Smart Farming Partnerships

Six monthly progress report

Progress reporting period

Report	1	2	3	4	5	6
Select	☐	☐	☐	☐	☐	☒
Due	19/08/20	17/02/21	17/08/21	15/02/22	16/08/22	14/02/23
Financial Statement	Not required	Yes, please include as attachment	Yes, please include as attachment	Yes, please include as attachment	Yes, please include as attachment	Yes, please include as attachment

- *Each progress report should build on the previous one. Please do not repeat information already supplied in previous reports.*
- *Where there are text fields – space can be increased or deleted as required to accommodate information to be reported.*
  Please send the completed report to: DAWE.Manage@communitygrants.gov.au and cc landcare@agriculture.gov.au

Application ID:	SFP1-167
Grantee Name:	Guy Roth
Project Title:	DigiFarm. A digitally enabled durable agroecosystem
Grantee contact person who prepared the report:	Guy Roth
Report authorised by (Grantee):	Guy Roth [Signature] Date: 15/02/2023
Date submitted	15/02/2023

Overview of progress during this reporting period

How is the project progressing at this stage? *(short summary)*
The project is entering its final stages and so the majority of activities have been approaching completion or have been completed during this period. The **University of Sydney Narrabri Field Day** was held on 15th September 2022 which showcased the activities and research on the farm to over 250 visitors. The **soil water nowcasting and forecasting** activities are underway still with the main activity in this reporting period being the development and testing of L-band radiometers to determine soil moisture. Initial testing has now concluded and field testing will continue at Llara Farm, Narrabri. The **remote and automated farm sensing** activities have been completed with the data currently being analysed and compiled into the final report. The Pairtree dashboard continues to be a valuable source of DigiFarm data such as to obtain soil moisture and temperature data from the soil probes which are being used in the low THC industrial hemp trial. The **cropping and farm management systems** activities are continuing well. The third season of the John Deere Cotton Trial was planted in November 2022 with a drone flight carried out in December 2022. The DigiFarm project has also been involved with the AgriFutures LOW THC Industrial Hemp project by using the soil probes to monitor soil moisture and temperature during the growing season as well as a drone flight in December 2022. A field day for growers and farmers to inspect the crop was also held in February 2023. Activities relating to **livestock management and pastures** have experienced delays due to repeated flooding leading to damaged equipment as well as due to a lack of livestock staff on northern farms. Instead, research efforts have been concentrated on developing prediction equations for the chemical composition of livestock feedstuff, greenhouse gas emissions and supplement intake of grazing cattle from faecal samples using NIRS smartphone sensors. The main advances with the **precision weed management** activity is the 'See and Spray' Weed Assessment Trial in partnership with John Deere. Two trial sites (Llara & Edgeroi) are being used to assess the effectiveness of their 'See and Spray' technology which uses cameras to identify weeds so that sprays can be targeted in fallow fields to reduce herbicide use. All field and laboratory work for the **soil health systems** activity has ceased with the focus having been the analysis of data from the cover crop and soil biodiversity investigations. For cover cropping, different treatments including fallow, cover cropped, mix and single species were compared between 2020 and 2021 for their impact on yield and harvest index. With regards to water, soil moisture has been monitored throughout the trial sites with capacitance probes providing encouraging results for future water consumption methodologies. Soil biodiversity samples from 2019 and 2020 are currently under analysis. The **feral pig collaring** part of the project is now complete with all pig collars now removed. Data from the last six months is currently being analysed for the final report. A landholder meeting and field day were also held in this period and a debrief with landholders is planned for the coming months.

With regards to **natural capital and biodiversity**, the bird diversity data on the ecoacoustic database and dashboard is currently being updated. Over 50,000 hours of audio data has been analysed with 105 species of birds identified. Data collection for terrestrial mammal diversity is also continuing too. From a teach perspective, two groups of summer scholarship students produced their project reports from their studies on Llara Farm. One project analysed avian bird diversity while another monitored grass tree and eucalyptus species in agricultural land adjacent to native forests. In addition to this, the DroughtNet add-on project activities have also continued with cattle exclusion fencing, irrigation tanks and pipes installed. The summer 2022/23 survey has also been completed. Data has also been shared with the international DroughtNet experiment for global analysis and plant samples will be sent to Utrecht University in The Netherlands to contribute to a global plant nutrient availability study in March 2023.

The sustainability report is taking shape. We have met with the Grains industry representatives and now have their framework and indicators.

Finally, the **native grains and food** activities held a networking session demonstration day in November 2022 to which 30 people from a range of backgrounds, institutions and community groups attended.

Is the project on target to achieve contracted activities, measures and outcomes?	**Yes** ☒	**No** ☐
If No, is a variation required to the Grant Agreement?	**Yes** ☐	**No** ☒
If Yes, please explain the nature of the variation. The department will contact you regarding the detail of the variation to the Grant Agreement once this Activity Work Plan has been approved.		
Have you had any major incidences which required risk management and implementation of mitigation strategies as outlined in your Risk Management Plan in the Work Plan?	**Yes** ☐	**No** ☒
If Yes, please explain the nature of the incidence and mitigation strategies applied		

Project Administration

Please provide a summary of project administration activities undertaken during the reporting period e.g. progress towards implementing the Project Work Plan; appointment of or changes to Project staff; establishment of agreements/contracts with Project participants, compliance with terms and conditions of the Grant Agreement.

- Regular **monthly meetings** with stakeholders in the DigiFarm project have continued to be held over the course of the last reporting period.
- A **Program Evaluation Report** titled 'DigiFarm: A Digitally Enabled Agro-Ecosystem' has also been produced since the previous milestone report. The report summarises the outcomes of the project in order to evaluate the impact and legacy of DigiFarm through desktop analysis, interviews with participants and partners and two online sruveys. A brief summary of the findings from the report are below:
    - From a **research perspective**, the evaluation report found that all sub-projects delivered research outcomes including multiple peer reviewed papers. It was identified that the flexible approach and adaptations made allowed the sub projects to still deliver the majority of planned activities. The evaluation report also identified key achievements of the project which were the integration of on-farm biodiversity and natural capital monitoring as well as the fulfilment of student outcomes including 3 PhDs and 11 honours students. The report concluded that the program has resulted in a digitally enhanced farm environment on Llara including an integrated whole-farm data platform as well as a research and learning centre which will continue to manage digital data into the future.
    - With regards to **technology adoption**, the report evaluated that this had been challenging due to drought and Covid-19 disengaging farmers into forward thinking and investment in novel technologies. However, despite these setbacks, numerous technologies have been adopted across the 13 satellite farms including soil capacitance probes, in-field cattle weighing devices, pasture assessment probes and pest animal monitoring.
    - As with technology adoption, the extent of **outreach** during the project has also been limited by Covid-19 restrictions. During periods of restrictions, outreach activities such as demonstrations and field days were moved online while social, film and print media streams were also used for outreach. Since restrictions eased in 2022, the report found that the number of outreach opportunities had increased greatly and has been successful in establishing on-going and future partnerships with local entities.
    - **Natural capital and sustainability** of products is becoming increasingly important with the evaluation report finding that the DigiFarm project has demonstrated how environmental credentials can be effectively proven at a farm level. The evaluation report found this to be a very important outcome in order to allow farmers to better access markets and premiums for products by allowing them to evidence the sustainability of operations.

- A key aspect of the report was to evaluate the **legacy and long-term impact** of the project. It was concluded that despite the project establishing the foundations to achieve long term data collection through digital technologies, ongoing funding will be required for long-term research and datasets to be achieved. This additional funding has only so far been realised for one of the 11 sub-projects. However, the evaluation found long term potential in the partnerships build through the project which will help build the legacy of the DigiFarm project.
- The evaluation report made **8 recommendations** to ensure a continuing legacy from the program. These included continued engagement with local Aboriginal communities and farmers as well as continuing to seek ongoing funding for further relevant research. A further recommendation of the report was to explore further opportunities for how natural resource management and natural capital outcomes can be incorporated into mixed farming enterprises. (The full report is attached).

Project Activities Record

Reflecting on progress against Project Activity Outputs, Communications and Extension Plan, and MERI Plan

Project Activity 1

Project Activity Output name *(As per the Work Plan)*
Soil water nowcast and forecast

Activity status as of this reporting period

Planned	Started	Underway	Finished	Delayed
☐	☐	☒	☐	☐

Is this project activity on track?	**Yes** ☒	**No** ☐

If No, what is being done to remedy the situation and put it back on track:

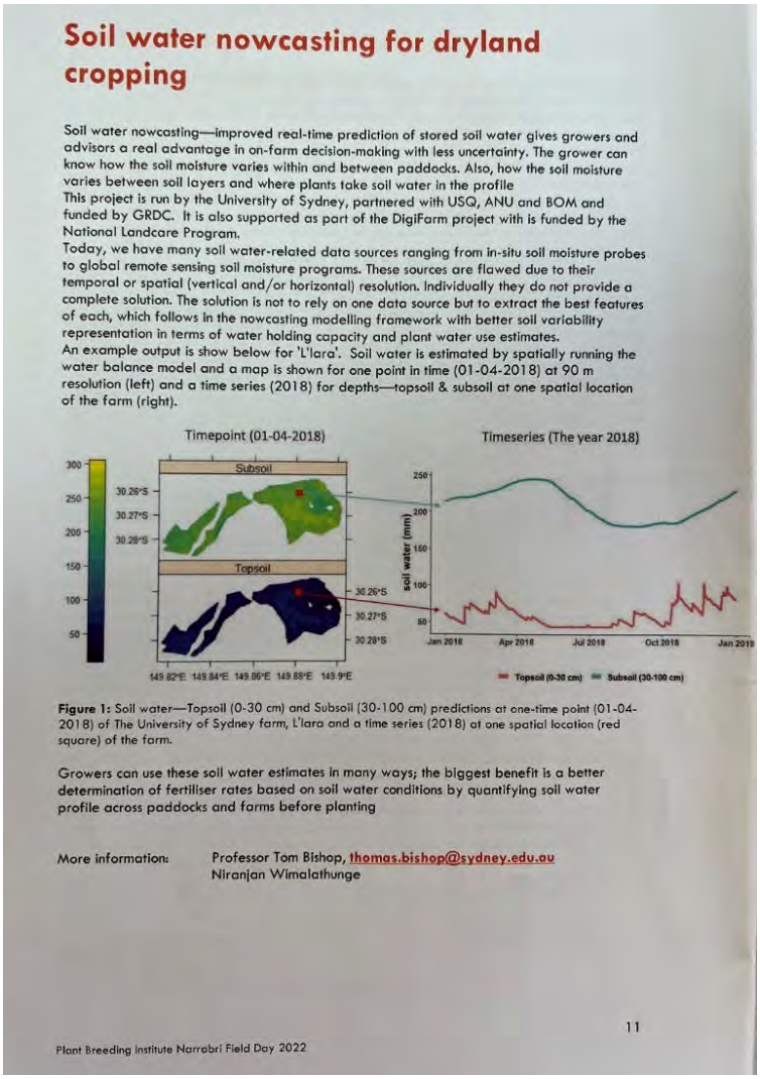
Outline the work that was undertaken on this project activity output in this period. Please include any communications (field days, publications media etc.).
The main activities relating to soil moisture in this reporting period have been the development and testing of the use of L-band radiometers to determine soil moisture. Initial testing has now concluded and next, field testing will begin at Llara Farm in Narrabri. In addition to the L-band radiometry work, soil water nowcasting and forecasting work was also included as part of the field day which was held in September 2022 (Figure 1). <u>L-Band Radiometer & Soil Moisture:</u> Soil moisture is the limiting factor in most Australian precision agricultural systems as it is highly variable spatially within a field. There is a need for better soil moisture information at the farm scale for improved farm management. Satellite-based radiometers lack spatial resolution on the farm scale; radars are hindered by vegetation, and vegetation indices, e.g., NDVI and LAI, cannot see through crops. Drone-based multi and hyper-spectral sensors can monitor the top layer of crops but have no sub-surface measuring capability. The soil moisture probes cannot quantify spatial variability. TerraRad's vehicle-mounted portable L-band Radiometer (PoLRa) uses cutting-edge microwave remote sensing technology to measure soil moisture. It is based on the same technology as the European Space Agency (ESA) Soil Moisture and Ocean Salinity (SMOS) and the NASA Soil Moisture Active Passive (SMAP) satellites use. Microwave technology can penetrate vegetation and measure sub-surface soil moisture near the crops' root zone. The sensor, which can be mounted to a vehicle to collect measurements is shown in Figure 2. Passive microwave remote sensing is another name for the use of microwave radiometers. Water increases soil's reflectivity and thus increases the contribution of "cold" space measured at the antenna. PolRa microwave radiometer operates in the 21 cm wavelength ("L-band") of the electromagnetic spectrum between 1400 and 1426

MHz. The penetration depth of L-band microwaves in the soil is 5 and 10 cm through the vegetation. The track path and the soil moisture is seen spatially in Figure 3 on 25th January 2023 of Eveleigh Green in Australian Technology Park in Redfern, Sydney, Australia.

This technology can also measure vegetation moisture (Optical Depth) by measuring the antenna's microwave power at two independent polarisations.

This result is the initial testing of the instrument and will commence the actual field testing at Narrabri, Llara University farm. PolRa, the Ground-based L-band radiometer, can be used to survey a large area that estimates the soil moisture at a point in time for important decision-making, e.g., when to sow, determine fertiliser rates, etc., in precision agriculture systems. This can be achieved by assimilation of the observations into a water balance model.

What evidence is available? (Please provide photographs, copies of communications materials etc.)



Soil water nowcasting for dryland cropping

Soil water nowcasting—improved real-time prediction of stored soil water gives growers and advisors a real advantage in on-farm decision-making with less uncertainty. The grower can know how the soil moisture varies within and between paddocks. Also, how the soil moisture varies between soil layers and where plants take soil water in the profile

This project is run by the University of Sydney, partnered with USQ, ANU and BOM and funded by GRDC. It is also supported as part of the DigiFarm project with is funded by the National Landcare Program.

Today, we have many soil water-related data sources ranging from in-situ soil moisture probes to global remote sensing soil moisture programs. These sources are flawed due to their temporal or spatial (vertical and/or horizontal) resolution. Individually they do not provide a complete solution. The solution is not to rely on one data source but to extract the best features of each, which follows in the nowcasting modelling framework with better soil variability representation in terms of water holding capacity and plant water use estimates.

An example output is show below for 'L'lara'. Soil water is estimated by spatially running the water balance model and a map is shown for one point in time (01-04-2018) at 90 m resolution (left) and a time series (2018) for depths—topsoil & subsoil at one spatial location of the farm (right).

Timepoint (01-04-2018) Timeseries (The year 2018)

Subsoil Topsoil

30.26°S 30.27°S 30.28°S

149.82°E 149.84°E 149.86°E 149.88°E 149.9°E

soil water (mm)

Jan 2018 Apr 2018 Jul 2018 Oct 2018 Jan 2019

Topsoil (0-30 cm) Subsoil (30-100 cm)

Figure 1: Soil water—Topsoil (0-30 cm) and Subsoil (30-100 cm) predictions at one-time point (01-04-2018) of The University of Sydney farm, L'lara and a time series (2018) at one spatial location (red square) of the farm.

Growers can use these soil water estimates in many ways; the biggest benefit is a better determination of fertiliser rates based on soil water conditions by quantifying soil water profile across paddocks and farms before planting

More information: Professor Tom Bishop, thomas.bishop@sydney.edu.au
Niranjan Wimalathunge

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Plant Breeding Institute Narrabri Field Day 2022

Figure 1: Extract from Narrabri Field Day 2022 Brochure - Soil Water Nowcasting for Dryland Cropping

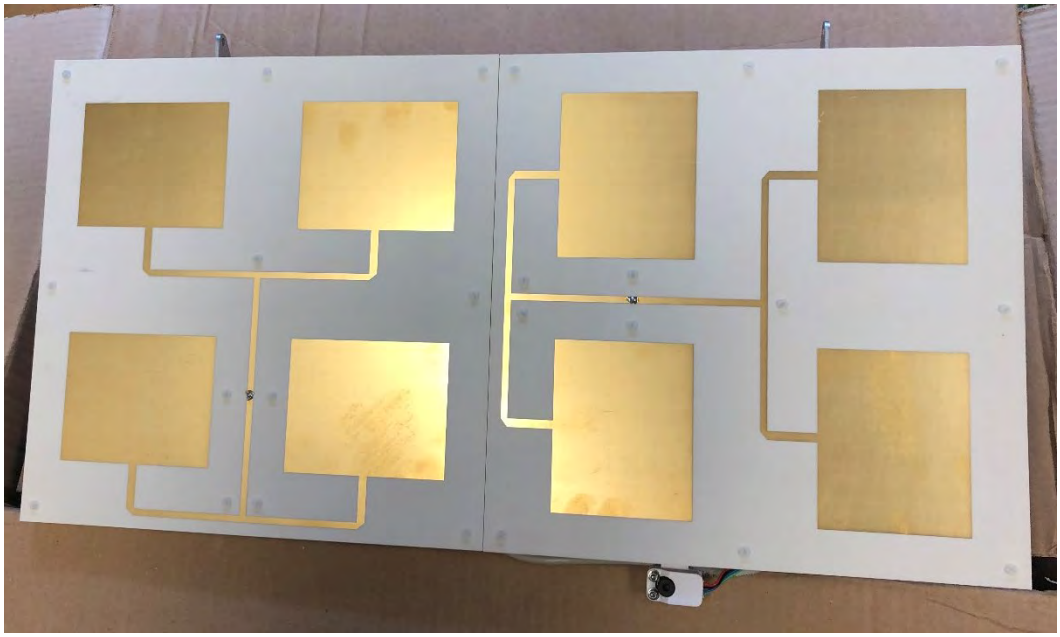

Figure 2: The L-band radiometer (PoLRa).

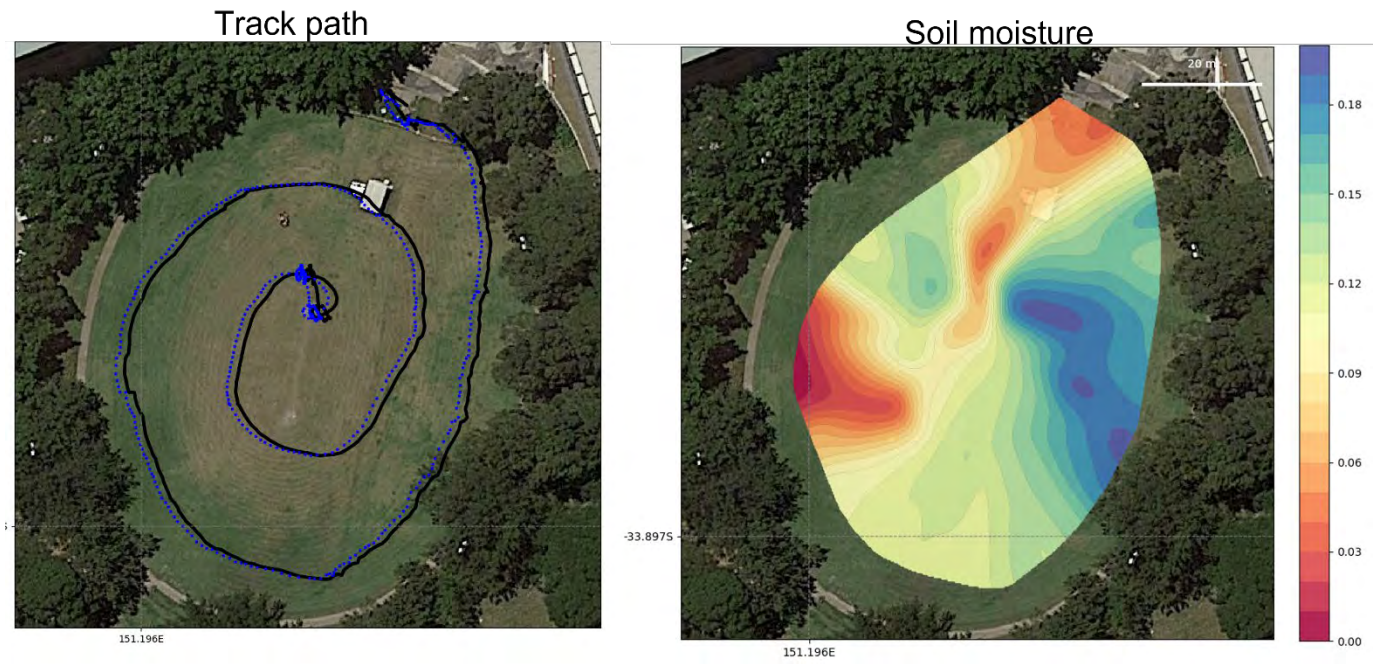

Figure 3: Track path and the soil moisture of Eveighly Greens in Australian Technology Park, Redfern, measured from the Polra on 25th January 2023.

Can you quantify the impact of this project activity? *(Count of X number of events, Y count of publications etc.)*
1 Event – Field Day – September 2022

Project Activity 2

Project Activity Output name *(As per the Work Plan)*
Remote and automated farm sensing

Activity status as of this reporting period

Planned	Started	Underway	Finished	Delayed
☐	☐	☐	☒	☐

Is this project activity on track?	**Yes** ☒	**No** ☐

If No, what is being done to remedy the situation and put it back on track:
Outline the work that was undertaken on this project activity output in this period. Please include any communications (field days, publications media etc.).
The project activities for the remote and automated farm sensing activities have now been completed with the data currently being analysed and compiled into the final report.
What evidence is available? (Please provide photographs, copies of communications materials etc.)
The data is currently being compiled and analysed in preparation of the final report.
Can you quantify the impact of this project activity? *(Count of X number of events, Y count of publications etc.)*
This activity is now complete – 0 Events or Publications in this reporting period.

Project Activity 3

Project Activity Output name *(As per the Work Plan)*
DigiFarm data management

Activity status as of this reporting period

Planned	Started	Underway	Finished	Delayed
☐	☐	☐	☒	☐

Is this project activity on track?	**Yes** ☒	**No** ☐

If No, what is being done to remedy the situation and put it back on track:

Outline the work that was undertaken on this project activity output in this period. Please include any communications (field days, publications media etc.).
The Farm dashboard is complete and continues to be operational and used regularly. Data from soil probes for temperature and moisture is stored on the Pairtree platform (Figure 1) as well as mapping data which is entered, stored and managed via the data integration platform, also powered by Pairtree. The use of the dashboard was also demonstrated at the Field Day on 15th September 2022 (Figure 2).
What evidence is available? (Please provide photographs, copies of communications materials etc.)

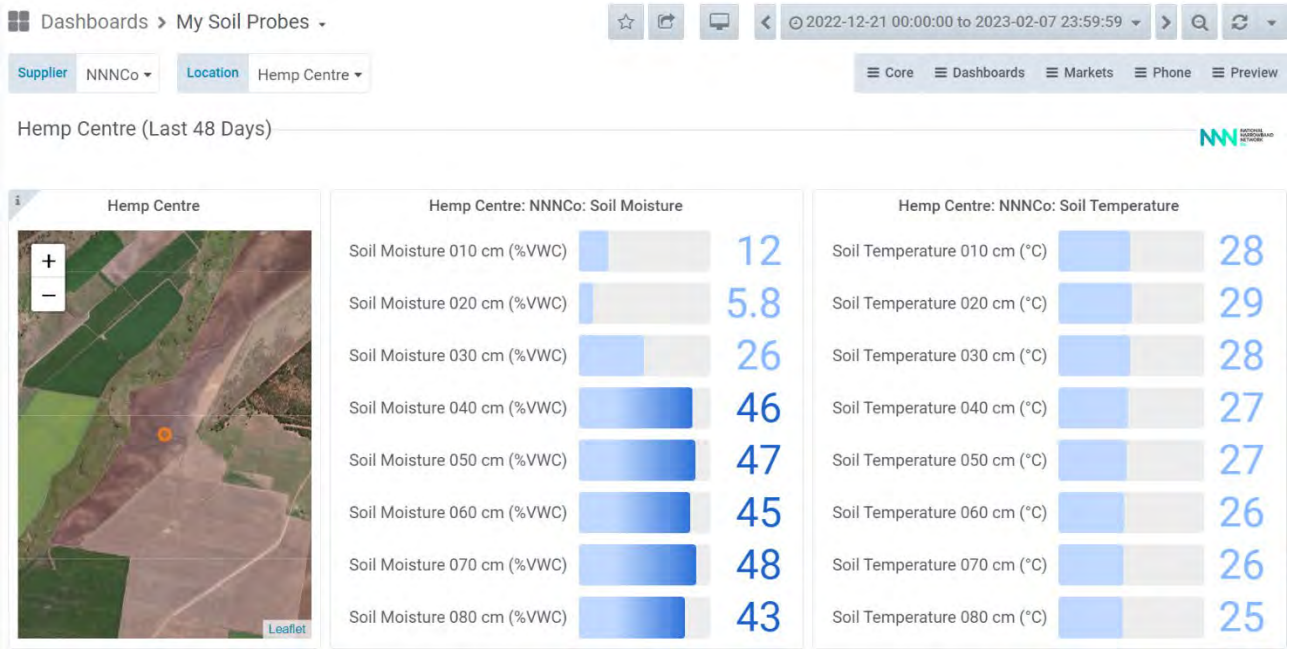

Figure 1: Soil moisture and temperature data displayed and stored on the Pairtree dashboard.

Figure 2: Pairtree dashboard being demonstrated at Narrabri Farm field day on 15th September 2022.

Can you quantify the impact of this project activity? *(Count of X number of events, Y count of publications etc.)*

1 Event – Field Day – September 2022

Project Activity 4

Project Activity Output name *(As per the Work Plan)*
Cropping and farm management systems

Activity status as of this reporting period

Planned	Started	Underway	Finished	Delayed
☐	☐	☒	☐	☐

Is this project activity on track?	**Yes** ☒	**No** ☐

If No, what is being done to remedy the situation and put it back on track:

Outline the work that was undertaken on this project activity output in this period. Please include any communications (field days, publications media etc.).

John Deere Cotton Planting Experiment

The third season of the field trial in partnership with Dryland Cotton Growers Association and John Deere was planted in November 2022. Data has been gathered from the trial for emergence, singulation and skips during November and December 2022 and a drone flight was also carried out in December 2022. The photos in Figure 1 show the crop at various stages of growth in December 2022 and January 2023. A media release on Facebook was also done in December 2022 (Figure 2).

AgriFutures Hemp Variety Trial:

In December 2022, the first time of sowing of a variety trial of low tetrahydrocannabinol (THC) industrial hemp was planted. To become a valuable crop in Australia, the industry requires an increased scale of production, access to regionally suitable varieties, better understanding of the agronomy and more efficient mechanisation for harvesting and processing. The project is funded by the AgriFutures Emerging Industries Program with the current trial focussing on researching the performance of different varieties from around the world. This aims to improve access to regionally suitable varieties in order to establish industrial hemp as a profitable industry in Australia.

Following the demonstration of the soil probes at the field day in September 2022, DigiFarm has been involved in the project through the use of the soil probes (Figures 3 & 4) to record data for soil temperature and moisture (Figures 5 & 6). A drone flight over the crop was also carried out in December 2022 to analyse emergence (Figure 7). Figures 8 & 9 show the crop approximately 2 months after sowing.

A field day for farmers and growers to inspect the crop was held on 14th February 2023 with Figures 10 and 11 showing the media releases associated with it via Facebook and the local newspaper and Figure 12 showing a photo from the day.

What evidence is available? (Please provide photographs, copies of communications materials etc.)

Figure 1: John Deere Cotton Trial crop at different growth stages - December 2022 (Top Row & Bottom Left) and January 2023 (Bottom Right)

Figure 2: Facebook media release about the John Deere Cotton Seeding Rate Trial – December 2022

Monitoring Soil Moisture

Use of capacitance probes in dryland cropping

At a study site in Mullaley, the change in soil moisture measured by soil coring near the probe reflected the change in soil moisture measured by the capacitance probe, giving confidence that probes accurately reflected changes in soil moisture.

How is this useful?

Cropping in Australia is limited by moisture supply, and in Northern cropping areas soil moisture is of particular importance. However, some methods of measuring soil moisture are time and labour intensive. Capacitance probes now offer remote real-time access to soil moisture levels.

How does it work?

Capacitance is defined as the amount of charge a substance can hold. Capacitance probes work by measuring the change in capacitance of soil related to changes in moisture content. This can be used to monitor changes in soil moisture over time.

Pros/Cons to the use of capacitance probes

- The lower labour input involved (installation and maintenance is usually carried out by a service provider) and remote access to data is appealing to growers.
- The volume of soil with which the probe interacts is quite small, meaning the placement of the probe is important.
- To understand variation in soil moisture across an area multiple probes at increased cost are required and cost is still a deterrent to wider application.
-

What's next?

Greater use of capacitance probes in dryland crops and fallows will depend upon reductions in cost, particularly if the industry is to move towards spatial management of water. This technology may become linked to crop growth models that provide real-time estimations of potential yield.

To find out more

Name: Bill Manning
Mobile: 0428 607 731
Email: william.manning@lls.nsw.gov.au

NSW GOVERNMENT Local Land Services

Figure 3: Extract from Field Day Brochure from September 2022 where the use of soil probes was demonstrated

Figure 4: Low THC Hemp trial in January 2023 showing soil probes used to record soil moisture and temperature

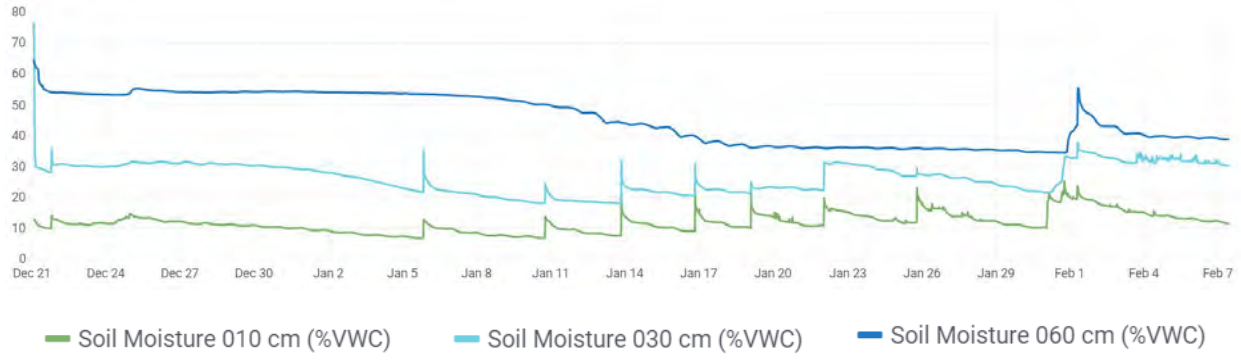

Figure 5: Soil moisture (%VWC) at different depths of the soil profile in low THC industrial hemp trial

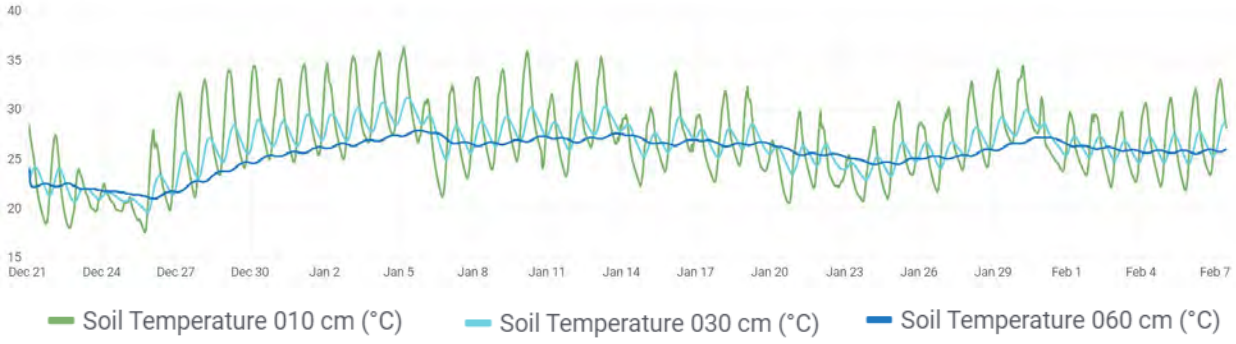

Figure 6: Soil temperature (ºC) at different depths of the soil profile in low THC industrial hemp trial

Figure 7: Images from drone flights in December 2022 (upper photos) and January 2023 (lower photo)

Figure 8: Two of the low THC industrial hemp varieties being trialled in January 2023.

Figure 9: Guy Roth, Ed Chaplin & John Bateman with the low THC hemp trial in January 2023.

Figure 10: Facebook media release about the Low THC Hemp Variety Trial Field Day – January 2023

THE COURIER THURSDAY, FEBRUARY 9, 2023

MARKETPLACE

The Industrial Hemp Varietal Trial is being conducted at the University of Sydney in Narrabri and is funded by the AgriFutures Emerging Industries Program. Pictured, Guy Roth, Ed Chaplin and John Bateman.

Growers invited to learn more about industrial hemp at University of Sydney field day

The University of Sydney, Narrabri, is holding a field day event about the Industrial Hemp Varietal Field Trial currently taking place which is funded by the AgriFutures Emerging Industries Program.

Farmers and growers interested in finding out more about the crop are invited to inspect the site and find out more at a field day on Tuesday, February 14 from 9 to 11am.

Industrial hemp has a low level of tetrahydrocannabinol (THC) with the industrial hemp industry currently experiencing significant growth.

It has a wide range of uses including value-added food products for human consumption, textiles, paper, rope, fuel, oil, stockfeed, building materials, cosmetics and pet food.

However, to become a valuable crop in Australia, the industry requires an increased scale of production, access to regionally suitable varieties, better understanding of the agronomy and more efficient mechanisation for harvesting and processing.

The current trial is focussing on researching the performance of different varieties from around the world.

This aims to improve access to regionally suitable varieties in order to establish industrial hemp as a profitable industry in Australia.

Associate Professor Guy Roth, Director of Northern Region Agriculture at the University of Sydney, says "we are trialling varieties from across the world in order to better understand the suitability of different varieties to climates across Australia."

For more information about the field day event and to register your interest, call Ed Chaplin from the University of Sydney on 0435 577 722.

INDUSTRIAL HEMP FIELD DAY EVENT

Date: Tuesday, February 14, 2023
Time: 9:00-11:00am
Location: University of Sydney, Newell Highway, Narrabri

For more information and registration call Ed Chaplin from the University of Sydney on

0435 577 722

THE UNIVERSITY OF SYDNEY

Figure 11: Local newspaper article advertising the field day event for the AgriFutures low THC hemp variety trial in February 2023.




Figure 12: Hemp Field Day Photos – 14th February 2023

Can you quantify the impact of this project activity? *(Count of X number of events, Y count of publications etc.)*
1 Publication in Local Newspaper – February 2023 *2 Field Day Event held for local growers and farmers – September 2022 & February 2023*

Project Activity 5

Project Activity Output name *(As per the Work Plan)*
Livestock management and pastures **Balancing productivity and environmental management in beef cattle production**

Activity status as of this reporting period

Planned	Started	Underway	Finished	Delayed
☐	☐	☒	☐	☐

Is this project activity on track?	**Yes** ☐	**No** ☒

If No, what is being done to remedy the situation and put it back on track:
In both commercial sites we experienced delays due to flooding and lack of livestock staff on northern farms

Outline the work that was undertaken on this project activity output in this period. Please include any communications (field days, publications media etc.).
We have been concentrating our efforts on developing prediction equations for the chemical composition of livestock feedstuff, greenhouse emissions and supplement intake of grazing cattle from faecal samples using a smartphone NIRS sensor. We have previously reported on the use of a smartphone NIRS sensor to scan faecal samples of beef cattle and predict greenhouse emissions, supplement intake and performance of individual animals. This work continues with these sensors to measure chemical composition of the diet consumed by animals, performance, emissions and feedstuff evaluation.

What evidence is available? (Please provide photographs, copies of communications materials etc.)

Figure 1. Yard set-up for collecting LW, supplement intake and emissions data, and greenhouse gas emissions

Figure 2. Identification of wet faecal samples post thawing

Figure 3. NIRS scanning of wet faecal samples using the handheld NIRVAScanTM device

Figure 4. Wet samples being dried at 65°C for 72 hours

Figure 5. Dried faecal samples prior to NIRS scanning

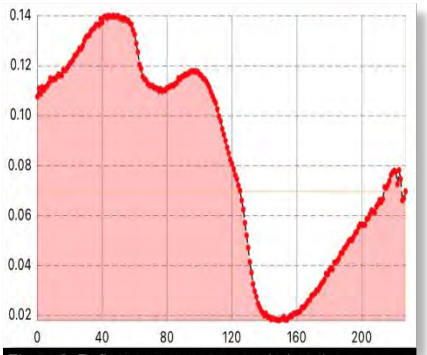

Figure 6. Reflectance spectra recorded on the NanoScan mobile app and used for statistical analysis

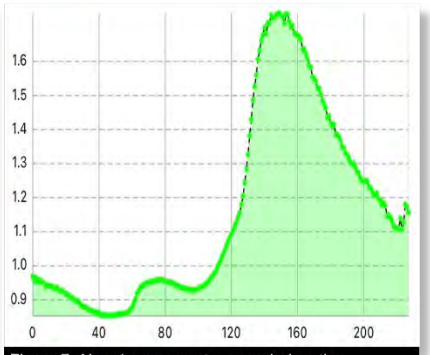

Figure 7. Absorbance spectra recorded on the NanoScan mobile app and used for statistical analysis

Can you quantify the impact of this project activity? *(Count of X number of events, Y count of publications etc.)*

We are now refining the algorithms/prediction equations from the NIRS sensor and drafting a paper for publication on the topic. There is interest from the livestock industries to have a sensor that can operate on farm for livestock applications.

Project Activity 6

Project Activity Output name *(As per the Work Plan)*
Precision Weed Management

Activity status as of this reporting period

Planned	Started	Underway	Finished	Delayed
☐	☐	☒	☒	☐

Is this project activity on track?	**Yes** ☒	**No** ☐

If No, what is being done to remedy the situation and put it back on track:

Outline the work that was undertaken on this project activity output in this period. Please include any communications (field days, publications media etc.).

Autonomous Spot Spraying Technology:

The Open Weed Locator (OWL) autonomous spot spraying technology was demonstrated at the Field Day in September 2022 (Figure 1). It is a digital camera-based weed detection system which allows site-specific fallow and fence line weed control.

John Deere See & Spray Weed Assessment Trial:

We have 2 trial sites (Llara & Edgeroi) where we are carrying out a weed assessment trial with John Deere as part of their 'See and Spray' weed technology. They have provided their 'See and Spray' equipment as their contribution to the project. Using computer vision and advanced technology, the see and spray machine target sprays weeds in fallow fields which significantly reduces herbicide use by applying only what is required. By only spraying weeds, this significantly reduces herbicide use by upto 77%, leading to lower input costs and reduced drift.

The targeted sprayer has small cameras which are integrated into the boom which continuously scan the field and send data to the sprayer's vision processing unit. The See and Spray select's processors detect the colour green and apply non-residual herbicide only on weeds. Once weeds are identified, specific nozzles are activated to target spray under them. The number of nozzles activated varies based on weed pressure within that part of the field. In addition to this, the in-cab display documents where herbicide was applied in order to produce a coverage map to track performance and make weed management decisions (Figure 2)

The first spray applications of the trial using the See and Spray technology were carried out in January 2023, as pictured in Figure 3.

What evidence is available? (Please provide photographs, copies of communications materials etc.)

OpenWeedLocator (OWL)

Image-based, DIY weed detection system

What is the OpenWeedLocator (OWL)?

The OWL uses a Raspberry Pi computer and green-detection algorithms to provide a low-cost, DIY option for image-based weed detection.

Community Development via GitHub

Built globally: *US, Canada, UK, Australia, France*
Used for: spot spraying herbicide, desiccant, fungicide; hooded sprayers; robot/ute-mounted.

Why is this research important

- Image-based weed recognition for site-specific weed control is becoming more widely available.
- DIY, low-cost, system puts development in the hands of farmers. Determining impact of speed and software on performance is important for farmers.
- OWL is an educational opportunity.

What is the next step for this research

- Understanding new camera options and settings under day/night conditions and at different speeds.
- Implementing weed recognition algorithms to recognize weeds in-crop instead of green-only.
- Continuing to improve useability of and engagement with the device. OWL is an educational opportunity.

Further potential improvements

- New global shutter camera modules
- More powerful artificial lighting

To find out more

Angus Macintyre
Dr. William Salter
Guy Coleman E: guy.coleman@sydney.edu.au Twitter: @geezacoleman

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Plant Breeding Institute Narrabri Field Day 2022

Weed Mapping

Spot spraying technology

Spray nozzle activates in the vicinity of piece of Astro-turf that was previously mapped using a drone.

Why is this useful?

Increased levels of herbicide resistance and community concern about use of pesticide have forced the industry to look for alternate strategies for weed management.
Spot spraying technology has become increasingly popular over the last several decades for maintaining fallows. This technology senses green plant material as a spray boom passes over and triggers a spray nozzle (s) to selectively spray fallow weeds leaving bare ground unsprayed.

How does it work?

This technique involves several steps commencing with a photographic survey completed of the fallow paddock completed by a drone. The photographs are then stitched together to produce a mosaic which is then analysed by software to identify the position of weeds. A map of targets is produced that can be read by the spray controller to trigger the appropriate nozzles or section of boom as the sprayer passes over the targets.

Pros/Cons

- The main advantage of this technology is the capital saving that can be made by using existing boomsprays to function as "spotsprayers".
- Savings in herbicide can be made, as only a small proportion of the paddock is sprayed which may in turn enable the use of higher rates of more expensive chemicals to be used on hard to kill weeds.
- The time and cost needed to to fly the drone, stitch the images, correct the GPS data, produce a map and load the map into the sprayer in between weed germination and spraying could make this method unsuitable in some settings.

What's next?

The increasing number of dedicated spot boomsprays are reducing the potential for this technology, and beyond that "green on green" spray technology which uses image recognition to target weeds in crops and pasture may also find use in fallow situations. There may be application in situations of extremely low weed populations where the cost of running a boomspray is not justified. In this situation a weed map could guide an operator to individual weeds which could then be chipped by hand.

To find out more

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NSW GOVERNMENT Local Land Services

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Plant Breeding Institute Narrabri Field Day 2022

Figure 1: Extracts from Field Day Brochure (September 2022) where The Open Weed Locator (OWL) technology for image based DIY weed detection and spot spraying technology was demonstrated.

Figure 2: John Deere See & Spray Technology for Precision Weed Management. Top Left – Cameras to scan and detect weeds, Top Right – Vision Processing Weed Identification Unit, Bottom Left – Activation of only required nozzles, Bottom Right – In cab display to record herbicide applications.

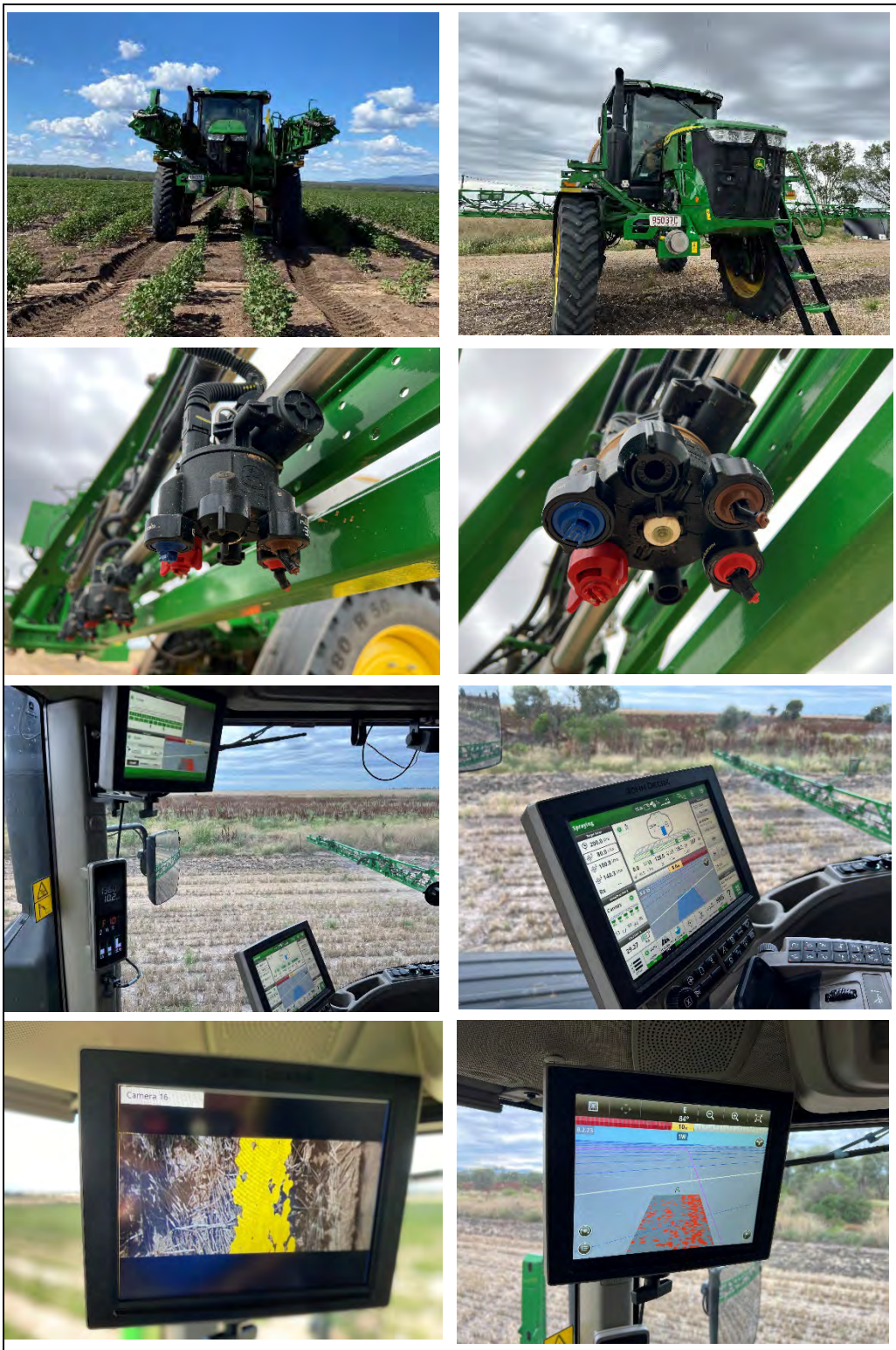


Figure 3: John Deere See & Spray Technology for Precision Weed Management being used for the weed assessment trial – February 2023

Can you quantify the impact of this project activity? *(Count of X number of events, Y count of publications etc.)*

Further information about the See & Spray Technology available on the John Deere Website - See & Spray™ Select | Sprayers | John Deere AU

Project Activity 7

Activity Output name *(As per the Work Plan)*
Soil Health Systems

Project Activity status as of this reporting period

Planned	Started	Underway	Finished	Delayed
☐	☐	☒	☒	☐

Is this project activity on track?	**Yes** ☒	**No** ☐

If No, what is being done to remedy the situation and put it back on track:

Outline the work was undertaken on this activity output in this period. Please include any communications (field days, publications media etc).

The most advances upto Feb 2023 are in the data analysis for (a) cover crops and (b) soil biodiversity investigations. Therefore, all field and laboratory activities have ceased before the end of 2022.

(a) Results from cover crops trials: aspects related to cash crops and water

- Crops
    - Following on from the previous 6 monthly report, 2020 wheat yield data has been processed further. Harvest index cuts allowed for yield losses due to mouse pressure to be quantified. Yields as measured by combine, hand actual (harvest index), and hand potential (harvest index adjusted for the number of heads lost to mice) are shown in Figure 1 for the fallow control and three cover cropped treatments, mixed/single species and rolled or standing cover crop termination method.
    - For comparison the same measures are shown in Figure 2 for the 2021 harvest. No significant differences were observed between these comparable treatments, though yields between years differed by a factor of two.

- Water
    - Calibration work presented in the previous 6-month report have been used to monitor soil moisture throughout the trials. Capacitance probes have provided encouraging results for future water consumption methodologies. Constant monitoring allowed for daily variations in profile moisture content to be quantified, how these changes over time is shown in Figure 3 for the two wheat crops. Grey boxes indicate no communication, red bars show moisture deficits and blue increases, the y-axis is constant while the x-axis and hence bar width varies.
    - While these plots show averaged consumption across all treatments, summarising these by cover cropped and fallow plots shows a high level of agreement between probes and a measure of the moisture consumed for the dominant treatments.

- Unfortunately, given that there was missing data, caused by probe communication down time (days shown in brackets within Table 1), direct comparisons of water consumption between crops cannot be made. Regardless for the periods that were available, the 2021 crop has consumed more water, the cover cropped plots in both years also consumed considerably more water than the fallow plots. In 2021 the cover cropped plots also harvested more rainwater. The consistency of measures across the few probes considered and the ability to report in mm is encouraging for future farmer facing applications.

(b) Results from soil biodiversity analyses

- Soil biodiversity:
  - Soil biodiversity from samples taken in Aug 2019 and Dec 2020 are under analyses using different indicators for a deeper understanding of soil health. For instance, bacteria and fungi communities' relationships provide useful information. Diverse populations of soil bacteria and fungi can suppress root diseases, among other functions. Previously, we reported that both communities' diversities were lower in 2019 compared to 2020 for all land uses. Ultimately, we found that the most affected areas are drylands on clayey soils. In Figure 4, we explore these relationships in Vertosols only. For these soils, dryland shows more impacts in microbial diversity, particularly in bacteria. There is a negative relationship between bacteria and fungi (Shannon diversity) but only in dryland. In pastures, bacteria and fungi diversities are significantly positive correlated in a more wet year and most differences are between 2019 and 2020, likely related to the drought in 2019. Bacteria are generally more affected by soil chemistry than fungi, and this can be the reason for a larger impact that we need to investigate further.

What evidence is available? (Please provide photographs, copies of communications materials etc.)

Figures & Tables:

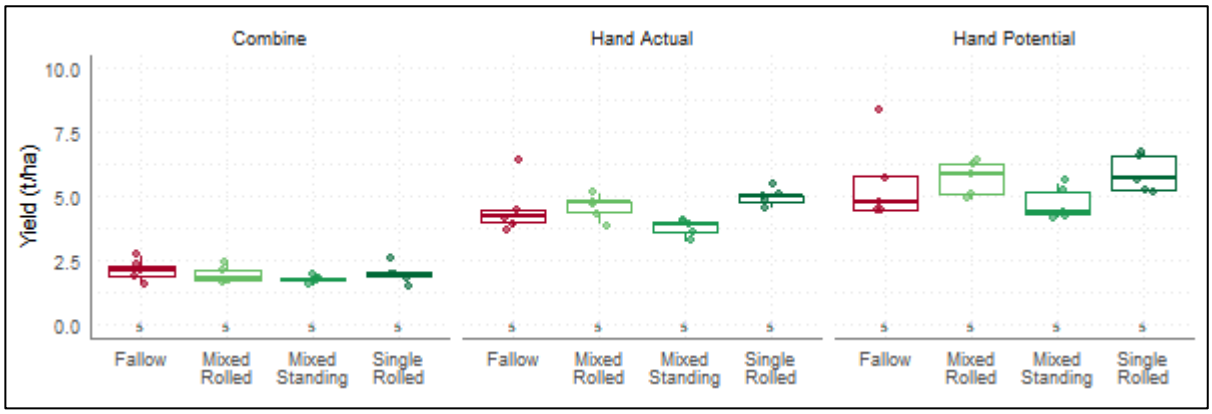


Figure 1: Trial 1 wheat yield 2020 – fertilised treatments.

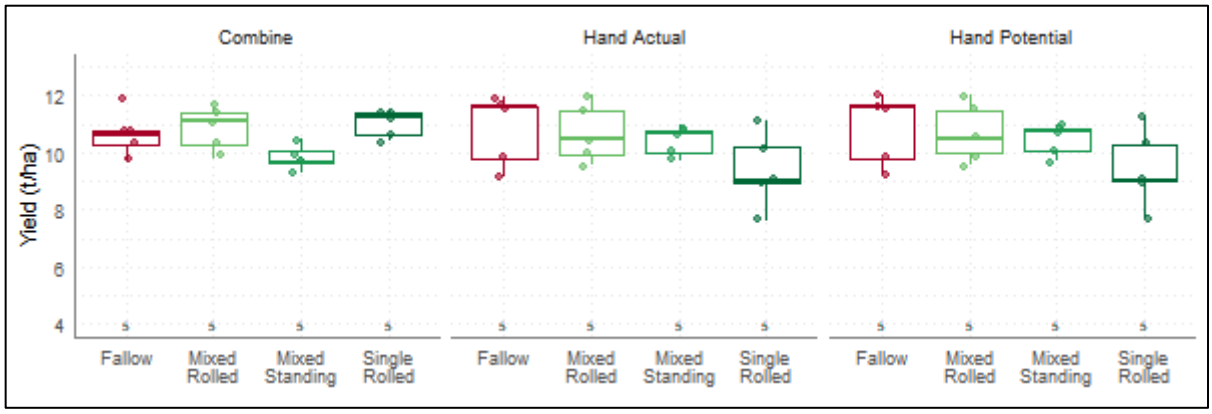


Figure 2: Trial 1 wheat yield 2021 – fertilised treatments.

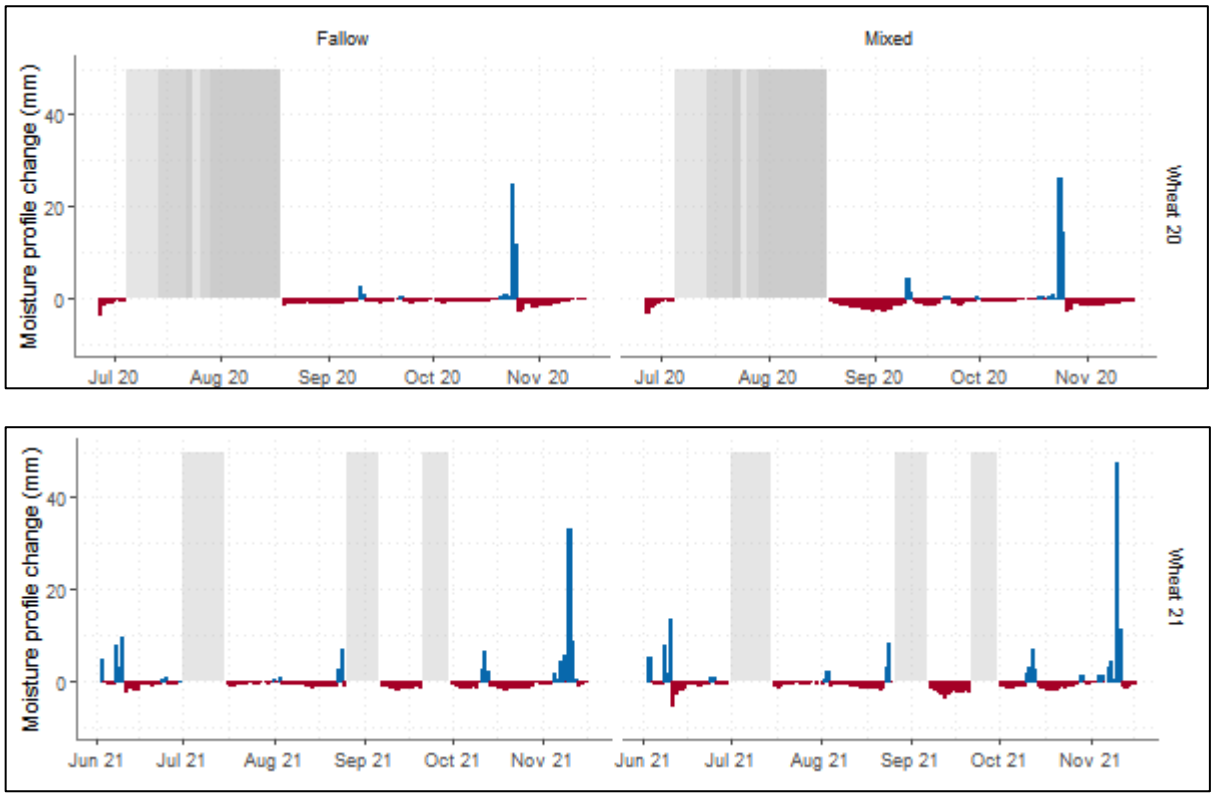


Figure 3: Trial 1 – Capacitance probes infiltration (rain harvest) and consumption

Table 1: Trial 1 rain harvest and soil moisture consumption summary

Period	Aspect	Harvest (mm) Cover	Harvest (mm) Fallow	Consumption (mm) Cover	Consumption (mm) Fallow
Wheat 2020 (97/156)	Mean	50	43	-97	-68
	Min	43	41	-90	-52
	Max	56	44	-104	-83
	Probes	4	2	4	2
	Exc.	-	-	-	-
Wheat 2021 (130/194)	Mean	130	104	-126	-99
	Min	126	104	-118	-90
	Max	137	104	-136	-107
	Probes	3	2	3	2
	Exc.	A5, 35mm	-	A5, -62mm	-

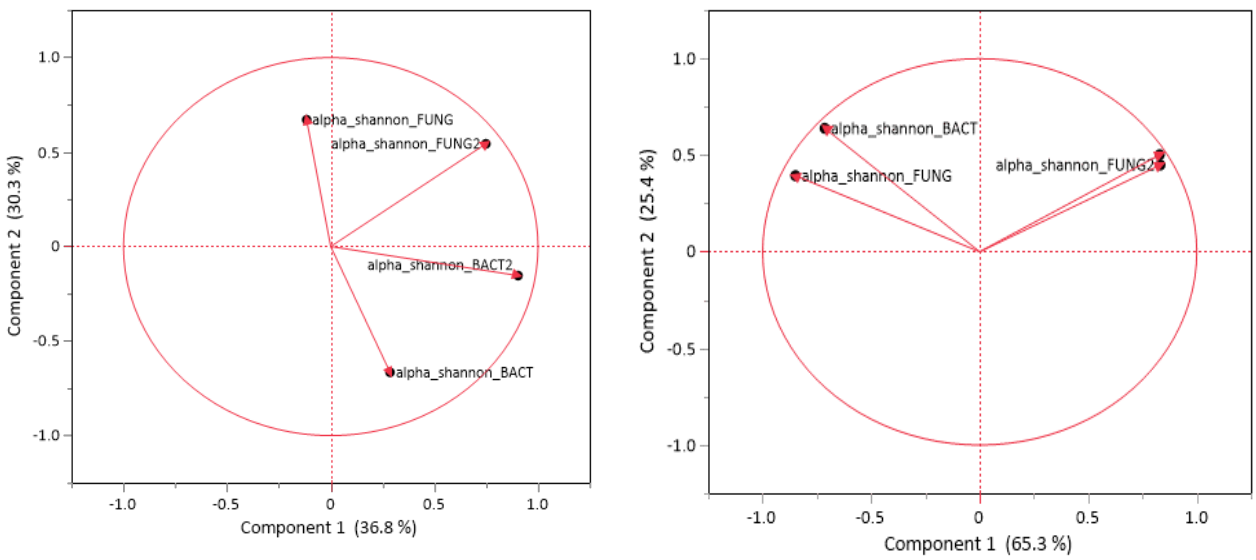


Figure 4*:* Soil bacteria and fungi diversity relationships from Aug2019 and Dec2020 in Vertosols from drylands (left) and pastures (right).

Can you quantify the impact of this project activity? *(Count of X number of events, Y count of publications etc.)*

Publications

2 publications under review, 1 publication in preparation:

The Regen Ag paper submitted in Jun, was revised in Nov and remains under review with Precision Ag Jn.

Optimising POXC effective sensitivity as a soil indicator in Australian soils.

Project Activity 8

Project Activity Output name *(As per the Work Plan)*
Feral pig collaring project

Activity status as of this reporting period

Planned	Started	Underway	Finished	Delayed
☐	☐	☐	☒	☐

Is this project activity on track?	**Yes** ☒	**No** ☐

If No, what is being done to remedy the situation and put it back on track:

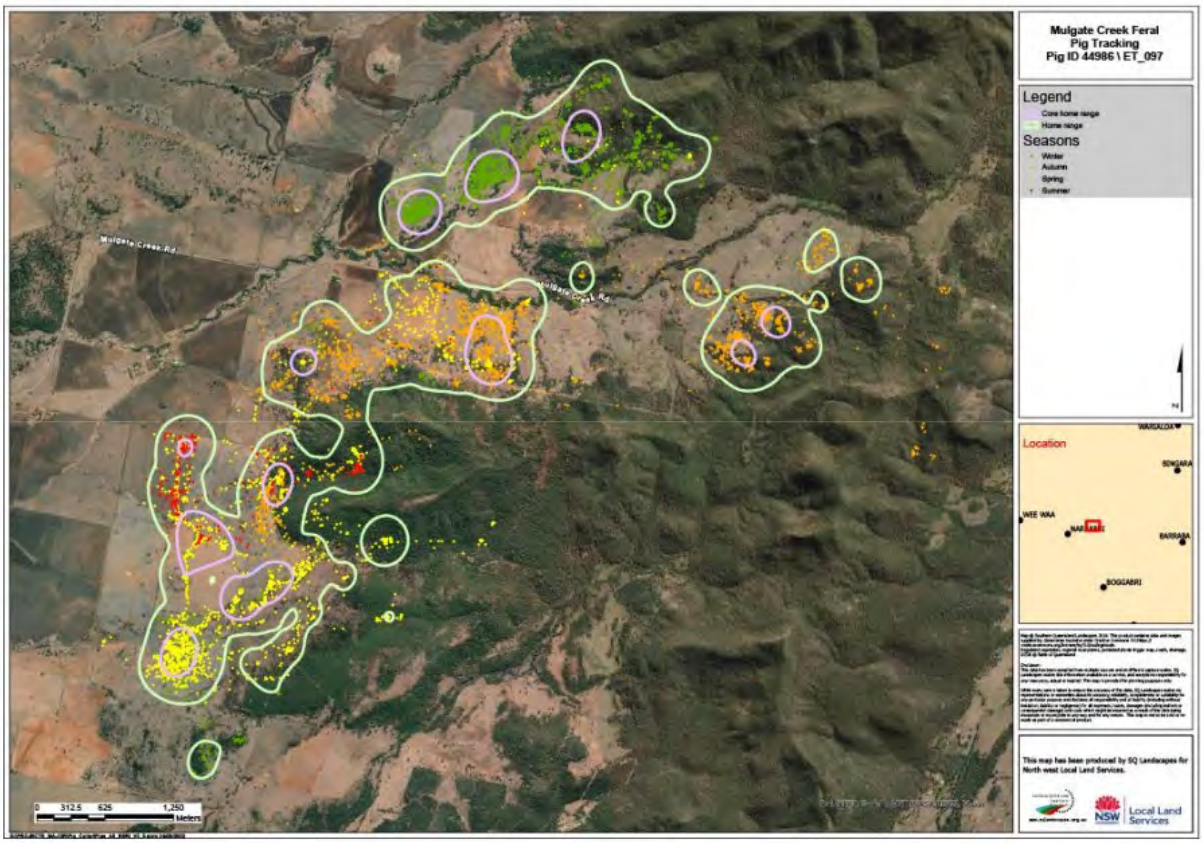
Outline the work that was undertaken on this project activity output in this period. Please include any communications (field days, publications media etc.).
All pig collars have now been retrieved in the last reporting period. Data from the past six months is being analysed currently for final report and we are planning a landholder meeting for a final update of all seasonal data. A total of fourteen individual pigs were collared during this program, eight boars and six sows. The average home and core home range to be 2.9km2 and 0.40km2 respectively. Sows were found to have home and core home ranges ≈ 70% smaller than the mean. On average boars had ≈ 5 times larger home and core home ranges than sows (Table 1). The data analysis showed that the collared pigs utilised different parts of the landscapes throughout different seasons (Fig. 1). This is valuable information when targeting this animal as it indicates that throughout the year the animal is utilising different resources and an informed decision can now be made to target that animal when it is in a more suitable locations for effective management. A field day and landholder meeting were also held in this period, including a report which was produced, extracts of which are below.

What evidence is available? (Please provide photographs, copies of communications materials etc.)

Table 1: Home and core ranges of sows and boars

Ear tag number	Sex	Home range (km^2)	Core home range (km^2)
89	Sow	0.08	0.01
90	Boar	5.76	0.83
95	Boar	2.00	0.22
97	Boar	9.52	1.39
99	Boar	2.94	0.39
100	Sow	1.51	0.21
101	Boar	0.52	0.08
102	Sow	0.80	0.12
	Average	2.90	0.40

Figure 1: Map showing movement data of Pig ID 97



Can you quantify the impact of this project activity? *(Count of X number of events, Y count of publications etc.)*

Two landholder meetings, one field day at the university and plan to have a debrief with the landholders in the coming months.

Project Activity 9

Project Activity Output name *(As per the Work Plan)*
Biodiversity, Natural Capital and Integrated Pest Management Identifying invertebrate biodiversity and encouraging the adoption of IPM practices in the dryland cropping industry through Llara.

Activity status as of this reporting period

Planned	Started	Underway	Finished	Delayed
☐	☐	☒	☒	☐

Is this project activity on track?	**Yes** ☒	**No** ☐

If No, what is being done to remedy the situation and put it back on track:

Outline the work that was undertaken on this project activity output in this period. Please include any communications (field days, publications media etc.).

DigiFarm Biodiversity Activity:

Teaching:

- BIOL3007 Ecology group project (8 students) – Vertebrate dynamics using camera traps. This project supported students who had to remotely learn.
- One Hons students (AVBS) investigating temporal and spatial trends in biodiversity on Llara from acoustic camera data. In addition, the student is investigated using AI for identifying bird calls in acoustic recordings.
- Three undergrad research placement students who've worked on DroughtNet camera data

Bird diversity:

- Update to ecoacoustic database and dashboard underway from resources from DARE.
- Code and pipeline developed to process ecoacoustic indices. Bird ecoacoustic results (Nov 2019-Sep 2021) are up-dated on internal Github Webpage (link) and dashboard.
- >51,970 hrs of audio data analysed.
- Daily ecoacoustic indices calculated from Nov 2019-Oct 2022; monthly spatial ecoacoustic layers produced.
- ~105 species of birds identified.

Terrestrial mammal diversity:

- Data collect continues (Nov-2019 – Jan 2022)

Add-on project – DroughtNet:

- Maximising the resilience of pastures to grazing and extreme drought events (Funder: Herman Slade Foundation). PhD student Elise Verhoeven.
- Cattle exclusion fencing installed, and first herd grazed experimental plots. Irrigation tanks and pipes also installed to simulate extreme rainfall.
- Summer 2022/23 survey completed, and nutrient treatments applied. Preliminary results show plant diversity and biomass are responding to precipitation, nutrient, and grazing treatments. Nutrient addition increased biomass and reduced plant diversity in ambient and extreme rainfall plots. Nutrient addition had no effect on biomass, but still reduced diversity under drought conditions. Grazing did not mediate the increase in biomass where nutrients were added in ambient and extreme rainfall plots. Grazing reduced plant biomass and increased diversity under drought conditions, but had no effect where nutrients were added.
- Phenocams are installed and have been collecting since Oct 2020. Preliminary results indicate a greening effect from nutrient addition to pastures and seasonal changes. In addition, there is a productivity response to drought with reduced productivity during the growing season and delayed vegetation green-up. These results were presented at the Northwest Slopes Landcare Seed Conservation Training and Research Workshop in August 2022 and the Plant Breeding Institute field day in September 2022.
- Data sharing with international DroughtNet experiment for global analysis, and plant samples will be sent to Utrecht University in The Netherlands to contribute to a global plant nutrient availability study in March 2023.

Summer Scholarship Students

During this reporting period, two groups of summer scholarship students from the University of Sydney produced the reports from their projects carried out on Llara farm relating to natural capital and biodiversity. One student 'Analysed Avian Bird Diversity in a Farm Landscape' while the title of another student's project was 'Monitoring grass tree and eucalyptus species in agricultural land-adjacent native forest'. The abstracts and key figures from each project are given below.

Avian Bird Diversity Project:

Australia is heavily reliant on agriculture for food supplies to support a constantly growing population. However, consequent mass land modifications as a result of farming practices often result in a decline in bird species and abundance. Therefore, analysing avian populations and species presence is often a key indicator of biodiversity status, and proves useful in agricultural regions, as it can help farmers improve general farm health and productivity.

This investigation involved analysing data from previously collected bird surveys based on visual and auditory observations, across six sites (dam, grassland, cropland, woodland, State Conservation Area (SCA) and garden) in the NSW agricultural region of Narrabri. The dataset was collected between February 2019 and September 2022. This study explored the trends and differences in bird species richness (amount of unique species) and abundance (amount of birds total) across different land uses to assess how farming practices may affect avian biodiversity. Furthermore, we also investigated whether the drought of 2019-2020 and seasonal variations caused fluctuations in avian populations.

The results showed an increasing trend in both avian species abundance and richness throughout the investigated timeframe, suggesting a stable recovery from the drought period. Species abundance was highest in SCA and dam area, with a total abundance of 1897 and 2197 birds (respectively), compared to the cropland area which had the lowest value of 359. Similarly, the SCA and dam area recorded 75 and 80 unique species, while cropland had 15. This can be attributed to the more complex and diverse vegetation compared to the cropland area which is mostly made up of crop monocultures, as well as greater water sources available in the dam area, especially during the drought. The knowledge acquired from this study can assist farm managers in monitoring biodiversity levels to ensure the continuing productivity and effectiveness of their farmland.

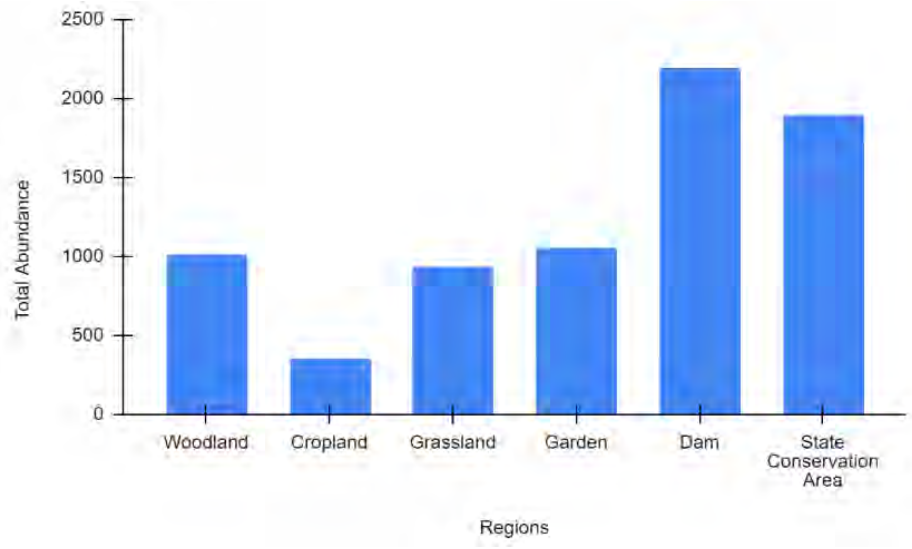


Figure 1: Total abundance (bird count) of each of the six regions on the Narrabri farm, obtained by a cumulative sum of abundance in each survey. This data was taken between May 2019 to September 2022

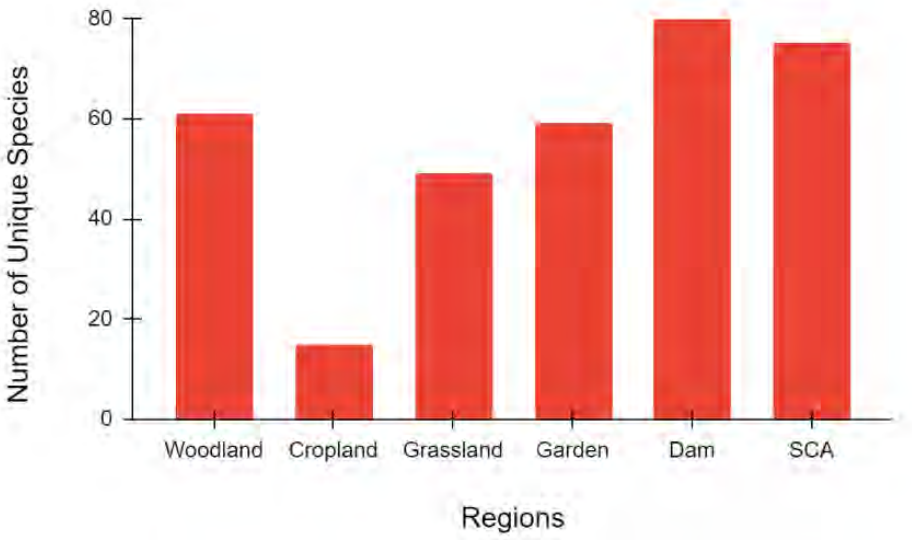


Figure 2: Total richness (unique species count) of each of the six regions on the Narrabri farm, obtained by analysing whether a particular species was recorded at least once during the 3.5 years (May 2019 to September 2022).

Native Vegetation Project:

The University of Sydney owns a commercial farm of 1830 hectares in Narrabri in northwest New South Wales. As the composition and health of the native vegetation adjoining the farm remains largely unsurveyed, this investigation initiates the ongoing monitoring of biodiversity by mapping and establishing a database on grasstrees (Xanthorrhoea johnsonii) and eucalypts (Eucalyptus camaldulensis and Eucalyptus melanophloia) in Llara Forest and Mulgate Creek, respectively. For each species, height, trunk circumference and GPS data (using a real-time kinematic device) were collected. In total, 519 trees were recorded. Their distribution was mapped using the Google Earth and QGIS software and uploaded to the iNaturalist and Campus Flora databases. When mapped, a greater proportion of taller grass trees (>100 cm) were found in the eastern region of the habitat due to soil variation, species competition and plant cover being potential factors. Juvenile river red gums were most abundant along Mulgate Creek, with three large clusters identified. This indicated that the heavy flooding of 2020 was a contributing factor to their capacity to survive and reproduce, and in turn their potential for forming future wildlife corridors. Tree height and diameter were strongly correlated (positively) for eucalyptus species, but weakly correlated for grass trees. These primary survey findings will enable future researchers to test hypotheses while adding to the database in an ongoing effort to monitor and improve the farm's biodiversity credentials.

Figure 1: Distribution of grasstrees (*Xanthorrhoea johnsonii*) on Llara and Campey Farm.

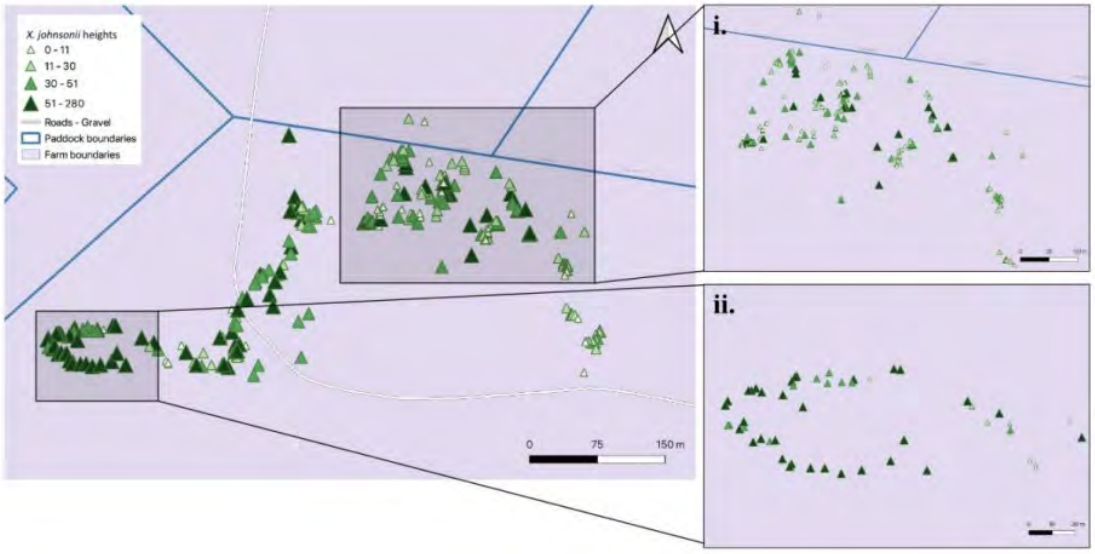


Figure 2: Distribution grasstrees (*X. johnsonii*) on Campey Farm and Llara constructed using QGIS. Grass trees are categorized by height. To the right, a zoomed in maps (i.) and (ii.) show heights of grass trees are spatially distributed, with taller trees in the western region (ii.) and shorter trees in the eastern region (i.).

Figure 1: Distribution of eucalypts (*E. camaldulensis and E. melanophloia*) on Llara and Campey Farm.

What evidence is available? (Please provide photographs, copies of communications materials etc.)

DigiFarm – Biodiversity:

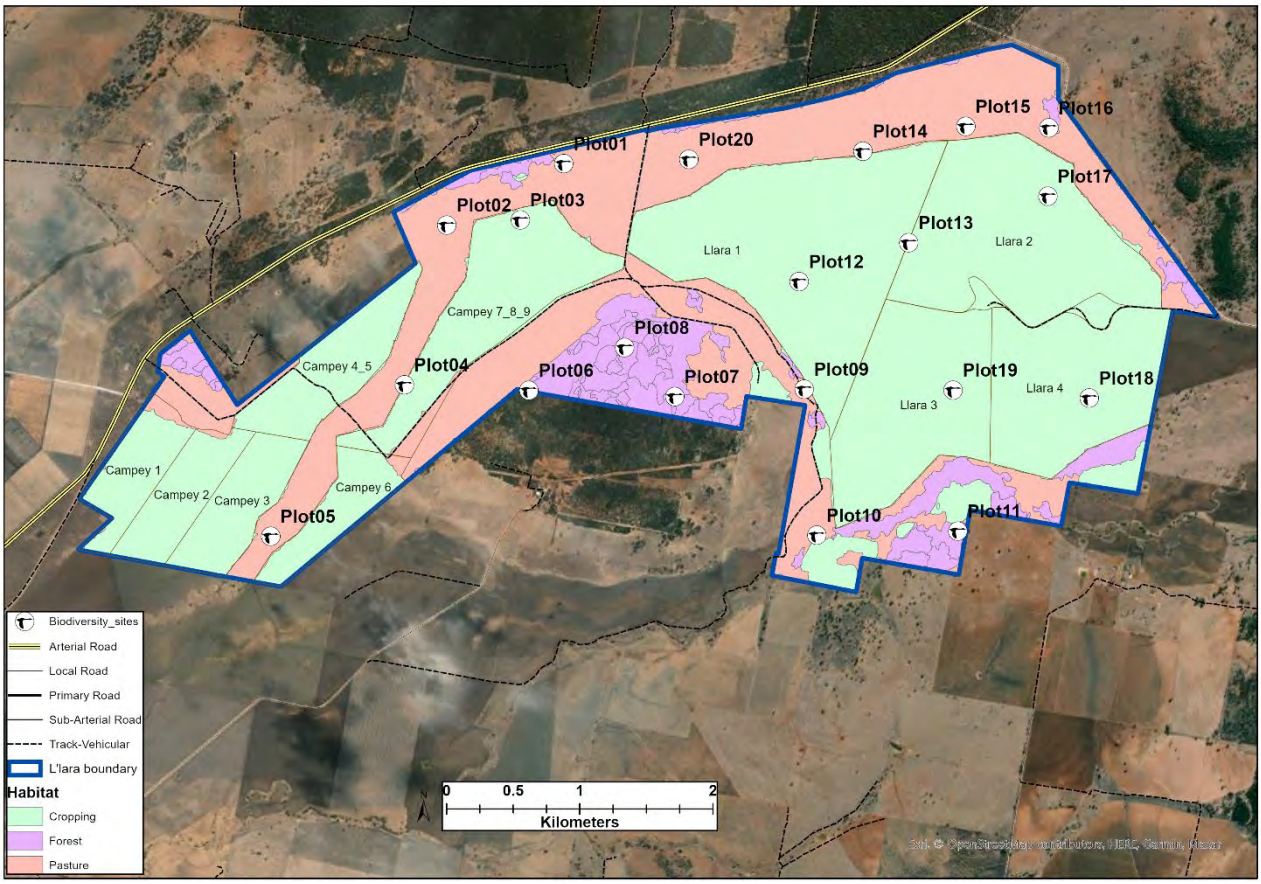


Figure 1: Habitat types and monitoring plots on Llara.

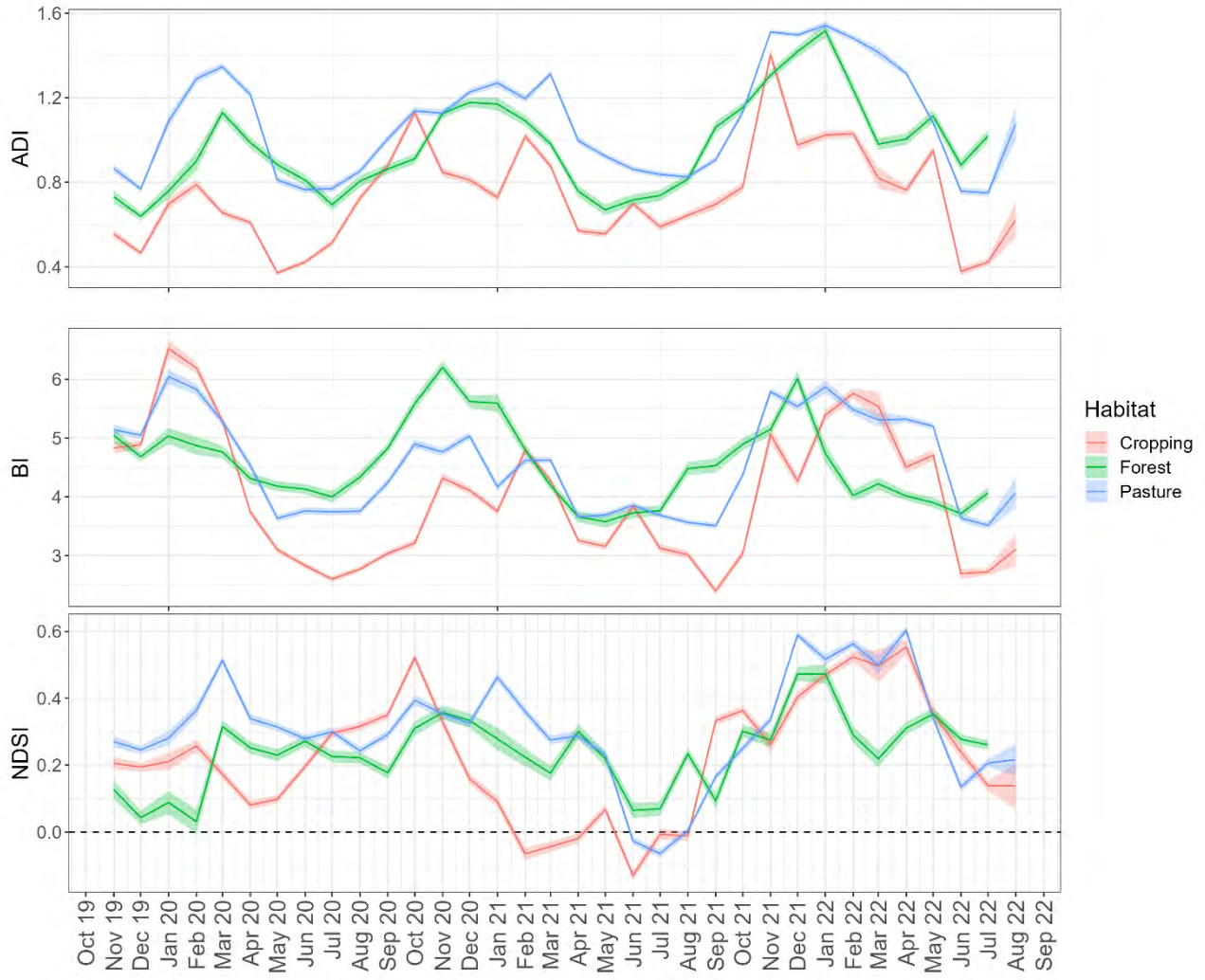


Figure 2: Monthly ecoacoustic indices in each habitat on Llara and rainfall from Narrabri. NSW. Acoustic Diversity Index (ADI) represent bird call diversity, Bioacoustic Index (BI) assesses relative avian abundance, and Normalized Difference Soundscape Index (NDSI) estimates the level of anthropogenic disturbance on the soundscape (> 0 more natural sounds relative to anthropogenic sounds and <0 more anthropogenic sounds relative to natural sounds).

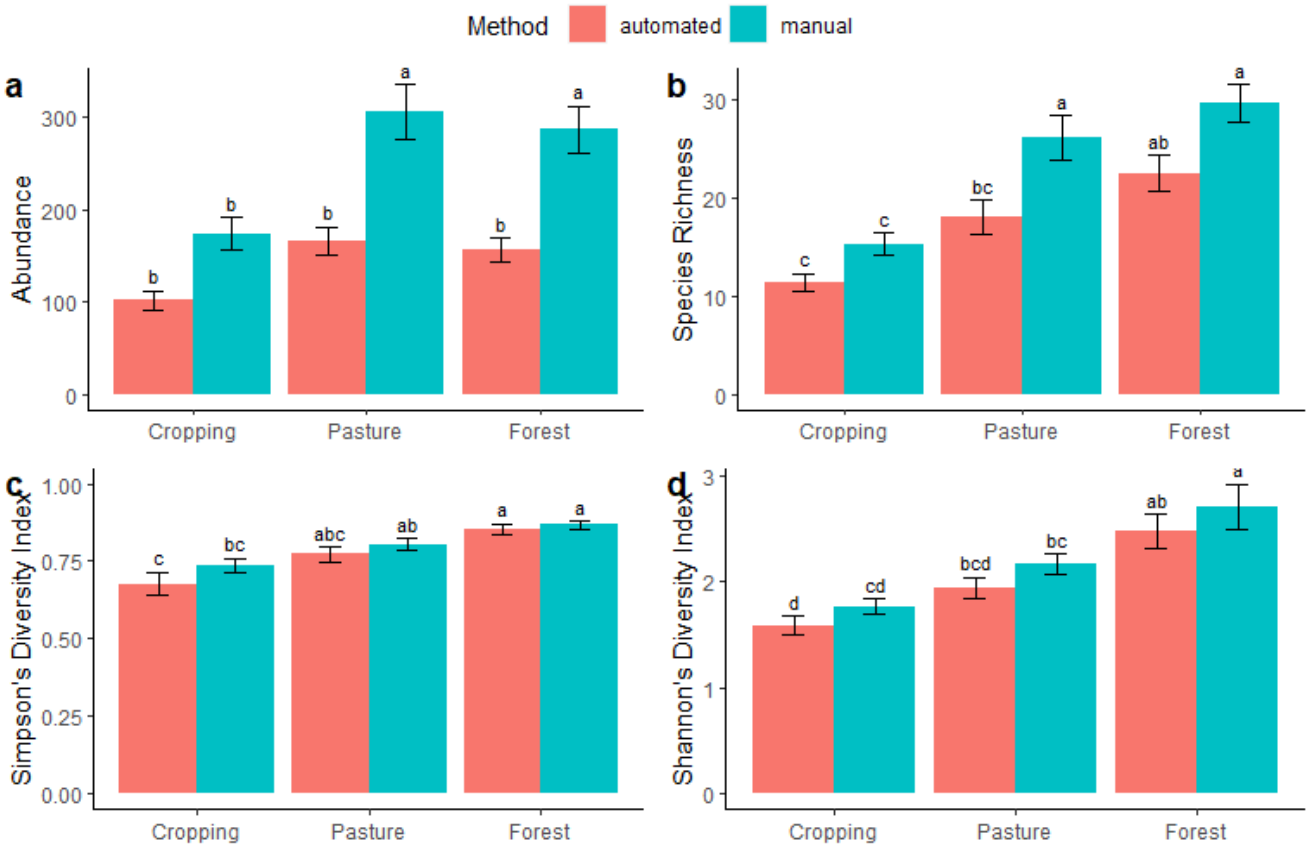


Figure 3. Comparison of means species richness (**a**), abundance (**b**), Simpson's diversity index (**c**) and Shannon's diversity index (**d**) across the three habitat types (cropping, pasture and forest) and method of analysis (manual and automated AI) in L'lara farm, Narrabri. Error bars represent one standard error. Letters above error bars in each plot (a, b, c, d) represent significance in measures between habitats and methods with significant differences ($p<0.05$) represented by a unique letter and non-significant differences represented by a similar letter (Tukey HSD post-hoc test). From Glenyse Villanueva Honours 2022.

Add-on project: **DroughtNet**

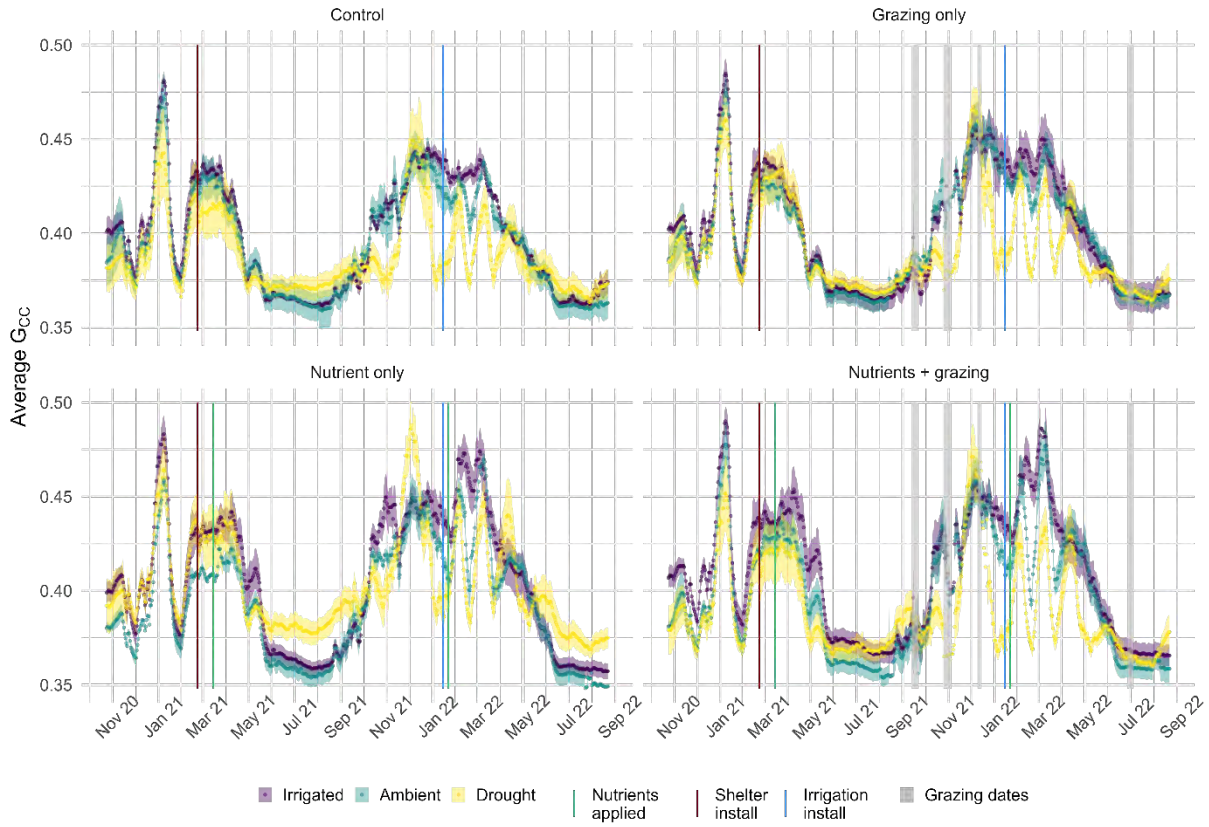


Figure 4. Average plant greenness (G_{CC}) for control, grazing only, nutrient only, and nutrient + grazing treatments under extreme drought (~50% rainfall reduction), extreme rainfall (irrigated; ~50% rainfall increase), and ambient conditions. Ribbons indicate SE.

Can you quantify the impact of this project activity? *(Count of X number of events, Y count of publications etc.)*

2 Groups of Summer Scholarship Students carried out Projects

Project Activity 10

Project Activity Output name *(As per the Work Plan)*
Native Grains & Food

Activity status as of this reporting period

Planned	Started	Underway	Finished	Delayed
☐	☐	☒	☒	☐

Is this project activity on track?	**Yes** ☒	**No** ☐

If No, what is being done to remedy the situation and put it back on track:

Outline the work that was undertaken on this project activity output in this period. Please include any communications (field days, publications media etc.).

- Networking Session Demonstration Day
    - The main activity carried out since the last Milestone Report was a Networking Session Demonstration Day about Native Grains for the surrounding communities in mid-November 2022. 30 People attended the event including people from surrounding Indigenous communities, local farmers, LLS and the National Parks and Wildlife Service.
    - The Networking Day included a demonstration of different threshing and milling methods as well as talks regarding the commercial aspects of native grain use and the opportunities presented by the use of native Australia ingredients. In addition to this, the day also included foods made with Native Grains.
    - Figure 1 shows some of the activities of the day

- In addition to the demonstration event, three students have also successfully completed their honours projects on the topic of Native Grains.

- In the last reporting period, the Indigenous Food Research Park, Native Grains Update Newsletter was published in January 2023

What evidence is available? (Please provide photographs, copies of communications materials etc.)

Figures:

Figure 1: Activities from the Networking Session Demonstration Day. Top Left – Threshing and sorting grain, Top Right – Processing tall oat grass, Bottom Left – Children learning about native grasses, Bottom Right – Learning about native grains at the NDCAS Youth Centre

Can you quantify the impact of this project activity? *(Count of X number of events, Y count of publications etc.)*

Education:

- Three Honours research projects completed

Outreach:

- One Networking Session Demonstration Day with 30 people in attendance.

Publications:

- Indigenous Food Research Park, Native Grains Update Newsletter Published – January 2023

Are you proposing any amendments the Project Activity Work Plan? For example: change of trial sites, key personnel etc.	**Yes** ☒	**No** ☒
If Yes please clearly explain the reason for the proposed changes below and attach an updated version of the relevant section of the Project Work Plan, with the proposed amendments **in track changes**, for consideration.		

Project finances

Progress against Project Budget

Complete this section for every report. For reports 2, 4 and 6, please also attach the Financial Statement spreadsheet.

Is Project expenditure on track and in accordance with the Project Budget provided in the Project Work Plan?	**Yes** ☐	**No** ☐
If you have ticked no, and there is a variance of more than 10% between the expenditure detailed in the Project Work Plan budget, please explain the reasons and what is being done to address the issue. What are the implications if these issues are not addressed and what does this mean for the Project in terms of outcomes?		
Is the receipt of grantee and project partner co-contributions on schedule and in accordance with the Project Budget provided in the Project Work Plan?	**Yes** ☐	**No** ☐
If you have ticked no, and there is a variance of more than 10% between the actual receipt of co-contributions and the Project budget, please explain the reasons and what is being done to address the issue. What are the implications if these issues are not addressed and what does this mean for the Project activity in terms of outcomes?		
Are you proposing any amendments to the Project Activity Work Plan budget?	**Yes** ☐	**No** ☐
If Yes, then clearly explain the proposed changes and attach an updated version of the Project Work Plan budget, with any amendments **in track changes**, for consideration.		

Is there any other information you think we may be interested in for this project?

Field Day Community Engagement Event – September 2022:

The University of Sydney Plant Breeding Institute Narrabri
21 Sep 2022 ·

Narrabri Field Day 2022. We had over 250 attendees, exhibitors, reseachers and local farmers.
Thankyou to everyone who attended, assisted and presented at the field day, we have received great the feedback and can't wait to see you all again at 2023 field day.

Photo credit - Guy Coleman

Visit from UNE Students to Study Soil Science – November 2022:

The University of Sydney Plant Breeding Institute Narrabri
11 Nov 2022 ·

Students from UNE visiting to study soil science.
Found quite a few earthworms.

Daniel Tan and 15 others

Like Comment Share

Sustainability Discussion with GrainGrowers:

We had a meeting and discussion with Fiona McCredie from GrainGrowers to talk about farm sustainability on 9th February 2023. We discussed the growing importance for industries to prove their sustainability to consumers with sustainability challenges being one of the main issues for the grain industry. Fiona discussed how there are 12 pillars of sustainability which are split into 3 key areas to the Grain Growers Sustainability Framework. These are responsible stewardship, building capacity and wellbeing, and consumer confidence and trust. We will now decide on sustainability metrics to use for sustainability reporting before then obtaining data from the farm to benchmark our performance again national and international averages. We aim to produce a sustainability framework and report by the end of March 2023.