



strategic plan

Salinity research and management strategies for the cotton growing areas of Australia



australian
cotton

healthy
rivers



renewable
resources



**COOPERATIVE RESEARCH CENTRE FOR
SUSTAINABLE COTTON PRODUCTION**



STRATEGIC PLAN:

**SALINITY RESEARCH AND
MANAGEMENT STRATEGIES FOR
THE COTTON GROWING AREAS
OF AUSTRALIA**



Acknowledgements

Prepared by:

J. TRIANTAFILIS

CRC for Sustainable Cotton Production
Department of Agricultural Chemistry and Soil Science
The University of Sydney, NSW 2006

with contributions from:

A.B. McBRATNEY, I.O.A. ODEH and A. TODD

CRC for Sustainable Cotton Production
Department of Agricultural Chemistry and Soil Science
The University of Sydney, NSW 2006

J.D. RHOADES and S.M. LESCH

United States Salinity Laboratory
450 West Big Springs Road, Riverside, California 92507-4617

R. SHAW and I. GORDON

Department of Primary Industries Queensland
Meiers Road, Indooroopilly, Queensland 4068

T. ABBOTT¹, D.C. McKENZIE¹ and T. WILLIS²

NSW Agriculture

¹Biological & Chemical Research Institute, Rydalmere NSW 2116

²Trangie Agricultural Research Centre, NSW 2823

D. MacLEOD and J. DOUGLAS

CRC for Sustainable Cotton Production
Department of Agronomy and Soil Science
University of New England, NSW 2351

G. A. CONSTABLE

CRC for Sustainable Cotton Production
Australian Cotton Research Institute, Narrabri NSW 2390

©Copyright 1996 The Cooperative Research Centre for Sustainable Cotton
Production

ISBN 0 9586829 0 9

Design and Layout - Melissa Bawden, CRC for Sustainable Cotton Production

Cover photographs: *Australian Cotton* courtesy of David Larsen, CRC. *Healthy Rivers* courtesy of Gus Shaw, CRC. *Renewable Resources* courtesy of David Larsen, CRC.



Contents

4	Acknowledgements
6	Mission Statement
7	Executive Summary
9	Introduction
10	Action Plan
10	Objective One
12	Objective Two
14	Objective Three
20	Objective Four
22	Linkages
23	Research Targets
24	Priority Areas
25	Appendix

Figures

8	Figure 1. Cotton growing areas of northern NSW and southeastern Queensland.
10	Figure 2. Secondary salinity caused by dam leakage in the lower Macquarie Valley, NSW.
11	Figure 3. Discussion about soil salinity as a result of leaking storage, Bourke NSW.
13	Figure 4. Discussing suitability of slightly saline groundwater for irrigation, Dalby Queensland.
14	Figure 5. Soil sampling for broadscale-baseline reconnaissance studies.
16	Figure 6. Mobile EM38 salinity assessment module of the US Salinity Laboratory.
17	Figure 7. Salinity tour raising awareness of water management practices, Dalby Queensland.
19	Figure 8. Salinity tour raising awareness of salinity management practices in Bourke.
21	Figure 9. Shallow water table caused by dam leakage in the Bourke area, NSW.
22	Figure 10. Integrated salinity research and management strategies for cotton growing areas.
26	Figure 11. Sealing irrigation supply channels with concrete and other suitable membranes.
27	Figure 12. Locating storage dams on suitable relatively nonpermeable soil materials.

Tables

23	Table 1. Summary of projects, principal researchers, funding, research outcomes and target dates for completion.
----	--



Mission Statement

To have profitable and sustainable cotton farming in Australia free from high water tables, seepage and soil salinity through: the investigation of the current status and future potential threat; and the development, adoption and evaluation of on-farm best management practices and systems.



Prevention is better than cure



Executive Summary: Salinity Research and Management Strategies for the Cotton Growing Areas of Australia

The Cooperative Research Centre for Sustainable Cotton Production (CRC) was established in 1993 to develop and implement management practices to ensure the sustainability of the cotton industry. This aim will be met through high quality and integrated scientific research by the combined efforts and resources of the CRC's core participants: the Universities of Sydney and New England, NSW Agriculture, Department of Primary Industries Queensland, CSIRO and the Cotton Research and Development Corporation (CRDC). The CRC is based at the Australian Cotton Research Institute, Narrabri.

The CRC has four major programs including: protecting the resource base and environment; crop protection; product development; and education, transfer and adoption of technology. Soil salinity research forms part of the resource base and environment protection program. One of the major aims of the salinity sub-program is to identify the potential salinity threat in the various cotton growing areas. Currently, many different groups are working independently and in collaboration on a number of research projects. Most are funded partially or wholly by the CRC or CRDC.

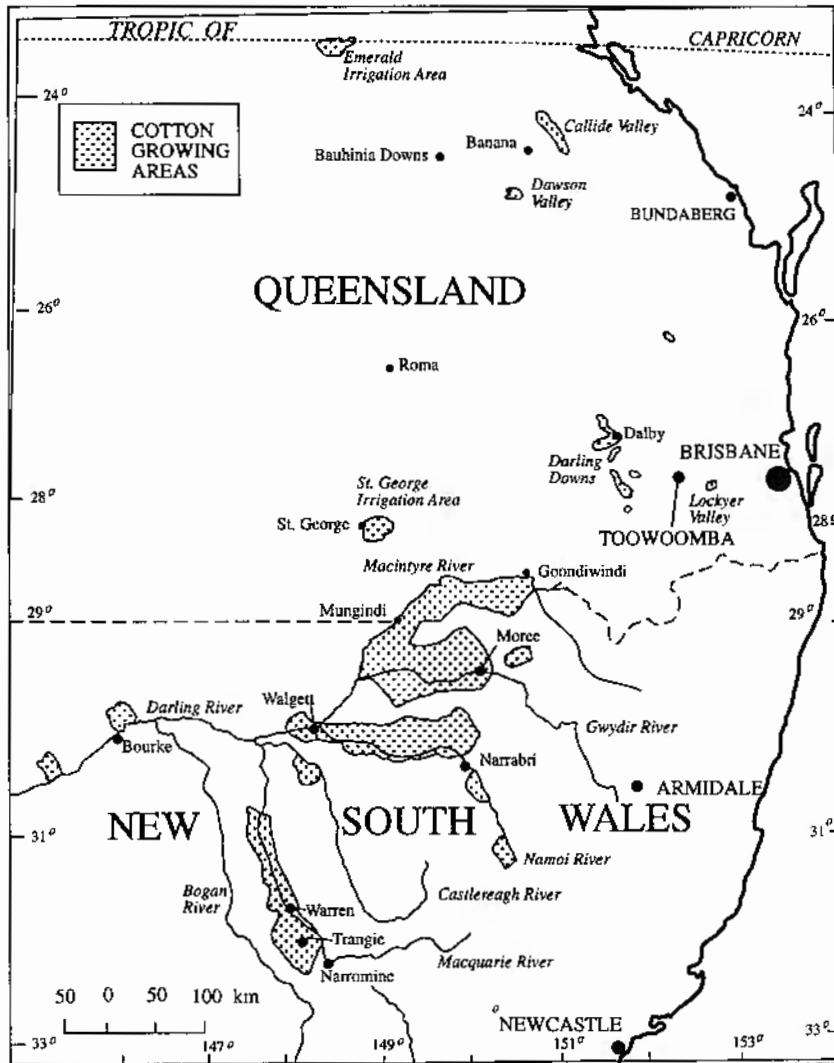
To help coordinate and ensure good collaborative ties between these research groups and to broaden the understanding of soil salinity within the industry, the CRC initiated the development of a Strategic Plan on salinity research and management for the cotton growing areas of Australia. The following Plan complements the comprehensive salinity management strategy document of NSW Agriculture.

This Plan's main purpose is to:

- a) briefly state the current extent of soil salinity and shallow water tables within the cotton growing areas
- b) raise awareness and educate the industry as to the potential threat of soil salinity
- c) provide a framework for best management strategies to minimise the threat or spread of soil salinity
- d) identify key gaps in knowledge to ascertain the potential threat to cotton production
- e) describe and outline the linkages between current work in progress
- f) provide a time frame for the completion of key actions.



Figure 1. Cotton growing areas of northern New South Wales and southeastern Queensland.





Introduction

The Australian cotton growing industry is predominantly located in west and northwest New South Wales and central and southeast Queensland lying between the southern latitudes of $23^{\circ}30'$ and $32^{\circ}30'$ (Figure 1). The major cotton growing areas of northern New South Wales include the lower Gwydir, Namoi, Macintyre and Macquarie valleys with cotton also grown in the lower Castlereagh valley and near Bourke on the Darling River. Recently, cotton has been grown along the lower Lachlan valley (near Hillston), at Tandou in central New South Wales and in the Murrumbidgee Irrigation Area (near Hay). The areas of St George, Emerald, Callide valley and the Darling Downs are the major areas sown to cotton annually in Queensland. Smaller areas including the Dawson and Lockyer valleys and the Murgon area also produce cotton.

Since the late 1980's secondary soil salinisation has been recognised as a potentially threatening problem in many of the irrigated cotton growing areas. This has been most apparent in the lower Macquarie valley and at Bourke (Figure 9, page 21) where large earthen storage dams constructed from semipermeable soil materials have leaked. Owing to the presence of subsurface textural boundaries shallow water tables have been created in adjacent irrigated fields which have redistributed stored soluble salts within the rootzone. In Dalby and the Lockyer valley, the application of poor quality irrigation water has resulted in minor problems with salinisation of surface soil. Fortunately, there have been no widespread occurrences of secondary soil salinisation as a result of rising water tables or the prolonged use of poor quality irrigation waters.

Nevertheless, the Cotton Research and Development Corporation (CRDC) and the Cooperative Research Centre for Sustainable Cotton Production (CRC) recognise that secondary salinisation is of potential concern to the long term sustainability of irrigated cotton production and have become pro-active in determining this threat. To assist in developing discussion and further awareness of salinity within the industry, the CRC initiated the production of a salinity research and management plan for the cotton growing areas of Australia. This Plan includes a mission statement and goals and provides a detailed presentation of objectives and strategies for education, management and research programs. In addition, it indicates the linkages between these programs and their expected adoption time.



Action Plan

Objective One *To increase awareness and understanding of cotton advisors and growers of the causes, symptoms and impacts of high water tables, seepage and salinity*

Increasing awareness and education about the potential negative environmental consequences of long term irrigation will encourage discussion on ways to minimise its impact socially, environmentally and economically. This will circumvent the need for action from environmental groups, agencies and governments to enact legislation. It will also provide the necessary climate for open discussion and adoption of best irrigation practices.



Figure 2. *Secondary salinity caused by dam leakage in the lower Macquarie Valley, NSW.*

Strategies

- a) Compile and disseminate information describing symptoms and causes of secondary salinisation and seepage with respect to cotton production (e.g. CRC Newsletters, SOILpak, Landcare).
Extension: New Position (Salt Action)



Time Frame: 1996-97

- b) Papers and lectures by appropriate resource people to raise awareness of potential secondary salinity in cotton growing areas (e.g. ACGRA-conference).

Researchers: I. Gordon and R. Shaw (CRC, QDPI)
Others (CRC, University of Sydney, UNE, NSW)

Time Frame: 1996-98

Funding

At present there are few community awareness programs or education packages available which have been specifically designed for irrigated cotton growing areas. Funds for their production can be sought from various sources for costs involved in compilation and publishing. One possible funding body is Salt Action. Similar funding can be obtained for the development of training manuals for extension personnel, consultants and land holders to manage salinity when and where it occurs. Prior to the development of these packages small surveys could be carried out in order to determine the extent of soil salinity awareness and the understanding of the processes involved.

Figure 3. *Discussion about soil salinity as a result of leaking storage, Bourke, NSW.*





Objective Two *To increase the skills of irrigators, extension officers, consultants and researchers in identifying symptoms and understanding the processes of secondary salinity and determining appropriate management actions*

The preparation of manuals and guidelines as education and extension packages will highlight the state of the art research and management tools available to assist in determining the most appropriate course of action before secondary salinity is apparent. This will equip land holders, consultants and extension officers with the necessary information required to make decisions about most appropriate best management practices.

Strategies

- a) Promote the adoption of best soil, water and crop management practices to minimise the occurrence of secondary salinity via technical manuals (e.g. SOILpak, LANDpaks, ACGRA-conference proceedings).
Researchers: I. Gordon and R. Shaw (CRC, QDPI)
Others (CRC, US, UNE and NSWA)
Time Frame: 1996

- b) Disseminate latest industry research results through research bulletins (CRC News), magazine articles (Australian Cotton Grower), newspaper articles (The Land), technical manuals (SOILpak), conference proceedings (ACGRA) and international journal articles (Geoderma).
Researchers: (CRC, US, UNE, NSWA, QDPI)
Time Frame: 1996-97

- c) Conduct field days and farm tours of best management practices and systems for preventing and controlling salinity.
Groups: Water Users Associations
Landcare Groups
Time Frame: 1996-97

Where salinity is well understood and apparent, more advanced kits can be developed containing general management options including crop, soil and irrigation management.



Figure 4. *Discussing suitability of slightly saline groundwater for irrigation, Dalby, Qld.*

Other possible strategies

Of course, no single method for salinity control is sufficient, but rather, a number of combined practices will provide the appropriate management strategy depending on the economic, climatic, social, physical and hydrological factors. In general, and prior to the development of other information booklets, a few important principles can be considered for selecting appropriate salinity management practices for implementation. These include: control of plant toxicity and rootzone salinity and sodicity; growing suitable salt-tolerant crops; minimizing salt accumulation in the seed bed; applying water uniformly and efficiently; irrigating frequently to maximise soil water potential; ensuring adequate leaching and drainage to avoid rootzone salt accumulation; controlling salinity of water resources; minimising leaching and deep percolation; and intercepting, isolating and recycling drainage waters. Additional management strategies are provided in the Appendix.



Objective Three *To increase knowledge of the current status and potential threat of secondary salinity in the cotton growing areas of Australia*

Soil salinisation is almost an inevitable consequence in extensively irrigated areas. At present the extent of the potential salinity threat is unknown in the cotton growing areas of Australia. In conjunction with education packages and implementation of management strategies to minimise the threat of soil salinisation, research is required to elucidate over the long-term the potential threat. At present many research projects are being conducted covering a wide array of salinity studies. These vary from monitoring the movement and dynamics of water tables, determining optimal rotations to minimise excessive deep drainage, the development of predictive models to determine areas of potential threat to measuring and mapping soil salinity at different scales.

Overall, the focus of research currently being undertaken is based on providing methods and techniques to determine the current state and potential threat of soil salinity in the cotton growing areas of Australia. These projects are mostly funded by the CRDC and CRC and are outlined in more detail below.

Strategies

(a) BROADSCALE-BASELINE SOIL STUDIES

Conduct baseline broadscale reconnaissance soil surveys to characterise the current status of the soil conditions (including salinity) relevant to sustainable



Figure 5.
Soil sampling for broadscale-baseline reconnaissance studies.



cotton production.

Researchers: I.O.A. Odeh and A.B. McBratney (CRC, University of Sydney)

Time Frame: 1996-97

In the cotton growing areas of northern NSW little soil information is currently available. To address this lack of information the CRC is funding a baseline reconnaissance soil survey in the three major cotton growing valleys of northern NSW including the lower Macintyre, Gwydir and Namoi. The research is being undertaken by the University of Sydney (I. Odeh and A. B. McBratney). The major aims of the work are to provide information on the current status of the soil attributes relevant to sustainable cotton production including soil salinity data.

Despite the fact that sampling sites are widely spaced, analysis and subsequent mapping of trends of salinity within the profile and across each of the valleys would identify problem areas where more detailed investigations are required. The information can be stored in a GIS format, forming a network of monitoring sites with necessary information generated for use in the models of soil/water balance. Such models could be used for prediction of soil salinity, and hence identify areas that can potentially be salinised. Better management practices could be adopted in such areas. The collected information could also act as reference points in time whereby longer term trends can be established, monitored and modelled as different management strategies are implemented. Decreasing salinity as a consequence of altered management practises can also be determined from subsequent more detailed surveys.

(b) Salinity measurement and mapping

Provide methods and techniques to measure, map and monitor the current status of secondary salinity and potential future threat.

Researchers: J. Triantafyllis and A.B. McBratney (CRC, University of Sydney)

Others: L. Kirk (Salt Action)
R. Beasley (DLWC)

G. Street (World Geoscience/NLP)

Time Frame: 1996-98

Where incipient traces of soil salinity occur or where large amounts of stored soluble salts are apparent in the landscape, the nature, origin and spatial distribution needs to be assessed to determine the current and potential salinity threat. A number of field instruments have successfully been used to increase the efficiency of generating appropriate data for such assessments. Calibrated electromagnetic (EM) induction instruments, such as the EM38, EM31 and EM34-3, have recently been used successfully in the lower Namoi valley for this purpose. In conjunction with geostatistical techniques, such as ordinary, regression and indicator kriging, maps can be generated to describe and assist in determining the spatial distribution of soil salinity on the field and

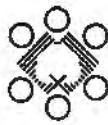


Figure 6. *Mobile EM38 salinity assessment module of the U.S. Salinity Laboratory.*

catchment scale.

Mounting EM instruments, usually independently of each other, onto mobile modules can greatly improve the speed and efficiency of data generation once coupled to a Global Positioning System (GPS). Such mobilised EM systems have been developed including: an EM31 slung from a motorbike (i.e. R. Beasley-DLWC); and a hydraulically lowered EM38 mounted on a modified spray rig as illustrated in Figure 9 (J. Rhoades-USSL). Each configuration allows for real-time data generation. In order to develop a similar module fitted with many EM instruments and capable of traversing the irrigated cotton growing fields, researchers at the University of Sydney (J. Triantafilis and A.B. McBratney) have obtained funds from the CRDC (module development) and Salt Action (EM instruments and data loggers). Once developed the salinity module will be used on the field and catchment scale to determine and assess the potential salinity threat. The salinity module can also be used in follow-up investigations to assess the usefulness of management strategies to remediate areas that become salinised.

With the successful application of ground-based EM instruments to rootzone, shallow subsoil and deep subsoil salinity assessment, the potential use of airborne-EM to delineate the potential salinity threat on a catchment or valley scale would appear to



be great. Many studies have previously been undertaken but without appropriate scientific ground-truthing procedures attempted. Hence the applicability of these techniques cannot be determined. Nevertheless, developments in this area are of potential interest owing to the large cotton growing areas that need to be surveyed. Contacts with appropriate groups and agencies conducting aerial-EM research will be established and the EM research will be constantly evaluated for its potential application (L. Kirk - Salt Action and G. Street - World Geoscience/NLP).

c) Quantitative irrigation water quality

Develop predictive models to elucidate areas of greatest potential salinity threat and incorporate into GIS for modelling and mapping purposes.

Researchers: I. Gordon, B. Wilshire and R. Shaw (CRC, DPIQ)
B. Swann (Macquarie) (NSW Agriculture)
M. Grundy and B. Slater (DPIQ)
J Triantafyllis and I. Odeh (CRC, University of Sydney)

Time Frame: 1996-98



Figure 7.
*Salinity tour
raising awareness of water
management
practices,
Dalby, Qld.*

The widespread use of irrigation for cotton production is altering the hydrology of the landscape, and where surface waters are used for irrigation there is an increased potential for rising water tables. Conjunctive use strategies, where surface irrigation is supplemented by reuse of local groundwaters provides one option for controlling water table levels without significantly altering the cropping system. The option requires an understanding and ability to predict the effect of groundwater quality on soil behaviour. Salinity and sodicity are the key water quality parameters determining the suitability of



water for irrigation.

Similar knowledge is required for successful irrigation with waters of moderate to high salt content. Leaching to prevent excessive salt accumulation in the root zone is an essential management step, but in slowly permeable soil the rate of soil leaching is determined by soil properties, hence management options are limited. Therefore, in the development of water quality guidelines a prediction of the leaching fraction is crucial. An estimate of leaching fraction will allow a prediction of salt accumulation in the root zone and a prediction of the amount of water draining below the root zone. This information is important for management of poor quality waters and for identifying the potential for rising water tables.

An empirical model of leaching fraction based on rainfall and easily measured soil properties (SaLF) has been developed to predict leaching under irrigation by the Queensland Department of Primary Industries (I. Gordon, B. Wilshire and R. Shaw). At this stage the impact of high levels of sodium in irrigation waters has not been fully accounted for in this predictive model. One of the aims of the project is to enhance leaching estimates by the incorporation of a dynamic sodicity component into current models. This will allow changes in ESP and soil behaviour to be assessed in terms of changes in the leaching of the soil profile. New models will be linked to an irrigation scheduling program to assess the impact of irrigation with poor quality water based on historic rainfall records. This will also allow an assessment of the effect of irrigation in extended dry periods when greater salt accumulation may occur.

The expected outcome from this project is the development of more quantitative guidelines for decision making on the optimal use of surface and groundwaters, which will minimise water level rises and soil degradation and improve groundwater quality and long term cotton productivity.

(d) Hydrogeology and estimation of groundwater recharge in irrigated cotton systems

Hydrogeological investigations in the lower Macquarie Valley

Researchers: G. Brereton (Macquarie, DLWC)
T. Riley (Namoi, DLWC)

Time Frame: 1996-98

Managing the hydrological cycle in relation to cotton

Researchers: R. Faulkner, J. Douglas and D. McLeod (CRC,
UNE)

Time Frame: 1996 - 1998

Estimation of groundwater recharge in irrigated cotton systems

Researcher: T. Willis, (NSWA)

Time Frame: 1992-1995



Significant increases in piezometric pressure have been observed throughout the Macquarie Valley since the 1970s, thus indicating the potential for development of shallow regional water tables. The DLWC postulated several sources of groundwater recharge including: river leakage, leakage from channels and reservoirs, and deep drainage under irrigated and dryland agriculture. In addition, small areas had developed shallow perched water tables by the late 1980s. These perched water tables were caused by seepage from storage dams and deep drainage from cotton irrigation, and eventually resulted in isolated areas of salinity.

As a result of these discoveries, the DLWC (G. Brereton) has been investigating the hydrogeology of the lower Macquarie Valley. The aim has been to identify aquifer systems and their connections in the Valley, along with the continuous monitoring of groundwater levels. The extent and site of river leakage has also been investigated.



Figure 8.
*Salinity tour
raising awareness of salinity
management
practices in
Bourke.*

In the cotton growing areas of Northern NSW, the occurrence of heavier soil types with low hydraulic conductivity suggests that soil salinity is not perceived as a significant threat. However, excessive deep drainage beneath irrigated agriculture could potentially lead to shallow water tables and subsequent soil salinity. Therefore it is also necessary to quantify deep drainage beneath irrigated cotton in these areas. Various methods are currently being employed to measure deep drainage, including Darcy's law and chloride mass balance (J Douglas).

A rise in soil salinity may also be a result of applying poor quality water. Salt levels in the irrigation and rain water will also be monitored over the growing season to determine the amount of salt added to the soil. Changes in the salt content of the soil over the cotton season will also be examined.

The chloride mass balance model (SODICS) will be used to predict future trends in soil salinity in various soil types in the Namoi and Gwydir Valleys. To ensure reliability of output the model will be evaluated by comparing modelled and measured data such as drainage rate and the distribution of salts in the soil profile.



Objective Four

To increase the knowledge of appropriate management strategies to minimise secondary salinity in the cotton growing areas of Australia

Research will be undertaken on management options which maximise yield in affected areas and minimise the potential spread or threat of secondary salinity in the cotton growing areas of Australia. This will provide agronomic options to combat the onset of soil salinisation and provide crop rotations to maximise soil water uptake, reducing deep drainage.

Strategies

(a) Salt tolerance levels

Identify the most salt tolerant cotton varieties and rotation crops for use in saline areas.

Students: Post-graduate and undergraduate
(CRDC/CRC Scholarships)

Time Frame: 1996-97

Preliminary research work, carried out at the University of Sydney, involved determination of salt tolerance of a number of yet to be released cotton cultivars (S. Spoljaric and A. B. McBratney). Initially, the salts of sodium and chloride were used in differing concentrations to determine salt tolerance. Following this salt tolerance of cotton cultivars were assessed by determination of salt constituent ratios within saline subsoil obtained near Galathera Creek within the lower Namoi valley. A similar trend in the results was observed although it appears that some cultivars are more tolerant of sodium chloride salts rather than sulphate salts. The cultivars also exhibited lower than expected tolerances (i.e. 50% reduction in germination) than that claimed in existing published literature. A similar but more detailed study of salt tolerance is currently being undertaken. The results of this study will act as a stop gap method until more suitable management strategies can be implemented to reduce the saline build up within the rootzone.



(b) Groundwater recharge

Assessment of winter crop rotation phases for salinity prevention in cotton rotation systems.

Researcher: T. Willis (CRDC - NSW)

CRC Systems Trial: Warren

Time Frame: 1996-99

Specific management strategies aimed at salinity prevention require assessment in the cotton growing areas of Australia. The benefit of a winter crop to dry the soil and minimise groundwater recharge, while maintaining acceptable root zone salinity, will be assessed. The effect of two different winter crop rotation phases will be compared with a bare fallow, on two soils in the Macquarie Valley. Chloride mass balance modelling will be used to estimate deep drainage under each rotation phase and to predict future trends in salinity. A suitable crop/soil water simulation model will also be used to assess the effect of varying weather conditions on deep drainage and salinity.

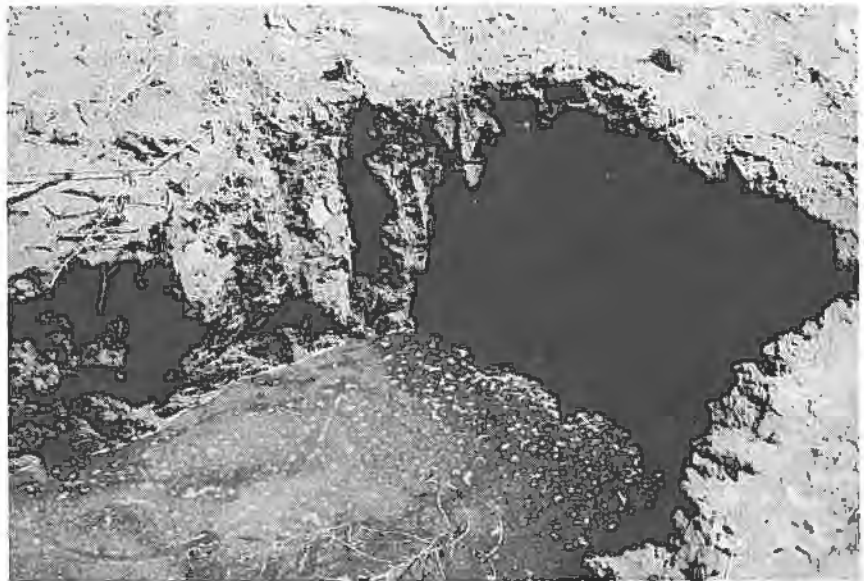


Figure 9. *Shallow watertable caused by dam leakage in the Bourke area, NSW.*



Linkages

Overall, the current research projects and management strategies being developed will contribute significantly to an increased knowledge of the processes that have the potential to cause soil salinisation in the cotton growing areas of Australia and more importantly identify the potential threat. The results obtained within each project have the scope to be used by other researchers to modify and enhance their individual work. Ideally, this can be represented schematically as illustrated in Figure 10. Here measurement, mapping, modelling and a monitoring protocol is developed independently with the results integrated, possibly within the SOILpak management package.

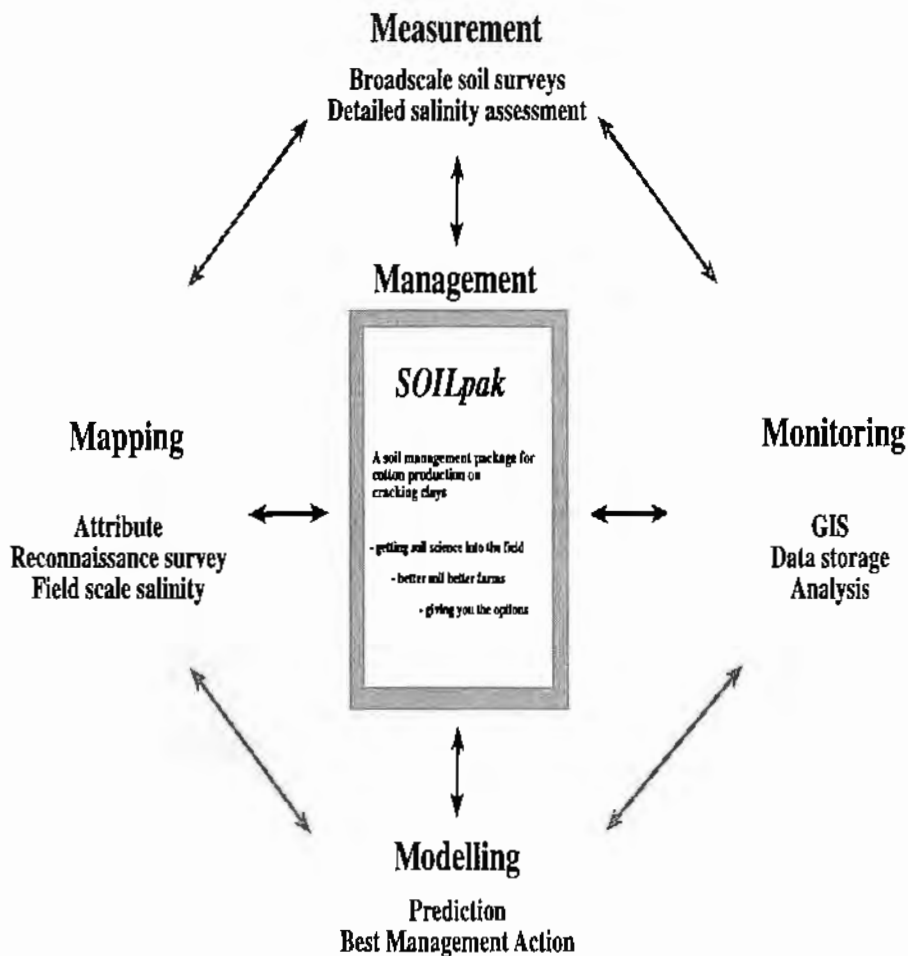


Figure 10. Integrated salinity research and management strategies for cotton growing areas.



Research targets

The research projects described above have relatively short term funding periods of approximately three years duration. As such the results and outcomes of these projects should be available for application/extension soon after their completion. A time frame for their application is given in Table 1. It is suggested as a guide to when tools for consultants, farmers, land managers and extension staff could be available. Cost-benefit analysis could be used to determine the rate of adoption and impact of each research project in terms of dollars used to fund and benefit in terms of increased or maintained yield.

Table 1. Summary of projects, principal researchers, funding, research outcomes and target dates for completion.

Project	Researcher	Outcomes	Target Date
Reconnaissance soil studies	I. Odeh (CRC - US)	Conduct reconnaissance surveys. Development of GIS. Identify areas of salinity threat.	June 1997
Understanding the salinity threat in the irrigated cotton growing areas of northern NSW	J. Triantafyllis (CRDC - US)	Development of salinity module. Determine salinity threat. Assess usefulness of aerial-EM.	June 1998
Modelling and management decision support tools	I. Gordon (CRC - QDPI)	Development of irrigation water quality guidelines.	June 1997
Rotation cropping systems	T. Willis (CRDC - NSW)	Application and extension of appropriate cropping systems.	June 1999
Geohydrologist	J. Douglas (CRC - UNE)	Quantify processes of water application and infiltration.	June 1998
Extension	(US, UNE, NSW, QDPI)	Extension of research and best management strategies (i.e. SOILpak).	June 1998



Priority areas

The extension strategies outlined here will lead to an increased awareness and understanding of the processes that could potentially lead to soil salinisation in some of the cotton growing areas of Australia. They will also provide extension officers, consultants and farmers with the necessary information to assist in determining the most optimal management strategies to remediate the problem given a certain set of circumstances. The research programs described will assist in determining the potential salinity threat, quantitatively, through the development of field methods and computer modelling techniques. In addition, research will also provide suitable management options to limit the spread of soil salinity in affected areas. Each of the objectives described here, therefore, have a role to play in the overall salinity education, research and management of the cotton growing areas.

In the event of future drought conditions, similar to those which affected many of the major cotton growing areas during the seasons of 1994-95 and 1995-96, funds for these objectives may be reduced. With such restrictions, it is important that researchers and extension personnel target priority areas and be efficient with CRC, CRDC and other sources of external funding.



Appendix

Outlined below are possible measures to minimise the extent of salinity in cotton growing areas. The management of cropping through planting techniques, soil management through good land preparation, irrigation management by efficient use of water as well as constant monitoring all have a role to play in reducing the impact of soil and water salinisation.

Soil management

The suitability of soil for cropping depends principally on its ability to conduct water and air and on aggregate properties that control friability of the seedbed. As such the preparation of the soil and its condition prior to germination is of critical importance to crop germination and productivity. In order to ensure optimal conditions a number of management considerations are of importance particularly in an irrigated system. Some of these include land preparation, the use of ameliorants, mulching and seed bed orientation.

Land Management

Land preparation is critical in preparing soil that is to be flood irrigated. Care should be taken at the land planning stage of development to ensure that a uniform grade is achieved across the field. This will produce an area of land that will have more uniform water application and as a result better salinity control.

Seed bed design

Despite the preparation of a uniform grade, problems may arise in the seedbed due to the movement of salts during wetting up of the soil by furrow irrigation. Salts in low concentrations within the irrigation water and the soil will be mobilised and concentrated in particular areas within the seedbed. Therefore, it is critical to ensure that the design of the seedbed and the subsequent placement of the seed is not where salts will concentrate after water application.

Ameliorants

When considering sodic soil profiles particularly those affected at the soil surface, crusting and consolidation of the soil will occur and may prevent seed emergence. The most commonly used ameliorant is gypsum, particularly for sodic soil reclamation and when using saline water with a high SAR value for irrigation. Calcium chloride, a highly soluble molecule, would also be a satisfactory ameliorant especially when added to irrigation water. The amendments are usually applied to either neutralise soil reaction (decrease pH of an alkaline soil), or exchange sodium with calcium.

As a result of these ameliorants the water entry and storage of the soil is improved with removal of salts, a desirable side effect in the long term. The maintenance of large amounts of organic material at the surface will also maintain good soil tilth. More frequent and less voluminous irrigations are recommended in excessively sodic profiles to overcome structural problems at the soil surface. The effect is to maintain a moist



soft surface to allow the seeds to germinate.

Deep ploughing

Where salinity is severe deep ploughing is an option, albeit expensive. It involves ploughing to depths ranging between 0.40 to 1.50 m. In this way the salt is mechanically redistributed to deeper parts of the profile. The procedure can also be used to break up slowly permeable soil layers that prevent deep percolation of water and the necessary leaching of salt. Special equipment that can invert whole soil profiles can be used to alter profiles to depth. Care should be taken when such a mechanical procedure is undertaken because a plough pan layer may be produced and a deeper salt rich layer in the profile may be brought closer to the surface.

Sanding

Sanding is the procedure that applies sand to the surface to make a finer textured soil that is more permeable and improves root penetration, better water and air permeability. The resulting improvement in water penetration facilitates leaching of sodic and/or saline water. The procedure produces a relatively permanent change to the surface texture.

Organic manures

Growing legumes and the use of green manures will improve soil structure. Green manure has a similar effect to organic manure. Mulching can be used to reduce evaporative losses from the soil thereby reducing the opportunity for soil salinisation, particularly during a fallow period.

Water management

The most important considerations for salinity control in irrigated schemes are frequent irrigations, adequate leaching, drainage and water table depth control. In any irrigation scheme the efficient transport, application and reuse of water is also of paramount importance, since it is these processes which can seriously impact the long term sustainability of the system.

Figure 11.
*Sealing
irrigation
supply chan-
nels with
concrete and
other suitable
membranes.*





Delivery system

The greatest loss of water in most irrigation systems is due to leakage from supply canals and storage structures. This is generally attributable to the construction of walls from permeable soil materials. To improve the efficiency of the delivery system and prevent deep drainage of water a number of management options are available. Channels can either be lined with non-permeable materials such as concrete or the soil may be compacted with heavy machinery to achieve lower permeability. In addition, where suitable soil materials are located in close proximity to the structure their use may be facilitated by excavation and transportation for lining of the channel/dam. An alternative to this is the use of bentonite and other geomembranes which have been successful in stopping leakage. Closed conduits of concrete and polyvinyl chloride are other practical alternatives which reduce evaporation, produce a pressure head and can be buried below the land surface.

Management of the system is then required to ensure the efficacy of water transport is maintained. The system should continually be monitored to ensure that future leaks are sealed. This requires information to be gathered, including measurement of amounts of water entering the system and volumes passing points located around the farm. Metered devices are required but once installed will be able to identify areas of leakage.



Figure 12.
Locating storage dams on suitable relatively non-permeable soil materials.

Prior to the construction of such structures an effort should be made to determine the suitability of a site for such a purpose. The location of a site based on the area being the least productive is not necessarily the most suitable location. Site selection should be based on choosing an area where suitable soil materials exist. An area where large amounts of clay are located would be more preferable than an area where coarser soil material predominates. In addition, aerial photos and geology maps of the selected area often identify the potential impact a particular structure may have. To date some leaking storages located in stratigraphic alluvial environments have led to some soil salinisation in adjacent irrigated cotton fields. Such structures have in some instances been sealed with great effect, whilst others have been abandoned for this purpose.



On-farm irrigation

General improvements in salinity control can be made from maximising on-farm irrigation efficiency. This is achieved by supplying the necessary amount of water at the appropriate time with high uniformity. The ideal irrigation scheme should provide water more or less continuously to the growing crop to match evapotranspiration losses and to keep water content in the rootzone within narrow limits. Continual irrigation will reduce salt build up around the growing roots ensuring a low osmotic potential in this volume of soil and optimal conditions for water and nutrient uptake.

Drainage and reuse

Secondary salinisation of soil usually occurs as a consequence of rising water tables. Essentially, this is due to deep percolation of water beyond the rootzone. Adequate leaching in irrigated areas is a necessary evil, however. This ensures that the rootzone is free of salt build-up, particularly if the water used for irrigation is of a poor quality. Management strategies should therefore be aimed at minimising the volume of drainage water generated. This is achieved principally by irrigating with the minimum amount of water required to lower leaching and recycling unused water.

Leaching

The earliest remediation of saline soil involved leaching by ponding water on the soil surface. To prevent the accumulation of salts in the rootzone, irrigation must be sufficient to leach out harmful salts. At the same time accumulations of salt near the soil surface as a consequence of excessive irrigation, must be minimised. Salt will accumulate in the rootzone as the plant extracts water necessary for growth. The removal of the water due to transpiration and evaporation creates the potential for water to flow upwards. This may lead to the steady accumulation of salts if a shallow saline water table begins to rise.

Irrigation Timing

The success of irrigation on a saline soil is heavily reliant on a sufficient irrigation strategy. The more frequent the irrigations the lower the osmotic stress the plant will encounter and the less chance there will be of salts accumulating near the developing root mass. Scheduling in this way will enable the depth of leaching water to be accurately determined and will prevent excessive deep percolation. More frequent irrigation will also tend to soften surface crusts on sodic soil and will encourage better stands.

Conjunctive water use

Often irrigators have access to two or more sources of water. The primary source may be river water, water from aquifers or water tables or even tail or other drainage waters. Each will vary in levels of soluble salt. Therefore, each can be utilised at different times with respect to the irrigation management of a particular crop. When the crop is most susceptible to salinity stress, at germination, good quality water can be used to ensure establishment. Subsequent irrigations may be facilitated with water



of poorer quality where the plant is not nearly as sensitive to saline conditions. At crop maturation a return to the use of good quality water is used to leach any undesirable or excess salts that may have accumulated and ensure that the crop is able to set satisfactorily.

Monitoring/control

To maintain a viable irrigated industry, up-to-date information is continually required, on a field by field basis, to assess the level and distribution of salts within the rootzone. What is necessary is precise data about the amounts of salts present in the rootzone, particularly information on the distribution of salts. Water quality measurements are also needed. The use of gross salt balance models based on the field scale are inadequate since the results obtained are a generalisation of the whole area and may not be indicative of the variability of soil in a particular field. Many laboratory and field based methods of data generation are available in this regard and should be used periodically for continual assessment and monitoring purposes.

Crop management

The most important stage in crop growth is germination. In most cases it is the most sensitive growth stage and is crucial in terms of maximising economic return. That is, optimal productivity is not possible without satisfactory establishment. The choice of crop as well as planting strategies can be used to great effect where the presence of excessive amounts of salts has the potential to reduce productivity.

Choice of crop

The tolerance of plants to salinity varies between species and cultivars. Where salinity cannot be contained within suitable limits by leaching, selection of a particular crop of greater tolerance is suggested. Many sensitive crops can still be grown in soil of high salinity. This is achieved by nursing them through critical stages of growth, particularly at germination when plants are most vulnerable. Often as part of the management strategy temporary sprinklers are installed that enable the surface soil to remain constantly moist and free of the harmful effects of salt. Pre-irrigation to remove these salts can also be used to great effect. Surface irrigation is then applied to grow the established crop.

Planting techniques

In a furrow or seed bed that contains excessive amounts of soluble salts, concentrating these salts in parts of the seed bed away from the germinating crop is sufficient to enable establishment. Designing a seedbed or furrow may be accomplished by a simple alteration to existing tillage implements. The seeds are then planted on the sides of these furrow ridges away from the saline areas. Further, on replanting of an annual crop an effort should be made to place the seeds in that part of the seed bed where the previous year's crop was grown. To ensure a good stand, plant density can also be increased to compensate for smaller plant sizes that occur under saline conditions.