Leveraging Hyperspectral Sensing for Nutrient Profiling in Winter Wheat

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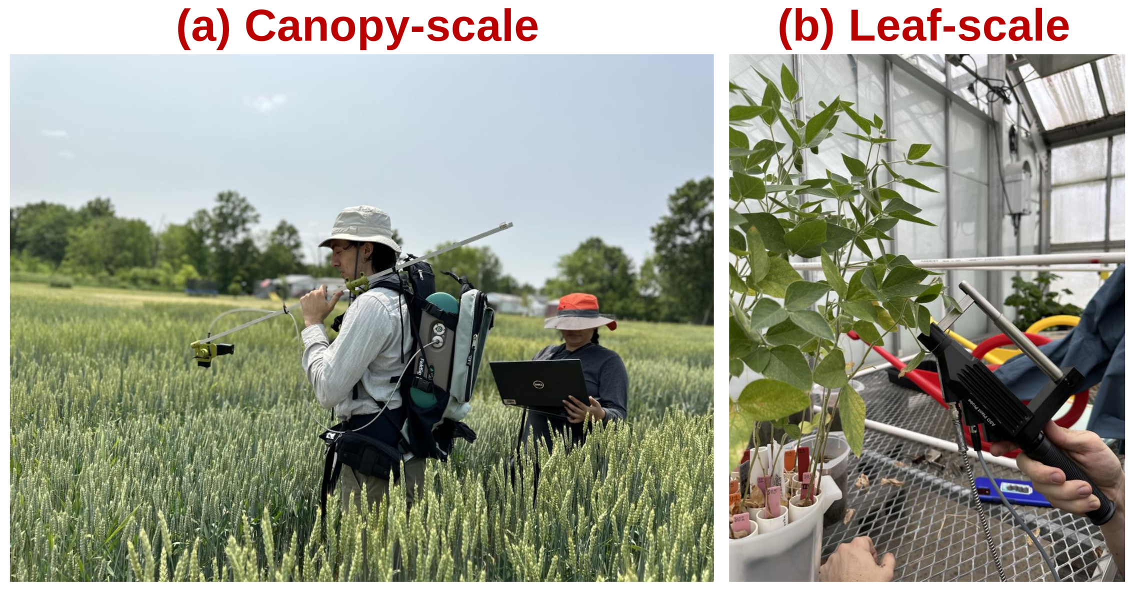
INTRODUCTION

- Rising global population necessitates doubling crop production by 2050 for which enhancing crop breeding efficiency is crucial.
- **Hyperspectral sensing (HS)** is an effective technique, which measures the amount of sunlight reflected by plants [1]. This method explores the structural and functional relationship between plants and electromagnetic energy across the visible, near-infrared, and shortwave infrared ranges.
- To extract interpretable information from the spectra, researchers these days are employing modern machine-learning techniques such as **partial least squares regression (PLSR)**.
- PLSR is an eigen-technique that projects highly correlated predictor variables onto a reduced number of orthogonal latent variables while maximizing the correlation with the response variables [2].
- It is well-suited to vegetation data as (a) HS data contains numerous predictor variables (reflectance at each wavelength) compared to the number of observations, (b) It effectively handles collinearity among predictors, and (c) It addresses high cross-correlations in response data.
- Previous studies have demonstrated a significant correlation between leaf nutrients and HS reflectance, making the measurement of leaf traits a crucial aspect of plant phenotyping [3].
- **Here we focus on breeding trials of 380 winter wheat genotypes grown in field settings. The genotypes were sampled across 3 different growth stages at (1) Leaf-scale (2) Canopy-scale and (3) Airborne platform.**

Fig.1 Field data acquisition.

(a) Canopy-scale (b) Leaf-scale



(c) Airborne platform

Fig.2 Schematization of the methodology.

Data Acquisition

Hyperspectral Data

Research Site: Wooster, OH
Data Collection Dates:
- 2022 (11 May, 3 June, 17 June)
- 2023 (18 May, 26 May and 1 June)

Instrument:
- FieldSpec 4 Standard-Res Spectroradiometer (ASD Inc., Boulder, CO, USA), Cubert Ultris S20 HSI camera.
- Sensors: VNIR (350-1000 nm), SWIR1 (1000-1800 nm), SWIR2 (1800-2500 nm)
- Spectral resolution: 3 nm in VNIR and 10 nm in SWIR

Leaf Sampling:
- In each trip leaf samples were collected from 60 plots with diverse wheat genotypes, using a leaf clip assembly and contact probe for controlled illumination (1500 h halogen bulb).

Tissue Chemistry

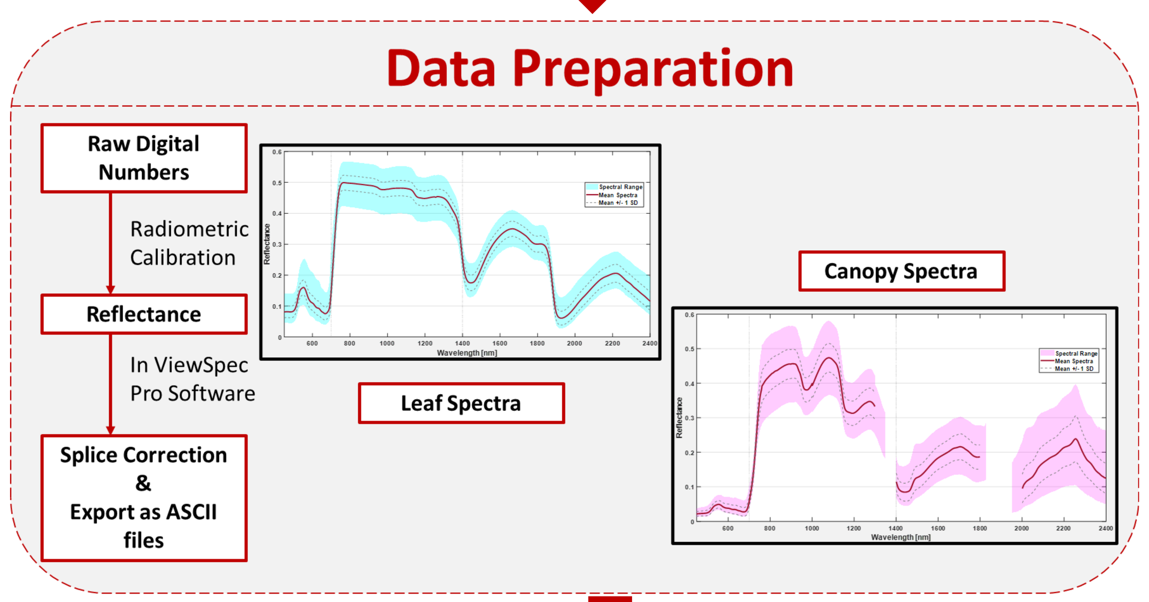
Sample Preparation: Involved drying leaves with forced air circulation at 50°C and weighing them to determine moisture content (MC) based wet basis.

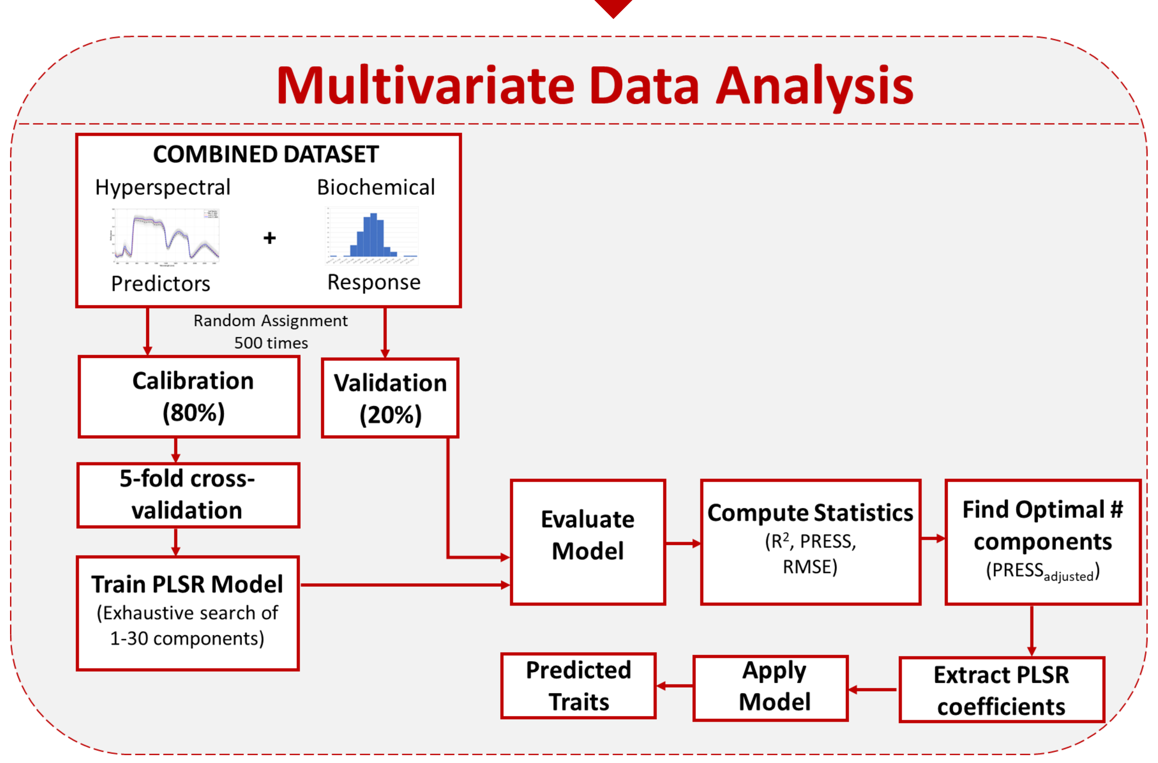
$$MC\ (\%) = \frac{WW - DW}{WW} \times 100$$

WW = Wet weight (g), DW = Dry Weight (g)

Nutrient Analysis*:
- N measured on a percent basis by Duma's method.
- Major suite of elements (P, K, Ca, Mg, S, Al, B, Cu, Fe, Mn, Mo, Na, and Zn) measured in µg/g by nitric acid microwave digestion system.

*Plant tissues analyzed by Service Testing and Research (STAR) Lab, Wooster, Ohio





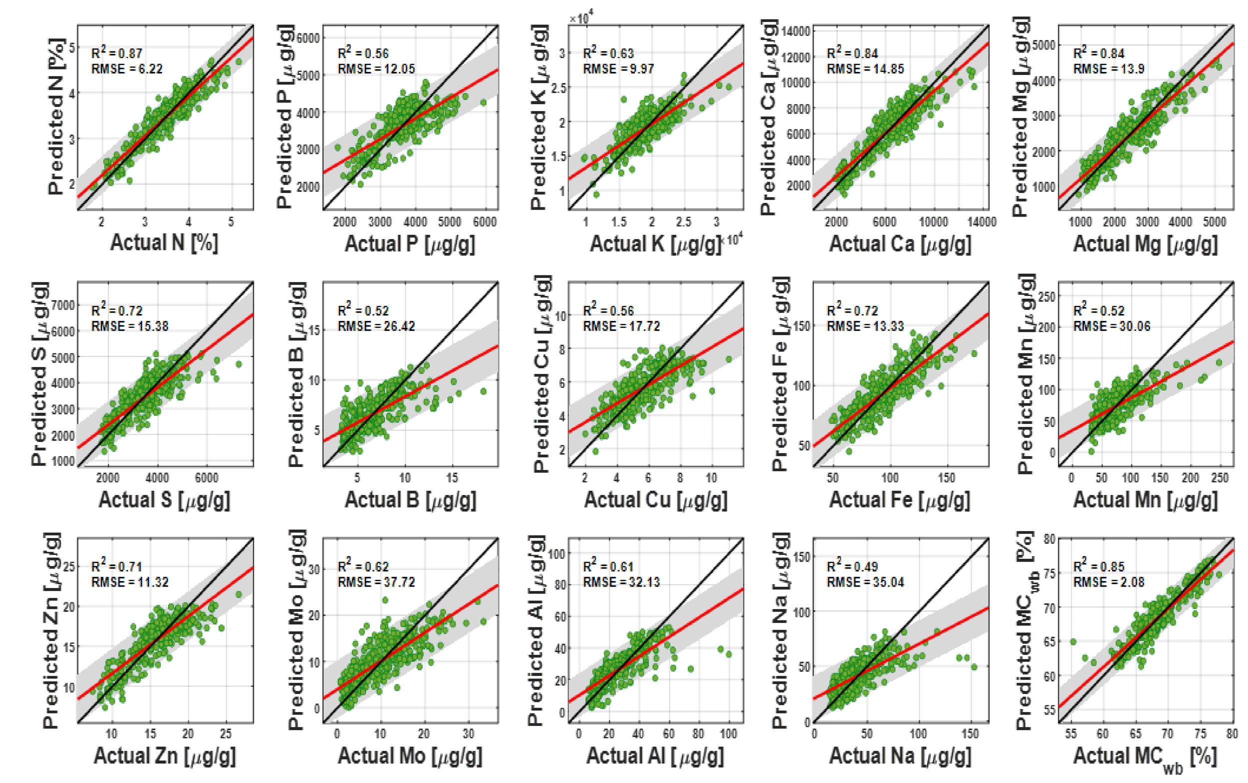
ENGAGEMENT WITH COMMUNITY PARTNERS

- **Local Farmers and Agricultural Cooperatives**: They will assist in collecting on-ground data for expanding the database on which models are built, as well as putting our research into practice and validating its findings, all while reaping the benefits of the latest agricultural innovations.
- **Environmental Organizations**: Their valuable contribution lies in evaluating how optimized farming practices affect the environment, making certain that our research remains in sync with practical environmental concerns.
- **Government Agricultural Agencies:** They will formulate informed policies and support programs for farmers. This collaboration can lead to more efficient resource allocation and improved agricultural practices.
- **Educational Institutions:** They contribute to the progression of precision agriculture and remote sensing knowledge. Additionally, they ensure that the concrete advantages of our research are disseminated to the intended audience through their outreach initiatives.

BENEFITS TO FIELD & PARTNERS

- The predictive models offer a powerful tool for optimizing crop management practices, ensuring that farmers can make data-driven decisions for improved agricultural outcomes.
- Timely and site-specific application of fertilizers will lead to increased crop yields and reduced production/input costs. This not only leads to higher profitability but also strengthens our local food security and economic resilience.
- Efficient nutrient management is central to our approach, reducing the environmental impact of agriculture. With minimized nutrient runoff, our sustainable farming practices protect our water sources, ecosystems, and public health.
- Precision agriculture can help provide enough food for the growing world population's needs.

Fig. 3 Response plots illustrating a comparison between predicted values and laboratory chemical measurements.



CONCLUSIONS

- Leaf and canopy hyperspectral reflectance combined with ML techniques effectively estimates nutrient concentrations in wheat, improving breeding efficiency.
- Accuracy and information retrieved vary based on the target nutrient and the algorithm used.

BIBLIOGRAPHY

[1] Araus, J. L., & Cairns, J. E. (2014). Field high-throughput phenotyping: The new crop breeding frontier. Trends in Plant Science, 19(1), 52–61.

[2] Wold, S., Sjöström, M., & Eriksson, L. (2001). PLS-regression: A basic tool of chemometrics. Chemometrics and Intelligent Laboratory Systems, 58(2), 109–130.

[3] Burnett, A. C., Anderson, J., Davidson, K. J., Ely, K. S., Lamour, J., Li, Q., Morrison, B. D., Yang, D., Rogers, A., & Serbin, S. P. (2021). A best-practice guide to predicting plant traits from leaf-level hyperspectral data using partial least squares regression. Journal of Experimental Botany, 72(18), 6175–6189.

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