

## **Validation of metrological techniques for characterising complex geometrical networks in bioscience applications**

*Application for EPSRC studentship in 'Complex Systems and Processes'*

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The soil surface is a highly active and important interface where many complex factors contributing to soil productivity interact (e.g. supplying nutrients and water to crops). Many soils have a thin layer at the surface, referred to as a 'crust' that can be generated by different mechanisms. A 'physical' soil crust develops due to both the kinetic action of falling raindrops and aggregate dispersion forming a surface layer (up to 10 mm deep) that is less porous or conductive than the underlying bulk soil. The presence of a physical crust can alter the characteristics of the soil surface by smoothing and sealing the soil surface, thus decreasing rainfall infiltration and increasing the volume and velocity of water runoff. Physical crusts often inhibit plant seedling emergence which can have major agricultural, hydrological and environmental effects, potentially compromising our food security. Also, the microbial community phenotype in the soil surface zone modulates soil water interactions and structural resilience when raindrops impact the surface.

The Soil Science Group based at the Hounsfield Facility within the School of Biosciences have recently applied X-ray computed tomography (XCT) to non-destructively quantify soil crusts generated in a range of soils under different biological contexts (i.e. relative roles that fungi, bacteria and photoautotrophs play in mediating the complex biophysical properties of the developing soil surface). They have developed a series of parameters to quantify the irregular geometry of the soil surface; however, currently they have no method to verify the accuracy or suitability of these measurements and mathematical characterisation techniques. Furthermore, measurement accuracy is influenced by the image processing method (e.g. filtering, threshold algorithms) which highlights a need for appropriate standardised approaches. Surface and volumetric metrology in the soil sciences is a relatively new research area and would significantly benefit from colleagues in the physical sciences and engineering.

The project would be to enhance existing, and develop new, measurement and characterisation methods that can be applied to the quantification of the complex geometry of the soil surface (and sub-surface). XCT systems, available in both the Hounsfield Facility and the Faculty of Engineering, with varying resolutions will be used to understand the effect of the imaging characteristics on the measurement results. Traceable data from surface topography instrumentation (in Engineering) will be compared to XCT measurements to understand the accuracy and transfer function of the imaging methods. Mathematical techniques will be developed that can detect geometrical edges (and surfaces), filter and segment areas/volumes of interest and output functionally-significant parameters. This mathematical process: from data input to parameter output, will be analysed in detail and validated with suitably-designed reference datasets. Finally, an uncertainty model will be constructed to estimate the measurement uncertainty in both the physical and mathematical processes. This work is expected to significantly enhance the analysis field in soil science and will lead to a number of high impact journal papers.

Note that the outputs from this project will not just be specific to the area of soil science – the project is expected to have impact on many areas where complex 3D geometrical analysis is required (e.g. defect detection in materials, vascular systems analysis, topological design for additive manufacturing).