FORAGE PRODUCTION AND SOIL RECLAMATION USING SALINE DRAINAGE WATER

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INTRODUCTION

In semi-arid or arid locations, salinity can become a problem for farmers who irrigate crops (Hillel, 2000). This is the case in the western San Joaquin Valley of California where soils are naturally saline and where the presence of shallow, saline water tables threatens crop production. Without a means to dispose of drainage water in the western San Joaquin Valley, increasing amounts of farm land will become salt impaired. The use of underlying groundwater and limited numbers of evaporation basins for disposal of the large volume of drainage water produced is not sustainable. A multi-disciplinary team has assembled to test the hypothesis that saline-sodic drainage water can be used in an environmentally sound manner for forage and livestock production. The goal is to use salt tolerant forages to support economic weight gain by cattle or sheep, or for sale to dairies and other cattle feeding operations. If economic forage and livestock production can be based on the reuse of drainage water or other waste waters in the San Joaquin Valley, this unused water will be transformed from an environmental burden into an economic asset. The amount of water that must be disposed to groundwater or in evaporation ponds will be reduced dramatically. Other economic and environmental benefits associated with irrigated pasture also will be realized.

The study's objectives are to:

1. Measure forage biomass accumulation, nutrient and trace element uptake, and the quality of salt tolerant forages produced using saline-sodic drainage water.
2. Monitor the mineral status and general health of cattle and measure the growth rate of cattle fed or grazing forages produced with drainage water.3. Quantify the effects of saline-sodic drainage water on overall water use, drainage water quantity and quality, salt and trace metal balances, soil organic matter, and soil chemical and physical properties over time.4. Model changes in important soil chemical, physical and biological properties at the local and field scale.
5. Develop economic models for drainage water reuse on forages.

This paper reports forage quality and yield data to date.

METHODS

An 80 acre site near Stratford in Kings County was developed to study the use of drainage and other waste waters for the production of forages and cattle. The site had been abandoned for annual crop production and was saline and highly variable. The site was leveled and tile drains were installed at a depth of 4 feet, 120 feet apart. A detailed baseline soil assessment for soil

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physical and chemical properties was done before the project began in summer 1999. Soils were characterized initially for chemical and physical properties using electromagnetic induction techniques followed by directed soil sampling. All survey work was done with GPS mapping and soil sample site locations were determined using ESAP software (Lesch et al., 2000, 1995). A second, similar survey was carried out in March 2003 to assess changes in the same soil properties. Bermuda grass (*Cyanodon dactylon*) was planted on the site in 1999, and the site was divided into 8 paddocks, each approximately 8 acres in size, to facilitate rotational grazing. In four of the paddocks, the cultivar Giant was planted to facilitate hay making, and in the other four, common Bermuda grass was planted. Livestock trials were carried out for three years (2001-2003), but grazing has continued through 2004. Regular forage sampling occurred at soil sample and other locations during the grazing season. Forages were cut to 2 to 3 inches in height when sampled. After drying, samples were analyzed for quality and mineral content. Additional samples were collected each year by stratifying samples by height. Samples were divided into three levels(top, middle, and bottom) and quality parameters were compared with average values for the combined sample. Continuous monitoring (water volume) and automated sampling (for EC_w) of irrigation and drainage water has been carried out in four of the eight paddocks using automated sampling equipment since irrigation was initiated in 2000. Livestock performance and health were monitored for three years (2001 to 2003) but these data are not reported here.

RESULTS TO DATE

Selected soil chemical and physical properties were measured using electromagnetic induction techniques followed by directed soil sampling. A comparison of averages by depth of selected soil properties from the larger set analyzed is presented in Table 1. The Table compares values observed in 1999 before the project began and in 2003. Se, which is a problem in other parts of the western San Joaquin Valley, is deficient at this site. In the four years of irrigation and crop growth using moderately saline water, salinity related properties declined on average in the first two feet of the soil profile, while the lower two feet were largely unchanged.

The quality of irrigation water used is represented by data from 2002, which was typical for the first three years of the project's operation, is presented in Table 2. Salinity in irrigation water was variable and incorporated drainage water as it became available during the growing season and water from the Kings River. In 2003, water from the city of Lemoore's waste water plant and from a recently opened cheese factory also were used for irrigation as part of the mixture of waste waters applied. The leaching fraction observed was less than 10%, suggesting that most of the water applied was used by the grass crop. Runoff was negligible, but some loss to groundwater occurred that could not be measured in drain tiles.

Forage biomass and quality were measured at sites selected to reflect soil variation. Pastures were grazed rotationally throughout the 2001-2003 seasons by beef cattle. Bermuda grass grew well at moderate salinity levels but failed to produce where salinity (EC_e) exceeded 22 dS m^{-1} (fig. 1). Standing biomass amounts at the start of grazing during the warm months varied from approximately 1.5 mt dry matter per ha in paddocks withe cultivar *Giant*, to 2.5 mt DM per ha in paddocks with cultivar *Common* (fig. 2). Amounts varied because of differing times of year, fertilization, and grazing practices. Intake by cattle was less because grazing allowed for selection by the animals. Average forage quality values (hay equivalent) and the range observed during 2001, 2002, and part of 2003 are presented in Tables 3 to 5. For comparison, average values reported by the National Research Council (1989) are included. Data reported are for Bermuda grass hay equivalents. Cattle, however, removed 50 % or less of the standing forage biomass while grazing, selecting leafier and younger material preferentially (data not shown). During each season, a varying number of forage samples were collected and analyzed for quality by dividing the standing biomass by height into thirds. Differences in quality and mineral content were observed (fig. 3). Crude protein in the upper portion of the canopy was 20 to 30 % greater than in overall samples. Trace elements tended to be greater than in the younger leafier material, particularly B, and most minerals as well, with the exception of Na, which was much higher in the lower third of the grass canopy.

At this location, Mo, rather than Se is found in large amounts in some area of the pastures. Excess Mo can interfere with Cu metabolism in ruminants and may cause a range of adverse physiological effects. Generally, Cu:Mo ratios in ruminant diets below 3 or 4 are thought to lead affect cattle health but there is little formal research in this area (Suttle, 1991). On average, CU:Mo ratios are 5 to 6 or larger. No Mo toxicity has yet been observed in grazing cattle. But the tendency fo trace elements to be higher in the portion of the canopy selected by cattle when grazing suggests that cattle performance must be monitored for adverse effects when using saline drainage water as an irrigation source for cattle.

CONCLUSIONS

1. After 5 years of irrigation with moderately saline water, pastures remain are increasingly productive.
2. Salinity related properties in soils have declined in the upper profile, indicating that soil reclamation is occurring through the use of moderately saline water.
3. A large proportion of the irrigation water applied is being used by crops, reducing the amount of saline water for final disposal by 90%.
4. Beef cattle have been grazed on salt-affected pastures without apparent ill effects on livestock health and with acceptable rates of gain. Trace element imbalances in forages and cattle have been managed and were not a significant concern.

REFERENCES

Corwin, D., Kaffka, S.R.,Oster, J. R., Hopmans, J., Mori, Y., van Groenigen, J-W., and van Kessel, C. (2003). Assessment and field-scale mapping of soil quality properties of a saline-sodic soil. Geoderma **114:231-259.**

Hillel, D. 2000. Salinity Management for Sustainable Irrigation. The World Bank, Washington , D.C. 92p

Lesch, S.M., Rhoades, J.D., Corwin, D.L., (2000). ESAP-95 version 2.0 user manual and tutorial guide. Research Report No. 146, George E. Brown, Jr. Salinity Laboratory, Riverside, CA.

Lesch, S.M., Strauss, D.J., Rhoades, J.D., (1995). Spatial prediction of soil salinity using electromagnetic induction techniques: 2. An efficient spatial sampling algorithm suitable for multiple linear regression model identification and estimation. Water Resour. Res. 31, 387-398.

National Research Council, 1989. Nutrient Requirements of Dairy Cattle. National Academy Press, Washington, D.C.

Suttle, N. F., 1991. The interactions between copper, molybdenum, and sulphur in ruminant nutrition. Ann. Rev. of Nutrition., 4:121-140.

Table 1. Selected average soil properties in 1999 and 2003.

Variable	0 to 1 ft		1 to 2 ft		2 to 3 ft		3 to 4 ft	
	1999	*2003*	*1999*	*2003*	*1999*	*2003*	*1999*	*2003*
EC (dS/m)	13.0	11.4	20.2	17.5	22.5	22.5	25.2	24.3
pH	7.6	7.67	7.58	7.87	7.63	7.87	7.57	8.03
Cl (meq/L)	21.8	18.3	35.3	30.2	47.1	30.2	58.7	55.6
SAR	28.2	23.5	51.4	40.3	59.0	40.3	64.9	57.5
B (mg/L)	17.0	14.2	19.0	19.1	17.5	19.1	17.9	21.7

Table 2. Irrigation water quantity and quality (2002).

Value	Irrigation volume (inches per event)	Drainage volume (inches per event)	Irrigation water (EC_{iw}) (dS/m)	Drainage water (ECdw) (dS/m)	Leaching fraction
Average	3.5	0.1	3.6	33.9	0.06
Range	3.2 to 3.9	trace to 0.2	2.0 to 8.0	30 to 40	0.05 to 0.08

Table 3. Bermuda grass forage quality under saline condition (2000-2003).

Variable	*n*	*Mean*	*Median*	*SD*	*SE*	*Max*	*Min*	*NRC**
N (%)	414	1.43	1.42	0.36	0.023	2.58	0.67	1.92
P (%)	414	0.18	0.18	0.036	0.002	0.34	0.10	0.20
K (%)	414	1.63	1.60	0.40	0.020	3.41	0.76	1.70
Ca (%)	414	0.41	0.40	0.11	0.005	0.77	0.19	0.32
S (mg kg^{-1})	236	15430	5470	1093	72.1	9450	2670	---
Na (mg kg^{-1})	414	5026	4400	3210	158	23920	530	---
Mn(mg kg^{-1})	414	89.6	84.0	31.0	1.52	234	34.0	---
Fe (mg kg^{-1})	414	386.5	243.5	466.0	22.9	4714	78.0	---
Mg (%)	414	0.193	0.180	0.60	0.003	0.56	0.10	0.16

* hay, sun cured (29-42 days growth)

Table 4. Bermuda grass forage quality under saline condition (2000-2003).

Variable	*n*	*Mean*	*Median*	*SD*	*SE*	*Max*	*Min*	*NRC**
CP (%)	414	10.7	9.9	3.78	0.186	22.1	4.2	12.0
ADF (%)	414	29.6	29.4	3.03	0.149	42.3	20.7	38.0
NDF (%)	414	60.4	60.4	4.01	0.197	71.2	40.8	76.0
Ash (%)	414	10.4	9.3	3.34	0.165	24.1	5.8	10.0

* hay, sun cured (29-42 days growth)

Table 5. Bermuda grass forage quality under saline condition (2000-2003).

Variable	*n*	*Mean*	*Median*	*SD*	*SE*	*Max*	*Min*	*NRC**
Zn (mg kg^{-1})	414	27.3	26.0	8.49	0.414	58.0	12.0	---
B (mg kg^{-1})	414	245.3	209.0	131.7	6.48	1004	73.0	---
Cu (mg kg^{-1})	414	7.34	7.10	1.79	0.088	14.4	3.4	---
Mo(mg kg^{-1})	414	1.44	1.2	0.95	0.047	5.30	0.3	---
Se (µg kg^{-1})	129	84.9	84.0	47.3	2.31	328	10.0	---

* hay, sun cured (29-42 days growth)

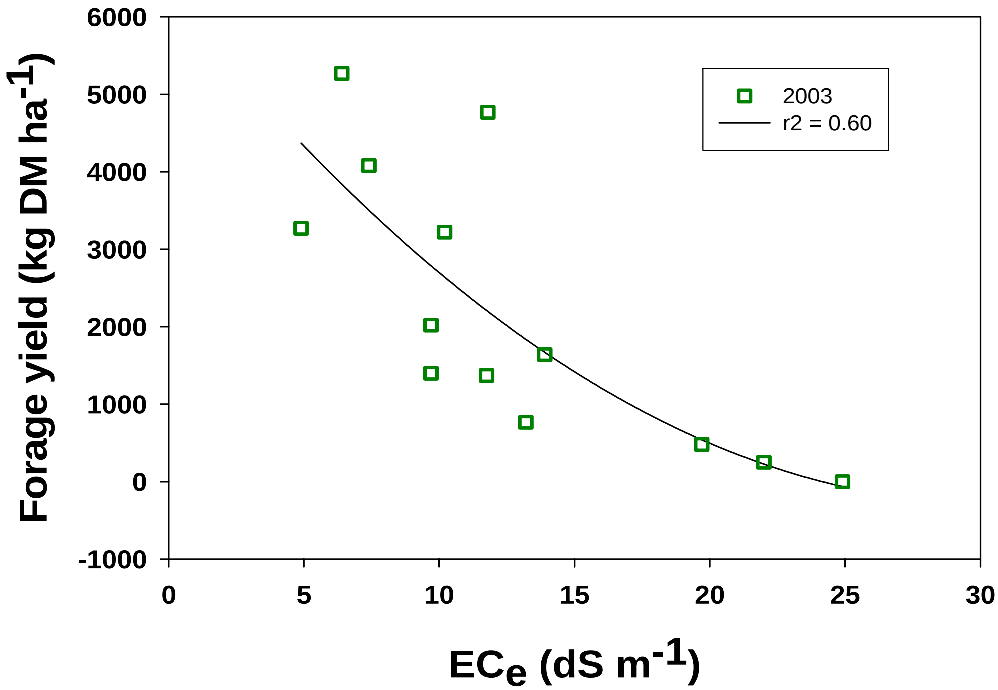

Fig. 1. Forage yield as a function of soil salinity (2003 data)

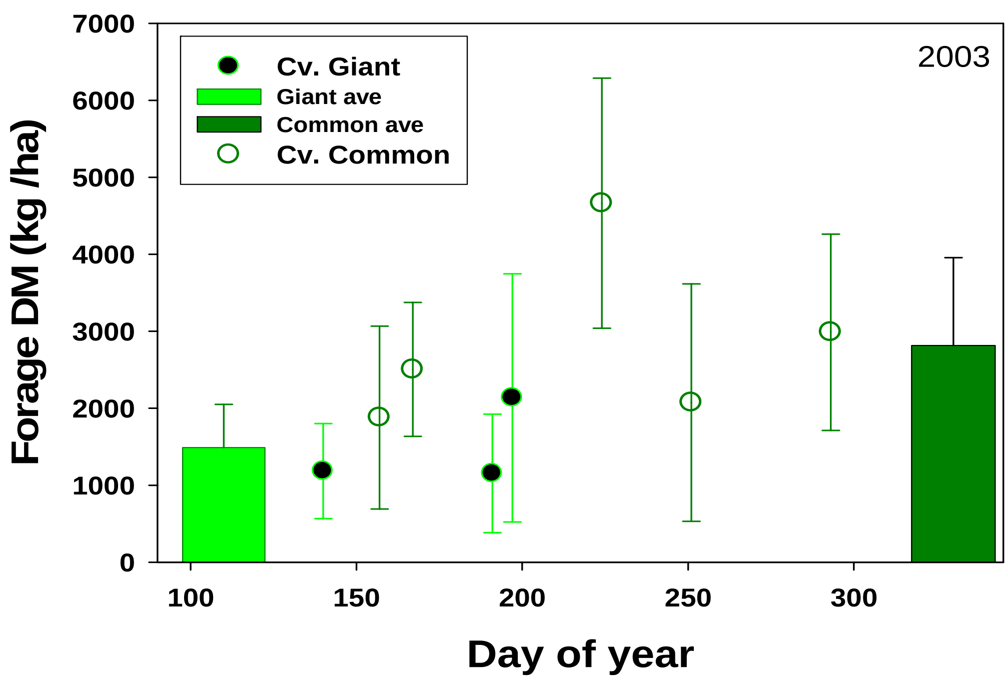

Fig. 2. Yields of *Giant* and *Common* Bermuda grass at the start of grazing and overall season-long average yields for each cultivar.

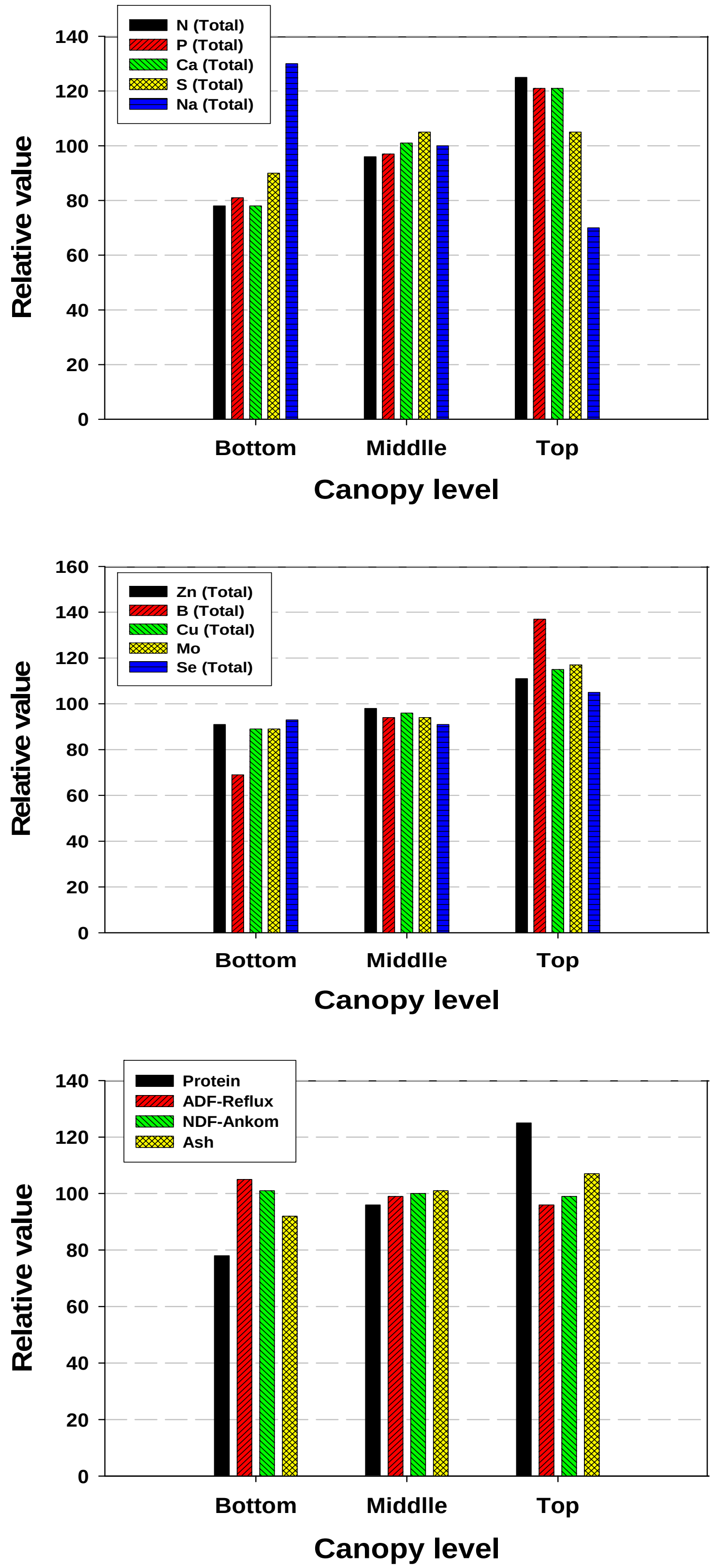

Fig. 3. Relative forage quality values by canopy height.