Inventory of Australian Software Tools for On Farm Water Management

Geoff Inman-Bamber and Steve Attard

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CRC for Irrigation Futures

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The authors want to thank the many developers and users of the various software packages, for their time and information freely given during and after interviews, or in some cases for providing all the information when we could not arrange an interview. We thank Dr Emma Jakku (CSIRO) for assistance in drawing up the questionnaires and Dr Kelvin Montagu (CRC IF) for reviewing the inventory. We also acknowledge the CRC IF for providing funds and many suggestions for the project. We also thank CSIRO for partly funding the project.
Executive Summary

The Australian irrigation industry is fortunate to have a large investment in software development for improving management of water on farm. In the first phase of the Cooperative Research Centre for Irrigation Futures (CRC IF) it was essential to assess the state of development of such software before investing in new research and development. A list of Australian software developers was compiled from information available on the web and in the scientific and popular literature. Most of the developers contributing to this inventory were interviewed in person. A report on each software package was compiled from notes taken during the interviews and from published details. Formal publications were available for only a few packages. Each developer was asked to edit the draft reports and approve them for inclusion in the software inventory for circulation. Some developers did not approve the reports and these were omitted. We have not altered the intended meaning of any of the reports provided by the software developers. The collators of the inventory and the CRC IF do not endorse claims and comments by developers.

While some duplication of effort was evident across the 19 software packages, most developers had unique ideas and products well tailored to the needs of their clients. In some cases software packages were mature having been through many cycles of redevelopment and interaction with users. In many cases this iterative process involving end users had only begun. A common theme was the wish to expand the usefulness of their software by linking with other software developments which may be able to deliver a more rounded product to growers and consultants. Few developers had chosen the web as a delivery mechanism which was surprising given the increasing use of the internet. Nearly all software packages are still under development and this inventory will be out of date as soon as it is published. Nevertheless the inventory is a benchmark for software developers and users and it will be instructive in assessing progress in software development and usage in a few years from now.
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<th>Pg</th>
<th>Package</th>
<th>S/W</th>
<th>Owner</th>
<th>Lead developer</th>
<th>Does what?</th>
<th>Main application</th>
<th>Main benefit or strength</th>
<th>Main limitation</th>
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</thead>
<tbody>
<tr>
<td>Whole of farm packages</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Aquatech</td>
<td>S</td>
<td>Aquatech</td>
<td>Jim Purcell</td>
<td>Spatial &amp; temporal farm water balance</td>
<td>Whole farm water loss reduction</td>
<td>Improved recording and water use efficiency (WUE)</td>
<td>Requires professional support</td>
</tr>
<tr>
<td>8</td>
<td>DamEdBy</td>
<td>S</td>
<td>APSRU/CSIRO</td>
<td>Shaun Lisson</td>
<td>Interactive database of biophysical and economic factors</td>
<td>Assess investments in on farm storage and/or irrigation</td>
<td>Rapid financial screening of dam and irrigation options</td>
<td>Limited to use in sugarcane in Bundaberg</td>
</tr>
<tr>
<td>11</td>
<td>FlowCast</td>
<td>S</td>
<td>QCCA</td>
<td>Yahya Alawi</td>
<td>Processes model output</td>
<td>Forecasting stream flow</td>
<td>Fast and friendly</td>
<td>Professional use only</td>
</tr>
<tr>
<td>14</td>
<td>iRES</td>
<td>S</td>
<td>PIRSA</td>
<td>Tony Adams</td>
<td>Stores detailed irrigation records, calculates ETc from weather data (FAO 56), simulates daily soil water balance, for whole farm</td>
<td>Generates reports on irrigation management and WUE evaluation</td>
<td>Comprehensive irrigation records, easy record analysis, water use efficiency (WUE) improvement, reports from single valve to whole property scales</td>
<td>Kc values for ETc estimation require improvement</td>
</tr>
<tr>
<td>16</td>
<td>SWAGMAN - Farm</td>
<td>W &amp; S</td>
<td>CSIRO</td>
<td>Shabnaz Khan</td>
<td>Seasonal water and salt balance balances</td>
<td>Assess farm cropping options on $ and environment</td>
<td>Fast screening of crop/water options</td>
<td>Input data is demanding</td>
</tr>
<tr>
<td>20</td>
<td>WaterSupply</td>
<td>S</td>
<td>APSRU</td>
<td>Don Gaydon</td>
<td>Water and solute balances of water sources (dams, rivers, bores)</td>
<td>Assessing water supply options</td>
<td>Linked to powerful APSIM simulation environment</td>
<td>Users need experience with APSIM (not friendly)</td>
</tr>
<tr>
<td>Paddock level packages</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>HydrolOGIC</td>
<td>S</td>
<td>CSIRO</td>
<td>Michael Bange</td>
<td>Crop simulation, daily water balance</td>
<td>Scheduling and increased water use efficiency (WUE)</td>
<td>Easy use of powerful crop simulation model</td>
<td>Probabilities are not reported</td>
</tr>
<tr>
<td>26</td>
<td>IrrMAX v6</td>
<td>S</td>
<td>Sentek</td>
<td>Tim Waterhouse</td>
<td>Access, process and interpret soil water and climate data</td>
<td>Irrigation and salt management</td>
<td>Schedule based on soil water monitoring</td>
<td>May contain too many features for growers</td>
</tr>
<tr>
<td>30</td>
<td>Magpie</td>
<td>S</td>
<td>MEA</td>
<td>David Peacock</td>
<td>Access and report soil water and climate data</td>
<td>Irrigation planning and management data</td>
<td>Easy access and display of weather data</td>
<td>Can only be used with MEA systems</td>
</tr>
<tr>
<td>32</td>
<td>MaizeMan</td>
<td>S</td>
<td>CSIRO &amp; L&amp;W</td>
<td>Elizabeth Humphreys</td>
<td>Crop simulation, daily water and salt balance balances</td>
<td>Risk analysis and scheduling</td>
<td>Easy use of powerful crop simulation model</td>
<td>Input data is demanding</td>
</tr>
<tr>
<td>36</td>
<td>Micromet</td>
<td>S</td>
<td>Micromet</td>
<td>Jim Townsend</td>
<td>A daily water balance from climate data</td>
<td>Scheduling irrigation of urban parkland</td>
<td>Reduced wastage of urban water</td>
<td>Embedded in service from Micromet</td>
</tr>
<tr>
<td>38</td>
<td>Multi-Log</td>
<td>W &amp; S</td>
<td>Research Services New England</td>
<td>Trevor Finch</td>
<td>Graph soil moisture and weather data</td>
<td>Irrigation and farm management</td>
<td>Handle data from different sources</td>
<td>Training and on-site support required</td>
</tr>
<tr>
<td>41</td>
<td>Probe for Windows</td>
<td>W &amp; S</td>
<td>Research Services New England</td>
<td>Trevor Finch</td>
<td>Process and interpret soil water and climate data</td>
<td>Irrigation management</td>
<td>Schedule based on soil water monitoring</td>
<td>Training and on-site support required</td>
</tr>
<tr>
<td>47</td>
<td>VineLOGIC</td>
<td>S</td>
<td>CRC Viticulture</td>
<td>Rob Walker</td>
<td>Crop simulation, daily water and salt balance balances</td>
<td>Education, irrigation and salt management</td>
<td>Viticultural knowledge package; easy to use for learning and training</td>
<td>One dimensional soil water flow; not a day-to-day decision support tool</td>
</tr>
<tr>
<td>53</td>
<td>WaterBalance</td>
<td>W</td>
<td>CSIRO</td>
<td>Geoff Inman-Bamber</td>
<td>A daily water balance from climate data</td>
<td>Irrigation scheduling for full irrigation</td>
<td>Fast and friendly</td>
<td>Limited to AWS network and sugarcane</td>
</tr>
<tr>
<td>57</td>
<td>WaterSense</td>
<td>W</td>
<td>CSIRO</td>
<td>Geoff Inman-Bamber</td>
<td>Runs APSIM from web interface</td>
<td>Irrigation scheduling for limited irrigation</td>
<td>Use of limited water at critical periods</td>
<td>Automatic but slow (40 min per paddock)</td>
</tr>
<tr>
<td>60</td>
<td>WeatherFare</td>
<td>S</td>
<td>NSW DPI</td>
<td>Helen Fairweather</td>
<td>Calculates Crop Evapotranspiration from web climate data and FAO 56 equations</td>
<td>Irrigation scheduling for full irrigation</td>
<td>Seamless web access and auto ETc calculation and graphics</td>
<td>Excel with internet macros is required</td>
</tr>
</tbody>
</table>

Research and education packages:

| 16 | SWAGMAN - Destiny | S | CSIRO | Emmanuel Xevi | Crop simulation, daily water and salt balance balances | Assess farm cropping options on $ and environment | Caters for salt, water table and waterlogging balances | Professional use only. Input data is demanding |
| 64 | SWAGMAN - Whatif | S & W | CSIRO | Wayne Meyer | Calculates water and salt balances, water table depth and crop stress | Education tool allowing users to assess system response to climate and management | Simple inputs and sound underlying mechanisms for salt and water transport | Not a decision support tool – starting base for awareness and training |
1. Introduction

Over the past 25 years a plethora of software tools have been developed for farmers in the expectation that when these farmers have computers they would use these tools to improve management and profitability of their enterprises (McCown et al, 2002). However use of these tools has not grown with computer ownership as expected. Crop simulation models which often support these software tools have nevertheless been used extensively in research and education. These simulation models were first built in an attempt to integrate complex physiological processes to explain crop responses to management and the environment. Researchers have continued to develop and improve their models and there have been many attempts to transfer the knowledge encapsulated in these models to support decisions on farm. Some of these attempts have been reasonably successful but many have been disappointing (McCown, 2002). There is still much to learn about the adoption of software tools on farm and the ease of access to the internet is a new factor which has yet to be fully understood and exploited in the dissemination of computer based information for farmers.

1.1. Approaches to Decision Support Systems tools

A comprehensive review of Decision Support Systems (DSS) philosophy and history is provided by McCown (2002). The modern concept of DSS derives partly from a radical notion which assumed that not only could the natural world be explained scientifically but the management practices to control the world could be scientifically designed (McCown, 2002). The advent of the computer made this assumption appear all the more plausible, particularly when engineering and computer technology was combined to develop mostly successful exploits into space. McCown (2002) reviewed literature on the 'gap' theory which attempts to define the gap between scientific models (and science per se) and practice. One of the papers reviewed (Ackoff, 1979) identified a key factor in the 'gap' problem in that the principle benefit of planning comes from engaging in it. Ackoff (1979) states that 'no one can plan effectively for someone else. It is better to plan for oneself no matter how badly than to be planned by others, no matter how well'. If this is true then this would explain to a large extent why even the most accurate and scientific DSS have not been widely adopted. McCown (2002) encourages us not to give up but to acknowledge the challenge of the 'gap' problem and for researchers to engage the decision makers early in the development of DSS’s and to continue to work with them on the full technical and social impact of the DSS after its completion.

2. Methodology

In the first phase of the CRC IF it was essential to assess the state of development of irrigation technology before investing in new research and development (R&D). In the case of software for management of water on farm it was clear that many products or packages have been or are being developed for irrigation management, scheduling and generally for improving water use efficiency (WUE).

A list of Australian software developers as well as some users was compiled from information available on the web or in the scientific and popular literature. Software tools which had application for managing water on farm were distinguished from those which were aimed at water management in catchments. Not many software packages were devoted solely to on farm irrigation management and some were rather indirectly linked to water management issues on farm but were still included.
Packages dealing mainly with water and salt management at the catchment scale were not included.

Most of the developers contributing to this inventory were interviewed face to face. A report on each software package was compiled from notes taken during the interviews and from details available on the web or in the popular press. Formal publications were available for only a few packages. Each developer was asked to edit the draft reports and approve them for inclusion in the software inventory for circulation. Some developers wrote reports on their software without much help from us. We have not altered the intended meaning of any of the reports. The CRC IF does not necessarily endorse claims and comments by developers.

Nearly all software packages are still under development and this inventory will be out of date as soon as it is published. Nevertheless the inventory is a benchmark for software developers and users and it will be useful to assess progress in software development and usage in a few years from now. We hope that the inventory will make us all aware of the tremendous effort expended in the past and now being applied to delivering technology for improving management of water on farm. We also hope that the report helps to foster collaboration amongst scientists, software developers and users across different regions and crops. Most people interviewed expressed a desire to know what others were doing in different regions and to collaborate if possible.

3. Categories of software

It is difficult to place software packages into separate categories because each package is unique and may perform a number of functions or may be dedicated to a single function. Four broad categories could be distinguished in the software reported in this inventory.

3.1 Farm level packages

There is an ill defined boundary between tools operating at the paddock level and those operating at the whole farm level. However the main focus of the whole farm packages is on whole farm decision making or record keeping.

3.1.1 Aquatech Consulting Pty Ltd

Jim Purcell and Anthony Fairfull, Aquatech Consulting Pty Ltd

Background

Surface irrigation is the oldest, simplest, most reliable and often the most cost effective form of irrigation available. But it needs the correct soils to be efficient and it is one of the hardest forms of irrigation to model mathematically. The difficulty in modelling the infiltration characteristics of the soil under surface irrigation to date has been the lack of reliable equipment to measure the many variables involved and this has held back the adoption of technology to optimise this simple form of irrigation. Fortunately the mathematical modelling was progressed well by Walker and Shobergoe of the Utah State University in the mid to late 1980s and is available as a Windows compatible computer program. This program was upgraded by the University of Southern Queensland (USQ) in the 1990s and additional software
added. The National Centre for Engineering in Agriculture (NCEA) at USQ then developed specialised siphon meters and advance sensors with data loggers and software. The result is the commercial surface irrigation evaluation package called Irrimate™. Aquatech Consulting, a small firm of consulting engineers specialising in irrigation and water resources based in Narrabri, NSW, began using this package with their clients in the 2000–01 cotton season. After two seasons, Aquatech worked with NCEA to upgrade and refine the package to its current form.

Irrimate™ allows measurement of an irrigation event detailing the depth of irrigation water application down the field from the headditch to the taildrain. The computer package Infilt determines the soil infiltration characteristics and the program Sirmod allows simulation of the measured irrigation event. Sirmod then allows optimising of the irrigation application by changing any of:

- siphon flow rate,
- irrigation setting time,
- row length, or
- field slope.

Changes in any of these variables can be trialled on the computer to select the combination that best suits the irrigator and results in the highest reasonable application efficiency and distribution uniformity.

Having commercialised the Irrimate™ Surface Irrigation Package to reduce losses in irrigation application, Aquatech then concentrated on measuring and improving the whole farm WUE. The first step was to obtain equipment to measure seepage and evaporation losses in channels, drains and ring tank storages. A device was developed from a research tool first used by NCEA Toowoomba to measure evaporation losses in ring tank dams. The device is based on a very accurate pressure sensor which can measure water level changes of less than 0.5 millimetres. This is connected to a data logger and power source and measurements are taken every 15 minutes. The total losses during the day are the combined evaporation and seepage losses and the losses between 10:00 pm and 4:00 am are seepage alone. The device is suitable for measuring losses in channels, drains and ring tank storages.

Having measured:
- the amount of water entering the farm irrigation system,
- the amount applied to the field,
- typical seepage and evaporation losses in channels, drains and storages,
the basis is available to construct a whole farm water balance. Aquatech, Sustainable Soil Management of Warren and Scolari Software of Dubbo have developed a dedicated software package called WaterTrack™ to allow irrigators to maintain a daily on farm water balance.

A crop water use module and soil water balance module are linked to a seepage and evaporation model for channels, drains and ring tank storages. A visual interface which imports farm plans, allows the detailing of the geometry of channels, drains, fields and storages to construct a mathematical model of the whole farm. By adding water inputs from rivers, bores or overland flows and allowing the program to extract crop water use, seepage and evaporation from each element of the system, a daily water balance is calculated. By monitoring the water level storages, a gross check on the model can be made daily, weekly or whenever it suits the irrigator. Measurement of actual seepage and evaporation for selected elements can be made as required to refine and balance the model. Simple measurement of flow onto and off selected
fields with the Irrimate™ siphon meter and tailwater flume can be used to calibrate the volumes of water applied to the fields.

As irrigators begin to measure these elements and have the ability to balance the water distributed around their farm, their practices will quickly improve and losses will be reduced allowing more water to be used for production.

Target users

These are growers and/or consultants. Cotton growers use agronomic consultants regularly for solving agronomic and pest and disease problems. With the backing of specialised irrigation consultants like Aquatech, cotton consultants can provide irrigation advice to growers. Irrigation engineers are in short supply and will need to work through cotton consultants to provide irrigation and water advice. Aquatech now has Irrimate™ trained consultants in every cotton growing valley in Australia.

While Irrimate™ is configured for surface irrigation, the WaterTrack™ daily water balance model could be applied to any irrigation system anywhere. There are hundreds of thousands of hectares of bay irrigated pasture in the diary industry that would benefit from these packages. Of the 2000 cotton irrigators it is hoped that at least 650 will adopt Irrimate™ and WaterTrack™.

About the technology (WaterTrack™ only)

WaterTrack™ is designed to develop a whole farm water budget taking a wide range of water sources and sinks into account such as crop evapotranspiration as well as drainage and evaporation losses in the field, in transit and in storage. The package is designed to be used together with other software and hardware tools to allow consultants to model the whole farm water balance for the purpose of gaining efficiencies through improved design and operation1.

WaterTrack™ is written in C#.NET language using Microsoft VISUAL STUDIO.NET rather than spreadsheets which are less user friendly and less efficient. WaterTrack™ displays an interactive map of the farm with details of storages, reticulation and drainage systems and fields. Drainage and evaporation losses from storages, canals and drains are measured with high precision equipment. Flow rates through the reticulation system and onto and off the fields are also measured for selected elements. Crop evapotranspiration is estimated using FAO 56 guidelines (Allen et al., 1998). Once the irrigation farm is set-up for WaterTrack™, ‘what if’ scenarios can then be performed to assess the benefits of upgrading sections of the system or changing management to reduce water losses.

Promotion and further development

Promotion will be mainly through word of mouth, selected seminars and field days and industry journals. Growers like to talk about how they have saved water and made more money which is what this package should help them achieve. There is already a good level of awareness in the cotton industry about Aquatech through many seminars over the last four seasons.

The WaterTrack™ software can be promoted separately provided flows around the farm are measured by some package other than Irrimate™. Alternatively,
WaterTrack™ can be used by selecting empirical or assumed values for water losses without any field measurements, to produce useful results. Field measurements could follow to refine and calibrate the model for better results. However WaterTrack™ and Irrimate™ tools have been developed as an integrated package and should be used together for optimum results.

Promotion will also occur through agricultural consultants who will adopt the package to add to the range of services that they can offer. Promotion will also be done by DNR (QLD), IAA, CRC Irrigation Futures, NCEA and area wide management groups.

Benefits

The package should improve WUE by at least 15% but its developers are confident that eventually WUE would increase by up to 25%. The benefit of the package is that it encourages good management of water on the farm. A 10% increase in WUE could convert to $100 000’s through increased area planted to cotton. Aquatech will benefit small (one-man) consultancies that run fragile businesses, by providing them with greater skill to assist growers with water management on farm. Aquatech will provide specialised training to consultants to raise the level of skill required to support these packages to meet the challenge of the current water reforms.

Applications

The package will generally reduce water loss from the irrigation system and improve opportunities for increasing yield. Currently water is measured out of the river and sometimes into the dam but little else is measured. The volume of water in the storage is normally obtained from contractor's calculations which can sometimes be out by quite a lot.

Sources of greatest water loss can be identified and actions can be taken to minimise this loss through engineering and/or irrigation management options. Before the growing season, growers assess their water budget by considering the amount of water in storages and in the soil, as well as accounting for future inflows from rain, scheme, bore and river allocations. WaterTrack™ will allow irrigators to look at various options with reasonable accuracy so that budgeted water can provide the greatest benefit.

Limitations of the technology

Measurement of water flows and losses in irrigation systems has not been good in the past and the lack of good data has been the major limitation to date. Instrumentation and consultation is provided to make the required measurements as easy as possible. The aim is to make the water balance component (WaterTrack™) similar to doing a financial budget (like MYOB or Best Books).

Barriers to adoption

Adoption depends on the investment the farmer is prepared to make in improving WUE and yield. Government bodies could provide an incentive for growers to adopt this technology. Innovator growers (about 5%) want this technology right away. Growers may worry that regulators could insist that they use the package and measure more components of the farm water balance. This could lead to higher benchmarks for WUE which are already high. A more likely scenario is that of self regulation where an Irrimate™ / WaterTrack™ type of package is part of BMP (best
management practice) guidelines. This happened with pesticides and water is a much bigger issue.

Access to Aquatech

For further information contact Jim Purcell, Director of Aquatech Consulting:
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Postal: PO Box 443, Narrabri, NSW 2390, Street: 1 Bowen Street, Narrabri, NSW 2390

3.1.2 Dam Ea$y

Shaun Lisson\textsuperscript{acd}, Lisa Brennan\textsuperscript{acd}, Keith Bristow\textsuperscript{ab}, Brian Keating\textsuperscript{acd}, Dene Hughes\textsuperscript{cd}, and Rachel Hughes\textsuperscript{cd}
\textsuperscript{a}CRC Sugar, \textsuperscript{b}CSIRO Land and Water, \textsuperscript{c}CSIRO Sustainable Ecosystems, \textsuperscript{d}Agricultural Production Systems Research Unit

Background

The need for \textit{Dam Ea$y} arose from shortages of water for irrigating sugarcane in the Bundaberg area. Growers were seeking advice on the value and the size of storages required. Funding from the CRC for Sustainable Sugarcane Production was provided and all of the developers were at some stage involved in the Sugar CRC. \textit{Dam Ea$y} was voted one of the top ten achievements of the CRC. While the principle role of \textit{Dam Ea$y} is to investigate on farm water storage (OFWS) investment options, it is also possible to consider rain fed systems and other irrigated systems based on the settings used. \textit{Dam Ea$y} contains a database of over 65 000 combinations of OFWS designs (including no storage), water allocations, irrigation strategies and soil types. APSIM-Sugarcane was used to generate the data base. APSIM which stands for Agricultural Production Systems simulator, is a modelling framework designed to simulate complex production systems (McCown et al., 1996). APSIM is able to link a wide variety of modules representing different crops and different aspects of the production system including detailed energy, water, nutrient and carbon balances. A description of APSIM and the sugarcane module can be found online\textsuperscript{2}. For \textit{Dam Ea$y} simulations, logic was developed in the manager module of APSIM, to cope with the complexities of water flows and fluxes into the OFWS from catchments, bores, rivers, rain and out of the OFWS via evaporation, seepage and irrigation. A ‘plug-in’ module called \textit{‘WaterSupply’} was developed from this logic and is described elsewhere in this document.

Settings for APSIM-Sugarcane that define the scope of the database were selected through consultation with a group of local farmers and representatives from organisations with an R&D interest in the Bundaberg sugar industry. For each farm system, the APSIM simulations were conducted over a 40-year period using historical climate data from 1957-1997. This allows investments in OFWS and irrigation infrastructure to be assessed over a selection of 20 year periods.

Target users

\textit{Dam Ea$y} in its current form is a decision support tool solely for sugarcane growers in the Bundaberg region. It has been developed principally for extension officers or

\textsuperscript{2} See http://www.apsim.info/apsim/Documentation/ for more information.
industry consultants, working in collaboration with, or on behalf of, their farmer clients to investigate the cane yield and economic and environmental implications of incorporating an OFWS into an existing sugarcane farming enterprise. **Dam Eashy** could be expanded for use in other sugarcane productions regions or for other crops. Funding for such expansion has not yet been forthcoming.

**About the technology**

**Dam Eashy** incorporates a database of pre-run output from the biophysical model, APSIM, which is linked to an economic model. The database greatly simplifies the operation of **Dam Eashy** and allows simultaneous evaluation of a range of potential farm designs. This makes it possible to conduct sensitivity and ‘what if’ analyses. The database covers a large range of farming systems relevant to sugarcane production in the Bundaberg region. The scope of farms included in the database has been developed through close industry consultation to capture typical farm designs in this region.

Operating **Dam Eashy** does not require previous modelling experience or extensive computing skills. **Dam Eashy**‘s easy-to-use interface provides a range of graphical and tabular reports for viewing output. These features make it possible to view and investigate different OFWS design options directly with a farmer, on site.

**Biophysical Factors**

There are potentially an infinite number of possible farm designs that could be configured. Consequently, the scope of the database has been carefully defined to use standard computing resources and yet cover a sufficient number of farm designs for useful analysis. Users can select and interpolate between the farm designs in the database that most closely resemble the scenarios they wish to analyse (Table 1).

**Table 1. Biophysical and economic factors that define a scenario in Dam Eashy**

<table>
<thead>
<tr>
<th>Biophysical factor</th>
<th>Operating cost factors</th>
<th>Capital costs ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil type</td>
<td>Sugar price ($)</td>
<td>Pump system</td>
</tr>
<tr>
<td>Allocation (ML/ha)</td>
<td>Inflation rate for input costs (%)</td>
<td>Dam construction</td>
</tr>
<tr>
<td>Access to water out of allocation (Yes or No)</td>
<td>Inflation rate for cane receipts (%)</td>
<td>Reticulation</td>
</tr>
<tr>
<td>OFWS capacity (ML)</td>
<td>Number of partners</td>
<td>Payment period</td>
</tr>
<tr>
<td>Catchment area (ha)</td>
<td>Investment interest rate (%)</td>
<td></td>
</tr>
<tr>
<td>Irrigated area (ha)</td>
<td>Allocation water price ($/ML)</td>
<td></td>
</tr>
<tr>
<td>Irrigation efficiency (%)</td>
<td>Out of allocation water price ($/ML)</td>
<td></td>
</tr>
<tr>
<td>Irrigation refill point (fraction of available soil water, 0 to 1)</td>
<td>Storage pumping cost ($/ML)</td>
<td></td>
</tr>
<tr>
<td>Sucrose content (CCS)</td>
<td>Overheads ($)</td>
<td>Harvesting and levies ($/t)</td>
</tr>
</tbody>
</table>

APSIM accounts for various elements of the OFWS water balance including surface evaporation, direct rainfall capture, tailwater recycling, seepage through the lining of the storage, catchment runoff, irrigation outflow, overflow when the storage capacity is exceeded, and the transfer of surplus ‘out of allocation’ (OOA) water and allocated scheme water.

**Economic factors**

Planning an investment in an OFWS requires a long-term view. However, short-term considerations, such as variation in year-to-year cash flow, are equally important. **Dam Eashy** allows both the short and long-term benefits of an OFWS to be calculated and compared using the following criteria:
• net present value (NPV) of capital invested
• annual net cash flow over the life of the investment.

The NPV calculations help the user decide between investing in a new storage or irrigation system versus investing in some other enterprise (e.g., the bank). Annual net cash flow indicates how often the new storage will make or lose money. The cash flow could be negative in some years if the stored water is not needed because of well-timed rainfall.

Promotion and further development

There is no ongoing support for development and promotion of Dam Ea$y. However, developers have done the basic programming for a ‘real time’ version of Dam Ea$y (database free), in which the users could configure and run the biophysical model and therefore have complete control over the farm design. This would produce precise and farm-specific output but would take longer to produce output, making the assessment of a variety of options a time-intensive activity. It would not have the ease-of-use that is available with the database version. A user-friendly interface still needs to be developed for the real-time version.

Benefits

Dam Ea$y has been used extensively in the Bundaberg region to assess the viability of constructing OFWSs. Mr. Maurie Haines from Bundaberg Sugar Services has assessed over 40 farms for suitability of OFWS construction. Many of these assessments have been positive resulting in the construction of OFWSs. An example of benefits from Dam Ea$y can be seen online.

Applications

Dam Ea$y can also be used to educate and train extension officers and other industry consultants on the implications, costs and benefits, and sensitivities associated with different OFWS investment options. Trained officers can assist client farmers to make better OFWS investment decisions through appropriate application of Dam Ea$y.

Limitations of the technology

Dam Ea$y is limited for use in sugarcane in Bundaberg only. It was developed with an early version of APSIM (2.1) and the database should be updated using the more recent version (4.1) which now includes the WaterSupply module. Lodging has been found to limit the yield response to increased water supply. Irrigation can even reduce yield because of lodging which needs to be considered in any investment to increase water for irrigation of sugarcane. Lodging events and consequences can now be simulated in APSIM (Inman-Bamber et al., 2004).

Barriers to adoption

Benefits from Dam Ea$y have been achieved through the enthusiasm of Bundaberg Sugar Services, principally Maurie Haines and Tony Linedale. Further adoption depends on further development of Dam Ea$y and on committed consultants such as these. The current database developed for Bundaberg means that in its current form, Dam Ea$y cannot be used outside the Bundaberg region.

**Access to Dam Ea$y**

Contact Dr Keith Bristow (Keith.Bristow@csiro.au). Some training will be required. For further information about this product please contact: APSIM help desk, CSIRO Sustainable Ecosystems 306 Carmody Road St Lucia, Queensland, 4067, Phone: 61 7 3214 2343

**3.1.3 FlowCast**

Yahya Abawi and David McClymont, Queensland Centre for Climate Applications (QCCA), Department of Primary Industries and Fisheries, Toowoomba, Qld.

**Background**

FlowCast is a decision support tool for use by climate researchers, water agencies, policy makers, consultants and corporate irrigators to make better decisions on water allocation, water harvesting, crop type and area, and the management of environmental flows. It has been developed as a stand-alone application written in C++ as part of a Murray Darling Basin funded project. The project was conducted under the guidance of a steering committee with representatives from the research and grower groups. Originally designed specifically for the analysis of hydrological data generated by IQQM (Integrated Quantity and Quality Model, NSW Department of Land and Water Conservation), it has now evolved into a generic tool capable of handling many forms of modelled or measured time-series outputs. FlowCast allows users to quickly and easily analyse and correlate large number of hydrologic and climatic data in order to generate short-term (up to one year) predictions of future events.

**Target users**

FlowCast is designed for decision makers and researchers such as climatologists, water-managers, consultants and corporate-irrigators. Climate-researchers can use FlowCast to determine which climatic factors have the most influence on regional variables. Water-managers can use this information to forecast river flows for purposes such as dam management, irrigation allocations, fish breeding, salinity management and the maintenance of wetlands. Consultants and irrigators can predict the water available from various sources (including allocations) to determine crop type and planted area.

**About the technology**

While the stand-alone tool was originally designed to analyse streamflow data from the IQQM model it can process data from a variety of sources such as climate stations or even other models. The package was designed as a decision tool for agri-business, water managers and researchers but benefits will flow to the whole community. FlowCast is a time-series analysis tool for exploring and forecasting time-series data and for investigating means to improve the reliability, range and accuracy of these forecasts. It is comprised of a data management interface, a data analysis interface and a forecast analysis interface, linked together by a unique and powerful graphical interface for manipulating and designing the analyses. Both graphical and tabular outputs are available for all analyses. The graphical outputs are
highly configurable with multiple options for combining/separating data and for navigating (zooming/panning) though the outputs.

As an example, the screen in Fig. 1 allows the user to select a position on a stream in a catchment. Figure 2 shows annual stream flow for that position and Figure 3 shows a probability distribution by SOI phase and lead time.

Figure 1. FlowCast database interface, showing catchment map with IQQM node locations

Figure 2. Exploring Streamflow data using the browsing tools
Promotion and further development

Development of FlowCast was funded by the Murray Darling Basin Commission (MDBC) and the Australian Centre for International Agricultural Research. There has been wide interest in its use particularly from overseas but limited funding is preventing further development and promotion. The cotton industry was the initial target for the use of the tool. The tool has been used mainly by its developers in projects such as urban and metropolitan water supplies, exceptional circumstance applications and drought policy issues, water allocation and forecasting of streamflows for the irrigation industry.

Benefits

Financial benefits from using the tool have the potential to be in the millions of dollars with resulting forecasts leading to better WUE and on farm management. The tool is flexible and fast, with a powerful graphical user interface for exploring, transforming and analysing input and output variables.

Limitations of the technology

While the graphical interface makes the data easy to interpret through excellent graphics and mouse/screen controls, a sound knowledge of climate science as well as some basic training is required. Without this training the software could be misused. The tool is still undergoing development and requires further ‘bulletproofing’. The package needs to be verified in some case studies so people can gain confidence in its use.

Access to FlowCast

FlowCast is available free on request as long as there is no commercial gain made. Minimum user support is available.

3.1.4 Irrigation Record and Evaluation System (IRES)

Tony Adams, Irrigated Crop Management Services (ICMS)

Background

As an integral component of the MDBC Strategic Investigation & Education Program, the former Irrigation Issues Working Group conducted knowledge gap analyses on natural resource management particularly from an irrigation futures perspective. In addressing the identified key priority areas, the Working Group initiated the WaterMARK suite of projects including this 3 year project, I2003, undertaken in collaboration with the land and water resource agencies in the Lower Murray region, comprising the South Australian Murray-Darling Basin, the Sunraysia districts in Victoria and the irrigation districts in western New South Wales.

Irrigated agriculture and the environment are increasingly competing for the scarce water resources of the Murray-Darling Basin. Efficient use of water allocations is a logical foundation for irrigators to retain current levels of production while satisfying expectations of accountable water used for irrigation purposes. In addition, our exporters of food and fibre products are now increasingly challenged to substantiate their ‘clean and green’ claim of their irrigation practices and crop production systems, in order to retain their market share and expand their market opportunities.

In collaboration with government and water management agencies, the Murray Darling Basin Commission initiated the I2003 project in July 2000 to develop methodologies and associated tools to standardise WUE reporting at various levels from irrigation valve units on individual properties to the catchment boundary. The methodologies and tools of the project enable the incorporation of WUE as a factor in the active management of farms, irrigation districts and catchment planning. The set of tools provide a resource that can also contribute to other activities including benchmarking of environmental management systems.

Target users

IRES is intended for use by growers on irrigated horticultural properties with pressurised irrigation systems. It has the potential to be a tool that supports initiatives and targets implemented by irrigation district or community based water management committees and agencies.

About the technology

The I2003 project developed two modules, one is the Irrigation Inventory Module (IIM) designed to report WUE at irrigation district scales. The other is the Farm Level Water Management Module (FLWMM) intended for use by growers on farm. FLWMM is a methodology for optimising irrigation system performance and irrigation management to ensure efficient water use. Key functions of FLWMM are computerised in IRES, which is a prototype software tool in development since the completion of the 2003 project in June 2004.

IRES is an irrigation record and evaluation system that allows irrigators to keep comprehensive irrigation records, analyse the records and evaluate water use
efficiency down to the irrigation valve unit level. It generates comprehensive irrigation reports in table and graph formats.

**IRES** enables irrigators to record irrigation management on an event basis, evaluate WUE and review irrigation management to meet market requirements and improve profitability. Detailed crop and irrigation system information is entered for each planting patch and irrigation valve unit. Irrigation dates, irrigation hours and valve units included in each irrigation shift are also entered. Water meter readings are desirable but are optional. The prototype software allows irrigators to track the distribution and volume of irrigation water applied across the property on an event and annual basis. **IRES** calculates irrigation depth (mm) and kilolitres applied for each irrigation valve unit, planting patch and crop type on an annual basis or for specified time periods. Irrigation volumes calculated from irrigation hours can be reconciled with water meter readings.

**IRES** allows users to calculate reference crop (ETo) and crop evapotranspiration (ETc) from daily weather data according to FAO 56 (Allen et al., 1998). ETc rainfall and irrigation records are combined to simulate changes in daily soil water content within crop root zones. The results are used to generate WUE indicators.

**Promotion and further development**

Stage one of the prototype software is currently in trial as part of Land and Water Management Plan Case Study (LWMPCS) projects in the Riverland of South Australia. The LWMPCS project will enable further development and testing using real property inputs and feedback from approximately 80 growers over the next two to three years. **IRES** is funded by Primary Resources SA to promote profitable irrigated agriculture production with efficient use of water resources.

**IRES** may potentially be an important tool in supporting irrigation communities to implement targets within local or community developed Land and Water Management Plans.

**Benefits**

**IRES** software enables irrigators to generate comprehensive irrigation reports in order to review and improve irrigation management and so to meet processor expectations and WUE targets. It automates the complex analysis of irrigation records and generates a range of WUE indicators in a standard and consistent manner. This is essential in facilitating meaningful benchmarking and comparison with peers. Outputs from **IRES** will assist irrigators to provide information required by processors, water management and government agencies.

**Applications**

- Comprehensive irrigation record analysis and reporting
- Planning irrigation hours and valve unit combinations for desired flow rates, shift areas, irrigation depths, volumes and litres per plant
- Generating daily ETo and ETc from weather data
- Simulated daily changes in root zone soil water content
- Forecast crop water use and changes in root zone soil water content
- Review history to identify periods of optimal and sub-optimal irrigation management
Limitations of the technology

The crop coefficients used to simulate crop water use are based on FAO 56. Although they provide a very good guide, there is need to refine crop coefficients to reflect differences between varieties within crop types, canopy management and irrigation regimes. Reasonable computer literacy is required but at least 50% of growers within the Irrigation Trust involved in the project, use their computers to order water on the web. The present case study will determine the extent to which computer literacy may be a limitation to broader adoption of IRES. Soil water balance calculations require good information on soil water holding capacity within crop root zones for the property. Soil water monitoring needs to be performed in conjunction with IRES.

Barriers to adoption

Implementing IRES on a broad scale will require significant resources to provide adequate support to growers, particularly during the set-up phase. Inadequate computer confidence and old computer equipment may frustrate adoption by growers. Winning confidence from growers that information on water use generated by IRES will be used appropriately and in the best interest of irrigators will be essential. However, initial response by growers shown the prototype software, has been very positive and supportive.

Access to IRES

IRES is not available for use by growers outside the project at this stage. Growers in the case studies will use the first prototype software version commencing in April 2005. For more information please contact:
Tony Adams, Rural Solutions SA, PIRSA Loxton Centre
Phone: 61 8 8595 9142, Email: adams.tony@sa.gov.au
Website: www.ruralsolutions.sa.gov.au

3.1.5 Swagman-Destiny and Farm

Emmanual Xevi and Shahbaz Khan, CSIRO Land and Water

Background

Swagman – Soil WAter and Ground MANagement model – has a variety of versions and applications. Here we will describe the underlying process level model (Swagman - Destiny) and refer briefly to Swagman–Farm which is a static ‘lump sum’ model. A simpler and earlier version of Swagman – Destiny called Swagman – Whatif is being revised for new operating systems and is described as a separate software package in this inventory. Generic Swagman was initiated by Dr Wayne Meyer who noticed the importance of ground water level on farm production. Existing crop models were not able to account adequately for ground water effects. Initial model development was based on the DSSAT (USA) suite of crop models and effects of water table, salinity and water logging were added. Swagman- Farm® modelling system was developed with the aid of funding from the Rice CRC, Murray Irrigation and Coleambally Irrigation Authority (CIA).
Target users

Farm: Farmers and irrigation authorities, agricultural extension officers  
Destiny: A research tool for scientists (CSIRO, Universities). There are consultants who want to use it but they are not target users, although in time they may become skilled enough to use it. Destiny generates salt forecasts which are then used in simpler models.

About the technology

Farm

Swagman Farm® is a management-oriented, multi-disciplinary computer modelling system developed to help determine cost-effective options to achieve farm scale water and salt balances within irrigation areas. The model takes into account distribution of soils within the farm, potential land uses, crop evaporative requirements, current irrigation practices, leaching requirement, annual rainfall, runoff, leakage to deeper aquifers, depth to watertable, capillary upflow from shallow watertables, salt concentration of water (irrigation, groundwater and rainwater) and the economic returns from potential land uses.

The model can be used to:

- provide farmers with a method to simulate and assess various farm cropping scenarios in terms of economic return and environmental effects
- determine environmentally optimal irrigation intensity and encourage improved WUE through water and salinity auditing in an integrated model
- assist irrigation authorities (public & private) develop policy to achieve improved economic and natural resource sustainability.

Swagman Farm® considers the whole farm on a seasonal basis. It uses a Delphi interface and Gams optimization framework. The Gams licence costs >$10 000 so a shell was developed in C++ to bypass Gams. Two versions are available, one with and one without the use of Gams. A web ‘lump sum’ version was also developed and is available on the CIA web server. The ‘lump sum’ model is not dynamic or crop specific. Default coefficients are provided for a range of crops. The model looks at a management unit which could be the paddock or the irrigation area. Long term trends would have to be assessed by running the model for each season (wet, medium and dry inputs are required).

Destiny

Destiny simulates soil water, ground water, salt balances and crop growth. It is generic to many crops but differences between cropping systems can be achieved by entering crop specific coefficients. The biophysical processes are the same for all crops. Destiny simulates the water balance by considering 15 layers in the soil regardless of the number of soil

horizons. Water penetrates the soil surface depending on infiltration characteristics and percolates down the profile depending on saturated conductivity and water holding capacity of each layer. Water redistribution is based on DSSAT water balance algorithms and salts move with water to determine the salt mass and electrical conductivity (EC) of each layer. The biophysical processes are coded in FORTRAN and the interface is written in Delphi.

The following processes are simulated:

<table>
<thead>
<tr>
<th>Canopy development</th>
<th>Biomass partitioning (no respiration)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root growth and distribution</td>
<td>Roots</td>
</tr>
<tr>
<td>Root senescence</td>
<td>Shoots</td>
</tr>
<tr>
<td>Vegetative/reproductive development</td>
<td>Leaves</td>
</tr>
<tr>
<td>Stress effects (0 to 1)</td>
<td>Crops (15 species/systems)</td>
</tr>
<tr>
<td>Water deficit</td>
<td>Water balance</td>
</tr>
<tr>
<td>Water logging</td>
<td>Evapotranspiration</td>
</tr>
<tr>
<td>Salt</td>
<td>Runoff</td>
</tr>
<tr>
<td>Biomass development</td>
<td>Root zone drainage</td>
</tr>
<tr>
<td>Salt balance</td>
<td>Tile drainage</td>
</tr>
<tr>
<td>Leaching</td>
<td>Watertable height</td>
</tr>
<tr>
<td>Runoff</td>
<td>N balance (very simple)</td>
</tr>
<tr>
<td>No salt uptake by the plant</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Simulated electrical conductivity and salt concentration in selected soil layers
Promotion and further development

CSIRO has promoted Destiny through fliers and workshops. It has been promoted mainly within CSIRO Land and Water and amongst scientists visiting from overseas and elsewhere in Australia. There are no funds for further development.

Benefits

Many models simulate the water balance including Destiny but the strength of Destiny is its simulation of the salt balance, waterlogging and watertable which affect not only crop yield but soil health and environmental health in general. Destiny will be of benefit mainly to scientists. The output is clear and can be easily manipulated.

Applications

Destiny is suitable for ‘what if’ scenarios, for example what will variation in weather do to the water table and salt balance. There is less confidence with the ability to predict yield than for crop specific models like MaizeMan however the output from Destiny could be used as input for crop specific models. Destiny will be useful in project proposals to demonstrate the importance of research issues on salt levels for example. Destiny could be used for irrigation scheduling.

Limitations of the technology

Destiny is not crop specific and requires comprehensive inputs some of which are hard to obtain (eg hydraulic conductivity). Users often don’t take the time to get inputs right and incorrect inputs will give incorrect outputs. The model then gets blamed for incorrect answers. It is possible to bypass the interface by accepting all default inputs which could lead to strange results. The sequence of data entry is important and this may not be very obvious. Users of APSIM or Ceres-Maize windows version will find that Destiny is quite different.
Barriers to adoption

The complexity of inputs is probably a barrier. This could be overcome by making Destiny web based in which case soil and weather inputs could be controlled centrally. There are no funds for this.

Access to Destiny

Swagman Destiny is available provided users agree to intellectual property rights of CSIRO Land and Water and are prepared to share information with the developers. Contact Dr Emanuel Xevi, CSIRO Land and Water, Griffith NSW 2680, Phone: 61 2 6960 1581, Email: Emanual.Xevi@csiro.au

3.1.6 WaterSupply

Don Gaydon and Shaun Lisson, CSIRO Sustainable Ecosystems

Background

WaterSupply is a stand-alone module of the farming systems model APSIM (Agricultural Production Systems sMulator, McCown et al., 1996) that simulates the design and management of different irrigation supply systems. WaterSupply arose from two separate irrigation studies; one relating to the optimum design and management of on farm water storages in the sugar industry (ie Dam Ea$y, see description in this report) and another dealing with the development of best bet management strategies for recycled water on the Darling Downs in Queensland (ie DDV2000-Darling Downs Vision 2000 study6). Incorporation within the broader modelling framework of APSIM enables full integration of this irrigation capability with other crop, soil and climatic processes and the influence of different management options.

Target users

APSIM and its component modules including Water Supply are primarily designed for use by researchers and accredited consultants. While capturing the complexity of the farming system, various user friendly tools have been developed from APSIM which have enabled more widespread and immediate usage (eg APSFRONT7, Dam Ea$y and WaterSense). It is envisaged that WaterSupply will be used by experienced APSIM users to do research or contract work or to develop simpler tools and rules of thumb for the benefit of growers and advisors. Web interfaces such as WaterSense and Yield Prophet8 (not described in this manual) could be developed if there is a demand for specific and routine applications of WaterSupply on line.

About the technology

WaterSupply simulates the design and management of irrigation systems. All possible irrigation sources (including combinations) can be represented including bore, river, recycled and on farm water storage (OFWS). Storage architecture (eg gully vs ring) is

modified through the selection of different depth and surface area combinations. Different lining characteristics can also be set to reflect actual permeability and seepage attributes of the OFWS. Water and solute balances are maintained in each source and take into account all inputs and outputs. Inputs include scheme allocations (bore and river), overland flow into OFWS, direct rainfall capture by the OFWS and recycled tailwater diverted into OFWS. Outputs include OFWS evaporative losses, irrigation and OFWS seepage. The model also allows for the presence or absence of scheme carryover and the transfer of water between sources. Linkages to other modules of APSIM (i.e. Crop, Manager and Irrigate), enable simulation of the full array of irrigation management options such as the timing and amount of irrigation in response to crop demand, delivery efficiency and so on.

**Promotion and further development**

This will be done at annual Agricultural Production Systems Research Unit (APSRU) science days, in APSIM release notes available on the web and via direct application in research projects. There is no other formal plan for promotion of WaterSupply. Further development will be undertaken by APSRU and by Don Gaydon in particular at least in the short term.

**Benefits**

WaterSupply provides an efficient means for researchers and consultants of testing rules of thumb relating to the design and management of irrigation and provides a means of evaluating the economic, production and environmental risks and benefits of various alternatives. A wide range of alternative design and management practices can be rapidly tested in a desktop manner prior to major investment. This has proved the major benefit of the Dam Ea$y, WaterSense and DDV2000 studies.

**Applications**

Applications such as Dam Ea$y, DDV2000 and the Hobart water recycling project have been mentioned already. WaterSupply has been used with an allocation forecast model like FlowCast to assess the value of forecasting water allocations. The combined models can assess the risks of running out of water and growers can then assess the risk of planting if a low allocation is forecast. Conversely if the allocation forecast is high they can assess the value of using the allocation fully themselves against selling water to other growers. WaterSupply and its precursors have been used with Swagman-based catchment models (Dr Shabaz Khan) to assess the impact of recycled water in the Riverina and Darling Downs. APSIM modules can account for vertical movement of salts through soils but not horizontal movement through the catchment. The primary focus of the Hobart project for example is to understand the fate of salt movement through the farming system and impact of salt on soils and irrigation water. APSIM with WaterSupply and Shabaz Khan’s hydrology model are required for this.

WaterSupply can be applied to water policy development and legislation and to scheme management in order determine how best to use water on a range of crops.

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Limitations of the technology

In the past APSIM had limited capability to simulate multiple paddocks simultaneously. Competition for water between paddocks can now be simulated in a ‘work-around’ arrangement but soon this limitation will be removed by advanced software developments. More testing of the WaterSupply logic and of APSIM crop modules is probably required. In sugarcane for example the simulated yield response to increased water allocation was recently found to be inadequate. Algorithms were added to simulate lodging which reduced the yield response appropriately when considering large water allocations. Similar testing and model refinements may be required for other crops. This is not a limitation in WaterSupply but in the crop modules required to simulate farming systems. Crop modules in APSIM generally do not respond to levels of salt because of the lack of physiological knowledge.

Barriers to adoption

WaterSupply will not be widely adopted as in other software packages which are mostly designed for direct use by growers or consultants. WaterSupply will be used for consultancies as in the DDV2000 and Hobart projects or it will be used to develop software packages like Dam Ea$y.

Access to WaterSupply

WaterSupply is a module of APSIM and the arrangements for use of APSIM depend on what it is to be used for. License costs are low for module developers for example but high for consultants who will generate income from its use.11

For more information please contact Don Gaydon, Phone: 61 7 3214 2230, Email: Don.Gaydon@csiro.au, 120 Meiers Road Indooroopily 4068
Shaun Lisson, Phone: 61 3 6226 1861, Email: s.lisson@utas.edu.au
c/o Tasmanian Institute for Agricultural Research, PMB 54, Tasmania 7001

3.2 Paddock level packages

The majority of the tools operate at the paddock or point scale even if they present data for the whole farm. Tools which allow the user to interact with a process level crop model (HydroLOGIC and Maizeman for example) assume that the paddock is represented by the processes operating at a point in the paddock for which soil, plant and atmospheric conditions have been defined. Tools which allow access to soil moisture monitoring equipment (IrriMAX, Multi-Log for example) work on the assumption that the sensors in the paddock represent the whole paddock. Several of these tools present a summary of all paddocks simulated or monitored but interactions between paddocks on the farm are not represented. For example, an irrigation schedule for all paddocks on the farm may not take into account the real limitations of irrigating more than one paddock at a time.

3.2.1 HydroLOGIC

Dirk Richards and Michael Bange, CSIRO Plant Industry and Australian Cotton CRC

Background

The background to the development of HydroLOGIC has been fully described by Hearn and Bange (2002). The cotton industry has a long history of development and testing of DSS tools with CSIRO, starting with SIRATAC which was used mainly for record keeping and insect pest management. CottonLOGIC, which superceded SIRATAC, contains a suite of models dealing with various components of the cotton production system including pest, nutrient and water management. The most recent addition to the CottonLOGIC suite, the HydroLOGIC furrow irrigation management system, was developed with support from the Cotton Research and Development Corporation and the Australia Cotton CRC, to assist with decisions about water management in cotton. The impetus for the development arose from reduced water allocation for cotton and low rainfall during recent droughts as well as increased scrutiny on the use of water for irrigation of cotton. Neutron and capacitance probes are used quite extensively for managing irrigation in cotton. HydroLOGIC complements these technologies by introducing crop physiology and climate variability into the decision making process. HydroLOGIC is a powerful means of integrating a range of soil, crop and climate information for decision making. It has the advantage over soil monitoring technology in being able to predict crop growth for the remainder of the growing season and also provide a variety of 'what-if' scenarios.

Target users

Growers and cotton consultants in the cotton industry are the main target users. So far about 70% of software users and trainees have been consultants which include large corporate agronomists, independent advisers and resellers. Up to 500 copies of HydroLOGIC are in circulation and about 240 people have been trained in its use since its release in 2003. Other trainees include researchers, extension officers, irrigation engineers and soil monitoring equipment suppliers.

About the technology

HydroLOGIC provides information to allow growers to explore different irrigation management scenarios. Cotton growers can then integrate this information with outside influences such as future water allocations, cotton prices, and other resource constraints to determine the most risk appropriate irrigation management plan for the current season.

HydroLOGIC employs OZCOT which is a cotton crop simulation model also developed by CSIRO Plant Industry. The OZCOT model is based on research from experiments on how cotton grows and develops in response to its environment. OZCOT is continually updated and embodies expert knowledge from people working in Australian cotton research. OZCOT has undergone rigorous field testing in the industry and research has shown that is has an excellent ability to predict yield (Figure 1).

To use HydroLOGIC, cotton growers collect data from their cotton crops including:
- Soil moisture deficit obtained by using any existing soil moisture monitoring equipment that has been calibrated to volumetric soil moisture.
• Fruit load – a measurement of the number of fruiting structures (squares and bolls) and
• Leaf area index – a simple estimate of the amount of leaf area present on the crop that affects the amount of soil evaporation and crop transpiration.

Figure 1. An example of a HydroLOGIC screen

Promotion and further development

Current awareness of the tool is very high and most people in the cotton industry know about it although it is still being developed further. CSIRO, CRDC and the Cotton CRC are providing support but alternatives are being investigated, including an accreditation system. Through accreditation consultants and growers will be able to contribute directly or indirectly to ongoing development and support. A number of agencies could be involved in further development and support including the Cotton CRC, agribusiness, CRC IF, NSW Agriculture and DPI. Collaboration with other research efforts is being investigated.

Benefits

Research data obtained from a large on farm experiment showed that a grower could increase WUE from a standard of 0.5 bale/ML to 1.0 or even 1.5 bale/ML of net irrigation.

**HydroLOGIC** provides growers with simple information regarding how frequently they should be irrigating. Growers using **HydroLOGIC** may be able to reduce their water use through the fine tuning of their water management allowing them to irrigate to fulfil the exact water requirements of the crop without applying water
unnecessarily, essentially timing water application to maximise production. Predictions of the total number of irrigations, timing of the next irrigation, total water use, WUE and estimated yield can be made by HydroLOGIC before harvest, based on historical climate. This allows growers time to alter their irrigation strategy to maximise yield and develop their own rules of thumb. Users can assess a range of strategies quantitatively, quickly and without the risks associated with experimenting on farm (Figure 2).

**HydroLOGIC** can be used to improve yields compared with standard management and when water is restricted.

**Using HydroLOGIC crops can be grown to maximise yield in water restricted conditions, optimising irrigation water use efficiency.**

**Figure 2. Yield and irrigation water use index (efficiency) predictions under various water management options, with and without HydroLOGIC**

**Applications**

**HydroLOGIC** can assist an irrigator to:
- Determine the optimum cropping area for a defined water allocation
- Decide when to schedule the next irrigation
- Assess the consequences of different irrigation management strategies and ask ‘what if’ questions such as changing the timing of irrigations and the effect of different water allocations
- Benchmark actual crop growth with the predicted crop growth at the end of the season to assess the current management strategies

**Limitations of the technology**

**HydroLOGIC** reports averages rather than percentiles or other types of probabilistic data, although this type of information will be generated in future versions. Growers would prefer to see the risks of a certain strategy as affected by the climate and SOI for example. Since the software is not web based it is difficult to know how it is being used. Information from **HydroLOGIC** could be misinterpreted as with all software DSS tools but this is preempted to a large extent by the training workshops that
precede its distribution. In essence the risks of using HydroLOGIC are associated with normal climatic risk of farming.

**Barriers to adoption**

There are few barriers to adoption. Care has been taken to consult potential users widely. The interface fits in with the way people manage their irrigations including those who use soil water monitoring systems. Users need to attend a four hour training session but this is not regarded as a problem for adoption in the cotton industry which is young and adaptive. Early adopters are regarded highly by the industry since new technology has kept the cotton industry competitive and in business. Users do not want to enter the same data repeatedly for different software tools. They would like to use one tool for all their applications. Developers are aware of this and are endeavouring to provide a ‘one-stop-shop’ for declared needs of users through linkages with other software.

**Access to HydroLOGIC**

HydroLOGIC is provided free to Australian cotton growers and consultants. For more information or to receive a copy contact NSW or Qld Cotton Industry Development Officer, the Australian Cotton CRC Technology Resource Centre on 02 6799 1534 or visit http://cotton.crc.org.au/CottonLOGIC/

For more information contact Dirk Richards, Phone: 61 2 6799 2416, Email: Dirk.Richards@csiro.au or Dr Michael Bange, Phone: 61 2 6799 1540, Email: michael.bange@csiro.au, CSIRO Plant Industry and Australian Cotton CRC, Myall Vale, Wee Waa Road, Narrabri, NSW 2390

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**3.2.2 IrriMAX**

*Tim Waterhouse and Peter Buss, Sentek Sensor Technologies*

**Background**

IrriMAX 6.1 was developed from earlier versions to improve access and interpretation of soil water and salinity data obtained from Sentek’s variety of soil water and salinity monitoring devices. There are a number of reports available on the web on case studies on how IrriMAX is used with these sensors for managing irrigation of various crops. IrriMAX was developed by Sentek Sensor Technologies which is an Australian based company with 13 years of experience in soil water monitoring and operation in over 25 countries. Sentek’s technology is used to visualise the invisible dynamics of the plant-water-salt-soil-atmosphere interactions, translating these into easy to understand pictures that irrigators use to manage their day-to-day irrigation, fertigation and soil salinity status. The products have applications in agriculture, turf, mining and environmental management.

**Target users**

Target users include irrigation consultants, waste water managers, researchers, environment consultants and generally all who manage very complex irrigation systems. IrriMAX is used by small growers as well as multinational corporations.

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Some ABS statistics are available for use of soil monitoring in Australian agriculture. About 16% of respondents nationwide and 30% of respondents in SA monitor soil water (70 to 80% in Renmark) but not all use Sentek products.

**About the technology**

**IrriMAX 6.1** is a stand alone windows based software product designed to aid easy interpretation of Sentek’s soil moisture and salinity sensing probes as well as ‘rainfall’ and ‘irrigation’ data to enhanced irrigation management.

Key Features:

- Display salinity and fertilizer data in conjunction with soil moisture data in the same graph window.
- Directly compare trends of salinity, (including fertilizer salts) and soil moisture data alongside corresponding irrigation, fertigation and rainfall events (Figure 1).
- Graph annotations. This feature allows the user to add management comments anywhere on the graphs thus allowing the user to store historically critical notes and data for later references (Figure 2).
- Manual or automatic input of amount and duration of rainfall and irrigation events.
- The rainfall and irrigation data can be viewed in multiple modes to suit individual user needs.
- Importing and exporting data between various file formats through the powerful Data Exchange application for which the end user or third party integrator, can develop drivers to support their own source file formats or communication protocols.

IrriMAX is a graphic tool that can be used to display data from other soil water monitoring devices as well as weather data. It is a service package to be used together with hardware and agronomic support. It is not an off-the-shelf product for use in isolation.
Figure 1. Continuous TriSCAN data displayed in IrriMAX 6.1

Figure 2. Diviner 2000 data displayed in IrriMAX 6.1
Promotion and further development

Promotion will probably continue as in the past through diffusion amongst growers (over the fence). More recently, scientific publications and web exposure are promoting awareness of IrriMAX (along with other Sentek products). Distributors of hardware will also play a role. Education rather than promotion is required. The role of government agencies is diminishing but they can deliver best practice benchmarks so that private services can help people meet these standards. Education of farmers needs to be undertaken by government.

Benefits

Graph annotations can be used as a powerful communication tool between the consultant and the user. Recommendations by the consultants can be stored as annotations and the graph document with annotations can be emailed to the user. IrriMAX 6.1 provides users with a clear continuous picture of crop water use as well as fertilizer fate in the root zone, in the context of events such as irrigation and rainfall. This new software solution has more power and greater functionality than earlier versions including, a choice of graphs and an easy exchange of information between third party software applications. **IrriMAX 6.1** will help many growers redefine their irrigation and farming practices allowing them to save water and fertilizer, reduce labour and increase yields. IrriMAX is evolving into a standalone irrigation scheduling software able to be seamlessly integrated with third party hardware equipment thus making it suitable for licensing and bundling by OEM vendors and integrators.

Applications

Applications include irrigation and fertilizer management as well as salinity monitoring. Soil water graphs representing different fields and crops show a ‘water status’ gauge which depicts the latest soil water status between a set ‘Full Point’ and a set ‘Refill Point’. The user is able to detect the field and crop needing most urgent attention, by looking at the lowest ‘water gauge’ status in one glance (Figure 3).

![Figure 3. ‘Water gauge’ screen for a number of vineyards for prioritising irrigation](image)
Limitations of the technology

There is limited compatibility between IrriMAX and other hardware devices (e.g. Campbell loggers) but the intention is to facilitate sharing between hardware and software developed by others. A basic level of training is required to interpret the data correctly and to manage irrigation accordingly. Competing but inferior services and products are turning the industry off this sophisticated technology.

Barriers to adoption

There is some confusion about all the soil monitoring hardware and software in the market place which could impede adoption. Adoption is all about education and understanding benefits. It takes at least one crop cycle to be able to see the benefits. The wise use of the soil moisture graphics in publications and meetings has changed the way growers view water and irrigation. Their thinking is now more aligned with the ‘look and feel’ of IrriMAX and this aids adoption. Other factors are growers' preparedness to innovate and change, level of crisis (cost – price squeeze, regulatory requirements), education, and quality of local advisory and support services.

Access to IrriMAX

This is a commercial package obtainable from Sentek along with Sentek sensors. Contact Sentek, 77 Magill Road, Stepney, South Australia 5069, Australia Free call (in Australia): 1-800-SENTEK (1-800-736-835) International: 61 8 8366 1900, Website: www.sentek.com.au

3.2.3 Magpie

David Peacock, Measurement Engineering Australia (MEA)

Background

Measurement Engineering Australia (MEA) was formed in 1984 to design and manufacture remote environmental monitoring systems including automatic weather stations, soil moisture monitoring systems, water quality and flow systems, and custom designed measurement systems. Magpie was designed by MEA in 1996 to replace an ageing DOS based application, and to resolve a number of key issues that impeded easy, day to day operation of an MEA measurement system. As a result, Magpie was born out of the needs of customers and today is one of the easiest and most intuitive packages in use for viewing data collected from a measurement system. A list of environmental monitoring equipment used in MEA systems can be seen on their web site13.

MEA’s latest version of Magpie (Magpie 2) now includes the ability to have support for other data logging and measurement devices written into it in the form of plug-in support modules. Though currently Magpie supports only the Unidata logger, when support for other devices is added in the future, an MEA user will not be faced with the need to learn a new software package in order to gain access to the benefits of different measurement hardware.

About the technology

Magpie is a Microsoft Windows compatible program and is used in all measurement systems designed and manufactured by Measurement Engineering Australia Pty Ltd (MEA).

Figure 1. An example of data display of soil moisture and rainfall

The aim of the software is to provide a functional, easy to use tool for the collection and display of the recorded information: a tool with a high level of flexibility making it suitable for all applications. Magpie creates new graphs with just a click of a button. Sensors from any monitoring site can be included on a graph (Figure 1). Magpie offers a variety of graph customisations to generate a graph view most appropriate for the application. These customised graphs can be saved as favourites for fast recall at a later date. Magpie’s tabular data display is useful to track down specific times or values. Tables can be easily navigated to find data of interest. Data can be selected and exported for further processing in third party applications. For telemetry based systems, Magpie provides a manual dial/hang-up facility which lets you call a site, unload the data and even check the current sensor readings. Calls can be automated using the Windows Scheduler. Magpie supports multi-user access to the scheme and scheme data so information can be shared over a network.

Target users

Any users of MEA systems including scientists, advisors and irrigators.

Promotion and further development

MEA promotes Magpie through advertising (MEA resellers don’t do that). A national awareness campaign in 1998 resulted in Magpie as an icon. The web presence is good. Promotion is being carried out in partnerships, for example with the wind industry who support MEA systems as well as agronomists, consultants and the Central Irrigation Trust (CIT).

Benefits

Close to 350 copies of Magpie are in service. The software provides improved decision making by easy access to environmental information. It offers an integrated
approach which provides easy access to data. The program is very easy to use providing ready access to soil and climate variables. This was the goal from the outset. Competitive tools go through a number of processes to do what Magpie does in a single step.

**Applications**

Applications include irrigation planning and management which is based on soil and climate monitoring by MEA (and other) hardware, climate based application of chemicals, pest and disease monitoring and the analysis of long-term trends.

**Limitations of the technology**

Magpie is written to support MEA measurement systems and data presentation for a wide range of industries. Therefore, Magpie does not provide a high level of integration around the exact requirements of any one selected industry. Magpie 2 attempts to overcome this by allowing industry specific modules to be written and plugged into the application.

**Barriers to adoption**

People will need an understanding of the technology and the reasons for its use before adopting it. Generally they will wait till they have to measure water use due to water cost or environmental concerns.

**Access to Magpie**

Street: 41 Vine Street, Magill, South Australia 5072, Post: PO Box 476, Magill, South Australia 5072, Phone: 61 8 8332 9044, Email: mea@mea.com.au

### 3.2.4 MaizeMan

*Elizabeth Humphreys, CSIRO Land and Water*

**Background**

In 1993/94, Dr Wayne Meyer initiated the development of a DSS for irrigated maize in discussion with farmers and the maize industry. GRDC eventually decided to fund the development in 1998, and the work was undertaken by a team led by Liz Humphreys (CSIRO), with Bob White (consultant) as the software developer, and Doug Godwin (consultant) as the principal crop modeller. Some local key figures within the maize industry and leading farmers were keen to have a tool to allow farmers to explore management options by simulation, and felt that they were lagging behind cotton and rice growers with the decision support tools available to them. A survey suggested that water and N management were the main components of the system that were of interest to growers. A model was proposed with the capability of taking into account upflow from shallow watertables and salinity which are common problems in irrigation areas. Water tables have subsequently receded, irrigation water has become less available and the value of such a tool in assisting with water budgeting has become more apparent. Currently the main use is probably decision
support for irrigation scheduling. Irrigation scheduling by most growers is based on experience. A few growers hire consultants for monitoring soil water content. Flexibility in irrigation scheduling can be limited by the time taken to get water around the farm so scheduling with the help of a model in such situations may be less useful.

**Target users**

These are growers and agribusiness advisors (Wesfarmers, Landmark, private consultants) and state agency extension staff. The model could be particularly useful for new growers of which there may be many when planned ethanol plants are built in northern Victoria and southern Queensland. Some farmers are interested in software tools and are even using web tools developed overseas (USA). Users need to have a reasonable science background to cope with the model output. Some growers would cope but most would need technical help. Growers will benefit in the end from *MaizeMan*. Researchers and students would also benefit from using the model. As far as is known, *MaizeMan* is not being used by many farmers at the moment although there are many copies of older versions in circulation. Version 2, released in July 2004, is a vast improvement on previous versions. All people who attended workshops in 2004 (about 45) have various issues of version 2 which they can upgrade to the most recent version by downloading from the web, free of charge. The current version, 2.2, was released for sale recently at $55 per copy. Four copies have been sold to date, 3 to growers and 1 to a consultant.

**About the technology**

*MaizeMan* is based on a crop and soil simulation model derived from both the *CERES-Maize* (the crop growth model) and *Swagman~Destiny* (the water and salt balance) models. *MaizeMan* processes user inputs by simulating crop growth and development as well water, N and salt balances (see *Destiny*) all of which affect crop performance and system response. *MaizeMan* can be used to examine crop performance from past seasons and to investigate what the effect of different management strategies might have been, to assist in irrigation scheduling and nitrogen management decisions for the current crop, and to explore other options for growing maize as affected by location (climate), seasonal weather conditions, site conditions (soil type, groundwater) and management. *MaizeMan* simulates in four modes:

1) Historical - simulations of crops grown in past seasons, which require information about crop management and observations, soils (Figure 1) and weather. The multi-scenario viewer enables graphical comparison of the results of up to 10 simulations
2) Current season – simulation of the current crop which requires information about the crop until ‘yesterday’. *MaizeMan* can be used to assist irrigation scheduling (Figure 2) and nitrogen management for the current crop.
3) Whatif – in this mode, any changes made to the management of the crop will not be recorded in the database.
4) Forecasting – management decisions made for a paddock up to the chosen date are used, then from that point onwards, each past year’s weather data is used to provide a probability of likely crop performance, water use, stresses, WUE, N losses etc. The level of information that can be explored depends on whether the model is being run in potential yield mode, yield limited by water management (which the user specifies) or yield limited by water and N management (which the user specifies).
Promotion and further development

This has been done largely by CSIRO running workshops. About 160 growers, agribusiness people, extensionists and consultants have been to workshops on MaizeMan. The MaizeMan website can be accessed via the Maize Association of Australia website\textsuperscript{14}. Articles in farmers’ newsletters are raising awareness. The GRDC project which funded the development of MaizeMan, terminated in 2004 and there is no current funding supporting the use of the tool. Training in MaizeMan will be offered in 2005 care of Murrumbidgee College of Agriculture, and at the triennial Australian Maize conference in Griffith in February 2006.

Benefits

MaizeMan is good for demonstrating a range of management scenarios which people can compare with what they are currently doing. The speed and clear graphical presentation of results are highly suited to this. MaizeMan is excellent for group discussions and for one-on-one consultation. Growers can consider many options for saving costs in irrigation and N management. These options can then be compared in demonstration trials. One of the main advantages of MaizeMan is for water budgeting and scheduling the use of water. It can be used for seasonal or longer-term strategic planning both by growers and water supply managers. MaizeMan is an excellent educational tool as it helps people to visualise the cropping system in a way that has not been possible before. For example one can see where the roots are active and learn how to use N and water better.

Applications

- Potential and actual yield comparisons
- Risk analysis from probability distributions for many crop, N and water parameters
- Forecasting water use requirement and yield
- Gross margin analysis
- Assess influence of water table
- Sowing date analysis
- Prioritising management options
- Irrigation scheduling

Limitations of the technology

The accuracy of the model has not been tested at all levels and all testing has been in southern NSW, however the CERES Maize model behind MaizeMan has been widely tested around the world. The model relies on genetic coefficients which are difficult to get. The present ones are only derived from one year's data in one environment. These coefficients will improve with experience. Soil data required for the model may limit its usefulness for some applications, especially irrigation scheduling. Users will need assistance to characterise soils with properties that match more closely their own soils in the field, especially the properties of upper and lower limits, and hydraulic conductivity. The model needs to be tested more against experimental data (validation) in a range of environments. There has been limited opportunity to validate the model against growers' observations or measurement. Ongoing support for use of MaizeMan is a major limitation.

Barriers to adoption

Growers and other users require confidence in the model and any results that disagree with their observations could limit its adoption. Users need more support to learn about the technology, such as running the model with grower groups, and comparing model predictions and observations for commercial crops. Water shortage and increased maize production to supply ethanol plants may encourage adoption.

Access to MaizeMan

Contact Liz Humphreys, Private Bag 3, Griffith NSW 2680, Phone: 61 2 6960 1528, Email: Liz.Humphreys@csiro.au. Cost $55.00 (to cover handling, CD and postage costs). Further information is available at http://www.maizeaustralia.com.au
3.2.5 Micromet

*Terry Crawn, Jim Townsend and Andrew Wilshire, Micromet Pty Ltd*

**Background**

*Micromet* was established by South Australians, Jim Townsend and Chris Laurie, as a hi-tech, IT/resource and irrigation management company. *Micromet* have developed a water balance program using rainfall, irrigation and evaporation estimates based on the Priestly-Taylor equation, to control irrigation of open spaces (parks) in urban environments. While they are active in a number of municipalities in SA and NSW, their goal is to establish a global market for, and to become the leader in, the provision of irrigation scheduling management services, including agriculture. Their work is thus pertinent to this inventory but they do not market their software independently.

**Target users**

The main target ‘users’ or clients are local authorities and corporations who use expensive water to irrigate open spaces.

**About the technology**

*Micromet* allows the weather to ‘drive’ irrigation. The technology calculates the ‘optimum irrigation event (OIE)’ and applies it whenever needed. This means that a site will be irrigated more frequently in hot weather than in milder weather. When *Micromet* is installed at a site, the soil texture, root zone depth and precipitation rate of the irrigation system are measured. These measurements allow the irrigation system to run for the time necessary to refill the root zone. The *Micromet* central computer uses weather stations spread throughout the city to accurately calculate the water use at each site each day. When the soil moisture is reduced by plants to a level below the refill point (usually 50% of the available water within the root zone), the site is listed for irrigation that night. The *Micromet* devices at the listed sites each receive an ‘irrigate’ message from the *Micromet* computer and allow their controllers to operate on that particular night. If it rains during irrigation, the irrigation will stop.

Examples of *Micromet* screens follow.

![Figure 1 Affect of mild weather.](image1)

![Figure 2 Affect of severe weather.](image2)
During cool or cloudy weather (Figure 1), available soil water (AW – blue line) declines slowly after rain or irrigation however in hot, dry weather (Figure 2), it only takes only a couple of days for the AW line to drop below the bottom of the shaded area and thus cause the system to apply an irrigation to the site.

**Promotion and further development**

The **Micromet** service is being promoted as a commercial venture both locally and overseas. Radar measurement of rainfall is being investigated to greatly expand the number of sites and controllers that can be independently regulated.

**Benefits**

The system has reduced water consumption from 20 to 50% and in Adelaide for example where water costs $1000/ML this amounts to large dollar savings. The problem in many municipalities is that open spaces are over watered which not only wastes water directly but indirectly through reduced rooting depth of grassed areas. It is easy to calculate the benefits of the system by comparing the amount of water and money grounds men have used, with what would have been the case if **Micromet** controlled the irrigation. Areas of 1800 to 2000 m² are required to break even. Apart from the benefits of saving water and money and reducing off site impacts, it is important for our mental health to have well maintained grassed areas in our cities.

**Applications**

**Microment** runs about 1000 sites in Australia (mainly Adelaide and Melbourne) and overseas (California). Irrigation of lawn grass is the widest application however garden beds in open spaces also get watered. Sporting stadiums are considered to be a core business application. The system is designed to switch on during periods when irrigation is not required, just to keep the hardware working. The system is designed to accommodate sporting requirements such as specific surface conditions for sporting events.

**Limitations of the technology**

The system is aimed at being affordable and for this reason there is no feed back and little monitoring of soil water content (as in Figures 1 and 2). The system does not know if an irrigation actually occurred. The grounds man is the only source of feedback. The system is highly dependent on the weather monitoring network which can fail but the system will send a mobile message (SMS) to **Micromet** staff as soon as a failure occurs and problems can be addressed immediately.

**Barriers to adoption**

Market awareness is moderate to poor. People who run urban irrigation systems are worried about their jobs, but they need not be since they are still required to maintain the irrigation system. People feel threatened with hi-tech systems. The price of water is important and the value of the system increases with the costs of water. Client perception is good and most clients are happy with the service although some have dropped out. The main problem in councils is the large staff turnover, so new staff have to be convinced of the value of the system.
Access to Micromet

Micromet is a service and available through contractual arrangements with the company. Contact Micromet:
Postal: PO Box 2267, Kent Town, 5071, Street: 50 King William Street, Kent Town SA 5067, Phone: 1300 130 425, Email: info@micromet.com.au
Website: www.micromet.com.au

3.2.6 Multi-Log

Trevor Finch, Research Services New England

Background

Multi-Log was developed to graph data from a wide range of data loggers, portable instruments, and internet data. The aim was to provide the same capability as typical software provided by general purpose logger manufacturers, plus some extra features specifically for agriculture and irrigation scheduling. It was also developed to provide a simpler alternative to ‘Probe for Windows’.

Target users

The target users are growers and irrigators who operate a range of different loggers and instruments and who have data downloaded from the internet or manually recorded data.

About the technology

The software can read data from a wide range of formats from different loggers. In most cases the data is read in the ‘foreign’ format, but for some systems (e.g. Adcon C-probe) the data needs first to be exported by other software. It can also graph data (or show comments) entered manually or downloaded from the web. Manual entry allows manually recorded fruit size or plant height to be compared with soil moisture and air temperature. The software is in use with TekSmart, Decagon Echo, Diviner2000, Delta-T ProfileProbe, Adcon C-Probe, EnviroSCAN, Monitor, Campbell Scientific and other sensors and loggers in Australia, New Zealand, UK, China, South Africa and USA.

The software is able to overlay data from different sensors on the same graph even though the data was logged on a different logger at different dates and frequencies. For example, weather data from an MEA weather station could be plotted on the same graph as Gbug soil tension and Delta-T Profile Probe.

Examples of graph types are:

- A single sensor
- Stacked graph of soil moisture at different depths (Figure 1)
- Layered soil moisture (all at the same scale)
- Daily water use derived from soil moisture sensors compared with ET downloaded from a web site.
The software can present various derived variables (virtual sensors) such as:

- Calculated total water content from individual soil moisture sensors
- Calculated growing degree days from temperature
- Smoothed data to give a daily average.
- Calculated daily water use from continuous soil moisture data (Figure 2).
- Calculated the effective gain from an irrigation (the net rise in water content) (Figure 2)

Irrigations can be scheduled using calculated daily water use to predict when soil water content will reach the lower limit. For drip irrigation the amount required to maintain a target water content can be determined. Users can also enter their own estimate of the daily water use or they can use ET data downloaded from the internet. The volume of water required (for both drip and flood), can be displayed in mm, hours or ML, with the output printed as a report. Output can be to the screen or printer and the water content of each field can be shown as a ‘fuel gauge’ superimposed over a map or aerial photograph (Figure 3). Printed reports summarise data by the day or hour, and can be saved in HTM format to build a web site (Figure 4).
Figure 2. Total water content, with daily water use, effective gains, and an irrigation forecast

Figure 3. Example of a farm map with ‘fuel gauge’ showing available water in each field
Some loggers (e.g. Campbell Scientific, Monitor) can be downloaded via a serial port and data files can be sent to and from FTP sites. The FTP facility enables a consultant to implement a network across farms. For example, ET files can be prepared by a consultant and uploaded to a central file server. The files can then be downloaded by individual growers to overlay over their own logged data. In turn, the grower’s data can be uploaded to the consultant so that the consultant can see the same data as the grower.

**Promotion and further development**

New loggers and formats are being added on an on-going basis in response to feedback and suggestions from growers and consultants.

**Access to Multi-Log**

The software is normally provided via logger manufacturers or system integrators. For more information contact Research Services New England, 8/16 Nicholson St, Balmain, NSW 2041, Australia, Phone: 61 2 9810 3563, Email: support@rsne.com.au, Website: http://www.rsne.com.au

### 3.2.7 Probe for Windows

*Trevor Finch, Research Services New England*

**Background**

This software was originally developed for the CPN 503 neutron probe to run on VAX and other mainframe computers. It now runs on Windows and Macintosh and also handles data from the TekSmart, Diviner2000, EnviroSCAN, Delta-T Profile Probe, Adcon C-Probe, and similar systems. It is currently in use in Australia, South Africa, USA, China and other countries and can be easily translated into languages other than English.

**Target users**

The target users are consultants, corporate farms and growers operating their own instrumentation.
**About the technology**

A crop that is growing can be examined above the ground but it is difficult to find out what is happening below the surface, what the roots are doing and where they are extracting water. Soil moisture, measured at different depths down the profile, provides a ‘virtual test-pit’, or an ‘X-ray’, of what is happening below the surface. The key is interpreting the data. Absolute accuracy of the sensor is not as important as stability. The user needs to be confident that if a sensor has changed from the previous week, or the previous season, then the soil is wetter or drier. Absolute accuracy only becomes important if daily water use or irrigation amounts are calculated, but even then only the slope of the calibration curve is important. After installation, the sensor can be calibrated against known applied amounts of water from a rain gauge, catch cans or meter on the pump.

If soil moisture is measured at different depths down the soil profile, and if you know how much water has been applied, then if follows that:

- the rate of soil moisture depletion is the daily water used by the crop after allowing for through-drainage.
- this rate enables the date at which the soil moisture will fall to the ‘refill’ point to be calculated.
- the amount of water, in mm, that needs to be applied to bring the profile back to the ‘full’ point can then be calculated.
- for drip systems, the amount required to maintain a target water content can be calculated.
- the full point, the maximum water holding capacity of the soil profile, can be accurately identified when through drainage starts (a rise in the bottom sensor).
- the refill point, below which a specific crop in a specific soil type is stressed, can be accurately determined by noting a reduction in daily water use or a reduction in water content at the bottom sensor.

Soil suction, or tension, controls the water available to a plant, and irrigation recommendations are often given in kPa units. The problem with measuring water tension is that the transducers are not as stable over time as those for soil moisture, and tension does not give a linear prediction of when the plant will be stressed, making it difficult to predict when the next irrigation is due. In practice there is a strong correlation between moisture and tension for a given soil type at the refill point (onset of stress). The full point (maximum water holding capacity) can be closely defined from soil moisture monitoring.

**Software**

Data from portable instruments like the neutron probe, Diviner2000, Delta-T ProfileProbe; and also continuous logged data from TekSmart, Echo, EnviroSCAN and C-Probe can be used. Continuous data can be received from local loggers; local radio; or GSM telemetry via the internet.

The software is designed for handling a large number of sites. A typical scenario is for a consultant to:

- Measure and inspect 10-50 sites on a farm
- Analyse the data and make irrigation recommendation
- Print a graph report for each site
- Discuss the recommendations with the grower

Some consultants will later print and then fax their report but notebook PC’s and portable printers allow everything to be done on the farm. The software allows the user to see a summary of the current state of all sites but also gives access to all readings for each site if required. An interactive, combined depth and time graph gives the user the ability to see where the applied water is going, and where the plant roots are extracting water. From this, the full point and the refill (stress) point for that crop in that specific soil profile, can be found.

Examples of screens and graphics follow.

Figure 1. Interactive, combined depth and time graph. A cursor (vertical dotted line) on the time series graph (left), allows the user to step through the season to show clearly on the depth graph (right) where the water went each day. For example, with the cursor on 13 January the user can see through drainage resulting from an over irrigation on 10 January. The software calculates the effective gain in soil water from each irrigation and is therefore able to calculate the application efficiency.
Figure 2. Irrigation scheduling using crop daily water use (DWU) derived both from a moisture probe (red), user entry (blue) and a formula (green). The software calculates the amount (in mm, ML or hours) of water that needs to be applied. For intermittent irrigation systems (flood, pivot or sprinkler) this is the amount required to bring the profile back to the full point. For continuous systems (drip) it is the amount required to maintain a target water content.

Figure 3. Upper and lower limits for target water content can be varied during the season, to follow Reduced Deficit Irrigation (RDI) requirements. RDI is a strategy that aims to improve grape quality by deliberately stressing the vine at different stages during the season. The pink line shows an ideal soil water pattern resulting in a good vintage in 97/98 and the green line shows a successful attempt to reproduce the favourable soil water conditions for the subsequent season.
Figure 4. The allocation report which allows managers to balance water requirements. The requirements (in mm, ML, or hours) can be output as a printed report such as this, or exported to irrigation control systems. In turn, the software can import from the control system software, the amounts that have been delivered, and so calculate the efficiency of the irrigation. Communication between the Probe for Windows software and the irrigation control system allows for continuous monitoring and improvement of irrigation efficiency, only applying the amount required. The amounts required for each field can be aggregated over the entire farm, giving total farm requirements for water ordering. The net gain in soil water content from each irrigation and rainfall is calculated, giving efficiency (delivered/net gain).

Figure 5. Report printed at the end of the season summarising total water use for each field. The season summary report shows the efficiency of each gain in soil water from irrigation or rain, plus the total season efficiency of the field. The yield of each field allows the WUE to be calculated. The amounts can then be aggregated over the entire farm to give total farm water use.
Promotion and further development

The software is normally provided and supported through local agents and is under continuous development in response to user requests.

Version 2 is now running in New Zealand and Australia. It can

- Automatically build web sites from reports, and email results to growers.
- Automatically transfer files between computers using FTP.
- Estimate water requirements for the remainder of the season.

The whole season calculations take into account

- The actual soil profile water holding capacity.
- Varying ET and crop factors during the season.
- Varying target water content (RDI).
- Rainfall patterns from historical records or simulations.

The predicted water used can then be aggregated to give total water requirements by farm, by valley and by crop. New Zealand requires that each valley provide accurate estimates of water requirements for the remainder of the season.

Benefits

The main benefit to the grower is improved yield and crop quality. The benefit to the wider community is improvements in the effective use of water.

Applications

On-going on-the-farm support is essential. This is done commercially in Australia, but on a much wider scale in South Africa, with corresponding improvements in yield and quality. Growers are willing to pay for on-the-farm advice because it allows them to grow better crops.

 Soil moisture measurements are typically used to schedule the next irrigation but much more extensive use could be made of the data. The data could also be used to:

- Calculate the efficiency of each irrigation and rainfall
- Provide estimates of water requirements for a whole valley and region, to predict how much water will be required for the remainder of the season.
- Aggregate WUE by farm, valley and crop.

In Australia a water audit would be done by an accredited adviser, who would need to measure and record water applications and water used. The audit could be combined with an irrigation scheduling advisory service - a typical cost of a combined service would be from about $5,000 p.a., but large corporate farms would probably have the expertise to do the audit in-house. The cost would not be prohibitive, but there would be many benefits. As well as recording water use, the consultant would also be advising the grower on scheduling to improve crop yield and quality. The data collected could also be used for water ordering, and at the end of the season would form an invaluable dataset on water use. Such a system would make it very easy to
aggregate the data from each farm into total water consumption, by valley, crop or climactic region. New Zealand is implementing this approach.

**Limitations of the technology**

The user needs to have a PC, and be prepared to spend time to analyse and interpret the data. Alternatively they need to use a specialised consultant.

**Barriers to adoption**

Soil moisture monitoring is widely known in Australia, and the technology has been exported world-wide. Users in other countries are amazed that we design and manufacture so many different instruments and systems and we are essentially exporting our expertise in managing this scarce resource. A current limitation is that some teachers and researchers have often have not worked with the growers and consultants who are using this technology. A typical grower’s response is ‘why weren’t we shown these techniques at college’. The hardware or software is not important. It is the interpretation of the data that is the key. Training needs to be on-the-farm in the context of the specific problems of the farm.

**Access to Probe for Windows**

For more information contact Research Services New England, 8/16 Nicholson St, Balmain, NSW 2041, Australia, Phone: 61 2 9810 3563, Email: support@rsne.com.au, Website: http://www.rsne.com.au

### 3.2.8 VineLOGIC: Vineyard Performance Simulator

**Dr Rob Walker, CSIRO Plant Industry/Cooperative Research Centre for Viticulture**

**Background**

VineLOGIC is a simulation model of grapevine growth and development that incorporates a model of soil water balance and soil salt balance.

The concept of VineLOGIC was initiated in 1994 following discussions between CSIRO Horticulture (later merged to become part of CSIRO Plant Industry) and the Grape and Wine Research and Development Corporation (GWRDC).

With funding from GWRDC and CSIRO the initial work was undertaken by Dr Karl Sommer (vine physiologist, CSIRO Horticulture/CSIRO Plant Industry), Dr Doug Godwin (principal crop modeller) and Mr Bob White (software developer). Ian Goodwin (DPI Victoria) made a major initial contribution by setting-up and managing a trial site at Mt Helen, Victoria, which provided one of two key data sets upon which the vine component of VineLOGIC was built. Another major experimental site was at Merbein, Victoria, which was managed by Dr Karl Sommer. The water balance component of the model was derived from the Swagman Destiny model, the development of which was coordinated by Dr Wayne Meyer of CSIRO Land & Water. Mr Peter Clingeleffer and Dr Rob Walker (CSIRO Horticulture/CSIRO Plant Industry) provided additional viticultural input to the development of the model. Validatory data sets were provided by Dr Michael McCarthy (South Australia Research and Development Institute) and Dr Peter May (formerly CSIRO Horticulture).
By 1999, after 5 years of funding from GWRDC and the collaborating agencies, a beta test version of VineLOGIC was developed. At that time (July 1999) the Cooperative Research Centre for Viticulture (CRCV) was formed for a second term and further development of VineLOGIC was continued through the CRCV. Dr Karl Sommer left CSIRO in 2000 and the on-going coordination of VineLOGIC development was continued by Dr Rob Walker with input from Dr Doug Godwin, Bob White, Peter Clingeleffer and two postdoctoral fellows, Drs Xike Zhang and Anne Pellegrino.

In brief, VineLOGIC simulates the effects of water deficits, water logging and soil salinity on vine growth and yield. The model operates at a point scale, using a daily time step and requiring daily weather data as inputs. The initial version of VineLOGIC, released in 2003, is an education and training package comprising the simulation model, a graphical interface for ease of interaction with the user, a comprehensive help system and data bases of weather, soil, variety and rootstock. The user is able to undertake a wide range of ‘what if’ scenarios based on menu-driven choices for weather, soil, vineyard design, variety and rootstock, irrigation and hydrology.

**Target Users**

To better define the market for VineLOGIC, a series of focus group meetings with potential users was conducted in 2000. A total of six focus group workshops were conducted in Mildura and Adelaide, with the specific target groups being viticulture extension, education, consulting, corporate (wine and supply company) technical services and growers. The focus group format was designed with the aid of a marketing consultant. Conduct of the workshops was funded by GWRDC through the CRC for Viticulture.

Each workshop commenced with a facilitated discussion on current approaches to decision-making in relation to vineyard design, establishment and management. Participants were then informed about the aims and background of VineLOGIC. Subsequently, the VineLOGIC computer program was demonstrated to groups and thereafter individuals were given the opportunity to operate the software on a computer. Participants were then invited to comment on the software and to provide constructive criticism and guidance towards further development.

Overall the majority of participants endorsed VineLOGIC and expressed support for further development. Views on different applications of VineLOGIC were quite diverse and in many cases depended on the specific requirements of individuals or groups within the viticulture industry. The main points in support of the package were that it was an excellent education tool, with education representatives expressing strong interest and seeing immediate application in the area of teaching. Extension and corporate technical service representatives expressed the view that it had good scope as an extension tool and as a support tool in company-grower liaison and that there was also scope for application as a corporate and consulting tool to assess options for vineyard development or redevelopment. The comprehensive databases were also seen as a valuable resource. Growers regarded most of the applications of VineLOGIC as strategic and therefore saw limited applications for day-to-day management issues on their vineyards.

The focus groups also identified deficiencies in the package and recommended that these be addressed in further research and development through the CRC for
Viticulture. This information has been used to guide the development of VineLOGIC to the present time.

Overall, the consensus was that VineLOGIC should be refined for initial release as an education package and that the long-term aim should be to develop a professional package tailored to the needs of extension providers, consultants, corporate technical services personnel and advanced growers.

To refine VineLOGIC for use as an education package, the team was joined by Bob Barrett (University of Adelaide), Dr Dejan Tesic (Charles Sturt University) and Dr Judy Tisdall (La Trobe University). With their input VineLOGIC Education Version I was further refined, culminating in its release in April 2003 (Figure 1). It was made available to teaching institutions and viticulture students in Australia for $45 (CD only) or $90 (CD and hard copy manual). The manual contained a range of student exercises developed with input from Bob Barrett, Dejan Tesic, Judy Tisdall and Kirsty Neaylon, a viticulture PhD student.

The package was not restricted to teaching institutions and students. It was also made available to people from within the grape and wine industry and to their service industries, provided they were agreeable to becoming part of a VineLOGIC user’s network. Currently there are over 100 copies in use for teaching purposes, with an additional 100 copies in use by practitioners within the grape and wine industry.
About the technology

VineLOGIC simulates water balance, salt balance, vine development, including vine growth and yield formation. The water balance component of the model is derived from the Swagman Destiny model that has been described in detail by Meyer et al. (1996) and in summary form by Godwin et al. (2002). The user is able to set-up water inputs according to an irrigation schedule (Figure 2) and each day in the simulation, the model takes into account the daily weather, rainfall, humidity, temperature (chosen from a database of historical weather for a particular region or location). The model calculates all components of the vineyard water balance, including vineyard evapotranspiration, vine transpiration, soil water evaporation, deep drainage, run-off and tile drainage outputs.

![VineLOGIC Simulation Selector](image)

Figure 2. Example of VinLOGIC set up options for irrigation

The salt balance component of the model takes into consideration the salt content of the irrigation water, the salt content in the soil layers and the salinity of the watertable (if present). The model simulates salt movement downward through the soil profile with draining water (leaching) and also upward with water gradients created by soil surface evaporation and root water uptake (Godwin et al., 2002). To simulate salinity impacts on vines the model uses a system of three coefficients derived from the Maas and Hoffmann (1977) ranking of plant salt tolerances (Godwin et al., 2002).
The vine development component of the model allows simulation of the vine's phenology from bud dormancy, through to bud burst, flowering, veraison, harvest date and leaf fall (Godwin et al., 2002). Vine growth from bud burst onwards is simulated on the basis of daily increments of leaf and shoot growth. The number of retained buds after pruning in the preceding winter is an important initialising factor for the simulation of vine growth (Godwin et al., 2002). Canopy growth from these buds is simulated daily using temperature and the availability of assimilates as the main drivers. Each day, the energy intercepted by the canopy is converted into biomass that is partitioned into leaves, shoots, and fruit, roots and vine reserves. The reserves are an important source of assimilate for shoot growth early in the season or until assimilate from the current season’s photosynthesis provides sufficient supply for growth (Godwin et al., 2002). Simulated stresses due to water deficit, waterlogging and salinity are used to modify rates of plant growth during simulations. The model computes a potential fruit load from the size of the shoots, with adjustments to fruit load made throughout the growth period on the basis of assimilate availability and water and/or salt stresses (Godwin et al., 2002).

**Promotion and further development**

The model has been promoted through CRCV newsletters, website, field days, conferences, leaflets and other communication materials. The web site has been an effective medium with many enquiries, particularly from overseas. The model has also been promoted through CSIRO newsletters and leaflets.

Further development of *VineLOGIC* has occurred through the CRCV, with *VineLOGIC* Education Version 2 in an advanced stage of development. Version 2 will incorporate a range of additional features including an expanded soils data base (35 soil types plus capacity for the user to insert own soil data), the ability to simulate cover crop growth and development, an expanded range of viticultural regions/locations and 30 years of weather data for each region/location, an enhanced rootstocks module including improved capacity to simulate salinity impacts on vine performance, the ability to calculate a fruitfulness index and to carry this forward into yield simulations for the following season; an improved trickle irrigation routine and enhanced user interface and outputs screens including a focus on environmental consequences (for water and salt).

Enhanced options for viticultural researchers are also planned, including the capacity to input their own data files and run *VineLOGIC* predicted versus measured comparisons.

In addition, work is in progress to develop simulation routines for grape berry growth, sugar accumulation, changes in titratable acidity and, if possible, changes in total anthocyanins (for red grapes).

A further development has been a linkage of *VineLOGIC* with APSIM (Agricultural Production Systems Simulator, a model developed by APSRU – Agricultural Production Systems Research Unit) through collaboration with CSIRO Sustainable Ecosystems (Drs Peter Carberry and Neil Huth). The linked *VineLOGIC*-APSIM model is now being used by CSIRO Sustainable Ecosystems and Yalumba Wines to assess landscape scenarios within a key viticultural region.

**Benefits**

The following comment was provided by Bob Barrett, Lecturer, Horticulture Viticulture and Oenology, University of Adelaide: ‘Viticultural students tend to be taught one
thing at a time about vineyard management because this is the logical way of teaching all the various subjects. The VineLOGIC software will help students conceptualise how these different areas of management interact in a real situation. While students have a lot of exposure to actual vineyards during their degree, this (VineLOGIC) allows them to experiment with all kinds of management scenarios and compare the best practice for various regions in Australia which react differently due to things like climate, soil and irrigation water salinity'.

One of the best parts of the package is that both the outputs and the scenario are shown, allowing students to directly see how particular conditions have led to the outcome. The results are also available as a textual description or as a graph, providing students with a lot of information.

When asked their opinion about the best features of VineLOGIC the following organisations elected:

- Sunraysia Rural Counselling Service Inc: ‘The yield and irrigation scenarios’
- Professor John Considine, University of Western Australia: ‘The scenario testing facility’
- Dr Dejan Tesic, Charles Sturt University: ‘The weather and soils database’
- Ashley Wheaton, Dookie College, University of Melbourne: ‘Ability for students to experiment virtually’

Applications

A wide range of ‘what if’ scenarios examining various aspects of vineyard management can be easily run with VineLOGIC. For example, any of the following inputs can be changed and the model re-run: soil type, components of soil water content, weather, trellis height and width, row spacing, retained bud number, vine reserves, variety, rootstock, irrigation schedule, irrigation water salinity, water table depth and salinity.

The model is especially useful for addressing ‘what if’ questions in relation to water management. For example, if there is a limit to available water supply, when is the best time to apply the available water for best vine performance? To analyse this possibility, the user is able to apportion the available water to particular growth stages. Any of these growth stage allocations can then be changed and the model re-run.

Limitations of the technology

VineLOGIC Version I is a one-dimensional model with respect to water movement in the soil profile. It thus cannot accurately represent the situation where a wetted volume of soil may occur under the vine caused by irrigation while dry soil remains between the rows. This limitation is currently being addressed for Version 2.

Further validation of the model is also required, as it has not been exhaustively tested across the very wide range of vineyard locations and input options.

Deficiencies in VineLOGIC Education Version I, noted through the focus group process, will largely be overcome through the release of VineLOGIC Education Version 2 with the range of new features as described earlier.

The ability to simulate key components of grape berry maturation, in particular changes in grape berry sugars, total acids and, if possible, anthocyanins (for red grapes) is anticipated through a later version of VineLOGIC. This later version will
largely meet the specifications of the ‘Professional’ version identified through the focus group process.

**Barriers to Adoption**

Based on the October 2004 *Survey of Small to Medium Wineries – Technology and Information Needs* conducted by Mark Dignam and Associates for the Cooperative Research Centre for Viticulture, the following barriers to the use and adoption of VineLOGIC were identified:

- 12% indicated that the package was too hard to use
- 7% advised that they did not have the time to use the software, that it would take too long to implement
- 6% explained that there were too many variables in the vineyard
- 3% could not use a computer
- 3% regarded the software as inflexible
- 2% cited cost/expense of the software
- 2% indicated that they would need more information prior to purchase.
- 25% were happy with their existing procedures
- 34% of small vineyards were not interested in the software

The focus group process indicated that the group least likely to use VineLOGIC would be growers. Growers expressed the view that they are mostly pre-occupied with the day-to-day management of their vineyards, particularly with regard to irrigation and disease management. One grower commented that he would like to have the facility to phone or sit down with somebody able to run the package so that he could ask for various scenarios to be compared. Another grower commented that he would use the package to run scenarios, but it was likely that once the results of these scenarios were learned he would be less likely to use it thereafter. Clearly, with this market segment, more focus group work needs to be done. This, together with greater promotion of VineLOGIC capabilities, may better illustrate to growers how they can use the package to add to the bottom line.

**Access to VineLOGIC**

Contact: Bridget Ransome, Marketing and Commercial Consultant, Cooperative Research Centre for Viticulture, PO Box 154, Glen Osmond SA 5064, Phone: 61 8 8303 9663, Email: bridget.ransome@crcv.com.au. For more information contact Rob Walker, CSIRO, PMB Merbein, Victoria 3505, Phone: 61 3 5051 3100, Email: rob.walker@csiro.au

3.2.9 WaterBalance

*Geoff Inman-Bamber, Steve Attard, Shaun Verrall, and Mike Spillman, CSIRO Sustainable Ecosystems*

**Background**

Precise estimates of water use by sugarcane were obtained using Bowen ratio energy balance (BREB) technology in the Burdekin, the Ord and in Swaziland in Southern Africa (Inman-Bamber and McGlinchey, 2003). Crop factors (Kc) were derived directly from BREB measurements and the FAO 56 Penman-Monteith
equation (Allen et al., 1998). These crop factors were later tested in irrigation experiments which were scheduled with $K_c$ varying above and below the derived values ($K_c = 1.25$ for mid to late growth stages). Soil moisture measurements confirmed that a schedule based on $K_c = 1.25$, prevented the soil from drying out or from getting too wet. Thus irrigation applied according to the water balance based on $K_c = 1.25$ was equal to the water used by the crop. The APSIM-Sugarcane model was then used to derive canopy cover estimates for sugarcane over a wide range of conditions. Equations were then developed to predict canopy cover from standard weather variables (temperature and radiation) to avoid having to use APSIM which is very slow. During the BREB work it was noted that $K_c$ reached a maximum when canopy cover exceeded 80% so $K_c$ was derived from canopy cover as $K_c = \text{Cover}/0.8$.

**Target users**

Innovative growers and extension staff will use this technology at first and will help to improve it for wider use by sugarcane irrigators. The system could easily be expanded to include other crops.

**About the technology**

At 9am each day a computer at Davies lab in Townsville downloads data from a network of automatic weather stations (AWS) including three at Bundaberg, one at Childers, three in the Burdekin and one in the Ord. Any well maintained AWS could be fitted with a modem and added to this system. A program does some elementary error checking of the data before passing it on to a database on a CSIRO server in Canberra. The system is then ready to update the water balance as at midnight. The first screen displays daily rainfall since 1 January 2004 and the user is asked to enter his/her own data if available. The program then shows a ‘main page’ (Figure 1) where all paddocks are listed along their condition at the time of the last update. Once an update is requested the user is asked to add the date and amount of the past irrigations. The current soil water deficit, crop development and days to the next irrigation for each paddock are then displayed with paddocks needing the most urgent attention at the top of the list. The user can go deeper into the details if required by requesting a graphical display of the water balance (Figure 2) or a comprehensive table of all the data. However the main idea is to report days to the next irrigation for all paddocks on the farm as quickly as possible. A series of photographs display the growth stage (Figure 3) assumed by the model. The user can correct the model by selecting a photo that best represents the crop under consideration. More paddocks can be added at any stage from the main page and the system will guide the user through simple steps to enter appropriate soil and crop characteristics.
Figure 1. Main Page of WaterBalance, displaying a summary of paddock details including days to next irrigation, soil water deficit, crop canopy cover and status.

Figure 2. Graphical display of soil water deficit, rainfall and irrigation
Promotion and further development

**WaterBalance** is being developed in consultation with growers in the Burdekin and with advisors and agronomists in the Ord and Bundaberg regions. Projects in the Ord and Bundaberg region have a few more years to go during which development and refinement will take place. The web system is being promoted and tested in both these regions through workshops and case study groups. A few key Ord and Burdekin growers will try operating with the scheduling system but full-scale promotion will occur only after a variety of users have helped to make it as easy to use as possible.

**Benefits**

Users will benefit from more precise timing of irrigation which will probably save water and could increase yields. **WaterBalance** is an improvement on scheduling systems such as the mini-pan, in that it deals with all stages of crop growth and with irrigation or rainfall events that do not fill the profile. **WaterBalance** indicates how much water should be applied and not only when it should be applied. Very little evidence-based scheduling is practiced in the sugar industry. **WaterBalance** introduces state-of-the-art energy balance technology into scheduling.

**Applications**

**WaterBalance** was developed for only one purpose and that is precise scheduling of irrigation. Water balance could apply to any crop where canopy cover can be predicted from AWS variables and where the relationship between Kc and cover is known.

**Limitations of the technology**

**WaterBalance** requires modem access to well maintained AWSs. This limitation may be removed when a new CRC IF project delivers readily accessible daily ETo values. For most efficient use of water, **WaterBalance** requires a good estimate of the readily available water (RAW) content of the soil and this is not known for some soils. At present **WaterBalance** uses an Access data base which cannot support multiple users so each farm will have its own database until we convert to an SQL database.

**Barriers to adoption**

Scheduling systems have a poor record for adoption along with many other DSS tools. Developers of **WaterBalance** have argued that web access, speed and visual appeal will reduce barriers to adoption of this technology. Two projects supporting **WaterBalance** development are also considering factors responsible for uptake of this kind of technology. These studies will also help to remove these barriers.

**Access to WaterBalance**

Access is free via the web but during the trial phase access by arrangement with CSIRO is encouraged and the URL and passwords are not presented here. Please call Geoff Inman-Bamber at 61 7 47538587 or Steve Attard at 61 418 155 844.
3.2.10 WaterSense

Geoff Inman-Bamber, Steve Attard, Shaun Verrall, and Mike Spillman, CSIRO Sustainable Ecosystems

Background

In many regions growers have to contend not only with variable and unpredictable rainfall but also with variable water allocations. Because of uncertainty about the season’s water allocations, which are usually announced at the start of the water year (1 July in most regions) and are generally a fraction of the full allocation, growers are reluctant to use all their assured allocation early for fear of dry periods later in the growth of the crop. In sugarcane early applications of water can be highly beneficial provided rainfall in the ‘wet’ season is sufficient to complete the growth cycle. Cane yield was increased 41 t/ha by applying only 1.79 ML/ha irrigation in the Herbert in a year when conditions were dry from August to December and then wet for the remainder of the crop (Inman-Bamber et al., 1999). In many seasons, allocations are not fully utilised even when their use would be highly beneficial. Water providers tend to increase allocations only when they can be certain that the water can in fact be provided. By then it is often too late to use the water efficiently or at all and some allocated and purchased water goes unused. When to apply limited irrigation was a key issue in the R&D program of phase 1 of the Rural Water Use Efficiency Initiative (RWUEI). WaterSense was developed after considerable modelling and field trials conducted on growers farms.

Target users

Innovative growers and extension staff will use this technology at first and will help to improve it for wider use by sugarcane irrigators.

About the technology

A technique for determining the best time to irrigate sugarcane with limited irrigation was developed using the APSIM-Sugarcane model. This model has been tested under a wide range of conditions in several countries. WaterSense allows the user to run APSIM and an optimisation procedure after entering paddock details as in Figure 1. These details are stored in a database for use at the time of the next update. The paddock details prepare APSIM to simulate crop growth up to the end of the current climate record obtained from the same AWS network described in WaterBalance. Crop development to the anticipated harvest date is simulated using 40 years of climate records from the BOM, for the given calendar period between the current and harvest dates. Thus, each crop in the simulation ends in 40 different ways depending on which year in the climate record is used to complete the simulation. For each year in the simulation, irrigation is applied at 10 levels of water stress until the given allocation is exhausted. In the case of no stress, irrigation is applied as soon as the soil water deficit exceeds the amount to be applied and the allocation could run out soon unless rain occurs in time to prevent the deficit exceeding the amount that triggers an irrigation. The greater the stress level the longer it takes to use the given allocation. The strategy that minimises overall water stress and provides the highest yield is deemed to be the best strategy. In a dry year, it would be better to allow a moderate level of stress to develop before each irrigation rather than to avoid stress initially and then to run out of water and expose the crop to severe stress later in its growth. In a wet year, one would not want to deliberately impose water stress on the crop, and so irrigation would be applied at minimal crop stress. A distribution of best
irrigation dates is obtained from the best strategies in each of the 40 years in the simulation. WaterSense reports the date of next irrigation as the median date and hence at the point at which the chances of irrigating too early or too late are equal. Best bet irrigation dates for all future irrigations are reported but the user should only take the next date seriously and then update the forecast after this irrigation. Regular updating is essential to cater for short-term changes in weather conditions.

There is a lot of computation required for estimating the next irrigation date so after the answering the questions on the web page the system gets to work and sends an email with a report on irrigation dates and an estimated yield (Figure 2).

Figure 1. Main data entry/review page in WaterSense
Figure 2. Example of an email report for one paddock

Promotion and further development

**WaterSense** is being further developed in consultation with growers, advisors and agronomists in the Bundaberg and Sarina regions in an SRDC project that has a few more years to go. The web system is being promoted and tested in both these regions through workshops and case study groups. An excellent approach to emerge from these consultations is to combine **WaterBalance** and **WaterSense** technologies. Growers who have used **WaterSense** feel that it is too laborious as it deals with only one paddock at a time and will take at least 40 min for each. A system is now being developed in which **WaterSense** logic is used to forecast and optimum soil water deficit (SWD) rather than an optimum irrigation date. **WaterSense** can then be run automatically, on weekends for example, to forecast the optimum SWD for the next week or so. **WaterBalance** can then be invoked to quickly report the date of the next irrigation for all paddocks taking recent weather conditions into account. For this reason, **WaterBalance** is now being modified to cope with reduced water extraction when SWD>RAW by introducing a layered model similar to **Soilwat2** in APSIM.

Benefits

**WaterSense** has been tested on farm for three years in trials conducted with rigour and with intent by the growers to outwit the technology. **WaterSense** operating remotely was able to mimic decisions of two experienced growers who could assess the condition of their crops and current weather conditions on a daily basis. **WaterSense** may not improve irrigation practice by experienced growers but could do so for new growers. The main benefit will be to encourage growers to start using their allocations early rather than to wait to see how the season unfolds. This should
result in a greater proportion of the limited allocation actually being used, which seldom occurs at present.

Applications

**WaterSense** is designed for seasonal irrigation planning and scheduling of limited water but can also be used for yield prediction/benchmarking and scenario analysis because it uses the full power of the APSIM model.

Limitations of the technology

Like **WaterBalance**, **WaterSense** requires modem access to well maintained AWSs at present and so is limited for use in Bundaberg and Childers. However the Bureau of Meteorology’s SILO database contains all the variables required for **WaterSense** and access to SILO would permit **WaterSense** to be used in as many sites as are represented in SILO. **WaterBalance** is slow and reporting is not immediate via the web but via email. If a user initiated a lot runs it could be a day or so before all replies are received. The reporting from **WaterSense** has limited probabilistic information and users could believe that the median results have no associated error term. This is being addressed by teaching potential users to interpret cumulative distribution frequencies which can then be used as well as median data.

Barriers to adoption

The logic in **WaterSense** is not easy to convey. However when irrigation date forecasts make sense to them, growers readily accept the validity of the technology. The converse is also true. Adoption would be greatly helped by an allocation forecasting system such as FlowCast. Growers often feel unable to plan seasonal use of water that they have not received yet. However some assurance of forthcoming increases in allocation will help them feel more secure about using limited water when it would benefit the crop most.

Access to WaterSense

As with **WaterBalance**, access to **WaterSense** is free via the web but during the trial phase access by arrangement with CSIRO is necessary. A password and email address is required before the database can be accessed. Please call Geoff Inman-Bamber on 61 7 47538587 or Steve Attard on 61 418 155 844.

**3.2.11 WeatherFare**

**Helen Fairweather, NSW DPI**

Background

For several years, the NSW Department of Agriculture (now NSW DPI), has been running the ‘Water Wise Introduction to Irrigation Management Course’. This course covers the basics from soil characteristics, crop water use to scheduling irrigations using evapotranspiration (ET) data. Anecdotal evidence received from NSW DPI staff who delivered the courses is that a large number of participants found the information very valuable and a common question at the end of the session on

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weather based scheduling was 'now where do I get ET data?'. Unfortunately, the most common answer to this question was that if the participant did not have their own weather station or direct access to a nearby one, then it was not available.

This desire of the irrigators who attended the courses to access ET data also coincided with the release of statistics by the ABS, that showed that by far the majority of irrigators use subjective methods to schedule irrigations (such as local knowledge or observation), with comparatively few using objective methods (such as weather based systems or soil moisture monitoring equipment). Staff in NSW DPI identified that weather based scheduling was a comparatively easy method to assist irrigators to later move to more sophisticated scheduling techniques based on soil moisture monitoring. It was generally agreed that providing irrigators with basic ET data was an important first step in moving the majority towards more objective irrigation scheduling methods.

To achieve easy access to ET data for a range of irrigators across NSW, the feasibility of accessing the required data to calculate ETo daily was firstly investigated. In the first attempt, data was integrated from two sources (the BoM Ag Obs Bulletin and SILO data) and then sent via FTP to a central Access database using some cumbersome scripts. ETo was then derived from maximum and minimum temperature, solar radiation, vapour pressure and wind speed using FAO 56 daily ETo PM equation (Allen et al., 1998) Data had to be downloaded daily using this method in order to ensure a continuous record of ETo and the number of sites which could be used were limited to the matched Ag Obs and SILO sites. It soon became apparent that this was not a satisfactory method.

After further development another dataset was discovered on the BoM website that reported sufficient parameters for calculating ETo (sunshine hours, maximum/minimum temperature and relative humidity and wind speed). Though not the ideal dataset, it nevertheless provided an easy and efficient method for downloading and calculating ETo daily as far back as July 2003 for many of the 155 BoM stations reporting data in NSW.

**Target users**

Irrigators, and agency and commercial extension staff who provide advice to irrigators (and dryland farmers, if required). At this stage the target users are primarily in NSW, but it would be relatively simple to extend to other states.

**About the technology**

The current version of the ET/scheduling program has been developed in the Excel environment and requires the user to have an internet connection so that the latest data can be seamlessly downloaded from the BoM internet site to the spreadsheet application. A spreadsheet can be developed for any site in Australia that the BoM records and reports sufficient daily data to calculate ETo. The spreadsheet can be provided with monthly averages, which can be used when daily data are missing. If the monthly averages are not provided, the ETo calculation is not carried out on days when data are missing.

There are two versions of this software, the first one is used to calculate ETo only (Figure 1), though rainfall and evaporation are also included in the dataset that is downloaded from the BoM.
Figure 1. User interface to the first version of the ET spreadsheet

The second version incorporates the Kc values reported in FAO 56 and adjusts these values daily as outlined in FAO 56 to cater for variations from 'normal' conditions (RH = 45% and wind speed = 2 m/s). Also incorporated into this second version, which is still in an early development stage, is a cropping calendar (Figure 2). Graphs of ETo and ETo are displayed to the user interface. The user can also interrogate the data directly in the spreadsheet for incorporating into their own scheduling software, if desired.
Promotion and further development

The program has only been provided to a few people on a trial basis and has not yet been endorsed by the BoM. Further testing is required to validate and verify the algorithms. It is envisaged that this spreadsheet will be the basis for a water balance planning tool to aid in decision making not only during the season, but also at the beginning of the season. It is also planned to eventually incorporate some short (daily/weekly) and medium term (seasonal) climate predictions into the calculations.

Benefits

A very simple spreadsheet tool that seamlessly downloads data from the internet to calculate ETo daily. Further developments, as outlined above, will develop this into a fully fledged irrigation scheduling tool.

Applications

The main application at present is to calculate ETo to be used as the basis for weather based irrigation scheduling.

Limitations of the technology

Users must have Excel with the capability to run Macros and an internet connection to download the latest data. If the software is used on a frequent and regular basis the user is required to connect to the internet each time data needs to be updated (e.g. daily).

Barriers to adoption

Lack of expertise in using Excel, though a user friendly (hopefully!) interface is provided.
Access to WeatherFare

Directly through Helen Fairweather, PO Box 865 DUBBO NSW 2830
Phone: 61 2 6881 1211, Email: helen.fairweather@dpi.nsw.gov.au

3.3 Scale free packages

Some tools operate at a scale depending on the data or instruments to which they are linked (scale free tools). FlowCast was designed to process data from catchment hydrology models and in this sense it is a catchment level tool but it can also process data from crop simulation models (paddock scale) and automatic weather stations (farm level).

3.4 Research and education packages

No doubt all software tools contribute to the education of users and even the simplest of tools can help growers to think more quantitatively about their enterprises. However some tools are designed mainly for education or research and are therefore best used by scientists or teachers rather than by practitioners.

3.4.1 SWAGMAN Whatif

Wayne S Meyer, CRC for Irrigation Futures

Background

SWAGMAN® Whatif is an interactive computer program designed to teach salinity relationships in irrigated agriculture. It was originally developed by Chuck Robbins, Wayne Meyer, SA Prathapar and Bob White in Griffith NSW (Robbins et al., 1995) to describe the frequently seen situation of irrigation associated with shallow groundwater and increasing salinity problems. The computer program was combined with additional information such as conversion tables, explanation indexes and illustrative images to assist people to better understand the dynamic interactions between climate, crop, soil, groundwater, irrigation practice and salinity levels. During the mid 90’s the Whatif package enjoyed modest distribution among extension agencies and teaching institutions.

Target users

The intended users are at 3 levels, namely senior secondary, tertiary university and agricultural extension personnel.

About the technology (Abridged from Robbins et al. 1995)

Water balance

The model operates on a daily time step although an hourly step is invoked for infiltration. Daily potential ET values are interpolated between the monthly mean values given in a climate file. A rainfall pattern is generated for each run period (365
d) as follows. The number of rain days and total rainfall for the month is read from the climate file. The number of rain days and amounts are then allocated randomly within the month. Water additions to the soil surface are partitioned into potential infiltration, ponded, and runoff depths. The partitioning is soil and ponding depth dependant and uses time-to-ponding concepts. Water is added to the soil surface at a constant rate for irrigation and a variable for rainfall, assuming a maximum rate at midday. If the hourly application rate does not exceed the hourly saturated hydraulic conductivity (Ksat), all water infiltrates. Amounts of irrigation or rainfall which exceed Ksat will runoff.

The profile is divided into three horizons. The root zone changes in thickness depending on the crop grown. The subsoil is the zone between the bottom of the root zone and the water table surface. The third horizon is the saturated water table. Infiltrating water is assumed to move as a plug through the root zone and subsoil before reaching the water table. The root zone is assumed to reach field capacity before the water plug moves to the subsoil. The infiltrated volume in excess of that needed to bring the root zone to field capacity enters the subsoil. Similarly, if the water entering the subsoil is greater than the volume needed to bring it to field capacity, then the excess enters the water table.

Daily ET loss is subtracted from the total water content in the root zone. The matrix suction within the root zone and the unsaturated hydraulic conductivity of the subsoil is then determined using Campbell functions (Campbell, 1974). The capillary flux from the water table into the root zone is determined by a steady state analytical solution (Prathapar et al., 1992).

Lateral groundwater flow and leakage of the groundwater to deeper aquifers varies between 0.1 mm d⁻¹ for clay soils and 0.5 mm d⁻¹ for sand. The water table depth change is then calculated as a function of leakage and capillary rise.

**Salt balance**
Salt is assumed to move as a plug with water during application and capillary rise within the soil matrix. The mechanical dispersion of salt due to the movement of soil water and diffusion due to concentration gradients are assumed to be negligible. Salt in the profile is assumed to be conservative, that is, precipitation and exchange reactions are not considered. The salt concentration of the water table does not change due to recharge or capillary rise. A mass balance approach is used to account for soil salinity changes due to salt added with irrigation water and capillary rise from the water table.

**Crop growth**
The 39 crops in the crop file are specified as summer crops in the U.S. version. The cool-season crops are specified as winter crops in the Australian version. This sets the beginning of the cropping year (1 January vs. 1 July). The crop file also contains default planting dates, days to full cover, and maturity or harvest, root zone depth, ET coefficients, and the salinity, soil water, and water logging stress coefficients for each crop. The planting dates can be changed, within limits, to fit seasonal differences among sites.

The potential ET values are multiplied by the crop and growth stage coefficients interpolated from the crop file values, to give daily ET values. A value of plant-available water below which stress for a particular crop occurs is given in the crop file. A linear interpolation of increasing deficit stress (expressed as a fraction between 0 and 1) is made between the onset of stress and the lower limit of available water. Waterlogging stress is scaled as the proportion of the root zone that is saturated. Thus, if the water table rises such that 50% of the root zone is saturated, the relative
stress factor is 0.5. The daily values are summed, divided by the season length, and reported as relative yield reductions due to water deficit and waterlogging stress.

The root zone saturation extract EC value is calculated from the daily salt balance. This EC value is then adjusted depending on the growth stage of the crop such that it is 20% higher during early growth, grading to a 20% lower value at maturity. The daily EC values are summed and a mean is calculated for the season. Relative yield loss due to root zone salinity uses Maas (1986) coefficients from the crop file.

![Fig. 1. Example of an input / output screen from SWAGMAN Whatif](image)

**Promotion and further development**

The need for the current generation of people to better understand irrigation and salinity is apparent. SWAGMAN Whatif can greatly assist as an education package that has an element of experiential learning associated. However the package needs to be re-implemented in a currently compatible IT platform and to have the accompanying instructional material updated. This is actively being pursued within the CRC for Irrigation Futures with the intention of establishing Web access and promoting its use through short courses.

**Benefits**

The education package (SWAGMAN Whatif) illustrates the interaction between irrigation, weather, soils, crop, groundwater, salinity and likely yield outcomes. The aim is to provide an awareness raising, teaching and dialogue facilitating package that is promoted through teaching and training providers. The ultimate aim is to raise the level of understanding of the complexity of maintaining irrigated crop productivity in dynamic weather, crop, soil and salinity environments.

**Applications**

SWAGMAN Whatif is a simple simulation modelling and information package. The crop, soil, groundwater, irrigation and weather system is represented in a generic way to demonstrate the interactions between irrigation, groundwater, salinity and crop yield. The package includes help capability to convert between water volumes and salinity units and indicative salinity responses of different crops. If you are confused by salinity units, the interaction between watertables, salt and crops this
package can help you. You can play with “what if?” questions about irrigation without waiting 10 years to find out. It can be used in a directed demonstration mode, a “hands on” tutorial and self learning mode or simply as an illustrative “reality checking” and awareness mode.

**Limitations of the technology**

This is not a decision support system – the model is generic, requires generalised inputs, represents point scale and runs only for a nominal one year period.

Its use is as an illustrative dynamic system representation and as such it conveys a sense of what is reasonable rather than providing a specific representation or recommendation for a particular location.

**Barriers to adoption**

This is a package that will get intermittent use as a new generation of learners move through. It needs to be continuously promoted to make people aware of its existence (a problem for short term project funding!) and there needs to be readily useable instructional material available for busy presenters and lecturers to pick up and use.

**Access to SWAGMAN Whatif**

The current version is unlikely to run on windows based operating machines. A re-implemented version (Web compatible and accessible) will be available from the middle of 2006. For more information contact Wayne Meyer: c/- CSIRO Land and Water, Street: Adelaide Laboratory (Waite Road, Urrbrae, South Australia), Postal: PMB 2 Glen Osmond SA 5064 Australia, Phone: 61 8 8303 8683, Email:Wayne.Meyer@csiro.au
4. Future developments and linkages

During the process of obtaining information for the Inventory we asked software developers and users about their interest in linking efforts with others in the country doing similar work. Those who were interested in further collaboration were contacted again to discuss possible linkages with complementary work being carried out elsewhere in the country. The following list of possible linkages and further developments were suggested.

1) Linking rainfall or stream flow forecasting (StreamFlow) with allocation forecasting and then irrigation optimisation (WaterSense, Hydrologic)
2) Combining ideas in WaterSense and Hydrologic
3) Web based scheduling as in WaterBalance and WeatherFare for more crops and regions
4) Expanding use of Dam Ea$y for other crops and regions and/or web access to WaterSupply
5) Combining Irrimate™ and a Dam Ea$y like product or WaterSupply
6) Improving the ET₀ based water balance in IRES from experience with WaterBalance, Hydrologic, Maizeman, Swagman and WeatherFare
7) Linking ET₀ water balance (as in WaterBalance) and soil water monitoring (as in IrriMAX 6.1)
8) Linking Irrimate™ with scheduling models and simulation models
9) Standardizing units and terms in software tools
10) Programmers to use XML in order to link software.

The CRC IF provides an ideal opportunity for developers to collaborate. Developers are welcome to explore the above ideas and to talk to the CRC about how it can assist in the collaboration.
5. References


