Assessing the Salinity Threat to Sustainable Irrigated Cotton Production in the Lower Gwydir and Macintyre Valleys

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ABSTRACT

Worldwide, the incidence of soil and water salinisation is increasing. This is particularly the case in irrigated agricultural regions and potentially in Australia's intensively irrigated cotton-growing areas. This paper describes a broad scale approach to estimate this threat in the cotton growing areas of the lower Gwydir and Macintyre valleys using baseline soil and water information and a steady-state soil and water balance model. Results suggest with the current water quality and soil types, irrigated cotton production appears to be sustainable. Using the geostatistical method of indicator kriging and several 'worst case' scenarios in the model, areas that are at risk if saline water is used for irrigated agriculture are identified.

Introduction

Irrigation with moderate to highly saline and\or sodic water can create problems in the root-zone. Application of saline water leads to increased salinity in the seedbed if leaching of salts is insufficient. Where deep drainage is excessive, shallow water tables may be created, resulting in concentrations of salts through capillary rise. Information on the spatial distribution of current soil and water resources is required to determine possible long-term sustainability of irrigated agriculture in a particular area. When coupled with soil-water balance models this can give realistic estimates of soil salinity build-up and deep drainage beyond the root-zone.

A number of models have been developed, including the steady-state leaching requirement model of the US Salinity Laboratory (1954) and SODICS, a transient mass balance model (Rose *et al.*, 1979). Each requires a small number of input parameters, the former assuming steady state while the latter requires chloride data at different times to estimate deep drainage. Owing to the large area of irrigated cotton production in Australia, a simpler model requiring only rudimentary soil data would be more appropriate. The so-called Salt and Leaching Fraction Model (ie. SaLF) was developed by Shaw and Thorburn (1985) for this purpose and is based on the assumption that deep drainage relates to hydraulic conductivity that is influenced by clay content and mineralogy (Cation Exchange Capacity/Clay %) and exchangeable sodium percentage (ESP). These variables, water quality and crop parameters are entered in the empirically based model that predicts deep drainage (DD in mm/year) and average root zone EC_e (dS/m) at steady-state.

This paper shows how the SaLF model and data generated from a broad-scale soil and water survey are used to assess the current status of soil salinity and the potential threat due to the application of poor water quality in the lower Gwydir and Macintyre valleys of northern New South Wales, Australia.

Materials and Methods

The lower Macintyre and Gwydir valleys soil formed primarily from alluvial clay depositions of basaltic origin. The profiles are clay rich and fertile and in combination with warm to hot temperatures, make the area suitable for irrigated agriculture. Soil was sampled at 120 locations in the lower Macintyre, mainly in irrigated cotton fields from Goondiwindi in the east to Mungidi in the west, and 153 sites in the lower Gwydir valley near the townships of Moree in the east and Collarenebri in the west (Fig. 1). At each site, six samples were collected at depths: 0-0.1, 0.3-0.4, 0.6-0.7 and 1.1-1.2 m. The soil was analyzed for clay content and cation exchange capacity (CEC) using the method of Tucker (1974) and Holmgren *et al.*, (1977). Water was surveyed in the lower Gwydir valley to assess the current water quality. Similar water quality for the Macintyre valley is assumed.

Results and discussion

The suitability of water for irrigation depends on crop, climate, soil, irrigation and water quality (Rhoades *et al.*, 1992). Despite this, a general statement can be made that the average EC_w in the Gwydir valley is 0.435 dS/m and is within acceptable limits for irrigation (ie. <0.7 dS/m) (Table 1). The samples collected also fell beneath critical values of <3 $mmol_c$/l for sodium and <3 meq/l for chloride with Sodium Adsorption Ratio's (ie. SAR) less than 3 making them all non-sodic.

The water quality and soil information was used in conjunction with the SaLF model to determine the current status of salinity in the root-zone with respect to an average water salinity of 0.44 dS/m. Each of the 273 sites were entered into the program along with the measured attributes of clay content and cation exchange capacity at depths of 0-0.1, 0.2-0.3, 0.6-0.7 and 1.1-1.2 m, and exchangeable sodium percentage at 1.2 m. We also assumed that at each site average rainfall is 584 mm and 600 mm of irrigation water is applied annually. In order to determine the effects of applying progressively more saline water with respect on increasing soil salinity and deep drainage we also simulated scenarios in which water with EC_w of 1.4 (slightly saline), 4.0 (moderately saline) and 9.0 dS/m (moderate-high salinity) were applied at each site.

Figs. 2 and 4 present the distribution of estimated average root-zone EC_e (dS/m) and deep drainage (mm/year) generated by SaLF at steady state. The simulation using the current water quality of EC_w 0.44 dS/m suggests it is sustainable for irrigated cotton production since average root-zone salinity across the valley would be 0.64 dS/m. This value is well below an average EC_e of 4.0 dS/m at which susceptible crop species are affected (eg. beans) and well below the value to affect wheat (ie. 6.0 dS/m) and cotton (ie 7.7 dS/m). Similarly, if slightly saline water (EC_w 1.4 dS/m) were applied, average root-zone salinity would be 1.6 dS/m that would also have negligible effects on susceptible crops. If EC_w of 4.0 was applied, some crop management could be necessary (ie. selection of tolerant crops), since the salinity level within the root-zone would approach concentrations that may reduce yields of sensitive crops by perhaps 5 % (ie. 3.3 dS/m).

If on the other hand an EC_w of 9.0 dS/m was applied, susceptible crops could possibly still be grown with reasonable success if suitable crop, soil (e.g. seed-bed design) and\or irrigation management (i.e. method of application) were adopted. However, soil types of a heavy clay nature, irrigated cotton production should theoretically be uninhibited by an EC_e of 5.96 dS/m, although for rotation crops such as wheat, these levels may cause some reduction in yield.

The soil or areas at risk if only saline water was available (i.e. EC_w 9 dS/m) for irrigation can be shown using a geostatistical method known as indicator kriging. Triantafilis and McBratney (1986) previously showed how this method can be used to prepare probability maps. For example, if average EC_e exceeds 4.0 dS/m we can anticipate there will be a high probability (i.e. 1) that some loss in production will occur if sensitive crops are planted. The probability map illustrated in Figure 3a shows areas where soil salinity could be expected to be greater than this critical level in the lower Macintyre and Gwydir valley. Figure 3a also suggests that at steady state, the application of EC_w 9.0 dS/m would most likely result in approximately 30 % of the land irrigated (i.e. dark shaded area with probability of 0.9-1) with this water would have an average soil salinity greater than 4.0 dS/m and may result in some yield reduction if no soil or water management were carried out, particularly on sensitive crops.

Unlike the more sensitive crops, moderately tolerant wheat and cotton crops would probably not be as severely restricted by the salinity levels in the soil when the moderate to high EC_w 9.0 dS/m is used (Fig. 3b). What is more clearly apparent is the areas least likely to be affected as illustrated by the white areas in Figure 3b (i.e. probability < 0.5). The reason appears to be that the soil is slightly sandier, due to the closer proximity of these areas to the current Macintyre and Gwydir River floodplains and prior stream channels. Consequently, fewer soluble salts are stored in the profile and are more likely to have been leached. However, with the increased electrolyte concentrations, soil permeability is also improved, leading to increase deep drainage.

Using progressively more saline water would result in a steady increase in deep drainage (Fig. 4). For the most part, excessive deep drainage is limited to only a few soil profiles but it is of concern in some clayier soil types where leaching fraction would increase to about 10-25 % if a moderately high saline water were applied. This has implications for the creation of rising water tables and water logging and also soil salinity since deep draining salts may resurface.

Conclusions

The work described here is based on simulations generated from an empirically based model and samples collected on a 2.5-5 km grid in the lower Macintyre and Gwydir valleys. The results suggest that using the water quality currently available for irrigation should not result in rising levels of soil salinity nor excessive deep drainage. In considering the worst case scenario of moderate to highly saline water (i.e. EC_w of 9.0dS/m) the resulting levels of soil salinity may be economically sustainable using a combination of suitable crop, soil or irrigation management. What may be of more concern is excessive deep drainage, as simulated here, and the potential for shallow saline water-tables to develop.

Acknowledgments

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Table 1. Water quality attributes of some samples collected in the lower Gwydir valley.

Location	Water Course	EC_w (dS/m)	Chloride (meq\l)	Na+ (mmol $_c$/l)	SAR
Moree	Mehi River	0.44	0.57	1.13	0.96
Combadello Bridge	Mehi River	0.42	0.57	1.19	1.04
Hickey Bridge	Mehi River	0.47	0.55	1.34	1.11
Mallowa	Mehi River	0.51	0.63	1.44	1.15
Mogli Mogli	Mehi River	0.48	0.61	1.46	1.22
Collaernebri	Mehi River	0.44	0.52	1.32	1.18

Figure 1. Soil sampling sites located in the lower Macintyre and Gwydir valleys.

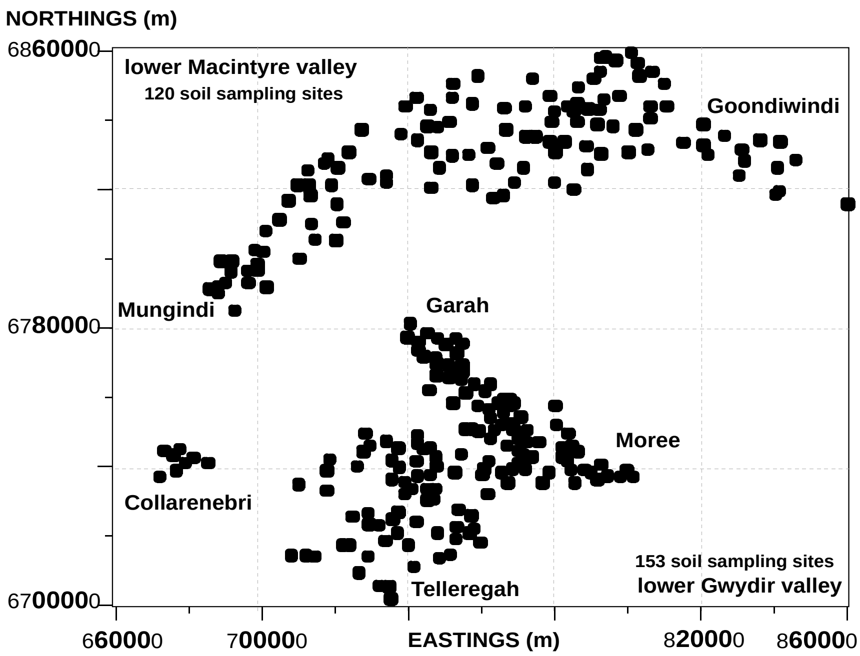

Figure 2. Histograms of estimated average root-zone salinity (dS/m) at steady state using SaLF and various EC_w water quality values.

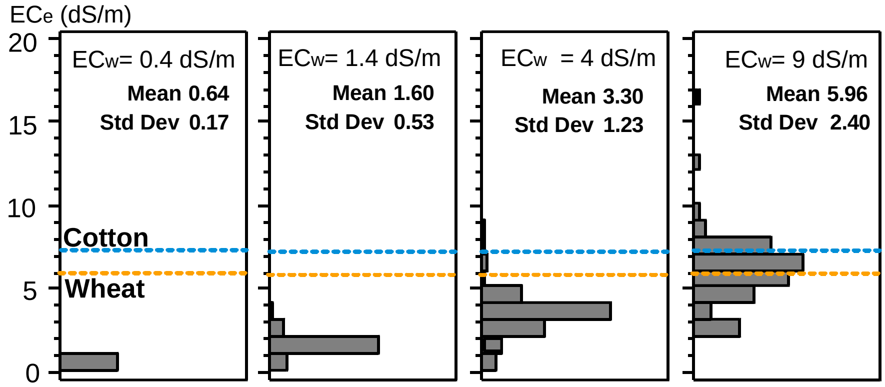

Figure 3. Indicator kriged maps of: a) **average root-zone EC_e > 4, and;** b) **average root-zone EC_e > 6 when water with an EC_w = 9 dS/m is applied.**

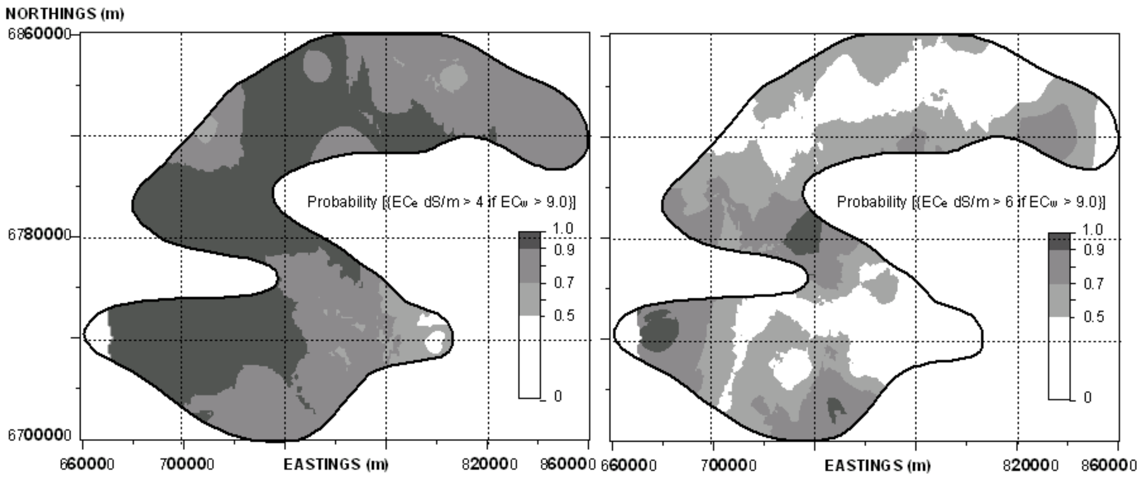

Figure 4. Histograms of estimated deep drainage (mm/year) at steady state using SaLF and various EC_w water quality values.