Using Open-Source Abiotic Sensors to Monitor Forest Restoration Treatments

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Background

- Forest structure of mixed-conifer stands in the Western U.S. has been altered since early European settlement and caused negative ecological and social impacts (reduction in understory diversity, alteration of nutrient cycles, increased wildfire severity). (2)
- **Restoration** is being carried out on millions of acres in the Western US. (3)

Abiotic Measures

- We can cheaply and efficiently monitor restoration impacts by measuring microclimate conditions with **low-cost, microcontroller-based, open-source sensors.** (4)
- Soil moisture is an important condition for regeneration, therefore in this study we evaluate soil moisture sensors. (5)
- Moisture sensors give a reading of **capacitance**, which is a measure of electrical energy storage based on water content in the soil.
- Must calibrate these sensors by relating capacitance to measured soil moisture content.

Image of a sensor with power source in the field.

Methods

- We supplemented soil samples across a range of **soil types** and **treatments** with varying amounts of water to evaluate how this effects calibration, and then took capacitance readings with sensors.
  - Woodland soil topographic blocks (mid, ridge, toe.)
  - Grassland soil treatment blocks (ungrazed, heavy grazing, grazing with prairie dogs)
- We then calculated **gravimetric water content (GWC)** of harvested soil samples in lab, which was used to calculate **volumetric water content (VWC).**
- Then established a relationship between soil capacitance readings and VWC using **linear regression**.

Results

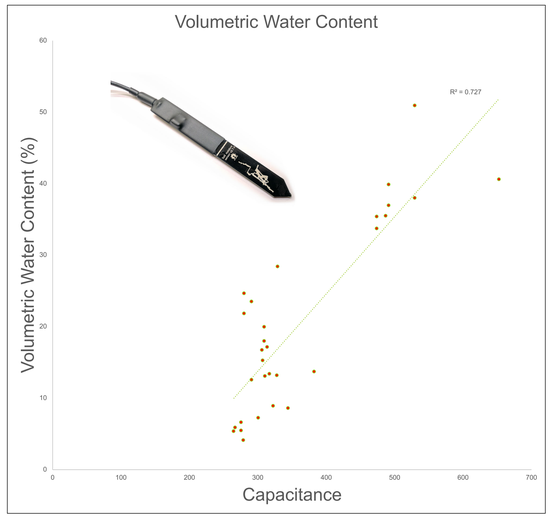
- Linear model resulted in a calibration equation relating VWC to capacitance ($p < 0.0001$, $R^2 = 0.727$)
- Found no evidence that this relationship was significantly different statistically across soil types ($p = 0.952$) and treatment blocks.

$$GWC\ (g) = \frac{wet\ soil\ weight - dry\ soil\ weight}{dry\ bag\ weight}$$

$$VWC\ (\%) = GWC\ (g) * Bulk\ Density(g/m^3)$$

$$y = 0.108x - 18.629$$

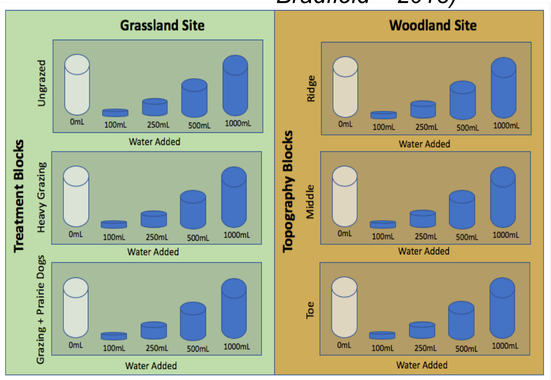
Pictured above: Equations for Gravimetric Water Content, Volumetric Water Content, and our final Calibration Equation. Other equations not shown here.
Pictured on right: Graph showing the capacitance and net Volumetric Water Content relationship



Discussion

- Our results support the conclusion that this relationship can be generalized and used with two soil types in Colorado.
  - This relationship can be used to evaluate moisture conditions across a range of restoration treatments and areas using inexpensive capacitance sensors.
  - Land managers can implement the use of these sensors and monitoring in management plans to cheaply and efficiently monitor conditions in fields like restoration or agriculture.
- This is important because this is a practical solution to **extensive** and **intensive** monitoring of our impacts on the land and more effective forest restoration.
- This finding supports the validity of developing other types of open-source sensors besides soil moisture sensors, such as humidity and temperature sensors.

Pictured below: Diagram representing the amounts of water added and the organization of sites and treatments.



Pictured on right: Woodland Site pictured on the left (Garrett Stephens–2018) and Grassland Site pictured on the right (Scott Bradfield – 2018)

Further Research

- This study evaluated two soil types (Ardisol/Mollisol and Resort-Sphinx) in Colorado, however, there are many different soil types within the Front Range and across ecosystem types.
  - Calibration of sensors across additional soil types and locations can expand the utility of theses sensors.
- Other studies have found additional factors affecting sensor readings such as the depth of measurement, the frequency at which sensors take readings, and soil salinity, demonstrating a need for monitoring these conditions along with soil capacitance. (6, 7)
- A study evaluating stand spatial patterns effects on micrometeorological conditions could provide valuable information about variation in stand conditions and assist in predicting stand dynamics.

Example of a change in wildfire severity as a result of a fuels treatment (Agee & Skinner, 2005)

Conclusion

- Our study contributes to development of open-source digital sensors for a variety of applications.
- In this study, we demonstrated the suitability of open-source sensors for both extensive and intensive monitoring of abiotic forest conditions in two soil types in Colorado.

Citations:
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- (4) Fisher D.K., and Gould, P.J., 2012. Open-source hardware is a low-cost alternative for scientific instrumentation and research. Modern Instrumentation 1: 8-20.
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- (6) Kizito, F., et al. 2008. Frequency, electrical conductivity and temperature analysis of a low-cost capacitance soil moisture sensor. Journal of Hydrology 352: 367-378.
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