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Multiscale continuum modelling for water and nutrient uptake from a single root scale to whole architectural root system

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Water and nutrient transfer in plant-root-soil system are crucial processes in agroecosystems. Therefore, root-soil interaction modelling has become essential to describe physico-bio-chemical processes in 3D root-soil system such as root growth, water and nutrient uptake or root exudation. Although water and nutrient uptake modelling for 3D architectural root system has become advanced in recent years, the local steep gradient of nutrient concentration at root-soil interface is still one of the main challenges for a better prediction of water and nutrient uptake in root system scale simulation. Conventionally, it requires soil mesh refinement to improve the accuracy of water and nutrient uptake. The simulation with high resolution of soil domain and complex architectural root system can take several hours even days and becomes impossible for real applications. This contribution presents a continuum multiscale modelling approach for water and nutrient transport and investigates the effect of transient soil moisture content and water flux on nutrient uptake in a virtual root-soil system. By applying rhizosphere models at root segment scale, the prediction of nutrient uptake rate at macroscopic scale has improved significantly. The newly developed model not only resolves the steep gradient of nutrient at single root scale but also still keeps the macro-scale simulation for the whole 3D architectural root system at a low computational cost by using coarse soil mesh. Using in silico experiments, the virtual root-soil system was utilized for investigation of water and nutrient uptake for a single root, multiple roots and whole architectural root system in different soil conditions. The results showed that the multiscale simulation becomes more feasible in computational time aspect and high accuracy compared to high resolution resolving approach. Overall, we present an advanced modelling method for water and nutrient uptake across various scales: from single root scale to the whole 3D root system and its benefit for studying virtually root-soil interactions processes under different soil conditions.