Assessing Multi-season Table Beet Root Yield from Unmanned Aerial Systems

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Introduction

- Table beets have gained popularity due to their health benefits, including cardiovascular improvements and anti-inflammatory properties.
- Remote sensing is essential in precision agriculture for estimating crop yields, but subterranean crops like beets present unique challenges.
- Most yield estimation studies rely on specific growth stages or growing seasons, making models less robust to changes across stages and seasons.

Objective:

- Develop a robust model to predict table beet root yield using multi-season UAS and meteorological data.
- Compare the predictive performance of multispectral systems with hyperspectral + LiDAR systems to assess their relative utility in yield estimation.

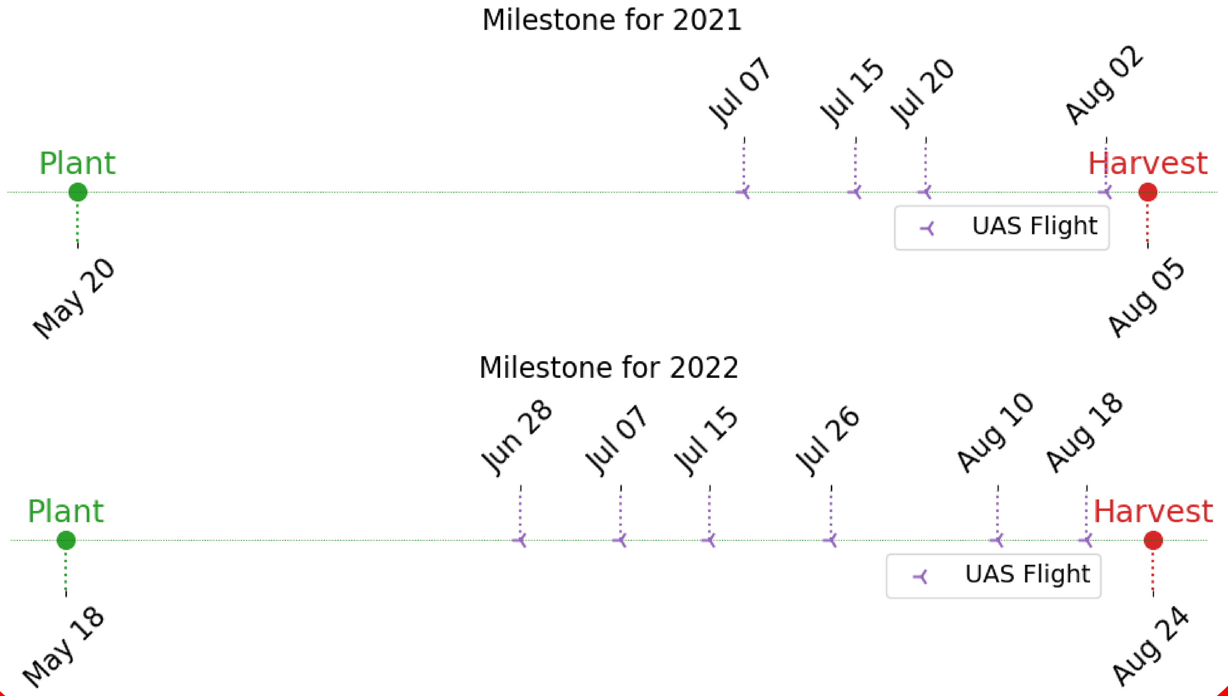
Data Collection

Study location: Geneva, New York, USA, at Cornell AgriTech.

UAS setup

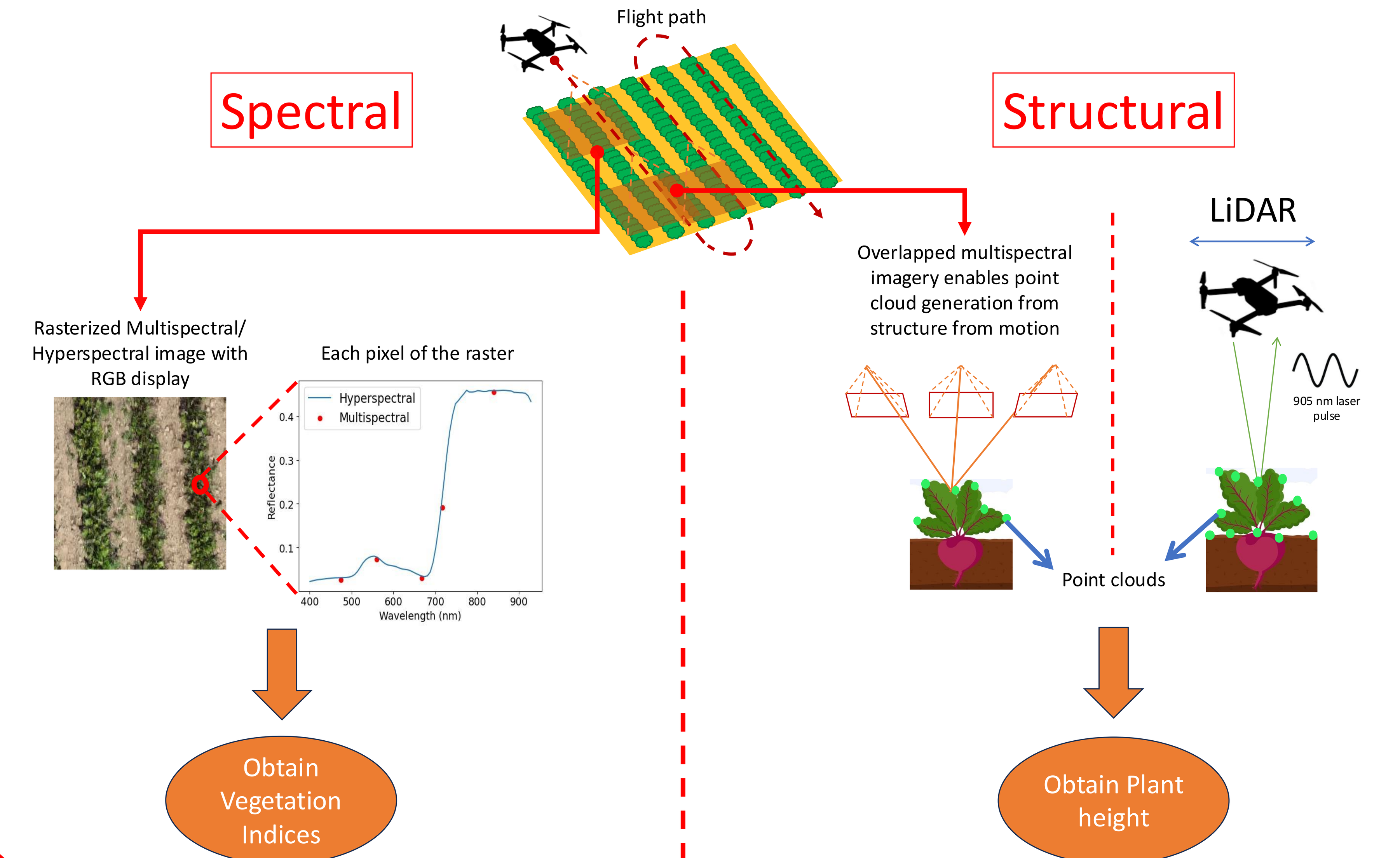
Timeline

UAS flight dates for each season:



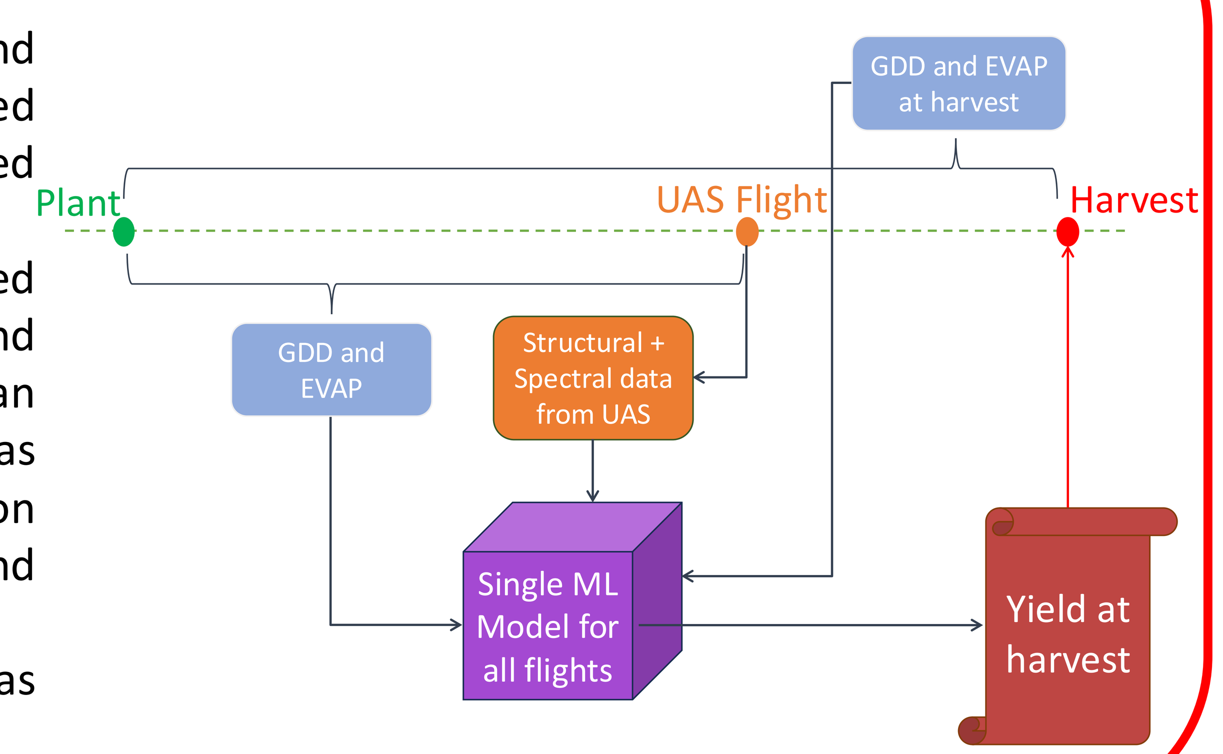
Input Features from UAS

Extracting features from each imaging systems

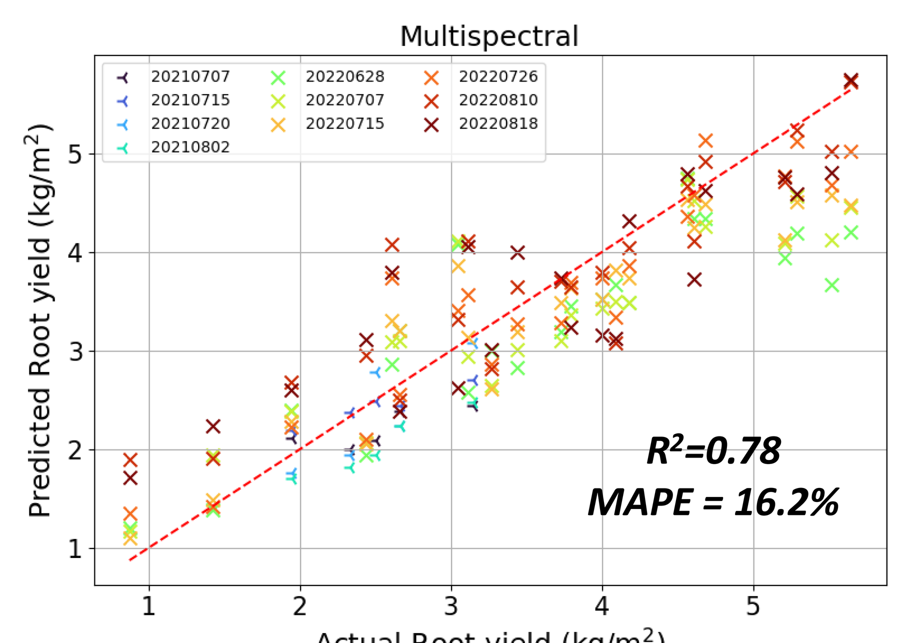


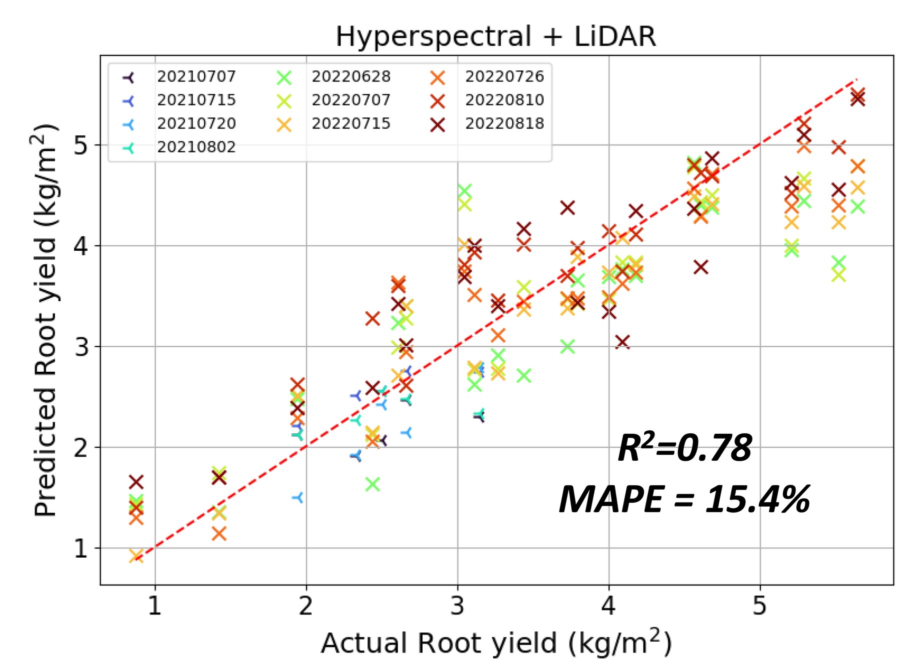
Modelling Root Yield

- Growing Degree Days (GDD) and evapotranspiration (EVAP), obtained from local weather stations, were used as meteorological inputs.
- Several vegetation indices were derived from both multispectral and hyperspectral imagery, while the mean plant height for each plot was calculated using Structure-from-Motion (SfM) with multispectral data and LiDAR.
- Gaussian Process Regression (GPR) was applied to predict harvest root yield.



Overall Model Performance





Model Performance by Flight

The average coefficient of determination *(R^2)*, mean absolute percent error (MAPE) and standard deviation for model prediction within each flight date for each system are shown below.

Multispectral

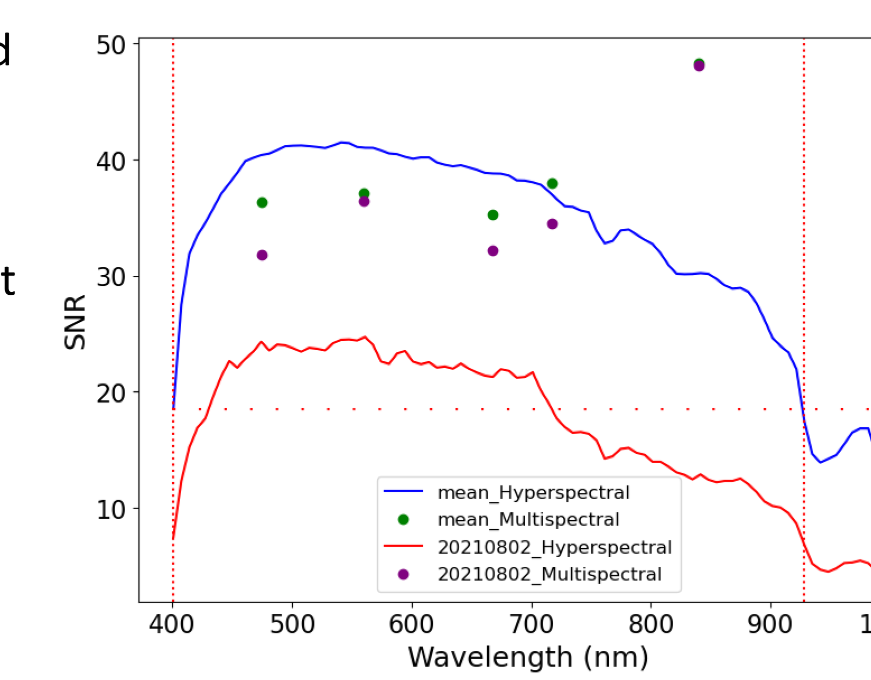
Flight	R^2	MAPE (%)	std_dev (kg/m^2)
20210707	0.62	18.28	0.25
20210715	0.81	15.03	0.22
20210720	0.88	10.39	0.24
20210802	0.76	13.40	0.32
20220628	0.75	15.71	0.19
20220707	0.77	16.16	0.16
20220715	0.79	15.43	0.16
20220726	0.88	11.22	0.17
20220810	0.85	14.47	0.19
20220818	0.84	14.85	0.20

Hyperspectral + LiDAR

Flight	R^2	MAPE (%)	std_dev (kg/m^2)
20210707	0.51	19.62	0.26
20210715	0.81	15.00	0.23
20210720	0.85	10.41	0.25
20210802	0.84	7.64	0.37
20220628	0.75	16.64	0.18
20220707	0.76	16.97	0.15
20220715	0.79	15.38	0.16
20220726	0.85	13.02	0.16
20220810	0.86	14.27	0.20
20220818	0.84	14.47	0.23

Discussion

- Earlier flight dates exhibited lower prediction accuracy.
- 2021 data had higher uncertainty due to fewer instances; 2021/08/02 flight had elevated uncertainty across both systems.
- Five-band multispectral sensor demonstrated comparable performance to hyperspectral + LiDAR system.



Acknowledgments

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References

- Chancia, R.; Bates, T.; Vanden Heuvel, J.; van Aardt, J. Assessing Grapevine Nutrient Status from Unmanned Aerial System (UAS) Hyperspectral Imagery. Remote Sens. 2021, 13, 4489.
- Sishodia, R.P.; Ray, R.L.; Singh, S.K. Applications of Remote Sensing in Precision Agriculture: A Review. Remote Sensing 2020, 12, 3136, doi:10.3390/rs12193136.
- Martínez-Ferrer, Laura, Maria Piles, and Gustau Camps-Valls. "Crop yield estimation and interpretability with Gaussian processes." IEEE Geoscience and Remote Sensing Letters 18.12 (2020): 2043-2047.
- Gu, Yangyang, et al. "Novel 3D photosynthetic traits derived from the fusion of UAV LiDAR point cloud and multispectral imagery in wheat." Remote Sensing of Environment 311 (2024): 114244.

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