

Quantum-Enhanced Multispectral Vegetation Intelligence for Precision Agriculture

Dhanya Boyapally¹, Noel Aloysius^{2,3,4}

¹Electrical Engineering and Computer Science, University of Missouri

²Chemical and Biomedical Engineering, University of Missouri, ³School of Natural Resources, ⁴Missouri Water Center, University of Missouri

INTRODUCTION

UAV multispectral imaging enables detailed crop monitoring, but conventional vegetation indices and classical machine learning may miss complex plant-level stress patterns. Quantum AgroAgent integrates multispectral, thermal, and environmental data with quantum-classical computing to investigate plant-stress classification and resource-constrained intervention. Using 8-qubit quantum kernel learning and QAOA, the study evaluates the potential and current limitations of quantum methods for precision agriculture.

RESEARCH QUESTIONS

RQ1 - Multimodal Crop Intelligence

To what extent can spatiotemporal fusion of multispectral, thermal, physiological, and environmental observations reveal early and persistent plant-stress signatures across heterogeneous field conditions?

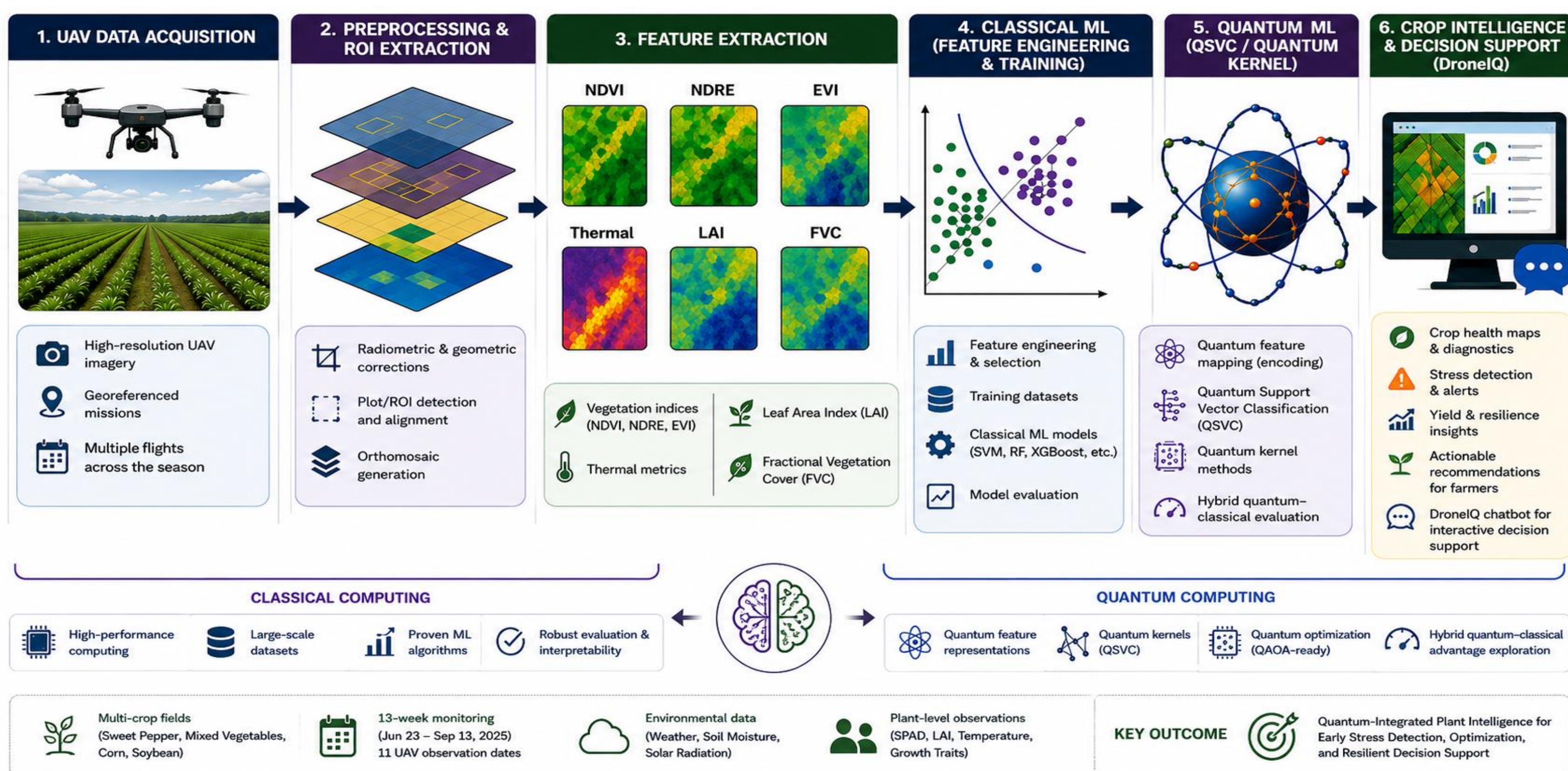
RQ2 - Quantum-Classical Learning

Under what data, feature-space, and circuit conditions can quantum kernel learning provide complementary or competitive representations to classical learning for nonlinear plant-stress classification?

RQ3 - Quantum Decision Intelligence

Can quantum optimization enable effective resource-constrained intervention prioritization by translating plant-level stress intelligence into spatially targeted agricultural decisions?

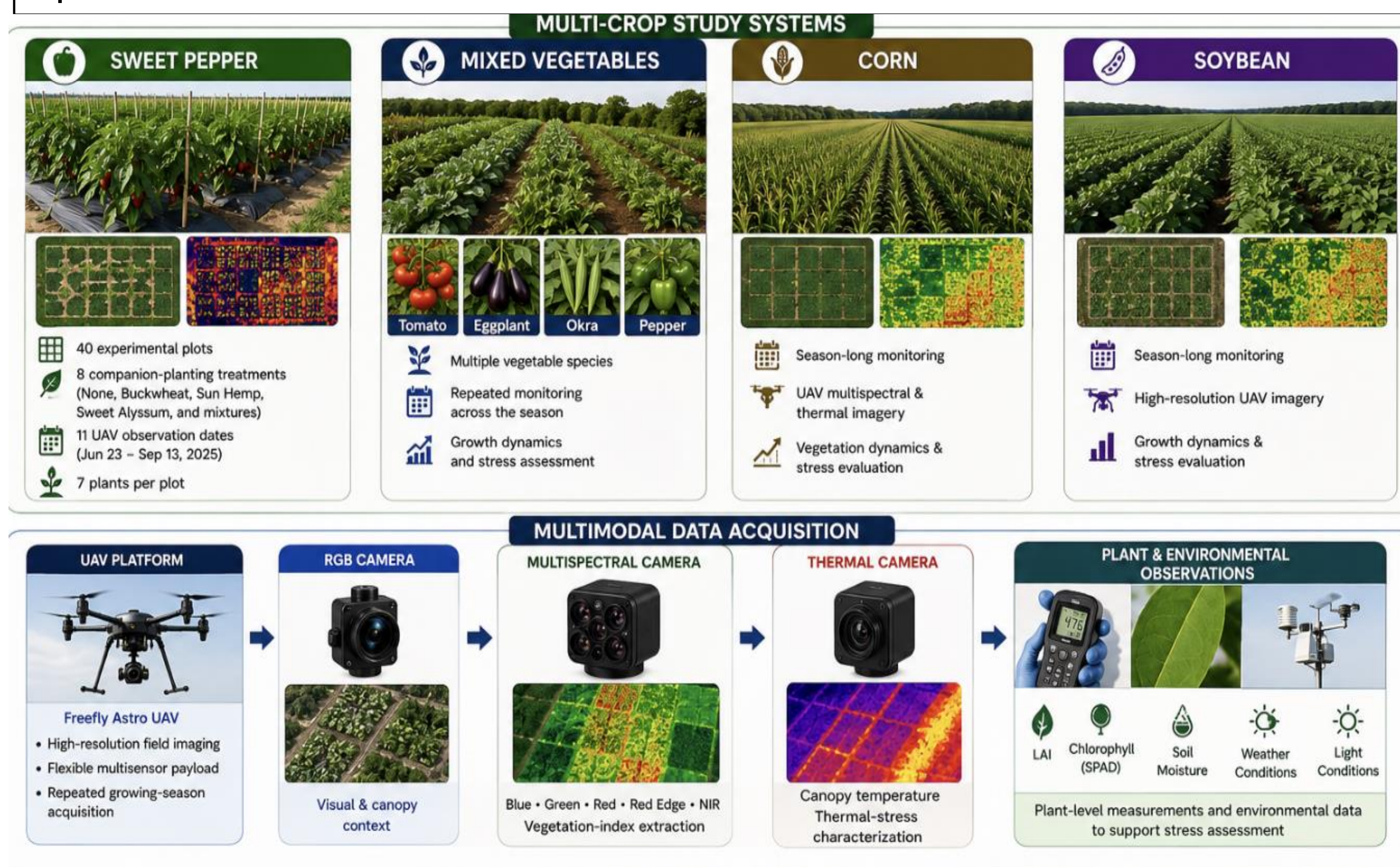
METHODOLOGY



UAV-derived multispectral, thermal, plant-level, and environmental features are integrated within a unified quantum-classical pipeline. Geospatial features are processed for classical and quantum-kernel stress classification, while model outputs support plant-level crop intelligence and targeted decision-making.

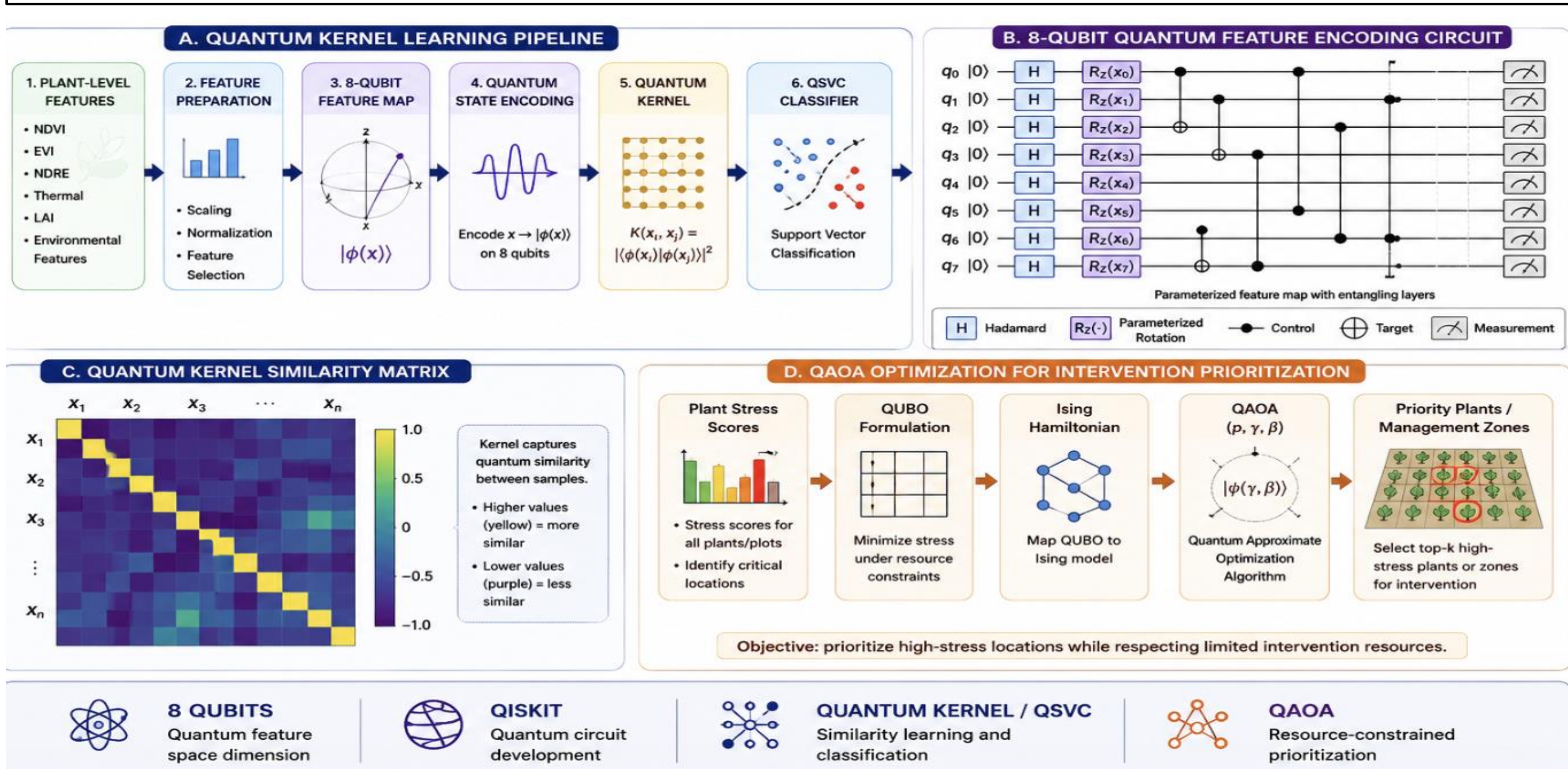
STUDY SYSTEMS & MULTIMODAL DATA ACQUISITION

A 13-week multi-crop study across Mid-Missouri integrated repeated UAV observations with RGB, multispectral, and thermal sensing across sweet pepper, mixed vegetables, corn, and soybean. Plant-level measurements and environmental observations complemented aerial data to characterize crop growth, canopy condition, and stress from plant to field scales.

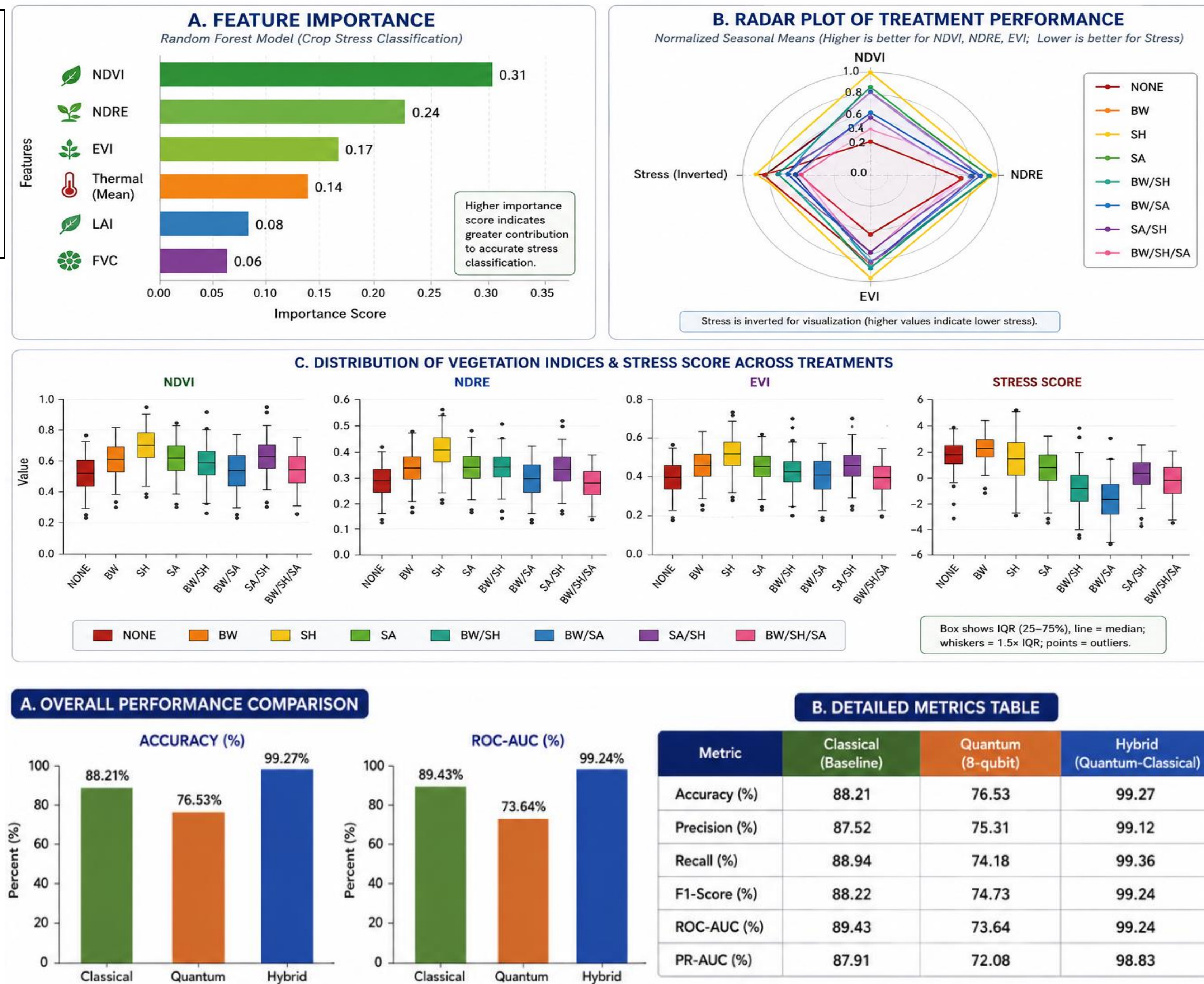


QUANTUM COMPUTING FRAMEWORK

Quantum kernel learning was investigated using an 8-qubit quantum circuit to capture nonlinear relationships in plant-level geospatial features. Quantum-kernel classification was benchmarked against classical and hybrid approaches, while QAOA was explored to prioritize high-stress plants or management zones under limited intervention resources.



RESULTS



Quantum experiments used an 8-qubit feature-encoding circuit implemented with Qiskit and executed using IBM Quantum resources. The ibm_miami and ibm_pittsburgh backends supported quantum-circuit execution, kernel evaluation, and validation of the quantum-classical workflow.

CONCLUSION

This research integrates UAV geospatial sensing with classical and quantum computing for plant-level crop intelligence. The framework enables stress characterization, evaluates quantum-kernel learning against classical approaches, and explores QAOA for resource-constrained intervention prioritization, providing a foundation for targeted and data-driven precision agriculture.

ACKNOWLEDGEMENTS

The authors acknowledge the Mizzou Quantum Innovation Center, University of Missouri, for support through the QIC Internship Program and sincerely thank all collaborators, researchers, and team members who provided data, field observations, technical assistance, computational resources, and research support throughout this work.



Quantum Innovation Center
University of Missouri



Engineering

