EVALUATION OF SOIL SALINITY CONDITIONS IN CALIFORNIA CENTRAL COAST WINEGRAPE VINEYARDS

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ABSTRACT

Soil salinity conditions in the winegrape vineyard areas of the California Central Coast were assessed by regional surveys of surface soils over multiple years, and by comprehensive evaluations of deeper salinity profiles at select locations. The multiple-year survey indicated that salinity conditions were increasing significantly, during a period characterized by below-average rainfall for the region. The survey also indicated that salinity conditions were at levels which would be expected to lead to measurable reductions in vine growth or yield at those vineyards where levels exceeded the mean values. The evaluation of the deeper salinity profiles indicated that salt accumulations at relatively shallow depths, potentially within the vine root zone, were occurring at some locations. These deeper soil salinity conditions were highly variable by location, and hence occasional on-site assessments of deeper salinity profiles will be important to determine if irrigation management practices are effective in preventing deleterious salinity accumulations.

INTRODUCTION

In the relatively dry irrigated winegrape areas of the California Central Coast, soil salinization is increasingly being recognized as an important factor in the successful and sustainable cultivation of winegrapes. This region utilizes irrigation water exclusively sourced from groundwater, which can be of marginal quality due to elevated levels of sodium and other ions. The irrigation practices normally utilized with these winegrape vineyards, including the extensive use of precision drip irrigation systems and the broad use of substantial deficit irrigation regimes, lead to very efficient water use and the production of marketable, high-quality winegrapes. However, these same irrigation practices do not achieve leaching of the salts which are unavoidably applied with the irrigation water. Where natural leaching with rainfall is limited and no additional intentional leaching with sprinkler or drip irrigation systems is utilized, the soil salinity levels can increase markedly relative to uncultivated soils to the point that vine growth and production can be negatively affected.

The purpose of this project was to characterize the current and developing soil salinity conditions in the winegrape regions of the Central Coast, focusing primarily on the large winegrape production area east of the city of Paso Robles.

METHODS

In the fall of 2006 soil samples were collected from 100 vineyards in the area east of Paso Robles. At each site, 15 cores were taken randomly along one vine row and bulked together, and from this a sub-sample was taken for analysis. Each core was one foot deep; this depth was sampled because it has the largest proportion of active roots under these drip irrigation systems during the bulk of the irrigation season, which often runs from late spring to late fall. In the fall of 2007 and again in the fall of 2009, the same sampling was repeated in an identical manner at all 100 locations, which were located again using the GPS coordinates recorded in 2006. The soil samples were oven dried and analyzed for EC_e, pH, Ca^{2+}, Mg^{2+}, Na^+, Cl^-, HCO_3^-, CO_3^{2-}, and the Saturation Percentage by the UC ANR Analytical Laboratory. The Sodium Adsorption Ratio and Exchangeable Sodium Percentage were subsequently calculated from the lab results. Any changes in the soil salinity parameters in the 2007 and 2009 season samplings compared to the 2006 sampling were evaluated using Repeated Measures ANOVA with StatMost™ software (Dataxiom, Inc.). Mapping of soil salinity characteristics was done using kriging techniques with Mapviewer™ software (Golden Software, Inc.).

In the late spring and summer of 2010, detailed assessments of the soil salinity distribution both laterally and with depth in the soil profile were made at seven vineyards. Four of the vineyards were at locations identified as having elevated salinity levels in the above mentioned regional salinity survey, while three more were in winegrape vineyards of Santa Barbara County. Soil cores were taken at one-foot increments down to eight feet deep, at locations in the vine row, in the row middle, and halfway between these two areas (the wheel track zone). Soil samples were analyzed for EC_e, pH, Ca^{2+}, Mg^{2+}, Na^+, Cl^-, HCO_3^-, CO_3^{2-}, and the Saturation Percentage by the UC ANR Analytical Laboratory. Additionally, irrigation water samples for the four Paso Robles area sites were analyzed for EC_w, pH, Ca^{2+}, Mg^{2+}, Na^+, Cl^-, B, HCO_3^-, and CO_3^{2-} by the UC ANR Analytical Laboratory. The distribution of soil salinity components as a soil cross-section was estimated with the inverse-distance interpolation using Mapviewer™ software (Golden Software, Inc.).

RESULTS AND DISCUSSION

The summary results of the survey of surface soils from the 100 vineyard locations are presented in Table 1. The values indicate the mean of the 100 samples for that year. Repeat-Measure ANOVA results comparing the following samplings to the 2006 sampling are indicated with asterisks (P<0.05 = *, P<0.01 = **)

Table 1. Summary soil salinity levels from the regional surveys

Parameter	*2006*	*2007*	*2009*
EC_e (dS/m)	2.23	2.51 **	2.80 **
pH	7.34	7.30	7.31
Na^+ (meq/L)	9.07	11.05 **	11.50 **
Cl^- (meq/L)	3.34	4.40 **	3.35
SAR	3.52	4.21 **	4.08 **
ESP	25.2	26.8	27.2

These results indicate that as of the baseline 2006 sampling date, electrical conductivity conditions were on average near the threshold value of 2.5 dS/m where yield declines would be observed (Christensen et al, 1978). Depending upon the rootstock used, declines in vine growth and yield can occur when EC_e values are as low as 1.8 dS/m (Walker et al, 2002). The very high levels of the Exchangeable Sodium Percentage indicate the high levels of sodium relative to other cations in these soils; this is due to the constant addition of sodium through the irrigation water, which itself is most commonly dominated by sodium and bicarbonate, and due to the naturally low potassium levels of the area soils.

Importantly, the 2006 sampling followed the very wet winter of 2004/2005, which was the second wettest winter on record since 1952; thus the soils were in a relatively leached condition when the 2006 sampling was conducted. The winter of 2006/2007 was the second driest on record since 1952, and it is unlikely that much if any natural leaching with rainfall occurred. Thus, the 2007 sampling indicates the potential annual increase in salinity parameters, absent any significant natural leaching. The results indicate that highly significant increases in the most important soil salinity parameters of EC_e, Na^+, Cl^- and the calculated SAR occurred. The two subsequent winters were also drier than average, with limited natural leaching conditions. Relative to the 2006 baseline, the 2009 sampling also indicated highly significant increases in fundamental salinity parameters.

The spatial distribution of 2009 ECe levels are shown in Figure 1; the areas with the most elevated soil salinity values generally correspond to vineyards utilizing relatively poorer quality irrigation water.

The 2010 sampling of the eight foot deep transects across the vineyard rows demonstrated that soil salinity conditions at depths below the surface are reaching levels of concern in some locations. In Figure 2a, the soil electrical conductivity for the most impacted site is presented as a cross-section diagram with interpolated estimations of values in between the 24 sampling points; Figure 2b, the exchangeable sodium levels, show similar patterns as the EC_e. Some common themes of the deeper salinity patterns are visible in these charts.

The shallow soil directly beneath the vines benefits from some leaching of salts with the drip irrigation, and hence has moderate salinity levels. As depth increases beneath the vines, salinity levels increase, reaching maximum levels at depths of about five or six feet. This depth corresponds to a soil layer with high levels of clay in many of these alluvial soils in the region; this clay layer impedes downward water drainage and hence salts tend to accumulate near that depth. Figure 2d shows that the clay layer was slightly shallower at this site, mostly at a depth of four to five feet.

Salts also move laterally from the irrigation application point across the soil profile, but then are subject to limited further leaching with the drip irrigation system. Thus, very elevated salinity levels occur in the “wheel track” area of the row middles, both near the surface and at depths of five to six feet. Such lateral, near-surface movement of water will be higher in soils which have their infiltration rates impacted by high sodium content.

The surface soil layers in the row middle (the location farthest away from the drip emitters) are not be wetted by the drip irrigation applications, and thus likely represent closely the salinity levels of the native soil prior to vineyard development. However, at depths of five to six feet the salinity levels were more elevated, likely due to lateral movement of salt-laden soil moisture in the clay horizons.

Boron levels as shown in Figure 2c tend to be elevated in that portion of soil that has been exposed to current-season wetting by irrigation. The relative lack of boron accumulation deeper in the soil is likely a result of the greater mobility of the boron anions to move in the leaching fraction, and thus winter rainfall amounts may be sufficient to prevent boron from accumulating in the soil depths measured in this sampling. The irrigation water analysis for this site is shown in Table 2; this location is using relatively poor quality irrigation water for the area.

Table 2. Well water analysis from 2010 site with highest salinity; as applied to the vineyard

pH	EC (dS/m)	SAR	Ca (meq/L)	Mg (meq/L)	Na (meq/L)	Cl (meq/L)	B (mg/L)	HCO3 (meq/L)	CO3 (meq/L)
7.8	1.81	4.6	3.40	5.96	9.93	6.39	0.93	4.8	<0.1

SUMMARY

This study has indicated that 1) current soil salinity levels in some vineyards of the Paso Robles area are sufficient to lead to measurable reductions in vine growth and yield; 2) that these salinity levels increased significantly over three years with below-average rainfall, and 3) that salinity accumulations at lower soil depths, both in the vine rootzone and deeper, can be at very elevated levels at sites with high irrigation water salinity and limited soil leaching.

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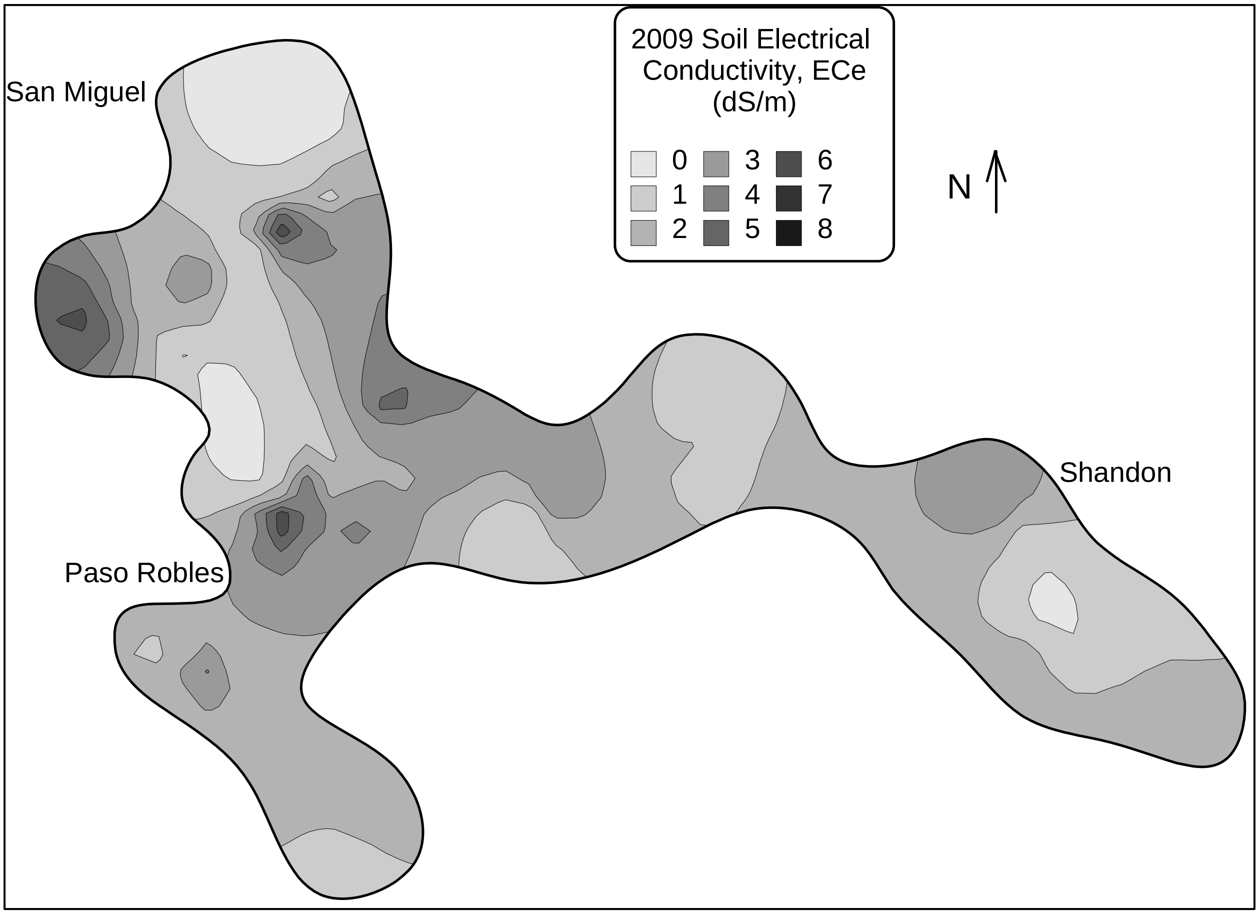
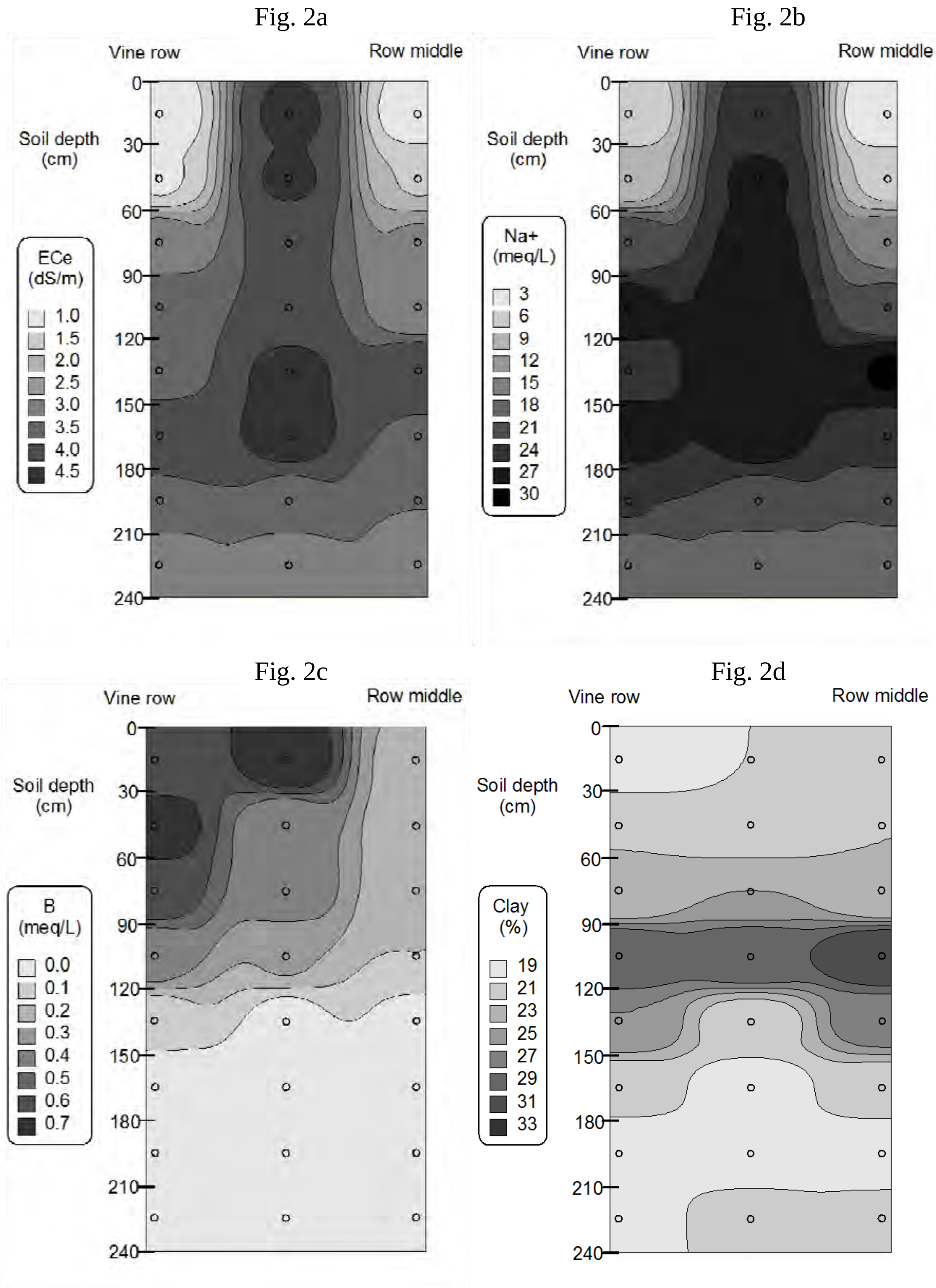


Figure 1. Spatial distribution of the soil electrical conductivity as measured in the 2009 sampling throughout the 100 vineyard locations east of Paso Robles, CA. Samples were collected in the vine row, at a depth of 1 foot.



Figures 2a-d. The soil EC_e, exchangeable sodium, extractable boron, and percentage clay, as vine row soil cross-sections at the 2010 site with the highest salinity levels. Drip irrigation is applied only in the vine row. Each 30 cm depth increment is equivalent to 1 ft. The distance between the vine row and row middle was 4 feet at this location.

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