Modelling yield and quality of Bermuda grass irrigated with saline drainage water

M Alonso[1], **D Corwin**[2], **S Kaffka**[1], **John Maas**[1]
[1]University of California, Davis
[2]University of California, Riverside, USA

Introduction

The western San Joaquin Valley (WSJV) has large areas with shallow, saline water tables. At low lying sites salt in shallow water tables limits crop choice, reduces productivity, and may lead to land abandonment. The amount of land affected in this way is reported variously to be between several hundred thousand to more than 200,000 ha depending on the rainfall. To farm these areas subsurface drainage is required, but agricultural drainage water often contains trace elements such as Se that can harm wildlife or Mo that may affect ruminant performance (Suttle, 1991; van Schilfgaarde, 1990; Deverel et al., 1984; Deverel and Fujii, 1988; Deverel and Millard, 1988; Fujii and Deverel, 1989; Fuji and Swain, 1995).

Current practices for the disposal of saline drainage water in the WSJV are not sustainable. A limited amount of drainage water is returned to the San Joaquin River in the northern San Joaquin Valley, but the amount is subject to real-time monitoring for Se concentrations, which must decline with time to comply with standards (ANON, 2004). In other locations (primarily in Kings County) a limited area of evaporation ponds is available. These are a concern because of potential harm to shore birds that use them for feeding and nesting (Skorupa, 1998). Other alternatives such as land retirement and waste water treatment are not economically sound at the moment. The reuse of drainage water may be the most suitable alternative for growers who currently rely on natural drainage to dispose the excess water.

Profitable livestock production based on forages irrigated with saline drainage water would transform drainage water from an environmental burden into an economic asset, and would help alleviate the shortage of forages in the region (Corwin et al., 2003; Kaffka et al., 2004; Robinson et al., 2004). The suitability of forages for reuse systems, however, will depend upon their production potential under saline-sodic conditions and the nutritional quality of the resulting forage (Grattan et al., 2004a, b; Grattan et al., 2002). The physiological mechanisms of salt tolerance in most halophytic plants involve, at least partly, the ability to take up and accumulate relatively large concentrations of salt in their tissues (Gorham et al., 1985). Since salinity and trace metals occur together in soils and drainage water in the WSJV, trace elements will accumulate in plants and may threaten livestock and human health (Grattan et al., 2004a, b; Grattan et al. 2002; Zurayk et al., 2001; Suttle, 1991).

Bermuda grass is considered a moderately salt-tolerant species (Maas and Hoffman, 1997). There are several studies on Bermuda grass yield and quality (Overman, 1988; Overman and Wilkinson, 1989 and 1992; Overman and Scholtz, 2002), but simple extrapolation from other studies is of limited value to conditions in the WSJV where climate and soil types differ, and there is high level of salts and trace elements.

The objective of this study was to evaluate the potential of using saline drainage water to irrigate Bermuda grass used for beef cattle production in the WSJV.

Materials and method

The study site is located on Westlake Farms (latitude 36° 11’ 24.827” N, longitude 119° 52’ 45.455” W), in Kings County on the west side of California’s San Joaquin Valley. The soil at the Westlake Farm site is part of the Lethent clay loam series (fine, montmorillonitic, thermic, Typic Natrargid, USDA, 1986). The site is a 32.4-ha field laser leveled and divided in 8 similar paddocks. Tile drains were installed at 1.1 m depth on each side and in the center of each paddock. In 1999 instrumentation was installed to monitor drainage water flows and quality on the central drain in paddocks 2, 3, 6, and 7.

Additional details of the site preparation and experimental design can be found in Kaffka et al. (2002).

Bermuda grass (*Cynodon dactylon (L.) Pers.*) was established in fall 1999 and spring 2000. Two varieties were planted; Giant, a hay type in paddocks 1 to 4, and Common, a pasture type in paddocks 5 to 8. ESAP software (Lesch et al., 2000) was used to identify all sampling locations within the 32.4 ha site. Soil and forage samples have been collected primarily from these locations since fall 1999 to the present. Soil samples were collected at the same locations and analyzed for salinity, fertility and trace elements (Corwin et al., 2006). During each grazing season, a subset of the forage samples collected were harvested by dividing the standing biomass by height into thirds and analyzed separately for nutritional content. Livestock trials were carried out for three years (2001-2003). Pastures were grazed rotationally by beef cattle from May to November during these years. Weights, condition scores, blood and liver samples were collected before and after grazing.

In 2007 a surface renewal station (CR-1000 Measurement and Control System, by Campbell Scientific Inc.) was installed in paddock 7 to monitor ETc of the pasture. We used ETo values from a CIMIS station located approximately 3 miles from the site in Stratford, and the RS-Excel software developed by Snyder (2006) to estimate the Kc values for the pasture. In the same year a greenhouse trial was establish at UC Davis to determine Bermuda grass growth rate under different soil salinity and nitrogen levels. 48 pots of 56.8 l were filled with soil collected at the field site. The soils corresponded to three salinity levels: 7, 14 and 24 dS/m. The pots were seeded with Bermuda grass on May 2007 and irrigated with 2 l of a saline water solution of 6 dS/m 2-3 times a week. The fertilization regime was equivalent to 0, 150 and 300 kg N/ha. The pots were harvested every 4-6 weeks to estimate the crop growth rate (r) under different conditions.

Specific crop parameters (Kc, r & leaf/stem ratio, [B], [Mo] & [Se]) along with soil (ECe, [B], [Mo] & [Se]), irrigation and drainage water (volumes, ECiw, ECdw, [B], [Mo] & [Se]) and atmospheric variables (precipitation & ETo) were used in a model formulated in Stella® to estimate forage yield and quality in saline-sodic conditions. Soil salinity was estimated through the balance of total dissolved solids (TDS) in the soil, irrigation and drainage water, and leaching fraction. Crop growth was described by a logistic equation adjusted by the potential yield, the soil nitrogen level, and the intrinsic growth rate of the crop. Crop quality was predicted by the leaf/stem ratio and the concentration of B, Mo and Se in the harvested biomass throughout the growing season. Average monthly weight gain and stocking rate for beef cattle were estimated based on dry matter (DM) and energy balance.

Results

Results to date have demonstrated the viability of using forages and livestock production for the disposal of saline drainage water and other wastewaters (Kaffka et al., 2004). Soil and forage quality are either improving or remaining constant, suggesting that these practices will be sustainable.

From 2000–2004 using moderately saline water for irrigation (ECiw range: 3.6 to 10 dS/m), salinity related properties declined on average in the first two feet of the soil profile, while the lower two feet were largely unchanged (Corwin et al., 2006). Salinity in irrigation water was variable with multiple sources used: saline drainage water as it became available during the growing season supplemented with better quality water from the Kings River. In 2003, water from the city of Lemoore's waste water plant was also used for irrigation as part of the mixture of waste waters applied. The pasture received from 3 to 5 irrigations of 90 mm per season followed by a drainage event of 2.8 mm. ECiw was 3.6 dS/m and ECdw was 33.9 dS/m. 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.

Soils in the study site vary over the range from 6 to 24 dS/m ECe. Bermuda grass grew well at moderate salinity levels but failed to grow where salinity (ECe) exceeded 22 dS/m. Standing biomass amounts at the start of each rotational grazing period varied from approximately 1.5 mt DM/ha in paddocks with the cultivar Giant, to 2.5 mt DM/ha in paddocks with cultivar Common. Average forage quality values were: N(%): 1.43; P(%): 0.18; K(%): 1.63; Ca(%): 0.41; Mg(%): 0.193; Na(mg/kg): 5026; B(mg/kg): 245.4; Mo(mg/kg): 1.44; Se(μg/kg): 84.9; Cu(mg/kg): 7.34; CP(%): 10.7; ADF(%): 29.6; NDF(%): 60.4 and Ash(%): 10.4. Differences in quality and mineral content between different forage height fractions were observed. Crude protein (CP) in the upper portion of the canopy was 20 to 30% greater than in overall samples. Trace elements tended to be greater in the younger leafier material, particularly B, with the exception of Na, which was much higher in the lower third of the grass canopy.

Intake by cattle was 40 to 60% of standing biomass, depending on variable stocking rates and management. Unsupplemented average daily gain (ADG) was 0.75 kg/d in year 2003 when the stocking rate averaged about 1 AU per 0.4 ha. ADG's were lower in years 2001 and 2002 at higher stocking rates.

The model reasonably simulates Bermuda grass yield and quality in a saline-sodic soil irrigated with saline drainage water. Predicted ADG and stocking rate coincide with the values observed at the site. The model is being adapted for use by farmers at other locations to predict forage and livestock production based on available weather data (precipitation and ETo) and field scale measurements of soil salinity (ECe).

Data collected to date demonstrate that cattle will tolerate grazing forages grown on salt affected sites irrigated using saline drainage and other waste waters, and that soil quality can be maintained. The data provide a range of estimates of Bermuda grass growth and quality under varying grazing intensity. The tendency for 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. Simulation modeling will allow estimates of potential performance by livestock at other locations and salinity conditions.

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