Pacific Northwest NATIONAL LABORATORY

PNNL-30772

Monitoring of Terrestrial Aquatic Ecosystems Through analysis of time-Variant Hyperspectral Imagery

December 2020

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U.S. DEPARTMENT OF ENERGY

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◆ Project Summary

Time-variant spectral analysis of plants can classify stress-based perturbations (e.g., dry soil or increased salination) and quantify mechanistic attributes associated with plant photosynthesis, respiration, hormone function, and plant morphology. This project will investigate the utility of hyperspectral cameras for detecting and monitoring these perturbations.

Introduction and Project Description

Spectral analysis has been used widely in in chemistry, biology, and physics for almost a century. The application of these methods to monitor ecological system, however, has only been recently explored in the last 25-30 years with spectral analysis methods being primarily statistical in nature.

This project will leverage state-of-the-art hyperspectral cameras and a combination of supervised and unsupervised learning methods to classify plants that have been subjected to drought or saline-based stresses.

Results and Accomplishments

Contemporary hyperspectral plant analysis relies exclusively on spectral magnitude (i.e., absorbance over wave number) and large temporal differential analysis.

We extend current approaches by leveraging Kramers-Kronig relation to reconstruct the original phase and time-domain signal of a changing system. This time-domain analysis enables reverse-engineering of the dynamics underlying the experimental system being interrogating.

In our experiments, we divided 15 plants (Setaria viridis) into three groups: control, drought, and saline. These plants were grown for 4 weeks with identical conditions needed for healthy development. After this development period, saltwater and drought perturbations were introduced to the saline and drought group respectively. These treatments were continued for 2 weeks.

Throughout the experiments, hyperspectral images were taken of each plant, twice daily: at pre-dawn stages and noon. This longitudinal data was then processed with our analytic framework that applied unsupervised, supervised, and Kramers-Kronig methods.

Figure 1 shows the results of our supervised machine learning method based on validation data. This method can clearly separate plants based on perturbations. Numbers indicate the day after treatments began; for example., 3 indicates 3 days of treatments, 8 indicates 8 days of treatments.

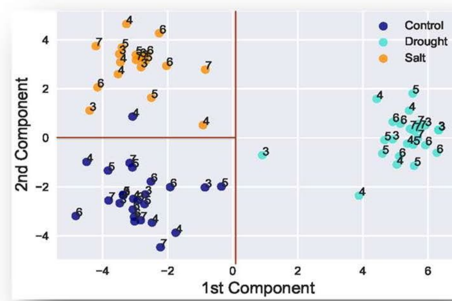

Figure 1: Supervised learning results for plants show clear separation of validation data.

Based on our classification results, we identified the dominant features used by the classifier and visualized these using weighted feature weights. Figure 2 shows (in absorbance vs. wavelength) the clear separation of the different plant groups based on decreased absorptivity in the 1.4-1.6 micrometer range. The loss of absorption in drought corresponds to reduced amounts of sugar and cellulous.

This work was funded for one year, and all goals were met.

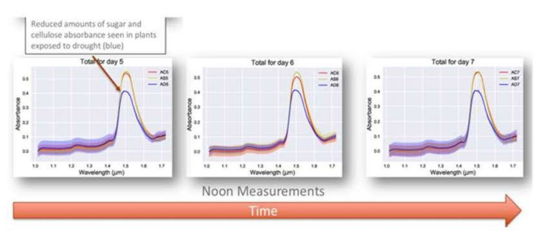

Figure 2: analysis of absorptivity spectra for plants at different days of the study.

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