Evaluating UAS Imaging Technologies for Precision Agriculture: Yield Prediction and Disease Assessment in Table Beets

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Introduction

- **Motivation:** Unmanned Aerial Systems (UAS) equipped with multispectral, hyperspectral, and LiDAR sensors offer promising tools for non-invasive crop monitoring—but their comparative effectiveness across different agricultural tasks remains underexplored.
- **Gap:** Most existing studies focus on single sensor modalities or isolated crop parameters. There is a need to evaluate sensor performance across multiple tasks, such as root yield prediction and disease severity estimation, particularly for specialty crops like table beets.
- **Objective:** This study compares the performance of **multispectral**, **hyperspectral**, and **LiDAR** sensors in predicting harvest table beet **root yield** and *Cercospora* Leaf Spot (CLS) **disease severity**, aiming to identify the most practical and effective sensing strategies for precision agriculture.

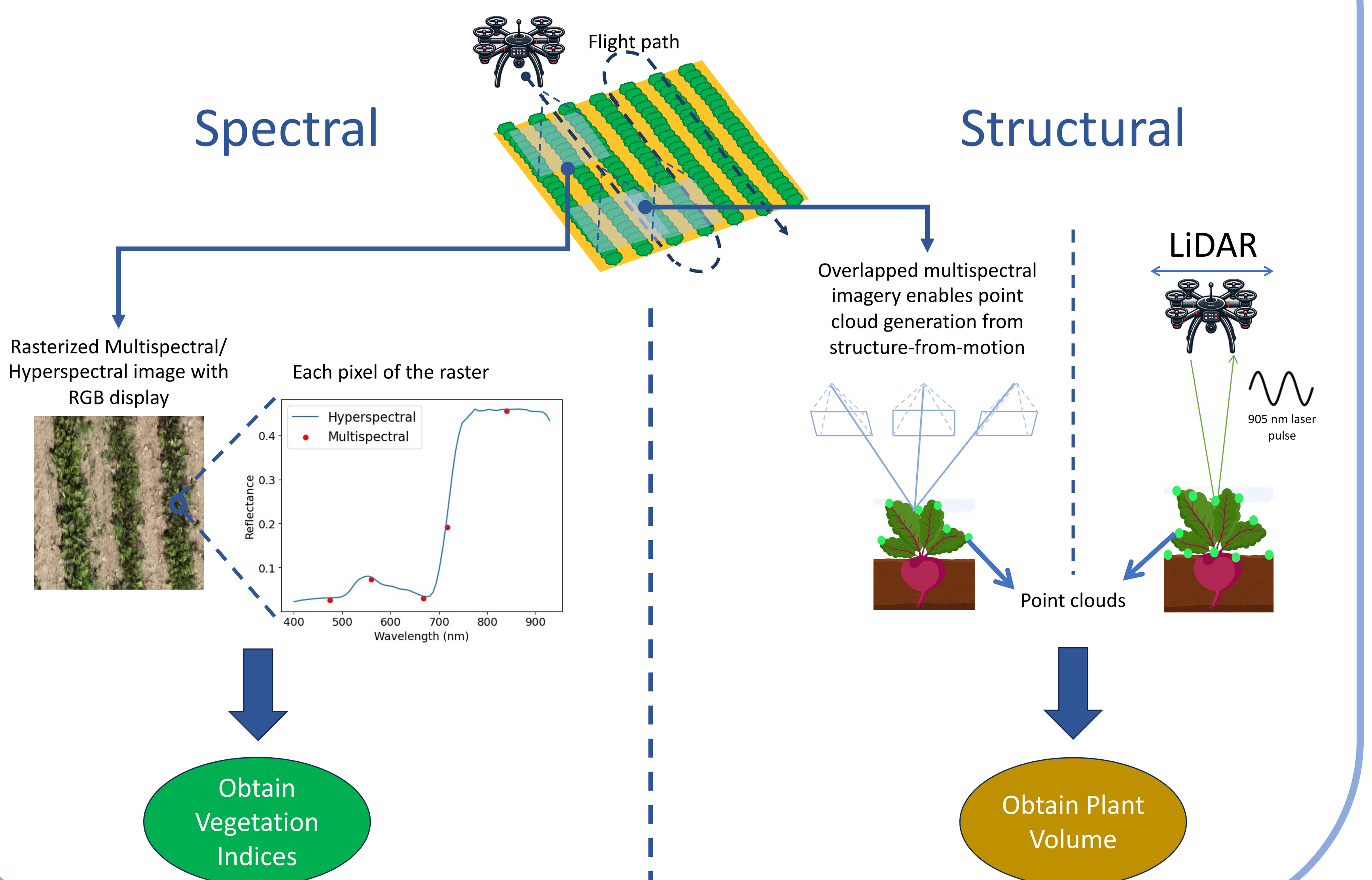
Data Collection

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

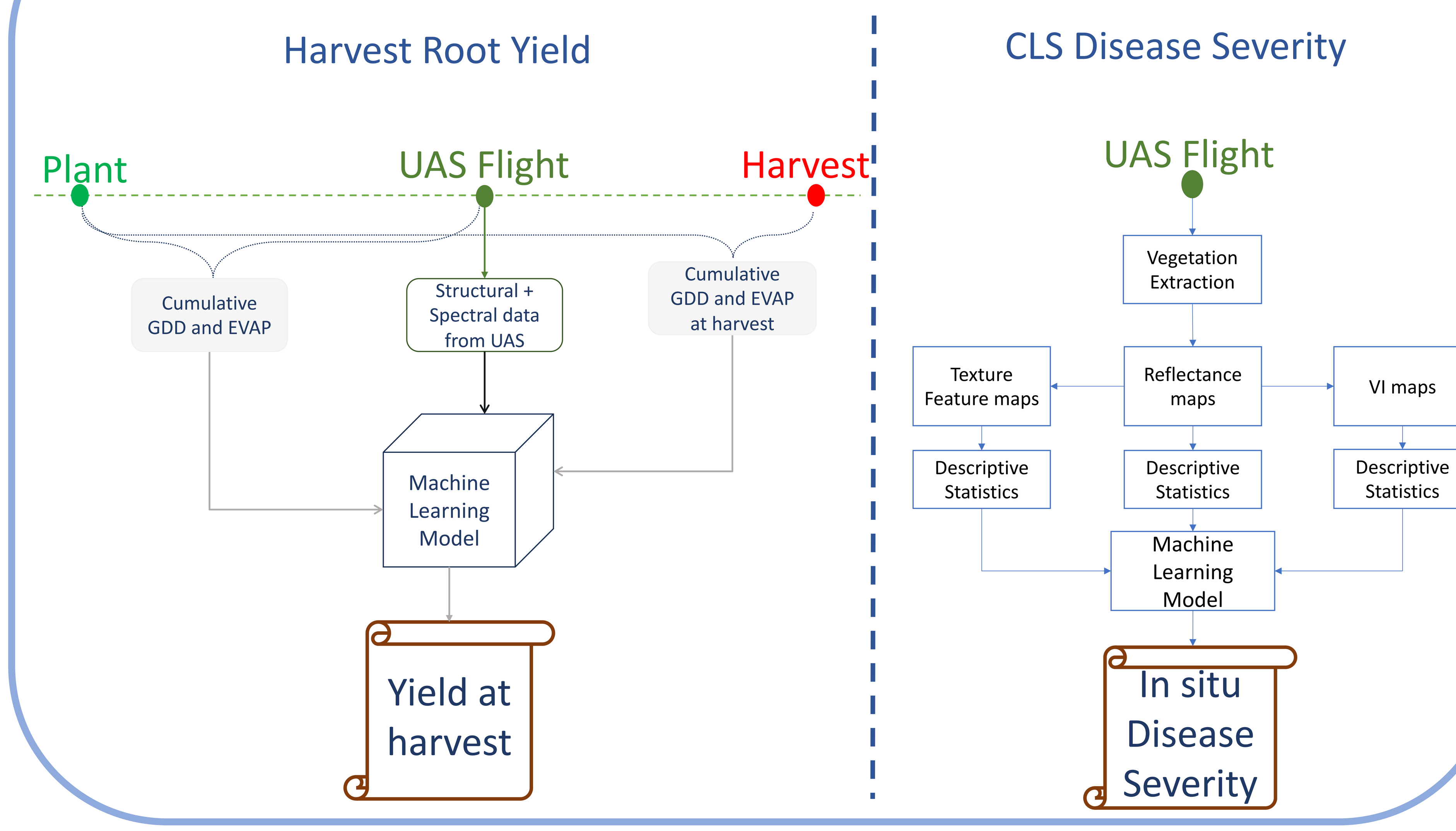
UAS setup

Input Features from UAS

Extracting features from each imaging systems

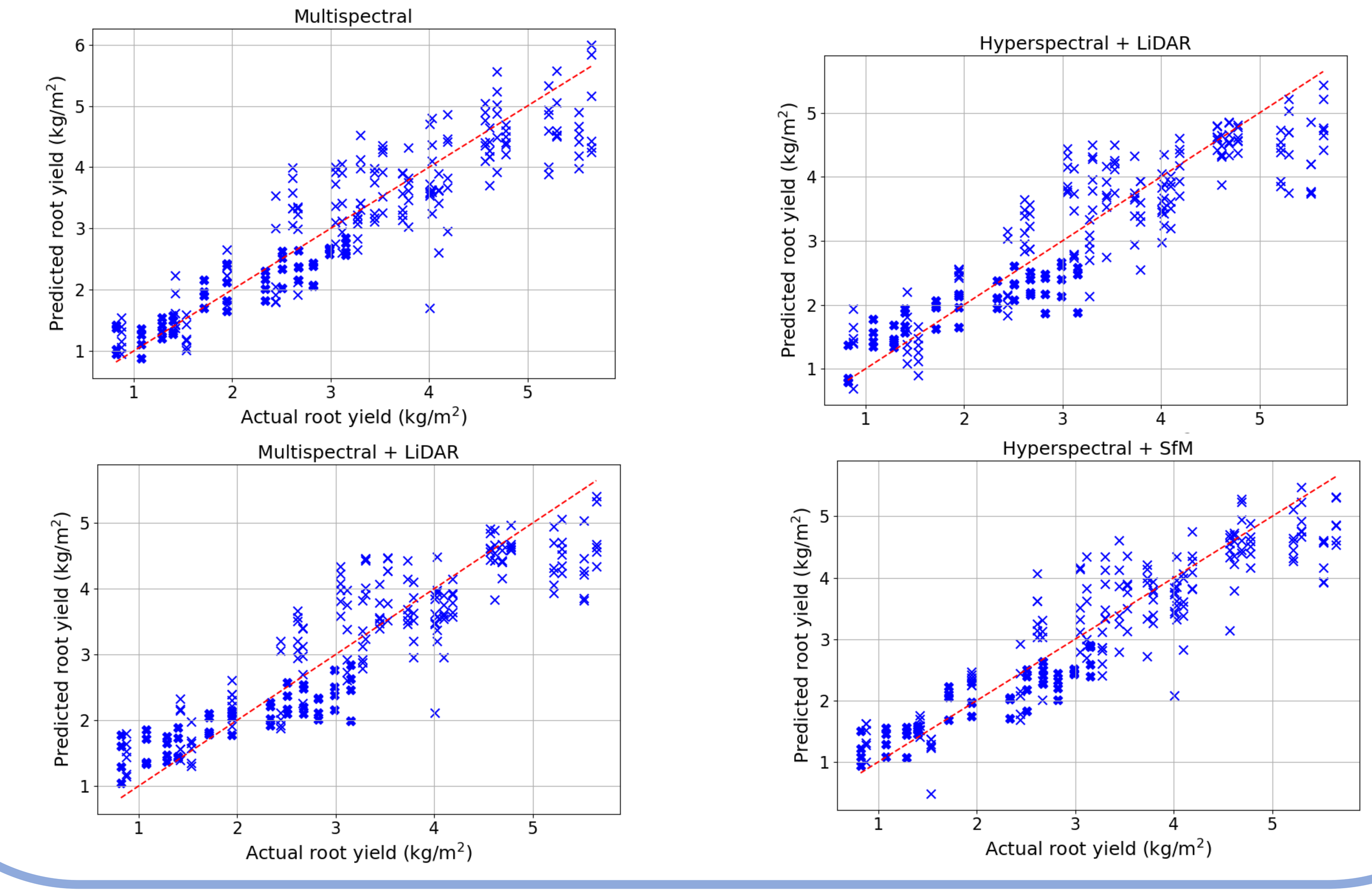


Modeling Approaches

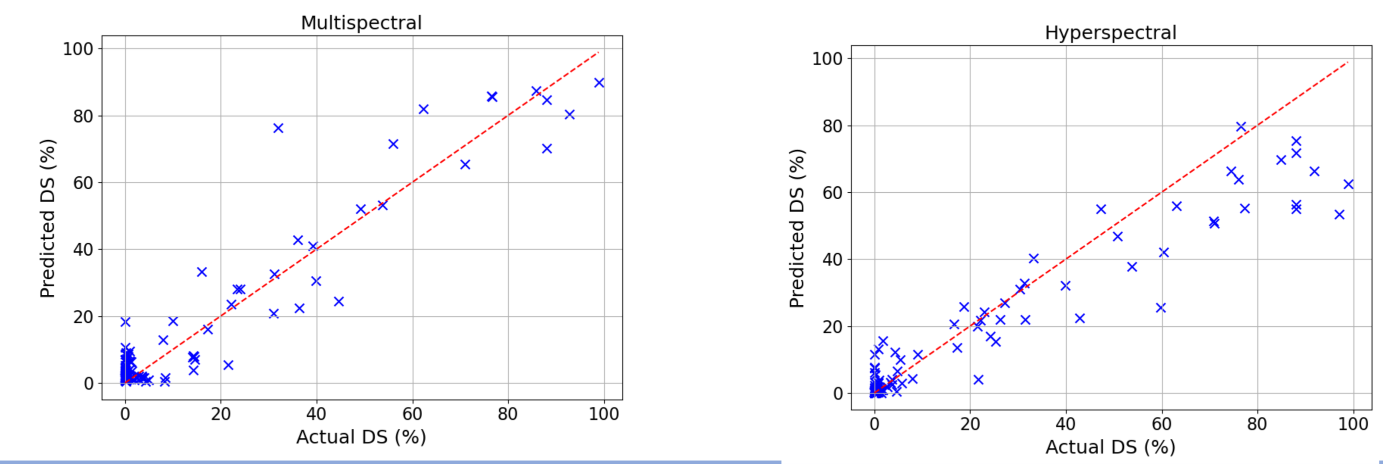


Model Performance Root Yield

Performance of various sensors



Model Performance CLS Disease Severity



Sensor Performances

Harvest Root Yield

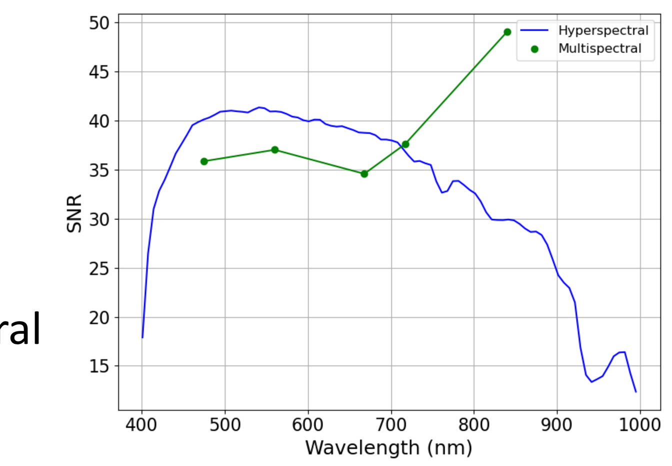
	Multispectral + SfM	Hyperspectral + LiDAR	Multispectral + LiDAR	Hyperspectral + SfM
R^2_{Train} / $RMSE_{Train}$ (kg/m²)	0.88 / 0.46	0.82 / 0.55	0.81 / 0.57	0.88 / 0.46
R^2_{Test} / $RMSE_{Test}$ (kg/m²)	**0.81 / 0.58**	**0.79 / 0.61**	**0.79 / 0.60**	**0.82 / 0.56**

Disease Severity Estimation

	Multispectral	Hyperspectral
R^2_{Train} / $RMSE_{Train}$ (%)	0.94 / 6.02	0.95 / 5.07
R^2_{Test} / $RMSE_{Test}$ (%)	**0.90 / 7.18**	**0.87 / 10.1**

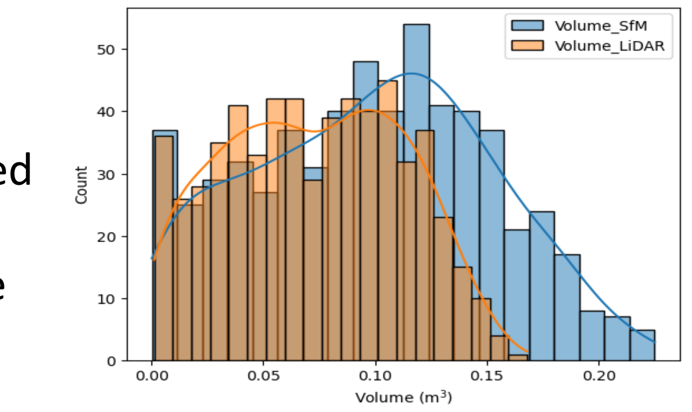
Spectral

- **Yield Prediction**: Hyperspectral performed slightly better than multispectral; spatial resolution and SNR had minimal impact.
- **Disease Estimation**: Multispectral performed better due to better spatial resolution and NIR SNR.



Structural

SfM-derived canopy volume outperformed LiDAR-based volume estimates. This was primarily attributed to LiDAR's penetration, leading to underestimation in dense, low-stature beet canopies.



Conclusion

Multispectral imagery performed well for both yield and disease estimation. Hyperspectral slightly improved yield prediction, but struggled with disease mapping. SfM outperformed LiDAR for structural features.

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.
- Saif, M., Chancia, R., Sharma, P., Murphy, S. P., Pethybridge, S. J. and Aardt, J. van., “Estimation of Cercospora Leaf Spot Disease Severity in Table Beets from UAS Multispectral Images” (2025)

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