Plant spies: Using foliar messages to remotely detect tunneling

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Enabling remote measurement of key vegetation properties

Motivation: Exploit the biophysical links between optical, thermal, and active sensing systems to quantify vegetation states, properties, dynamics, surface targets, and change from near-surface to regional scales

Serbin & Townsend, (2020)
Spectroscopic detection of plant traits

Structural traits

Physiological traits

Biochemical traits
Fingerprints of stress in vegetation

Physiological Fingerprint

- (a)
- (b)
- (c)
- (d)
- (e)

Legend:
- red: temperature
- blue: health
- green: growth rate
- pink: stress
Objectives:

- Grow plants and simulate tunneling
- Measure plant physiological, biochemical, and remote sensing properties
- Develop algorithms to link physiological responses with remote sensing signatures
Simulated tunneling by removing 50% of rooting volume
Lower stomatal conductance with tunneling

* 2019-09-04  p = 4.588e-06
* 2019-09-05  p = 0.0009838
* 2019-09-07  p = 1.399e-06
* 2019-09-09  p = 0.004208
* 2019-09-12  p = 0.01713
* 2019-09-19  p = 0.001448

Blue: Control
Red: Tunneled
Response of canopy reflectance to tunneling

Blue: Control
Red: Tunneled

Wavelength (nm)

Reflectance (%)

2019-09-04

2019-10-15
Tunneling significantly changed reflectance

\[
\frac{688nm + 710nm}{697nm^2}
\]
Machine-learning approach to detect tunneling

Out-of-sample Validation data
The most robust physiological signal associated with tunneling was a reduction in stomatal conductance (plant water relations).

Remote sensing data showed a range of responses, but strong links with changes in plant water status.

Even with a significant decline in leaf conductance, canopy transpiration was largely maintained, and we didn’t observe a strong thermal response (with TIR imagery).

Despite large variation in functional properties across time and leaf age, spectroscopy showed strong predictive capacity for key physiological changes and an ability to directly detect tunneling stress signatures through reflectance alone.
Impacts of iron limitation and zinc excess on spectra

Zinc Excess Sorghum
21 Days after Treatment

Dynamic Water Stress Index

Reflectance (%)

Wavelength (nm)

Relative difference (%)

Iron limitation

Zinc excess

Control
Treatment
Relative Difference

500 750 1000 1500 2000

2 4 7 14 21

Control
FeLim ZnLim
FeLim ZnLim
FeLim ZnLim
FeLim ZnLim
FeLim ZnLim

2 0 0.2 0.4 0.6 0.8 1.0

0 5 10 15 20 30 40
Physiological traits for drought detection can be predicted with reflectance spectroscopy.

We have developed a series of models across a range of structural, physiological, and biochemical traits.

Burnett et al., Plant Cell & Environment (in press)
Sink manipulation increased plant vigor while drought stress increased canopy temperatures in zucchini plants.

More vigorous plants w/ sink manipulation

"Warmer" plants w/ drought

Burnett et al., Plant Cell & Environment (in press)
BNL facilities for controlled plant manipulations

Glasshouse facility

Fenced field space

BNL forests

Controlled manipulation Pad