3rd Funding Call: Prof Donal M O’Sullivan

November 26, 2021 (updated January 21, 2022)

University of Reading

Project Title

*Continuous, large-scale, dynamic soil moisture mapping to capture root growth and dynamic water use traits in field conditions.*

Total Funds Requested

£24,665

Project Summary

Water use efficiency is a key trait that the crop science community must address to be able to breed crops capable of coping with a warming climate, and ever more extreme and uncertain variable precipitation and drought events. Nowadays, the transpirative and photosynthetic demand of a plant or crop stand can readily be estimated via a series of direct and indirect phenotyping methods. However, the extent to which the plant or crop root system utilises and/or conserves soil moisture available to it through a season is not currently something which can be measured easily. The gambit of this proposal is that we have identified Active Distributed Temperature Sensing (Active DTS) as a technology that has the capability to turn whole fields into virtual lysimeter arrays, allowing high temporal and spatial resolution by mapping of water use across many hundreds of plots through the whole season under field conditions, on undisturbed soil and under actual agronomic practices. We propose that automated dynamic soil moisture mapping can be used as a powerful new below-ground field phenotyping tool to move plant and crop research on from its current reliance on a combination of low-to-moderate throughput imaging (e.g., shovelomics, rhizotrons, X-ray computed tomography) and physical measures (e.g., lysimeters) to actually capture season-long continuous water use on undisturbed soil reflecting root growth and water use dynamics. Challenges this pilot project will address include system parameter optimization, validation of robust calibration routines, and multiscale data management and analysis. The proposed work will support an early career researcher at Reading and the results from this study will advance the capabilities and knowledge in field phenotyping, plant physiology and crop breeding.

**Phenotyping need**

Water use strategies and availability are important under water limiting conditions, but they are traits that also present strong interactions with the cross-tolerance to most abiotic and biotic stressors. As a well-studied example, water limitations on UK wheat production on an average year cause losses of 1-2 t / ha (equivalent to 12-20% of potential production) with a loss of c.£72 million (Foulkes et al, 2007, Ober et al, 2014). However, there are considerably more losses in severe drought years or when the timing of water limitations matches sensitive stages of crop development. Indeed, climate-crop modelling indicates that the likelihood of drought affecting wheat reproductive development is on an increasing trajectory across large parts of Europe (Senapati et al, 2019), making drought tolerance and water use efficiency key breeding targets to secure robust yields. As the ability of roots to extract soil moisture is critical for maintaining yields during drought, selection for genotypes that can better access soil water should improve yield stability in increasingly variable rainfall environments (Ober et al, 2014). Crop breeding programmes therefore urgently require high-throughput phenotyping tools which sensitively and specifically measure crop water use traits, and which can be validated within real-life production environments.

Current water use phenotyping relies on low-to-moderate throughput measures of root system architecture (by imaging techniques) or punctual physical quantification of water in soil (lysimeters, soil water potential and content sensors). Other functional measures of water use efficiency are indirect, expensive and/or have limited temporal resolution (e.g., isotopic discrimination, gas-exchange, canopy temperature, spectral emission, root system capacitance). Notably (other than few very low throughput very large scale lysimeters), no current technique can provide non-invasive continuous direct measures of Soil Water Content (SWC) with a dense enough spatial sampling to capture both the dynamics of water extraction by actively growing plant root systems, and to measure and compensate for the high variability of undisturbed soil in the field. Validation of the phenotypes targeted by crop breeding programmes within real-life production environments is essential. For example, there is a lack of detailed studies of the real SWC distribution during recharge events (irrigation and precipitation) and their interaction with root system architecture, mainly due to the difficulties to gather SWC measurements with high spatial and temporal resolution (Rodríguez-Sinobas et al, 2021). A phenotyping tool with this capacity would open the opportunity to not only study and breed more efficiently for water use traits, but to also evaluate the impact of any combination of crop, soil and cropping system management practices and techniques (e.g., crop cover, rotations, irrigation systems).

**Distributed Temperature Sensing (DTS) systems for soil water content determination**

DTS systems are distributed optoelectronic devices that work by sending a laser light pulse down the optical fibre and collecting the temperature-dependant backscattered light (**Fig 1**). Combined with time-of-flight of the signal, the DTS receptor provides many spatially distributed precise temperature readings thorough the fibre length in milliseconds. Temperatures are recorded along the optical sensor cable, thus not at points, but as a continuous profile with a high accuracy. Typically, the DTS systems can locate the temperature to a decimetre spatial resolution with accuracy to within ±1°C at a resolution of 0.01°C in fibres of up to many kilometres in length.