MANAGING SALINITY IN COTTON AREAS

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INTRODUCTION

Salinity problems are due to the presence of a high concentration of soluble salts in soils or waters. Salinity processes are natural processes closely linked with landscape and soil formation processes, however, human activities such as agricultural development can accelerate salinity processes, contributing to long-term land and water degradation.

Dryland and irrigation salting processes for most regions where salinity problems occur are generally well understood, for example Peck and Williamson (1987) and Shaw et al. (1987). An understanding of these processes provides the foundation for providing effective and sustainable management approaches which can be applied to cotton growing areas.

Although the processes causing salinity are the same for both dryland and irrigated agriculture, it is easier to gain an understanding of the salinity management options for cotton production if we consider dryland and irrigated production issues separately.

SALINITY ISSUES IN DRYLAND COTTON PRODUCTION

Root Zone Salinity

Production of dryland cotton relies on the storage of water in the soil to supply the plant's requirements. In subsoils with high salt content , or high sodium levels, the available water for plant growth may be limited. This limitation is induced by the osmotic effect of high salt levels and through physical limitations to root growth and function due to poor soil structure with high sodium levels. High levels of salt and/or sodium may also induce toxic effects on the plants growth. Due to the nature of many of the soil types utilised for cotton production high levels of salinity and sodium are not uncommon within the root zone. However, due to the high salt tolerance level of cotton, few soils will have an inherent salinity level which places a restriction on cotton production. However, there may be some limitations on rotation crops, especially legumes, as they have significantly lower salt tolerance levels. An overview of salt tolerance levels for crops commonly grown in cotton growing districts is provided in Table 1.

Table 1. Yield thresholds for crops commonly grown in cotton production districts. (data from Shaw et al., 1987)

Crop Type	Salinity Tolerance	Salinity Threshold EC_{se} (dS/m)	Yield Decline (% reduction per dS/m)
Cotton	Very tolerant	7.7	5.2
Wheat	Tolerant	6.0	7.1
Barley	Very tolerant	8.0	5.0
Sorghum	Tolerant	6.8	15.9
Maize	Moderately sensitive	1.7	12.0
Lucerne	Moderately tolerant	2.0	7.3
Faba beans	Moderately sensitive	1.6	9.0
Mung beans	Sensitive	0.8	7.9

Whether soil salinity will be a problem can be quickly determined by a simple salt content measurement in the field ($EC_{1:5}$) together with an estimate of texture to allow conversion to the more standard unit of salinity EC_{se}, (electrical conductivity at saturation extract). A more accurate laboratory measurement should include soil chloride content. The EC of the saturation extract, EC_{se}, is a more meaningful measurement being closer to field water content and can be related to the large amount of published data on plant salt tolerance.

More recently the use of electromagnetic induction survey methods has been utilised to indicate an overall depth integrated salinity. Surveys in the lower Namoi Valley using the EM38 and EM31 instruments have proven the usefulness of these tools for root zone and subsoil salinity assessment, after appropriate field calibration (Triantafilis and McBratney, 1994). Increased speed and efficiency of salinity surveys can be attained by the mobilisation of the EM instruments and data acquisition coupled to a global positioning system (GPS) will provide spatially accurate data for monitoring and management activities.

Landscape salinity

A simple water balance concept considers landscapes in terms of a recharge, transmission, and discharge model (Figure 1). The more permeable areas, usually on upper slopes, often on shallow soils act as recharge areas for ready entry of water and movement downwards to the groundwater.

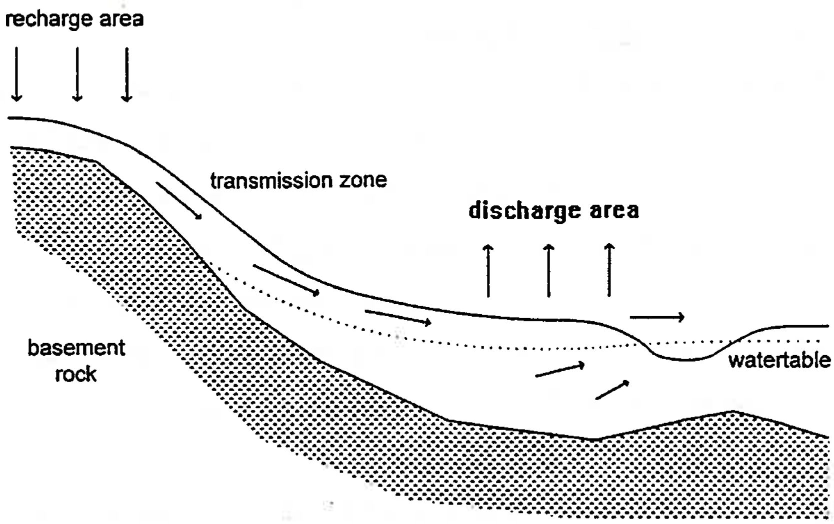

Figure 1. A simple water balance model to describe water movement in the landscape (from Shaw et al. 1987)

A transmission zone occurs where lateral water movement within the groundwater system dominates. Where there is some hydrologic restriction to lateral groundwater flow, groundwater will flow upwards towards the soil surface creating a discharge zone. The presence of a discharge area indicates an imbalance between inputs through recharge and the capacity of the groundwater flow system to move water out of the catchment laterally.

In a sensitive catchment, a change in land use may result in a rising water table which can mobilise salts stored in the landscape and allow water table to approach the soils surface. If vegetation can maintain the area in hydrologic balance and the water table does not rise to within the depth for capillary rise, then there will be no salt concentration at the soil surface. The important feature of the areas that show salinity is the presence of some restriction to groundwater flow that raises the water table and results in evaporative concentration of salts. A wide variety of restrictions to groundwater flow exist, and are well documented in literature available from extension agencies.

Dryland salinity is not widely reported in areas utilised for cotton production, however it is likely to become a more significant issue with the expansion of dryland cotton production. Dryland salinity has been observed on basaltic soils of the eastern Darling Downs and Emerald districts and is the focus of extensive research activities in the Liverpool Plains catchment of northern New South Wales.

Managing salinity in dryland cotton areas.

The management of salinity requires a catchment approach where we need to consider all the inputs and outputs to the groundwater system. For the inputs, the amount of recharge is the only factor that is able to be modified by management activities. This is most commonly achieved by land use changes that reduce the proportion of rainfall passing through the root zone. Options include revegetation with trees of significant areas of the upper catchment, perennial pastures and opportunity cropping. Any system which maximises the use of water available from rainfall and in the soil water store will be beneficial in terms of recharge control.

For effective management of discharge areas in the long term, evaporation needs to be reduced in the presence of a shallow saline watertable, particularly where there is no seasonal flushing of salts from the soil surface or the root zone. This can be achieved by a lowering of the watertable or physical removal of the salt out of the system. Options for lowering of the watertable include, selective revegetation to intercept and use extra water moving in shallow watertables before it gets to the most affected area, pumping of aquifers if aquifer properties and water flow are suitable, drainage in more permeable soils, and use of salt tolerant vegetation.

The risk of a salinity problem can only be assessed in conjunction with groundwater and catchment hydrology information. On-farm and regional monitoring, utilising existing bores and wells or by insertion of piezometers, is extremely valuable in providing an overview of potential or developing salinity problems. 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 to far for cost effective reclamation.

SALINITY ISSUES IN IRRIGATED COTTON PRODUCTION

Salinity issues in irrigated cotton are attributable to the same processes that operate under dryland conditions, however the increased volume of water moving in the catchment and associated increase in salt loads leads to an acceleration of the salinity process under irrigated conditions.

Root zone salinity

Although irrigation removes the restrictions to plant growth from limited water supply, unless there is some level of leaching (movement of water past the root zone), there will not be removal of accumulated salts in the subsoils and the crop will exhibit symptoms of water stress even under irrigated conditions due to the osmotic effect of high salinity levels.

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 soil - water - plant guidelines are followed. Research projects supported by the CRC for Sustainable Cotton Production have been developing such guidelines to allow water quality to be appropriately matched to soil type based on previous research of Shaw and Thorburn, 1985. Leaching can be managed to control salt accumulation in the root zone and the extent of downward salt mobilisation. Management of leaching by changing water application rates is satisfactory for permeable soils, but for slowly permeable soils (most of the cotton soils), leaching is dominantly controlled by soil properties rather than irrigation water management. For clay soils leaching is also strongly influenced by the electrolyte concentration and sodicity of the irrigation water. Therefore, we need to provide water quality guidelines which define the influence of both salinity and sodium adsorption ratio of applied water on infiltration and leaching through the soil profile. Specific relationships need to be developed for the individual soil types utilised for cotton production. Figure 2 provides results from an early version of a quantitative soil-water property decision model, demonstrating the influence of soil type and water quality on relative cotton yields.

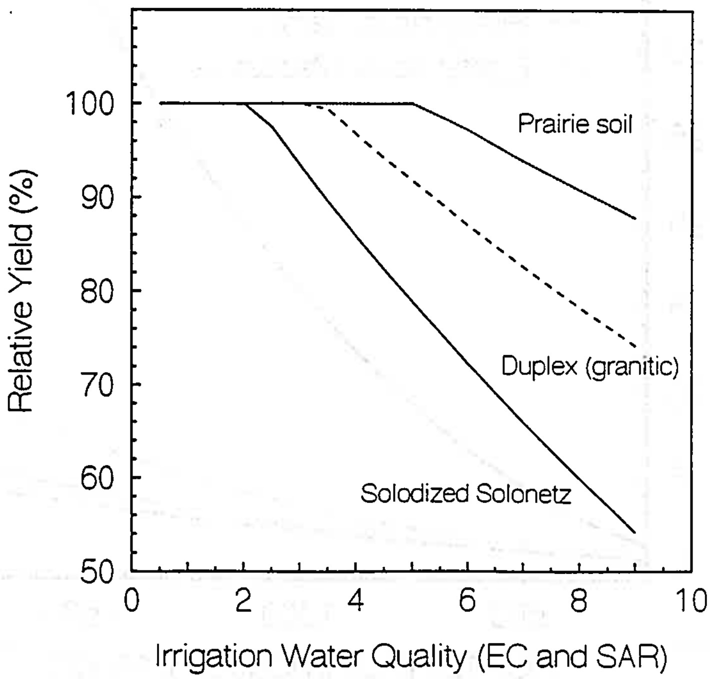

Figure 2. The influence of water quality and soil type on relative cotton yield - results from a quantitative irrigation water quality model.

Landscape salinity and waterlogging

The development of land for cotton production involves the removal of native vegetation which generally will have the ability to use more water by evapo-transpiration than cotton and the addition of extra water through irrigation. Applied water in excess of crop requirements will move below the rooting depth which then recharges the groundwater system. Where groundwater flow out of the catchment is restricted, due to landform or geology as discussed in previous sections, the extra water will raise the groundwater level with the risk of salinity, seepages, or waterlogging.

Three aspects are important in determining the potential impact of irrigation in cotton areas; (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. The quantitative soil - water decision model described previously can also predict the change in deep drainage under irrigation for a particular soil type. Figure 3 shows the response to additional water application (irrigation) of typical soils from the Emerald, St.George, Namoi and Macquarie districts.

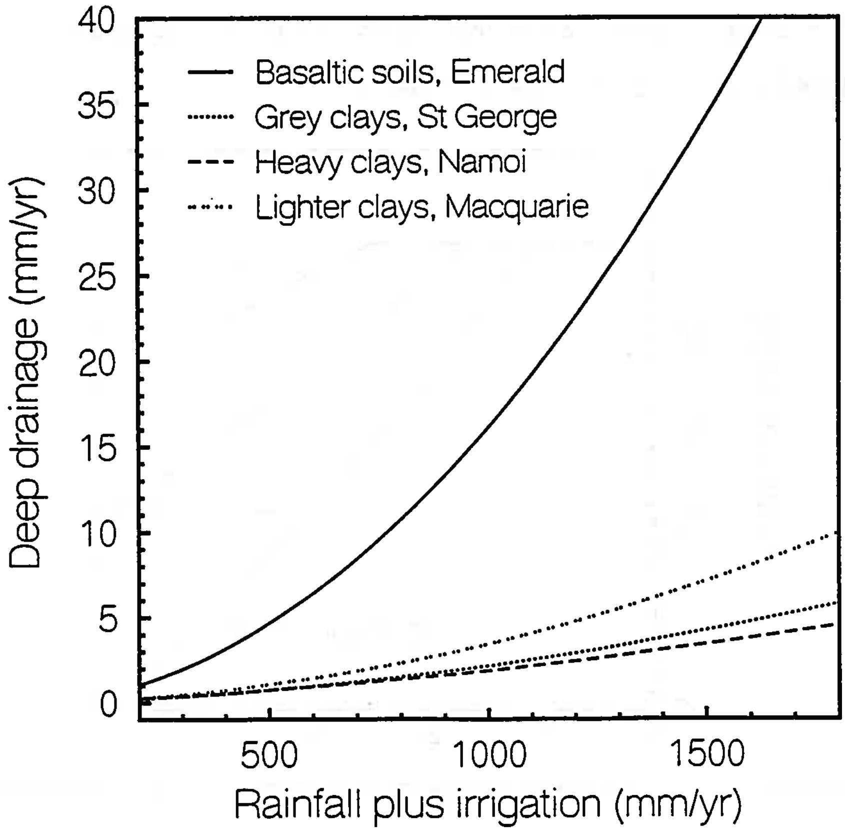

Figure 3. Predicted drainage below the root zone for soils from Emerald, St.George and the Namoi irrigation areas.

The risk of watertable salting problems for a region can only be adequately assessed in conjunction with groundwater and catchment hydrology information. As for dryland salinity, monitoring of groundwater depth and quality via a network of bores, wells and piezometers should be considered an essential component of an irrigation scheme.

Salt mobilisation

In most cases the increased movement of water below the root zone as a result of irrigation will leach salts which have accumulated in the soil profile downwards to the watertable. However, there are wider consequences of increased salinity in groundwater and eventually in stream water quality where groundwater levels reach stream bed elevations and contribute significant amounts to stream base flow. An increase in groundwater salinity levels since commencement of irrigation has been reported from several irrigation areas. 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.

Managing salinity in irrigated cotton areas

The management options available to reduce irrigation salting largely depend on the cause of the salting. Salt-tolerant crops such as cotton, will reduce the severity of production losses due to salinity problems. However, in most cotton production systems a salt sensitive legume crop is used in rotation and salinity effects will first become apparent in these alternative crop types.

The efficient management of water is essential to prevent rises in watertable levels, especially in surface water irrigation schemes. There is a need for good baseline soils and hydrological information in the planning and development of irrigation areas. Projects currently being undertaken by researchers with the CRC for Sustainable Cotton Production are collecting and collating baseline soils data for the McIntyre, Gwydir and Namoi valleys (Odeh et al., 1996). Restrictions to drainage in the landscape should be identified and control of watertables in these regions planned. Reduction in accessions of water to watertables can be achieved by a reduction in the amount of leaching when irrigation water quality is good, since excess leaching is not required for salinity control. Surface levelling and drainage to provide uniform wetting and better run-off of rainfall after irrigation will reduce deep drainage.

It many surface water schemes, seepage from supply channels and storages can contribute significantly to watertable rises. Appropriate lining of channels or use of pipes or fluming for on-farm distribution can reduce this problem. Drainage can be used to control watertable levels, but effective drainage requires a height difference between the watertable and drain outlet and spacing matched to soil hydraulic properties. In clay soils, drain spacing may need to be so close that management of the land becomes impractical. The safe disposal of effluent from drains is a sensitive issue especially in irrigation areas where drainage water may not only be saline, but carry high levels of nutrients and chemicals.

Pumping of water directly from aquifers is an option where aquifers with high transmissivity and relatively good water quality are the cause of high watertables. Conjunctive groundwater use schemes should be considered in areas where surface water is the sole source of irrigation water.

The best approach to manage marginal quality waters is to match soils, irrigation waters, and crops to minimise negative impacts of irrigation on soils. Models developed by the Salinity and Contaminant Hydrology Group within the Queensland Department of Natural Resources, will provide guidelines to assess the suitability of irrigation water for a particular soil type. Where it is not possible to match all these factors, a number of irrigation management practices can be implemented to minimise the impact of irrigating with marginal quality water.

Provided the root zone is wet, more frequent irrigation reduces plant water stress, dilutes the soil solution and sometimes increases the leaching of salts. This method is appropriate where irrigation water is available on demand and the soils are relatively permeable. The application of additional water with each irrigation will also enhance leaching in soils with good drainage, or specific leaching irrigations can be included into the irrigation schedule. The timing of leaching irrigations will depend on crop salt tolerance and water salinity.

The method of irrigation used can affect salt accumulation from poor quality irrigation water: Flood irrigation provides an even application of water but can be wasteful, particularly in a high frequency irrigation scheme; Furrow irrigation contributes to salt accumulation in adjacent rows through capillary rise and evaporation from the highest parts of the ridges; Sprinkle irrigation provides good control of water application, but it can cause leaf damage and salt precipitation on leaves; Trickle irrigation is efficient but contributes to salt accumulation in the soil surface, unless a surface mulch is applied to minimise evaporation or the emitter is buried at some depth in the root zone.

The mixing or blending of water supplies can reduce salinity problems if good quality water is available in addition to the poor quality water. Two options are preferred for using good and marginal quality water supplies for irrigation:

1) Alternate applications of marginal quality water with application of good quality water, when available, or water quality can be matched to the crop's salt tolerance at different stages of growth.
2) Alternate salt-tolerant and salt-sensitive crops with different irrigation waters. This option should be viable in cotton growing areas where good quality water is available and seasonal rainfall promotes leaching.

If irrigation waters are sodic, the points listed above are generally relevant, but some additional factors must be considered. The addition of gypsum can be used as a soil amendment to improve the structure of surface soils and to alleviate some of the adverse effects of high sodicity waters. Gypsum improves soil structure by increasing flocculation of clay particles through increased electrolyte concentration and by exchange of calcium for sodium on the soil exchange complex. Other soil amendments, such as sulphur can be useful on sodic soils if there is a high level of calcium carbonate at the soil depth required.

In summary, the risk of salinity problems in cotton growing areas is expected to be much less than the major problems of the Murray Basin due to the relationships between climate, hydrology, geology, soils and geomorphological history. However, ongoing monitoring and detailed analysis of specific regions is needed to confirm this statement and to ensure information is available before developing salinity problems become too difficult or costly to manage.

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