National Aeronautics and Space Administration

FY23 Strategic University Research Partnership (SURP)

Building the foundations of a global plant disease surveillance system: Detecting plant-microbe interactions through integrated proximal and remote imaging spectroscopy

Principal Investigator: Ryan Pavlick (382)**; Co-Investigators:** Katie Gold (Cornell University), Fernando Romero Galvan (Cornell University)

Objectives: The overall goal of this work is to enhance our capacity to detect and monitor the impacts of pathogenic plant-microbe interactions on plant health through integrated proximal and remote imaging spectroscopy. We are developing a scalable, remote sensing framework for detecting plant-pathogen interactions using an economically important specialty crop, grapevine (Vitis spp.) as a model system for this proof-of-concept work.

Background: Plant disease is one of the greatest threats to the environmental and financial sustainability of crop production worldwide. Even with the remarkable advances of 21st century agriculture, plant disease results in 15-30% global crop loss, equating to losses upwards of $220 billion annually. To combat these losses, United States farmers apply over one billion tons of pesticides annually to prevent pest damage and disease at great financial and environmental cost. Plant disease changes how solar radiation interacts with leaves, canopy, and plant energy balance, which can be sensed with proximal and remote sensing. However, plant disease remote sensing remains underdeveloped despite its potential to revolutionize surveillance and intervention through low cost and high accuracy decision support. Integrated proximal and remote sensing offers the potential to revolutionize plant disease detection and management with lower cost, rapid, non-invasive, non-destructive, and higher accuracy detection and diagnosis, yet has been sorely underexplored. This project is relevant to JPL's strategic focus areas in biodiversity and applied science. It will put the JPL-led SBG mission in a better position to make an important contribution to a global disease surveillance and monitoring system for the grape and broader agricultural community.

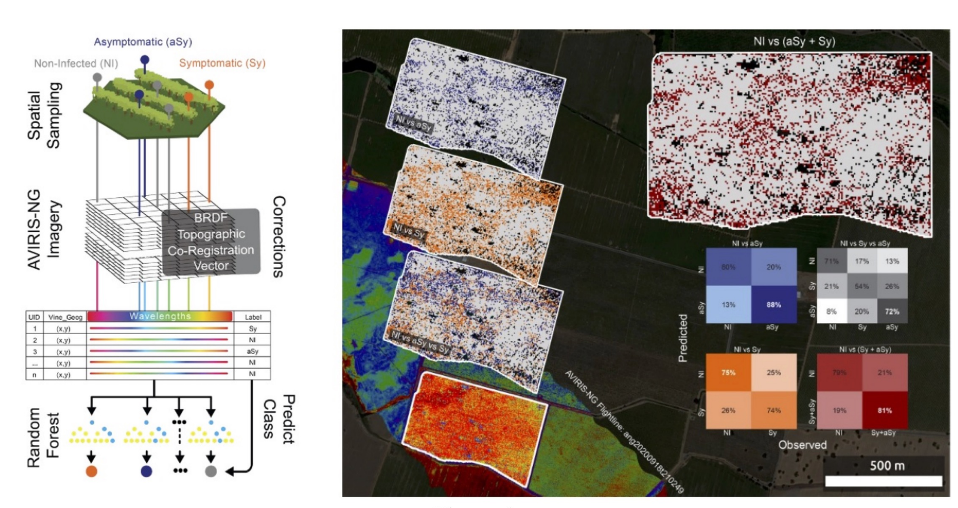

Figure 1.

We developed and validated an empirical machine learning model that could distinguish asymptomatic and symptomatic grapevines infected with Grapevine Leaf Roll Virus from healthy vines using airborne imaging spectroscopy (Romero-Galvan, Pavlick, et al 2023).

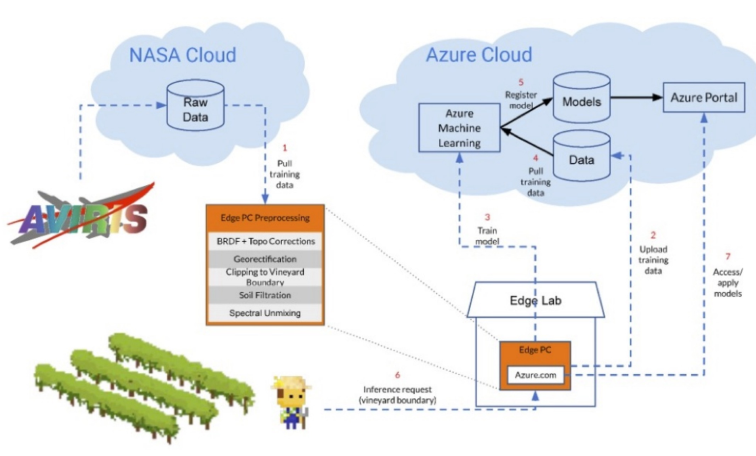

Figure 2.

We published a paper demonstrating a cloud-based platform for deploying plant-disease detection models in a way that would be useful for food growers while preserving their privacy.

Significance/Benefits to JPL and NASA: The use of remote sensing to advance plant disease detection represents an innovative opportunity to further the use of Earth system science research to benefit society and inform decision making while advancing applications-focused research in precision agriculture, one of the priorities outlined for Surface Biology and Geology in the 2018 Earth Science NASA Decadal Survey and strategic priorities. The ability to non-destructively sense plant disease would greatly benefit modern agriculture and food security. Early intervention is key to successful disease mitigation. Farmers can apply systemic fungicides to stop disease before it spirals out of control, but these are only effective when applied early during the infection process. Worldwide, plant disease research and early intervention efforts are often constrained by a lack of local expertise to devote to prevention, a lack of resources to devote to monitoring and/or remediation, and a lack of qualified personnel to allocate to both these tasks. The use of remote sensing to advance plant disease research represents an opportunity to avoid these challenges and make a difference in the lives of farmers worldwide while advancing applications focused research on precision agriculture, one of the goals outlined in the NASA Earth Science Decadal Survey.

Approach and Results: - In September 2020, our team used external funding to conduct an AVIRIS-NG imaging spectroscopy campaign over 37,317 acres of California vineyards.

- We collaborated with grape growers near Lodi, California to validate the data by scouting vineyards for Grapevine Leafroll Virus Complex 3 (GLRV) on a vine-by-vine basis at several vineyards.
- We developed the "QScout" pipeline and tool suite to standardize the ground date for GIS-friendly analysis (Evans, Romero Galvan, et al 2022).
- Mined historical AVIRIS data over California, totaling 883,772 acres.
- Developed and tested a workflow to detect GLRV in Cabernet Sauvignon grapes using AVIRIS-NG spectral imagery.
- Our best model achieved 87% accuracy and 0.73 kappa score for distinguishing non-infected vs. asymptomatic and 85% accuracy and 0.71 kappa score for non-infected vs. symptomatic grapevines (Romero Galvan, Pavlick, et al 2023).
- We conducted a field campaign in September 2022 at a Santa Barbara vineyard, collecting geotagged data through human scouting, a ground-based robot, and tissue samples for lab analysis to validate the algorithm and develop a new deep learning model.
- We plan to submit a manuscript on this new model by the end of CY23 (Liu et al 2023)
- Published a methods paper describing a prototype cloud-based architecture for crop disease detection models at scale in a way that is useful for end users like grape growers (Rumbaiza, Romero Galvan, et al 2023)
- We are planning a follow-up manuscript in CY24, detailing interviews with California grape growers to understand their needs and challenges in the digital agriculture space.
- We leveraged the outputs from this SURP project to develop a proposal to NASA for a sustained multi-year field campaign and that would produce a novel remote-sensing capability that will reveal basic pathomechanisms across many crop type and inform crop management and agricultural policy.

Figure 3.

We completed robotic and manual scouting campaign at a California vineyard coincident with airborne imaging from AVIRIS-NG during the SBG SHIFT campaign.

Publications:

[1] Romero Galvan, F., Pavlick, R., Sousa, D., Starr, C., Bolton, S., Marti, M., Dokoozlian, N., and Gold, K.M., 2023. "Scalable early detection of grapevine virus infection with airborne imaging spectroscopy". Phytopathology. 2023. [2] Rumbambiza, G.*, Romero Galvan, F.*, Pavlick, R., Weatherspoon, H., Gold, K.M., 2023. "Towards Cloud- Native, Machine Learning Based Detection of Crop Disease with Imaging Spectroscopy". JGR Biogeoscience. 2023. [3] Evans, J., Romero Galvan, F., Cadle-Davidson, L., and Gold, K.M. 2022. "QScout: an open source, remote sensing tool suite for plant disease scouting and decision making". The Plant Phenome Journal. [4] Liu, E., Kanaley, K., Romero Galvan, F.E., Combs, D., Gold, K. M., Pavlick, R.P., and Jiang, Y. 2023. Autonomous Detection and Severity Estimation of Grapevine Leafroll Disease in the Vineyard. In 2023 ASABE Annual International Meeting American Society of Agricultural and Biological Engineers. https://elibrary-asabe- org.proxy.library.cornell.edu/abstract.asp?aid=542143.

PI/Task Mgr. Contact Information:

Ryan Pavlick, rpavlick@jpl.nasa.gov

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

Clearance Number: CL#32-1199
Poster Number: RPC#191