Accumulation of Soil Salinity in Landscapes Irrigated with Reclaimed Water

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Abstract

The long-term use of reclaimed water for landscape maintenance and the effects on soil chemistry and soil structure were investigated. Irrigation with reclaimed versus potable water for five years or more affects chemical properties of soil. Soils irrigated with reclaimed versus potable water had higher EC. Monsoon precipitation had less of a leaching effect than anticipated and significantly reduced EC only on two out of 13 sites. Soils irrigated with reclaimed water had higher SAR values than those irrigated with potable water and can potentially develop infiltration problems in the future. Contour maps of the EC for three depths of one site as measured by soil samples and EC as predicted by EM38 measurements for pre- and post-monsoon sampling times were developed.

Introduction

This project addressed the long-term use of reclaimed water for landscape maintenance and the effects on soil chemistry, soil structure, and plant performance. Reclaimed water availability is increasing in Arizona and it is likely that greater quantities of reclaimed water will be used for landscape maintenance. Reclaimed water generally has higher salinity than potable water and unless adequate leaching fractions are used, salts will accumulate in the root zone of plants. Potential problems of using irrigation water with higher salinity are a deterioration of soil quality, including increasing soil salinity, accumulation of specific ions, increasing sodicity, and decreasing soil permeability and water infiltration. These conditions can cause damage to many commonly used landscape plants that are sensitive or only moderately tolerant of saline and sodic soil conditions.

Materials and Methods

Seven sites in urban landscapes irrigated with reclaimed water for five or more years were identified in the Tucson area in Pima County, Arizona. Six sites in nearby urban landscapes irrigated the previous five years or longer with potable water were identified to serve as control sites. Selected areas of each landscape site were surveyed with a handheld EM38 conductivity meter (Geonics Ltd., Mississauga, Ontario, Canada) and vertical and horizontal conductance of the soil was recorded.

Soil samples were collected to calibrate the EM38 readings and to produce a salinity profile of the area surveyed. Between six to ten soil samples, each with three sub-samples at 0-10 cm, 10-25 cm and 25-40 cm depth were collected per site. A total of 174 soil samples were collected, 85 before the summer rains (6/15 - 7/17/2006), and 89 after the summer rains (9/11 – 9/25/2006). Textural properties, soil moisture, and chemical composition (EC, pH, Na, K, Cl, Ca, Mg, and sodium adsorption ration (SAR)) of each of the sub-samples were determined.

EM38 readings and results from soil analyses were used to generate horizontal and vertical profiles of soil salinity for selected sites. Analysis of variance was used to compare soil chemical properties of sites irrigated with reclaimed versus potable water. Regression and correlations were calculated to determine the relationship between EM38 readings and soil physical and chemical properties.

Results and Discussion

Physical soil properties The landscape soils surveyed in this study were highly variable in composition because they are generally constructed from disturbed natural soil after construction. Samples varied in the amount of gravel (particle size >2 mm) which ranged from 15% to 43%. Moisture in soil samples was highly variable due to the varying irrigation schedules at the different sites, the presence or absence of emitters at individual sample points, and precipitation. Pre-monsoon moisture averaged by site ranged from 3.5% to 22.4% and post-monsoon moisture ranged from 4.9% to 19.8%. Overall, moisture percent was higher post-monsoon compared to pre-monsoon, but values differed by site. The summer rains as reported by AZMET for Tucson were 16.6 cm (6.3 inches) between the dates of the last pre-monsoon and the first post-monsoon sampling. A total of 4.1 cm (1.6 inches) precipitation was recorded during the pre-monsoon sampling time.

Chemical soil properties Analyses of the chemical properties of soil samples showed considerable variability between sites and water source and soil depth for most parameters measured as well as the pre- and post-monsoon sampling times. The average pH of samples from various sites ranged from 7.6 to 8.4. All chemical characteristics measured except for K were affected by the quality of irrigation water (Table 1). Compared over all sites, EC was 1.8 dS/m in soils irrigated with potable water and 3.2 dS/m in soils irrigated with reclaimed water. Our hypothesis was that EC would be lower post-monsoon compared to pre-monsoon, especially in the upper soil surface because we expected salts to be leached by the rains into the lower soil depths. This occurred on five of the six sites irrigated with potable water and on four of the seven sites irrigated with reclaimed water (Fig. 1). On one site (12R) EC values were the same before and after the summer rains and on the other sites EC increased from pre-monsoon to the post-monsoon sampling. A number of factors including general site variability and variability in rainfall received at each site could have affected these results.

Sodium, chloride, and SAR changed based on the water source and by soil depth (Table 1, 2). In soils irrigated with reclaimed water, sodium, and chloride were found in greater abundance and SAR almost doubled with increasing soil depth. Soils irrigated with potable water had SAR values just below 4.0 pre-monsoon and post-monsoon with one exception (Fig. 2). Samples near the surface had significantly ($p<0.05$) lower SAR values than those at greater depths for sites 5P, 13P, 6R, 7R, 9R and 12R. Pre- and post-monsoon samples were significantly different for sites 1P and 3R, but SAR changed little on the other sites when comparing pre-monsoon and post-monsoon values. The high SAR values of some sites irrigated with reclaimed water point to the risk of creating increasingly impermeable soils at a depth where roots of trees and shrubs would be expected to grow.

Our analyses show that irrigating with reclaimed versus potable irrigation water for five years or more affects chemical properties of soil. We found great variability in chemical soil characteristics between sites which are likely due to irrigation management, cultural practices, and site history. We documented a greater accumulation of salts in soils that were irrigated with reclaimed versus potable water as expected. Monsoon precipitation had less of a leaching effect than anticipated and significantly reduced EC only on two out of 13 sites. SAR values of soils irrigated with reclaimed water were higher than those irrigated with potable water and in some cases these soils may develop infiltration problems in the future.

EM-38 measurements Conductivity measured with the EM38 varied greatly since it is dependent on both moisture percentage and soil salinity. Average vertical conductivity values for each site ranged from 9 to 91 pre-monsoon and from 15 to 108 post-monsoon. Figure 1 shows contour maps of the EC for three depths of one site as measured by soil samples and EC as predicted by EM38 measurements for pre- and post-monsoon sampling times. Significant positive correlation coefficients were found for post-monsoon EC values and vertical and horizontal conductivity readings of sites treated with potable and reclaimed water. Pre-monsoon EC of sites irrigated with reclaimed water was positively correlated with soil moisture, and vertical and horizontal EM38 readings. Further analysis of the data will evaluate uses and limitations of the EM38 for estimating soil salinity in urban landscapes.

Table 1. Significance (p-values) of main effects of type of water, time of sampling, and sample depth and interactions of all factors on soil chemical characteristics.

Variable	Water (W)	Time (T)	Depth (D)	Significant Interactions (P<0.05)
EC	0.0001	-	-	-
Mg	0.001	-	-	-
K	-	-	0.02	-
Ca	0.002	-	-	W*T
Na	0.0001	-	0.008	W*D
Cl	0.0001	0.048	0.0001	W*D
SAR	0.0001	-	0.0001	W*D

Table 2. Interaction effects between water source and soil depth on Na, Cl, and SAR.

Water	Soil depth	Na (ppm)	Cl (ppm)	SAR
Potable	1	120	162	1.7
	2	120	141	2.3
	3	135	148	2.8
Reclaimed	1	210	308	3.0
	2	305	372	5.0
	3	357	417	5.9

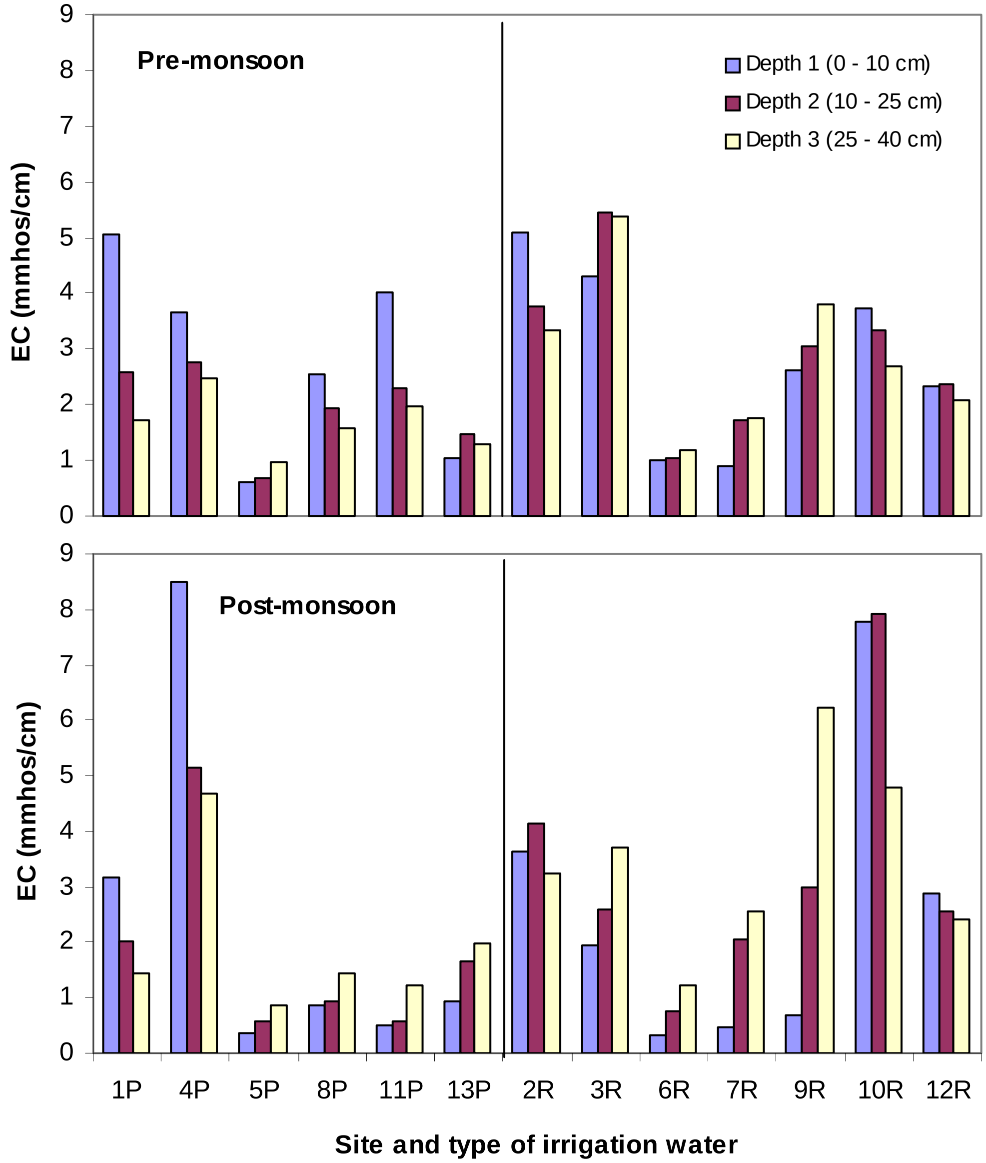

Fig. 1. Average electrical conductivity (EC) of soil from sites irrigated with potable (P) or reclaimed (R) water and measured before and after the monsoon at three different depths.

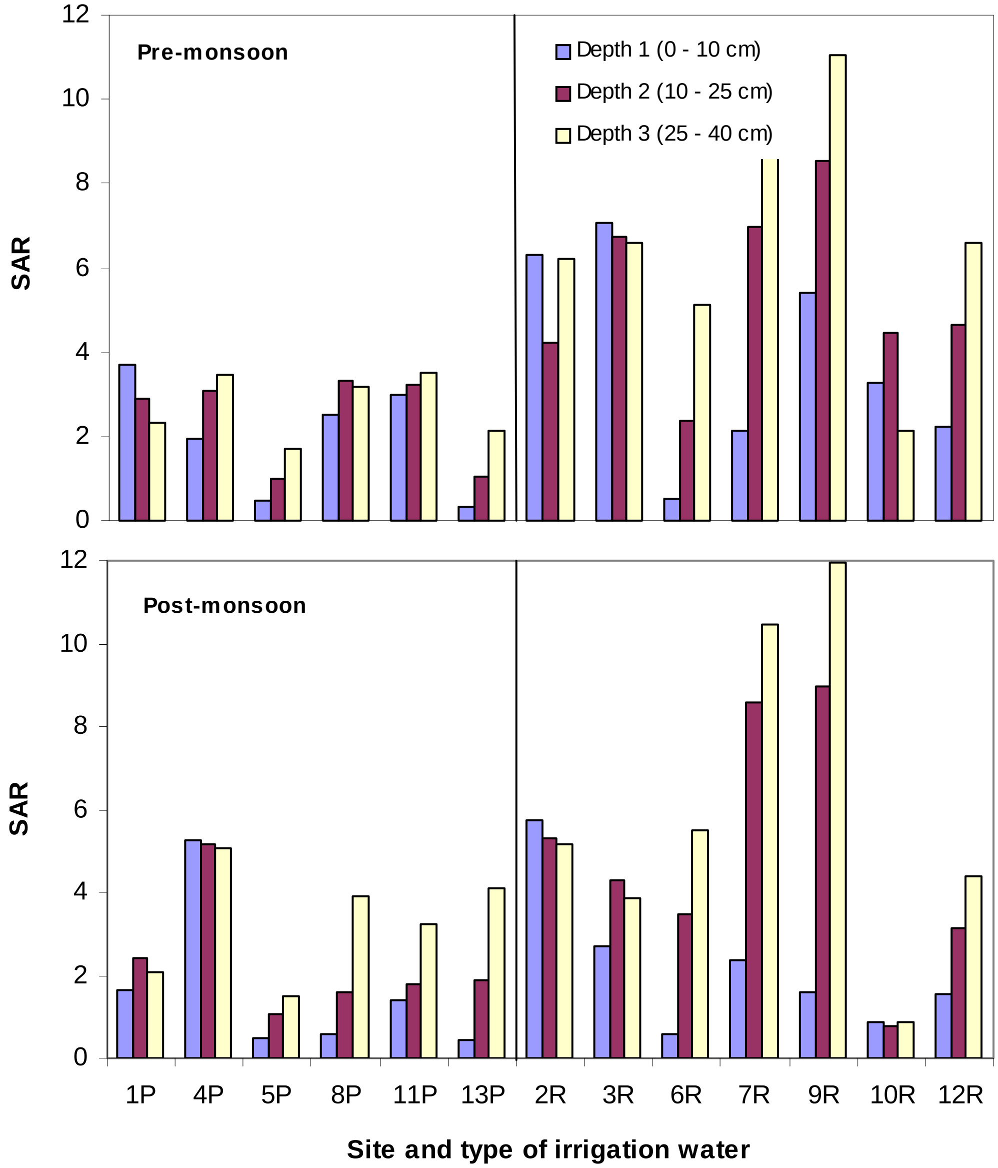

Fig. 2. Average sodium absorption ratio (SAR) of soil from sites irrigated with potable (P) or reclaimed (R) water and measured before and after the monsoon at three different depths.

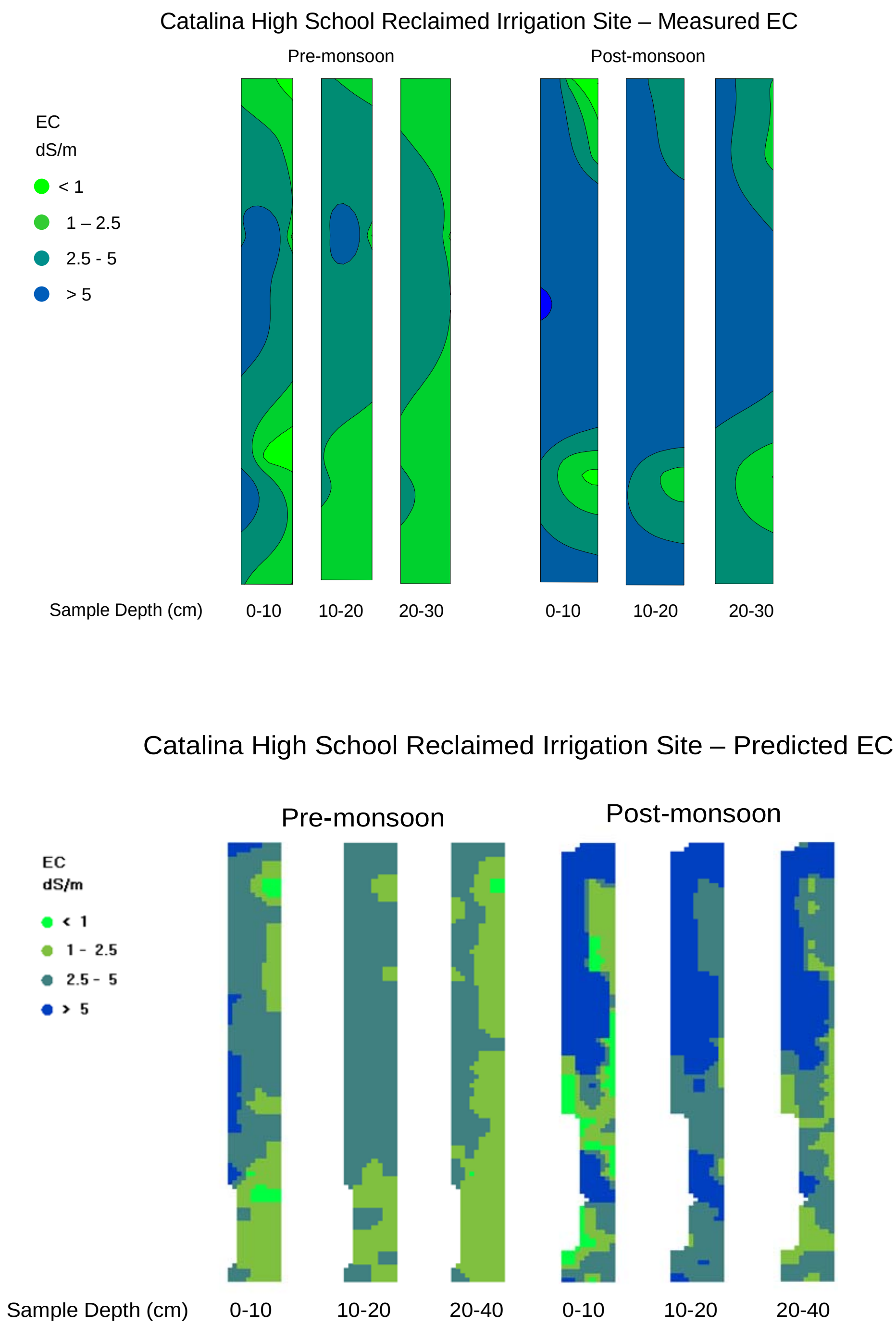

Figure 3. Contour maps of EC for three depths of one site as measured in soil samples (top) and EC as predicted by EM38 measurements (bottom) for pre- and post-monsoon sampling.