



Disease and Weed Detection with RGB Type Drones

by

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Summary:

- Different Kinds of Camera Drones
- Imagery Indices
- Measurement of Disease Severity in Crops with RGB Drones
- Weed and Close-Up Detection

Different Types of Remote Sensing Drones:

■ 1) Retail Store Type Drones:

- RGB, visible wavelength
- Easy to fly and use
- Record RGB imagery in easy-to-use file types
- Low-cost (\$500 to \$7000)



■ 2) Dedicated Units:

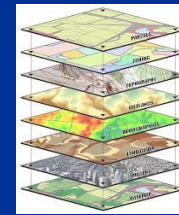
- Example: Wingtra
 - Special high-end cameras;
 - Usually Multispectral, lidar, thermal, etc.
 - Very expensive (> \$20,000)
- Heavy data loads



Future Drone Field Inspection System:

- Drone located near multiple fields
- Drone flies field every day, twice per week, weekly, etc.
- Data sent to computer automatically
- Daily maps (layers) created
- Multiple maps analyzed for crop health (damage areas, etc.
- Drone flown to specific areas to obtain close-up for reason of disease or damage, etc.
- System also allows farmer to have manual control to real-time visually inspect fields, or monitor conditions and farming operations, etc.

Data and Evaluation Computer / Center



Field Data Recorded Daily, Weekly, Hourly, Etc.



Drone Stationed in Field with Recharging / Launching Station

- 1) Fly high for large area mapping
- 2) Fly low to specific trouble spots to determine actual disease or pest and cause

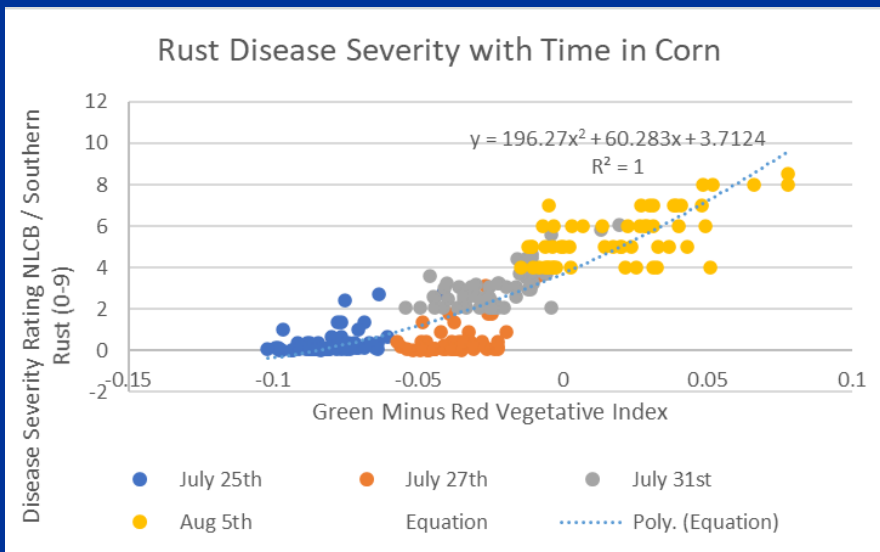
The Need for High Frequency/High Resolution Data:

■ High Frequency Data:

- Example: monitoring NCLB or Rust propagation in corn field (< 10 days from zero to full severity)
- In a producer's field it maybe even harder to recognize as the whole field may be changing color at the same time!!!

■ High Resolution Data => Drone can be brought down to the top of the crop for high resolution photos that will be needed for A.I. and disease analysis

- < 15 ft or so
- Some newer drones rated at 100 Megapixels resolution or more



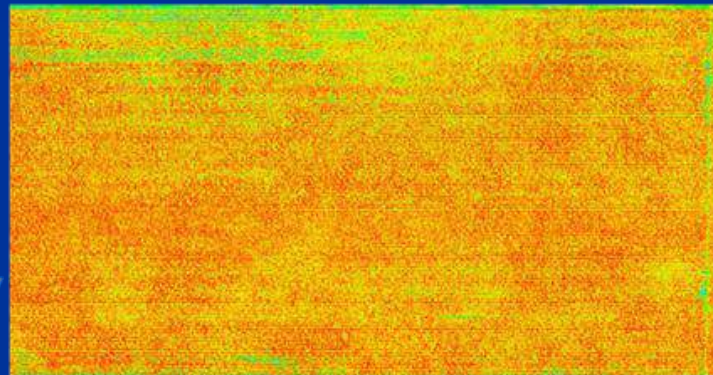
Indices:

- Imagery is changed from three numbers (RGB) to one number with an index (calculation of the colors) that represent a property you are trying to detect:
- Examples VARI, NDVI, CLI, etc.
- We use GR (Green – Red)

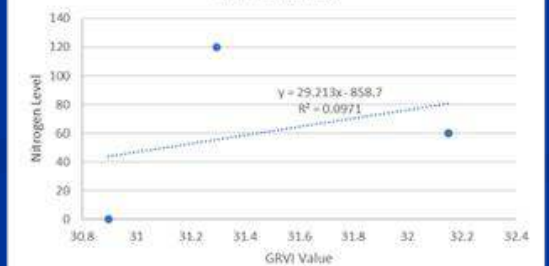
Raw RGB Image of Cotton Field:



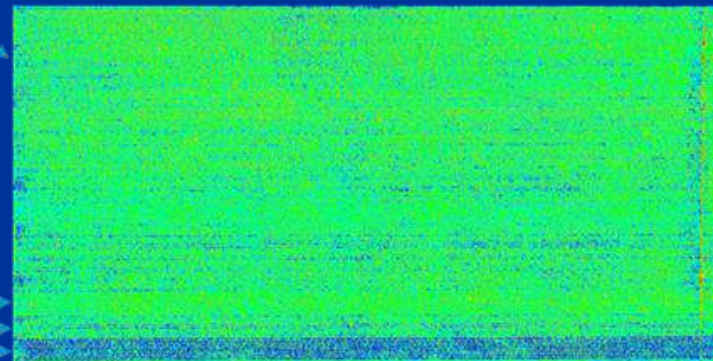
GR Image – General Crop Variability



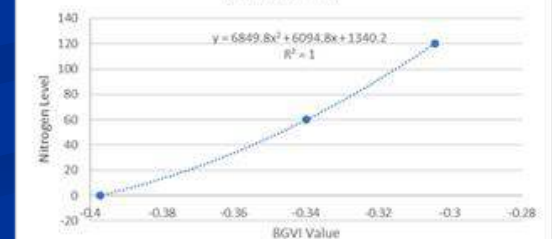
Gr-Red Indices:



BGVI Image - Nitrogen Detection:



BGVI versus Nitrogen Level in Cotton (Bl-Gr/Bl+Gr)

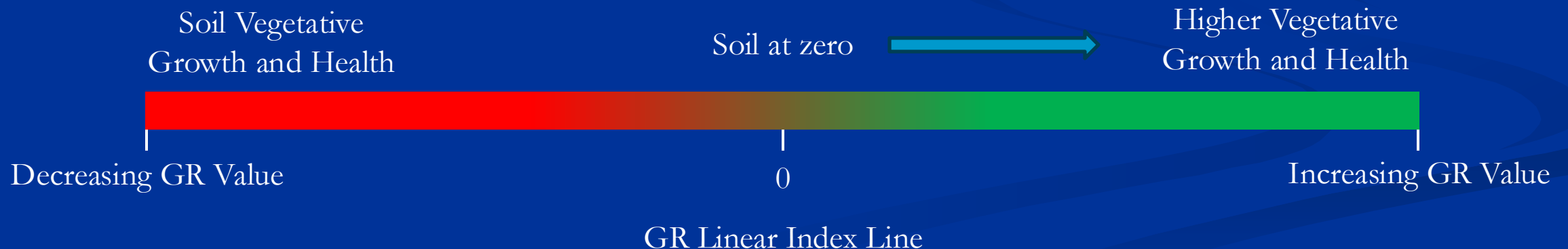


120 lbs./acre
60 lbs./acre
0 lbs./acre

120 lbs./acre
60 lbs./acre
0 lbs./acre

GR Index:

- GR (G minus R) is related to crop vegetative health and stand quality
- GR is the top part of VARI index $\Rightarrow (G - R) / (G + R - B)$
- The GR index creates a linear number line where:
 - Higher GR values indicate higher vegetation and plant health
 - Lower GR values indicate lower healthy plants and vegetation
 - Soil typically breaks at 0 (+/- 5 GR values, etc.):



GR Index Compared to Different NDVI Values:

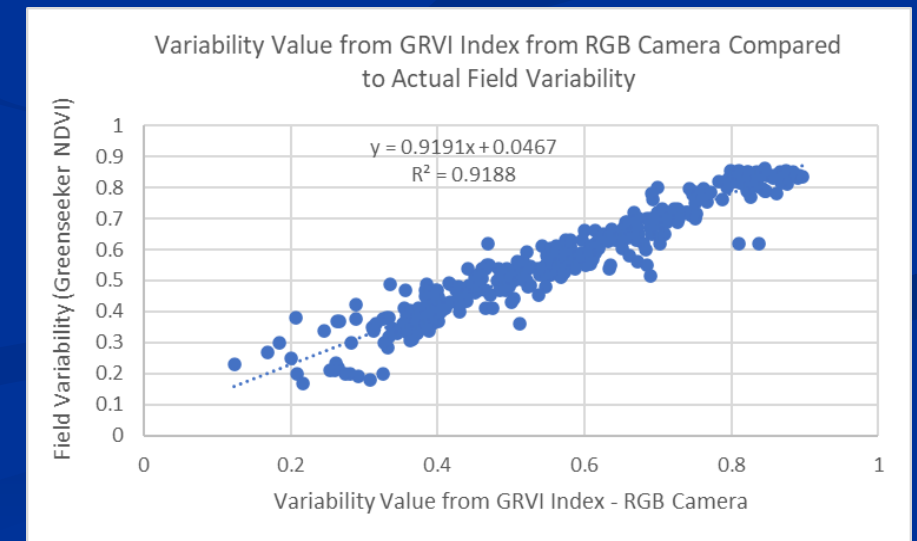
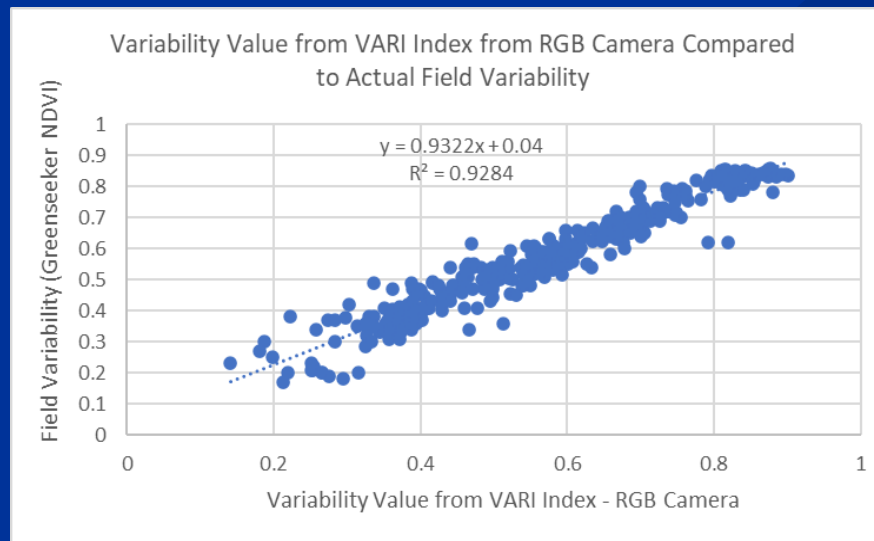
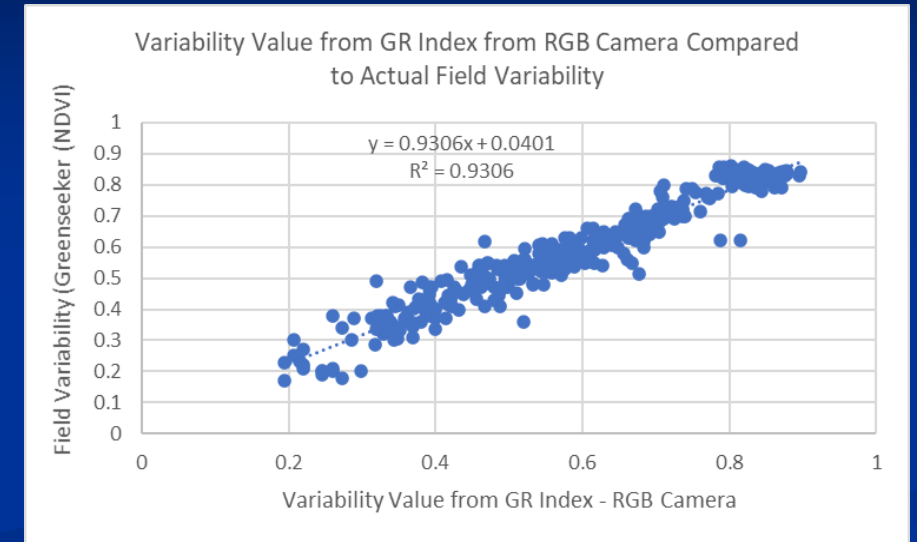
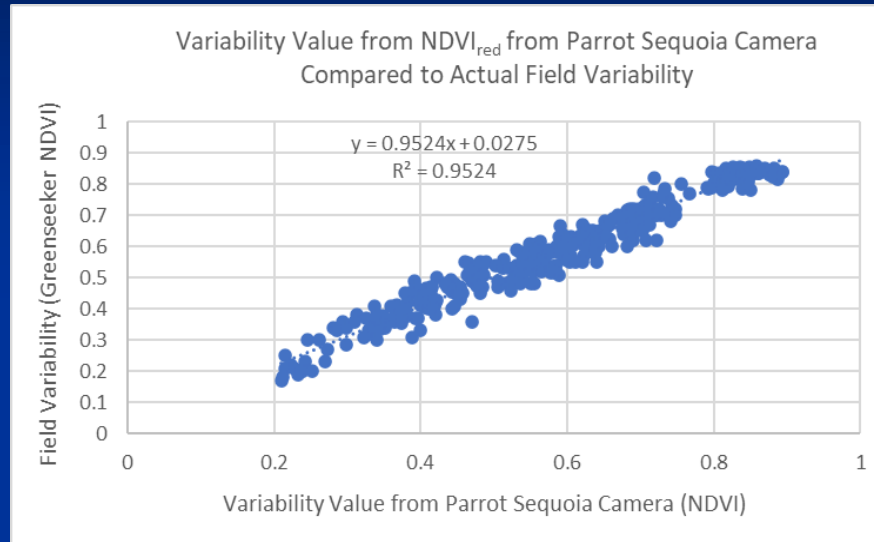
- Comparison of Parrot Sequoia Multispectral camera and standard RGB camera on drones
- 700 readings taken in 17 different fields over a three-year period



Standard RGB Camera



Multi-Spectral NIR Camera



Example of GR Indices Related to Field Differences Versus NDVI:

- Low-cost RGB drones in many cases indicate field variances as well as higher priced NIR-type (NDVI) cameras:

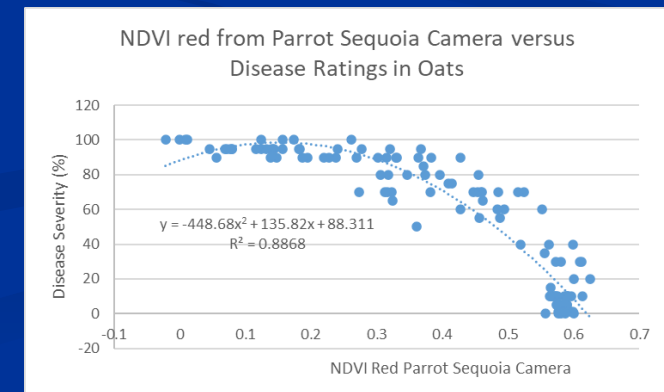
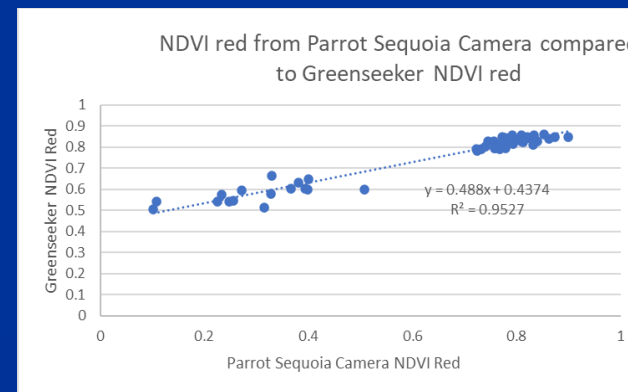
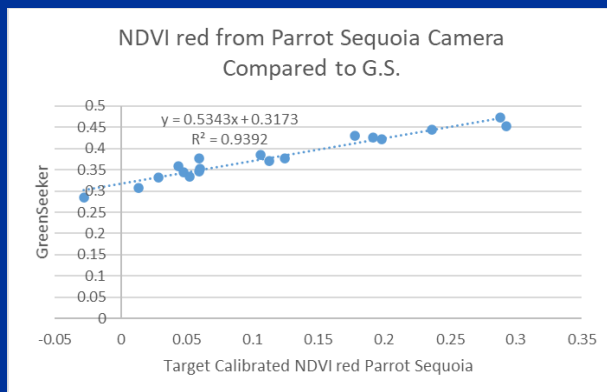
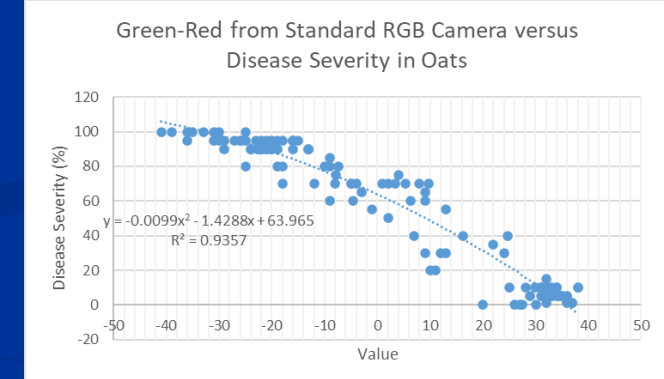
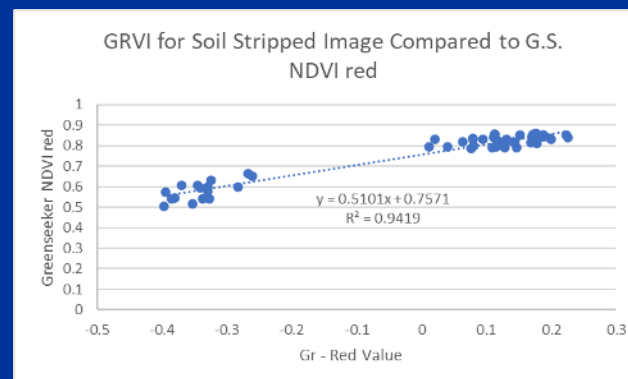
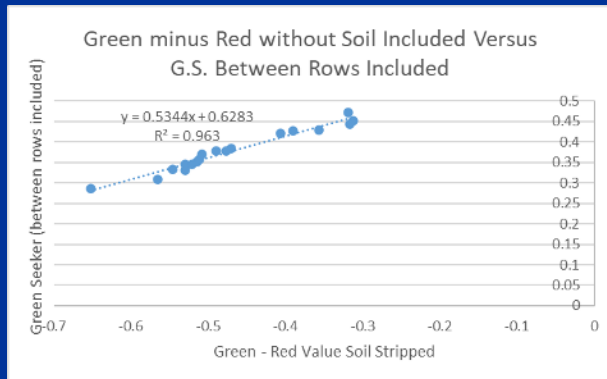
Early Season Soybean Plots



Early and Mid-Season Soybean Plots



Oats Disease Plots



Programs to Calculate GR and Associated Indices:

- Analyze up to 1200 to 1500 plots in 12-15 minutes



Application Exit

Image Parameters:

Width: 575
Depth: 271
Images: 1

Load and Process Image According to Checked Box Below

Note: new images and text results saved on desktop in "ImageFolder"

Uncheck to not save new images and allow program to run faster on large datasets

Uncheck to Analyze Part of Image Using Image Dimensions Above - Select one less than max values!!!

Threshold Values for Removing Light Color Soils in Images
Light Soils Typically Removed by setting three color values high (such as >150, etc.)
Wetness will bring Blue value down - Adjust as Needed

Red (0 - 255) Green (0 - 255) Blue (0 - 255)
150 150 150

Threshold Values for Removing Shadows in Images
Shadows: Put in Low Values to Remove Shadows (such as R,G,B < 60, etc.)
Adjust as Needed

Red (0 - 255) Green (0 - 255) Blue (0 - 255)
60 60 60

*Use ImageJ (or other program) to determine actual pixel values

Convert RGB Image to Green Minus Red (GR) Image and rescale from 0 to 255 (Maximum range) into green band and threshold at 5 GR to separate soil background and not include in plants only (P) calculations
Uncheck to see regular image GR ranges from -50 to -50, with plus values being plants, minus values being soil, and usually changes between the two around 0

Check here to save original color pixels with stripped soil background using GR principle and thresholding for shadows (upper right)

Check here to make soil background red

Check here to use and map BR calculation instead of GR

Check here to use and map G+R-2B (yellow) calculation instead of GR

Values for each Image / Evaluation Box shown below and written to data file "data1.txt" in "ImageFolder" folder on Desktop.

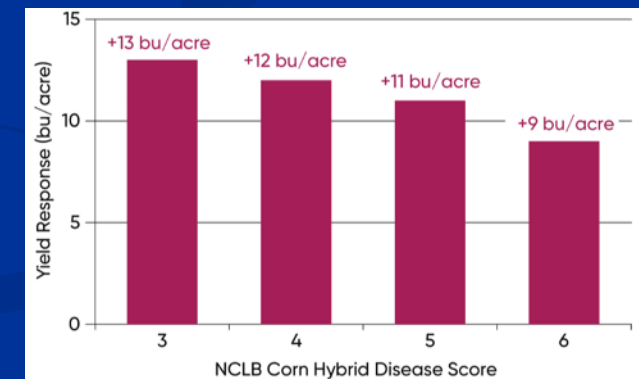
Whole Image / Analysis Area Pixels (soil included):			General Plant Health Parameters:			Yellowing/Chlorosis Parameter:		Standard Indexes	
Red	Green	Blue	Green-Red	Blue-Red	G+R-2B	GRVI	VARI	Percent Plants (%)	% Soil Background
159.7	157.7	122.7	-2.0	-37.0	72.0	0.006	-0.010	43.914	56.086
Plant Pixels Only - soil pixels not included, threshold at (Green - Red) < GR set above and soil shadow set above to the right									
PRed	PGreen	PBlue	PGreen-PRed	PBlue-PRed	P(G+R-2B)	PGRVI	PVARI		
90.2	100.7	70.5	10.4	-19.8	49.9	0.055	0.087		

Red	Green	Blue	GR	BR	GRVI	VARI	%Plants	%Background	PRed	PGreen	PBlue	PGR	PBR	PGRVI	PVARI		
152.6	179.7	148.5	-12.9	-44.2	75.4	-0.035	-0.058	22.00	78.00	107.9	114.6	77.9	6.7	-30.0	66.6	0.030	0.046
204.2	188.8	159.9	-15.4	-44.3	73.2	-0.039	-0.066	14.00	86.00	119.9	123.3	83.5	3.4	-36.4	76.2	0.014	0.021
198.3	184.0	156.2	-14.3	-42.1	69.9	-0.037	-0.063	16.47	83.53	116.8	122.9	85.3	6.1	-31.4	69.8	0.026	0.040
159.7	157.7	122.7	-2.0	-37.0	72.0	-0.006	-0.010	43.91	56.09	107.9	114.6	77.9	6.7	-30.0	66.6	0.030	0.046
176.8	156.7	135.8	-10.1	-41.0	71.9	-0.029	-0.048	25.08	70.92	102.6	110.3	77.5	7.8	-25.0	57.8	0.037	0.055
199.7	182.4	154.3	-17.1	-45.4	73.7	-0.045	-0.075	13.77	86.23	119.6	123.0	86.7	5.5	-32.8	69.1	0.014	0.022
204.6	187.4	161.6	-17.2	-43.0	68.7	-0.044	-0.075	10.41	89.59	124.7	128.0	91.6	3.3	-33.1	69.5	0.013	0.021
152.4	152.5	119.6	0.1	-32.8	65.7	0.000	0.001	47.10	52.90	98.5	101.4	72.7	18.9	-17.8	46.5	0.065	0.092
156.7	156.9	123.4	0.2	-35.2	66.7	0.001	0.002	45.81	54.19	90.3	102.8	72.7	12.5	-17.8	47.6	0.065	0.092
106.7	175.9	145.2	11.6	-41.4	71.3	0.032	-0.054	26.25	73.75	112.9	118.8	85.3	5.9	-27.7	61.2	0.025	0.040
169.1	164.4	134.0	-4.6	-35.1	65.5	-0.014	-0.023	38.07	61.93	101.2	110.3	79.1	9.1	-21.9	62.8	0.041	0.069
167.5	163.1	132.5	-4.4	-34.9	65.5	-0.013	-0.022	39.75	60.25	102.0	111.2	80.5	9.2	-21.5	62.1	0.041	0.070
197.6	186.9	161.5	-10.7	-36.1	61.4	-0.028	-0.048	20.76	79.24	110.8	119.8	86.0	9.0	-24.8	58.5	0.039	0.062
181.7	174.9	147.1	6.8	-34.6	62.4	-0.019	-0.033	31.01	68.99	107.9	115.5	84.6	8.4	-22.4	53.3	0.038	0.061
193.1	184.6	158.7	-8.5	-34.4	60.4	-0.022	-0.039	25.75	74.25	115.1	123.9	88.4	7.1	-26.7	60.6	0.030	0.047
205.2	192.0	167.4	-13.2	-37.8	62.3	-0.033	-0.057	15.80	84.20	120.6	125.7	89.9	5.1	-30.8	66.6	0.023	0.033
143.3	148.9	116.4	5.6	-26.9	59.4	0.019	0.032	51.11	48.89	92.4	106.1	77.6	13.7	-14.8	43.3	0.069	0.113
135.6	141.8	111.7	6.2	-24.3	54.7	0.022	0.038	54.07	45.93	89.6	102.1	75.7	12.5	-13.9	40.3	0.065	0.108
202.7	194.1	171.2	-13.4	-36.5	59.5	-0.031	-0.058	11.72	86.28	129.1	132.2	93.5	3.1	-35.6	74.1	0.017	0.019
206.7	193.2	168.5	-13.4	-38.2	65.1	-0.033	-0.058	16.78	83.22	129.3	133.0	93.4	0.1	-35.9	75.3	0.016	0.024
183.5	178.8	151.6	-4.9	-31.0	58.1	-0.019	-0.023	32.86	67.14	115.7	122.9	91.5	9.1	-22.2	53.6	0.039	0.063
191.6	183.2	158.5	8.5	-33.2	57.8	0.023	0.039	24.73	75.27	109.4	117.0	85.2	7.6	-24.1	55.9	0.034	0.054
204.5	193.4	169.6	-11.1	-35.0	58.8	-0.028	-0.049	17.29	82.71	125.7	131.2	94.6	5.5	-31.1	67.8	0.027	0.034
201.5	198.7	163.2	-10.8	-38.3	65.7	-0.028	-0.047	22.05	77.95	120.1	125.5	87.5	5.4	-32.6	70.8	0.022	0.030
213.0	199.2	177.6	-13.7	-35.4	57.0	-0.033	-0.059	9.14	90.86	141.9	144.8	105.9	3.9	-35.0	73.9	0.014	0.022
198.7	186.7	161.0	-12.1	-37.8	63.5	-0.031	-0.054	28.59	79.41	115.3	121.7	95.6	6.4	-29.8	66.0	0.027	0.042
146.7	151.0	120.5	4.3	-26.1	46.6	0.015	0.024	51.55	48.45	91.0	101.9	76.6	12.9	-14.4	41.1	0.066	0.109
194.8	184.6	154.1	-10.2	-40.7	71.2	-0.027	-0.045	28.84	71.16	111.4	119.5	82.3	8.1	-29.1	66.3	0.035	0.054
207.9	195.2	173.6	-12.7	-34.3	55.8	-0.031	-0.055	14.25	85.75	123.6	130.3	95.5	6.7	-28.1	62.9	0.027	0.043
153.6	154.6	123.0	1.1	-30.6	62.2	0.003	0.006	46.83	53.17	90.2	102.7	73.9	12.5	-16.3	45.1	0.065	0.105
201.2	190.1	161.8	-11.0	-37.3	63.7	-0.028	-0.049	23.88	76.12	121.1	128.6	92.4	7.5	-29.7	65.0	0.030	0.048
211.2	194.4	167.6	-16.8	-45.6	70.3	-0.043	-0.071	16.09	83.91	120.8	126.1	98.9	5.3	-32.6	70.3	0.021	0.033
197.9	186.6	160.8	-11.3	-37.1	62.9	-0.029	-0.050	20.67	79.33	120.4	127.8	93.0	7.5	-27.4	62.3	0.030	0.048
141.5	141.2	110.8	-10.3	-41.0	71.7	-0.038	-0.058	26.11	73.89	114.1	120.8	94.4	6.7	-29.8	65.7	0.037	0.043

Rotate, Straighten, Crop, and Slice Image Into Equal Segments (Image to Stacks)

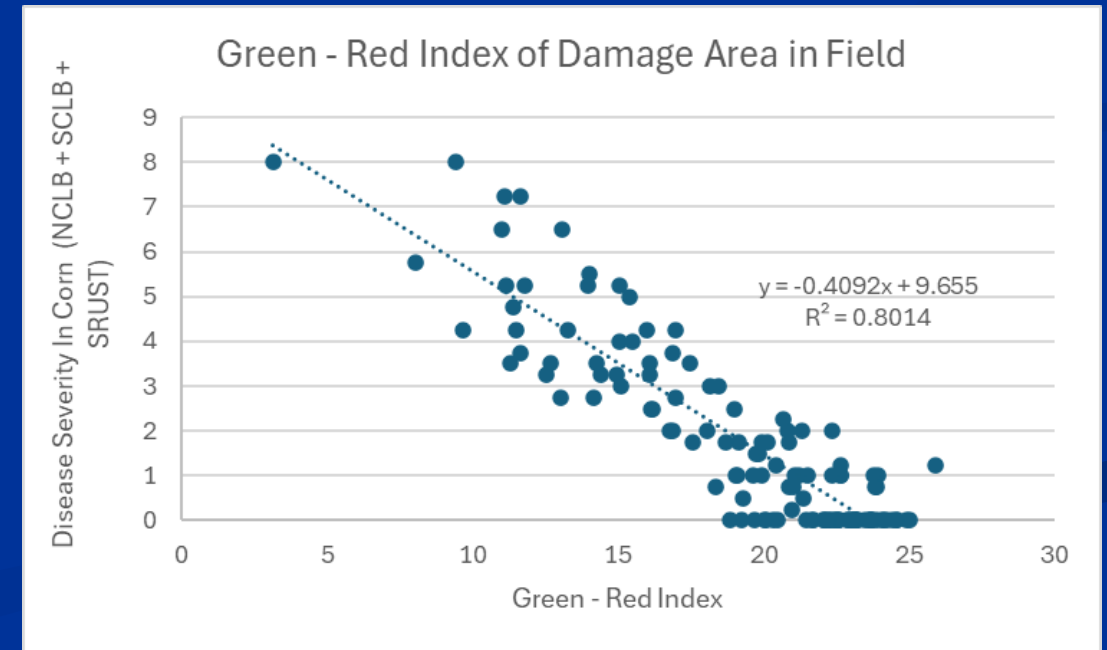
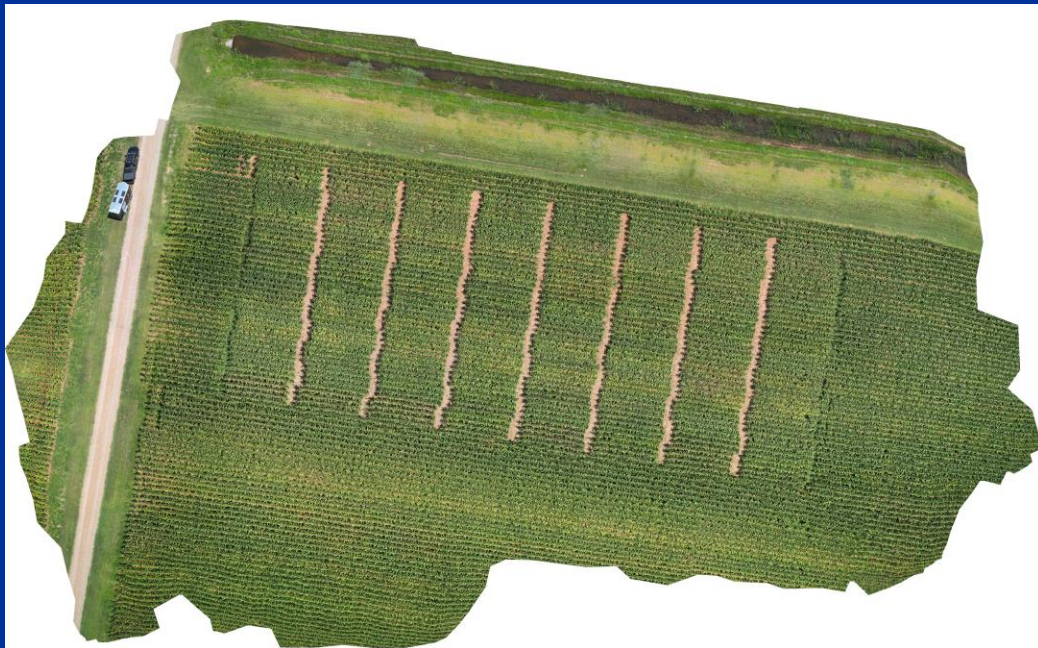
Using RGB Cameras to Indicate Disease Severity in Crops:

- Disease severity a standard damage estimator in fields for insurance, area assessment, and yield loss/gain.
- Ratings usually done on a rating system of 0 to 9
- Published tables on yield losses from these values in corn
- Drones a good way to measure this parameter
 - Could be flown in the field while consultant is in the field providing ground truthing



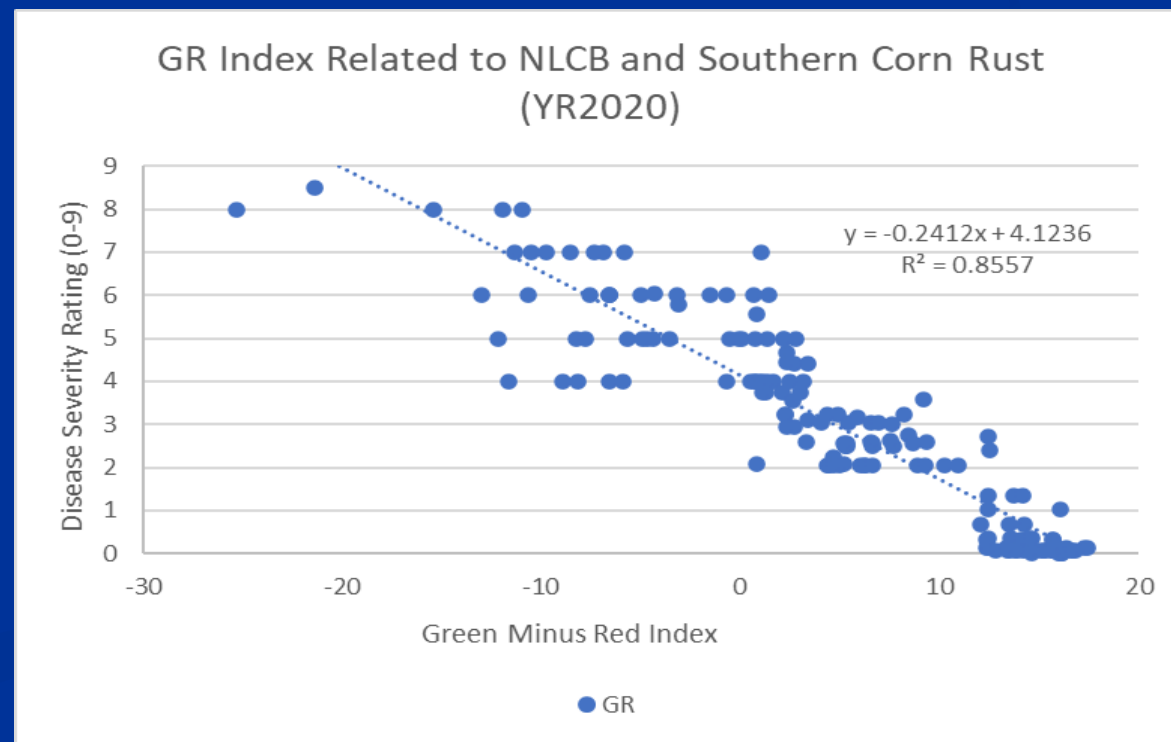
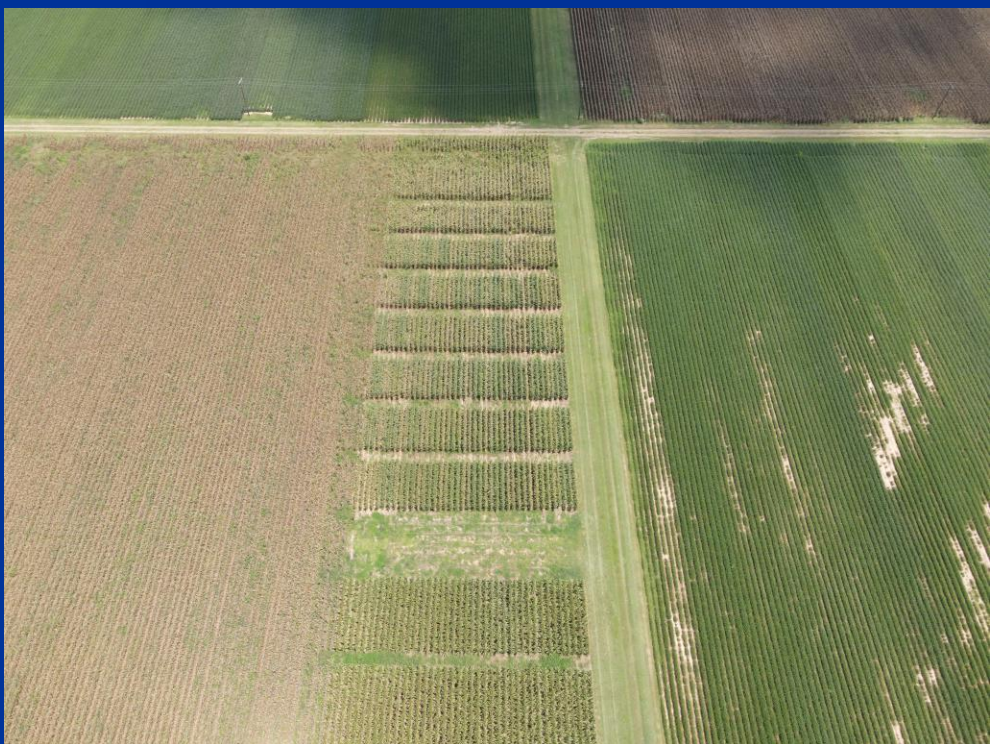
GR Index Related to NCLB, SCLB, and Rust in Corn (2024):

- NCLB and Rust in Corn Plots
- 652 plots / 153 values (when averaged)
- Data taken YR2024 @ 5/29, 6/10, 6/17, 7/1 => 4-week period
- Results: $R^2 = 0.80$



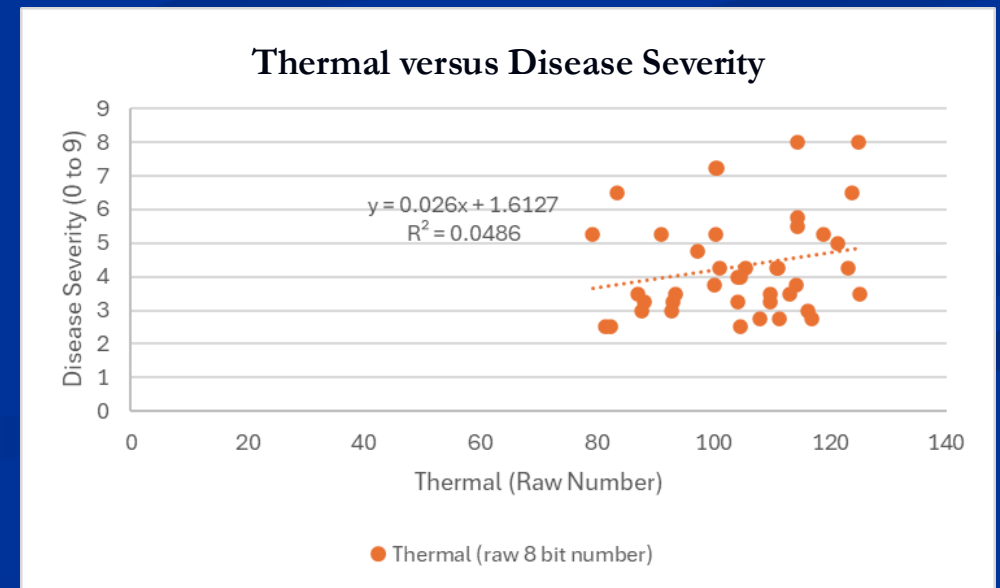
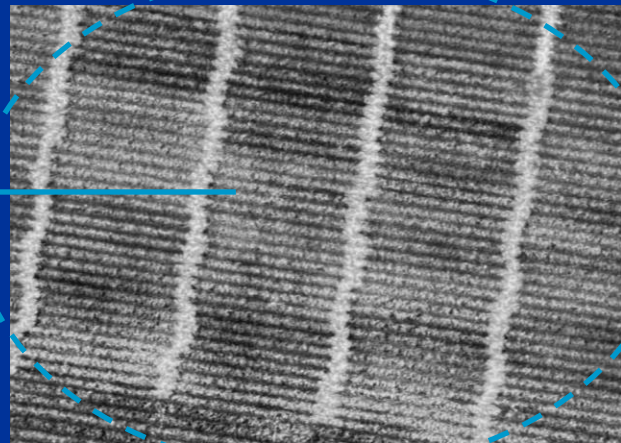
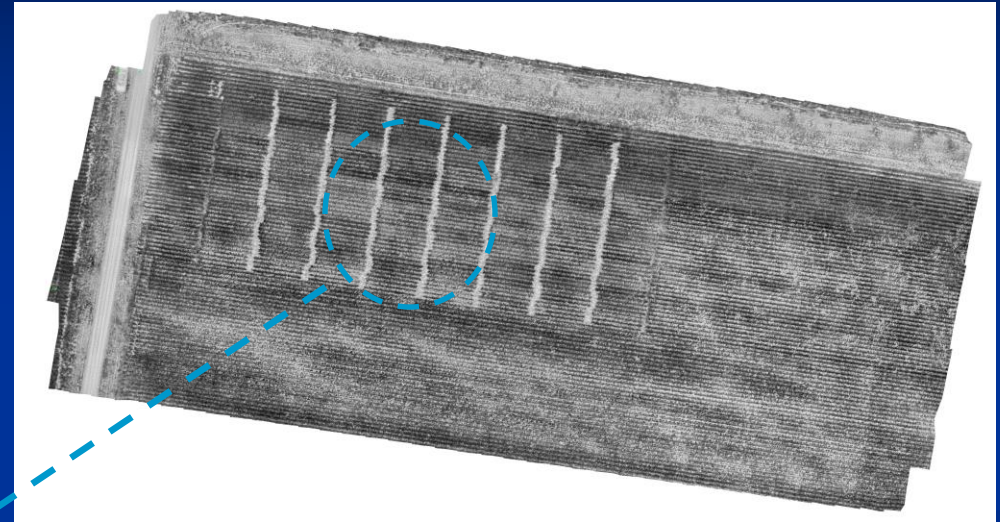
RGB Imagery Related to NCLB, SCLB, and Rust in Corn (2020):

- 225 plots / values
- Data taken YR2020 over a five-day period (7/28 to 8/03) as disease progressed through field
- Results:
 - GR index related to disease severity with an $R^2 = 0.86$



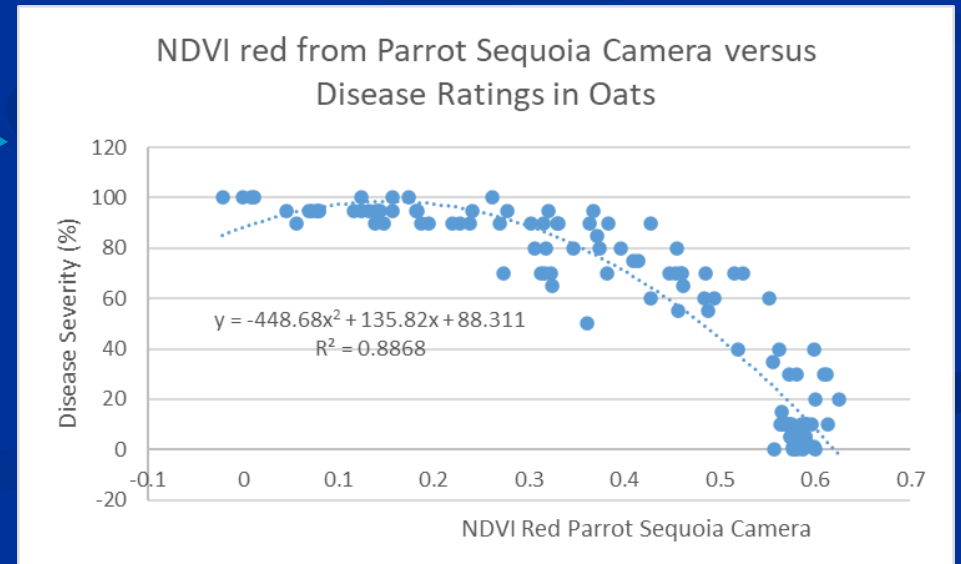
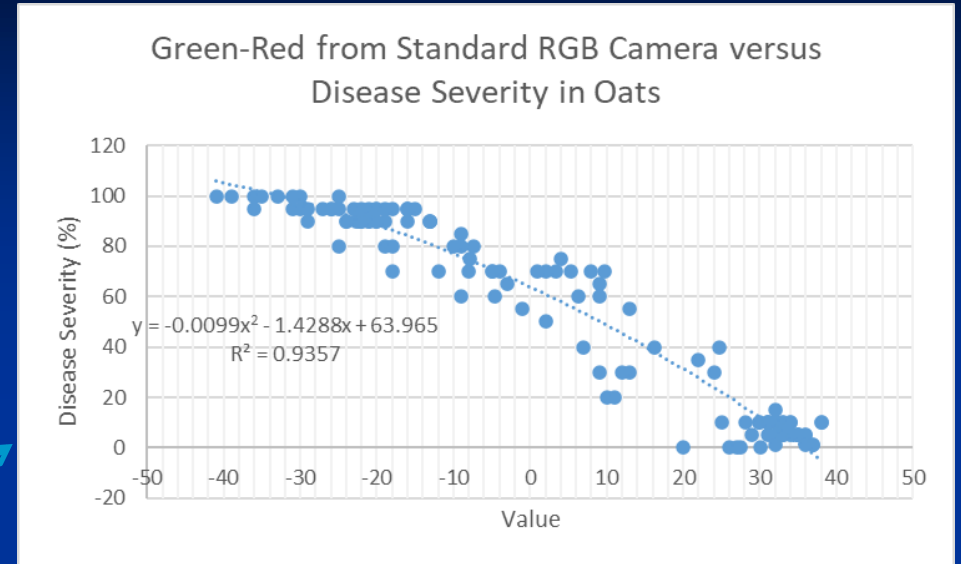
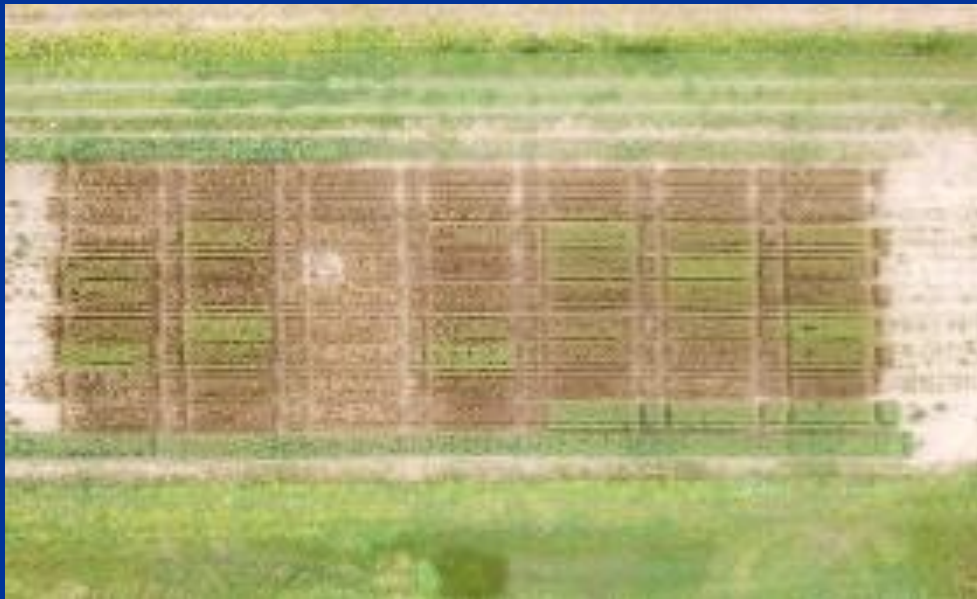
Other Cameras Tested (Corn 2024 Data):

- Thermal => did not work well!!!
 - Always looks good, but never pans out
 - Too many other variances???
 - Thermal hard to work with because of background temps and when you should record it (high noon, midnight, etc.)



Crown Leaf Rust in Oats:

- Crown Leaf Rust
- Data taken over 4-to-6 week period
- GR index performed better than $NDVI_{red}$
 - GR: $R^2 = 0.94$
 - $NDVI_{red}$: $R^2 = 0.89$



Insect Damage Detection in Soybeans

Wire Worm Damage



GR values for Different Areas:

- Wire Worm damage in field with time:

9/9/20 => **3 days** => 9/11/20 => **4 days** => 9/15/20



Stripe (Yellow) Rust in Wheat:



GR = 16.02

GR = 6.45

Close-Ups with Drones Needed for Identification of Type of Disease Detection

- Can detect damage well, but don't know what type of damage without ground truthing
- Close ups needed to have complete answer
- Can fly 2 to 15 ft. off crop
- Drone camera increasing in resolution (100 Megapixels, etc.)



Oblique
Image flown
15 ft (4 m)
above crop
(12 Meg.
Pixel)

48 Meg. Pixel:



Brown Stripe in Sugarcane:

- 20 Megapixels
 - Not enough to clearly identify feature of Disease



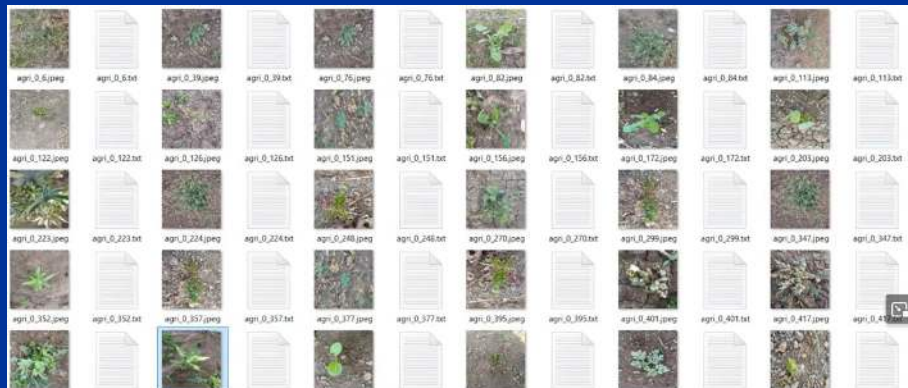
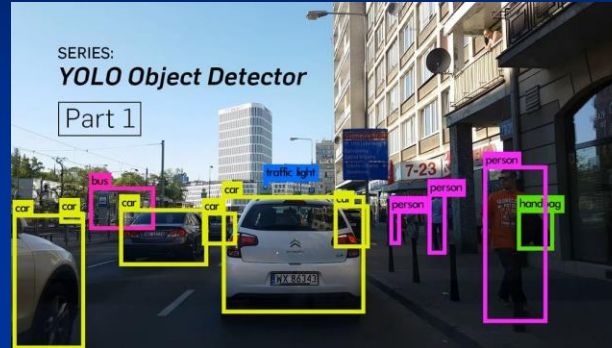
Brown Stripe in Sugarcane:

- 200 Megapixel Imagery:



YOLO Stuff:

- A.I. Object Identification
 - YOLO - “You Only Look Once”
 - YOLO1,2,3,4, 28
- Training set to find and identify objects in images
- Very fast – 45 fps
- Needs Large Training Sets:
 - 3,000 to 30,000 images



Roboflow:

- Object and feature detection
- Based on model like YOLO (“You Only Look Once”) - SAM3, etc.
- Agricultural datasets

Browse > Agriculture


Top Agriculture Datasets

The use-cases for computer vision in agriculture are endless. From weed detection, to crop disease treatment, to automated spraying via drones, to autonomous tractors, to color sorting, to livestock monitoring, these datasets and pre-trained models can be used to optimize farmers' productivity, and boost yield, decrease costs, and increase profits.


For more information: <https://roboflow.com/industries/agriculture>

Top 6 agriculture datasets: <https://blog.roboflow.com/top-agriculture-datasets-computer-vision/>


PlantDoc dataset overview: <https://blog.roboflow.com/introducing-an-improved-plantdoc-dataset-for-plant-disease-object-detection/>



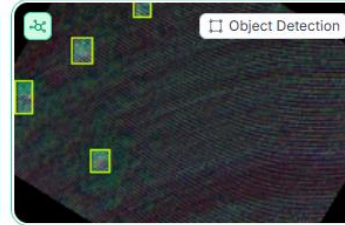
Weeds
by Augmented Startups
4.2k images · 1 model · 1.65k



cotton
by Roboflow 100
406 images · 1 model · 527



grass weeds
by Roboflow 100
2.49k images · 1 model · 543



cotton plant disease
by Roboflow 100
1.02k images · 1 model · 244



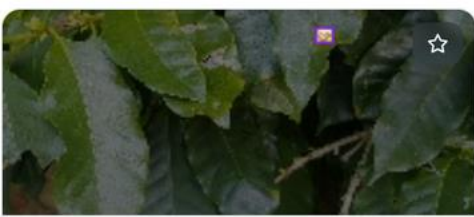
coffee leaf rust x 🔍

Search By **Subject** Has a Model Project Type **Model Type** **Advanced Filters** 50 results per page

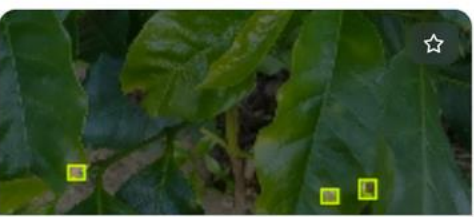
Related Objects of Interest: [red_spider_mite](#), [ferrugem](#), [rust](#), [leaf_miner](#), [brown_eye_spot](#), [leaf_rust](#), [ferrugemw](#), [bicho_mineiro](#), [leaf_miner](#), [healthy](#) Showing 1 - 50 of 300 1 2 3 4 5 6 >



Instance Segmentation
Yolov8
by Yolov8
105 images
[rust](#) [cosp](#) [phom](#)



Object Detection
tflite
by 864953792@qq.com
2847 images
[brown_eye_spot](#) [leaf_miner](#) [leaf_rus](#)



Object Detection
CoffeeLeafDisease
by AGROCTOR
2847 images
[brown_eye_spot](#) [leaf_miner](#) [leaf_rus](#)



Object Detection
liscie_rust_2
by Rafix
542 images
[rust](#) [leaf_miner](#)

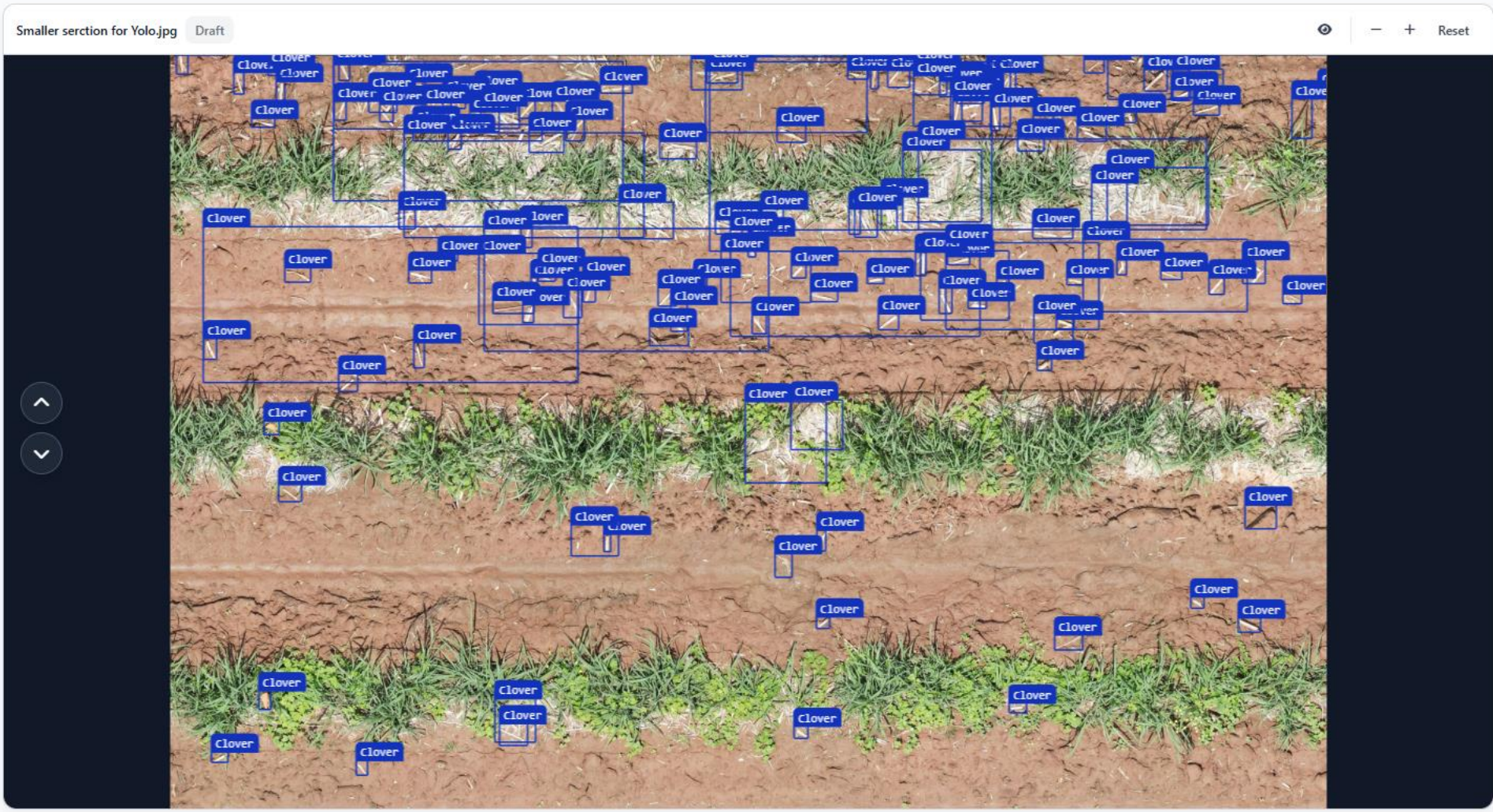


Files 5

+

^

v



How is your model looking?

You can adjust the slider to show more or less objects before taking your next action.

+ Test on More Files

Adjust Objects

Objects 133

Slider control for adjusting the number of objects.

← Relabel Objects

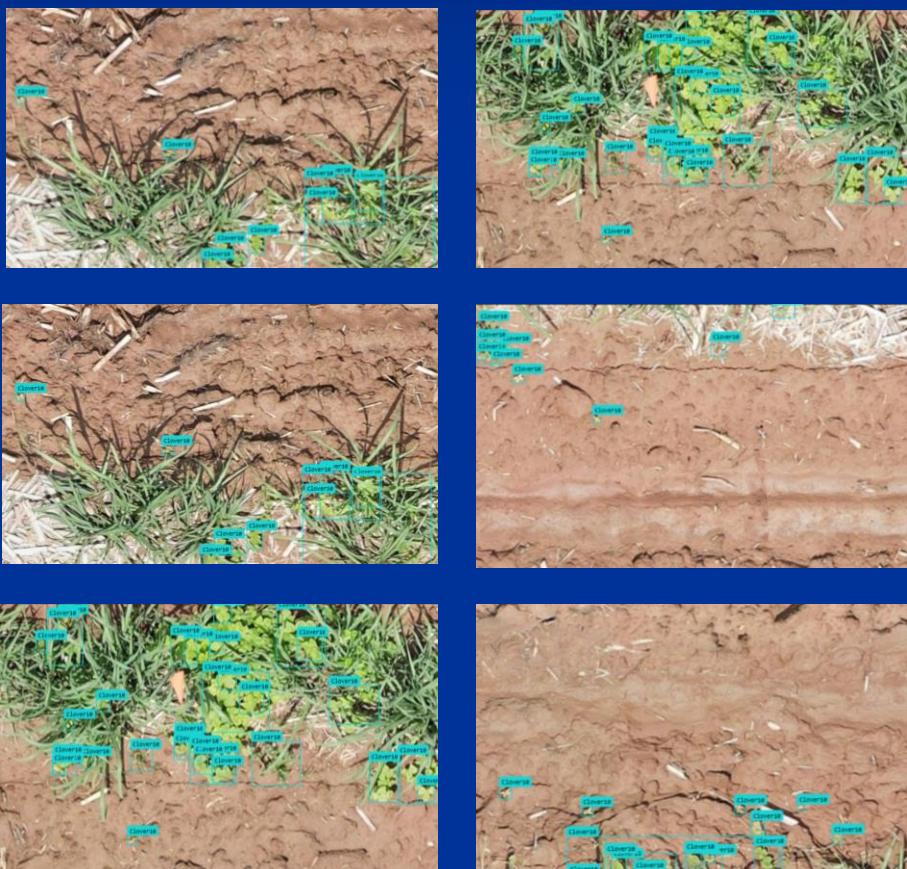
Publish and Use Model

Weed Identification in Sugarcane Plot:



Example (SAM3):

■ Training Images:

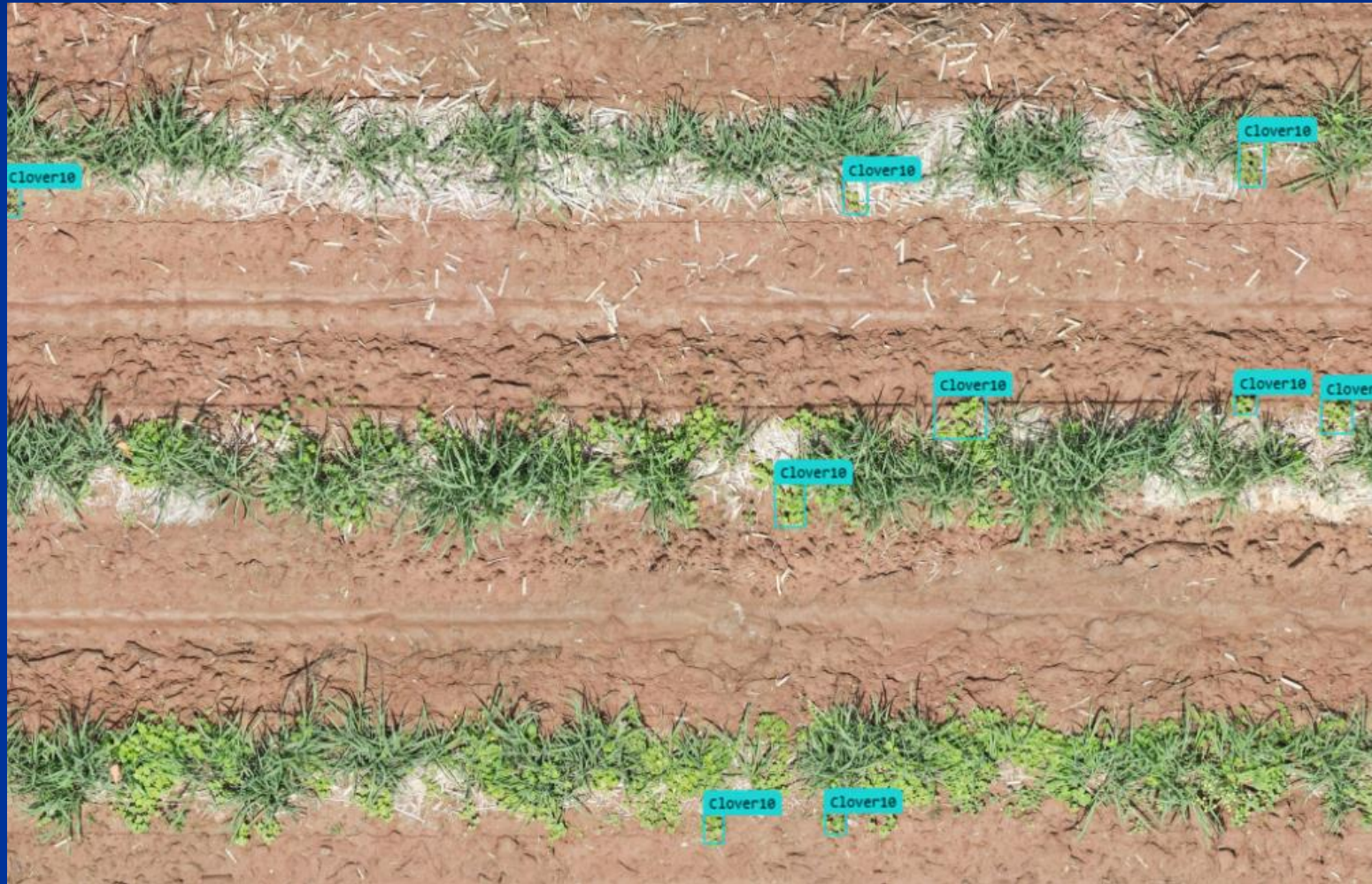


■ Test Images:



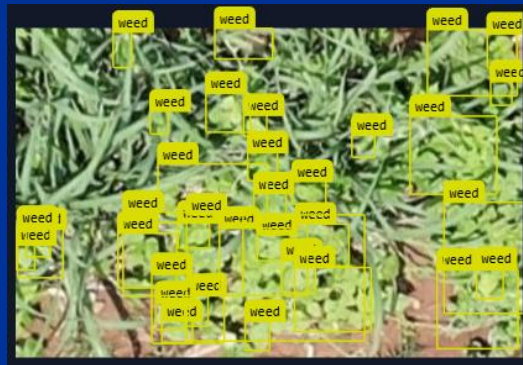
Larger Image Section:

- Did not work as well in larger images:



Results:

- Tried to train it to see smaller, each clover plant

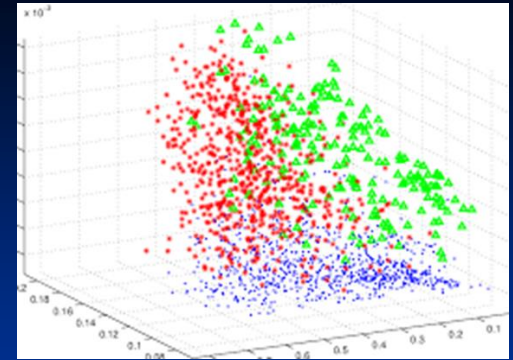


Larger Area Images:

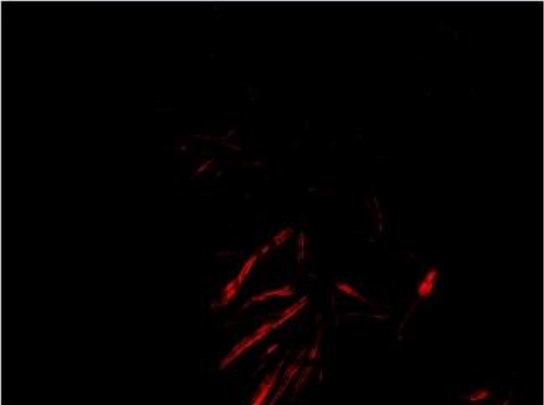



Classifier Method: Detecting Johnson Grass from Sugarcane:

- Calculate median color for each color (RGB) and select based on standard deviation around that mean
- Works when colors different
- High speed: can do 10 to 20 images per second
- Doesn't handle sunlight changes very well (could be more automated with white standards, etc.)



RGB Drone Imagery Analysis Program



Input average values for plants (or object of significance) using ImageJ (or similar program) to obtain Average RGB pixel values and standard deviation of those values (Use RGB analyze and put into Excel to Calculate these values).

Average Value:

Red (0 - 255)	Green (0 - 255)	Blue (0 - 255)
163	206	126

Standard Deviation:

Red (0 - 255)	Green (0 - 255)	Blue (0 - 255)
8	7	18

*Use ImageJ (or other program) to determine pixel values
Standard Deviation Multiplication Factor to Use in Classification:
(1, 2, or 3 => 1 = 65%; 2 = 95%; 3 = 99% of Gaussian Hist. Curve)
Decimals Allowed: like 0.8 or 1.2, etc.

1

Find Plants (or objects) in image that meet statistical values from above (Use ImageJ or some other program to find the average RGB color values and statistical mean using histogram and analyze functions and average values in Excel:)

Percent Plants:	0.887	Plant Pixel Counts:
% Background:	99.113	106431

Current Image Date / Time: _____
GeoSpatial Latitude: _____
Coordinates: Longitude: _____

Image Parameters:
Width 4000
Depth 3000
Images 1

Analysis Box Size:
Upper Left Lower Right
Width 700 1200
Depth 200 700

Load and Process Image According to Checked Box Below

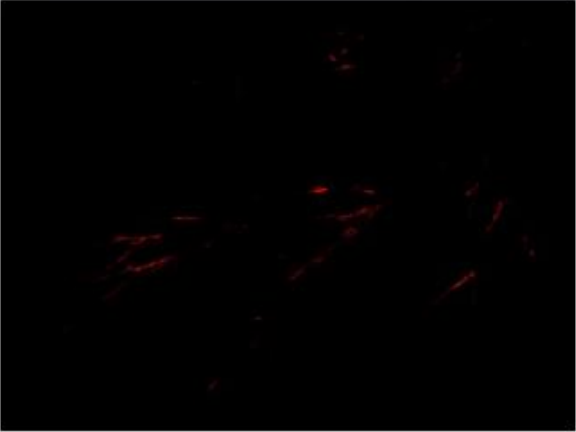

Note: new images and text results saved on desktop in "ImageFolder"

Check if image has GPS values to read and display

Uncheck to Use Partial Image
 Analysis Box from Parameters Above

Detecting Johnson Grass from Sugarcane:

RGB Drone Imagery Analysis Program



Input average values for plants (or object of significance) using ImageJ (or similar program) to obtain Average RGB pixel values and standard deviation of those values (Use RGB analyze and put into Excel to Calculate these values).

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Decimals Allowed: like 0.8 or 1.2, etc.

1

Find Plants (or objects) in image that meet statistical values from above (Use ImageJ or some other program to find the average RGB color values and statistical mean using histogram and analyze functions and average values in Excel:)

Percent Plants:	0.268	Plant Pixel Counts:
% Background:	99.732	32179

Current Image Date / Time
GeoSpatial Latitude
Coordinates: Longitude

Image Parameters:

Width	4000
Depth	3000
Images	1

Analysis Box Size:

	Upper Left	Lower Right
Width	700	1200
Depth	200	700

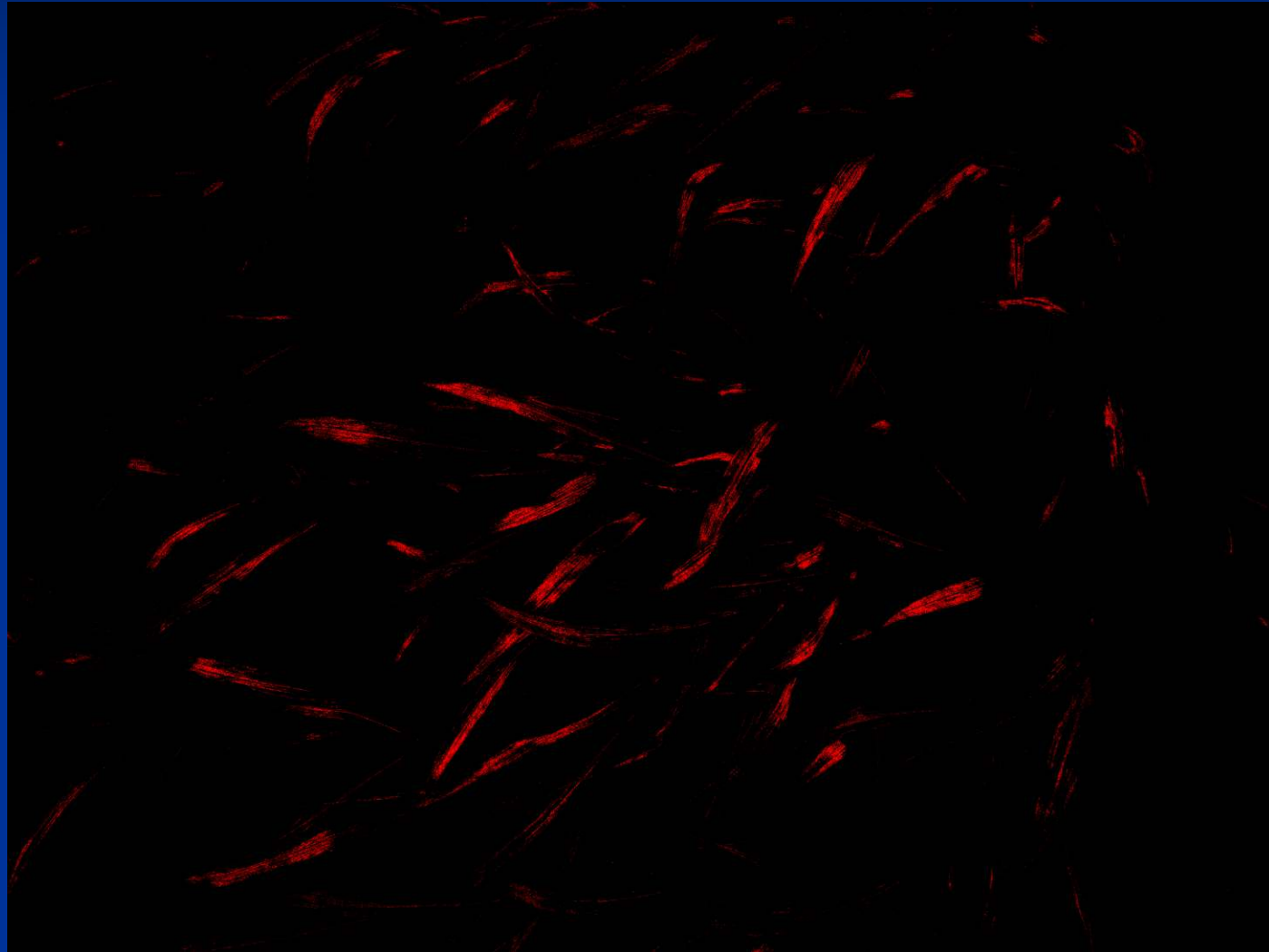
Load and Process Image According to Checked Box Below

Note: new images and text results saved on desktop in "ImageFolder"

Check if image has GPS values to read and display

Uncheck to Use Partial Image Analysis Box from Parameters Above

Close-Up of Johnson Grass Selection:

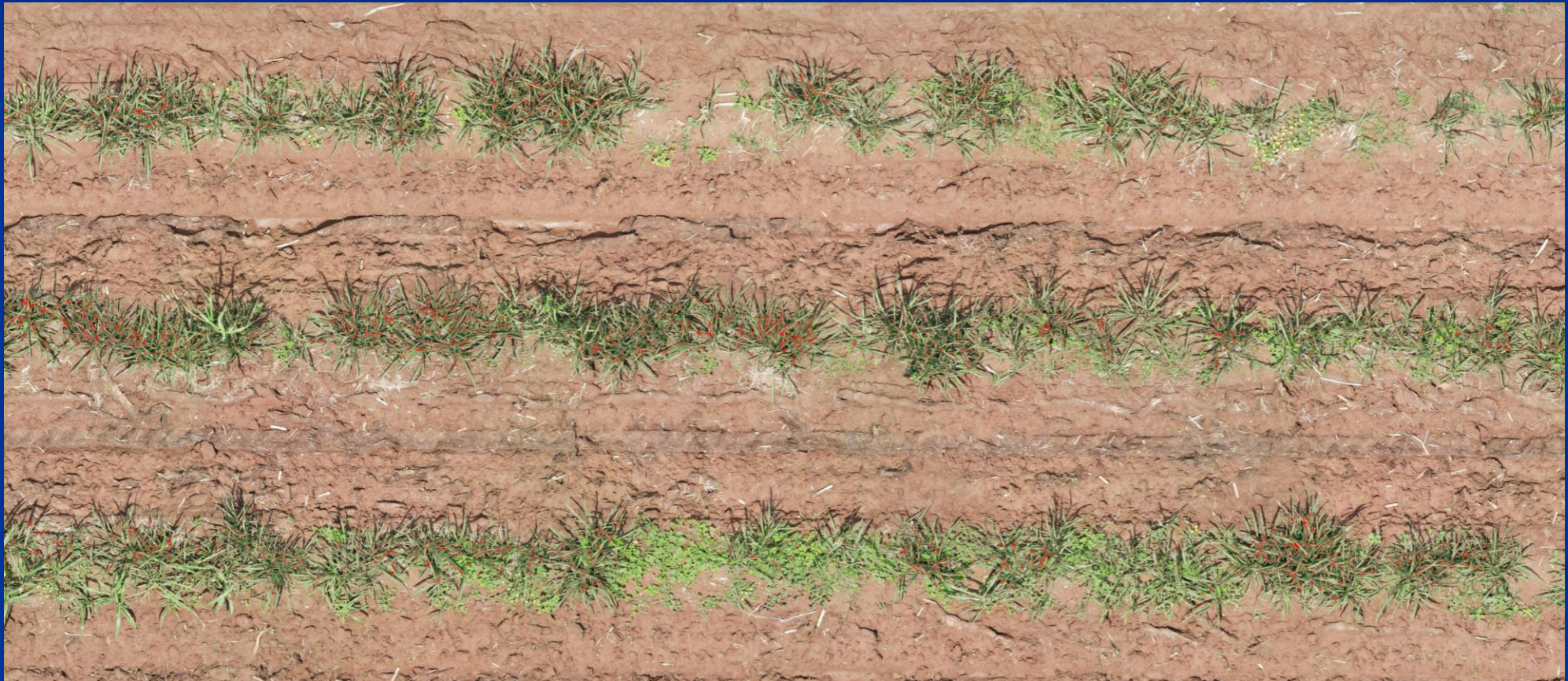


Detect of Sugarcane from Johnson Grass:

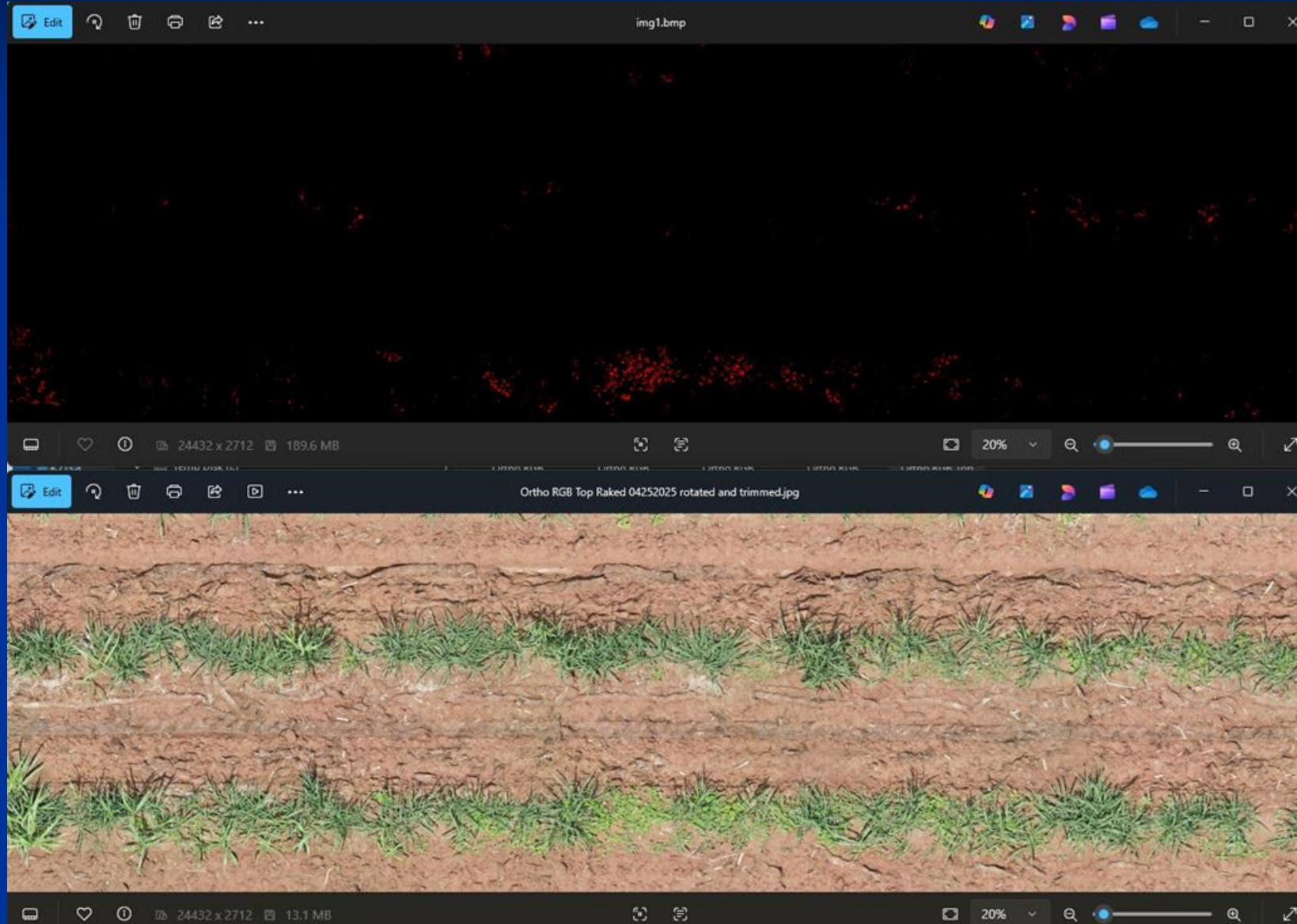


Detection of Sugarcane from Clover:

- Larger Image did not affect classification quality:



Detection of Clover From Sugarcane:



Close-Up:



Conclusions:

- Crop disease damage detection and quantification possible with RGB drones
- RGB drones were able to detect crop disease severities with $R^2 = 0.78$ to 0.93 using the GR Index.
- Ground truthing currently required to determine type of disease or damage.
- Total solution will (disease detection and severity) will require both close-up and long-distance imagery.
- Drones will become capable of obtaining both as Pixel resolutions increase
- Newer A.I. systems and machine learning algorithms will most-likely help in this area.

The End

Questions?

Contact Information: Dr. Randy Price, LSU AgCenter, Dean Lee Research and Extension Center,
8105 Tom Bowman Drive, Alexandria, LA 71302; Email: rprice@agcenter.lsu.edu ; Phone: 225-936-
7593

Thanks to Following Commodity Boards for Support:



Typical Drone System We Use:

- Low-cost RGB Retail Store Camera Drone:
- Components:
 - Drone (\$700 to \$3000)
 - Tablet or Smart Phone
 - Recommend iPad or Android fine
 - Program to Operate Drone
 - Manufactures (Free)
 - Mapping software
 - Cables (Longer cables – 10 ft., Adapters, etc.)
 - Storage Case (Optional)
 - Extra batteries (3) and charger in truck, etc.



Figure 1: Complete real-time mapping system: DJI Mavic Pro, case, Apple iPad, DroneDeploy and an extra-long lightning to USB cable.

Index Change:

- Map conversion done to imagery to help highlight properties that you are interested in:
 - For example vegetative state: NDVI, VARI, etc. are good ones
- Index transformations help eliminate camera and sunlight inconsistencies

Table. Available indices in *FIELDImageR*. Any other index can be implemented using the option *myIndex* and the new formula (*FIELDImageR::fieldIndex*).

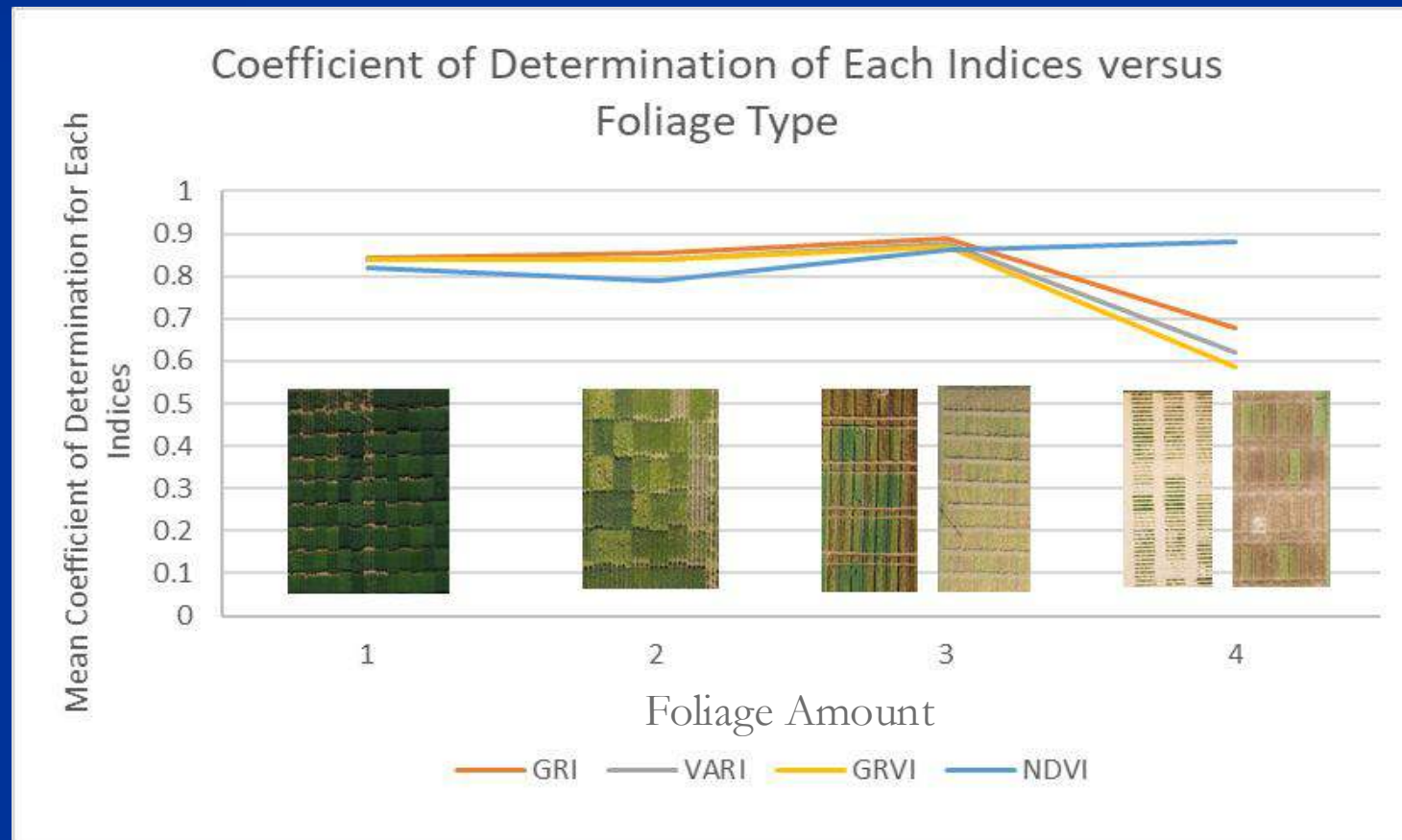
Description	Index	Formula	Related traits	References
Brightness Index	BI	$\sqrt{(R^2+G^2+B^2)/3}$	Vegetation coverage, water content	Richardson and Wiegand (1977)
Soil Color Index	SCI	$(R-G)/(R+G)$	Soil color	Mathieu et al. (1998)
Green Leaf Index	GLI	$(2*G-R-B)/(2*G+R+B)$	Chlorophyll	Louhaichi et al. (2001)
Primary Colors Hue Index	HI	$(2*R-G-B)/(G-B)$	Soil color	Escadafal et al. (1994)
Normalized Green Red Difference Index	NGRDI	$(G-R)/(G+R)$	Chlorophyll, biomass, water content	Tucker (1979)
Spectral Slope Saturation Index	SI	$(R-B)/(R+B)$	Soil color	Escadafal et al. (1994)
Visible Atmospherically Resistant Index	VARI	$(G-R)/(G+R-B)$	Canopy, biomass, chlorophyll	Gitelson et al. (2002)
Overall Hue Index [#]	HUE	$\text{atan}(2*(B-G-R)/30.5*(G-R))$	Soil color	Escadafal et al. (1994)
Blue Green Pigment Index	BGI	B/G	Chlorophyll, LAI	Zarco-Tejada et al. (2005)
Plant Senescence Reflectance Index	PSRI	$(R-G)/(RE)$	Chlorophyll, nitrogen, maturity	Merzlyak et al. (1999)
Normalized Difference Vegetation Index	NDVI	$(NIR-R)/(NIR+R)$	Chlorophyll, LAI, biomass, yield	Rouse et al. (1974)
Green Normalized Difference Vegetation Index	GNDVI	$(NIR-G)/(NIR+G)$	Chlorophyll, LAI, nitrogen, protein content, water content	Gitelson et al. (1996)
Ratio Vegetation Index	RVI	NIR/R	Biomass, water content, nitrogen	Pearson and Miller (1972)
Normalized Difference Red Edge Index	NDRE	$(NIR-RE)/(NIR+RE)$	Chlorophyll	Gitelson and Merzlyak (1994)
Triangular vegetation index	TVI	$0.5*(120*(NIR-G)-200*(R-G))$	Green LAI, chlorophyll, canopy	Broge and Leblanc (2000)
Chlorophyll vegetation index	CVI	$(NIR*R)/(G^2)$	Chlorophyll	Vincini et al. (2008)
Enhanced vegetation index	EVI	$2.5*(NIR-R)/(NIR+6*R-7.5*B+1)$	Chlorophyll, biomass, nitrogen	Huete et al. (2002)
Chlorophyll index – green	CIG	$(NIR/G)-1$	Chlorophyll	Gitelson et al. (2003)
Chlorophyll index – red edge	CIRE	$(NIR/RE)-1$	Chlorophyll	Gitelson et al. (2003)
Difference Vegetation Index	DVI	NIR-RE	Nitrogen, chlorophyll	Jordan (1969)

[#] Index HUE was modified to capture better the soil color. Original equation: " $\text{atan}(2*(R-G-B)/30.5*(G-B))$ " (Escadafal et al., 1994)

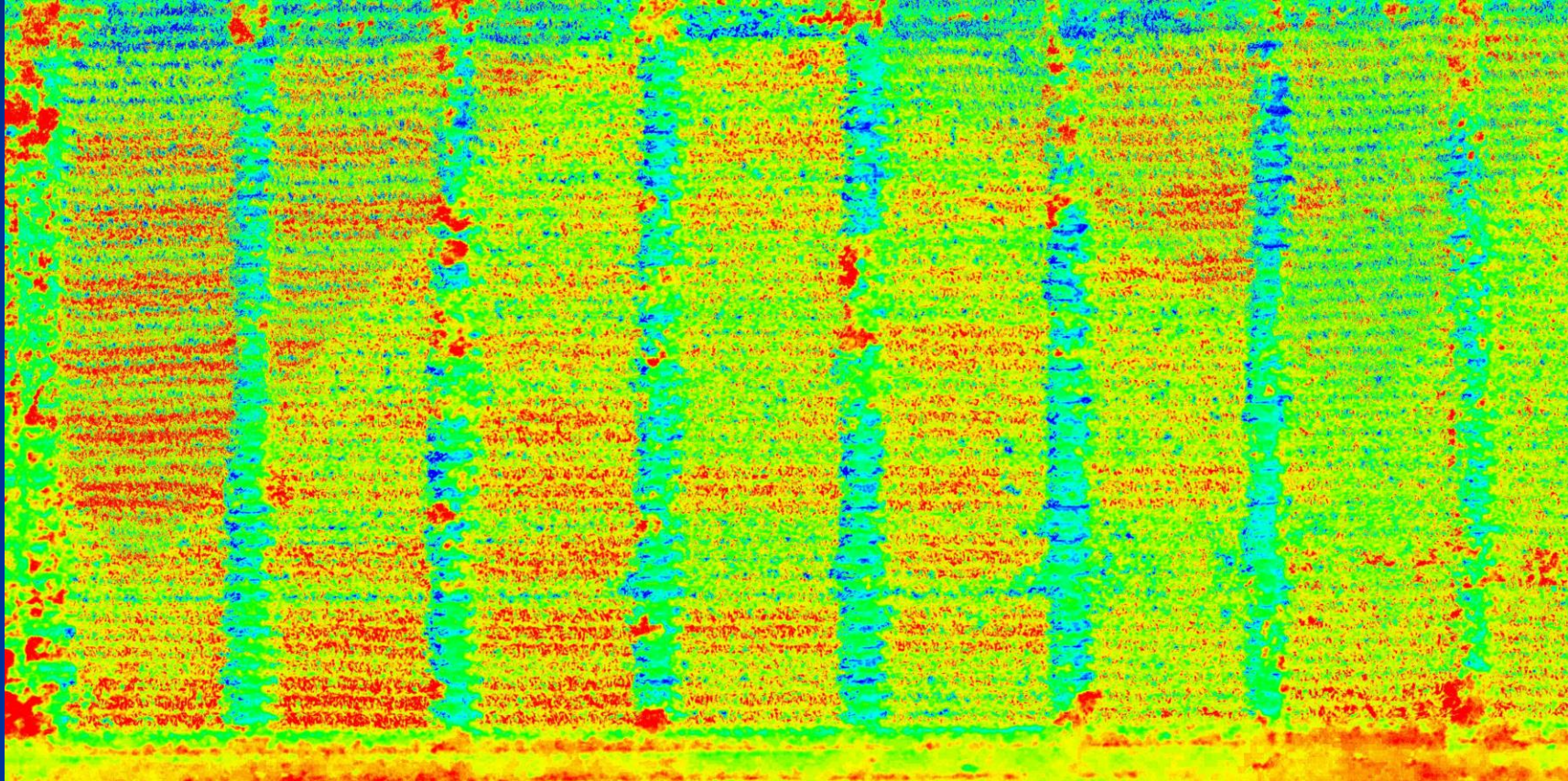
RGB Camera compared to NIR for Detecting General Field Variability:

Field Variability:

- RGB cameras (and associated indices) had higher correlation coefficients than NIR cameras with NDVI.
- The NIR cameras (with the $NDVI_{red}$ Index) perform better in fields with less foliage and higher amounts of dead foliage.



GR of 2020 Corn Plot Using Heat Scale:



pGRVI Index Related to NCLB, SCLB, and Rust in Corn (2024):

■ $R^2 = 0.83$

