Smarter Irrigation for Profit

A SNAPSHOT

This Project is supported by funding from the Rural R&D for Profit Program

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The project is supported by funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural Research and Development for Profit Program.

The project, *Smarter Irrigation for Profit*, is a partnership between the major irrigation industries of cotton, dairy, rice and sugar, and was led by the Cotton Research and Development Corporation (CRDC) in conjunction with Dairy Australia, AgriFutures Australia Sugar Research Australia and research partners including; CSIRO, NSW DPI, USQ, TIA, SARDI, DEDTJR Victoria, Gwydir Valley Irrigators Association and other industry organisations.

Contents

Background

Smarter Irrigation for Profit is a national collaborative research, development and adoption project involving 16 research partners, the cotton, dairy, rice and sugar industries and 19 farmer-managed irrigation technology learning sites. It aims to enable irrigators to improve their productivity and profit. The project is part of the Australian Government's *Rural Research and Development for Profit* program.

The sub-projects are focused on:

- irrigation scheduling technologies
- precise, low cost, automation for a range of irrigation systems
- a national network of farmer-managed learning sites, located in major irrigation regions and referred to as "optimised irrigation" farms, provides irrigators with practical demonstrations of the research.

The project is based on the premise that improving the application, scheduling and automation of irrigation will reduce costs (such as labour, energy and fertilisers) and increase water productivity and efficiency, resulting in increased profit. Sustainability outcomes, such as less deep drainage and water-logging, and improved soil health are expected as longer-term impacts.

This snapshot report integrates information from across the sub-projects in *Smarter Irrigation for Profit* into a comprehensive body of knowledge. Sections of the report are summarised below.

Location of the major field sites and key learning sites.

Ruth Redfern

Key Findings

Irrigation Systems

Guy Roth

System Selection

There is no universal best type of irrigation system – even within a region and a production system. It is a matter of selecting the system that offers the best fit for purpose. Considerations include topography and soil types, the nature and security of the water supply, and the style of management. Establishment (or conversion) costs and payback periods, along with productivity, water use, and operating, labour and energy costs affect the attractiveness of options.

Smarter Irrigation for Profit compared different systems and showed their various strengths and weaknesses, and how they varied in different seasons – enabling irrigators to make more informed choices. A key message for farmers evaluating irrigation system comparisons is to look for long term data over a number of irrigation seasons (wet, dry, hot, cool).

Lou Gall

System Design & Drainage

Surface irrigation (be it by furrow or in bays) is the most common form of irrigation due to its low capital cost and low energy requirements. Well-designed and well-managed surface irrigation can achieve application efficiencies of 95% - showing that efficiency comes from design and management, and is not an inherent characteristic of the system itself.

Smarter Irrigation for Profit trials showed that application efficiencies for surface irrigation can often be improved by better design and scheduling – reducing losses through deep drainage and run-off. Key measure; measure to manage.

Melanie Jenson

System Efficiency

Smarter Irrigation for Profit included on-farm audits of energy efficiency and irrigation uniformity (checking that irrigation systems are performing as they were designed to). They exposed considerable variation in efficiencies – even with recently installed irrigation systems.

The audits showed that many farmers could save money and improve productivity by running periodic checks or audits and giving attention to maintenance. Irrigators should also ensure suppliers provided a commissioning test before hand-over, to ensure equipment is operating within specification.

A **key message** for farmers evaluating irrigation system comparisons is to look for long term data over a number of irrigation seasons

Irrigation Practice

Joe Foley

Automation

The flow of irrigation water can now be controlled automatically from source to within a field. It relies on sensors and telecommunication to control automated equipment, permitting the remote control of irrigation through a computer or smart-phone interface. Coupling automation with precision scheduling packages ensures the resultant irrigation is optimal, not just the remote control of automated, poor practice.

Smarter Irrigation for Profit trialled automated systems across several commodities and irrigation systems. It found significant benefits to irrigators through convenience and time-saving, as well as improved irrigation practice. The work showed that highly automated, if not autonomous (self-controlling), systems are feasible and they have potential for continued development and wider application. Automation can be phased into a farm beginning with simple monitoring.

Melanie Jenson

Monitoring

Scheduling irrigations to provide plants with the right amount of water, at the right time, depends on knowing what is happening in the soil and to the plant. Models or ‘rules of thumb’ can contribute, but monitoring is a mainstay for accurate scheduling. Monitoring options range from high-tech to low-tech and encompass soil-water, plant condition, and weather (especially the weather conditions influencing evapotranspiration).

Smarter Irrigation for Profit explored innovative options for plant sensing, including infrared canopy sensors to detect stress, remotely sensed data and the use of smartphone cameras mounted on irrigators. It also trialled the use of drones equipped with a thermal-infrared camera to provide real-time information on the advance of surface irrigation to enable smarter scheduling, and demonstrated the value of a network of autonomous rain-gauges to improve water budgets and irrigation scheduling.

Guy Roth

Scheduling

Irrigation scheduling is determining when to irrigate, at what rate, and for how long. It’s about getting the timing, volume and rate right for optimum crop growth or yield. Scheduling uniform applications (e.g. to maintain a water balance) is a first step toward efficient irrigation. Adding elements of precision – varying application rates in response to variations in soil type or crop requirements – is another step. Increasing the degree of precision even further, (e.g. with a wide array of real-time sensors or sophisticated scheduling software), is another.

Evidence in the project found progressions like improved scheduling can produce step-changes in irrigation operations. *Smarter Irrigation for Profit* has assessed scheduling tools, enhanced some selected options, and promoted wider appreciation of the gains in production and profit from improved scheduling. A report was compiled summarising the pros and cons of the many tools in the market place.

Alexis Killoran

Precision Irrigation

Poor irrigation uniformity results in areas of over and under-watering on uniform paddocks, but more precision is needed if all parts of a variable paddock are to be irrigated optimally.

Precision irrigation relies on being able to monitor variations in the water needs of plants and to variously apply water to meet them. Sophisticated irrigation scheduling is used to link the monitoring with more precise irrigation. *Smarter Irrigation for Profit* trialled and further developed variable rate irrigation systems, improved scheduling for more precision in furrow irrigation, and tested sophisticated scheduling tools with the potential to control fully autonomous variable rate irrigation systems.

Learning & Capacity Development

Hiz Jamali

Extension & Adoption

Grower-led, field-scale trials were widely used to show the practical implications of incorporating new technologies. The network of 'optimised farms' enabled exploration of the issues behind farm scale performance that are otherwise left to early adopters to sort out. It also provided a ready platform for farmers to share directly with other farmers through field days, videos and podcasts – and it helped researchers see issues from irrigators' perspectives.

Guy Roth

Cross-Sector Research Directions

Cross-sector collaboration, initiated through the *Rural Research and Development for Profit* Program, has generated considerable interaction, knowledge sharing and collaboration between research institutions to generate the findings presented in this report. Research needs, to build on the findings to date could include:

- **Monitoring** – robust and novel soil moisture and crop sensors, pasture growth rate monitors, and infrared canopy sensor commercialisation.
- **Scheduling** – enhancing scheduling tools, remote sensing, and adaptation of tools to different production systems.
- **Automation** – improving components, and integrating them into practical, user-friendly systems.
- **Climate risk** – better managing drought, heatwaves and low water availability.
- **Design for adoption** – incorporating social science to design 'adoptable' solutions for irrigators.
- **Capacity development** – building on the optimised farms network and further exploring the complexities around water, labour, energy, nutrition and net profit.
- **Agronomy** – optimising production from available water with different crops or pastures.
- **Future researchers** – postgraduate training for the next generation of researchers.
- **Addition** of some more key learning sites.

Further investment in topics such as these and others will maintain the momentum of technical advancement in Australian irrigation to generate gains in productivity and profit, and optimise the sustainability of irrigation as a water use.

Conclusions

Hallmarks of *Smarter Irrigation for Profit* include:

- The research emphasis in *Smarter Irrigation for Profit* on design, sensing, scheduling, precision irrigation and automation, has advanced technical solutions for improved productivity and profit in Australian irrigation.
- Collaboration between research agencies, commercial interests, commodities and other parties has resulted in the sharing of ideas, and the faster and wider trialling and demonstration of new technologies.
- The participative and applied nature of the work, well-illustrated by the network of grower led, on-farm learning sites, has helped ensure technical solutions addressed irrigators' needs in a practical way.

Smarter Irrigation for Profit has primed investors, researchers, commercial interests and irrigators for another wave of research, development and extension for continued innovation in irrigation practice.

Introduction

Background

Globally, irrigated agriculture covers about 20% of agricultural cultivated land – but accounts for 40% of global food production.

$12 billion

This use of Australia's water resources produces 30% of the nation's agricultural production and contributes $12 billion in export income.

80%

More than 80% of all fresh fruit and vegetables are produced using irrigation and in many regional areas irrigated production is the most significant and profitable land use.

The impressive, continued increase in productivity of irrigated production would not be possible without improvements resulting from research, innovation and application.

Changes in research and extension were initiated to help irrigators, industries and communities deal with the new policies, environmental realities and broader expectations. Significant outputs from collaborative research and development initiatives such as the CRC for Irrigation Futures and the National Program for Sustainable Irrigation (and its predecessor, the National Program for Irrigation R&D), stimulated changes in irrigation practice through improved design, technology, and information. These programs effectively finished in 2010.

The effects of ongoing changes in governance and regulation of Australia's water resources, and the digital revolution of communication and computing, have brought a new era to irrigation practice.

Improved irrigation system hardware, along with new communication technology and stand-alone and networked instrumentation, provide an unprecedented opportunity for a step change improvement in irrigated water productivity; providing an opportunity to break the nexus.

Realisation of this opportunity and a concomitant improvement in irrigated business profit is only likely if the need for change is identified and the combination of learning, deployment and maintenance of know-how, technology and practice is implemented. This is the setting for the *Smarter Irrigation for Profit* project.

Smarter Irrigation for Profit

The *Smarter Irrigation for Profit* initiative is a collaborative, cross-sectorial research project focused on:

- Practical, reliable irrigation scheduling technologies.
- Precise, low cost, automated control systems for a range of irrigation systems.
- A network of farmer-managed learning sites, located in major regions and referred to as 'optimised irrigation' farms.

The *Smarter Irrigation for Profit* Project involves Rural Research and Development Corporations (RDCs - Sugar, Dairy, Rice and Cotton) and numerous research institutions, coordinated by the Cotton Research and Development Corporation. The project has 10 key activities, four industries, 16 research partners, and 19 farmer-managed learning sites across five states.

It is one of 36 projects in the Australian Government's *Rural Research and Development for Profit* Program.

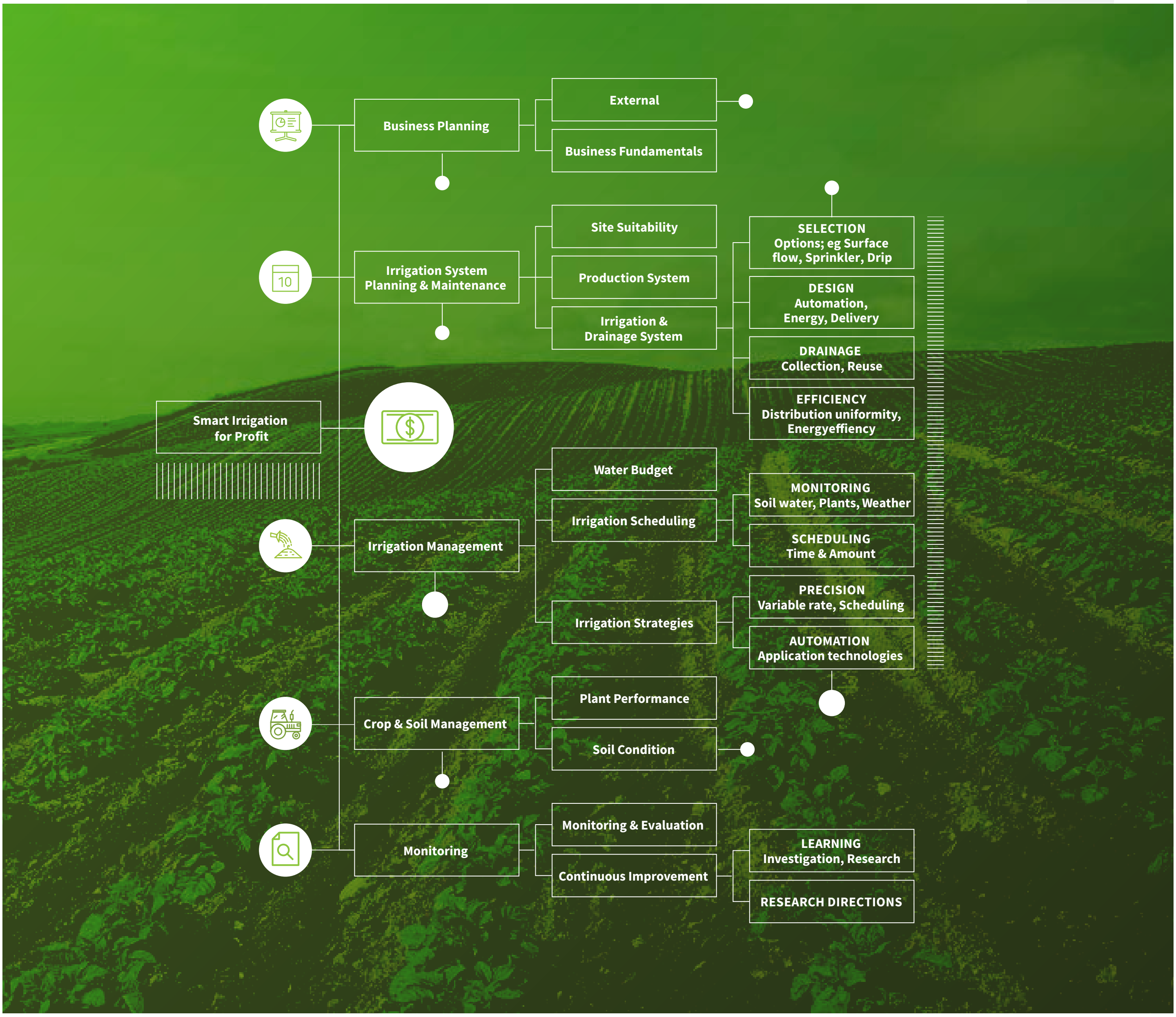
The potential for significant improvement in water use productivity and business profitability was identified by Smarter Irrigation participants. The project set out to realise the potential by fostering developments in sensor technology, greatly improved data analysis, and demonstration of improved water use productivity. Harnessing the learning that can occur when different regions, commodity groups and research institutions interact has been a very effective way of increasing the delivery of new practices.

This snapshot is a compilation of the learning and its application that have come from the *Smarter Irrigation for Profit* project. Case study reports are used to illustrate the output, outcomes and effects that have resulted from the research, development and extension process.

Irrigation Essentials

Smarter Irrigation for Profit follows in the footsteps of previous collaborative irrigation research programs such as the National Program for Sustainable Irrigation which developed a framework in a format that was easy to digest and useful to any irrigator – no matter what their circumstance. That framework (shown in blue in the following diagram) was used as a basis for this *Smarter Irrigation for Profit* snapshot, with some amendment (shown in green) to reflect the focus of the Project.

The structure of this report reflects that framework.



Smarter Irrigation for Profit – A Knowledge Framework of Key Topics.

Irrigation Systems

This section explores the interplay of factors influencing the selection, design and maintenance of on-farm irrigation systems.

Context – Influencing irrigation choices

Water trade

An important feature of modern water policy in Australia is tradeable property rights in water, with the environment as a stakeholder.

System modernisation

The modernisation of irrigation supply networks, such as pressurisation has opened up new options in the types of irrigation system now feasible for farmers. Many irrigators are better able to order water 'on demand', getting it when they want it. Advances in on-farm irrigation technology, and the spread of high-volume telecommunications, have supported the growth in options for irrigation systems and their management.

Diversity

Many traditional irrigated areas now have more diversity in crops, irrigation systems and enterprises. As an example, centre pivots are now seen in landscapes where they were previously absent. The demographic of irrigation operators is also changing. Many operations now have corporate structures, and/or are larger. They are managed by people with technical skills while in other areas labour shortages is a key driver for automation.

Labour

The range of demands for labour is often not met by a well aligned supply of labour – as evidenced by the use of temporary work visas, and difficulties in accessing highly technical support in some regions.

The time and cost implications of accessing and managing labour are important considerations for many irrigators – especially as some irrigation systems may impose a trade-off between labour and energy costs.

Energy

The rising cost of energy used for pumping water and pressurisation in some systems is leading to irrigators to rethink which irrigation system is best in terms of overall farm profit.

A systems approach

Factors like the terrain and the availability, quality, supply and reliability of water, and the crops chosen for production, remain as determinants in the selection and design of irrigation systems.

Melanie Jenson

System Selection

General principles

There is no universal best type of irrigation system – even within a region and a production system. It is a matter of selecting the most appropriate system based on the physical and financial situation, production system, and the style of operation desired – and then managing it correctly. Some key factors are:

- Topography and soil types. As examples, overhead systems generally suit soils with higher infiltration rates, while sites that are too flat may not have sufficient grade for effective drainage in bankless channel irrigation.
- The nature of water supply and the security of water. Pressurised supply systems may more easily be used for sprinkler systems without incurring excessive additional energy costs, while the reliability of supply affects the type of system chosen through returns on capital invested – for example, if expensive improvements cannot be used and lie idle in times of reduced water availability.
- Establishment (or conversion) costs and payback periods.
- Style of management and required features to fit with other aspects of farm management.
- Productivity, water use and operating, labour and energy costs. There can be trade-offs to consider between these aspects, e.g. saving labour may require increased energy consumption.

Water use efficiency and productivity

The term Water Use Efficiency (WUE) is a generic label for measures (or indices) of crop water use, comparing outputs (e.g. yield) to inputs (e.g. applied water). The indices are usually calculated over a season or a year. As discussed below, ‘efficiency’ and ‘productivity’ can be viewed and measured in many different ways and at various scales. To avoid confusion in interpretation it is important to be clear what entities and units are being used, and to thus appreciate how the ratios were calculated.

The engineering definition of ‘efficiency’ is the ratio of like inputs to outputs, which are measured in the same units. Hence a ratio of mass of yield per unit volume of water used is more correctly termed an index, than an efficiency.

Examples of water use indices (WUI), as defined by Fairweather et. al., include:

- Gross Production Economic WUI = Gross return / Total water applied ($/ML).
- Irrigation WUI = Yield / Irrigation water applied (kg/ML).
- Crop WUI = Yield / Evapotranspiration (kg/mm).

Efficiency indices can also be referred to as water productivity measures. Water productivity is generally expressed as the mass of plant matter generated per unit of water used (e.g. kg/ML). It can also be expressed more specifically, for example, as crop yield or total above ground plant mass. Sometimes the amount of water will be expressed as units of mass or as depth.

Producers often express productivity as the financial return per unit of water used (e.g. as $/ML). The dollars could measure gross financial return or profit – which reflect crop choice and quality as well as the yield.

Another important consideration in defining water productivity is what is meant by ‘per unit of water used’.

- At a plant scale the ‘water used’ will be the water that evaporates (transpires) from the plant surface.
- At the field scale, the water used will be by evaporation from crops or pastures and the ground surface (evapotranspiration), surface drainage and water draining below the root zone.
- At a regional or catchment scale, drainage water re-use will increase total water productivity.

An objective to maximise ‘water productivity’ is to maximise the proportion of water that is transpired by the plants – giving the best chance of optimising returns (either of mass or financial yield) and minimising unnecessary, non-productive loss of the water resource.

Yet another perspective can be gained by defining the ‘efficiency’ of an agricultural system in terms of energy – reflecting the aim of crop and pasture production as the capture and conversion of the sun’s radiant energy into plant matter. The quantity of plant material produced and the volume of water evaporated during the growth of the plant can both be expressed in energy terms; to provide an energy capture efficiency value, that typically ranges from 0.001 to 0.005 (i.e. 0.1% to 0.5%).

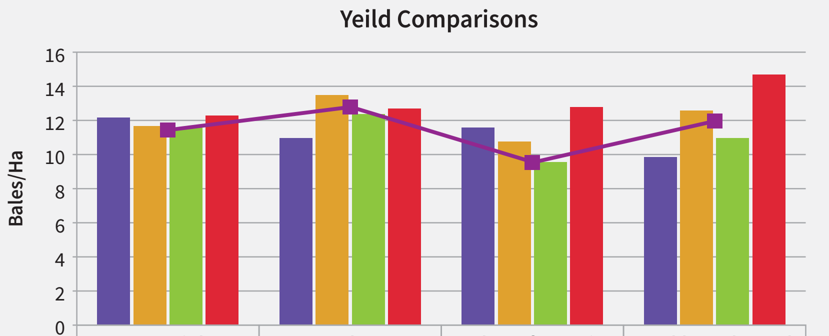
Specifics

Cotton

A multi-year commercial field-scale trial on vertisol soils at Keytah in north-west NSW at Moree considered four different irrigation systems from several perspectives. It showed that each had their own strengths and weaknesses, and that they changed in different years, as seasons varied.

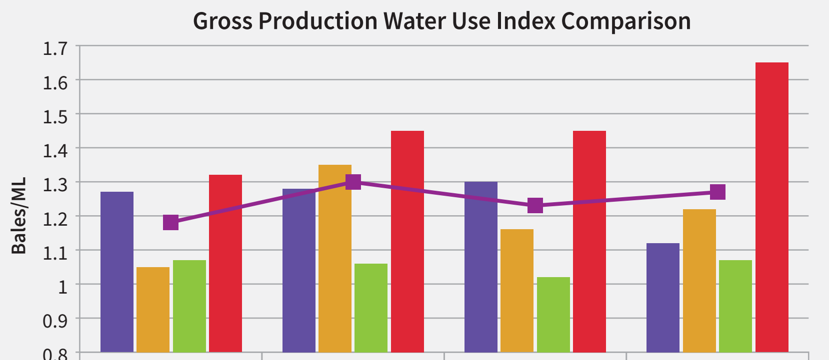
- **A lateral move irrigation system** consistently produced good yields, but productivity (the Gross Production Water Use Index - GPWUI) was much lower in dry years. It is well suited to wet seasons providing increased flexibility to avoid water logging. It generally has higher capital set up costs and higher maintenance costs than flood irrigation systems. The energy costs reflect the requirements of a pressurised system. It is less well suited to regions with low irrigation water reliability.
- **Sub-surface drip irrigation** showed encouraging results in terms of water use, but failed to produce good yields - which reduced the GPWUI for the system. System capacity needs to be designed to manage irrigation during dry conditions, when water application needs are large. The high capital cost of drip is an issue, as is the maintenance and need for skilled operators. Sub-surface drip lends itself to full automation but has limited fit where the reliability of irrigation water is low.
- **Bankless channel irrigation** had low labour requirements and was the most energy efficient of all systems trialled, resulting in the lowest operating cost. With good management it also resulted in very little tail-water (run-off), and generated good yields (despite high yield variability). The topography and elevation of the site will influence the suitability of the system, although it is the system of choice in areas where labour resourcing is difficult.
- **Furrow siphon surface irrigation** is relatively efficient and produces consistent yields in all seasons. It has low energy requirements but high labour costs. There is significant scope to optimise siphon irrigation under automation thus improving the GPWUI and reducing the potential for large volumes of tail water.

Annual seasonal variations are evident in the following graphs. As an example, bankless channel performed least well in 2009-10 (due to delayed development of the site), but was the best performer in 2015-16. Averages should be used for indicative purposes only.



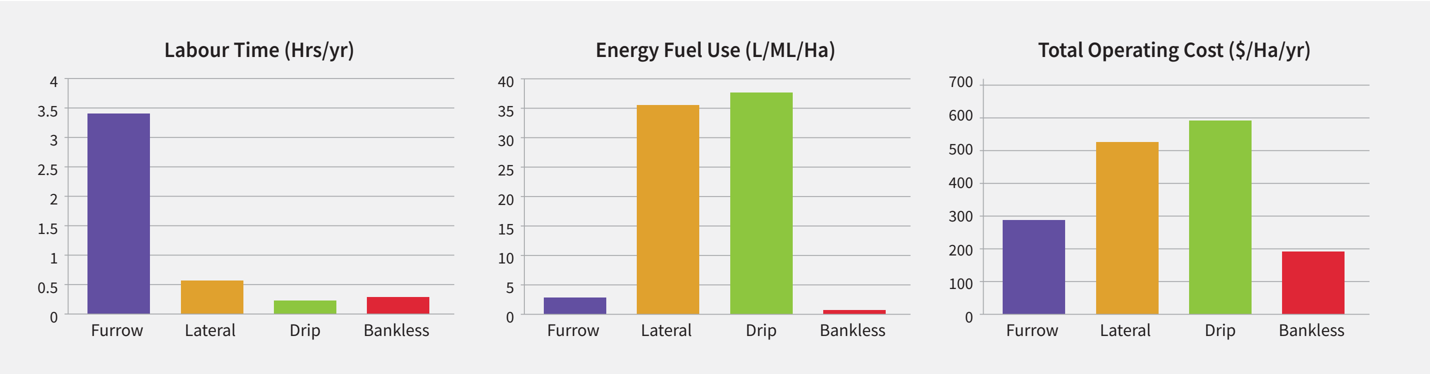
	Furrow Siphon	Lateral Move	Sub-surface Drip	Bankless Channel
2009-2010	12.1	10.9	11.5	9.8
2011-2012	11.6	13.4	10.7	12.5
2013-2014	11.5	12.3	9.5	10.9
2015-2016	12.2	12.6	12.7	14.6
Average	11.8	12.3	11.1	12.0

Annual cotton yields from four irrigation systems (2009 – 2016). Source: GVIA, 2016



	Furrow	Lateral	Drip	Bankless
2009-2010	1.27	1.28	1.3	1.12
2011-2012	1.05	1.35	1.16	1.22
2013-2014	1.07	1.06	1.02	1.07
2015-2016	1.32	1.50	1.45	1.65
Average	1.18	1.30	1.23	1.27

Annual GPWUI from four irrigation systems (2009 – 2016). Source: GVIA, 2016



Indicative trade-offs across four irrigation systems. Source of data: GVIA, 2016

Key message

The key message is that the data clearly shows variations between seasons. There is no single system suited to all seasons or regions.

- The lateral move produced the highest average yield of 12.29 bales/ha and GPWUI of 1.3.
- The furrow siphon was the most consistent yielding system with a n average of 11.84 bales/ha.
- The bankless channel had an average yield of 11.95 bales/ha.
- The drip had an average yield of 11.12 bales/ha.
- The furrow siphon has high labour costs, but low operating energy costs.
- The lateral move and sub-surface drip have high operating energy costs.
- The lateral move and sub-surface drip have high capital costs.
- The bankless channel had the lowest total operating cost and the lowest operating, maintenance and ownership costs.

As a follow-on to this work, attention has turned to enhancing the furrow irrigation systems through automation. An example is the replacement of traditional hand siphon systems with 'smart siphons'; sets of small pipes, installed through the banks, fitted with rotatable siphons on the water channel side.

The right-angled siphons can be turned (lowered or raised) to initiate or cut-off irrigation in sets of up to 150, controlled manually by a cable and winch or, more recently, through telemetry and a smartphone App.

Lou Gall

Smart siphons – small Pipe Through the Bank irrigation system.

Economics

Smarter Irrigation for Profit also investigated the economics of irrigation system improvement through six case studies in southern NSW and northern Victoria, involving rice, cotton and maize production. Three of the case studies involved layout changes from a side-ditch delivery contour layout to either a terraced bankless layout or a border check layout. The other three case studies retained the existing layouts (furrow or border check) but invested in efficiency gains such as channel improvements and automation.

The economic analysis methodology provided in the report includes:

- Gross margin analysis.
- Whole farm returns.
- Marginal rate of return on capital investment.
- Discounted cash-flow benefit (cost) analysis.

The case studies demonstrated the potential returns from investment in irrigation efficiency or in recommended layouts, and showed that economic returns can be positive.

However, the marginal rates of return vary widely, due to the different levels of capital expenditure and the impact on the gross margin.

Individual development and financial plans are essential for each case before the investment in any capital development.

For all crops, water productivity within the irrigation system was improved with either improved irrigation efficiency or improved layout such as terraced bankless designs. The improved water productivity influences the positive economic returns shown in the case studies.

Although only drawing on a few years of trials, the case studies indicate that in favourable seasons:

- Rice growers can change to terraced bankless and double cropping and realise good returns. Growers can target crop production systems targeting the most suitable soil types, and they can incorporate winter crops (wheat and canola) into their production system to gain an acceptable return on investment.
- Cotton and maize growers can improve yields and reduce water use through investment in recommended layouts. The benefits have been sufficient to gain acceptable marginal returns on capital investment in layout changes.

Economic case studies – Summary Results

Case Study	Previous System Description	New System Description	Change & Benefit Description	Capital Cost & Area Developed	Average Gross Margin Net Benefit (Cost)	Marginal Return on Capital Invested	Discounted Cashflow Return (NPV at 7%)
Murrumbidgee 1	Furrow-Cotton / Winter Crop **(F-Co/WC)**	Furrow-Cotton / inter Crop **(F-Co/WC)**	Automation and Earthworks. Water logistic efficiency, more cotton area grown.	$237,500 250 ha $950/ha	$195,429	66%	$1,712,723
Murrumbidgee 2	Furrow-Maize **(F-M)** + Contour-Rice double crop **(C-R/dc)**	TerrBank-Cotton **(TB-Co)**	Change in layout. Labour efficient and machinery efficient.	$3,520,000 1600 ha $2,200/ha	$1,144,201	26%	$3,879,822
Murray 1	Contour-Rice double crop **(C-R/dc)**	Contour-Rice double crop **(C-R/dc)** + TerrBank-Cotton / Maize **(TB-Co/M)**	Part change layout. New system allows more flexibility in crop rotations and crops that can be grown.	$454,050 150 ha $3,027/ha	$129,097	23%	$490,284
Murray 2	Contour-Rice / Winter Crop **(C-R/WC)**	TerrBank-Rice double crop **(TB-R/dc)**	Change in layout. More crops in shorter period, water use down.	$862,860 360 ha $2,397/ha	$150,564	14%	$365,277
Victoria 1	Border-Check-Maize / Winter Crop **(BC-M/WC)**	Border-Check-Maize / Winter Crop **(BC-M/WC)**	Re-lasered, channel upgrades, bigger border check. More maize area, efficiency, yields up, water use down.	$1,210,000 550 ha $2,200/ha	$890,077	59%	$6,358,422
Victoria 2	Border-Check-Maize / Winter Crop **(BC-M/WC)**	Border-Check-Maize / Winter Crop **(BC-M/WC)**	Re-lasered, total automation, infrastructure upgrades. More maize area, efficiency, yields up, water use down.	$675,000 250 ha $2,700/ha	$123,402	15%	$754,071

Key: Layouts - F = Furrow; TB = Terrace Bankless; C= Contour; BC = Border Check. Crops - Co = Cotton; WC = Winter Crop; M = Maize; R = Rice; dc = double crop

Source: Rollin et al (2018)

Key References

Fairweather H, Austin N & Hope M. *Water Use Efficiency, an information package. Irrigation Insights No. 5*. Land & Water Australia, National Program for Sustainable Irrigation.

Gwydir Valley Irrigation Association. (2018) *System Comparison Trial 2009 – 2016*. GVIA, Moree, NSW.

Gwydir Valley Irrigation Association videos:

- Integration of automated systems into irrigation in the Gwydir Calley field day video 2017: **https://vimeo.com/241117788**
- GVIA system comparison video: **https://vimeo.com/174306570**

Meyer WS. (2018) *Increasing water productivity in agriculture: an overview. Ch. 21 in Water Management for Sustainable Agriculture Vol1*. Burleigh Dodds Science Publishing Limited.

Rollin M, Scott F & Hoogers R. (2018) *Maximising On-farm Irrigation Profitability: Economic Analysis Report*. NSW DPI Economic Report.

Roth G, Harris G, Gillies M, Montgomery J, and Wigginton DW (2013) A review of water use efficiency and productivity trends in Australian irrigated cotton. *Journal of Crop and pasture Science, 64,1033-1048.* (Review synthesis of water research. Most downloaded paper of the Journal in 2014)

System Design & Drainage

General principles

Surface irrigation (be it by furrow or in bays) is by far the most common form of irrigation in Australia (and globally) due to its low capital cost and low energy requirements.

Well designed and well managed surface irrigation can achieve application efficiencies of 95% - showing that efficiency comes from design and management, and is not an inherent characteristic of the system itself. However, in practice, most surface irrigation systems operate at much lower, and highly variable, efficiencies – marked by uneven and residual ponding, deep drainage and run-off. Application efficiencies for surface irrigation can often be improved by system design and scheduling (managing in-flow rates and irrigation durations); reducing losses through deep drainage and run-off.

The high labour demands of siphon or border-check surface irrigation are compounded as the scale of operations increase. Automation is increasingly being used to address labour shortages, reduce labour costs, and manage the sheer size of large operations, as well as to help improve irrigation efficiencies.

The role of irrigation and crop models

Modelling is used to help in the design and testing of new systems. It allows people to quickly assess a range of different variables and to simulate a range of different seasonal conditions. Without modelling numerous trials would be needed, and they would have to be repeated over an extended period (e.g. a decade) to assess performance in a range of wet and dry years. Physical (hydrological) models and crop growth models are both applied, and can be run in conjunction with each other.

As an example, the ANUGA 2Dimensional surface-water flow model has been adapted for testing border-check irrigation bay design. An infiltration algorithm has been included, using the Modified Kostiakov (MK) equation, which calculates infiltration as a function of ponding time. Following the revision, the ANUGA model successfully simulated border-check surface irrigation, and was used in *Smarter Irrigation for Profit* to help assess drainage options for irrigated dairy pastures.

In other work, a *Smarter Irrigation for Profit* review of existing basin irrigation models, and models for determining infiltration parameters from field irrigation data, concluded that:

- SISCO is the most appropriate model for determining infiltration and surface roughness characteristics in basin irrigation systems using inflow and advance data.
- WinSRFR is able to determine the optimum bay size for basin systems, for a range of inflow rates, on three common soil types.

B2B is the most appropriate model for modelling multiple, hydraulically connected basins; though further work is needed to adequately incorporate feed-back whereby the head of water in the bay being irrigated affects the drainage rate from the upstream bay.

Guy Roth and John Smith inspecting experiments at Yanco, NSW.

Audits of irrigation systems conducted by *Smarter Irrigation for Profit* revealed major issues with the operation of irrigation systems – even for new ones. They highlighted the need for regular attention to the issue and how important it is for farmers to insist on commissioning checks as part of the installation of new systems. Good design is an essential building block for efficient irrigation, but installation can be problematic, and on-going maintenance even more so. For more information, see the 'Efficiency' section of this report.

Understanding 'system capacity' (the maximum possible rate at which water can be applied to the irrigated area, e.g. as mm/day) is integral to effective irrigation scheduling – ensuring the scheduled amount of water can be supplied in the time required. For more information, see 'Irrigation Practice: Scheduling'.

Specifics

Spinner drains for border-check pasture irrigation

Gravity-fed border-check, a form of surface flood irrigation, is a lower capital cost irrigation system suited to relatively flat land (slope >1:1,500) with medium to low permeability soils. In many regions dairy farmers employ it to grow pastures. Being gravity-fed, it has minimal ongoing energy costs.

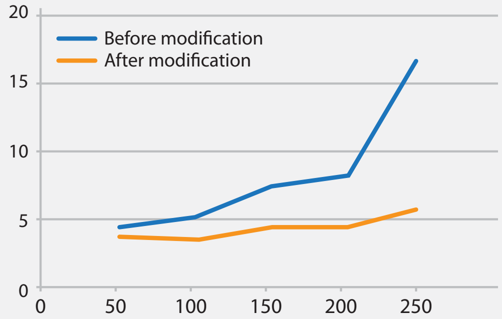
An inherent feature of border-check systems is non-uniform surface water ponding duration. Surface water is generally ponded for longer as the distance from the water supply outlet increases, because the rate of surface drainage is slower than the rate of inflow. The problem is exacerbated over time as graded bay surfaces become more uneven. Uncontrolled surface ponding increases the risk of excessive deep drainage and prolonged inundation adversely affects plant production, while high variation in the duration of surface ponding within bays reduces the value of more precise irrigation scheduling.

Farmers have long used ‘spinner drains’ to help overcome surface drainage problems. The innovation in this study has been to use shallow drains installed down each irrigation bay, from top to bottom, in order to improve irrigation performance in a dairy pasture. Field measurements have confirmed the value of this modification, and a two dimensional surface irrigation model, based on the ANUGA inundation model, has confirmed its value over a wide range of conditions.

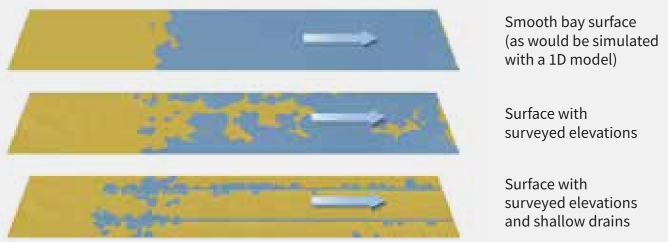
Smarter Irrigation for Profit trials have introduced and extended awareness of spinner drains to the Gippsland region in Victoria.

As illustrated below, the duration of ponding is reduced with spinner drains and water is distributed more evenly and more quickly. The drains are already being recognised as an easy solution to waterlogging and, although trials are still in their early stages, the manager of a trial farm has seen their advantage and installed them more widely across the property. Areas that were previously water-logged and growing weeds now support more pasture and the reduction in weed growth is visibly apparent.

Measured surface water ponding duration with bay surface modification



2D simulations with different bay surface treatments 5 hours after start of irrigation



Source: Mike Morris (2018)

Mike Morris

Installing in-field spinner drains.

Surface drainage has been a historic problem in areas of Gippsland with heavy soils and slow infiltration rates. With modernisation of supply systems in the region there are opportunities for the wider adoption of spinner drains, or changes to inflow rates or bay size and length, plus improved scheduling with automated irrigation.

Optimised furrow irrigation – Cotton beds and row spacing

Cotton growers vary the density of a crop to optimise available water in any season, by planting in different configurations. *Smarter Irrigation for Profit* trialled the planting of cotton in rows that were the standard 40 inch (1m) apart, as well as 30 inch (75cm), 60 inch (150cm), and 80 inches (200cm) apart.

The trials confirmed the importance of well-established bed structures to begin with. The 1.5m beds used in the 30 and 60-inch row configurations need to be established well in advance, and the edges should be rolled to minimise slumping. Where the bed structures were new there were significant issues with slumping and difficulty creating an evenly wet seed bed.

Trials showed that when sufficient water was available to fully irrigate, then the narrower (denser) 30 and 40-inch plantings were similar in performance, and produced higher yields with better water productivity, as measured by Gross Production Water Use Index. However, when irrigation water is limited, the 60-inch option can be a viable alternative as, although it yielded nearly 20% less than the 40-inch rows, it used more than 10% less water – with less than a 5% drop in water use efficiency.

On farms with broadacre cropping and cotton production, 30 and 60-inch options allow equipment with a three metre wheel spacing to be used for both enterprises, reducing the extent of soil compaction that would occur with vehicles on different wheel spacings.

Rice irrigation bay design to improve productivity

Changes to current rice growing practices are proposed to increase water productivity, without penalising rice yields or quality. *Smarter Irrigation for Profit* is investigating how to achieve that through double cropping. Growing a crop straight after rice and using the water stored in the soil profile is expected to increase the overall profitability of water use, by improving total crop productivity and water use efficiency.

A key impediment to the productivity of non-rice crops in rice systems is the strongly 'reduced' soil conditions which

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occur under ponded rice and the high risk of waterlogging in the winter season after rice harvest. Two potential solutions were investigated:

- The use of raised beds.
- Draining rice at early grain filling, followed by flush irrigating until physiological maturity.

Two separate measurements were used to assess the effect of these treatments on root zone conditions from under rice and into the following winter crop. These measurements were redox potential (an indicator of soil oxygen content), and matric (water) potential. Soils were also sampled for nitrate, ammonium N, and soluble reactive phosphorous.

The results showed the following:

- The beds dried more at 15 and 30 cm depth when the rice was drained, and the soil at five and 15 cm returned to an aerobic condition earlier.
- The soil at 30 cm depth under the beds maintained a higher redox potential and was aerobic for a longer period through a very wet (2016) winter.
- There was no detectable nitrate in the soil either under or after ponded rice, so the wheat crop following the rice relied on ammonium N applied at sowing (d). Phosphorous availability declined when the rice was drained and the soil dried.
- Draining rice at early grain fill resulted in the soil returning to an aerobic condition 30 days earlier than the conventionally ponded rice.
- There was no significant effect of any treatment on rice yield or quality.

Redox & Matric Potential

SOIL REDOX POTENTIAL
(Eh - the ratio of oxidised to reduced forms in a solution – measured as mV) is a measure of the oxidation-reduction status of the soil. Eh levels are mainly driven by microbial respiration. At Eh values less than 350 mV, molecular oxygen is absent from soils and respiration is anaerobic. These conditions reduce crop growth and are conducive to damage from waterlogging.

The optimum Eh for plant growth is generally in the range of +400 to +450 mV.

MATRIC POTENTIAL is the suction pressure with which water is held within the pores of soil (the soil matrix). As a suction pressure, it is a negative value and is measured in kPa. Soils are saturated at values between sero and -10 kPa, which is the drained upper limit. The need for irrigation is generally indicated when readings at the bottom of the active root zone reach -60 to -70 kPa. Lower readings at these soil depths indicate crop water stress.

A 'take home message' for irrigators with low permeability soils or shallow water-tables is to 'Pick your best paddock and make it better', with an eye toward automation to support better scheduling and the management of labour costs.


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Researching rotation crops for rice fields at Jerliderie, NSW.

Despite its preliminary nature, a number of important messages have come from this work.

- It is possible to flush irrigate to finish rice in southern NSW without serious consequences to yield or grain quality.
- Flush irrigating to finish rice allows the soil to return to an aerobic state earlier. This has the following potential benefits for crops following rice which need further investigation.
  - Drier soil profiles at rice harvest should result in better trafficability, less soil compaction, reduced need for re-grading, and a lower incidence of waterlogging in the following winter.
  - Aerobic soils favour nitrification over denitrification, which should benefit all crops following rice.
- Double cropping has the potential to improve water productivity in rice farming systems, but further work is required to find.
  - More suitable, short(er) season winter crop types and varieties;
  - Easier, quicker and lower cost methods of dealing with high rice stubble loads to allow timely sowing of the winter crop;
  - The feasibility of seeding a winter crop/pasture under a rice crop that is being flush irrigated during grain filling.
- While the benefits of raised beds in rice farming systems has been demonstrated elsewhere, there remains a need to demonstrate their effectiveness for double cropping to rice growers.

This 'farming systems' work has the potential to improve the profitability of Australian rice farms by reducing fallow periods, improving the range of crops that can be successfully grown, and increasing returns to capital and water. However, shifting to a more aerobic rice culture will only be practicable if surface irrigation layouts are properly designed so they allow:

- Water to be applied and drained from bays faster and more precisely than most layouts currently permit.
- Low cost, capital effective automation.

Currently, there are no design guidelines for basin surface irrigation systems. Evidence based criteria are needed to answer two key design questions:

1. What is the maximum bay size that will allow water to be applied and drained within 10 hours for a paddock's supply flow rate and soil type?

2. What is the paddock slope for a given bay size and surface geometry (i.e. storage volume), soil type, surface roughness, and flow rate below which water backs up in side-ditch/bankless channel systems and impedes drainage?

To answer these questions, in-field evaluations were conducted on the following basin systems:

- Conventional rice contour system
- V-bay rice contour system
- Bankless channel cotton system

Literature values and field data was used to determine typical hydraulic roughness and infiltration characteristics using the SISCO model.

To answer the first question, the WinSRFR model was used to determine bay size for three inflow rates, three soil types and three bay surface configurations. Answering the second question requires further work. The B2B model is the only model available that can simulate hydraulically linked systems, but it does not allow feedback between bays. Consequently, it cannot adequately represent side-ditch/bankless channel systems in which a rising water level in the filling bay affects out-flow from the draining bay.

Developing these design criteria will allow future basin systems to be built so they water and drain quickly and to specification - enabling greater irrigation precision and lower cost automation in basin systems on suitable soil types. As a consequence, it will be possible for the rice industry to move from a ponded culture suited mainly to rice only, to a mainly flush irrigated, aerobic system suited to rice and all other crops. This is anticipated to increase profitability by increasing cropping flexibility, reducing crop losses to water logging and water losses to deep drainage, whilst maintaining the advantages of low capital and low labour in basin systems.

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NSW DPI researcher Sam North explaining the outcomes of rice rotation research at the Rice Research Australia Pty Ltd site at Jerilderie in Southern NSW.

Key References

Beecher HG, Thompson JA, Dunn BW, Sing RP & Mathews SK. (2007) *Using Raised Beds on Rice Farms – sustainable cropping systems on rice farms*. Rural Industries Research & Development Corporation, Canberra.

Githui F, Hussain A & Morris M. (2015) *Adapting ANUGA model for border-check irrigation simulation*. 21st International Congress on Modelling and Simulation, Gold Coast, Australia.

Gwydir Valley Irrigation Association. (2017) *Optimised irrigation Row Configuration*. GVIA, Moree, NSW.

Irrigation Australia. (2017) *Irrigation System Design Guidelines*. Irrigation Australia Ltd. https://www.irrigationaustralia.com.au/documents/item/434

Morris M, Githui F & Hussain A. (2015) *Application of Anuga as a 2D surface irrigation model*. 21st International Congress on Modelling and Simulation, Gold Coast, Australia.

Morris M. (2017) *Smarter Irrigation. Improving irrigation bays*. Presentation. Agriculture Victoria.

North SH, Brinkhoff J & Quayle W. (2017) *Continuous monitoring of soil redox potential to compare layouts for post-rice crops*. International Temperate Rice Conference, Griffith, 7-8 March 2017

Smith RJ, Uddin MJ, Gillies MH & Morris M. (2013) *Selection of flow rate and irrigation duration for high performance bay irrigation*. Society for Engineering in Agriculture Conference, Mandurah, WA.

Smith J, North S, Quayle W, Quarisa I, Ballester Lurbe C, Brinkhoff J, Chua L, Griffin D, Hoogers R, Hornbuckle J, Molesworth A, Scott F, Schultz A, Regan P, Rollin M, Zorriasateyn N (2018) *Technical Research Report 3.12*. NSW DPI, Yanco, NSW.

System Efficiency

General principles

Smarter Irrigation for Profit included on-farm audits of irrigation uniformity (checking that irrigation systems are performing as they were designed to) and energy efficiency. They exposed considerable variation in efficiencies – even with new irrigation systems – and showed that even standard checks were not being conducted on a routine basis.

The sort of issues identified included:

- **Irrigation Audits –** Systems designed to deliver water uniformly often didn't, resulting in areas of over and under-watering. Factors like poor design, not performing to design (e.g. due to pressure or nozzle issues), and lack of maintenance or repair, resulted in reduced water use efficiency, lost production and profit opportunities.
- **Energy Audits –** Once again, issues were uncovered involving design, commissioning and maintenance. Incremental change was also noted, where one component in a system may be changed, altering the efficiency of the whole system. Wear and tear on pumps (e.g. impellers) was often identified, and repairing or replacing pumps generated savings in energy and energy costs.

The audits showed that many farmers could save money and improve productivity by running periodic audits and attention to system maintenance – and ensuring suppliers provided a commissioning test as part of any supply and installation of new equipment, to ensure it is operating to specification to begin with.

Many farmers could save money and improve productivity by running periodic audits

Melanie Jenson

"A commissioning audit of the pivot found that both the water application depth and the uniformity could be improved. As a result of the Smarter Irrigation project we have made changes to our practices and are now producing more feed from the same amount of water. The project also assisted us to address a range of soil constraints that were reducing our crop yields".

The Hoffman family, Warwick, Qld.

Specifics

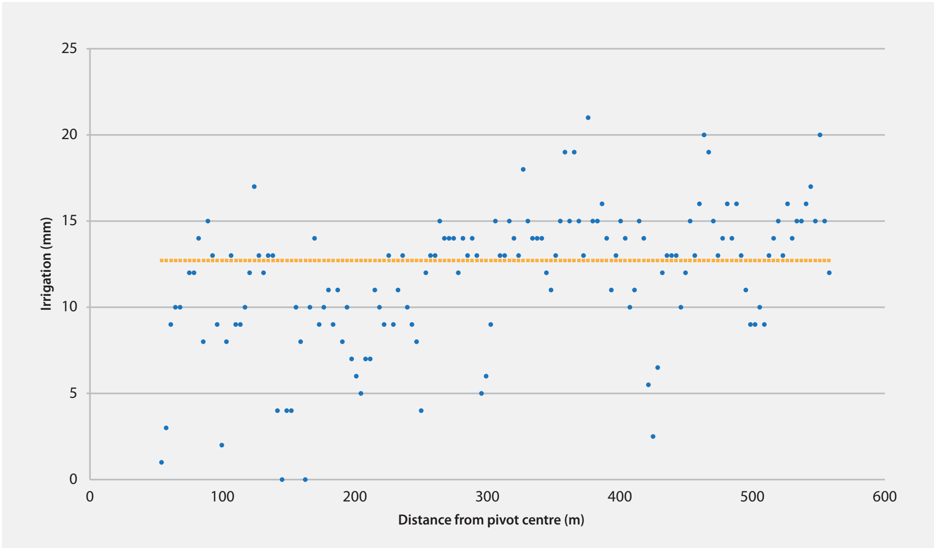
Irrigation uniformity – centre pivot on pasture

Irrigation uniformity is assessed using catch-cans to collect water from sprinklers on an irrigation system. Christiansen's Uniformity Coefficient (CU_{HH}) is calculated to provide an indication of the extent to which individual cans vary from a mean depth of application. In the example below, the applied depth ranged from zero to over 20mm, even though the pivot was set to deliver just over 12mm. The CU_{HH} was 78.8% - the closer the CU_{HH} is to 100%, the more uniform is the water application from the system.

To really appreciate the importance of these findings, it is useful to estimate the effect of over and under-watering on pasture production, and to put a dollar value on that. A South Australian example (see below) indicated that underperformance in irrigation uniformity resulted in lost production worth $15,980 per year.

Another measure of irrigator performance is the Distribution Uniformity (DU), where the average of the lowest quarter of catch can readings is divided by the average overall. The closer DU is to 100%, the better.

Optimum irrigation efficiency needs high application efficiency (80%+) and uniformity. High uniformity doesn't guarantee efficiency though – over and under water may still occur if good irrigation scheduling is not practiced.



Variability in irrigation application from a centre pivot. CU_{HH} was 78.8%. Source: Hills, J.

Alexis Killoran

Practical Tip

Use some plastic take away food containers and spread them along the irrigation line and measure how much water goes into each after the irrigation.

	Over-watered area (5.6ha)	Under-watered area (14.5ha)
ML of water wasted	16.51ML	-
ML of extra water needed	-	40.34ML
% of water wasted or needed compared to the pivot settings	39%	37%
Likely production loss due to over or under watering (conservative)	25%	25%
Lost production Oct–April (212 days) if assumned production should be 75kg/ha/day	22.3 tons	57.6 tons
Lost production if feed valued at $200/ton	$4,460	$11,520
ML/ha water applied	10.45ML/ha	4.72ML/ha

Total conservative production losses for this pivot are estimated at $15,980 per year in feed value.

Consequences of over and under-watering. Source: White, M.

Energy audit

The weight of water – 1ML/ha of irrigation (which is equivalent to 100mm of rainfall) equates to 1,000 tonnes/ha – means that shifting water requires lots of energy.

Audits showed that matching the pump and motor with the irrigation system can provide significant energy cost savings, and that a change in the system requires a re-evaluation of the pump design. In addition, maintenance of existing systems can also make a big difference.

Energy audits from 10 pivots in the South East of South Australia, (which were supported by the local Regional Natural Resource Management body), showed considerable variation in performance:

- $32 - $70/ML pumped.
- 35% - 75% pump efficiency.
- 16m – 33m head at pivot centre.

Annual potential savings, based on an application rate of 5ML/ha were:

- $600 - $2,400/yr by reducing pivot pressure.
- $300 - $1,500/yr by improving pump efficiency.

Electricity tariffs ranged from 18 to 24.2 cents/kW.h, with one farm having a saving of $4,500 a year by changing tariff alone.

In an example from NSW, $15,000/yr was lost because a power meter was incorrectly mixing up peak and non-peak periods – encouraging irrigation during peak price periods.

In Tasmanian audits of five centre pivot properties, benchmarks were established of 150-300 kW.h/ML and $30-$70/ML. Once again, there was a wide range in efficiencies, as shown by the audit results presented below.

PivotSite	kW.h/ML	$/kW.h	$/ML
1	113	0.23	$26.08
2	157	0.23	$36.16
3	220	0.23	$50.65
4	304	0.23	$70.00
5	787	0.23	$181.05

Audit results from five pivots. Source Hills, J.

Sites 3 and 5 made the following changes:

- Site 3 replaced an old pump with a new one of the same specification, and went from $50/ML to $43/ML, saving $4,900 for irrigation of 6ML/ha.
- Site 5 replaced a pump and motor, going from 787 to 266 kW.h/ML, and saving $120/ML or $20,000 for an irrigation season.

Given that profit is often small when compared to operating costs in irrigated agriculture, a small reduction in costs can mean a relatively large increase in profit.

Key References

Dairy Australia videos: http://www.dairyingfortomorrow.com.au/tackling-specific-issues/water/smarter-irrigation-for-profit

- The green drought
- Catch can testing
- Variable rate irrigation
- Variable speed drives

Dairy NZ (2017) *DIY Irrigation Evaluation. Farmer workbook for checking the performance of spray irrigation systems*. Dairy NZ

https://www.dairynz.co.nz/publications/environment/diy-irrigation-evaluation-guide

Foley J (2018) *Centre Pivot Irrigation & Energy Use Implications*. TIA SA Dairy Farmers Tour of Tasmania - Presentation. NCEA.

Hills J, McLaren D, Foley J & McCarthy A. (2017) *Smarter Irrigation for Profit*. Presentation to Meander Discussion Group. TIA.

White M (2018) *Do you know what uneven irrigation cost you*? DairySA.

TIA

Melanie Jenson

Irrigation Practice

The aim of the irrigator is to maximise crop growth and avoid water deficit stress by applying the right amount, in the right place at the right time.

Context – Principles of Irrigation

Plants need to grow and renew roots during their entire life cycle to continually access water and accumulate soil nutrients. The effective volume of soil that the root system is able to explore largely determines the amount of water that a plant can access. This volume of water, described as the plant available water (PAW), is a product of both soil and root system characteristics.

Plant growth is retarded by water deficit stress before all of the PAW has been extracted. The volume of water that can be extracted from the soil root zone before significant growth reductions occur is approximately 70% of PAW. To be conservative and to avoid any water deficit stress, the trigger for replenishing the soil water by irrigation (the 'refill point') is usually set at 50% of PAW. For ease of communication, this amount is referred to as readily available water (RAW). Understanding the concepts of PAW and RAW is fundamental for most irrigation scheduling processes and there are many published resources available on line.

If the aim of the irrigator is to maximise crop growth, then it is important to avoid water deficit stress. World experience has consistently demonstrated that successful scheduling involves some system of weather based estimation of crop evapotranspiration (ETc), and some consistent on-ground, within field measurement.

Weather based determination of ET enables a cumulative water budget to be calculated (i.e. how much RAW has been used), and also permits a forecast of how much ET can be expected - which then suggests the date of the next required irrigation. Scheduling irrigation involves timing (when), rate and volume (how much and how long). The application rate depends on both the ability of the irrigation system and the rate at which water can infiltrate the soil.

Evapotranspiration

Evapotranspiration (ET) is the amount of water lost through evaporation (e.g. from soil) and transpiration (from plants). It is often expressed as mm/day, although an equivalent measure is the amount of energy needed to evaporate the same amount of water.

- **ETo** – Reference crop evapotranspiration: evapotranspiration from a grassed surface of 12cm height.
- **ETc** – Crop evapotranspiration: evapotranspiration from a specified crop in optimum conditions.
- **Kc** – Crop coefficient: a factor of difference between ETo and Etc calculated for specified crops.

For more information: FAO crop evapotranspiration guidelines.

As irrigation systems become more controlled the opportunity to monitor, control, irrigate with precision and automate increases. Ongoing interest in reducing the labour requirements and time taken for management decisions is encouraging the development of larger and more automated system configurations. To be successful in achieving complete automation more instrumentation for monitoring, both the supply system and the soil and plant conditions, is needed. With more information that this monitoring generates there is then a pressing need for accurate interpretation and well tested actions to follow.

Monitoring

General principles

Scheduling irrigation to provide plants with the right amount of water, at the right time, depends on knowing what is happening in the soil and to the plant. Models or 'rules of thumb' can contribute to that, but monitoring is a mainstay for accurate scheduling. Monitoring options range from high-tech to low-tech.

Once a paddock and crop's features are well understood, (such as soil type, any impediments to growth from compaction or impervious layers, and plant root size), then attention can focus on variables such as:

Soil water – sufficient water must be available to plant roots, so the plants can transpire enough to avoid stress; i.e. keeping the soil above the refill point – but not so wet it 'drowns' the plant.

Plant – plant water use (transpiration) is driven by the plant growth stage and weather, especially solar radiation (sunlight), wind speed, humidity and temperature.

Weather – evaporation (which together with transpiration is termed evapotranspiration) and rainfall. Reference crop evapotranspiration (ETo) is calculated several times a day by the Bureau of Meteorology using weather data and a standard model for an assumed area of 12cm high grass.

Weather data and knowledge of crop transpiration can be combined to predict crop water use and hence, irrigation demand. Evapotranspiration (ETo) multiplied by a crop coefficient (Kc) gives a ready estimate of water use for different crops.

The condition of plants can be monitored to determine any water stress, but field applications have traditionally been difficult to use on farms. *Smarter Irrigation for Profit* has explored technologies to counter that.

Soil-water can be monitored to understand when a refill point may be approaching, using a gravimetric method (e.g. oven drying soil to determine water content), or monitors which are volumetric (such as capacitance probes or neutron probes, indicating mm of water per metre of soil depth), or tension-based (such as tensiometers or gypsum blocks). Soil water monitors can be placed at different depths, in different soil types, to give a better picture of how the amount of water in the soil is changing across a paddock over time.

Scheduling software may use all three types of information; weather, plant and soil-water status.

Specifics

Plant monitoring – canopy temperature

Monitoring canopy temperature is one way to monitor plant condition and any signs of water stress, and it can be done continuously using low-cost infrared sensors.

The temperature of a plant's canopy (the part above ground) is affected by the minute to minute weather conditions (incoming sun energy and ambient temperature) and the plant's access to soil water. As root access to water reduces, plants close their leaf stomata (leaf pores through which plants 'breath' – exchanging gases, including water vapour, with the atmosphere). Closing the stomata increases leaf temperature, and also reduces photosynthesis and growth.

Hiz Jamali

Solar powered canopy temperature sensors in a cotton crop.

Plants have an optimum temperature range, or thermal kinetic window, for growth. For cotton it is around 28°C. Well-watered plants are able to contain leaf temperatures (and maintain growth) at higher ambient air temperatures, by reducing their heat load through transpiration. Evaporating water (transpiring) through the leaf stomata uses large amounts of heat energy so there is less available to heat the leaves and plant. Irrigation helps plants maintain lower leaf temperatures when weather conditions are very hot, by improving soil-water content and lowering overall plant canopy temperature.

Soil water sensors can provide information on how much water will be needed to fill the soil profile, while canopy temperature sensors provide information on the availability of water to plants (which can be affected by different soil and environmental factors). Measuring the two simultaneously can give greater insight to plant vigour, and hence provide information for improved management.

Work is continuing to refine scheduling based on canopy temperature to develop irrigation strategies in water-limited situations; and discussions have been held with a partner about commercialisation.

Plant monitoring – remote sensing

Healthy plants reflect green light and near-infrared (NIR) wavelengths, while absorbing more red and blue light. Satellite-borne sensors are able to detect NIR and red wavelengths, and measure the difference between them to assess plant cover (known as the Normalised Difference Vegetation Index – NDVI – which ranges from +1 to -1). A NDVI value of +1 indicates dense green foliage, while a negative value suggests it may be water.

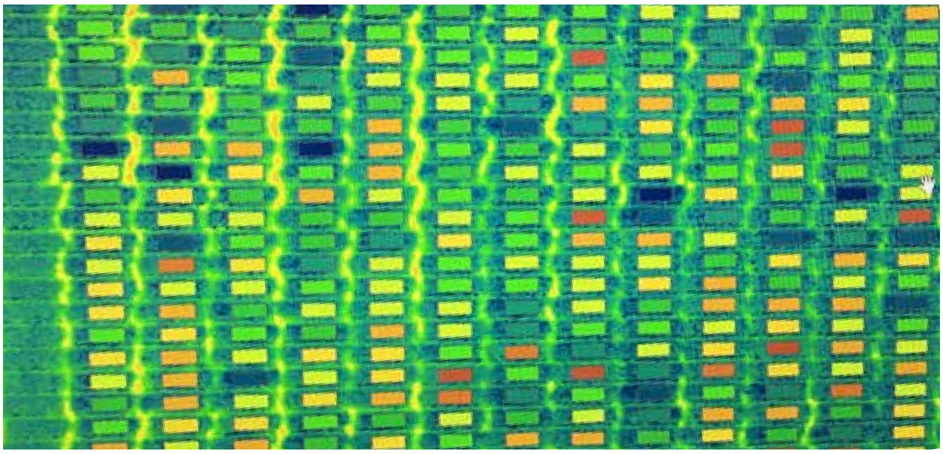
NDVI scores are derived by calibrating sensed data with on-ground measures (e.g. from bare ground, water and vegetation). As such they are not absolute, or immediately transferable between sites. Satellite-derived NDVI values are not available if the areas of interest are covered by cloud.

However, the NDVI can be used to estimate ETc, and as freely available, remotely sensed data it has the potential to more easily provide information for irrigation scheduling than field monitoring. Several *Smarter Irrigation for Profit* trials explored the potential of NDVI:

- Field measurements at an optimised dairy in NSW were compared with results based on NDVI. Both showed a similar pattern of under-watering, which wasn't remedied until there was a sufficient rainfall event.
- A review of opportunities in the sugar industry noted that although NDVI can have issues in fully developed cane canopies, other vegetation indices using different combinations of wavelengths (e.g. Green-NDVI) may be more suitable. There is also potential to supplement free satellite sensed data with information from paid-for satellite imagery.
- Satellite-based irrigation scheduling methods, using NDVI and Bureau of Meteorology information, were trialled for Northern Victoria dairy pastures. They placed minimal reliance on in-field hardware, and avoided the maintenance of costly on-farm instrumentation for the large numbers of bays that are needed on modern dairy farms. The method is considered as readily scalable to large farms, and capable of incorporation into whole-farm automation systems.
- A comparison of weather-station based ETc, in-field ECV crop water use, NDVI generated ETc using IrriSAT and BOM ETo data was completed over two seasons on solid and single-skip (two of every three rows planted) cotton in north west NSW. Good correlation between satellite based ETc data, and ECV based ETc data, were recorded in both solid and skip-row cotton fields across the seasons. This work is still to be fully reported.

In other *Smarter Irrigation for Profit* work, the NDVI and NDRE (Normalised Difference Red Edge) indices were tested as predictors of nitrogen uptake in cotton and maize crops. The results showed strong relationships, with potential to more accurately predict nitrogen uptake and identify spatial variability in responses – which may enable more accurate application of fertiliser and improved nutrient use.

Drones (Unmanned Aerial Vehicles – UAV) have also been used as convenient, low-cost ways to collect plant growth information, which is estimated from UAV imagery. They are very good at observing in-field variation and can fly under covering clouds. The challenge can be interpreting the variability detected and identifying suitable management responses. In *Smarter Irrigation for Profit*, the information from drone-borne sensors has been used in the crop growth model OZCOT, together with historical and predicted weather and soil water data, to predict yields from cotton crops. The technology is a component of the VARIwise software package, which is used to help manage irrigation schedules.



UAV imagery can be used to determine spatial variation using the NDVI index or other systems such as thermal infrared.

Pasture growth – camera based

As part of the trialling of VARIwise and variable rate irrigation on dairy pastures, solar-powered smartphone cameras were used to assess pasture growth – which is usually done by labour-intensive in-field surveys using hand-held rising plate meters. In the *Smarter Irrigation for Profit* trials the cameras were fixed to the travelling arm of a centre pivot irrigator. Besides saving labour, the approach promises improved temporal and spatial resolution, with the data being used to optimise irrigation.

Automated image analysis from cameras usually assesses canopy cover using green channel or near infrared (NIR) imaging, which helps to increase contrast to distinguish canopy from bare soil or stubble. However, NIR cannot detect chlorophyll or stress levels in plants. As an alternative, the trials used texture analysis software to assess the number and length of blades of grass (in a ryegrass pasture) and the greenness of the canopy.

Blade length, density and greenness were found to be correlated to pasture height, but there was no relationship between canopy cover and height. Estimates of dry matter based on the camera data were combined with information about soil type, grazing dates and local weather, and linked with the APSIM AgPasture model to optimise irrigation scheduling using VARIwise – which produced a prescription map for the variable rate centre pivot irrigator.

Smarter Irrigation for Profit has shown that camera-based growth rate monitoring has the potential to reduce pasture survey costs, while giving more timely and more spatially accurate data, which can be integrated into precision irrigation scheduling software and variable rate irrigation control systems.

Soil water – remote sensing

In another *Smarter Irrigation for Profit* investigation, surface soil water content and temperature were monitored using sensors mounted on an airplane (a Polarimetric L-Band Multi-beam Radiometer, digital cameras covering different wavelengths, and a thermal infrared camera). Data was also collected from a buggy-based mobile system, fixed monitoring systems, and a hand-held hydraprobe soil water sensor. A full analysis of the results is yet to be completed, but indications are that remote sensing has the potential to help illustrate the spatial variability of soil water and assist irrigation scheduling.

Weather – rainfall

A daily calculated site water balance is a basic input for precision irrigation. It requires knowledge of the applied irrigation depth, daily crop water use (ETc), and rainfall. Factors affecting ETc are relatively uniform across a field, but rainfall can vary considerably across irrigated areas on large properties. *Smarter Irrigation for Profit* has worked with Taggle low power wide area (LPWA) radio networks to receive data from a network of automated rain-gauges so water balances in large fields or remote locations can be more accurate.

In the trials, Davis tipping bucket rain-gauges were fitted with Taggle transmitters, relaying data to a Taggle receiver tower – from whence the processed data was available via a smartphone fitted with Google maps and a National Centre for Engineering in Agriculture App. The Narrabri Shire Council assisted the project with a network of towers to provide wide coverage in the region. The autonomous system can be set up for $300 per gauge, for up to 10,000 rain-gauges, out to between 15 and 20km from each Taggle receiver tower.

Melanie Jenson

VARIwise has moved into the dairy industry with trials in Tasmania.

Irrigation – furrow advance

Furrow irrigation is the most common form of irrigation for row crops, but faces efficiency challenges through deep-drainage and excess run-off. To optimise irrigation it is important to know how water is progressing along a furrow, to help determine when to stop applying additional water. It is difficult to determine where the advancing water is in large fields with good canopy cover, and practicalities limit the number of in-field sensors that can be used.

Smarter Irrigation for Profit used a combination of soil water sensors, modelling, telemetry and SMS notifications to alert irrigators when irrigation water has reached its end-point along a furrow. The service is especially useful when irrigating distant fields at night time. It uses the Taggle IrriMATE Irrigation Advance Sensors and SMS system - which was developed to detect furrow irrigation advance for use in the IrriMATE process, based around the SISCO surface irrigation model.

Smarter Irrigation for Profit also trialled the use of drones (UAV) equipped with a thermal-infrared camera to provide real-time information as an alternative to manual in-field checks. Using specially developed algorithms to interpret the data, researchers found that the drones effectively detected the moving waterfront across whole fields, down to individual rows, when flown at less than 20 metres height. Accuracy declined at heights of 30 metres. True colour imagery was not able to detect the water fronts through the crop canopy. The use of drone-mounted thermal-infrared cameras shows promise as an aid to optimising furrow irrigation.

To optimise irrigation it is important to know how water is progressing along a furrow, to help determine when to stop applying additional water.

Lou Gall

Irrigation advance sensors being used in the Gwydir Valley, Moree.

Key References

Foley J & Kelderman S. (2018) *Smarter Irrigation for Profit – NCEA Taggle rain-gauge network & Google Earth App*. NCEA. Field Day Handout – GVIA & Waverley Field Days.

Gillies MH & Smith RJ. (2015) *SISCO: surface irrigation simulation, calibration and optimisation*. Irrigation science, *33*(5), pp.339-355

Jamali H, Brodrick R, May T, Smith V & Bange M. (2017) *Irrigation scheduling with canopy temperature sensors*. Presentation to Cotton Conference. CSIRO.

Joshua E. *Remote sensing water use of irrigated pasture*. NSW DPI, Dubbo, NSW.

Long D, McCarthy C & Jensen T. (2016) *Row and Water Front Detection from UAV Thermal-infrared Imagery for Furrow Irrigation Monitoring*. IEEE International Conference on Advanced Intelligent Mechatronics, Alberta, Canada.

McCarthy A. *Smarter Irrigation for Profit – In-season yield potential estimation using UAVs and VARIwise*. NCEA

McCarthy A. (2018) *Automated camera-based pasture monitoring for variable-rate irrigation.* Presentation. NCEA.

North Carolina State Extension Publications *Measuring soil water for irrigation scheduling: Monitoring methods and devices*. https://content.ces.ncsu.edu/measuring-soil-water-for-irrigation-scheduling

Sinha P, Lamb DW & Robson A. *An assessment of the potential of remote sensing based irrigation scheduling for sugarcane in Australia*. (*Report to SRA for RRDP1609*). UNE, Armidale, NSW.

Smith J, North S, Quayle W, Quarisa I, Ballester Lurbe C, Brinkhoff J, Chua L, Griffin D, Hoogers R, Hornbuckle J, Molesworth A, Scott F, Schultz A, Regan P, Rollin M, Zorriasateyn N (2018) *Technical Research Report 3.12*. NSW DPI, Yanco, NSW.

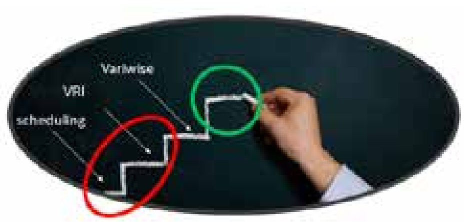
Walker J. (2017) *Multi-source remote sensing for smart automated irrigation.* Monash University, Victoria.

Scheduling

General principles

Irrigation scheduling is determining when to irrigate, at what rate, and for how long. It's about getting the timing, volume and rate right for optimum crop growth or yield. Scheduling with uniform application is the first step toward efficient irrigation. A water balance (current soil water = previous soil water, less evapotranspiration and drainage, plus rainfall and irrigation) is a common starting point. Adding elements of precision – varying application rates in response to variations in soil type or crop requirements, as in variable rate irrigation (VRI) – is another step. Increasing the degree of precision even further, e.g. with a wide array of real-time sensors or sophisticated software, such as VARIwise, is another.

If the basics are sound (good design, performance to specifications, and an understanding of the principle concepts involved in irrigation) it is possible to make step-changes in irrigation operations. Adding additional components (like improved scheduling, precision irrigation and automation) can produce more than incremental change. *Smarter Irrigation for Profit* has been active across all those levels, in recognition of the differing situations and motives of irrigators – while also exploring possible next steps.



McLaren D. (2018)

'Irrigators' range from farmers focused on optimised profit from irrigation and able to mix or swap crops as markets change, to those for whom irrigation is a minor part of their selected production system, such as growing some supplementary feed. Add to that a cross-section of ages and experience, together with diverse climates, soils and delivery systems, plus rapidly evolving technologies, and it is clear that irrigation is not a 'one size fits all' operation.

Specifics

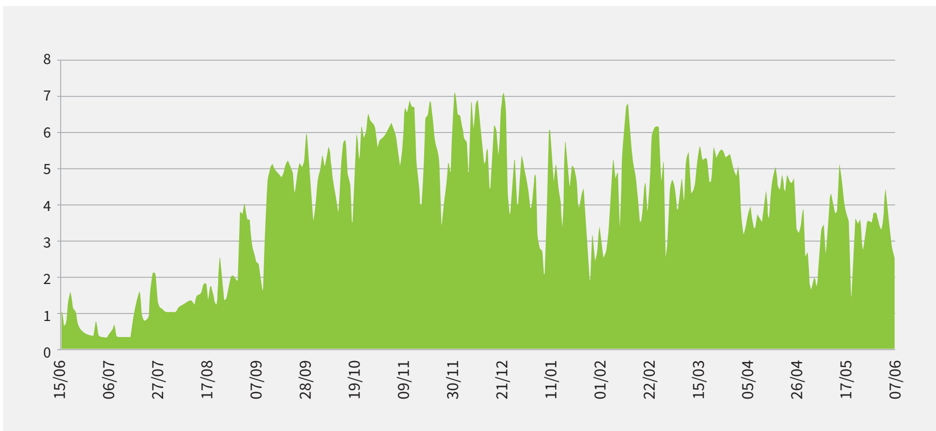
Scheduling tools

There are a plethora of tools available to help irrigators with irrigation scheduling. So many that it can be hard to decide which to use, and adoption rates are not high. *Smarter Irrigation for Profit* is stocktaking the tools to help irrigators, and irrigation advisors, pick an option best suited to them.

The introduction to the stock-list is likely to begin by asking irrigators what they'd like to monitor (e.g. soil, plant or weather based), and how they'd like information (e.g. a smartphone App, an automated message, or a weekly information update). Their production-irrigation system and degree of automation are also likely to influence their selection – as may their access to technical support if required.

IrrigWeb

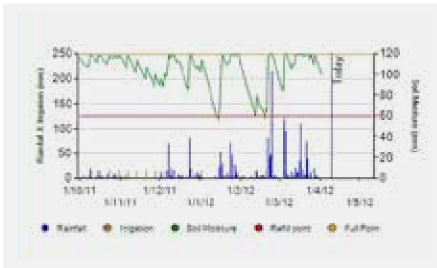
IrrigWeb is a scheduling tool designed for the sugar industry, which incorporates the CANEGRO crop growth model to calculate daily crop water use and yields. It allows for different crop water requirements at various stages of growth; initial, mid-season, and end-season. *Smarter Irrigation for Profit* has been investigating ways to increase the use of the tool, and soil water sensors, within the sugar industry. It is working with industry advisors and a small group of interested growers to upskill them in the use of IrrigWeb, to better appreciate adoption from their perspective and so they may become advocates within their communities.



Examples of IrrigWeb information for sugarcane. Source A Jaramillo.

Scheduling Irrigation Diary - Dairy

In other work an existing tool, 'Scheduling Irrigation Diary' (SID), is being modified and tested for the dairy industry. Modifications include crop growth curves for different pastures and a crop coefficient (Kc) adjustment to cater for pasture removal by grazing or forage cutting. The Diary is a simple web-based tool, which replaces paper records and also generates an irrigation schedule. Five dairy farmers in the Hunter Valley are trialling it, along with soil water sensors. They have provided feedback to designers, to help tailor the tool for dairy applications.



Scheduling Irrigation Diary.
Source: https://sid.usq.edu.au

Satellite based scheduling – dairy

Smarter Irrigation for Profit has sought to include satellite derived information (NDVI) to help schedule the automated irrigation of dairy pastures. A prototype scheduling software package has been developed as a web-based application, founded on a volume (water balance) approach. It has been designed to work with a Rubicon surface irrigation automation solution and the associated FarmConnect irrigation monitoring and management software. However, the scheduling package will be freely available to anyone wanting to incorporate it in other commercial packages, via FarmBuild – a platform used by the Victorian Government to share access to tools and products that advance agriculture.

Green drought – pastures

If the plant root zone dries out, creating an 'empty bucket' with regard to Readily Available Water (RAW), then subsequent irrigation may be insufficient to refill it. In what is referred to as a 'green drought', plants remain green and looking healthy, but their production is well below par.

If, once the 'refill point' is approached, irrigation just replaces water lost through evapotranspiration, it is effectively only partially filling the bucket and fully watering only part of the root system. Plants stay alive, but do not thrive. Growth rates and total production levels will be constrained due to the late start to irrigation at the beginning of the season or after a significant rainfall event.

Refilling the bucket, getting back to field capacity, can be difficult for an irrigation system. There may be limits in how much water can be applied (e.g. the time taken for an irrigation cycle or the maximum rate of irrigation possible), or taken up (e.g. due to low infiltration rates). A long soaking rain may be needed to ever recover. In the end, the 'saving' in water applied due to a late start in irrigation is more than offset by the 'cost' of production foregone.

On-farm – Pasture irrigation

The on-farm trialling of satellite based sensing has been on a dairy farm in northern Victoria, receiving water from an upgraded supply system with total channel control. Surface irrigation of pastured bays is by automated pipe and risers, in conjunction with a pump and storage set-up. Modelled projections of the advised day for irrigation and the duration of the irrigation event are sent to the farm manager by SMS, with two days lead time.

Irrigation is scheduled to apply water to the end of the bay to refill the soil profile from a pre-irrigation deficit of 50mm. An aim is to minimise irrigation duration to get uniform watering and minimised ponding, with surface drainage being less than 10% of the water applied. The trial has guided irrigations to be a little less frequent and shorter than previously, while achieving application efficiencies of 85%.

The scheduling tools and approaches developed in this work at a 'bay' scale are now ready for development at the 'farm' scale. As the farm manager observed, '*The real big challenge now is to link up the advisory scheduling information with all of the other things we need to decide on each day.*'

Farm manager Nick Ryan – second from right and research team Amjed Hussain, Des Whitfield and Andy McAllister.

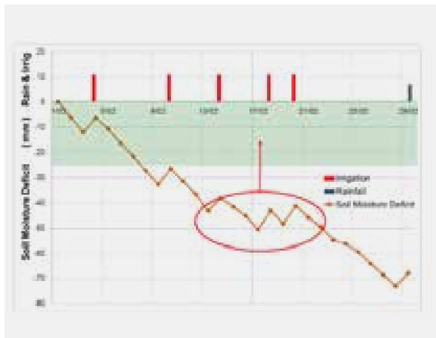
Automated outlet riser from a pipe source.

Timing the start of the irrigation season to keep soil near field capacity, is as important as applying sufficient water during the season to meet the needs of plants.

'It's better to water half the area properly, than all the area without keeping it at the right moisture level. Once it dries it can be very hard to catch-up again.'

'For every day's delay in irrigation start-up there is a potential reduction in pasture utilisation of approximately 105kg DM/ha/days-delay.'

James Hills, TIA.



Insufficient irrigation is failing to refill the soil profile – resulting in 'green drought'. Source: Hills, J.

Avoiding a green drought is achieved by irrigating before the soil profile dries out, and continuously topping up to keep the soil near field capacity.

Reduced deficit irrigation – maize & cotton

Smarter Irrigation for Profit highlighted the importance of monitoring soil water in conjunction with irrigation scheduling strategies. It showed that selecting a soil water deficit level to trigger irrigations should be done in conjunction with an understanding of how quickly soils can be returned to field capacity, given the soil infiltration and irrigation supply characteristics.

A study of irrigated maize revealed that applying water more quickly, often seen as an ‘improvement’ in water management, did not improve crop performance. Initially a soil water deficit of 45kPa was used to schedule irrigation, but soil water monitoring, (matric potential in this case), showed that the quicker irrigation did not allow enough time for the water to infiltrate sufficiently to refill the soil to field capacity. The soil water data highlighted that simply concentrating on improving water management, without understanding the impact on soil water, can be detrimental to crop productivity and profitability.

With the benefit of automation, a smaller irrigation deficit of 30kPa could be used. The earlier irrigation better matched crop water needs and provided a yield advantage.

The new schedule for irrigations would not have been practical with a manually operated system.

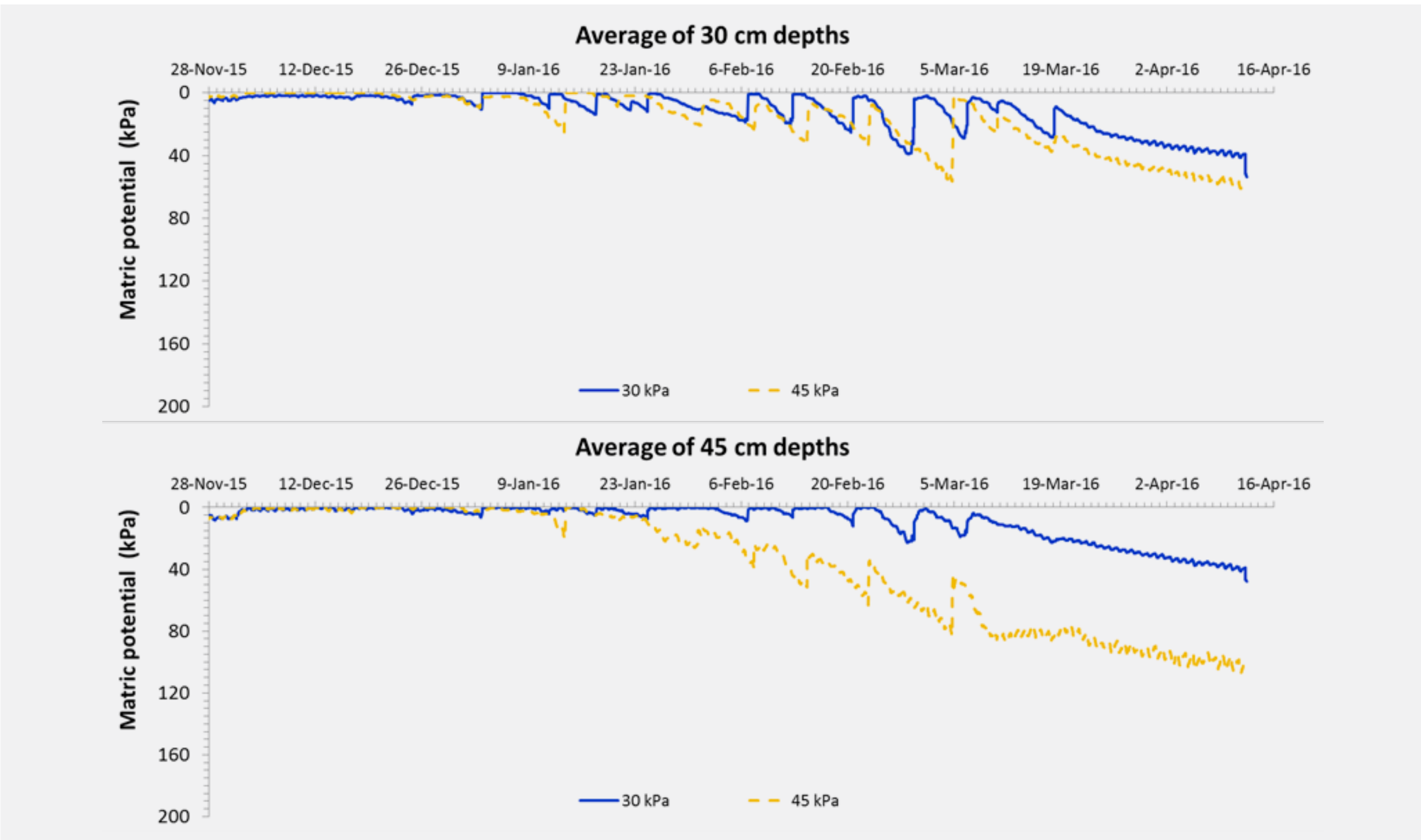
However, with the smaller irrigation deficit the plant was also accessing a smaller volume of soil - which has flow-on implications for productivity and profitability with nutrient budgeting.

Similar results were observed in cotton. Small irrigation deficits produced higher yield but this does not translate directly to the profitability of the crop.

Excessive vegetative growth (which required more management at the end of the season), and delayed maturity of the crop (that exposed the crop to greater risk from weather damage), were also consequences of the small irrigation deficit.

Key References

Foley J, Scobie M & Shippam R. (2018) *Smarter Irrigation for Profit NCEA Technology Transfer. SID for Dairy - Hunter Valley Trial*. NCEA presentation DA Zoom Teleconference.



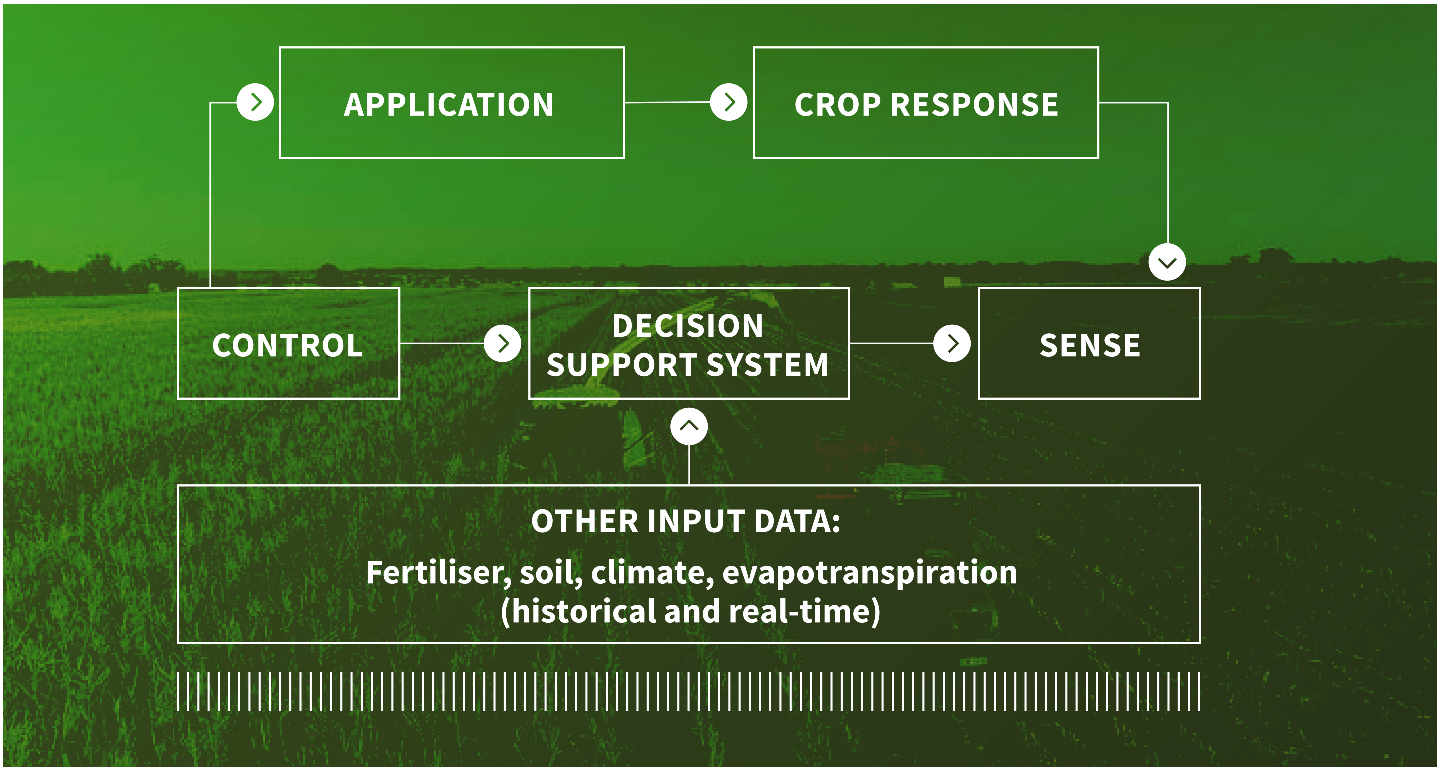
Larger irrigation deficit, 45kPa, is not being refilled during the latter part of the season, (shown by the increasing matric potential at 45cm depth), due to irrigation not matching soil infiltration characteristics and the field being watered too fast. Source: North, S.

Precision Irrigation

General principles

Poor irrigation uniformity results in areas of over and under-watering on uniform paddocks, and is a priority for irrigation set-up. However, in paddocks with variable soils and elevations, uniform applications will also result in areas of over and under-watering due to different spatial requirements. More precision is needed if all parts of a variable paddock are to be irrigated optimally.

Precision irrigation relies on being able to monitor, or sense, variations in plant water need and to variously apply water to meet them. Sophisticated irrigation scheduling links the two aspects, as a decision support or control system. Ideally, precision irrigation occurs as an adaptive process, where feedback in the system enables further improvement. As an example, the VARIwise feedback loop (which is illustrated below) uses APSIM crop models to allow choice between irrigation control for maximum crop yield, or maximum water use efficiency.



Source: Foley, J.

Specifics

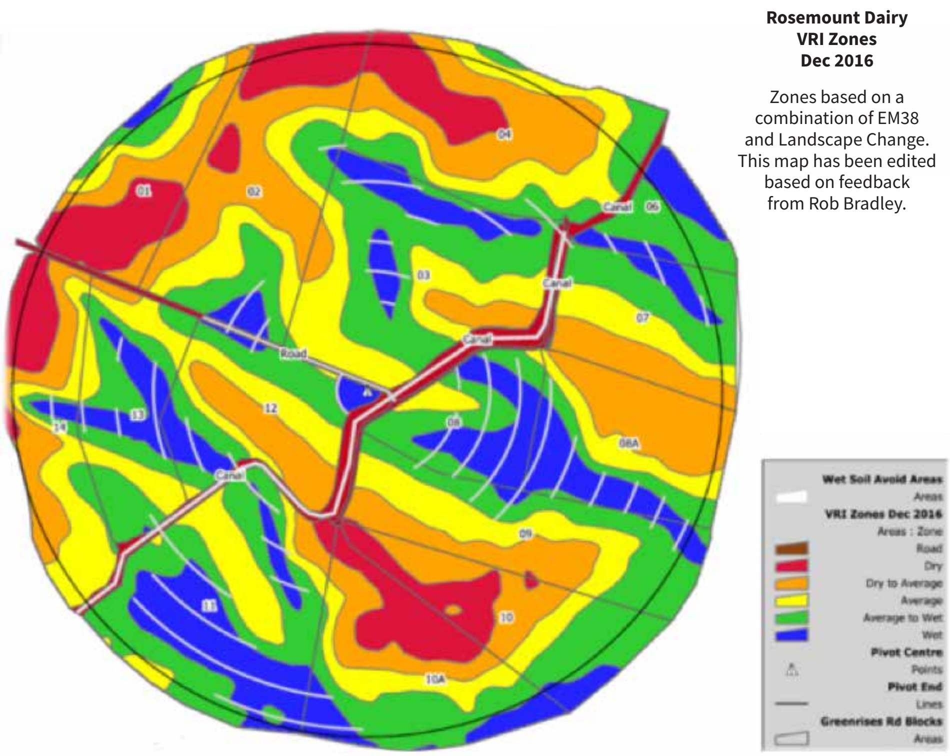
Precise irrigation – variable rate irrigation

Variable rate irrigation (VRI) is the application of different amounts of water to different parts of a paddock. Centre pivot irrigators use this technology, with applied irrigation depths controlled by changes in the speed of travel of the irrigator or the amount of time individual sprinklers effectively operate. It is ideal on areas of variable soil and elevation. It also functions very well when different crops or pastures are grown under the one pivot, and if there are areas (such as laneways or roads) which should not be irrigated.

Good set-up is vital if a VRI system is to be effective. Soil or EM surveys, elevation models and infrastructure maps are used to produce base maps and define management zones, as the foundation for VRI scheduling (see map below). Crop and pasture growth varies as a season progresses, so several zone control maps can be required to reflect the changing requirements.

Some of the immediate advantages of VRI are:

- Savings of water by not irrigating laneways etc. On dairy farms, it has the added value of maintaining dry laneways for stock movement – needing less on-going maintenance, and being better for animal health and welfare.
- Permitting irrigation to start earlier. With variable rate applications, irrigation can occur as soon as the driest areas need it. There is no need to wait for wet areas to dry as they are not watered until irrigation is needed.
- Good prospects to increase production through optimal irrigation. On dairy farms the value of pasture production is realised when the extra pasture growth is converted with increased cow utilisation (increased stocking rate) for more milk production.



Prescription map to control variable centre pivot irrigation. Image: Ag Logic Pty Ltd. Source: David McLaren.

Smarter Irrigation for Profit monitored centre pivot VRIs on several Tasmanian dairy farms, together with soil water and pasture growth monitoring, over three years. As the years progressed the researchers shared increasing amounts of information and ideas with the irrigators, being able to track improvements in irrigation and production as the irrigators increasingly optimised their irrigation. A summary of the benefits, of increased pasture production and water savings, from more precise irrigation and scheduling, for two of the farms follows.

Research team members Dave McLaren and James Hills in Tasmania.

Year Oct-Mar	Average growth rate (kg/DM/ha.d)	Pasture Grown (t DM/ha)	Irrigation (ML/ha)	Rain (mm)	GPW (t) DM/ML
15/16	34*	6.2	6.2	215	0.74
16/17	54	9.8	4.1	319	1.34
17/18	74	13.5	4.6[a]	203[a]	2.04

Improved productivity from changed irrigation practice over three years on Farm 2. Source: McLaren, D.

Detail	Water saving	Improved production	Both
Pivot (ha)	55	55	55
Extra production consumed t DM/ha	0	1	1
Value of extra feed $ / t DM	250	250	250
Water saving ML/ha	1.4	0	100
Value irrigation water saved $/ML	100	100	100
Capital costs $	47225	47225	47225
Years to pay back	**9**	**3**	**Less than 2**

Benefits from irrigation improvements on Farm 3. Source: Dave McLaren

Explanation of the Tables:

- The 'water saving' compares water used with and without a VRI map activated. It is assumed that the map would be used for the entire season, but this is rarely the case.
- The 'improved productivity' figure is derived from a model that was reviewed and verified for the *Smarter Irrigation* project – pending the analysis of growth rate data from replicated sectors, with and without VRI, under the same pivot at the same time.
- The figures for the value of extra feed and water saved are quite realistic for conditions in northern Tasmania.

Variable rate irrigation system used with VARIwise prescription maps.

Precise scheduling – furrow irrigation

For surface irrigation the main irrigation controls are the flow-rate of irrigation water and the duration of the irrigation (i.e. cut-off time). *Smarter Irrigation for Profit* work with furrow irrigation involved measuring inflows, estimating infiltration (using the SISCO - Surface Irrigation Simulation Calibration and Optimisation – model), and simulating irrigation performance to generate recommended inflow rates and cut-off times.

Changes such as increasing the flow rate and reducing the cut-off time can improve irrigation efficiency, resulting in water savings (through less run-off and deep-drainage), and increased production. The systems rely on monitoring devices, (such as through IrriMATE), and a degree of automation for precise, reliable control. See the following section for more information on automation.

IrriMATE & SISCO

The **IrriMATE** process combines in-field measures of surface irrigation water advance, knowledge of soil water deficit, and surface irrigation models for the evaluation, simulation and optimisation of surface irrigation events. It can use the IPARM volume-balance based infiltration model, the older Infilt model, or SISCO to obtain parameters for the modified Kostiakov infiltration equation.

SISCO (Surface Irrigation Simulation Calibration and Optimisation) model is the latest surface irrigation model to be used in the IrriMATE process of measurement and modelling. It has self-optimising capabilities, and accommodates spatial and temporal variability of infiltration, to give a recommended flow rate and cut-off time to maximise performance of the surface irrigation event.

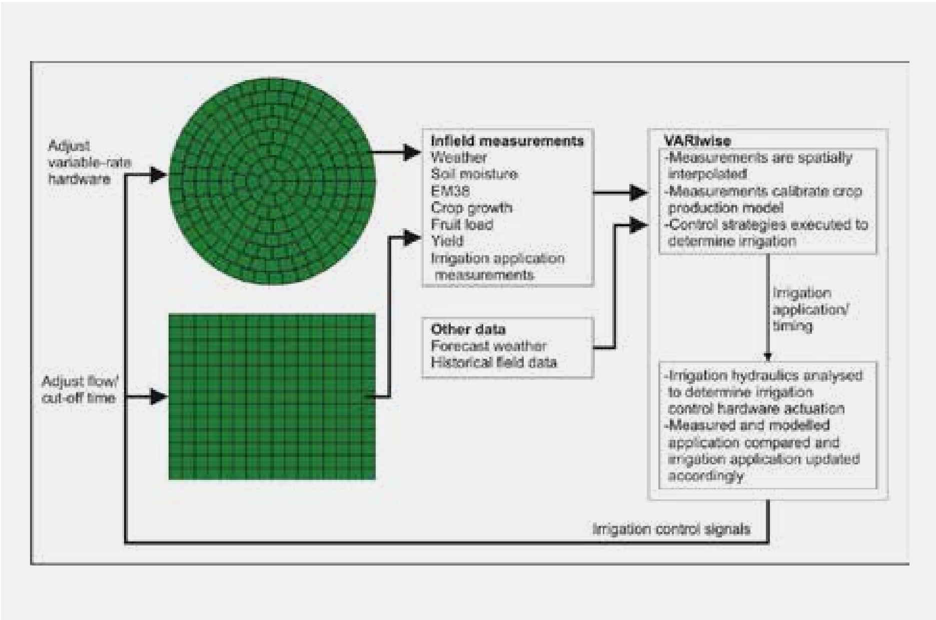
Precise scheduling – centre pivots

For improved scheduling with centre pivot irrigation, *Smarter Irrigation for Profit* extended the use of the VARIwise control platform to commodities other than cotton, for which it was first developed; e.g. dairy. Trials of VARIwise on a 40ha irrigated cotton field in Yargullen, QLD, lead to a 9% water productivity improvement through irrigation optimisation. The farmer now plans to increase irrigated land by 33% by using the optimised variable-rate technology.

This work is also the first time that VARIwise has been applied to a pasture based system, and it has produced increases in pasture production, along with water savings. One of the farmers involved now plans to increase the herd size by 20%, largely due to increased pasture production from VRI technology and improved scheduling aided by VARIwise.

VARIwise uses field sensors (e.g. soil water monitors and low cost, irrigator mounted cameras that track pasture growth), other data inputs (e.g. ETo), and crop growth models (APSIM) to generate irrigation scheduling/control strategies for optimal irrigation. Combined with variable rate irrigation it produces a variable pattern of irrigation, matching crop and soil requirements.

VARIwise is summarised in the figure below.



Summary of the VARIwise system. Source: McCarthy, A.

Key References

Gillies MH & Smith RJ. (2015) *SISCO: surface irrigation simulation, calibration and optimisation.* Irrigation Science, 33 (5). pp. 339-355. ISSN 0342-7188

Hills J. *Precision Dairy Technology. Variable Rate Irrigation*. Dairy Australia.

McClaren D. (2018) *Smarter Irrigation for Profit*. Presentation Knowledge Sharing

McCarthy A (2014) Presentation to IRRICOM

Automation

General principles

The flow of irrigation water from system supplies to, and within, the field can now be controlled automatically. At the farm scale it can range from controlling irrigation valves and gates to controlling the operation of large variable rate irrigation systems. It relies on sensors and telecommunication to control automated equipment, often fitted with solar power panels, permitting the remote control of irrigation through a computer or smart-phone interface. Coupling automation with precision scheduling packages ensures the resultant irrigation is optimal, not just the remote control of automated, poor practice.

Autonomous systems, with adaptive or real-time control by the system itself, are the next step in automation and are becoming increasingly practical. The parts are now often available – it is the integration and user-interface where development is re-focussing. The advent of smart-phone apps enables ease of use and is a key to labour saving.

Specifics

Furrow automation - Sugarcane

Fully automated, furrow irrigation for gravity fed, open channel systems have been trialled in *Smarter Irrigation for Profit*, consisting of:

- Linear actuators on valves
- Pressure sensors in cylinder/pipe
- Flow meters on supply
- Buried water advance sensors
- Rain gauges

The main scheduling controls for surface irrigation are the rate of irrigation and the duration (i.e. the cut-off point). In the Automation of Surface Irrigation in the sugarcane industry trial, safety controls for the inflows and soil water sensors were mainly used. Modifications to the flow rate and reduced cut-off times improved irrigation efficiencies, resulting in water savings (through less run-off and deep-drainage), and increased production (through more uniform wetting patterns). The systems rely on monitoring devices, (such as through WiSA). Automation has also enabled growers to reduce energy costs (by choosing cheaper energy tariffs), reduce vehicle use, and reduce labour costs associated with shifting irrigation sets.

Costs of installation and savings varied depending on farm layouts and the area under automation, ranging from $600 to $2,000 per hectare. Even at double this cost, growers are now installing automated furrow irrigation systems at their cost across large areas. The ease of operation, and not having to be in the field to manage night-time irrigation, has been one of the plusses from the system.

On-farm – sugarcane in the Burdekin

One of the trial cane farms is in the Burdekin River Irrigation Area. The entire irrigation system on the farm is now automated and irrigation can be remotely operated. For manager Aaron Linton, who lives 35km from the farm, this means a big saving in time and fuel.

The automation also allows Aaron to manage his irrigation in ways that would not have been possible if he was manually operating the system. He is now able to run all his irrigation sets overnight and on the weekend, and has been able to change to the cheapest irrigation tariff.

He is also experimenting with pulse irrigation on some blocks where there is poor lateral soakage. This involves irrigating one poor soaking set for an hour, changing to a second set for an hour, changing to a third set with better soakage for four hours, and then switching back to the first blocks for another hour each. This appears to be improving the wetting and infiltration on these blocks, something that would not have been possible without the automation.

The convenience of automated furrow irrigation has greatly reduced average water run times, and the ease of operation has resulted in more regular irrigations - replenishing root zones and keeping soil water within optimal levels, with consequent yield improvements.

Brad Pfeffer

Furrow automation - cotton

As discussed under 'System Selection', siphon irrigation has the advantage of low energy demands, but relatively high labour costs. Low cost automation offers the prospect of reducing operating costs, without increasing energy bills. The sPTB (small Pipe Through the Bank) system is an example.

Fully automated sPTB furrow irrigation is commercially available and viable at ~$1000/ha. Growers have chosen sPTB on very large broad-acre fields, as it provides more precise furrow irrigation control than bankless irrigation systems, at less than half the cost.

Lou Gall

On-farm – small Pipe-Through the Bank (sPTB)

Small Pipe Through the Bank (sPTB) has been implemented on 2,200 hectares at Waverley Ag, (near Wee Waa, NSW), providing fully automated remote control capability. It cost around $1,000/ha, on a 200 ha trial area. Rubicon FarmConnect gates can be remotely opened into a 300 metre wide blind head-ditch, to start 150 pipes per set, from web connected devices.

On an area of roughly 1,200 irrigated hectares at Waverley, seven staff would be engaged to manually start siphons for four hours each day, for every day of a seven day irrigation cycle. There would typically need to be four LandCruiser utes operating during irrigation, to transport staff for siphon work and to monitor water levels across the farm's channel network. Today, one staff member can monitor that same area. The labour cost (at a standard unskilled rate of $32/hr all-inclusive) has been reduced to one seventh.

Complete irrigation costs on the farm have been estimated at between $200 to $250 per hectare, per year. In the farm manager's opinion, automation provides a three to four year pay-back on their investment, and allows them to retain their good staff doing more technical work rather than back-breaking, hot, siphon starting. The lifestyle change on farm is life-altering.

Simple water level monitoring sensors, and surveys of pipe outlets, provide an accurate understanding of the flowrate of each of the 150 pipes in a sPTB set, with the use of one water level sensor. Using a smartphone to monitor water level data from around the farm saves a 10m round trip that would typically be needed at least four times per night and day during irrigation. The same result can now be achieved with two finger taps on a smartphone.

In one of the hottest seasons on record (2016/17), the farm manager was able to trial furrow irrigation optimisation recommendations on 18 hectares. They chose to implement the recommendations on over 1100 hectares that season - increasing the depth applied per irrigation, with lower flowrates and longer times-to-cutoff, compared to normal. In their words, 'This saved our crop.'

Melanie Jenson

Steve Carolan and Andrew Greste.

IrriMATE and SISCO analyses of all irrigations on the trial areas over the last three years have revealed two challenging pieces of information. Through the summer of 2016–17 many of the early furrow irrigations monitored, revealed infiltrated depths of 40 to 50mm, with measured deficits of 65 to 75mm. This challenges the notion prevalent in common crop models that furrow irrigation always satisfies the deficit, entirely – and implies that precise water balances must be generated by combined field measurement and modelling. The second challenge came in the form of a significant change in the infiltration characteristic through the season; which challenged researchers to vigorously pursue the development of a Taggle IrriMATE advance sensor, to continuously and automatically monitor every furrow irrigation event. Success will lower the cost of furrow advance and inflow measurement, and assist in providing precise water balances.

In the first and third season of trials, optimised run times for furrow irrigation reduced flow durations by one-sixth over normal practice, leading to pumped water savings in the vicinity of 20%, or 2.5 ML/ha.

Surface – border-check

A number of factors often combine to generate real benefits for irrigators. Improved water supply (e.g. through system modernisation), can enable full on-farm automation, and automation can capitalise on improvements in irrigation scheduling; removing obstacles to timely irrigation. As an example, other factors besides irrigation compete for a farmer's attention – things like calving or milking or cutting hay on a dairy farm. Automation saves labour and frees a farmer's schedule so they can more easily, and promptly, control irrigation while busy with other activities.

On one of the Smarter Irrigation trial farms in Gippsland, automated outlet timers were installed as part of a trial and provided the farm manager with immediate benefits – including being home in bed instead of in a field managing an overnight irrigation. Ignoring the matter of improved convenience, and looking only at the time/labour saved per year, low level automation saved the manager over $6,000 per year – with payback for the capital outlay ($10,280) within two years.

Centre Pivot – Cotton

Smarter Irrigation for Profit trials of variable rate, centre pivot irrigation of cotton has provided crop yield uniformity benefits on fields with relatively little inherent natural soil variability. Cotton yield prediction from boll counts during the mid to late season is proving to be of value to growers and agronomists.

The work has shown that automated robotic image analysis of important crop model parameters from sensors (camera images off drones, fixed cameras on poles, and centre pivot spans), is essential to the continual re-parameterisation, or tuning, of the crop model to continue to accurately simulate reality.

Autonomous systems

The components for fully autonomous (self-controlling) systems are now available. Sensors, telemetry, automation, and sophisticated scheduling/control packages all exist. Autonomous systems offer the prospect of another tier of benefits for irrigators in the same way that automation does – saving time, labour, and decision-making; providing greater convenience; and resulting in increased productivity and profit.

As one farmer struggling with the apparent complexity of a potentially autonomous system said;

'It's not that simple. I'm making decisions that it's never going to make. Like I'm running out of water, or I've got to run more cows.'

The costs include capital expenditure, operating and energy costs, and system maintenance. There may be costs for professional services as well, such as expert technical advice and the provision of sensed data or sensor services. Trust and confidence in the system from a farmer is a basic prerequisite.

Learnings from social research will need to compliment technical research to develop trust and suitable user-interfaces, with appropriate alerts and options for management intervention.

An emphasis on real-time sensors and feedback may also help build trust and confidence in autonomous systems.

Key References

Davis M, Attard S, Gillies M & Jaramillo A. *Automation of furrow irrigation. Overview, Information Sheet #2 Aaron Linton & Information Sheet #3 Denis Pozzebon*. Sugar Research Australia.

Gillies M, Attard S & Foley J. (2017) *Modernisation of furrow irrigation in the sugar industry: final report 2014/079*. Sugar Research Australia Limited. Brisbane.

Gwydir Valley Irrigators Association – Irrigation Efficiency.

https://www.gvia.org.au/community-and-industry-initiatives/irrigation-efficiency

Gwydir Valley Irrigators Association - video clips:

- Integration of automation system into irrigation in the Gwydir Valley https://vimeo.com/241117788

Sugar Research Australia - Furrow automation in sugar cane, case studies – video clips:

- https://sugarresearch.com.au/caneclip/automation-furrow-irrigation-aaron-linton
- https://sugarresearch.com.au/caneclip/automation-furrow-irrigation-denis-pozzebon
- https://sugarresearch.com.au/caneclip/automation-furrow-irrigation-russell-jordan

Learning & Capacity Development

Participative research in action is a hallmark of Smarter Irrigation for Profit.

Context – Research and adoption

Smarter Irrigation for Profit has engaged strongly with irrigators through on-farm trials and a network of farmer managed ('optimised') learning sites across Australia. Farmers and researchers, and in many cases private providers as well, have interacted and shared ideas and knowledge. It has been an example of participative research in action, and there have been many associated field days and tours providing opportunities for farmers to learn from other farmers as well. These measures have helped to develop the understanding, knowledge and capacity of all those involved.

All the elements of research, development and extension have been in the Project – as has the delivery of technology by private providers. It may be time for a new paradigm - of Research, Development, Extension and Delivery. The attention to 'delivery' is timely and reflects two changes in context:

- Opportunities for improved irrigation productivity and profit seem to hinge on doing the basics right (even in 'simple' systems), and the adoption of integrated high-tech packages including sensed data, automated equipment, and sophisticated scheduling or control platforms. The latter can leave irrigators requiring specialist technical services.
- The changing nature of business and the 'internet of things', where enterprises operate in an increasingly connected, digital world. In this world, approaches like 'data as a service' (where an irrigator would simply subscribe for the provision of data required for wise scheduling) step over the challenges of getting farmers to worry about things like in-field sensors and their maintenance, or gathering information themselves. The delivery of ag-tech services is an opportunity for a new generation of service providers.

Melanie Jenson

Findings from Smarter Irrigation for Profit dairy pasture irrigation trials explained at a farm field day at one of the five farms involved in the project in Tasmania.

Melanie Jenson

Farm field day Moree, NSW.

The face of rural Australia is changing. Farmers are as connected as any other sector of the community through social media (subject to the telecommunication challenges of the bush), while increasing size and business acumen, coupled with labour supply and management challenges, are driving changes in operations. There is likely to be much to learn about optimising social media and communication with corporate agriculture as extension tools, and *Smarter Irrigation for Profit* has a foot in the door to that arena.

A factor that will remain however, is the diversity amongst irrigators – their preferred learning styles and the degree to which they embrace different aspects of their production systems. That diversity may run through other ways of segmenting irrigators such as by irrigation system, commodity or production system, age, technical bias and technical skills, or the scale of operation. Any future program of irrigation research will need to retain the ability to connect with the diverse interests within the breadth of Australian irrigators.

Any future work must also acknowledge that current benchmarks in practice are uneven – there are highly varied rates of adoption for irrigation technologies. Adoption of practices like soil water monitoring is high in some industries (e.g. cotton) but low in others (e.g. dairy and horticulture). Different drivers in various production systems mean the relevance of a single practice may differ between commodities.

A recent investigation for horticulture highlighted reasons for low adoption, or trial and subsequent disadoption, concluding that tools for irrigators needed to be simple to install, adopt, and interpret, and be supported by good service. They advocated social research, a more holistic approach to frame technologies, an emphasis on irrigation scheduling and nutrient tracking, and building capacity for irrigation design.

Different drivers in various production systems mean the relevance of a single practice may differ between commodities.

Melanie Jenson

Melanie Jenson

Dairy farmers from the mainland states out and about in Tasmania.

Extension & Adoption

General principles

In *Smarter Irrigation for Profit*, grower-led, field-scale trials have been widely used to show the practical implications of incorporating new technologies, ahead of plot-scale replications to investigate the technologies. It has enabled exploration of the issues behind farm scale performance that are otherwise left to early adopters to explore and sort out. It also provides a ready platform for farmers to share directly with other farmers through field days, videos and pod-casts. Social media can help in sharing the latter.

Specifics

Knowledge needs

A significant challenge in irrigation extension is the wide range in knowledge needs amongst the equally wide range of irrigators.

For many, e.g. those new to irrigation or where it is a minor aspect of a much larger production system, the needs may be for a good basic understanding of irrigation (e.g. field capacity and Readily Available Water), their property (e.g. soil characteristics), and how to go about it (e.g. design and scheduling) – rather than more high-tech options. Information about the concepts, examples of options, and checklists for system development and operation may meet their needs.

Stimulated by *Smarter Irrigation for Profit*, the dairy industry (where irrigation can be a lesser part of the total production system), is about to develop an industry-based training package, based on the cotton industry's WATERpak but including irrigation agronomy for different pastures.

Those for whom irrigation is a very high priority will have more technical and operational needs; seeking detailed information and evidence. A mix of communication channels and information products will be needed to cater for that diversity.

The conclusions of a 2004 review of the knowledge needs of cotton and grain irrigators are probably still relevant today. The review concluded their needs would be met by:

- Personal contact (where possible one-on-one)
- Regional research
- Detailed, practical irrigation training for consultants
- Better targeting consultants in activities
- Concise practical information (especially *Cotton Tales*)
- Cross-industry co-operation
- Developing integrative information tools (e.g. WATERpak, and trial books).

Managing the Mix

Smarter Irrigation for Profit used a broad mix of 'extension' tools in recognition of the varied learning and information needs of irrigators. The mix included:

- **Participatory, action research**, with a mix of farmers and farms. Individual farmers, their neighbours and personal networks soon appreciate the benefits and challenges of technology and they, and the site, become engines for wider extension.
- **Workshops** provide the chance to get into detail, with service providers or farmers wanting that level of information.
- **On-farm field days and tours** let farmers see for themselves, and hear from farmers – as do discussion groups with their peers. Cross-commodity tours have been useful in making people 'stop and think', while commodity specific tours are of wider and deeper immediate interest. A good challenge with both is to maintain momentum and keep up the enthusiasm after a trip.
- **Rural media** is still a highly regarded source of information and has been widely used.
- **Social media** has provided up to date information and helped direct people to websites with more information and podcasts or videos.

Iva Quarisa

Brendan Watson from Kilter Rural at Griffith attended 2017 IREC Max Northern Tour which included visiting key learning sites at Wee Waa and Moree in Northern NSW. "Since the tour to Moree last season we have set up a 30 hectare trial site of the automated siphon system we saw at "Waverley". Brendan has now expanded to set up another 80 hectares with plans to convert 500 hectares all up.

- In districts where field day attendance is low, podcasts have been well received as people can listen live and join in with questions, or farmers can listen later while busy on other work – or even just driving into town.
- Weekly irrigation newsletters with information on hot topics (e.g. automation), or a monthly reminder of what is coming up irrigation-wise for local farms, have also been used for communication.

Some trials have held weekly phone-conferences or meetings with involved farmers to talk through information and irrigation management options for the coming week. A degree of 'hand-holding' can be needed to begin with – 'here's how you go about it' – when introducing new technology with seemingly untested ramifications for farm management.

Partnerships

Through *Smarter Irrigation for Profit*, other players are also getting on board, to help promote the adoption of 'smarter irrigation' practices. They have included:

- Regional Natural Resource Management bodies, providing incentives for on-ground action or additional educational materials.
- Local government, assisting with infrastructure that will enhance automation and telecommunications for data-handling.

Service providers, such as irrigation advisers, have been involved in a two-way exercise, where they provide information, ideas and in-kind services, and get access to researchers and emerging technology.

Equipment (hardware and software) suppliers, providing assistance to demonstrations or offering innovations for field-testing and feedback.

These examples highlight the importance of regional service chains being in place – and hint at the wider economic multipliers arising from irrigation. The more partners in irrigation extension there are, the greater their combined impact. In the same vein, if key elements of the service chain are missing, e.g. a lack of technically skilled service providers, then the more difficult it is for irrigators to adopt measures they are interested in. *Smarter Irrigation for Profit* has identified a need for the development of technical services in some regions.

Guy Roth

Key References

Callan VJ, Christiansen I, Harris G & Cotton CRC National Extension Network. (2004) '*Knowledge management for cotton and grain irrigators*.' Cotton CRC.

Gwydir Valley Irrigators Association video:

- Why Farmers Get involved in Research and Field Days: https://vimeo.com/258894152

Yiasoumi W & Giddings J. (2016) '*Review of current vegetable irrigation technologies - VG14048 Desktop Review and Project Extension*.' NSW DPI (Local Land Services, Greater Sydney), Horticulture Innovation Australia, and Irrigation Australia.

The more partners in irrigation extension there are, the greater their combined impact.

Research Directions

Researchers involved in *Smarter Irrigation for Profit* have reflected on the needs for any follow-on research program. Points raised in their reflections follow.

Monitoring

Some issues have arisen with the robustness of soil water sensors, during field trials. Farmers tend to expect the devices to be set-and-forget but there have been cases of failure after only a few years – limiting the enthusiasm of farmers recommending them to other irrigators. New, or more robust, technology would assist in the promotion and adoption of soil water sensors. Remotely sensed soil water data could also assist in understanding the spatial variability of soil water within the soil profile and across a field.

Smarter Irrigation for Profit advanced the technologies associated with infrared canopy temperature sensors and camera-based growth rate monitoring. Both technologies have potential applications and could benefit from further development, testing, integration with other sensors (e.g. integrating soil and canopy data) and with scheduling tools, plus the investigation of pathways to adoption or commercialisation. However, there are a range of other plant sensors that could be included in future evaluations.

A challenge is to introduce automation across a farm, without increasing the complexity for irrigators.

Pasture irrigators would welcome advances in the sensing or ground truthing of pasture growth rates. Unlike cropping production systems, pasture monitoring has to contend with the periodic removal of canopy by stock or mowing for conversion to hay or silage.

As the range sensors and their output increases there may need to be more attention to data analytics and integrating data from multiple sources into decision support tools for irrigation scheduling and control.

Scheduling

Similarly, there are prospects to further develop scheduling tools trialled in *Smarter Irrigation for Profit* (such as the Scheduling Irrigation Diary for Dairy), and options to enhance or supplement plant-based sensors for early season irrigation scheduling (when sensed signals from canopy cover can be over-ridden by the soil background). Further exploration of means to incorporate remotely sensed data may also be worthwhile.

Advances in scheduling packages may need to include more agronomy (growth modelling) aspects. Any future tools will need to be readily scaled-up for application on large farms – while reducing the complexity of decision-making - if irrigators are to be confident to use them.

Large farms with complex production systems involve inevitable trade-offs between plant requirements (different crops / varieties), and constraints imposed by the irrigation supply and by other farming operations (grazing, spraying, etc). To adopt scheduling systems other than the calendar, farmers need a system that can forecast what will be happening and where, and that adapts as conditions change.

Automation – surfing the crest of a wave

Researchers believe the irrigation industry is on the verge of a step-change, with automation driving gains in productivity and profit. There are associated questions in improving elements of automated systems (e.g. energy options with micro-grids and solar/batteries), as well as how to bring all the elements together in user-friendly and capital efficient ways, and to scale up to a large farm level. A challenge is to introduce automation across a farm, without increasing the complexity for irrigators.

An approach already being trialled is to have sub-components of an automated system evaluated by experienced extension officers and agronomists, for advice on the staged delivery of outputs.

Climate risk

Risks associated with climate will always be present for irrigators, putting a focus on developing systems to respond when water is scarce, to minimise losses (such as through evaporation from soils and on-farm storages and supply channels), and to help plants cope with extreme heat.

Design for Adoption

Adoption, productivity and profit have been central to *Smarter Irrigation for Profit*. The emphasis placed on those aspects has helped researchers explore ways to maximise the adoption and gains from smarter irrigation practices. Several themes have emerged for future research or application.

One theme is a deeper consideration of the practices themselves – the reasons why they may not be adopted as well the gains they may provide. There may be options to include social researchers in research teams, or to make more use of tools designed by social researchers, such as ADOPT – which highlights the importance of 'relative advantage' and 'trialability' to adoption. Some early applications of this approach in *Smarter Irrigation for Profit* have already raised questions about whether more effort should be placed on getting farmers to ask the right questions or upskilling advisers to better present relevant information.

Some researchers have spoken about these matters as a need to better understand the value proposition being presented to irrigators, in order to get a better focus and achieve wider impact through adoption. It involves understanding the end-users needs and assessing how well they are met, not just better promotion of research outputs. Grower-led 'participative' research can help ensure researchers understand the end-user needs from the beginning.

Agronomy

Smarter Irrigation for Profit has had limited involvement in crop or pasture agronomy. Sometimes improvements in agronomy are required to supplement changes in irrigation practice, so there may be scope to introduce more agronomy in future collaborative irrigation research programs.

As irrigators have better appreciated concepts like Readily Available Water and seen how their systems operate there has been interest in better using available water. Examples are double-cropping (e.g. options to go with rice) or alternative (e.g. deeper-rooted) pastures.

Capacity development

The network of grower-led field sites used by *Smarter Irrigation for Profit* has proven to be very effective, and there is strong support to see them maintained, if not expanded. More sites across a wider range of landscapes would further spread the benefits of Smarter Irrigation. There may also be benefit in supporting ‘communities of common practice’ to bring together farmers from different regions trialling similar technologies, e.g. a national VRI users forum.

Further advantages could come from standard benchmarking across the network and referral to some common, high-level, research questions. More comprehensive data on improved irrigation efficiency, productivity and profit (e.g. $/ML) would increase irrigator willingness to adopt new techniques and make infrastructure investment decisions. High-level research questions provide a common focus for different sub-projects and enhance communication and shared efforts at problem solving. They can help construct a framework for research including risk assessment (e.g. climate variability and water availability), profit and sustainability.

Working with additional commodity partners could enhance the Project and, at a different scale, it could be beneficial to stimulate links with similar research programs and researchers overseas. International collaboration is likely to generate advances, in the same way that cross-regional and cross-commodity collaboration has in *Smarter Irrigation for Profit*. It may also attract opportunities to include PhD students in the program to maintain and build future research capacity.

Regional trials have exposed the limited capability to implement and service advanced technology in some rural areas, which will restrict the uptake of precision, automated irrigation systems. As an example, the variable rate irrigation technical support capability for the dairy industry is low and limiting the uptake of VRI technology in some regions. A future program could explore options to fill that gap, such as training advisers, encouraging a new generation of service providers, or creating an environment conducive to ag-tech start-ups and stimulating regional development.

Melanie Jenson

Researcher James Hills, TIA, Joseph Foley NCEA and Queensland dairy farmer David Roderick at a key learning site in Tasmania where variable rate irrigation and VARIwise is being used for the first time in pasture production.

Melanie Jenson

Irrigators from the Riverina Gavin DalBroi and Mat Stott visiting optimised irrigation farms in the Gwydir Valley. Mat’s farm at Darlington Point is also a key learning site, where he has implemented knowledge from travel to other regions.

Guy Roth

Smarter Irrigation team on tour in southern NSW.

Guy Roth

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