University of Saskatchewan

Using Overhead Images to Determine Volume and Ground Cover of Lentil (*Lens culinaris* Medik.)

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MSc Student

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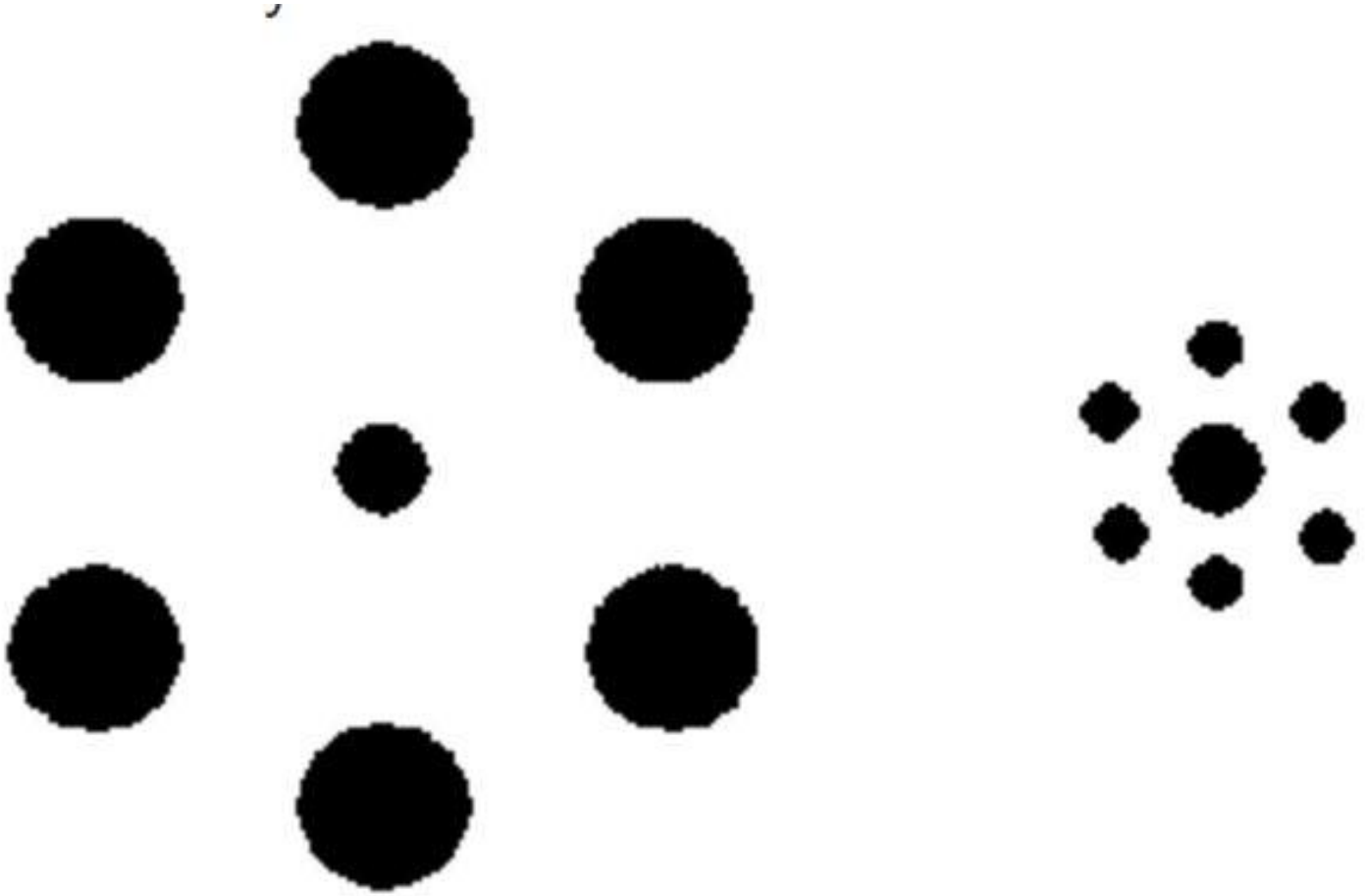
Phenotyping

- “Assesses physical and biochemical characteristics of a plant in its environment.”
- Essential to breeders for variety development and improvement.

<u>Problems</u>

- Qualitative ratings are often given to quantitative traits
- Monotonous
- Questionable consistency and objectivity between observers and over time

Which dot is bigger?



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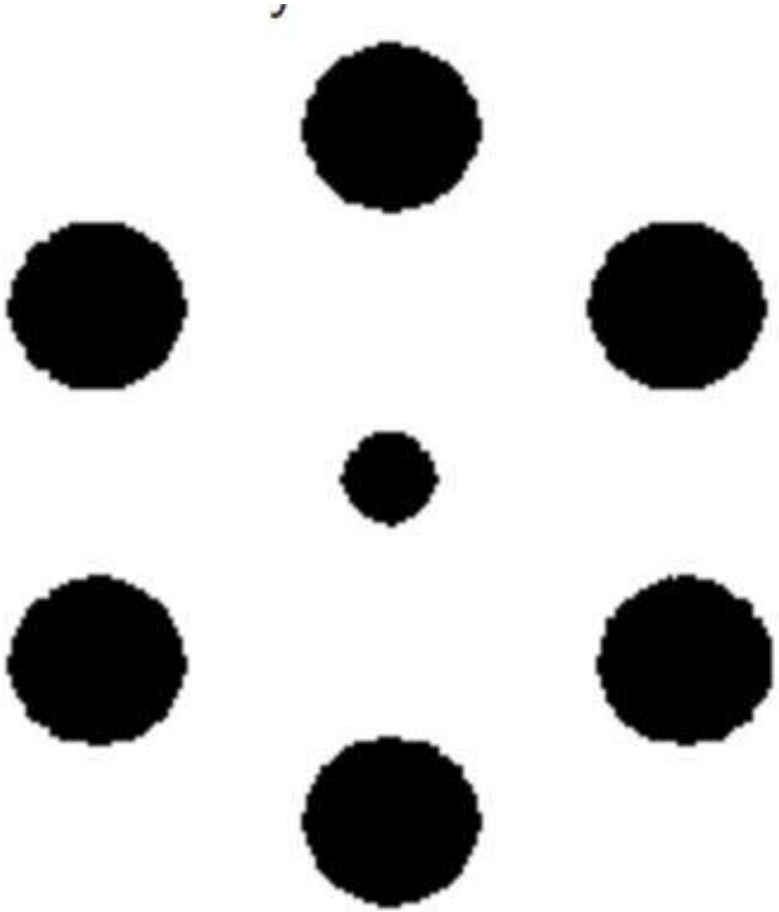

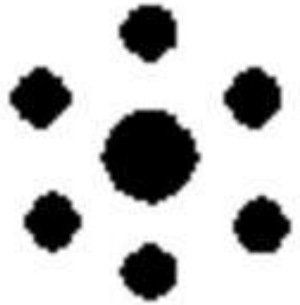

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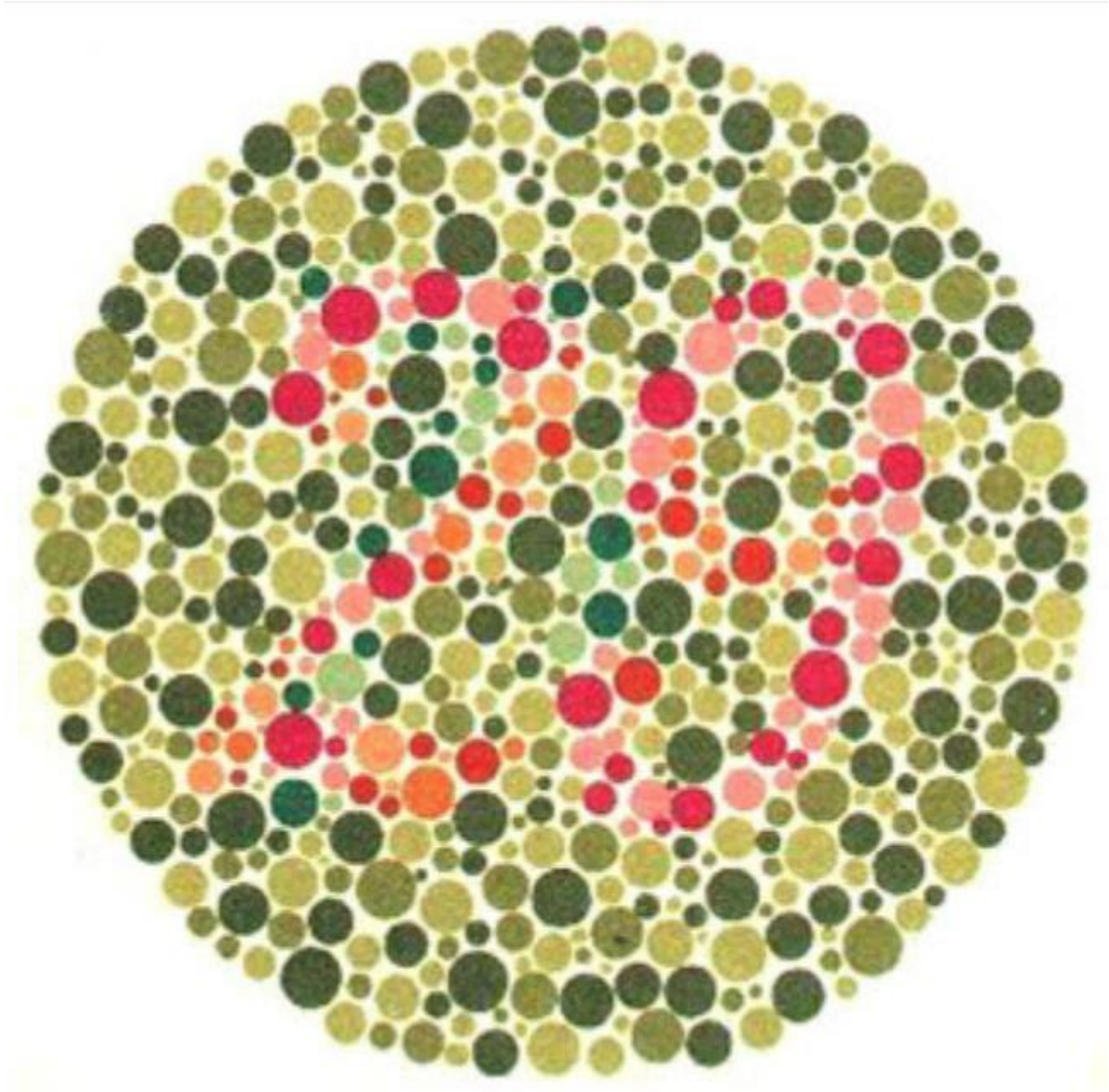

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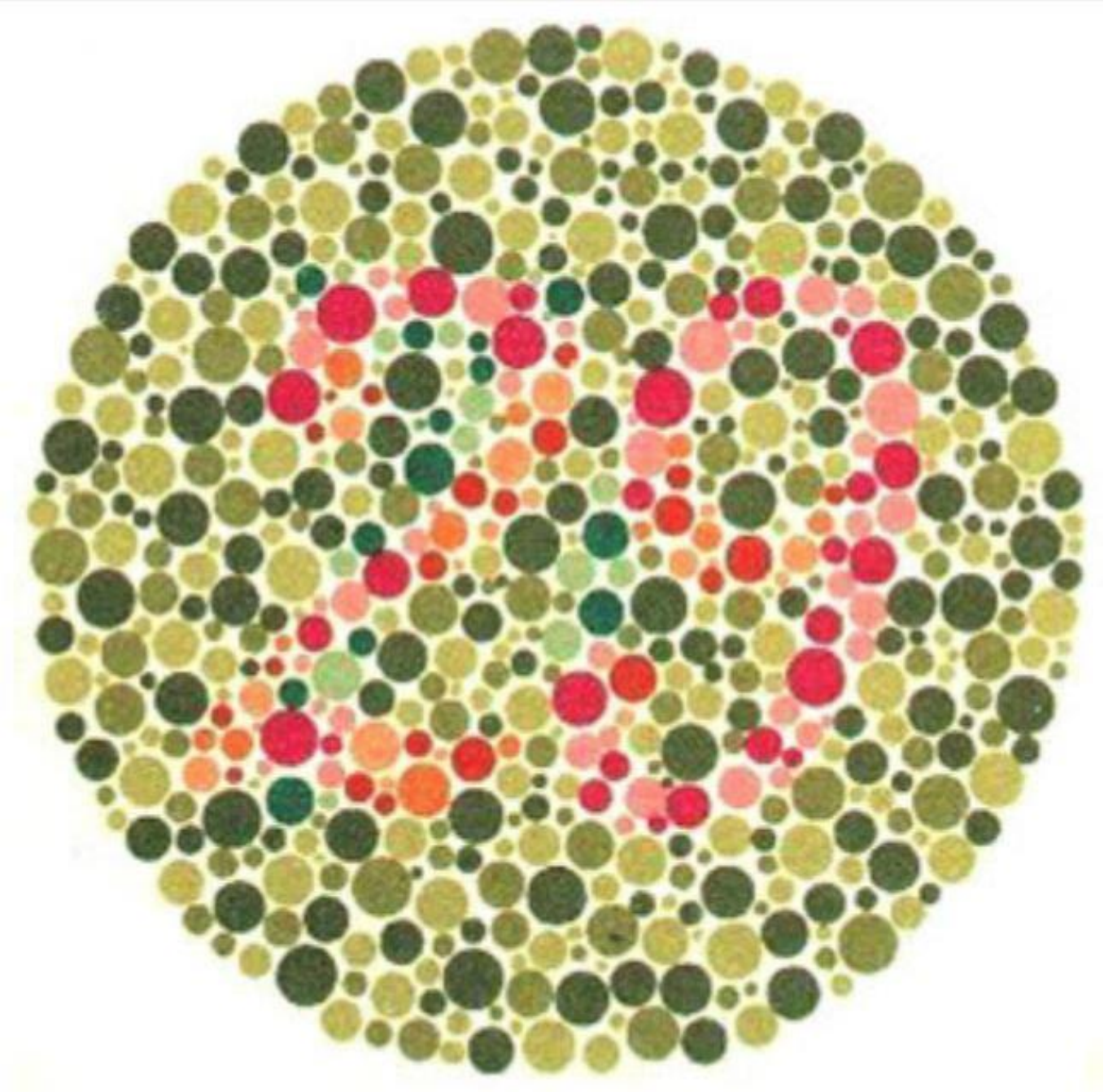


29 = normal

70 = red-green issues

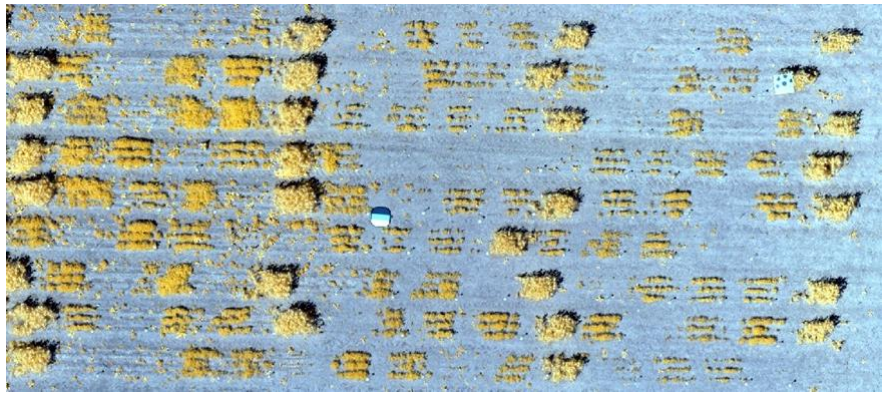
http://ishiharatest.blogspot.ca/2011/03/ishihara-color-blindness-test.html

Solution: Image-Based Phenotyping

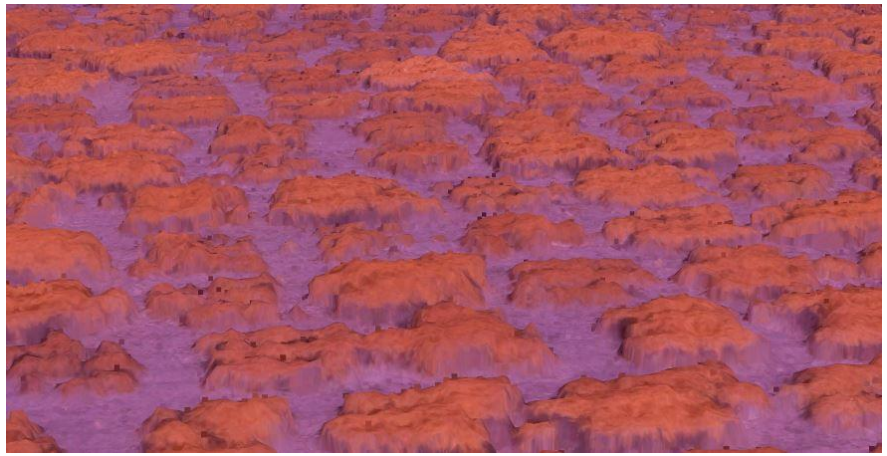
- Utilize UAV images
- High-Throughput
  - High Temporal Resolution
  - Rapid
  - Reduces/Eliminates need for human observers
  - High Spatial Resolution = accurate, looks at *entire* plot
  - Consistent

Goal: Determine a Method to Estimate Plant Biomass Using Overhead Images

- **2-Dimensional Approach**
  - Measure area of vegetation
  - Make assumptions about shape and height



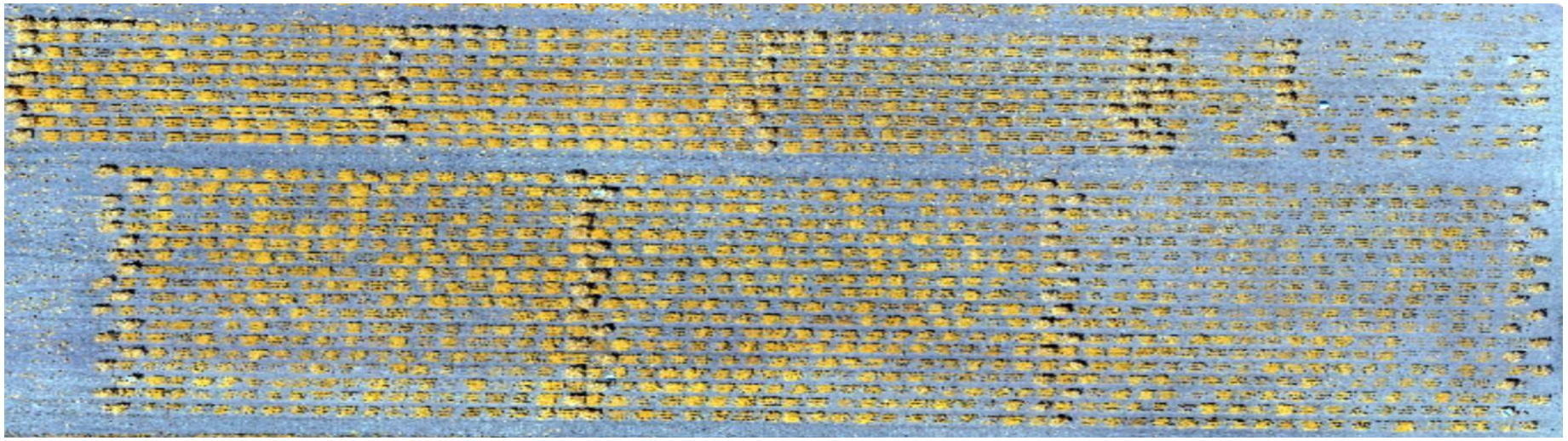
- **3-Dimensional Approach**
  - “cut” vegetation at ground-level
  - Measure 3 dimensional space (volume) filled by vegetation
  - Make some assumptions about density



Germplasm Observed

- Lentil AGILE (Application of Genomic Innovation in the Lentil Economy)
  Lentil Diversity Panel (LDP)
  - 324 Diverse Lines in 3 replicates
  - Microplots (approximately 1m x 1m)
  - Sutherland and Rosthern

- Subset of Lentil AGILE Lentil Diversity Panel (LDP):
  - 6 Diverse Varieties
  - 6 Biomass Collection dates
  - 3 Replicates
  - Microplots (approximately 1m x 1m)
  - Sutherland, Nasser, and Rosthern



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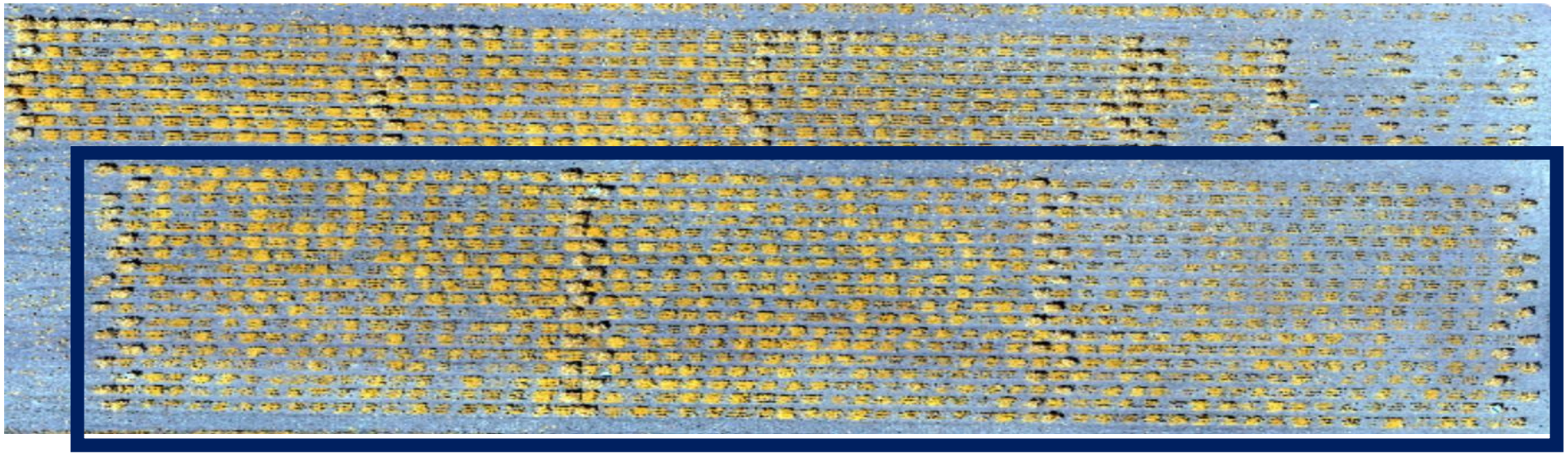

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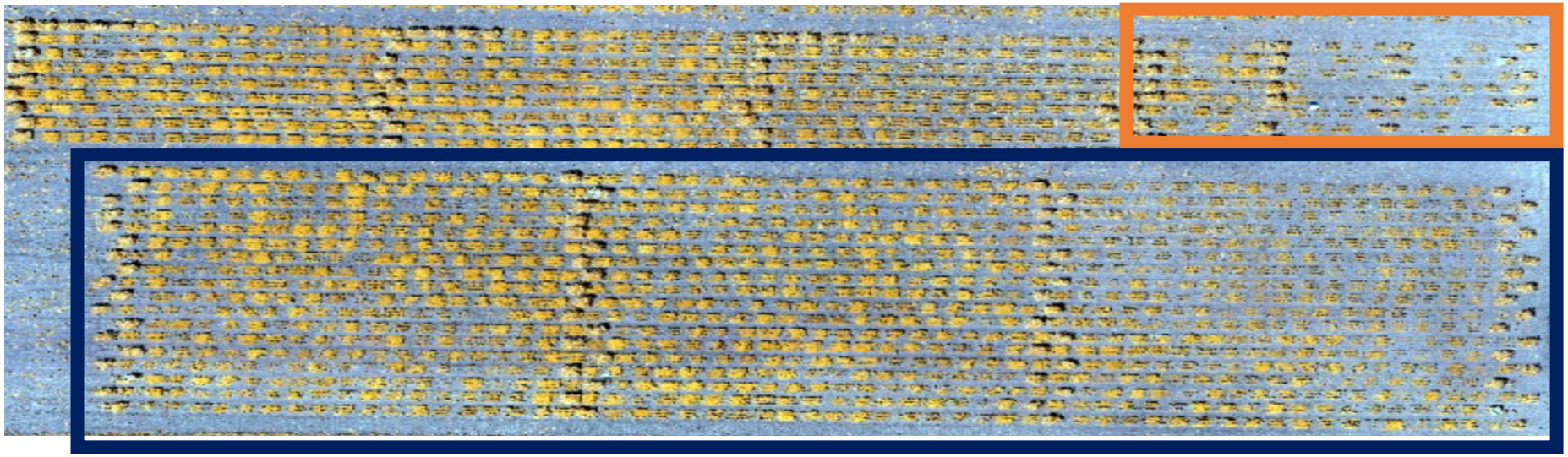
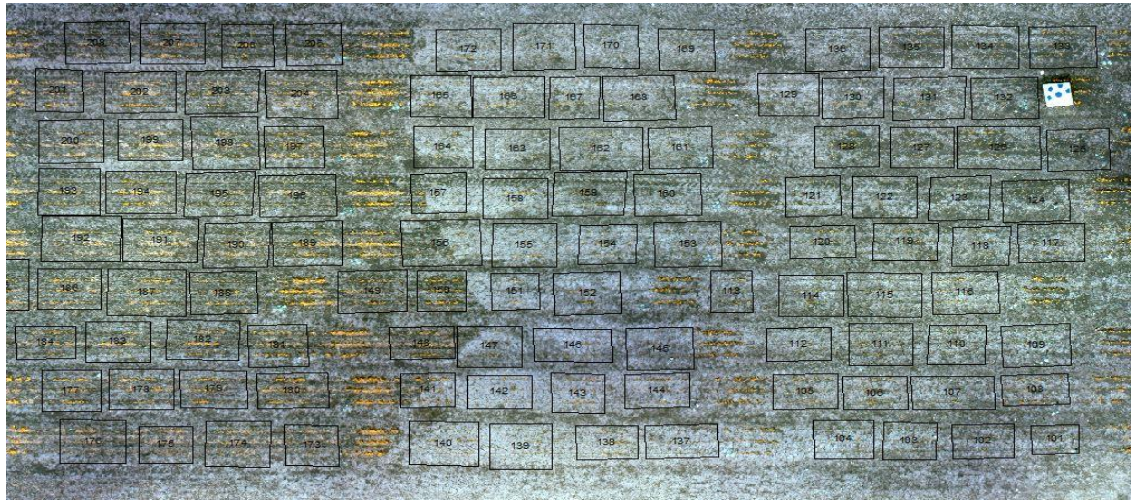


DraganFly UAV

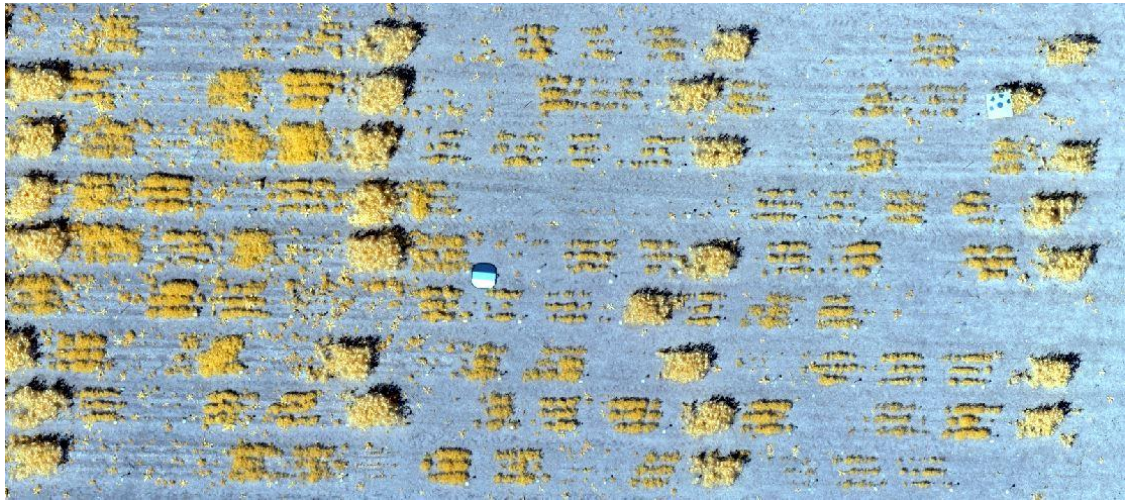
- Manufactured in Saskatoon
- Flys a pre-programmed flightplan without operator inputs
- Converted Sony A5100; 24.3 megapixels; NIR-G-B
- Stabilizing Gimbal

Preliminary Research - Overlapping Images are Stitched Using Pix4D Software

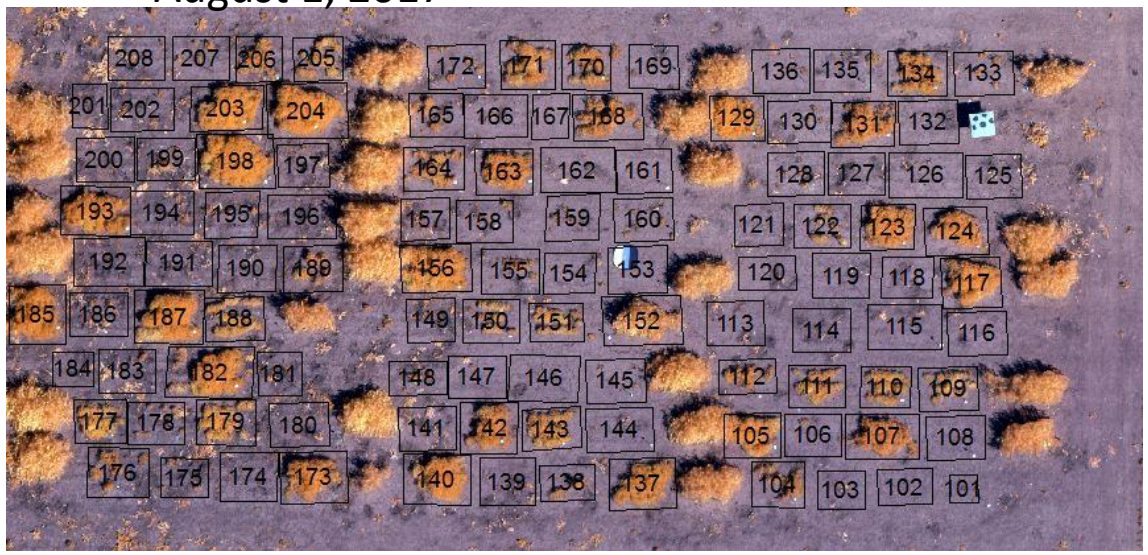
June 5, 2017



July 4, 2017



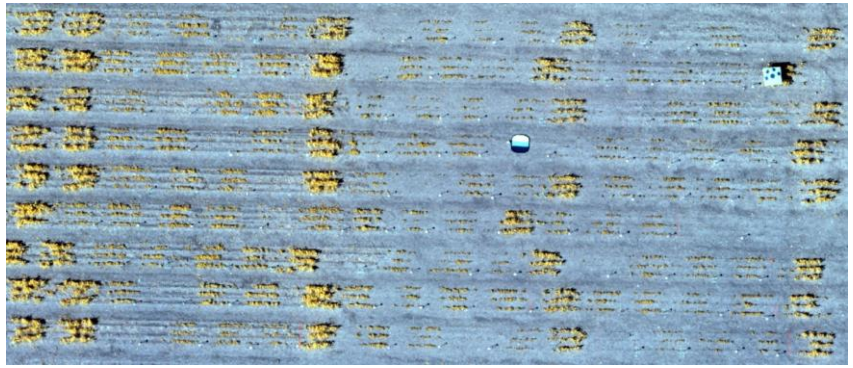
August 1, 2017



August 17, 2017

2-Dimensional Approach: Image Segmentation and Data Extraction

Stitched Orthomosaic



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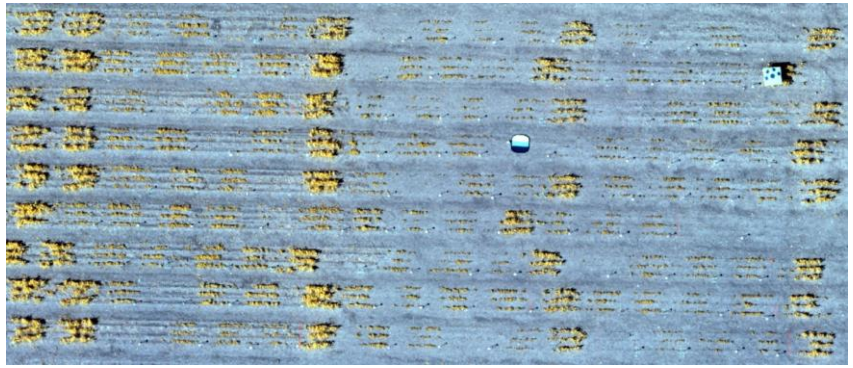

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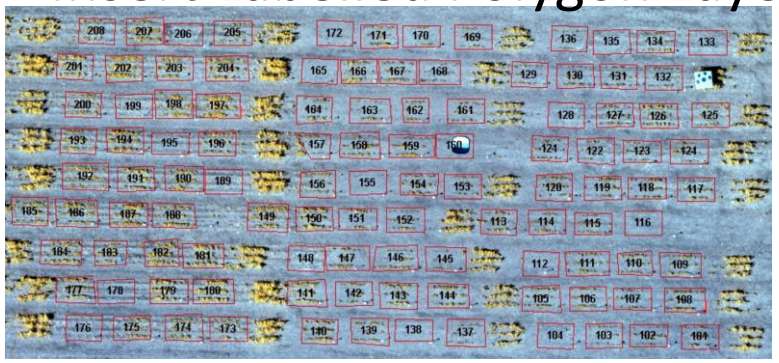

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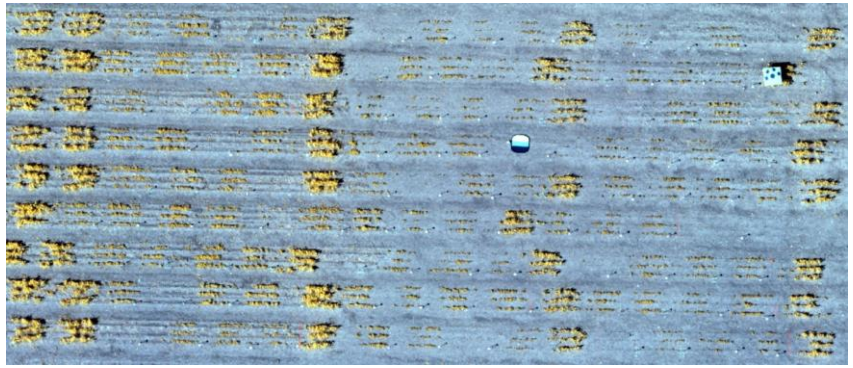

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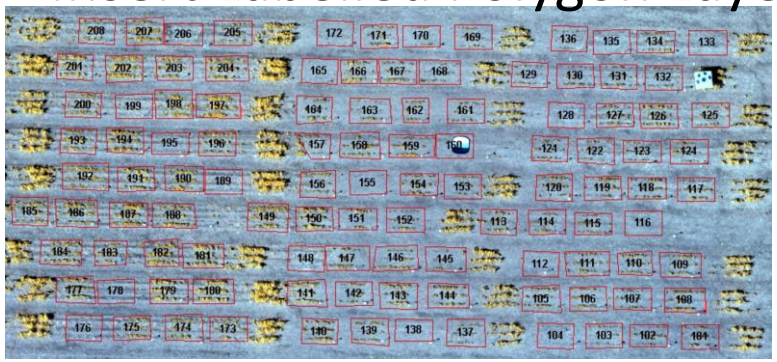
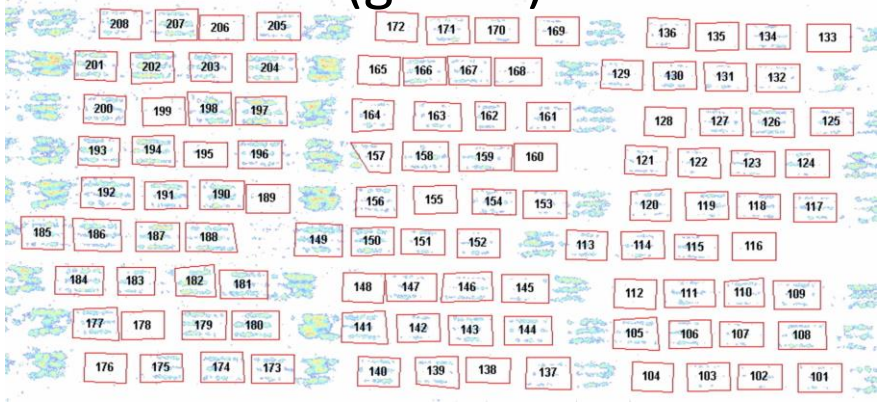


Calculate Indices (gNDVI) and Threshold



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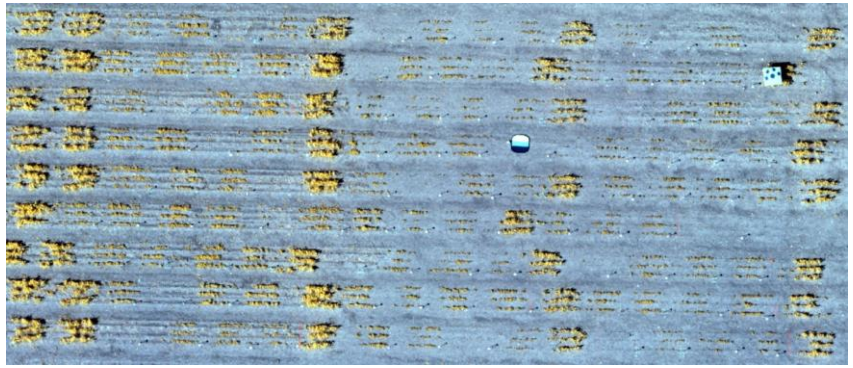

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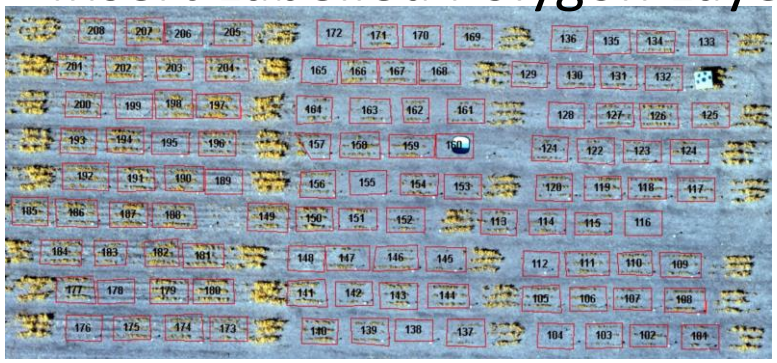

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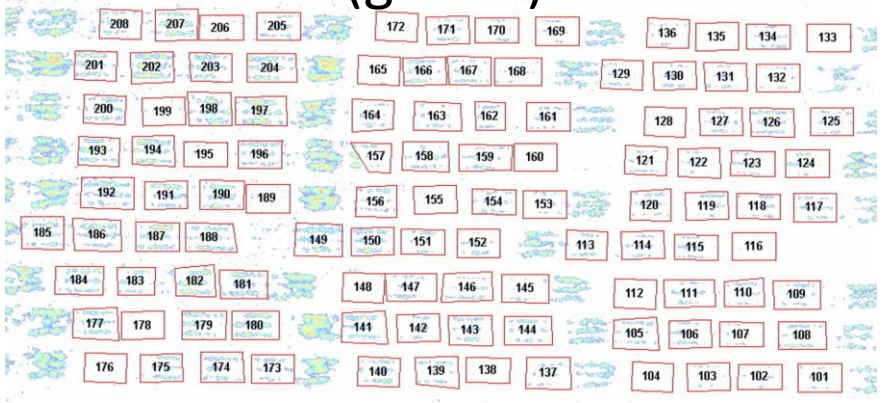

Data Output

B	C	D
Plot_Num	COUNT	AREA
101	33328	0.218418381
102	70154	0.459761254
103	48551	0.318183834
104	31520	0.206569472
105	47538	0.311545037
106	43163	0.282873037
107	69803	0.457460941
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123	25580	0.167641088
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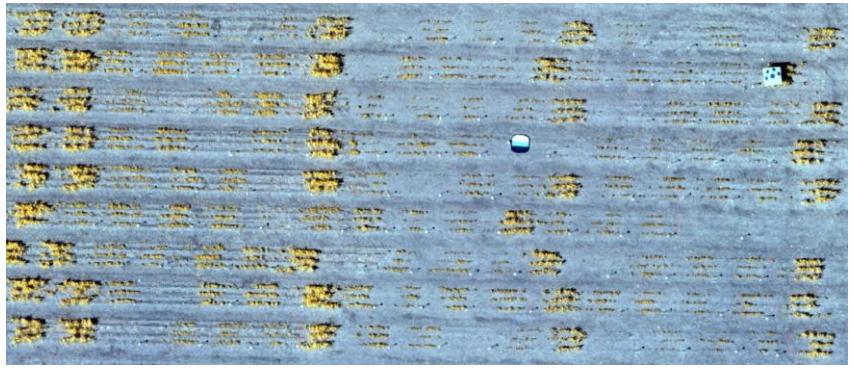

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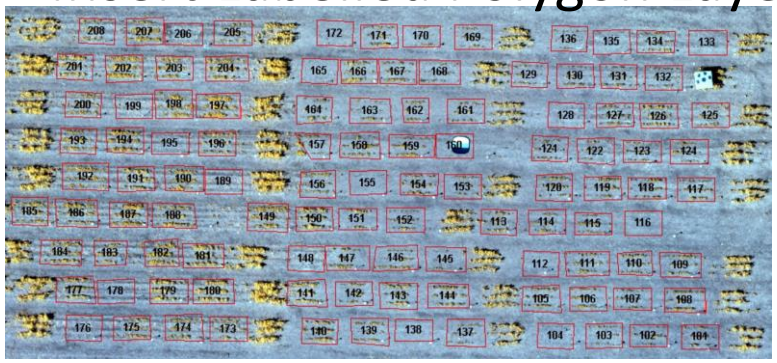

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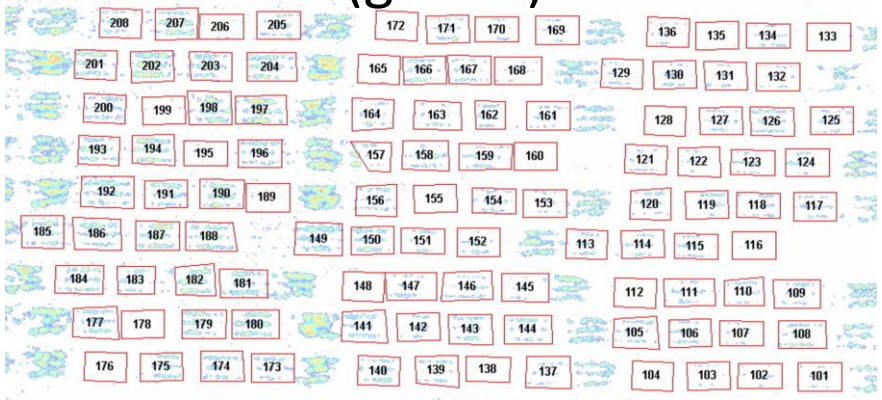

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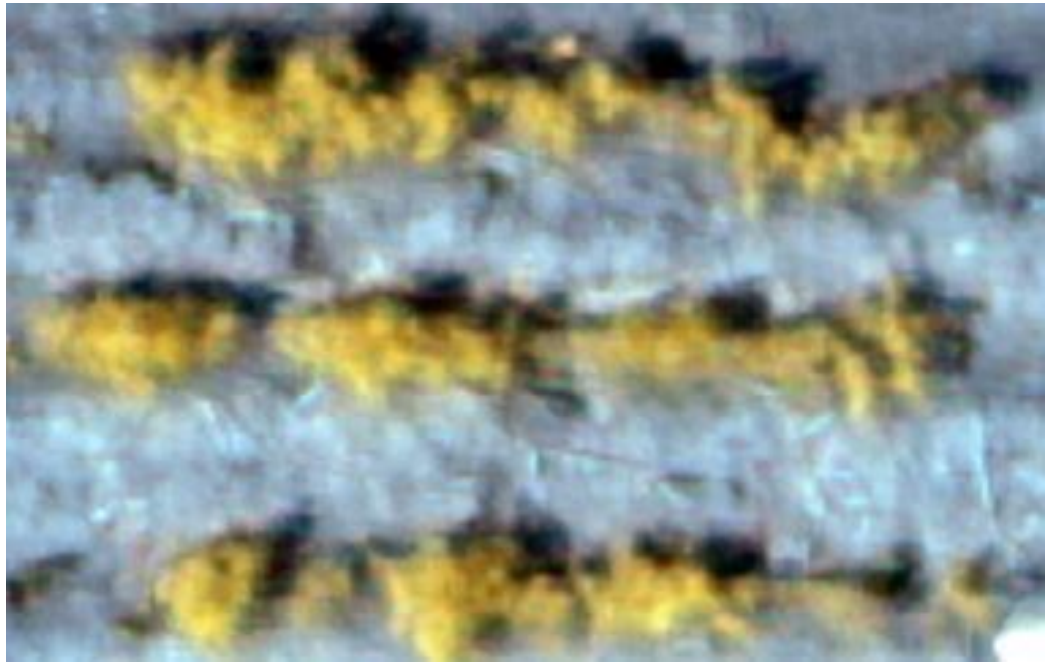
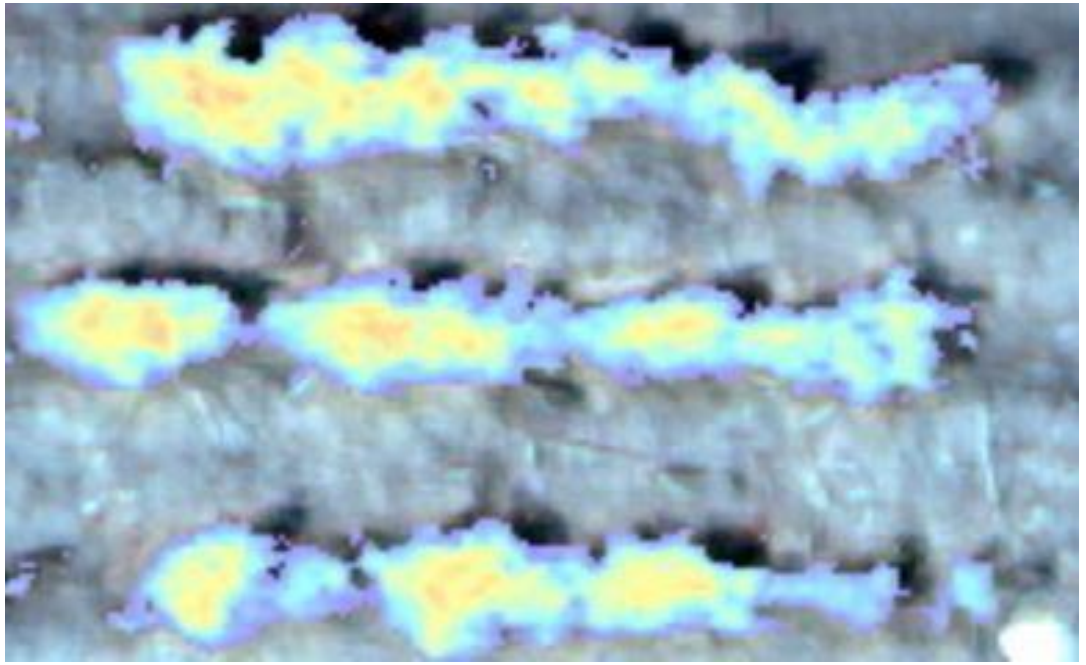
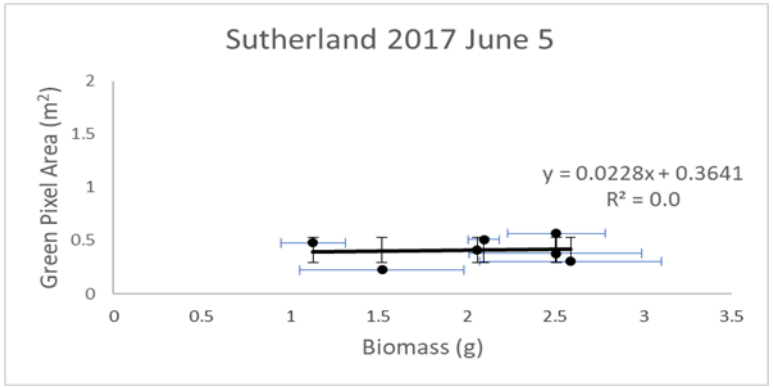
Result of Indices and Thresholding Calculations





Green Pixel Area Compared to Ground Truth Biomass Data at Sutherland, 2017



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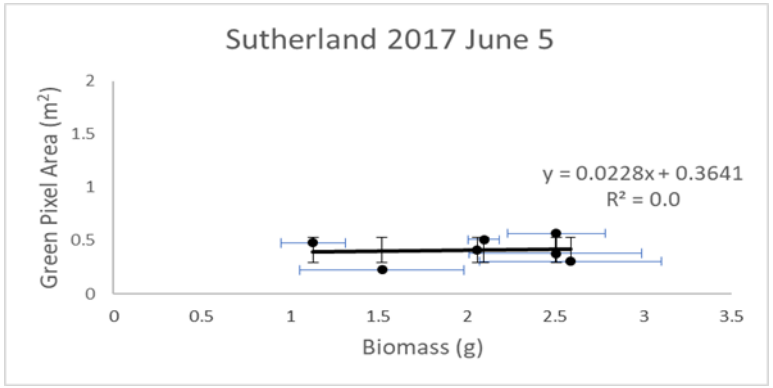

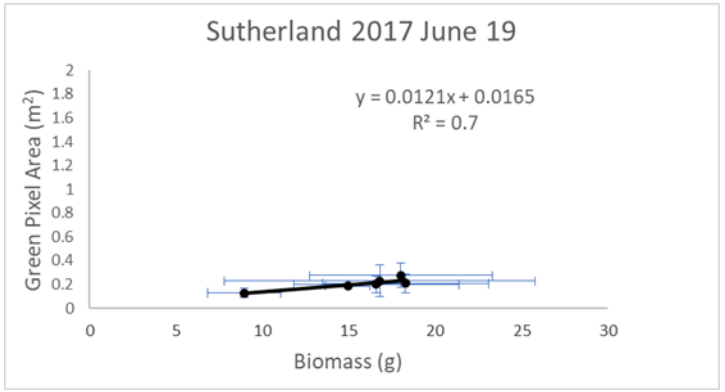

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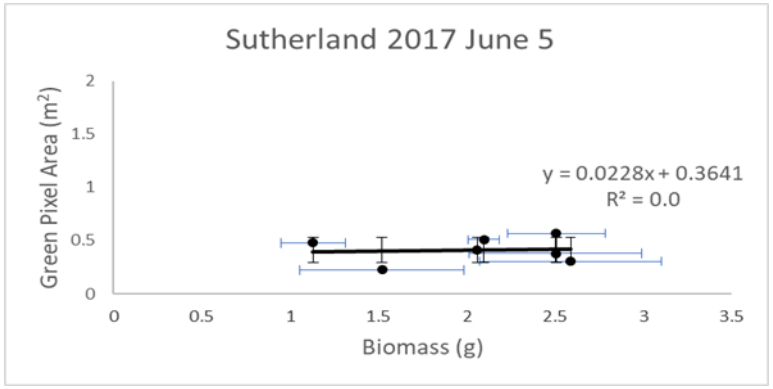

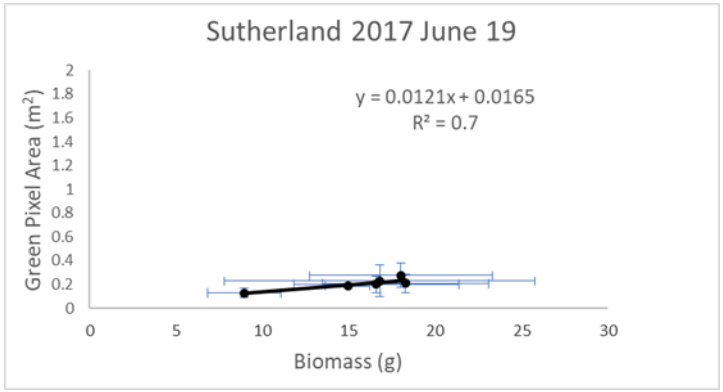

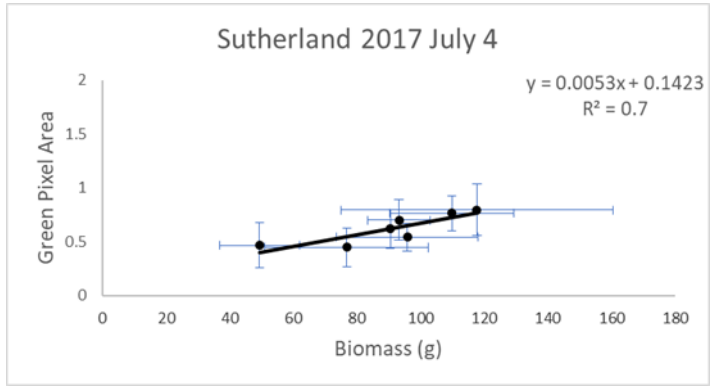

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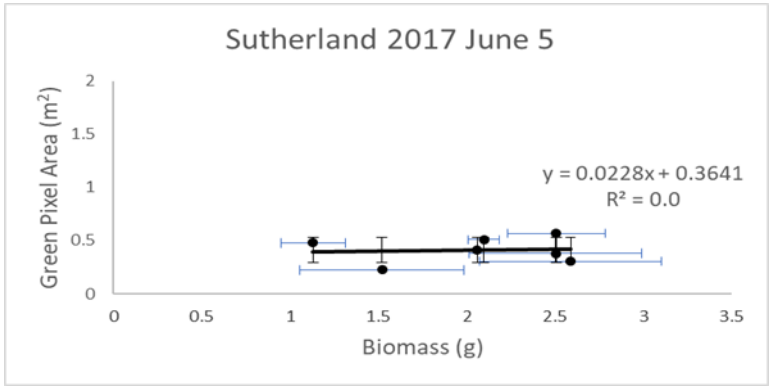

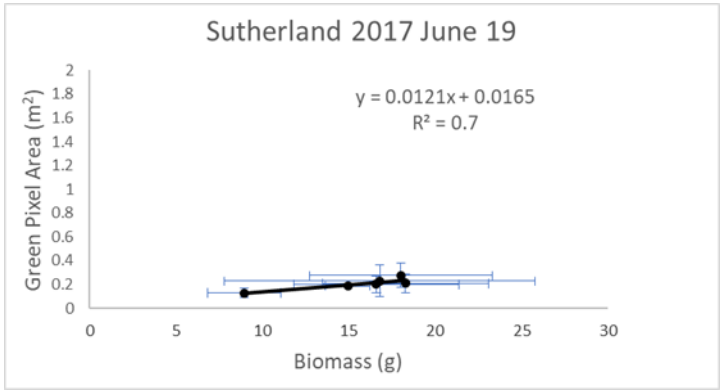

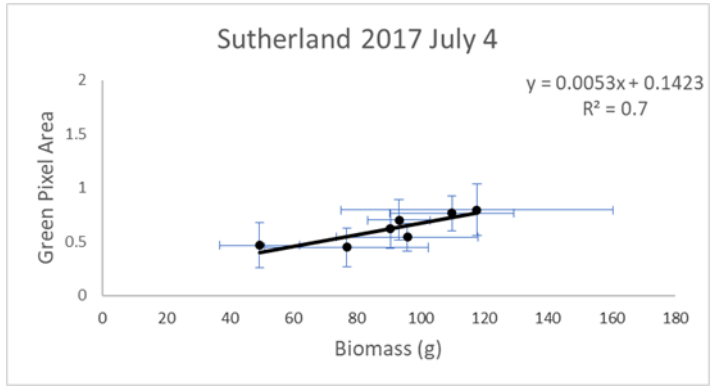

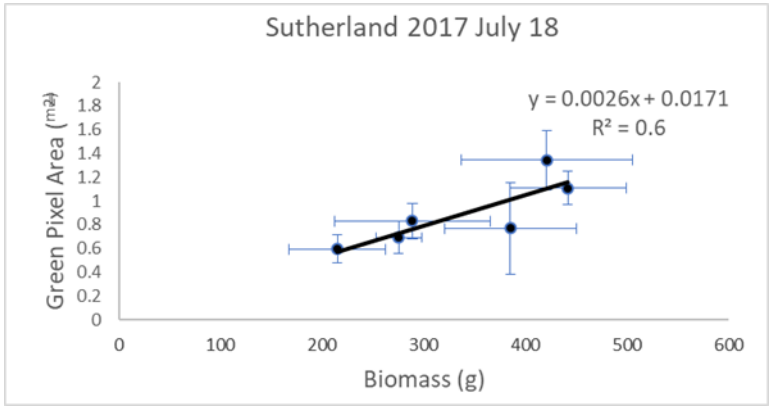

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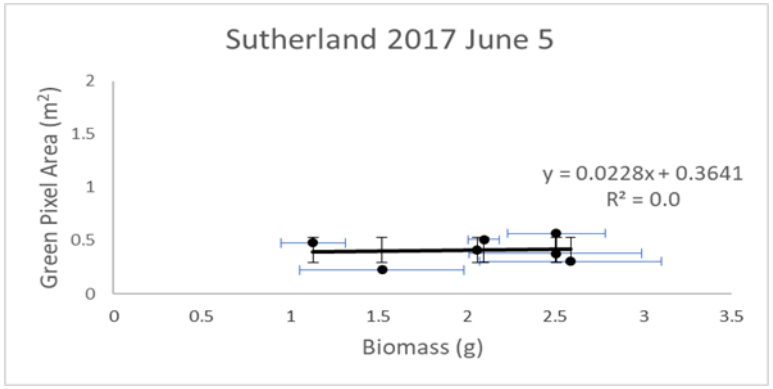

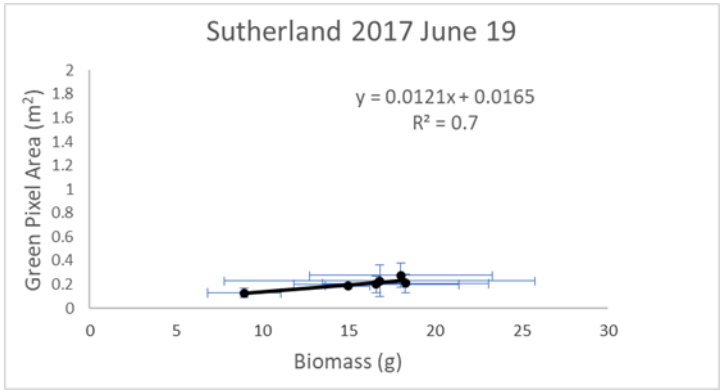

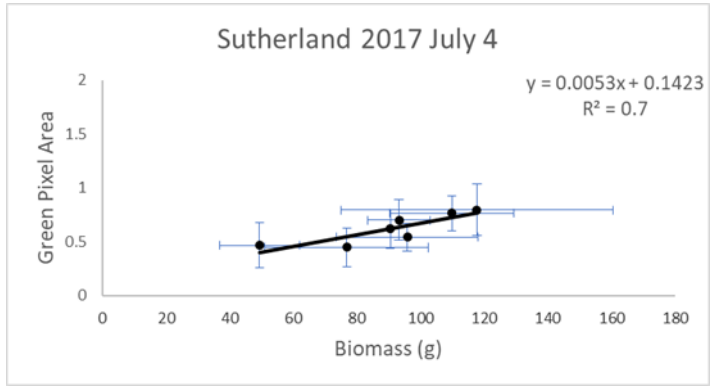

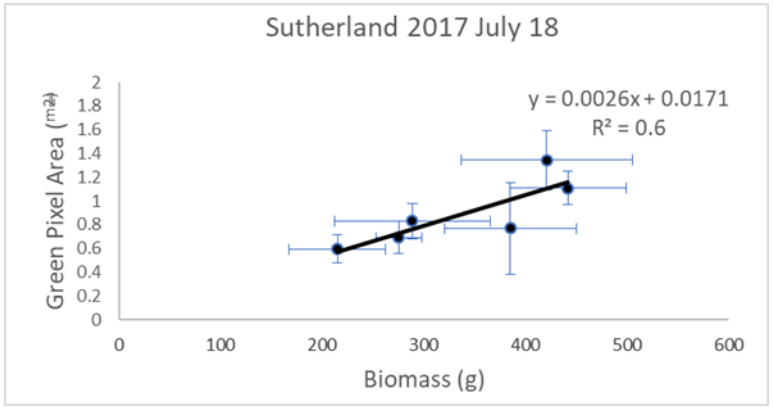

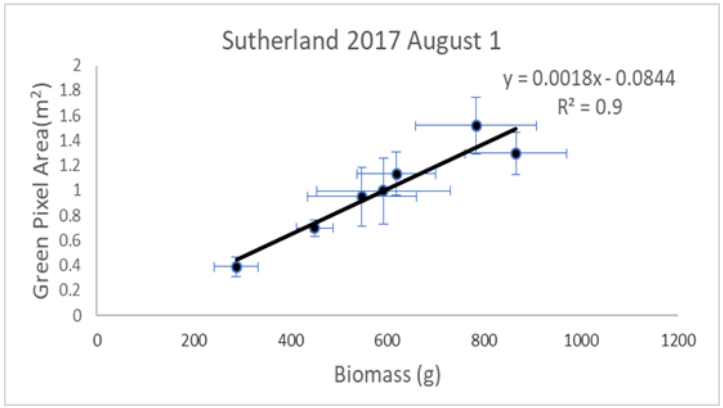

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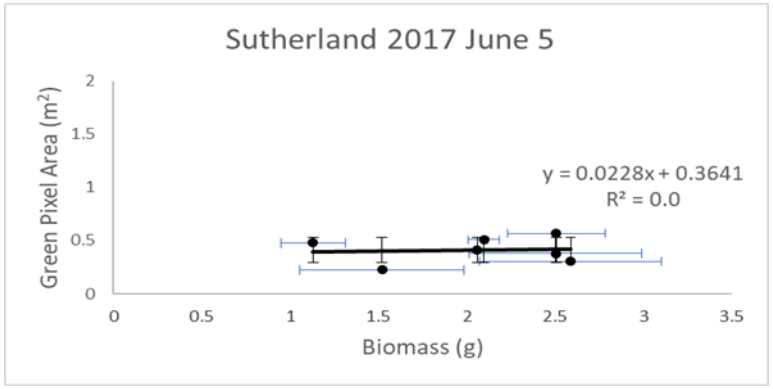
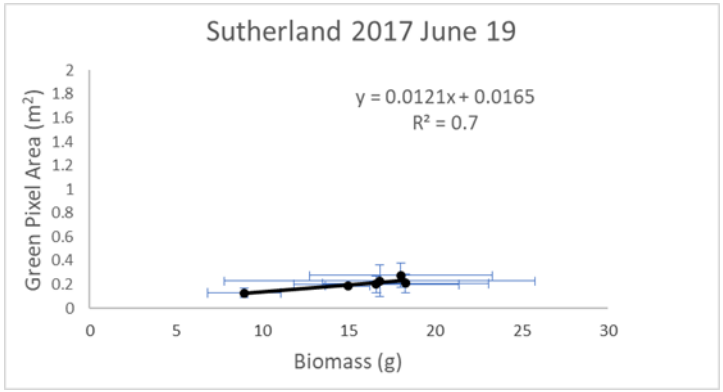
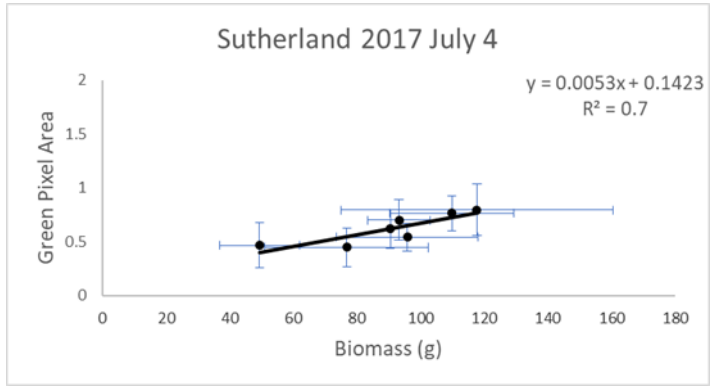
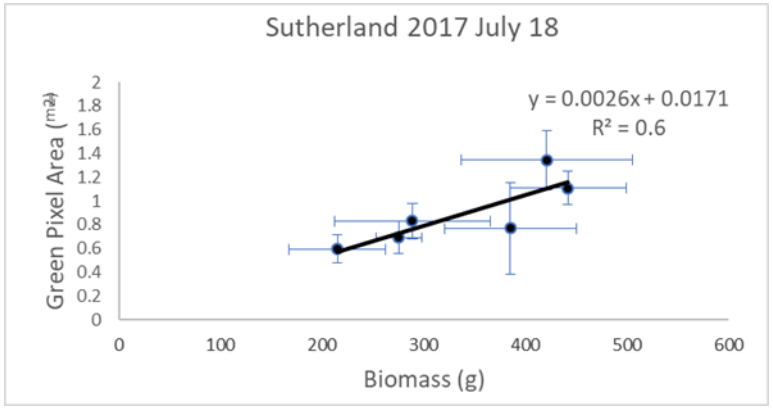
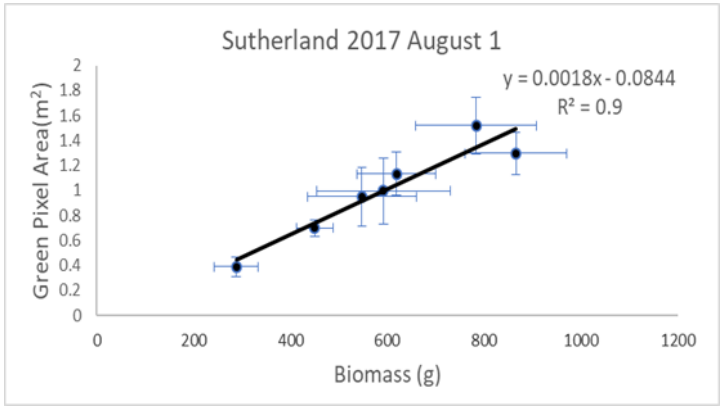
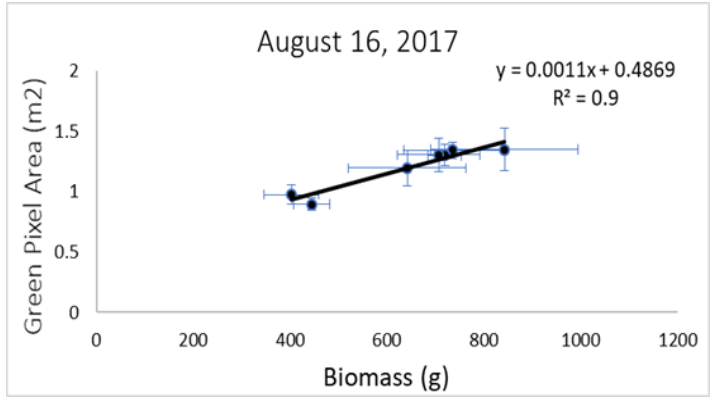




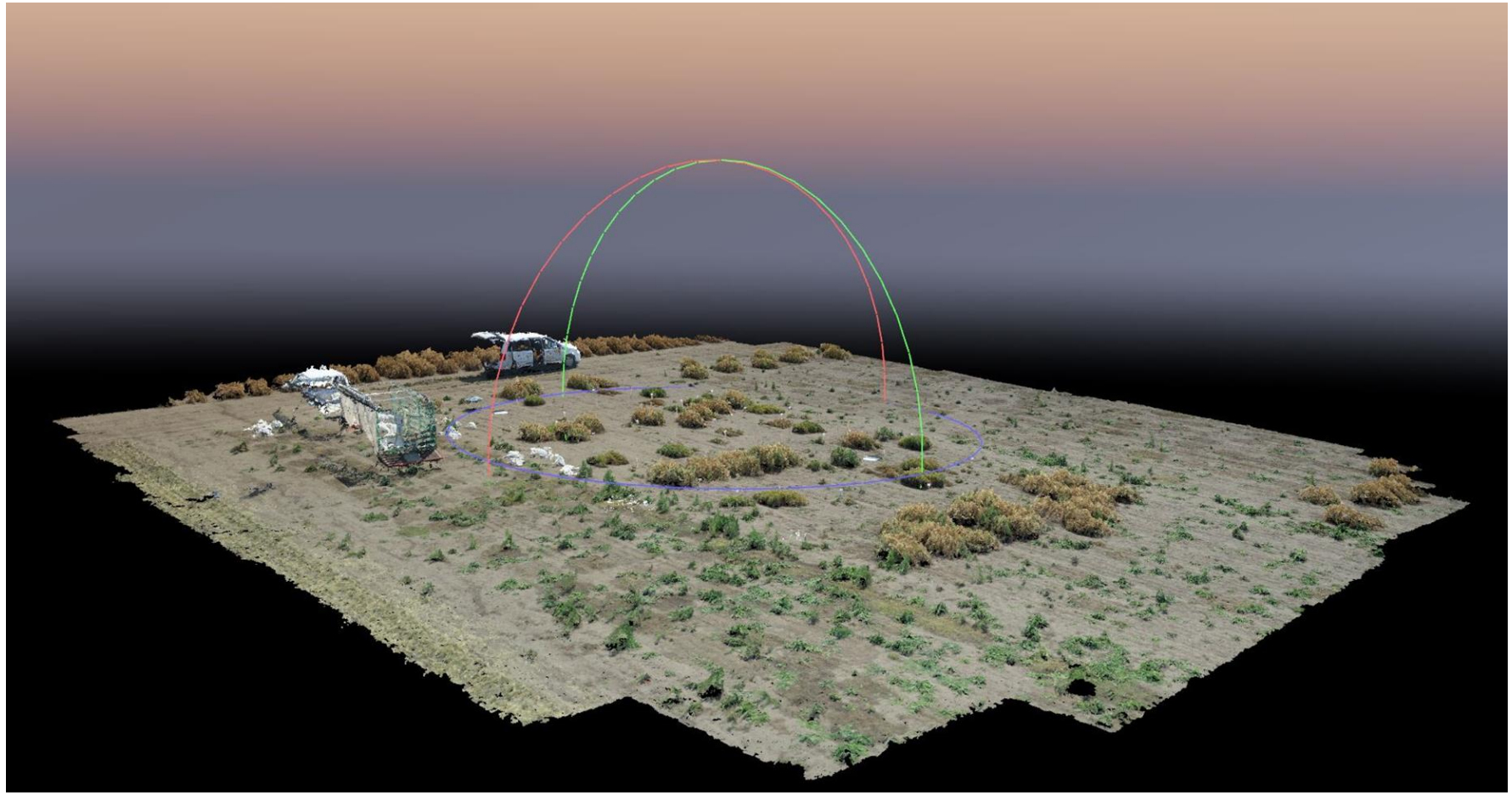




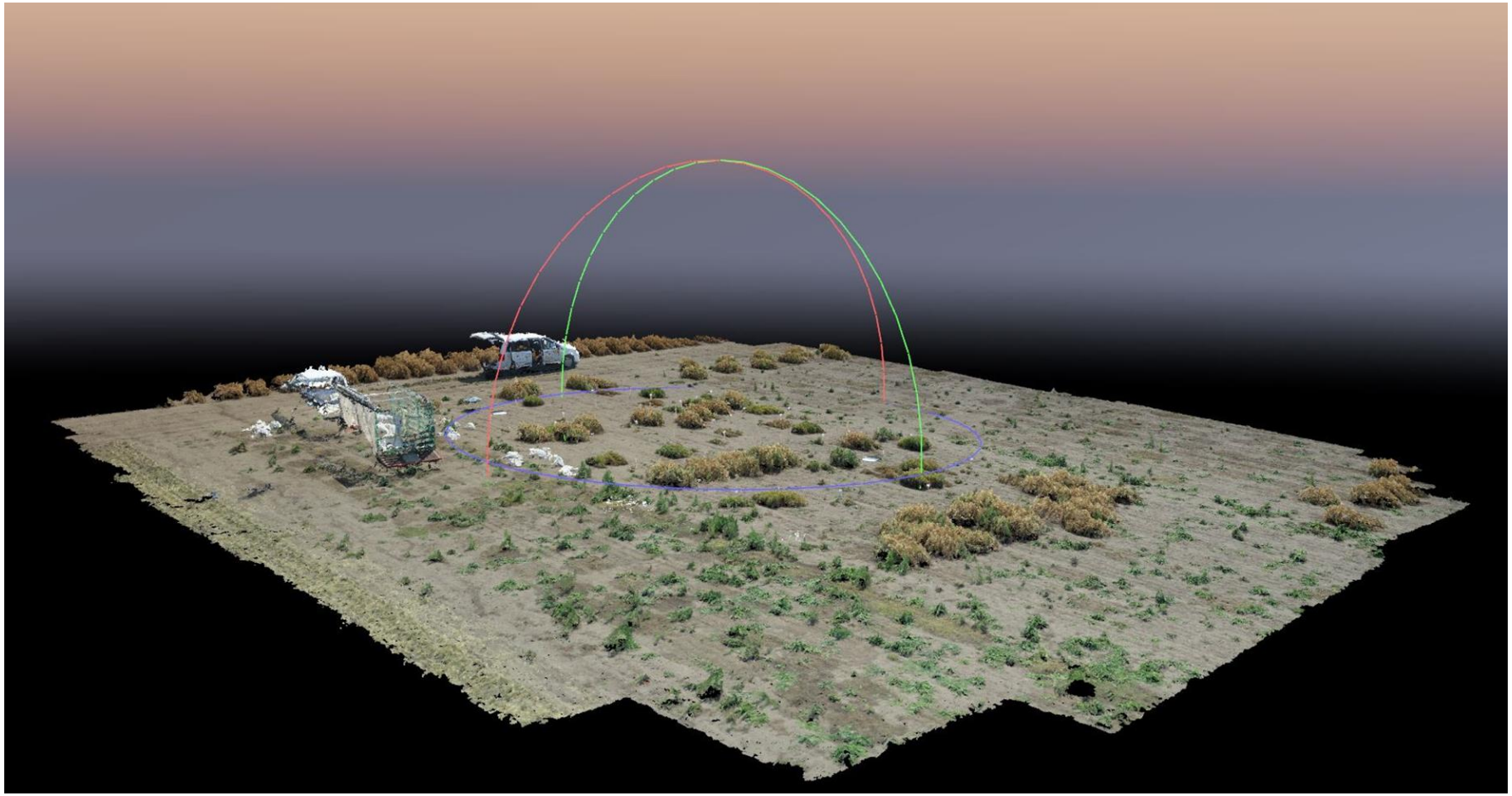




Three-Dimensional Analysis to Measure Plot Volume



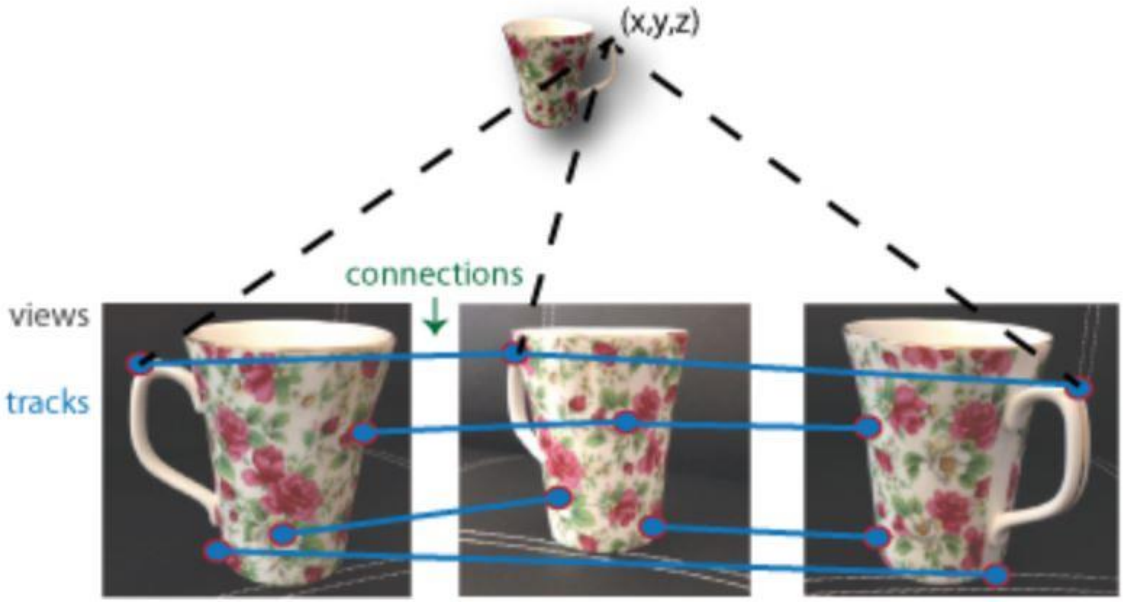
Three-Dimensional Analysis to Measure Plot Volume



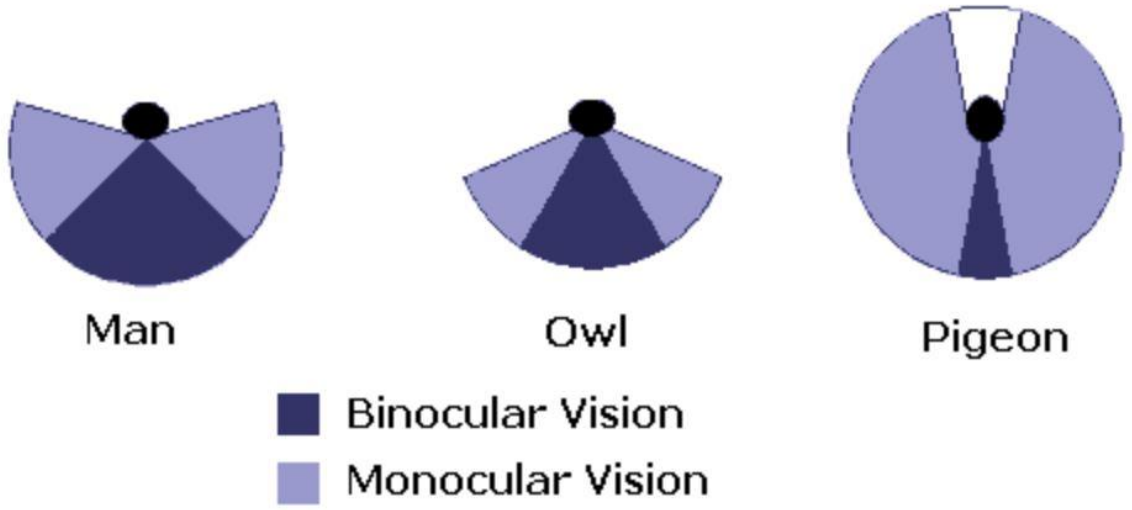
Torres-Sanchez J, Lopez-Granados F, Serrano N, Arquero O, Pena J. 2015. High-Throughput 3-D monitoring of agricultural tree plantations with unmanned aerial vehicle (UAV) technology.PLOS ONE. DOI:10.1371

Structure from Motion (SfM)

- Multiple perspectives to interpret structure
- Humans see with stereovision
- Some birds (pigeons, waterfowl, etc.) see depth by bobbing their head (SfM)

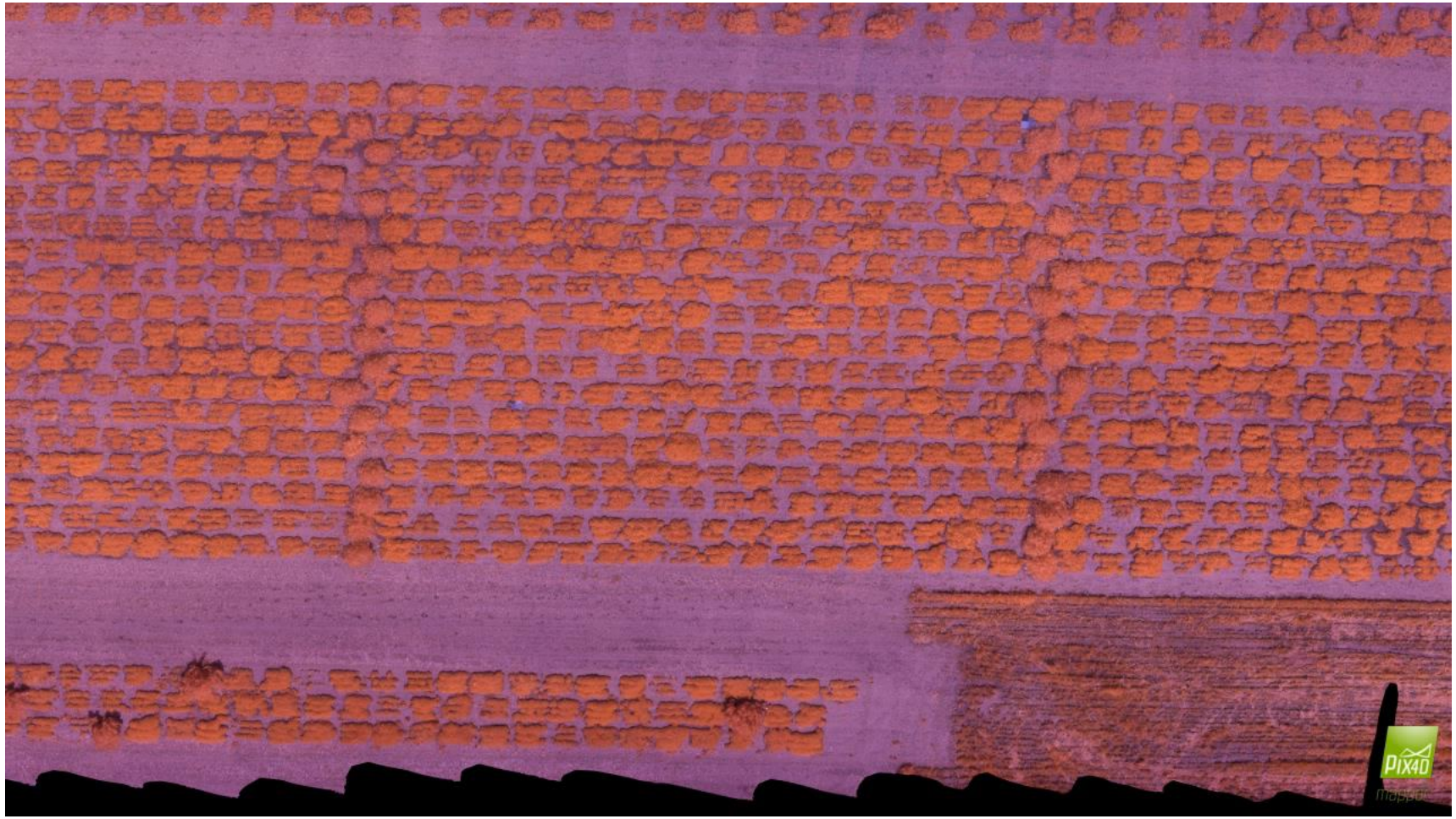


https://www.mathworks.com/help/vision/ug/structure-from-motion.html



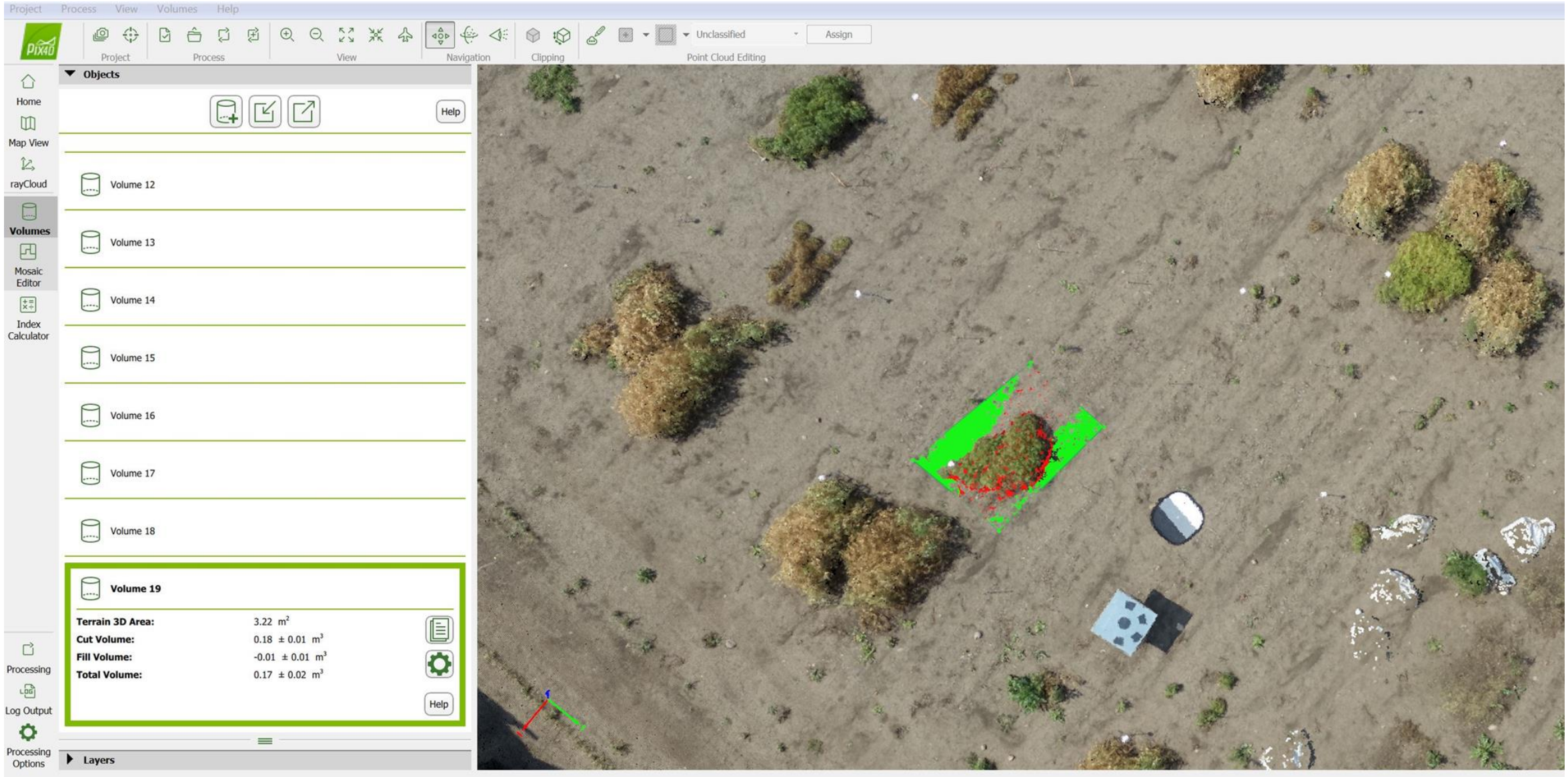
https://www.quora.com/If-most-birds-cant-see-depth-how-do-they-catch-food-and-not-crash-into-things

3-Dimensional Analysis for Phenotyping

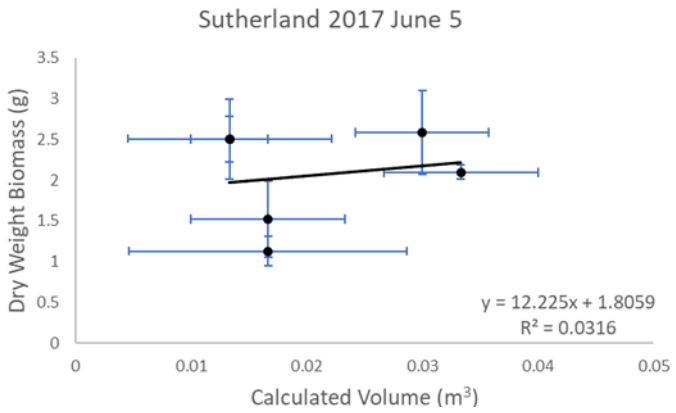


- More perspectives than 2-D approach
  - more accurate than 2-D
  - Fewer assumptions
- Requires much more computing power

Utilized Volume Estimation Tool in Pix4D



Results of Volume Measurement Compared to Ground-Truthed Biomass Measurement



*Error Bars show Standard Error

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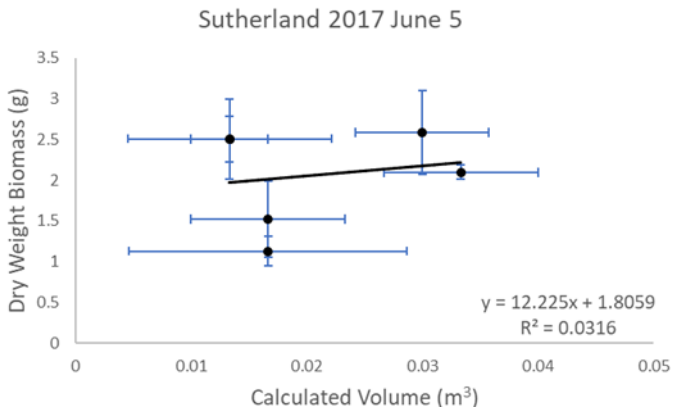

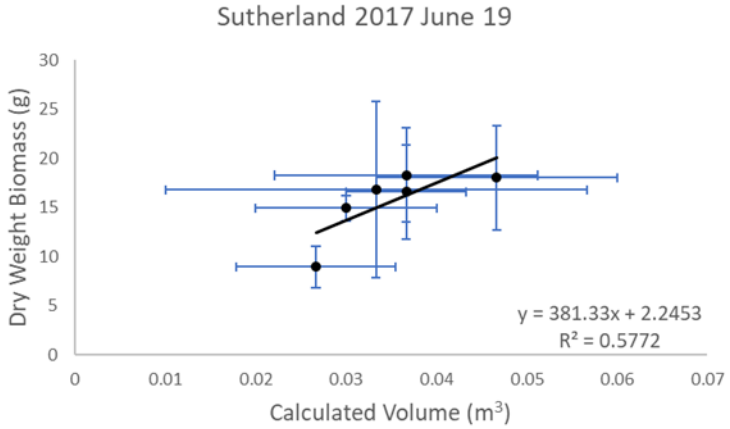

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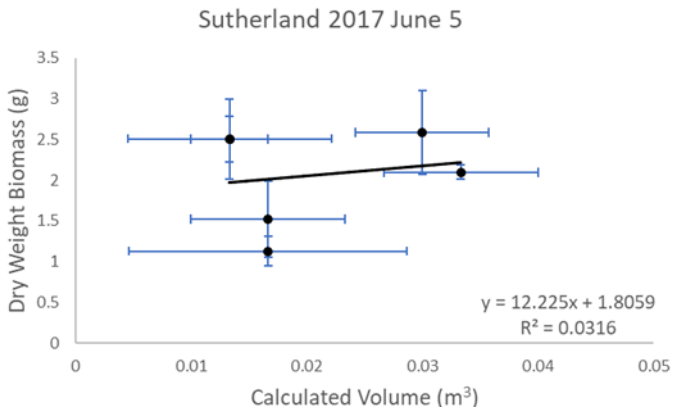

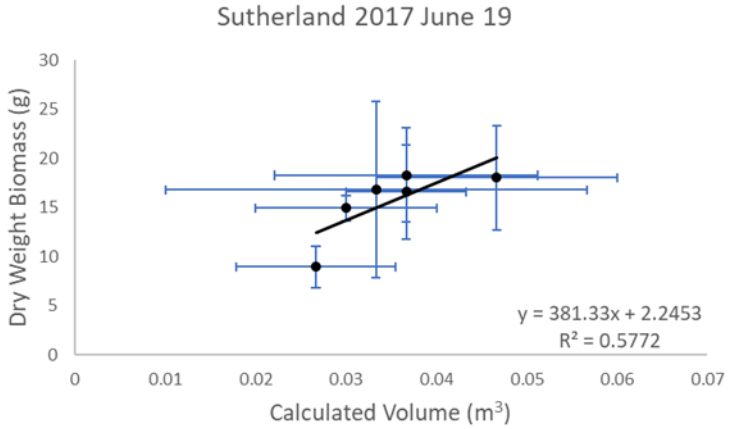

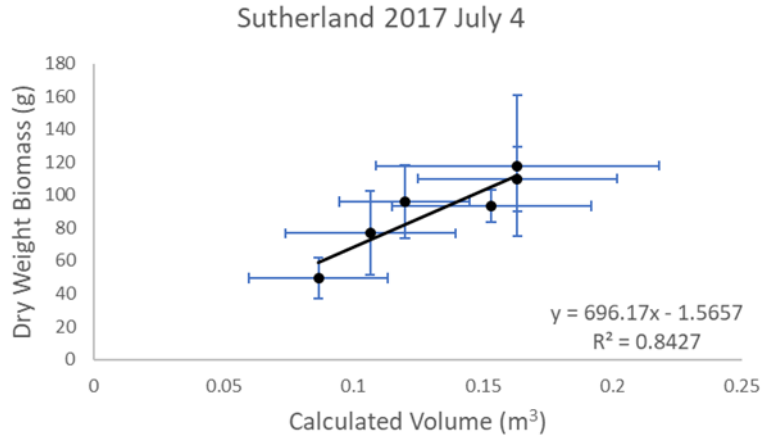

*Error Bars show Standard Error

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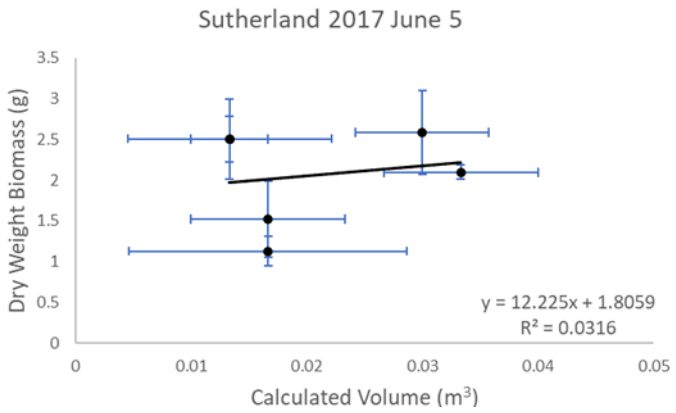

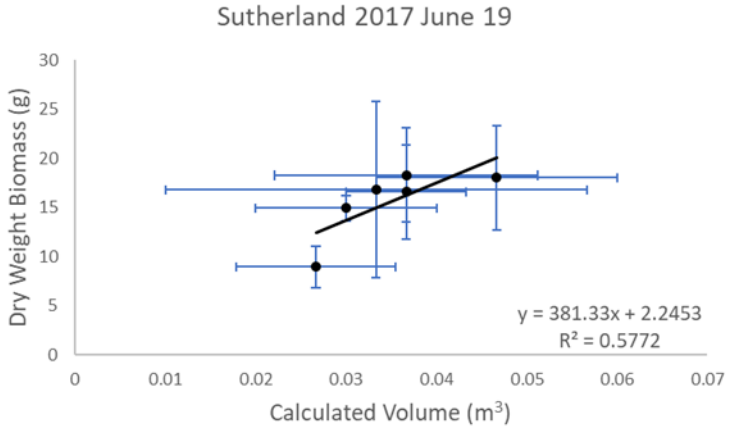

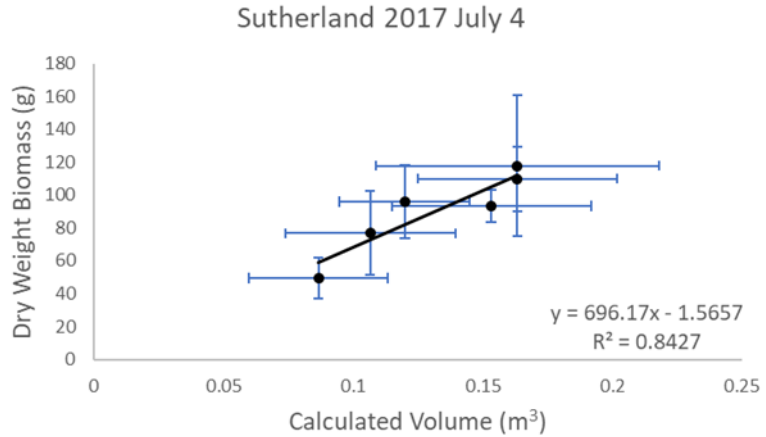

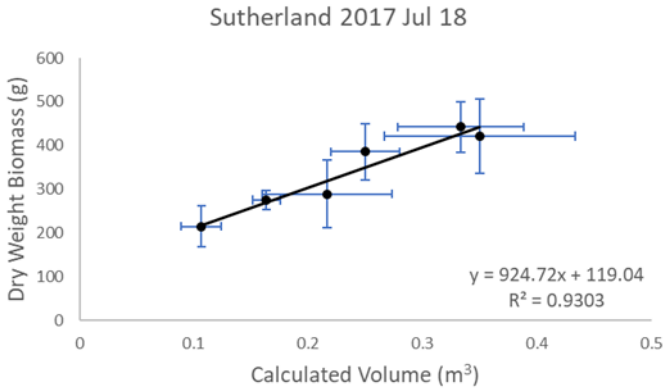

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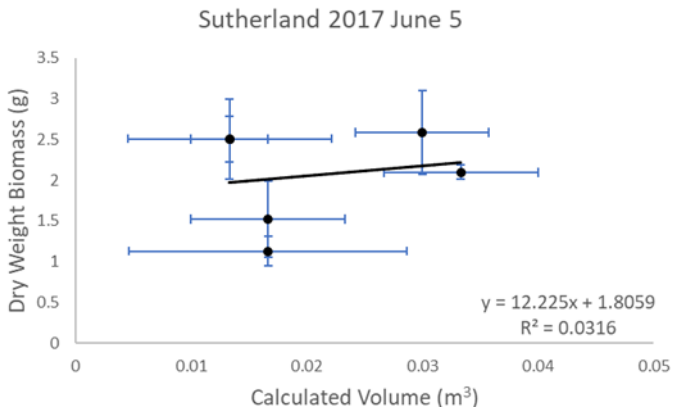

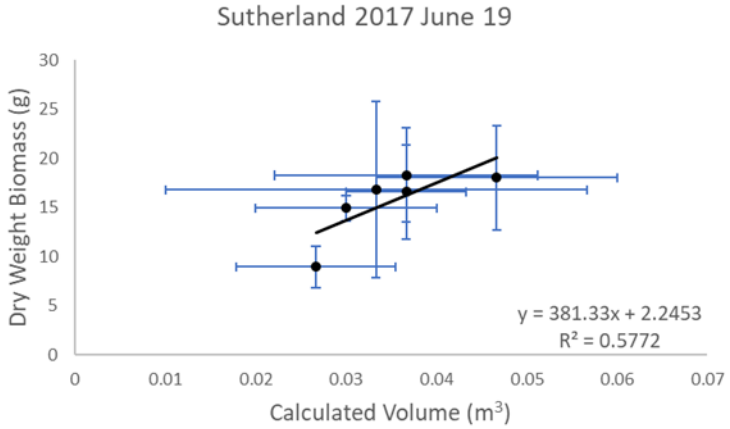

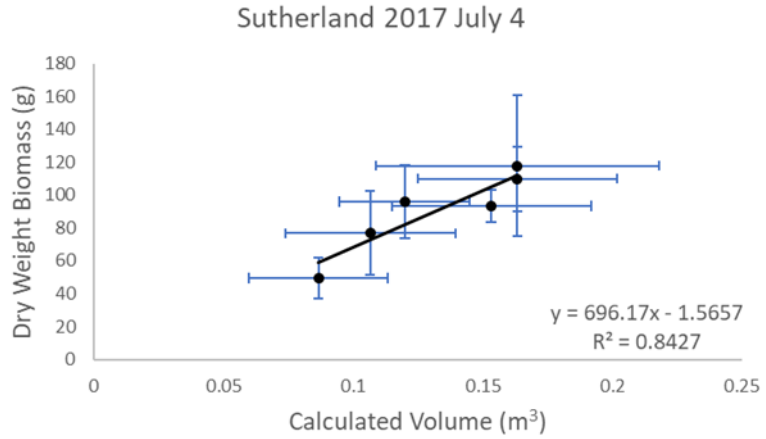

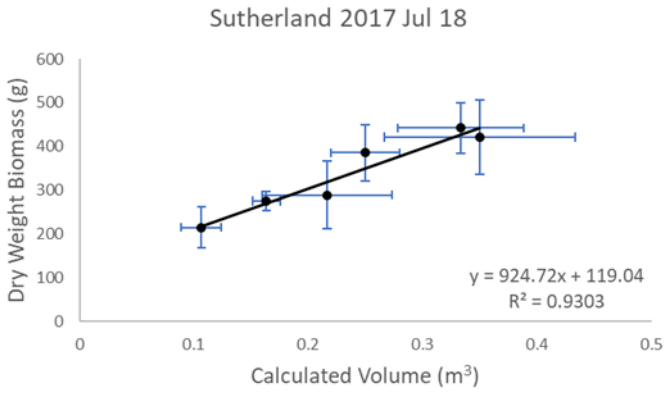

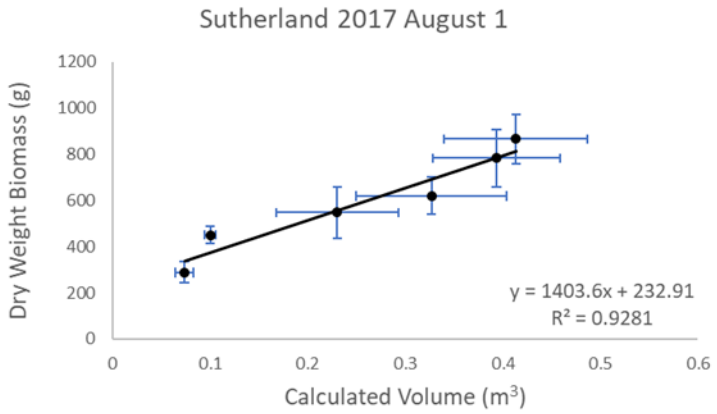

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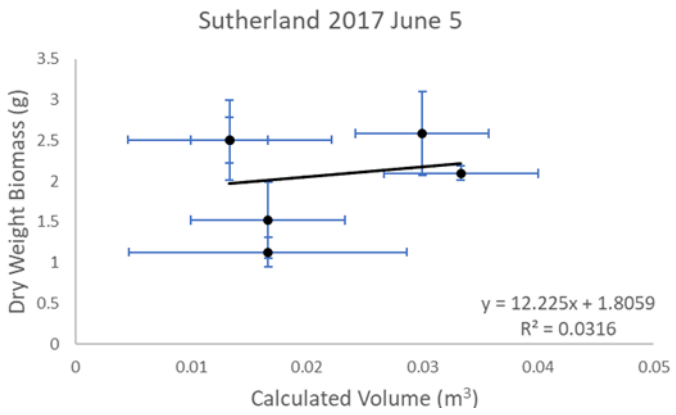
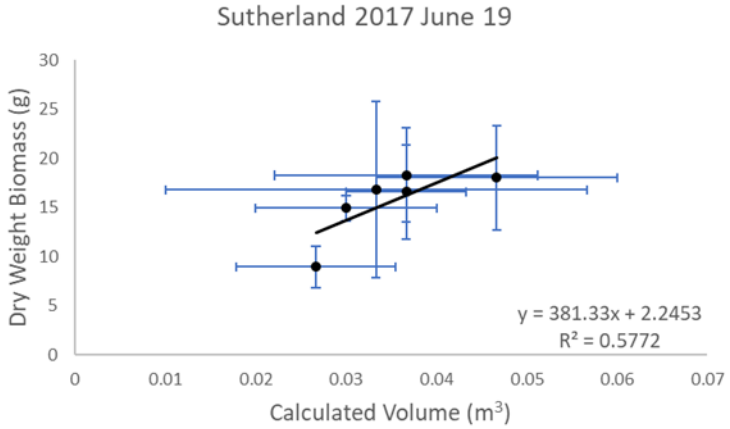
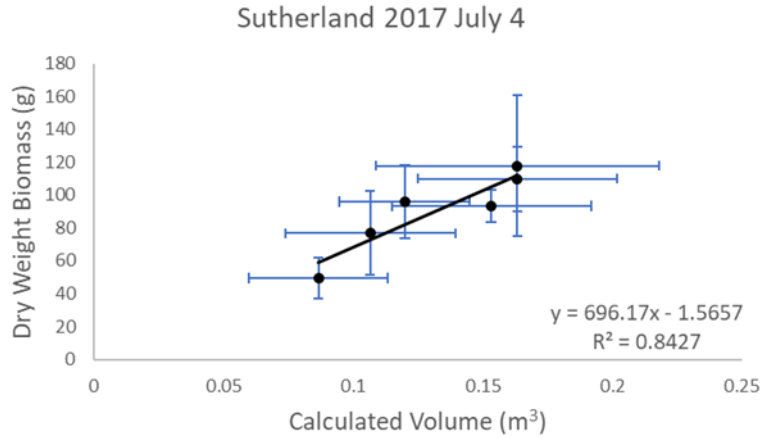
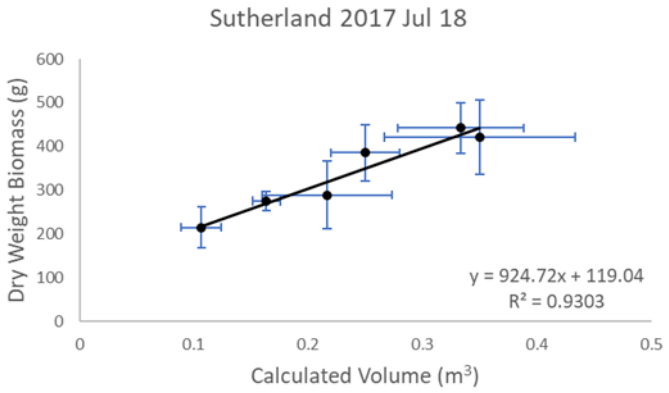
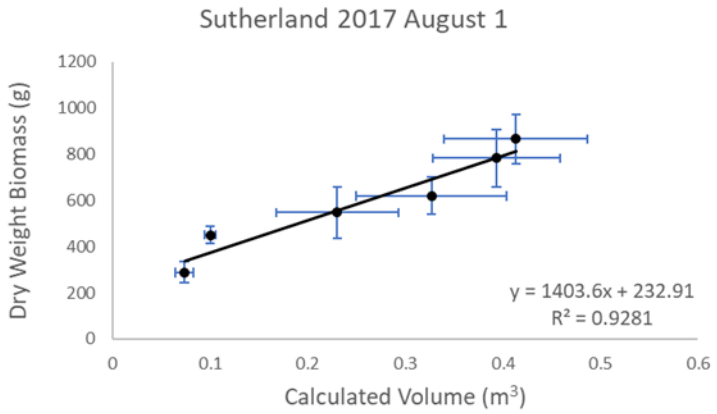
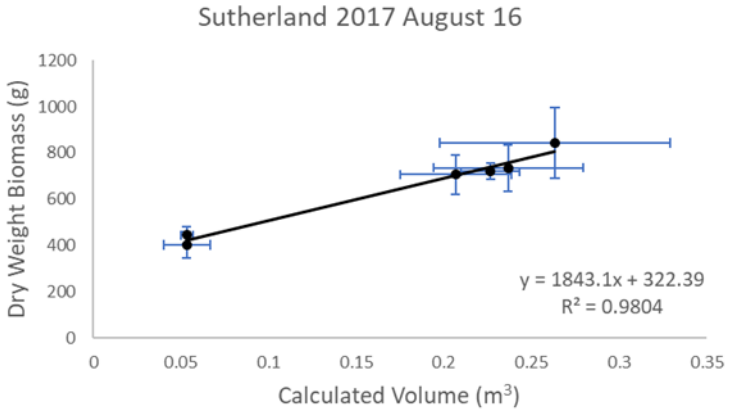






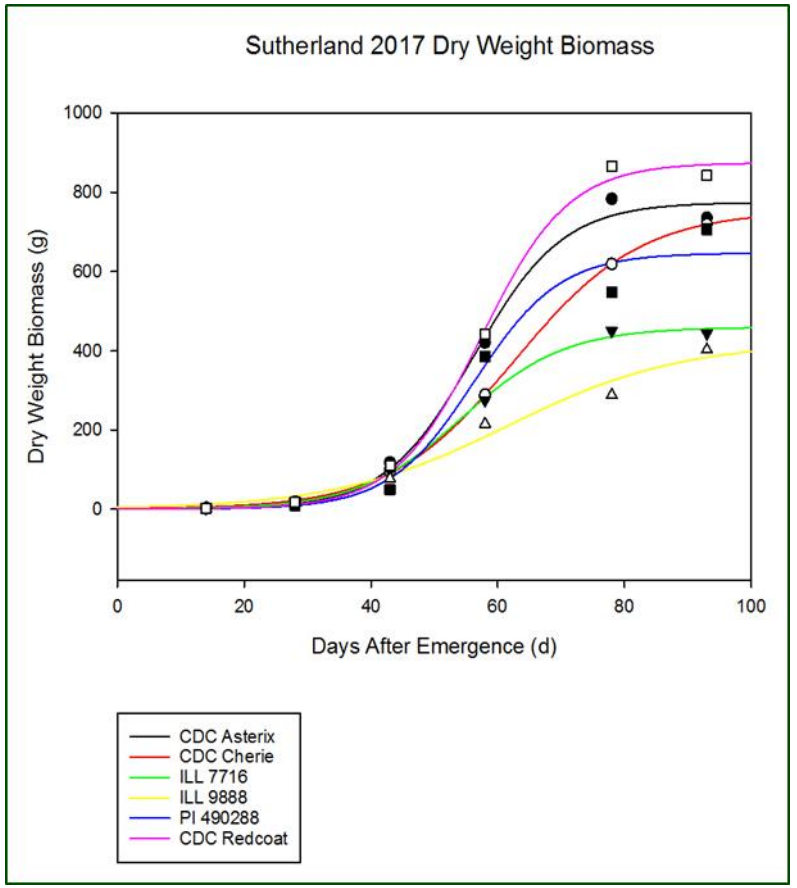




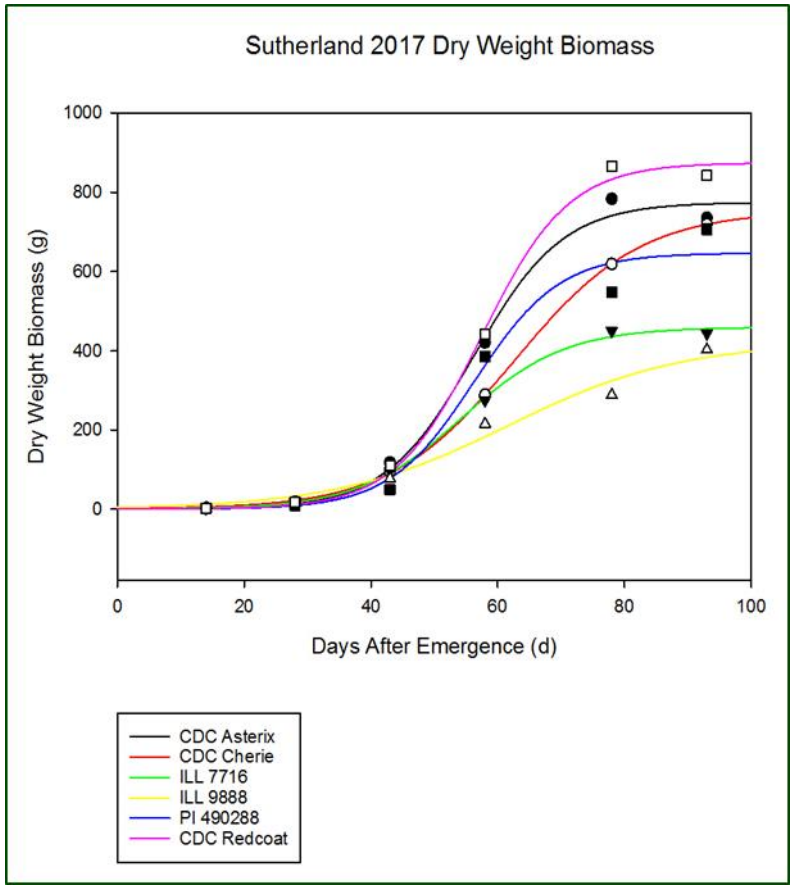


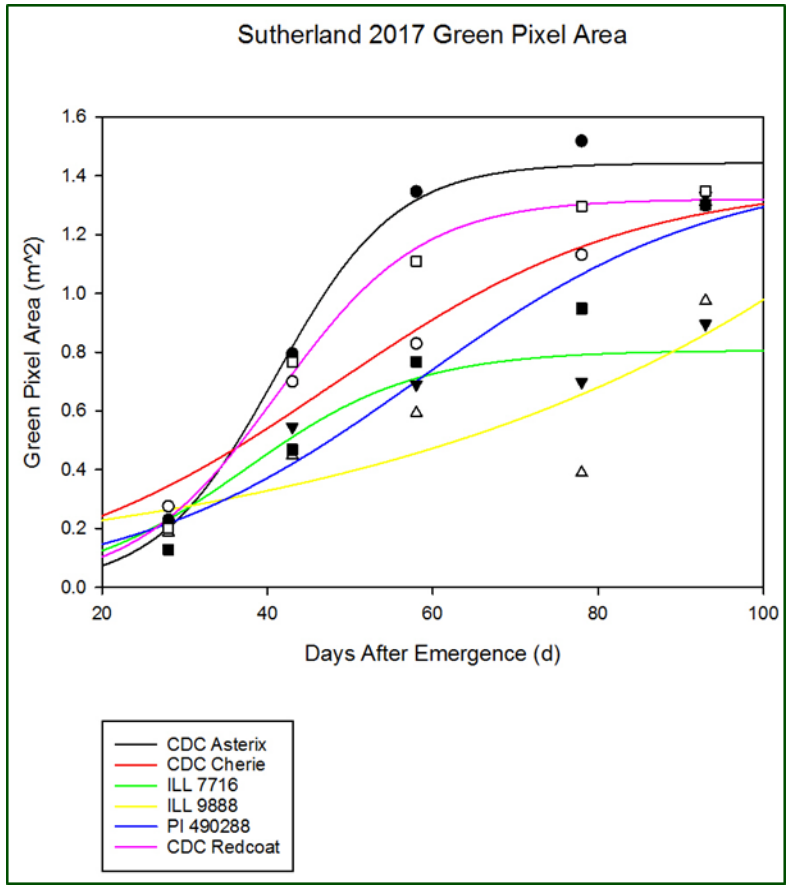
*Error Bars show Standard Error

Biomass Accumulation Throughout the Growing Season



Biomass Accumulation Throughout the Growing Season





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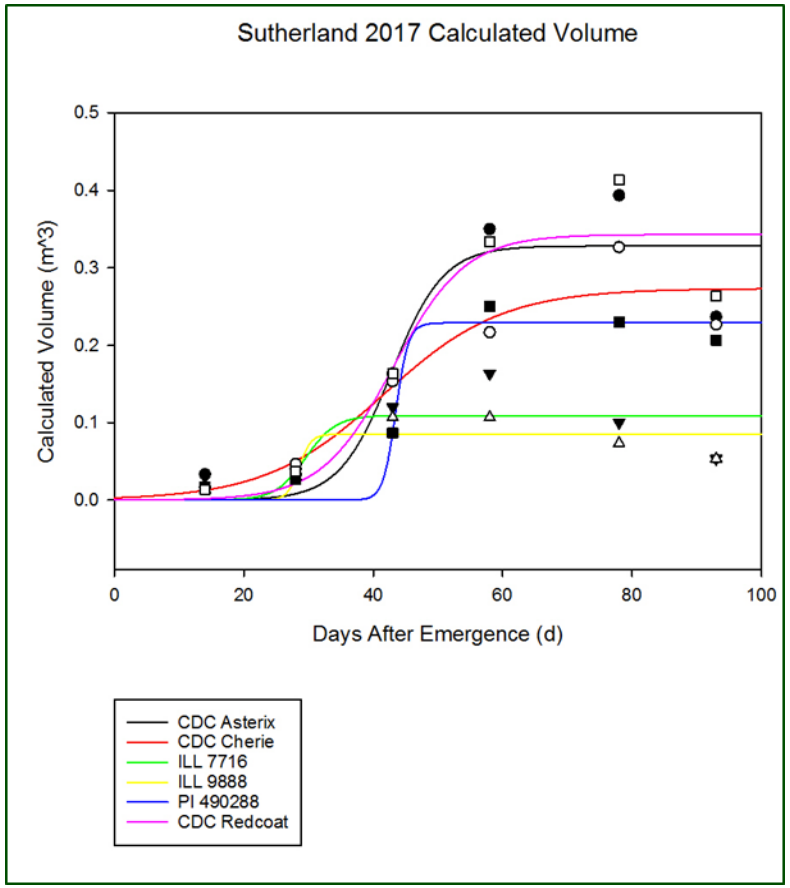

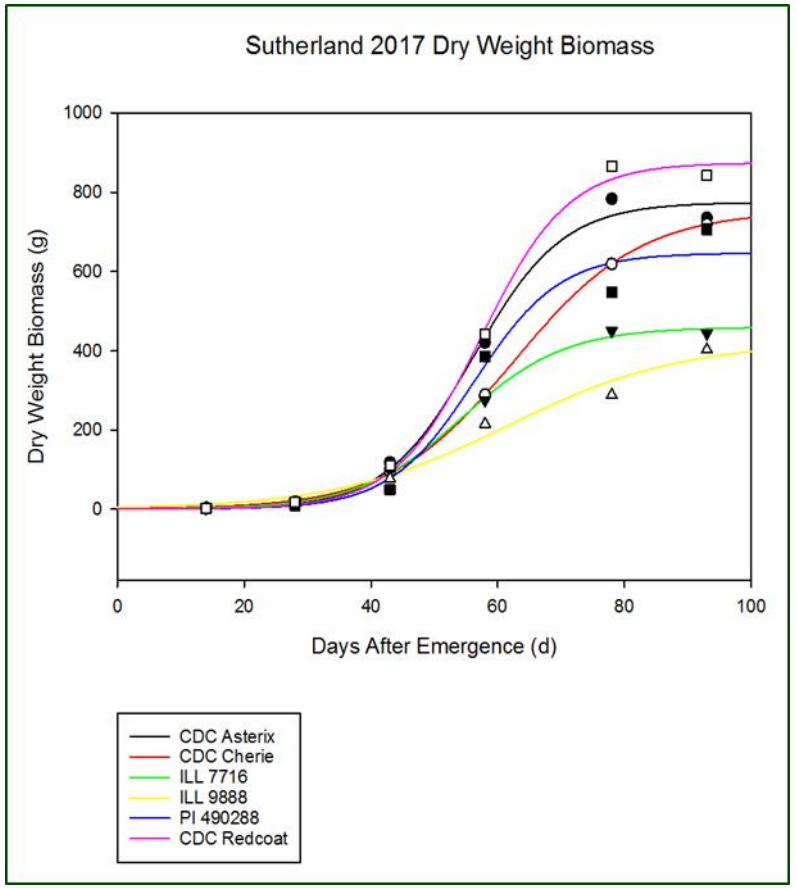

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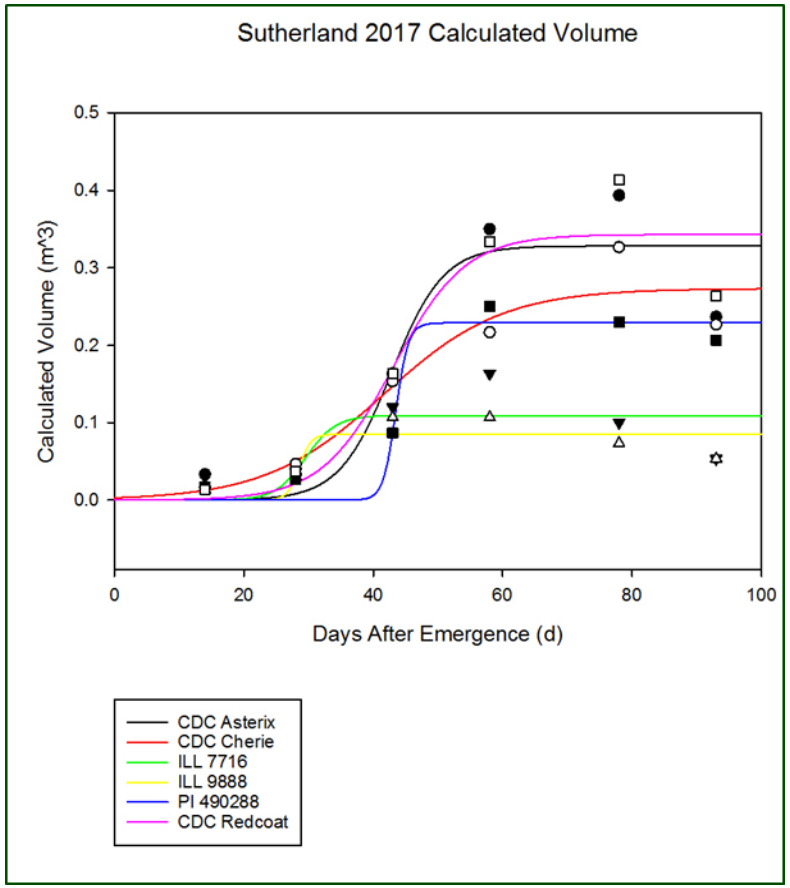
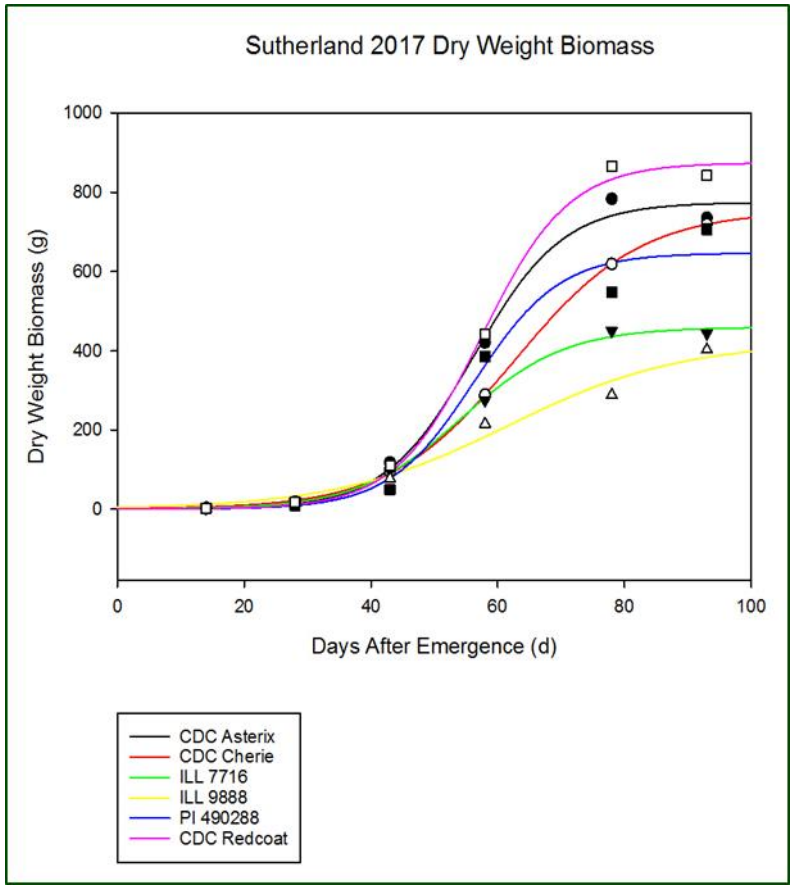
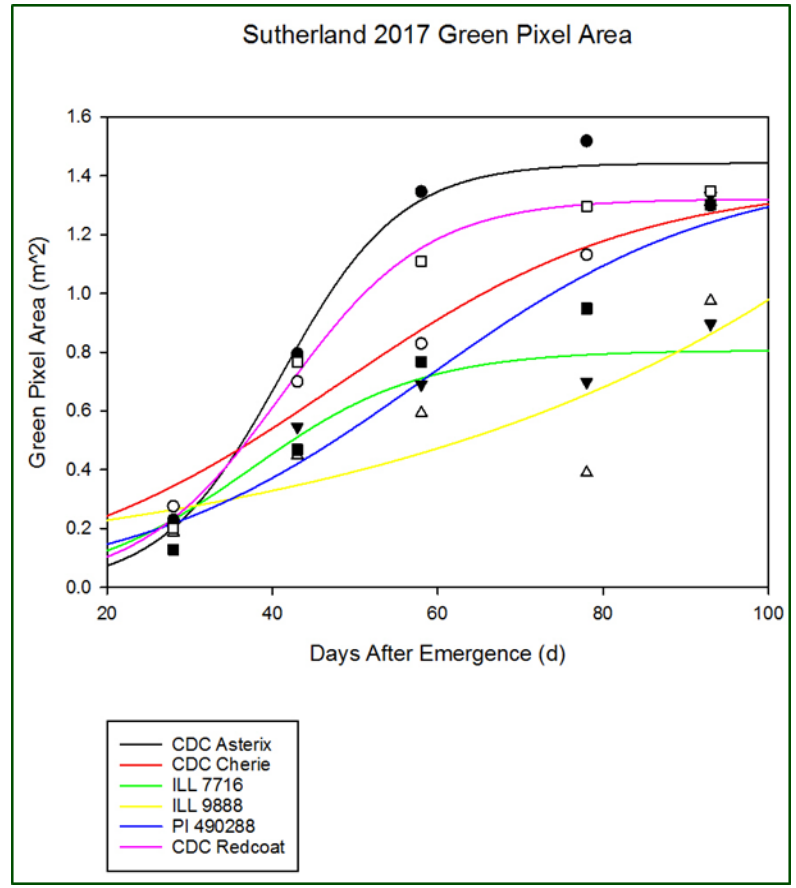
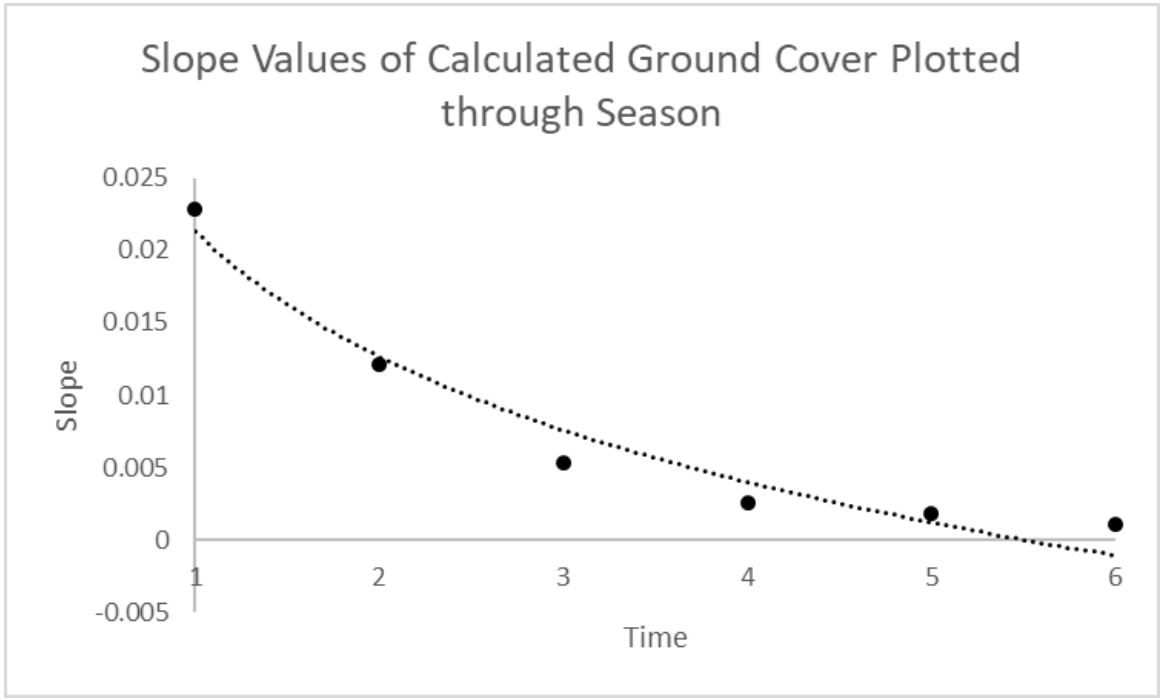
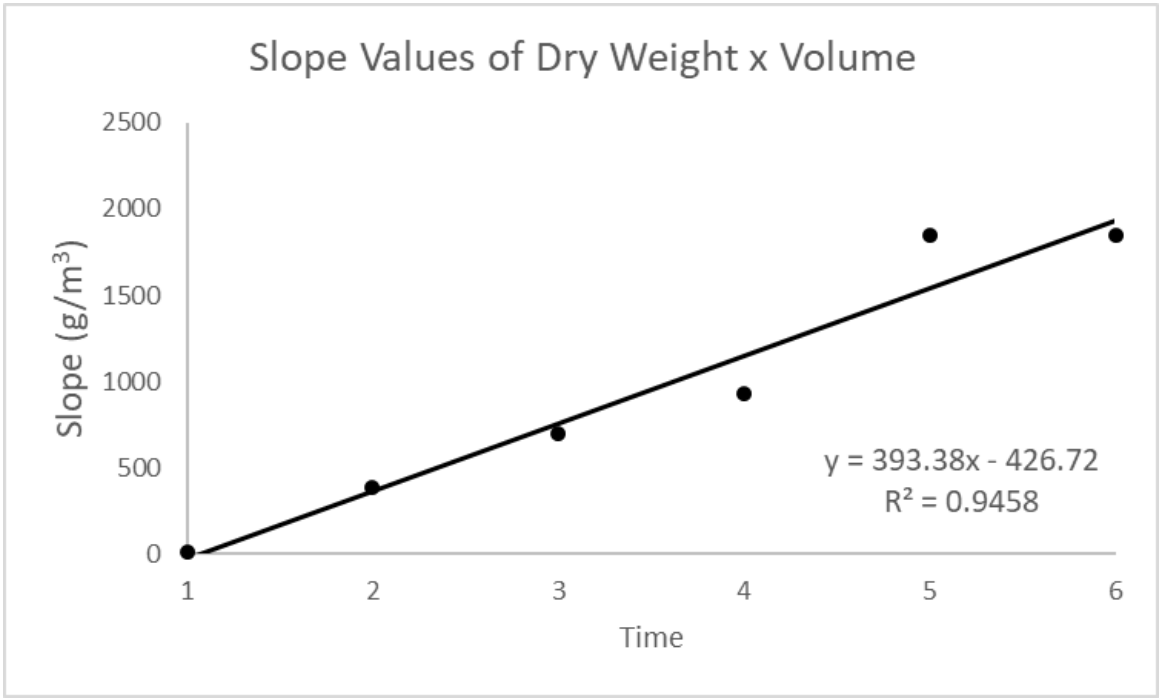






Slope Decrease Indicates Breakdown in Ability to Predict Biomass Later in the Season





Conclusion

- 2-D approach is a good measure of ground cover and is indicative of early season biomass
- 3-D approach correlates better with biomass throughout the season better than the 2-D approach
- Future work will involve analysing growth curves
- Volume and ground cover are different from each other and are *not* the same trait as biomass

Take-Home Message

- Overhead imaging techniques have great potential for use for trait selection in breeding programs

- Volume, ground cover, and biomass can all useful in calculating plant growth rate – a desirable trait for breeders.

Thank You

- Dr. Kirstin Bett
- Dr. Steve Shirtliffe
- Menglu Wang
- Dr. Hema Duddu

- Pulse Crop Field Lab Crew & Graduate Students
- Agronomy Field Crew & Graduate Students
- Department of Computer Sciences, U of S

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