A Remote Sensing Approach to Measuring In-Season Canopy Cover Percentage of Sugarbeets

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Abstract

In agricultural research, optimizing and standardizing in-season data collection methodologies is critical for creating a workflow that produces accurate, reliable, and repeatable results. In trials where experimental treatments are expected to impact sugarbeet growth, canopy cover % provides valuable insights to help quantify treatment effects. Unfortunately, it is often time consuming and challenging to accurately capture canopy cover % in a truly representative way. Amalgamated Sugar agronomists have used a range of methods to measure canopy cover, including manually counting sugarbeet leaves and employing RGB imaging software such as the Canopeo App (http://www.canopeoapp.com). These methods have proven useful; however, they still have room for improvement. In 2024, we tried a remote sensing-based approach to address these concerns. We used unmanned aerial vehicle (UAV) technology paired with geospatial software to measure canopy cover percentages of field trials throughout the growing season. Images collected by the Mavic DJI 3M drone during autonomous flights were stitched using PIX4D Fields software, then uploaded into ArcGIS Pro where the Difference Vegetation Index (DVI) was used to calculate canopy cover percentage for the center two data rows of individual plots. This new method has greatly improved the accuracy of our canopy cover measurements, standardized our approach, and enabled us to confidently compare rates of canopy growth between different treatments in various locations and across multiple years. In 2025, we look to further expand on this work by using multispectral UAV technology to measure early season stand counts and a range of plant health metrics such as NDVI and NDRE.

Introduction

In sugarbeet research trials, accurate and timely canopy cover measurements are essential for evaluating treatment effects and understanding crop development. Traditional methods, such as manual leaf counting and RGB imaging software like Canopeo, often fall short due to limitations in accuracy, efficiency, and repeatability. To produce reliable, comparable results across trials and growing seasons, it is crucial to develop standardized workflows that improve data collection methodologies. Remote sensing methods, particularly UAV technology paired with geospatial software, have the potential to address these challenges and improve in-season data collection, like canopy cover development.

Objective

Develop and implement a UAV-based methodology integrated with geospatial software to improve the efficiency and standardization of canopy cover measurements in sugarbeet research trials.

Background: Scientific Basis

Light Interactions

Vegetation and soil exhibit distinct spectral reflectance patterns across the electromagnetic spectrum, as shown in Figure 1. Healthy plant tissues absorb significant amounts of blue and red wavelengths for photosynthesis while reflecting high proportions of green and near-infrared (NIR) wavelengths. In contrast, bare soil reflects lower levels of NIR and higher levels of red light, enabling the differentiation between vegetative and non-vegetative surfaces in multispectral imagery.

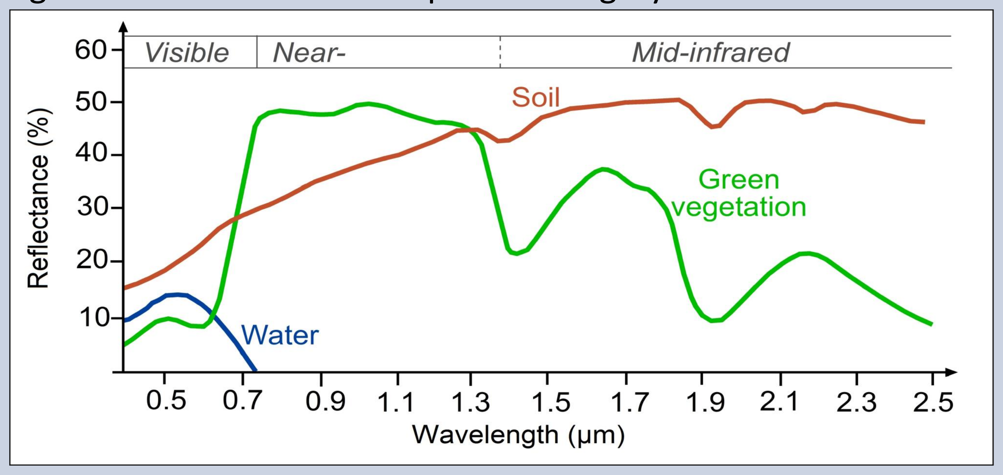

Figure 1. Reflectance curves across different wavelengths of light for water, soil, and vegetation (ESERO n.d.)

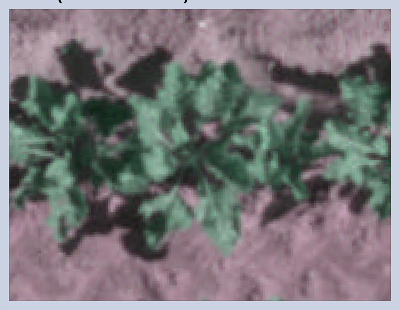

Figure 2. Visible light (RGB) image.

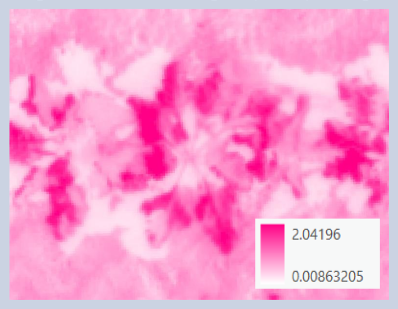

Figure 3. NIR reflectance.

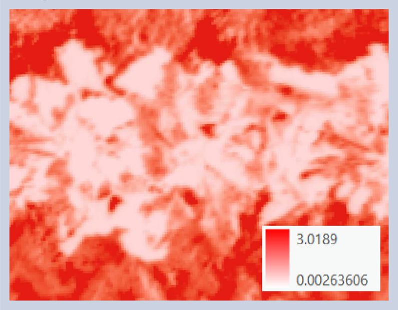

Figure 4. R reflectance.

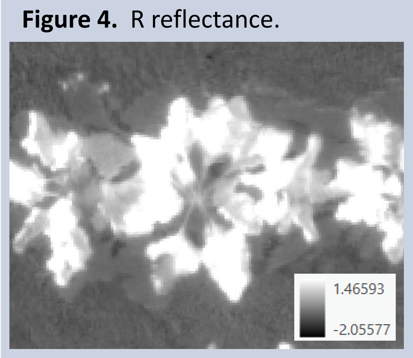

Figure 5. DVI values calculated as the difference between reflectance values in R and NIR wavelengths.

Data Capture

Unmanned Aerial Vehicles (UAVs) equipped with multispectral sensors record light reflectance across different wavelengths. Each pixel within a drone image contains values corresponding to the amount of light reflected in each captured wavelength.

Reflectance Interpretation

Vegetative indices are often used to translate reflectance values into usable data. These are generated by mathematically combining reflectance values in specific wavelengths on a pixel-by-pixel basis. The Difference Vegetation Index (DVI), calculated in Equation 1, is an example of a vegetative used to exploit the strong contrast between NIR reflectance from vegetation and R reflectance from the soil.

$$DVI = NIR - R \quad \text{Equation 1}$$

Figure 2 shows a sugarbeet image in the visual spectrum. The same image is shown in Figure 3 using NIR reflectance and in Figure 4 using R reflectance. Figure 5 shows the DVI values generated by subtracting the R reflectance from the NIR reflectance, amplifying the difference in reflectance between foliage and soil.

Methods

Current methods that Amalgamated researchers use for collecting vegetative growth data include field auditing and collecting canopy cover measurements. Field auditing is done by a senior researcher capable of identifying weak stand development. Canopeo images can be collected by field staff and provide canopy cover data that can then be analyzed at a later date. Both methods are proven and accepted methods to measure crop development.

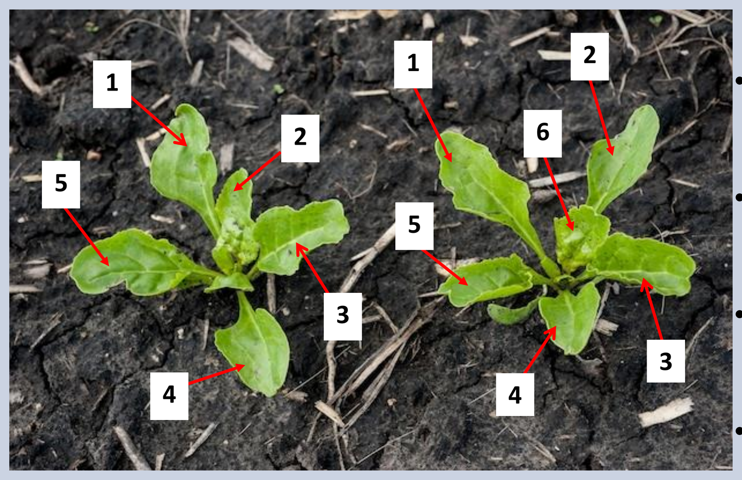

Figure 6. Counting individual sugarbeet leaves as a method of measuring crop development.

Pros.
- Boots on the ground insight
- No licensing required
- Real time answers
- **Free**

Cons.
- Time consuming
- Human error
- Results can be inaccurate and unrepeatable
- Limited scope of interpretability

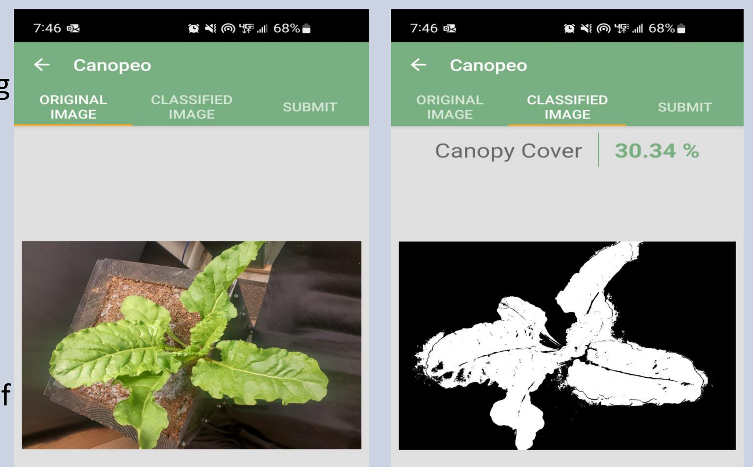

Figure 7. Using the Canopeo App (Oklahoma State University 2024) to measure canopy cover.

New Method

Figure 8. DJI Mavic 3M drone used for multispectral data acquisition.

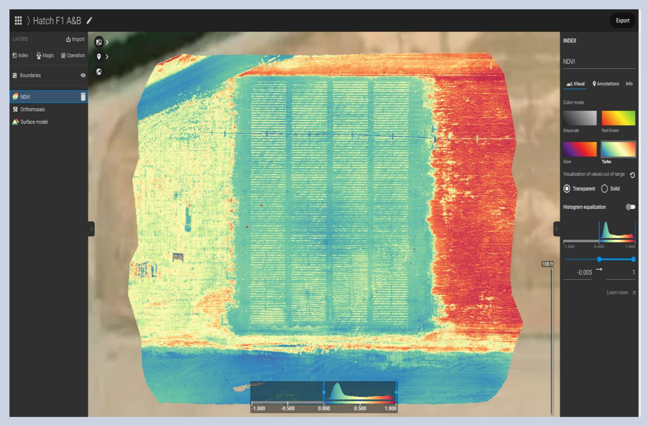

Figure 9. Screenshot of Pix4D Fields software used for image stitching.

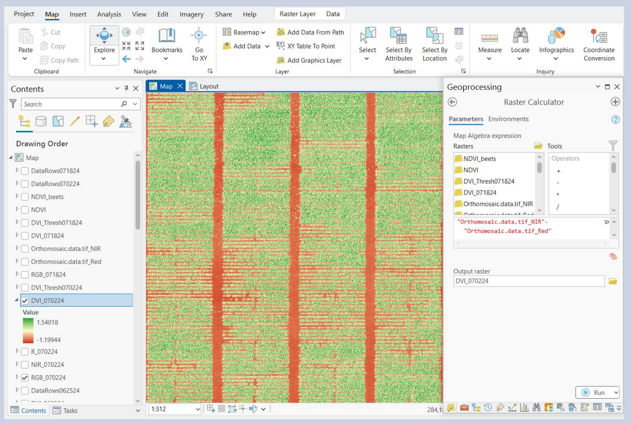

Figure 10. Screenshot of ArcGIS software used for image analysis.

DJI Mavic 3M

The DJI Mavic 3M (Figure 8) performs autonomous flights that capture images in identical locations during flights at different times in the season. This ensures the repeatability of the data collection method, making the final imagery more dependable.

Specifications:
- 4/3 CMOS RGB Camera
- Green, red, near infrared and red edge multispectral camera bands.

Pix 4D Fields

Pix 4D Fields (Pix4D 2024) is a stitching software that utilizes photogrammetry to align individual pixels in multiple images to form a single output of a high-resolution image. In this application, we are using imagery collected by each camera on the drone, including Red, Green, Blue, Near-Infrared, and Red-Edge. The software is capable of producing images containing NDVI and visual spectrum data.

ArcGIS Pro

ArcGIS Pro (Esri 2024) is a comprehensive spatial analysis software where data can be visualized and analyzed. Different layers of stitched imagery are imported from Pix4D software into ArcGIS Pro, where various geospatial tools are used to determine canopy cover in individual research plots.

Geoprocessing tools used:
- Raster Calculator
- Generate Grid from Area
- Zonal Statistics as Table

ArcGIS Workflow

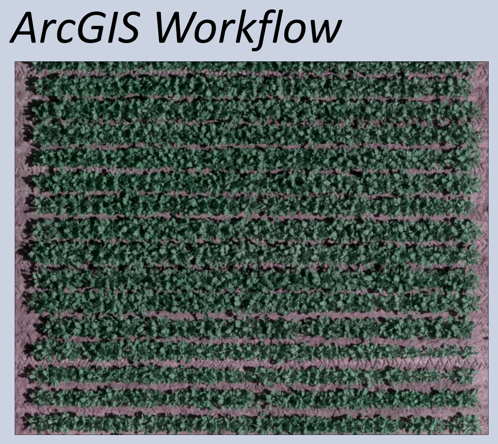

Figure 11. RGB image collected by drone of plots in a 2024 research trial.

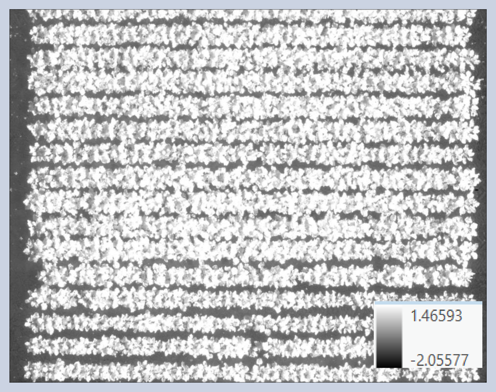

Figure 12. Image of calculated DVI values.

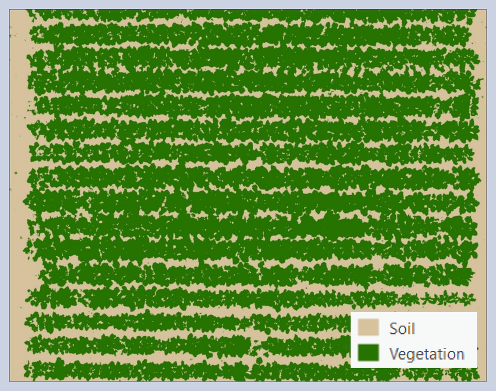

Figure 13. A threshold of DVI is applied to classify vegetation from soil.

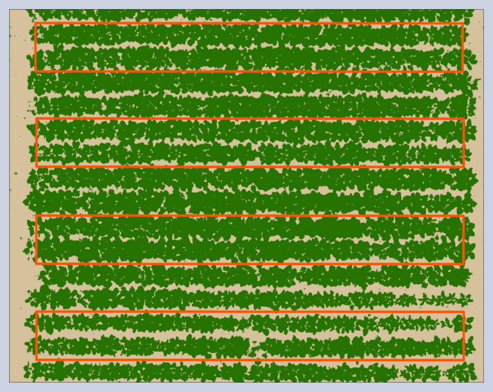

Figure 14. Data rows of research plots are delineated on the map containing the DVI threshold data.

- Figure 11: Visible light (RGB) image of the plots captured by the drone.
- Figure 12: The Difference Vegetation Index (DVI) was calculated using Equation 1 to emphasize the difference in soil and plant reflectances. White represents higher DVI values which indicates vegetation.
- Figure 13: To classify pixels into categories of either soil or vegetation, a threshold value was established for the calculated DVI values. Pixels exceeding this threshold were classified as vegetation (sugarbeet canopy), while those below were categorized as non-vegetative (soil).
- Figure 14: A grid was then created and overlaid onto the map with each box containing an identical area encompassing the center two data rows of research trial plots. By calculating the proportion of vegetation-classified pixels within each delineated area, plot-level canopy cover percent was measured
- Figure 15: An example of the output for this plot-level canopy cover analysis.

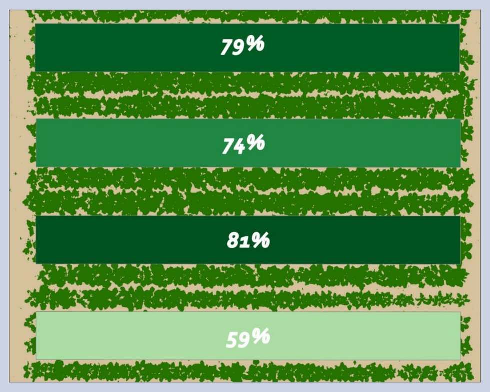

Figure 15. Example output from canopy cover analysis using this methodology for research plots.

Results & Discussion

Workflow and Quality Improvements

Traditional measurements of canopy cover and development rely on visual estimates and limited sample sizes, which introduces variability and inefficiency. Multispectral drone imagery provides a dense, pixel-by-pixel dataset across an entire research field, allowing for precise and repeatable measurements across plots. This allows researchers to collect canopy data for greater areas using less time and labor with greater confidence in the resulting data. The repeatability and reduced subjectivity of the approach also allows for detection of changes in plant growth and treatment effects over time and across varying locations.

Research Application Example

This new canopy cover measurement methodology was used for plot-level analysis of canopy development in Olsen et al. (2024), where effects of different fertility treatments were compared. As shown in Figure 16, canopy cover was measured at 9 timepoints between June 6th and August 1st, 2024. At two timepoints, June 25th and July 18th, canopy cover of was analyzed to determine if there were significant differences in canopy growth. The results of this analysis indicated that the various fertility regimes in this trial resulted in different rates of canopy growth.

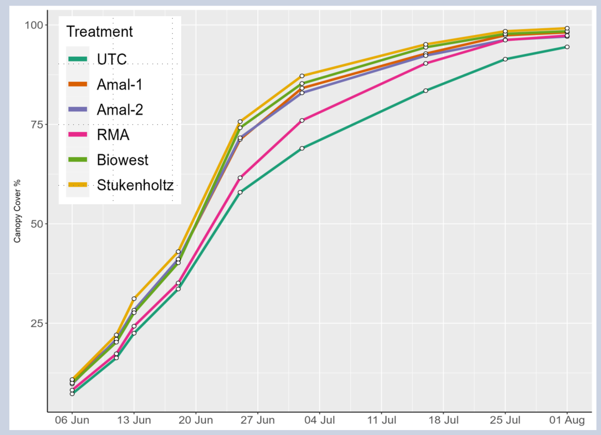

Figure 16. Canopy cover percent over time in a 2024 sugarbeet fertility trial.

Table 1. Statistical analysis of canopy cover at two timepoints indicated that canopy cover was significantly different among different fertility treatments.

Treatment	Canopy Cover %			
	June 28th		July 17th	
UTC	57.9%	*b*	83.5%	*c*
Amal 1	71.2%	*a*	92.8%	*ab*
Amal 2	71.6%	*a*	92.3%	*ab*
Biowest	74.2%	*a*	94.4%	*ab*
RMA	61.6%	*b*	90.3%	*b*
Stukenholtz	75.7%	*a*	95.1%	*a*
P>F	<0.001		<0.001	

The improved precision and repeatability of this methodology provides increased confidence in the resulting data, which allows canopy cover measurements to be used as additional data in research trials.

Future Applications

- In-season nitrogen availability: Vegetation indices like the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Red Edge Index (NDRE) have potential to assess in-season nitrogen status of sugarbeets. This could provide insight to fertility-related issues and aid in making more precise nutrient management decisions.
- Disease detection: Multispectral data can be used to monitor plant health and identify early symptoms of diseases or pest infestations, enabling more targeted and efficient crop protection measures.
- Yield Prediction: Drone imagery can be used to predict final yields by assessing canopy development, plant vigor, and growth patterns throughout the season.
- Stand counts: Multispectral imagery by drone is currently used to automate stand count estimations in various row crops including corn and soybeans. A similar technique can be used to perform stand counts across research plots to ensure stand establishment across treatments.
- Canopy height and volume calculations: UAVs are capable of georeferenced autonomous flights, so every photo can be restructured into accurate 3D models.

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Esri. (2024). *ArcGIS Pro* (Version 3.3) [Software]. Environmental Systems Research Institute, Inc. https://www.esri.com/en-us/arcgis/products/arcgis-pro

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