

Drone-Based GPR Innovations for High-Resolution Soil Moisture and Conductivity Mapping

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Abstract

Accurate monitoring of root-zone soil moisture is essential for optimizing irrigation in precision agriculture, where high-resolution spatial data can lead to reduced water usage and increased crop productivity by addressing the inherent variability in agricultural soils. As part of the DuraTechFarm project, we deployed gprSense, an innovative Ground Penetrating Radar (GPR) system developed by Sensor Consulting (Belgium), to map soil moisture across various fields throughout their growing seasons.

This lightweight (<2 kg), drone-compatible system allows for automated, real-time root-zone moisture mapping. Developed under the EU-funded agROBOfood and ICAERUS projects, gprSense integrates frequency-domain radar with full-wave inversion, providing precise measurements of soil dielectric properties and water content. The system's versatility also extends to its integration with the irrigation robot 'Oscar' by Osiris Agriculture (France).

In addition to generating detailed soil moisture maps—correlating strongly with field topography, soil electrical conductivity, and pedological data—we investigated the effects of radar incidence angle on inverse estimates of soil permittivity. Furthermore, we explored the use of low-frequency drone-borne GPR for mapping soil electrical conductivity, further broadening the system's applicability.

Finally, time-lapse GPR data collected over a spinach field effectively tracked moisture variations due to precipitation and irrigation events, confirming gprSense's reliability in capturing the spatiotemporal dynamics of soil moisture. With its accessible interface designed for both scientists and farmers, gprSense simplifies advanced radar data processing, making it a powerful tool for precision agriculture.

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Keywords

Ground-penetrating radar, full-wave inversion, drone, soil moisture, irrigation, digital soil mapping.