Hort Innovation

Final Report

Digital remote monitoring to improve horticulture's environmental performance

Delivery partner:

Applied Horticultural Research, Freshcare, Hitachi Consulting, Landcare and industry bodies Greenlife Industry Australia, AUSVEG, the Australian Banana Growers' Council, the Australian Macadamia Society and Growcom.

Project:

Digital remote monitoring to improve horticulture's environmental performance

Disclaimer:

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Overview of Project delivery

Executive summary

Use this section to summarise the findings of the Activity.

Explain how the outcomes and outputs of this Activity will benefit Australian agriculture.

Include key findings, and the significance of these findings for policy makers and the Australian agricultural industry.

Identify any questions that remain unanswered or arose as a result of the Activity.

Digital remote monitoring was assessed as a method of improving the environmental performance of Australian horticulture. The development of a farm management tool, called Control Tower aimed to improve environmental compliance and productivity by facilitating industry best practice. Four pilot smart farms were established in Great Barrier Reef catchments to demonstrate the benefits of digital remote monitoring and the Control Tower. These pilot smart farms were selected from the banana, nursery, avocado and vegetable industries.

A framework for the digital remote monitoring of environmental performance was developed in consultation with each of the target industries. Industry feedback overwhelmingly recommended using digital remote monitoring to simplify compliance with best practice. Existing environmental sustainability frameworks for horticulture were adapted for digital remote monitoring. The resulting environmental sustainability framework for horticulture was integrated into the Control Tower.

The collection of compliance information by the Control Tower allowed the project to facilitate a remote audit at the banana pilot farm. The Control Tower provided additional value to certification records by combining chemical application data with the GPS location of farm vehicles. The collection of this data enabled an auditor to access the Control Tower remotely and verify key certification records. The success of this remote audit demonstrates significant progress in lowering the barries to environmental compliance and proved that rigorous audits can conducted remotely.

The Control Tower was developed as a combined productivity and environmental monitoring tool. Integrated with sensors from multiple technology providers, the Control Tower is a sensor agnostic farm management system. All pilot farms were installed with soil moisture, plant growth and weather monitoring equipment. The presentation of multiple sources of plant stress data to the growers led to improved water use efficiency and reduced labour requirements.

Innovative technological solutions were developed for the pilot farms and their associated industries. Comprehensive water monitoring equipment was installed at the smart production nursery. The quality of water entering and exiting the nursery was monitored and used to automate digital records.

A nitrate monitoring system was deployed to measure subsurface leachate at the banana pilot farm. The data from this system was used to develop a nutrient loss prediction model, providing growers with decision support. Forecasting nitrate runoff and leaching, allowing growers to adjust their practices and minimise negative environmental impacts.

Applied Horticultural Research led the communication and extension of the benefits of digital remote monitoring for environmental performance. The project was showcased at multiple conferences, through presentations, posters, and workshops. The benefits of the project were communicated through webinars, factsheets, case studies, guides, and interviews.

The project was delivered by Hort Innovation, Applied Horticultural Research, Hitachi Vantara, Greenlife Industry Australia, AUSVEG, Avocados Australia Limited, Landcare Australia, Freshcare, Growcom and the Australian Banana Growers' Council.

The project conclusively demonstrated that digital sensors and technology can be used to efficiently manage environmental performance and prove compliance with industry best practice. Digital remote monitoring reduced costs, improved input efficiency and opened new sustainable markets for Australian horticulture.

Project Activities

Use this section to provide details of how the Project activities were conducted including any unanticipated events or technical/resourcing difficulties and how these were overcome. If there was a need to change the Project activities, please explain how this change was incorporated into the Project

Explain how each Project activity contributed to the Project objectives as listed, including metrics if relevant (e.g. hectares impacted, number of landholders impacted etc.). Where possible include evidence of activities (e.g. data, photographs etc.) and list any communications materials that resulted from the activity.

These activities should match those listed in your Project WorkPlan and budget template.

Project Activity 1 • Environmental sustainability framework for horticulture – "Horticulture for Tomorrow" as well as updated industry specific BMPs	
What did you do?	The existing environmental sustainability frameworks for horticulture were adapted for digital remote monitoring. The project team reviewed the best management practice (BMP) guidelines and environmental management systems (EMS) most relevant to the partner industries. The goal of this review was to align each BMP and EMS and determine the viability of each for remote monitoring. An environmental sustainability framework was developed and incorporated into the Hitachi Control Tower.
How did you do it?	Each BMP and EMS was reviewed to determine which parameters were suitable for digital remote monitoring. Each parameter was assigned a traffic light score, based on whether the parameter was suitable for digital reporting. These categories were green (confident), yellow (potential) and red (unlikely). Each parameter was also given a score based on the priority of the relevant industry (low, medium and high). These scores were assigned in collaboration with the relevant Peak Industry Body (PIB). The parameters with high potential for digital remote monitoring and high industry priority were prioritised when developing the remote monitoring framework. These priorities also informed the sensor procurement for each pilot site.
When did you do it?	April – November 2020
Who participated?	This activity was completed by Applied Horticultural Research with input from all relevant project partners.

Who will delivered the activity?	This activity was delivered by Applied Horticultural Research.
What was the output? *How did this contribute to Program objectives listed in the WorkPlan?*	Summaries were developed for each BMP and EMS, which incorporated feedback from key stakeholders to determine the priority areas for digital remote monitoring. These summaries informed the development of metrics for environmental performance and the sensor procurement for the pilot farms. Input provided to the environmental sustainability framework for digital remote monitoring.
What evidence can you provide? (e.g photographs?	BMP and EMS summaries are attached as Appendix 5.

Project Activity 2 • Metrics on environmental performance to inform management decisions determined	
What did you do?	Key environmental metrics for monitoring environmental performance and farm productivity were developed by AHR and presented to the project steering committee on 02 November 2020. The metrics that supported environmental and productivity gains were prioritised. Process diagrams were developed for target environmental metrics for measurement using sensors, satellite data, modelling, and on-farm sampling. The process diagrams are rankedbelow: 1. Nitrate runoff and leaching 2. Soil erosion 3. Water use efficiency 4. Irrigation water quality 5. Spray drift 6. Plant health productivity 7. Nutrient budget 8. Biodiversity 9. Odour and air quality 10. Waste
How did you do it?	The Freshcare and EcoHort environmental management systems, and Banana, EnviroVeg and Hort360 best management practices were reviewed. The key areas for digital remote monitoring were prioritised, such as automated fertiliser application records.

When did you do it?	2021
Who participated?	This activity was completed by Applied Horticultural Research with input from all relevant project partners.
Who delivered the activity?	This activity was delivered by Applied Horticultural Research
What was the output? *How did this contribute to Program objectives listed in the WorkPlan?*	A framework of metrics was produced that aligns the reporting requirements of Freshcare Environmental, EcoHort, EnviroVeg and Hort360 with available commercial sensors and data inputs.
What evidence can you provide? (e.g photographs?	The framework is attached as Appendix 6.

Project Activity 3 • Remote monitoring digital dashboard built and tested	
What did you do?	Applied Horticultural Research provided significant contribution to the development of the Hitachi Control Tower.
How did you do it?	**Control Tower UI design** The AHR team provided input into the design of the Hitachi Control Tower through the development of draft iterations. The draft iterations were refined and eventually incorporated into the Hitachi Control Tower. **EMS and BMP report design** The AHR team provided significant input into the design of the EMS and BMP report forms for the Hitachi Control Tower. The design of these forms was based heavily on the work conducted in project activity 2. **Growing Degree Day (GDD) model** The GDD model was initially developed for chillies, before being expanded to other commodities. The GDD model predicted harvest using real-time and predicted weather. **Weather forecasting** The AHR team reviewed available weather forecasts and determined that Willy Weather was the best option for accurate weather data for the Control Tower. Willy Weather was chosen due to the publicly available API and accurate data provided by the Bureau of Meteorology. **Facilitation of feedback and improvement of Control Tower** Through ongoing engagement with the pilot farm management teams, PIB representatives and other key stakeholders, AHR and Hitachi facilitated the continuous improvement and development of the Control Tower.
When did you do it?	2020-2023
Who participated?	All project partners.

Who will delivered the activity?	All project partners.
What was the output? *How did this contribute to Program objectives listed in the WorkPlan?*	Hitachi Control Tower UI GDD model Automated EMS and BMP forms Weather forecast selection and integration
What evidence can you provide? (e.g photographs?	Dashboard UI mock-up attached as Appendix 7.

Project Activity 4 • AHR - Four pilot digital smart farms set up, supported, evaluated and showcased.	
What did you do?	Four pilot smart farms were established in the targeted horticultural industries: 1. Banana: Bartle Frere Bananas, Innisfail QLD 2. Nursery: Golden Grove Wholesale Nursery, Torbanlea QLD 3. Avocado: Austchilli, Bundaberg QLD 4. Vegetables: Austchilli, Bundaberg QLD Each industry was extensively consulted during the initial phase of the project in 2020. A workshop was held with each industry, which included the relevant peak industry body, Hort Innovation, Hitachi, Freshcare and the pilot farm. A set of priorities for each industry was developed and a key theme was produced: 1. Banana: Nitrate leaching and on-farm activity tracking 2. Nursery: Irrigation water quality 3. Avocado: Tree health and productivity 4. Vegetables: Harvest date maturity predictions Using feedback from the industry workshops and requirements for digitised environmental reporting, a suite of sensors was designed and pitched the project team. The sensors were installed between June and November 2021. Applied Horticultural Research regularly supported the pilot farms with the sensor relocations, adaptions and maintenance. The benefits of smart farming were showcased from the pilot sites through field days, industry videos, webinars, factsheets and industry events. A full list of communication outputs is provided in Appendix 3.
How did you do it?	The success of the pilot smart farms was ensured by thorough industry consultation with peak industry bodies, Hort Innovation, Hitachi, Freshcare and pilot farms.

When did you do it?	2020-2023
Who participated?	All project partners
Who will delivered the activity?	All project partners
What was the output? *How did this contribute to Program objectives listed in the WorkPlan?*	4 pilot farms established
What evidence can you provide? (e.g photographs?	Photographs, data, webinar recordings, factsheets, and the list of outputs provided in Appendix 3.

Project Activity 5 • Leading growers engaged to champion the approach	
What did you do?	Gavin Devaney, Wayne Parr and David De Paoli were chosen as industry leading growers. These growers were recognised as innovative and environmentally conscious prior to their involvement with the project. Their input and support of the project was essential in showcasing the benefits.
How did you do it?	Gavin Devaney was engaged through regular update meetings involving the AHR, Hitachi, ABGC and Hort Innovation project teams. Gavin represented the project at multiple events, including at the Australian Banana Industry Congress in 2021 and 2023. Gavin Wayne Parr was engaged through regular update meetings involving the AHR, Hitachi, GIA and Hort Innovation project teams. Wayne represented the project by presenting at multiple webinars. David De Paoli was engaged through regular update meetings involving the AHR, Hitachi, AusVeg, Growcom, Freshcare, AAL and Hort Innovation project teams. The AustChilli team presented at the virtual field day.
When did you do it?	2020-2023
Who participated?	All project partners.
Who will delivered the activity?	All project partners.
What was the output? *How did this contribute to Program objectives listed in the WorkPlan?*	The pilot farm growers presented on behalf of the project at multiple events. The pilot farm growers shared their experiences of the project with other growers within their networks.
What evidence can you provide? (e.g photographs?	Meeting notes and agendas Recordings of presentations

	Grower presence at key events Awards and nominations

Project Activity 6 • AHR - "How To" guides (4) and fact sheets produced as required to operate the smart farms	
What did you do?	Applied Horticultural Research produced a *Smart Farming Technology Guide for Horticulture* that encompasses all technologies piloted through the project, three factsheets and five case studies as listed below: • Soil moisture sensor factsheet • Dendrometers factsheet • Remote auding factsheet • Nitrate leaching in bananas case study • Bartle Frere Banana case study • Golden Grove Nursery case study • Austchilli Avocado case study • Austchilli vegetable case study ***Smart Farming Technology Guide for Horticulture*** A full list of communication outputs is provided in Appendix 3.
How did you do it?	A *Smart Farming Technology Guide for Horticulture* has been distributed widely in printed and digital formats through industry events and direct communications.
When did you do it?	2022-2023
Who participated?	Applied Horticultural Research and key partners
Who will delivered the activity?	Applied Horticultural Research and key partners
What was the output? *How did this contribute to Program objectives listed in the WorkPlan?*	A full list of communication outputs is provided in Appendix 3.
What evidence can you provide? (e.g photographs?	A full list of communication outputs is provided in Appendix 3.

Project Activity 7 • AHR - Webinars and training on how to use the digital tools as required	
What did you do?	AHR delivered webinars and training throughout the length of the project. **Grower interviews/case studies**

	A series of interviews with the pilot farm owners were recorded. The purpose of these interviews was to provide the growers with a platform to share their thoughts on the project and offer insight into how they utilise the Hitachi Control tower. **Webinars and Workshops** A series of webinars and workshops focussing on the technologies installed on the pilot farms was planned and delivered with input from project partners. **Field days** In-person and virtual field days were delivered in collaboration with project partners and the pilot farms. **Presentations** AHR presented the project at a significant number of high-profile events such as Hort Connections and the Australian Banana Industry Congress. **Training** The project team provided the pilot farm staff with training throughout the length of the project.
How did you do it?	Physical and digital communications material were developed and distributed. In-person training was provided at multiple events and directly to the management teams of the pilot farms.
When did you do it?	2022-2023
Who participated?	Applied Horticultural Research and key partners
Who will delivered the activity?	Applied Horticultural Research and key partners
What was the output? How did this contribute to Program objectives listed in the WorkPlan?	A full list of communication outputs is provided in Appendix 3.
What evidence can you provide? (e.g photographs?	A full list of communication outputs is provided in Appendix 3.

Project Activity 8 • AHR - Evidence of engagement with industry extension programs, e.g. VegNET for vegetables and Nursery Production FMS for nursery stock and the Horticulture extension network (Hort Innovation)	
What did you do?	Applied Horticultural Research coordinated with all relevant horticultural extension programs, such as VegNET, SoilWealth, PotatoLink, industry magazines.

	VegNET Project communication outputs such as the *Smart Farming Technology Guide for Horticulture,* factsheets, videos and webinars have been shared through the VegNET program. A detailed presentation on smart farming technologies for improving horticultural environmental performance was given to all VegNET Industry Development Officers on 28 October 2022. **Soil Wealth** Project communication outputs such as the *Smart Farming Technology Guide for Horticulture,* factsheets, videos and webinars have been shared through the Soil Wealth website and bulletins. **Australian Banana Industry Congress 2021, 2023** The project was showcased at the bi-annual banana congress in 2021 and 2023, which is the premier communication event in the banana industry. Exhibitor booths, scientific posters and presentations were used to communicate smart farming technologies available for improving horticultural environmental performance. **Hort Connections 2022, 2023** The project was showcased at the 2022 and 2023 Hort Connections conferences, which is the premier event for Australian horticulture. An industry workshop *Getting Hands-on with Sensors: A Practical Workshop for Growers* was hosted at Hort Connections with 70 registrants was hosted by Applied Horticultural Research, Hitachi and Greenlife Industry Australia. **Nursery Industry Workshops** Applied Horticultural Research presented at the nursery industry Smart Farming industry workshops held in Brisbane, Sunshine Coast, Perth, Sydney, Melbourne and Fraser Coast. **Cassowary Coast Banana Growers Meeting** The project team presented at the Cassowary Coast Banana Growers meeting held in Silkwood, Queensland in May 2022. **PotatoLink** The project was presented at the PotatoLink R&D forum and shared in the PotatoLink magazine.

How did you do it?	Project resources were shared to industry, presentations were given
When did you do it?	2021-2023
Who participated?	
Who will delivered the activity?	Applied Horticultural Research
What was the output? *How did this contribute to Program objectives listed in the WorkPlan?*	A full list of communication outputs is provided in Appendix 3.
What evidence can you provide? (e.g photographs?	A full list of communication outputs is provided in Appendix 3.

Project Activity 9 • AHR - Evidence of linkages with aligned projects (e.g. Hort360, Soil Wealth, EcoHort)	
What did you do?	The project formed linkages with aligned projects, through the engagement of relevant project managers.
How did you do it?	The environmental sustainability framework for horticulture was aligned with environmental management systems and best management practices such as Freshcare, Hort360, EcoHort and Banana BMP. The nutrient monitoring and modelling components of the project were aligned with the RP191 and Paddock 2 Reef projects.
When did you do it?	2020-2023
Who participated?	Applied Horticultural Research and aligned project leaders.
Who will delivered the activity?	Applied Horticultural Research and aligned project leaders.
What was the output? *How did this contribute to Program objectives listed in the WorkPlan?*	Aligned environmental sustainability framework Aligned nutrient monitoring and modelling program
What evidence can you provide? (e.g photographs?	

Project Activity 10 • Evidence of linkages with the private sector: retailers, exporters, PIBs, agronomists	
What did you do?	The project engaged with private sector, peak industry bodies and agronomists throughout the project term. **Technology Providers** The project successfully collaborated with technology providers such as ICT International, Wildeye, Sentek, Chemtrol, Escavox, Eratos, TriOS, Goldtech, DHM Software, Back Paddock. There was unsuccessful collaboration with companies that did not agree to share data from their platforms, such as CropX and Phytech, and organisations that were unable to share data such as the Bureau of Meteorology. **Peak Industry Bodies** The project worked closely with Greenlife Industry Australia, Australian Banana Growers Council, AusVeg and Avocados Australia to ensure the pilot smart farms were designed to suite industry needs and to communicate results to industry. Other peak industry bodies such as Berries Australia published articles on behalf of the project. **Agronomists and Farm Managers** The project consulted with agronomists and farm managers throughout the life of the project at industry events, through online webinars and meetings. **Retailers** Coles recognised the success of the project by awarding Bartle Frere Bananas a Coles Nurture Fund grant to use the Hitachi Control Tower to calculate greenhouse gas emissions and produce low carbon bananas.
How did you do it?	There were regular meetings held with key project partners such as the relevant peak industry bodies and technology partners. Project outputs were communicated through industry events, direct mail outs and industry extension projects.
When did you do it?	2021-2023
Who participated?	All project partners
Who will delivered the activity?	Applied Horticultural Research led the activity
What was the output?	A full list of communication outputs is provided in Appendix 3.

How did this contribute to Program objectives listed in the WorkPlan?	
What evidence can you provide? (e.g photographs?	A full list of communication outputs is provided in Appendix 3.

Project Activity 11 • Evidence of linkages with Regional NRMs engaged in the project	
What did you do?	
How did you do it?	
When did you do it?	
Who participated?	
Who will delivered the activity?	
What was the output? *How did this contribute to Program objectives listed in the WorkPlan?*	
What evidence can you provide? (e.g photographs?	

Project Activity 12 • Evaluation of Weight Based Irrigation Controller.	
What did you do?	
How did you do it?	
When did you do it?	
Who participated?	
Who will delivered the activity?	
What was the output?	

How did this contribute to Program objectives listed in the WorkPlan?	
What evidence can you provide? (e.g photographs?	

Discussion

Use this section to fully describe the results of each outcome and output. Include a description of the Activity overall achievements against the objectives, deliverables and key performance indicators.

Include tables, diagrams or graphs as required.

Environmental sustainability framework for horticulture

Review of existing sustainability frameworks

The existing environmental sustainability frameworks for horticulture were adapted for digital remote monitoring. The project team reviewed the best management practice (BMP) guidelines and environmental management systems (EMS) most relevant to the partner industries (Figure 1). Each BMP and EMS was reviewed to determine which parameters were suitable for digital remote monitoring.

Each parameter was assigned a traffic light score, based on whether the parameter was suitable for digital reporting. These categories were green (confident), yellow (potential) and red (unlikely). Each parameter was also given a score based on the priority of the relevant industry (low, medium, and high). These scores were assigned in collaboration with the relevant Peak Industry Body (PIB). A summary of these parameters is included as an Appendix 5.

The parameters with high potential for digital remote monitoring and high industry priority were selected when developing the remote monitoring framework. These priorities also informed the sensor procurement for each pilot site. It is important to highlight that only EcoHort has specific target levels for water quality measurement, as show in Figure 1.

Industry or sector	Organisation	BMP	Monitoring	Specific target levels
Vegetables	AUSVEG	EnviroVeg	Freshcare Environmental	No
Nursery	Greenlife Industry Australia	EcoHort	EcoHort	Yes
Bananas	Banana	Banana BMP	Freshcare Environmental	No
Avocados	Avocados Australia	hort360	Freshcare Environmental	No
Hort 360 Reef Cert.	growcom	hort360	Freshcare Environmental	No

Figure 1. Organisational chart of target industries, peak industry bodies and their relevant BMP and EMS guidelines

Feedback from industry

A draft framework for digital monitoring was developed and shared with each EMS/BMP manager for comments and review. These frameworks (Appendix 6) were reviewed by each EMS/BMP manager.

The AHR team held consultations with the following EMS/BMP managers:

EnviroVeg — Danielle Park and Zarmeen Hassan, AUSVEG

The key feedback and recommendations from AUSVEG:

- Satellite imagery could be used to map and measure the performance of environmental infrastructure
- Groundcover measurements should consider the season and length of time with and without cover
- Existing systems for recording nutrient applications and spray diaries should be investigated.

Ecohort — Barry Naylor, Greenlife Industry Australia

The key feedback and recommendations from GIA:

- Monitoring wastewater at a property boundary should occur both upstream and downstream of the property and is considered a high priority.

Banana BMP — Michelle McKinlay and Amelia Foster, Australian Bananas Growers Council

The key feedback and recommendations from ABGC:

- The feasibility of using satellites to monitor groundcover was queried, citing the difficulty in penetrating banana canopies and appropriately assessing interrows

- Remote monitoring could be useful for biosecurity through using cameras to monitor feral pigs and trespassers.

Hort360 and Reef Certification — Scott Wallace, Growcom

The key feedback and recommendations from Growcom:

- Linking weather and spray application per block has high potential for remote auditing.

Freshcare Environmental — Angela Steain

The key feedback and recommendations from Freshcare:

- Sections on chemicals are considered a high priority as improved chemical management is seen as a starting point for growers to explore further environmental program outcomes
- Supporting adoption of IPM through digital monitoring or sensors is considered a high priority; these technologies could be used to demonstrate benefits for broader adoption
- General grower priorities are water (efficient use and access), biosecurity (threat prevention and management challenges), chemical use, pest and disease management and increasing costs (high potential for cost savings from digital monitoring).

Overall feedback from industry was that remote monitoring data should be used to simplify monitoring where possible, such as recording weather conditions during spray application.

Environmental sustainability framework

The summarised EMS/BMP frameworks were combined into a master document before being developed into process flowcharts for each key parameter. The priorities of the partner industries were compared to create an environmental sustainability framework for horticulture.

The key outcome of the sustainability framework was to assist growers' management decisions to improve both environmental performance and productivity.

Metrics on environmental performance to inform management decisions determined

Environmental metrics

Key environmental metrics for monitoring environmental performance and farm productivity were developed by AHR and presented to the project steering committee on 2 November 2020. The metrics that supported environmental and productivity gains were prioritised.

Process diagrams were developed for target environmental metrics for measurement through sensors, satellite data, modelling and on-farm sampling. The process diagrams are ranked below:

1. Nitrate runoff and leaching (Figure 2)
2. Soil erosion
3. Water use efficiency
4. Irrigation water quality
5. Spray drift
6. Plant health productivity
7. Nutrient budget
8. Biodiversity
9. Odour and air quality
10. Waste

The Freshcare and EcoHort environmental management systems, and Banana, EnviroVeg and Hort360 best management practices were reviewed. The key areas for digital remote monitoring were prioritised, such as automated fertiliser application records.

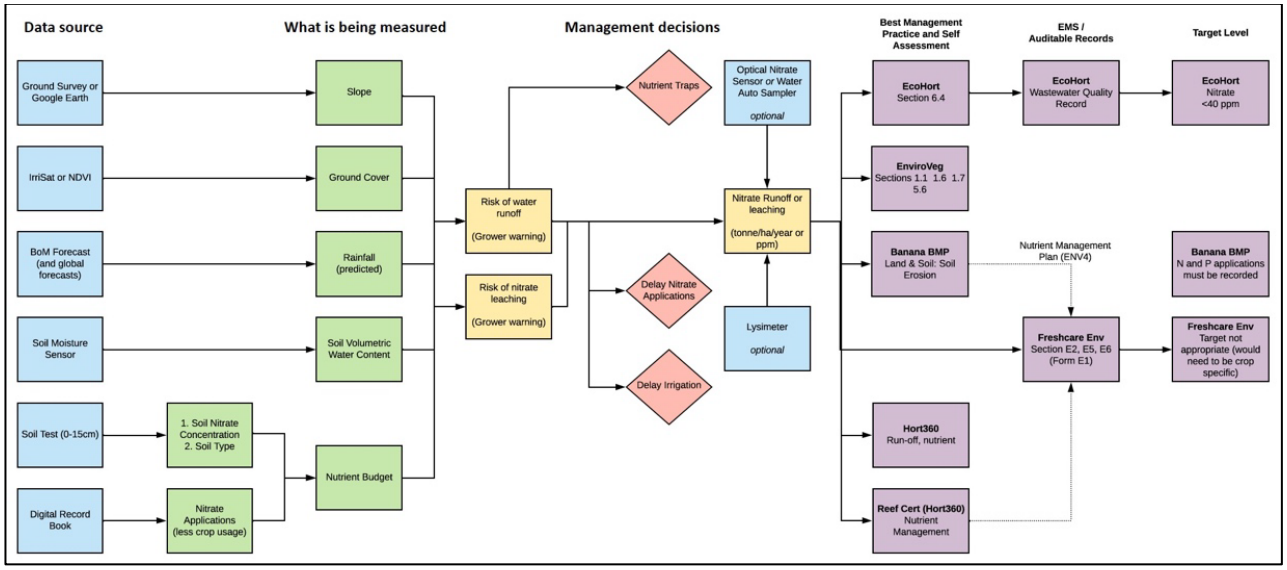


Figure 2. Process diagram of measuring or modelling nitrate leaching and how it relates to industry best management practices and environmental management systems

Freshcare and EcoHort compliance forms were selected based on their suitability for automation. Fertiliser and pesticide application records were highlighted as some of the most used forms that would benefit from automation using on-farm sensors. Inputs into the forms were mapped out and sensors were selected that could pre-fill as much information as possible.

Sensor selections

After the review of the industry best management practices, environmental management systems and industry priorities (Appendix 5), a set of key metrics for measurement and monitoring was developed (Appendix 6). This was combined with the priorities of each of the pilot farms to develop a comprehensive suite of sensors to address the sustainability requirements of industry and the productivity requirements of the individual farms.

Each pilot farm had a unique focus area, such as irrigation water quality, farm activity tracking or harvest date predictions.

Top rated sensors are shown below in Figure 3, Figure 4, Figure 5 and a full set of the project sensors and equipment installed at the four pilot sites is listed in Table 1.

Figure 3. Top three sensors at Austchilli as rated by the grower. Left to right: Soil moisture sensor, band dendrometer and field cameras for growing degree day models

Figure 4. Top three sensors at Golden Grove as rated by the grower. Left to right: Electrical conductivity sensor, soil moisture sensors and pest trap camera

Figure 5. Top three sensors at Bartle Frere Bananas as rated by the grower. Left to right: Soil moisture sensor, nitrate photometer and vehicle trackers

Table 1 Summary of sensors and equipment installed at the four pilot sites

Sensor	**Quantity**	**Industries**
Soil moisture sensors	20	Banana, avocado, nursery, vegetable
Weather station	3	Banana, avocado, nursery, vegetable
Dendrometers	11	Avocado, nursery, vegetable
Vehicle GPS trackers	6	Banana
Cameras	6	Banana, nursery, vegetable
Rated flumes and transducers	5	Banana, vegetable
Weight based irrigation controller	2	Nursery
Leachate volume gauges	2	Nursery
pH sensors	3	Nursery
EC sensors	3	Nursery
Nitrate photometer	1	Banana
Irrigation pressure transducer	3	Banana, nursery
Desktop photometer	1	Nursery
Free chlorine sensor	1	Nursery
FullStop wetting front detectors	40	Banana, avocado, vegetable
Runoff samplers	12	Banana, avocado, vegetable

Sensor systems developed

Applied Horticultural Research (AHR) developed two sensor systems for the unique requirements of the banana and nursery industries.

Nitrate photometer

The Australian Banana Growers Council (ABGC) recommended that the project invest in a high-quality nitrate photometer, based on the experience of the Wet Tropics Major Integrated Project (MIP). There were three main challenges for measuring nitrate leaching with a TriOS NICO nitrate photometer:

1. **Communications** — The TriOS is designed for data to be downloaded through a Wi-Fi connection which was unavailable in the paddocks of Bartle Frere Bananas. ICT International was commissioned to develop a communications node for the TriOS NICO data controller and an off-grid power system.
2. **Flow rates** — Flow rate measurements were required to calculate loads of nitrate leaching from the ground water. SMS Laser Cutting was commission to modify and construct the RBC-200 flume design to fit the TriOS NICO (Figure 6).
3. **Subsurface measurements** — Measurements were required to be collected from at least one meter below the surface. A trench was dug into the sub-surface ag-pipe system at Bartle Frere Bananas to install the flume and TriOS below ground.

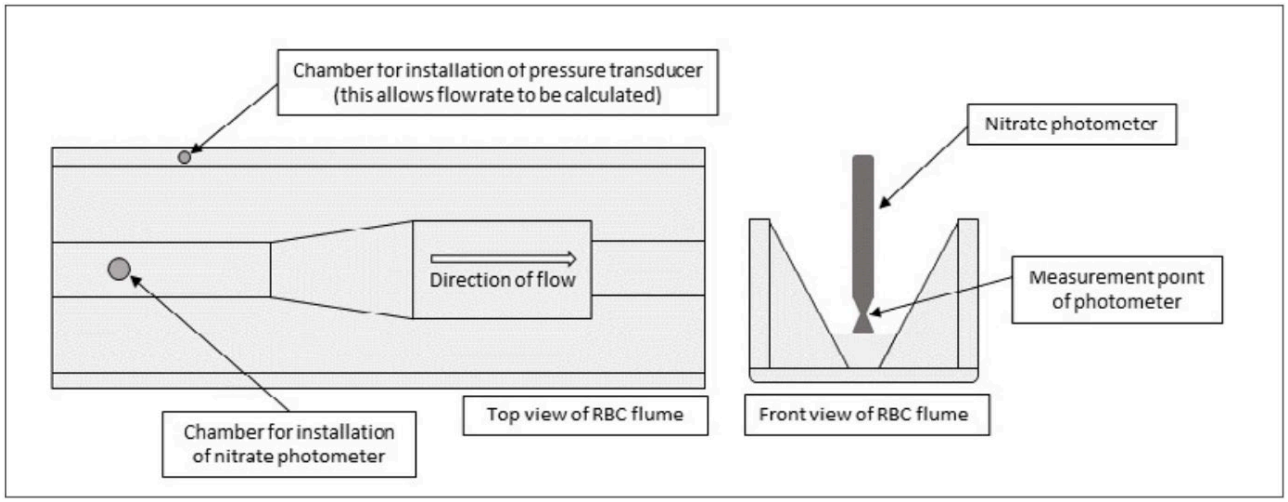


Figure 6 Schematic of the TriOS NICO and RBC-200 flume

Free chlorine sensor

Greenlife Industry Australia (GIA) requested a system to automatically measure chlorine concentration decay over time, which is required for the EcoHort irrigation water disinfection record. Industry best practice is to target a residual chlorine concentration of 2 ppm after eight minutes of contact time, which is traditionally measured manually with varying levels of accuracy.

A commercial system was not available, so AHR and GIA developed a system using a commercial chlorine sensor, an electronic flushing cistern and Arduino controller (). ICT International designed a communications node for the chlorine sensor.

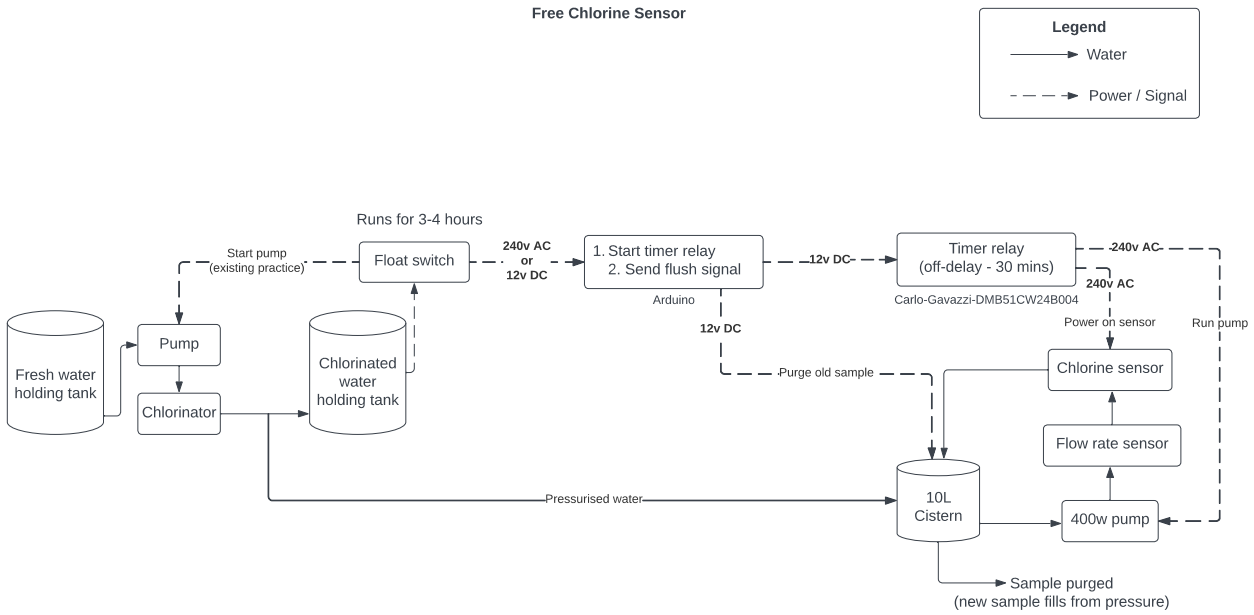


Figure 7 Process flow of the free chlorine system

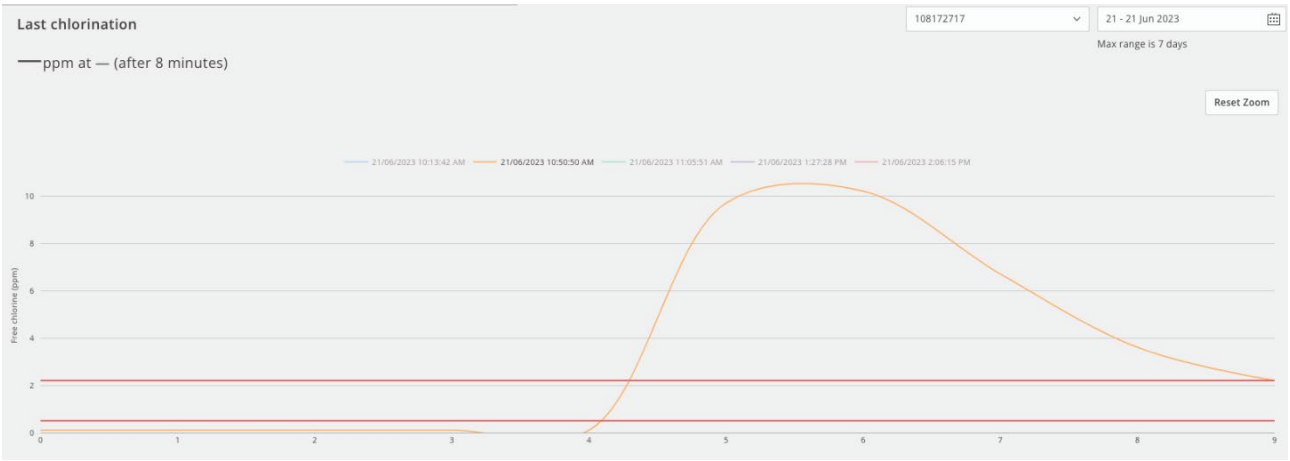


Figure 8 Example of data from the free chlorine sensor indicating the chlorination system is well calibrated for the water quality

HowLeaky nutrient loss model

A key outcome of the project was the development of a decision-support tool for the management of nutrient loss. The AHR team conducted extensive research to determine the most appropriate tool for this outcome. The following models were considered:

1. HowLeaky
2. APSIM
3. SafeGauge

The HowLeaky model was deemed to be the most appropriate because it focusses on water quality and erosion. It was developed by the University of Southern Queensland for Australian conditions; it has the support of Australian academics and is free for use under a Creative Comments license. The model is currently being used by a range of Queensland Government scientists and private consultants and is a key tool in Queensland's Reef Rescue Project.

AHR designed the data requirements (Figure 9) for the HowLeaky model to run automatically each day using farm records from the Hitachi Control Tower (and, potentially, other platforms), and adapted this model to run on the Senaps platform (Figure 10) hosted by Eratos. The model was connected to the Hitachi Control Tower through Application Programming Interface (API) and provided outputs on estimated nitrate leaching risk of planned fertiliser application events (Figure 11).

The AHR project team contacted and maintained engagement with HowLeaky experts such as:

1. David Freebairn - Environmental Scientist: David was engaged for the length of the project, he provided the project team with training and scientific resources.
2. Mark Silburn - APSRU & P2R Reef Project Leader: Mark assisted the project team in the model selection process and helped the team contact other industry experts.
3. Dr David McClymont - Principal Software Engineer DHM Software: The project coordinated with DHM Software to update the accuracy of nitrate modelling in How Leaky.
4. Dan Rattray - Soil Scientist and Engineer: Dan has conducted extensive research using HowLeaky in Banana modelling. He used HowLeaky in the paddock scale modelling component of the Paddock to Reef reporting project.

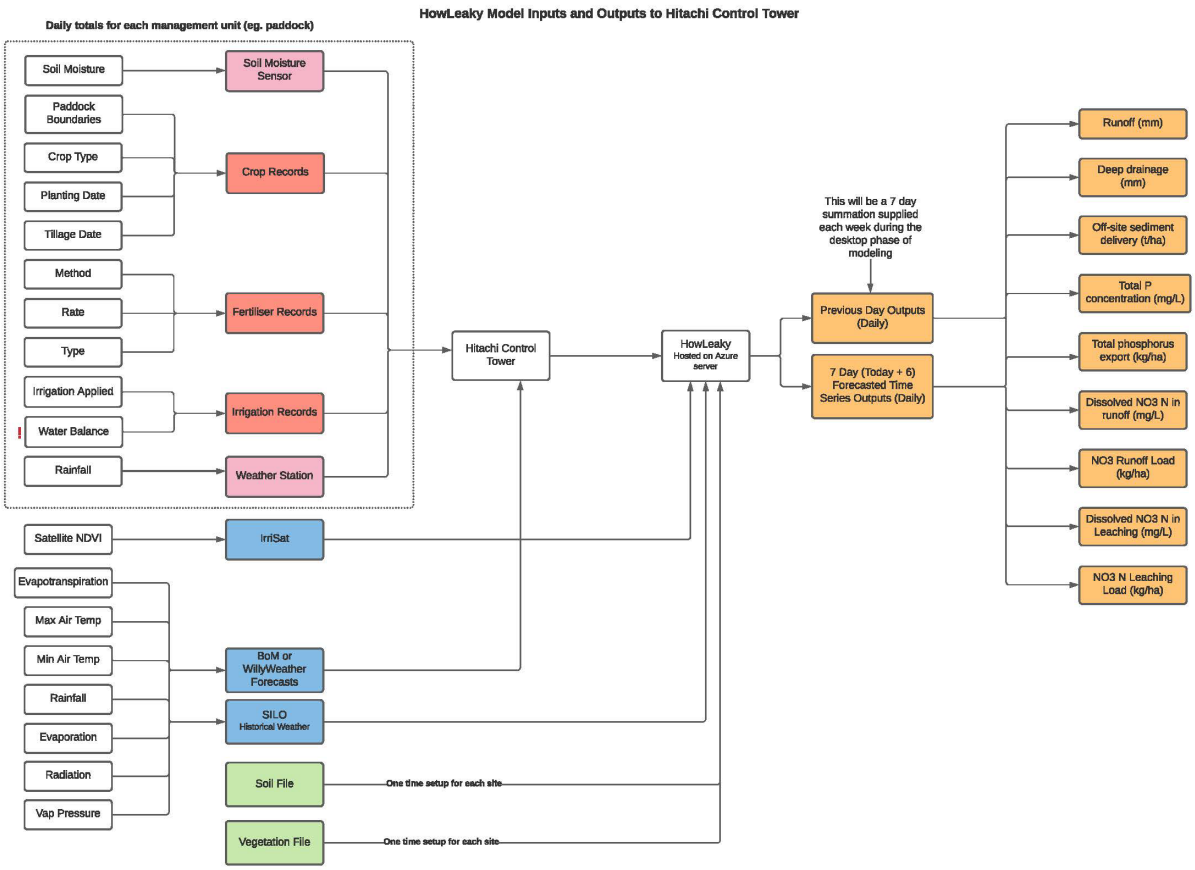


Figure 9 Process diagram for automating the HowLeaky model using farm records from the Hitachi Control Tower

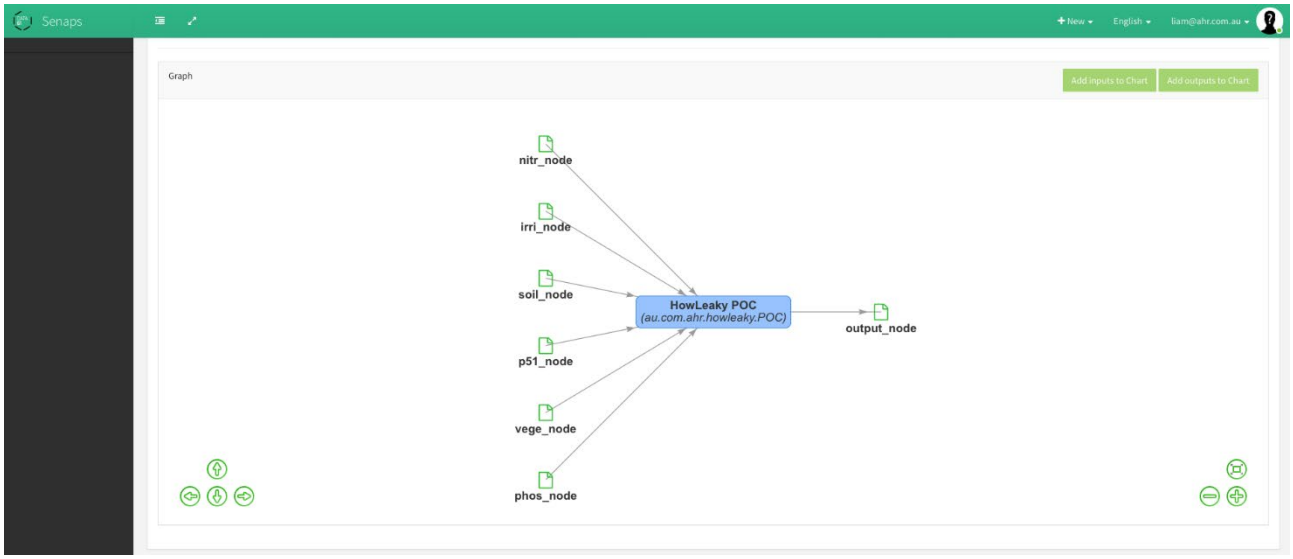


Figure 10 HowLeaky model hosted on Senaps and designed to automatically run each day

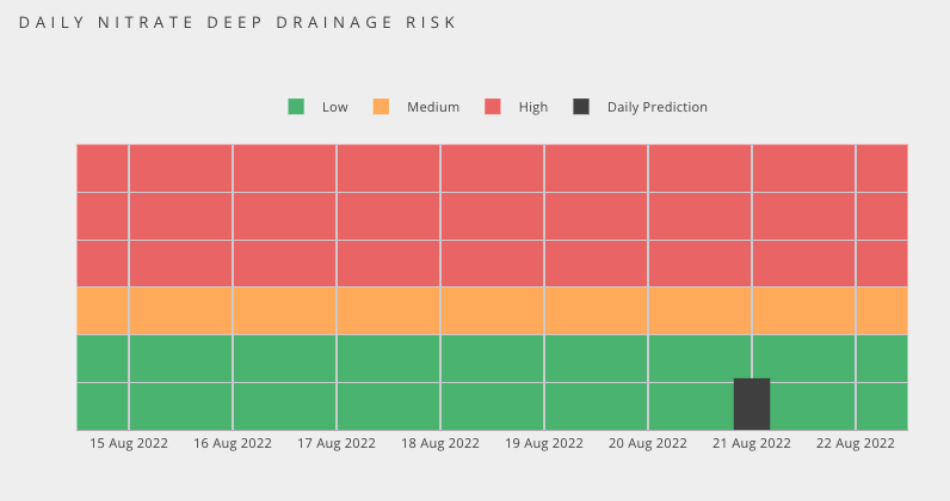


Figure 11 Example of nitrate leaching (deep drainage) 7-day risk warnings provided to the Hitachi Control Tower

Remote monitoring digital dashboard

Hitachi Control Tower User Interface development

The AHR project team provided significant input and support to the development of the Hitachi Control Tower User Interface (UI). A draft Hitachi Control Tower UI provided by AHR was developed by Hitachi using the following design principles:

- Standardised UI across all industries where appropriate
- Clear and uncluttered visualisation of data
- High value data accessible from multiple locations from the Hitachi Control Tower UI
- Alerts providing the user with status updates
- Custom design, allowing users to tailor to their needs.

The AHR project team conducted a desktop study of existing farm management platforms. The learnings from this study were collated into an initial Hitachi Control Tower UI draft.

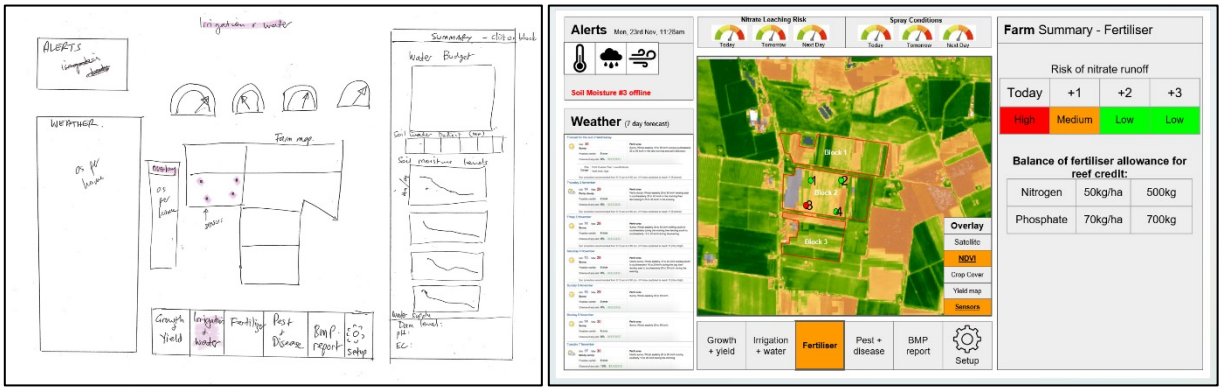


Figure 12 Left: Initial Hitachi Control Tower UI draft. Right: Interactive Hitachi Control Tower UI draft

The initial draft (Figure 12 Left) provided the basis for future development of the Hitachi Control Tower UI. The use of 'fuel gauges' to represent water use, a central map with sensor locations and multiple pages for different data sources remained a key component of the Hitachi Control Tower UI.

After feedback had been received on the first draft, the AHR team created a refined interactive version of the Hitachi Control Tower UI (Figure 12 Right) to demonstrate how the user would be able to interact with the data. This interactive draft piloted the idea of separating the farm into an 'overview' and splitting data into management blocks. The user can see a summary of the entire farm and query block-specific data by interacting with the farm map.

The key pages of the Hitachi Control Tower UI were also developed here. These started as growth and yield, irrigation and water, fertiliser, pest and disease, BMP report and setup.

The interactive mock-up was shared with Hitachi who developed the final version of the Hitachi Control Tower UI (Figure 13) The full interactive version of this mock-up is attached as an Appendix 7.

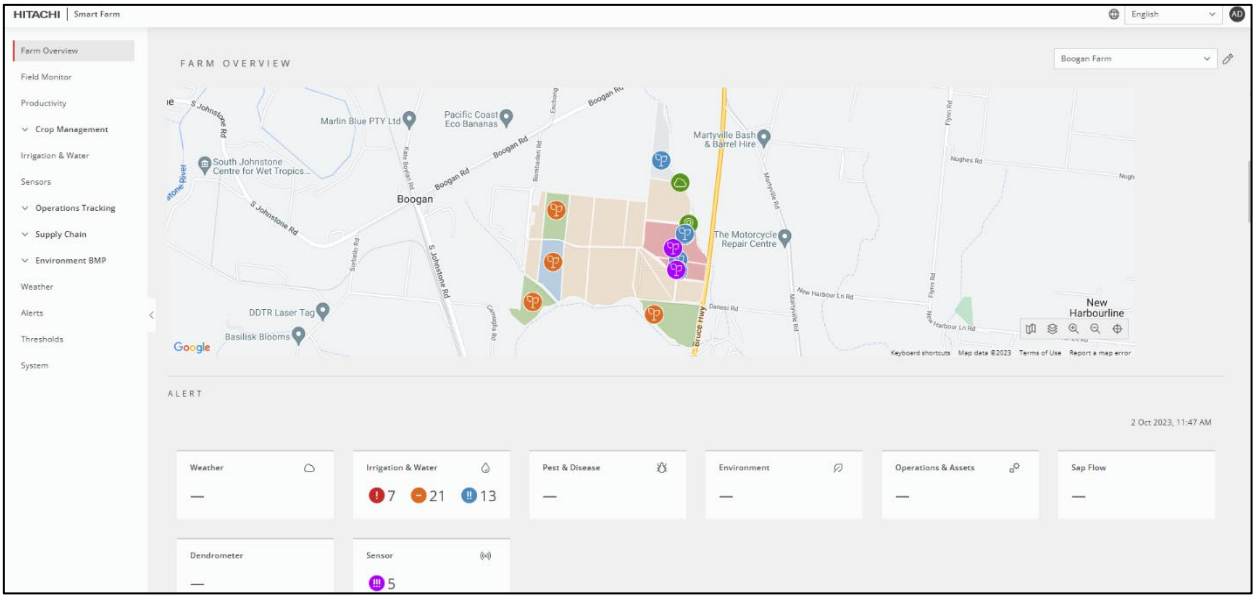


Figure 13 Final Hitachi Control Tower UI

Growing Degree Day model

Kelvin Montagu (AHR) developed a Growing Degree Day (GDD) model for integration into the Hitachi Control Tower. This model provided a predicated crop harvest date using real-time and predicted weather. The following data sources were required for this model (Figure 14):

1. Daily max and min temperatures from local BoM station or on-site weather station
2. 10-day weather forecast for daily max and min temperatures
3. Long-term seasonal forecast for daily max and min temperatures

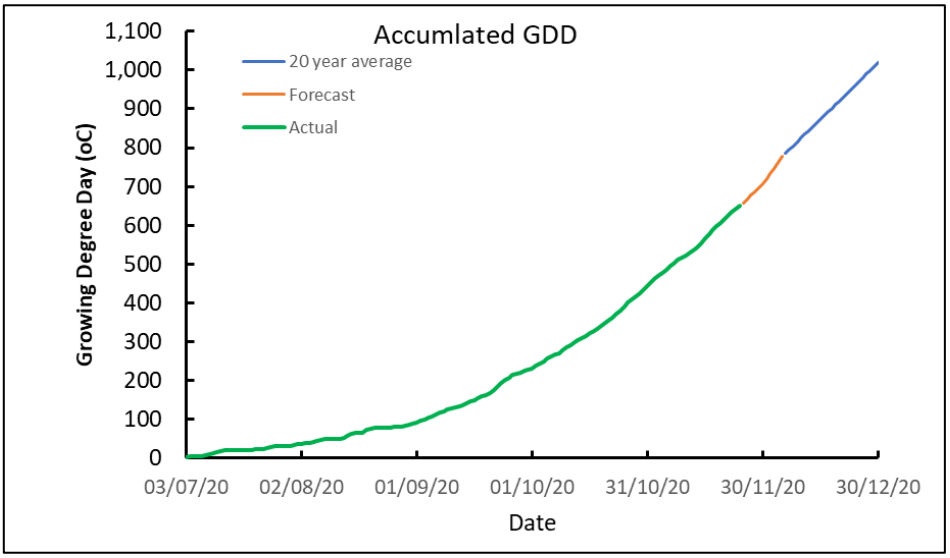


Figure 14 GDD model concept, demonstrating actual, short and long-term weather data

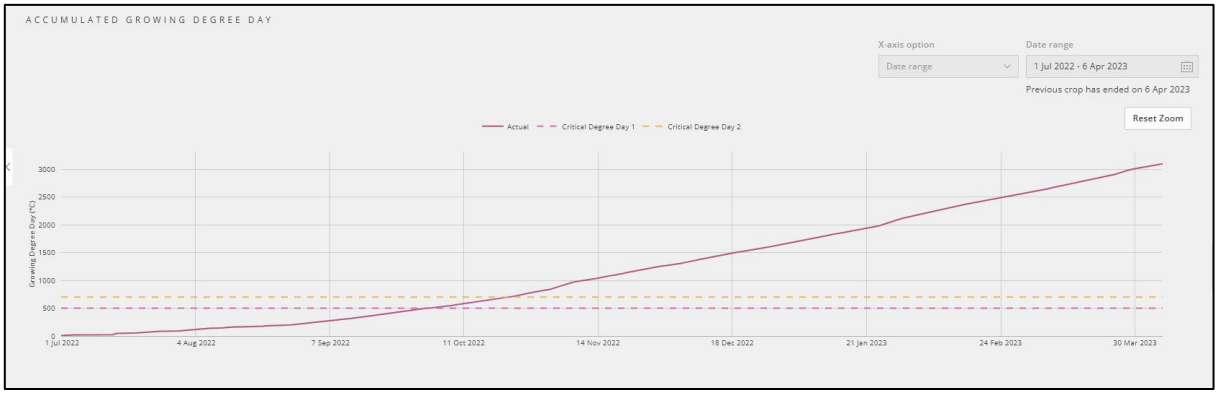


Figure 15 Full integration of the GDD model into the Hitachi Control Tower

The model requires user input to determine the following dates for chillies — planting, first branching, first flower set, second flower set, third flower set, green maturity and red maturity. Once integrated into the Hitachi Control Tower (Figure 15), a camera was used to remotely capture key dates (Figure 16). The GDD model provided the grower with an indication of growth stage for their crop, informing management decisions around irrigation and fertilisation.

Figure 16 Example image from remote camera, showing growth stage of chili crop

Weather data validation and forecasting

The AHR project team assisted with the selection of weather data sources for the Hitachi Control Tower. Two main formats of weather data were determined; these were observed (Table 2) and forecasted (Table 3). Observed weather data would primarily be collected from the on-site weather station and supplemented using the WillyWeather API (Figure 17).

WillyWeather was chosen as a source for observed and predicted weather data after a comprehensive review by the AHR project team. WillyWeather displays data produced by the Bureau of Meteorology and National Oceanic and Atmospheric Administration. The final weather display on the Hitachi Control Tower UI combined these sources of data to provide the user with the most accurate information available.

Table 2 Observed weather data parameters

Parameter	Units	Main Source	Alternative Source
Air Temperature	°C	SNiP weather station	WillyWeather
Relative Humidity	%	SNiP weather station	WillyWeather
Wind Direction	°	SNiP weather station	WillyWeather
Wind Speed	m/s	SNiP weather station	WillyWeather

Rainfall	mm	SNiP weather station	WillyWeather
Barometric Pressure	kPa	SNiP weather station	WillyWeather
Delta T	-	WillyWeather	

Table 3 Forecasted weather data parameters

Parameter	**Units**	**Source**
Maximum Air Temperature	°C	WillyWeather API
Minimum Air Temperature	°C	WillyWeather API
Wind Direction	°	WillyWeather API
Wind Speed	m/s	WillyWeather API
Rainfall	mm	WillyWeather API
Rainfall probability	%	WillyWeather API

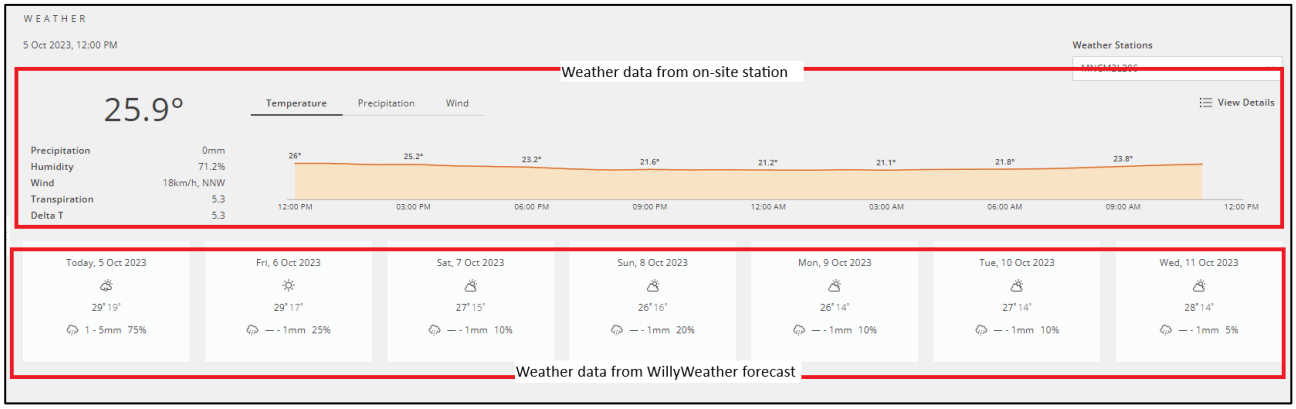


Figure 17 Observed and forecasted weather data as displayed on the Hitachi Control Tower UI

EMS Report Design

After stakeholder consultation, it was determined that the Freshcare fertiliser application record (Figure 18) was a particular pain point for horticultural growers, and it was selected as the first case study form. The project sought to demonstrate how data capture could be streamlined and then validated.

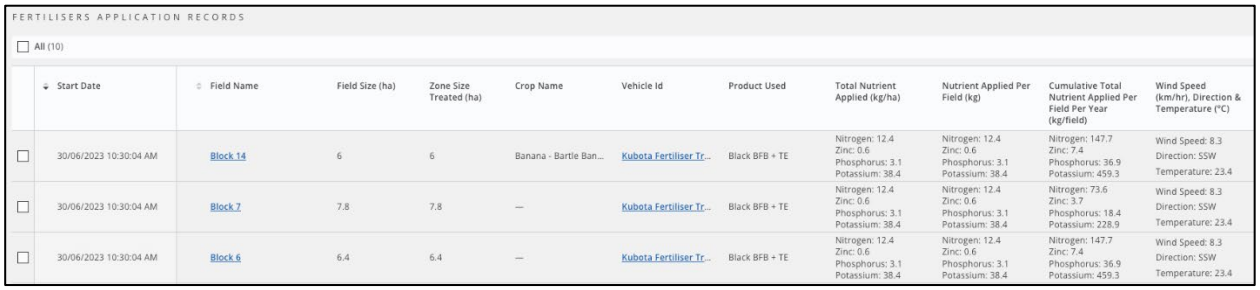
The project team reviewed the existing fertiliser application record and created a template for digital input. The purpose of this digital form was to make it easier for users to enter data by automating certain fields.

One of the key outcomes of this process was the ability to verify the authenticity of records, with automatic capture of weather data and application vehicle location. The form logs a running total of nitrogen and phosphorus applications to ensure compliance with the Queensland Government's Reef Regulations.

Using this system, the project team was able to demonstrate easily that the banana pilot farm was within the Reef Regulation limits of 400kg/ha/year of nitrogen for ratoon stage bananas.

Date	Specific location/ block	Product used	Product percentage of N and P* *(if fertiliser)*	Product batch code *(where applicable)*	Rate of application *L/ha or tonnes/ha*	Wind speed and direction	Method of application/ incorporation	Name and initials of operator

Figure 18 E5 fertiliser and soil additives application record



FERTILISERS APPLICATION RECORDS

All (10)

Start Date	Field Name	Field Size (ha)	Zone Size Treated (ha)	Crop Name	Vehicle Id	Product Used	Total Nutrient Applied (kg/ha)	Nutrient Applied Per Field (kg)	Cumulative Total Nutrient Applied Per Field Per Year (kg/field)	Wind Speed (km/hr), Direction & Temperature (°C)
30/06/2023 10:30:04 AM	Block 14	6	6	Banana - Bartle Ban...	Kubota Fertiliser Tr...	Black BFB + TE	Nitrogen: 12.4 Zinc: 0.6 Phosphorus: 3.1 Potassium: 38.4	Nitrogen: 12.4 Zinc: 0.6 Phosphorus: 3.1 Potassium: 38.4	Nitrogen: 147.7 Zinc: 7.4 Phosphorus: 36.9 Potassium: 459.3	Wind Speed: 8.3 Direction: SSW Temperature: 23.4
30/06/2023 10:30:04 AM	Block 7	7.8	7.8	—	Kubota Fertiliser Tr...	Black BFB + TE	Nitrogen: 12.4 Zinc: 0.6 Phosphorus: 3.1 Potassium: 38.4	Nitrogen: 12.4 Zinc: 0.6 Phosphorus: 3.1 Potassium: 38.4	Nitrogen: 73.6 Zinc: 3.7 Phosphorus: 18.4 Potassium: 228.9	Wind Speed: 8.3 Direction: SSW Temperature: 23.4
30/06/2023 10:30:04 AM	Block 6	6.4	6.4	—	Kubota Fertiliser Tr...	Black BFB + TE	Nitrogen: 12.4 Zinc: 0.6 Phosphorus: 3.1 Potassium: 38.4	Nitrogen: 12.4 Zinc: 0.6 Phosphorus: 3.1 Potassium: 38.4	Nitrogen: 147.7 Zinc: 7.4 Phosphorus: 36.9 Potassium: 459.3	Wind Speed: 8.3 Direction: SSW Temperature: 23.4

Figure 19 Automated fertiliser application record

Form E5 was digitised by the Hitachi team and integrated into the Hitachi Control Tower (Figure 19). The form was automated as much as possible during this process and the following data fields were updated:

Date — The start and end time/date of applications are entered using a clock and calendar system. If multiple applications occur on the same day, the entire record can be duplicated to avoid replication.

Specific location/block — The user selects the target block from those which have already been established within the Hitachi Control Tower. Once the block is selected, field/block name, field size, zone size treated and crop name are populated automatically.

Product used/product percentage of N and P/product batch code/rate of application — The user creates a database of regularly used products on the property. When creating a product, the user specifies the percentage content of nutrients such as nitrogen and phosphorus. The user can also specify the product batch code and rate of application. When a product is selected, all relevant data fields are automatically populated.

Wind speed and direction — Weather information (including temperature) is automatically populated using the on-site weather station.

Method of application/incorporation— The method of application/incorporation is specified by the user using a dropdown list.

Name and initials of operator— The employee responsible for the application can be assigned by selecting them from a dropdown list.

Figure 20 Example of chemical application GPS data

The quantity of data collected by the Hitachi Control Tower UI allowed additional value to be added to the digital records. Each application vehicle on the pilot banana farm was fitted with a GPS monitoring device (Figure 20). When adding an application record, the user can select the application vehicle. The Hitachi Control Tower UI uses the start and end time/date information in conjunction with the GPS location data to record the exact location of the application vehicle during application process.

The collection of this information makes the verification of the authenticity of application records significantly easier. It is also possible for an auditor to log into the Hitachi Control Tower UI remotely and confirm where an application took place. The following forms were automated and integrated into the Hitachi Control Tower UI using the same method: pesticide and chemical application record (Freshcare Environmental), water disinfestation record (EcoHort) and irrigation water quality record (EcoHort).

Remote Freshcare Audit

A remote audit was organised and paid for by Freshcare and supported by AHR in May 2023 using records contained within the Hitachi Control Tower UI and an online meeting with an auditor (Figure 21). The remote audit of Bartle Frere Bananas was considered a success by the auditor and Freshcare.

Figure 21 Farm tour using a mobile phone and Zoom meeting as part of a remote Freshcare Environmental audit of Bartle Frere Bananas

Pilot digital smart farms

Four pilot smart farms were established in the targeted horticultural industries:

1. Banana — Bartle Frere Bananas, Innisfail QLD
2. Nursery — Golden Grove Wholesale Nursery, Torbanlea QLD
3. Avocado— Austchilli, Bundaberg QLD
4. Vegetable— Austchilli, Bundaberg QLD

Each industry was extensively consulted during the initial phase of the project in 2020. A workshop was held with each industry, which included the relevant peak industry body, Hort Innovation, Hitachi, Freshcare and the pilot farm. A set of priorities for each industry was developed and a key theme was produced:

1. Banana — Nitrate leaching and on-farm activity tracking
2. Nursery — Irrigation water quality
3. Avocado — Tree health and productivity
4. Vegetable — Harvest date maturity predictions

Using feedback from the industry workshops and requirements for digitised environmental reporting, a suite of sensors was designed and pitched by the project team. The sensors were installed between June and November 2021.

AHR regularly supported the pilot farms with the sensor relocations, adaptions and maintenance. A full list of maintenance and support trips is included as Appendix 4.

Bartle Frere Bananas

Bartle Frere Bananas (BFB) is a 100 ha, family owned and operated, Freshcare Environmental certified plantation in Boogan, Queensland. There is increasing pressure on the banana industry in Queensland to manage phosphorus and limit inorganic nitrogen loads, which are notoriously difficult to measure and model. Runoff from the farm drains to the Moresby River, which is 30 km from the Great Barrier Reef.

Bartle Frere Bananas converted a sugar cane block to bananas in 2019, providing an ideal location for the pilot project. The block was built up to provide industry-leading drainage, with a vegetated drain designed to absorb nutrients and retain soil.

Grower Input

The project team worked with BFB, Australian Banana Growers Council (ABGC) and Freshcare to design a suite of sensors best suited to monitor leaching, irrigation and on-farm activity. A series of inception meetings and project steering group meetings were held throughout 2020 to refine the pilot smart farm design. A map of the sensor layout is shown in (Figure 22). The suite of sensors installed consisted of:

1. Industry leading real time nitrate photometer (TriOS NICO)
2. Soil moisture sensors (ICT SMT-100, Wildeye GS1)
3. Weather station (ICT AWS5)
4. Stem dendrometers (ICT DPS-40)
5. Vehicle GPS trackers (Binary Tech)
6. Irrigation pressure transducer
7. Rated flumes (RBC-200, Keller AccuLevel)

8. Remote camera (Swift Enduro)

The project team maintained regular fortnightly meetings with Gavin Devaney (BFB) and Michelle McKinlay (ABGC) to manage the pilot banana smart farm and address any activities planned for the site.

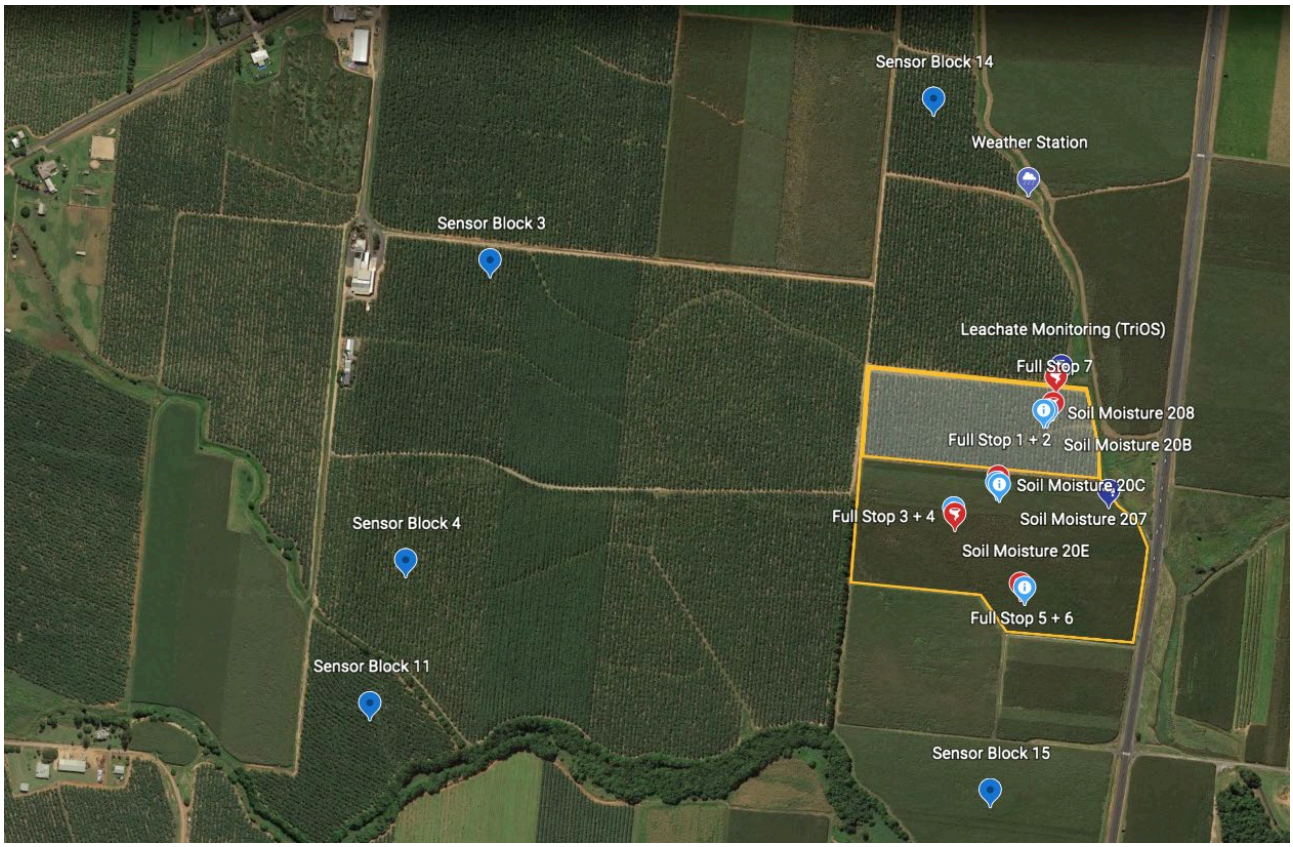


Figure 22 Bartle Frere Bananas farm map and sensor layout

Leaching and Runoff Trial

An irrigation trial was established at the banana pilot farm to compare nitrate runoff and leaching under drip and sprinkler irrigation. The average concentration of the nitrate runoff was found to be 0.6 ppm NO3-N ± 0.22 with drip irrigation and 2.7 NO3-N ± 2.1 with sprinkler irrigation (Figure 24). The average concentration of the nitrate leaching concentration was found to be 1.6ppm NO3-N ± 0.37 under drip irrigation and 9.5 NO3-N ± 5.34 under sprinkler irrigation (Figure 25).

These results are to be communicated to industry through a nitrate leaching case study in late 2023.

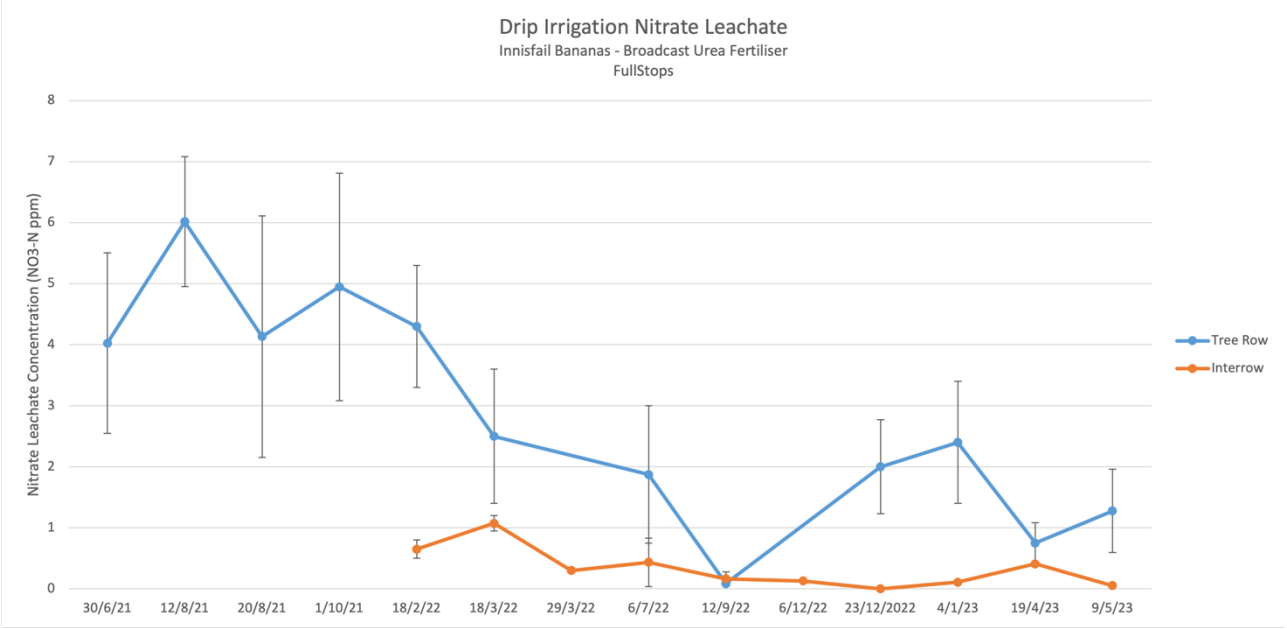


Figure 23 Nitrate leaching at Bartle Frere Bananas. Leaching is compared against the tree row and interrow (wheel track).

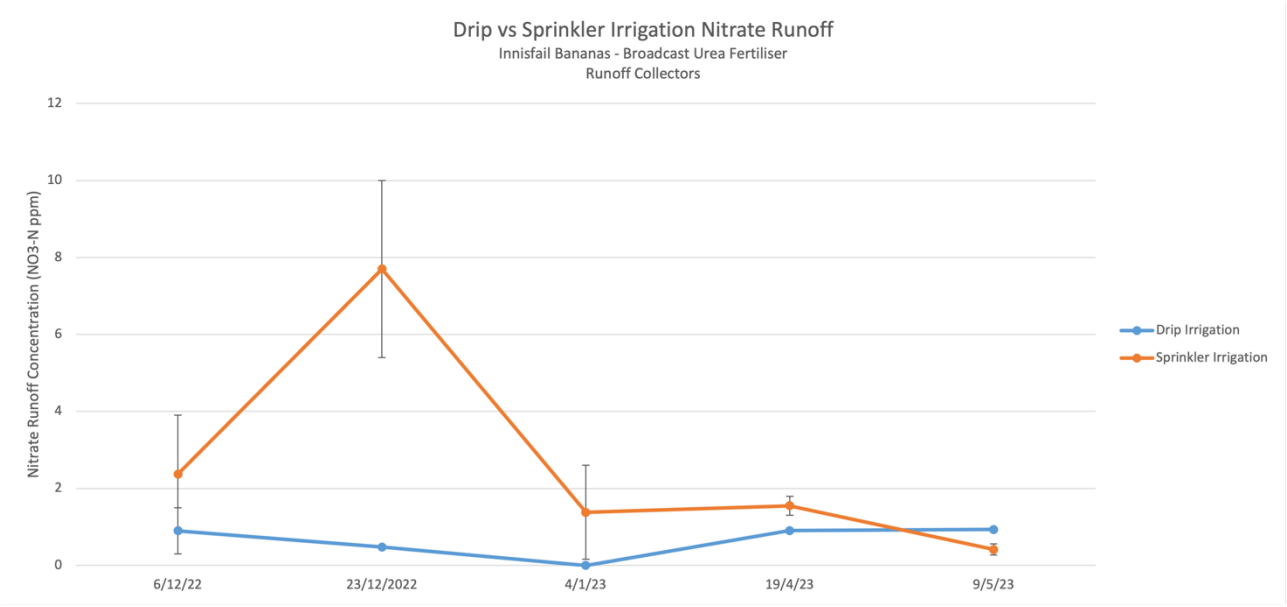


Figure 24 Nitrate runoff at Bartle Frere Bananas. Runoff is compared against the drip irrigation and sprinkler irrigation.

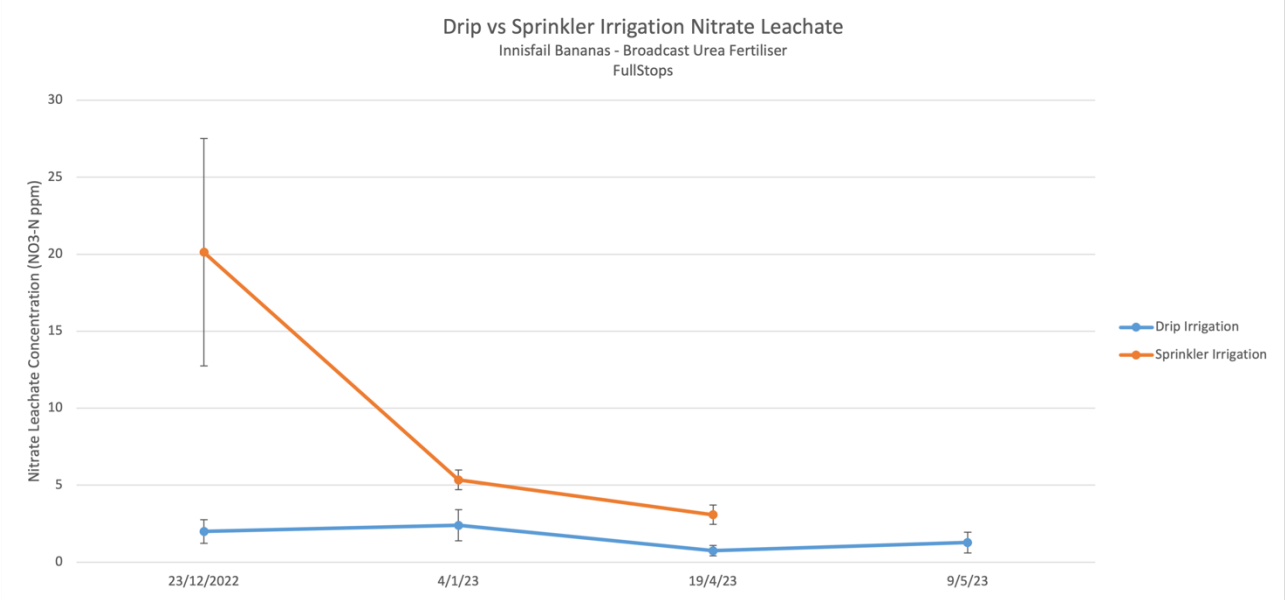


Figure 25 Nitrate leaching at Bartle Frere Bananas. Drip irrigation is compared to the sprinkler irrigation.

Outcomes

Bartle Frere Bananas better managed their irrigation and crop management through the project. Gavin used soil moisture sensors to maintain an efficient soil moisture content at depth. Vehicle trackers were used to manage the farm workers' jobs and returned an immediate improvement in labour efficiency.

The Hitachi Control Tower UI has replaced the farm's paper-based fertiliser and chemical records, which were successfully integrated into a Freshcare audit with excellent feedback.

Golden Grove wholesale nursery

Golden Grove nursery is a 2 ha, citrus production nursery in Torbanlea, Queensland, producing and supplying commercial growers with containerised fruit-tree nursery stock for planting in orchards.

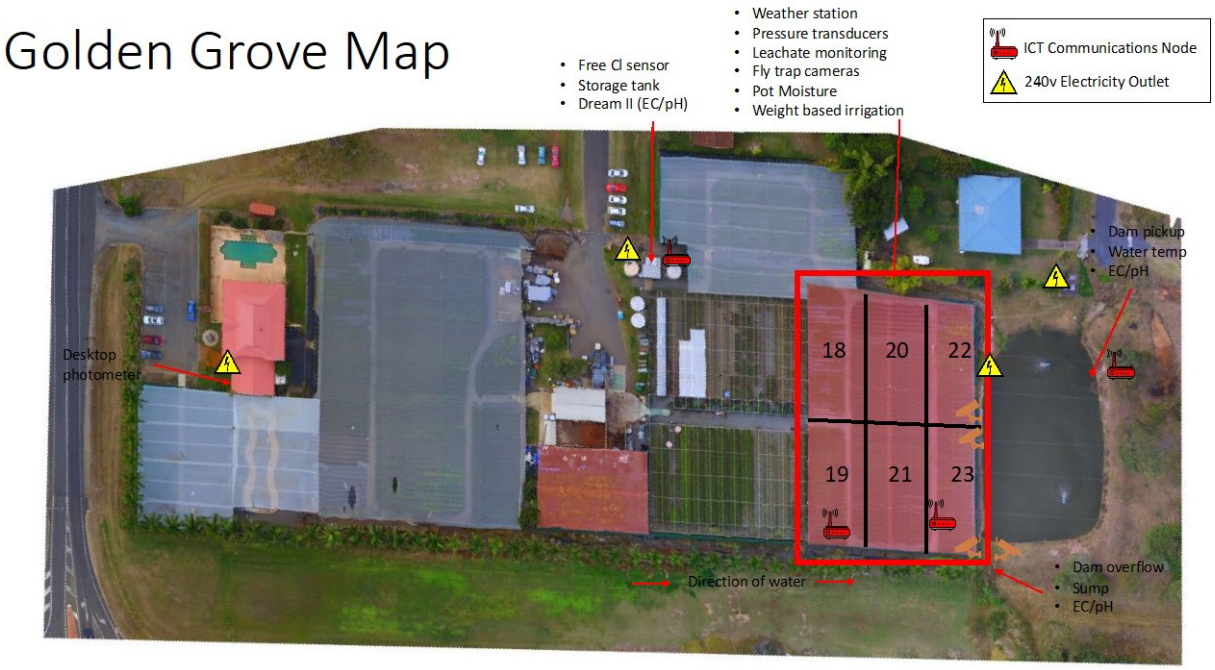


Figure 26 Map of Golden Grove nursery

Grower Input

The project team worked with Golden Grove and Greenlife Industry Australia (GIA) to design a suite of sensors best suited to monitor irrigation water quality and irrigation management. The suite of sensors installed consisted of:

1. Soil moisture sensors (ICT GS1)
2. Weather station (ICT AWS5)
3. Stem dendrometers (ICT DPS-40)
4. Weight based irrigation controller
5. Leachate volume gauges (ICT PRP-02)
6. Free chlorine sensor (customised solution developed by AHR)
7. Desktop photometer (HI83300)
8. pH sensors (ICT AWQ-pH)
9. Electrical conductivity sensors (ICT AWQ-C4E)

The project team maintained regular fortnightly meetings with Wayne Parr (Golden Grove) and David Hunt (GIA) to manage the pilot smart nursery and address any activities planned for the site.

Outcomes

Golden Grove was able to demonstrate a 30% reduction in irrigation run times by using their soil moisture, leachate volume and pot leachate EC sensors. Using the technology, Golden Grove was able to irrigate more frequently with lower volumes, which resulted in lower leachate volumes and less nutrient loss into the environment.

The Golden Grove site was used to host industry events such as field days, webinars and video interviews.

Austchilli

AustChilli is the largest chilli grower in Australia, has a young 40 ha avocado orchard, is family owned and operated, and has vertically integrated on-site production, processing and packing.

Grower Input

The project team worked with Austchilli, AUSVEG and Avocados Australia to design a suite of sensors best suited to tree health, productivity and harvest date predictions. The suite of sensors installed consisted of:

1. Soil moisture sensors (ICT SMT-100, Wildeye GS1)
2. Weather station (ICT AWS5)
3. Band dendrometers (ICT DBS-60)
4. Stem dendrometers (ICT DPS-40)
5. Vehicle GPS trackers (Binary Tech)
6. Rated flumes (RBC-100, Keller AccuLevel)
7. Remote camera (Swift Enduro)

Figure 27 Map of Austchilli avocado orchard

Figure 28 Map of Austchilli chilli production block

Groundcover Trial

A groundcover trial was established at the vegetable pilot farm. This trial will compare nitrate runoff and leaching in chilli rows managed with and without interrow groundcover (Figure 29).

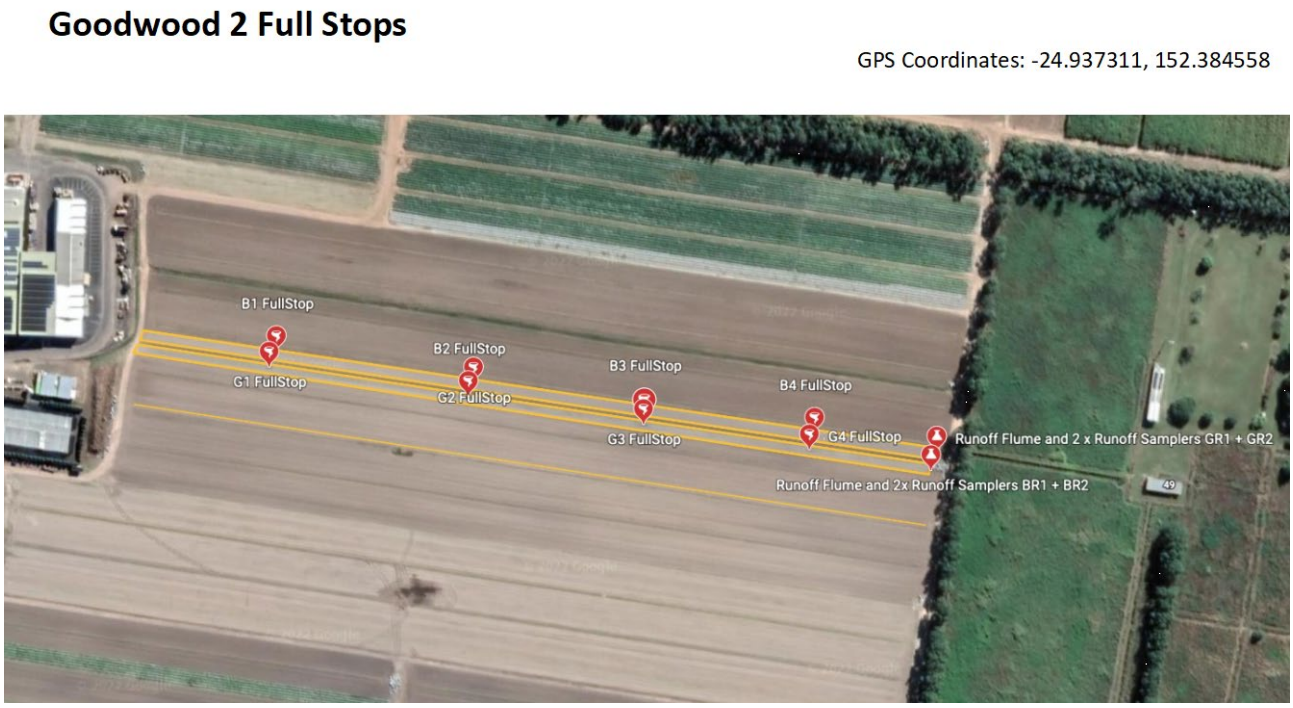


Figure 29 Map of a ground cover trial at Austchilli

Outcomes

Nitrate leaching trials were conducted under chillis and avocado trees to assess the level of fertiliser loss using FullStop Wetting Front Detectors. Low levels of nitrate leaching were found under avocados at an average of 13 ppm NO3-N, whereas higher levels of nitrate leaching of 47 ppm NO3-N were found under chillies. This is likely because leaching events occur less often under the plastic mulch of chillies, when compared to avocados.

There was better control over irrigation practices demonstrated at the avocado orchard with irrigations better matched to the tree requirements. This improvement in water-use efficiency was predominantly brought about using soil moisture sensors, dendrometer and sap flow sensors. Data from these three sensor types was combined to inform irrigation managers of when and how much to irrigate.

A growing degree day model was developed for the chilli industry, which uses the on-site weather station and Bureau of Meteorology forecasts to account for accumulated heat units and predict future heat units to determine fruit maturity date based on a pre-determined target.

A third and final ground cover trial is underway at Austchilli, which will be used to communicate the effects of interrow groundcover on nitrate leaching and runoff to industry in early 2024.

Leading growers engaged to champion the approach

Gavin Devaney – Bartle Frere Bananas

Figure 30 Gavin Devaney on-site at Bartle Frere Bananas

Gavin Devaney is an industry-leading banana grower who has a strong track record of facilitating environmental projects on his Boogan property (Figure 30). He was involved in the Queensland Government's Wet Tropics Major Integrated Project during which he implemented best management practice principles along with innovative drainage solutions to enhance water quality. Supported by Terrain NRM, Gavin installed an experimental in-drain wetland system. This system was trialled for its ability to remove nitrogen, sediment and pesticides naturally from agricultural runoff, aiming to lessen the environmental impact.

Gavin and Bernie Devaney provided significant input into the project through their assistance with the selection and installation of all sensors. Gavin facilitated the installation and validation of innovative technology such as the nitrate photometer and GPS activity tracking.

Gavin was regularly engaged by the project team through fortnightly meetings featuring team members from AHR, Hitachi, ABGC and Hort Innovation. Gavin's property was visited regularly by the project team.

Gavin represented the project at the following events:

Cassowary Coast Banana Growers Association

Gavin represented the project at meetings hosted by the Cassowary Coast Banana Growers Association. During these meetings, Gavin and the project team engaged with the local grower network and demonstrated the benefits of digital remote monitoring.

Australian Banana Industry Congress 2023 – Grower Innovation Panel

Gavin, along with representatives from AHR and Hitachi, gave a presentation at the Australian Banana Industry Congress 2023 as part of the Grower Innovation Panel. This presentation was titled, "Advanced data analytics to improve environmental performance." This was followed by an open discussion forum for the audience and presenters.

Hort Connections Workshop 2023

Gavin was invited to present at the workshop: Getting hands-on with sensors — a practical workshop for growers. During this workshop, Gavin shared his experiences with the project and engaged with the attending growers.

Gavin has received the following recognition as a sustainable and environmentally focused grower:

Australian Banana Industry Congress 2021 — Future Farming Award

Gavin received the future farming award at the Australian Banana Industry Congress 2021. This was awarded based on his work as part of the Wet Tropics Major Integrated Project.

COP26 2021: Technology and data are key to saving the environment

In November 2021, Gavin was featured at the UN Climate Change Conference (COP26) in Glasgow. The talk was called, "Technology and data are key to saving the environment." A recording can be viewed here: https://youtu.be/PDYXAgJOmTE?t=1214.

ITNews Benchmark Awards 2022 — Finalist best agricultural project

Gavin's farm was featured as a finalist in the best agricultural project category for his work in data-driven sustainable smart farming.

Coles Nurture Fund — 2023

Gavin's commitment to technology and the environment has led him to become a recipient of the Coles Nurture Fund. Gavin will receive a $445,000 grant from Coles to invest in new technologies to develop a carbon neutral banana range while reducing runoff into the Great Barrier Reef. The project will include the ability to calculate real-time greenhouse gas emissions on the family owned and operated farm.

Wayne Parr — Golden Grove Nursery

Figure 31 Wayne Parr at Golden Grove Nursery

Wayne Parr is a fourth-generation citrus producer who operates Golden Grove, an advanced citrus nursery in Torbanlea, Queensland (Figure 31). Golden Grove is one of the largest fruit tree production operations in Australia and has embraced the adoption of technology as part of the SmartFarming project. Wayne's involvement in the project has been instrumental in trialling novel sensors such as the free chlorine system, leachate monitoring sensors and remote pest trap cameras.

Wayne and his staff provided significant assistant to the project team during the procurement, installation and maintenance of the sensing equipment at Golden Grove.

Wayne has represented the project at the following events:

Nursery industry workshops and webinars

Wayne has presented at all nursery workshops and webinars throughout the length of the project. During these presentations, Wayne has been able to convey his experiences with digital remote monitoring to his fellow nurserymen.

International Nurseryman's Association Conference

Wayne presented on behalf of the project at the International Nurseryman's Association Conference in California on 3 October 2022. He focussed on the nursery-specific technology trialled at Golden Grove and described how it has helped him to improve his management practices.

Wayne has received the following recognition as a sustainable and environmentally focused grower:

ITNews Benchmark Awards 2023 — Winner best agricultural project

Wayne's involvement with and support for the SmartFarming project was recognised when he received the ITNews Benchmark Award for the best agricultural project.

David DePaoli – AustChilli Group

Figure 32 Left to right: Henry Hyde (AHR), David De Paoli, Dallas Gibb (Hitachi), Kaushal Gunasekara, Liam Southam-Rogers (AHR)

David De Paoli is a leader in sustainable agriculture. His team's existing knowledge of technology helped to support the technical requirements of the project (Figure 32). With a focus on sustainability, David and the Austchilli team have eagerly adopted the tech-forward approach to improve nutrient, water and labour efficiencies. AustChilli's staff assisted with the planning, installation and maintenance of sensors at both the chilli and avocado pilot farms.

David has represented the project at following events and interviews:

AustChilli Virtual Field Day May 2022

David and Kaushal presented on behalf of the SmartFarming project at a virtual field day in May 2022. During this presentation, the AustChilli team discussed how the Hitachi Control Tower UI is used on site, emphasising the value generated in irrigation and fertigation optimisation.

The full recording is available here:
https://www.youtube.com/watch?v=bmlLNILm_WM&ab_channel=AHRVideos

Talking Avocados Autumn 2022

David was interviewed as part of his involvement in the SmartFarming project. The interview title, 'Austchilli smart avocado farm — being an early adopter', was conducted by Avocados Australia Limited. During the interview, David emphasised that this technological adoption is vital for keeping Australian agriculture competitive on a global scale, especially when cheap labour isn't an option.

The full interview is available here:*https://avocado.org.au/wp-content/uploads/2022/05/AVO6308_TalkingAvocados_Autumn_22_FA_Web.pdf*

David has received the following recognition as an innovative, sustainable and environmentally-focused grower:

Hort Connections 2022 National Awards for Excellence

David was nominated for the Butler Market Gardens Environment and Sustainability Award and VISY Industry Impact Award.

Hort Connections 2023 National Awards for Excellence

David was nominated for the Hort Innovation Exporter of the Year and VISY Industry Impact Award.

Grower meeting (November 2022)

A meeting between the three pilot farm growers (Gavin, Wayne, David) was held at Austchilli in November 2022 to discuss the strengths and weaknesses of the project (Figure 33). Each grower presented on their top three technologies provided by the project, shared their experiences and discussed the future direction for the project.

Gavin Devaney rated his top three technologies as:

1. Soil moisture sensors
2. Nitrate photometer
3. Vehicle trackers

Wayne Parr rated his top three technologies as:

1. Electrical conductivity sensor
2. Soil moisture sensors
3. Pest trap camera

David De Paoli rated his top three technologies as:

1. Dendrometers
2. Soil moisture sensors
3. Field cameras for developing a growing degree day model

Figure 33 Gavin Devaney, Wayne Parr and the AHR team touring the Austchilli avocado orchard

How-to guide and fact sheets

Smart farming technology guide for horticulture

A comprehensive digital guide was been developed by Applied Horticultural Research with input from Hitachi, Greenlife Industry Australia and other project partners (Figure 34). This guide outlines some of the most useful and readily available sensors which are appropriate for smart farming. Features include clear instructions on how to select, install, and maintain sensors, and how to interpret measured data.

The guide contains the following chapters over 42 pages:

1. Is smart farming right for you?
2. Hitachi Control Tower
3. Sensor installation tips
4. Productivity monitoring
5. Irrigation water quality
6. Modelling
7. Cameras
8. Environmental monitoring

The guide is available here on the AHR website and is reported on in Appendix 3.

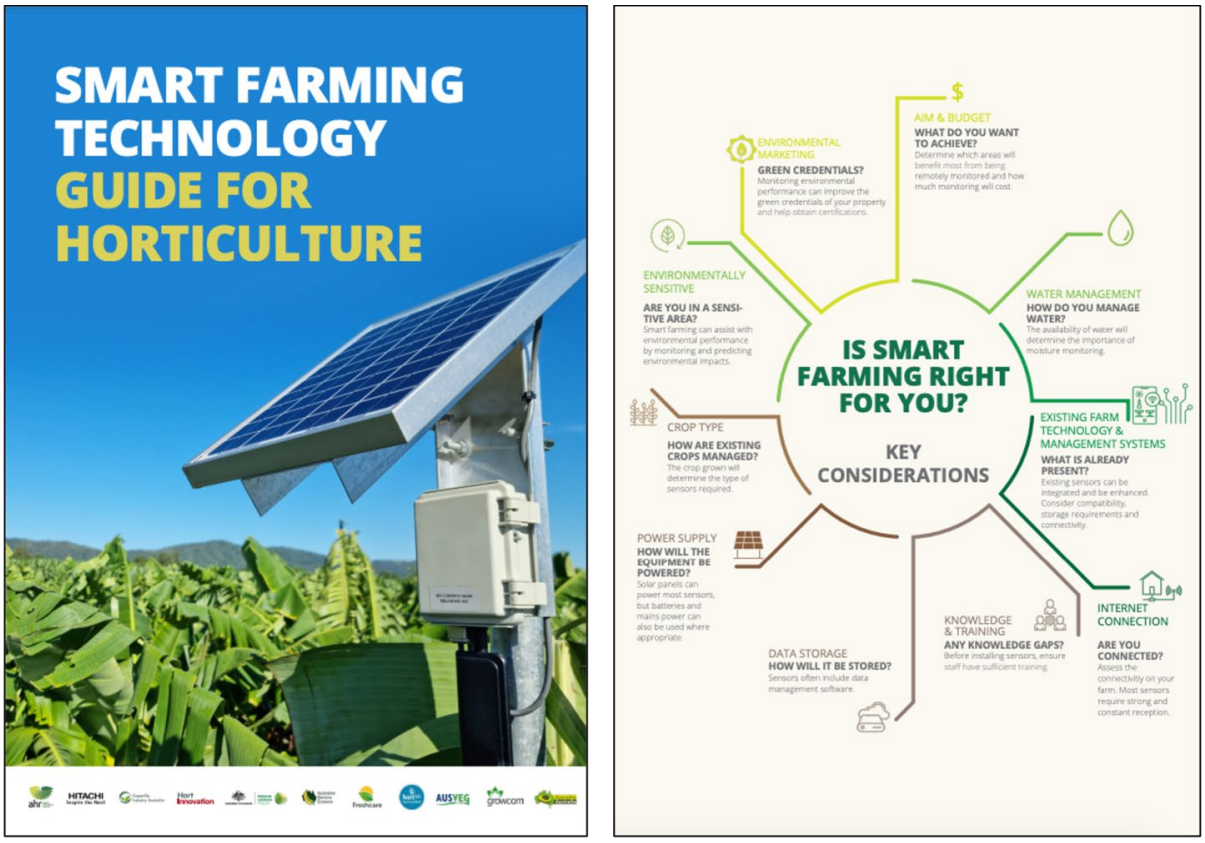


Figure 34 Smart farming technology guide for horticulture

Factsheets and case studies

AHR produced four case studies and two factsheets on the following topics with input from all relevant project partners (Figure 35). These outputs are reported on in Appendix 3.

1. Dendrometers
2. Soil moisture sensors
3. Avocado smart farming
4. Banana smart farming
5. Smart nursery production
6. Vegetable smart farming

Figure 35 Factsheets and case studies produced by AHR with input from project partners

Webinars and training

Grower interviews/case studies

A series of interviews with the pilot farm owners was recorded. The purpose of these interviews was to provide the growers with a platform to share their thoughts on the project and offer insight into how they utilise the Hitachi Control tower.

Smart Banana Farming in Queensland

Figure 36 Video thumbnail for the banana case study

Gavin Devaney from Bartle Frere Bananas was interviewed about his experiences with the Smart Farming project (Figure 36). This video interview provides an insight into the benefits of digital remote monitoring for Australian banana growers. The video focussed on the following technologies:

- Vehicle and banana bunch tracking
- Automated Freshcare records
- Real-time nitrate leachate monitoring
- Nitrate runoff and leachate forecasting
- Soil moisture sensors
- On-farm weather stations.

The banana case study has been viewed over 1,700 times on YouTube and is available here.

Smart Vegetable Farming in Queensland

Figure 37 Video thumbnail for the vegetable case study

David De Paoli from AustChilli was interviewed about his experiences with the Smart Farming project (Figure 37). This video allowed David to share his thoughts on using digital remote monitoring techniques to enhance the productivity and environmental performance of his chilli operation. The video focussed on these technologies:

- Dendrometers for plant growth rates
- Soil moisture sensors
- Growing degree day growth models for forecasting crop maturity
- In-field cameras
- Nitrate runoff and leachate forecasting
- On-farm weather stations

The vegetable case study has been viewed over 1,500 times on YouTube and is available here.

Smart Avocado Farming in Queensland

Figure 38 Video thumbnail for the avocado pilot farm

David De Paoli from AustChilli was interviewed about his experiences with the Smart Farming project (Figure 38). This video allowed David to share his thoughts on using digital remote monitoring techniques to enhance the productivity and environmental performance of his avocado operation. The video focussed on these technologies:

- Dendrometers for tree growth rates
- Sap flow sensors for tree transpiration
- Soil moisture sensors
- Advanced irrigation control
- Nitrate runoff and leachate forecasting
- On-farm weather stations

The avocado case study has been viewed over 1,600 times on YouTube and is available here.

Smart Citrus Nursery in Queensland

Figure 39 Video thumbnail for the nursery case study

Wayne Parr from Golden Grove Nursery was interviewed about his experiences with the Smart Farming project (Figure 39). This video allowed Wayne to share his thoughts on using digital remote monitoring techniques to enhance the productivity and environmental performance of his citrus nursery. The video focussed on these technologies:

- EC and pH sensors for irrigation, dam and runoff water quality
- Growing media moisture monitoring
- Automated EcoHort reporting
- Pest-trap cameras
- Dendrometers for plant growth rates
- Disinfestation free chlorine monitoring

The nursery case study has been viewed over 1,500 times on YouTube and is available here.

Webinars

Smart technology & remote sensing to improve nursery production (April 2022)

Figure 40 Snapshot from the webinar: Smart technology & remote sensing to improve nursery production

Greenlife Industry Australia (GIA) organised and promoted this webinar. This webinar provided an overview of the Golden Grove smart production nursery and how water quality sensors, remote cameras and container moisture and leachate sensors assist with monitoring production processes and automating data collection. A preview of the Hitachi Control tower showed how the collected data provides growers with decision support.

The webinar featured presentations from David Hunt (GIA), Thomas Parr (Golden Grove nursery), Liam Southam-Rogers (AHR), Henry Hyde (AHR) and Dallas Gibb (Hitachi).

There were 10 attendees, and all registrants received a link to the recording which has been viewed 220 times.

The webinar recording is available here.

Webinar: Using sensors to improve water management in horticulture (April 2023)

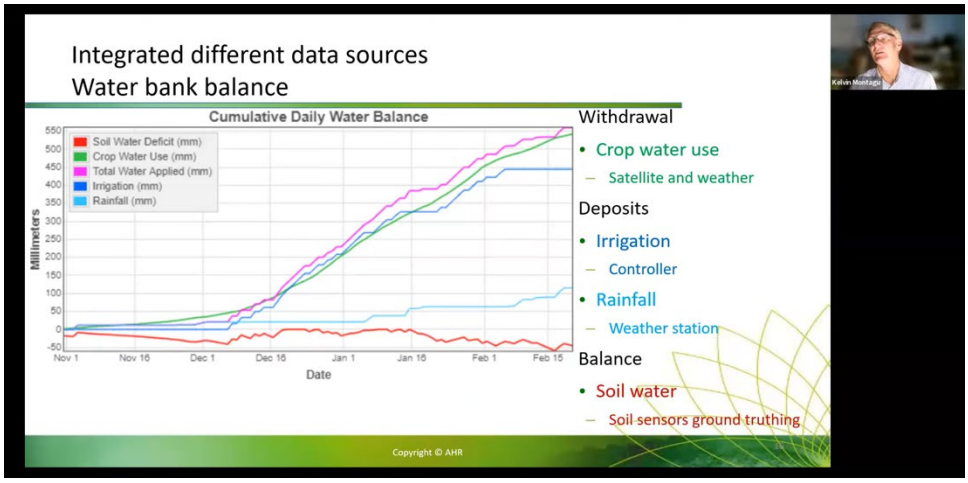


Figure 41 Snapshot from the webinar: Using sensors to improve water management in horticulture

AHR organised, promoted and delivered this webinar with assistance from Hitachi and Greenlife Industry Australia. This webinar covered different technologies for monitoring moisture in both field crops and nursery containers.

Some of the specific technologies covered included TDR soil moisture probes, weight-based irrigation scheduling, leachate fraction irrigation scheduling and water balance models. The webinar featured presentations from Dr Kelvin Montagu (AHR) on soil moisture monitoring and irrigation management, David Hunt (GIA) on weight-based irrigation and leachate monitoring and Dallas Gibb (Hitachi) on visualising and interpreting moisture data and automating irrigation. The webinar concluded with a Q&A session.

There were 68 attendees in total, of which at least 14 were growers. There were 129 people registered for the event and all registrants received a link to the recording.

The webinar recording is available here.

Webinar: Using dendrometers to manage plant stress (May 2023)

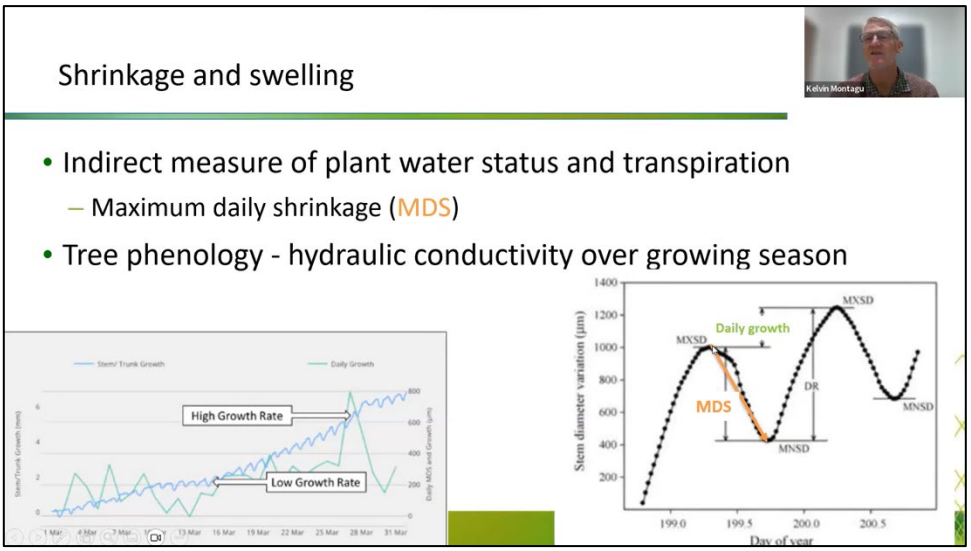


Figure 42 Snapshot from the webinar: Using dendrometers to manage plant stress

AHR organised, promoted and delivered this webinar with assistance from Hitachi. The webinar covered different technologies and methods for monitoring plant stress and growth. Some of the specific technologies covered included the application of stem and band dendrometers, interpreting and making decisions using dendrometers and using multiple data sources to add value to dendrometer data. The webinar featured presentations from Liam Southam-Rogers and Henry Hyde (AHR) on the application of dendrometers in the Smart Farming project, Dr Kelvin Montagu (AHR) on plant physiology and water use and Dallas Gibb (Hitachi) on visualising and interpreting dendrometer data. The webinar concluded with a Q&A session.

There were 95 people registered for the event and all registrants received a link to the recording.

The webinar recording is available here.

Workshops

Nursery workshops

Figure 43 Left: David Hunt (GIA) presenting at the Melbourne Nursery Workshop. Right: Dallas Gibb (Hitachi) presenting at the Sydney Nursery Workshop.

Nursery workshops were held in Melbourne, Perth, Adelaide and Sydney. These workshops were organised and promoted by GIA, and featured presentations from David Hunt, Wayne Parr, AHR and Hitachi.

Each of these workshops followed a similar format — David Hunt (GIA) introduced the SmartFarming project and provided an overview of the smart production nursery; Dallas Gibb (Hitachi) provided an in-depth walkthrough of the Hitachi Control Tower UI, emphasising the modules specific to the nursery industry; Henry Hyde and Liam Southam-Rogers (AHR) covered the selection and installation of sensors at the nursery; David Hunt (GIA) provided additional presentations on energy use and operating costs on nurseries and the importance of cyber security in digital remote monitoring. Each presentation session included interactive discussion sessions.

Nursery workshop — Melbourne (October 2022)

This workshop was organised by GIA and hosted at the Horticultural Hall in Forest Hill.

There were 30 attendees, of which 18 were growers. There were 25 growers registered for the event.

Nursery workshop — Perth (March 2023)

This workshop was organised by GIA and hosted at the Cockburn Wetlands Centre.

An executive officer from the local industry association mentioned that they now feel more confident in discussing smart technologies with their industry peers. This comment underscores the critical role that allied services play in fostering the adoption of smart technologies.

Both insights point to the workshop's effectiveness in not just educating but also in building confidence among various stakeholders.

There were 18 attendees (15 nursery staff and 3 allied services).

Nursery workshop — Adelaide (March 2023)

This workshop was organised by GIA and hosted at the Fullarton Park Community Centre.

Several attendees expressed that they gained a clearer grasp of the terminology relating to smart technologies, as well as how to make sense of the data. This improved understanding among the participants suggests that the event succeeded in its educational goals.

There were 28 attendees (11 nursery staff, 2 allied services and 15 TAFE horticulture students)

Nursery workshop — Sydney (August 2023)

This workshop was organised by GIA and hosted at the Local Land Services demonstration farm, Richmond.

There were 21 registrants, of which 16 attended.

Getting hands-on with sensors: A practical workshop for growers (June 2023)

Figure 44 Dallas Gibb (Hitachi), presenting technology from the smart production nursery

An interactive workshop was hosted at Hort Connections 2023. This workshop was delivered with assistance from Hitachi, Greenlife Industry Australia and Gavin Devaney.

The workshop introduced attendees to the Smart Farming project by giving an overview of the pilot farms and installed sensors. This section discussed the installation and maintenance of the installed sensors. A selection of sensors, provided by WildEye, ICT International, Binary Tech, Escavox, Sentek and CropX, was displayed and available for interaction by workshop attendees.

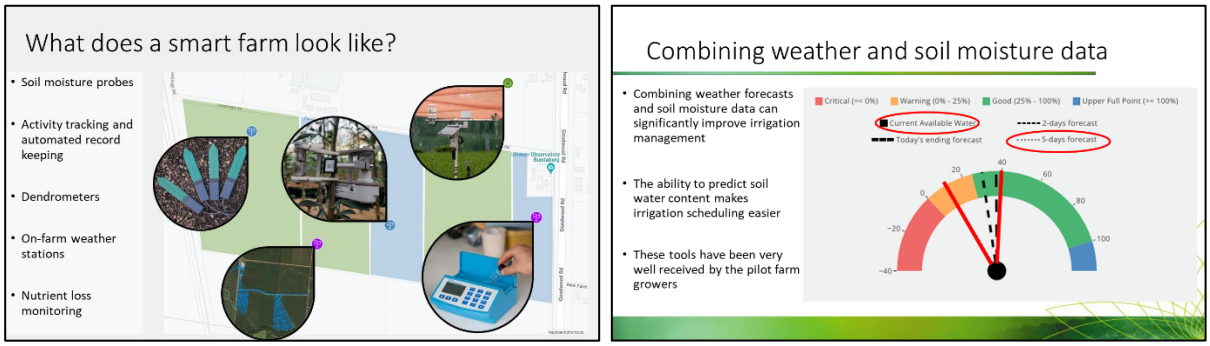


Figure 45 Key slides from the workshop. Left: Attendees were introduced to the SmartFarming project. Right: Attendees were taken through real-world scenarios, such as using weather and soil moisture data to inform irrigation management.

The project team worked through real-world scenarios with real data. These included soil moisture monitoring, dendrometers, sap flow, weather stations and nitrate measurement. This section concluded with a segment on combining data from multiple sources.

The session concluded with an open Q&A forum, allowing attendees to direct their questions to different members of the project team. Gavin Devaney, from the banana pilot farm, provided extensive insight into his experience with the project.

There were 78 registrants — 23 growers, 16 researchers/government, 24 suppliers/advisors and 15 other attendees.

Field days

Nursery field day (April 2022)

Figure 46 The farm walk at the smart production nursery field day

A field day was hosted at Golden Grove by Greenlife Industry Australia, AHR and Hitachi in April 2022.

There were 26 growers and allied services in attendance. Presentations from GIA, AHR and Hitachi were followed by a farm walk.

The attendees indicated, from the short survey, that they found the day highly informative.

Of the eight completed surveys:

- All selected irrigation management as a priority, followed by water quality monitoring and then track and trace of activities and shipments
- All indicated they would like to see data automated with EcoHort, so this is positive.

There were four requests for direct engagement in understanding how best such digital solutions and tools can support their business.

AustChilli virtual field day (May 2022)

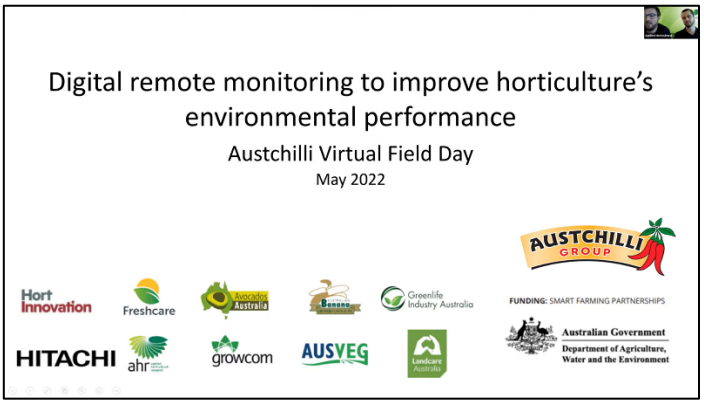


Figure 47 Introduction to the virtual field day

A virtual field day was hosted at Austchilli by AHR, Hitachi, AUSVEG, iMap Pests, Growcom, Freshcare and the Austchilli management team.

The field day featured live interviews with AustChilli staff, a demonstration of sensor integrations and activity tracking in Hitachi Control Tower UI, an overview of the sensor suite installed at Austchilli, and a preview of automated Freshcare Environmental compliance forms. AUSVEG provided an update on the iMapPESTS project and Growcom presented on Reef Certification. The event concluded with a Q&A session.

There were 92 attendees of which at least 24 were growers. Over 200 people registered for the event and received a copy of the recording.

The recording of the field day is available here.

Presentations

National Landcare Conference (August 2022)

Liam Southam-Rogers (AHR) provided a presentation on the project at the 2022 National Landcare Conference. This presentation focussed on the current benefits of digital remote monitoring tools in the context of managing nutrient loss in Queensland.

A link to the event and recording is available here.

VegNET presentation

A presentation was given to all VegNET RDOs at an online event organised by AUSVEG in October 2022

TropAg Conference poster presentation (November 2022)

Henry Hyde (AHR) provided a poster presentation at the 2022 TropAg Conference in Brisbane.

The poster is attached as an Appendix 9.

Avocado R&D Forum 2023

The Avocado R&D Forum was held in Brisbane in September 2023 to showcase projects to avocado industry researchers and growers. Liam Southam-Rogers (AHR) presented the Smart Farming project to the forum, with a focus on future research opportunities of digital agricultural technologies in the avocado industry.

Cassowary Coast Banana Growers Meeting

The project team (AHR, Hitachi) presented on the banana pilot smart farm at the Cassowary Coast Banana Growers meeting held in Silkwood, Queensland in May 2022. There was positive feedback and interest in banana farm activity tracking and remote Freshcare auditing.

There were 15 growers (including Gavin) and two ABGC staff in attendance.

Training

Figure 48 Gavin Devaney receiving training on interpreting soil moisture visuals on the Hitachi Control Tower UI

The AHR and Hitachi teams facilitated extensive training with the management teams of each of the pilot farms. This training focussed primarily on extracting the most value from the Hitachi Control Tower UI (***Figure 48***). The growers were trained in customising the Hitachi Control Tower UI, creating and editing management blocks, setting full and refill points, interpreting sensor data and diagnosing problems. The growers were also trained in the installation and maintenance of sensor equipment. The Smart Technology Guide for Horticulture was produced using some of the learnings gained through this process.

Engagement with industry extension programs, aligned projects, private sector and regional NRMs

The AHR team coordinated with all relevant horticultural extension programs, such as VegNET, SoilWealth, PotatoLink, Hort Innovation extension network and industry magazines.

The Smart Farming project has been promoted to all horticultural industries and regions in Australia. There has been significant interest in the project concept from the wine grape industry, which has environmental reporting requirements.

There has been direct interest in the Hitachi Control Tower UI from at least five nurseries, three banana farms, one macadamia farm, one avocado farm and QLD DRP.

The how-to guide, Smart farming technology guide for horticulture, will be shared through the Hort Innovation extension network.

Industry events

Australian Banana Industry Congress 2021, 2023

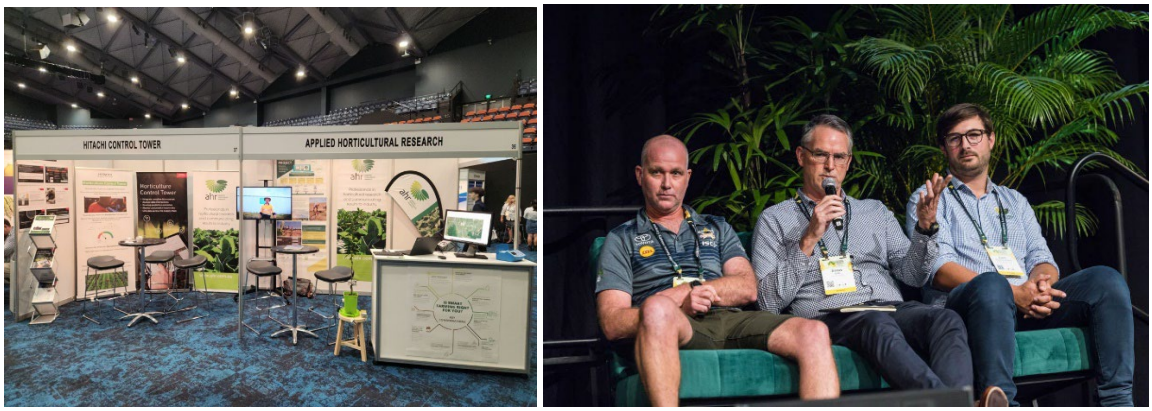


Figure 49 Left: The AHR and Hitachi booth. Right: Gavin Devaney, Dallas Gibb and Liam Southam-Rogers presenting as part of the grower innovation panel

The project was showcased at the bi-annual Australian Banana Industry Congress in 2021 and 2023. This is the premier communication event for the banana industry. Exhibitor booths, scientific posters and presentations were used to communicate smart farming technologies available for improving horticultural environmental performance.

Liam Southam Rogers (AHR), Dallas Gibb (Hitachi) and Gavin Devaney participated in the grower innovation panel presenting “Advanced data analytics to improve environmental performance” (Figure 49). Henry Hyde (AHR) provided a science pitch and poster presentation. The poster is attached as an Appendix 8.

Hort Connections 2022, 2023

The project was showcased at the 2022 and 2023 Hort Connections conferences. Hort Connections is the premier event for Australian horticulture. An industry workshop, “Getting Hands-on with Sensors: A Practical Workshop for Growers,” was hosted at Hort Connections by AHR, Hitachi and Greenlife Industry Australia. There were 70 registrants.

Nursery Industry Workshops

The AHR team presented at the nursery industry Smart Farming project industry workshops held in Brisbane, Sunshine Coast, Perth, Sydney, Melbourne and Fraser Coast.

Industry Extension programs

VegNET

Project communication outputs such as The Smart Farming Technology Guide for Horticulture, factsheets, videos and webinars have been shared through the VegNET program. A detailed presentation on smart farming technologies for improving horticultural environmental performance was given to all VegNET Industry Development Officers on 28 October 2022.

Soil Wealth

Project communication outputs, such as The Smart Farming Technology Guide for Horticulture, factsheets, videos, and webinars, have been shared through the Soil Wealth ICP website and bulletins.

PotatoLink

The Smart Farming project presented at the PotatoLink R&D forum, an annual event to provide insights into the latest potato research and innovation for Australian potato levy payers. The presenter, Henry Hyde (AHR), focussed on soil moisture monitoring, irrigation management, crop maturity monitoring, automated record keeping and operations tracking.

Project communications outputs and events were also shared in the quarterly PotatoLink magazine.

Peak Industry Bodies

The project worked closely with Greenlife Industry Australia, Australian Banana Growers Council, AUSVEG and Avocados Australia to ensure the pilot smart farms were designed to suit industry needs and to communicate results to industry. Other peak industry bodies, such as Berries Australia, published articles on behalf of the project.

Australian Banana Growers Council

The Australian Banana Growers Council (ABGC) was engaged for the length of the project. Representatives from ABGC joined all banana pilot farm update meetings and provided valuable contributions to the project. The ABGC team visited the site multiple time and provided logistical support to the project team. The ABGC team assisted in the delivery of communications outputs for the banana pilot farm. ABGC helped to guide the development of the Hitachi Control Tower UI as a tool for the broader banana industry. The AHR project team ensured that the environmental monitoring framework aligned with the Banana BMP guidelines.

Freshcare

Freshcare and AHR worked together to design an environmental sustainability framework for horticulture, to amend key Freshcare forms for automated reporting and trial a remote Freshcare Environmental audit. Freshcare was updated quarterly on the progress of the project and joined AHR on two trips to the Austchilli pilot site.

Greenlife Industry Australia

The AHR project team closely aligned the design of the smart production nursery with the monitoring requirements of the EcoHort program. EcoHort data forms were digitised and integrated into the Hitachi Control tower. David Hunt, SmartFarming project officer for GIA, provided significant support to the AHR and Hitachi teams throughout the project. David organised the delivery of multiple events and contributed to events organised by the AHR project team. David also provided on-site maintenance support for the project team.

Growcom

The AHR project team received significant input from Scott Wallace into the design and execution of the groundcover trials at the vegetable pilot farm. The AHR project team worked closely with the Hort360 program to ensure that the environmental monitoring framework aligned closely with reporting requirements.

AUSVEG

The AHR project team engaged with AUSVEG regarding the alignment of EnviroVeg with the environmental monitoring framework. AUSVEG staff visited the avocado and vegetable pilot farms and assisted with the distribution of project communications. AUSVEG promoted events through their weekly updates.

BFVG

Project events and resources were promoted in the BFVG fortnightly newsletter. AustChilli will be featured in the BFVG grower profile article in October 2023.

Related Projects and Aligned Research

Banana Nutrient Trials (RP191)

The Banana Nutrient Trials project is about optimising fertiliser use, mainly focusing on nitrogen and secondarily on phosphorus, for banana farms in Queensland. The goal is to help farmers maximise crop yields while minimising nutrient waste. It's currently in its second phase, running from 2022 to 2026.

The Smart Farming project linked with the RP191 project by closely aligning the methodology of the nutrient monitoring work at the banana pilot farm, especially the monitoring conducted during the irrigation trial. The AHR project team met with Alex Lindsay (DAF), who reviewed the sampling methodology and provided recommendations.

Wet Tropics Major Integrated Project

The AHR team engaged with William Darveniza regarding his work on the Wet Tropics Major Integrated Project. William shared nitrate results from the banana pilot farm with the project team (Figure 50). These results helped the team to design a nitrate monitoring strategy. This information was essential in determining the location for nitrate monitoring.

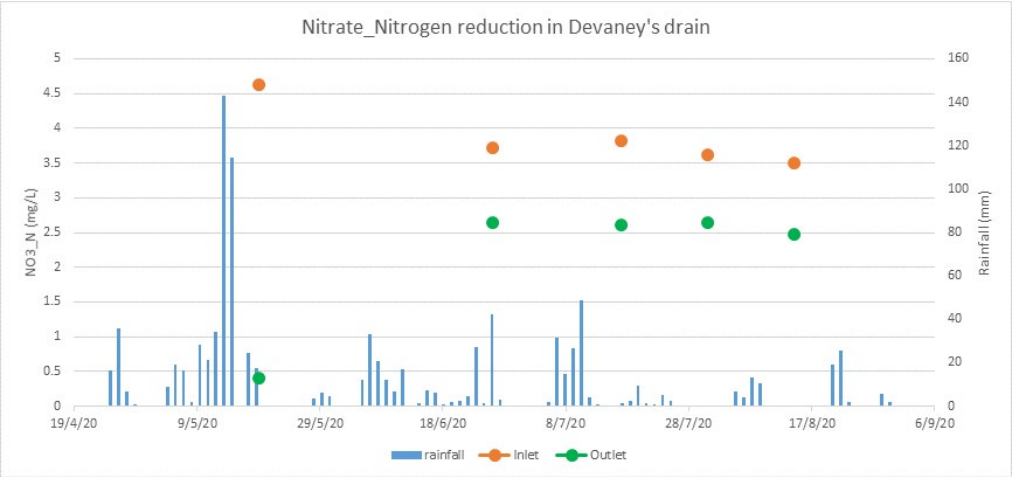


Figure 50 Nitrate data from the vegetated drain at Bartle Frere Bananas, courtesy of William Darveniza and the Wet Tropics Major Integrated Project

HowLeaky (P2R)

The nutrient model developed was aligned closely with the work conducted during the P2R project. This was done through collaboration with project staff from the P2R project.

Private sector

The project engaged with private sector, peak industry bodies and agronomists throughout the project term.

Technology Providers

The project successfully collaborated with technology providers such as ICT International, Wildeye, Sentek, Chemtrol, Escavox, Eratos, TriOS, Goldtech, DHM Software and Back Paddock.

There was unsuccessful collaboration with companies that did not agree to share data from their platforms, such as CropX and Phytech, and organisations that were unable to share data such as the Bureau of Meteorology.

Retailers

Coles recognised the success of the project by awarding Bartle Frere Bananas a Coles Nurture Fund grant to use the Hitachi Control Tower UI to calculate greenhouse gas emissions and produce low carbon bananas.

Linkages with Regional NRMs

Burnett Mary Regional Group

The Burnett Mary Regional Group (BMRG) is the peak body for Natural Resource Management (NRM) within the Burnett Mary region. AustChilli and Golden Grove are both within the Burnett Mary region.

Project alignment

The AHR project team shared communication outputs with BMRG. The AHR project team reviewed the Water Quality Improvement Plan for the Burnett Mary Region and BMRG NRM and Climate Resilience Plan 2030 and worked to ensure that the project aligned closely with the strategic pillars of BMRG:

- **Sustainable Agriculture —** The project promoted innovative and sustainable farming practices that enhanced productivity, profitability, and ecological resilience in the Burnett Mary region
- **Climate Change Adaptation —** The project developed and implemented strategies that enable the region's agriculture and natural systems to adapt and thrive in the face of climate change and extreme events
- **Biodiversity Conservation —** The project aimed to protect natural ecosystems, ensuring the preservation of threatened species while improving biodiversity
- **Community Engagement and Education —** The project communicated outcomes through the BMRG network.

Terrain NRM

Terrain NRM is the natural resource management organisation responsible for the Wet Tropics region of Far North Queensland.

Project alignment

The AHR project team aimed to align the project with the Wet Tropics Plan, specifically for the Northern Cassowary Coast region.

The plan highlighted three priority areas for the region:

1. Biodiversity — The plan aims to leverage stakeholder engagement to collaboratively tackle habitat loss, climate change and other threats, aiming to fortify the resilience and long-term prospects of local wildlife and ecosystems.

The project aligned with this component of the plan by reducing the use and impact of chemicals on the environment.

2. Water — The plan aims to enhance the health of waterways through riparian restoration and on-farm water treatment, benefiting not just the ecosystem but also boosting recreational value and strengthening community ties to the water.

The project aligned with the water component of the plan by increasing the knowledge about best farm practices for ground water management and engaging with landholders to improve methods and cooperation.

3. Biosecurity — The plan encourages a collaborative approach in managing biosecurity risks, including tackling issues like feral pigs, to protect natural ecosystems and agricultural industries.

The project aligned with the biosecurity component of the plan by trialling remote camera technology and mapping vehicle movement.

Water sampling

AHR engaged with Emma-Lee Harper from Terrain to seek expertise on selecting a suitable water auto sampler for collecting a small number of samples during farm runoff events, specifically for nitrate analysis. Emma provided detailed recommendations, endorsing ISCO autosamplers for their durability and optional refrigeration features. She also emphasised the importance of refrigeration for maintaining nutrient integrity in samples.

FullStop sampling and modifications

AHR engaged with Fiona George from Terrain to discuss the logistics and methodologies surrounding nutrient leachate sampling efforts. Fiona provided insights into her team's standard operating procedures, mentioning a shift from taking a small sample to pumping the whole volume into a bottle for more accurate analysis (Figure 51).

Kelvin from AHR coordinated with Fiona to discuss FullStop modification and installation. Kelvin sought advice on installation tips specifically for bananas, to which Fiona responded by sharing modifications Terrain made to their own systems. She included pictures illustrating how they cut the funnel and retrofitted the hose connection to a modified section of PVC pipe. Fiona also advised adding gauze or fine cloth on top of the funnel to prevent dirt from contaminating the receptacle.

Figure 51 Terrain NRM's FullStop modifications (Images supplied by Fiona George)

Contribution to the Smart Farming Partnerships outcomes

Explain the contribution that this project has made to the Smart Farming Partnerships outcomes (as detailed in Section 2.4 of the Program Guidelines).

Outcome 1 – Innovation in sustainable resource management practice

The project has contributed to innovation in sustainable resource management practices in four ways:

1. Enhanced Environmental Reporting: New methods for environmental reporting were introduced, such as photometers, vehicle GPS trackers, and automated Freshcare compliance forms. Accurate and real-time environmental reporting is fundamental for effective sustainable resource management. The introduced technologies enhance transparency and accountability, providing a comprehensive picture of resource usage and impact. This directly facilitates improved decision-making in resource allocation and management.

2. Remote Auditing Capabilities: An effective remote audit system was developed for Freshcare Environmental using on-farm sensor data, farm records in the Hitachi control tower, and satellite data. Remote auditing reduces the need for physical inspections, saving time and resources. More importantly, it provides an almost instantaneous snapshot of on-ground conditions, allowing for timely interventions and ensuring that best practices in resource management are consistently upheld.

3. Nitrate Loss Prediction Models: The project successfully developed nitrate loss prediction models utilising fertiliser records, sensors, and forecasted weather. Predicting nitrate loss is crucial for sustainable soil and water management. By forecasting nitrate runoff and leaching, farmers can adjust their practices, minimising negative environmental impacts and ensuring that soils remain nutrient-rich for future crops.

4. Data-Driven Management Practices: Data was generated on the effects of different management practices on nitrate runoff and leaching. The research compared the effects of ground cover management techniques and evaluated the efficiency of different irrigation methods. Ground cover management and optimised irrigation directly influence soil health, water usage, and overall ecosystem balance. By understanding the effects of these practices, better recommendations can be provided to farmers. The specific comparison between grassed interrow in vegetables and irrigation methods in bananas offers actionable insights that can be implemented to promote sustainable resource management in these crops.

Outcome 2 – Innovation in capacity building and promotion of sustainable resource management practice

The project focused developing communication activities to support capacity building and promotion of sensors and data to improve productivity through improvements in environmental performance and compliance reporting.

Horticultural farms were educated on the benefits available to them with agricultural technology through industry events, webinars, videos, guides and articles. The project team responded to the requirements put forward by the peak industry bodies partnering in the project and listened to the

feedback from participants at industry events, such as a requirement to discuss sustainability topics through a farm productivity lens. The project received excellent feedback on the capacity building activities and there is still a huge unsatisfied demand for more impartial education on digital agriculture technologies and methods to streamline compliance reporting.

Benefits of sustainable resource management were promoted through the lens of improving labour, nutrient and water efficiency. The project used a wide range of communications mediums to reach a broad cross-section of the horticultural industry. The communications included printed materials, online webinars, videos (with over 6700 views), workshops, conferences and magazine articles.

Is there any other information you think we may be interested in for this project?
None to report

Attachments

Appendix 1: Project summary
Appendix 2: Project materials including intellectual property
Appendix 3: Project media, communications and extension materials
Appendix 4: Pilot farm maintenance and support trips
Appendix 5: Summary of key environmental parameters
Appendix 6: Environmental Sustainability Framework
Appendix 7: Dashboard Mockup
Appendix 8: Banana Congress 2023 Poster
Appendix 9: Trop Ag Poster

Attachment 1 Project Summary

Digital remote monitoring was assessed as a method of improving the environmental performance of Australian horticulture. The development of a farm management tool, called Control Tower aimed to improve environmental compliance and productivity by facilitating industry best practice. Four pilot smart farms were established in Great Barrier Reef catchments to demonstrate the benefits of digital remote monitoring and the Control Tower. These pilot smart farms were selected from the banana, nursery, avocado and vegetable industries.

A framework for the digital remote monitoring of environmental performance was developed in consultation with each of the target industries. Industry feedback overwhelmingly recommended using digital remote monitoring to simplify compliance with best practice. Existing environmental sustainability frameworks for horticulture were adapted for digital remote monitoring. The resulting environmental sustainability framework for horticulture was integrated into the Control Tower.

The collection of compliance information by the Control Tower allowed the project to facilitate a remote audit at the banana pilot farm. The Control Tower provided additional value to certification records by combining chemical application data with the GPS location of farm vehicles. The collection of this data enabled an auditor to access the Control Tower remotely and verify key certification records. The success of this remote audit demonstrates significant progress in lowering the barries to environmental compliance and proved that rigorous audits can conducted remotely.

The Control Tower was developed as a combined productivity and environmental monitoring tool. Integrated with sensors from multiple technology providers, the Control Tower is a sensor agnostic farm management system. All pilot farms were installed with soil moisture, plant growth and weather monitoring equipment. The presentation of multiple sources of plant stress data to the growers led to improved water use efficiency and reduced labour requirements.

Innovative technological solutions were developed for the pilot farms and their associated industries. Comprehensive water monitoring equipment was installed at the smart production nursery. The quality of water entering and exiting the nursery was monitored and used to automate digital records.

A nitrate monitoring system was deployed to measure subsurface leachate at the banana pilot farm. The data from this system was used to develop a nutrient loss prediction model, providing growers with decision support. Forecasting nitrate runoff and leaching, allowing growers to adjust their practices and minimise negative environmental impacts.

Applied Horticultural Research led the communication and extension of the benefits of digital remote monitoring for environmental performance. The project was showcased at multiple conferences, through presentations, posters, and workshops. The benefits of the project were communicated through webinars, factsheets, case studies, guides, and interviews.

The project was delivered by Hort Innovation, Applied Horticultural Research, Hitachi Vantara, Greenlife Industry Australia, AUSVEG, Avocados Australia Limited, Landcare Australia, Freshcare, Growcom and the Australian Banana Growers' Council.

The project conclusively demonstrated that digital sensors and technology can be used to efficiently manage environmental performance and prove compliance with industry best practice. Digital remote monitoring reduced costs, improved input efficiency and opened new sustainable markets for Australian horticulture.

Attachment 2

Project materials including intellectual property

Please list all Project materials including all intellectual property created or arising over the life of the Project.

Attachment 3

Project media, communications and extension materials

Please list of all media, communications and extension materials produced and all extension activities held over the life of the program.

Media, communications, and extension materials	Date produced/published	Purpose
Smart Farming Technology Guide for Horticulture	January 2023	A comprehensive digital how to guide by AHR with input from Hitachi and Greenlife Industry Australia. Available here
Smart Vegetable Farming in Queensland video	January 2023	A video interview with farm owner David De Paoli and agronomy manager Kaushal Gunasekara at Austchilli was produced. Recording available here
Smart Banana Farming in Queensland video	January 2023	A video interview featuring farm owner Gavin Devaney from Bartle Frere Bananas was produced. Recording available here
Smart Avocado Farming in Queensland video	January 2023	A video interview was filmed with farm owner David De Paoli at Austchilli. Recording available here
Smart Nursery Production Queensland video	January 2023	A video interview with nursery owner Wayne Parr at was filmed at Golden Grove. Recording available here
Factsheet: Using sensors to improve water management in horticulture	April 2023	This factsheet outlines how to correctly install and use the data provided by soil moisture sensors. Available here
Webinar: Using Sensors to Improve Water Management in Horticulture	April 2023	A webinar on soil moisture sensors was delivered on 20 April 2023. There were 68 attendees in total, of which at least 14 were growers. There were 129 people registered for the event, all registrants received a link to the recording, which is available here
Factsheet: Using dendrometers to	May 2023	This factsheet outlines how to correctly install and use the data provided by dendrometers. Available here

manage plant stress		
Webinar: Using dendrometers to manage plant stress	May 2023	There were 95 people registered for the event and all registrants received a link to the recording. Available here
Nursery workshop Perth	March 2023	A presentation was given covering the Golden Grove Smart Production Nursery. There were 18 attendees (15 nursery staff and 3 allied services)
Nursery workshop Adelaide	March 2023	A presentation was given covering the Golden Grove Smart Production Nursery. There were 28 attendees (11 nursery staff, 2 allied services and 15 TAFE horticulture students)
Nursery workshop Sydney		This workshop was organised by GIA and hosted at the Local Land Services demonstration farm, Richmond.
Nursery workshop Brisbane South	May 2023	This workshop was organised by GIA and hosted in Loganholme, Qld.
Nursery Workshop Brisbane North	July 2023	This workshop was organised by GIA and hosted at Sports Central Caboolture Qld.
Australian Berry Journal article	March 2023	An article was produced in collaboration with Berries Australia to promote the benefits of digital environmental monitoring to other horticultural sectors. The article is available here
Austchilli virtual field day	May 2022	A virtual field day was hosted at Austchilli by AHR, Hitachi, AusVeg, iMap Pests, Growcom, Freschare and the Austchilli management team in late May 2022. There were 92 attendees of which at least 24 were growers. Over 200 people registered for the event and received a copy of the recording. Recording available here
2022 National Landcare Conference	August 2022	Liam Southam-Rogers (AHR) provided a presentation on the project at the 2022 National Landcare Conference. This presentation focussed on the current benefits of digital remote monitoring tools in the context of managing nutrient loss in Queensland. A link to the event and recording is available here.
VegNET presentation	October 2022	A presentation was given to all VegNET RDOs at an online event organised by AUSVEG in October 2022
Webinar: Smart technology & remote sensing to improve	November 2021	A webinar was hosted by Greenlife Industry Australia, AHR and Hitachi in November 2021. Recording available here

nursery production (		
Smart production nursery field day	April 2022	A field day was hosted at Golden Grove by Greenlife Industry Australia, AHR and Hitachi in April 2022. There were 26 growers and allied services in attendance. Presentations from GIA, AHR and Hitachi were followed by a farm walk.
Australian Bananas magazine article	December 2021	The banana pilot smart farm is featured in the December issue. Page 24-25. Available here
Talking Avocados magazine article	April 2022	The avocado pilot smart farm is featured in the Autumn issue. Page 29-31. Available here
TropAg Conference poster presentation	November 2022	Henry Hyde (AHR) provided a poster presentation at the 2022 TropAg Conference in Brisbane. The poster is available as an appendix.
Smart production nursery fact sheet	November 2021	This factsheet introduces the smart production nursery and highlights key technology. Available here
Banana smart farm factsheet	November 2021	This factsheet introduces the banana smart farm and highlights key technology. Available here
Vegetable smart farm factsheet	November 2021	This factsheet introduces the vegetable smart farm and highlights key technology. Available here
Avocado smart farm factsheet	November 2021	This factsheet introduces the avocado smart farm and highlights key technology. Available here
Getting hands-on with sensors: A practical workshop for growers	June 2023	An interactive workshop was hosted at Hort Connections 2023. This workshop was delivered with assistance from Hitachi Vantara, Greenlife Industry Australia and Gavin Devaney.

Attachment 4

Pilot farm maintenance and support trips

Date	Pilot farms	Purpose and outcome
December 2020	AustChilli Bartle Frere Bananas Golden Grove	- Site selection completed - 4G Connectivity assessed - FullStop wetting front detectors installed - Baseline soil samples collected - Leaf samples collected - Water samples collected
February 2021	AustChilli	- FullStop wetting front detectors installed
May 2021	AustChilli Golden Grove	- Runoff flume installed - Passive runoff samplers installed - Manual rain gauges installed - Desktop photometer installed and training provided - Maintenance conducted
June 2021	AustChilli Bartle Frere Bananas Golden Grove	- Soil moisture, dendrometers, weather stations installed
September 2021	Bartle Frere Bananas Golden Grove	- Install TriOS - Maintenance conducted
December 2021	Bartle Frere Bananas	- Gas sampling - Maintenance conducted
January 2022	AustChilli Golden Grove	- Sap flow sensor installed - FullStop wetting front detectors installed - Maintenance conducted
February 2022	Bartle Frere Bananas	- FullStop wetting front detectors installed - Camera installed - Maintenance conducted
March 2022	Bartle Frere Bananas	- Cassowary Coast Banana Growers presentation - Maintenance conducted
April 2022	AustChilli Golden Grove	- Maintenance conducted - FullStop wetting front detectors installed - Relocate sensors
May 2022	AustChilli	- Austchilli Field day

June 2022	Bartle Frere Bananas	- Maintenance conducted
July 2022	AustChilli Golden Grove	- FullStop wetting front detectors installed - Install free chlorine sensor
September 2022	Bartle Frere Bananas	- Setup irrigation trial - Install irrigation pressure sensor - Maintenance conducted
October 2022	AustChilli Golden Grove	- Establish ground cover trial - Install WildEye soil moisture sensors
November 2022	AustChilli Golden Grove	- Grower meeting - Video interviews - Maintenance conducted
January 2023	AustChilli Golden Grove	- Remove ground cover trial - Maintenance conducted
February 2023	Bartle Frere Bananas	- Maintenance conducted
March 2023	AustChilli Golden Grove	- Establish ground cover trial - Maintenance conducted
May 2023	Bartle Frere Bananas	- Freshcare remote audit - Banana Congress - Maintenance conducted
June 2023	Golden Grove Austchilli	- Maintenance conducted