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Modeling gravity-driven fingering by using the moving boundary approach

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The modelling of preferential flow that is induced by gravity-driven fingering in porous media, using classical soil physics models has not yet been resolved. Being a parabolic PDE, the Richards equation is not capable of coping with sharp changes in moisture content along the finger edge, nor with the pressure/water content non-monotonicity associated with the saturation overshoot at the fingertip. Moreover, the processes that induce the finger formation in general and the saturation overshoot in particular remain unclear. It has been recently suggested and experimentally proven that these phenomena are driven by a non-zero contact angle between water and soil particles which hinders the spontaneous invasion of the dry pores. A 1D mathematical model that is based on the moving-boundary approach, a follow up of the postulation of the non-zero contact angle, was developed, solved, and validated by its comparison with experimental results. This model demonstrates the effect of contact angle, wetting and drying soil characteristic curves and influx on the soil's dynamic water-entry pressure and propagation rate of the wetting front. The model results show how lower soil wettability (i.e. larger contact angles) together with a higher influx, induces water accumulation behind the wetting front (saturation overshoot). An extension of the above-mentioned 1D model into a 2D model will be presented. The dependence of flow pattern (stable or unstable), finger dimension and propagation rate on the contact angle, soil characteristics, and influx will be demonstrated and discussed.