Smarter Irrigation for Profit 2

RRDP 2010 What's My Yield Gap? Maximising Water Productivity

Final Report

Australian Government
Department of Agriculture, Fisheries and Forestry

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Dairy Australia

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Plain English summary

Research Development and Extension activities conducted under Smarter irrigation for Profit Phase 1 (SIP1) found considerable opportunities for improved water productivity and efficiency even on well managed dairy farms. *Smarter Irrigation for Profit 2 (SIP2): What's my yield gap? Maximising Water Productivity* aimed to fast-track adoption of key irrigation principles determined in SIP1 by addressing the barriers to adoption identified.

Method

All Australian dairy regions have businesses that use irrigation, but the types of application and agronomic systems are diverse. New and existing irrigation technologies and strategies were trialled and evaluated in a local context, with input from farmers and service providers through different extension models.

Ten *Dairy Optimisation sites* were established across the seven dairy regions of mainland Australia to capture data for up to three irrigation seasons or defined irrigation periods. Site reference groups were established to act as a discussion and support group and included farmers and private sector providers.

The objective for each irrigated dairy optimisation site was to decrease the 'yield gap' between modelled yield potential and measured yield, using the first season as a baseline. Data on irrigation system performance and design, water and energy usage, and pasture productivity was collated each year for each site to provide objective measurement of system performance and to determine changes throughout the project.

Each site was an example of the primary irrigation system or irrigation system of interest to regional dairy irrigators and was representative of the regional dairy feedbase. Local farmers and service providers helped to determine the *Dairy Optimisation Site* research questions to be addressed over the project's duration. The research, extension and communication activities at each site was conducted by a locally based *Optimisation Site Coordinator*.

Standardised data collection and analysis was adopted to assess the efficiency and profitability of practices and improvements, or constraints associated with closing the yield gap. Water and power efficiencies were identified and evaluated by collecting site data including growth rates and water and power usage. The metrics used were:

Production

- Pasture or crop growth rate (kgDM/ha/day)
- Gross Productivity Water Use Index (GPWUI - tDM/ML (Irrigation + rainfall))
- Energy Efficiency (kWh/ML pumped, kWh/tDM produced, kWh/ML/ metre head)

Costs

- Water use costs ($/tDM)
- Energy use costs ($/tDM)
- Energy Efficiency ($/ML pumped, $/ML/metre head)
- Total Cost per tDM (Cost Energy + Cost Water= $/tDM)

Relevant dairy and irrigation benchmarks were used to assess performance against industry standards.

The irrigation scheduling technologies trialled by the *Dairy Optimisation Sites* were:

1. Soil moisture probes (EnviroPro®) which were installed across various soil types of the site and connected to a cloud-based reporting platform using telemetry (Wildeye®);
2. The weather-based irrigation scheduling tool, IrriPasture, developed by the project (www.app.irripasture.com);
3. The weather forecasting system, SWAN Systems Weatherwise daily 7-day forecast ETo/rainfall report;

4. Pasture.io, a cloud-based spatial satellite and modelling online software package, used to validate accuracy of yield data reported against measured data collected on-site; and
5. A prototype of an automated irrigation scheduling tool using field-based equipment linked to the SWAN Systems water scheduling tool (Mepunga East & Bega Only).

Outcomes

Using irrigation scheduling and soil moisture monitoring technologies, the *Dairy Optimisation Site Farmers*, and engaged peers, made informed irrigation decisions. The technologies allowed the farmers to evaluate the impact of weather conditions (evapotranspiration and rainfall) on their irrigation strategies and build their confidence to maintain soil moisture within the Readily Available Water (RAW) zone, the optimal soil conditions at which plants can easily access water to grow.

By trialling the technologies and strategies on local farms, and having local farmers communicate and discuss their experiences in using the data to inform irrigation decisions, the benefits, and challenges of closing the irrigation yield gap were identified and explored. The project identified increased water productivity can be gained from implementing the following key irrigation principles:

1. Maintain irrigation systems to ensure efficient and effective operation;
2. Determine Readily Available Water (RAW) for each soil type being irrigated;
3. Use a water balance calculator tool to inform irrigation scheduling decisions to apply water at the right time and right rate to maintain soil moisture in the RAW zone;
4. Monitor forecast ETo and rainfall information to assist in more immediate decisions;
5. Monitor soil moisture, using professionally installed soil moisture monitors and reliable telemetry, to inform irrigation start-up decisions at the commencement of the season or after rainfall events;
6. Commence irrigation on-time at the beginning of the season or after rainfall to avoid a green drought scenario where future irrigation are ineffective;
7. Know the capacity of the system and schedule irrigation accordingly to maintain soil moisture requirements whilst deploying other cost-effective measures e.g., off-peak power; and
8. Maintain soil moisture within the RAW zone to create the ideal platform for strategic nitrogen use.

The data generated by the adopted technologies, and support provided by the *Optimisation Site Coordinator* and local service provider and farmer participants, gave *Optimisation Site Farmers* greater confidence to adopt strategies to address the gap between modelled potential yield and actual yield, including:

- Commencing irrigation earlier in season two and three
- Commencing irrigation on time after rainfall events
- Changed application frequency and rate to maintain RAW in Season 3
- Overhauling or purchasing new pumps to improve performance and increase efficiency; and
- Overhauling or purchasing new sprinkler packages to operate within specification, improving application uniformity.

Benefits to industry

Analysis of the data generated from each *Dairy Optimisation Site* was used to evaluate the effectiveness of the changed practices. Seasonal conditions as well as changed practices had an impact on performance metrics. Most sites experienced high variation in seasonal conditions across the three years with heat events or saturated conditions or both. The core strategies implemented delivered productivity and profitability change across the sites.

Across the ten *optimisation sites*, on average there was a 46.76 per cent improvement in Gross Productivity Water Use Index (tDM/ML). The range in percentage improvement for the Gross Productivity Water Use Index was -24.6 to 181. Both the significant average improvement and the wide range in overall productivity

highlights the potential productivity benefits for Australian dairy irrigators if they adopt the irrigation strategies and principles identified by the project.

The water use efficiency target from the Australian Dairy Industry Sustainability report is to "Improve water use and water productivity to utilise 2.0 tonnes of dry matter per ML used. The range from the optimisation sites for this target is from 0.89 to 3.03 tDM/ML. There are still significant gains needed to reach this Dairy Industry sustainability benchmark, however the SIP2 project has established a range that exists and can be used to increase water productivity.

The project delivered 101 extension activities: 25 field days, 5 professional technical workshops, 47 reference group meetings, 8 webinars and 16 farmer/service provider workshops. These activities had 1,734 attendees- 811 farmers, 735 service providers and 163 other roles, including researchers, government agencies and commercial operators.

SIP2 participants reported the activities, including field days, workshops, webinars and meetings improved their knowledge of irrigation practices that could increase productivity, and that the activities were highly valuable to their business. Evaluation results of these activities showed that 91 percent of participants were likely to change irrigation practices and that 81 per cent of these participants were likely to change that practice within the next two years.

Survey respondents reported improved knowledge on average of 1.7 on a rating scale of 1 – 10. Farmers reported improved knowledge on practices that impacted on farm irrigation decision making on a daily basis, e.g. soil moisture monitoring and interpretation, whereas service providers reported greater improved knowledge of irrigation system performance and basic system checks. Tools and activities that could improve productivity, such as soil moisture monitoring to determine irrigation scheduling were widely adopted. Irrigation start-up time and rates of irrigation were areas where a high level of practice change occurred. More than 65per cent of participants changed start up time at the beginning of the season, after major rainfall events, and irrigation application rates as a result of being involved in SIP2. Eighty percent stated they had increased productivity under irrigation.

SIP2 increased the use of soil moisture monitors with telemetry. Of the 81per cent of respondents who were not already using this tool 52per cent reported they had started using the tool as a result of being involved in SIP2 and 43 per cent were still considering it. Only 5 per cent were not considering it at all.

The level of uptake of system performance evaluations and the basic system checks was not as great as the soil moisture monitoring. However, 62 per cent of those who were not already doing basic system checks have adopted this through SIP2, whilst 23 per cent are still considering. The Dairy Australia Land, Water and Climate survey report (2020) indicated that 18 per cent of farmers did no system checks at all on their irrigation systems.

Of the 88 per cent of respondents who were not completing whole system performance evaluation prior to SIP2, 39 per cent started because of SIP2 and a further 52 per cent are still considering. The lower rate of adoption of this activity may reflect the difficulty in accessing service providers with the skills to complete the assessments.

Within a cross sectoral evaluation of the SIP2 project, 58 per cent of dairy farmers reported that improving the management of their irrigation system was very important, with 98 per cent of dairy farmers rating this somewhat important, important, or very important.

Compared to other issues on farm, 56 percent of dairy farmers reported that improving their irrigation system is very important.

Collaborations

The most successful collaboration was between this project and TIA's *SIP2: Beyond Water Smart: advancing dairy irrigation system performance* project. The collaboration between Dairy Australia, TIA and USQ was built on from a previous relationship between these organisations within SIP1. Cross-project and industry collaboration was invaluable.

By working closely together over a total of six years via SIP1 and SIP2, long-term working relationships across industries and organisations, to advance irrigation management and innovation to improve productivity and profitability, is a legacy of the Rural R&D for Profit program, RDC and research organisation investment.

This project was supported by funding from Dairy Australia and the Australian Government Department of Agriculture, Fisheries and Forestry as part of its Rural R&D for Profit program.

Abbreviations and glossary

EM38 Electromagnetic Mapping method for accurately measuring and quantifying soil variation within a specified area, giving farmers spatial information on where irrigation application rate and frequency may require separate management strategies to most efficiency use water and energy to maximise growth. EM38 surveys involve a vehicle towed sensor that is used across the area to measure electrical conductivity (EC) in the soil at designated depths. EC is primarily influenced by soil texture, in particular clay content, soil salinity and moisture levels.

Etc Estimated crop water requirement, obtained by multiplying the specific crop coefficient (Kc) by the reference evapotranspiration (ETo) (Etc= ETo x Kc).

ETo Reference evapotranspiration is a standard estimate of evapotranspiration usually using a reference stand of actively growing well-watered grass at 120mm. It is an estimate of the loss of water from both plants and the soil. The main drivers of evapotranspiration are sunlight, wind, humidity and temperature. ETo is usually given in daily measurements (mm/day).

RAW Readily Available Water is the term used for the water available within the effective root zone of a crop or pasture, that is *easily* extracted by the plant. The amount of RAW in the soil is reduced as plants take-up water and can be replenished with irrigation and rain. The maximum RAW a soil can hold will vary with the crop and soil type.

SMM Soil Moisture Monitoring for this project was comprised of EnviroPro® probes with sensors at 10cm increments, linked to Wildeye® telemetry units that reported volumetric soil moisture status hourly at each depth to a cloud-based platform accessible from a PC or Smartphone.

VRI Variable Rate Irrigation is the ability to spatially vary water application depths across an area to address specific soil, pasture/crop, and/or other conditions. This strategy requires VRI prescription maps to be developed from EM38 survey information and crop/pasture information. Irrigation systems can be designed and commissioned to apply water variably using basic segmentation (decreasing/increasing wheel speed) to individual sprinkler control through solenoid technology to precision apply along the irrigator span.

VSD A Variable Speed Drive is used to adjust a pump's flow or pressure to the irrigated area requirement, or actual demand requirement. Adopting VSDs in irrigation was historically for operational reasons such as providing constant pressure outputs, 'soft starts', or reducing pump wear. More recently, as energy prices continue to rise, the opportunity to save energy has emerged as a more important objective. VSDs allow the farmer to better control water if multiple irrigators, with varying demand requirements, are connected to the one pump.

1 Project rationale and objectives

Irrigation underpins dairy feedbase production in Australia with 58 per cent of all dairy farmers irrigating some or all their land. Regional differences occur with feedbase production supported by irrigation in Murray Dairy (95%), DairyNSW (71%), DairySA (75%) and DairyTas (80%).

Although reduced water availability because of changes to water policy and increased climate variability is impacting how farmers utilize and manage water, dairy farmers have not utilized technologies available to improve irrigation scheduling decisions. This sub-optimal irrigation performance reduces farm forage production and utilisation, impacting farm profits. It also erodes natural capital through soil structure decline and increased deep drainage, impacting water quality and salinity. In addition, it has implications for market access and industry reputation.

Technology is available to assist farmers to improve decision making around irrigation start up times and scheduling and to improve water productivity, energy efficiency and farm profits. However, research from Smarter Irrigation for Profit 1 (SIP1) found that farmers do not get the basics right or utilise these technologies to the fullest.

The Dairy Australia Land Water Climate survey report (2020) found that 79per cent of farmers indicated that irrigation scheduling decisions were based on the appearance of the crop and 48 per cent of farmers were still following a regular scheduling approach. Almost half of those farmers that irrigate (44%) use a water balance approach (29%) and/or soil moisture monitoring (21%), however only 5 per cent use a weather-based water balance tool and 7 per cent use soil moisture probes with telemetry.

SIP2 provided an opportunity to address the findings of SIP 1. RD&E conducted as part of SIP1 found considerable opportunities for improved water productivity and efficiency even on well managed dairy farms. Getting the start-up time and uniformity right and avoiding the 'green drought' increased productivity by 20-40 per cent on the majority of demonstration sites, with an estimated average increase in profit/pivot of $20,000 - $60,000. Addressing pump inefficiencies and existing soil constraints also added to increased productivity.

The SIP1 project also identified key barriers to the uptake of good practice irrigation that needed to be addressed if the industry is to remain a competitive user of water. These barriers are:

- Lack of awareness of poor practice and limited understanding of the potential to increase economic returns.
- The complexity of decision making in relation to irrigation performance given the bespoke nature of many dairy irrigation systems.
- A service industry with limited knowledge about optimising irrigation performance to maximise dry matter production per ML of water.
- Competing management demands with irrigation system maintenance and performance being viewed as a low priority.
- Lack of evidence-based information on how to capture the economic and management benefits of new technologies.
- Uncertainty about future water availability.

At the beginning of the SIP2 project, given 59 per cent of Australian dairy farmers are irrigators and the majority are below good practice there were potentially 3000 dairy businesses that could increase their farm profit by getting the basics of irrigation "right". (Roth et al, 2018 Smarter Irrigation for Profit: A Snapshot; Watson, P; Watson D. 2015 Sustainability Framework NRM Survey).

The SIP2 project aimed to help producers improve soil, water and natural resource management practices for productivity, long-term use and profit, and improved environmental outcomes.

Does a participatory action approach to RD&E build service provider and farmer capacity to identify and mitigate the irrigation "yield gap?"

The key objective of SIP2 was to drive faster adoption of good practice irrigation by addressing the barriers to adoption found in SIP1. To focus and improve the lack of awareness and skills gap established in SIP1, ten *Dairy Optimisation sites* were established across the seven dairy regions of mainland Australia. Site reference groups were established to act as a discussion and support group and included farmers and private sector providers. Data on irrigation system performance and design, water and energy usage, and pasture productivity was collated for each site to provide benchmarking of system performance for the *Dairy optimisation sites.* The objective was to further increase the finding from SIP1 that highlighted the industry need to understand the opportunity to increase water productivity and decrease the yield gap (the gap between potential dry matter (DM) production and actual DM production/ML).

Identify the farm scale costs/benefits of addressing the yield gap caused by poor irrigation system performance and incorrect irrigation

The farm scale costs/benefits of addressing the yield gap caused by poor irrigation system performance and incorrect irrigation scheduling practices were calculated and cost-effective strategies to address poor performance were implemented where data was available. Local and specialist service providers were actively involved in the collection and analysis of data and provided recommendations for improvement of irrigation management or systems where appropriate. The sites provided a practical basis for professional development of farmers and service providers.

Determining the value proposition of new technologies and decision support tools including automated biomass measurement

The sites also served as a platform for demonstration and evaluation of new technologies and decision support tools. Technologies that can reliably take the complexity out of irrigation decision making were favoured for evaluation. The technologies included automated biomass measurement, and soil moisture monitors with telemetry for real time information. The SWAN system using automatically ingested irrigation application rates and timing and weather information to assist irrigation decision making was evaluated on two sites on the mainland.

2 Method, activities, and project locations

The following is the Season 3 (2021/2022) team. There was a total of 19 Optimisation Sites Coordinators, 4 Dairy Australia Project Managers and 3 Dairy Australia Communication Advisors over the three-year duration.

Name	Organisation/Business	Role
Cath Lescun	Dairy Australia	National Soils and Irrigation Technical Lead
Marguerite White	ICD Project Services	SIP2 Optimisation Sites Coordinator
Dr James Hills	Tasmanian Institute of Agriculture	SIP2 Science Leader
Ashley Black	Dairy Australia	Project Manager
Simon Steere	Dairy Australia	Communications Advisors
Sam Taylor	AgVivo	Dardanup Dairy Optimisation Site Coordinator
Cathy Ashby	DairySA- Regional Extension Officer	Mt Compass & Mt Gambier Dairy Optimisation Sites Coordinator
Greg Mitchell	FPAG	Mt Compass Agronomy Advisor
Michael Cutting	Natural Resources, SA Murray Darling Basin	Mt Compass- technical assistance
Rick Jordan	Rick Jordan & Associates	Mt Gambier Agronomy Advisor
Graeme Ward	Graeme Ward (Sole Trader)	Mepunga East Dairy Optimisation Site Coordinator
Libby Swayn	WestVic Dairy	Lead Regional Extension Officer
Peter Gaffy	WestVic Dairy	Regional Extension Officer
Billy Marshall	Agriculture Victoria- Irrigation Officer	Yarram & Cobains Dairy Optimisation Sites Coordinator (Technical)
Robyn Mclean	GippsDairy- Regional Extension Officer	Yarram & Cobains Dairy Optimisation Sites Coordinator (Extension)
Natalie Eckard	Murray Dairy- Regional Extension Officer	Tongala Dairy Optimisation Site Coordinator

Kym Revington	Kym Revington (Sole Trader) via Far South Dairy Development Group	Bega Dairy Optimisation Site Coordinator (Technical)
David O'Donnell	David O'Donnell (Sole Trader) via Far South Dairy Development Group	Bega Dairy Optimisation Site Coordinator (Extension) Irrigation System Evaluation Technical Specialist
Peter Smith	Sapphire Irrigation Consulting	Tocal Dairy Optimisation Site Coordinator Irrigation System Evaluation Technical Specialist
Ross Warren	Queensland Government Department of Agriculture and Fisheries	Coraki Dairy Optimisation Site Coordinator
Marek Matuszek	AgLogic	Technical Specialist- Wildeye® Soil Moisture Monitoring platform
Assoc. Prof. Joseph Foley	University of Southern Queensland- Centre for Engineering in Agriculture	IrriPasture Web App development partner
Ivor Gaylard	Swan Systems	Swan Systems automated Irrigation Scheduling tool

The following is a list of the locations of all commercial farms involved in the SIP2 project activities.

Name & type of site (field site, laboratory, project partner sites, RDC headquarters)	**Street Address**	**State**	**Postcode**
Dairy Optimisation Site	Subtropical Dairy, Coraki	-28.948063, 153.269998	New South Wales
Dairy Optimisation Site	Dairy NSW, Tocal	-32.6321944, 151.598561	New South Wales
Dairy Optimisation Site	Dairy NSW, Bega	-36.7185194, 149.8697992	New South Wales
Dairy Optimisation Site	Murray Dairy, Tongala	-36.207034, 144.934223	Victoria
Dairy Optimisation Site	GippsDairy, Yarram	-38.5610786, 146.7101765	Victoria
Dairy Optimisation Site	GippsDairy, Cobains	-38.0968270, 147.1158734	Victoria
Dairy Optimisation Site	WestVic Dairy, Mepunga East	-38.442555, 142.692268	Victoria
Dairy Optimisation Site	DairySA, Mt Gambier	-38.0110623 ,140.8911265	South Australia
Dairy Optimisation Site	DairySA, Mt Compass	-35.4175139, 138.6937861	South Australia

Dairy Optimisation Site	Western Dairy, Dardanup	-33.450682, 115.757956	Western Australia

Regional Applicability

Each of the ten *Dairy Optimisation Sites* represented an irrigated dairy regions on the Australian mainland, with the the feedbase system and the primary irrigation system or irrigation system of interest to regional dairy irrigators representative of the area.

Each site had variations in soil type and landscape characteristics that were considered.

Data was collected for the duration of the "typical" irrigation period of the region. The table below provides a summary of the *Dairy Optimisation Sites*.

Optimisation Site	Optimisation Site Farmer	Irrigation System	Dominant Pasture/ Crop Type	Readily Available Water (mm) of soil types
Coraki	Brian Chappell	Fixed Sprinkler	Kikuyu/ Annual ryegrass	21 - 24
Tocal	Matt Brett	Centre Pivot	Kikuyu/ Annual ryegrass	27-35
Bega	Will Russell	Centre Pivot	Kikuyu/ Annual ryegrass	17
Tongala	Andy Tyler	Surface Irrigation	Maize	50
Yarram	Shelley Field	Centre Pivot	Perennial ryegrass & millet (Season 2 only)	25.5 (ryegrass) -48 (millet)
Cobains	Garry Cook	Surface Irrigation	Perennial ryegrass	30
Mepunga East	Stephen Smith	Centre Pivot	Perennial ryegrass	9-22
Mt Gambier	James Mann/ Cornelius Zonneveld	Centre Pivot	Perennial ryegrass	12
Mt Compass	Ben McHugh	Centre Pivot	Biennial ryegrass (Season 1) & Lucerne (Season 2 & 3)	27(establishing lucerne)-39 (established lucerne)
Dardanup	Michael Twomey	Centre Pivot	Biennial ryegrass, however, was white clover dominant.	15

Appendix 1 provides the *Dairy Optimisation Technical Report* for each of the ten *Dairy Optimisation Sites*.

Whilst each of the sites focused upon a particular irrigation and pasture or crop system, the key messages are transferable across all regions where similar systems are used. Evapotranspiration (ETo), frequency/ intensity of rainfall (mm) and duration/ intensity of heat events influence irrigation decisions and should be considered when transferring key messages.

Emanating from the outcomes of SIP1, SIP2 applied a key set of principles across all *Dairy Optimisation Sites*. These key principles are applicable across climatic conditions, agronomics, soils, and irrigation systems.

SIP1 Key Principles

Increased water productivity can be gained from implementing key principles.

- **Maintain your irrigation system** to ensure efficient and effective operation. Start with a comprehensive irrigation system performance evaluation and implement recommendations. Use available system check lists to prepare for the coming season.
- **Determine Readily Available Water (RAW)** for each soil type you are irrigating. RAW is the term used for the water available within the effective root zone of a crop or pasture that can be easily extracted from soil without impacting growth. By maintaining RAW, the plant converts energy into growth rather than using it to extract water.
- **Use a water balance calculator tool** to inform your irrigation scheduling decisions to apply water at the right time and right rate to maintain soil moisture in the RAW zone. IrriPasture is the free online tool for perennial/ annual ryegrass pastures, maize, millet, sorghum & lucerne.
- **Monitor forecast information** to assist in more immediate decisions. Consider ETo and rainfall predictions when deciding to irrigate and whether to adjustment rate of application. Swan Systems Weatherwise 7-day forecast emails are free and are considered highly reliable by dairy farmers using the reports.
- **Monitor your soil moisture**, using professionally installed soil moisture monitors and reliable telemetry, to inform irrigation start-up decisions at the commencement of the season or after rainfall events. This technology provides a measurement of the effectiveness of rainfall and irrigation on raising or maintaining soil moisture within the RAW zone.
- **Commence irrigation on-time** at the beginning of the season or after rainfall to avoid a green drought scenario where future irrigations are ineffective, failing to lift soil moisture back into the optimal RAW zone for maximised pasture growth.
- **Know the capacity of your system** and schedule irrigation accordingly to maintain soil moisture requirements whilst deploying other cost-effective measures e.g., off-peak power. If soil moisture levels are depleted below the RAW zone, the potential of the irrigation system to raise soil moisture back- up into this ideal zone for plant growth can become limited by its capacity.
- **Maintaining soil moisture within the RAW** zone creates the ideal platform for strategic nitrogen use.

Method & Activities

The *SIP2:What's my yield gap? Maximising water productivity* project established ten *Dairy Optimisation Sites* across seven mainland dairy regions of Australia to capture data over up to three defined irrigation periods. . Project staff worked closely with staff from the Tasmanian Institute of Agriculture's (TIA) *SIP2: Beyond Water Smart: advancing dairy irrigation system performance* project and undertook similar activities as on the five sites in Tasmania. Targeted research on selected mainland sites contributed to further work in the SIP2 *Beyond Water Smart* project.

The *Optimisation Farmers* were selected in consultation with the regional dairy programs using the following criteria:

- Needs to be engaging and open to discussing issues/ solutions with local peers.
- Willing to make changes to the way they determine irrigation scheduling and irrigation system management, including trial of a simple app based scheduling tool.
- Willing to provide and collect available usage and cost data related to water and power.
- Ability to self-measure and record pasture Dry Matter (DM) approximately every ten days using a standardised measurement tool (i.e., plate meter, C-dax meter) to ensure measurement is consistent.
- Willingness to share any data collected from soil moisture probes, flow meters, pasture measurements and local weather data directly related to this project.
- Willingness to host field days and participate in communication activities such as media articles and case studies.

Whilst overall these criteria were met, DM measurements were primarily undertaken by a third party, except for Brian Chappell at Coraki.

Each of the sites was overseen by an *Optimisation Site Coordinator* who was responsible for implementation of site data collection, regular communication with the *Optimisation Farmer* to discuss interpretation of the site data and irrigation response, extension of the site learnings through reference groups and annual events (workshop + field day), and regional communications. Engagement of suitably qualified personnel into these roles was specific to each region. At certain sites, the role was divided into separate technical and extension/communication roles.

Each *Dairy Optimisation Site* reflected local systems and conditions and as such local site questions were developed in consultation with local farmers and service providers, to focus the discussion and trials on local needs.

Demonstrated and trialled technologies

Based on SIP1 outcomes the following technologies were installed on each *Dairy Optimisation Site*:

1. **Soil moisture monitors (SMM), installed by a suitably experienced person, comprising:**
    - Capacitance probes with sensors at 10cm increments to a depth suitable for the pasture/ crop of the site over the three-year period.
    - Tipping bucket rain gauge.
    - Loggers with real-time telemetry; and
    - Smart-phone accessible logger data platform.

Why was this technology used? *To indicate the depth irrigation and rainfall has moved to and understand where soil moisture is being extracted from in the soil profile. This provides information on where refill/field capacity points should be set. Farmers are more likely to use this information if it is readily available and user friendly.*

Locating SMM sites was determined by using data from the Electromagnetic Conductivity survey (EM38) mapping at East Mepunga, Bega, Mt Compass, Mt Gambier and Dardanup. At other sites, the location was determined by farmer knowledge of the soil types/ characteristics. The probes were installed into the most representative soil type of the trial area and into other soil types and/or dry-land sites to increase the understanding of different soil responses to irrigation, rainfall and ETo..

For each probe location, the RAW was determined through soil sampling and soil texture analysis. The *Determining Readily Available Water from Soil Texture Information* resource was developed and used to calculate how much RAW was in the effective root zone for each soil and plant combination being monitored.

EnviroPro® probes (40cm or 80cm) and Wildeye® telemetry units were installed on each site. In some instances, a suitably qualified technical specialist travelled large distances to install the equipment. On the South Australia sites (Mt Compass & Mt Gambier), Terros-12 soil probes had been installed during SIP1 , that measure to 30cm only. An 80cm EnviroPro® was later installed at Mt Compass to reflect the rooting depth of an established lucerne plant. The Tongala site removed the probes prior to maize harvest and reinstalled after maize sowing. All systems determined volumetric water content (VWC).

The Wildeye® reporting platform was set-up for each site by Marek Matuszek of AgLogic, who also supported the *Optimisation Site Coordinators* for the duration of the project to interpret the data and trouble-shoot issues as they arose. The refill and field capacity lines of the summed graphs for all sites was adjusted as necessary by Marek in consultation with the *Optimisation Site Coordinator*.

Optimisation Site Coordinators were responsible for supporting the *Optimisation Farmer* and reference group members in use and interpretation of this SMM technology.

2. **IrriPasture a free and readily available weather-based irrigation scheduling tool**(https://app.irripasture.com/) **:**
    - A "Crop Type" was established for separate management areas of the optimisation site. Management areas were based on plant species or soil texture.
    - Nearest Bureau of Meteorology (BOM) or NRM Board (SA) weather station was linked to the site for automated ingestion of ETo and rainfall data.
    - *Optimisation Farmer* was supported to input irrigations.
    - IrriPasture water budget and Etc graphs were used by Optimisation *Site Coordinator* and *Optimisation Farmer* in conjunction Wildeye® graphs and observations on site.
    - Water balance information was integrated into weekly or monthly *Irrigation Requirement* Reporting.
    - The new "Stop Monitoring" function was used in Season 3 to enable a new water balance to be created for each new season.

Why was this technology used? *This is a simple water budget and irrigation scheduling tool developed to assist farmers make informed irrigation decisions.* Improvements to *IrriPasture were made in response to farmer and service provider feedback over the duration of the project.*

3. **SWAN Systems Weatherwise daily 7-day forecast ETo/rainfall emails:**
    - *Optimisation Site Coordinator* set-up the optimisation site by locating the nearest grid-point on the 6km x 6km grid system.
    - Daily emails were received by both the *Optimisation Site Coordinator* and *Optimisation Farmer* with a 7-day forecast of ETo and rainfall.
    - Forecast information was integrated into weekly or monthly *Irrigation Requirement* Reporting

Why was this technology used? *This is a simple and free service for farmers to monitor 7-day forecasts of ETo and rainfall. The tool had been used by dairy farmers in NSW previously with promising results. The service was considered more accurate than other sources and gave irrigators more confidence to postpone irrigations when rainfall was predicted or bring forward irrigations when high ETo events were predicted.*

4. Pasture.io comparison with measured data

- *Optimisation Site Coordinator*, in consultation with the *Optimisation Farmer,* selected paddocks where Pasture.io technologies using satellite imagery and modelling were used to report growth rates and pasture covers.
- Grazing events were entered within 3-days of grazing to optimise modelling results.
- Feed wedge and mapped growth rates were used in some weekly or monthly *Irrigation Requirement* Reporting.
- For each season, Pasture.io growth rates were graphed against modelled and actual measured data collected for the site.

Why was this technology used? *To test whether this technology is an accurate, user friendly and cost-effective replacement for manual, time consuming DM measurement. Making changes to irrigation practices can only be truly assessed through growth rate data.*

5. SWAN Systems Precision Irrigation software (Mepunga East & Bega Only)

FieldWise "Nano" telemetry units were installed on the centre pivot irrigators of the Mepunga East and Bega *Dairy Optimisation Sites* to detect and record the flow rate, duration and the frequency of irrigation events. The data automatically uploaded, along with other meteorological data and predictions, to the "SWAN Systems" precision irrigation software program. This automation removed the task of inputting irrigations into the software. Trialling this automated process to inform irrigation scheduling occurred on two sites in the *What's My yield Gap?* project in parallel with two sites in the *Beyond Water Smart* (Tasmania) project.

Evaluation of irrigation technologies and strategies

A standard set of metrics was applied across all sites to assess the efficiency and profitability of changing practices and adopting technologies.

Production

- **Growth rate** - kgDM/ha/day
- **Gross Productivity Water Use Index** (GPWUI) - tDM/ML (Irrigation + rainfall)
- **Energy Efficiency** (within site/across seasons)- kWh/ML pumped & kWh/tDM produced
- **Energy Efficiency** (comparison between sites)- kWh/ML/ metre head

Costs

- **Water**- $/tDM
- **Energy**- $/tDM
- **Water Efficiency** (within site/across seasons) - $/ML pumped
- **Energy Efficiency** (comparison between sites) - $/ML/metre head
- **Total Cost per tDM** - Energy + Water= $/tDM
- **Total Cost per ha** -Energy + Water =$/ha

Data was collected across two or three seasons to enable evaluation of the water and energy efficiencies. Data was stored, entered into the *Site Data Spreadsheet*, an Excel based template stored on the project One Drive, IrriPasture (irrigations & weather station rainfall) or the Wildeye® platform (site rainfall & soil moisture status).

- **Dry Matter**- electronic rising plate meters (RPM) were used on all sites to undertake post and pre grazing measurements along a determined transect to determine growth rates (tDM/ha/day) for the

grazing rotation. All RPM were calibrated using pasture cuts to prepare a calibration curve or a published correlation was used. In Season 3 at Tocal, pasture cages and dry matter cuts approach was used in time with the grazing of the site.

- **Energy use and costs** were determined through electricity bills or using the results of the irrigation system evaluation (kWh/ML).
- **Water use** was determined through on-site flow meters, irrigation system platforms (such as AgSense® or FieldNET®), local water authority flow meters, or irrigation applications entered into IrriPasture. A combination approach was used when necessary to validate data.
- **Water costs** were determined through water access and usage charges.
- **Effectiveness of irrigations and rainfall** was determined through Wildeye® and IrriPasture reporting graphs.

Collecting data during Covid-19 restrictions. *All sites were heavily impacted in timeliness of data collection, especially DM measurement. During lockdowns, engaged agronomists or the Optimisation Site Coordinators were unable to visit sites for certain time periods. Estimates were determined when appropriate, however, for certain seasons, the entire season was impacted. Details of reportable seasonal data can be found in Appendix 1- Dairy Optimisation Technical Reports.*

Irrigation System Evaluations

Comprehensive irrigation system evaluations were completed by Irrigation Australia certified evaluators, Peter Smith and David O'Donnell. Where local non-certified consultants undertook certain components of a system evaluation, Peter Smith was engaged to validate the findings. (Yarram, Mt Compass, Mt. Gambier and Dardanup). A lack of national accredited system evaluators and Covid-19 border closures impacted the project's ability to complete all evaluations during Season 1. Second evaluations were hampered by extreme wet conditions across all NSW sites. The table below outlines the irrigation system evaluations:

Optimisation Site	Evaluation 1	Evaluation 2
Coraki	Peter Smith (2019)	Not completed due to flooding
Tocal	Peter Smith (2020)	Not completed due to excessive wet
Bega	David O'Donnell (2020)	Postponed due to excessive wet. David O'Donnell to complete (2022)
Yarram	David Shambrook (Catch-can only- 2020)	David O'Donnell (2022)
Mepunga East	Peter Smith (2020)	David O'Donnell (2022)
Mt Gambier	Tim Powell (limited- 2020)	Peter Smith (2022)
Mt Compass	Michael Cutting & Rob Welke (limited- 2020)	Peter Smith (2022)
Dardanup	Les Bekker (Catch-can only- 2020)	Peter Smith (202)

To assess the performance of an irrigation system, pressure was measured at key points in the system, the operating speed (centre pivot) and the output of the emitters were measured, and the energy use and flow rate were recorded. The catch-can tests for centre pivots were conducted in accordance with International Standard ISO 11545. For a comprehensive overview of the methodology, refer to *Appendix 2- Smith, P. (2022) SIP2 Irrigation System Evaluations Report, Tamworth, NSW.*

The following steps were taken:

- Details of the installed sprinklers were checked against specification
- Wind speed and direction were recorded
- Control panel settings/readings were recorded
- Two rows or a grid of catch-cans were laid out at intervals no greater than 5 metres

- When the centre pivot had passed over all the catch-cans or a suitable time period for solid-set had passed, the volumes in each can were measured and recorded
- Tyre sizes and pressures were checked (centre pivots)
- Wetted width or diameter of the wetting pattern was measured
- Centre pivot speed was measured by timing the outer wheel track over a measured distance
- Flow rate from selected sprinklers was measured and compared to specification
- Flow meter readings were recorded and the time interval between them
- Electricity meter readings were recorded and the time interval between them

Calculating the results

Measurements were entered into the dedicated online calculator *Knowledge Management System for Irrigation*, developed and maintained by the University of Southern Queensland - CEA. Results were determined from the tool's output system, with certain results calculated by manual means.

Benchmarks

Potential Yield

To determine the potential yield of each *Dairy Optimisation Site*, the Tasmanian Institute of Agriculture was engaged to conduct modelling and prepare reports for (1) pasture systems and (2) cropping systems of the *Dairy Optimisation Site*s.

Christie, Karen (updated 2022), Yield gap modelling for the Smarter Irrigation for Profit II project, Tasmanian *Institute of Agriculture, Burnie, Tasmania* (Appendix 3) used the dairy industry's *DairyMod*, to determine the yields of perennial ryegrass systems (Mt. Gambier, East Mepunga, Yarram, Cobains), annual ryegrass over sown into kikuyu (Coraki, Tocal, Bega) and sub-clover and ryegrass (Dardanup)). The treatments applied were:

1. unlimited irrigation with monthly N fertiliser
2. unlimited irrigation with Growth Limiting Factor (GLF) N fertiliser regime (strategic N applications)
3. scheduled irrigation with monthly N fertiliser,
4. scheduled irrigation with GLF N fertiliser regime
5. rainfed with monthly N fertiliser; and
6. rainfed with GLF N fertiliser regime (green hashed boxplots and lines).

The simulations commenced from the 1st of January 1979 and extending through to the 31st of March 2022. The most recent 22 years of data (Jan 2000 to Mar 2022) was used for the analyses. For the mixed pasture systems, date of emergence, anthesis and number of days from anthesis to maturity was used to determine the "typical" seasonal scenario of the relevant *Dairy Optimisation Site*.

The scheduled irrigation with GLF N fertiliser regime was compared to the actual measured DM data to determine the "yield gap".

For the cropping sites, Agricultural Production Systems sIMulator (APSIMv7.10) was used to model the crop yields. *(Hill, J., Harrison, M. and Liu, K. (2022), Fodder yield gaps for maize, millet and lucerne in Australia, Tasmanian Institute of Agriculture, Burnie, Tasmania* (Appendix 4)). Potential DM production, in the absence of nutrient and water stresses for millet, maize and lucerne biomass production was determined for Yarram, Tongala and Mt Compass respectively. APSIM was used to simulate millet and maize biomass production for the period of 1981–2021 and lucerne biomass production for the period of 1991-2022.

The APSIM "cut manager" was used to simulate four grazings for the millet crop (the first is 30 cm and second to the fourth was at 15 cm) on 18-day intervals between 1 January and the 28 February with the biomass harvested 1.8tDM/ha. Irrigation efficiency was set at 0.7. Sowing rates were set at 10 kg/ha with sowing depth of 50 mm. Though these parameters were the 'best fit' parameters with practices on the *Dairy Optimisation*

Site, a APSIM does not have data on newer varieties of millet and therefore the results were lower than the modern cv. Shirohie can potentially achieve.

For the maize simulations, biomass was harvested at maturity for each sowing date. Flood irrigation was set to an irrigation efficiency of 0.9. Sowing density was set at 10 plants per m2 with sowing depth and row spacing at 50 and 500 mm, respectively. These parameters were the 'best fit' parameters with practices on the *Dairy Optimisation Site*.

For lucerne simulations, daily growth rate was simulated from 1 January to 31 December from 1991 to 2022. Grazing was emulated with the APSIM cut manager at the first day of each month to a height of 80 mm. Automatic irrigation was applied when soil water deficit reached 10mm; this procedure represents minimal stress associated with the water-deficit for the crop. Rates varied between 12 and 18mm per application. The amount of water applied year-round was compared to that applied during the long-term deficit period (1st October to 30th April). However, the production reported is based on irrigating year-round. No N fertiliser was required for the crop. Pasture production was calculated as the sum of growth rates for each year. These parameters were the 'best fit' parameters with practice on the *Dairy Optimisation Site*.

Gross Productivity Water Use Index

Under the Australian Dairy Sustainability Framework, goal nine, the industry has committed to improving water use and water productivity to utilise 2tDM/ ML by 2030. A benchmark between 1-2 tDM/ML was used for the project.

Irrigation System Performance benchmarks

Benchmarks were set based on international and Australian standards, Irrigation Australia performance indicators and equipment specifications.

Measure	Description	Benchmark
Flow rate	Measured flow v specified;	±5%
System Capacity	Flow rate ÷ irrigated area	Minimum: peak pasture water use
Coefficient of Uniformity	Measures of evenness of application	85% centre pivot, solid-set
Distribution Uniformity		80% centre pivot, 75% solid-set
Application v Setting	Measured depth applied compared to set depth applied	±5%
Pump Efficiency	Measured efficiency of motor-pump unit	75%
Energy Use Efficiency	Allows comparison with all electric pumps	3.8–4.5 kWh/ML/m head
Average Application Rate (AAR)	Measured from high output sprinkler	Should not exceed soil infiltration rate
Emitter flow rate	Measure flow from selected emitters	±5%
Centre Pressure	Variation from specified pressure at centre of pivot	+10%
End Pressure	Variation from specified pressure at end of pivot	+10%

Extension and Communication

Optimisation Farmer and Optimisation Site Coordinator partnership

Particularly during the irrigation measurement periods, the relationship between these two roles was integral to broader extension and communication activities of the project. Across all sites, information exchange occurred about data and to inform weekly site reports, the site metrics, and discuss possible irrigation management strategies in relation to current conditions and forecast data. The farmers were willing to allow external consultants to visit the site and to host core extension activities.

Dairy Optimisation Site Reference Groups

This project set-out to establish a Participatory Action Learning (PAR) model across all sites. It was intended that each *Dairy Optimisation Site* would be supported by a reference group comprised of local dairy farmers and service providers who were motivated to provide ongoing input, learn from engagement activities, and apply new practices to their own irrigated areas, and evaluate as applicable.

In practice, there was a variation in reference group models used across the sites (refer Appendix 1) reflecting group makeup and skills, input and feedback from local dairy groups.

At four of the sites (Mt Compass, Mt Gambier, Yarram and Cobains), the SIP2 reference group was integrated into existing regional dairy discussion groups already supported by the regional dairy programs of Dairy Australia. Coraki, Bega and Dardanup held the core site extension activities (see below), drawing on the existing regional dairy groups to promote and communicate on the project. In Season 2, Bega managed to conduct three reference group meetings. Season 1 was affected by post bushfire impacts, and Season 3 by flooding an insight into the extremity of conditions experienced at this site. Both Coraki and Dardanup were supported by local farmers in initial site start-up activities, both holding on-site planning meetings to commence the project.

Murray Dairy formed two "Technical Coaching Groups" as an output of an aligned project and drew upon the membership base to provide input into the project and to attend the core site activities (see below). Workshops were conducted specifically on using soil moisture monitoring technologies as each of the members were supplied with GoannaAg® technology.

Tocal and East Mepunga were the only sites to form separate, stand-alone reference groups, with ongoing meetings held during irrigation periods. The frequency, topics, location and technical speakers for the reference group meetings were determined by the group themselves. These groups did not have a measurable impact on the practices of the *Optimisation Site Farmer.* The success was in their willingness to explore topics of interest, such as variable rate irrigation (VRI) and integrated topics such as energy efficiency, agronomy for irrigated sites and nutrient management.

Each of the sites set site research questions, formed in consultation with their various reference group members or at initial start-up events. Refer to Appendix 1 for the detailed research questions.

Core Site Extension Events

Greatly impacted by Covid-19 throughout the project duration, the SIP2 team was highly responsive to local sentiment on group gatherings and pivoted around government-imposed restrictions when required to. There were many occasions when planned and promoted activities had to be either postponed or cancelled.

Each of the *Dairy Optimisation Sites* delivered at least two field days and two workshops during 2020-2022. Some of these events were online, but whenever possible were conducted face to face, the preferred approach of dairy farmers in "typical" times.

In early 2020/2021, a national approach was taken to extension activities in response to ongoing lockdowns, particularly in Victorian and NSW. Four major online webinars were conducted with expert speakers, resulting in over 200 attendees:

- July 9, 2020: *Using Pasture.io on your farm- The impact of monitoring yield under irrigation*
- July 28, 2020: *Using energy data to optimise irrigation system efficiency, effectiveness and operating costs*
- August 5, 2020: *Using weather forecasting and soil information for irrigation decisions- The impact of improving irrigation decisions*
- August 19, 2020: *Using soil moisture monitoring and data to maintain RAW- The impact of RAW to improve irrigation decisions.*

Core Site Communication Activities

The *Optimisation Site Coordinators* were supported, by the communication personnel of Dairy Australia's regional dairy programs. Annually, at least two articles were published in regional printed or electronic newsletters. Local dairy development groups (i.e., Bega- Far South Dairy Development Group, Tocal- Mid Coast Dairy Action Group & Hunter Dairy Development Group) supported the publication of articles.

Weekly or monthly *Irrigation Requirement Reports* were a core activity undertaken at most of the sites. In general, these reports contained:

- The SWAN Systems Weatherwise 7-day forecast for ETo/rainfall at the optimisation site.
- ETo and rainfall data for 7-days previous recorded at the nearest BOM AWS and rainfall at the optimisation site.
- A simple water balance calculation to inform irrigation requirements
- A representative Wildeye® soil moisture graph to demonstrate current moisture status
- Commentary on the information and what it meant for irrigation requirements and management.
- A short item on relevant weather or irrigation related issue: e.g., seasonal climate outlooks.
- Upcoming events for the group.

For further detail on the format and distribution of the site *Irrigation Requirement Reports,* refer to the *Optimisation Technical Reports* provided in Appendix 1.

Site Coordinator Knowledge Exchange

An *Optimisation Site Coordinator* meeting was conducted for 1.5 hours monthly, online during each of the irrigation seasons with the SIP*2 Optimisation Sites Coordinator* (Marguerite White), Dairy Australia National soils and Irrigation Lead (Cath Lescun), and SIP2 Science Leader (James Hills). These were an opportunity to share new knowledge and understanding and collaborate on irrigation strategies used across sites. They were also used to plan for extension and communication activities.

Annually, a team forum was conducted with TIA's site coordinators:

- November 14th, 2019 (face to face, Melbourne)
- August 4th & 5th, 2020 (online)
- September 8th & 9th, 2021 (online, was planned for face to face, East Gippsland)
- April 12th & 13th, 2022 (face to face, Melbourne)

The first forum objective was to upskill and create a consistent approach to the optimisation sites data collection and activities, with the later forums focused on *Optimisation Site Coordinator's* presenting their seasonal findings and updating on "winning moments and challenges" in undertaking research, extension and communication activities.

3 Project Outcomes

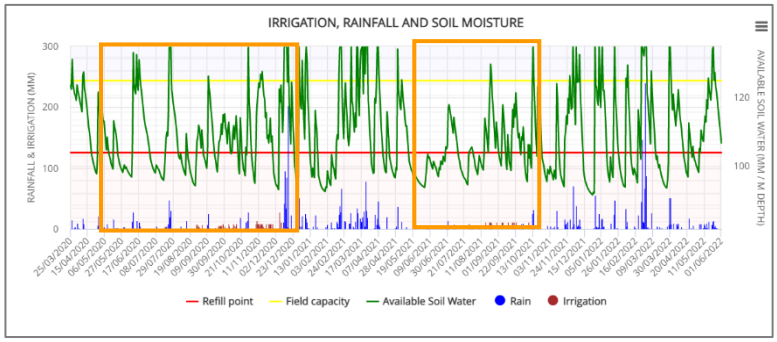
3.1 Project level achievements

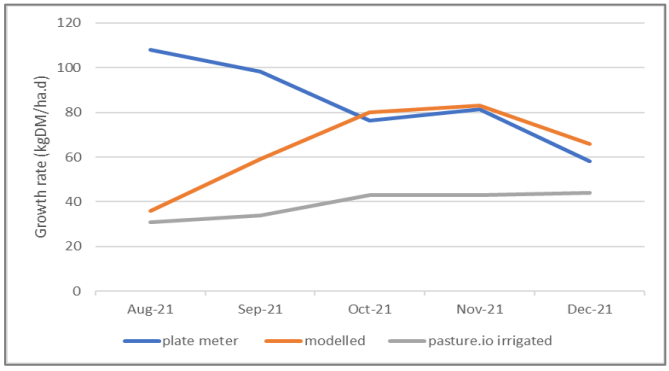
Output and KPI numbers and description	Summary of achievements
Activity output 5.3(a) Establish and maintain 10 mainland Australia optimised dairy irrigation sites and associated satellite farms to demonstrate and validate the benefits of closing the irrigation yield gap.	Ten *Dairy Optimisation Sites* were established to capture data over up to three irrigation seasons, located within the seven mainland dairy regions of Australia. The networks and irrigation technologies outlined in Section 2, supported local dairy irrigators to increase their knowledge and understanding on how the SIP1 key principles applied to the climate, soil types, agronomy, and irrigation systems of their regions. Through trialling the technologies and strategies on local farms, and having local farmers communicate and discuss their experiences in using the data to inform irrigation decisions, the benefits, and challenges of closing the irrigation yield gap were identified and explored. The information provided by the adopted technologies, and support provided by the *Optimisation Site Coordinator* and local service provider/ farmer participants, gave *Optimisation Site Farmers* greater confidence to trial certain strategies to address the gap between modelled potential yield and actual yield. Strategies included • Commencing irrigation earlier in Seasons 2 and 3 prior to soil moisture declining below the refill point on the Wildeye® soil moisture graphs. *Past practice addressed: Dairy irrigators commence irrigation too late at the beginning of the irrigation season, using surface/ plant visual observations to make irrigation decisions. Delaying start-up, requires increased amounts of irrigation to lift and maintain soil moisture in RAW and sometimes needing the irrigation system capacity to be larger than it is or run the system for longer using peak power. A Green Drought scenario can prevail for the entire season if there is limited capacity, therefore impacting yield for the entire season.* • Using the Wildeye® soil moisture graphs to evaluate the effectiveness of rainfall events to decide when to commence supplement irrigation to maintain RAW. *Past practice addressed: Dairy irrigators commence irrigation too late after rainfall events as they cannot evaluate the effectiveness of rainfall upon soil moisture other than through surface/ plant visual observations. By starting irrigation too late, the value of rainfall is*

	not recognised, and late irrigations require increased volumes of water and the use of unnecessary power to pump. Again, a Green Drought scenario can prevail for the remainder of the season if there is limited system capacity, therefore impacting yield. • Changed application frequency to maintain RAW in Season 3 based on under or overwatering indications on the Wildeye® soil moisture graphs, evaluation of forecast weather implications, and the IrriPasture water balance. At times, increased frequency with decreased rate was the strategy needed. *Past practice addressed: Dairy irrigators use a standard frequency of irrigation events governed by past practices and off-peak power windows. Periods of no irrigation without consideration for ETo can quickly see soil moisture decline below the refill point. Applying irrigation without consideration for forecast rainfall can see soil moisture levels lift above field capacity. Both require unnecessary use of water and power to rectify the situation and cause impact to yield.* • Changed application rate to maintain RAW at-depth in Season 3 based on under watering indications on the stacked Wildeye® soil moisture graphs, evaluation of forecast weather implications, and the IrriPasture water balance. *Past practice addressed: Dairy irrigators use a standard application rate governed by past practices and off-peak power windows. Irrigation rates need to consider soil water dynamics, especially infiltration, and the rooting depth of the plant. Soils with poor infiltration usually require increased frequency with decreased rates of application to get an at-depth response.* • Overhauling or purchasing new sprinkler packages to operate within specification, improving application uniformity. *Past practice addressed: System evaluations identified that most pressurised systems had areas under the pivot that were being under or over watered due to sprinklers not being within specification. Yield of these areas of the system is being impacted.* • Overhauling or purchasing new pumps to improve performance and increase efficiency. *Past practice addressed: System evaluations identified that a number of pumps were not operating within the recommended performance curve (approx. 75%) because they were not properly maintained or not adequately sized to meet demand.* Appendix 5- *SIP2 Yield Gap Collated Site Data* provides a collated summary of the project metrics to evaluate the outcome of changed

	practices. The data highlights the impact of not only practices, but seasonal conditions on yield and irrigation performance. Most sites experienced high variation in seasonal conditions across the three years with heat events and saturated conditions influencing yield. **These core strategies implemented delivered significant but varying change across the sites, in summary:** **Coraki:** Yield was increased by 15.8 per cent in Season 2 compared to season 1 and exceeded modelled potential yield. GPWUI increased from 2.31 to 3.3 tDM/ML, and energy costs decreased by 13.7per cent. Increased rates of application from 2-5mm to 10-11mm influenced yield increases. **Tocal:** Yield in Season 3 exceeded modelled potential yield by 17per cent with a GPWUI of 1.61tDM/ML, the most efficient across all seasons, whilst energy costs at $24.38/ML pumped was the lowest. **Bega:** The optimisation site performed equally (kgDM/ha/day) to the modelled growth rates in Season 2 and exceeded them by 10 kgDM/ha/day in Season 3, with an improved GPWUI of 1.72 tDM/ML compared to 1.50 tDM/ML in Season 2. RAW was maintained in Season 3 with an irrigation application rate increasing from 8.5mm to 10.0-11mm per application. **Tongala:** Yield results across the three seasons were very similar, with Season 2 having the most efficient water use of 2.40 tDM/ML. Season 3 was the most cost-effective crop grown at $46.06/tDM. This reflects the volatile nature of the region's water market and the price of market water. APSIM Modelling demonstrates there is still room for improvement, including bringing irrigations forward 2-3 days to better match ETo rates over summer and to better supplement rainfall events. **Yarram:** The aging ryegrass pasture of Paddock 6 improved its GPWUI from 0.96 tDM/ML in Season 2 to 1.26 tDM/ML in Season 3, reflecting the greater amount of time soil moisture was within RAW throughout the season. A yield gap of 30% remains between the modelled potential yield and the measured ryegrass yield. Millet grown in Season 2 was the outstanding performer across all seasons with a GPWUI of 2.23 tDM/ML with the lowest irrigation input costs at $5.27/tDM, compared to the highest cost of $18.62/ tDM to produce ryegrass in the same season in Paddock 6. Ryegrass for the same season had a GPWUI of only 0.96 tDM/ML. **Cobains:** There remains a significant gap between modelled yield of 56kgDM/ha/day and measured yield ranging from 17.36 to 29.53 kgDM/ha/day across the 3 bays in Season 3. The project has highlighted that there may be other constraints impacting bay 3 other than irrigation. **Mepunga East:** The results demonstrate that seasonal conditions

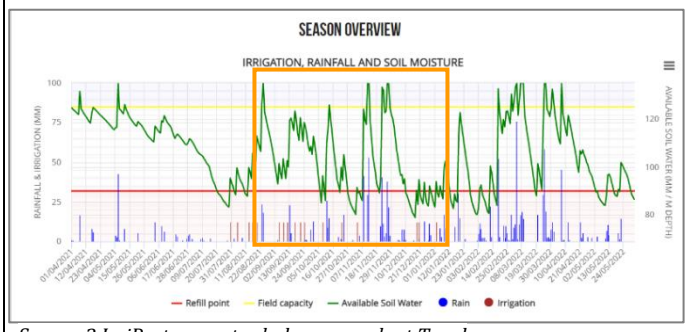
	play an integral role in the efficiency of irrigation inputs. Average pasture DM growth rates across the irrigation seasons were consistently in the range of 50 – 60 kg DM/ha/day. Average growth rates were maintained around 53.5 kg DM/ha/day in both the wet of Season 2 and very dry of Season 3, largely due to improved irrigation practices and increased system performance that maintained RAW in this final season. Energy use efficiency was improved from 4.66 to 4.10 kWh/ML/ m head over the three seasons. Whilst 13.74 kWh/ML were saved in Season 3 compared to Season 2, costs increased by $3.74/ML. Energy was the most expensive variable cost in DM production between $38 - $58/tDM, the highest across all sites of the project. **Mt Gambier:** Season 3 energy costs demonstrated that the new strategy of applying irrigation over a 20hr period (9pm to 5pm), as well as improved energy efficiency (8.30 to 6.81tDM/ha/day), resulted in reduced energy costs from $56.49/tDM in Season 2 to $33.99/tDM in Season 3. Overall, this site pays the most for energy per ML of irrigation per metre head because the water is directly sourced from a bore. Costs reduced from $1.67 to $1.16 /ML/m head from Season 1 to Season 3. Irrigation start-up commenced on-time in Season 3, and soil moisture was kept mostly within RAW throughout the summer, resulting in the measured yield the same to slightly exceeding the modelled yield by 5%. **Mt Compass:** Lucerne yielded an average 62.03 kgDM/ha/day in Season 3 compared to the biennial pasture growing 35.51 kgDM/ha/day in Season 1. The GPWUI also markedly improved from 1.91tDM/ML compared to 0.67tDM/ML. Similar improvements are reflected across all associated production and cost metrics. There are still opportunities to improve the production on this site by better maintaining soil moisture within RAW. Demonstrated over a small window, double irrigations to apply approximately 20mm per application are needed 2-3 times per week in the height of summer. The current system capacity is the limitation to expanding lucerne production under the pivot. **Dardanup:** Learnings from the site highlighted that while optimising irrigation is important, there are other influencing factors that impact yield performance under irrigation such as site soil characteristics, irrigation water quality and pasture/ crop selection. Irrigation scheduling changed from frequent and smaller rates of application (5-6 mm) to less frequent and higher rates of application (ranged 12-13mm). In Season 2, the use of soil moisture monitoring and pasture measurements demonstrated that irrigation was uneconomical at the height of summer, and irrigation ceased. This was a good, informed decision for the site. A significant difference was within the first 3 months of the irrigation season (October-December) where in Season 3 an average growth rate of 63 kgDM/ha/day was achieved compared to 37 kgDM/ha/day in Season 2. The achieved Season 3 GPWUI, however, remains well below the industry benchmark of 1-2 tDM/ML at 0.89 tDM/ML.

Final report. Provide a brief and final report on the economic and productivity benefits of addressing the yield gap for each site, the productivity benefits of new technologies and the extent to which participating service providers and farmers have changed irrigation practices (Activity output 5.3a).	The stand-out economic and productivity indicators of trialling new irrigation technologies and strategies was provided above, with detail provided in the *Dairy Optimisation Technical Report* for each of the ten *Dairy Optimisation Sites* (Appendix 1) and the supporting data provided in the *SIP2 Yield Gap Collated Site Data* (Appendix 5). Below is a selection of key scenarios for each site that demonstrate the benefits or challenges of the trialled technologies and irrigation management strategies: **Coraki:** • Coraki increased yield from 95 to 110.88 kgDM/ha/day, significantly exceeding modelled yield. • GPWUI was improved from 2.31 to 3.30 tDM/ha, significantly exceeding the benchmark.  *Season 1 & 2 IrriPasture Water Balance Graph at Coraki* The IrriPasture water balance graph demonstrates that Brian Chappell commenced irrigation earlier in Season 2, but overall, the season was much shorter as the kikuyu became dominant earlier. The developing ryegrass root system was watered adequately and RAW was maintained well throughout a dry spell from August to October during which DM peaked at 170kgDM/ha/day in September. Total irrigation costs improved by 30 per cent. Brian used forecast information to inform irrigation which resulted in some irrigations being applied too late or at a reduced rate. Therefore, opportunities to make improvements still exist. It is important to note this property was extensively flooded in February and March 2022. **Tocal:** • Measured yield of 85 kgDM/ha/day in Season 3 exceeded modelled by 17 per cent (graph below) by starting irrigations well. • GPWUI was improved from 0.69 to 1.61 tDM/ha, within the benchmark of 1-2tDM/ha.



Season 3 Yield measurements at Tocal

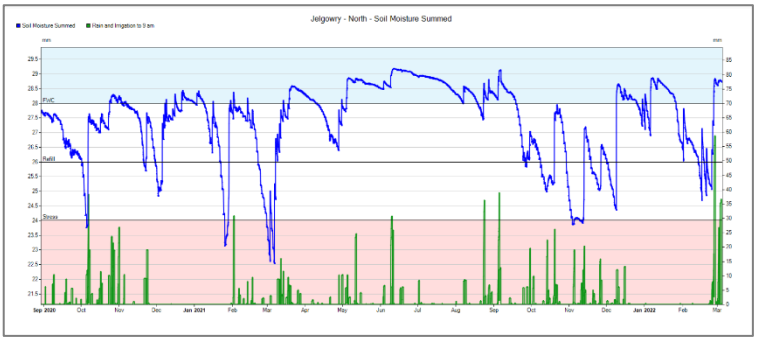
Referring to the IrriPasture water balance graph below, in October there were incidences when the calculated water balance declined to near, or just under, the refill point. Whilst there were irrigations applied, these came too late after rainfall events, and soil moisture remained low until rainfall did eventuate. Therefore, opportunities to make improvements still exist.



Season 3 IrriPasture water balance graph at Tocal

Bega:

- The site performed equally to the modelled in Season 2 and exceeded by 10 kgDM/ha/day in Season 3.
- GPWUI improved from 1.49 tDM/ML in Season 2 to 1.72 tDM/ML in Season 3, attributed to an improved distribution uniformity of rainfall/irrigation.
- Energy use efficiency was improved from 4.06 to 3.75 kWh/ML/ m head over the three seasons, reducing energy costs by 21% /ML/ m head.



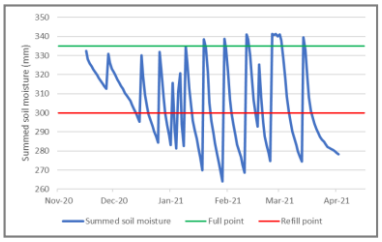
Season 2 and 3 North Summed Soil Moisture at Bega

In Season 2 and 3 (above Wildeye® soil moisture graph), irrigation commenced slightly earlier after rainfall than past practice aiming to maintain soil moisture within the RAW zone, and to avoid the green drought throughout the season. It was found that an irrigation schedule that delivers regular, moderate application rates of ~10mm is best suited to the dominant soil type of the Bega Valley and local climate (ETo rarely exceeding 9mm/day), applied every 36-48 hours during the height of summer to replenish moisture loss through ETo and maintain RAW. Will Russell modified his irrigation scheduling by monitoring his soil moisture data and when a significant rainfall was forecast, he allowed the soil moisture levels to drop to near refill point in order to most efficiently capture and store rainfall in the soil profile, reducing irrigation inputs that drove improvement in water use efficiency.

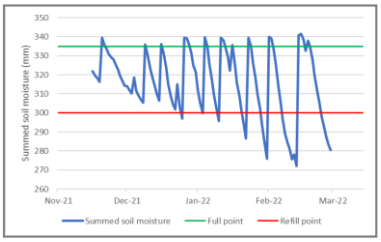
Retrofitting VRI technologies (>$50,000) to improve uniformity of irrigation distribution versus improving the sprinkler pack of an already aging centre pivot was evaluated. The $8-10,000 cost of a sprinkler refit will lower the regulated pressure, improve wetted width, add dry wheel packs and result in a more effective end-gun. It was determined the most cost-effective solution, when compared to VRI, is to replace the sprinkler pack that will perform at the limited pressures available, especially at the higher elevation.

Tongala:

- The measured yield across all seasons at Tongala was significantly under the modelled potential yield.
- By Season 3, soil moisture graphs demonstrate improved practice in irrigating earlier to maintain RAW more consistently across the season.
- Irrigating at certain stages of crop growth have a significant impact on yield. There were periods in February across both Seasons 2 and 3 (see below) when delayed irrigations saw plant stress occur during the tasselling/silking stage. This would have impacted yield. Therefore, opportunities to make improvements still exist.



Tongala Season 2 Summed Soil Moisture



Tongala Season 3 Summed Soil Moisture

Yarram:

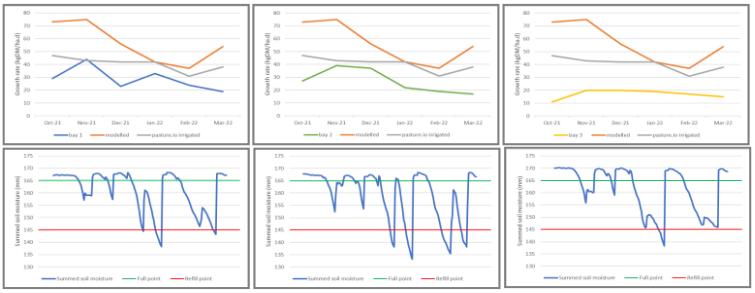
- In season 2, the performance of irrigated millet was compared with an adjacent irrigated ryegrass paddock. The growth rate of the perennial ryegrass averaged 45kgDM/ha/day over the 171

	days of irrigation growing 7.73 tDM/ha (1.77tDM/ha less than modelled). The millet grew 89kg/ha/day and 4.81 tDM/ha over 54 days. Perennial ryegrass was the better performer in Season 2, when pasture termination, fallow and establishment periods of the millet is taken into account. However, the cool, wet summer of Season 2 was more ideal for ryegrass relative to the typical hot, dryer summers of recent years in Yarram better suited to millet. • The GPWUI for the perennial ryegrass was 1.12 tDM/ML compared to 2.23 tDM/ML for the millet. Shelley Field made the decision to irrigate the millet less frequently and at lower rates (4.1 – 8.2mm) than the ryegrass (8.2-16.4mm). • While data demonstrates certain economic advantages in growing a short summer crop versus an ongoing perennial ryegrass under irrigation (i.e., power costs of the millet were $4.91/ tDM compared to $13.78/ tDM for the ryegrass), energy to the milking herd and overall economics of the millet needs to be considered • Irrigation was scheduled accurately throughout Season 3, particularly following heavy rainfall events. As a consistent perennial ryegrass site for the entire project, Paddock 6 is a good indicator of improved performance. Whilst no significant difference occurred in the growth rate between there was an an energy and water cost reduction of $2.54/tDM or $19.06/ha. **Cobains:** • In Season 3, different irrigation treatments were applied to the 3 bays of the optimisation site to evaluate the effects of dry-off periods. • Significant rainfall during the dry off times resulted in no dry off periods on the treatment bays. Bay 1 received two irrigations (0.55ML, irrigated 3rd December & 24th January). Bays 2 and 3 received one irrigation (0.28 ML, irrigated 3rd December). In early January, soil moisture did drop below the refill point in Bay 2 (Summed soil moisture graph), however, with rainfall forecast Garry Cook held-off irrigating and benefited from the significant rainfall that eventuated to increase soil moisture near full-point. • The additional irrigation resulted in 0.31tDM/ha higher yield in Bay 1 compared to Bay 2, and 1.88tDM/ha than Bay 3. • The DM results indicate that there may be another constraint to production other than irrigation on Bay 3. The fact that it had exactly the same water inputs as Bay 2 but yielded only 17.36 kgDM/ha/day, compared to 27.52kgDM/ha/day highlights there may be other factors effecting water use efficiency and therefore cost of irrigation inputs ($4.43 tDM/ha V $7.03 tDM/ha). Interestingly, the first measurement of the season in October was only 11 kgDM/ha/day for Bay 3, whereas Bay 1 (29 kgDM/ha/day) and Bay 2 (27 kgDM/ha/day) were not significantly different. Coordinator observations were that Bay 3

remained saturated for longer after rainfall and was particularly weed infested in the lower section of the bay.

- With all bays growing substantially less than the modelled growth, opportunities to make improvements exist. Investigations to determine why the growth rate is lower should be considered.

Season 3 Perennial ryegrass growth rate measures Bay 1 to Bay 3 at Cobains



Season 3 summed soil moisture graphs of Bay 1 to 3 at Cobains

Mepunga East:

- Overall results were highly influenced by seasonal conditions, with Season 3 being a dry summer period (19% water applied was rainfall), compared to Season 2 being a wet summer (52% water applied was rainfall), with Season 1 having 37% of total water applied being rainfall).

- Average pasture DM growth rates across the irrigation seasons were consistently in the range of 50 – 60 kg DM/ha/day. Average growth rates were maintained around 53.5 kg DM/ha/day in both the wet of Season 2 and very dry of Season 3, largely due to improved irrigation practices and increased system performance that maintained RAW in this final season.

- A prepared partial budget* indicates a 3-year payback period for the installation of a VRI system on the 7-span centre pivot irrigator based upon an estimated capital cost provided by site collaborators, Windmill and Irrigation (Colac). Stephen Smith has decided to install VRI on one of the pivots as an outcome of the SIP2 Project.

- With energy being the most expensive variable cost in DM production ($38 - $58/tDM over the three Seasons), Stephen Smith adopted several key recommendations of the first system evaluation undertaken in 2020.

Evaluation Year		System Capacity (mm/d)	CU	DU	Application V panel (%)	Pump Efficiency (%)	Energy use (kWh/ML/m)	Average application rate (mm/h)	Centre Pressure (%)	End Pressure (%)
2020	4-span	7	81%	69%	-38	60	5.2	85	+83	+168
	7-span		84%	70%	-2.5	63	4.9	83	+13	-11
2022	4-span		94%	86%	-22	88	3.4	81	+4	+26
	7-span		94%	94%	+3	65	4.6	87	+11	-40

Comparison of irrigation system evaluation metrics at Mepunga East

- Energy use efficiency on the 4-span irrigator improved from 5.2

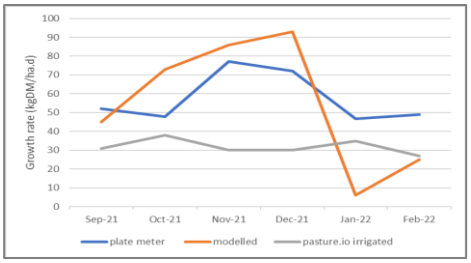
to 3.4 kWh/ML/m head. Although energy used per ML applied reduced, this was not reflected in cost savings due to increased power costs. Whilst 13.74 kWh/ML were saved in Season 3 compared to Season 2, costs increased by $3.74/ML.

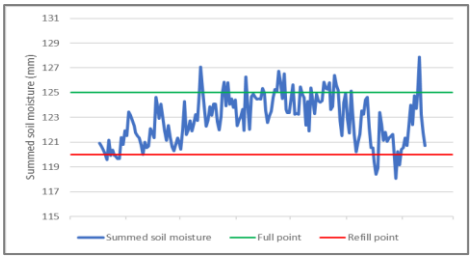
- Fitting of a new sprinkler pack on the 7-span pivot (also addressing iron bacteria issues), recalibrating the 4-span pivot control panel and improved maintenance of the equipment, including pulling the pump from the bore and cleaning, improved the energy efficiency, accuracy of irrigation rates, and more uniform irrigation distribution as assessed in the second evaluation of April 2022 (Season 3).

Mt Gambier:

- Growth rates at this site were similar for season 2 and 3 and slightly below the modelled yields.
- The GPWUI was 1.15 tDM/ML in Season 1, this declined to 0.84 in Season 2, then increased again to 1.23 in Season 3. This is on the lower side of the dairy industry benchmark of 1 – 2 tDM/ML.
- Start-up time at the beginning of the season and after rainfall was well managed in season 3. and this benefited GPWUI results. The trends between soil moisture and pasture growth rate were very much aligned (See below graph)

Season 3 Pasture Comparison growth rate measures at Mt Gambier





Season 3 Summed soil moisture graph at Mt Gambier

- Pump performance was poor (45-57%), well below the theoretical efficiency for these duties (79-80%). A major recommendation was to replace the pump. Assuming the duty is 108 L/s @ 44.5 m head and the pump efficiency was improved to 80%, the cost saving per ML (@ 30 c/kWh) would be $20.14 per ML. Based upon the 72ML applied by Pivot 6 in Season 3, the energy cost saving would be $1,450.

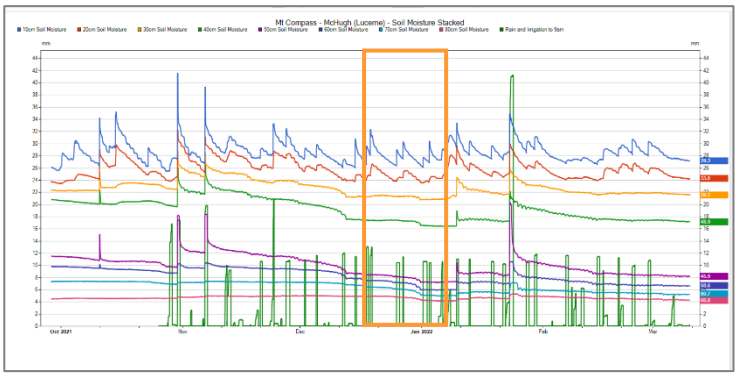
Mt Compass:

- During the irrigation season, there is a marked yield difference

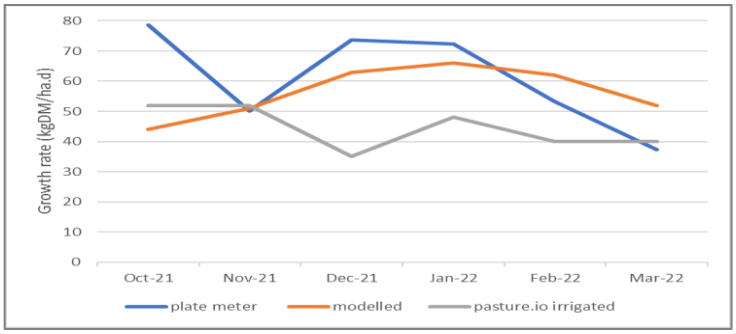
(35.51 V 62.03 tDM/ha/day) and energy/ water cost improvements ($108.42 V $22.75/tDM) between biennial ryegrass and established grazed lucerne.

- The GPWUI achieved in Season 3 was within the industry benchmark (1.91 tDM/ML), and a large improvement on the 0.67 tDM/ML of the biennial ryegrass. The irrigation costs per tonne of dry matter were a fifth at $22.75/tDM compared to the ryegrass at $108.42/tDM.
- The key strategy for optimised lucerne irrigation in Season 3 was to apply two 10.5mm applications within a 48hr period. This achieved improved at-depth penetration, shown in the Wildeye® stacked graph below, between the 25th of December and 8th of January, delivering a good yield response. This practice was not

  continued in January and February and watering did not keep up with ETo as it increased, and growth rate declined. This was a lost opportunity and the strategy needed to continue.



Season 3 Wildeye®80cm stacked soil moisture graph for lucerne at Mt Compass

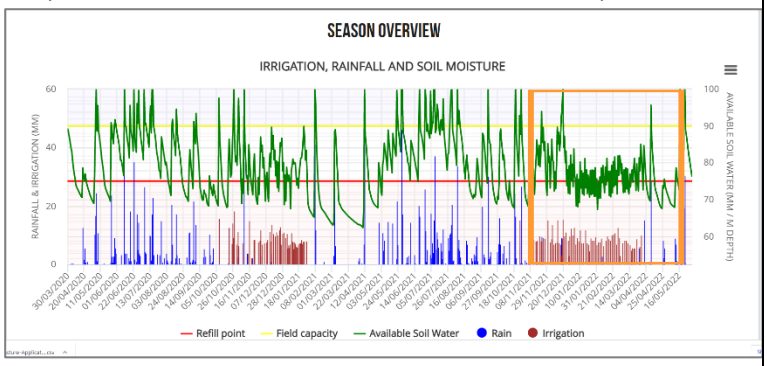


Season 3 Lucerne comparison growth rate measures at Mt Compass

- The efficiency of the pump was determined to be poor at 59per cent. The potential for improvement via an overhaul was determined to be an 8 per cent efficiency, representing a 7 per cent annual saving or $750 annually.
- Installing a new pump with VFD control from the end of the pivot could be economically beneficial. Approximately $1094 annually (12%) electricity costs could be saved with an estimate return on investment of 6 yrs.

Dardanup

- Yield of the irrigated white clover improved from 28.78 kgDM/ha/day to 48.56 kgDM/ha/day, though remaining under industry benchmark with a GPWUI of 0.89 tDM/ML.
- The greatest constraint to production at Dardanup were soil constraints and pasture selection rather than irrigation. Addressing these issues and considering the regional climatic conditions will deliver increased yields.
- Irrigation scheduling changed from frequent and smaller rates of application (5-6 mm) to less frequent and higher rates of application (ranged 12-13mm) to achieve optimal soil conditions at-depth. The impact upon RAW was captured by both soil moisture monitoring and by IrriPasture (see below).
- These irrigation events were targeted at weekend off peak power periods, though some were necessary during the week and subsequently overlapped into peak periods. This did not impact overall energy costs but improved the efficiency of costs ($56.07/tDM in Season 2v $29.67/ tDM in Season 3).



Season 1 & 2 IrriPasture water balance graph at Dardanup

Season 3 Summed soil moisture graph at Dardanup (orange box on IrriPasture graph)

- Poor pump efficiency of 55 per cent means higher than necessary energy costs are being incurred. If pumps were upgraded so efficiency was improved to 75 per cent, cost saving per ML for operating Pivot 3 would be $19.89/ML. Based on the applied water of 41.49 ML in Season 3, the seasonal energy cost saving would be $825.24 for Pivot 3 alone. With 4 pivots in use, the estimated savings would be approximately $5,000 annually.

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Outlined below is an indication of the extent to which farmers have changed irrigation practices:

The section on Monitoring and evaluation has an extensive report on the changes in irrigation knowledge and practice due to SIP2 participation. The table below highlights the percentage of respondents who changed practices throughout SIP2.

<table>
<tr><th>Practice</th><th>Percentage</th></tr>
<tr><td>Changed your irrigation start-up time at the beginning of the season</td><td>68</td></tr>
<tr><td>Changed your start-up time after major rainfall events</td><td>72</td></tr>
<tr><td>Changed irrigation application rates to reflect available soil moisture and plant requirements</td><td>68</td></tr>
<tr><td>Increased productivity under irrigation</td><td>80</td></tr>
<tr><td>Become more energy efficient and/or reduced energy costs</td><td>44</td></tr>
<tr><td>Become more water efficient and/or reduced water costs</td><td>48</td></tr>
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<tr>
<td>Activity output 5.3(b) Conduct 3 field days and 3 service provider workshops for each optimised dairy irrigation site.</td>
<td>
The project extension activities were progressively updated in the RRDP2017 Smarter Irrigation M&E Database and have been collated in Appendix 6- SIP2 Yield Gap (9) _Communications, Extension, Collaboration & Materials.

Although greatly impacted by Covid-19, the project responded accordingly to implement extension activities that endeavoured to continue to engage with the local farmers and service providers of the optimisation sites.

Each of the Dairy Optimisation Sites delivered at least two field days and 2 workshops during 2020-2022. Some of these events were online, but whenever possible were conducted face to face.

Overall, the project delivered 101 extension activities: 25 field days, 5 professional technical workshops, 47 reference group meetings, 8 webinars and 16 farmer/service provider workshops. These activities had 1,734 attendees- 811 farmers, 735 service providers and 163
</td>
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	other roles. Additionally, the 30 co-learning workshops/ information exchange activities were conducted between the SIP2 delivery team through monthly meetings during irrigation seasons and annual forums. Importantly these built the knowledge and capacity of regionally located service providers to support and evaluate irrigation technologies and strategies on Australian dairy farms. In early 2020/2021, a national approach was taken to extension activities in response to ongoing Covid-19 lock-downs, particularly in Victoria and NSW. Four major online webinars were conducted with expert speakers, resulting in over 200 attendees: • July 9, 2020: *Using Pasture.io on your farm- The impact of monitoring yield under irrigation* • July 28, 2020: *Using energy data to optimise irrigation system efficiency, effectiveness and operating costs* • August 5, 2020: *Using weather forecasting and soil information for irrigation decisions- The impact of improving irrigation decisions* • August 19, 2020: *Using soil moisture monitoring and data to maintain RAW- The impact of RAW to improve irrigation decisions.* The key outcomes of these activities were improved knowledge and intention to change practices within the next two years. A rating of 8.3 out of ten was given for the value of activities to the business. Further information is given in the monitoring and evaluation section of this document.

3.2 Contribution to the SIP2 program objective

The *SIP2:What's my yield gap? Maximising water productivity* project achievements included establishing and operating ten *Dairy Optimisation Sites* and demonstrating that there are technologies and key strategies that can be used on irrigated dairy farms to improve both productivity and profitability. These strategies begin at fundamental, no-cost to precision and automated higher cost and longer-term return on investment. The project worked collaboratively with farmers to investigate and interrogate different solutions to irrigation challenges. There are three levels of technology (investment) on offer to Australian dairy farmers to better inform irrigation decisions. These investments strongly align with productivity priorities.

Fundamentals with no technology investment: Adoption of *IrriPasture* to undertake an irrigation management area water balance to inform irrigation frequency and rate decisions, together with daily *Swan Systems Weatherwise 7-day forecast* reports to consider upcoming ETo and rainfall in scheduling.

Greater precision through soil moisture monitoring with some investment costs based upon a per unit and annual scenario (Approximately $2,000 supply/install & $250/year subscription) to evaluate the impact of irrigation, rainfall and ETo upon the most representative soil/plant type of an irrigated area. Irrigation rate and frequency is applied according to the representative soil/plant type being monitored.

Precision variable rate irrigation based on different soil/plant types within an irrigated area (>$200,000 greenfield to ~$50,000 retrofit) to apply different rates of irrigation according to prescription maps determined by EM38 survey. Capability to automate dependent upon APIs with other technologies that may include soil moisture monitors and more sophisticated water balance tools, such as SWAN Systems.

However, as the project has also highlighted, there are many external and practical factors that have a significant impact upon overall business outcomes in relation to irrigation. The sites have demonstrated (refer to Appendix 1 and Appendix 5):

- Irrigators need to have the capacity to change their irrigation practices season to season based upon the climatic conditions (drought to flooding) and likelihood of extreme weather events (prolonged heat, East Coast Lows). Those sites where farmers quickly developed the knowledge, technology and systems to apply a more flexible approach managed these factors well and maintained or increased production whilst increasing efficiencies.

  Example: *At Bega, Will Russell quickly developed his skills to use soil moisture monitoring and forecast data to change the application frequency and rate of his applications. He started irrigation earlier after rainfall events in Season 2 and postponed irrigation when rainfall was forecast in wet Season 3. His application rates changed from a standard approach of 8.5mm to 10-11mm, twice within a 48-hour period in ETo highs. His yield increased by 20% to close his 'yield gap' whilst reducing his energy costs by 17% ($/ML) from season 1 to season 3.*

- Irrigation systems that are fit for purpose and ready to perform are more energy and water efficient, and effectively apply water to the irrigated area to optimise conditions for plant growth. Those sites that responded to irrigation system evaluation report recommendations have increased pump performance, reducing energy use, or have responded by evaluating the cost effectiveness or pay-back periods of installing new pumps, variable speed drives or sprinkler packs to specification.

  Example: *At Mepunga East, fitting of a new sprinkler pack on the 7-span, recalibrating the 4-span pivot control panel and improving maintenance of the equipment, including pulling the pump from the bore and cleaning it, saw improvements in the energy efficiency and accuracy of irrigation rates, along with more uniform irrigation distribution as assessed in the second evaluation of April 2022. These actions improved pump efficiency when operating the 4-span from 60% to 88%, resulting in energy use improvements from 4.66 to 4.10 kWh/ML/ m head, while distribution uniformity of the system saw an improvement on the 7-span pivot from 70% to 94%.*

- Irrigating to maintain RAW, together with using off-peak power, and peak power when required, delivered improved productivity whilst increasing the efficiency of power use.

  Example: *At Mt. Gambier there was a strong relationship between pasture growth rates (kgDM/ha/day) and soil moisture traces. In Season 2, growth rate declined in November to December when soil moisture declined below the refill point. At the same time in Season 3, growth rates significantly increased as soil moisture was steady, just below the full point. Growth rates were similar in season 2 (47.23 kgDM/ha/day) and (51.22 kgDM/ha/day) in Season 3, whilst energy costs decreased from $56.49/tDM to $33.99/tDM.*

There is further energy efficiency (use & costs) to be gained by also addressing pump efficiency in the future.

- In order to capitalise on efficient operation of irrigation assets and precision scheduling, all limiting factors to maximising water productivity must be addressed. At Dardanup and Mt. Compass, agronomic constraints were identified, and solutions applied to deliver or plan for future improved productivity and profitability. At Mepunga East, grazing management impacted yield potential early in the irrigation season (October-December), though this was a conscious decision made by the farmer due to his calving pattern and supply contract.

  Example: *At Mt. Compass, changing from a biennial ryegrass to lucerne pasture delivered improved productivity (35.51 kgDM/ha/day V 62.03 kgDM/ha/day) whilst decreasing irrigation input costs ($108.42/tDM V $22.75/tDM), with further opportunities to improve identified. Lucerne is better suited to the heat extremes experienced in this dairy region.*

- Extensive investment in VRI may not always be the solution, whilst for others the return on investment may demonstrate the decision makes good business sense. Both Bega and Mepunga East undertook EM38 surveying to map the variation in soil characteristics and topography of the optimisation site. The final decisions on VRI adoption were very different.

  Example: *At Bega, the topography of the centre pivot location ranged from a sandy ridge to alluvial flats, first thought to be a prime reason to investigate the potential of VRI to maximise yield. Pasture measurements showed that the lowest yielding paddock on the ridge yielded half that of the best performing paddock, lowest on the hill side. The system evaluation determined the sprinkler pack fitted required a higher water pressure to operate than available, particularly at the higher elevations where water pressure was the lowest. The site research showed that should irrigation distribution uniformity be improved by replacing the sprinkler pack to perform at the limited pressures available, an additional 20% or 2 tDM/ha could be grown each irrigation season. The cost of replacing the sprinklers was $7,000 with a lifespan of 10 years. An estimated additional 500tDM/ha could be grown over the ten years at a current value of $125,000. The pay-back period is less than one season.*

  At Mepunga East, a prepared partial budget indicated a 3-year payback period for the installation of a VRI system on the 7-span centre pivot irrigator based upon an estimated capital cost of $50,000 provided by site collaborators, Windmill and Irrigation (Colac). Stephen Smith has decided to install VRI on one of the pivots as an outcome of the SIP2 Project.*

  **Water and pumping costs, and value of additional pasture consumed, used SIP2 site results. Estimates of likely water savings and additional pasture consumed were from earlier Tasmanian VRI studies on sites with similar variable topography.*

3.3 Contribution to SIP2 program outcomes

1. Improved on farm water productivity/water use efficiency through use of optimised irrigation practices, precision irrigation technologies and autonomous irrigation systems on participating farms.

As the primary measure of improved water productivity for the project, an analysis of GPWUI (tDM/ML) is outlined in the table below. On average, 46.76 per cent improved GPWUI was achieved.

Optimisation Site	Site Benchmark GPWUI tDM/ML	Highest GPWUI achieved tDM/ML	+/- Difference (%)	Influencing factors
Coraki	2.31	3.03	+31%	Increased precision timing and rate of

				applications. Objective to maintain RAW using SMM.
Tocal	0.69	1.61	+133%	Improved start-up after rainfall events and extreme variation in climatic conditions across seasons.
Bega	1.50	1.72	+14.7%	Improved start-up after rainfall and increased rates of application during periods of high ETo. Objective to maintain RAW using SMM.
Tongala	2.22	2.40	+8%	Scheduling irrigations according to forecast data with greater confidence to adjust frequency.
Yarram (Pdk 6 ryegrass)	0.96	1.26	+31%	Improved start-up early in season, after rainfall and flexible rates determined by forecast ETo and status of SMM.
Cobains	3.41	2.88	-15.5%	Wet and saturated conditions impacted growth in Season 3. Bay 3 reduced yield although management unified across bays.
Mepunga East	1.34	1.01	-24.6%	First season provided ideal conditions whilst final season was very dry, impacting yield.
Mt Gambier	1.15	1.23	+7%	Soil moisture was well maintained in RAW on shallow soils- earlier start-up and increased frequency when needed using SMM to evaluate.
Mt Compass	0.67	1.91	+181%	Planting of lucerne after biennial ryegrass was terminated. Irrigation managed well to establish a good stand.
Dardanup	0.44	0.89	+102%	Improved start-up early in season, after rainfall and increased rate determined by ETo improving at-depth moisture levels. Overall performance limited by soil, agronomics and water quality.

Increasing water productivity was achieved by:

- **Identifying and addressing irrigation system performance issues** so that irrigation was more efficiency and effectively applied when needed. This improved agronomic performance as well as increased energy and water use efficiency with reduced cost benefits.
- **Determining Readily Available Water (RAW)** for each soil type irrigated so that the pasture/crop was irrigated to maximise plant growth. By maintaining RAW, plants require less energy for water uptake than if soil moisture is reduced below refill.
- **Using a water balance calculator tool** to inform irrigation scheduling decisions to apply water at the right time and right rate to maintain soil moisture in the RAW zone. IrriPasture was a valuable tool to evaluate how well plant water requirements (Etc) were matched by applied water, and to inform irrigation scheduling based upon a simple water balance model. It was best used in conjunction with SMM.

- **Monitoring forecast information** to consider ETo and rainfall predictions in irrigation decisions. Irrigators were better armed to bring forward or postpone applications by using the free SWAN Systems Weatherwise 7-day forecast irrigation reports.
- **Monitoring soil moisture** using professionally installed soil moisture monitors and reliable telemetry, to inform irrigation start-up decisions at the commencement of the season or after rainfall events. The technology allowed irrigators determine if soil moisture was within the RAW zone and schedule irrigations based on current soil moisture status and forecast information.
- **Commencing irrigation on-time** at the beginning of the season or after rainfall to maintain soil moisture in the RAW zone. Benefits include avoiding a green drought scenario and reducing growth rates and avoiding the need to operate systems for longer or during peak power periods to lift soil moisture back into the optimal RAW increasing energy use.
- **Knowing the capacity of the irrigation system** and scheduling irrigation timing and rates accordingly to maintain soil moisture requirements whilst deploying other cost-effective measures e.g., off-peak power.
- **Maintaining soil moisture within the RAW** zone creates the ideal platform for strategic nitrogen use.

Increasing water productivity was constrained by:

- **Other constraints of the irrigated area** such as soil physical and chemical parameters, irrigation water quality (i.e.., high sodium), agronomy versus climatic conditions, and poor drainage/ infiltration causing saturation.
- **Extreme heat events** when the system capacity cannot match the ETo , or the rate of application needed exceeds soil infiltration rate, it is difficult to maintain soil moisture in the optimal RAW zone. High temperatures, especially over prolonged periods, cause heat damage to plant foliage.
- **Extreme wet events** when the irrigated area is saturated or waterlogged for prolonged periods, reducing plant water uptake and reducing oxygenation of the soil. Long-term seasonal changes in soil physical characteristics occurred ie., compacted areas reducing the soil RAW, reducing root at-depth penetration, and reducing the infiltration rate causing run-off.
- **Nitrogen management changes** constrained potential growth rates when soil moisture was ideal. Increasing nitrogen prices during the project saw farmers reduce nitrogen use or seek alternative sources of nitrogen. The transitional 'trial' phase of amended nitrogen management coincided with Seasons 2 and 3, although unable to be quantified, likely had an impact upon production.
- **New identified strategies for the site not continued** as they did not align with other practices of the farm (i.e., grazing management/ rotations), the farmer returned to "what feels comfortable" or they had a lack of confidence to make significant changes without longer-term evidence and support.
- **Irrigation system failures** still occurred in some seasons on certain sites. Sizeable pivots are still going to have simple operational issues such as tyre "blow-outs", bird damage to pipes and embankment erosion or river debris causing issues to pump suction.
- **Technology failures/ constraints** reduced information on-hand to make informed decisions. The project experienced practical issues such as rain-gauges ceasing to operate due to mechanical issues, API break-down between weather stations and IrriPasture**,** certain sensors on probes going "off-line" for prolonged periods and soil monitoring equipment being removed and reinstalled requiring "calibration" before confident data is produced during critical crop stages (i.e., early maize) or seasonal timing (i.e., seasonal start-up).

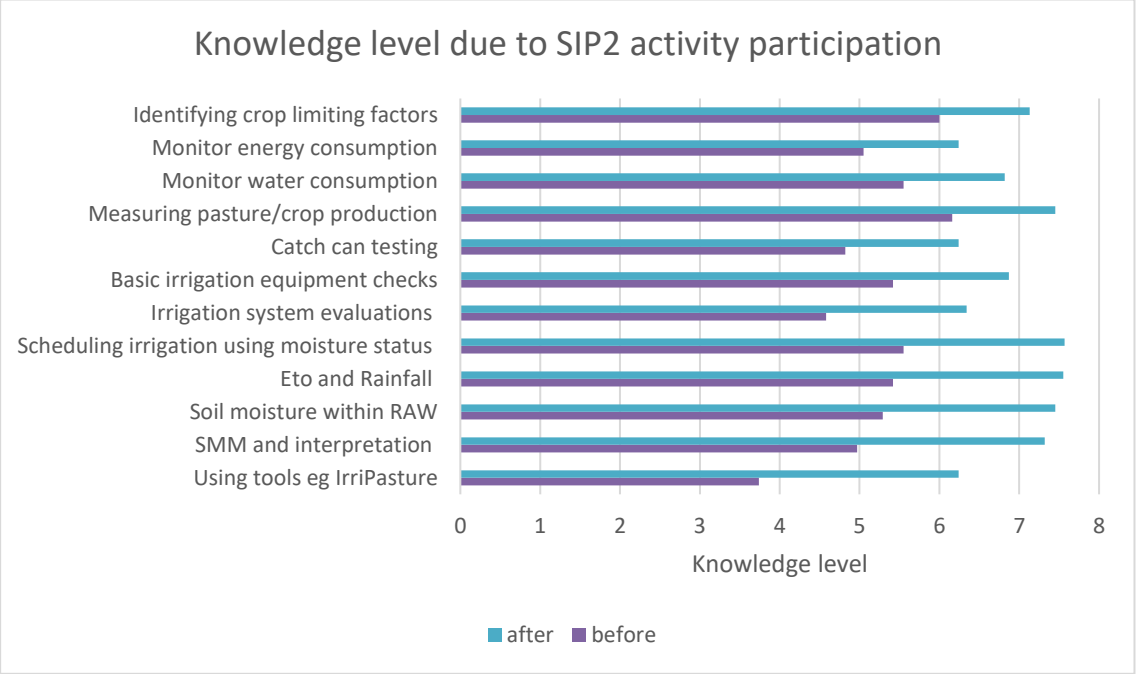
80% of participating producers adopt or intend to adopt precision irrigation strategies and technologies.

SIP2 What's My yield gap? Maximising water productivity project considers that the technologies implemented on the optimisation sites all improve the precision of irrigation. These include the use of weekly ETo and rainfall forecast information for irrigation decisions, soil moisture monitoring with telemetry and tools such as IrriPasture. The SIP2 participants adopted these technologies with 88 per cent, 62 per cent and 39 per cent of participants forecast information, the soil moisture monitoring and IrriPasture respectively. A further 12 per cent, 35 per cent and 42 percent are considering adopting within the next two years. which brings the adoption or intending to adopt rate above 80 per cent for the three technologies.

2. A more knowledgeable and skilled irrigation community with greater confidence in their ability to optimise irrigation performance.

Extent to which service providers and producer's express confidence in their capacity to optimise irrigation performance.

SIP2 What's My yield gap? Maximising water productivity determined the knowledge levels of service providers and farmers at the completion of the project. Knowledge levels, as a result of participation in the project increased over the duration of the project with participants recording an average knowledge above 6 out of 10 for all activities and tools.



The average confidence rating among dairy farmers that they have enough access to information to make changes to their irrigation system is 7.4 out of possible 10. The same rating was found regarding the confidence in information and support to manage their current or new system.

The project set out to increase the rate of adoption of tools and technologies that would support farmer decision making to improve irrigation productivity and increase water and energy efficiency.

The Dairy Australia Land Water and Climate survey report (2015) indicated that only 12 per cent of farms used specific devices to guide irrigation decisions and in 2020 the same survey reported that almost half (44%) used a water balance approach or soil moisture monitoring. Evaluation conducted by the SIP2 project highlighted increases in the use of tools to guide irrigation decisions. Of note is the increased use of soil moisture monitors with telemetry where of the 81 per cent of respondents who were not already using this tool 52 per

cent reported they had started using the tool as a result of being involved in SIP2 and 43 per cent were still considering it. Only 5 per cent were not considering it at all.

The level of uptake of system performance evaluations and the basic system checks was not as great as the soil moisture monitoring. However, 62 per cent of those who were not already doing system checks have adopted this through SIP2, whilst 23per cent are still considering. The Dairy Australia Land, Water and Climate survey report (2020) indicated that 18per cent of farmers did no system checks at all on their irrigation systems. The comparisons of this information should be viewed cautiously due to the small SIP2 evaluation sample size.

Of the 88per cent of respondents who were not completing whole system performance evaluation prior to SIP2 39per cent started because of SIP2 and a further 52 per cent are still considering. The lower rate of adoption of this activity may reflect the difficulty in accessing service providers with the skills to complete the assessments.

4 Collaboration

4.1 Project collaborations

Appendix 6 outlines the formal collaboration activities that were undertaken over the three years. Covid-19 did impact the project's ability to meet face to face with research collaborators, project partners and industry stakeholders. Online meetings and forums were conducted as needed, with the opportunity for a face to face forum in the very late stages of delivery. There is no doubt that limited opportunity to come together, in one room, impeded the usual working relationships that bring about greater efficiency and innovation by contributors of a large scale, multi-faceted project such as this one.

National level

The project collaborated extensively with TIA's *SIP2: Beyond Water Smart: advancing dairy irrigation system performance* project on establishment and delivery of the *Dairy Optimisation Sites*, measurement methodology, and deployment/evaluation of technologies and strategies. Dr James Hills and the TIA team provided invaluable input into the science applied and extension models used, as well as contributions to monthly team meetings and annual forums to exchange on site activities, explore potential solutions to challenges faced e.g., seasonal conditions and evaluate the outcome of technologies and strategies.

Dairy Australia, USQ and TIA worked collaboratively to develop the IrriPasture prototype into a fully deployed online tool with API capabilities to ingest automated weather information. This partnership saw the tool trialled with farmers and service providers engaged in the project as well as used on each of the *Dairy Optimisation Sites* in Seasons 1 and 2. Through IrriPasture workshops with farmers, reference group meetings and coordinator monthly meetings, feedback on limitations and functionality challenges of the tool were received. Solutions were investigated and resolutions deployed by the partnership.

Commercial partners

SWAN Systems worked collaboratively with Dairy Australia and TIA to trial APIs between equipment and decision support tool technologies with an aim to automate ingestion of irrigation information to the tool. The partnership was two years in duration, resulting in greater knowledge and practical experience in linking existing commercially available technologies together to assist dairy irrigators increase water and energy efficiencies through more informed irrigation decisions.

AgLogic supported both Dairy Australia and TIA across the fifteen sites in purchase, installation, maintenance and reporting (via Wildeye®) of the soil moisture monitors and rain-gauges. Technology issues regularly arise, therefore it was integral to have a trusted partner to assist the Optimisation farmers and Coordinators to trouble-shoot technical issues and assist in layout and interpretation of the data as site conditions changed. This type of assistance is missing in many regions of Australia. This Tasmanian based company was used nationally by the project.

Dairy processors, Norco Cooperative Pty Ltd and Bega Cheese Pty Ltd assisted to establish the Coraki and Bega *Dairy Optimisation Sites* respectively, and supported extension and communication activities through newsletters. This relationship broadened the audience of the project to over 800 other dairy farmers.

At the local level, each of the *Dairy Optimisation Sites* involved local service provider companies that supply irrigation, soils, nutrients and agronomy advice and services. Whilst some were engaged to assist in measurement activities or supply/maintain of equipment, others were involved in-kind as members of the reference group. These roles were invaluable in providing local interpretation of the irrigation key principles with consideration for local seasonal climatic conditions, soil characteristics and, agronomic, farming and irrigation systems.

Dairy Industry level

The regional dairy programs of Dairy Australia each played a role in delivery of the project. Murray Dairy, DairySA and GippsDairy had extension officers engaged in SIP2 roles. All regions supported extension and communications, especially through eNewsletters, quarterly publications and social media. This ensured that SIP2 was extended to a much broader target audience, within the context of regional conditions, priority topics and seasonal issues. Several SIP2 extension activities were conducted as a part of the region's existing extension model or events calendar. For example, conducting reference group meetings through discussion groups (e.g., Gippsland), making linkages with aligned projects (e.g., Murray Dairy) or presenting or hosting at annual field days or forums (e.g., Western Dairy).

In NSW, local level dairy organisations played an important role in extending information to members. These were Far South Coast Dairy Development Group, Hunter Dairy Development Group, Mid-coast Dairy Action Group, Far North Coast Dairy Industry Group Inc. and Subtropical Dairy Programme Ltd- Far North Coast NSW Regional Group. These groups assisted with the establishment of their local *Dairy Optimisation Site,* had ongoing input into site activities, and publish reports and articles emanating from the project.

Project level

The project conducted **40** formal collaboration activities, with **614** participants. The primary collaborative platform for the *Optimisation Site Coordinators* was the monthly meetings. Each coordinator was required to give a site update, including presenting 1 IrriPasture water balance graph and 1 Wildeye® soil moisture graph to demonstrate the challenges, opportunities and wins of the month, followed by a key question for the group. This exercise assisted to improve the skills of each coordinator in interpretation of site data and applying this information to how to support the farmer in their decisions. Annual forums also assisted to build the capabilities of this group, provided with a template to report and interpret the seasonal data for their site, as well as evaluation of the decisions made, especially identification of the opportunities lost and demonstration of the improved practices.

The leadership team of Cath Lescun, James Hills, Marguerite White and the current Dairy Australia Program Manager, together with the Dairy Australia communication advisor when required, met weekly for one hour to oversee management of the project but importantly to collaborate on both science and logistical execution of all activities.

4.2 Recommendations for activities to support future collaborations.

The most successful collaboration was between this project and TIA's *SIP2: Beyond Water Smart: advancing dairy irrigation system performance* project. This partnership was established well in the project design stages and developed further as both projects delivered upon aligned milestones. Ongoing exchange between personnel was coordinated and encouraged by the leadership team.

The collaboration between Dairy Australia, TIA and USQ built on an existing relationship between the organisations from SIP1. As all parties trusted that the tasks allocated to develop, test and amend the IrriPasture tool would be executed as planned and with science integrity by all, the collaboration was successful and will continue as the tool is further used by the dairy industry more broadly.

Within the specific project team, regular online meetings ensured regular exchange, however, the most powerful collaboration certainly came from meeting face to face- only possible twice in November 2019 and April 2022. Ongoing personnel changes did constrain opportunities for the team to keep pushing forward on their knowledge and understanding. Whilst opportunity to collaborate assisted to build a strong appreciation for how core irrigation best practice principles could be applied, implemented and evaluated in location regions, the need to constantly repeat coordinator training to onboard new staff was frustrating and impacted the potential to execute more in-depth development opportunities. Those *Optimisation Site Coordinators who* delivered over the entire project certainly built strong partnerships and now consider one another as professional peers to draw upon when needing to seek input. On the whole, the most successful *Optimisation Site Coordinators* were those who were external consultants with agronomy, soils or irrigation skills who had existing trusted relationships with farmers of the region.

Cross-project and industry collaboration was invaluable, as it always is with these collaborative research programs. Whilst online meetings held regularly were appreciated, there is no doubt that the most valuable opportunity provided was the face-to-face forum held in Launceston, April 2022. By working closely together over a total of six years via SIP1 and SIP2, long-term working relationships across industries and organisations, to advance irrigation management and innovation to improve productivity and profitability, is certainly a legacy of the Rural R&D for Profit program, RDC and research organisation investment. The role CRDC has played, together with the three coordinators over time (Guy Roth, Cathy Phelps & Lou Gall), has been extremely well executed and has fostered a platform for both project duration and long-term collaboration. It is important that this has also been achieved within the science community context, to ensure the findings and learnings are communicated through peer reviewed articles and conferences. As such, the special SIP2 session at the 2022 Irrigation Australia International Conference in October is an important legacy collaboration activity of SIP2.

Fostering the existing collaborations ongoing is needed to aid the continual improvement in water productivity and profitability of farmers. As highlighted throughout this report, and evidence from surveys within this project, there is a small group of service providers with the skills required to assist farmers with irrigation technologies and often long distances are travelled to provide this service. The science community supports the upskilling of personnel in these roles as well as the innovation and development of new technologies. Integral to the improvement of productivity on farm is the collaboration between all roles within the R, D and E spectrum, including both the public and private sector. Formally organising collaborative approaches across the sectors would benefit all.

5 Extension and adoption activities

5.1 Project extension & adoption activities

A comprehensive list of the extension activities conducted by the project is provided in Appendix 6. Refer to section 3.1, Activity output 5.3(b), for a report on the evaluation of extension events.

Overall, the project delivered **101 extension activities**: 25 field days, 5 professional technical workshops, 47 reference group meetings, 8 webinars and 16 farmer/service provider workshops. These activities had **1,734 attendees-** 811 farmers, 735 service providers and 163 other roles, including researchers, government agencies and commercial operators.

Each *Dairy Optimisation Site* delivered *at least* two local field days and workshops, either on site, at a nearby irrigated farm to provide attendees with an opportunity to consider the learning of the site within the context of another farming business and farming system, or at the local hall/ community club. These were not necessarily SIP2 specific events. Where there was an opportunity to partner with a popular annual regional event that had potential to expose the project to a large audience, the opportunity was embraced. For example, two of the three Tocal field days were part of the popular Hunter Local Land Services Tocal Pasture Discussion Day held in February each year, or for the Dardanup site the SIP2 project field day was part of the Annual Innovation Day, with the *Dairy Optimisation Site* being part of the tour program.

Workshops (entered into the SIP2 M&E Database as webinars or workshop/training) were primarily held in-room or online (as webinars). For example, 'IrriPasture' workshops were conducted for the Yarram and Cobains *Dairy Optimisation Sites* where farmers brought along their laptops to set-up and be guided in use of the tool. 'Interpreting soil moisture graphs' workshops were held online by AgLogic for Bega, Mt. Compass and Mt. Gambier, while at Tocal a series of workshops were conducted over one day encompassing energy pricing, system maintenance, IrriPasture and pump efficiency. East Mepunga draw upon the existing regional nutrient advisor breakfasts, coordinated by AgVic, to conduct workshops with service providers the day following the farmer targeted field day. Where possible, visits by Peter Smith or David O'Donnell to undertake the irrigation system evaluations for the *Dairy Optimisation Sites* was used as an opportunity to integrate "System Performance" into a workshop or field day program. These were an opportunity to particularly focus upon energy efficiency as the core, and very popular, topic.

Additionally, 30 co-learning workshops/ information exchange activities were conducted between the SIP2 delivery team through monthly meetings during irrigation seasons and annual forums (entered as 'Collaborations' in the SIP2 M&E Database). Importantly these built the knowledge and capacity of regionally located service providers to support and evaluate irrigation technologies and strategies on Australian dairy farms.

In early 2020/2021, a national approach was taken to extension activities in response to ongoing Covid-19 lock-downs, particularly in Victoria and NSW. Four major online webinars were conducted with expert speakers, resulting in over **200** farmer, service provider and researcher attendees:

- July 9, 2020: *Using Pasture.io on your farm- The impact of monitoring yield under irrigation RECORDING*
- July 28, 2020: *Using energy data to optimise irrigation system efficiency, effectiveness and operating costs RECORDING*
- August 5, 2020: *Using weather forecasting and soil information for irrigation decisions- The impact of improving irrigation decisions RECORDING*

- August 19, 2020: *Using soil moisture monitoring and data to maintain RAW- The impact of RAW to improve irrigation decisions.* RECORDING

5.2 Lessons learnt and recommendations for future extension.

- Working with farmers who embraced the opportunity to learn, use and adopt new ideas and technology was integral to not only the implementation of the project activities, but the way in which the opportunities and challenges of improved irrigation management was extended peer-to-peer. For example, Will Russell of the *Bega Dairy Optimisation Site* willingly presented how he was applying what he was learning to other areas of his farm at field days and on videos, including developing his own case studies and the fact he believes he is making better grazing decisions and has improved his pasture management as a direct result of the project.
- "Irrigation" as a stand-alone topic is not necessarily a drawcard for farmers, so where possible, aligned farm management system topics were used along-side irrigation topics. For example, nitrogen management became the 'hot-topic' as prices increased, soil management as interest grows around soil carbon (including the use of soil pits), and energy efficiency as a general topic across all areas of the farm business rather than solely related to irrigation systems.
- Seasonal conditions play a major role in the motivation of farmers to embrace opportunities to build knowledge and understanding in irrigation practices. SIP2 was commenced in drought and completed during flood conditions along the east coast, making irrigation as a core topic very difficult to market. Even in middle-ground seasons, where rain was somewhat consistent, irrigation scheduling was not at the forefront of farmer's minds as they were simply using it from "time to time" to supplement rainfall. Whilst in theory these conditions are the ideal opportunity to leverage more production from rainfall by irrigating on-time after events, the farmer's generally believed conditions were 'ideal' and used safety of the season to focus upon other more pressing issues.
- The reference group, participatory action research model was not embraced in most regions. Generally, farmers are time poor and found it extremely difficult to make an ongoing commitment across the busy irrigation season and during a period of ongoing labour shortages. At Mepunga East, where the most successful group operated, there was difficulty in consistency of attendees, often requiring a repeat of updates/topics each month. The *Site Coordinator* attempted to address this issue by having a focused topic, with an external expert guest speaker, and new location each meeting as farmers were keener to 'look over the fence' across the region than regularly attend the *Dairy Optimisation Site*.
- Workshops where farmers were encouraged to come together to learn and be supported in a new innovative skill or use of a new technology worked well, such as Murray Dairy's 'Soil Moisture Monitoring Coaching Groups' or East Mepunga's VRI excursion.
- *Weekly Irrigation Requirement Reports* were extremely well received by the farmers, especially those that were emailed directly rather than via an eNewsletter. These provided an opportunity to demonstrate how the key principles are applied in practice and how the use of the technologies helped to inform decisions throughout the season. It also built a trusted advisor-farmer relationship between the *Optimisation Site Coordinator* and reference group/ local irrigators, whilst being an effective way to communicate and maintain farmer interest in the project/ topic.
- *Optimisation Site Coordinator* changes during the project meant there was a loss of knowledge and 'lessons learnt' that was not always passed on to the next coordinator, impacting the way in which site activities were delivered and received by the farmers on certain sites.

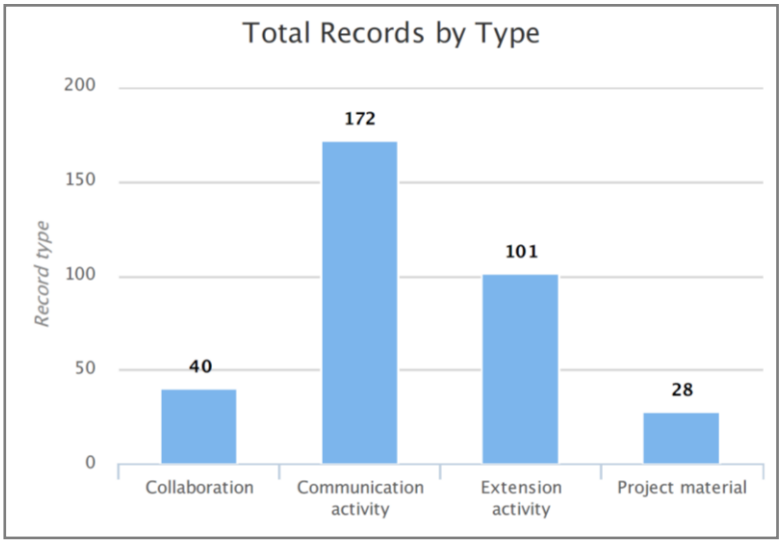
- During lockdowns, all *Optimisation Site Coordinators* attempted to conduct online extension events or reference group meeting, and social media "chats" using WhatsApp and Facebook. Farmers were very reluctant, and these valiant methods generally did not last the course of the project.
- Between lock-down periods, and once restrictions were lifted longer-term, the farming community was flooded with events, all vying for their attention and attendance. Whilst attendance at field days in Gippsland were very strong in April, most other sites struggled for numbers.
- As there are still adoption activities to be implemented on most sites as a result of final findings/recommendations, recent farmer confidence, delays in access to capital equipment and materials or financial constraints, an opportunity to evaluate the economic outcomes in the future would provide a more comprehensive analysis for the dairy industry and would build greater farmer confidence in the long-term benefits to business profit and operation efficiencies.
- Dairy Australia plans to prepare more case studies and fact sheets after completion of the project, ideally to be integrated into the existing extension model of the organisation. Post SIP2 Workshops will be conducted with Extension Officers/ Coordinators who are responsible for soils and water portfolios to ensure they understand the content and how it relates to aligned programs being delivered in the regions.
- Whilst AgVic will continue to provide *Irrigation Requirement Reporting* in Gippsland (Cobains & Yarram) and Murray Dairy (Tongala) regions, there is strong interest by farmers in other regions, where this service was provided by the *Optimisation Site Coordinator,* to see this continue post-SIP2 and continue to use *Dairy Optimisation Site* data to do so. Dairy regions are being encouraged to investigate options to support this initiative (Western Dairy (Dardanup), Subtropical Dairy (Northern Rivers-Coraki), DairyNSW (Hunter/Mid-coast- Tocal), WestVic (SW Victoria- Mepunga East) and DairySA (Central -Mt Compass & SE SA-Mt Gambier)).

6 Additional project information

6.1 Sub-project, media and communications material and intellectual property

All extension, communications and project materials developed and extended by the project have been comprehensively detailed in the *RRDP2017 Smarter Irrigation M&E Database and* have been collated in *Appendix 6- SIP2 Yield Gap (9) _Communications, Extension, Collaboration & Materials.* As the graph below demonstrates, a total of **341 activities** have been reported, with further information on social media and web-based analytics provided in 6.1.1.

In summary the project activities delivered at the local, regional and national levels are as follows: 40 formal collaborations (641 participants), 172 communications (circulation of 136,603), 101 extensions (1,734 participants) and 28 project materials. The SIP2 website (also continues to be a valuable hosting site of the 15 resources developed to date for the project, as well as videos and podcasts.



6.1.1 Social media and web analytics

Dairy Australia used, numerous communications threads to deliver SIP2 messages to dairy farmer audiences. The majority of these have directed dairy farmers and stakeholders to the Smarter Irrigation for Profit 2 webpage on the Dairy Australia website (dairyaustralia.com.au/sip2) to find information and resources on SIP2 and irrigation management.

Since Q4 2020, 1,942 unique visitors have been recorded to the webpage, an average of 323 visitors per month. This peaked during a national campaign during August 2021, recording 1,620 total webpage views. An overall time spent on the page of 3 minutes 25 seconds during this period shows the visitors to this page generally stay on the page to peruse the information and resources contained for longer than the average of other pages.

Posts on Dairy Australia social channels throughout the project culminated in a total of 52,581 impressions made on both Dairy Australia Twitter and Facebook social accounts. This peaked in certain quarters, spread out over the entire project timeline, where campaigns were ongoing to drive traffic to the webpage.

Regional social channels were also utilised throughout the various dairying regions. These communications were technically approved and provided to regional communications advisors to add a regional tint to the content, ensuring a regionally tailored approach. In Q1 and Q2 2021, a total of 14 newsletter articles around the various regions were delivered, peaking with the Subtropical Region delivering six of these, to a distribution list of 1,000 customers.

6.1.2 Summarised update on activities- detailed in Appendix 6

Nature of materials / activities	**Number**	**Details** (Please provide details if appropriate (eg links to publicly available documents)
Media appearances – press and TV	**37** Newsletters **12** Major industry publications	Regional eNewsletters, newsletters of RDPs and local dairy groups The COB Magazine (Spring edition 2020)- Newsletter of Maize Association of Australia, ABC Rural Radio (2)- South Australia & Bega, ABC Rural online (Bega), 3CS Radio interview Warnambool, Farmonline.com (Dardanup), Australian Irrigation Online article (Dardanup)
Brochures, fact sheets, posters and newsletters	**6** videos **2** Podcasts **20** Fact Sheets	**Update provided on previous 12 months (Since 31st May 2021- Milestone 3 Report) of major activities:** **Videos** Smarter Irrigation for Profit Background-Dairy Australia CEO David Nation Benefits of Variable Rate Irrigation for Dairy Pastures- Mepunga East Tools and Techniques for Smarter Irrigation-Dardanup Dairy Farmer Michael Twomey TIA's Dr James Hills in on Irrigation Basics IrriPasture Video- A Free Irrigation tool for dairy farmers (animation used) **Podcasts** Dairy Pod Podcast 55: Making every drop count with Will Russell (Bega Optimisation Farmer) Dairy Pod Podcast 28: How Smarter Irrigation can boost production- James Hills **Fact Sheets** Following all available from www.dairyaustralia.com.au/SIP2: ✓ Australian Dairy Irrigation Manual ✓ IrriPasture Use Guide ✓ Precision Dairy Technology- Variable Rate Irrigation Fact Sheet

	392 Irrigation Requirement Reports	✓ Planning for Variable Rate Irrigation - EM 38 Mapping Fact Sheet ✓ Determining Readily Available Water Fact Sheet ✓ System Maintenance Checklists (5 different systems) ✓ Optimisation Site Case Study Booklet Pages (10) Dependent on site, weekly or monthly reports prepared by the Site Coordinator to provide overview of the collected data, using reports/graphs from technologies being used (Soil moisture graphs, IrriPasture Graphs, SWAN forecasts, Pasture.io graphs and DM measurements), commentary on farmer irrigations decisions and tips for coming period. Distributed to reference group members or through eNewsletters more broadly.
Web pages	**2** Webpages developed and maintained. www.dairyaustralia.com.au/SIP2 www.app.irripasture.com	Smarter Irrigation for Profit Website- Dairy Australia: Analytics report for the period November 2020 to May 30, 2022: 2847 views (709 from search engine searches) with average time on page of 3:40 minutes, 239 downloads. IrriPasture Tool: Analytics report for the period November 2020 to May 30, 2022: 824 registered users with an average time on site of 7 mins 29 secs and 5.21 sessions per user. Supporting resources used to promote and extend the tool: IrriPasture Video IrriPasture User Guide
Field days, expos, field walks	**25** Field Days (730 participants) **5** Training Workshops, **8** Webinars, **16** Workshops (498 participants) **47** Reference Group Meetings/ Technology Group Sessions	Conducted across all regions, though Coraki heavily impacted in final year by record flooding. **Snapshot of evaluation results:** As a result of these activities, knowledge improved overall by 1.4 to an after-project figure of 7.8 out of 10 for *Knowledge of common industry practices that impede the yield potential of irrigated areas* and by 1.6 to 7.7 for the *Knowledge of demonstrated research, tools and management strategies can assist in improving optimal yield potential under irrigation?* Evaluation results of these events showed that 91 percent of participants were likely to change irrigation practices and that 81 per cent of these participants were likely to change that practice within the next two years. Participants rated the value of the activity to their business as 8.3 out of 10.
Stakeholder forums, meetings, presentation	**26** Monthly Optmisation Site Coordinator Meetings & 4 *Annual Optimisation Site Coordinator forums*	Information exchange, upskilling and planning over three years.

s, workshops, webinars	(with TIA). **4** Private sector/ commercial provider meetings **6** Participations in cross-SIP2 exchange opportunities.	 Development of partnerships with Swan Systems, AgLogic and Pasture.io Presentations provided to all partners of the SIP2 Project and substantial contributions to innovation, planning and feedback sessions.
Social media presence	**10** on social channels 18,490 impressions 657 engagements	Major SIP2 Campaign in August, 2021 using Facebook & Twitter (Refer to full report Section 6.1.1). Webpage experienced major spike over this period with 1620 page views (173 in the July) Regional social media used to share infographics, podcasts, videos, promote IrriPasture and promote events. IrriPasture animation promoting the tool achieved 475 views during the campaign period.
Scientific conference presentations	**4** 2022 IAL Conference Abstract Acceptances	✓ Leading Author Cath Lescun, 2022 IAL Conference Abstract: *What's My Yield gap? Improving water productivity in dairy systems.* ✓ Leading Author Sam Taylor, 2022 IAL Conference Abstract: *Maximising pasture productivity through enhanced irrigation management* ✓ Leading Author Graeme Ward, 2022 IAL Conference Abstract: *Improving energy efficiencies an important opportunity for southwest Victorian irrigation* ✓ Leading Author Marguerite White, 2022 IAL Conference Abstract: *IrriPasture - A simple water budget tool for irrigated dairy pastures*
Project Materials	**28** Project Materials	**Listed here are those other than fact sheets and guidelines listed above:** ✓ Site System Irrigation Reports (uploaded to M&E Database) ✓ *Smith, P. (2022) SIP2 Irrigation System Evaluations Report, Tamworth, NSW.* (Appendix 2)- collated analysis of the outcomes of the system evaluations of the SIP2 Project. ✓ *Christie, Karen (updated 2022), Yield gap modelling for the Smarter Irrigation for Profit II project*, Tasmanian *Institute of Agriculture, Burnie, Tasmania* (Appendix 3) ✓ *Hill, J., Harrison, M. and Liu, K. (2022), Fodder yield gaps for maize, millet and lucerne in Australia, Tasmanian Institute of Agriculture, Burnie, Tasmania* (Appendix 4) ✓ EM38 Survey Reports (Bega & Mepunga East)

6.2 Equipment and assets

No major assets or equipment were purchased during the project period.

6.3 Monitoring and evaluation

If you have any sub-project specific M&E material, please summarise, and attach findings

6.3.1 Project extension and workshop activity evaluation

A monitoring and evaluation process was established at the beginning of the SIP2 What's my yield gap? Maximising water productivity project with questions relating to the knowledge gained about common industry practices that impede the yield potential of irrigated areas, resources, tools and strategies that can assist in improving yield and the intention to change practices and in what time frame.

The field days, workshops, webinars or zoom meetings held at all sites (refer to Appendix 6 SIP2 Yield gap (9) Communications, Extension, Collaboration & Materials for the full list of activities) were evaluated using survey monkey. Over the project period there were 239 responses over the 54 field days, training workshops and webinars. Of these respondents 52per cent were part of a *Dairy optimisation site* reference group and 51per cent were farm owners, employees, or sharefarmers with 49per cent agribusiness professionals.

The table below highlights the self-assessed score (out of 10) in knowledge of practices that impede yield, and tools and management strategies that improve yield as a result of extension activities.

Description	**Before activity**	**After activity**	**Change as a result of the activity**
Knowledge of common industry practices that impede the yield potential of irrigated areas?	6.33	7.76	1.43
Knowledge of demonstrated research, tools and management strategies can assist in improving optimal yield potential under irrigation?	6.11	7.71	1.6

SIP2 activity participants reported an increase in knowledge of 1.4 for common impediments and a higher change in knowledge of 1.6 for research, tools and management strategies. This indicates a positive shift in knowledge in these areas. The after-activity ratings of 7.7 for both knowledge areas would be considered good knowledge.

Participants rated the value of the extension activities to their business as 8.3 (out of 10) on average and the presentation and quality of content as 8.5 and 8.5 respectively.

As a result of participating in SIP2 What my yield gap? Maximising water productivity 91per cent of respondents were *somewhat likely*, *likely* or *very likely* to take action to do things differently in the way they manage their farm or conduct their business with 72per cent stating changes would be made in the next twelve months or earlier.

These survey results indicate that participants of the SIP2 activities overall improved knowledge, were quite likely to take action over the next twelve months to change practices in relation to irrigation decisions on their farms. They also indicted that the value to their business of the activities was high.

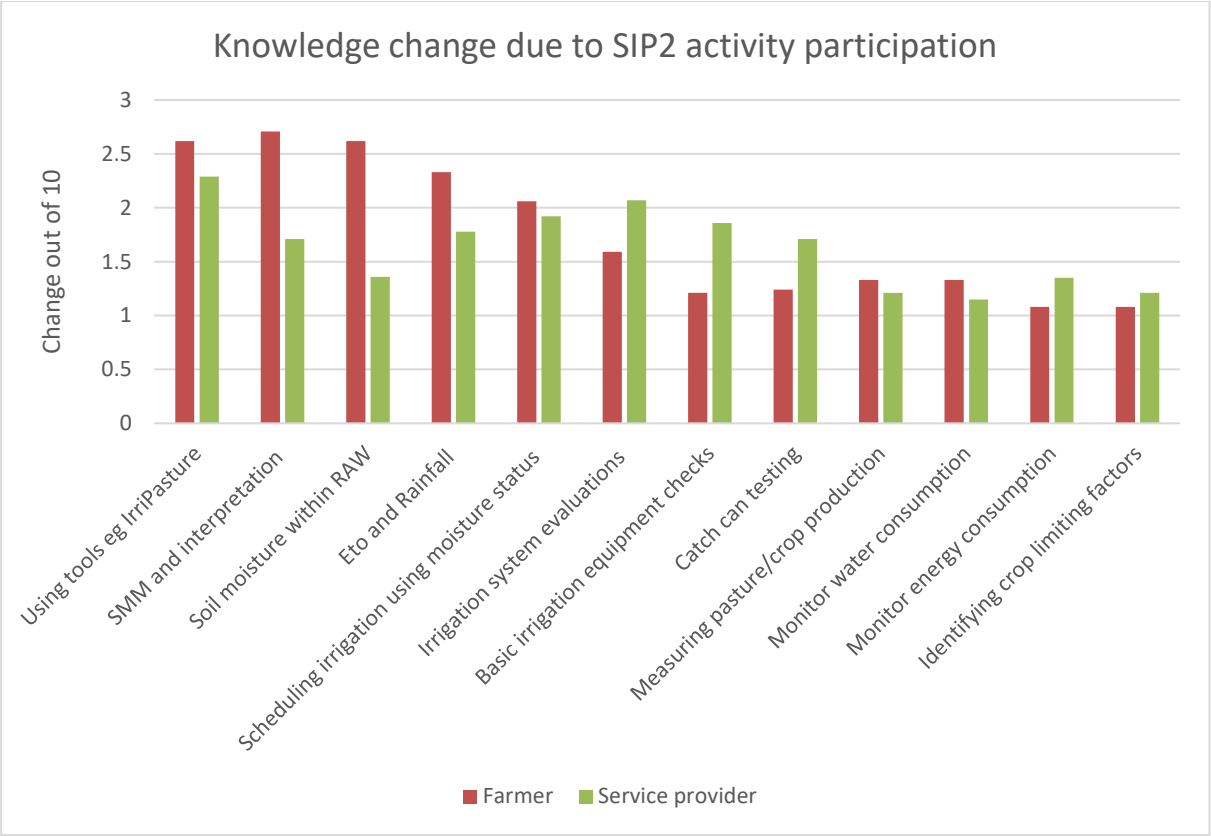
6.3.2 Final survey – Evaluation of overall knowledge and practice change

Further evaluation was completed during the final stages of the SIP2 project. This evaluation was to determine the knowledge and practice changes over the life of the project. The final survey was conducted in May 2022 and obtained 40 survey responses. Due to the smaller sample size, some of these results should be viewed carefully.

Farmers, share farmers, employees and farm managers made up 60 per cent of the respondents whilst agribusiness professionals made up the other 40 per cent.

Increased knowledge was reported by both farmers and service providers in terms of irrigation technologies used to make decisions about irrigation start up timing and scheduling, system performance, crop monitoring and water and energy efficiency.

In a rating out of ten, farmers average increase in knowledge was 1.7 and service providers was 1.6. Farmers highest increase in knowledge was around the tools and information that assist in frequent irrigation scheduling decisions. Service providers had greater increased knowledge in using tools such as IrriPasture and whole irrigation system performance evaluations and catch can testing.



The above figure shows the change in the self-assessed rating of farmer and service provider participants of SIP2 activities.

The total respondents *before* SIP2 project ratings ranged from 3.7 to 6.2 with the *after* ratings ranging from 6.2 to 7.6, indicating that although there have been good increases in knowledge there is still potential for improvement.

Farmer practice change was assessed through the survey, with 26 farmers participating in this part of the survey.

Respondents were asked "*What best describes the practices undertaken on your farm during the irrigation season"* with four responses available (*had started*, *were still considering* or *not considering* the practice. Respondents could also indicate they were *doing the practice before SIP2.* This translates to a lower number of respondents that could change practices due to SIP2 and was different for each of the practices investigated.

Interestingly, practices where there was greater than 50per cent of respondents still considering or not considering the practice were activities that required (or most likely required) assistance from service providers. These activities, included catch can testing, completing and applying whole farm irrigation system performance evaluation and monitoring energy use.

Conversely, where action could be taken by the farmers independently, such as using evapotranspiration rates and rainfall for irrigation decisions, completing system checks on equipment, and monitoring and addressing production constraints other than irrigation, greater than 50per cent of participants had started doing as a result of SIP2.

Qualitative feedback showed that the evapotranspiration rates and rainfall forecasts emailed weekly to participants were used widely for irrigation decision making. Survey results confirmed this. Forty six percent of

respondents were already using this information prior to SIP2, and of the 54 per cent that could therefore adopt and use the information, 79 per cent did because of SIP2.

At the other extreme, catch can testing had the greatest number of participants (27%) who were not considering adopting this practice and had only 23 per cent of participants who had adopted. One survey limitation was that there was no indication gained as to why these practices would not be adopted.

More than 65per cent of participants changed start up time at the beginning of the season, after major rainfall events, and irrigation application rates because of SIP2.

Eighty per cent stated they had increased productivity under irrigation.

The tools and activities that had the largest impact on irrigation performance on participant farms was the soil moisture monitoring (68%) and the weatherwise watering forecast emails by SWAN systems or other reports providing site weekly irrigation requirements (48%). Each of these provides information to improve precision of irrigation decision making at the farm level. Nearly fifty percent of respondents (44%) mentioned that reference group meeting, field days and workshops had a large impact on their irrigation performance.

Of the tools listed IrriPasture had the least impact on irrigation performance (8%). Challenges farmers highlighted for the practical use of IrriPasture continued to be investigated and developed throughout this project. Further development and extension are required to increase the uptake of IrriPasture and to ensure it is seen as a valuable tool to assist in irrigation scheduling across a range of seasons and sites.

Irrigation system evaluations and recommendations had a large impact on only 28 per cent of respondents. It is possible that this figure was low due to the low number of service providers who provide this service. Increasing the number of service providers who can provide system evaluations for the dairy industry is seen as a future requirement to improve water and energy efficiency on farm**.**

The participant survey evaluating the impact of SIP2 What's My yield gap? Maximising water productivity shows that farmers highly valued tools and activities that helped their irrigation decision making. The greatest change in knowledge was also around the on-farm irrigation decision making. Knowledge change and impact for tools such as system evaluation where service providers are required was lower.

Research results from SIP1 showed that farmers were not getting the basics right and that increases in profit could be achieved by accurate irrigation start up time and scheduling. More than 65 per cent of respondents in SIP2 had changed start up time, irrigation timing after rainfall and irrigation application rates. Eighty percent believed that their productivity had increased.

Further research is required to investigate the relationship between the improvement in knowledge and the application of that knowledge in relation to irrigation decision making and system performance. This survey does not provide that information. These results are an indication of the success of SIP2 *What's my yield gap? Maximising water productivity.*

6.4 Budget

Appendix 1. Dairy Optimisation Site Technical Reports

Appendix 2. SIP2 Irrigation System Evaluations Report

Appendix 3. Yield gap modelling for the Smarter Irrigation for Profit II project

Appendix 4. Fodder yield gaps for maize, millet and lucerne in Australia

Appendix 5. SIP2 Yield Gap Collated Site Data

Appendix 6. SIP2 Yield Gap (9) Communications, Extension, Collaboration & Materials.

Appendix 7. Monitoring and Evaluation survey results