Optimizing Flood Irrigation to Flush Accumulated Salts through Zonal Flooding

Conclusions

With increasing pressure on water resources around the world, there is growing recognition of the need to balance efficient water use with maintenance of soil quality, in particular as it relates to salinization. One approach to treating salt accumulation is through periodic flooding. We examine two alternative approaches to flooding and compare them to fully flooding the field throughout treatment. Sequentially increasing the flooded area toward the drain reduces the treatment time and water use, but may enhance subsurface mixing. Sequentially decreasing the flooded area away from the drain has no effect on the treatment time, but it requires the least amount of water and does not enhance subsurface mixing.

Methods

We conduct a numerical investigation of three approaches to salt flushing. We consider a rectangular domain bounded below by an impermeable boundary (Fig. 2). We assume that there is a repeating series of horizontal drains, represented by zero flux vertical symmetry boundaries. We further assume that the system can be modeled using a sequence of steady state, saturated flow models because we expect that travel time through the vadose zone will be short compared to transport through the saturated zone and transport will be dominated by advection for the relatively high Infiltration rates used for flushing. The steady state flow model is written in MATLAB.

Problem Statement

In arid and semi-arid areas, efficient irrigation is defined as applying the minimum amount of water necessary to provide sufficient water for crop health, while minimizing deep drainage. While this approach has clear benefits for water conservation, it necessarily leads to salt accumulation within the root zone. Furthermore, this salt accumulation can be heterogeneous, even in a homogeneous soil.

One approach to remediating salinization is to flood-irrigate fields periodically to drive salts to subsurface drains. To achieve overall efficiency of water use, including these flood irrigation periods, it is desirable to minimize the amount of water used for salt flushing. In this study, we consider three approaches to flushing.

Full flooding refers to flooding the entire field throughout the treatment. Increasing zonal flooding begins with a small area far from the drain and sequentially increase the flooded area. Decreasing zonal flooding begins with full flooding and sequentially removes flooded areas closest to the drain. These three approaches are compared based on the time required and the total water needed to flush the field and the potential for enhanced mixing of salt or other contaminants during flushing.

Results

Full flooding results in sub-parallel flow lines throughout the domain. The minimizes mixing of laterally heterogeneous salt deposits, but it requires overflushing of the area near the drain.

Increasing zonal flooding minimizes overflushing near the drain. Solutes are "swept" towards the drain, but the resulting tracks show enhanced mixing. Flushing requires 22% less water than full flooding.

Decreasing zonal flooding initially displaces shallow contaminants vertically (blue tracks). Later reduction in flushed area have little impact on the particle trajectories, resulting in particle tracks that are very similar to those of full flushing, with reduced subsurface mixing. Flushing requires 54% less water than full flooding.

Full flooding and decreasing zonal flooding establish near identical particle, resulting in very similar particle residence times. Increasing zonal flooding displaces particles laterally toward faster flow paths, leading to the shortest treatment time.