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Mountains & Minds

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"Design and fabrication of an automated soil-water micro-sample extractions system"

Abstract:
The loss of nutrient-dense soils and available fresh water for irrigation will continue to impede the ability of producers to meet market demands in the agricultural sector. A deeper understanding of plant macronutrient levels in soils is necessary for sustainable and successful growing seasons in the future; however, drought conditions in western soil systems have rendered traditional soil-water collection techniques impractical because of the inadequacy of available water in the vadose zone. Additionally, field sampling is labor intensive and introduces sample handling errors.

This work presents a solution at the intersection of automation, microfabrication, and environmental monitoring systems. The Microfluidic Environmental Solute Analysis (MESA) system can provide spatial and temporal resolution in measurements of chemicals critical to the success of biomass production. Using only 100 µl of water extracted from the soil, the MESA system provides onboard, real-time electrical conductivity analysis (future work will include temperature, pH, and nitrate sensing). The MESA system features three core modules used to facilitate soil chemistry measurements. The Smart-Reservoir Module (SRM) indicates precisely when the soil-water extract has been collected. The Multifunctional Sensor Module (MSM) is a 3D-printed microsensor package with an integrated micro-dispensing pump to facilitate sample infusion to the measurement chamber. The Cleaning Solution Module (CSM) stores and transports the cleaning solution (conductivity strength 100 µS cm-1) through the internal capillaries to physiochemically erase the previous measurement.

The electrical conductivity (EC) sensor uses single-frequency electrochemical impedance spectroscopy (EIS) to measure the bulk fluid resistance within the measurement chamber of the MSM. Calibration of the MSM of EC ranging from 100 – 6440 µS cm-1 has shown that the cell constant is 9.53 cm-1, although this parameter is sensor and package dependent. In-situ conductivity measurements in engineered soil columns have revealed that the sand tested has an intrinsic conductivity of ~350 µS cm-1. The maintenance-free system is intended to be buried in the soil and provide automatic measurements throughout the Montana growing season without being disturbed. The deployment of the MESA system will provide researchers with new data that may enhance our understanding of biogeochemical cycling in dry-land agricultural settings.