Drone-based physiological index reveals long-term acclimation and drought stress responses in trees

Petra D'Odorico

Ecosystem Ecology group
Forest Dynamics

Evolutionary Genetics group
Biodiversity and Conservation Biology

14/02/2022 Pfynwald Workshop, WSL Birmensdorf

Plant, Cell & Environment

ORIGINAL ARTICLE | Open Access

Drone-based physiological index reveals long-term acclimation and drought stress responses in trees

Petra D'Odorico, Leonie Schönbeck, Valentina Vitali, Katrin Meusburger, Marcus Schaub, Christian Ginzler, Roman Zweifel, Vera Marjorie Elauria Velasco, Jonas Gisler, Arthur Gessler, Ingo Ensminger,

First published: 31 August 2021 | https://doi.org/10.1111/pce.14177

Lib4RI Services

Arthur Gessler and Ingo Ensminger should be considered joint senior authors.

Funding information: Swiss National Science Foundation (SNSF), Grant/Award Numbers: CRSK-3_190802, 310030_189109; National Science and Engineering Council (NSERC), Grant/Award Number: RGPIN-2020-06928

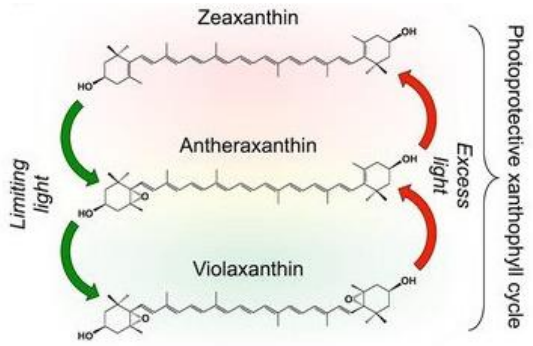
1. Test a drone-based remote sensing approach to capture and **scale** tree **invisible** physiological adjustments in response to drought.

2. understand the role of tree acclimation (and thus **past** environmental conditions) in defining **current** tree drought stress responses.

Mechanistic basis

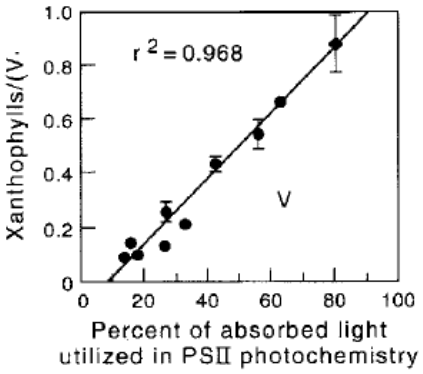
During drought periods light cannot be used for photosynthesis and needs to be safely dissipated via pigments interconversions.

Xanthophyll pigments interconversion safely dissipates excess light



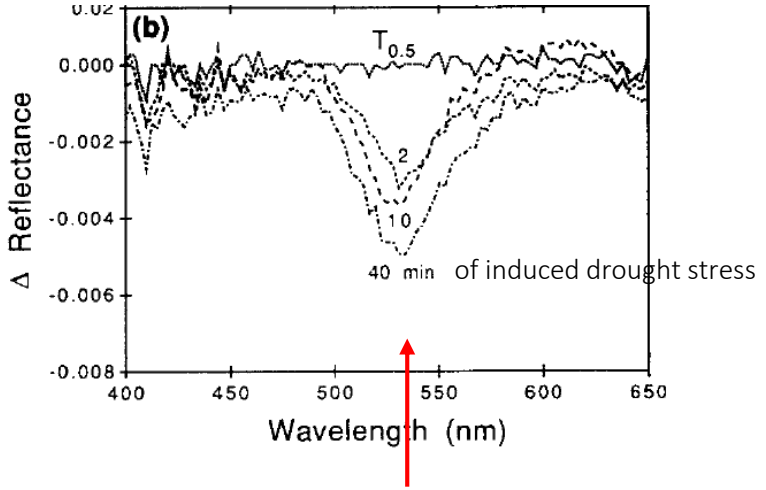
Pigment interconversion correlates with light absorbed for photosynthesis

Pigments interconversion



Light used in photosynthesis

Pigment interconversion changes light reflected by leaves



of induced drought stress

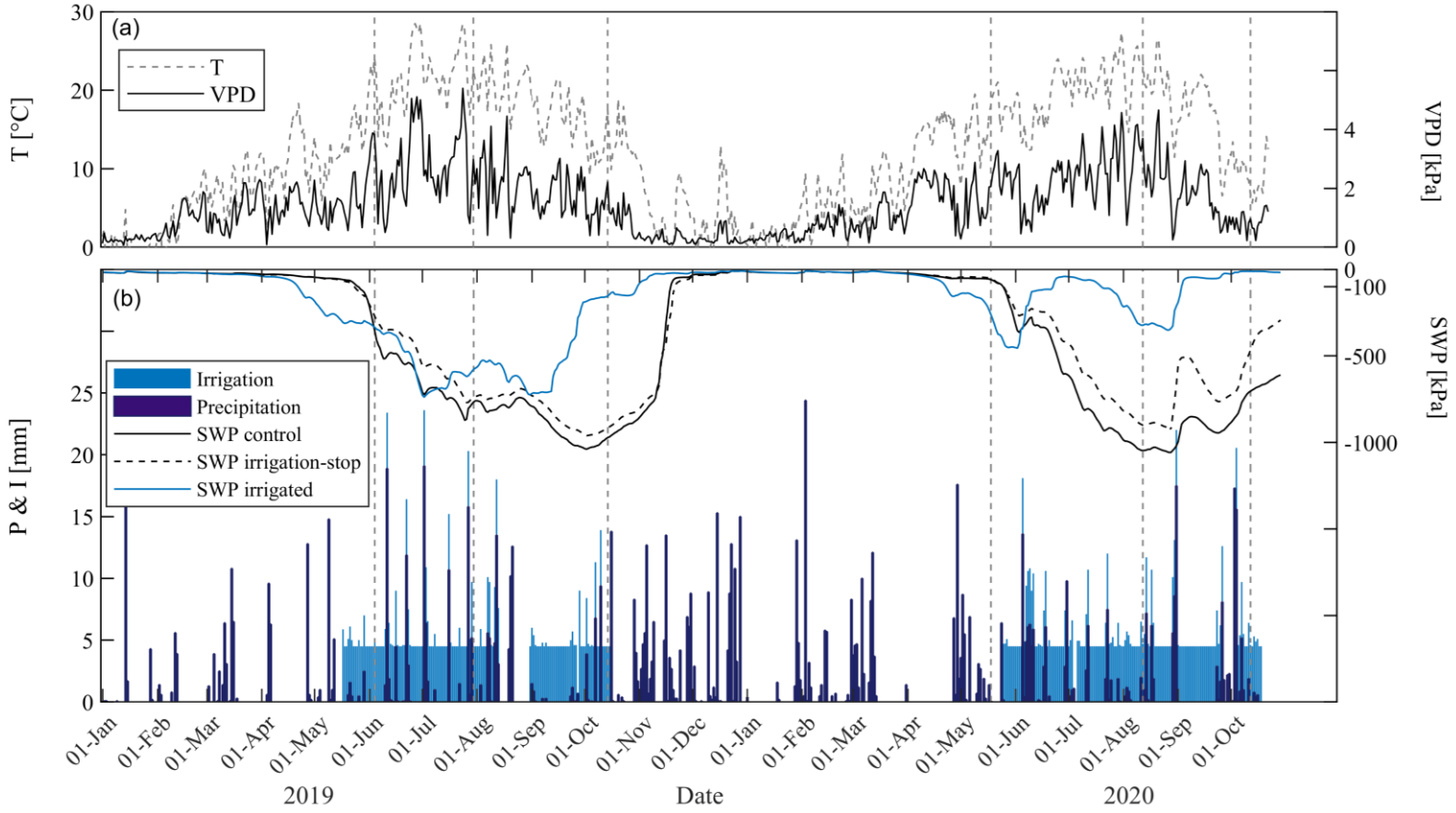
xanthophyll-induced reflectance change at 531 nm

Photochemical Reflectance Index $PRI = (R_{531} - R_{REF}) / (R_{531} + R_{REF})$

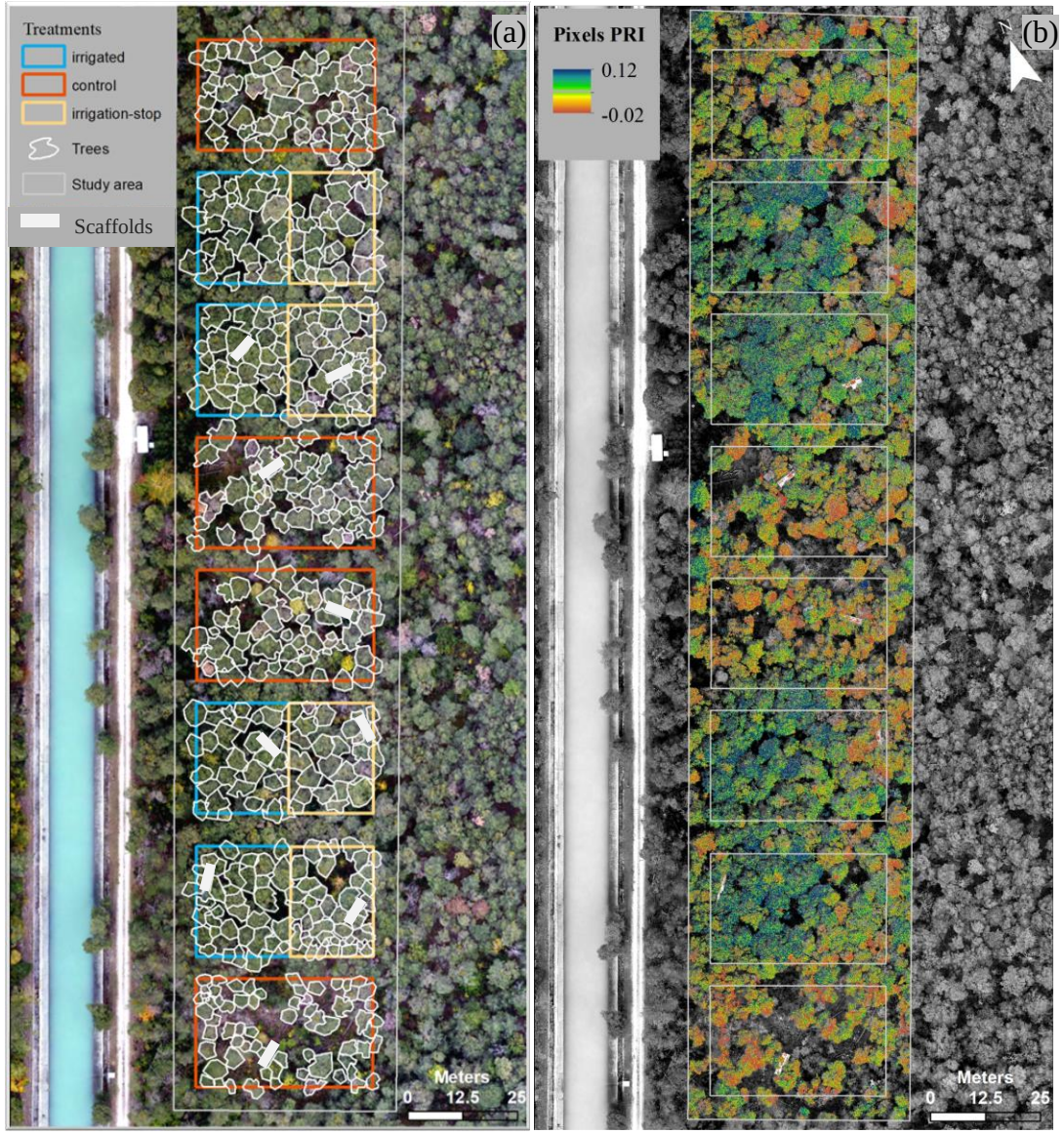
Figures were modified from Demmig-Adams et al. 1995, 2020 and Gamon, Peñuelas, & Field, 1992.

Experimental design

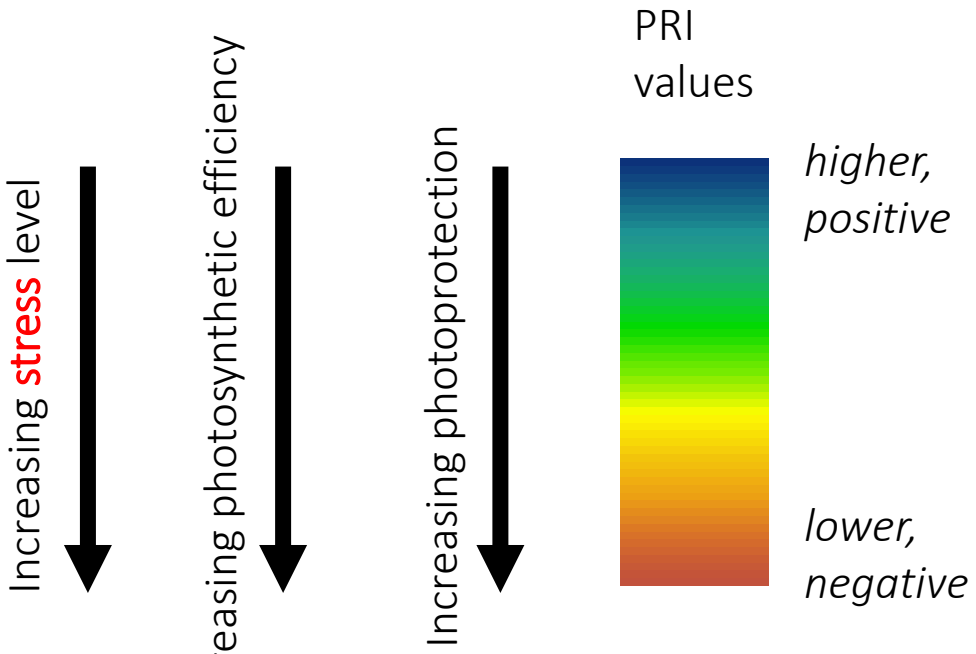
Field campaigns for two growing seasons (2019 & 2020) in spring, summer and autumn



The Photochemical Reflectance Index

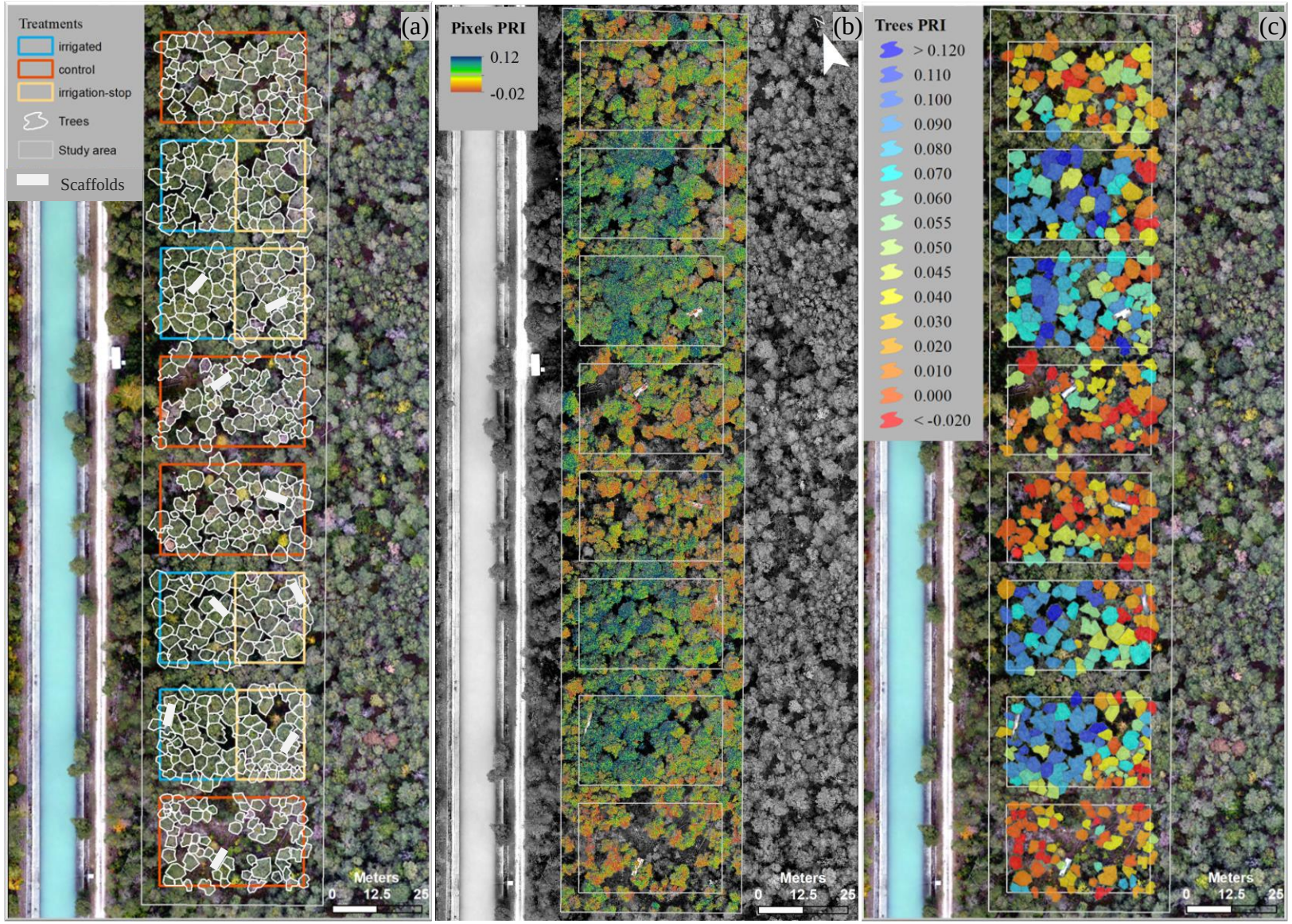


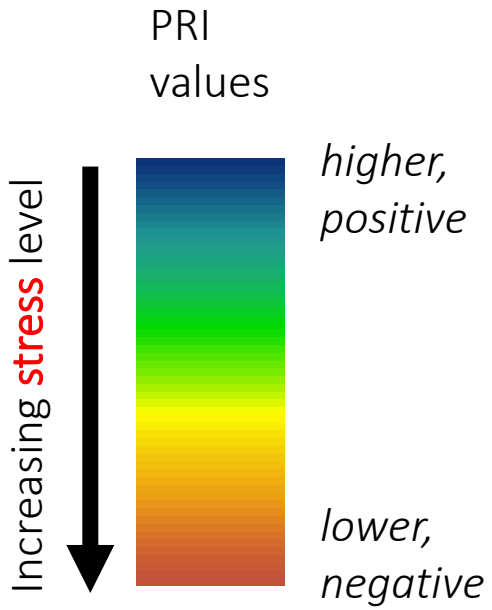
1 pixel ≈ 3 cm



D'Odorico et al. PCE 2021

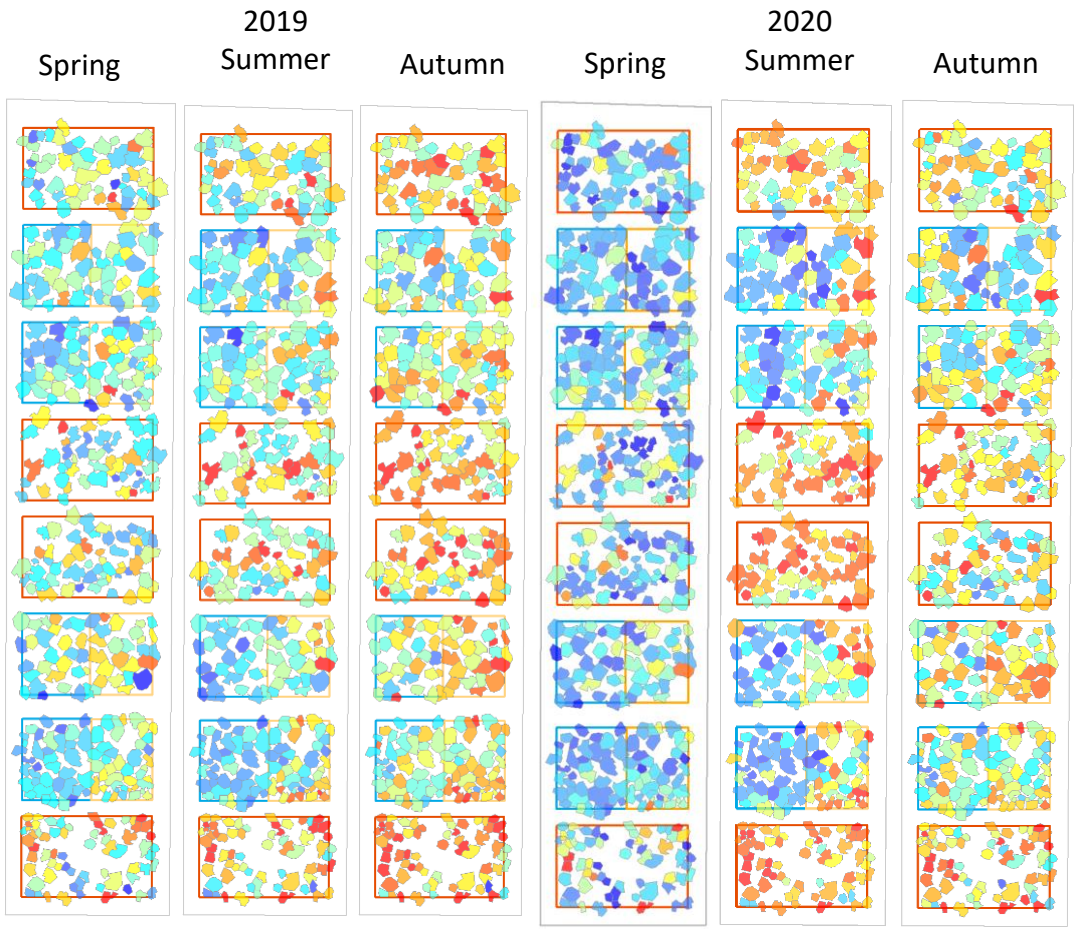
The Photochemical Reflectance Index



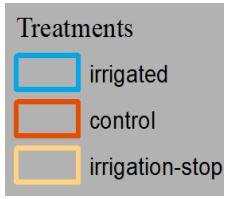


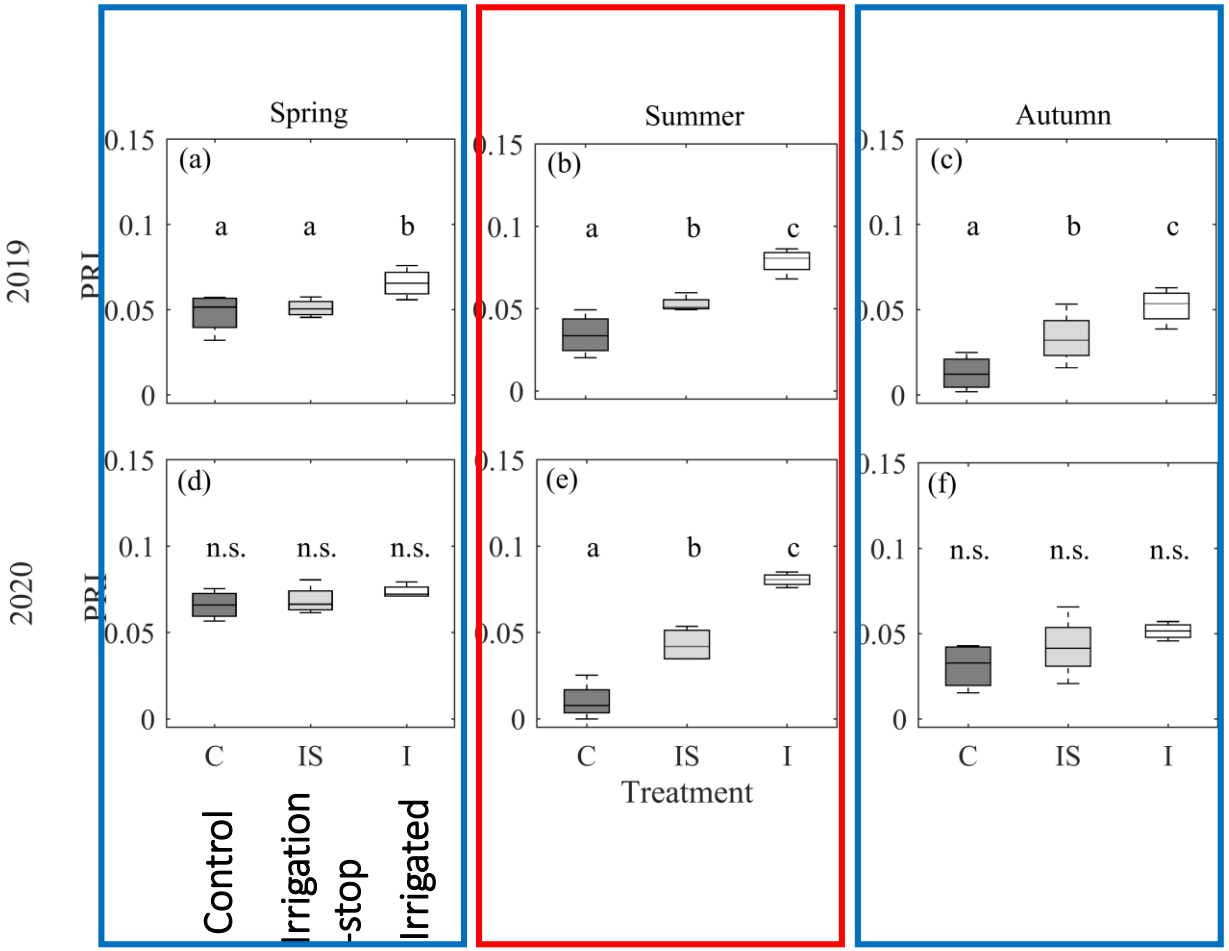
D'Odorico et al. PCE 2021

Treatment differences



increasing stress response

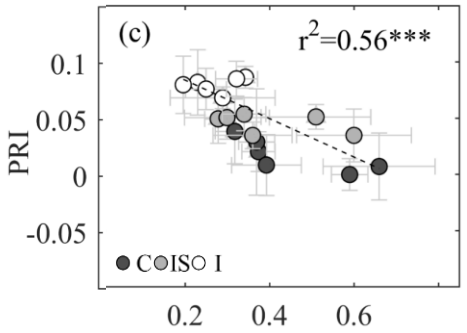


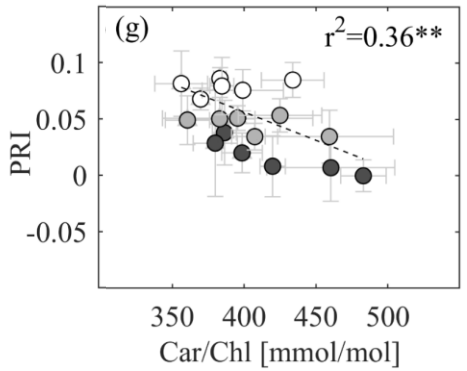


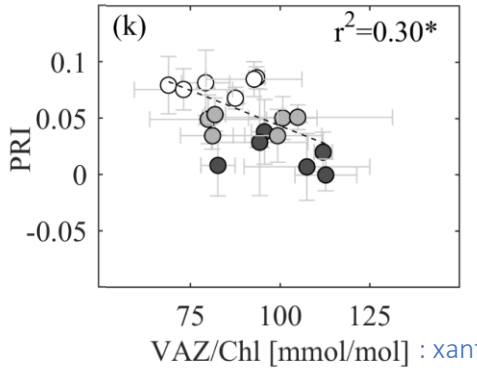
D'Odorico et al. PCE 2021

Physiology validation

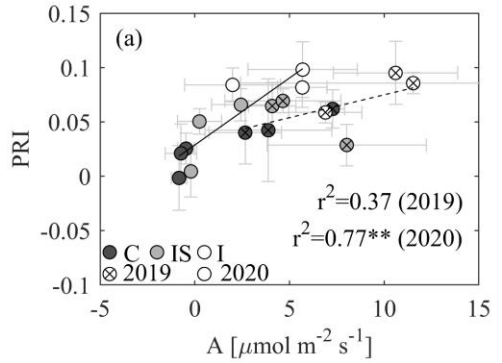
Pigments

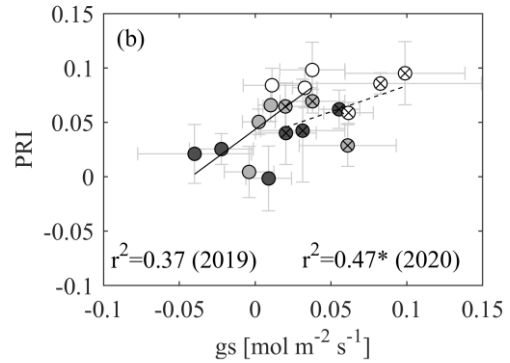


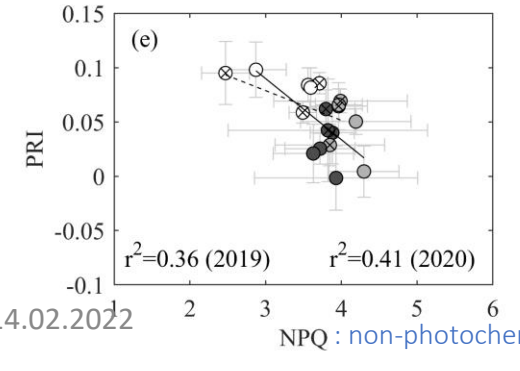


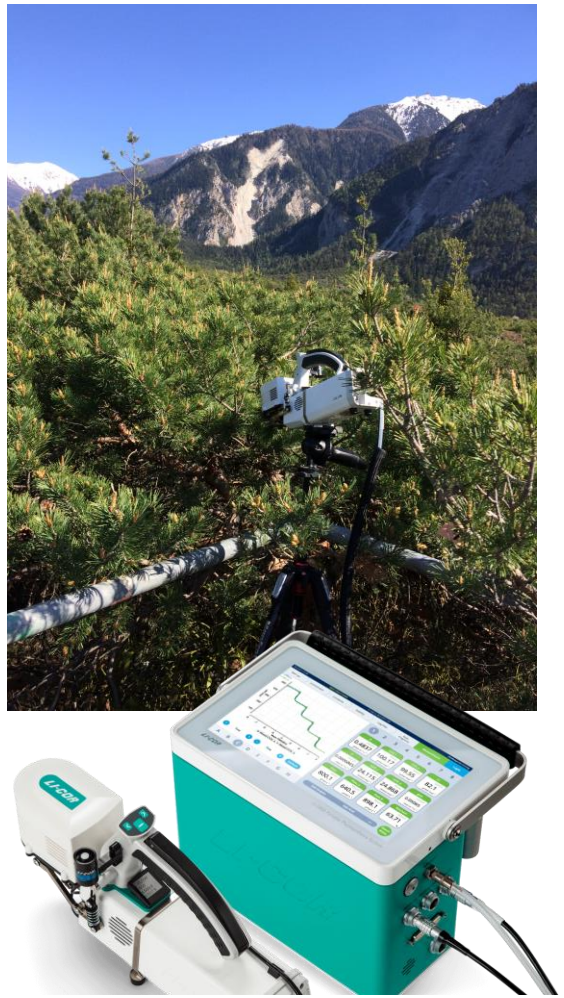


Gas exchange & fluorescence









© LI-COR Biosciences

D'Odorico et al. PCE 2021

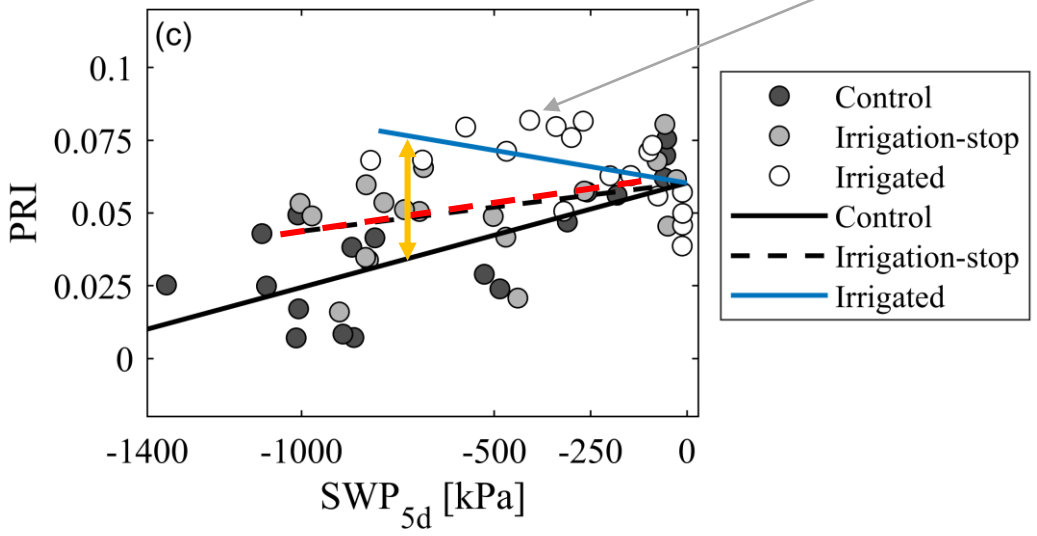
Response drivers

1. Soil and atmospheric drought are respectively main seasonal and diurnal drivers.
2. Past environmental conditions, and acclimation to it, influence current response.
3. Differences in traits acclimation rates influence response.

Drone-based stress index

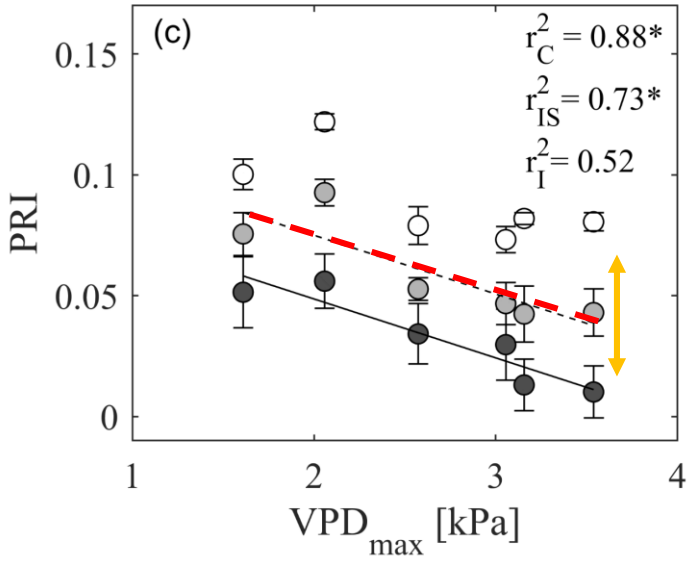
Seasonal timescales

each individual point represents an average plot value on a specific day



Soil water availability

Diurnal timescales



Atmospheric water availability

D'Odorico et al. PCE 2021

Conclusions & Next steps

- Drone-based remote sensing is effective tool to monitor **physiological adjustments** in response to current environmental stress, but also highlights slow transitions resulting from **acclimation** to prolonged pressures.

- More holistic approach **combining traits** linked with physiological processes and structural development of crowns, as well as below ground traits, needed to understand tree adaptation strategies.

Ongoing/proposed activities:

- Improved characterization of water use efficiency, including thermal remote sensing
- Integration with structural parameters from ground inventories or terrestrial / airborne LiDAR measurements?

Thank you for your attention!

Acknowledging the collaboration and support of many colleagues, especially: Arthur Gessler, Ingo Ensminger, Leonie Schönbeck, Marcus Schaub, Jonas Gisler, Katrin Meusburger, Andreas Rigling, Christian Ginzler, Valentina Vitali, Yann Vitasse, Michèle Dobbertin, Roman Zweifel, Ruedi Bösch, Mauro Marty.

FONDS NATIONAL SUISSE
SCHWEIZERISCHER NATIONALFONDS
FONDO NAZIONALE SVIZZERO
SWISS NATIONAL SCIENCE FOUNDATION