RIT

Predicting Table Beet Root Yield via UAS-based Hyperspectral Imagery

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Objectives

We proposed to develop UAS-based techniques to forecast *beet root weight.* This includes:

- **Identifying the spectral regions that are predictive of beet root weight.**
- **Evaluating the predictability at five different growth stages.**
- **Assessing the extension of results to affordable, operational silicon-based detectors. Note: We used hyperspectral imagery to determine the optimal wavelengths in the Si-range (400-900 nm).**

Data collection process

Headwall Nano Hyperspec

400-1000 nm: Visible and Near Infrared (VNIR)

272 bands; 2-3 nm spectral resolution

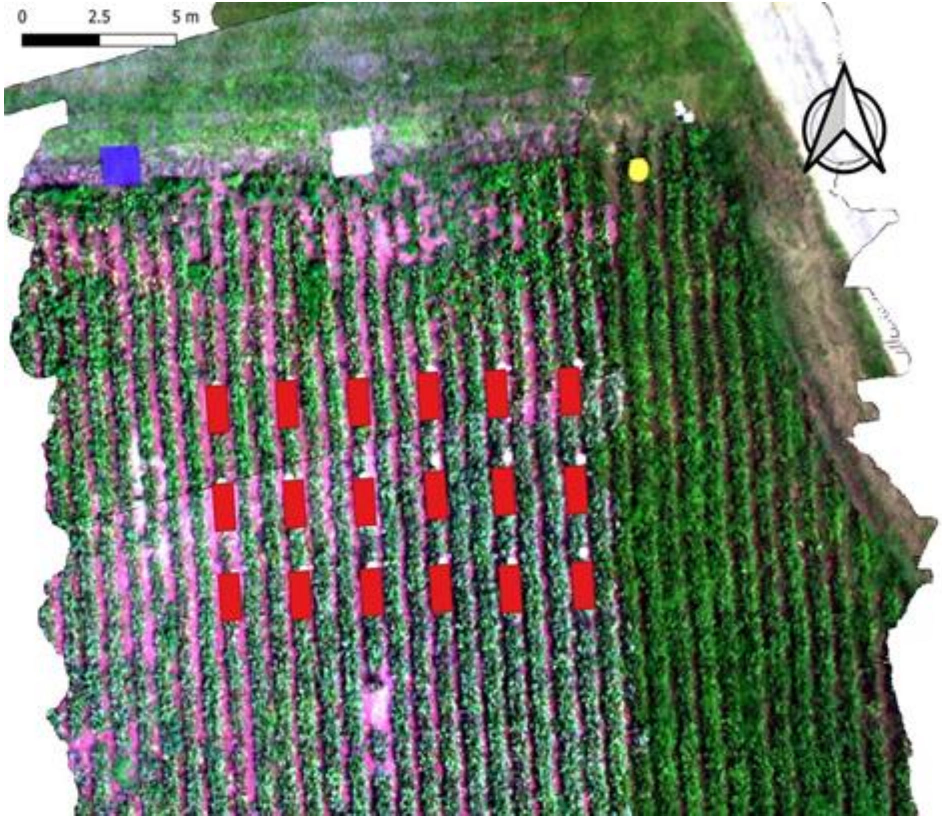
Image credit: Jan van Aardt

UAS data collection: 2021 flight milestones

Date	Milestone	Growth Stages
May 20	Beets planted	Germination
June 16	1st Flight	Leaf Development (Crop Emergence)
July 7	2nd Flight	Leaf Development (more than 9 leaves unfolded)
July 15	3rd Flight	Rosette growth
July 20	4th Flight	Rosette growth
August 2	5th Flight	Harvest-ready
August 5	Harvest	Harvest-ready

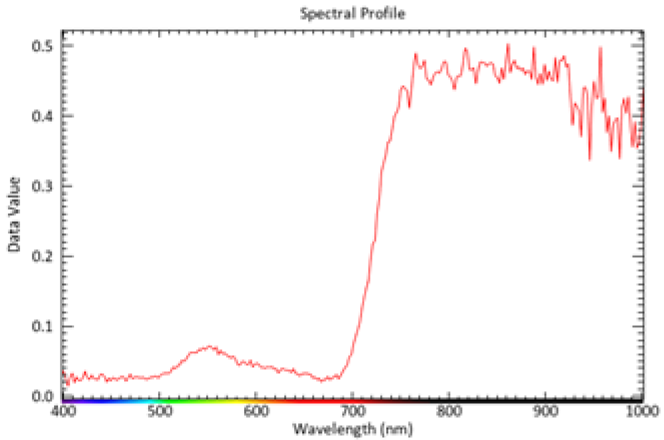
Plot extraction

- Convert from radiance to reflectance (via ELM)
- Perform denoising
- 18 plots in our study
- Width of box = 0.67 m (roughly the distance between two adjacent rows)
- Height of box = 1.46 m (roughly the size of the plot)



Challenges related to hyperspectral data

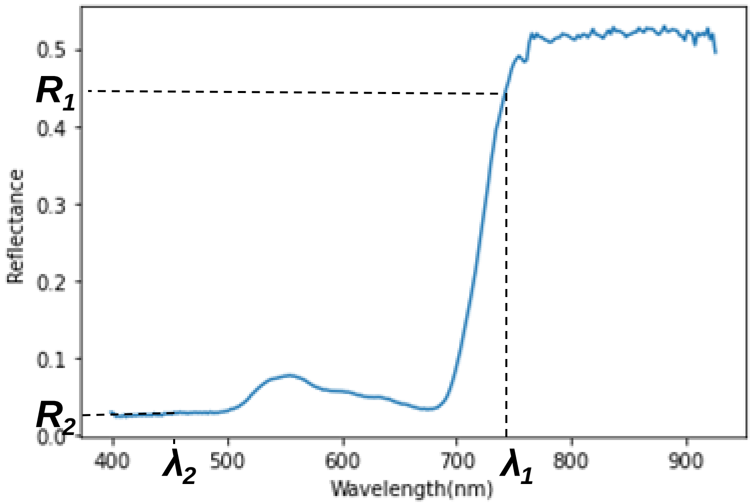
- **We have ~272 spectral bands**
- **Hyperspectral data suffer from the curse of dimensionality**
- **Identify the useful features:**
  - Find all possible pairs of normalised difference indices from mean vegetation spectra of the plot (reflectance features).
  - Find the GLCM mean of a plot (texture features).
  - Find all possible pairs of normalised differences for the GLCM mean



Predictor variable extraction

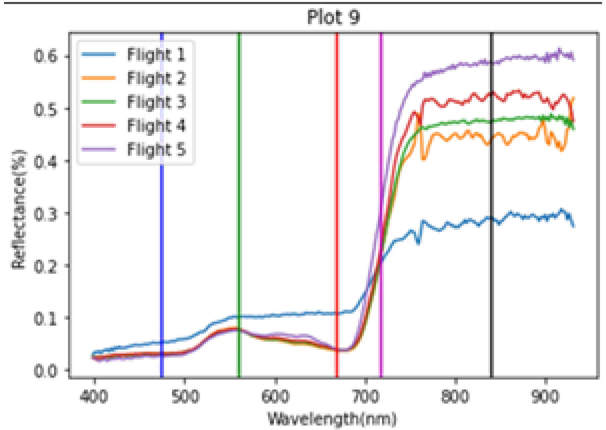
- **Extract normalized difference indices at various wavelength pairs**
  - We calculate for both reflectance and texture features
  - For reflectance: Normalized difference reflectance indices (NDRI)
  - For texture: Normalised texture reflectance indices (NDTI)
- **Fit a linear relationship between this feature and the value to predict (e.g., root weight)**

$$\textit{Normalized Difference Indices} = \frac{R_1 - R_2}{R_1 + R_2}$$

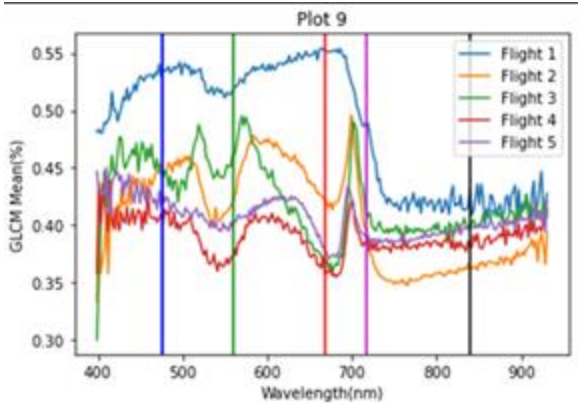


Feature extraction

Reflectance features



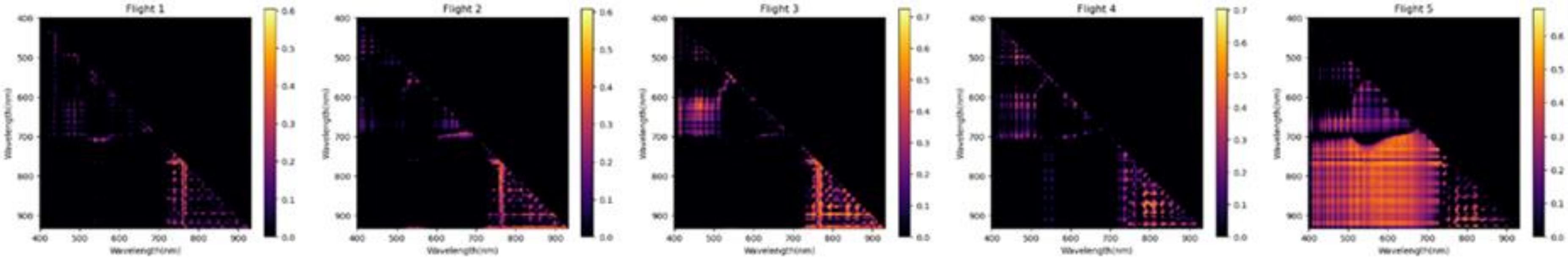
Texture features (GLCM)



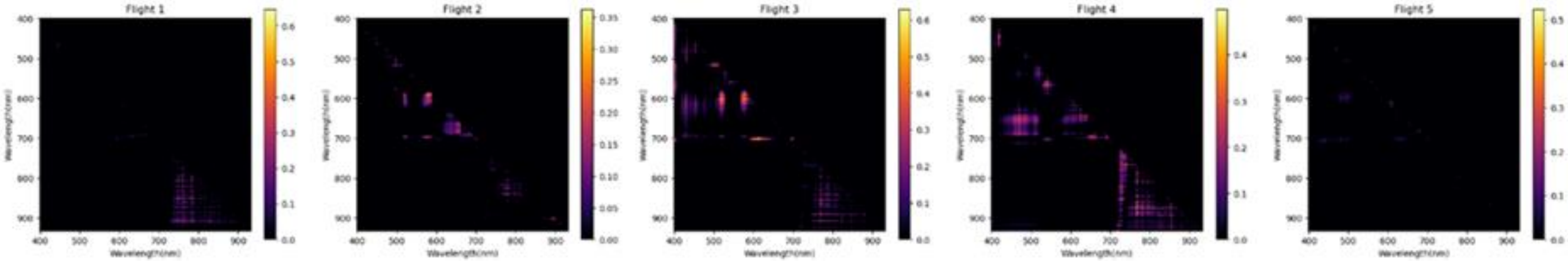
Extract a spectrum of mean reflectectance features and mean texture features from each plot

Plot of coefficient of determination at various wavelength pairs during each flights

NDRI



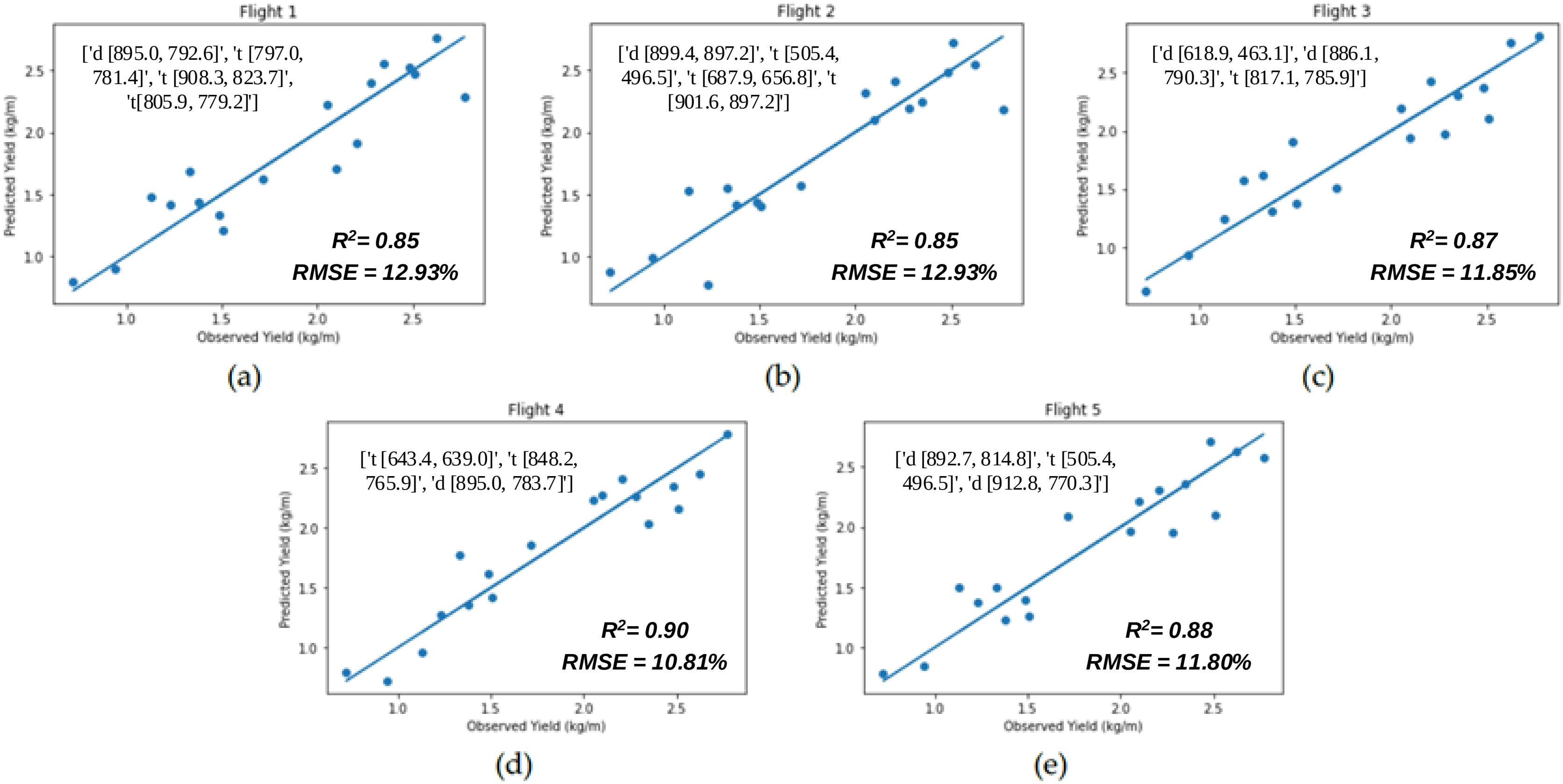
NDTI



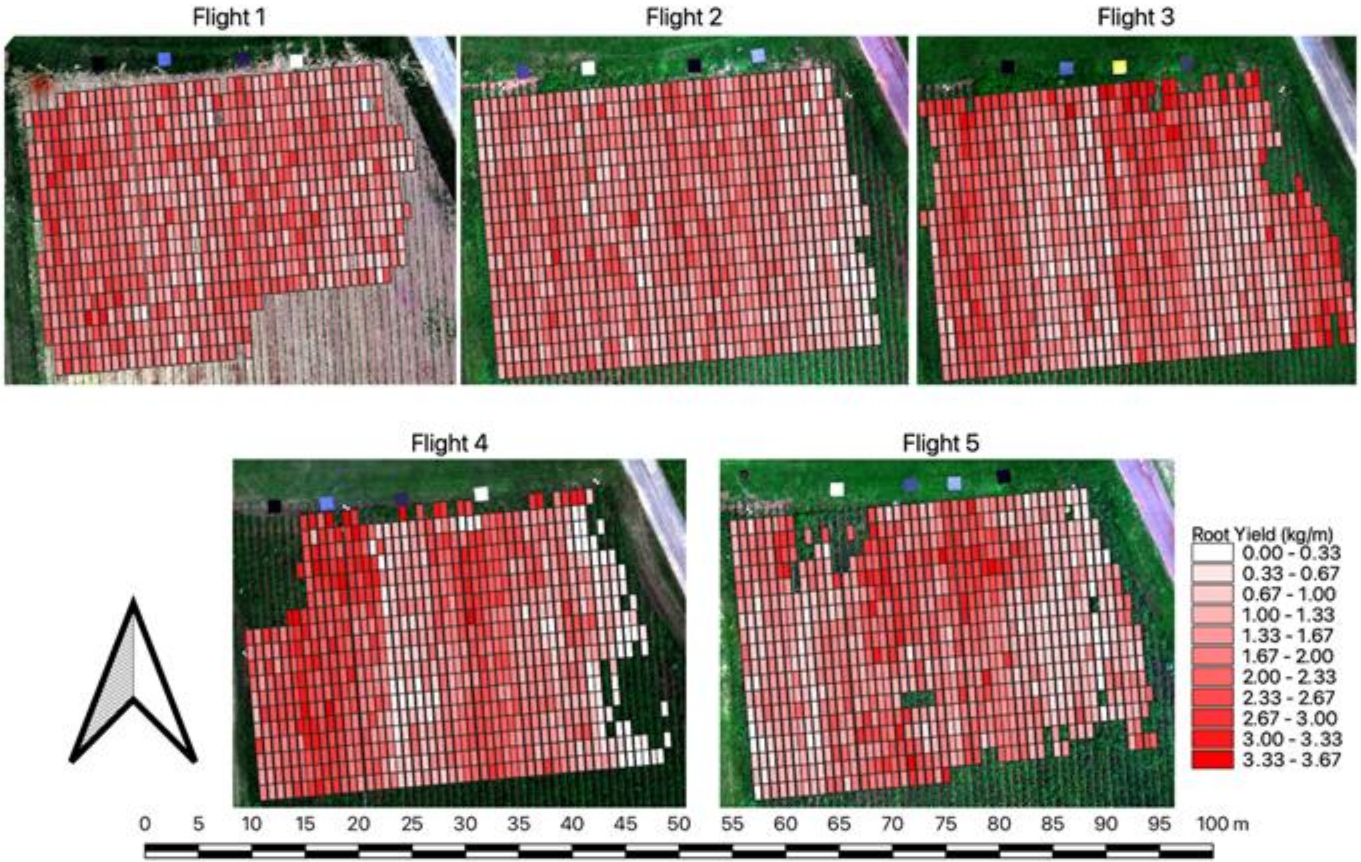
Feature selection for better-performing model

- **Select top 10 (R^2) from each indices**
- **Run modified stepwise regression**
  - Stepwise regression only accounts for a particular set of features at fixed permutations
  - Here all the top performing feature combinations are reported
  - We randomly select the order of feature
  - First forward select, then perform backward elimination after each selection (to ensure model with a low number of features)
  - Filter out the models containing low VIF (variance inflation factor)

Performance of the best performing models



Extrapolating yield results to the field scale



Conclusion and future work

- Feature pairs around the NIR region are most responsive to root yield
- The spectral region of most responsive predictive regions changes with time
- The “rosette” growth stage (flights 3 & 4) are the most suitable time to collect data
- Further verification of the features are required with data sets collected across growing seasons

Questions?

For more details: **Forecasting Table Beet Root Yield Using Spectral and Textural Features from Hyperspectral UAS Imagery**, *Remote Sensing* 2023,15

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