop yields
  - Crop modeling (Adapt-N, Encirca, ClimateCorp)

Comparison Between Airplanes and UAVs



Airplane based FSA-NAIP derived NDVI for Theilman, MN (around V6)
Red colors indicate N deficiency, green colors indicate no N stress

Comparison Between Airplanes and UAVs



UAV based NDVI for Theilman, MN (around V6)
Red colors indicate N deficiency, green colors indicate no N stress

Challenges to Implementation of VRN

- What algorithm should be used to estimate N fertilizer recommendation?
  - UofM is developing algorithms based on many site years of research
  - One alternative is to use a sufficient N reference in the field (180 lb N/ac in corn-soybean rotation)
  - Another alternative is to use a virtual reference N location, the location with highest biomass growth
  - GreenSeeker®, CropCircle® and Yara® have proprietary algorithms not specific to Minnesota
  - Technically no difference between satellite imagery based NDVI and sensor based NDVI except spatial resolution

Conclusions

- VRN side-dressing at V6 reduced nitrogen fertilizer rate by 25-30% without impacting yield

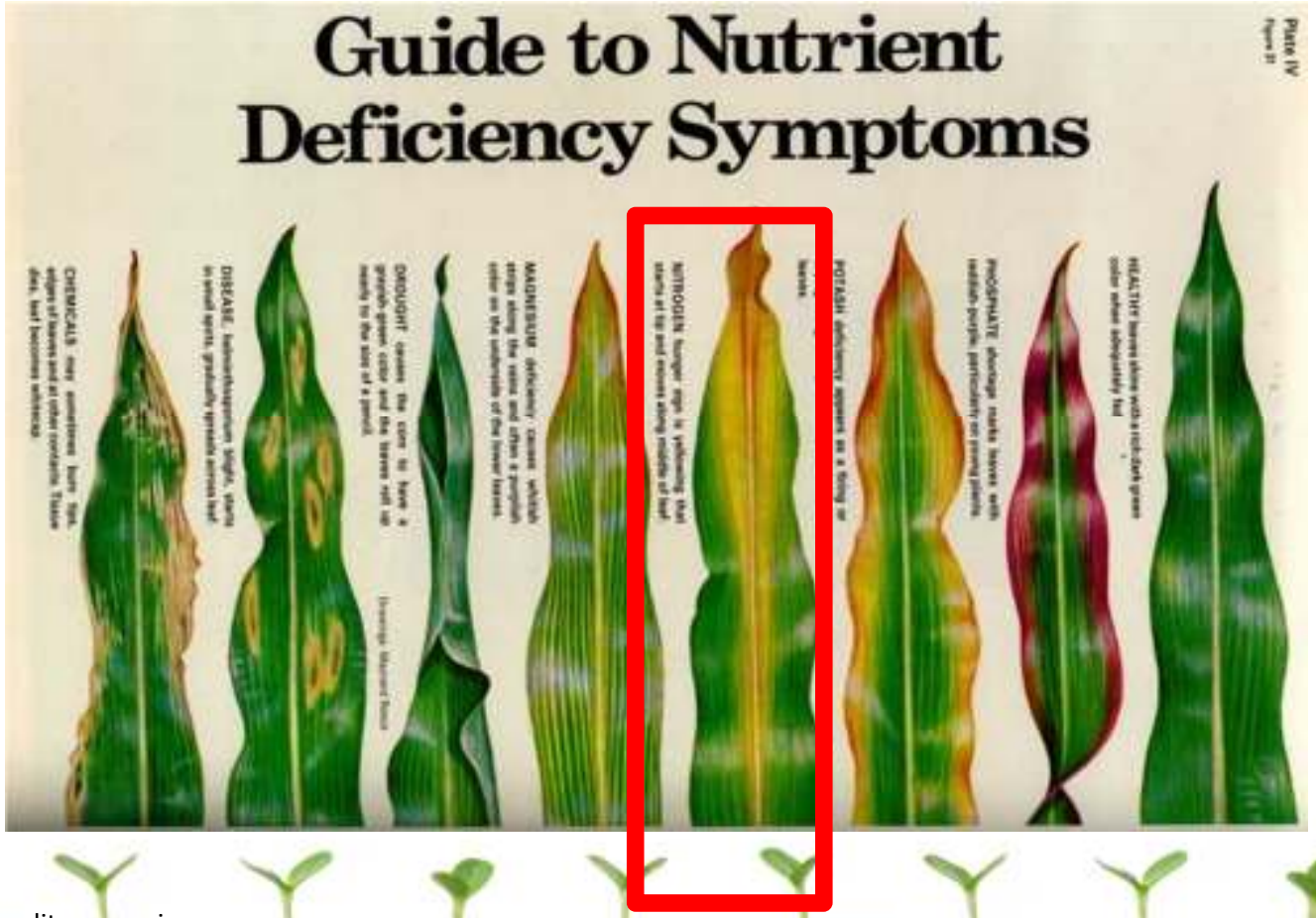
- High ROI even in the absence of yield improvement

The Problem with NDVI

- Current aerial surveillance methods can detect yellow regions in corn fields using NDVI

- Need more information:
  - The exact nature of the stress (e.g. N vs S)
  - The severity of the stress

Nitrogen Deficiency has V-Shape Yellowing

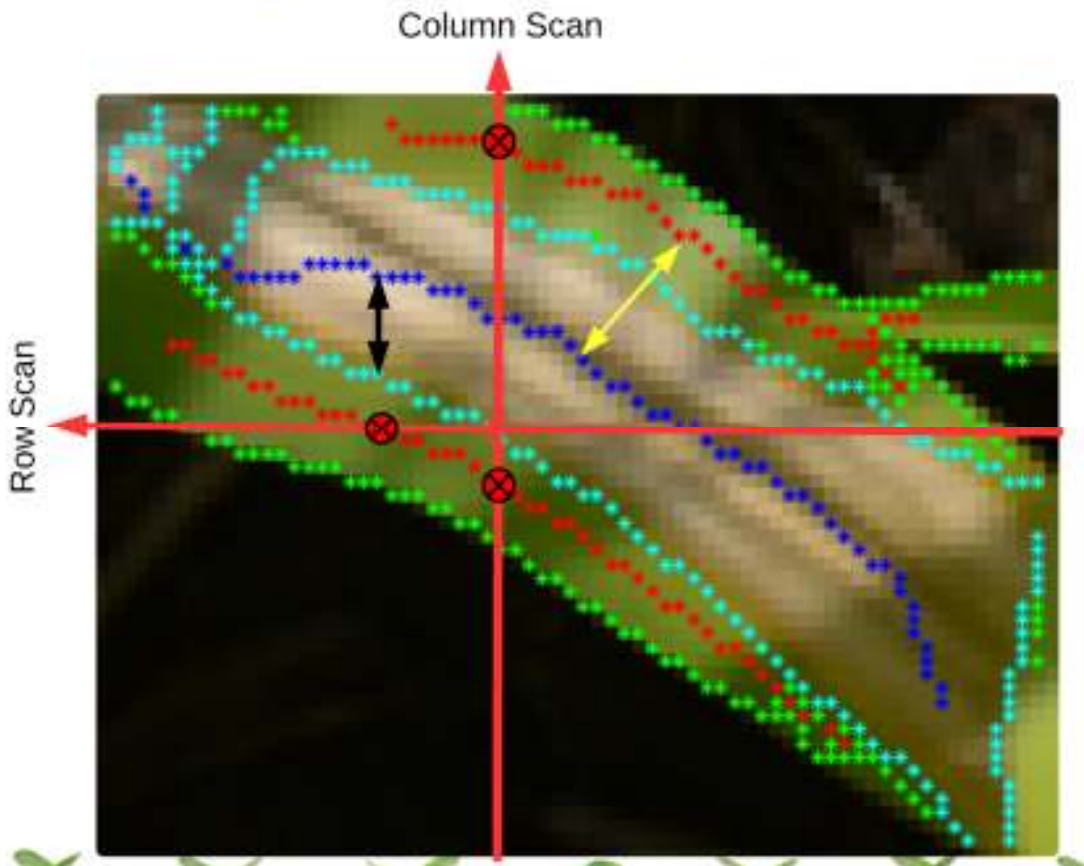


credit: www.pioneer.com

High Resolution Approach

Fly low and pay attention to the details!

Identify V-Shape Yellow Areas

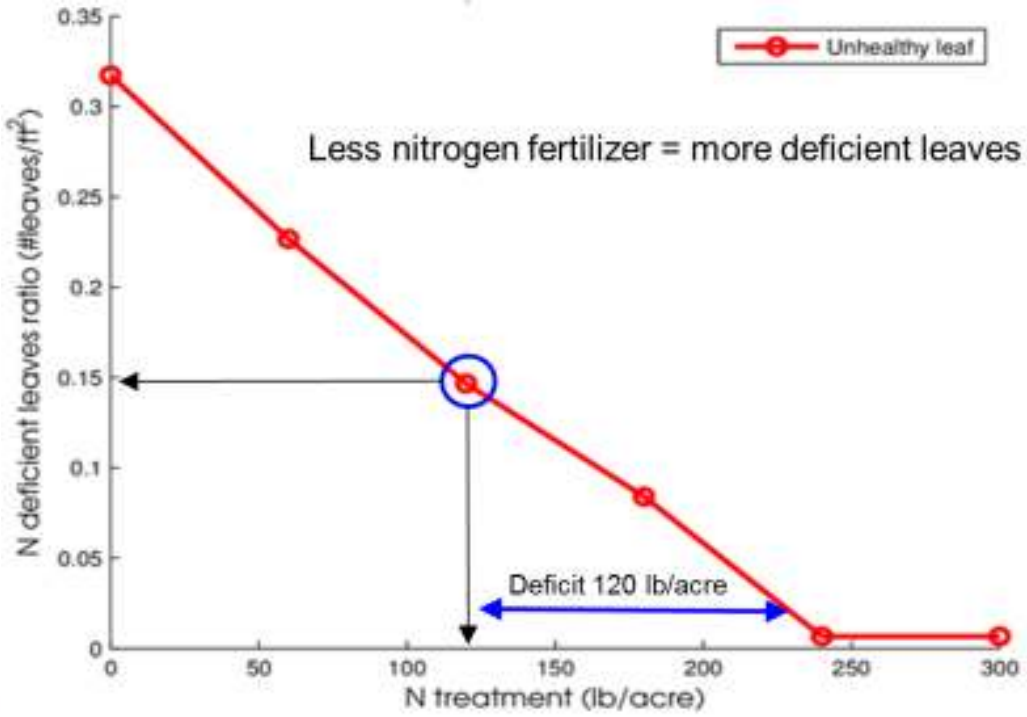


- Skeleton of green
- Skeleton of yellow
- Edge of green
- Edge of yellow

Identify Nitrogen Deficient Leaves

Determine Stress Severity

Assess density of nitrogen deficient leaves for N fertilizer recs



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