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Emergent properties of the fungal-soil complex

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The microscale physiological processes accomplished by hyphal networks make soil fungi crucial actors in the global Carbon cycle (Cromack and Caldwell, 1992). Fungi decompose, uptake and mineralize stable biomolecules such as cellulose and lignin, which are key processes in many ecosystems. The geometry of the pore-solid soil matrix not only effects fungal growth and colonisation but also governs fungal interactions. Soil structure is crucial in the interaction, we have previously shown that on a 2D agar plate (or any structure-less environment) two fungal species will always meet and they will compete. However in soil the 3D geometry of the pore space may provide refuges and separates pathways for fungal spread enabling species to coexist (Falconer et al 2007). It is not only the soil structure that effects fungal colonisation, fungi, rely on the coexistence of water and connected air filled pore spaces to permit their development and connectivity to the wider soil ecosystem (Young et al 2008). Thus, the ability of soil to allow water to penetrate into it, and hold water is a key characteristic of all soil ecosystems as it effects microbial populations.

There have been recent efforts to determine the liquid/solid interfaces in 3D soil samples via X-ray tomography (Carminati et al 2008), however experimental techniques to determine both the location of these interfaces and the micro-distribution of fungi has to date been impossible. This work draws together quantification and modelling efforts that can elucidate the role of soil structure and moisture distribution on fungal colonisation, which may be validated by experimental data when available. Towards this we combine physical (Lattice Boltzmann Methods) and biological (fungal model of Falconer et al 2007) compartments which are integrated in a 3D pore scale representation of soil obtained using X-ray CT .We concentrate on two aspects of heterogeneity that we anticipate being key for fungal colonization in soil, namely (a) the soil structure, and (b) the spatial distribution of liquid/air interfaces within soil structure. This integrated framework models the micro-environment dynamics as an emergent consequence of the interactions between pore structure, physical processes (Carbon and air/liquid interface dynamics)and fungal growth.

This involves three main components which are:
1) Characterization of the microscale soil environment,
2) Prediction of the spatial distribution of air/liquid interfaces in unsaturated soil using Lattice Boltz,mann Methods and
3) Assessment of the impact of soil structure and liquid/air interfaces on predicted fungal colonisation using Minkowski functions.

We show that the set of functional measures: surface area (SA), volume fraction (VF), integral mean curvature (IMC) and total mean curvature (TMC) forms a multi-dimensional space in which each point summarizes key structural properties and can be used to quantify the effect of the static soil pore network and the dynamic liquid volume on the fungal network. Transformation of structure, of fungal network, can thus be understood as motion through functional space.

References
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