Non-Invasive Investigation of the Internal Structure of Tree Trunks Using High-Resolution Ground Penetrating Radar (GPR) Measurements

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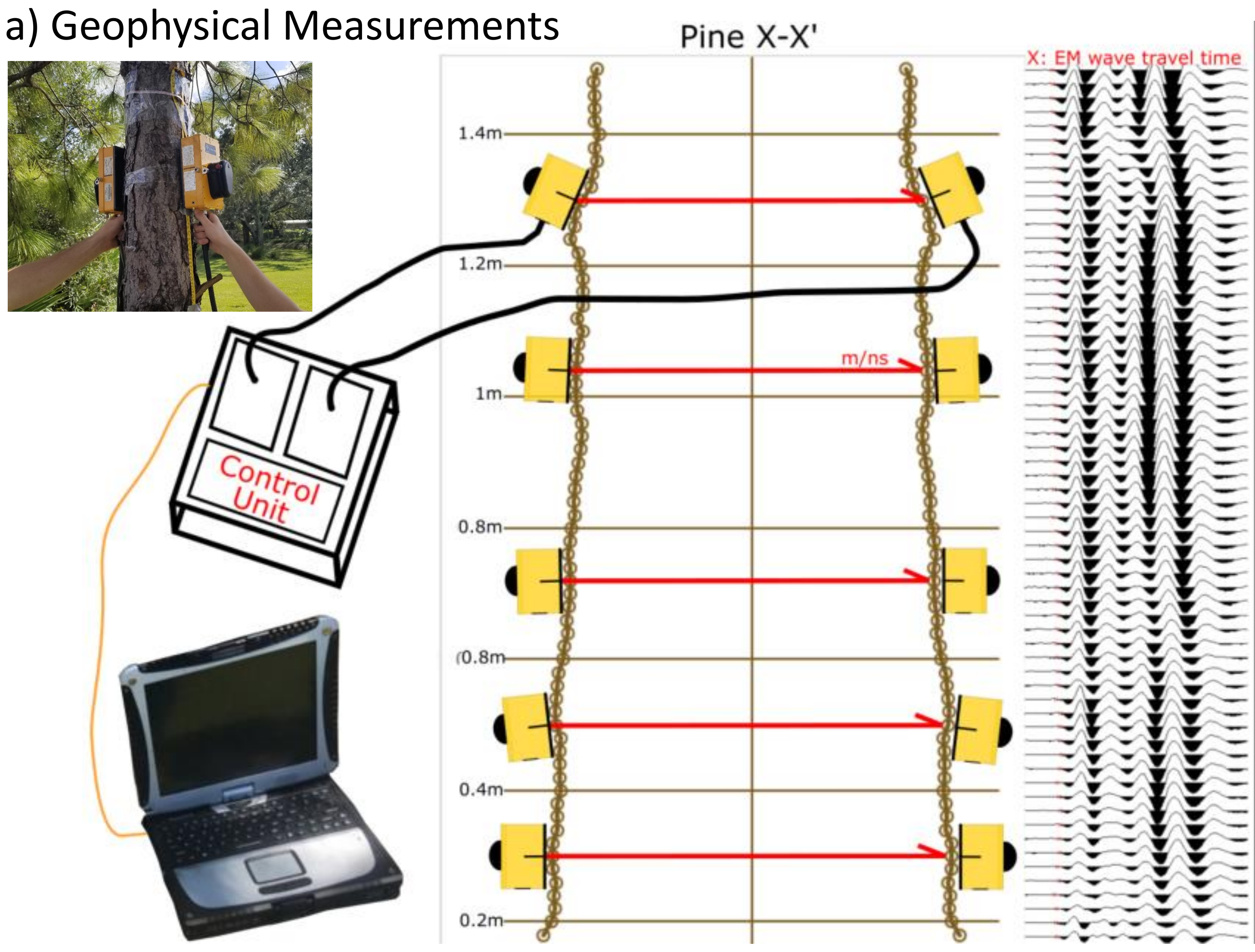
1. ABSTRACT

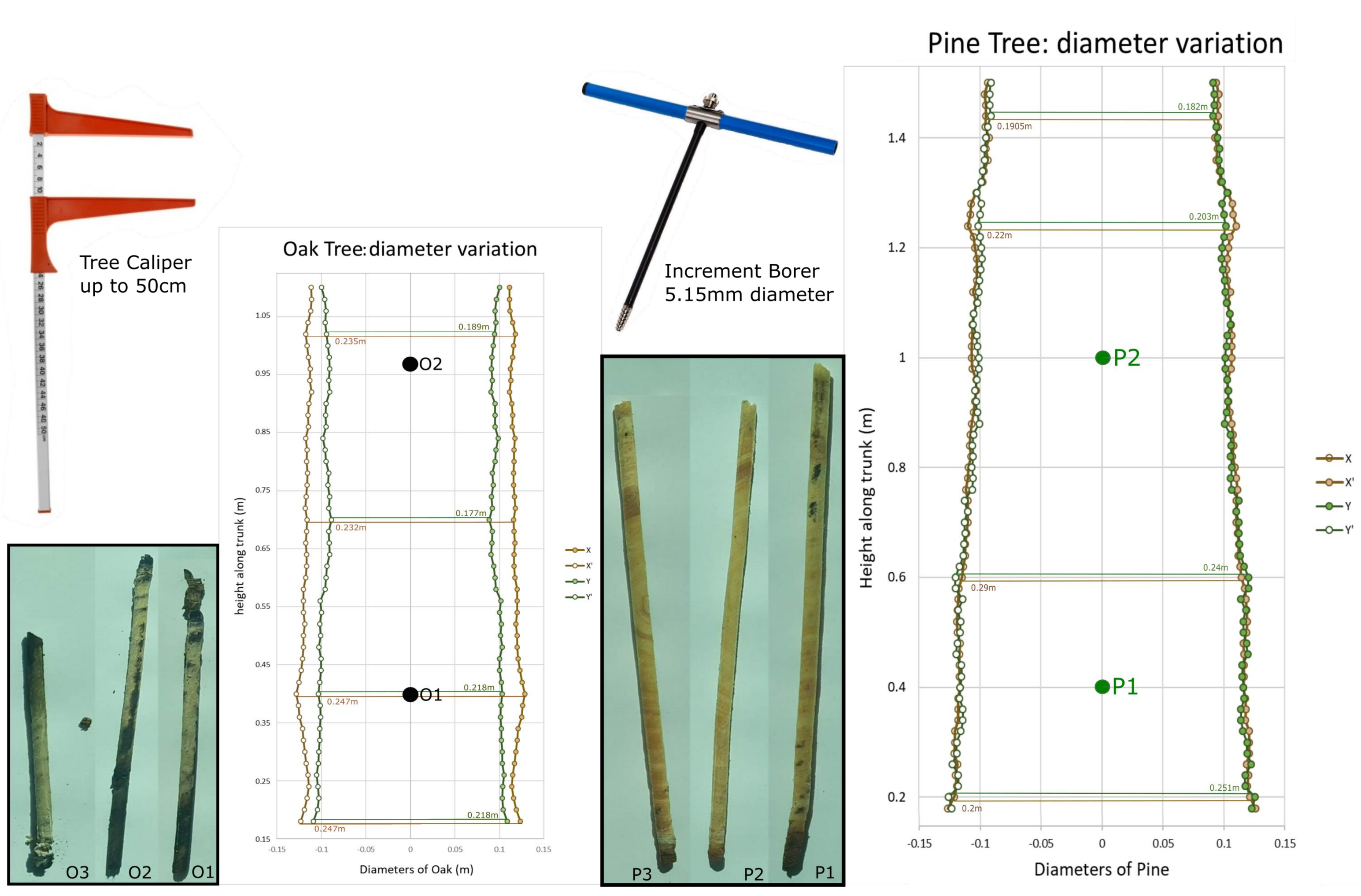
Tree anatomy is a critical aspect for properly understanding the patterns of transpiration and soil moisture distribution in trees. Moisture content distribution along the tree trunk can provide valuable information about the health of the tree and help detecting the presence of rotting or dry cavities. At the same time, internal anatomy dictates sap flow dynamics in trees which can provide critical information on water use and function under different environmental conditions. Despite this importance, current methods exploring the internal structure of trees are limited to traditional invasive methods, and only a handful of studies have used non-invasive geophysical methods like electrical resistivity or ground-penetrating radar (GPR) to explore various aspects of the tree anatomy. In this study we use a unique array of high-frequency GPR antennas (1,200 MHz) deployed in high-resolution transmission mode, to estimate changes in electromagnetic (EM) wave velocity, and use petrophysical models (like the complex refractive index model, CRIM) to infer moisture content variability within the tree trunk of several trees including softwood and a hardwood species. This study shows the potential of the method to non-invasively investigate the spatial distribution of moisture content in a variety of trees (both as one-dimensional profiles and tomographic images), as well as its temporal distribution when expanding surveys in time-lapse mode.

2. METHODOLOGY

a) Geophysical Measurements



b) Tree Diameter and Porosity



c) Model: from waves to water

Complex Refractive Index Model (CRIM)

$$\varepsilon_{r(b)}{}^{\alpha} = \theta\varepsilon_{r(w)}{}^{\alpha} + (1-n)\varepsilon_{r(s)}{}^{\alpha} + (n-\theta)\varepsilon_{r(a)}{}^{\alpha}$$

$\varepsilon_{r(a)}$: relative dielectric permittivity of air (=1)

$\varepsilon_{r(w)}$: relative dielectric permittivity of water (temperature dependent)

$\varepsilon_{r(s)}$: relative dielectric permittivity wood (pine=0.42, oak=2.5)

Mount, G., Comas, X., 2014. *Lestimating porosity and solid dielectric permittivity in the Miami Limestone using high-frequency ground penetrating radar (GPR) measurements at the laboratory scale.* Water Resources Research, Vol. 50.

Wharton et al., 1980 *Advancements in electromagnetic propagation logging* Soc. Petr. En. Paper 9041

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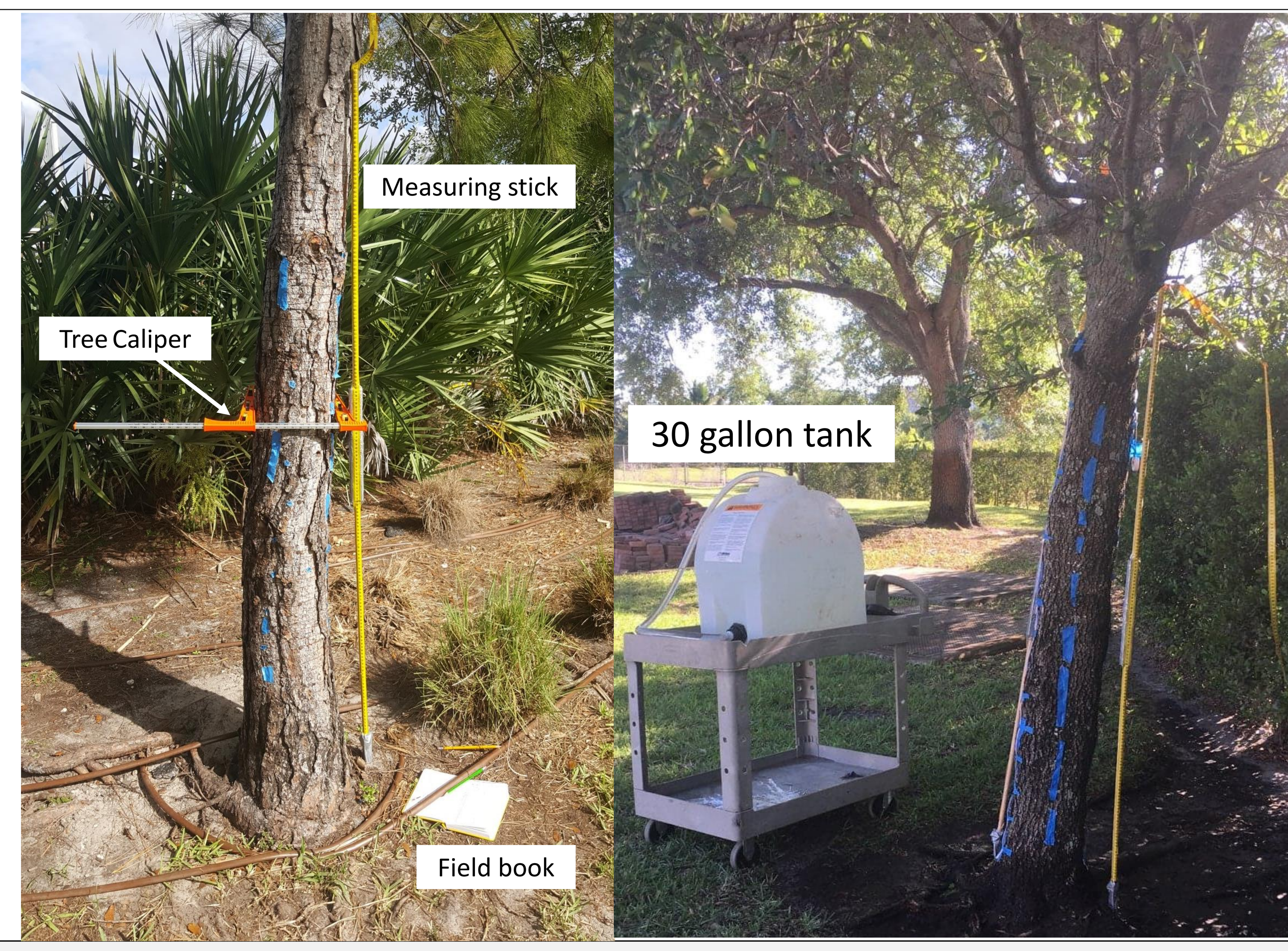
3. EXPERIMENTAL SETUP

To target:

a) spatial variability: discrete measurements on two different tree species and orientations

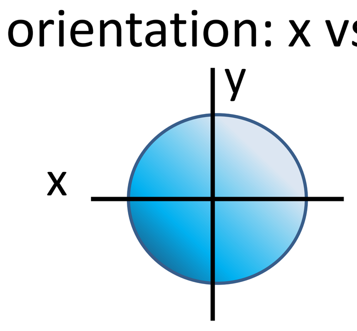


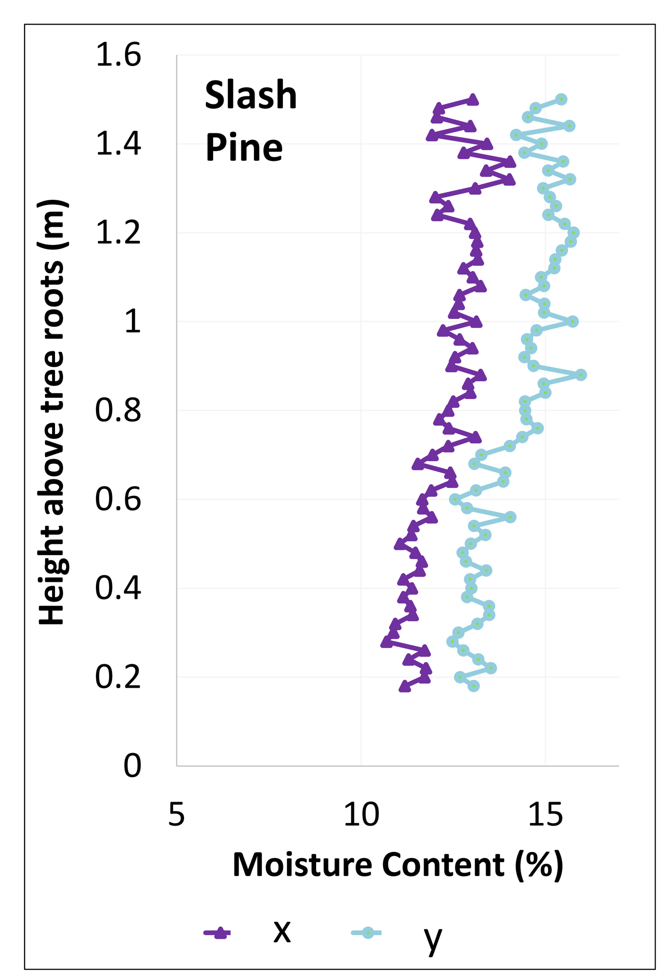
b) temporal variability: time-lapse measurements after addition of 30 gallons of water

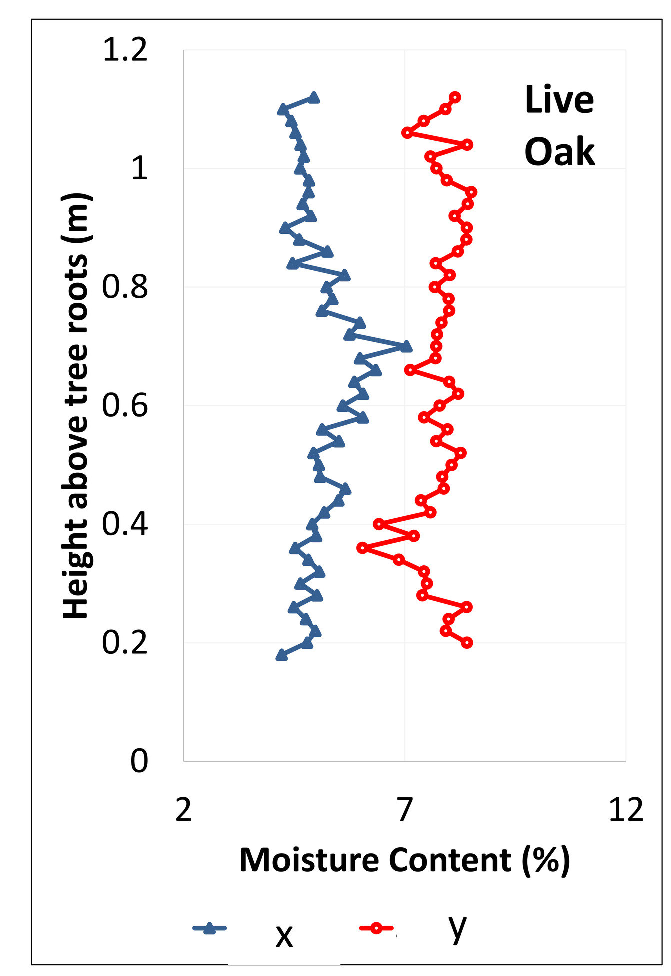
4. RESULTS

a) Spatial variability:

- Tree species: Slash Pine vs. Live Oak
- Transect orientation: x vs. y

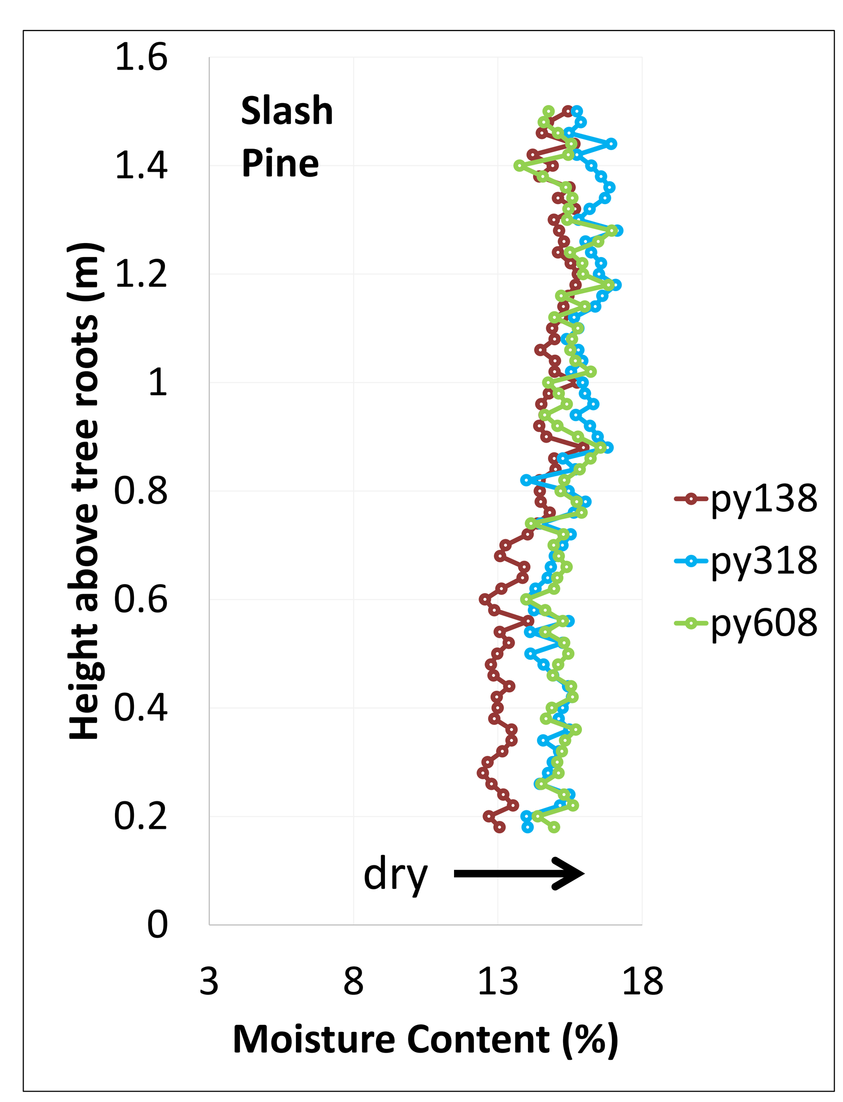


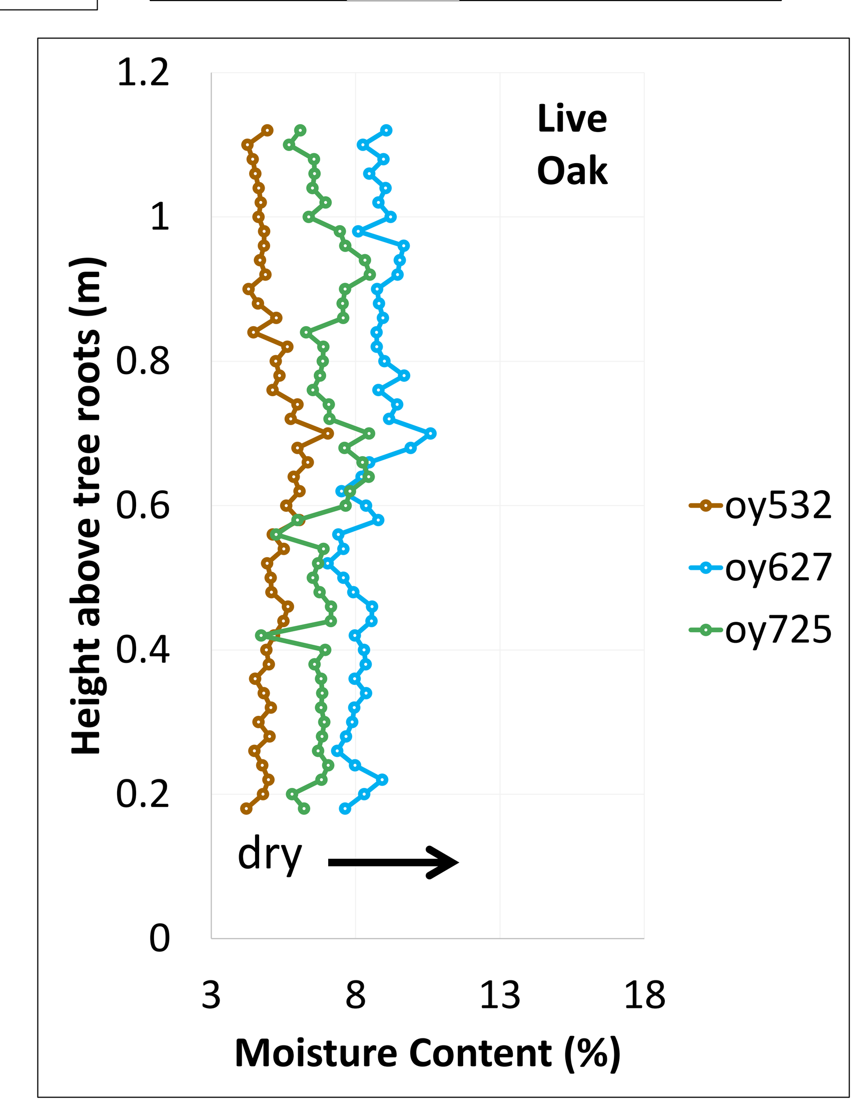




b) Temporal variability:

- Slash Pine vs. Live Oak: from dry to 30 Gal added





5. DISCUSSION

-High resolution GPR measurements provide 1D vertical distribution of moisture content at cm scale level resolution

-Time-lapse measurements show moisture content variability vertically as water is added and show differences in water intake for different tree species

-Future work will include tomography to capture 2D distribution of moisture content along different tree species to better understand moisture content distribution at specific fieldsite conditions