# Smarter Irrigation for Profit 2

RRDP 2003 New technologies integrated and automated smart sensing for cotton

Final Report

Australian Government
Department of Agriculture, Water and the Environment

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CRDC

DEAKIN UNIVERSITY

Irrigation Research & Extension Committee

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# Plain English summary

The Australian cotton industry is constantly searching for ways to manage irrigation water more efficiently and is currently a global leader. Smart sensing, understood as a wireless network of sensors, sensor hub and actuators connected through the Internet of Things (IoT) environment offers great potential for the agricultural sector in general. In irrigated agriculture, smart sensing is a powerful tool for the automation of irrigation. This technology allows farm managers to have information about soil, crop, and weather conditions available in real time at a lower cost than ever. This information is key for optimizing irrigation scheduling and water management decisions in broadacre farming, managing the water resources more efficiently and improving crop water productivity.

Research has shown that automated irrigation technologies have the potential to notably improve the efficiencies from a production and labour perspective in irrigated systems. While automation of irrigation has been adopted at commercial scale by farmers in pressurised irrigated systems, there is scarce work done on its application in gravity surface irrigated systems. The use of automated irrigation technologies for sensing and controlling irrigation structures that can fit across a range of irrigation stops/outlets without needing restructuring has the potential to make the adoption of automation irrigation systems more attractive and affordable for irrigators.

In this project, Deakin University in collaboration with growers, grower groups and commercial industry partners, Padman Automation and Goanna Ag, investigated the feasibility of using an integrated system for automation of irrigation in commercial cotton farms based on smart sensing. The project research team developed and tested a cloud-based platform based on fully replicable microservices capable to sense and monitor soil, crop, and weather data, forecast relevant parameters, and interact with external (weather and remote-sensed data providers) and third-party cloud services for planning and automatically controlling irrigation events. The project assessed the suitability of a range of parameters and sensor types for irrigation decision making in automated irrigation systems and identified and communicated the requirements of a smart sensing and automation platform for its use at a commercial scale.

The results obtained demonstrated that automation of irrigation in gravity surface irrigated cotton is feasible with minimum human intervention and the smart sensing and automation systems developed in this project were shown to be cost effective. Soil water tension at the root zone along with water depth in bays measured with pressure transducer sensors were identified as the most appropriate parameters to monitor for determining the recommended start and end of irrigation events. The project developed a methodology using machine learning algorithms that could be integrated into cloud-based platform systems for estimating soil tension in the root zone of cotton plants in areas not equipped with on ground sensors from freely available high-resolution satellite imagery. The machine learning algorithms used in this study were capable of estimating soil tension from satellite imagery accurately and therefore offer the industry benefits from this methodology for monitoring soil tension with a reduced number of physical sensors on the ground, thereby further reducing costs.

Economic analysis of the results found smart sensing and automation in bankless channel systems showed benefits of reduced labour (–85%) with a likely water saving of 10–20%. For the technology used in the project, investment costs (10 years, 5% discount) for 100 ha cotton area

ranged from $155/ha (30 ha bays) to $328/ha (10 ha bays) and a positive return on investment in smart sensing and automation from all bay sizes was found in the analysis.

Key learnings

Conducting research at a commercial scale and communicating the costs of smart sensing and automation on a per ha basis has been a major factor in helping growers understand the relative costs of automation and facilitating adoption. We found that providing smart sensing and automation costs on a per ha basis (varies with bay size) allows irrigators to very easily see the benefits.

Extension networks need to build their capacity in information technologies such as Precision and Digital Agriculture, big data, Artificial Intelligence, and IoT. These are areas where irrigators are rapidly moving toward and need extension networks that are ag focused but have expertise in these areas.

In conclusion, the project 'New Technologies Integrated and automated smart sensing for cotton' has shown that smart sensing and automation are powerful tools for integrating sensing, data analytics and control of irrigation structures and that automated irrigation of gravity surface irrigated cotton with minimum human intervention is feasible and affordable using systems developed and studied in the project.

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

# 1 Project rationale and objectives

The Australian cotton industry has remained at the forefront of adopting technologies and techniques to continuously improve yields per hectare and per mega litre of water used. With the rapidly developing technologies of Internet-of-Things sensors, big data processing and automated control systems, it is vital that the industry leads the adoption of these new technologies in order to remain ahead of the industry internationally.

The Australian context demands ever-smarter ways of monitoring and controlling farming inputs in order to provide the best possible outcomes for the environment while maintaining profitability. Water is an increasingly precious and uncertain resource that requires attention. Any techniques that could be implemented to improve precision of irrigation, considering plant requirements and yield versus cost trade-offs, will be beneficial for the ongoing sustainability and profitability of the industry. Often farmers may be aware of more optimal irrigation strategies, but implementation of these strategies is unachievable because of the time required to start, monitor, and stop irrigation events over many fields on a farm. All these issues can be solved through increasing use of sensors and automation.

The project investigated the use of in-field sensing data to provide optimised and automated irrigation control. Algorithms to enable precise delivery of water to the crop were developed and integrated into automation infrastructure. The strategy makes use of sensor, weather and satellite data, all available online and integrated with automation infrastructure. This approach results in efficiency improvements, both from the point of view of time saving, and providing optimal irrigation amount and timing minimising over-watering while optimising the yield versus water input cost trade-off.

As new cotton growers are emerging in the south of New South Wales and existing cotton growers look to improve productivity efficiencies across existing systems in all cotton growing areas, there is a need to provide irrigators with smart sensing and automation systems that are adoptable on-farm and cost effective. This project aimed to provide these solutions for cotton irrigators.

# 2 Method, activities, and project locations

The work conducted within the three-year project (2019 to 2022) took place in three cotton farms located in the southern (Murrumbidgee Valley) and northern (Moree Plains Shire) cotton growing areas of New South Wales (Figure 1). While the equipment and technology used in the project was tested at the three sites shown in Figure 1, testing of the integrated irrigation system, including automatic irrigation control, during the 2020/21 and 2021/22 growing seasons and showcase of this technology mainly occurred at the experimental IREC (Irrigation Research and Extension Committee) site in Whitton and commercial cotton farms from the large cropping operator Keytah located in Moree. Cotton was furrow irrigated at all sites by means of a bankless channel irrigation system except for five bays at the IREC site where irrigation was applied via a pipe through bank downslope system.

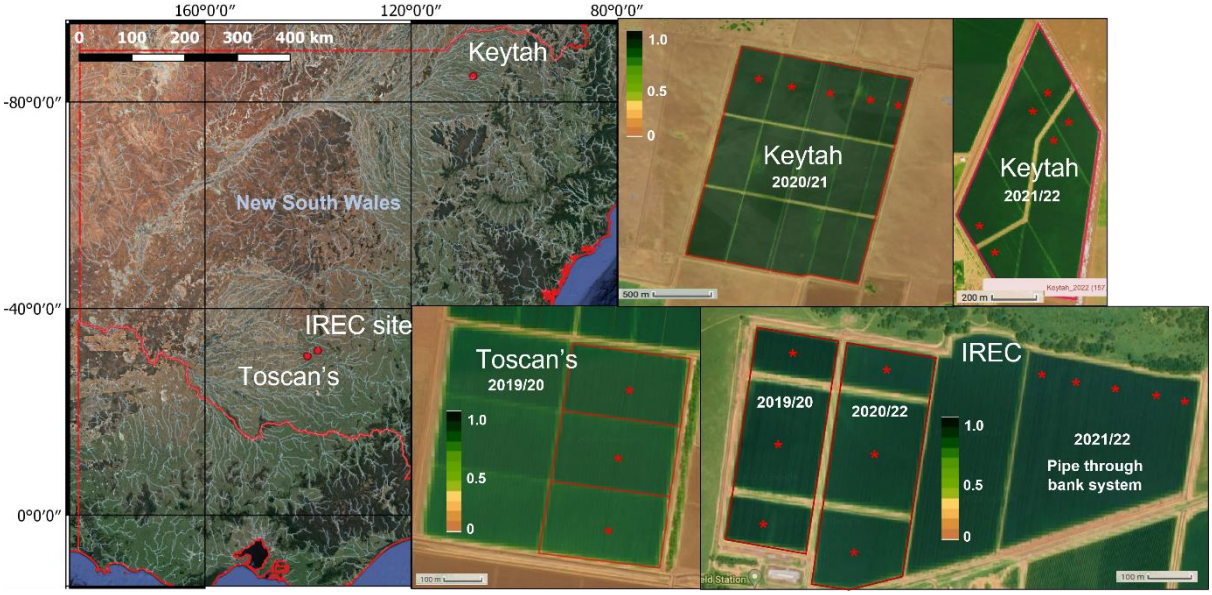


Figure 1 Location of the cotton sites where the automated irrigation system was tested, and the technology used showcased. Red asterisks indicate where the WiField stations with soil moisture sensors were installed at each site.

Sites were instrumented with a range of sensing technologies for monitoring both crop and environmental variables as explained in detail in the associated technical report. These included a range of soil sensors, water depth sensors, weather stations and remote monitoring through satellite platforms Landsat and Sentinel.

These sensing networks were then connected to irrigation control hardware capable of remotely controlling irrigation outlets (Figure 2) across the irrigation bays at each of the trial sites.

During the life of project, a range of investigations were undertaken to develop a smart sensing and automation system suitable for cotton irrigation on surface irrigation systems. This involved testing and developing various sensor control systems and developing cloud-based infrastructure and knowledge to allow this integration. Feedback from trials on the commercial farms was used to work with industry partners and commercial collaborators to develop knowledge and products suitable for adoption by commercial irrigators.

Figure 2 – Example Irrigation outlet at the IREC site with smart control irrigation outlet at the IREC site utilising pressure transducer sensor and the Seasonal AutoWinch control system.

The following table provides information on the team members and partners that were involved in the project.

| Name | Organisation/Business | Role |
|---|---|---|
| Rodrigo Filev Maia | Deakin University | Investigator |
| Carlos Ballester | Deakin University | Investigator |
| John Hornbuckle | Deakin University | Investigator |
| Josephine Schmid | Deakin University | Investigator |
| Iva Quarisa | IREC | Collaborator |
| George Revell | Ag Econ | Collaborator |

| | | |
|---|---|---|
| Nick Gillingham | Keytah | Farm Collaborator |
| Wil Jackman | Keytah | Farm Collaborator |
| James Toscan | Ringwood | Farm Collaborator |
| Rob Houghton | IREC/Irrigator | Farm Collaborator |
| Tom Dowling | Goanna Ag | Commercial Partner |
| Grant Oswald | Padman Automation | Commercial Partner |
| Gabriel Ballesteros | Padman Automation | Commercial Partner |
| Darshil Doshi | Padman Automation | Commercial Partner |

Locations of all project activities including the location of any commercial farms involved in RD&E activities during the life of the project.

| **Name & type of site (field site, laboratory, project partner sites, RDC headquarters)** | **Street Address** | **State** | **Postcode** |
|---|---|---|---|
| Padman Stops http://padmanstops.com.au/ (Partner) | 4948 Murray Valley Hwy, Strathmerton, VIC 3641, | VIC | 3641 |
| Irrigation Research and Extension Committee (IREC) | Lot 225 Research Station Road, Griffith NSW 2680 | NSW | 2680 |
| Goanna Ag https://www.goannaag.com.au/ (Partner) | 60 Hungerford St. Goondiwindi, QLD 4390 | QLD | 4390 |
| Sundown Pastoral Company (Research\Field Site) | Keytah, Moree, NSW, | NSW | 2400 |

| | | | |
|---|---|---|---|
| IREC Demonstration Farm | Stott Road, Whitton, NSW | NSW | 2705 |
| Casavo farming | Ringwood, Darlington Point, NSW | NSW | 2706 |
| Keytah commercial farm | 833 Goonal Road, Moree, NSW | NSW | 2400 |

The research activities undertaken within the project are applicate to the wider Australian cotton industry that uses irrigation water. The developed tools and techniques are suitable for any surface irrigation system that utilises inlet/outlet stops for irrigating crops.

# 3 Project Outcomes

## 3.1 Project level achievements

| Output and KPI numbers and description | Summary of achievements |
|---|---|
| Activity output 5.2(a) Establish two automated irrigation sites for cotton in NSW to demonstrate and validate the performance of low-cost automation. | In the 1st year of the project, two demonstration smart sensing and automation sites were established. One at the Irrigation Research and Extension Committee (IREC) demonstration farm near Whitton in NSW (Lat. -34.542, Long. 146.186) and a second trial site at Ringwood near Darlington Point, NSW (Lat. -34.638, Long. 145.963). Due to drought conditions and lack of available water at the proposed northern Keytah, NSW demonstration site, this demonstration site was moved to Ringwood, which had available irrigation allocation for the 2019/2020 irrigation season. However, ETo networks and LoraWAN networks were established at the Keytah site.<br><br>During the 2020/2021 irrigation season, experiments were undertaken to test the performance of the smart sensing and automation system across two field sites in southern (IREC, Whitton, NSW) and northern (Keytah, Moree, NSW) NSW cotton growing regions. A fully automated smart sensing and automation trial was undertaken on 17 ha of cotton at the IREC farm. The three bankless fields were operated throughout the irrigation season by the IRRISENS system (https://www.mdpi.com/1424-8220/20/24/7163) and smart in-field sensing and forecasting was used to trigger irrigation events and then water height sensors used to control within irrigation gate drops to subsequent bays. At Keytah, smart sensing and automation trials were undertaken across a new bankless channel irrigation layout of approximately 500ha with large bays (~35ha) as part of the trial (https://www.youtube.com/watch?v=DeZbigYdPWk).<br><br>During the 2021/2022 irrigation season, the trial sites at IREC and Keytah were again used. Additionally, a further 25-ha pipe through bank down slope irrigation system was established at the IREC site which allowed the smart sensing and automation technologies to be validated across a wider range of surface irrigation layouts.<br><br>The demonstration sites were fully instrumented with in-field sensors using Goanna Ag Wi-field nodes for the sensing network and Padman seasonal autowinches for the automation control hardware. |

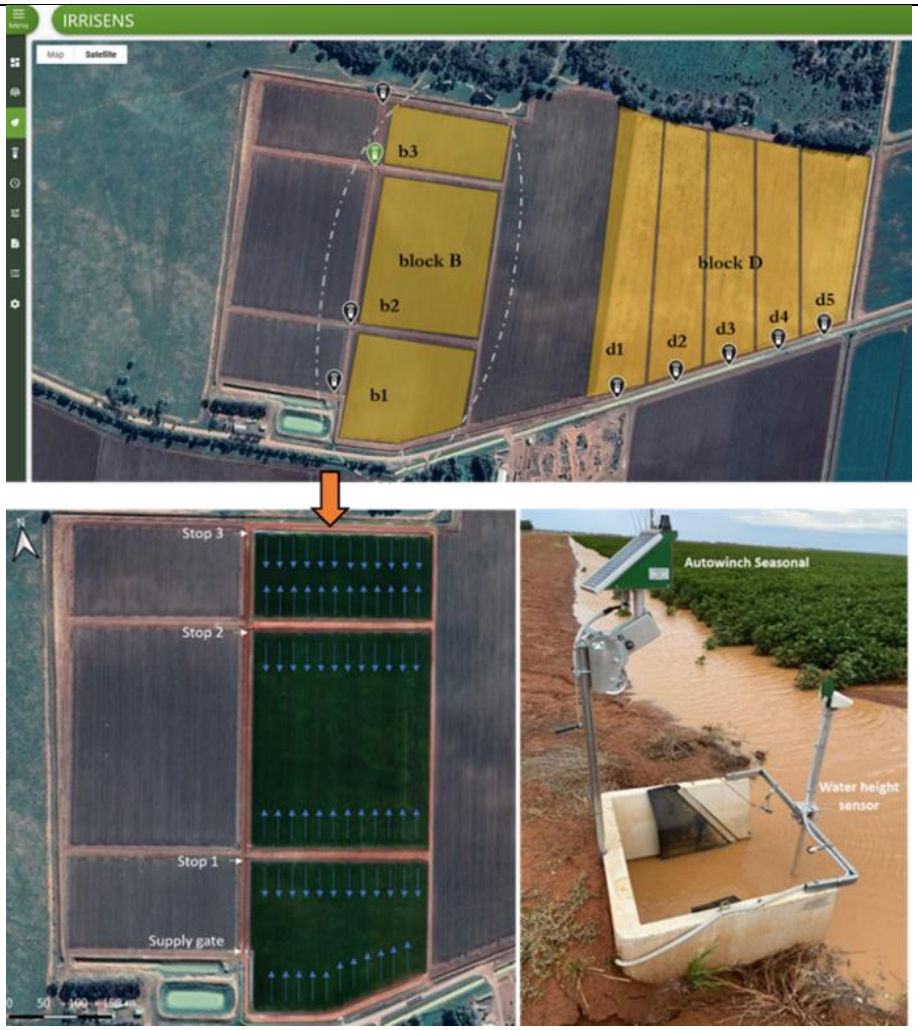


Figure 3 Image of the IREC experimental site showing the two surface irrigation systems bankless (Block B) and pipe through bank downslope (Block D), the differences in bay organisation between block B and D (top), and the typical IoT irrigation control structure used across the project (bottom right).

The performance and operational aspects of the smart sensing and automation systems developed in the project were showcased at a range of field days across the project (see section 6.1) and also through a range of industry communications in industry journals such as *The Australian Cotton Grower* where the article "IoT enables automated, low cost surface irrigation" was published in the August-September 2021 edition (https://www.cottongrower.com.au/read/60#22), *Farmers Newsletter* and industry R&D updates.

| | |
|---|---|
| Activity output 5.2(b) Conduct experiments to validate | Field demonstrations undertaken in the project were used to actively engage with commercial irrigators and commercial partners and refine sensor/hardware systems and algorithms for automation control form sensor networks.<br><br>The project team developed a web-based sensing and automation system interface within the Google Cloud Platform utilizing interoperable MQTT |

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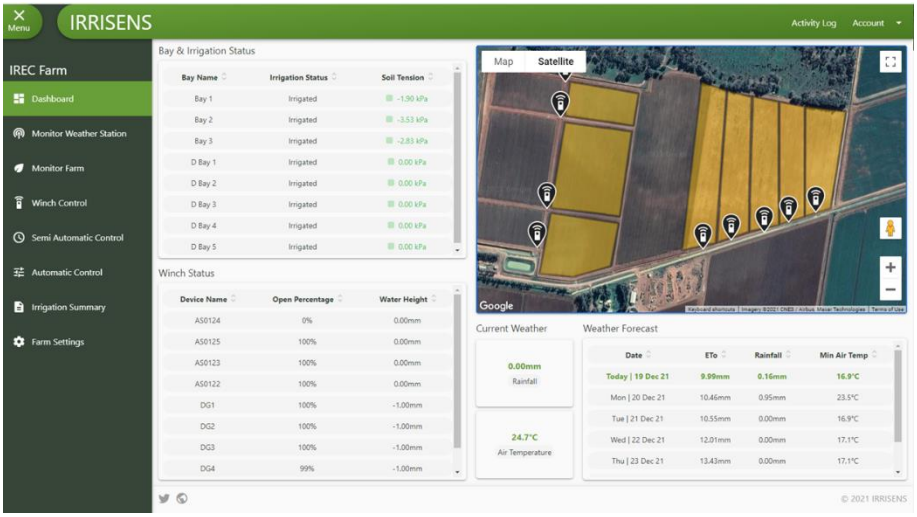
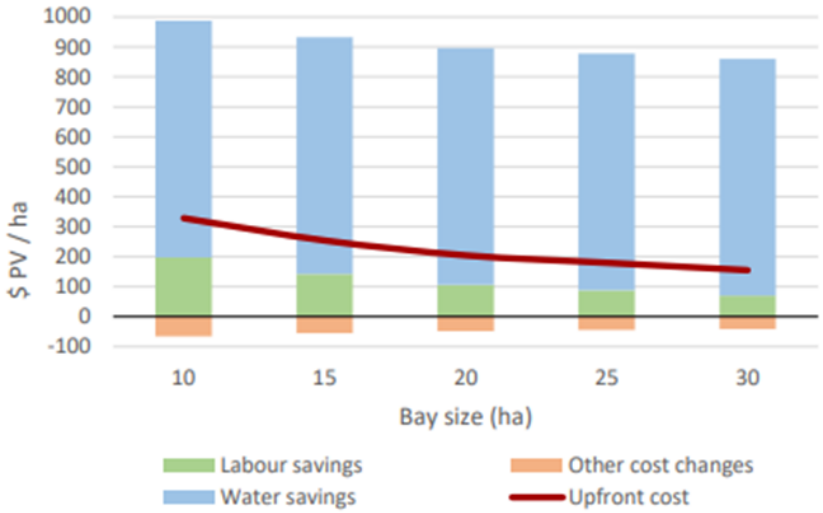
| the suitability of irrigation sensing-control algorithms for optimising cotton irrigation management | messaging for control. This platform integrates sensing data from sensing nodes and Padman Automation hardware. The platform utilizes the concept of software microservices and data exchange occurs over HTTP and JSON protocols. This architecture easily allows integration of various services/products and flexibility with integrating various software and hardware platforms into the future.<br><br>A range of sensors measuring soil, weather and plant performance were used to parameterize irrigation scheduling and irrigation management events. This was then linked to Padman seasonal autowinch automation hardware to control irrigation. The sensing and hardware used a range of Wi-Fi, LoRA and CatM1 communication protocols established across the farms and linked to a Google cloud-based management platform known as IRRISENS (https://www.mdpi.com/1424-8220/20/24/7163) that undertook data analytics and control of irrigation system hardware. The experiments were able to demonstrate that linkage of smart sensing and automation through a cloud-based platform can be achieved within an irrigation farming system across a range of sensing and hardware platforms and protocols for IoT based approaches. Data from the previous seasons were used to refine the IRRISENS cloud-based platform algorithms and further enhance its functionality during the life of the project.<br><br>  <br>Figure 4: IRRISENS dashboard showing bay and winch status and weather parameters. Note two irrigation layouts and associated smart sensing and automation systems are being controlled, a “Bankless” and a “pipe through bank downslope furrow” system.<br><br>Work was undertaken on using a range of parameters for controlling irrigation in an autonomous fashion and expand on the projects earlier work (https://www.sciencedirect.com/science/article/pii/S2405896319325078) particularly in relation to soil moisture forecasting using machine learning. Soil moisture tension is seen as a key measurement which can be used for autonomous irrigation due to its ‘absolute’ measurement nature which allows it to be used across multiple soil types without site specific calibration issues. This is a particularly important consideration when |

| | |
|---|---|
| | using such data in an autonomous irrigation situation as 'calibration' and 'drift' in sensor data across an irrigation season are major issues when using this data for autonomous irrigation hardware control.<br><br>Additionally, in control during actual irrigation events as opposed to scheduling timing of events, the use of water level data for triggering gate drops between irrigation bays has been refined using water level pressure transducer sensors. The IRRISENS cloud-based app has the ability to control watering events automatically now using this data. This is particularly important for example on "difficult" soil types where infiltration is an issue. These algorithms have the ability to be run in a supervised or unsupervised fashion allowing full automation from the channel delivery outlet.<br><br>Algorithms used in the system for forecasting and sensors used for irrigation scheduling and monitoring of water in channels and bays were refined over the irrigation seasons during the project. Low cost ultrasonic water height sensors did not produce suitable resolution and accuracy for irrigation outlet hardware control. Pressure transducer water height sensors on the other hand, showed sub cm resolution, allowing accurate water control during irrigation events, which is particularly important on large bay sizes. The best sensor combination found was one that incorporates watermark sensors for irrigation scheduling and pressure transducer sensors for water height monitoring. This sensor combination was shown as the most symbiotic when coupled with automation hardware. The watermark soil tension sensors do not need site specific soil calibration, do not display large sensor drift during the irrigation season, and readings do not require human interpretation. Additionally, both watermark and pressure transducer sensors are at a price point that allows commercial providers to offer these at a price that farmers are willing to pay. These smart sensing and automation systems are now being offered commercially through Padman Automation and are having high demand from irrigators. |
| *Final report KPI. Provide a final report on the economic benefits (labour, cost, profitability, etc.) for automated irrigation* | The project also undertook basic economic analysis of smart sensing and automation systems using data collected in the project and with the help of project partner Ag Econ who undertook an economic analysis focused on developing simple metrics for cotton irrigators to assess the benefits of investment in these technologies used in the project.<br><br>This resulted in the development of a case study fact sheet https://smarterirrigation.com.au/wp-content/uploads/2021/08/Smart-Sensing-and-Automation-in-Cotton_Case-Study_Aug-2021-.pdf<br><br>This information highlights key messages and provides a simple-to-understand analysis of costs on a per ha basis which growers can easily relate to as they are used to gross and profit margins on a per hectare basis. Economic analysis showed costs were found to range from $350/ha to less |

| | |
|---|---|
| *(Output 5.3b).* | than $200/ha across typical bay sizes used in the cotton industry and a positive return on investment in smart sensing and automation from all bay sizes was found in the analysis.<br>  <br><br>Figure 5: Investment costs and benefits (10 years, 5% discount) for 100 ha with different bay sizes |
| | |

## 3.2 Contribution to the SIP2 program objective

The project has been able to develop smart sensing and irrigation automation technologies that have considerable benefits for irrigators. These benefits include significant labour and water savings that are achievable with the technology and economically viable for growers as demonstrated in the economic analysis presented in this report.

The developed smart sensing (i.e. Padman Sensor Pro) linked to autowinches to control irrigation outlets by both soil tension measurements and/or water levels offer irrigators the ability to optimise irrigation management in a labour saving manner. Additionally, through this project and with close collaboration with project partner Padman Automation these technologies are now being offered commercially at price points that we believe will allow irrigators to adopt these technologies without the economic support of government programs in cost sharing in on-farm water investment. Previously, these types of technologies were not at a price point that saw widespread adoption of on-farm surface irrigation automation by farmers without support from government incentives. Current economic analysis and direct experience with irrigators now investing in these developed technologies indicates that the incentive through direct benefits in labour and water savings now is at a price point that cotton irrigators are willing to invest in these technologies.

## 3.3 Contribution to SIP2 program outcomes

Provide a description of how your project contributed to the achievement of the following SIP2 outcomes. Only comment on the SIP 2 outcomes relevant to your project.

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

- *20% increase in water productivity on SIP2 optimisation and key learning sites.*
- *20% improvement in irrigation water productivity through use of autonomous irrigation and/or autonomous components on SIP2 research and demonstration sites.*
- *80% of participating producers adopt or intend to adopt precision irrigation strategies and technologies.*

The smart sensing and automation technologies used in the projects at the trail sites lead to irrigation management decisions that were optimised for the individual conditions present during irrigations. This led to irrigation management decisions that increased water productivity across the sites. On non-automated fields often irrigation bays/siphons changes occur when the irrigator has time to make the change occur, not when it should occur optimally. Compounded across the irrigation season these non-optimal irrigations affect water use productivity, both through water usage and non-optimal conditions for irrigated crops.

Economic analysis of the results found automation was assessed to provide benefits of reduced labour (–85%) with a likely water saving of 10–20%. For the technology used in the project,

investment costs (10 years, 5% discount) for 100 ha cotton area ranged from $155/ha (30 ha bays) to $328/ha (10 ha bays). The increase in IWUE productivity was found to be 11% and this combined with labour and energy productivity benefits gave a multi-factor productivity increase for automated smart sensing of 6% based on an average capital cost/ha. Productivity outcomes will vary with different climates and soil types. (data taken from AgEcon report)

All participating producers that were involved in the project have already begun to increase their commercial area under smart sensing and automation based on outcomes from the demonstration sites. At the IREC demonstration farm a second area of pipe through bank was developed in the third year of the project and fitted with smart sensing and automation based on success early in the project. Likewise at the commercial demonstration site in Darlington Point utilised in the 1st year trials, these commercial operators have now expanded the technology to cover farms. At Keytah in northern NSW expansion of the surface irrigation automation has continued.

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

*Indicator*

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

The tools developed in the project provide irrigators with insights and operations that allow them to make better decisions. The project has developed a grower base that now has a significantly improved understanding of the ability of smart sensing and automation technologies to improve their irrigation performance. This has seen a number of cotton irrigators investing directly in these technologies to improve their ability to optimise irrigation decisions.

*3.* ***Improved project RD&E efficiency through knowledge sharing, integration and collaborations between researchers, project participants, and commercial partners.***

*Indicator*

- *Changes in the number and type of partnerships between SIP2 irrigation research organisations, industry partners and commercial technology providers.*

There has been an improved efficiency in the RD&E chain from the project through the linkage of project partners and collaborators, which span across this spectrum. Knowledge sharing across the different irrigation industry commodities has also seen gains in efficiency with expert knowledge shared between industry groups across the research and extension spectrums.

Examples of this include the economic analysis of smart sensing and irrigation which was first used within the rice industry project and then expanded upon within this project using developed methodologies, which allowed a more efficient use of resources.

***5. Increase in the number of cost-effective precision irrigation technologies able to be integrated into autonomous irrigation systems/platforms.***

*Indicator*

- *Number and type of new precision irrigation technologies and/or fully automated irrigation systems developed/refined as a result of your projects research activities.*

Through the project, tailored smart sensing and automation systems are now available that have been developed across a range of surface irrigation system types used in the cotton industry. New precision techniques utilising machine learning and remote sensing data have now also been developed for use in precision irrigation technologies.

***6. Commercially available fully autonomous irrigation systems for sugar, rice, grains, and cotton.***
*Indicator*

- *Number and type of new precision irrigation technologies and/or fully automated irrigation systems developed as a result of SIP2 research activities.*

The project has been able to develop an economically viable smart sensing and automation solution for cotton growers in Australia. The technology is being offered commercially through Padman automation and already within the life of the project cotton growers across the Australian cotton industry have begun to invest in the technology.

The linked smart sensing (Sensor Pro) and automated outlet controllers (Seasonal Autowinch) have the ability to provide a cruise control approach to irrigation scheduling and water management for the Australian Cotton Industry as demonstrated in this project at the IREC field site.

# 4 Collaboration

## 4.1 Project collaborations

Strong project collaborations have been formed with the Irrigation Research and Extension Committee (IREC) on the resource and knowledge sharing fronts. The project has been able to work alongside IREC in continuing to develop a unique community demonstration farm at Whitton in NSW with a range of irrigation automation technologies on display. The compact nature of the demonstration site and its proximity to many cotton growers in the southern districts has seen the site and its annual field day become an important resource for irrigators in these regions looking to learn and understand the opportunities irrigation technologies can provide to their business.

The commercial irrigated sites used in the project at Keytah in northern, NSW and Ringwood in southern NSW have been important collaborations that have really showed the potential for smart sensing and automation at large commercial scales. These sites and associated farmers/managers have really paved the way in testing and implementing irrigation automation technologies at a commercial scale and had a willingness to share experiences and knowledge freely with the project and wider irrigator community.

Padman Automation have been a strong supporting commercial partner within the project with strong collaboration on development of products to suit the needs of smart sensing and automation irrigation technologies and also with knowledge sharing. This partnership has been able to tailor equipment to meet the needs of irrigators at price points that makes the technology attractive to irrigators.

Collaboration with service providers within the irrigation industry has also been important for the success of this project. This includes Goanna Ag on weather station and soil moisture probe equipment, Yenda Producers on agronomic advice/ interaction at trial sites, Summit Ag on agronomic advice/ interaction at trial sites.

Overall, the collaborations made during the project have been very beneficial both directly for the project staff and their development and understanding of irrigator issues and also more widely to the irrigation community. The project collaborations have been utilised to further undertake research and extension activities collaboratively between partners.

## 4.2 Recommendations for activities to support future collaborations.

Collaborations in the project were overall seen as successful. Recommendations to support future activities include the continuation of supporting activities to allow follow up interactions to take place. Often collaborations are very project based due to competing demands from partners and collaborators and successful collaborations are costly (not just in dollar terms but also

time/commitment) so acknowledgement should be made that long term collaborations need support to flourish.

The project undertaken here was non-typical in that it had industry partners involved form the start. We believe this model is much more successful in developing outcomes for industry over shorter time frames. However, this model does have its challenges and needs to be able to remain flexible in delivery over the life of the project to meet needs of both research and industry partners.

# 5 Extension and adoption activities

## 5.1 Project extension & adoption activities

Overall, the target audience for the project was cotton irrigators and associated industry that support irrigation activities in cotton. Extension activities were aimed to give irrigators a wide range of options to learn about smart sensing and automation technologies and how these can be used in their current farming systems.

The project undertook a wide range of extension and adoption activities within the project. These ranged from industry field days and farm walks to industry and journal articles.

Extension and adoption efforts within the project were aimed at providing a number of opportunities for cotton irrigators to see the technology at first hand and its use through field days and events on demonstration farms across the life of the project. Additionally, efforts were made to create content on-line and through irrigation industry journals used by farmers, such as *Farmers Newsletter* and *The Australian Cotton Grower* to reach a wider audience than possible solely with field days. This was also supplemented with a range of youtube videos covering aspects of the project and updates particularly when COVID impacted the project.

A list of activities and materials produced from the project is provided below with additional details provided in Table 6.

Extension and adoption activities included:

- GVIA 2021 showcasing smart sensing and automation technologies (10th Feb. 2021).
- IREC field day 2020 showcasing irrigation sensing technologies (Jan 29th 2020).
- IREC field day 2021 showcasing irrigation automation technologies (Jan 21st 2021).
- IREC field day 2022 showcasing smart sensing and automation technologies (Jan 21st 2022).
- IREC/GRDC Irrigated Farm Walk showcasing smart sensing and automation at the IREC demonstration farm (27th October 2020).
- Southern Valley's CRDC R&D Update 2020 Yanco, 14th August 2021 Presentation on Precise real time automated cotton irrigation for improved water productivity.
- Southern Valley's CRDC R&D Update 2021, 12th August 2021 (Online) Presentation on *Integrated smart sensing & automation for cotton*.
- Youtube video outlining Goanna Ag involvement in project 3rd June 2021.
- Youtube video outlining Padman Automation involvement in project 23rd June 2020.
- Youtube video outlining Casavo farming involvement in project 30th June 2020.
- Youtube video outlining GVIA smart sensing and automation 19th April 2021.

- Farmers Newsletter - *SMART SENSING AND AUTOMATION — CRUISE CONTROL FOR YOUR IRRIGATION SYSTEM* - Autumn 2020.
- Australian Cotton Grower article *IoT enables automated, low-cost surface irrigation.* August-September 2021.

We have received feedback from industry partners that the project has been very successful in creating practice change with irrigators. The commercial industry partner Padman Automation (Grant Oswald Pers. Comm.) have reported an increased awareness by irrigators on the benefits of smart sensing and automation and also an increase in enquiries by cotton irrigators looking to invest in the technology based on interactions at field days and events in which producers have become aware of the capability of the technology and its benefits.

## 5.2 Lessons learnt and recommendations for future extension.

Communication of costs of smart sensing and automation on a per hectare basis has been a major factor in helping growers understand the relative costs of automation. This had not been done previously which had most irrigators confused about an outlet cost or a total farm cost. We have found that providing smart sensing and automation costs on a per hectare basis (varies with bay size) allows irrigators to see the benefits very easily as they generally have good knowledge on production costs, gross and profit returns on a per hectare basis for their enterprises.

Commercial scale interactions are a leveller for many research “ideas”. While we should never discourage blue-sky small-scale research activities for developing tools and approaches for refinement of irrigation management to the last 5%, we should also equally ensure that commercial scale implementation should be a long-term goal. Shifting the middle 50% of irrigators to improve their water productivity by 20% has a lot greater impact at an industry or national level than shifting the top 5% to increase their water productivity by 10%. What may work well in a single field or trial plot often would never scale to see industry wide adoption. This project has shown the benefits of having such commercial involvement in research projects and resulted in tailored commercial smart sensing and automation products at a shorter timeline than expected without commercial involvement from an early stage.

Lastly, it was observed that extension networks need to build capacity with an emphasis on information technologies such as Precision and Digital Agriculture, big data, Artificial Intelligence, and IoT. These are areas where irrigators are rapidly moving toward and need extension networks that are agriculture focused but have expertise in these areas. In the future, these technologies will play as big a part as traditional agronomy in profitability of irrigated cotton farms and the industry needs to acknowledge and support this moving forward.

# 6 Appendix - additional project information

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

| Nature of materials/activities | Number | Details |
|---|---|---|
| Press releases | | |
| Media appearances – press and TV | | |
| Brochures, fact sheets, posters and newsletters | 2 | Article published in *The Australian Cotton Grower* "IoT enables automated, low-cost surface irrigation" Available at: https://www.cottongrower.com.au/read/60#22<br>Economic case study: New tech integrated smart sensing & automation for cotton: Application in bankless channel irrigation Available at: https://smarterirrigation.com.au/wp-content/uploads/2021/08/Smart-Sensing-and-Automation-in-Cotton_Case-Study_Aug-2021-.pdf |
| Web page | 1 | How agricultural technology is helping Aussie farmers fight drought. Available at: https://www.westpac.com.au/business-banking/business-help/run-business/agricultural-technology-helping-farmers-drought/ |
| Field days, expos, field walks | 5 | 2020 Irrigation Research and Extension Committee Field Day held on 29th January.<br>IREC Field Day had 90 participants, https://twitter.com/IRECNSW/status/1214681748132356096<br><br>2021 Irrigation Research and Extension Committee Field Day held on 21st January.<br>IREC Field Day had >100 participants, https://twitter.com/IRECNSW/status/1341254131760054273<br><br>2022 Irrigation Research and Extension Committee Field Day held on 21st January.<br>IREC Field Day had >100 participants, https://twitter.com/IRECNSW/status/1477105798119522307<br><br>GVIA – Keytah Field Day February 2021. Field day within field showcasing of smart sensing and automation products. |

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| | | IREC/GRDC Farm Walk had 30 participants<br>https://twitter.com/IRECNSW/status/1318444873712726016 |
| Stakeholder forums, meetings, presentations, workshops, webinars | 6 | August 2019 Partner workshop on integrating sensing and automation hardware, Griffith, NSW<br><br>Cotton Research update, 2019. Yanco.<br><br>2021 Annual Southern Cotton R&D update On-line and recorded due to COVID. Presentation link below:<br>https://www.youtube.com/watch?list=PLQy8KAPn-DyoYlCTbkAJL-XtP9Ca8olqC&v=jmTxC49sYwk&feature=emb_logo<br><br>Goanna Ag outlining collaboration video:<br>https://www.youtube.com/watch?v=dfS7uYU5Uzc<br><br>Casavo Farming collaboration video:<br>https://www.youtube.com/watch?v=I_J3oK85bqc&list=PL4eP0DWzvlguRG1KUartXK3pF_41SCibI<br><br>Padman Automation collaboration video:<br>https://www.youtube.com/watch?v=hpEqZxQwSWc |
| Social media presence | | @CeRRF_Griffith<br>https://twitter.com/CeRRF_Griffith |
| Scientific conference presentations | 2 | International webinar organized by the International Commission on Irrigation Drainage (ICID) and Irrigation Australia Limited (IAL) as a prelude to the 2021 IAL Irrigation Conference.<br>150 registered participants: https://smarterirrigation.com.au/ial-icid-webinar-addressing-the-global-water-challenge-through-autonomous-irrigation/<br><br>Presentation on smart sensing and forecasting of soil deficits for irrigation automation at the AACS 2019 Australian Cotton Research Conference, *Taking cotton research to new heights,* UNE Armidale, 28-30 October 2019.<br><br>IAL Irrigation Conference 2022. Oral presentation (by Rodrigo Filev-Maia) and paper accepted on MACHINE LEARNING APPROACH TO ESTIMATE SOIL MOISTURE IN PLANT ROOT ZONE BASED ON REMOTE SENSING DATA. |
| Peer-reviewed scientific papers | 4 | Filev Maia, R., Ballester-Lurbe, C. & Hornbuckle, J. (2022) *Machine learning approach to estimate soil matric potential in the plant root zone based on remote sensing data,* Frontiers in Plant Science (Submitted).<br><br>Ballester, C; Hornbuckle, J; Brinkhoff, J and Quayle, W (2021) *Effects of three frequencies of irrigation and nitrogen rates on lint yield, nitrogen use efficiency and fibre quality of cotton under furrow irrigation*. Agricultural |

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| | | Water Management, Volume 248, 1 April 2021, 106783. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0378377421000482?via%3Dihub<br><br>Brinkhoff, J. Hornbuckle, J. & Ballester-Lurbe, C. (2019) *Soil Moisture forecasting for irrigation recommendation*, IFAC Papers Online, Elsevier https://www.sciencedirect.com/science/article/pii/S2405896319325078<br><br>Filev Maia, R., Ballester Lurbe, C., Agrahari Baniya, A., Hornbuckle, J. (2020) *IRRISENS: An IoT Platform Based on Microservices Applied in Commercial-Scale Crops Working in a Multi-Cloud Environment*. *Sensors*, *20*, 7163. https://doi.org/10.3390/s20247163 |