UNIVERSITY OF GEORGIA
College of Agricultural & Environmental Sciences
Controlled Environment Agriculture Lab

Lettuce Biomass Estimation and Stress Detection Using Multiple Remote Sensing Technologies.

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INTRODUCTION

Cultivation of indoor leafy greens represents a promising avenue for sustainable production intensification. This alternative is characterized by standardized crop operations and high turnover rates, which demand timely decision-making to mitigate potential losses. Remote sensing technology has emerged as a potential solution for yield quantification, owing to its ability to simultaneously characterize the canopy structure of multiple plants.

Uniformity and control that characterize controlled-environment agriculture (CEA) facilities allows for a streamlined and straightforward integration of remote sensing technologies, providing producers with a continuous source of information throughout the plant production cycle. With this information, producers can take anticipatory action to address potential operational issues and ensure optimal crop growth and yield.

OBJECTIVES

1) Establish an image processing methodology using an RGB-D sensor to capture simultaneously multiple plants structural features growing in a DWC hydroponic cultivation set up

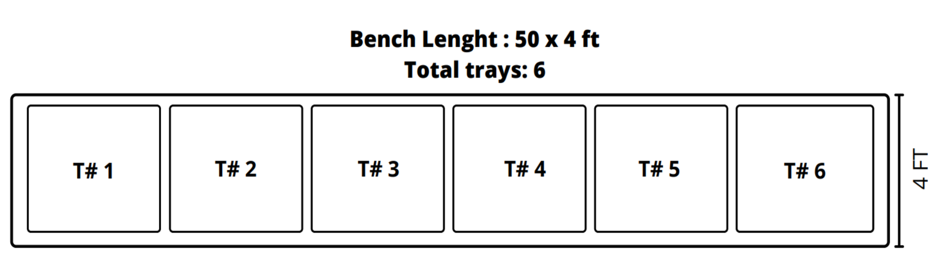
2) Integrate a machine learning pixel classification model using image color information to improve plant pixels identification under variable light greenhouse conditions.

3) Develop a non-destructive method for accurately estimating plant biomass, namely leaf fresh weight, leaf dry weight and leaf area using plant image derived features as predictors

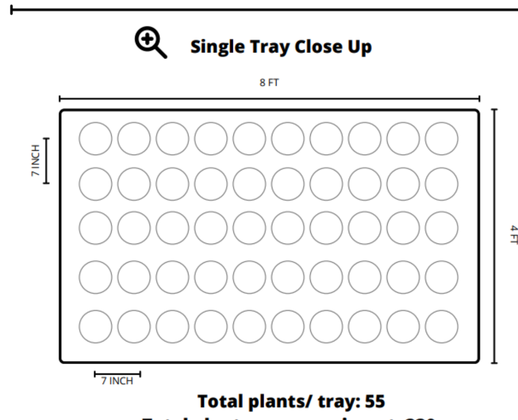
MATERIALS AND METHODS

DWC hydroponic system consist of 4 ft x 8 ft plastic trays filled up with nutrient solution, a polystyrene raft floating on top and air pumps with air stones blowing oxygen to keep the right dissolved oxygen level.

"Chicarita" romaine lettuce seeds were propagated using rockwool plugs and transplanted to a DWC system 12 days after germination.



Microsoft Azure Kinect



6 trays distributed along a 50 ft long bench. Each raft has 55 plant holes with a heart-to-heart distance 20 cm x 20 cm.

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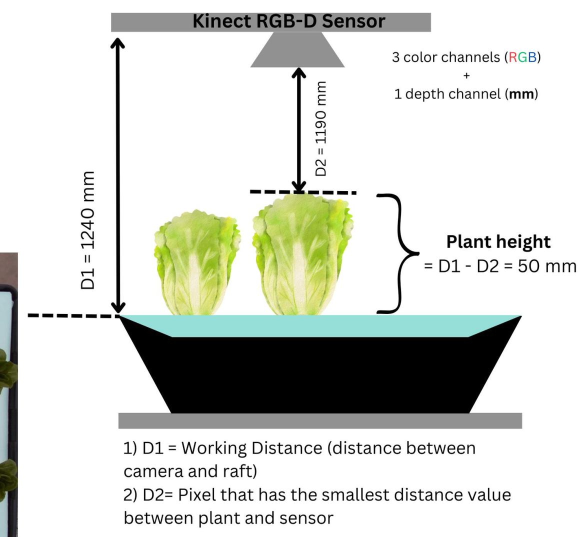
Regression Model Training



❶ **Aim:** Predict biomass as Leaf Fresh Weight (LFW)

Image-Derived Geometrical Features (potential predictors)

Plant Index	Feature_1	Feature_2	Feature_3	Feature_4	FW (g)
1					
2					
3					
4					
5					

❷ **Manual Measurements obtained in 3 harvest days** (LFW, LDW, LA)

Harvest 1
Labels **(LFW):** 2 – 5 g

Harvest 2
Labels **(LFW)**:5 – 20 g

Harvest 3
Labels **(LFW):** 75 – 160 g

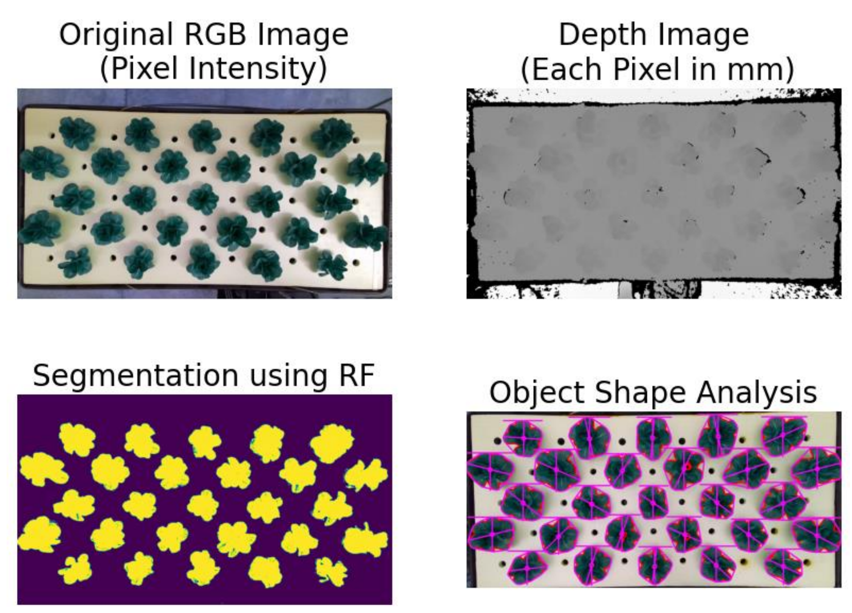
❸ **SUPERVISED LEARNING**

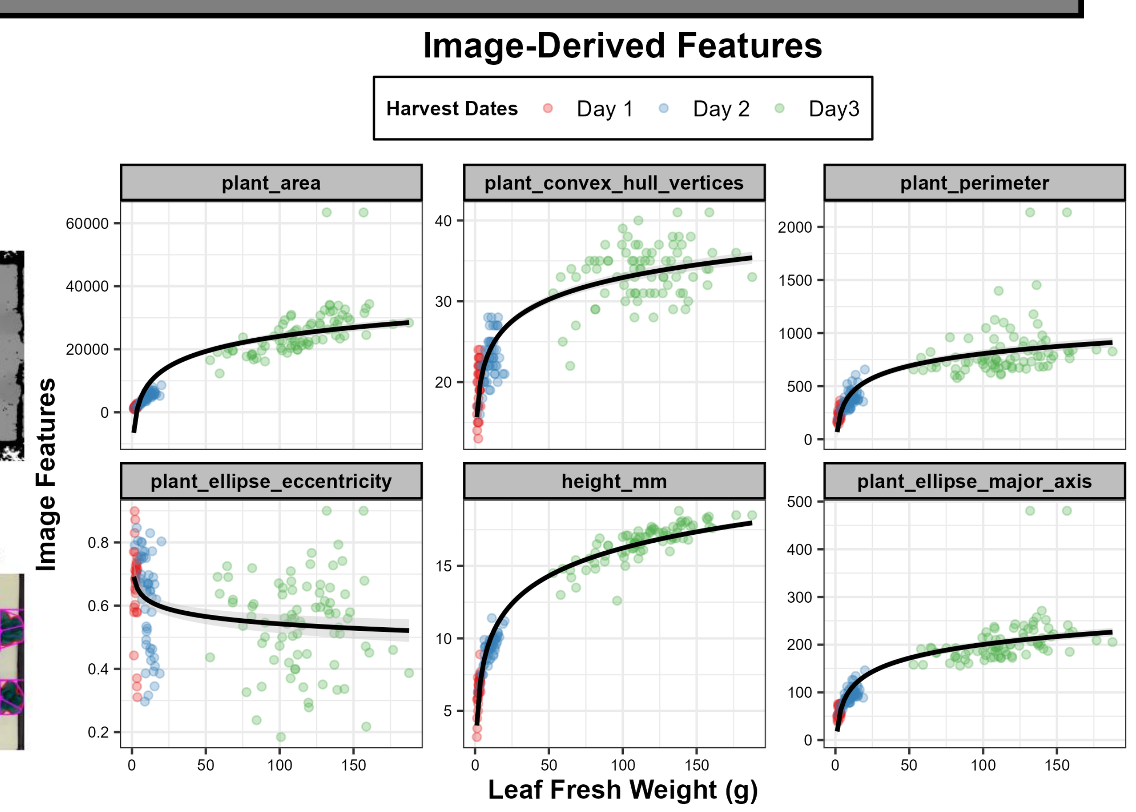
Labels: Ground truth manual measurements for model training (FW)

Choose regression model with the best prediction performance

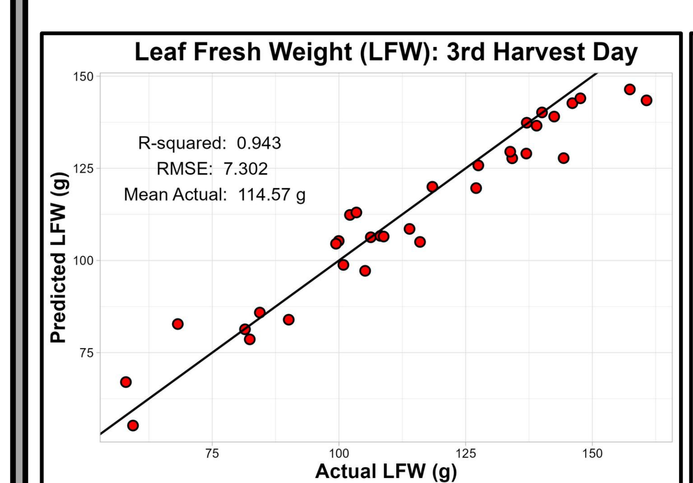
PRELIMINARY RESULTS

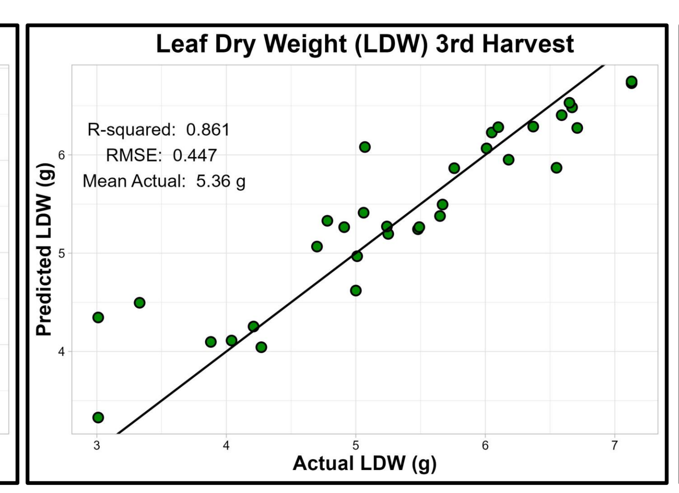
Image processing workflow

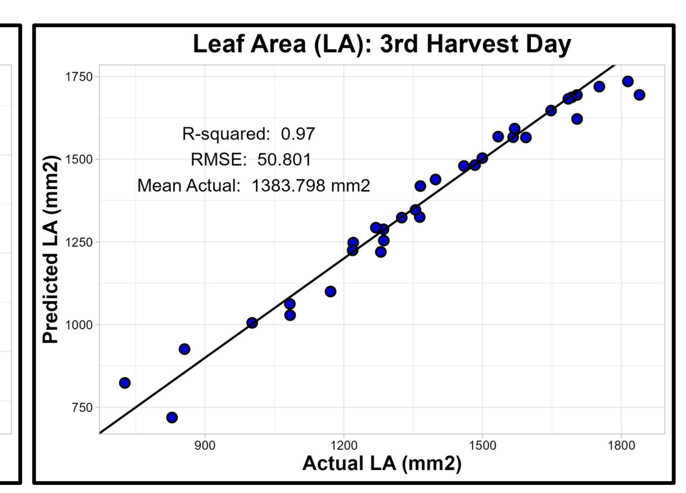




A **Random Forest Classification** strategy was implemented to improve the two-class (plant - background) segmentation process to obtain a more accurate and standardized plant pixels identification under different illumination conditions at the greenhouse.







Regression model performance: A RF model achieved the best prediction performance for all 3 biomass parameters considered. The performance on new unseen data (test sets) was acceptable not just for the last harvest day but also for the two previous harvest.

CONCLUSIONS

- Our imaging approach shows the potential of using RGB and depth image processing to extract morphological features from multiple plant simultaneously in a DWC hydroponic setup under semi controlled conditions.
- Despite of variable illumination conditions, the implementation of a RF segmentation strategy to improve plant pixel classification worked successfully to correctly identify plant pixels more uniformly across time
- Bringing together most of the geometrical features extracted from plants canopy shape as predictors allowed us to fit a Random Forest model that showed a satisfactory performance in the estimation of biomass accumulation at multiple time points for LFW, LDW and LA.

WHAT'S NEXT?

Plant Growth Rate Analysis

Increase the frequency of non-destructive plant data collection to track plant development using a growth rate approach combined with additional information coming from environmental sensors

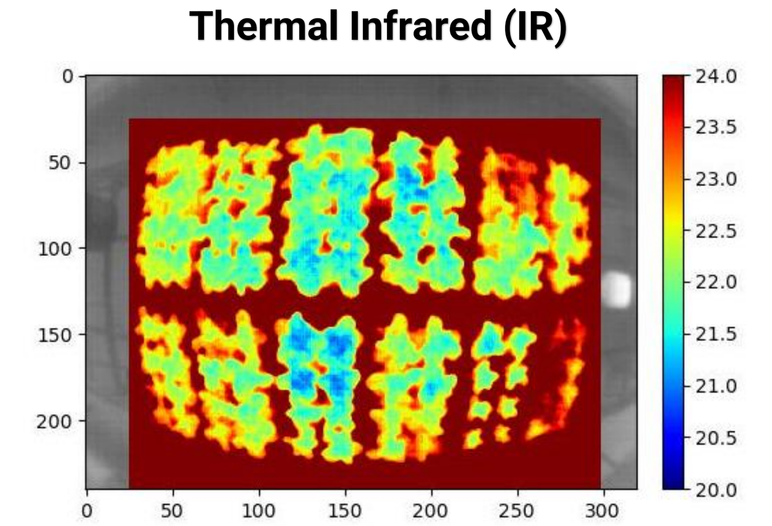
Look for a yield quantification strategy more adaptable to growing conditions with higher plant density, after certain point in the cycle the individual plant analysis is hampered by plants overlapping.

Multi-sensor information:

Spectral Reflectance (NIR)

Additional spectral information (NIR) using an RGB camera without infrared filter and bandpass filter

Thermal Infrared (IR)



Seek Thermal mosaic core captures temperature information per pixel. Low IR sensor resolution of 320x240 (low)

Acknowledgments

CATRIN Czech Advanced Technology and Research Institute

Horticultural Physiology, University of Georgia, https://hortphys.uga.edu/

PlantCV
Modular Python package for plant image analysis