Hydraulic and Chemical Properties of Soils Irrigated with Recycled Saline Sodic Drainage Water

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Abstract:

Irrigation with saline-sodic water affects soil physical properties. Knowing the effect of the soil chemical properties on soil water retention and hydraulic conductivity at various depths will lead to better management practices for soils irrigated with recycled drainage water.

Research in San Joaquin Valley (SJV), California, is addressing needs to reduce irrigation volumes and drainage. Fresh water demands have increased and saline irrigation water sources will be used to a greater extent. The objectives of this study are to determine the hydraulic conductivity and soil water characteristics of soils irrigated with recycled saline-sodic drainage water for the eventual use of these parameters in irrigation management models. This study will assist in development of these parameters.

Soils from Red Rock Ranch, west side SJV, were collected from areas with fresh-water and recycled drainage water irrigation to determine saturated conductivity and water retention characteristics. Irrigation water salinity ranges (EC) are < 1 dS/m to ~ 13 dS/m. Soils textures- clay loams. Soil salinity (ECe) was <2.4 dS/m to >50 dS/m and SAR was 8.6 to 85.4. The saturated flow rates (Ks) ranged from 1.02×10^{-3} to 7.58×10^{-7} cm per second.

Introduction:

Saline-sodic irrigation water with ECe > 4.0 dS/m and SAR of 13 or higher can degrade soil structure at pH of 7.8 to 8.5, and thereby reduce the rate at which water enters the soil (infiltration) and percolates through it (hydraulic conductivity). The extent to which soil electrical conductivity (EC) and sodium adsorption ratio (SAR) affects water infiltration into soil, depends on other chemical properties (calcium and organic matter contents), texture, and depth.

Current research conducted in agricultural areas in California, such as in the Imperial and San Joaquin Valley's, are aimed at reducing the volume of irrigation water applied and subsurface drainage by encouraging crop utilization of shallow groundwater, while still maximizing yields in salt affected soils. Soil salinity, shallow saline groundwater, and drainage water disposal all pose major challenges to agriculture on the west side of the San Joaquin Valley (SJV) (San Joaquin Valley Drainage

Implementation Program, 1998 and 1999). These soil constraints reduce yields and profitability, and they limit crop choices. Farmers are looking at management practices that will allow the production of agronomic crops utilizing low quality irrigation waters. The increased demands for fresh water is growing steadily in arid regions and it is likely that saline irrigation water sources will be used to a greater extent. Current infiltration models lack variables that account for different management practices. A study to provide expected infiltration rates for soils as affected by saline-sodic irrigation water management practices would prove valuable to on-going and future research. Refining the management of soils that are being irrigated with saline-sodic water is essential for the sustainability of agriculture on the Westside San Joaquin Valley.

The long-term benefits to alternative irrigation practices are to maintain soil structure and yields, while reducing erosion and the accumulation of salts in the soil. These strategies are needed to feed the growing masses and provide farmers and urban areas plenty of water for sustainability.

Research Objectives:

The objectives of this study are to determine the hydraulic conductivity and soil water characteristics of soils irrigated with recycled saline-sodic drainage water for the eventual use of these parameters in irrigation management models. If a correlation can be found, the results would give researchers and farmers current information on how to best manage their irrigations to optimize irrigation efficiency, maintain adequate soil structure, and reduce the volume of drainage below the crop root zone.

Materials and Methods:

Soils were selected from the west side San Joaquin Valley, California at Red Rock Ranch (RRR) in Five Points (Figure 1). In 1996, an Integrated on-Farm Drainage Management (IFDM) system was developed as a demonstration project at the Red Rock Ranch (RRR) out on the Westside SJV. For the past four years, one focus of our research at the RRR IFDM demonstration project has been the soil characterization of fields at the RRR. The site is a sequential reuse irrigation system with EC and SAR values that steadily increase in each stage. Soils were taken from a fresh-water irrigated area (Stage 1) and from each subsequent area that has been irrigated for seven years with recycled drainage water (Stages 2-4). Irrigation water salinity in Stage 1 is generally less than 1 dS/m and in Stage 4 it averages about 13 to 14 dS/m. Hand augers and a mechanized hydraulic corer, Giddings Rig, were utilized to collect core samples to a 120 cm depth at 30-cm increments.

Texture, pH, EC, and SAR analysis were conducted on samples from all locations and depths. Saturated hydraulic conductivity (Ks), water retention, gravimetric/ volumetric water content, and bulk density were also determined for these samples. Column samples were assessed for saturated hydraulic conductivity using a constant head soil core method (Reynolds and Elrick, 2002). Pressure plate chambers were utilized to simulate the drying out of the soil (de Jong, 1993). Initial readings at saturation were taken as well as readings from field capacity to wilting point.

Results:

Soil textures were mainly clay loams. Soil salinity (ECe) was less than 2.4 dS/m in Stage 1 to greater than 50 dS/m in Stage 4 (Table 1) and SAR was 8.6 and 85.4 for Stages 1 and 4, respectively. The natural process of salts accumulation in irrigated agriculture was evident in Stage 1 at the onset with such high EC and SAR values. Many cash crops can not tolerate these levels and severely hampers crop choice for valley farmers. The saturated flow rates (Ks) varied greatly with values ranging from 1.02 X 10^{-3} in stage 1 to 7.58 X 10^{-7} cm per second in stage 4 (Figure 2). As the soils become increasingly saline/ sodic, the water flow rates slow progressively from Stage 1 to Stage 4. Soil structure is compromised and deflocculating of the colloids occurs to the extent that Stage 4 often has extended periods of ponding and field capacity water levels for several days to weeks after rainy conditions (Buckland et al., 2002).

Conclusions:

Soil water retention and hydraulic conductivity rates vary with time, soil type, texture, rate of application, and the degree to which the soil has salinized and/or become sodic. The sodium cation along with the SAR, are the two factors which largely influence the hydraulic conductivity and degree to which the soil colloids are dispersed (Nielsen, 1986). Increased EC and SAR values in each sequential stage produced decreased hydraulic conductivity and water retention and a correlation needs to be established. Researchers in the past have not clearly defined the degree to which infiltration and hydraulic conductivity may be reduced in saline-sodic soils in the SJV. This is another attempt to add to the accumulation of knowledge on the subject. It is known, however, that variability in infiltration rates in a field will strongly influence the performance and management of surface irrigation systems. Much more must still be done to protect our soil and water resources from the dangers of salt loading and drainage water disposal issues.

For fields irrigated with saline-sodic irrigation water, there exists small scale and localized variability in hydraulic conductivity and hydraulic properties. Characterization of these properties is essential for better understanding of flow and solute transport.

Future Work:

- This data can then be used to determine infiltration rates which in turn, will then be correlated with the soil's physical and chemical characteristics.

- Water retention curve and saturated hydraulic conductivity Ks value may be evaluated to assess water flow and solute transport at the site, RRR.

- Data collected with the pressure plate apparatus will be used to predict the hydraulic parameters for the empirical equations soil water retention curves described by van Genuchten, (1980). For this purpose, we intend to use the non-linear least squares optimization program, RETC, available from the USDA Soil Salinity Laboratory in Riverside, CA.

- SWR curves are then correlated with soil salinity at the varying depths for each of the four fields in the project, e.g. ECe and SAR.

- Complete a regression analysis of established Ks values with those predicted by the same parameters in the RETC program.

Red Rock Ranch IFDM
Sequential Re-use, 4 stages (640 acres, 260 ha)

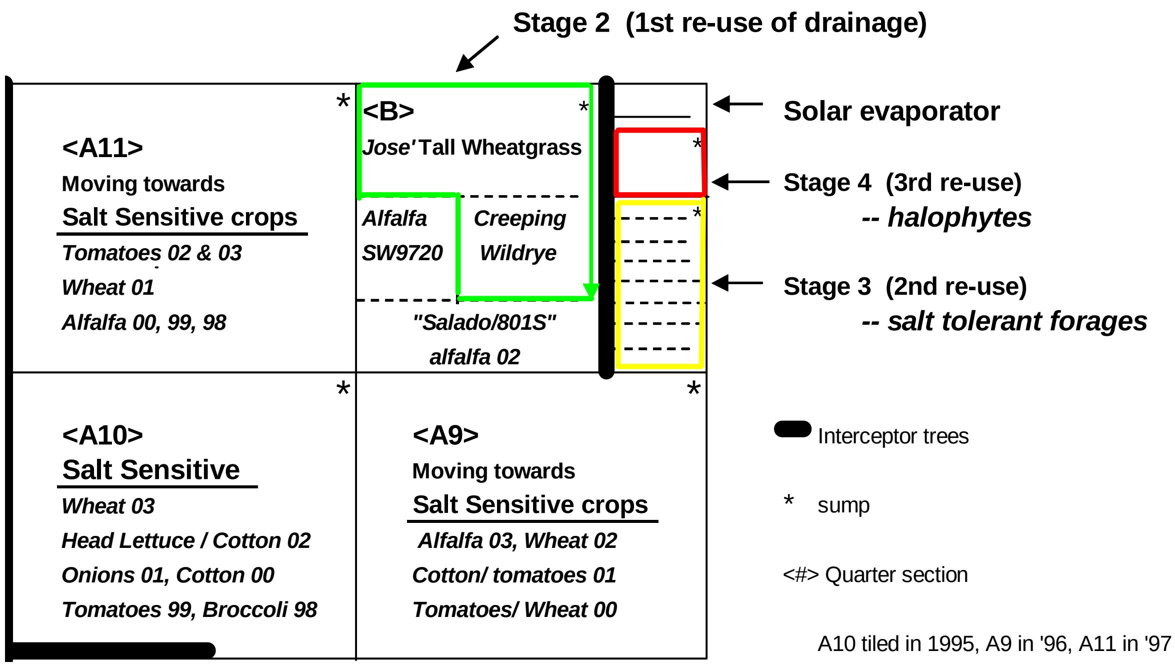

Figure 1. A map of Red Rock Ranch on the Westside of the San Joaquin Valley in Five Points, California. Fields A9, A10 and A11 (Stage 1) receive fresh water irrigation. Tile drains collect the drainage water from each field for its use in each subsequent stage.

Table 1. Average pH, EC and SAR with standard error.

Field Location	Depth (cm)	pH	ECe (ds/m)	SAR
A Stage 1	30	**7.3** 0.04	**3.61** 1.01	**17.98** 1.64
A Stage 1	90	**7.6** 0.13	**7.05** 1.88	**21.05** 2.10
B Stage 2	30	**7.4** 0.13	**15.50** 2.80	**26.23** 5.11
B Stage 2	90	**7.5** 0.20	**18.05** 0.71	**33.38** 2.79
C Stage 3	30	**7.3** 0.14	**20.34** 1.41	**34.50** 1.14
C Stage 3	90	**7.2** 0.13	**18.14** 1.59	**29.11** 4.98
D Stage 4	30	**8.4** 0.05	**35.88** 4.18	**76.10** 2.51
D Stage 4	90	**8.3** 0.16	**27.88** 0.79	**49.03** 5.70

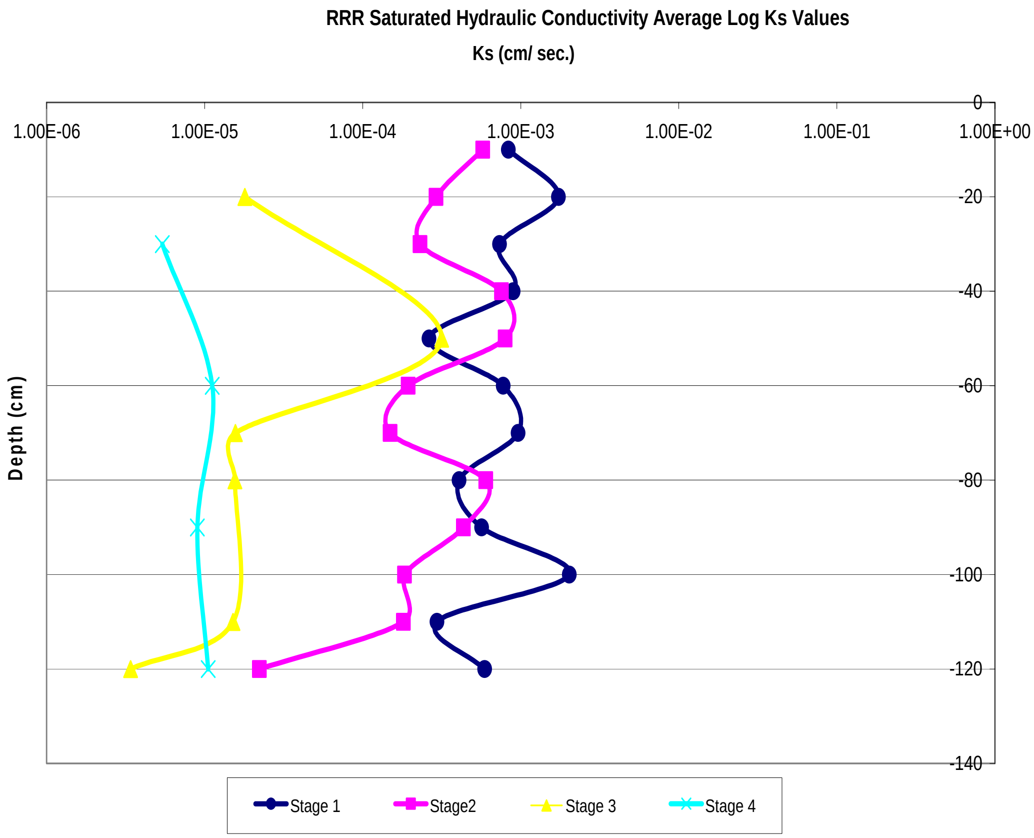

Figure 2. Log Ks changes over all four stages.

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