Final Report

Improved irrigation scheduling for crops underlain by shallow, fresh water tables

Land and Water Australia Project CTC026

Principal Investigator
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Australian Government
Land & Water Australia
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Project Reference CTC026

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- Ord irrigation Company
- Bundaberg Sugar
- CSR Sugar

Collaborators

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Project Title

Improved irrigation scheduling for crops underlain by shallow, fresh water tables

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Project Objectives

It is well known that shallow water tables supply substantial proportions of a crop's water requirements – up to 50 % in semiarid areas where water tables are fresh. Not accounting for this water uptake causes over irrigation and markedly reduces irrigation efficiency: it is akin to not accounting for rainfall. Yet in northern Australia, there are more than 200,000 ha of irrigated land, much of it on the coast, susceptible to the development of shallow, fresh water tables. While the potential for shallow water tables to cause water logging is often recognised, the potential for fresh water tables below approximately 0.5 m to be a source of water for crops is not recognized in these areas. Reversing this situation will reduce irrigation applications by 20-50 %. Achieving this will substantially increase utilisation of existing surface irrigation water resources. For example, it would "free up" enough water to irrigate an area equivalent to the Ord Irrigation Scheme. Additionally, it would reduce environmental impacts resultant from excessive deep drainage below the root zone.

This project's overall aim is to improve irrigation water use in northern Australia by accounting for contributions to crop water requirements from shallow, fresh water tables. This aim will be achieved by:

- Raising awareness amongst farmers, irrigation extension staff and water policy authorities in Qld and WA of the extent of shallow water tables and their impact on irrigation scheduling.
- Determining relationships between water table depth and upflow to the crop for a range of soils, climates and water table conditions.
- Conducting action learning programs so farmers will know (1) how to monitor shallow water table levels on their farms, and (2) how to incorporate knowledge of upflow into irrigation management practices.

Methods

The methods employed in the project were aligned with the specific aims, as described below.

Awareness raising

Awareness of shallow water tables was achieved by several means:

1. A review of scientific and technical literature was undertaken. This review aimed to put the issue of irrigation management in relation to shallow water tables in northern Australia into context of experience in other countries. Information gathered during the review was entered into the irrigation water balance review database developed in LWA-NPSI project CLW21, to provide a northern Australian focus for that database. As part of this review, water balance modelling (with SWIMv2.1; Verburg *et al.*, 1996) was employed in a 'desktop' study to generalise the findings of previous experiments. Full details of the modelling are given in Appendix 1.

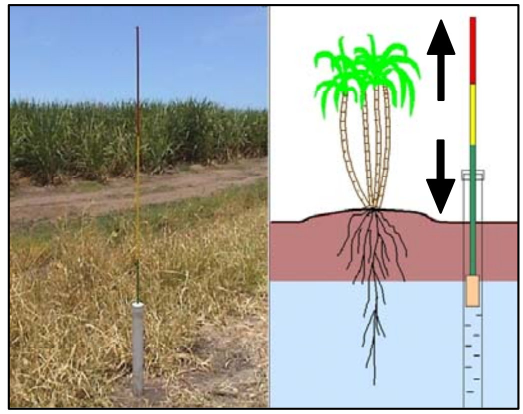
2. Awareness was also raised through presentations to irrigators within the Queensland Water Use Efficiency Initiative and the Ord Irrigation Area (OIA), and at industry conferences and training courses. Newsletter articles were also written where appropriate. Feedback from these groups led to the following two activities.

3. The above groups identified that there was very poor information on, and knowledge of the distribution of shallow water tables in some areas, particularly the Bundaberg and Burdekin areas. This situation contrasted that in the Atherton Tableland region (Shaw *et al.*, 1998), OIA (O'Boy *et al.*, 2001) and Emerald Irrigation Area (Bevin and Shaw, 1980; Gordon 1991) where water table information was available from previous salinity investigations, or the Herbert regions where waterlogging from very shallow water tables is a well known problem (Rudd and Chardon, 1977). The groups proposed that, to raise awareness of the issue, it would be important to produce maps of the likely distribution of shallow water tables. Existing groundwater information databases in Queensland's coastal irrigation areas were obtained (from Qld Dept. of Natural Resources and Mines). However, their value for predicting the occurrence of shallow water tables was poor because these databases contain information on aquifers than the ones generally influencing irrigated cropping systems (see Appendix 2 for more details). Methods were developed to estimate the likely occurrence of shallow water tables in the Bundaberg and Burdekin areas based on data from pre-European vegetation distribution and soil and landform properties. These methods are described more fully in Appendix 2. Maps were produced for these areas, as they are the coastal areas where (1) irrigation is important, (2) shallow water tables are potentially common and likely to be fresh, as well as (3) the knowledge of shallow water tables was poor. Another area where maps could have been developed was the Mackay region. However, discussion with local groundwater hydrologists and soil surveyors, and assessment of available data suggested that the extent of shallow water tables would be very limited in Mackay.

4. The groups listed in (2) also proposed that irrigators were unlikely to monitor water table depths if it had to be done manually, and that some rapid means of assessing water table depths would increase the attractiveness of monitoring activities. To achieve this aim, it was proposed that a simple float pole be placed in shallow wells to give a rapid visual indication of water table depths (Figure 1). The float device can be

made from off-the-shelf products, such as a length of dowel made buoyant using high-density polystyrene foam floats. The foam floats sit on top of the water table and the length of dowel protrudes out the end of the observation well making it visible above the surface. The device moves up and down with the movement of the water table, showing growers the current depth of the water table. This depth provides an indication of the possible contribution of water tables to crop growth through root uptake. A visible indication such as the float pole would also further and raises awareness of water role of tables in the area.

Figure 1. Diagram of a float pole, which is designed to monitor the depth of the water table. The float pole is placed within an observation well and floats on top of the water table.



Defining crop-watertable interactions

Several investigations were undertaken to define crop water table interactions. These centred on sugarcane, as it is the main crop grown in areas in northern Australia with potentially shallow water tables. The main irrigation area with shallow water tables where sugarcane is not the dominant crop is the Emerald irrigation Area but there the area with shallow water tables is small (~ 200 ha; Bevin and Shaw, 1980; Gordon, 1991).

The main investigations are described as follows:

1. Two field experiments were conducted in areas with shallow water tables to test the hypothesis that yield response to irrigation would be reduced if sugarcane crops were obtaining significant amounts of water from a shallow water table. Experiments like these had not been conducted in Australia before. The experiments were conducted in the Bundaberg and Burdekin areas. In the Bundaberg experiment there were three treatments: full irrigation, half irrigation and no irrigation. The experiment was conducted over two ratoon crops. Treatments in the Burdekin experiment were full and no irrigation and the experiment consisted of a single ratoon crop. Details are given in Appendices 3 and 4.

2. In the Ord Irrigation Area (OIA) there were two field-based activities. First, the proportion of ground water taken up by sugarcane crops was determined on four farms that were located in the area identified by the local group (see Awareness raising/2) and previous hydrogeological studies (Figure 2) as having the shallowest water tables. This information was obtained by sampling the concentrations of stable isotopes of water in the groundwater-soil-plant continuum (Walker *et al.*, 2001). Secondly, crop water stress was measured with and without irrigation in the area where water tables are shallowest. This latter activity was not a formal experiment, such as those undertaken in the Bundaberg and Burdekin areas. Rather it was an on-farm demonstration activity to confirm the results of the isotope study and water balance modelling (described below). Full details of both these field activities are given in Appendix 5.

3. Additional modelling of upflow from water tables was undertaken with SWIMv2.1 to determine how relevant the results of the 'desktop' water balance modelling study (described in the first point of *Awareness raising* activities, above) were to: (1) the two field study sites, and (2) the dominant soil type areas in the OIA with the shallowest water tables (i.e., the north east, Figure 2). Hydraulic properties of the soil profiles were measured at both the experimental sites and obtained from previous studies for the OIA. Details of the methods are given in Appendix 6 for the Bundaberg site and Appendix 7 for the Burdekin site. Full details of the modelling methods are given in Appendices 5, 7 and 8.

4. A cropping systems model was used to provide more general insights into the amounts of irrigation required in Australian sugarcane production systems in the presence of shallow, fresh water tables. This work was necessary as the SWIMv2.1 model uses a simplified representation of plants. Plants are represented as a ‘sink’ in the water balance equation, the strength of which is simply related to the canopy development and the evaporative potential of the environment. Thus, this model is not able to determine interactions between irrigation management, upflow and crop growth. The cropping system model, APSIM-Sugarcane (Keating *et al.*, 1999) is a more detailed model, employing fully dynamic crop growth and soil water modelling capabilities of the APSIM cropping systems simulator (Keating *et al.*, 2003). The ability of the model to simulate sugarcane yields under a different range of irrigation and water table conditions were first tested on the results of the field experiments. Then a range of simulations were undertaken to define irrigation production functions for sugarcane, under a range of soil types, climatic zones and water table depths. Full details are given in Appendix 3.

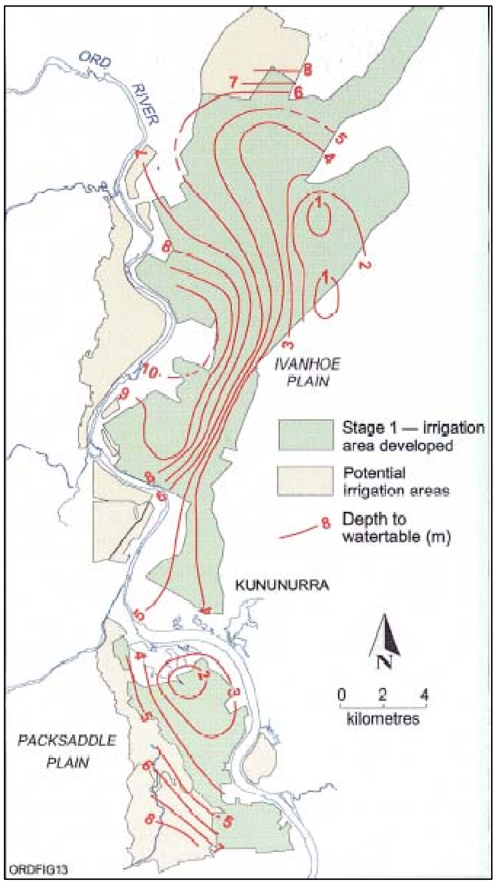


Figure 2. Depth to groundwater in the Ord Rive Irrigation Areas (O’boy *et al.*, 2001) highlighting that water tables are shallowest in the north eastern section of the area.

Scheduling information packages and demonstrations

Groups were formed in the Bundaberg and Burdekin regions to define the information packages and demonstration activities that were required to promote better irrigation management to irrigators and agency staff. Originally it was envisaged that the QWUEI groups would perform this role. However, at the time when information packages needed to be defined the QWUEI had ceased and new groups were needed.

In Bundaberg a group existed to advise irrigation research in two projects funded by Sugar Research and Development Corporation, CSE001[a] and CSE009[b]. The group consisted of BSES irrigation extension officers (previously involved with the QWUEI), a representative of the SUNWATER Bundaberg Customer Committee, Bundaberg Sugar (the biggest irrigator in the region), Queensland Dept. Natural Resources and Mines (DNRM) and Dr Geoff Inman-Bamber (leader of SRDC irrigation projects), and they agreed to become involved in the development of information packages.

In the Burdekin, the committee of the Lower Burdekin Initiative (LBI) provided the advice. Members of the LBI represent CANEGROWERS, BSES, North Burdekin Water Board, South Burdekin Water Board, Burdekin River Irrigators Association, Burdekin Bowen Integrated Floodplain Management Advisory Committee (BBIFMAC), CSR Sugar, and DNRM.

These groups agreed that activities should centre on promotion and demonstration of water table depth monitoring, and promotion of results from the experiments. They also identified that there should be a stronger link between the float pole water table monitoring concept and specific irrigation management actions. This link should also be part of the information package.

Information packages were not relevant in the OIA, because (1) there is an ongoing water table monitoring and reporting program in the region, and (2) results of field and modelling activities showed that water tables were unlikely to contribute significant amounts of water to crops in that region.

Results

Review and desktop modelling

The literature review showed that sugarcane has been found capable of exploiting shallow groundwater resources when the water table is within 1.5 m of the soil surface. The ability of sugarcane to extract shallow groundwater is further supported by a number of irrigation experiments where shallow water tables were present. In these experiments, sugarcane yields showed a small or negligible response to irrigation in environments where responses to irrigation were expected. Very little research has focussed on the effects of shallow water tables on growth and distribution of sugarcane roots and their ability to extract water at saturated or near saturated conditions. However, the few studies undertaken on this topic provide evidence that sugarcane roots are capable of functioning close (e.g., within 0.1 m) to water tables.

In agreement with the literature review, water balance modelling with SWIMv2.1 showed that for soils with a wide range of permeabilities, that upflow from static water tables within 1 m of the soil surface would be great enough to supply crop water needs and so no irrigation would be required (Table 1). Irrigation requirements when static water tables exceeded 1 m depth were dependent on the soil type (Table 1) and rooting characteristics (root depth and density). The modelling results also show that the near-saturated hydraulic conductivities are better indicators of the ability of water tables below 1 m to supply sufficient upflow as opposed to soil textural classifications. Full details of the review and modelling are given in Appendix 1.

Table 1. Indicative irrigation requirements for soils in different permeability classes, and for three specific soils from the field study sites (with maximum rooting depth assumed to be 0.8 m). Irrigation requirements are divided into three classes based on the proportion of transpiration simulated to be supplied by upflow from a water table: (1) No irrigation – transpiration needs likely to be fully met by upflow from the water table. (2) Reduced irrigation – transpiration needs likely to be approximately half met by upflow from the water table. (3) Normal irrigation – upflow from the water table only a small proportion of transpiration needs

[a] Increased profitability and water use efficiency through best use of limited water under supplementary irrigation. Led by Dr Geoff Inman-Bamber.
[b] Moving from case studies to whole of industry: Implementing methods for wider industry adoption. Led locally by Dr Geoff Inman-Bamber.

Water table depth (m)	Permeability of uniform general agricultural soils			Specific soils		
	Low	*Medium*	*High*	*Cununurra clay*	*Red Kandasol*	*Black Vertosol*
1	None	None	None	Reduced-normal	None	None
1.5	Reduced	None	None	Normal	Reduced	Reduced-normal
2	Normal	Reduced	None	Normal	Normal	Normal

Mapping areas likely to have shallow water tables

In the Bundaberg area there are isolated areas where water tables seem highly likely in the Fairymead and Kolan areas, and south of the Elliot River (Figure 3a). The main area likely to have shallow water tables is the coastal strip running north from Fairymead, through Moore Park and north of the Kolan River. This map has been presented to groundwater hydrologists and extension officers in the region, who agree with the predictions.

In the Burdekin region, the predicted occurrence of shallow water tables is more fragmented (Figure 3b), with areas between Clare and Barratta, around Giru, and between the river and Inkerman. The predictions in the Burdekin region may not be as relevant as those in Bundaberg because of groundwater salinity, often due to salt water intrusion. For example, shallow water tables were investigated on farms near Giru in an area mapped as likely to have fresh water tables. Two shallow wells were installed on the farm. Water tables were shallow as expected (~ 1 m below ground) but the groundwater was saline (EC > ~ 5 dS/m).

a **b**

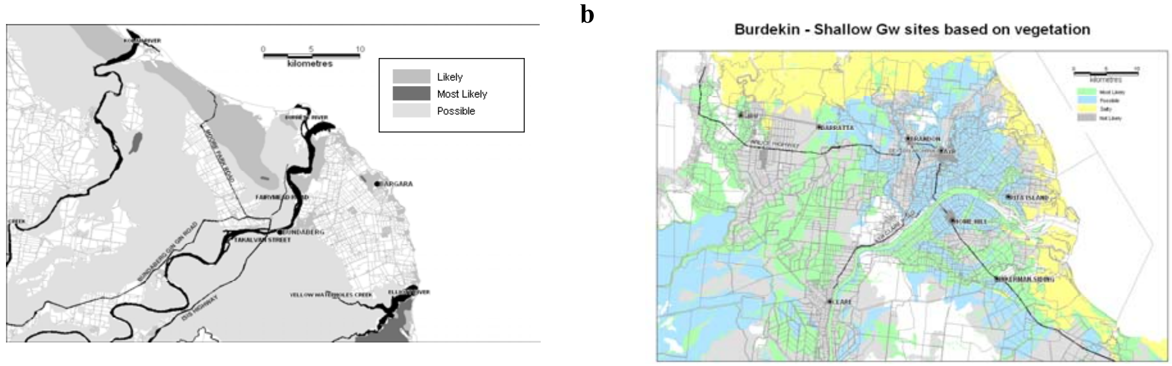


Figure 3. Potential fresh shallow water table regions in the (a) Bundaberg and (b) Burdekin areas.

Field experiments

In both field experiments there was no significant difference in the yields between the treatments with full and no irrigation (Figures 4 and 5). Water tables were at 1-1.2 m depth at Bundaberg and 1.2-1.5 m depth at the Burdekin experiment. Yields in the 1st crop at Bundaberg were substantially greater than those in the 2nd crop because harvester damage caused extensive gaps in the stool in the 2nd crop. In the Burdekin experiment, seven biomass measurements were made during the crop, and there were no significant treatments effect at any of these sampling times. Given the climatic conditions during both of these experiments, irrigations would have been expected to increase sugarcane yields in the experiment. The failure to obtain a significant treatment response in any of the crops within the experiments suggests that the half or unirrigated crops were obtaining sufficient water from the water table to prevent significant water stress. These results confirm the review of overseas studies, that shallow water tables can supply significant water to sugarcane crops, and that irrigation might not be necessary where water tables are 1-1.5 m deep. Details are given in Appendices 3 and 4.

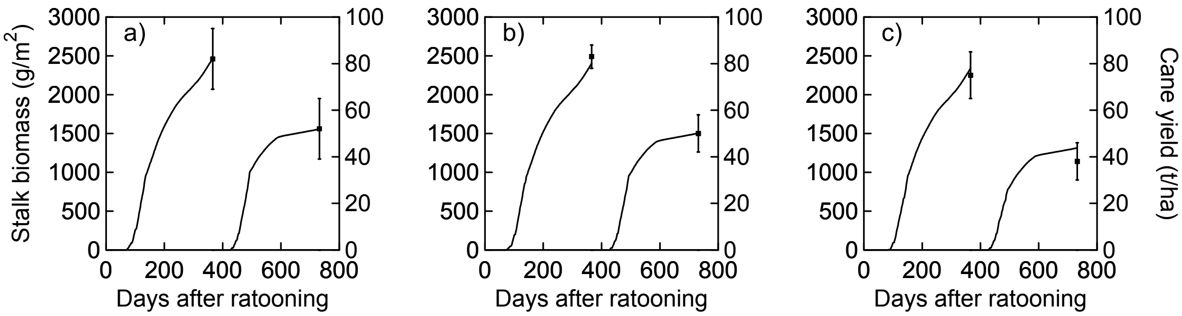


Figure 4. Comparison of simulated (lines) and observed (symbols) stalk biomass and cane yields for 3rd and 4th ratoons at Fairymead for the three treatments: a) full irrigation; b) half irrigation; and c) rainfed. Bars about the measured data points show ± standard deviation.

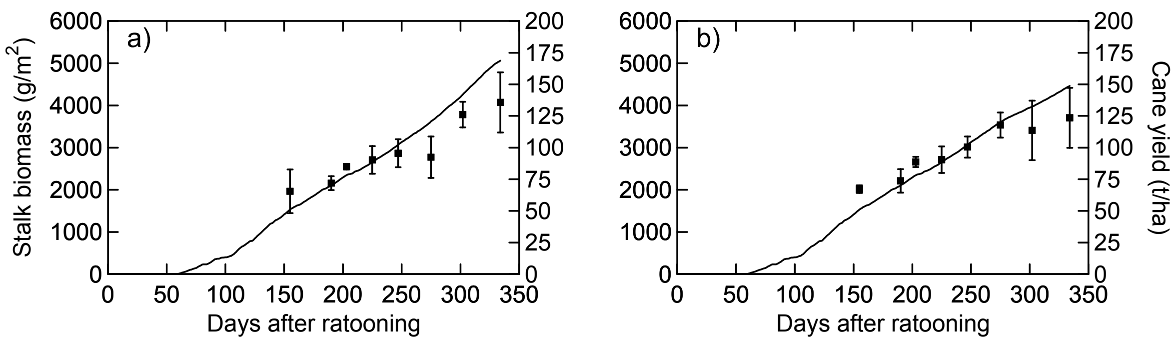


Figure 5. Comparison of simulated (lines) and observed (symbols) stalk biomass and cane yields for 2nd ratoons at Kalamia for a) irrigated and b) rainfed treatments. Bars about the measured data points show ± standard deviation.

Ord activities

There is little evidence that sugarcane was obtaining significant proportions of its water from groundwater in the OIA.

In the isotopic studies, the isotopic composition of the water from sugarcane was substantially different from that of the groundwater, but similar to that of water from some depth in the soil (Figure 6), at three of the four sites sampled. These results suggest that the sugarcane was not obtaining water from graoundwater, but the soil at the time of sampling. At the fourth site, R Lerch's farm – shallow water table site, isotopic composition of the water from sugarcane was similar to those of both the groundwater and the surface soil, suggesting that sugarcane could have been taking water from either or both sources. The possible uptake of groundwater at thus site may have been due to the shallower water table (1 m) than the other sites (~2 m). Thus the isotope data indicated that sugarcane only obtained water from the water table when the water table depth was <1 m, which occurs only in restricted areas in the Ord.

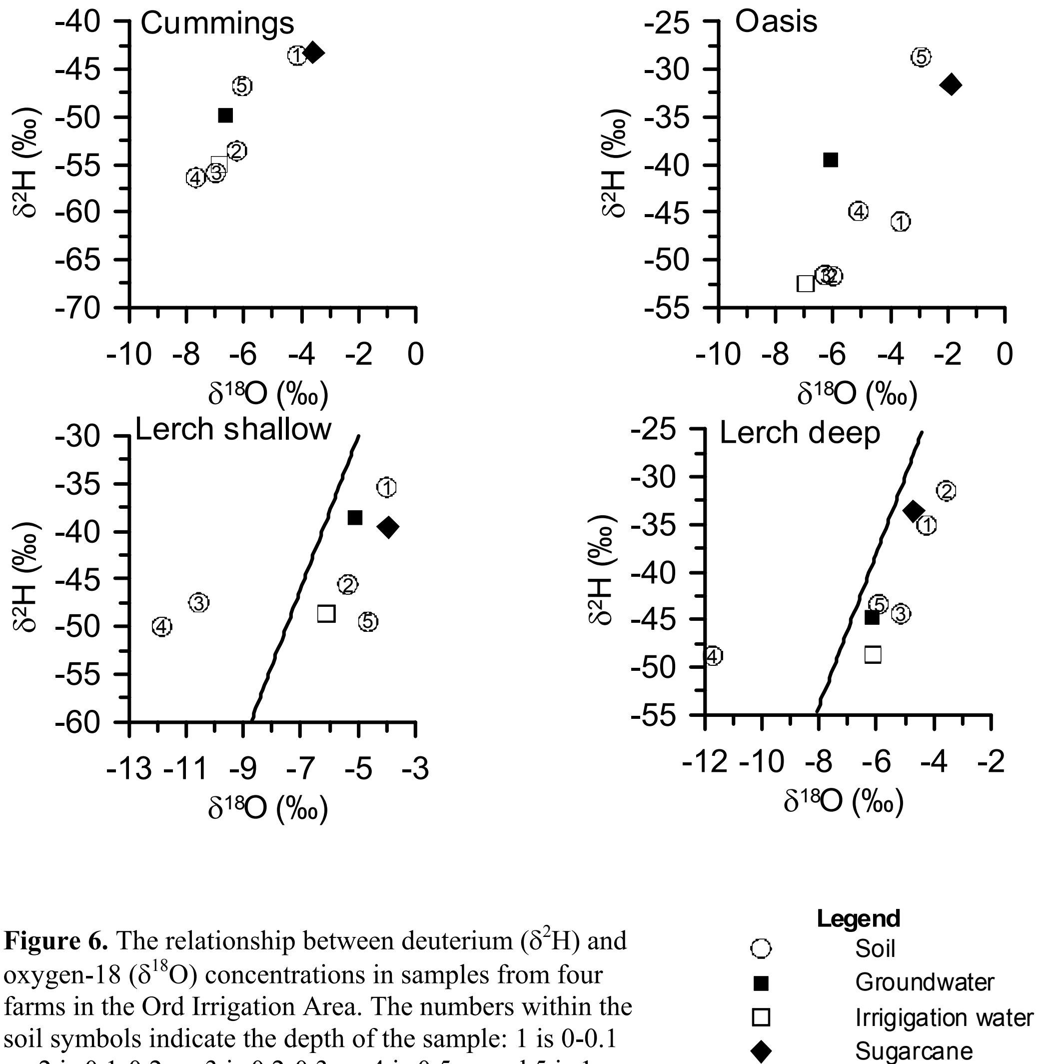


Figure 6. The relationship between deuterium (δ^2H) and oxygen-18 (δ^{18}O) concentrations in samples from four farms in the Ord Irrigation Area. The numbers within the soil symbols indicate the depth of the sample: 1 is 0-0.1 m, 2 is 0.1-0.2 m, 3 is 0.2-0.3 m, 4 is 0.5 m and 5 is 1 m depth.

The results of the modelling and water stress studies support those of the isotopic studies. With water tables at 2 m depth, similar to the conditions at three of the isotope sampling sites, the potential rate of water flow upwards from the water table was simulated to be small if roots were restricted to the top 1 m of soil (Figure 7).

Water stress observed after the cessation of irrigation (Figure 8) is consistent with the water table not playing a significant role in the crop's water supply. If the water table is at 1 m depth however, as at R Lerch's shallow water table site, the potential for crops to access groundwater is much higher (as illustrated by the simulation results in Figure 7).

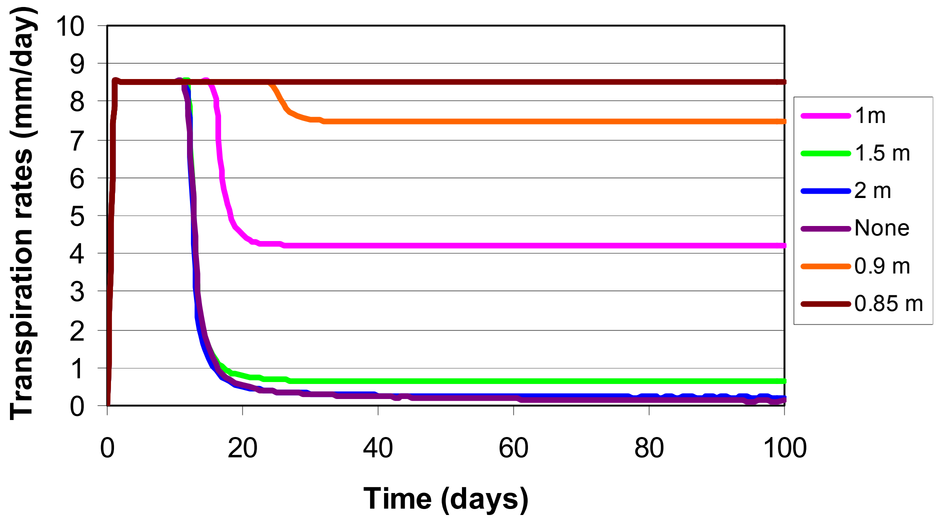


Figure 7. Simulated transpiration rates over 100 days for five water table depths, and with no water table, in Cununurra clay. The maximum rooting depth was 0.8 m in all simulations.

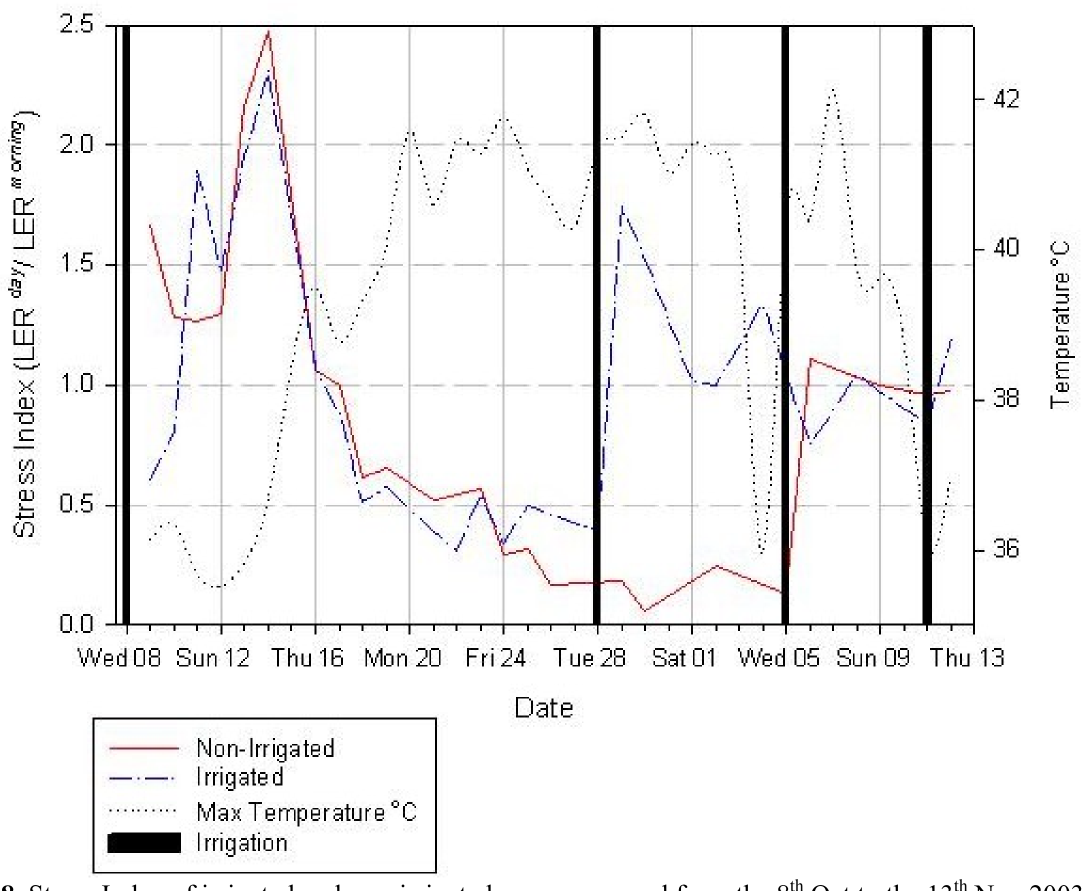


Figure 8. Stress Index of irrigated and non-irrigated areas measured from the 8th Oct to the 13th Nov 2003 with irrigation of the 8th Oct, 28th Oct, 5th Nov and 11th Nov.

The modelling results are likely to be an over estimate of the true value of upflow from the water table because salinity of the groundwater and the subsequent movement of salts into the root zone was not represented in the modelling. This process significantly limits the amount of groundwater taken by plants (Thorburn, 1997).

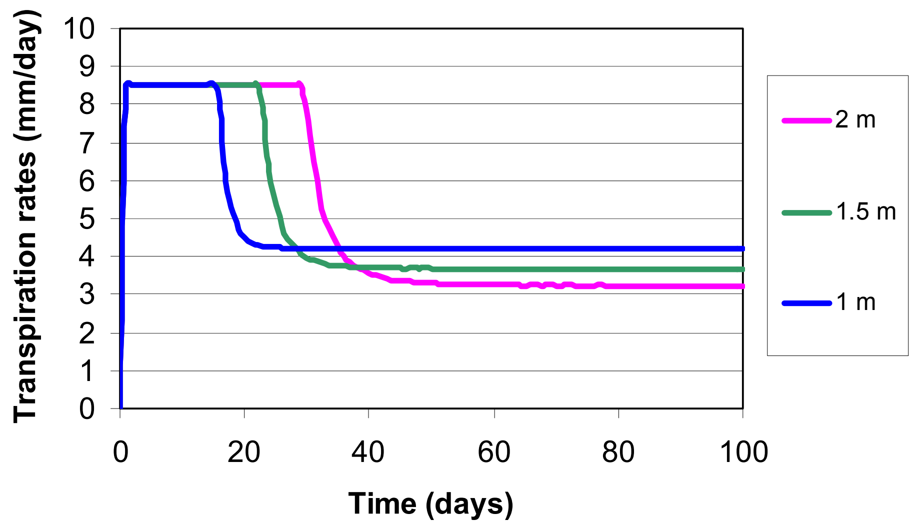


Figure 9. Simulated transpiration rates over 100 days for three water table depths in Cununurra clay. The maximum rooting varied in each simulation to maintain a 0.2 m distance between the bottom of the root zone and the water table.

A clear implication from the simulations (Figures 7 and 9) is that the distance between the bottom of the root zone and the water table is as important as the water table depth in determining upflow to crops. Water extraction by sugarcane has been measured at depths from 1 to 1.9 m in the OIA, depending on soil type and location (Plunkett and Muchow, 2003). Thus it may be possible for water tables at 2 m depth to effect crop water uptake and irrigation management of sugarcane. However, Plunkett and Muchow (2003) withheld irrigation for considerable times, e.g. 2 to 4 months, to obtain water extraction at depth. Deep soil drying and cracking was an important process in promoting water extraction from deep in the soil profile. Under more common conditions where plant growth aims to be maximised, there is little evidence of water extraction below 1 m depth (Muchow *et al.,* 2004). Additionally, the presence of a shallow water table would inhibit soil drying and cracking at depth, in turn limiting root function.

Thus, the overall conclusion from this study is that water tables at ~ 2 m depth supply little water to sugarcane crops and water tables need to be at 1 m depth or less to have a significant impact on the water supply and hence irrigation management (e.g. Cununurra clay – Table 1) of sugarcane crops. It implies that there is not a great deal of scope for modifying irrigation practices within the OIA to increase irrigation water use efficiency because of the presence of shallow water tables. This conclusion is likely to be applicable to other crops irrigated in the region as they will tend to have much shallower root zones. However, it may not be applicable to more coarse textured soils that occur in southern areas of the OIA (Anon., 2000).

This conclusion also suggests that the soil-plant relations in the OIA are different from those in sugarcane growing areas on the east coast of Australia. Soils in the OIA in general, and at the three farms studied in particular, are heavy clays with greater available water contents and lower permeability than most soils in eastern sugarcane growing areas. Thus strategies for maximising irrigation water use efficiency in the presence of shallow water tables developed in other regions cannot be blindly extrapolated to the OIA.

Other SWIM modelling

The water balance modelling with SWIMv2.1 undertaken using the hydraulic properties of the field soils from the Bundaberg (a Red Kandasol, Appendix 8) and Burdekin (Black Vertosol, Appendix 7) experimental sites showed that irrigation could be reduced in the presence of shallow water tables in a similar manner to that identified for the *low permeability* soil simulated in the desktop review study (Table 1). The similarity in behaviour of the Bundaberg and Burdekin soils and the *low permeability* soil is surprising, as the field soils would not normally be thought of as having low permeability. However, the horizon differentiation in the field soils, which restricts water flow, was not considered in the desktop review study.

APSIM Modelling

Yields in the two field experiments were well simulated with the APSIM-Sugarcane model parameterised to represent a water table in the root zone (Figures 4 and 5). Simulations of irrigation response curves for a range of soil types, climates and water table depths suggested water tables at 1 m depth could supply the water requirements of sugarcane, and deeper (2 m) water tables half the crops' needs (Figure 10), in many environments. These results are consistent with experimental results and modelling with SWIM. In addition, the simulations with APSIM showed the important impacts of climate, a fact not obvious from the limited number of experiments conducted on this issue. For example, simulated sugarcane yields with the Ayr climate responded markedly to irrigation in the Black Vertosol and Red Kandosol soils with a water table at 1 m depth (Figure 10). So the shallow water tables did not meet all the crops' water demands in these soils. In a climate such as Bundaberg where evaporative demand is lower, crop water requirements were almost fully met by a water table at 1 m depth in these soils.

This raises the question of how irrigation management plans should be changed to account for water tables. For example, if crops are obtaining all their water requirements from shallow water tables, irrigation will not raise yields and so will not be necessary. Alternatively, if crops are likely to obtain half their water from shallow water tables, either the irrigation amount or frequency should be reduced. An important issue to consider in framing management plans is the likely yield that will be obtained in the crop being irrigated. The long-term simulations (Figure 10) depict *potential yields*; those that would be obtained without the limitations of pests, diseases, lodging, crop damage during harvest, etc. Thus they represent maximum demand for water. Where yield limitations occur any or all of these effects, as exemplified by the reduced yield of the 4th ratoon crops in the Fairymead experiment (Figure 4), the crop's water demand may be reduced and so shallow water tables will meet a greater proportion of the crop's requirements. For example, if a sugarcane crop growing on a Black Vertosol at Ingham was expected to yield 70 t/ha, the simulation results in Figure 10g suggest that a fresh water table could supply all the crop's water needs unless the water table was below 1.5 m depth. Given that commercial sugarcane yields in Australia are often well below potential yields it is likely that fresh water tables will be able to meet the crop's water need in more situations than is apparent in the foregoing simulation analysis.

Knowing if water tables are present is also important in deciding on the appropriate approaches to irrigation scheduling. Concepts of replenishing a soil water reservoir as it becomes depleted are unable to be applied to root zones where upflow is a significant component in the water balance. In these circumstances direct measurement of soil water conditions or some plant attribute such as stalk elongation rate will be necessary.

Finally, it should be remembered that the range of soil types considered in these simulations is relatively small, and the APSIM results do not apply to very slowly permeable soils, such as occur in areas such as the Ord River Irrigation Area. Full details are given in Appendix 3.

Scheduling information packages

In consultation with the stakeholder committees in Bundaberg and Burdekin two types of information packages were produced. The first was in the form of a double-sided A5 fact-sheet aimed at irrigators (Appendix 9). The concept behind the fact-sheet was that irrigators could easily carry them in their utility as a reminder of shallow water table impacts on irrigation, and that they are cheap enough to produce in large numbers. The cards summarised the basic concepts of shallow water tables contributions to crops and listed the three steps required to make best use of shallow water tables; i.e. (1) identifying if shallow water tables were likely in the area, (2) the need to check the quality (salinity and acidity) of the water, and (3) monitoring water table depth (with float poles in shallow wells). Irrigation management response to shallow water tables was then summarised. Local contacts were also listed. Individual fact-sheets were produced for each region, and 200 were printed and given to the local contacts for distribution.

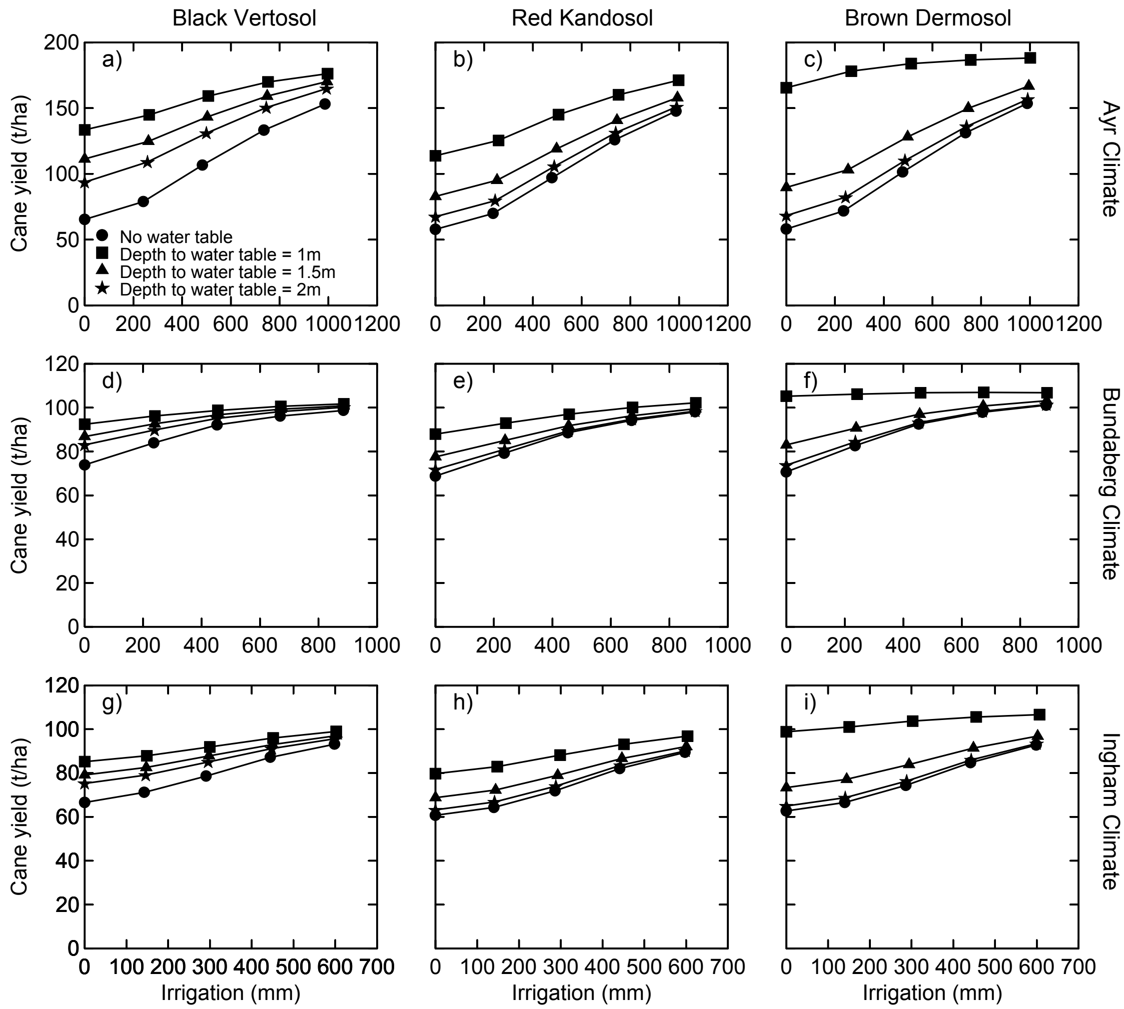


Figure 10. Simulated average cane yields for different irrigation amounts when no water table was present (●), depth to water table = 1m(■), depth to water table = 1.5m(▲) and depth to water table = 2m(★) using a) Black Vertosol and Ayr climate parameters; b) Red Kandosol soil and Ayr climate parameters; c) Brown Dermosol soil and Ayr climate parameters; d) Black Vertosol and Bundaberg climate parameters; e) Red Kandosol soil and Bundaberg climate parameters; f) Brown Dermosol soil and Bundaberg climate parameters; g) Black Vertosol and Ingham climate parameters; h) Red Kandosol soil and Ingham climate parameters; i) Brown Dermosol soil and Ingham climate parameters.

The second information package was a 7-page A4 booklet (Appendix 10). The booklet was aimed at extension officers and other agency staff, who have either not been involved in the project or are new to the district. The booklets provided a more detailed report on the concepts, findings and implications developed during the project. As with the fact-sheets, booklets were produced for each region, and 20 were printed and given to the local contacts for distribution.

As stated above, these information packages were not relevant in the OIA because results of field and modelling activities showed that water tables were unlikely to contribute significant amounts of water to crops in that region. However, this conclusion is documented in the report of work undertaken in the OIA (Appendix 5) and forms an information package that is available to new staff in the region, so they can understand the local situation.

As well as these information packages, information on irrigation scheduling in the presence of shallow water tables is also being distributed through computer-based irrigation scheduling tools being developed in SRDC projects CSE001 and CSE009. These tools include software packages and web interfaces for use by growers, extension officers, agricultural consultants, etc., that address the question of when to next irrigate a given field.

This question is answered through real-time simulation of crop growth and water balance for that paddock with the APSIM-Sugarcane model. The APSIM-Sugarcane modelling capability proven for shallow water tables in this project has been incorporated into these tools (Figure 11), so that there now is an option for shallow water tables. The coordination with these projects provides this project (CTC026) with an opportunity to have its outputs thoroughly integrated into 'cutting edge' irrigation extension material, which will be promoted, supported and delivered for the next two years through projects of SRDC and the CRC for Irrigation Futures.

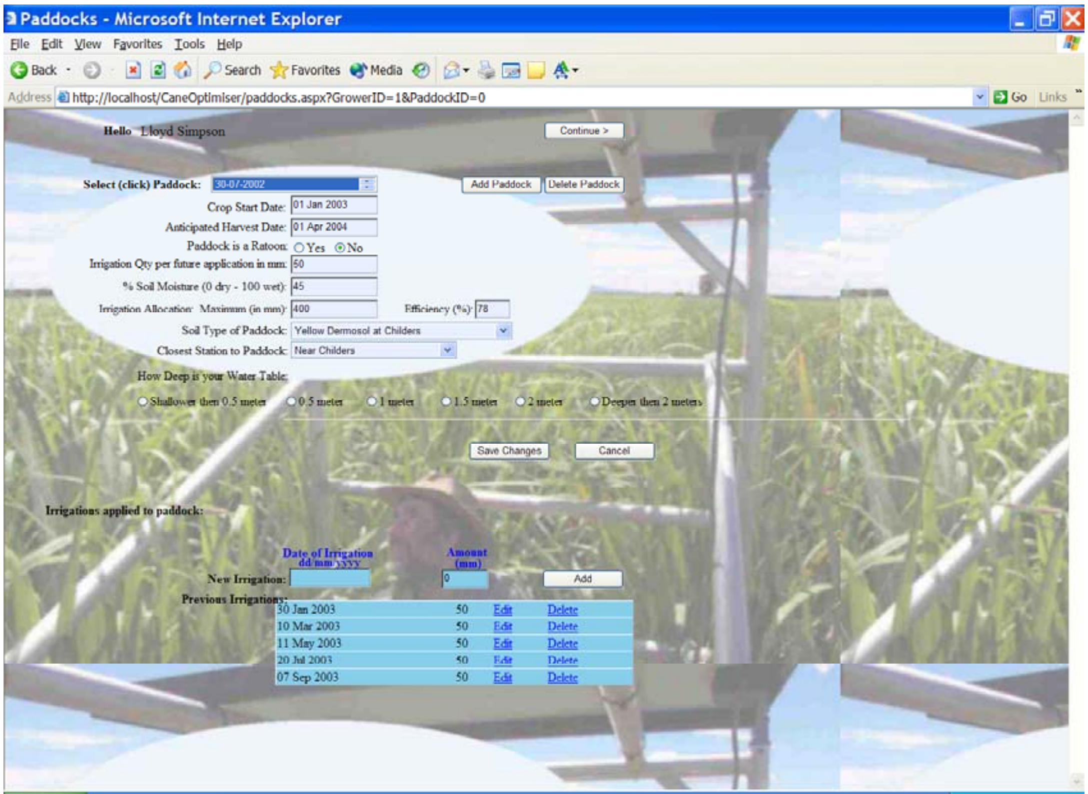
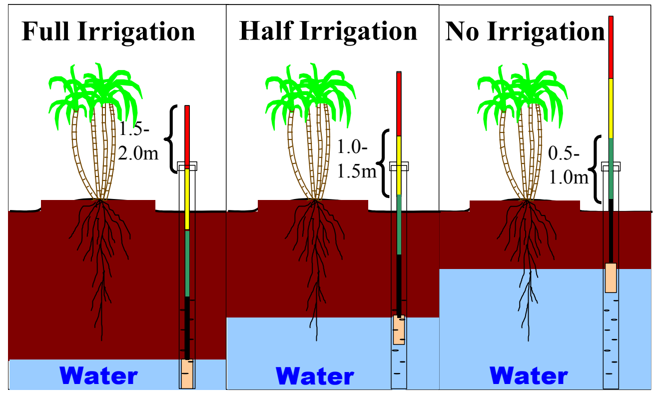


Figure 11. Example screen from the software package for scheduling the application of irrigation in areas were water qualities are limited.

Linking float poles to irrigation scheduling

Since crop-watertable interactions and hence irrigation scheduling are strongly related to the water table depth, the float poles promoted in the project can be modified to indicate the approach needed for scheduling irrigation. Colour schemes can be applied to the length of dowel (Figure 12) instead of depth increments, with the colours keyed to the irrigation requirements outlined in Table 1. This application of the float poles was promoted in the A4 booklets distributed during the project (Appendix 10).

Figure 12. Illustration of how a coloured float pole monitoring water table depth can also be keyed to irrigation management.



Demonstrations

Various demonstration activities were undertaken in the Bundaberg, Burdekin and Ord regions:

- A bus tour was arranged for growers to visit the experimental site in Bundaberg (February, 2003), highlighting the results from the experiment, the modified irrigation scheduling practices used on the Bundaberg Sugar Fairymead estate (they do not irrigate sugarcane when water tables are within 1 m of the ground surface), and demonstrating the float pole water table level indicator that has been installed at the site.
- The float pole concept was demonstrated to growers at, and after a DNRM field day on shallow water table management in the Moore Park area north of Bundaberg (on 7/3/03). Since the meeting several growers have expressed interests in the concepts described on the days and Mr Leon Dawes is following up these contacts.
- Irrigation extension staff in Bundaberg (Mr Tony Linedale and Mr Morrie Haynes) are promoting modified irrigation scheduling were water tables are found and demonstrating concepts in the project.
- A field day was help at Tom Lashmar's farm at Giru, in the Burdekin region, to inspect the groundwater monitoring undertaken by Tom Lashmar and communicate the details of shallow water table impacts on irrigation. Apart from growers, the field day was attended by Robyn Bell (Environmental Liaison Officer, Burdekin CANEGROWERS), Terri Buono (Coordinator BBIFMAC, Ayr), David Reid (Conservation Volunteers Australia).
- As a result of the field day at Tom Lashmar's farm, BBIFMAC and CANEGROWERS developed a Landcare Australia proposal to install a network of shallow wells in the Burdekin to better monitor shallow water tables and define the scope for modifying irrigation scheduling. This proposal was successful. The wells have been installed and water table depth and quality are being monitored.
- In the OIA, the lack of significant upflow was demonstrated in the growth monitoring activities, described above.

Adoption and Communication

Potential for adoption

The potential for further adoption of the findings from this project are significant. There is 'ownership' of the issue in the Bundaberg and Burdekin regions, and irrigation extension officers in these two regions are accounting for shallow water tables in their irrigation advice. There is also wider 'ownership' in the Burdekin, as evidenced by the pro-activity of local organisations in gaining more information on shallow groundwater in the region (described above).

A major avenue for future adoption is the incorporation of shallow water tables into the computer-based scheduling tools being developed in SRDC and CRC for Irrigation Futures projects. This outcome ensures that the results and insights gained from this project will be propagated through cutting-edge scheduling technology developed over the coming years. The capacity built in the regions and researchers associated with the project will support the practical application of shallow water table concepts in these tools.

The modelling approach adopted in this project is general and can be applied to other irrigation regions and/or crops. For example, the SWIMv2 model can be readily configures for other soils and climate conditions. The APSIM model contains modules for other crops and the soil water module can be configured to describe upflow for any soils, as described in Appendix 3. Both of these models are openly available. Further, the modelling undertaken with SWIMv2 is general to all plants, once they reach full canopy. Thus for the soils and climate modelled, the results can be extrapolated to other irrigated crops.

Communication, adoption and technical transfer activities in the project

Many of the communication, adoption and technical transfer activities conducted in the project have been described in detail in other sections of this report. In addition to those activities, the follow were undertaken:

Contributions to irrigation training workshops
Irrigation scheduling in the presence of shallow water tables was included in two training workshops sponsored by CRC Sugar and SRDC in July and December 2002. There was also a contribution on the subject at a third irrigation workshop sponsored by CRC for Irrigation Futures and SRDC in March 2004.

Regular presentations at grower meetings and industry conferences
Presentations were made at the following meetings.

- Ord Irrigation Research Update Workshops: November 2000, August 2001, April 2002, June 2003, November 2003
- QWUEI or similar meetings: July 2001, September 2001, October 2001, March 2003, June 2003, July 2003
- CRC Sugar annual meetings and public open days: March 2001, 2002 and 2003
- Industry conferences: Aust Sugar Cane Technologists Society (2001, 2002, 2003), Irrigation Association of Australia (2002, 2004), Australian Agronomy Conference (2003).

Popular articles
Popular articles were prepared as listed below.

Summary of key 'take home messages' arising from the project

- Shallow water tables can contribute significant amounts of water to crops, especially those with potentially deep roots like sugarcane, in northern Australia.
- Irrigation can be reduced where water tables are shallow and fresh. In many situations, irrigation is unnecessary when the depth to water tables is 1 m. However, water tables at 2 m depth will supply little water to crops unless their roots are active close to the water table.
- In the Ord irrigation Area, the low permeability and fine texture of the soil greatly reduces the upward flow of water and commonly restricts roots to the top 1 m of the soil profile. Thus water tables will generally have a small impact on irrigation management unless they are shallower than 1 m depth.
- Float poles in shallow wells can be a valuable, practical indicator of water table depth and can be easily linked to irrigation management.
- Cropping systems models can capture the impact of shallow water tables on crop response to irrigation, and these models can give valuable insights into irrigation scheduling. Future computer based irrigation scheduling tools in northern Australia will account for shallow water tables.

Commercial Potential

There are no easily recognisable commercialisation opportunities arising from this project, and benefits will be more quickly implemented and have greater impact by making results of the project available as widely and easily as possible.

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List of Appendices

Appendix 1: Sugarcane water use from shallow water tables: implications for improving irrigation water use efficiency.

Appendix 2: Mapping the likely occurrence of shallow water tables in the Bundaberg and Burdekin regions.

Appendix 3: Improving irrigation water use in areas of northern Australia with shallow water tables.

Appendix 4: Beneficial effects of shallow water tables: evolution of an irrigation trial.

Appendix 5: Impact of shallow water tables on crop water sources in the Ord River Irrigation Area.

Appendix 6: Soil hydraulic properties of the Fairymead soils, Bundaberg

Appendix 7: The Effects of Shallow Water Tables on Crop Water Demand within the Burdekin Region.

Appendix 8: The Effects of Shallow Water Tables on Crop Water Demand within the Bundaberg Region.

Appendix 9: Shallow Water Table Fact Sheets for Bundaberg and the Burdekin.

Appendix 10: Shallow Water Table Information Booklets for Bundaberg and the Burdekin

Appendix 11: Popular articles

Publications Arising From the Project

* Indicates the publication is given as an Appendix to this report.

Journal paper

* Hurst C.A, Thorburn P.J., Lockington D. and Bristow K.L. (2004). Sugarcane water use from shallow water tables: implications for improving irrigation water use efficiency. Agricultural Water Management, 65: 1-19.

Referred conference papers

* Stacey, S.P., Smith, M.A., Thorburn, P.J. and Dart, I.K. (2003). Beneficial effects of shallow water tables: evolution of an irrigation trial. Proceedings of the Australian Society of Sugar Cane Technologists, 25: 5pp.

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* Thorburn, P.J., Horan, H.L. and Inman-Bamber, N.G. (2004). Improving irrigation water use in areas of northern Australia with shallow water tables. In: Proceedings of the Irrigation Australia 2004 Conference, May 2004, Adelaide, Irrigation Association of Australia, Sydney, in press.

Other conference papers

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Sweeney, C.A., Stacey, S., Thorburn, P.J., Bristow, K.L. and Lockington, D. (2002). Shallow water tables and their potential to irrigation water use efficiency. CRC-Sugar 7th Year Review, Townsville, March 2002.

Popular Articles

* Free water for crops: Shallow Water Tables – A Potential Water Resource. An article for the Bundaberg Canegrowers newsletter, Vol 5(1), p 4. Sam Stacey

* Shallow water tables – a potential water resource. Australian Canegrower 24/3/03 Vol 25(6), p 20. Leon Dawes and Peter Thorburn

* Natural water for crops: Shallow Water Tables – A Potential Water Resource. An article for the Bundaberg Canegrowers newsletter, Vol 5(4), p 4. Leon Dawes and Peter Thorburn

* Functioning of near-surface water. Enviro News for Burdekin and Bowen, November 2003, 1 p. Terri Buono.