Addressing the Issues of Root Zone Salinity and Deep Drainage under Irrigated Cotton

Zischke, R. and Gordon, I.

Department of Natural Resources
80 Meiers Rd, Indooroopilly, Queensland
Australian Cotton Cooperative Research Centre, Narrabri

Introduction

Irrigation of cotton while substantially increasing yields, presents several new problems to the industry. Perhaps the most immediate of these is deep drainage, which in turn poses water use efficiency and groundwater pollution problems. Excess root zone salinity and soil structural problems due to irrigation should also be issues of great concern. There are many factors that contribute to the development of these problems, the most crucial of which is the irrigation water quality and the soil properties.

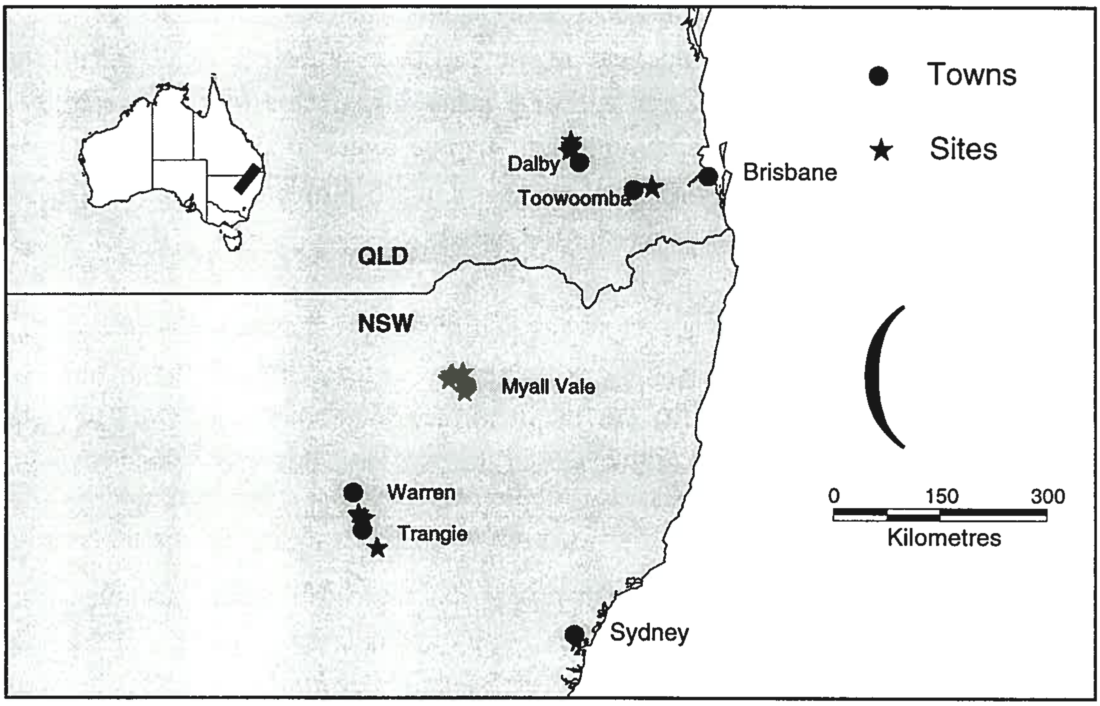
The expansion of cotton into areas such as the Darling Downs has seen the increasing use of higher conductivity, occasionally sodic groundwater for irrigation. With this trend set to continue, and with significant quality decline in surface waters predicted (MDBC Salinity Audit 1999), the need to investigate the extent of the problems this will cause is even more pressing.

Originally developed using mass balance principals, the SaLF model accounts for the effect of soil mineralogy and irrigation water quality on root zone salinity and drainage at steady state (Shaw and Thorburn 1985). Two sequentially completed projects, funded by the CRC cotton, assessed the accuracy and 'robustness' of the SaLF model as it was used to predict drainage and root zone salinity under cotton irrigation over a wide range of soils and climates. During this process, advantages and limitations of the model were revealed, with many interesting drainage and salinity predictions being generated. Some of these predictions were validated using measured drainage collected by large in-situ lysimiters while SaLF's estimations were also compared to those generated by two other models. Refinements were also made to the SaLF model including the addition of a 'sodicity correction', which adjusts the leaching fraction prediction based on a calculated reduction in permeability due to dispersion. The model was renamed Sodium SaLF (SSaLF) with this addition.

Methods

Soil Sampling

This project builds upon an initial soil and water sampling program undertaken in 1995 and 1996 for the purpose of validating the model Sodium SaLF. Thirty seven key sites were sampled on the Lockyer, Namoi and Macquarie Valleys and the Darling Downs (Map 1). These sites were further sampled in 1997 and 1998 to provide data on chloride and electrical conductivity levels over time.



Map 1 . Location of soil and water sampling

Selection of sampling sites was designed to give a range of soil types, variation of irrigation water quality (preference to ground water) and variation of irrigation practices in the majority of cotton growing regions in Queensland and New South Wales. Soil samples were taken from the irrigation sites with a known irrigation history and adjacent non-irrigated sites. For the purpose of validation it was preferable that the soils of the irrigated and non irrigated paired sites exhibited the same physical characteristics. This required that the soil samples for the paired sites were taken as close as possible to each other. Within the irrigated field, soils from the head-ditch and tail drain ends were analysed separately to gain some idea of within field variability, and to attempt to assess changes in soil chemistry due to variable infiltration.

Modelling

The SaLF (salt balance-soil property) was originally developed by Shaw and Thorburn in 1985 in order to capture the fact that soil mineralogy was one of the most critical factors determining the saturated hydraulic conductivity (Ks) of a soil. During this initial validation work at St George and in the Lockyer Valley, the effect of increased drainage due to high EC irrigation water was noted and a 'salinity correction term' was derived and added to the model. In the process of completing a PhD thesis, Shaw (1995) further developed the model using more advanced methods of regression.

The CRC (cotton) projects Irrigation Water Quality Guidelines, and Advancements in Irrigation Water Quality Guidelines involved the use of the soil property-salt balance model Sodium SaLF (SSaLF). The model was run on soils data collected from all unirrigated profiles for three of the four sampling years. From this model, a steady state estimate of leaching fraction and root zone salinity was obtained for each field. In order to assist in the validation of SSaLF, two other models were also run on the same data. These were SODICS, a transient mass balance model (Rose *et al* 1979), and a simple steady-state chloride mass balance model (USSL 1954). Additionally, actual drainage as measured by two in-situ lysimeters installed on the Darling Downs was also used to validate the drainage predictions of SSaLF.

Results

The results presented in table 1 below, are the averages of all predicted leaching fractions from each model for two fields per valley. The two fields sampled in on the Darling Downs in Queensland were both vertisols (dark grey/black cracking clays). Both fields sampled in the Lockyer Valley were vertisols , as was the Doreen field in the Namoi valley The Macquarie valley soils were generally lighter, especially the Nundah site, which had clay percentages less than 40%. The Belgammon site displayed highly sodic gradational soils.

Table 1: Irrigation Information and Predicted Deep Drainage for selected fields in 4 cotton growing areas in NSW and Queensland.

Area	**Property**	**yrs irr as of 1998**	**ave rain mm/yr**	**ave irrigation mm/yr**	**Irrigation EC dS/m**	**Predicted Flux mm/yr SSaLF**	**Predicted Flux mm/yr SODICS**	**Predicted Flux mm/yr USSL**
Darling Downs	Plains	20	664	450	1.5	81	145	145
Darling Downs	Maclee	23	664	420	4.1	290	367	358
Lockyer Valley	Moira (dam+bore)	27	786	457	1.1	165	112	108
Lockyer Valley	Moira (bore)	31	786	420	7.2	1009	597	628
Namoi Valley	Doreen	23	591	346	0.4	15	9	18
Namoi Valley	Belgammon	9	591	624	0.7	44	122	146
Macquarie Valley	Nundah	8	533	780	0.4	972	801	748
Macquarie Valley	Elengerah	11	533	685	0.5	51	61	61

Several aspects or advantages of SSaLF can be highlighted from the deep drainage estimates displayed in this table. Firstly, when looking at the results for the Darling Downs and Lockyer Valley, it can be seen that SSaLF predicts lower drainage where water of lower electrical conductivity is used for irrigation. This is due a 'correction term' component that was added to the model after its derivation by Thorburn and Shaw in 1995.

It was developed using the original soils data set that was used to develop the SaLF model, and accounts for the known effect of increased permeability due to increased electrical conductivity of the percolating water. This effect was shown to be linear up to water salinities of 3dS/m (Shaw and Thorburn 1985), after which it declined. This meant that when this correction term was applied to sites where high EC water was used than an overestimate of leaching fraction could occur. This is most probably the case for the 'Moira (bore) field in the Lockyer Valley.

The SaLF model was based on soils data from 766 non-irrigated sites. The data was provided by the collation of reports of soil surveys of Queensland agricultural areas. The soils were predominantly vertisols and alfisols (slowly permeable soils). In developing the model, Shaw (1995) identified the lack of data from soils with very low or very high clay contents as a limitation, and suggested a surface fitting approach with extra data as a way of improving the accuracy of SaLF. The inability of the current version of SaLF to predict accurately for lighter soils is the most probable explanation for the relatively high leaching fraction predictions at the Nundah site. The soils at this site grew furrow-irrigated cotton, even though they exhibited clay percentages of less than 40%. High drainage rates through such a soil may be expected, however if the SSaLF prediction of a 74% loss to deep drainage is accurate then this field may be considered unsuitable for furrow irrigation.

SSaLF appears to be one of perhaps a very limited number of models that take the effects of irrigation water quality in account when calculating drainage. As well as accounting for the effect of high EC water, the addition of the Suarez sodicity correction (Suarez 1981) into the SaLF model has now given the model the capacity to assess the effect on soil chemistry of high sodicity water. This predicted change in soil ESP is then fed back through the SaLF model to give an adjusted leaching fraction prediction. With the addition of Suarez correction SaLF was renamed to Sodium SaLF, which is abbreviated to SSaLF. If the water is high SAR but also high EC, then the floculation qualities of high electrolyte may maintain the stability of the soil The Belgammon site was irrigated with high SAR/low EC irrigation water which meant that the Suarez sodicity correction was triggered at this site, and the leaching fraction predictions were lower than site with similar soil types.

Very few sites sampled were estimated to be at steady state by the SODICS transient mass-balance model. However, estimations of deep drainage by the steady state mass chloride mass-balance model were similar to those predicted by SODICS, indicting that many of the sites were approaching steady state. What can be seen in table 1 is that where the two chloride models (SODICS and mass-balance) predicted high, so to did SSaLF. Where they predicted low, so to did SSaLF. Differences between the estimations of SSaLF and those of the other two models may be explained by several aspects of the SSaLF model, some of which have been discussed above. A more detailed account of the sampling regime, model predictions and similarities and disparities between these predictions are detailed in the project report Zischke and Gordon (2000) in press.

Lysimetry and Sodium SSaLF.

Table 2: Irrigation Information, measured chloride and nitrate fluxes, and measured and predicted drainage for two fields on the Darling Downs, Qld.

Sub-Surface Drip	**Irrigation (mm/yr)**	**Rainfall (mm/yr)**	**Total (mm/yr)**	**Drainage (mm/yr)** measured	**Leaching Fraction** measured	**Drainage (mm/yr)** predicted	**Leaching Fraction** measured	**NO3 flux** Kg/ha/yr	**Cl flux** Kg/ha/yr
96-97	150	478	628	305	0.49	38	0.06	691	4636
97-98	142	667	809	95	0.12	48	0.06	560	975
Furrow	**Irrigation (mm/yr)**	**Rainfall (mm/yr)**	**Total (mm/yr)**	**Drainage (mm/yr)** measured	**Leaching Fraction** measured	**Drainage (mm/yr)** predicted	**Leaching Fraction** measured	**NO3 flux** Kg/ha/yr	**Cl flux** Kg/ha/yr
96-97	327	478	805	182	0.23	209	0.26	212	3509
97-98	343	667	1010	162	0.16	263	0.26	174	2865

Despite short term irrigation on both of these fields, good correlation was found between predicted and measured drainage under furrow irrigation. The differences between predicted and measured drainage under drip irrigation could be due to a combination of factors. Firstly, SaLF uses soil properties including clay percentage and CEC averaged over the entire profile in its calculation of leaching fraction. Under sub-surface drip irrigation, the water is introduced at 40cm, thus the water avoids any soil physico-chemical interactions related to permeability that may occur in the top layers. Secondly, when the correction term was developed to account for the effect of high EC irrigation water, it was a weighted ratio. That is, it assumes some degree of mixing of irrigation and rainwater. If however, the high EC water is introduced at depth, there would be limited mixing of the high EC irrigation water and low EC rainwater, thus it could be theorised that drainage below 40cm is largely driven by the higher electrolyte concentration of the irrigation water.

Implications for the Industry.

With significant increases in river water salinities predicted by the Murray Darling Basin Salinity Audit (ref), and with some cotton areas already irrigating with high EC water, increases in drainage and root zone salinity that may occur as a result should be issues of concern to the industry. Losses to deep drainage increases the risk of shallow water tables and associated salinity problems, reduces water use efficiency and thus profits, and also significantly increases the possibility of pollution of the watertables by nutrients and chemicals. There is also a need for more investigation of the hydro-geology underlying cotton growing areas before the impact of increasing drainage can be fully assessed. Also the effects of increasing sodicity in irrigation waters, including the long term impact on soil structural stability, is also poorly defined within the industry.

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