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Background

Several irrigation scheduling tools have been developed and used overseas and in Australian agriculture in the last four decades. Some of those tools have been developed by research institutions and a handful by private investors with an eye towards commercialisation. Since the 90's, considerable efforts have been made by the different industries to get farmers and irrigators to understand and use these products.

Accurate irrigation scheduling is not widely practised in the sugar industry despite the many scheduling tools available to sugarcane growers. This leads to much less water use efficiencies than what could be achieved in theory. Irrigation scheduling can be defined as a programme of irrigation determining the amount of water and timing of application. Scheduling methods aim to maintain the soil water content in the optimal range by direct monitoring of soil water content or by estimating the soil water content through water budgeting (Oliver and Singles, 2004)

In the sugarcane industry in Australia, the use of irrigation scheduling tools has been rather limited in spite of the recognition that water is one of the main drivers of production. In September 2017, Sugar Research Australia (SRA) held an industry wide Irrigation Forum, in which the general consensus was that irrigation was the biggest single driver of productivity above other factors that the industry could control. Recent grower surveys[1], indicate the over 63% of the growers interviewed do not use any irrigation scheduling tool; so three out of five sugarcane farmers do not measure water in the soil or as inflow applied in each irrigation event. Statistics from the last decade, indicated that only 9% of growers plan future investment in soil water monitoring equipment.

Objectives

This study was commissioned to Sugar Research Australia (SRA) and AgriTech Solutions to evaluate the irrigation scheduling tools in the sugar industry and assess the feasibility of using satellite imagery as part of a scheduling platform for the sugarcane industry.

Methods

The methodology followed comprised the following aspects:

   a) *A review of industry requirements*
   - Irrigation use in the industry was summarised by district.
   - Industry advisors in each irrigated sugar district were surveyed for their attitudes to irrigation scheduling and their knowledge and/or experience of use of current and previous scheduling tools.

   b) *Capabilities of available scheduling tools*
   - Existing tools were evaluated in terms of their ability to provide for the scheduling needs of the sugar industry and their usefulness in practice (accessibility, ease of use, technical support, and cost).

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[1] SRA Grower Survey 2017 Report.

c) Potential for satellite imagery as part of a scheduling platform[2]
- The current and planned use of satellite imagery in irrigation scheduling was reviewed in other industries in Australia and, where relevant, overseas (e.g. in the sugar industry in South Africa).
- Potential for satellite imagery in Australian sugarcane will be evaluated according to required resolution, likelihood of obtaining suitable images at the relevant times of year, cost, delivery providers and inter-operability with scheduling platforms.

d) Uptake of IrrigWeb
- IrrigWeb, which is currently being trialled in some districts of the industry with financial support from the Queensland Rural Water Use Efficiency Initiative, will be evaluated by a survey of users and future development and accessibility needs assessed.

Results

A review of industry requirements

Irrigation practices in the sugarcane industry in Australia are essentially divided in two: areas under full irrigation and areas under supplemental irrigation. Irrigation is vital for the sustainable growth of sugarcane production in rainfall-deficient areas such as the Burdekin and some areas in the Bundaberg and Tableland regions. Efficient use of irrigation water remains a major concern because of increasing competition for water, major regional environmental concerns and a pressing need to improve productivity and profitability.

At an industry forum held in September 2017 in Brisbane, two topics were deemed high priorities: i) increasing the use of appropriate sensors and, ii) measurement and scheduling tools. Likewise, an on-going support for irrigation scheduling tools was listed as a way to increase irrigation efficiencies. The same forum determined that a platform that integrates measurements, scheduling tools and irrigation strategies was needed, so that growers are enabled to make decisions given their water allocation and their risk towards climate forecast (e.g. delaying irrigation to save water for a dry period, irrigating too soon and over irrigating or exhausting the limited water allocation well before harvest). Other important industry requirements discussed at the forum were those related to:

- Irrigation volumes and timing may be sub-optimal due to lack of understanding of irrigation principles, including the economics of irrigation.
- Lack of understanding of risk and uncertainty around climate forecasts for irrigation planning.
- Doubts about the return on investment from irrigation are resulting in water allocations not being used and therefore productivity losses.

The above concerns are intrinsically linked to irrigation management and particularly, proper irrigation scheduling.

The 2017 Grower Survey[1] carried out by SRA, reports that one of the main constraints to productivity is irrigation (64% in the Southern Region, 45% in the Burdekin, 32% in the Central Region and for 32% of the large producers). As far as the use of scheduling tools was concerned, 63% of the respondents did not use any tool (56% in the Southern Region, 69% in the Central Region, 55% in the Burdekin). Seventy-six percent of the small producers and 70% of the medium-size do not use irrigation scheduling tools. One of

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[2] This study was commissioned to the University of New England, the report presented in the Appendix 1.

the conclusions from the 2017 Grower Survey analysis was that a small proportion of sugarcane farms measured irrigation volumes or used scheduling tools; consequently more could be done to encourage these important practices.

Some industries have found it easier to start on the scheduling road than others. Cotton and grapes, for example, have been relatively strong adopters of irrigation scheduling. Others, such as sugar and vegetable production, lag behind (Stirzaker, 2006)

Advisors and extension officers involved in on-farm water management in the sugarcane industry were interviewed about their attitudes to and use of irrigation scheduling and their knowledge and/or experience of use of current and previous scheduling tools. The people surveyed were located in the Far North, the Burdekin, Bundaberg and Brisbane.

Capabilities of available scheduling tools

In the Australian sugarcane industry, both soil-water-content and soil-tension type of sensors have been and are currently being used. Table 1 shows the tools that have been or are currently available for use in extension as aids in irrigation management (scheduling):

Table 1. Main tools used for irrigation scheduling in the Sugarcane industry in Australia

Tool	Type
Tensiometers	Soil Moisture Sensor
Gypsum Blocks (G-dots)	Soil Moisture Sensor
Mini-pans	Gauge
Capacitance Probes	Soil Moisture Sensor
CropWaterUse[3]	Water Balance Model[4]
Watersense[5]	Crop Model
IrrigWeb	Crop Model
Scheduling Irrigation Diary	Water Balance Model

In sugarcane, it is highly recommended that stalk growth measurements are carried out to calibrate soil moisture sensors. Stalk growth rates are sensitive to stress, and in particular water stress. Understanding the relationship between growth rates and sensor values (readings) will provide guidance on the timing of irrigation events, i.e. when to irrigate. This technique also helps to identify water holding capacity variability within and among fields (SRA, 2014)

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[3] A new version of CropWaterUse was made available during the time of this evaluation which is now called waterschedpro and can be found at www.waterschedpro.net.au

[4] Developers of CropWaterUse deliberately did not include a module for sugarcane as at the time of its release, efforts towards irrigation scheduling tools for the sugarcane industry were diverted to WaterSense.

[5] WaterSense is no longer supported by its developers (SRDC, CSIRO, CRCIF).

A tensiometer measures the soil water potential which is the force with which water is held in the soil. As soil dries, plants have to work harder to extract the soil water, this is shown as an increase in the reading on the tensiometer gauge. As the soil dries, water is sucked out of the tensiometer through the ceramic tip. This creates a vacuum in the tube which is registered on the gauge. When the soil wets up again, through irrigation or rainfall, water moves back into the tip and the vacuum is reduced (SRA, 2015).

Gypsum blocks consist of a pair of electrodes embedded in a block of gypsum. A reader is used to measure the electrical resistance between the electrodes under the presence of moisture and those signals are related to soil moisture tension, that is, how hard it is for the plant to extract water. G-Dots use a similar principle as the gypsum block, with the electrodes embedded in a patented granular quartz material. GDots can be used in most soil types (although not recommended for use in light sands and heavy or cracking clays) and have an operational range of 0-100 kPa (SRA, 2017).

Minipans were once deemed to be one of the easiest and cheapest irrigation scheduling tools to use and to calibrate. For a number of reasons that are not part of this report to elaborate on, their use has declined in the last 10 years. Crop growth is recorded against evaporation from a container to determine the trigger point for irrigation. Once calibrated the minipan is used and maintained by waiting for the trigger point to be reached then refilling the bucket. Minipan deficit figures are not a measurement of actual soil moisture deficits. They only provide a guide on when to irrigate and were only recommended when the stalk height reached around one metre (SRA, 2017).

A capacitance probe measures water content by detecting how easily an electric charge travels through the soil. In continually logged systems (for example, EnviroSCAN and AquaSpy), the sensors are connected to a central data logger by cabling or radio frequency to record sensor readings. The probe measures at multiple depths. These can be analysed separately or combined to determine the moisture availability. The data logger records moisture variation at regular time intervals. The trends that are logged are used to determine optimal irrigation scheduling. Capacitance probe deficit figures are not a measurement of actual soil moisture deficits. They only provide a guide of when to irrigate not how much water to apply (SRA, 2015).

Crop models such as the Agricultural Production Systems Simulator APSIM and Canegro (specific for sugarcane), mainly used in research, have capabilities for irrigation scheduling but were not part of the survey. These crop models are not intended for growers or advisors as an extension tool, although research has been conducted in the use of APSIM as a tool for advisory staff[6]. Both models are similar in their ability to address production and research problems. The models use daily weather data to simulate canopy development, interception of radiation, biomass accumulation and partitioning. They simulate the effect of water stress and lodging on photosynthesis, growth and sucrose storage. To make these sophisticated, researcher-based crop models more accessible and user friendly for irrigators and extension staff, web-based versions, first WaterSense and then IrrigWeb, were developed.

Both WaterSense and IrrigWeb developed a simple user interface, allowing the farmer to customise each field with site specific parameters such as crop start and harvest date, crop class, soil type, water holding capacity, and burnt or green harvesting. Rainfall and irrigation quantities are usually entered manually by the farmer, while the local weather is automatically downloaded by the software from the SILO network or a locally installed weather station with telemetry. The generated irrigation schedule indicates the calculated date of the next irrigation and the volume to be applied. IrrigWeb also generates a number of reports that summarises the water balance for each field along with actual and predicted yields. While WaterSense

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[6] Hardie *et al.*, Can APSIM be used by advisory staff at a local level?. Proceedings Australian Society of Sugarcane Technologist, 2000.

delivered benefits to the industry, a lack of financial support resulted in WaterSense's demise around 2012. Since then, IrrigWeb has been developed by a commercial company (SQR Software Pty Ltd).

Scheduling Irrigation Diary (SDI) is a decision support tool developed by the National Centre for Engineering in Agriculture (NCEA) with simple irrigation recording and scheduling features based on evapotranspiration (ET) and crop coefficients. The Scheduling Irrigation Diary allows irrigators to record irrigation and rainfall while also calculating daily crop water use. The Scheduling Irrigation Diary assesses crop water needs based on the irrigation amount, irrigation frequency, rainfall and crop water use. The tool provides a useful reporting mechanism for users whilst allowing this data to be collated for benchmarking purposes. Nevertheless, SID is different to IrrigWeb/WaterSense in that it does not have a sugarcane specific crop model calculating the crop coefficients on a daily basis

The use of soil water monitoring equipment and irrigation scheduling tools have increased over the last decade although the wide adoption of these tools is still at low levels in the industry. Industry and government investments in extension and training services coupled with the provision of subsidies to purchase new equipment have contributed to the promotion of these tools.

Interviews with Industry Advisors

Industry advisors were surveyed for their attitudes to irrigation scheduling and their knowledge and experience of use of current and previous scheduling tools. Table 2 lists the industry's representatives who were visited and interviewed. Figure 1 shows a map of locations where the industry representatives were interviewed.

Table 2: District Representatives

Agency	Region
Canegrowers	Brisbane
Canegrowers Tablelands	Mareeba
Bundaberg Sugar Services	Bundaberg
Burdekin Productivity Services	Burdekin
Mackay Area Productivity Services	Mackay

The existing tools in Table 1 were evaluated in terms of their ability to provide for the scheduling needs of the sugar industry and their usefulness in practice (accessibility, ease of use, technical support, and cost). A short questionnaire was created to survey the different levels of awareness, promotion and opinion of the local advisors on irrigation scheduling tools available and the level of use of scheduling tools in different regions (number of units being regularly used compared to the number of fields in the region) (Table 3).

Table 3: Farmer's Level of use of the Scheduling Tools analysed in different sugarcane regions

Tool	Agency	Few	Moderate	High	Don't know / N.A
Tensiometres	Mareeba	X			
	Bundaberg		X		
	Burdekin	X			
	Mackay	X			
G-dots	Mareeba	X			
	Bundaberg	X			
	Burdekin		X		
	Mackay		X		
Mini-pans	Mareeba	X			
	Bundaberg	X			
	Burdekin	X			
	Mackay	X			
Capacitance Probes	Mareeba		X		
	Bundaberg		X		
	Burdekin	X			
	Mackay	X			
CropWaterUse	Mareeba				X
	Bundaberg				X
	Burdekin				X
	Mackay				X
WaterSense	Mareeba				X
	Bundaberg				X
	Burdekin				X
	Mackay				X
IrrigWeb	Mareeba		X		
	Bundaberg	X			
	Burdekin		X		
	Mackay	X			
Scheduling Irrigation Diary (SDI)	Mareeba	X			
	Bundaberg	X			
	Burdekin	X			
	Mackay	X			

Figure 1: Locations of where the industry representatives were interviewed.

Locations where interviews took place.

The Precision Agriculture Research Group of the University of New England, was commissioned to undertake the study of the Potential for satellite imagery as part of an irrigation scheduling platform. A comprehensive report was completed and submitted to SRA in August 2017. The review explores the usefulness of remote sensing (RS) based methods for irrigation water management, and irrigation scheduling for sugarcane. The main body of the report focusses directly on operational dimensions of remote sensing for irrigation scheduling for sugarcane. The review then discuss the strategies for RS based sugarcane irrigation scheduling in Australia. The report's Appendix provides the background to the fundamentals of sugarcane growing and biophysical processes and parameters which need to be understood in designing an appropriate scheduling tool. The report was accepted after a SRA peer-reviewing process. The report can be found in Appendix 1 of this final report.

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[7] This study was commissioned to the University of New England, the report presented in the Appendix 1.

Background

IrrigWeb uses a sugarcane specific crop model, Canegro. The main aim of IrrigWeb is to provide irrigators with current and local advice on sugarcane crop water use and development. The tool combines crop water use estimates with user-defined irrigation system constraints and crop cycle inputs to schedule future irrigation events (SQR, 2018). IrrigWeb was developed by SQR Software, the same company that developed CanePro (which uses the model Canegro) in 1995 in response to requests by South African sugarcane farmers for an agricultural management tool. Right from the conception of the model, CanePro has been developed in partnership with the sugar industry aimed at meeting the specific needs of sugarcane growing operations. Adoption of "Farmer CanePro" has been rapid and the number of users continues to grow. There are currently over 150 sugarcane farmers in Southern Africa using "Farmer CanePro".

For the Australian sugarcane industry market, SQR Software developed the Irrigation Module of CanePro which was registered as IrrigWeb. IrrigWeb was further refined using the results of a number of projects funded by the Sugar Research and Development Corporation (SRDC), CSIRO, and the Cooperative Research Centre for Irrigation Futures (CRCIF) that had been used to develop the web-based irrigation management tool named WaterSense. WaterSense, which used the crop model APSIM, is no longer available. IrrigWeb is a cloud-based application; data is saved in an SQL secure web database, giving the users access from any location or device connected to the internet.

Promotion and Adoption

Promotion of IrrigWeb as a solid and comprehensive crop model has been made by SQR Software and other important players in the industry: SRA, CANEGROWERS and the Burdekin Productivity Services (BPS) have all given IrrigWeb support as a reliable tool for irrigation scheduling. BPS are using IrrigWeb to assist farmers gain a better understanding of irrigation timing and crop water use. Across the district there is a tendency to over-irrigate young crops, and farmers have little understanding about how much water a sugarcane crop uses.

BPS are using IrrigWeb to support extension programs aimed at increasing irrigator understanding, while increasing productivity and reducing water and energy costs. BPS has opted to license IrrigWeb as a regional tool. CANEGROWERS has managed the Queensland Government Rural Water Use Efficiency for Irrigation Futures project (RWUE-IF) worth $2.87 million over four years. The project has invested in water use efficiency and decision support systems such as IrrigWeb, weather stations, moisture probes and pump efficiency assessments. Smartcane Best Management Practice (BMP) advisors have also been promoting the use of IrrigWeb for its record keeping function. Records for irrigation have been a challenge for growers and supporting farmers to use tools such as IrrigWeb will also assist farmers attain their Smartcane BMP accreditation.

SRA in its Fundamentals of Irrigation and Irrigation Essentials training courses for the promotion of the Smartcane BMP, have used and promoted the use of IrrigWeb as a fit-for-purpose tool for irrigation management. IrrigWeb is also supported as a tool for Irrigation Management on the Farming Systems section of the SRA webpage.

The Rural Water Use Efficiency – Irrigation Futures (RWUE-IF) in agreeance with the Department of Natural Resources, Mines and Energy (DNRM) has stated that *"the use of the scheduling program Irrigweb should be acquired as part of the information systems funding"*. Seven productivity services companies and two district offices were provided with the opportunity to have contracts for the use of IrrigWeb, but most have not maintained access.

Likewise, the Australian Government, through its Department of the Environment and Energy; have shown their support to this tool. As a requirement in the Burdekin Applicant Guidelines for funding through the Reef Trust Repeated Tenders, matching water use to crop requirement was requested, so the use of IrrigWeb was made essential for the 2017 round applications.

Notwithstanding the support and recognition above described, the actual adoption of IrrigWeb by the farming community has been rather limited. Increasingly user friendly and more cost-effective tools, the promise of better crop yields, reduced energy costs and the satisfaction of using a scarce water resource wisely have not been enough, collectively, to bring about the much needed wave of adoption (Jumman, 2017). This is also the case with IrrigWeb. Several studies in Australia and internationally have tried to understand the cause of non-adoption of these tools[8].

In Australia, adoption of irrigation scheduling in the sugarcane industry is below expectations. A number of entities (BSES, CRCIF, SRA) have over the last 25 years, funded several projects which produced and promoted different irrigation scheduling technologies (WaterSense, WaterBalance, Mini-pan, WaterSched, Cane Optimiser, APSIM Sugar). Whilst good quality work has gone into the development and promotion of these tools, the transferring and adoption of these technologies to farmers has been less than desirable. With a few exceptions in Bundaberg, the Burdekin and the Tablelands, very little evidence-based scheduling is practiced in the sugar industry in Australia at present.

IrrigWeb Users

As mentioned earlier, visits to sugarcane irrigation advisors were undertaken to the Tablelands, Mackay, Bundaberg and the Burdekin where they were interviewed about their exposure and usage of irrigation scheduling tools in their areas of influence.

IrrigWeb is not the preferred tool for irrigation scheduling in Bundaberg. Bundaberg Sugar Services Ltd (BSS) have developed the Irrigation and Climate Information Web Centre (www.bdbcanegrowers.com.au) which provides three levels of management support to irrigators in the region: Field Monitoring, Current Weather Information and Future Weather predictions. Figure 2 shows a map depicting the locations of weather stations and soil probes throughout the BSS region of influence.

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[8] Car el al (2012), (Inman Bamber et al., 2005), Juffs et al. (2004), Webb et al. (2006), Everingham et al. (2006), Jakku et al. (2007) and Thorburn et al. (2011), Whittenburry and Davidson (2010), Hochman and Carberry (2011), Boland et al. (2006), Kaine et al. (2005), Vanclay (2004), Raine et al. (1999)

Figure 2. Locations of weather stations and soil probes in the Bundaberg Sugar Services region.
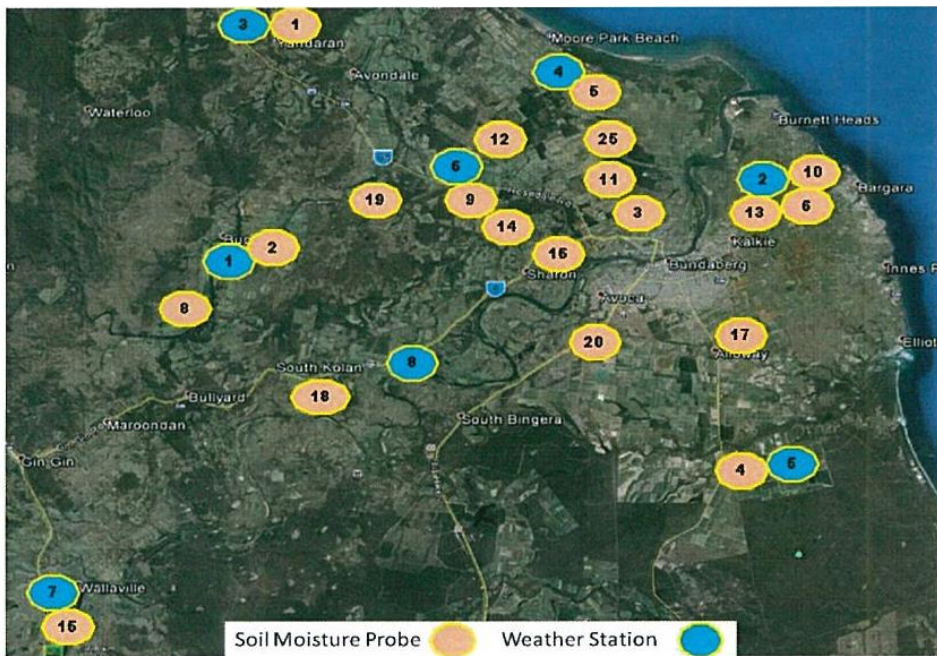
The scheduling of irrigation with this tool is based on the soil-water balance, which is, monitoring of the available soil moisture through a network of loggers. The BSS also provides a guide to soil moisture change in the monitored sites which are located in most areas of the district. Farmers log into monitoring probes located in sites (based on soil type) similar to theirs. The system has worked for BSS and for their growers and a consideration to adopt IrrigWeb has not been given. Figure 3 is an example of the type of information displayed by the BSS system of crop water use at Bundaberg (December 2011 – December 2012).

Figure 3. Crop water use in a non-stressed and stressed crop at Bundaberg.
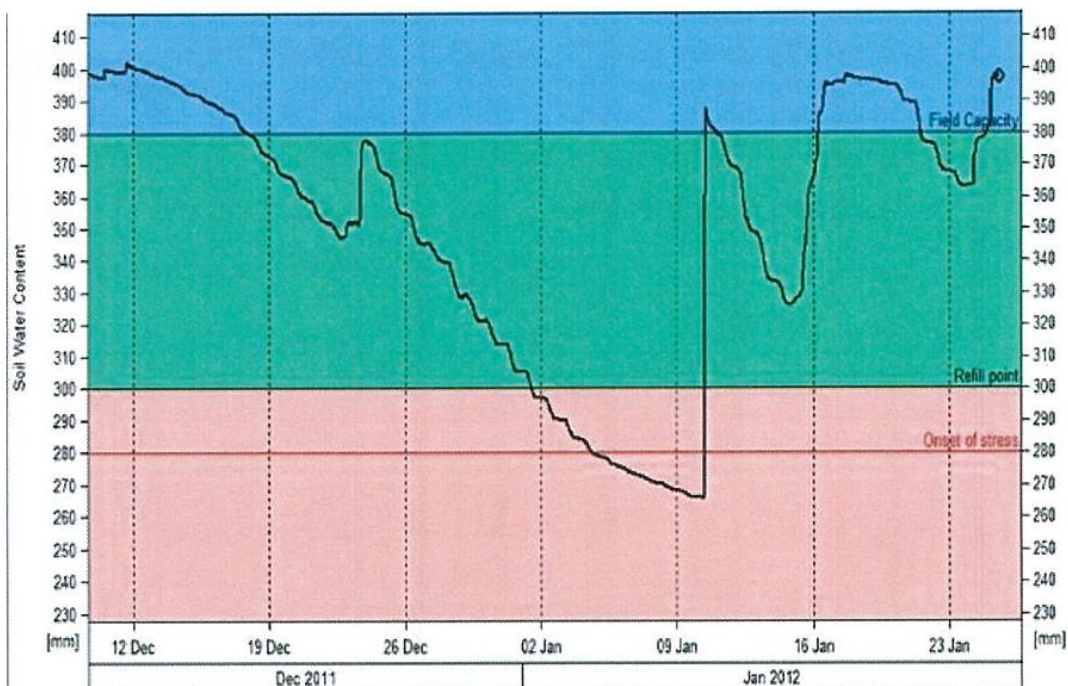
Advisors of irrigation in the Mackay do not use or recommend any particular tool for irrigation scheduling. Advisors in Mackay and Proserpine do not use IrrigWeb as a tool for irrigation scheduling. Officers at the Mackay Productivity Services (MAPS) have considered the KMSI tool (SID) and are aware of growers in their regions using soil probes for irrigation scheduling. They are not actively involved in advising on irrigation scheduling at present.

Burdekin Productivity Services Ltd (BPS) in Ayr, have been the most proactive entity in the sugarcane industry in the adoption and usage of IrrigWeb. The Burdekin region has approximately 80,000ha of sugarcane growing. The district annually produces between 8-9 million tonnes of sugarcane, from which about 1.3 million tonnes of raw sugar is produced at the regions four large-scale mills: Pioneer Mill at Brandon, Kalamia Mill at Ayr, Invicta Mill at Giru and Inkerman Mill at Home Hill.

The Burdekin Productivity Services in Northern Queensland have opted to license IrrigWeb as a regional tool. This provides full IrrigWeb access to all members of the BPS. Growers in the Burdekin will be able to define actual paddocks on their farms and generate irrigation scheduling advice unique to that paddock. In addition, growers can opt to receive proactive weekly advice via email to help raise the priority of this important and costly operation. BPS routinely runs IrrigWeb training courses for their associate growers and gives one-on-one advice to those interested in the adoption of the tool.

Also in the Burdekin, the Rural Water Use Efficiency (RWUE) project recently funded BPS to install a number of weather stations in the district. These stations will provide additional weather information for IrrigWeb. The weather stations have now been linked to IrrigWeb and growers can choose the closest weather station as their default rain gauge. Adding more rain gauges to IrrigWeb means that the automatically downloaded rainfall data should more accurately reflect actual on farm precipitation when compared to only obtaining data from a smaller number of SILO stations. This is especially helpful for growers that are away from their farms and are unable to check their own on-farm rain gauge. It is common to find an article about IrrigWeb on the BPS Newsletters. Figure 4 shows a Season's report for some of the BPS paddocks set-up in the system for December 2017.

Figure 4. Season's Report from IrrigWeb modelled paddocks by BPS

Paddock	Harvest Date	Total Irrig. (mm/ha)	Total Rain (mm/ha)	CWU (mm/ha)	Pot. CWU (mm/ha)	Run-off (mm/ha)	Deep Drain (mm/ha)
BPS_Jul	14/07/2018	490	131	507	741	0	66
BPS_Aug	14/08/2018	350	129	390	634	0	34
BPS_Sep	14/09/2018	280	128	297	500	0	62
BPS_Oct	14/10/2018	140	127	126	353	0	78

In the Canegrowers Tablelands Office, the sugarcane advisor uses IrrigWeb as an aid for irrigation scheduling tasks. He is an advocate of the system and, after having tried other methods, believes that IrrigWeb is the most comprehensive one to use. A number of growers in the Mareeba region have limited allocation of irrigation water, so he has used IrrigWeb to run different scenarios to present to them for decision making. In the past, he used WaterSense and was disappointed when the support to it was no longer available. With the arrival of SQR's IrrigWeb, the Canegrowers Tableland Office has better capability to advise growers on irrigation management. The knowledge and experience acquired with WaterSense in the past, has tremendously helped the advisor set up, operate and interpret the results calculated and shown by the program. There are not, however, many growers using the program themselves, the adoption of the tool has been chiefly through the Canegrowers Extension Officer. Figure 5, shows the output of a modelled paddock through IrrigWeb in the Tablelands.

Figure 5. Output for a paddock in the Tablelands modelled through IrrigWeb

Tablelands - 12 month 1R gctb with non-limiting irrigation
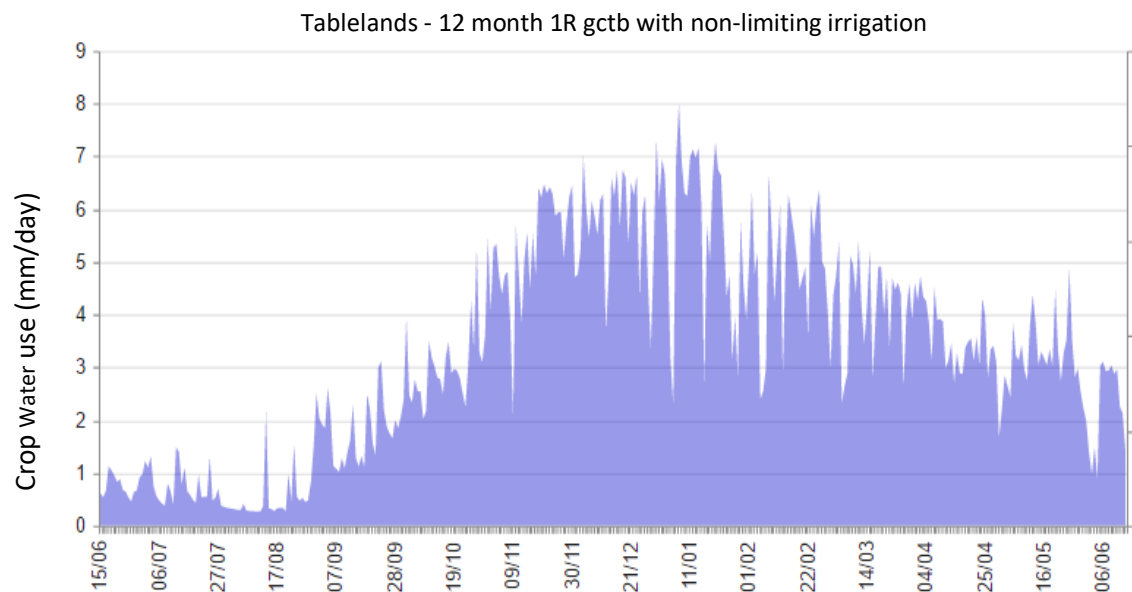
IrrigWeb and Best Management Practices

Smartcane BMP is a world-class best practice system for sugarcane growing in Australia. Industry researchers and sugarcane farmers put together the standards based on productivity, profitability and sustainability. The program is voluntary. The Queensland Government has provided funding towards this industry-developed, industry-owned program and said that growers who are engaged will not be the focus of its reef regulations. Smartcane BMP is about improving the bottom line of individual cane farms through:

- Solutions to on-farm challenges.
- Access to the latest information and research in sugarcane.
- Identifying latest technology and practices to achieve more with less.
- Proving to community and customers that Queensland sugar is produced in a sustainable way.

The SmartCane BMP program requires growers to know and record:

- Soil water holding capacity
- Crop water requirement
- Irrigation applications (volumes and timing)
- How scheduling decisions are made
- Rainfall records

All of these requirements are met by using IrrigWeb.

James Cook University

JCU and AgriTech Solutions are at present, undertaking investigations towards improving water quality for the Great Barrier Reef and wetlands by better managing irrigation in the sugarcane farming system. The project, funded through the National Environmental Science Program (NESP) works in partnership with industry, extension, natural resource management groups, research and government organizations to develop and deploy a smart irrigation system that links information from the IrrigWeb decision support tool and automated irrigation systems. The project's objective is to develop technology that will enhance the uptake of smart irrigation tools by overcoming the barriers to adoption.

Final Remarks and Conclusions

An evaluation of the irrigation scheduling tools in use in the sugarcane industry in Australia was undertaken. The evaluation was based on information received chiefly through personal communications with currently extension officers in different regions and some recent literature review.

At present, there is a number of tools for irrigation scheduling applicable to the sugarcane industry in Australia with varied degrees of complexity and practicability. To date, the knowledge gained and products developed have unfortunately only reached a small portion of the industry. Scheduling tools evaluated vary in accuracy, cost, simplicity, available support and skill and time requirements. These include, gypsum blocks, Tensiometres, soil sensors and computer models.

The cloud-based crop model application IrrigWeb is the tool that has more support in the wide sugarcane industry as the one with more potential for promotion and adoption. However, its use by the average farmer is still very limited. Some obstacles to the adoption of irrigation scheduling have been detected which are similar to obstacles found in other industries in Australia and overseas. One of these perceived barriers is that many irrigators are still not convinced that irrigation scheduling should be a priority. Across the industry, there is limited data on the irrigation water applied per irrigation event or the amounts they should use. Ongoing support, promotion and encouragement from productivity services and other extension agencies has also varied in the industry.

Irrigation scheduling is an essential practice for the efficient and effective use of a limited water resource. The literature confirms that the problem is not unique in the Australian sugarcane industry but other industries and in other countries, the adoption of irrigation scheduling tools have been a challenge for researchers and advisors alike. Some sugarcane advisors lack interest in irrigation and possess only a very general knowledge of irrigation science (water-soil-plant relationships). Many sugarcane growers lack the confidence or knowledge that investing in new tools to better manage irrigation, would pay off. For some growers and advisors, computer models as irrigation scheduling tools, are looked at with some degree of scepticism over the believed complexity of the tool and the uncertainty of these tools being best suited for the purpose.

The view that scientists, extension agents and growers have on irrigation scheduling tools is somewhat different and this may not help the processes and speed of adoption. Scientists are particularly concerned about accuracy and precision of the tools whereas irrigators in general are concerned with tools that are easy to install and operate.

Lastly, there appears to be a culture of resistance to change in the average sugarcane farmer towards the adoption of irrigation scheduling; the inherited knowledge about irrigation practices and the *status quo* is believed to be adequate. A beef up in the resources spent into irrigation scheduling through promotion, training, demonstrations and eventually financial incentives for purchasing irrigation scheduling tools would certainly be something that would further achieve adoption. Local advisory staff in the sugarcane industry, require more professional development and training on irrigation fundamentals, soil-water-plant

relationships and in particular, irrigation scheduling principles in order to be able to better assist growers in assessing irrigation performances and efficiencies and in doing so help growers achieve better productivity and profitability.

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The use of tools to support and inform irrigation scheduling in the Australian sugarcane industry has parallels with other irrigated crops in Australia and overseas. Overall, there is low usage of any form of irrigation scheduling tools. However, there are specific examples of individual irrigators and advisors using tools with a high degree of skill and success. In recent years there has been a renewed interest in some regions, e.g. Burdekin, where the local industry has embraced new technologies to support the adoption and use of irrigation scheduling tools.

For many, both irrigators and advisors alike, the term 'irrigation scheduling' refers only about 'when to irrigate' and rarely includes the 'how much needs to be applied'. A general lack of understanding about crop water use further adds weight to the belief that the sugarcane industry, like many others, has failed to invest adequately into professional development and training for irrigation related matters. This applies to both irrigation advisors and farmers.

While a number of different irrigation scheduling tools are used across the industry, visual tools such as the G-Dot and tensiometers, are popular because of they are simple to read and interpret; while the lower purchase cost is also an attractive feature. Fewer capacitance probes are found across the industry due mainly to their higher purchase cost, despite the ability to monitor multiple depths.

Irrigation scheduling with crop models has increased in recent years, particularly in the Burdekin industry. Burdekin Productivity Services Ltd currently use IrrigWeb, a sugarcane specific crop model, as their primary tool to support irrigation scheduling extension activities and the Smartcane BMP program. The ability to link IrrigWeb to other smart technologies, such as irrigation automation, removes the need for the irrigator to manually enter irrigation and rainfall events. Keeping records up to date is a known impediment to the uptake and use of tools. Linking information generated from satellite imagery to IrrigWeb, offers another opportunity to create 'smarter irrigation tools'. Satellite imagery has the potential to generate regular measures of canopy development and cane yield; both of these values are also generated by IrrigWeb. Having the ability to compare both values would serve to increase confidence and reliability of the irrigation schedule.

This example highlights the exciting potential to have multiple data sources, e.g. sensors in the field measuring soil moisture, crop based sensors, and weather forecasts, linked to each other in such a way to improve the value and reliability of any single tool. The ongoing development of new sensor technology along with the improvement in data access and transfer heralds an exciting period for smarter irrigation tools.

The sugarcane industry should carefully evaluate the benefits generated from embracing these new technologies into the irrigation sector. Equally there needs to be a focus on raising the fundamental skill level of all irrigators and irrigation advisors to maximise the benefits that could be realised.

Appendix 1

University of New England Report

"An assessment of the potential of remote sensing based irrigation scheduling for sugarcane in Australia"