Characterization of Spatial and Temporal Variability in Soil Salinity in Relation to Alfalfa (*Medicago sativa* L.) Productivity

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INTRODUCTION

Drought and competing water demands from municipal and environmental sectors necessitate the use of saline water sources for irrigation in California, especially for forages and row crops. Alfalfa (*Medicago sativa*) is a valued forage for dairy production in California because of its high yields, digestibility and protein content. The objective of this study was to examine the spatial variability of soil salinity imposed by saline irrigation in a field trial comparing alfalfa varieties for salinity tolerance and to develop the relationship between soil characteristics and alfalfa yield, and the ability to detect cultivar by salinity effects in the field

METHODOLOGY

Thirty-five alfalfa cultivars, including new salt-tolerant materials, were tested in a 3-year field trial in a clay loam soil, under saline, sub-surface drip irrigation. **Two irrigation water treatments (high saline (HS) = 8-10 dS/m and low saline (LS) = 0.3-1.0 dS/m EC_w)** were applied to field plots in a split-plot design with salinity as the main plot and variety as the sub-plot factor with four replications. Soil sampling (0-180 cm in 30 cm increments) was conducted in late spring and fall each year. The alfalfa was cut 7 to 8 times each year and shoot Na+, K+ and B were measured for selected cuts (data not shown).

Assessment of the spatial variability in soil salinity imposed by the saline-sodic irrigation was critical for a fair comparison of variety salt tolerance. Soil surveys were conducted using an EM38-MK2 electromagnetic induction sensor after each of four harvests (April, July, August & September) in the last growing season (2020). Ordinary least squares (OLS) regression was utilized to build the model for the correlation of the sensor-based (ECa) data to actual soil salinity (ECe) of soil samples collected after each survey. Bootstrapping statistics were performed to obtain the model coefficients for the ECa to ECe conversion with an R^2 value of 0.90, root mean squared error (RMSE) of 1.64 and mean absolute error (MAE) of 1.27. **The multilevel regression model was built to predict natural log transformed (ln) ECe over time using ECa, clay content, gravimetric water content (GWC,) and X and Y coordinates**

$$\ln(EC_e) = \beta_{0\,j,t} + \beta_1 X + \beta_2 Y + \beta_3 Clay + \beta_4 GWC + \beta_5 \ln(EC_a)$$

DATA

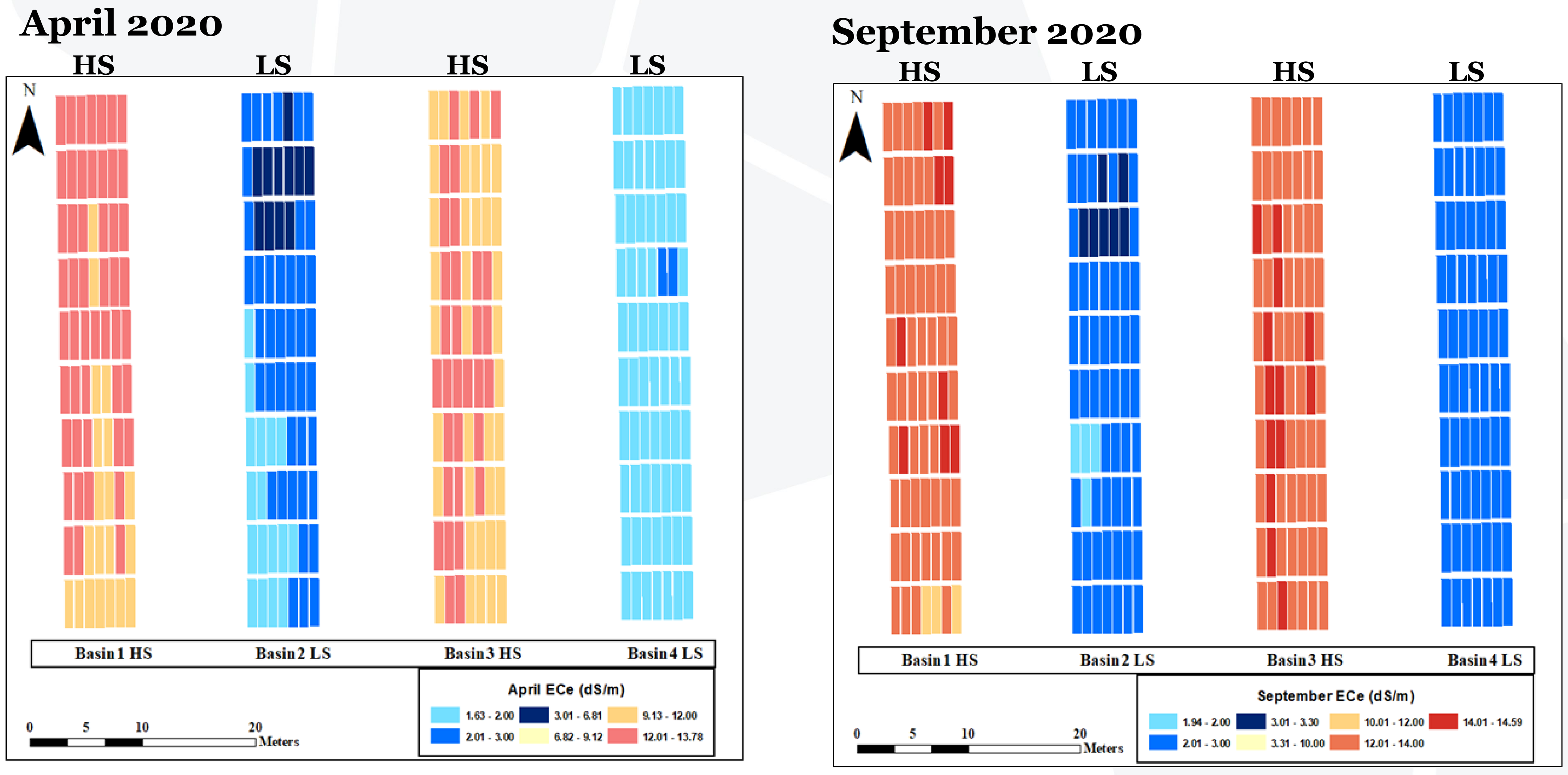

Fig 1. EM38-derived spatial map of predicted soil salinity (ECe) in LS or HS-irrigated basins in April (left) and September (right) of 2020 (third year of saline irrigation). Blue colors indicate low salinity. Orange, and red colors represent high salinity areas. Individual rectangles in each basin correspond to the 35 variety plots (0.91 x 4.6 m) in each of two blocks per basin.

Table 1 (below). Gravimetric soil water content (GWC), saturation percentage (SP) and soil salinity (ECe) for the ground-truthing samples collected after each EM38 survey. Data are averages for the 0-90 cm for samples taken in 30 cm increments. N=6

EM-Survey	Profile data	High Salinity		Low Salinity	
		Basin 1	Basin 3	Basin 2	Basin 4
APRIL	GWC (%)	21	21	18.5	17.7
	SP (%)	60.5	58.2	54.6	51.6
	EC_e (dS/m)	**12.5**	**12.3**	**2.6**	**1.9**
JULY	GWC (%)	20.1	17.4	14.6	15.2
	SP (%)	59.5	58.6	55	51.4
	EC_e (dS/m)	**12.8**	**12.6**	**2.4**	**2**
AUGUST	GWC (%)	21.3	20.8	16.7	13.6
	SP (%)	59.8	60.3	55.1	50.2
	EC_e (dS/m)	**12.6**	**13.7**	**2.8**	**2.2**
SEPTEMBER	GWC (%)	23.1	22.6	18.7	17.5
	SP (%)	59.8	59.5	55	52
	EC_e (dS/m)	**14.2**	**14.2**	**2.5**	**2.4**

Table 2 (below). Pearson's correlation coefficients for the relationship between ECe, clay content, and dry matter yield (DMY) for the September 2020 harvest. **= significance at *P* = 0.01.

	ECe (dS/m)	Clay (%)	DMY
ECe (dS/m)	1		
Clay (%)	0.805**	1	
DMY	-0.730**	-0.615**	1

Table 3 (below). Root zone salinity (ECe, 0 – 150 cm) and Cumulative Yield for 7 to 8 cuts per year (2018 to 2020) for alfalfa grown under low (LS) and high salinity (HS) irrigation. Yields are averages for the 35 varieties tested

Year	Root Zone ECe (dS/m)		Shoot DMY (MT/ha)		Yield loss
	LS	HS	LS	HS	
2018	2.12	7.45	27.6	21.5	22%
2019	1.58	9.89	32.3	25.8	20%
2020	2.12	12.51	33.0	22.9	31%

RESULTS

- Gravimetric soil water content (GWC) for HS basins was 4-5% higher than for LS basins during every survey (Table 1), possibly due to reduced water uptake and alfalfa ET under HS irrigation.
- Clay content was ~higher in the HS basins (44.6 - 47.3%) as compared to the LS basins (40.7 - 45.2%) (data not shown) and was therefore incorporated into the model used for the ECa to ECe calibration.
- Spatial maps of predicted ECe revealed considerable spatial and temporal variability in soil salinity within the experimental basins (Fig. 1).
- Pearson correlation coefficient analysis was significant for the predicted ECe and clay content and the September dry matter yield (n=280) (Table 2).
- Cumulative yield loss of the HS-irrigated alfalfa was 22% and 20% for the first two years, but increased to 31% in the third year (2020) when the average rootzone soil salinity (0 to 150 cm) was 12.5 dS/m ECe (Table 3)

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CONCLUSIONS

- Field trials are the "real test" for varieties improved/selected for salt tolerance, but variability in soil salinity can confound such studies, esp. under saline-sodic conditions

- Spatial analysis using EM38 soil surveys can provide accurate prediction of soil salinity throughout the experimental field provided that adequate ground-truthing is conducted and soil moisture is not limiting.

- Multi-level modelling approaches can account for soil factors other than salinity that influence ECa readings and improve the ECa to ECe calibration.

- Multi-variate statistical approaches combined with these modeling approaches have potential to allow for yield comparisons in variety trials where uniform soil salinity cannot be established. - Our yield data support research by Cornacchione and Suarez (2015) suggesting that improved varieties of alfalfa are much more salt tolerant than the established guidelines (yield loss threshold of 2 dS/m ECe) would suggest.

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SALT-AFFECTED SOILS

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