SALINITY IN COTTON AREAS

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Agriculture can change the hydrologic balance of a landscape either through a change from native vegetation or the addition of water by irrigation or both. Since salts move with water, a change in hydrology will mean a change in the salt balance which may cause land and water degradation. The basic principles of water and salt movement can be applied to cotton growing areas to identify potential salinity hazards both on the farm and in the catchment. Salinity problems are due to the presence of a high concentration of salts in soils or waters. A sodicity problem occurs where there is a high proportion of sodium compared to other ions resulting in degraded soil.

Table 1 lists the maximum potential risks of salinity and sodicity problems that could affect cotton growing areas in Australia. Three situations are covered; dryland cotton, irrigation with surface water and irrigation from groundwater. Each issue will be discussed and illustrated by examples. Approaches to their assessment and monitoring are given.

Root Zone Salinity

Dryland cotton relies on the storage of water in the soil to supply the plant. In subsoils with high salt content, or high sodium levels, the available water for plant growth may be limited due to adverse effects on the soil or directly on the plant. Table 2 lists the percentage of soils that could have a potential problem with salinity or sodicity at the bottom of the root zone. This is based on soils in potential cotton growing areas in Queensland, (rainfall from 400 to 1 000 mm) taken from a selected soils database of QDPI. Salinity risk is based on the published salt tolerance figures for cotton (Maas and Hoffman, 1977) that indicate a yield reduction

Table 1. Salinity issues, the effects in cotton growing areas, and the maximum likely risk of occurrence. Specific local conditions will modify these risk estimates.

Issue	Result	Maximum degree of risk		
		Dryland	irrigation with surface water	irrigation with groundwater
root zone salinity	high levels reduce water availability and cotton yield	medium	nil	high
increased recharge	raised groundwater levels in susceptible areas resulting in waterlogging and salinity	medium	high	low
	salt mobilisation to groundwater raising salinity levels and increasing stream salinity	medium	high	high
irrigation water quality	increased root zone salinity affecting cotton yield	-	nil	high
	increased soil sodicity reducing water entry, water availability and degrading soil behaviour	-	medium	high

when the root zone salinity (electrical conductivity of the saturation extract, EC_{se}) exceeds 7.7 dS/m. The clay minerals present in soils also determine their behaviour and permeability and this aspect is accounted for in the table. Soils most prone to high subsoil salinity are those with clay contents between 35% and 65% that are not derived from basalt nor are rigid soils. For these soils, the effect would most commonly occur in dry periods. Whether subsoil salinity will be a problem can be quickly determined by a simple salt content measurement in the field together with an estimate of texture and comparison with established criteria. A more accurate determination from laboratory measurement would include soil chloride content for prediction of EC_{se}. Electromagnetic induction survey methods indicate an overall integration of the salt concentration with depth, (for example, Triantafilis, 1993).

Table 2. The percentage of soils in each category within a rainfall range of 400 to 1 000 mm (from Queensland) that have a soil salinity at 0.9 m (3 feet) depth that would exceed the salt tolerance for cotton (EC_{se} 7.7 dS/m) under dryland conditions.

Clay content (%)	Percentage of soils where subsoil EC_{se} exceeds 7.7 dS/m				
	Rigid soils#	Mildly cracking	Grey and red clays moderate cracking	Grey and red clays high cracking	Black cracking soils on basalt
15-25	0	0	0	0	0
25-35	0	0	8	38	10
35-45	0	33	21	24	0
45-55	0	33	29	42	0
55-65	0	31	16	18	0
65-75	0	0	7	14	0
75-85	0	0	0	0	0

The broad soil descriptions are based on clay mineralogy, being the cation exchange capacity of the clay fraction (meq/g clay). Rigid soils <0.35, mildly cracking soils 0.35 to 0.55, grey and red cracking clays, 0.55 to 0.95 and black cracking clays >0.95.

Increased recharge

Salinity and waterlogging

Cotton uses less water by evapotranspiration than native vegetation. Excess water will move below the rooting depth which recharges the groundwater, particularly under irrigation. Where groundwater flow out of a catchment is restricted, due to landform or geology, the extra water will raise the groundwater level with the risk of salinity, seepages or waterlogging. Three aspects are important; (1) irrigation quantity, (2) soil properties which determine the extra recharge possible and (3) the catchment characteristics that determine groundwater flow out of the catchment. For the latter, a series of landform features have been identified that can identify catchments at risk, for example Shaw *et al.* (1987). Shaw and Thorburn (1985) developed a model that can predict the change in deep drainage under irrigation based on soil properties. Figure 1 shows the response to increased rainfall (that is rainfall plus irrigation) of typical shallow basaltic soils of the Emerald Irrigation Area, a typical grey clay from the St George Irrigation Area and typical lighter and heavier clay soils of the Namoi Valley. The soil data comes from Shaw and Yule (1978) for Emerald, Shaw and Crack (unpublished) for St George and McGarry *et al.* (1989) for the Edgeroi section of the Namoi Valley.

The predicted deep drainage values for the soils in Figure 1 are shown in Table 3. The reasons for the salinity and waterlogging problems that have occurred in the Emerald Irrigation Area are obvious. The deep drainage rates are much lower for the other two areas and the risks should be less depending on landform and groundwater features. The risks for a region can only adequately be assessed in conjunction with groundwater and catchment hydrology. When irrigated with a water of higher salt content than rainfall, deep drainage is increased considerably more than these figures indicate due to the effect of salt concentration on soil permeability.

The best on farm or regional monitoring is by measuring water levels. Insertion of piezometers to different depths, and the subsequent recording of water levels on a regular basis (manually or with cheap loggers and a computer) is an effective and simple monitoring approach. Existing bores and wells can also be used. If regionally significant problems eventuate, this data is enormously valuable. In large irrigation areas a regional network is essential. It is more important to monitor the cause of a problem, that is rising water levels, than the symptoms of soil salinity which will only result once the problems have progressed too far for cost effective reclamation.

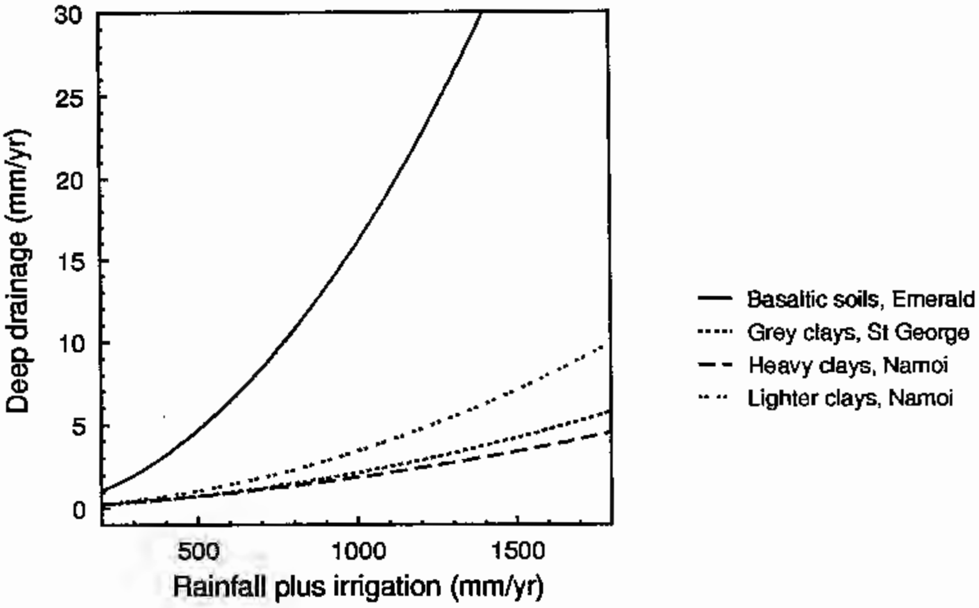

Figure 1. Predicted drainage below the root zone with change in rainfall plus irrigation for soils from Emerald, St George and the Namoi irrigated cotton areas.

Table 3. The predicted average annual deep drainage below the root zone for the typical soils in Figure 1 based on average rainfall and irrigation applications.

	Rainfall (mm/yr)	Deep drainage under rainfall (mm/yr)	Irrigation plus rainfall (mm/yr)	Deep drainage under irrigation plus rainfall (mm/yr)
Basaltic soils Emerald	630	7	1 200	22
Grey clays St George	510	1	1 050	2.5
Heavy clays Namoi	580	1	1 200	2
Lighter clays Namoi	580	1.5	1 200	4

Salt mobilisation

The movement of water below the depth of rooting results in a new equilibrium salt profile. In situations where there is no shallow water table, the extra water leaches out salts which have accumulated historically. Figure 2 shows the changes in soil salinity with time from the commencement of irrigation for two typical soils in the Emerald Irrigation Area. The root zone salinity in the alluvial cracking clay soil has been reduced considerably.

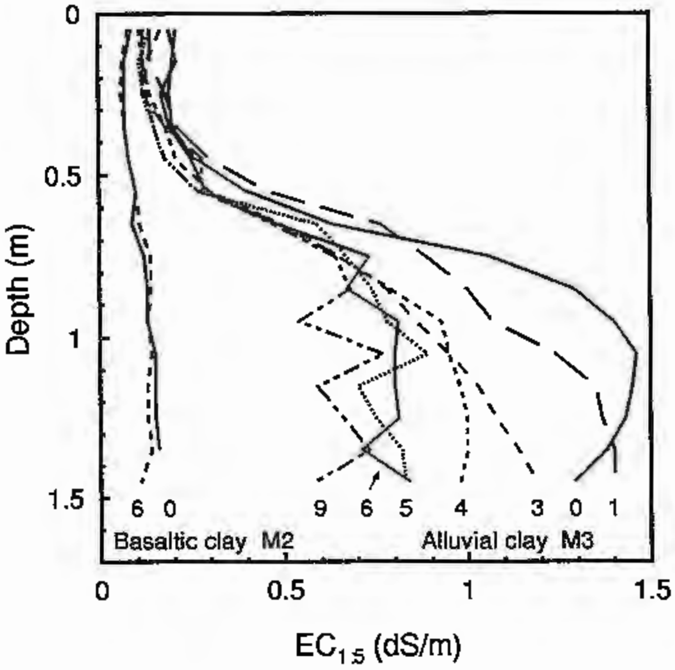

Figure 2. Change in root zone salinity (EC of a 1:5 soil:water suspension) in typical shallow basaltic (BUg soils), and alluvial cracking clay soils from Emerald with years since irrigation commenced. Year 0 was 1974. (Data courtesy of Don Yule QDPI).

However, there are wider consequences of increased salinity in groundwater and eventually in stream water where groundwater levels reach stream bed elevations. An increase in groundwater salinity levels since irrigation commenced has been reported from several irrigation areas. The change in groundwater salinity with time in two bores in the Burdekin River Irrigation Area is shown in Figure 3. The magnitude of the change in salinity depends on the depth to groundwater, the soil salt store, the rate of recharge under irrigation and the spatial dimensions of the aquifer system. Again, the best monitoring practice is to measure the salinity along with water level in shallow and deep piezometers.

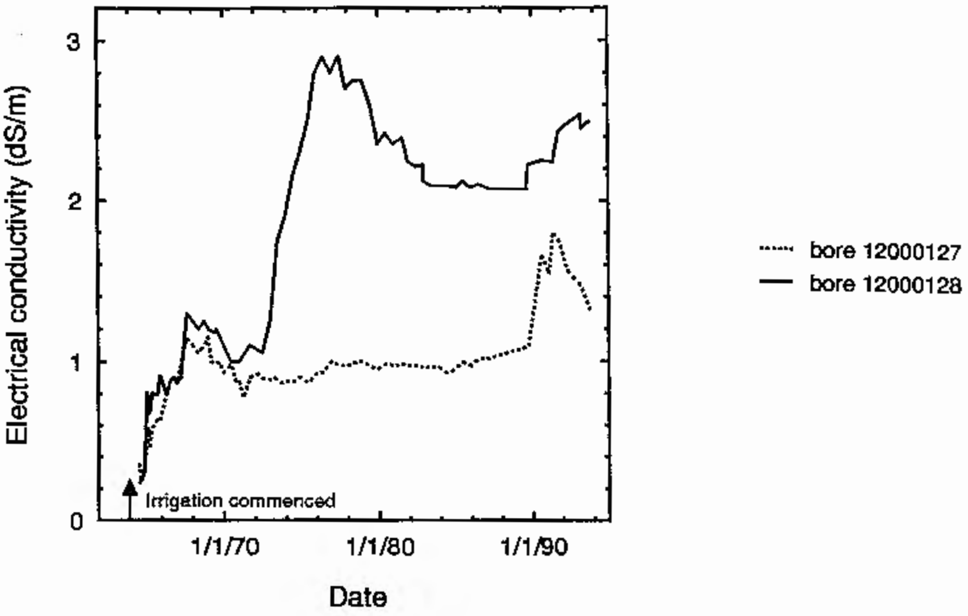

Figure 3. Change in groundwater salinity with time in the Mona Park section of the Burdekin River Irrigation Area following the commencement of irrigation of sugar cane in 1964. (Data courtesy of QDPI Water Resources).

Irrigation water quality

Where groundwater is also used for irrigation, the generally higher salinity levels of groundwater mean that there is a risk of increased root zone salinity levels unless appropriate plant-soil-water quality guidelines are followed. A weighted rainfall+irrigation water salinity (calculated from the depth of rainfall and irrigation and the EC of each) appears to be a satisfactory measure to assess salinity changes where supplemental irrigation is used. The change in soil salinity resulting from irrigation with different irrigation water qualities is shown for the Lockyer Valley in Figure 4. This soil type has been irrigated from 9 to 45 years and new long term equilibrium soil salinity and soil sodicity levels have developed. By estimating the amount of drainage below the rooting depth as discussed earlier and accounting for the salinity and sodicity of the irrigation water, an estimate of the permissible irrigation water salinity can be made. Taking Emerald for example, assuming 630 mm rainfall and irrigation of 600 mm, it is predicted that 25% of the applied water plus rainfall will move below the root zone. On this basis, it would be possible to irrigate with a water of EC 6.8 dS/m and obtain good cotton yields. A slow increase in groundwater salinity may occur depending on groundwater flow characteristics.

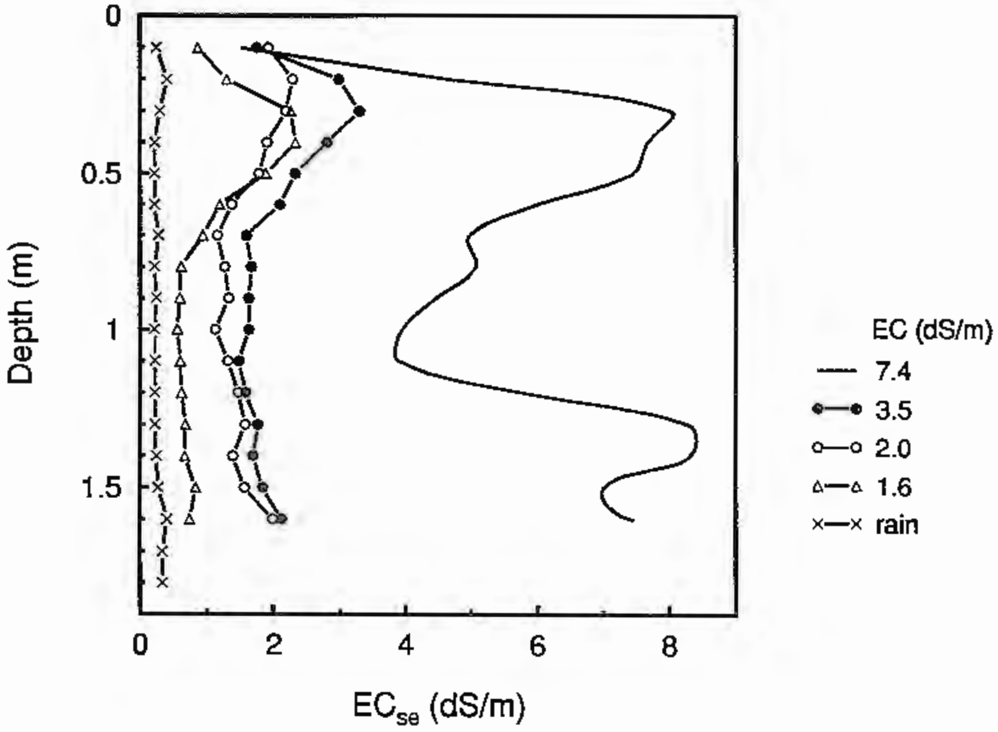

Figure 4. Soil salinity, EC_{se}, of a clay soil irrigated with different water qualities in the Lockyer Valley illustrating the establishment of new equilibrium salinity levels.

Because rainfall can leach any accumulated salts below the root zone, salinity accumulation can be managed. However more serious effects result from using waters with a high proportion of sodium, expressed as Sodium Adsorption Ratio, (SAR). High sodium levels affect soil behaviour by increasing soil dispersibility, reducing water entry, making cultivation and good seedbeds more difficult and reducing soil profile water availability. This is particularly so after rainfall where surface accumulated salts are washed out of the surface. The soils are then dispersed because of the higher sodium levels. Some general relationships have been established for many soils which indicate the combination of irrigation water EC and SAR where these dispersion problems are most likely to occur. Figure 5 shows the general relationships for irrigation water EC and SAR and the effect on soil permeability. For example, if an irrigation water of EC 4dS/m and an SAR of 8 is used for irrigation, the soil will be stable. If prolonged rainfall results in the leaching of salts out of the surface soil, the EC_{se} may drop to 0.25 dS/m causing some problems. Groundwaters derived from basalt have relatively higher calcium and magnesium concentrations relative to sodium which means lower SAR values than for areas derived from other materials. An assessment of the irrigation water quality in relation to soil properties and behaviour is the best method of avoiding these problems. There are appropriate management techniques to overcome many of the salinity and sodicity problems of irrigation (for example, Shaw *et al.* 1987).

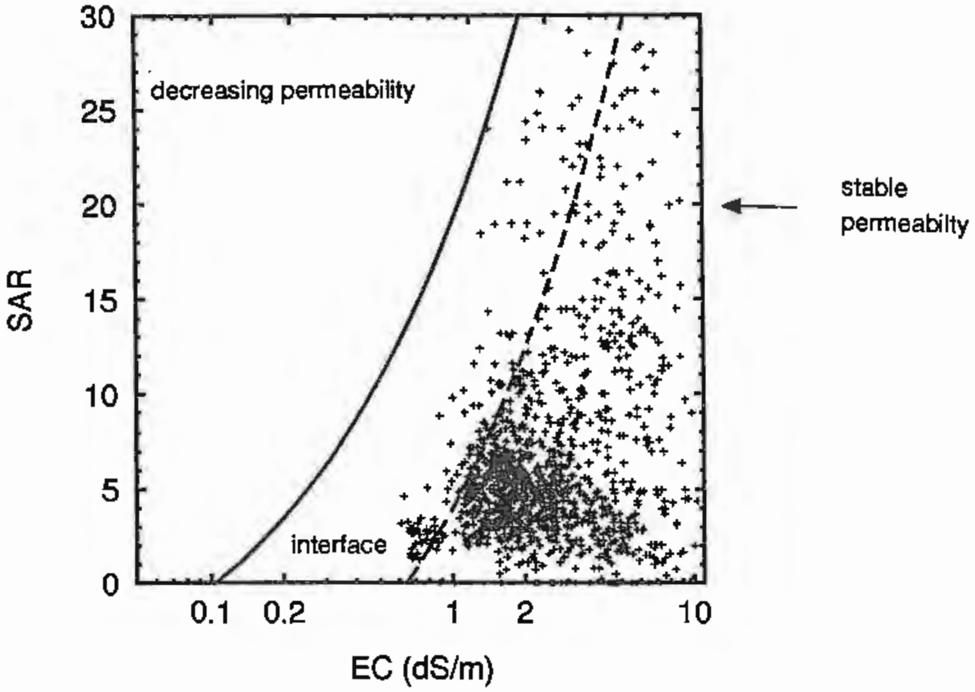

Figure 5. General relationships between irrigation water EC and SAR and their effect on soil permeability. Selected groundwaters for the Lockyer Valley are given to illustrate the likely composition of basalt derived waters.

In summary, the agricultural use of landscapes has disturbed the hydrologic equilibrium with consequent changes in salinity. The risks for cotton growing areas are expected to be much less than the major problems of the Murray Basin due to hydrology, geology, soils and geomorphological history. However this needs to be confirmed by a more detailed analysis of specific regions. Ongoing monitoring of groundwater levels and EC are absolutely necessary to indicate changes before the seriousness of the problems become too difficult or costly to manage.

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