Soil Moisture Modeling using Hydraulic Redistribution and Root Compensation Mechanisms of Plants in Stratified Vadose Zone

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Hydraulic redistribution (HR) refers to the mechanism by which passive movement of water takes place from wetter soil layers to drier root-zone via plant roots, driven by the moisture gradient. Likewise, Soil moisture stress that occurs in one part of the root zone can be compensated for by enhanced extraction from the other wetter parts through root compensation mechanism (RCM) under varying soil moisture conditions. A numerical model is developed in this study to understand the effect of these root water uptake mechanisms in multi-layered soil profile through coupled soil-water-root zone system. The governing equations of water flow in soil and root biomass are solved numerically using implicit finite difference method coupled with an iterative technique. Modeling of HR requires a sink/source term that allows flow of water in both directions, i.e. from soil to root and vice versa. For this a realistic non-linear function of root density distribution is incorporated in the soil moisture flow equation for simulating the rate of water removal with and without considering the HR and RCM mechanisms. The model was first tested for a barren layered soil profile before applying it to a rain-fed wheat (*Triticum aestivum*) plot using a dynamic root growth model. Model predicted soil-moisture parameters, i.e. moisture depletion, moisture profile at different depths, and the water uptake rate by plants. The model results indicate that in favourable soil moisture conditions, the water uptake is higher in the region close to ground surface as compared to the mid or lower region of the root zone. However after meeting the transpiration demand during the day time, moisture stress is developed in the upper soil profile which is compensated by water uptake from the lower wet layers due to HR mechanism during the night time. Results also show that under favorable soil moisture conditions, plants extract water at the maximum rate according to the root distribution pattern and when the moisture stress is developed in a part of root zone, the diminished water uptake rate in the water scarce region is compensated for by an enhanced water uptake from the surrounding wetter zones. An underestimation of root water uptake in wet soil zone and slight overestimation in dry soil part has been observed during dry days when the RCM is not considered. This shows that the optimal availability of water in some part of root zone and little moisture stress in top soil layers can significantly reduce the amount of evaporation without significantly affecting the water uptake by plants and, therefore, the plant growth. Thus, the developed hydraulic redistribution model can be used for planning better irrigation scheduling and practices particularly in the water scarce arid and semi-arid regions having deep vadose zone. The model can also be integrated with a transport equation to predict the solute uptake by plants and for accurate quantification of solute load to underlying groundwater resources.

Keywords: Hydraulic redistribution, Root compensation mechanism, Plant water uptake, Soil moisture modelling, Vadose zone

