Rural R&D for Profit Program

Smart Automated Irrigation: Increasing farm profit through efficient use of irrigation for dairy farms

Final Report

University of Tasmania

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Contents

Plain English summary **1**

Abbreviations and glossary **4**

1 Project rationale and objectives **5**

2 Method and project locations **6**

3 Project Outcomes **1**

3.1 Project level achievements 1

3.2 Contribution to program objectives 1

4 Collaboration **3**

5 Extension and adoption activities **4**

6 Lessons learnt **6**

7 Appendix - additional project information **8**

7.1 Project, media and communications material and intellectual property 8

7.2 Equipment and assets 13

7.3 Budget 14

7.4 Other project reports and documents 15

Note: the department will publish the final report on its website but <u>*will not*</u> *publish the appendices.*

Plain English summary

This project, led by the Tasmanian Institute of Agriculture focused on the use of data and autonomous technology in helping farmers make informed decisions and improve their irrigation efficiency on pastures. The project collected data on water and energy usage as well as pasture production from five commercial pivot irrigated sites across the North and Northwest of Tasmania over three irrigation seasons from 2015 to 2018. Using the data, the project team worked with the farmers involved to make changes improving water use efficiency and monitored each site to measure the success of these changes.

The major objective of the project was to identify key irrigation system modifications and practices that could be efficiently and effectively adopted by dairy farmers in achieving improvements in energy and water usage and increasing pasture production per ML of irrigation applied. A second objective was the development and testing of an autonomous sensor based pressurised irrigation scheduling system that could improve energy, water and labour inputs.

Each pivot's area was mapped to determine variability in soil types and elevation. Soil samples obtained provided the soils' water holding capacity and other details of major soil properties. Weekly pasture growth rates were collected from each of the sites during each irrigation season using a rising plate meter. As part of the programs management there was no interaction with the farmer's during the first irrigation season (2015/16). At the end of the first season, workshops were held with all participants to discuss what had been found with the energy and water use and pasture production, on each farm and to provide feedback on possible methods of improving the management of each irrigation system. During the 2016/17 irrigation season, a weekly update of rainfall and evapotranspiration for each site was provided to the participating farmers along with free access to soil moisture and temperature data that could assist with each properties irrigation scheduling.

In addition to providing weekly rainfall and evaporation data in the 2017/18 season, weekly discussions were held with each farmer to assist them with their irrigation scheduling decisions. On one of the five commercial sites, cameras were installed to assess the ability of cameras to measure pasture growth rates autonomously, and assist the development of the autonomous irrigation control platform (VARIwise). The camera technology was tested in the 2016/17 season and the VARIwise control platform tested during the 2017/18 season and compared to both flat rate and variable rate water applications based on VRI prescription maps developed from electromagnetic conductivity (EM38) and elevation data from the site.

Field days and workshops were held across Tasmania as well as in Victoria, Western Australia, South Australia and New South Wales, during the three year project. A series of presentations were developed for use at field days, workshops and online webinars. A factsheet was developed on Variable Rate irrigation and a number of short videos were developed and uploaded to YouTube for extension and training purposes. There were also a large number of media interactions including radio and TV presentations and publication of project outcomes in newspaper and magazine articles, both in Tasmania and nationally.

The project highlighted three areas where significant improvements could be made to irrigation efficiency and productivity. These included:

- The irrigation system design and function.
- Irrigation scheduling.
- The use of variable rate technology (VRI).

Two of the five farms monitored were identified with potential to save energy costs through replacement or modification of irrigation pumps and motors. On one site, installing a new pump and motor that is designed to meet the specific requirements of the site saved more than $15000 per year in energy usage. Another site, replaced a pump that had worn impellors with annual savings of over $2000. Three of the sites had a water distribution uniformity less than 85%, indicating the target application rate was not achieved uniformly across the site. Issues identified, included pressure being outside optimum specifications, worn nozzles or replacement nozzles at the wrong specifications and water leaks in infrastructure.

Irrigation scheduling was poorly implemented on all sites during the first year of the project. There were, due to a dry season and water availability, some system limitations but in particular, delayed irrigation start-ups at the beginning of the season and/or after significant rain events were identified as the primary reason why many sites suffered poor growth rates. Previous modelling had identified a penalty of 105kg DM/ha over the irrigation season for each days delay in start-up at the beginning of a season. One site in this project experiencing a 9 day delayed irrigation start-up lost production estimated at 60t DM, more than 130 kg DM/ha for each day start-up was delayed. Typically, irrigation was not being scheduled at a frequency to keep available water in the pasture root zone, leading to reductions in growth rates of a possible 80 kg DM/ha/day to less than 40 kg DM/ha/day during times of peak growth in summer.

Two of the sites had a variable rate system installed on their pivot. The irrigation inputs, water and energy requirements were measured with and without the use of variable rate and water savings of between 29 and 34% were achieved with the use of the variable rate technology. A model developed to assess the return on investment from installation of VRI technology of 1t DM/ha/season reduced the payback period for the investment from more than 9 years to less than 3 years. Evidence from the Cressy site, when VRI was implemented indicates an increase of 1t DM/ha is achievable as VRI technology enabled the pivot to continually operate with optimum scheduling (preventing issues with pivot ruts or paddocks drying out when stopping the pivot from management interventions, such as cutting silage).

In summing up the impact of the project on his farm, Rob Bradley stated “We’re putting the water where it needs to go, we’re using less power to do it, and we’re growing more grass”. Michael Palmer commented that “it was an “eye opener” to realise the importance of irrigation start-up at the commencement of the season, as I have always had a tendency to hold off and start irrigating later”. Nigel Brock summed up his experience by stating, “We definitely have changed how we irrigate. I learnt a lot more about how to use the VRI on my pivot. I have learnt to look at evapotranspiration figures from the Bureau of Meteorology, and found that soil moisture sensors are a useful method for identifying when to commence irrigation at the start of the season”. Wayne Saward indicated that “the timing of everything was the biggest learning for me. It’s possible to over irrigate and under irrigate on this site, I also understand more about readily available water (RAW)”. Luke McNab summed up his experience by saying “dollars saved were realised by not over watering, and understanding the importance of start-up at the commencement of the irrigation season”.

Future programs should focus on the extension of key messages around suitability of the systems, irrigation scheduling and variable rate technology. A series of demonstration farms across a variety of irrigation systems, linked to a local group of farmers and services providers should be established to enable benchmarking of performance and provide training opportunities for farmers and service providers. Potential areas for further research include continued development of an automation system (eg VARIwise), the integration of system alerts (eg Davy pumps Monsoon control system), automated biomass measurements, downscaling of regional pasture prediction models to a farm or paddock level (for benchmarking purposes), development and testing of tools for spatial measurement of soil moisture and the use of alternative energy sources such as solar and wind.

Abbreviations and glossary

TDH – Total Dynamic Head

RAW – Readily available water

CP – Centre pivot irrigator

L/S – Litres per second

ML/ha – mega litres per hectare

ETC – Crop specific Evapotranspiration based on a crop coefficient

ET0 – Reference Evapotranspiration

WUE – Water use efficiency

PUR - Pump utilization ratio

VRI – Variable rate irrigation

EM38 - Electromagnetic conductivity

TDR – Time Domain reflectometry

NCEA – National Centre for Engineering in Agriculture

TIA – Tasmanian Institute of Agriculture

TDRF – TIA Dairy Research Facility

KMSI - Knowledge Management System for Irrigation

1 Project rationale and objectives

According to the 2012-2013 ABS Water Account, the dairy industry is the second largest user of irrigation water in Australia and utilises 310,700 ha of irrigated land. An average of 6.3ML is applied per ha and each ML generates value of $500. Increasing costs and questions concerning consistency of water supply are major concerns for dairy farmers and there is a pressing need for industry to find and adopt innovative practises and technologies that utilise water as efficiently as possible. Effective management of the spatial and temporal variability in water demand is viewed as key to optimising pasture production. Over 75 percent of dairy farms in Australia are pasture-based systems and in spite of this fact, and in recognition that pasture utilisation is a key profit driver in pasture based dairy systems, pasture utilisation across Australia has remained at 50-60 percent of what is possible. Whilst improvements in system design and new technologies have increased in recent times, early adopters of new technology are often finding it difficult to capture all possible production improvements that justify the investment. Additionally, there is a cohort of farmers who are failing to optimise the productivity or profitability of their current irrigation system/s.

Increasing availability of irrigation water and milk processing capacity coupled with growing global demand for dairy produce has resulted in continual expansion of the Tasmanian dairy industry. Whilst some of the future growth is to come from established farms, new and conversion dairies will be required to achieve desired industry growth targets over the next five years. A significant proportion of the expected dairy expansion will be into non-traditional dairy regions, such as the northern and southern midlands of Tasmania, a region presenting challenges with highly variable and potentially difficult to manage soils under dairy. Managing irrigation on dairy farms in these regions will require delivery of precision irrigation to maximise production and alleviate unfavourable outcomes such as waterlogging, runoff and increased soil salinity.

This project was designed to address ongoing requirements to improve irrigation management, water use efficiency and sustainability and profitability from irrigated dairy systems in temperate environments, while protecting soil resources and minimising environmental impacts.

The project aims included:

a. Through detailed benchmarking of current irrigation system performance, site characterisation and a consultative farmer driven knowledge brokering environment, identifying key irrigation system modifications and practices that can be efficiently and effectively adopted to achieve improvements in energy, water use efficiency, pasture production and returns per ML applied.

b. Development of autonomous systems – Quantify the performance of autonomous sensor based pressurised irrigation scheduling systems in pasture-based dairy systems with respect to: pasture productivity, irrigation performance, labour requirements and management savings.

c. Development of information resources for the dairy industry that enhance irrigation scheduling decisions, improve understanding of uniformity, system design and key energy savings for pressurised irrigation systems.

2 Method and project locations

Five pivot irrigated pasture sites on dairy farms in north and northwest Tasmania (Table 1) were included in a program that collected data on power and water use, soil moisture and weather parameters. Locations in Tasmania are illustrated on the map in Figure 1

Table1. The location and soil characteristics of the five pivot sites

Site location	Farm	Soil characteristics
Cressy	Rob Bradley	Brown Dermosol - Cressy clay loam
Montana	Nigel Brock	Tenosol - Alluvial flood plain / loam
South Riana	Wayne Saward	Brown Ferrosol - Yolla clay loam
Sisters Creek	Michael Palmer	Red Ferrosol
Rocky Cape	Luke McNab	Sand

Figure 1. The five farm locations are identified by the blue diamonds.

Each of the five farms area under the pivot chosen for measurements, underwent a site characterisation process via detailed mapping including: elevation, contours, electromagnetic conductivity (EM38) and full soil description (bulk density, soil moisture retention curves at depths and associated texture). Installed at each site were, at least 3 soil, loggers that measured both soil moisture levels and temperature. Location of the soil sensors was determined using information from the EM38 maps as well as from feedback by the farmers with an aim to have one installed in a dryer area of the pivot, one in a wet area of the pivot and the third in an area that represented typical soil moisture for the site. Installed electricity metres measured the energy consumed by the pump set supplying the centre pivot irrigator. Ultrasonic flow metres were fitted to the delivery pipes to measure the total water used throughout the irrigation season. Following initial site characterisation and sensor deployment, a program of detailed monitoring and benchmarking for the 2015/16 irrigation season was undertaken. In-field monitoring of pasture growth rates (PGR) and key management events (e.g. fertiliser application rates and timing) were recorded. Pump assessments were completed in detail at two of the sites (Sisters Creek and Montana). These activities included reading motor current, flow rate and discharge pressures. Energy efficiency was calculated from the data and compared to the systems specifications. Drainage maps were generated for two sites (Cressy and Montana), areas where drainage is identified as a limitation for achieving optimal irrigation. A uniformity distribution test was conducted for each site. This involved placing catch cans at three-metre intervals along the length of the centre pivot and entering the resulting data into the KMSI toolbox to calculate a coefficient of uniformity.

Enabling practices that lead to improved irrigation decisions were undertaken using two pathways. Pathway 1 tested a machine interface (autonomous) process (VARIwise) on 1 of the five commercial dairy farms (Montana) as well as at the TIA Dairy Research facility pivot site at Elliott, Tasmania. This pathway involved developing optimised, daily variable-rate irrigation prescription maps from: (i) infield weather, soil, and pasture growth sensors; (ii) optimisation algorithms using calibrated crop production models in VARIwise; and (iii) automated irrigation prescription map uploads to commercial variable-rate hardware on the centre pivot irrigation control. Infield weather data was combined with data obtained from cameras installed on the pivots for unsupervised on-the-go pasture assessments. Automated image analysis algorithms were developed to determine the length of ryegrass tillers and then generate a map of estimated pasture dry matter as the pivot passed over the pasture sward. The pasture growth measurements were linked with the optimisation procedure in VARIwise to generate irrigation prescription maps. VARIwise updated and generated daily irrigation prescription maps compatible with the commercial variable-rate hardware fitted to the pivots. New VRI maps were uploaded daily to the Elliott and Montana field sites as soon as new weather data and pasture dry matter amounts were available. In the 2017/18 season, irrigation trials were conducted at both Elliott and Montana to compare three irrigation treatments: (i) uniform irrigation ('flat'); (ii) site-specific irrigation based on elevation maps ('VRI'); and (iii) site-specific irrigation based on VARIwise outputs calibrated from infield pasture assessments ('VARIwise'). Each pivot at the two sites were divided into nine equal sectors allowing for three replications of each treatment (see Figure 2, for an example of the replicated sectors for the Elliott site). Two GPS loggers were attached to the terminal section of the pivot in order to log the position of the machine at two minute intervals. The GPS point data was imported into a GIS package identifying the timestamp of the machine in the treatment sector. The flow data recorded captured the total water use over 13 applications in each individual sector.

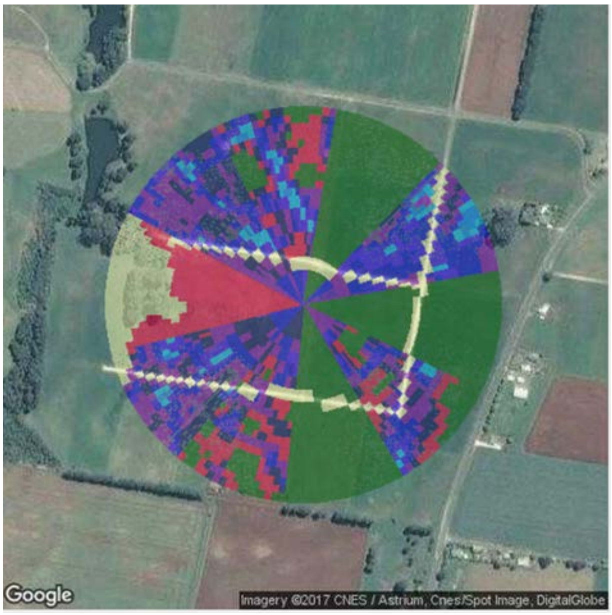

Figure 2. Replicated treatment sites at Elliott for comparing VARIwise with standard VRI and flat rate applications.

For the other four remaining farms, a human interface decision making process based on results from the benchmarking data obtained from all farms was applied. The management changes were evaluated in 2016/17 and re-evaluated, refined and reassessed in 2017/18. Evaporation and rainfall data were e-mailed to the participating farmers each week during the 2016/17 and 2017/18 seasons to assist with their irrigation scheduling. In the 2017/18 season each of the farmers were contacted weekly to discuss their individual irrigation requirements.

A number of other technologies were also tested as part of this project; including the use of satellite, airplane and ground vehicle mounted sensors (L-Band Radiometer and reflectometer) for measurement of soil moisture on a spatial scale, and various types of soil moisture probes (capacitance and time domain reflectometry (TDR) probes) for site specific soil moisture monitoring.

Broader dairy farmer engagement and extension of project results were conducted via workshops and field days on selected farms and discussed changes in irrigation scheduling, system design modification and water and energy saving associated with the five sites.

3 Project Outcomes

3.1 Project level achievements

The project aimed to increase farm profitability by integrating accurate irrigation scheduling and delivery technologies into good irrigation practice. It also attempted to improve cross-sector industry research collaboration with public and private sectors in the four major irrigation industries including cotton, sugar, rice and dairy, providing a legacy platform for other sectors to also benefit. It aimed to build on previous research to drive additional improvements in cotton, rice and sugar, and transfer learnings from the cropping industries to dairy with the aim of increasing on-farm profit through adoption of automated and precision application technologies across all industries.

The Project aimed to achieve:

(a) 10-20 per cent improvement in water productivity, efficiency and farmer profitability;

(b) adoption of new irrigation technologies and science application by farmers and irrigation professionals to improve farm profits; and

(c) improved cross-sector industry research collaboration with public and private sectors in four major irrigation industries providing a legacy platform for other sectors to also benefit.

The specific outputs defined for the dairy component of the Smart automated irrigation included the following:

- Output 3(e) selection of at least 5 farms across the dairy regions of Tasmania for assessing irrigation systems
- Output 3(f) deliver at least two workshops per year with dairy farmers on selected farms to discuss irrigation scheduling, energy and water use efficiency improvements
- Output 3(g) benchmark performance and evaluate cotton VARIwise control and sensing system at the Tasmanian Focus Farm
- Output 3(h) evaluate changes in irrigation scheduling, system design and irrigation uniformity on 5 participatory farms
- Output 3(i) undertake an economic analysis and productivity assessment on performance against benchmarks including comparison between 2016-17 & 2017-18 performance.

- Output 3(j) information resources published for improved management of, and design parametres for pressurised irrigation systems including information on the value of new technologies.
- Output 3(k) deliver a final report documenting outputs 3(f) to 3(j)

Deliveries against milestones and key performance indicators for these milestones for this project are summarised in Table 2.

Table 2 Outputs against key performance indicators for milestones 2, 3 and 4 of the project plan

KPI no.	KPI description	Due Date	Progress achieved against KPI	Outputs
2.8	Summary of outcomes of workshops with dairy farmers on 5 irrigated Dairy Farms (as per Outcome 3(e) and 3(f)) provided to the Department 3(e) selection of at least 5 farms across the dairy regions of Tasmania for assessing irrigation systems 3 (f) deliver at least two workshops per year with dairy farmers on selected farms to discuss irrigation scheduling, energy and water use efficiency improvements	30/05/2016	Five dairy farms were selected and sensors were successfully installed for collecting water and power use and soil moisture and temperature. Pasture productivity measures were also collected and the results were shared with each of the participating farmers. Workshops were held at each of the participating farms Between June and August 2016 to discuss relevant findings and plan for the next irrigation season	Power and water use and pasture productivity data was generated for each of the five pivot sites PowerPoint presentations were produced for use at field days and workshops Presentation of the project details and current results at two industry forums in 2015
2.9	Report on performance benchmark (as per Output 3(g)) provided to the Department 3 (g) benchmark performance and evaluate cotton VARIwise control and sensing system at the Tasmanian Focus Farm.	30/05/2016	Pasture Biomass sensing system was successfully set up and used to evaluate the VARIwise autonomous control platform	A technical report on performance was provided with the April 2016 Milestone report. An updated technical report has been provided as an attachment to the final report

3.9	Summary of outcomes of workshops with dairy farmers (as per Outcome 3(f)) provided to the Department 3 (f) deliver at least two workshops per year with dairy farmers on selected farms to discuss irrigation scheduling, energy and water use efficiency improvements	30/05/2017	Five workshops in Tasmania and 1 workshop in South Australia were held - based on the results and learnings from the 2015/16 irrigation season. Eight workshops, seven field days and various other forums have been held across Tasmania with farmers between May and October 2017 to discuss the results of the 2016/17 irrigation season and plan for changes.	Updated powerpoint presentations
3.10	Report on benchmark against performance (as per Output 3(g)) and evaluation as per Output 3(h) provided to the Department Output 3(g) benchmark performance and evaluate cotton VARIwise control and sensing system at the Tasmanian Focus Farm. Output 3(h) evaluate changes in irrigation scheduling, system design and irrigation uniformity on 5 participatory farms	30/05/2017	Cameras were installed at the focus farm in Meander and C-Dax biomass measurements were undertaken that enabled the development of an algorithm for estimating biomass from the camera images. Systems were also installed on the pivot to enable automated uploading of variable rate prescription maps in preparation for testing the VARIwise control platform in the 2017/18 irrigation season. Water, power, soil and climate variable were obtained from the pivots for the 2016/17 season and a summary of the systems performance at each site was included in the milestone 3 report	Abstracts summarizing findings of the VARIwise biomass assessments were presented at the irrigation Australia Limited conference in May 2016 and the Australasian Dairy Science Symposium in November 2016. A report is attached to the final report
4.9	Department advised of publication of information resources as per Output 3 (j) Output 3(j) information resources published for improved management of, and design parameters for pressurised irrigation systems	30/05/2018	The project final report and the attached technical report provides details of system design parameters, productivity assessments measured on these sites and information on the value of Variable rate technology An excel based model was developed to enable assessment of the likely return on	Excel based model for assessing the return on investment in variable rate technology

	including information on the value of new technologies.		investment in variable rate irrigation technology for pivots	
4.10	Final report on systems including economic analysis and productivity assessment and evaluation of changes (as per outputs 3(i) and 3 (k) provided to the department Output 3(j) information resources published for improved management of, and design parameters for pressurised irrigation systems including information on the value of new technologies. Output 3(k) deliver a final report documenting outputs 3(f) to 3(j) 3 (f) deliver at least two workshops per year with dairy farmers on selected farms to discuss irrigation scheduling, energy and water use efficiency improvements	30/05/2018	A report on the economic assessment of three of the irrigated pivot sites was completed. Various online resources have been provided for training purposes. These include a fact sheet for variable rate irrigation, a couple of webinars on irrigation scheduling, power use and a number of videos from presentations at field days. A few short videos on the autonomous control platform were also produced. Links to these resources can be found in the appendix to this report During the three years of the project there were a combined total of 45 workshops, field days and industry forums held across fives Australian states. There were 55 print and online media articles published, 6 media interviews conducted and presentations given at 5 conferences in 3 states. A further 2 conference presentations are planned for 2018.	Project final report Economic assessment final report. Included as an attachment to the final report VRI factsheet. Included as an attachment to the final report Online webinars and videos explaining various aspects of efficient irrigation Powerpoint presentations Conference abstracts

Details of the Technical outcomes and outputs are provided in the attached technical report for the project. A summary of the major outcomes for this project are provided below under the following 3 categories. A report detailing the financial assessment for three of the sites for the second and third irrigation seasons is attached to this report.

1. Irrigation system design and function.
2. Irrigation scheduling.
3. Automation

Irrigation system design and function

The most significant issues with the irrigation systems that were identified related to energy use and uniformity.

Energy

Monitoring the energy data at Sisters Creek identified that an energy intensive pump and motor were supplying the required duty. A new pump and motor were installed as well as improvements made to the irrigation pipework. The improvements in efficiency were dramatic with the required flow rate for the centre pivot achieved using a 30kW motor (previously 75kW) and a new 100x65-217 Southern Cross pump (previously 100x65-315). This resulted in a reduction of 508 kWh per mega litre pumped attributing to significant cost savings (figure?). The 75kW motor previously used for the pivot still supplies the farmers hard-hose irrigator, however the impeller was trimmed improving efficiency to 55kWh (previously 75kWh). Further details of the energy assessment can be found in an attached reports.

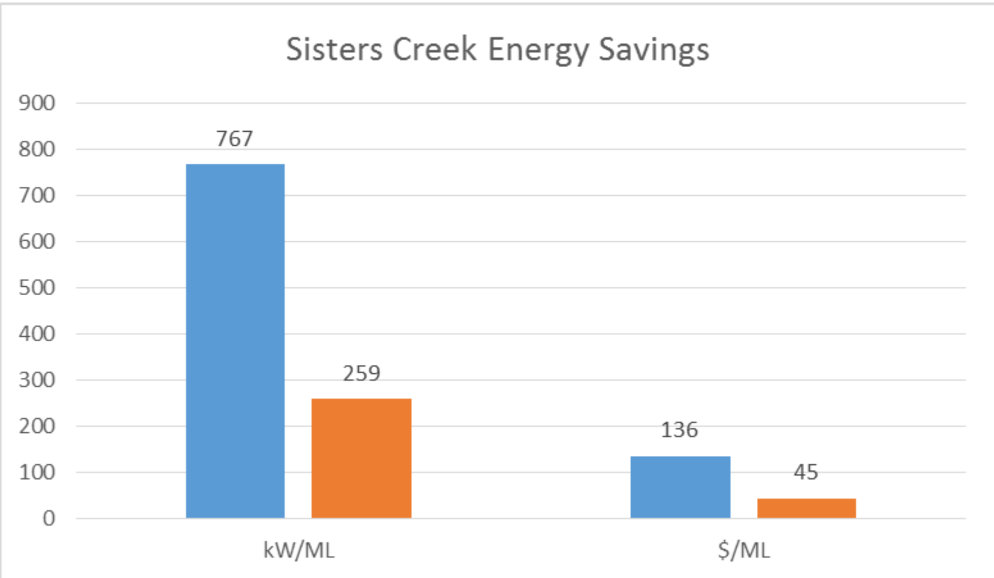

Figure 3. Energy and cost savings at Sisters Creek site before (blue bar) and after (orange bar) the installation of a new pump designed to meet the requirements of the pivot irrigator on the site.

At the Cressy site the impeller of the pump supplying the centre pivot was severely worn. The farmer made a $3,000 investment to replace the pump with a new unit to the same specification.

The energy monitoring allowed the differences of this change to be measured. Current draw (AMPS) decreased from 120 to 100 and kW consumption from 72 to 66. The energy savings picked up in one season translated into a dollar value of $2,254 (based on 700ML pumped). This means that 75% of the initial capital investment was paid for in one season. Worn equipment or equipment not fit for purpose can cost farmers significant amounts of money in energy costs. The final step of progression that was made at this site was the installation of a variable frequency drive (VFD). This reduced the kW/ML further. Figure 4 shows the savings achieved.

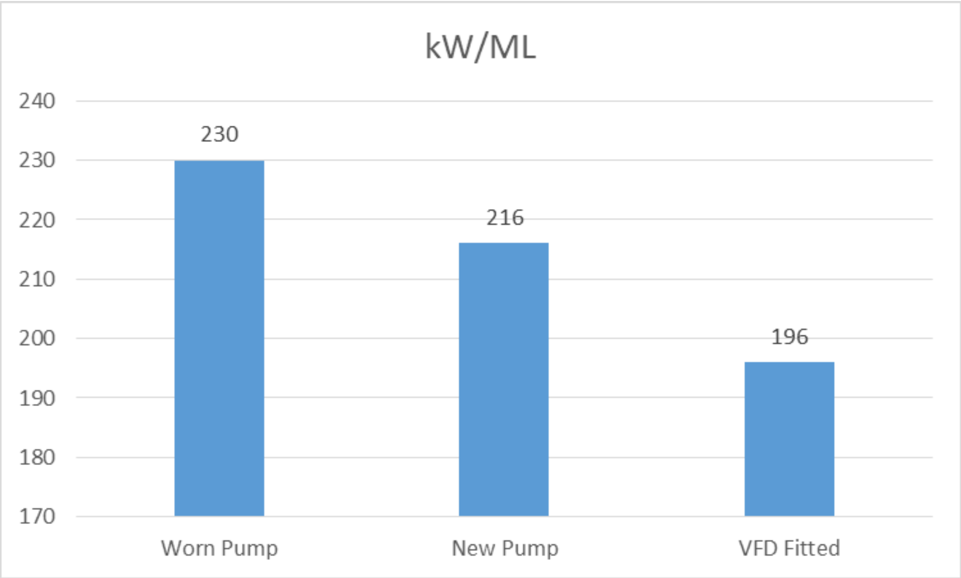

Figure 4. Energy savings achieved by replacing a pump and fitting a VFD and VRI system to the Pivot at Cressy, Tasmania.

Uniformity

Three of the sites measured had a water distribution uniformity less than 85%, indicating the target application rate was not achieved uniformly across the site. An example of poor uniformity for Cressy is illustrated in figure 5. The coefficient of uniformity for this pivot was 78% which is poor. Under watering occurred in the first 300 meters of the pivot and over watering occurred in the last 300 meters of the pivot.

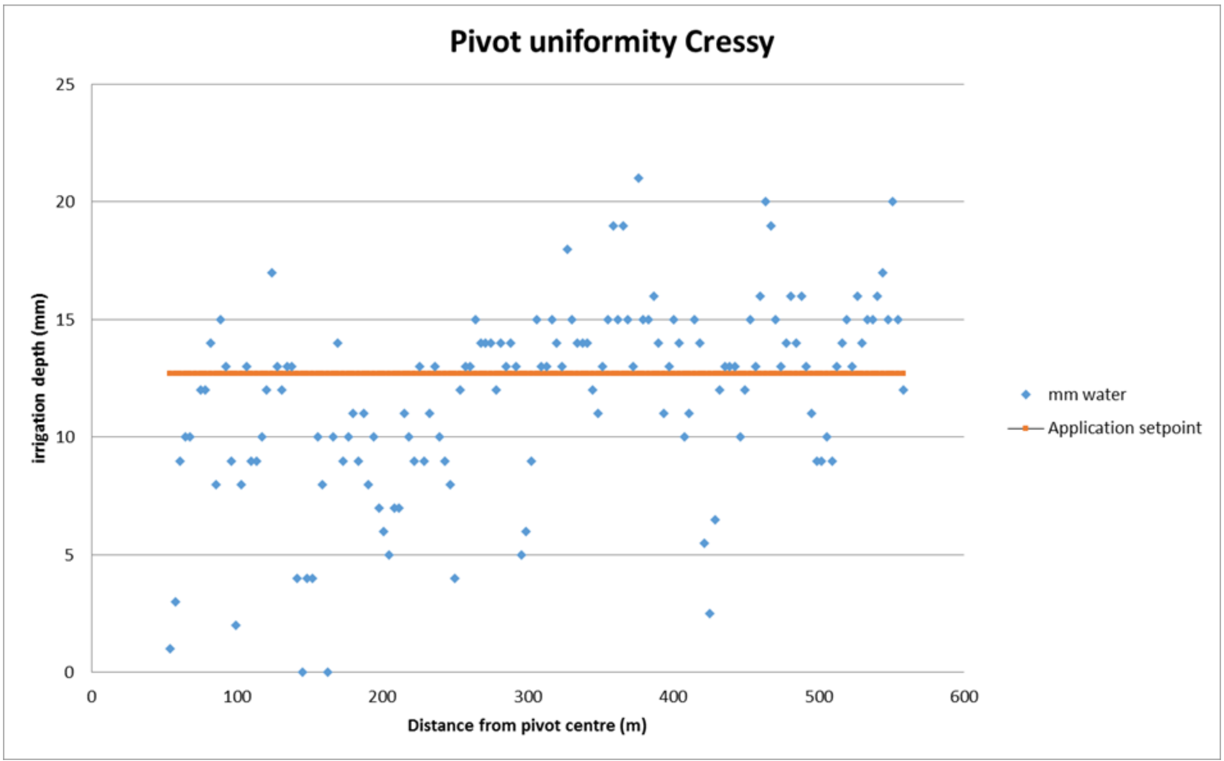

Figure 5. Pivot uniformity at the site in Cressy, Tasmania.

Irrigation scheduling

The most significant outcome related to poor irrigation scheduling practices involved a lack of understanding of the impact of start-up at the beginning of the season or after a rain event on subsequent pasture production. In this situation the soil moisture deficit drops below the soils readily available water storage levels. When the soil moisture drops this low the pasture is not able to easily and efficiently use the applied irrigation water for growth. The effect has been referred to as the 'green drought' where pastures stay green due to irrigation, but growth rates are significantly below optimum. Over two contrasting irrigation seasons (very dry in 2015/2016 and good rainfall in 2016/2017) it was observed that poor irrigation scheduling led to deficits at the Cressy site and the application of irrigation water only kept the grass green, but didn't result in optimum pasture growth rates. In the 2016/17 season pasture growth rates were cut in half, from over 80kg DM/ha/d to approximately 40 kg DM/ha/d. This was despite irrigation water being applied. In this case over one month there was an opportunity loss of about 140t DM pasture, with an extra cost for purchased feed to fill the gap of about $30,000. Scheduling irrigation to keep water in the soil's readily available root zone is really important to achieve maximum growth rates." An illustration of the green drought phenomena observed at the Cressy site is provided in figure 6

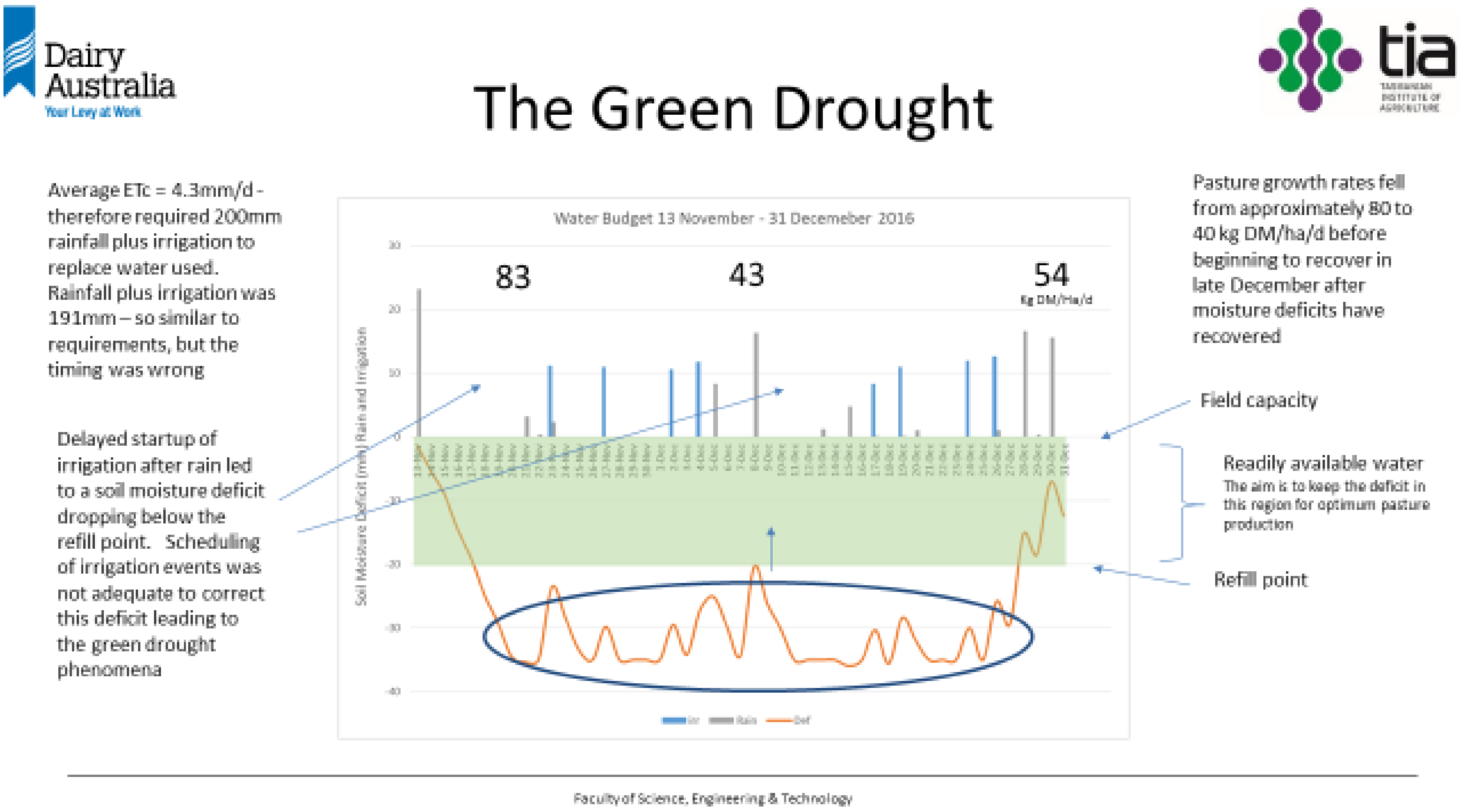

Figure 6. The green drought phenomena on a pivot irrigated pasture site in Cressy, Tasmania

Automation

Components of an automated site-specific irrigation decision-making system were developed and evaluated for three pasture sites in Tasmania and South Australia. This involved developing optimised, daily variable-rate irrigation prescription maps from: (i) infield weather, soil, and pasture growth sensors; (ii) optimisation algorithms using calibrated crop production models in VARIwise; and (iii) automated irrigation prescription map upload to commercial variable-rate hardware on centre pivot irrigation machines. Infield weather data was combined with data from cameras installed on the irrigation machines for unsupervised, on-the-go pasture assessment. Automated image analysis algorithms were developed to extract the length of ryegrass blades and generate a map of estimate pasture dry matter as the irrigation machine passed over the crop. The dry matter was determined by the cameras within 0.7-12.2% compared with manual measurements.

The pasture growth measurements were linked with the optimisation procedure in VARIwise to generate irrigation prescription maps. VARIwise was updated to generate and upload daily irrigation prescription maps that were compatible with the commercial variable-rate hardware. New VRI maps were uploaded daily to the Elliott and Montana field sites as new weather data and pasture dry matter was available.

Irrigation trials were conducted at Elliott and Montana to compare three irrigation treatments: (i) uniform irrigation ('flat'); (ii) site-specific irrigation based on elevation maps ('VRI'); and (iii) site-specific irrigation based on VARIwise outputs calibrated from infield pasture assessments ('VARIwise'). Over the trials, there was a 17.5% and 9.1% reduction in water use in the VRI and VARIwise trials compared with the flat rate trial. The trials aimed to improve productivity rather than only reduce irrigation use; hence the VRI applied less water than VARIwise.

This research demonstrate ability to automatically generate pasture growth maps and variable-rate irrigation prescription maps according to daily data. This has potential to enable real-time adaptation to environmental conditions without growers or consultants having to manually take measurements of pasture or update the irrigation maps.

3.2 Contribution to program objectives

The objective of the program was to realise significant productivity and profitability improvements for primary producers, through:

- generating knowledge, technologies, products or processes that benefit primary producers
- strengthening pathways to extend the results of rural R&D, including understanding the barriers to adoption
- establishing and fostering industry and research collaborations that form the basis for ongoing innovation and growth of Australian agriculture.

This project has led to a significant increase in the knowledge of the participants around three key areas of irrigation, namely:

- The irrigation system design and function.
- Irrigation scheduling.
- The use of variable rate technology (VRI).

The response to this increased knowledge has led to significant savings in power and water use and improvements in productivity.

One of the participating farmers replaced their pump and motor system in the second year of the project due to recommendations following assessment of the irrigation system in the first year. This change led to $15,000 per year savings in energy costs. A second farmer replaced their pump due to wear on the impeller, leading to an ongoing savings of approximately $2300 per year in energy costs. Another of the participants replaced the nozzle pack on two of his irrigators to improve the uniformity of the irrigation application after initial tests indicated very poor uniformity due primarily to worn or incorrect nozzle placement.

Changes to the way irrigation scheduling was managed led to a significant increase in pasture production on the Cressy site. Collection of data around water use and pasture production in the first year of the project highlighted the poor growth rates being achieved even with significant irrigation inputs (over 6 ML/ha). Calculations by the farmer estimated that by improving growth rates by 20 kg/ha/d from an average of 40 to 60 kg/ha/d, as was being achieved by another participating farmer, would increase pasture production by over 200 tonnes under the 117 Ha pivot. This would lead to a reduction in purchased grain, leading to a savings of $200 per tonne on feed costs, worth more than $40,000 over 3 months. During the second and third years of the project this farmer achieved more than a 20kg/ha/day increase in production through adjustments to irrigation scheduling and the implementation of VRI technology. He summed up the impact of the project for him by saying that "We're putting the water where it needs to go, we're using less power to do it, and we're growing more grass".

The impact of these changes on productivity have been communicated via field days and there is evidence that other surrounding farmers have also been adjusting their irrigation practices with improved productivity. One farmer commented to the Cressy participant, that the smarter irrigation projects findings have changed the way farmers are irrigating in the Cressy region with significant benefits in terms of increased pasture production with similar inputs.

One aspect of irrigation scheduling that has been identified by all participants as important for optimising irrigation performance is getting start-up timing right both at the beginning of the irrigation season as well as after rain events. Nigel Brock summed up his experience by stating, "We definitely have changed how we irrigate……. I have learnt to look at evapotranspiration figures from the Bureau of Meteorology, and found that soil moisture sensors are a useful method for identifying when to **commence irrigation at the start of the season**" Michael Palmer commented that "it was an "eye opener" to realise the **importance of irrigation start-up** at the commencement of the season, as I have always had a tendency to hold off and start irrigating later". Wayne Saward indicated that "**the timing of everything was the biggest learning for me**. It's possible to over irrigate and under irrigate on this site, I also understand more about readily available water (RAW)". Luke McNab summed up his experience by saying "dollars saved were realised by not over watering, and understanding the **importance of start-up** at the commencement of the irrigation season".

The introduction of VRI technology has been demonstrated to lead to a reduction in water use of between 29 and 34% across two of the sites, compared with flat rate applications. Other benefits have included better maintenance of laneways under the pivot and the ability to manage events such as silage making and other practices under the pivot without impacting on irrigation applications. In particular the introduction of VRI technology has led to increased pasture production through better management of scheduling (e.g. overcoming issues associated with wet areas and bogging that prevents the pivot from being run when required). Further details relating to the advantages of VRI technology can be found in the attached factsheet developed as part of the project.

There has been a very high level of interest in the outcomes of this project both across the dairy industry as well as from other agricultural industries that rely on irrigation. This has been demonstrated by the significant number of field days and workshops that have been requested throughout this project from farmer groups, agricultural consultants and other agribusiness representatives from the dairy, cotton, sheep, beef, potato and vegetable industries. A total of 45 field days, industry forums and workshops were held across 5 states with more than 1000 in total attending these events, indicating the size and national impact of the learnings from this project. The interest by consultants in improving their understanding of irrigation scheduling in particular provides a pathway for application of this knowledge to other primary producers which was one of the objectives of this national program.

4 Collaboration

This project involved funding contributions from the Commonwealth Government, Dairy Australia and the University of Tasmania. Shared learnings between all the projects occurred through visits to dairy regions and through contributions to field days in Western Australia, South Australia, Victoria and New South Wales, as well as from visits to Tasmanian sites by farmers and other industry representatives from mainland states.

This project involved a formal collaboration between the University of Tasmania and the National Centre for Engineering in Agriculture. The National Centre for Engineering in Agriculture collaborated with TIA to test the application of the VARIwise control platform, developed in the cotton and sugar industries, to a dairy pasture base. This is an important collaborative outcome because it builds on national expertise reducing the need to independently develop similar capabilities. Joe Foley (NCEA) also provided assistance with his understanding of the hydraulics of irrigation and methods that could improve the efficiency of power use across the Tasmanian sites. Both Joe Foley and Alison McCarthy (NCEA) presented at field days and workshops in Tasmania during the three years of the project. A number of visits were also made by TIA researchers and technical staff to the NCEA at the University of Southern Queensland for knowledge sharing and training purposes.

A number of consultants were engaged as part of the project to assist with the delivery of some technical aspects of the project. Reuben Wells from AgLogic Pty Ltd, provided EM38 and elevation mapping services for each of the farms. Reuben also supplied most of the soil moisture probes and assisted with their installation. Reuben also assisted with developing the prescription maps for the variable rate pivots' in the project and worked collaboratively on the development of the VRI factsheet. Reuben also contributed to a number of the workshops and field days, both as a contributor and to develop his own knowledge and skills. Through this process Rueben has had opportunity to engage with these farmers as well as others to assist with soil moisture monitoring needs and provide variability mapping and support for controlling variable rate irrigation pivots. James Currin, from Macquarie Franklin, assisted with the detailed assessment of the pump and motor at two of the five pivot sites and helped train David McLaren (TIA) in this assessment process. Because of this process, James was engaged directly by two of the farmers to develop plans for a number of new pivots on these farms. The use of a trained irrigation design engineer is an important step for the dairy industry as there are many examples of pivot installations that do not provide efficient 'fit-for-purpose' outcomes.

In the second year of the project, Monash University were contracted to test and demonstrate the potential of using remote sensing techniques for spatial measurement of soil water. This collaboration made it possible for some of the latest technology, including L-band radiometers and reflectometers, to be tested at the Cressy site and enabled sharing of data on soil moisture, water use and variability mapping. Due to the expense and limited availability of these type of sensors, the opportunity would not have been possible without this collaboration. There is now interest in testing this technology further in future projects. In particular, there is interest in putting the technology directly onto pivots and including the data obtained as part of the autonomous control platform for irrigation. It is expected there will be a number of journal papers developed as a result of this collaborative opportunity. A report of this work is attached to this document.

5 Extension and adoption activities

Details of the media and communication events that were used to extend the findings of the project and assist with adoption and practice change have been summarised under the following five categories in the appendix

1. Field days, workshops and industry forums
2. Newspaper and magazine articles – print and online
3. Media Interviews
4. Conferences/symposiums
5. Online resources

One of the key pathways to adoption and practice change involves farmers having access to information (records) about the productivity of their system compared with an understanding of the potential productivity of the system. In particular comparing how they are performing compared with similar enterprises in their region through benchmarking or other comparative recordkeeping provides farmers with confidence to assess future opportunities and make decisions that improve farm performance (Lydia et al. 2018). This project was designed to enable collection of power, water and pasture production data on five commercial dairy farms across the major dairy regions of Tasmania. Monitoring of all farms occurred in the first season (15/16) without interaction with the farmers to provide a baseline set of data on water and power use and pasture production. Following this, workshops were organised at each of the farms to discuss the results and to identify where changes could be made to improve the productivity. This process led to changes in practice on all of the participating farms. In particular there was a much greater focus on irrigation start-up time and the appreciation of the value of soil moisture monitoring to assist with the start-up decision. The second year of the project involved providing information back to the participating farmers (soil moisture, pasture growth rates and climate data including evapotranspiration and rainfall) to enable them to use this to form the basis of their scheduling decisions. During the third year of the project close interaction with the farmers on a weekly basis was made to help them understand the data and assist with the optimum timing of irrigation events. This process was very successful as indicated by the significant improvement in productivity for the Cressy farm, where unlimited access to irrigation water enabled ideal irrigation practices in the second and third years of the project to lead to a significant increase in pasture productivity, from an average growth rate of less than 40kg DM/ha/d to more than 60kg DM/ha/d.

In addition to impacting the farmers directly involved in the project, field days and industry forums were organised throughout the project to extend the findings to other farmers and service providers. Many of the field days were held on the participating farmer's properties and the farmers involved were able to interact directly with other farmers to provide firsthand knowledge around the impacts of changed practice on their farms. This often has greater impact than just relaying on knowledge transfer directly from researchers to other farmers. Having data from commercial farms rather than research farms or small plot experiments also seems to have an impact on the validity of the messages for farmers.

Workshops and industry forums were also held across Tasmanian and in South Australia, Victoria, Western Australia and New South Wales to extend the learnings beyond the farms and regions around these to the wider industry. A total of 45 of these events were held over the 3 years of the project.

Pasture growth rate data collected during the second and third years of this project, along with rainfall and evapotranspiration data was also included in the regular industry newsletters sent out to dairy farmers across Tasmania, to enable other farmers to benefit from the data collected on the five project sites.

A number of tours were also arranged for farmers from other states to visit the Tasmanian sites to interact with the participating farmers and assess the relevance of the outcomes for their operations. Perrin Hicks from Mt Compass South Australia, who attended the 2018 tour commented that "Something I'll take home is about our start-up times, we let our soils dry out a lot more where we are, and I think if we start our irrigation a bit sooner, which is something we've been working on with our moisture monitoring, I think we're going to get some gains in productivity and production from our paddocks". Vernon Brown, also on this tour, stated that "It's inspired me to step it up a bit and put the water on so we don't have those deficiencies in water that slow the growth down". Robert Russel from Bega NSW said that "It's very impressive what can and is being done here, and certainly we can adapt a lot of it to our own irrigation. There's certainly so much you can do these days with technology".

A factsheet was developed on VRI and put up on Dairy Australia's Website. A number of webinars were also recorded and videos of Researchers and farmers talking about the project and its outcomes o have been made available online.

The Twitter Hashtag #SmarterIrrigation was used to communicate events associated with the project.

The major barriers to adoption and practice change identified in this project included a poor understanding of system requirements, from the appropriate hardware through to soil and crop constraints, a low skill level and understanding amongst farmers and services providers on the value proposition of getting irrigation scheduling right and a poor understanding of the potential value of variable rate technology. Future programs should focus on the extension of key messages around suitability of the systems, irrigation scheduling and variable rate technology. A series of demonstration farms across a variety of irrigation systems, linked to a local group of farmers and services providers should be established to enable benchmarking of performance and provide training opportunities for farmers and service providers. More formal training opportunities for farmers focused on the practical aspects of irrigation should be developed.

Turner, L., Wilkinson, R. and Kilpatrick, S. 2018. Record keeping helps increase farmer confidence to change practice. Rural Extension and Innovation Systems Journal, 2018 14(1).

6 Lessons learnt

The major lessons from this project are summarised below.

Irrigation system design and function

- Benchmarking is an important first step to establish a base line from which gains in productivity and efficiency can be measured.
- Centre pivot system designs receive less attention than they should. Irrigators are predominantly price driven when making decisions for new irrigation infrastructure, this can result in a system with higher ongoing energy costs over its life. Evidence suggests a higher initial spend on capital (pipes, pumps) can reduce ongoing energy costs. To seal the deal, suppliers have the habit of compromising on critical aspects, like pipe diameters, which reduces costs for the service provider and increases energy usage for the owner. Currently pivots are often installed and paid for without having the design specifications validated. The Montana site provided a clear case study example, where a new pivot with VRI was installed. The pivot failed to perform to specification from day one and took two seasons to iron out all the hydraulic problems. These problems are listed in an attachment to this report.
- PUR (pump utilisation ratio) is an important metric. Keeping PUR high, is an indication the system is well designed. Centre pivots are designed to keep moving, it is possible to over capitalise and have the machine parked (not being used) lowering PUR.
- Understanding the difference between system capacity and managed system capacity and the trade-off between risk mitigation and capital costs are important.
- The higher the total dynamic head (TDH) the higher the energy demands.
- Nozzle charts and monitoring machine performance against designed specification is important. A Nozzle chart is an important document provided from nozzle manufacturers' outlining system capacity of the pivot, flow rates required (L/S), the span length (in metres), irrigated area and the nozzle sequence. Centre pivots are designed on a specific site basis so the metrics these charts provide are an essential point of reference.
- Variable speed drives are often not set correctly which results in the system under-performing.
- As topography and soil type changes with each site there is no "one size fits all".
- The hand-over process when installing pivots from a service provider to a farmer is often not handled well. C
- Consideration of infiltration rates on different soil types are critical with pivot design as water needs to reach the crop root zone and if instantaneous application rates exceed soil infiltration rates substantial levels of runoff are generated.

Available soil moisture and irrigation scheduling

- Understanding the soils readily available water content, the system capacity of the irrigator and the evapotranspiration rate is important in determining when to schedule irrigation and how much to apply.
- Overwatering and under watering are equally as bad.
- The green drought - the expensive implications of getting irrigation scheduling wrong. The “green drought” is a scenario where a farmer irrigates and the soil moisture deficit is already below the refill point. This means the plants have to work harder to obtain moisture than in an optimal situation. As a result plants stay green but without any active growth. The only way to exit the green drought is for the pivot’s irrigation applications to exceed ET for a number of consecutive days or a significant rainfall event to refill the soil profile. Keeping soil moisture levels in the RAW zone is critical in getting productivity gains from irrigation. In pastures, close monitoring of soil moisture is required as rooting depth of plants are shallow (30cm) in comparison to other crops and soil moisture levels can be depleted beyond the refill point in a matter of days.
- Irrigation is generally not well understood, potential yields are not achieved due to incorrect irrigation scheduling and poorly maintained machines.
- Measure to manage is an important principal. Irrigation can give farmers false assurance, water being applied does not necessarily mean water is being utilized effectively on a dairy business. Water on and water off principal needs to be understood which means putting the right amount on at the right time and in the right place.

Variable rate irrigation

- Return on investment in VRI technology depends on growing more grass. Increasing pasture utilisation by 1t DM/ha through the application of VRI technology will reduce the return on investment from 9 years to less than 3 years compared with savings from reduced water inputs alone.
- VRI interfaces and the map creation required to maximise benefits can be complex and time consuming, but significant benefits can be achieved by accounting for the basic factors such as avoiding irrigation applications to laneways, waterways and wet areas.
- During the growing season there are often changes in the spatial distribution of growth in the crop or pasture. Irrigation scheduling may call for a different water application rate to the different management zones as crop water demands change. This may require uploading of up to three zone control maps to the control panel and then choosing the appropriate zone map as the growing season progresses.

7 Appendix - additional project information

7.1 Project, media and communications material and intellectual property

Media and communication events have been listed under five categories below. A copy of some of the media articles, powerpoint presentations and other relevant documents are attached to this report

1. Field days, workshops and industry forums
2. Newspaper and magazine articles – print and online
3. Media Interviews
4. Conferences/symposiums
5. Online resources

Field days, workshops and industry forums

- Feedbase forum - Powerpoint presentation to farmers, researchers and industry representatives 13/10/2015
- Tasmanian Institute of Agriculture Dairy Research Facility Open Day – Powerpoint presentation to farmers, researchers and industry representatives - December 2015
- Cressy Workshop, 3rd June 2016
- Meander workshop, 26th July 2016
- Rocky Cape Workshop, 2nd August 2016
- South Riana Workshop, 10th August 2016
- Sister Creek Workshop, August 2016
- TIA Roadshow, 20th July 2016
- South Australian Workshop, 30th August 2016
- South Australian, Field Day, 31st August 2016
- Meander Field Day, 11th October 2016
- Mawbanna Field Day, 12th October 2016
- Ringarooma Field Day, 21st October 2016
- Sisters Creek Irrigation Field Day, 23rd November 2016
- TIA Dairy Research Facility Open Day presentation, 7th December 2016
- Presentation to Dairy Australia organized farmer tour group from Victoria and South Australia and visit to 4 of the 5 pivot sites, from 23rd to 25th January 2017
- CRDC organized webinar presentation to a farmer tour group in NSW, 9th February 2017
- Webinar presentation organized by Monique White to dairy researchers and advisors 5th April 2017

- Demonstration booth and discussions with farmers and industry representatives at the Tasmanian Agricultural Productivity Group (TAPG) Precision Agriculture Expo Deloraine, 20th April 2017
- Tamworth Optimized Dairy Irrigation Farm Open Day, 9th May 2017 – 15-20
- Keynote talk and a practical workshop at the Tasmanian Water for Profit day in Longford, Tasmania, 18th May 2017– over 100 farmer and industry representatives
- Irrigation workshop at Cressy, 5th July 2017– approximately 12 farmers attending
- Irrigation workshop at South Riana, 12th July 2017
- Keynote speaker at the Roberts Potato/Vegetable Industry Forum, 27th July 2017– over 100 farmer and industry representatives
- Sustainable Ag Irrigation workshop 31st July 2017
- Water for profit information session/workshop Launceston, 6th September 2017 – 15 industry and farmer representatives
- Water for Pofit farmer workshop, Cressy 7th September 2017 - 10-15 farmers plus industry people attending
- Irrigation Workshop Montana, 14th September 2017 - Involved the farmer and researchers working through the last seasons results
- South Riana Field Day, 18th September 2017 -15-20 farmers attending
- Smithton Field Day, 21st September 2017 – 15-20 farmers attending
- Ringarooma Field Day, 22nd September 2017 – 15-20 farmers attending
- Presentation at the Innovation Day, Warrnambool, VIC, 27th September 2017 Over 100 people attending
- Western Australian Irrigation Field Day, Bunbury, WA, 4th October 2017 – Three farmers and a number of industry people attending
- Central North Farmer discussion Group, TAS, 10th October 2017 – 8 farmers attending
- Devonport Discussion Group, TAS, 16th October 2017– approximately 15 farmer and industry representatives attending
- Irrigation Workshop, Sisters Hills, 20th November 2017 – Involved the farmer and researchers working through the last seasons results
- Meander Discussion Group ,29th November 2017
- Ask the Researcher AgVic Webinar, 12th December 2017
- Dairy Australia Irrigation Tour, 27th February to 1 March 2018
- Cressy Field Day, 1st March 2018
- Webinar recording for NSW farmers, 14th March 2018
- Statewide Irrigation Forum, 10th April 2018
- Dairy Business of the Year Field Day at Sisters Creek , 11th April 2018
- Sharefarmer of the Year Field Day at South Riana, 24th April 2018

Newspaper and magazine articles – print and online

- Media Release – Getting Smarter with Data 14/10/2015
- Newspaper article – Tasmania Country 16/10/2015
- Newspaper article – Advocate Primary Producer 22/10/2015
- Newspaper article – Weekly Times (Vic) 09/11/2015
- Magazine article – Australian Grain – November/December issue 2015
- Magazine article – Irrigation Australia – Summer 2016 issue

- Magazine article – UTAS Research to Reality Issue 22 2016
- Newsletter – Dairying for Tomorrow Newsletter, Dairy Australia – December 2015 Issue 31
- Newsletter – Dairy News New Zealand – 11/02/2016
- Article, Tassie Dairy News, June 2016
- Article, Launceston Examiner, 16 June 2016
- Article, Tasmanian Country, 17 June 2016
- Article, Burnie Advocate, 23 July 2016
- Article, Tassie Dairy South Australia Newsletter, November 2016
- Article (Dairy Open Day), Tasmanian Country, 18 November 2016
- Article (Dairy Open Day), Tasmanian Country, 25 November 2016
- Article, Water for Profit Newsletter, December 2016
- Article, From the Ground Up, Summer 2017
- Article, Tasmanian Country, 3 February 2017
- Article, Irrigation Australia Journal, March 2017
- Article, Tasmanian Institute of Agriculture Industry Newsletter, March 2017
- Print article, Farming Tasmania Magazine, Quarter 2 2017
- Article, Tasmanian Institute of Agriculture Irrigation Newsletter, May 2017
- Print article, Country Leader Tamworth, 1 May 2017
- Online article, Get Farming, 11 May 2017
- Online article, Get Stem, 11 May 2017
- Print article, Launceston Examiner, 11 May 2017
- Online article, Stock and Land, 13 May 2017
- Online article, North Queensland Register, 13 May 2017
- Online article, The Land Australia, 13 May 2017
- Online article, Good Fruit and Vegetables, 13 May 2017
- Online article, Farm Online, 13 May 2017
- Online article, Queensland Country Life, 13 May 2017
- Print article, The Land, 25 May 2017
- Print article, Tasmanian Country, 26 May 2017
- Print article, Tasmanian Country, 26 May 2017
- Print article, Tasmanian Country, 23 June 2017
- Print article, Australian Sugarcane, 1 July 2017
- Print article, Tasmanian Country, 21 July 2017
- Article, Tasmanian Institute of Agriculture Irrigation Newsletter, July 2017
- Print article, Launceston Examiner, 24 August 2017
- Print article, Burnie Advocate, 24 August 2017
- Print article, Tasmanian Farmer, 28 August 2017
- Online article, Tasmanian Examiner, 12 September 2017
- Online article, The Advocate, 12 September 2017
- Print article, Launceston Examiner, 14 September 2017
- Print article, Stock and Land, 21 September 2017
- Print article Australian Dairy Farmer 1st December 2017
- Print article Tasmanian Country 8th December 2017
- Print article Jimboomba Times 20th December 2017

- Print Article Irrigation Australia Journal Summer 2018
- Print article Examiner 1st March 2018
- Print article Examiner 8th March 2018
- Print article Advocate 05th April 2018
- Print article Tasmanian Country 13th April 2018

Media Interviews

- Radio interview - ABC Rural Report - aired on the morning of the 14/10/2015
- Radio interview - Tasmanian Country hour report 02/12/2015
- Radio Interview, ABC Northern Tasmania Rural Report, 21 July 2016
- TV interview, Southern Cross Nightly News, 18 May 2017
- Radio interview, ABC Northern Tasmania, 22 May 2017
- Radio interview, ABC Southern QLD, 26 May 2017

Conferences/symposiums

- Irrigation Australia Conference presentation 24-26th May 2016
- Australasian Dairy Science Symposium conference presentation 16-18th November 2016
- Tasmanian Dairy Conference presentation 29th March 2017
- School of Land and Food Conference presentation 14th June
- Red Meat updates conference presentation 28th July – Over 200 farmer and industry representatives
- *Planned presentations*
- Irrigation Australia conference presentation – 14th June 2018
- Dairy Research Foundation Symposium - 17th July 2018

Online resources

Project details

https://www.utas.edu.au/tia/centres/irrigation/projects-new/projects-new/smarter-irrigation-for-profit

Online presentations for training purposes

https://www.youtube.com/playlist?list=PLga0kEuG62TZhF7UOBw_yzsdDCoQEqXpi

Variable rate irrigation factsheet

https://www.dairyaustralia.com.au/farm/animal-management/technologies/pasture-and-feeding-technologies?section=variable_rate_irrigation#accordion-1

No Commercial IP was developed as part of this project. Commercial IP associated with the development of VARIwise for pasture based dairy systems resides in project 2a.This project explored the application of the VARIwise control platform in pasture based dairy systems. Non-Commercial IP was generated in the form of knowledge on the application of enabling practices and new technologies for advancing irrigation performance in pasture based dairy system. Supporting data, analysis and publications were generated and this non-commercial IP is available to support further applied research and for the generation of teaching and extension material

7.2 Equipment and assets

A List of all equipment acquired during the period covered by the project is provided below.

4 x Datataker DT80 loggers

4x Intercel UltraSAM3TG3G Modem

5 x Weidmuller 5 port Ethernet switch

5x Schneider PM800 power metre with ethernet card module

4 x AT600 Ultrasonic flow metres

9 x WDC100 Outpost telemetry system

1 x Druck DPI 705 pressure sensor

5 x Schneider 500x500 steel enclosures

9 x Sentek 60cm soil moisture probes

3 x Aquacheck soil moisture probes

4 x Envirpro 80cm soil moisture probe

6 x Acclima soil moisture sensors

1 x Environdata weather maestro AWS

Dewalt Power tools (Drill, impact driver, angle grinder, circular saw)

7.3 Budget

Budget details to the 30th April 2018 are provided in the Table below.

Source	Approved funding	Funding received	Funding spent to 30th April 2018	Remaining	Estimated expenses remaining
RRDP cash grant		$427,697			
Salaries	$367,573		$348,160	$19,413	$10,000
Interstate activities	$100,425		$61,950	$38,475	$25,000
UTAS Cash		$140,000			
TIA Farm Hire	$30,000		$30,000	-	
Capital	$120,000		$118,795	$1,205	
DA Cash		$180,000			
Tasmanian travel	$54,000		$47,588	$6,412	$1,000
Operating	$116,000		$99,664	$16,336	$2,000
Capital	$10,000		$10,000	-	
Total	$797,998	$747,697	$716,155	$81,841	$38,000

A complete financial statement will be provided by 30th June 2018 after all expenses in May 2018 have been accounted for

7.4 Other project reports and documents

Smarter Irrigation Technical report

Variable Rate Irrigation Factsheet

Energy Audits for Montana

Energy Audit for Sisters Creek

Monash report of spatial soil moisture measurements at Cressy

Final project interviews with participating farmers

Cressy drainage report

Montana drainage report

Penetrometer paper

ADSS conference paper

Rocky Cape FertSmart plan

Cressy FertSmart plan

Media reports