Postprint: Simulation of Soil Water-Salt Transport Under Open Ditch Drainage Conditions

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Abstract

Based on drainage experiments conducted on drainage ditches in the saline-alkali land of the 122nd Regiment, 8th Division of the Xinjiang Production and Construction Corps, this study controlled field irrigation, monitored changes in field soil salinity, and established a HYDRUS numerical model to simulate and analyze salinity dynamics in cotton fields under open ditch drainage conditions throughout one growth cycle. The results indicate that: the average desalination rate in the 0–80 cm soil layer reached 50.09%; the total salt content in the 80–200 cm soil layer remained essentially unchanged; the overall salt content in the 0–200 cm profile decreased by approximately 25%; salt removal efficiency was higher at locations closer to the open ditch; and the simulated values from the numerical model showed good agreement with the measured values, demonstrating that the model can accurately reflect the actual experimental conditions. These research findings can provide a reference for saline-alkali land reclamation in arid and semi-arid regions.

Full Text

1. Study Area and Methods

1.1. Experimental Site Description

The study was conducted at the 122nd State Farm of the Xinjiang Production and Construction Corps, located between 44°37 –44°48 N and 85°27 –85°41 E [FIGURE 1]. The site has an elevation of 2861.6 m, with a maximum temperature of 43.1°C and minimum temperature of -42.3°C. The frost-free period occurs during months 9-10. The groundwater depth in the test area is approximately 2.2 m, and the soil profile is shown in [FIGURE 2]. During the cotton growth period (April–October), the root zone depth reaches 1.75–2.1 m. The spatial distribution of sampling points is illustrated in [FIGURE 3], with measurement locations at distances of 8 m, 16 m, and 24 m from the drainage ditch.

The irrigation schedule and water volumes are detailed in [TABLE 2]. Groundwater level observations for 2013 are presented in [TABLE 1]. The experimental monitoring period spanned from April 20 to September 30, 2013, totaling 163 days with a simulation time step of 0.5 days.

1.3. Model Parameterization

The HYDRUS model was employed to simulate water and solute transport processes. Soil hydraulic parameters were determined using the van Genuchten-Mualem model, with characteristic values listed in [TABLE 3]: saturated water content , shape parameters and n, saturated hydraulic conductivity K , and pore-connectivity parameter l. Root water uptake parameters are provided in [TABLE 5].

Initial conditions were established based on measured soil moisture and salinity profiles at the beginning of the simulation period. Boundary conditions consisted of variable flux upper boundaries for irrigation events and constant pressure head lower boundaries representing groundwater dynamics. The root distribution function followed the standard HYDRUS formulation, with maximum rooting depth set at 2.1 m.

1.4. Model Validation

Model performance was evaluated using root mean square error (RMSE) and correlation coefficient (R^2) between simulated and observed values. The salt distribution pattern is depicted in [FIGURE 6], while [FIGURE 7] presents a direct comparison of simulated versus measured soil salinity at different depths and distances from the drainage ditch.

Statistical metrics are summarized in [TABLE 7] (RMSE values) and [TABLE 8] (correlation coefficients). The RMSE was calculated as:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(x_i - y_i)^2}{n}}$$

where x represents observed values, y represents simulated values, and n is the number of observations. The results demonstrate good agreement between model predictions and field measurements, with R^2 values exceeding 0.65 across all monitoring locations.

Abstract: This study monitored changes in saline-alkali soil salinity at the 122nd State Farm of Xinjiang Production and Construction Corps under controlled field irrigation. The objectives were to investigate soil water and salt migration processes under drip irrigation with plastic film mulching and open-ditch drainage, develop a HYDRUS numerical model, and simulate soil salinity dynamics during the cotton growth period. Results showed that the average desalination rate in the 0–80 cm soil layer reached 50.09%, while salinity in the 80–200 cm layer remained relatively stable, resulting in an overall 25% reduction in the 0–200 cm profile. Desalination efficiency increased with proximity to the drainage ditch. Simulated values showed good agreement with measured data, demonstrating the model' s reliability for predicting water and salt movement in arid saline-alkali regions.

Keywords: mulched drip irrigation; open-ditch drainage; soil water and salt migration; numerical simulation; Xinjiang Production and Construction Corps

Note: Figure translations are in progress. See original paper for figures.