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Numerical model of water flow and solute accumulation in vertisols using HYDRUS 2D/3D code

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Vertisols cover a hydrologically very significant area of semi-arid regions often through which water infiltrates to groundwater aquifers. Understanding of water flow and solute accumulation is thus very relevant to agricultural activity and water resources management. Previous works suggest a conceptual model of dessication-crack-induced-salinization where salinization of sediment in the deep section of the vadose zone (up to 4 m) is induced by subsurface evaporation due to convective air flow in the dessication cracks. It suggests that the salinization is induced by the hydraulic gradient between the dry sediment in the vicinity of cracks (low potential) and the relatively wet sediment further from the main cracks (high potential). This paper presents a modified previously suggested conceptual model and a numerical model. The model uses a simple uniform flow approach but unconventionally prescribes the boundary conditions and the hydraulic parameters of soil. The numerical model is bound to one location close to a dairy farm waste lagoon, but the application of the suggested conceptual model could be possibly extended to all semi-arid regions with vertisols.

Simulations were conducted using several modeling approaches with an ultimate goal of fitting the simulation results to the controlling variables measured in the field: temporal variation in water content across thick layer of unsaturated clay sediment (>10 m), sediment salinity and salinity the water draining down the vadose zone to the water table. The development of the model was engineered in several steps; all computed as forward solutions by try-and-error approach.

The model suggests very deep instant infiltration of fresh water up to 12 m, which is also supported by the field data. The paper suggests prescribing a special atmospheric boundary to the wall of the crack (so that the solute can accumulate due to evaporation on the crack block wall, and infiltrating fresh water can push the solute further down) - in order to do so, HYDRUS 2D/3D code had to be modified by its developers. Unconventionally, the main fitting parameters were: parameter a and n in the soil water retention curve and saturated hydraulic conductivity. The amount of infiltrated water (within a reasonable range), the infiltration function in the crack and the actual evaporation from the crack were also used as secondary fitting parameters. The model supports the previous findings that significant amount ($\sim$90%) of water from rain events must infiltrate through the crack. It was also noted that infiltration from the crack has to be increasing with depth and that the highest infiltration rate should be somewhere between 1-3m.

This paper suggests a new way how to model vertisols in semi-arid regions. It also supports the previous findings about vertisols: especially, the utmost importance of soil cracks as preferential pathways for water and contaminants and soil cracks as deep evaporators.