Final report

Using devices & data to generate ROIs in a mixed farming enterprise

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Abstract

This project consisted of several research activities in a mixed cropping and livestock enterprise, aimed at exploring the application of Internet of Things (IoT) devices to uncover their Return on Investment (ROI). Particular focus was placed on potential financial benefits gained through time savings, wages, overhead costs or increased -production. A range of other potential ROI's including, animal welfare, social license, traceability and biosecurity have been the predominant outcome in some activities undertaken.

To discover these ROI's it was fundamental that data generated and collected followed the FAIR data principles (Wilkinson, et al., 2016) which stipulates that data is Findable, Accessible, Interoperable and Reusable. This has been a challenge across the industry, which many have struggled to solve. In 2020, Coolindown Farms partnered with AxisTech in a pilot aimed at solving issues regarding data storage, ownership and control, resulting in the establishment of Coolindown's own farm data store within AxisTech's AxisStream platform, which addressed some of the issues around interoperability and reusability. This is demonstrated in the results of this project, whereby ROI's were created by enabling the ability to combine, collate and draw on agricultural data to visualise, investigate and analyse farm operations.

Most significantly, the ROI's, conclusions and findings of this project were discovered and articulated by a producer themselves, proving that when armed with the right tools, any producer can discover their own ROI's within their farming operations. This project also highlighted the ability of IoT devices to be utilised beyond manufacturers prescribed applications. There is the potential for additional ROI's using the devices and data collected for this project in the future, providing a multiplier effect in ROI's derived from the implementation and utilisation of devices and data generated.

Given that producers are capable of finding and generating ROI's when given the ability they can assist in driving IoT adoption across the industry, however, it's recommended that producers are taught how to use and create data visualisations and analysis within such platforms. Alternatively investment is needed to attract and support external parties with the right skills to provide these services to producers.

Executive summary

The report brings together the results of several research activities conducted on a commercial mixed farming enterprise and demonstrates the ability of a producer to deploy IoT devices for real time farm management and enabling the discovery of their own ROI's using the near real time data collected and the utilisation of longer term data for deeper operational insights through the implementation of an integrated farm database.

This project was comprised of five independent, but connected, activities which define and contribute to the overall project objective of identifying Return On Investments (ROI's) derived from the installation and deployment of IoT devices and utilising device generated data in a commercial mixed farming enterprise. These five activities represent the areas identified by the producer themselves as potentially having a ROI greater than expected due to being utilised further than the manufacturers prescribed application for the device.

Objectives

The key objective of this project is the creation of ROI's derived from devices and data relating to IoT devices in operation on a commercial mixed farming enterprise, to support producer adoption of software and hardware that will enhance animal productivity and improved animal welfare.

The below five subject areas were identified as being valuable to further investigate, to increase the knowledge in these subject areas through the analysis of data from the IoT devices used to assess the productivity and management of these areas and to derive their associated ROI's.

- Animal cropping interactions
- Summer joining
- Supply chain data transfer
- Water management
- Soil amelioration

ROI's in this project were generated with a focus on the devices used to measure and analyse each specific subject/research area, thereby establishing the suitability and feasibility of each device for the project use cases. The five activities and associated objectives are outlined below:

1 - Animal/Crop Interactions; This activity aimed to identify whether the information generated by GPS tracking collars on sheep could aid in the decision-making processes of animal management. Particularly, it aimed to identify the major factors contributing to sheep distribution within paddocks, and how the latter impacts other farm activities. Finally, given that the investment on GPS tracking devices forms an important factor in establishing the ROI's of these devices, we investigated lower device densities to assess whether they could sufficiently and accurately reflect mob activity.

2 - Summer Joining; This activity aimed to investigate three main aspects relating to the joining of ewes and the resulting conception rates to establish how GPS devices could contribute to joining management. Firstly, we aimed to investigate if distances travelled by sheep influenced average body condition scores at the end of season, potentially related to calory burn. Secondly, we aimed to understand if managing ewes with different body condition scores in the same paddock contributes further to the body condition score gap across weak (low body condition score) and strong ewes (high body condition score). Finally, we aimed to establish whether current management practices

regarding ewe joining could be altered or adjusted to further increase the ROI for GPS tracking collars.

3 - Supply Chain Data; The aim of this activity was to scope the requirements to transfer key lifecycle data from our database to a meat processor and to gain an understanding of the components necessary to receive feedback on individual animals throughout the slaughter process, or specifically for the genetic lines of trade lambs bought in for feed lotting to supply for the red meat market. To achieve this, we aimed to utilise a comprehensive farm dataset containing information on lambing, DNA, weights, treatment, condition scores, paddock movements, biomass, and shearing fleece weights. We also conducted an assessment to discover what, where and how information is generated and collected by our selected meat processors, and whether that information could be programmatically delivered directly into the farm database.

4 - Water Management; This activity investigated the ability of tank sensors to assess current water storage capacity and actual holding capacity, as well as the ability of flow meters to assess water consumption. Ultimately, we aimed to build a case study to analyse how this reflected on the ROIs for water management IoT devices. Similarly, we aimed to investigate the requirements to, both physically and programmatically, integrate tank level sensors and GPS tracking collars to manage and control water supply priorities into a complete and automated water management system.

5 - Soil Amelioration; This activity utilised soil moisture probes and weather stations to correlate data on, soil moisture content, water retention and penetration to the data generated by GPS tracking collars on sheep. By correlating this data, we aimed to determine how much sheep are contributing to soil compaction, and the potential impacts on key outcomes, such as crop yields and the associated costs of soil amelioration practices.

Methodology

All activities were undertaken on Coolindown Farms property “Yalabyn” located in Esperance, Western Australia. Activities 1 and 5 were conducted in ‘Two Tanks’ paddock and activity 2 was undertaken in ‘Wilsons’ paddocks 1, 2 and 3.

The IoT devices utilised as part of these activities include GPS Tracking Collars, Tank Water Level Sensors, Water Flow Meters, Weather Stations and Soil Moisture Probes.

Animal Ethics Approval

Animal Ethics Approval for undertaking this research project was provided by the Department of Primary Industries and Regional Development (DPIRD) Animal Ethics Committee under applications AEC 21-6-25 and AEC 19-2-07.

Data Processing and Analysis

Basic details regarding specific analytical techniques are reported within each project activity. The general processing and analytical techniques used are described below.

Data Cleaning

Data generated and collected from farming equipment such as weigh scales were converted into CSV files. The CSV files were quality checked and where no values were identified within the Electronic Identification (EID) or weight columns/rows they were removed. Missing data values are often generated due to delays in data transfer which uses Bluetooth signalling between reader panels and the main scale head. The cleaned CSV files were then uploaded into the AxisStream platform. Other data, including IoT data was cleaned as part of data ingestion and processing into the AxisStream platform.

Data Processing

IoT device data was fed into the AxisStream platform via a number of API's. Other data sets were ingested into the AxisStream platform via a combination of API's, data processing tools and CSV uploads.

Data Storage

Coolindown Farms has its own farm data store within the AxisStream platform. All data – IoT data, EID data and other data sets – were all stored within the Coolindown Farms data store for further reuse.

Report Format and Presentation

Each project activity is presented in case study format rather than using a traditional scientific report format. This partly reflects the nature of the co-development this work encapsulates but it's also anticipated that this will encourage the engagement of other producers to the activity outcomes when published.

Results/key findings

Listed below are some of the overarching results and key findings derived from this project:

- Activities undertaken have demonstrated the multiple uses and applications of data where the ability to reuse data has provided additional outcomes with varying ROI's. Therefore, suggesting that data following the FAIR data principles (Wilkinson, et al., 2016) can provide higher returns on investment than data that doesn't.
- IoT devices can provide powerful operational insights to producers and enable them to generate their own ROI's. The more data producers have the ability to access and analyse the more potential ROI's emerge.
- The automation pathway offers a breakdown of the specific elements involved with on farm processes, assisting both producers and AgTech providers in identifying areas which may provide better returns on investment.
- Producers can be empowered to undertake targeted research activities that enhance their own production systems

Results and key findings relating to each project activity are provided within the conclusion section of the respective activity within this report.

Benefits to industry

AgTech adoption can be driven from the ground up rather than the top down this will utilise the peer-to-peer learning that is known to exist at a grass roots level and the processes undertaken will be developed in a manner that minimises impact on already time poor producers.

Producer driven research has the potential to accelerate grass roots changes to production systems. Benefits to industry that are specific to the individual activities undertaken can be found within the respective activities conclusion section.

Future research and recommendations

Key recommendations arising from this project include:

- Deeper analysis into the aspects of the water efficiency calculation such as evaporation
- Trial of using collar data patterns as the trigger for supplement feeding of sheep
- Extension of crop grazing analysis to include respective enterprise input costs

Each project activity within the report includes a section for recommendations and further research that may be required to further expand or affirm the results and conclusions that have been identified and discussed in this report.

“Data is one of the few things that gains value the more times you use it” - J. Patrick Kennedy, founder OSIsoft.

Contents

1. Background

Technology is becoming increasingly important in the decision-making processes across various industries. In agriculture, its presence and adoption has been growing consistently throughout the years and resulting in great improvements in processes and management decisions (Suarez et al., 2018; Sanjeevi et al., 2020).

More recently, the adoption of IoT technology has been receiving growing attention as a new resource in the toolbox of sheep farmers. The ability to utilise sensors to measure multiple variables directly, remotely, and automatically on-farm, such as water levels present in tanks using tank sensors and tracking animals through GPS collars, has resulted in cost and time saving returns for farmers (Bailey et al., 2018). In the context of animal welfare and management, these devices offer the possibility to improve the pool of data growers can rely on to make more precise management decisions such as, when allocating animals to paddocks, or implementing targeted supplement feeding practices to improve body condition scores to achieve a rising plane of nutrition that is known to have a positive relationship to ovulation rates in merino ewes (Ovis aries) (Kenyon et al., 2009).

However, despite the numerous scientific experiments and industry application examples that have showcased the individual abilities of these sensors to aid on-farm management decisions, the adoption of these technologies is still evolving at a slow pace. In parts, this can be attributed to the inability of the industry to demonstrate a clear value proposition, with a defined and more attractive return on investment (ROI), and insufficient incentives to prompt changes to current practices (Baghurst, 2020). On the other hand, the lack of examples in a commercial setting utilising the data generated from these devices to aid in multiple process on farm may also be significantly hindering the adoption by growers, who often seek a more robust application and ROI prior to investing in new technologies.

Figure 1 - Yalabyn property (yellow); Two Tanks paddock (purple) and Wilsons paddocks 1, 2 & 3 (green).

This project aims to assist in grower adoption by generating ROI's from utilising IoT devices and data in a commercial mixed farming enterprise. It comprises five independent, but connected, activities that define and contribute to the overall project objective. The five activities represent specific areas identified by a producer as having the potential for increased ROI's from utilising devices beyond the manufacturers prescribed application.

All project activities were undertaken on Coolindown Farms property "Yalabyn", located in Esperance, Western Australia. Activities 1 and 5 were conducted in 'Two Tanks' paddock while activity 2 was undertaken in 'Wilsons' paddocks 1, 2 and 3 as shown in Fig. 1.

2. Activity 1 – Animal/Crop Interactions

2.1 Objectives

- Development of a novel methodology for multilayer, data triggered alerts for enterprise decision making.
- Potential improved production through alternative land management/use system based on IoT devices and data.

2.2 Methodology

Table 1 - Project Outline; Activity 1

NO	ITEM	ACTIONS	PROJECT UPDATE	DATE
1	Collars	Service and check collar connectivity in preparation for deployment	79 collars were ok. 21 collars were given to AxisTech to take back to Perth for repair. Belinda checked the pregnancy scanning data. 74 collars are required for the ewe trial so ok to go ahead.	12/5/2021
2	Camera	Pre flight check of Camera connectivity and function in the planned paddock	Wes Showed Belinda how to put the components of the Camera together. Wes provided all the components for the set up of the second camera trailer. Overview of the camera app.	20/5/2021
3	Camera Deploymen t	Deployment of camera to Two Tank paddocks	First Camera Installed – June 11th Second Camera installed – June 15th	15/06/2021
4	Collars	Reassemble and last minute check collar connectivity in preparation for deployment.	Belinda reassembled and checked with phone app	14/6/2021
5	Devices	Collect and charge devices for data collection. Transfer weigh scales to yards	Scale head and wand programmed and charged. Scales moved to the yards	15/06/2021
6	Weights & CS	Collect Weights and Condition Scores on trial animals	Weights and condition score collection was delayed by 2 days due to bad weather	17/06/2021
7	Pre lamb treatment	Deployment of collars and pre lamb treatment (vaccinate ewes, etc animal welfare)	Delayed 2 days due to bad weather but completed on the 18th	18/06/2021
8	Sheep on paddock	Allocate animals to Two Tank Paddocks at the start of the project	Ewes were enclosed into Two Tanks Paddock at 11:55am	18/06/2021
9	Data Handout	Provide Annie with collar matching data (EID/Collars), and any other relevant data on ewes for the project	CSV file from the Trutest wand was placed in Dropbox for Annie to ingest on Friday the 18th of June.	18/06/2021
10	Animal Manageme nt	Belinda to monitor animals and ensure animal welfare standards	Cameras were set up on pre-set locations and Zoomed in by Belinda and Lucas and checked over the weekend. Belinda learnt how to playback footage. Lucas download footage to be saved to an external hard drive later. Belinda conducted checks at intervals during the day. Visiting the paddock when necessary	30/08/2021
11	Lambing starts	Expected period where ewes are expected to start lambing	First lamb was born on the 30th of June	07/07/2021
12	Sheep out of paddock	Remove animals from paddock and generate report on animals' distribution across the paddock (generate heat map)	Animals were removed from the paddock on the 22nd of August and collars were removed. However, due to paddock availability management returned animals on the 23rd for a further 2 weeks. Heat map was generated in Power BI	22/08/2021

13	End of Collar data collection	Inform Annie data is no longer being collected for this trial	Belinda messaged Annie in Slack to inform of completion of data collection. Annie acknowledged on the 23rd	22/08/2021
14	Removal of Camera	Remove camera from paddock	Belinda and Deon removed cameras from paddock in preparation for the La Trobe pain relief study.	23/08/2021
15	Devices	Collect and charge Trutest devices for data collection	Belinda charged all devices ready for data collection the day before needed	22/08/2021
16	Weights & CS	Weigh and Condition Score Ewes as per animal ethics requirements	Belinda and Deon collected weights and CS scores of trial ewes	23/08/2021
17	Lamb Marking	Collect Data on Lambs & Survival rates	Data has been collected and submitted for analysis	30/09/2021
18	Device removal	Collars to be removed from Trial Ewes	Collars removed successfully no incidents involving collars recorded.	23/08/2021
19	Data Handout	To provide Annie with all remaining data	DNA results were received in December and uploaded for ingestion	30/12/2021
20	Harvest and yield map	Engage with Decipher to generate report on yield and biomass and generate maps. Once results available, provide to AxisTech	John Deere data uploaded into JD Data manager on January 12th informed AxisTech January 15th. Decipher biomass maps were created on January 20th and uploaded into slack	20/01/2022
21	PowerBI analysis and report	Conduct PowerBI analysis of all data and develop report; analyse compaction and animal distribution results with yield map generated during harvesting	AxisTech undertook the analysis and visualisation of data which has been used in this report	24/05/2022

The 74 ewes selected for this activity were identified during routine pregnancy scanning in April for the 2021 lambing season. The approved animal ethics research application required animals to be twinning ewes with body condition scores above 2 accordance to the Animal Ethics requirements in agreement AEC 19-2-07. The selected animals were brought into the yards in June 2021 for routine pre-lambing vaccinations where liveweights and condition scores were collected. The collar devices used for this trial were Digitanimal GPS tracking devices, weighing approximately 800g (Appx. 8.1 - Collar Spec Sheet) and connected through a SigFox connectivity network. These collar devices collect information relating to the animals' head position using a 3-axis accelerometer (X, Y and Z axis), as well as surface temperature and GPS location. The information from these collars is sent in data packets which are transmitted every 20mins to a SigFox tower previously installed at Coolindown Farms in 2019, and 'back hauled' via a Telstra mobile network.

Each collar device was fitted to the same side of the animals' neck with the printed edge facing forward, ensuring that the axis data received from the accelerometer sensor inside each device is uniform (Fig. 2). A weather station was installed in the corner of Two Tanks paddock (Fig. 3) to enable the assessment of animal movements and behaviour to be compared to weather conditions at any given point in time during the project.

A control mob of approximately 74 sheep was also kept ensuring collars do not have a detrimental impact on the condition of the animals being used in the trial, in accordance with the animal ethics AEC NO. 19-2-07 v1.0. agreement with the Department of Primary Industry and Regional Development (DPIRD).

Ewes were condition scored, weighed and drafted into the two treatment groups of control and collared sheep on the 14th of June 2021 using a Prattley 3 way auto drafter. Low stress handling of sheep was achieved by reducing human interactions and handling by aligning this activity with normal on farm animal management practices in which pre-lamb vaccinations are administered and long-acting fly prevention product was applied via jetting to the breech of each animal.

The pre-existing 9 digit EID numbers for each individual sheep was matched to the 3 digit collar ID number using a Trutest EID wand. To enable the verification of behavioural data and adhere to the Animal Ethics monitoring requirements, two Pan-Tilt-Zoom (PTZ) 25x Optical Zoom Cameras were installed on mobile trailers fitted with solar panels and batteries. These cameras have the ability to observe both individual animals and mob movements and behaviours (Appx. 8.2). To enable the identification of sheep on monitoring cameras, the 3 digit collar ID number was spray painted using branding fluid onto both lateral sides of each animal. Observations were made throughout the day using both the installed cameras and the Digitanimal app which shows animal locations in near real time from the fitted animal collars.

Figure 3 - Deployment of GPS Collars onto sheep

Figure 2 - Installation of weather station

Plant tissue tests were collected from locations indicated on the map below which correlate to soil test sample sites which were taken on the same day the ewes were released into the paddock (Fig. 4).

Figure 4 - Locations of plant tissue test samples - Two Tanks Paddock

Upon completion of the trial period animals were brought back into the yards. Collar devices removed, animals were weighed, condition scored, and lambs marked as per normal practise with the addition of also being weighed. The following lists the equipment used to collect lamb marking data and weights.

- EID tags and applicator
- Trutest Scalehead XR5000
- TSUs
- Barcode reader
- Trutest wand XR2
- Loadbars and box

Information collected on lambs included:

- Farm name
- Birth paddock
- Breed
- Birthing group (twin/single)
- EID number
- Vaccination details – Batch number, Dosage rate, Expiry, Withholding, Export withholdings, Sire (if known)
- Liveweight
- DNA sample

The data collected from this time period was then ingested into the AxisStream platform via the uploading of a CSV file or via an API. Biomass imagery of the paddock to assess grazing area was created using NVDI and downloaded from the DecipherAg platform (Fig. 6), with a correlating area mapped and calculated via google earth (Fig. 7). This was then further correlated after harvest when the harvest data was extracted from the Coolindown Farms John Deere operation centre which enabled the visualisation of machinery collected data.

The number of GPS collar devices required to accurately reflect the movements of sheep was investigated by assessing device densities i.e. number of collars: number of animals within a given paddock. The animal and crop interactions trial consisted of 140 sheep with 70 GPS collars deployed and therefore represents a GPS collar density of 50%. Collar device densities of 25% and 10% were assessed for accuracy against the full set of GPS collar data collected for activity 1 (50% density).

To achieve this, the 70 GPS collar ID's were listed in random order, then assigned an indexed number from 1 to 70. An online random number generator (dCode) was utilised to select a random set of 35 numbers (from 1 to 70 inclusive) to represent a 25% collar density, and another set of 14 numbers to represent the 10% collar density. The randomly selected numbers where then matched to GPS collar ID's and used to create heat distribution maps. The random number selected was then repeated using an alternative random number generator (CalculatorSoup) with additional heat maps created to ensure the same results were achieved.

2.3 Results

Utilising the GPS collar data collected throughout activity 1, heat maps representing collar densities of 50%, 25% and 10% (Fig. 5) were generated. This was done by using an online random number generator to select 35 and 14 collars from the original 70 collars deployed. This process was repeated using an alternative random number generator and this resulted in the same heat map distribution, confirming the results represent device deployment at their respective densities without interference from individuals within the population.

Across this 18 day period a clear distribution of animals can be observed across the three maps which have the same heat map settings including the heat radius of 10 pixels. As collar device densities decrease so too does the maps heat intensity, however even at a 10% device density a clear distribution was achieved.

Figure 5 - Heat maps with 50%, 25% and 10% GPS collar densities across 18 days (18 June to 28 June 2021)

NDVI biomass imagery (Fig. 6) shows the area of lowest biomass in yellow/orange. This area correlates to the area not harvested (Fig. 8) in 2021 due to depletion of crop. Correlation to animal distribution in this area is shown in (Fig. 9). The same animal distribution was observed for this paddock in 2020 (Fig. 10)

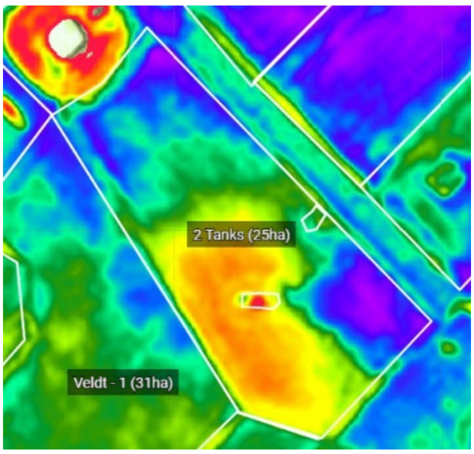


Figure 7 - NDVI Biomass Image 30th August 2021

Figure 6 - Google maps interpretation of biomass map to gain area

Figure 10 - John Deere yield map of harvested area confirming calculated affected area (2021)

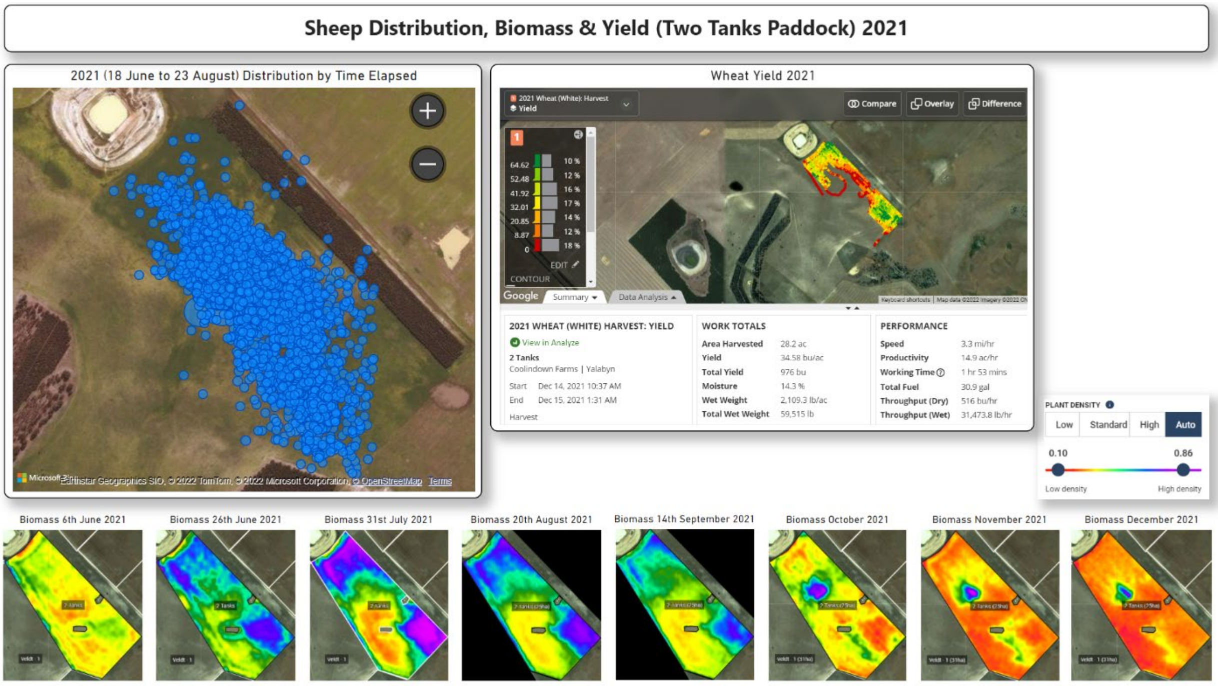


Figure 9 - Biomass, Crop Yield and Animal Distribution (2021)

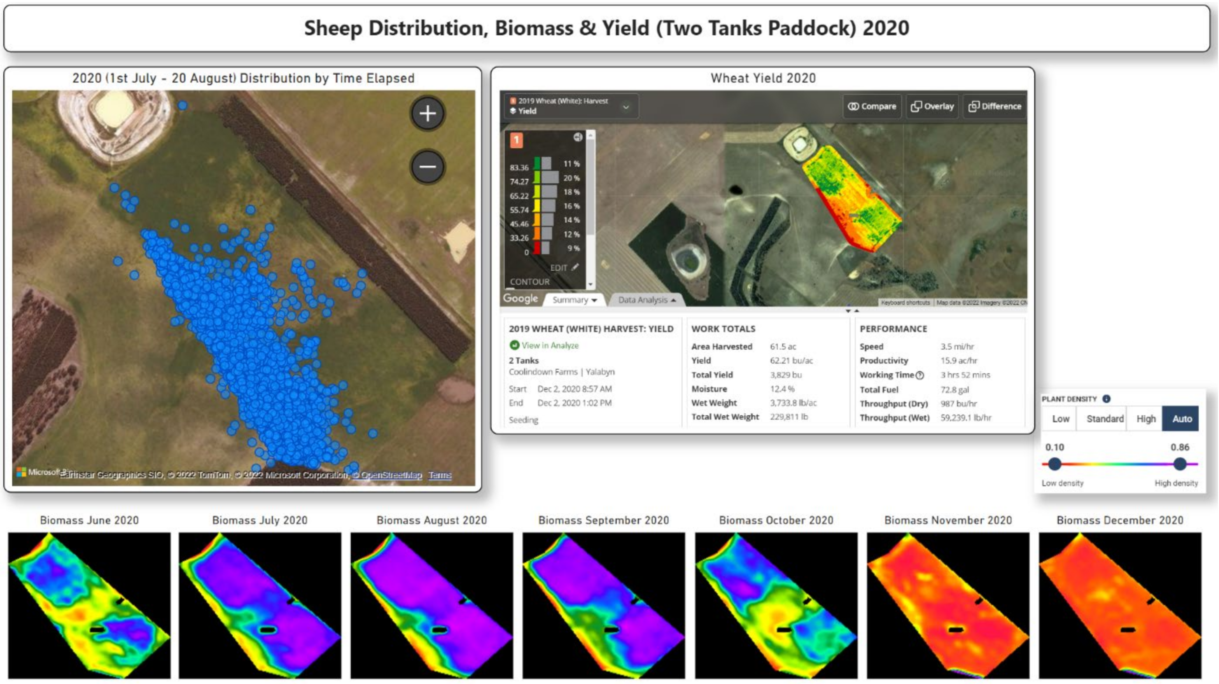


Figure 8 - Biomass, Crop Yield and Animal Distribution (2020)

The below image (Fig. 11) shows the elevation of two tanks paddock with the highest elevated areas indicated in orange/yellow with the maximum elevation being 384.2ft above sea level.

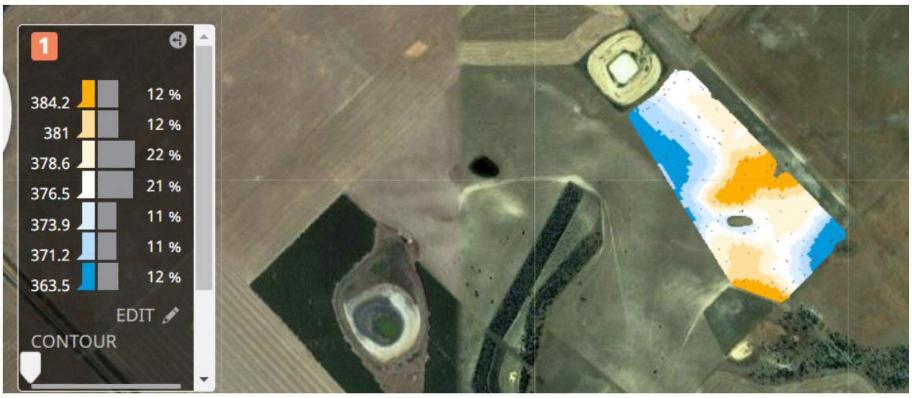


Figure 11 - Elevation map for Two Tanks Paddock

Site Lab Number Plant Weight:	Site 1 EFP21130 0.17g @ 32d	Site 2 EFP21131 0.12g @ 32d	Site 3 EFP21133 0.16g @ 32d	Site 4 EFP21134 0.21g @ 32d	Site 5 EFP21135 0.18g @ 32d
Total N [Leco] (%N) {9G2}	3.95 Marginal	5.29 Sufficient	3.96 Marginal	5.44 Sufficient	5.37 Sufficient
Nitrate-nitrogen (mg N/kg)	1714 Low	3660 High	450 Low	3878 High	3247 High
P (%P)	0.69 Sufficient	0.87 High	0.77 High	0.76 Sufficient	0.77 Sufficient
K (%K)	2.56 Low	3.41 Marginal	3.41 Marginal	4.43 Marginal	4.73 Marginal
S (%S)	0.31 Sufficient	0.37 High	0.30 Sufficient	0.40 High	0.37 High
N:S ratio	13 OK	14 OK	13 OK	14 OK	15 OK
Cu (mg Cu/kg)	5.9 High	5.8 High	5.1 High	5.3 High	3.3 Sufficient
Zn (mg Zn/kg)	33.1 High	38.2 High	30.3 High	31.0 High	33.9 High
Mn (mg Mn/kg)	22.8 Marginal	29.8 Sufficient	44.2 Sufficient	54.7 Sufficient	45.2 Sufficient

Figure 12 - Plant tissue test results (full report in Appx. 8.7).

Figure 13 - Day 1 to 7: Establishing Home Range

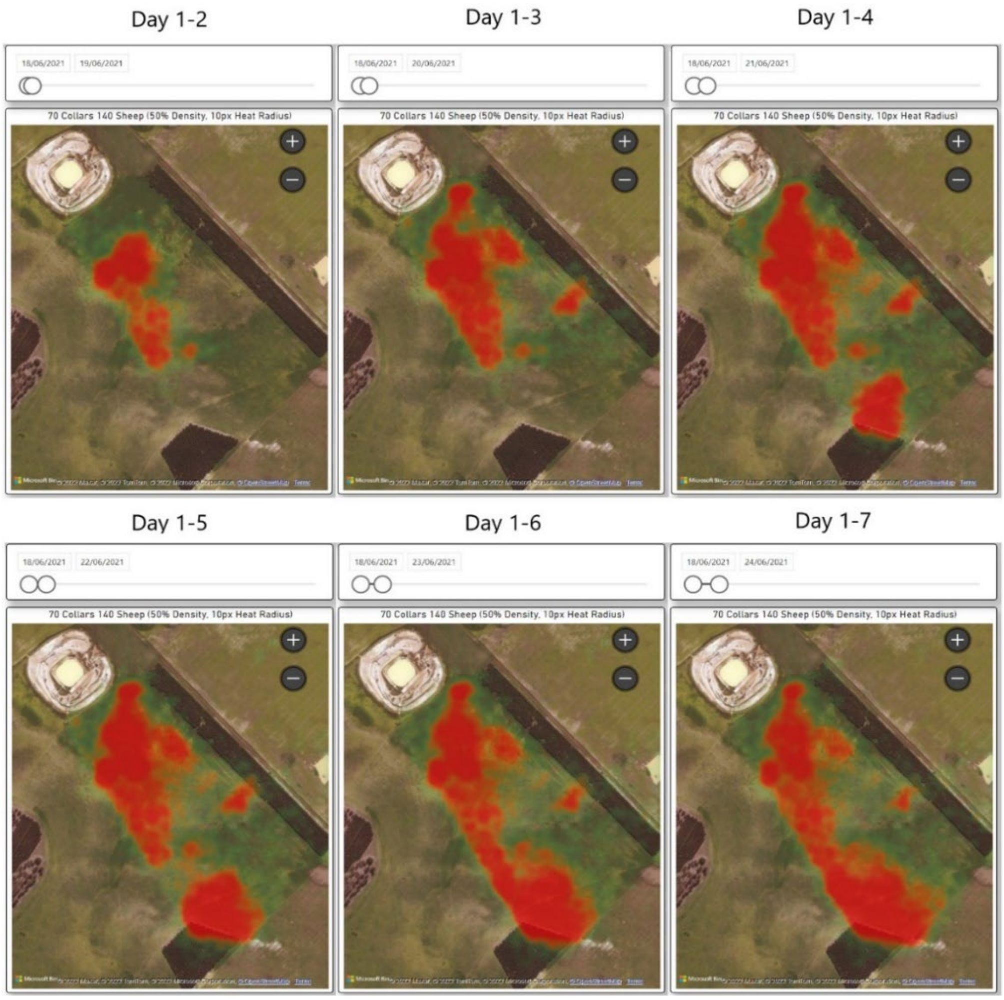


Figure 15 - Days from entering paddock to establishing Home Range

Figure 14 - Onset of Lambing

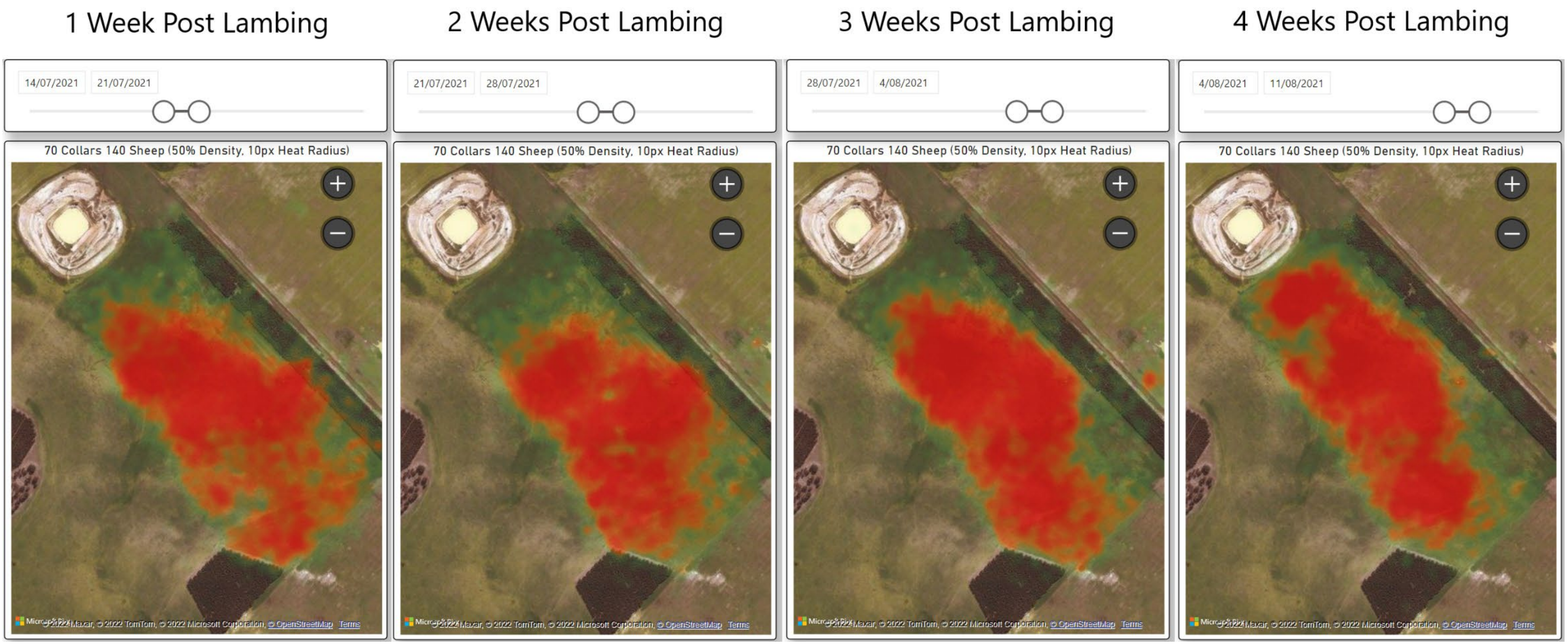


Figure 16 - Animal distribution during post Lambing periods

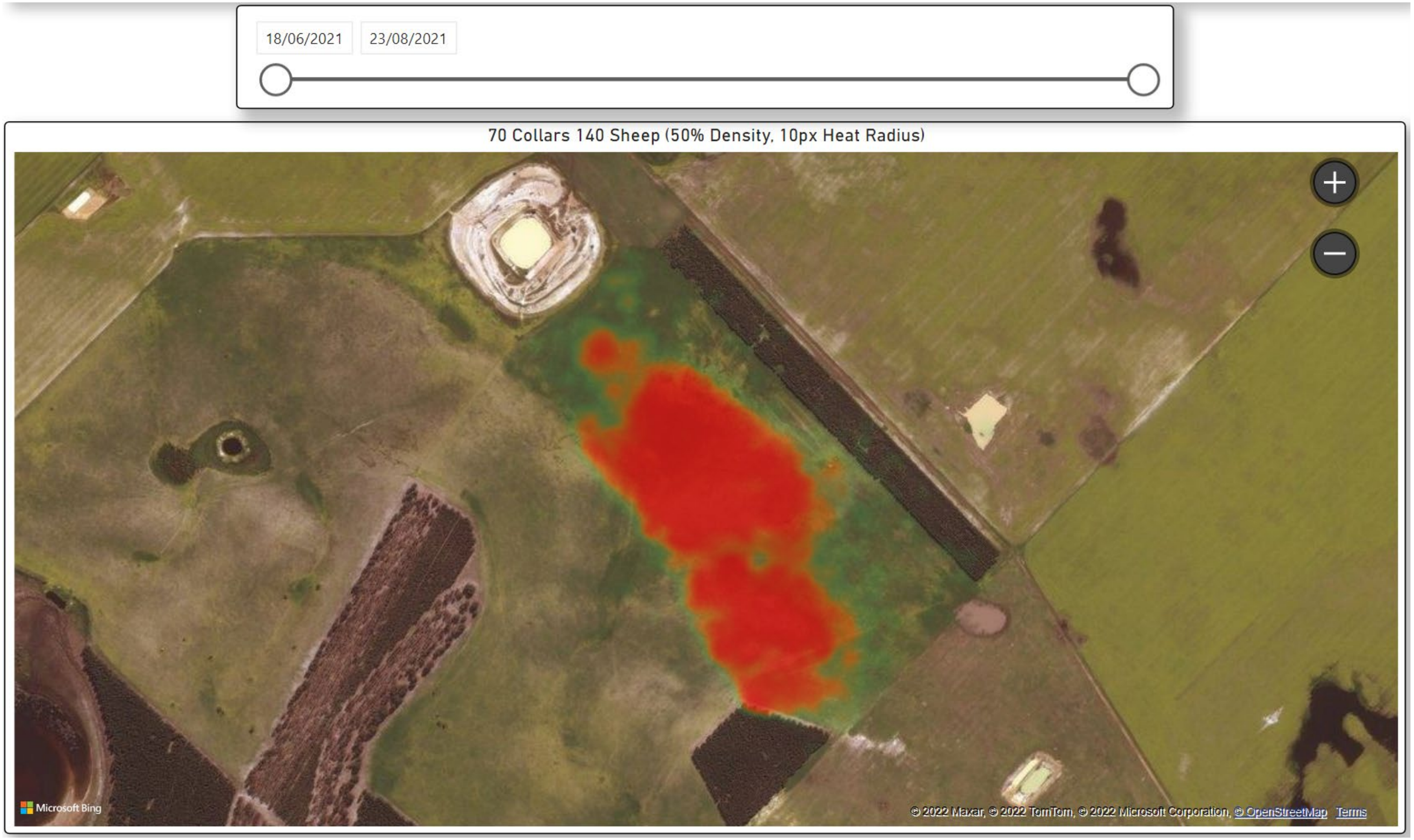


Figure 17 - Animal distribution entire trial

Coolindown Farms
Two Tanks Yeild Analysis
As at end of season 2020

Paddock Name:	Two Tanks		
Paddock Size (ha):	26.0		
Concentrated grazing area (ha):	5.8		
Low grazing area (ha):	20.2		
Planting variety:	Scepter Wheat		
Acheived price per ton ($/t):	$338		
Yeild Concentrated Grazing Area	3.06	t/ha	
Yeild Low Grazing Area	4.29	t/ha	
Yeild Concentrated Grazing Tonne	17.74		
Yeild Low Grazing Tonne	86.71		
Yeild Total Tonne	104.46		
Farm wide yield average	4.70		
Pregnancy Status:	Twins		
Number of Ewes:	44		
Max lambing potential:	88		
Lambs at marking	59		
Lambing percentage	134%		
Mortality at marking vs potential (pregnancies)	33%		Opportunity for additional work
Average lamb weight (kg):	15.5		Opportunity for additional work
Date of first lambing	10/07/2020		
Day prior to lamb marking	31/08/2020		
Projected price of lamb per kg ($/kg)	$2.50		
Ewe value	$200.00		
Lamb value at lamb marking	$38.75		

Crop Grazing		**Trial Results**	**Normalised Practice this season**	**Variance** #	%	
Cropping Analysis						
Predicted Yeild Rate - concentrated grazing area	t/ha	3.1	3.7	-0.6	-17.3%	
Predicted Yeild Rate - low grazing area	t/ha	4.3	4.7	-0.4	-8.7%	
Predicted Yeild Rate - whole of paddock	t/ha	4.0	3.5	0.5	14.8%	
Predicted Yeild Volume - concentrated grazing area	t	17.7	21.46	-3.7	-17.3%	
Predicted Yeild Volume - low grazing area	t	86.7	94.94	-8.2	-8.7%	
Predicted Yeild Volume - whole of paddock	t	104.5	91.0	13.5	14.8%	
Predicted Yeild Value Rate - concentrated grazing area	$/ha	$1,034	$1,251	-$217	-17.3%	
Predicted Yeild Value Rate - low grazing area	$/ha	$1,451	$1,589	-$138	-8.7%	
Predicted Yeild Value Rate - whole of paddock	$/ha	$1,358	$1,183	$175	14.8%	
Predicted Yeild Value - concentrated grazing area	$	$5,998	$7,253	-$1,256	-17.3%	
Predicted Yeild Value - low grazing area	$	$29,310	$32,090	-$2,780	-8.7%	
Predicted Yeild Value - whole of paddock	$	$35,307	$30,758	$4,549	14.8%	
Lambing Analysis						
Lamb productivity actual lambs at marking	#	59	0	59		
Value of lamb productivity	$	$2,286.25	0	$2,286.25		
Lamb Productivity Value Rate - concentrated grazing area	$/ha	$394.18	0	$394.18		
Lamb Productivity Value Rate - whole of paddock	$/ha	$87.93	0	$87.93		
Value Rate - concentrated grazing area						
Cropping	$/ha	$1,034.10	$1,250.60	-$216.50		
Lambs	$/ha	$394.18	$0.00	$394.18		
Total Value Rate	$/ha	$1,428.28	$1,250.60	$177.68		
Value Rate - whole of paddock						
Cropping	$/ha	$1,357.97	$1,183.00	$174.97		
Lambs	$/ha	$87.93	$0.00	$87.93		
Total Value Rate	$/ha	$1,445.91	$1,183.00	$262.91		
Yeild Value - whole of paddock						
Cropping	$	$35,307.33	$30,758.00	$4,549.33		
Lambs	$	$2,286.25	$0.00	$2,286.25		
Total Value Rate	$	$37,593.58	$30,758.00	$6,835.58		Does not include any increase in condition for ewes
Opportunity Gain/Loss Yeild ($)						
If planned cropping only then gain is lambing productivity, minus yeild reduction	$/ha	$6,835.58				
If planned sheep only then gain is crop yeild	$/ha	$35,307.33				

Lambing Management		**Trial Results** #	**Normalised Practice** #	**Variance**	Notes
Ewe mortality to unknown causes	#	-2	-5	3	Normal situation all mortalities would have occurred without any intervention
Ewe mortality due to known cause	#	-2		-2	Nutrient issues with calcium leading to birthing issues, ewes euthanased
Ewes survival due to intervention	#	1		1	Identified as in distress, exact location known, immediate intervention
Lambs survival due to ewe intervention	#	1	0	1	Saved and rejoined to ewe as a result of ewe survival
Lamb survival due to direct intervention	#	1	0	1	(Mr Green)
				2	
Ewe survival value	$	$200.00	$0.00	$200.00	
Lamb survival value	$	$0.00	$0.00	$77.50	opportunity value of $1500-$2000 as mature flock ram
Total Survival Value		$200.00	$0.00	$277.50	

Figure 18 - 2020 Enterprise Financial Results Evaluation Two Tanks Paddock

Coolindown Farms
Two Tanks Yeild Analysis
As at 1 Jan 2021

Paddock Name:	Two Tanks		
Paddock Size (ha):	26.0		
Concentrated grazing area (ha):	14.3		
Low grazing area (ha):	11.7		
Planting variety:	Scepter Wheat		
Achieved price per ton ($/t):	$343	actual from business analysis	
Yeild Concentrated Grazing Area	-	t/ha	
Yeild Low Grazing Area	2.33	t/ha	
Yeild Tonne	27.05		
Farm wide yield average	5.00		
Pregnancy Status:	mixed		
Number of Ewes:	150		
Max lambing potential:	155		
Lambs at marking	180		
Lambing percentage	120%		
Mortality at marking vs potential (pregnancies)	-16%		Opportunity for additional work
Average lamb weight (kg):	19.3		Opportunity for additional work
Date of first lambing	10/07/2020		
Day prior to lamb marking	31/08/2020		
Liveweight value of sucker lamb per kg ($/kg)	$3.50		
Ewe value	$250.00		
Lamb value at lamb marking	$67.55		

Crop Grazing		**Trial Results**	**Normalised Practice this season**	**Variance** #	**Variance** %	
Cropping Analysis						
Predicted Yeild Rate - concentrated grazing area	t/ha	0.0	4.0	-4.0	-100.0%	
Predicted Yeild Rate - low grazing area	t/ha	2.3	5.0	-2.7	-53.5%	
Predicted Yeild Rate - whole of paddock	t/ha	1.0	3.5	-2.5	-70.1%	
Predicted Yeild Volume - concentrated grazing area	t	0.0	57.2	-57.2	-100.0%	
Predicted Yeild Volume - low grazing area	t	27.2	58.5	-31.3	-53.5%	
Predicted Yeild Volume - whole of paddock	t	27.2	91.0	-63.8	-70.1%	
Predicted Yeild Value Rate - concentrated grazing area	$/ha	$0	$1,372	-$1,372	-100.0%	
Predicted Yeild Value Rate - low grazing area	$/ha	$798	$1,715	-$917	-53.5%	
Predicted Yeild Value Rate - whole of paddock	$/ha	$359	$1,201	-$841	-70.1%	
Predicted Yeild Value - concentrated grazing area	$	$0	$19,620	-$19,620	-100.0%	
Predicted Yeild Value - low grazing area	$	$9,339	$20,066	-$10,726	-53.5%	
Predicted Yeild Value - whole of paddock	$	$9,339	$31,213	-$21,874	-70.1%	
Lambing Analysis						
Lamb productivity actual lambs at marking	#	180	0	180		
Value of lamb productivity	$	$12,159.00	0	$12,159.00		
Lamb Productivity Value Rate - concentrated grazing area	$/ha	$850.28	0	$850.28		
Lamb Productivity Value Rate - whole of paddock	$/ha	$467.65	0	$467.65		
Value Rate - concentrated grazing area						
Cropping	$/ha	$0.00	$1,372.00	-$1,372.00		
Lambs	$/ha	$850.28	$0.00	$850.28		
Total Value Rate	$/ha	$850.28	$1,372.00	-$521.72		
Value Rate - whole of paddock						
Cropping	$/ha	$359.21	$1,200.50	-$841.29		
Lambs	$/ha	$467.65	$0.00	$467.65		
Total Value Rate	$/ha	$826.86	$1,200.50	-$373.64		
Yeild Value - whole of paddock						
Cropping	$	$9,339.42	$31,213.00	-$21,873.58		
Lambs	$	$12,159.00	$0.00	$12,159.00		
Total Value Rate	$	$21,498.42	$31,213.00	-$9,714.58		Does not include any increase in condition for ewes
Opportunity Gain/Loss Yeild ($)						
If planned cropping only then gain is lambing productivity, minus yeild reduction	$/ha	-$9,714.58				
If planned sheep only then gain is crop yeild	$/ha	$9,339.42				

Lambing Management		**Trial Results**	**Normalised Practice**	**Variance**	
		#	#		Notes
Ewe mortality to unknown causes	#	-2	-5	3	Normal situation all mortalities would have occurred without any intervention
Ewe mortality due to known cause	#	-2		-2	Nutrient issues with calcium leading to birthing issues, ewes euthanased
Ewes survival due to intervention	#	1		1	Identified as in distress, exact location known, immediate intervention
Lambs survival due to ewe intervention	#	1	0	1	Saved and rejoined to ewe as a result of ewe survival
Lamb survival due to direct intervention	#	1	0	1	(Mr Green)
				2	
Ewe survival value	$	$250.00	$0.00	$250.00	
Lamb survival value	$	$0.00	$0.00	$135.10	opportunity value of $1500-$2000 as mature flock ram
Total Survival Value		$250.00	$0.00	$385.10	

Figure 19 - 2021 Enterprise Financial Results Evaluation – Two Tanks Paddock

2.4 Conclusion

Crop grazing has been established as a great solution to the autumn feed gap and with careful management both crop and livestock enterprises can profit from the same piece of land. (Dove. H, Kirkegaard. J, 2013) The introduction of GPS animal tracking collars combined with other data sets forms a part of the foundation of Precision Livestock Farming (PLF) systems.

As the focus of this report is focussed on Return on Investment, we have looked at the application of IOT Collars from two different perspectives. The first is around the devices themselves and the quality of data given (Fig. 5) if the density of the devices were to be altered to 50%, 25% and 10%. As shown the intensity of the data diminishes with the reduction in device densities however the area utilised by the animals is still definable.

These findings have been based on a GPS tracking device that read every 20 minutes, it needs to be noted that another way tracking device manufacturers are reducing costs of the devices themselves is the through the reduction of reporting frequencies as this extends the life of batteries however this has been shown to have more impact on the accuracy of data than a reduction in device density. (Castro, J., et al., 2021)

The second aspect of ROI's for IoT collar devices is in the application of the data that has been collected from the devices themselves and applied to an enterprise analysis. It has been noted that the accuracy of these collars can sometimes be questionable, and thus GPS collar data has been cross referenced with DecipherAg NVDI biomass imagery and harvester yield data maps. (Fig. 10)

Traditionally paddock usage by animals has been calculated based on the hectares made available to the animals (i.e., entire paddock area) as opposed to the area they actually utilise. The utilisation of GPS collars facilitates the ability to calculate the intra-paddock area that sheep actually graze.

The heavily grazed area is shown to be up to 20 feet (6m) higher in elevation according to the John Deere Map Fig. 11 This higher elevation area comprises of deeps sands (>1m) according to the soils test results received for in activity 5 and could be an underlying factor to the reduced nitrogen levels due to apparent nutrient leeching through the soil (Field, T.R.O. et al., 2001). Sheep appear to have the ability to determine nitrogen levels in forage (Edwards. G.R., et al., 1993) given that ruminants are susceptible to nitrate poisoning when too much biomass is consumed that're high in Nitrates (Vough, L.R. et al., 2006). It would therefore be plausible that the areas favoured by sheep during this trial is potentially due to the significantly lower levels of overall Nitrogen and Nitrate levels as illustrated in the plant tissue test results (Fig. 12). If this area favoured by the ewes is also connected to low levels of nitrates, then it's possible that the sheep themselves could be utilised to highlight crop areas which may require a variable rate application of nitrogen i.e., precision nitrogen application. The reverse is also applicable on pasture grazing paddocks where the sheep tend to preference the higher nitrogen areas (Edwards. G.R., et al., 1993) therefore a reverse map could be created for pasture paddocks to guide nitrogen applications on pastures which in enterprises that don't have cropping and therefore yield maps to utilise, this method would be even more beneficial.

When breaking the data down in to shorter time frames (7 days) to look at grazing patterns another potential consideration for the preference to higher elevation is apparent safety due to predation. It appears that as the ewes commenced lambing the area grazed contracted to predominantly higher ground (Fig. 15) and then as lambs reached 2-3 weeks old the area utilised started to expand returning to the previously occupied area by 4 weeks. It is noted that more than half a dozen foxes were culled from the paddock area by the Producer over the duration of the 8-week trial predominantly during the lambing period. The reduced biomass and elevation combined would potentially give ewes the ability to spot predators and protect their young however there is currently limited research in this area.

Based on the factors discussed above regarding paddock elevation and the sheep's grazing preferences, the area affected by grazing sheep could therefore be predicted and included into the calculation model above to forecast the potential impacts of crop grazing including associated financial outcomes.

2.4.1 Key Findings

- A 10% collar device density generates a more favourable ROI when compared to 50% and 25% collar densities and appears to be at the lower limit for identifying paddock areas utilised by animals especially for shorter periods of time.
- The application of data from collar devices enables precision calculations of the financial impacts of management decisions such as crop grazing.
- The area utilised (home range) by animals takes approximately 7 days to be established
- Lambing events appear to have a short-term influence on the home range (area occupied by ewes)
- Area affected by animals correlated from 2020 to 2021
    - Deep sandy soils
    - Most time spent at location/area
    - Common grazing pattern at specific times of day
    - Sheep avoidance of high Nitrogen levels in crop plant tissue

2.4.2 Benefits to Industry

Moving forward these calculations based on actual data could be used to model optimal crop grazing areas. For example an estimation of the "sweet spot" between enterprises may be calculated to show how many hectares in a paddock could be impacted by sheep grazing, then using GPS collars and biomass imagery to determine when this has occurred so that sheep are moved from the paddock accordingly, or trigger a management decision beyond that point depending on seasonal circumstances.

2.4.3 Further research and recommendations

A repeat of this trial in the same paddock for a third year with the inclusion of a different paddock with additional repetitions of soil, leaf and palatability tests could further prove or disprove some of the results and conclusions derived from this project activity.

3. Activity 2 – Summer Joining

3.1 Objectives

- Better management of animal body condition, improving animal welfare and survival rates.
- Better management of input costs through targeted supplement feeding.

- Potential improvement in flock fertility resulting in increased production through improved and targeted supplement feeding.

3.2 Methodology

Table 2 - Activity 2 Project Outline

NO	ITEM	ACTIONS	PROJECT UPDATE	DATE
1	Paddock Preparation	Define controlled location across all paddocks to deploy feed and water points	Water and feed points identified	01/10/2021
3	Animal Handling	Supervise animals through the shearing process	Hoggets were shorn on the 6-7th January	07/01/2022
4	Weight & Condition Score (CS)	Collect weight and condition score of all 900 **PURPLE** tag ewes before allocation to different paddocks, tabulate and provide AxisTech with results	Condition scores and weights	06/01/2022
5	Fleece Weight	Collect Fleece weight of Hoggets	Hogget fleece weights were collected during shearing on January 9th – 10th	08/01/2022
6	Device deployment & Allocation of animals	Allocate animals into the 6 groups. Top 50% = high CS, Bottom 50% = low CS. Create excel document with list of animals EID present in each group and provide to data to AxisTech	Animal were split into 3 groups due to unfinished confinement pens. EIDs for groups were collected at the first weigh in on January 24th	10/01/2022
7	Data Handout	Provide AxisTech with EID + collar data matching, as well as results of weighing and condition scores	EID and collar data submitted via slack 17th January	17/01/2022
8	Camera Deployment	Install cameras on paddock	Camera 1 – set up and operational as of 23rd January Camera 2 – set up and operational as of February 7th	07/02/2022
9	Supplement Feeding	Feed of animals in all paddocks with basic maintenance ration	It is believed it will warp the scientific basis in preg scanning result if the animals are lupin flushed therefore a basic maintenance ration was introduced after feed analysis report was received.	30/03/2022
10	Rams on Paddock	Introduce rams on paddocks W1, W2, W3 Deploy collars on rams and ewes (ewes to be randomly selected for each group)	Collars applied to ewes January 18th. Collars applied to Rams February 1st	01/02/2022
11	Rams out of Paddock	Removal of rams from paddocks	Rams were removed and Conditioned scored	14/03/2022
12	Animals merged	Merge animals into one mob and manage as per current commercial practice	Animal merged on the 14th of March	14/03/2022
13	Weight & Condition Score (CS)	Collect weight and condition score of all Hogget ewes after rams are removed	Hoggets were weighed and conditioned scored on March 14th	14/03/2022
14	Collar Data Stop	Inform AxisTech of end of data collection and trial	Completed weight and condition score data provided to AxisTech	15/03/2022
15	Pregnancy Scanning	Conduct pregnancy scanning	Preg scanning was undertaken	27/04/2022
16	Data Handout	Provide AxisTech with all remaining data	Pregnancy Scanning results submitted	28/04/2022
17	PowerBI analysis and report	Conduct PowerBI analysis of all data and develop report; analyse compaction and animal distribution results with yield map generated during harvesting	AxisTech undertook the analysis of data which has been used in this report	24/05/2022

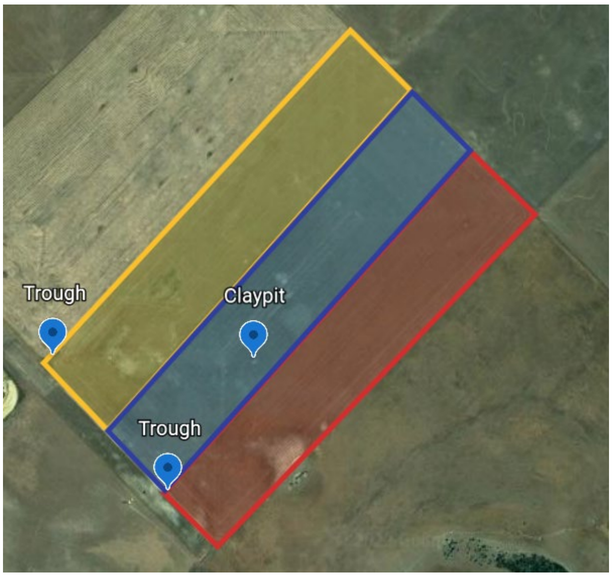


Figure 20 - Summer joining activity projects areas- Wilson 1, left. Wilson 2, in the middle. Wilsons 3, right. All paddocks are approximately 40 ha have been managed similarly for the past 10 years. In 2021 all have been seeded to Septer wheat at 80kg/Ha on the 7th May.

	Area	Arable	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
WILSON 1	40	40	EC	EC	CA	WCA	EC	EC	CA	VP	CA	W	WoW
WILSON 2	40	40	EC	EC	CA	WCA	EC	EC	CA	VP	CA	W	WoW
WILSON 3	40	40	EC	EC	CA	WCA	EC	LU	CA	VP	CA	Hay	Wh

Figure 21 - Historical Crop Rotation for Wilsons Paddocks

Weights and body scores of purple tag ewes were collected and assessed in order to allocate and group hogget ewes into either; high body condition, low body condition and mixed body condition scores. Animals without EIDs or condition scores recorded were removed from the dataset prior to body condition score analysis and trial group selection.

The resulting median value of body condition scores was 3 with an average of 3.06.

Selection pool was then split into top 50% and bottom 50%. Animals with condition scores 3 and below were allocated to the bottom 50% group, and those with condition scores higher than 3 put into the top 50% group.

This resulted in 531 animals in the bottom half, of which:

- 180 were selected at random and drafted into the low body condition group
- 90 were randomly selected and allocated to the mixed body condition group

The top half consisted of 290 animals and:

- 180 were selected at random and drafted into the high body condition group
- 90 were randomly selected and allocated to the selected at random to go into mixed body condition group

Due to paddock availability within the operation and the inability to delay the use of the paddocks set aside for the it was decided to bring the trial commencement date forward to the 18th of January 2022. The hoggets were separated into their respective trial groups 1- High Condition Score, 2 – Low Condition Score and 3 – Control (comprising approximately 50% high and 50% low body condition score). Each group had 18 collars deployed to random animals this represents approximately 1 in 10 animals.

Follow up weights were taken on Monday the 24th of January 2022, animals were then mustered on the Monday the 1st of February when rams were introduced into each treatment group after being condition scored and fitted with a GPS collar device. Cameras were set up in 3 positions around the trial paddocks to enable ongoing visual monitoring enable monitoring of animals for welfare purposes in a way that did not influence natural animal movements and behaviours.

Days that paddocks were visited were recorded along with days sheep were mustered.

Coolindown Farms usually undertake lupin flushing for their ewes, two weeks prior and during mating, at a rate of 500g per head per day however to ensure accurate results and maximise knowledge gained from this trial, lupin flushing was not carried out for the animals that were part of this trial prior to the introduction of rams.

Nine pasture samples were collected from 3 random locations within each paddock, the area that the samples were collected from was determined by the throwing of a tri square in the vicinity of the selected area. The samples were then sent for analysis by Dr John Milton, of Independent Lab Services, to assess the levels of metabolizable energy (ME), dry matter (DM) and digestibility.

This pasture testing was also used in assessing whether supplement feeding was required to ensure liveweight maintenance could be achieved during the trial and thus animals were not in exposed to harmful conditions as per animal ethics requirements.

The results of the nine stubble samples were received on the 2nd of February with the full report and analysis found in Appx. 8.8.

As part of the analysis Dr John Milton his analysis concluded that “At these levels of Crude Protein (CP) and with the ME all well below the approx. 8.0 MJ ME/kg DM needed to maintain a mature sheep, these “composite samples” of Wheat straw couldn’t maintain a mature sheep.”

It was decided that a maintenance ration should be provided to the trial animals. The ration was calculated using the Lifetime Ewe Management (LTEM) App developed by Meat and Livestock Australia (MLA) which determined that 2kg of lupins per head per week should be provided.

One kilogram of narrow leaf lupins has been found to provide 13.1mJ/kg of Dry matter (DM) (Appx. 8.9) therefore 2kg of lupins should hold 26.2MJ divided by 7 days equates to 3.74MJ/day combined with the available average of 5.36MJ/kg lifted the trial paddocks to 9.1MJ/kg DM. This may have appeared to higher than the recommended 8MJ/kg DM to maintain a mature sheep, but allowances were given for wastage and the deterioration in available energy over time due to stubble deterioration as the trial progressed.

The supplied ration worked out to approximately 285g of lupins/head/day compared to the normal lupin flushing ration of 500g/head/day provided to other ewes on the property. The supplement was fed out in two feeds occurring on a Monday and Friday at 1kg DM narrow leaf lupins per feed. It was determined that feeder supplied 8kg/second and therefore each feed was calculated to require 22 secs resulting in 22x8kg equating to 176kg.

On the day Rams were to be taken out of the end of the joining, ewes were weighed, condition scored again, and collar devices were removed. All three trial groups were then merged together and transported to a neighbouring property to join with the rest of the mob that were not part of the trial. All sheep were subject to the same paddock conditions and supplement feeding routines from that point onwards.

On Wednesday the 27th of April all hoggets were brought into the yards and pregnancy scanned by an independent contractor boasting 22 years' experience in animal ultra-sounding.

Figure 22 - Wilsons Paddocks 1, 2 and 3 (5th June 2021)

Figure 23 - Pasture Sample collection images

Figure 24 - Biomass Imagery of Wilsons Paddocks in January 2022 and image of the area represented by the yellow

Paddock	Distance to yards (km)
Wilsons 1	1.96
Wilsons 2	2.23
Wilsons 3	2.53

Figure 25 – Furthest point in paddock to yards to calculate distance when mustering

3.1 Results

The below figure (Fig. 26) shows locations of stubble testing sites along with a bar graph representing the results received after stubble analysis.

Wilsons 2 paddock has the lowest Dry Matter (DM) content of 85% compared to paddocks Wilsons 1 and 3 which both have a DM content of 92%.

All 3 paddocks have similar Neutral Detergent Fibre (NDF) levels of 81-83%, and Acid Detergent Fibre (ADF) level of 52-54%.

Crude Protein (CP) levels for all paddocks were 2%, and the Metabolisable Energy (ME) content was between 5-6 MJ/Kg across the 3 paddocks.

Wilsons 1 paddock had the highest Digestible Dry Matter (DDM) of 43%, and the highest Water Soluble Carbohydrate (WSC) of 9%. Wilsons 3 had the lowest DDM of the 3 paddocks with 39%.

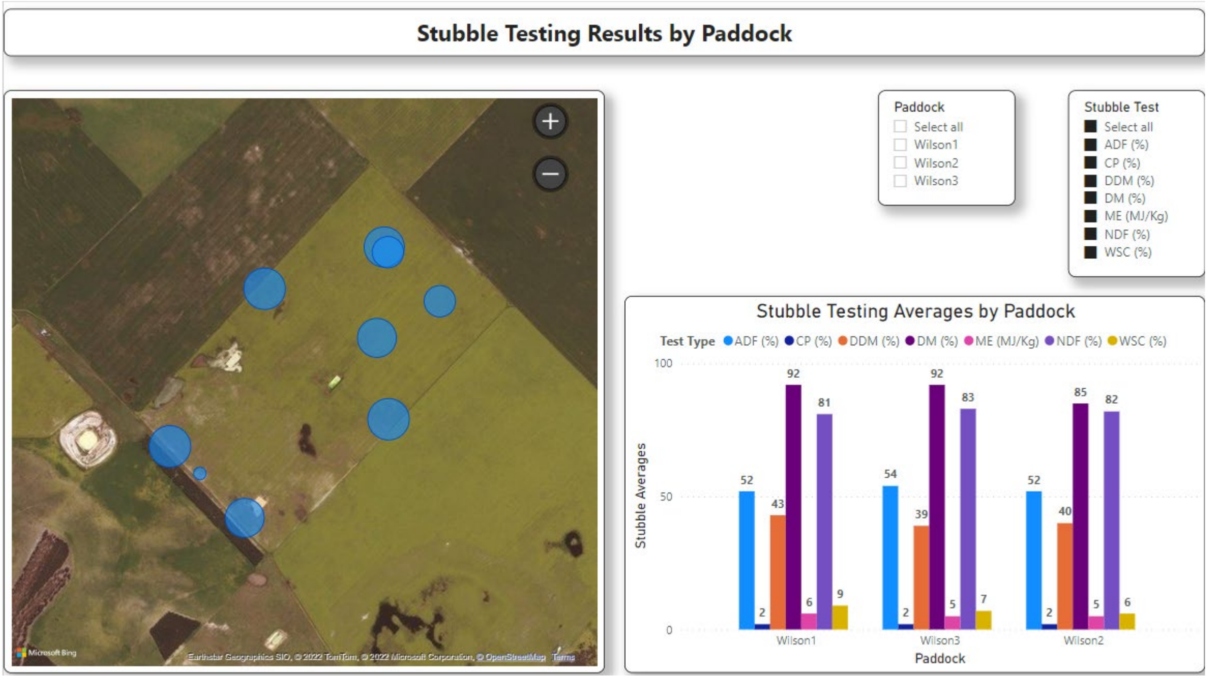


Figure 26 - Stubble test locations and results

The walking distances throughout the trial appear to follow the supplement feeding pattern, where distances travelled increase as supplement feeding occurs, or as FOO declines. Towards the end of trial there was a gap in the number of days between supplement feeding where there is an increase in distances even though supplement feed was not given (red arrows shown in Fig. 27). The overall average distance travelled per sheep across the three groups was 6,605.66 m/day.

The average change in Body Condition Scores (BCS) and weights for the three treatment groups, along with the pregnancy scanning results are shown in Fig. 28. The highest average change in BCS was seen in the low condition score group which averaged 0.89 increase from the beginning of the trial. The lowest average BCS change was seen in the high condition score group which was 0.63.

A similar pattern is seen with the average change in weights where the low condition score group averaged 8.05kg increase, however the lowest average weight change was in the control group with a 6.85kg increase in average.

Pregnancy results were analysed by type (single, multiple and dry), status (wet/dry) and foetus numbers.

The highest proportion of singles was seen in the control group contributing 26.38% of the singles scanned while the lowest proportion of singles came from the high condition score group with 21.65%. Of the multiples scanned the highest proportion came from the high condition score group contributing 10.04% while the control and low condition score groups were both recorded as 5.71% of multiples scanned. The highest proportion of dry ewes scanned was seen in the control group with 3.15% and the lowest proportion in the high condition score group with 0.98%.

The pregnancy scanning results were further broken down and assessed based on the top and bottom 10% of animals at drafting based on BCS. The sheep in the top 10% BCS at drafting resulted in 59.14% singles, 35.48% multiples and 5.38% dries. The bottom 10% BCS at drafting had 70.97% singles, 16.13% multiples and 12.9% dry. The same analysis was conducted based on drafting weights and followed the same pattern with very similar proportional results as the top and bottom 10% BCS at drafting.

The average distance travelled between the three treatment groups showed that there was a similar pattern in upward and downward trends between the high condition score and low condition score groups (Fig. 30). However, the control group showed a larger range on the upwards and downwards trends while also having a longer time period associated with these trends (Fig. 29).

The average daily gains (ADG) were mapped against average distances travelled and depicts a slight downwards trend during the first two weeks of the trial, with a slight upwards trend during the last 7 weeks (Fig. 31). A positive correlation between ADG and change in BCS was also seen (Fig. 31), as ADG increases so does the overall change in BCS. Average distance travelled was also graphed against change in BCS with a negative correlation, where walking distances decrease change in BCS generally decreases (Fig. 31).

Average distances travelled per sheep along with the associated BCS and weight changes across the three treatment groups are shown in Fig. 32.

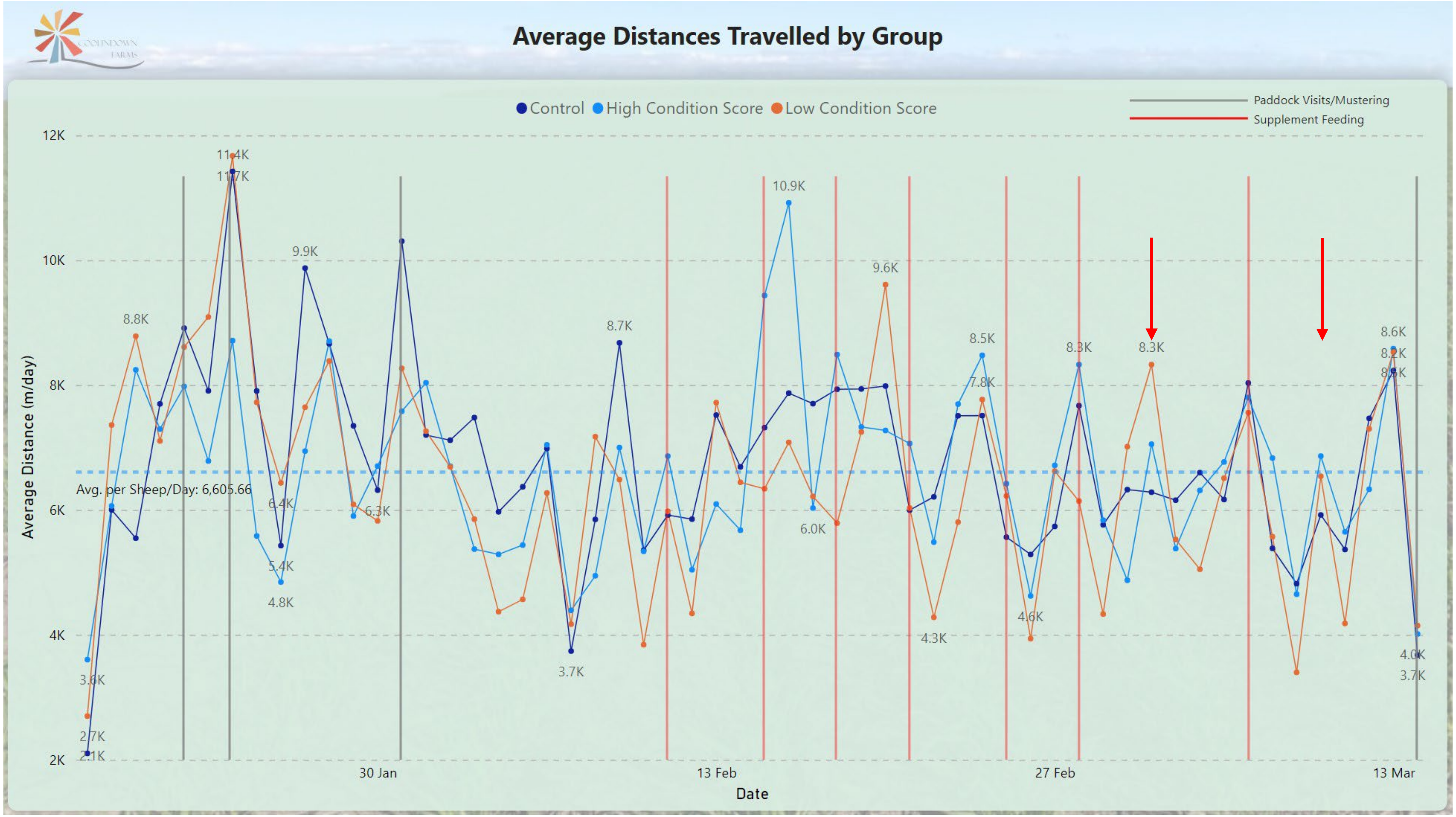


Figure 27 - Average Distances Travelled by Each Group

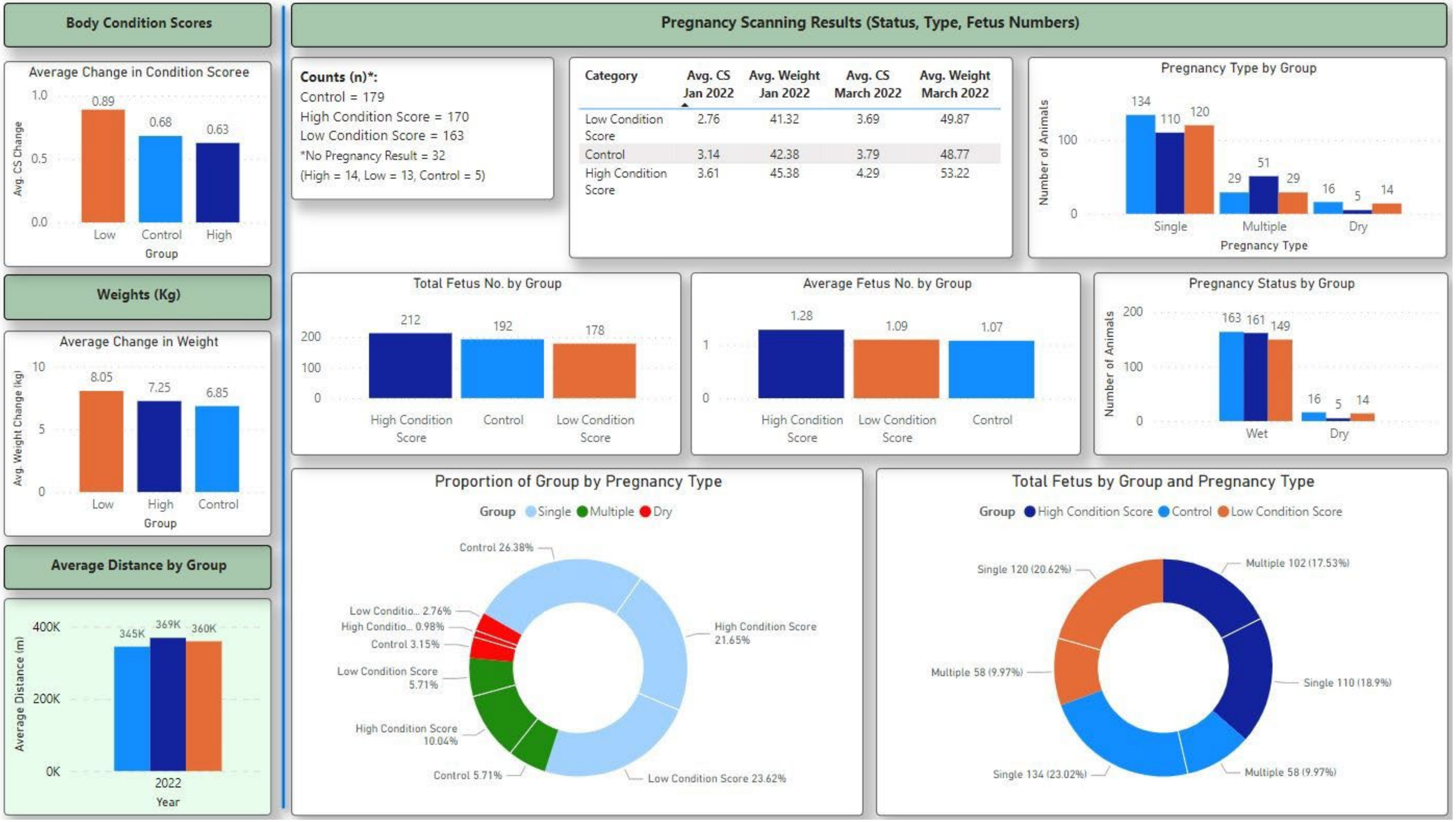


Figure 28 - Pregnancy Results Report

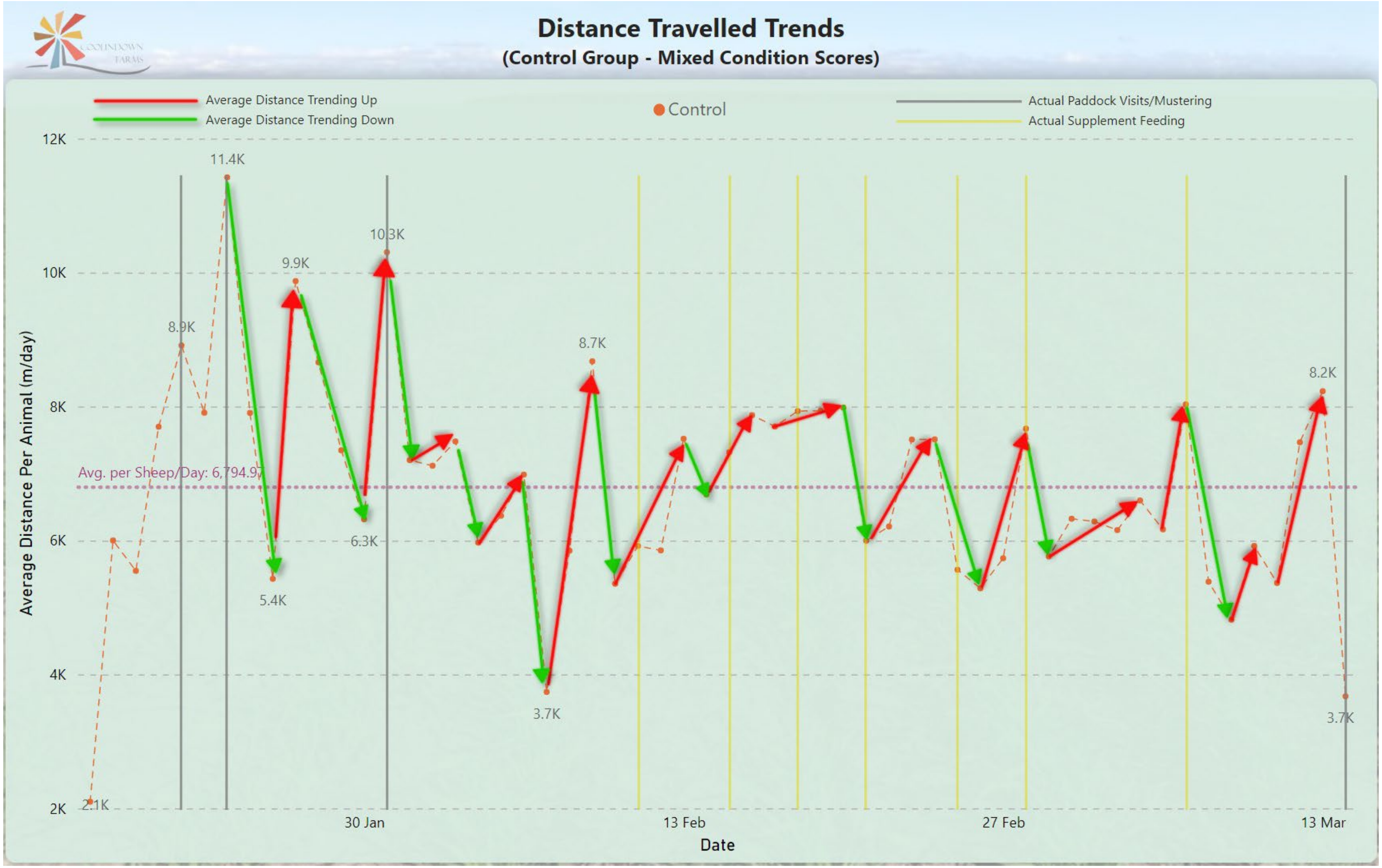


Figure 29 - Average Distance Trends - Control Group

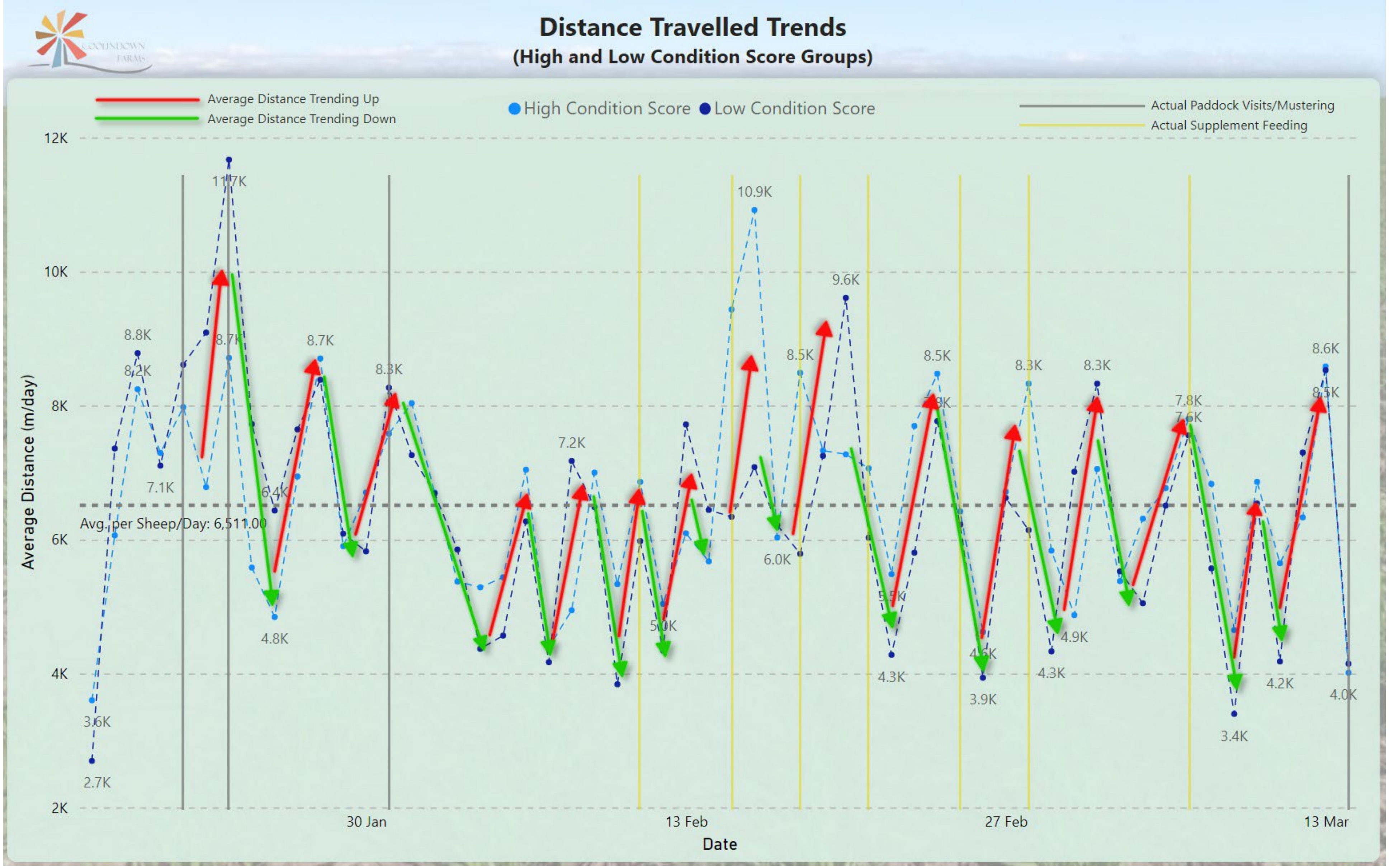


Figure 30 - Average Distance Trends - High and Low Condition Score Groups

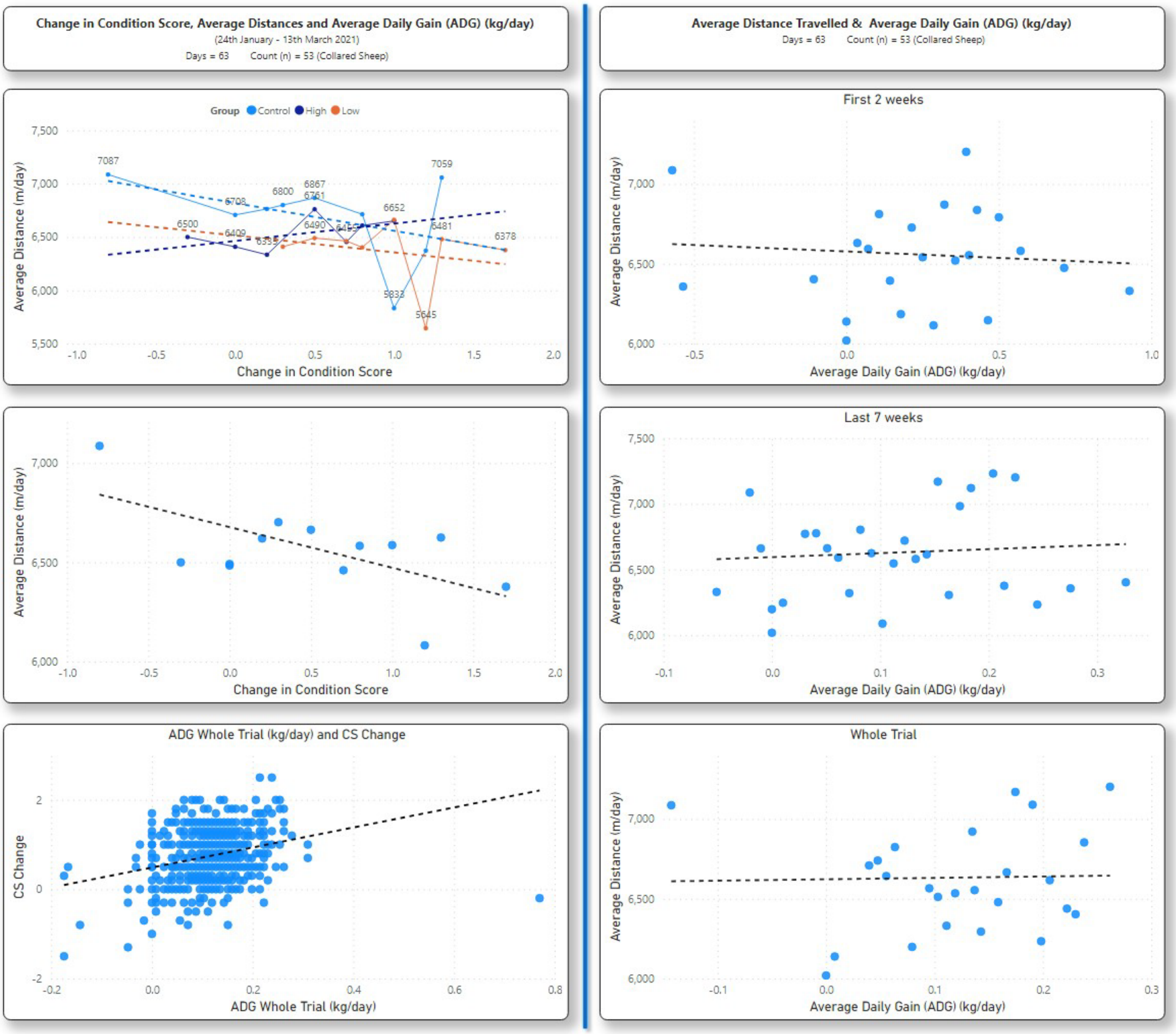


Figure 31 - Average Daily Gains, Distance Travelled per Group and Change in Body Condition Scores

Distances Travelled

Group	Avg. Distance per Sheep (m/day)	Standard Deviation	Variance
Control	6,794.97	292.02	85,277.51
High Condition Score	6,595.46	231.22	53,463.12
Low Condition Score	6,426.55	244.58	59,820.16

Average Change in Condition Score (CS) (% CS at Drafting)

Group	Bottom 10%	Middle 80%	Top 10%
Control	1.09	0.75	0.05
High	1.24	0.87	0.32
Low	1.10	0.93	0.05

Average Change in Weight (kg) (% Weight at Drafting)

Group	Bottom 10%	Middle 80%	Top 10%
Control	9.04	6.69	0.97
High	15.80	8.15	5.43
Low	8.56	8.53	6.64

Figure 32 - Group Summaries: Distance, BCS and Weight Changes

Table 3 - Calculation of Investment costs at different device densities (Digitanimal GPS Collar)

Device Density	Total Number of Collars (rounded up to be divisable by 3 groups)	Purchase Cost at $270 each (excl. taxes)	Ongoing costs (Batteries and connectivity services $30.64 each excl. GST)	Total costs for first year (excl. taxes)
100%	525	$141,750	$17692.50	$159,442.50
50%	264	$71,280	$8896.80	$80,176.80
25%	132	$35,640	$4448.40	$40,088.40
10%	54	$14,580	$1819.80	$16,399.80

3.2 Conclusion

The conception and joining of animals are important factors of animal management and welfare. The feed pressure at the end of summer caused by a reduction of quality stubbles due to deteriorating pasture conditions, reduces the feed on offer (FOO) and feed quality available to animals (Roberts, 2021). As a result, animals are assumed to travel further for food and water, potentially resulting in a more significant caloric burn. The issues associated with this increased caloric burn can ultimately be found when fertility assessment is carried out for the flock. Studies suggest that fertility is directly correlated to animal nutrition and thus recommended that animals are given supplement feeding with lupins to promote a fertility flush (short term) and to improve condition score (long term) (Knight et al., 1975).

Merino sheep have developed strong social bonds (Hulet CV, 1989) combined with strong flocking behaviours as a defence mechanism to predators (Cobb. R, 1999) given this behaviour the application of a lower density of devices had an impact on accuracy of flock movement as expected (Castro, J. et al., 2021) however the amount of devices used provided useful information to generate the results above and drastically reduce the investment and ongoing costs as shown in Table 3.

Return on the investment of these tracking collars is a little more nuanced, however when looking at the graphs there are some distinct areas in which a return could be derived. For example, when looking at the walking distance patterns there appears to be correlation for the high and low body condition score groups (Fig. 30). and a more variable pattern for the control group consisting of mixed body condition score sheep (Fig. 29). At the same time there is a higher proportion of singles and dry’s in the control group compared to lower condition score group and even higher again compared to the high condition score group. Highest proportion of multiples were in the high body condition score group as expected (Fig. 28).

Overall condition score and weight changes from the trial was highest in the low condition score group (Fig. 28). Considerations here include those dominant feeders would consist of higher body condition scores and weights within the mob at this stage of life. Therefore, by removing them from the lower condition scored sheep they have performed better in terms of weight gain and body condition scores as a result of a rising plain of nutrition which in turn has had a positive effect on the lower body condition score groups fertility.

Observed walking distances appear to follow supplement feeding pattern, as seen towards end of trial where distance increased with the anticipation of supplement feed, but they weren't fed at that day/time (Fig. 27). This raises the question whether supplement feeding stimulates the activity of foraging within paddocks which have been depleted of feed resources. Another question raised from this trial is whether the timing of supplement feeding could be correlated to increases and decreases in sheep distances travelled per day, rather than being supplement fed on set days as it was during this trial which is generally practised across the broader livestock industry.

In addition to the above, a repeat of the trial would be advantageous, we would like to allocate the 3 body condition score groups to different Wilsons paddocks to help eliminate any external or environmental factors that may have influenced walking behaviours, particular the Control group of mixed high and low body condition score as Wilsons 3 and High body condition score group in Wilsons 1 paddock as they potentially had outside influences such as a neighbouring mob of sheep or located on the property boundary where neighbouring activities may have influenced the distance travelled.

Given that each trial group still gained weight over the time period (Fig. 28) it stands to reason that either the supplement rate, the frequency of feeding or both has contributed to that weight gain and that there is actually a potential saving in feed, time, wages and overheads that could be obtained by further investigation into the use of GPS collars and in particular patterns in distances walked to trigger feeding regularity. An alternative may be to separate ewes by condition score and then vary the ration amounts between the two groups to maximise the benefit of the feed provided.

Finally, one of the simpler ROIs from this project came from the visibility of animals via the phone app to assist in the mustering of animals, in particular knowing where animals are located can help determine route leading to time and cost saving, small but still present.

3.2.1 Key Findings

- Separating ewe hoggets into low and high condition score reduces the distance walk compared to the mixed condition score control group thus reducing caloric burn.
- Separating out high condition score animals appear to have a positive effect on conception. The lower condition score animals appear to have little impact in conception compared to the mixed control.
- There is less variation and more distinct patterns in distances walked when animals are separated into condition score groups this could lead to more ability to predict animal movements.

3.2.2 Benefits to Industry

- There are economic benefits to managing ewes by condition score groups during summer joining.
- Animal movement patterns related to distances travelled could become the indicator of supplement feeding requirements as opposed to the current industry practise of prescribed days, this in turn could reduce costs associated with feeding too often. In the reverse could improve animal welfare by more timely feeds leading to better productivity through improved animal health.

3.2.3 Further Research and recommendations

- A repeat of this trial in the same paddocks with the 3 different body condition score groups allocated to different paddock to remove any environmental factors that may have influenced distances walked such as neighbouring mobs of sheep or other farm activities undertaken beyond the farm boundaries.

4. Activity 3 – Supply Chain

4.1 Objectives

- Potential improved producer engagement to understand and participate in the broader supply chain.
- Improved producer understanding of traceability and provenance
- Identification of barriers to data collection on farm.
- Potential improvement for future management and breeding decisions.

4.2 Methodology

Table 4 - Activity 3 Project Outline

NO	ITEM	ACTIONS	PROJECT UPDATE	DATE
1	DATA HANDOUT	Ingestions of kill sheets from V&V Walsh and WAMMCO	Belinda uploaded PDF kill sheets for ingestion	
2	Industry Engagement	Engage in discussions with V & V Walsh (Bunbury)	Teleconference with Hannah from V & V Walsh	25/01/2022
3	Data Mapping	Identify livestock data equipment and data collection points	Created a livestock lifecycle chart and the related data collection (touch points) along that lifecycle	
4	Data mapping	Identify all enterprise data	Mapped all the data collected across the business, where it is held and what format it is held in	
5	Staff Engagement	Discuss with staff the barriers they see to data collection	Observed and discussed elements of data collection with various team members	10/01/2022
6	Industry Analysis	Industry analysis on information of interest to meat processors and assessment on data format	Wes met with V & V Walsh to understand their data processes.	
7	Scoping Study	Completion of data scoping study on data to and from supply chain	Version 1 completed	01/02/2022

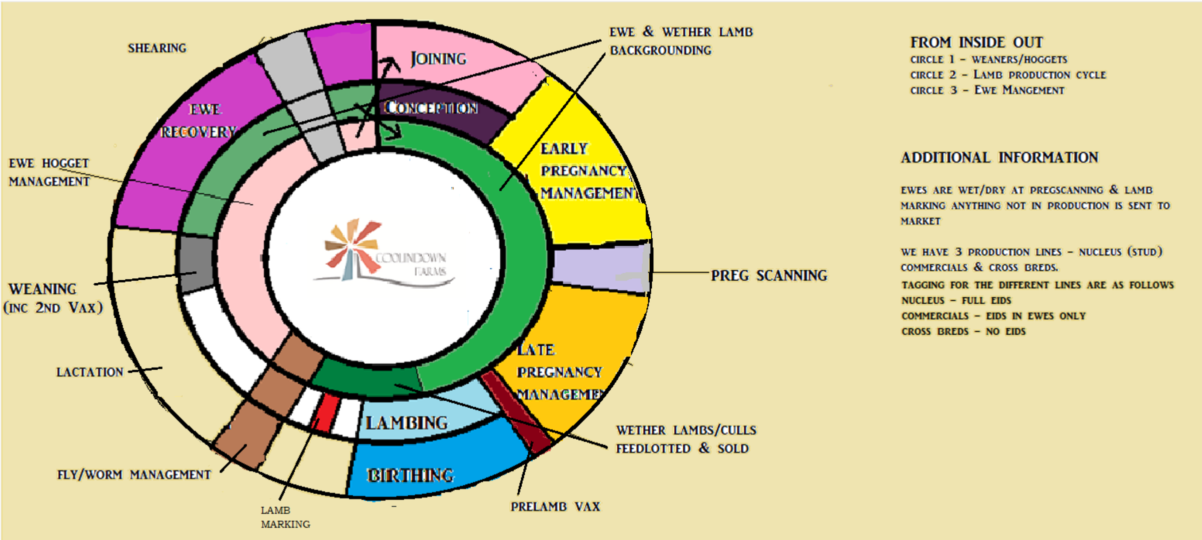


Figure 33 - Production and Lifecycle Diagram

To fully understand the key lifecycle data generated on the farm and to ensure we have all the relevant data sets. A lifecycle of sheep within the commercial operation was drawn up and mapped out into a production diagram (Fig. 33). This helped us to identify any potential gaps and optimal data collection points.

We then undertook to assess the data that is already being collected in relation to the above cycles and the equipment that is used to collect it. In additions an understanding of the process of data movement from collection to storage, where the data went and how it got there.

Table 5 - Data collection events

Animal Event	Data Recorded	Equipment	Software	Format
Joining	• Condition Score • Weight	• Weigh crate • EID reader	Trutest	CSV
AI Ewes	• Sire	• Wand	Trutest	
Preg Scanning	• Preg Status: Wet / Dry /Multiple • Condition Score • Weight	• EID reader • Weigh crate • Scalehead • Oviscan	Trutest	CSV
Pre Lamb Vax	• No data currently collected			
Lamb Marking	• Farm • Paddock born • Single/Multiple mob • EID number • Treatments – product, dosage rates, expiry dates, Withholdings, batch numbers • Wrinkle score	• Eid tags • EID reader • Scale head • Weigh crate • TSUs • Barcode reader	Trutest	CSV
Wether Lambs (Culls / Feedlotted / Sold)	• Limited individual animal data collected as not all purchased animals have EIDs • Mob based records on treatments are kept	• Mobile Phone	Agriwebb	Can be exported to CSV
Fly/Worm Management	• Product/ dosage • Withholdings	• Mobile Phone	Agriwebb	Can be exported to CSV
Weaning & 2nd Vax	• Product/ dosage • Withholdings	• Mobile Phone	Agriwebb	Can be exported to CSV
Shearing - General	• Date of shearing	• Mobile Phone	Agriwebb	Can be exported to CSV
Shearing – Ewe Hoggets	• Weight • Condition score • Fleece weight	• Scalehead x2 • Weigh crate x2 • EID reader x2 • Barcode printer • Barcode reader	Trutest	CSV
Spray Records / Diary	• Date • Chemical Name • Total litres • Rate of application • Stock Withholding	• Mobile Phone	Agriwebb	Can be exported to CSV

V&V Walsh were contacted for their input and participation in the data scoping study for this project with the aim to conduct a meeting to establish the requirements, limitations and barriers to supply chain data transfer.

Data flows and the identification of missing information including potential barriers are being assessed.

A meeting with V&V Walsh was conducted on the 25th of January 2022. The aim of that meeting was to establish the requirements, limitations and barriers to supply chain data transfer.

The final version of the scoping study is attached in Appx. 8.11.

4.3 Results

Table 6 - Potential use cases and applications of data transfer along the red meat supply chain

Potential Use Cases and Applications	
Data Flows	• Establishment of direct data flows to and from Producers and Processors • Decreases time required to send and follow up via emails and other communication pathways
De-identified Regional and/or State Level Benchmarking	• Average Liveweights (LW) • Growth Rates (GR) • Weaning Rate Averages • Hot Carcass Weights (HCW) • Weather data • Natural resource capital data • Soil health and management data • Crop yields • Pasture growth rates/FOO • Biosecurity and sustainability • Cold chain management
NLIS Database	• Livestock movement/transport data • Scheduled exports or potential data integration
ICS Integrity Systems	Data record sharing with: • Livestock Production Assurance (LPA) • National Vendor Declarations (NVD)
Meat and Livestock Australia (MLA) Database	• Aggregated data for analysis – national and state levels • Access to shared datasets for future projects/research
Collaborative Trials and Projects	• Growers and producers • Grower and producer groups • Group and regional research and trials • Natural Resource Management (NRM) centres • Research Institutions • Government

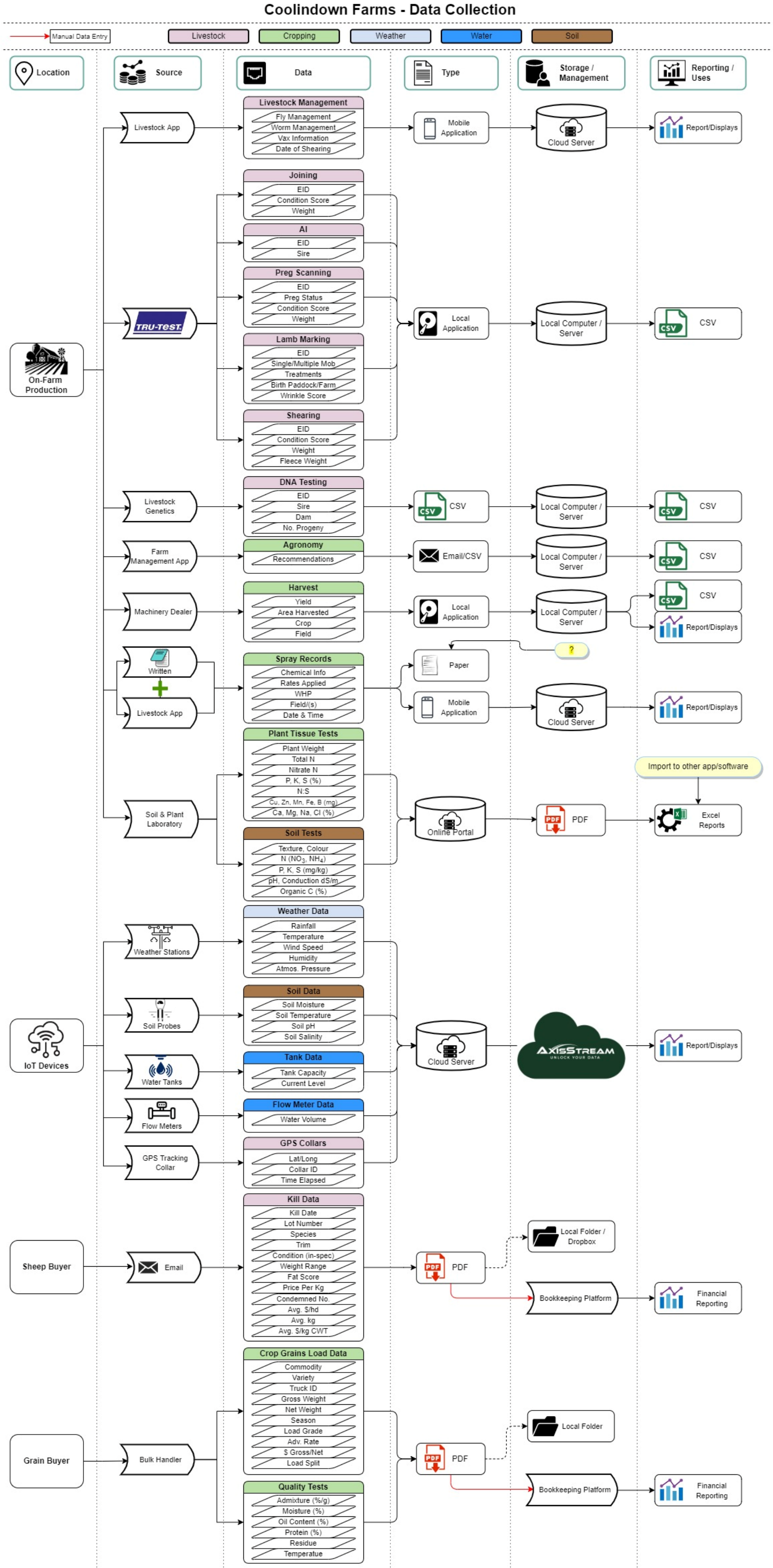


Figure 34 - Coolindown Farms current data collection map

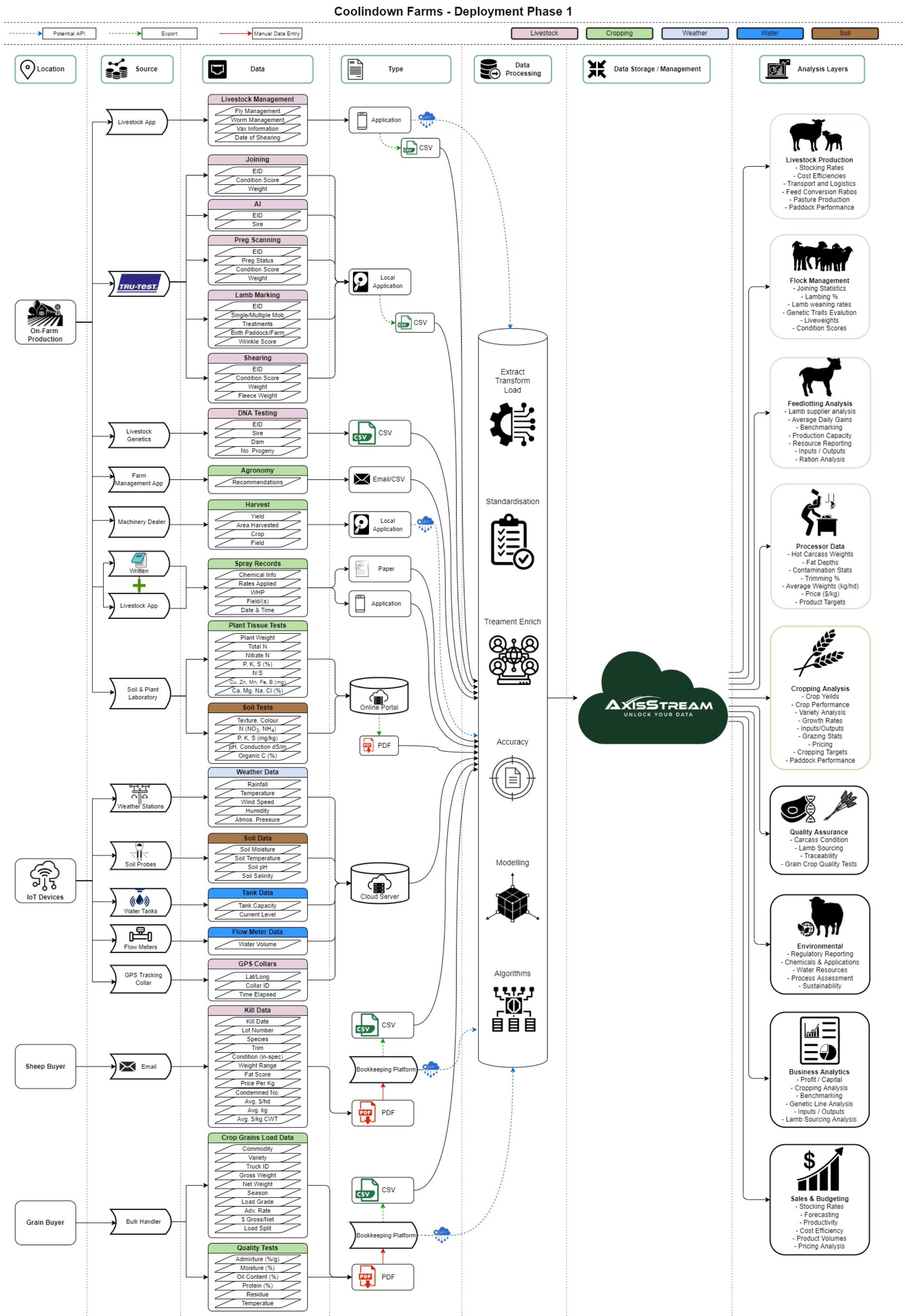


Figure 35 - Coolindown Farms deployment phase 1

4.4 Conclusion

Establishing data flows and data traceability along the red meat supply chain is complicated, but achievable if all key parties and individuals are open to collaboration and willing to put in the time and resources required to achieve this goal.

MLA's ambitious goal to reduce greenhouse gas emissions through the Carbon Neutral by 2030 (CN30) initiative, signifies that participants and businesses along the red meat supply chain require the suitable infrastructure and technologies to capture, store, analyse and report on their operational data relating to environmental and economic targets.

Coolindown's initiative in digitising their business using AxisStream means their agricultural data is standardised, accessible, re-usable and interoperable, which allows them to progress with supply chain data transfer opportunities.

Despite the achievements made in digitisation there are multiple barriers that are affecting the collection of on-farm data in relation to individual animals within farm operation, in particular for those animals that have a perceived lower value. The greatest impact appears to be the time poor environment that exists within a mixed farming enterprise as this severely limits the ability of both individuals and management to improve skills, processes and implement training.

4.4.1 Key Findings

- Until EIDs are compulsory the capacity for producers to collect, store and transfer lifecycle data will be impeded.
- Current on farm data collection activities and the determination or willingness to conduct these activities appears to be correlated to the perceived return on investment or the overall outcomes received from such data and not the ease of the activity itself.
- Educating staff on how to operate and correctly use current data collection systems, as well as communicating the importance of recording such data, is vital to establish the context and purpose for each data collection activity on farm.

4.4.2 Further research and recommendations

- A proof of concept project that looks at the transfer of data between two producers that have integrated lifecycle data into a data store to demonstrate the capacity for this to be achieved.
- Educating staff how to operate and use current data collection systems as well as communicating the importance of recording such data is vital to establish context and purpose for each data collection activity on farm.
- Businesses within the food supply chain should undertake a data flow and mapping exercise to enable a streamlined process for potential integration and to facilitate data sharing opportunities between participants along the red meat supply chain.
- Investigation into the Wool Supply Chain and the data that could be of benefit.

5. Activity 4 – Water Management

5.1 Objectives

- Development of a uniform methodology to calculate animal production water usage as a benchmarking tool for the entire industry.
- Development of a novel system that detects water wastage problems early, improving water usage and drought resilience
- Gain a better understanding of the other resource efficiencies that could be gained from implementing this novel system.

5.2 Methodology

Table 7 - Activity 4 Project Outline

NO	ITEM	ACTIONS	PROJECT UPDATE	DATE
1	Site Preparation	Coolindown Farms staff to prepare sites for installation of Water Tank sensors and Flow meters	Locations identified. Pipe sizes double checked. Installation and Device plan was developed, mapped in Google earth and communicated and put into Dropbox.	05/05/2022
2	Device Deployment	Conduct assessment of major water lines to install water flow meters at Tank exits and at water origins such as dams & soaks and install further water tank monitors	Installation and Device plan was developed, mapped in Google earth and communicated and put into Dropbox.	05/05/2022
4	Partial data analysis	Conduct analysis of historical data at AxisStream and collate weekly reports on data tank capacity vs current.		30/05/2022
5	Scoping Study	Completion of Water Automation scoping study	Version 1 completed	02/02/2022
6	Data analysis	Data analysis to establish if an allocation of water resources to animals can be accurately and efficiently calculated		

As an initial a part of this case study a range of IoT devices including Water Tank level sensors and flow meters were installed in May/June This enabled farm management team to familiarise themselves with the management apps and provide the ability to give genuine feedback as to any installation or other issues and insights that could be given; it was important to achieve this prior to the summer period when water management is critical to the welfare of the animals.

Once installations were complete a review of other water management practices were undertaken this study addressed the following:

- Literature Review
- Industry practices and current use
- Current Devices and Water Management
    - Aerial Map
    - Design Flow Chart
- Design/Chart – Device Requirements for fully automated system (Conceptual)
- Physical Device Requirements and Costs

- Approximation of ROI
- Limitations of Framework
- Framework Repeatability

Coolindown Farms water systems are based around a central water source being either a catchment dam or a naturally occurring soak. From these locations and windmill or a solar powered pump moves the water to tanks located on high elevation points of the property to then utilise gravity as a method of supplying water to animals via troughs. A property assessment was undertaken using Google earth on all Coolindown Farms current water infrastructure (Fig. 36). This enabled the pinpointing of optimal locations for flow meters and the ability to assess where to focus which sites that required preparation before installation.

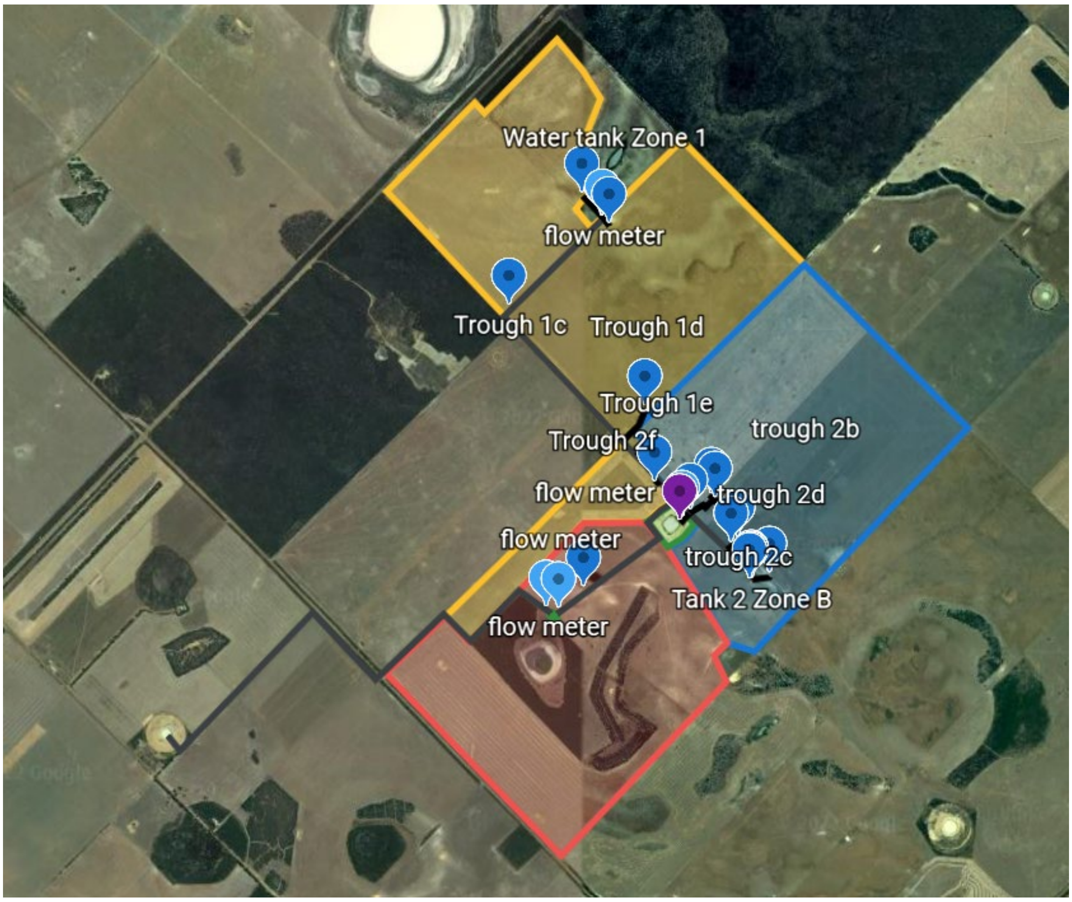


Figure 36 - Water Management Map - Yalabyn

Utilising the existing Sigfox connectivity network, custom made brackets were made by Coolindown's staff and the deployment of Waterwatch level sensors was undertaken on the 23rd of May 2021 on the required water tanks (Fig. 37). The sensors were then connected to the existing phone app as well as to the AxisStream platform on the 25th of May 2021. We then identified relevant locations and installed 7 Flow meters at each water source which comprises of two windmills and one solar pump and at the base of tank to monitor what flows to the troughs (Fig. 36).

Figure 37 - Waterwatch sensors on two Coolindown Farms water tanks

5.3 Results

Water Run Cost Assumptions

This assumption is underpinned by the vehicle logs on the farm that record average distance travelled is 40,000km/year.

40,000km /365 days =110km/day.

Vehicle wear/tear is assumed to be equal to current fuel cost Litres of fuel consumed per100 km = 6.5litre.

Therefore, the number of Litres of fuel consumed per vehicle equals 7 litres a day @ $1.52 brings the total fuel cost to$10.64 per day plus $10.64 for wear and tear equalling $21.28/day.

8 hrs day = $2.66/hr.

WATER RUN COST ANALYSIS

A standard water run includes checking water tank levels, cleaning water troughs, turning pumps and windmills on/off and changing taps if needed to redirect water. Standard water run takes approximately 3 hours to complete between the 4 properties.

Vehicle Costs – 3 x $2.66 = $7.98/water run

Wages Consideration – Currently hourly rate is $28/hr plus super $2.80 and workers comp at 10% ($2.80) = $33.60/hr.

Therefore 3 hr/water run = $100.80/run in wages and $7.98/run in vehicle costs.

<u>Summer Water Runs</u>

Conducted 7 days per fortnight during October to April equalling 105 summer water runs.

105 summer water runs costs $10,584 in wages and $837.90 in vehicle costs totalling $11,421.90.

<u>Winter Water Runs</u>

Conducted once weekly during winter equalling 22 winter water runs.

22 winter water run costs $2,217.60 in wages and $175.56 in vehicle costs totalling $2,393.16.

Total annual water monitoring costs for a year $13,806.06

NOTE: The above does NOT include any costs for the parts, time and travel to repair any issues found.

Return on investment comparison

Based on not being able to fully erase physical water monitoring until such time the system was to become fully automated it is foreseen that 70% could be reduced as has been indicated by the introduction of water tanks sensors. This would effectively reduce costs annual water monitoring costs by $9,664.24 a year from $13,806.06 to $4,141.82 and returning 88 hours of work that has been reallocated to other activities on the farm.

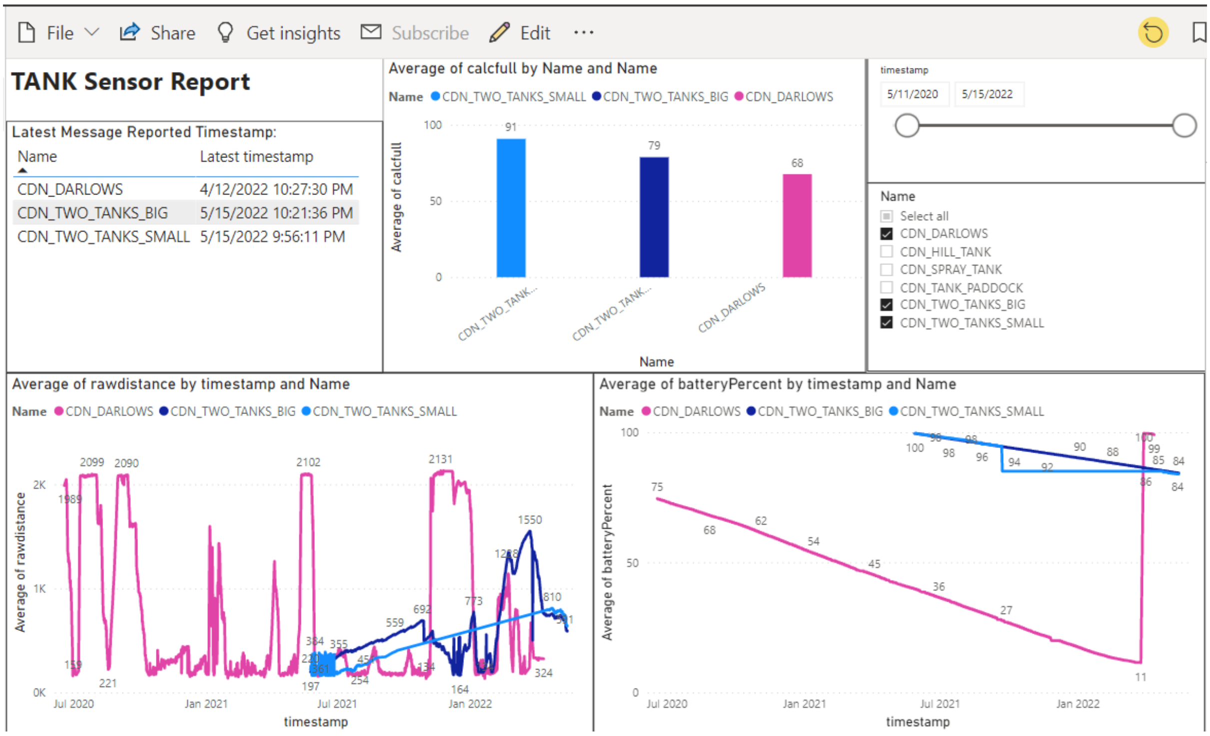


Figure 38 – Water tank levels report

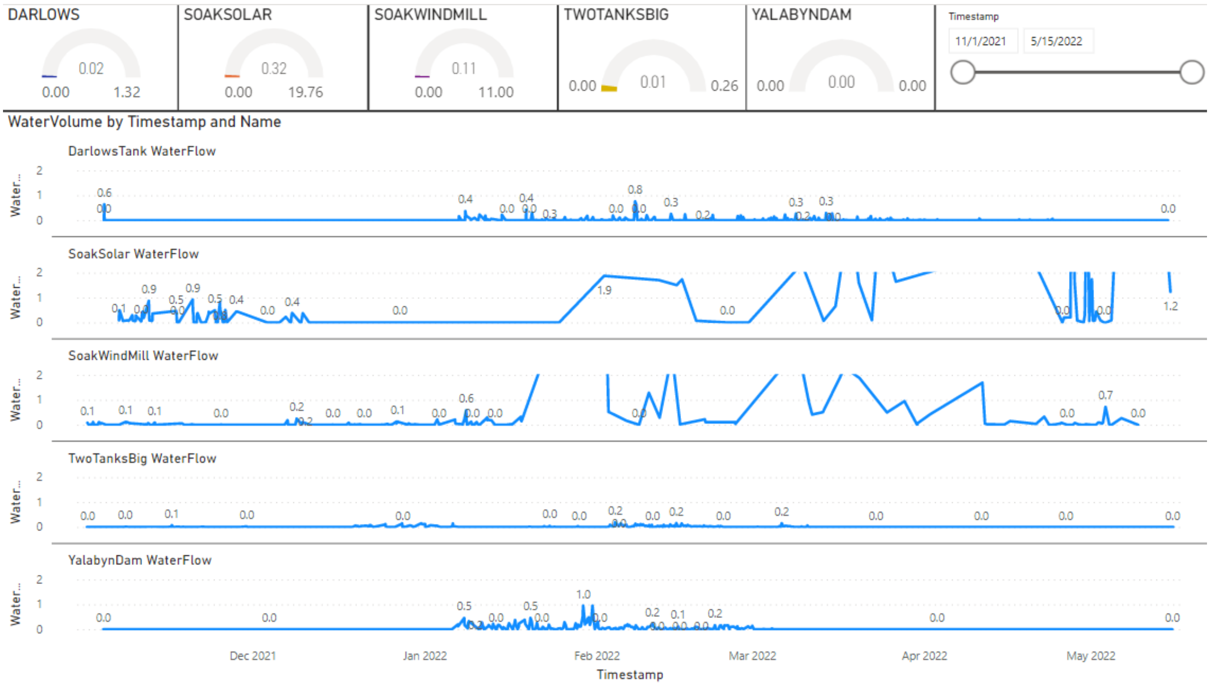


Figure 39 – Water flow meter report

DARLOWS TANK: WATER LOSS ANALYSIS

Darlows Tank Holding Capacity = 55,000 litres

No. of times water was lost = 5

Total water Lost = 275,000 litres

Cost to buy in = 75c/Kilolitre = $206.25

Litres transported per truckload = 55,000 (55tn)

Freight cost per truckload of water @$14/tn = $770

(275,000/55,000) x $770 = $3,850

Total Cost = $4,056.25

Cost of 55,000 litre tank = $8,500.00

Water Use Efficiency Calculation for Livestock

"A mature sheep on dry feed in summer might use 8 to 10 L per day whilst the same animal on dry feed in winter might use less than 4L per day. The amount of water used by animals also varies depending on their breed, type, age and weight" (Agriculture Victoria, 2021)

In such a dry, hot climate the evaporation of water needs to be accounted for when establishing a formula or calculation to determine livestock water consumption.
According to Agriculture Victoria, to calculate evaporation loses using the weather bureau's Class A Open pan evaporation rates they must be multiplied by a conversion factor of 0.67 (Agriculture Victoria, 2022)

Below is a conceptual formula that could be used as a basis for livestock water consumption, which would require trough water level sensors to be installed.

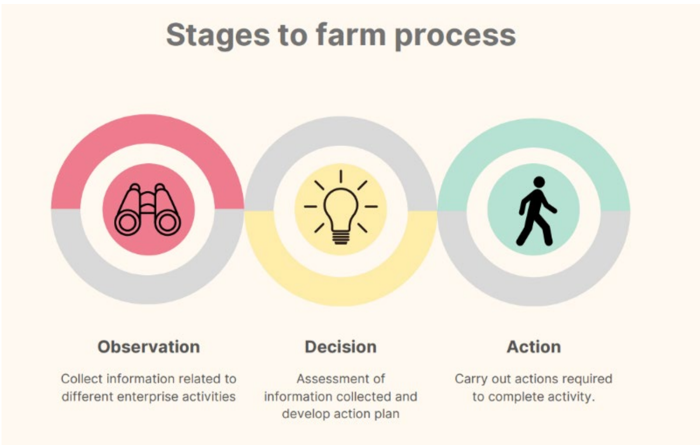
[((Actual trough holding level + Flows In) - Flows Out) - (evaporation calculation*)] /number of animals

*Evaporation calc: BOM total monthly avg evaporation in (mm) / days in month = daily avg evaporation amount (mm) -> converted to mL for based on trough dimensions

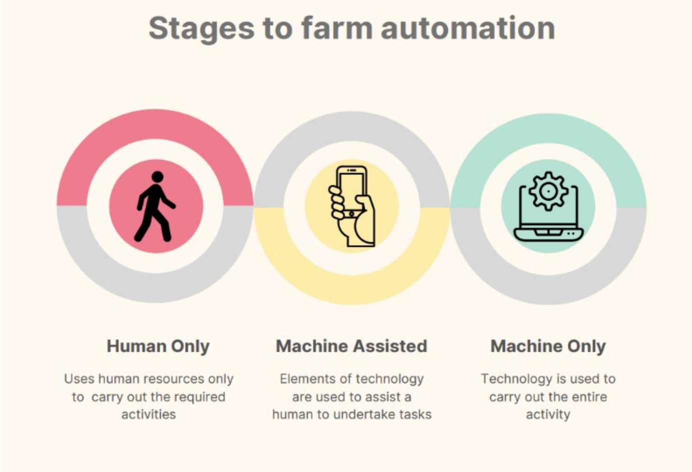
5.4 Conclusion

It is thought that Precision Livestock Farming (PLF) is potentially one of the most powerful developments that have the potential to revolutionise the livestock farming industries. (Banhazi, T.M et al., 2012). Under the banner of PLF sit Automation and Robotics, aspects of Automation provide ROIs through reducing labour cost, increasing output and mitigating risks (Gonzalez. CM, 2020)

In setting up this activity some key understandings of the automation process were established firstly it was identified that each and every farm process can be broken down into the key parts shown below



The significance of this is that it allows the application of automation stages to be applied to each step of a farm process which bring us to the stages of automation that we also formulated below.



When these two elements are combined is provides a framework of 27 possible pathways in which any or all parts of a farm process could be potentially automated.

Based on not being able to fully erase physical water monitoring until such time the system was to become fully automated it is calculated that 70% could be reduced by the introduction of water tanks sensors. This would effectively reduce costs annual water monitoring costs by $9,664.24 a year from $13,806.06 to $4,141.82 and returning 88 hours of work that has been reallocated to other activities on the farm.

In setting up the flow meters the phone app was bypassed to send information directly to the reporting platform. This removed visibility of daily flows from the producers on ground and proved to problematic and frustrating especially when one of the flow meters became blocked with algae causing a drastic reduction in water flow, fortunately this was picked up before it had a detrimental effect on livestock water supply.

The positive ROI from Water Tank Level sensors has been the instigator of the Case study in appendix 8.12 which looks at the infrastructure and process requirements necessary to automate other parts of water management processes and what is required to move those from Human Only to the final stage of Machine only Observations, Decisions and Actions.

This too has shown to have a positive Return on Investment however it requires a much longer period of time for the gains to be realised in comparison to the implementation of Tank Level Sensors.

PLF has the potential to return more benefits through improved animal welfare, reduction stock theft, improved market security and a reduction in environmental impacts (Banhazi, T.M et al., 2012)

In the process of undertaking this activity and assessment of existing water and water assets on the property "Yalabyn" was undertaken. As a result of this assessment (Fig. 37) Zone 3 shown in red was identified as not having a backup water supply in the form of tanks and troughs like Zones 1 and 2 and is fully reliant on water held in old claypits. Once these water sources evaporate the land is unable to be utilised for grazing over summer and potentially applying more grazing pressure to other paddocks. The return of investment for a tank, 2 troughs and some pipe with fittings is the ability to utilise 230Ha over summer.

The question is then should we call this situation a Water or a Water Asset deficit?

However, when looking at the recorded the observations of Water tank level movement though the AxisStream Platform report showed dramatic rises and falls in the tank level in Darlows Paddock (Figure 38) This was a major leak that had gone undetected over a period of a few months and the tank had been filled repeatedly only for 275,000 litres of water to be lost. A cost analysis of the water loss that occurred at Darlows tanks was done although it doesn't appear to be of significant economic value it raises question over the value of water and given that a 55,000 litre water tank cost $8,500, this could go some way to explaining hesitancy to invest in water infrastructure.

It was noted that prior to this activity, there was no current knowledge around farm water consumption and a value for water itself is not included in the balance sheet for Coolindown Farms.

5.4.1 Key Findings

- Implementing water tank level sensors can reduces costs by up to 70%.
- It appears that the best ROI's will be derived from moving towards automation in observation and action activities.
- An awareness of water consumption and farm requirements along with its financial value needs to come to the forefront of producers' minds as we face a forecast change in climate.
- The change in narrative from Water Deficit to Infrastructure Deficit is empowering and enables producer to be proactive in identifying and implementing drought mitigation strategies through the increased capacity to store, manage water and or wastage.

5.4.2 Benefits to Industry

The following are potential benefits of this project that have been identified:

- Reallocation of staff resources to other jobs due to reduction in water monitoring requirements.
- Facilitate the improvement in animal welfare from water shortage alerts.
- Ability to identify water wastage from spillage and leaks.
- Foundation for a water efficiency and usage system benchmarking tool.
- Water is key component of agricultural production and yet a value for water is not recorded on the balance sheet of broadacre farming enterprises.
- Investments into shifting decision making is difficult to evaluate and would potentially require machine learning and algorithms which are beyond the skillset and ROI of the average producer but would fit more suitably in the AgTech sector.

5.4.3 Further Research and recommendations

- The Livestock water efficiency ratio calculation requires further work and testing of its different elements

6. Activity 5 – Soil Amelioration

6.1 Objectives

- Establishment of novel methodology to detect and assess soil compaction caused by sheep treading.
- Contribution to better understand and showcase ROI's around soil management.
- Case study report/article on the potential of integrated loT devices deployment on soil moisture monitoring

6.2 Methodology

Table 8 – Activity 5 Project Outline

NO	ITEM	ACTIONS	PROJECT UPDATE	DATE
1	Collars	Service and check collar connectivity in preparation for deployment	79 collars were ok. 21 collars were given to AxisTech to take back to Perth for repair. Belinda checked the preg scanning data. 74 collars are required for the ewe trial so OK to proceed	12/05/2021
2	Purchase Orders	Compile & place purchase orders for required devices and connectivity. Coordinate with AxisTech to undertake activities related to Milestone 1	Contact made with the Agronomist, AxisTech & Ezifarm to start activities.	20/05/2021
3	Elevation Analysis	Engage with Optisurface to conduct elevation analysis of two tanks paddock and generate visuals using MyJohnDeere data	Optisurface was contacted on the 5th of May. Belinda was able to generate an elevation map from the John Deere information collected from the Harvester on Two Tanks paddock in 2019 in the My John Deere App.	05/05/2021
4	Travel	AxisTech Team to Prep & travel to Coolindown Farms site in Esperance	Alefe flew to Esperance on Monday the 17th with soil moisture probes. Wes Drove on Wednesday the 19th bring the camera trailer, cameras, sensors and Wi-Fi connectivity devices.	19/05/2021
5	Induction	AxisTech Team to undertake Coolindown Farms site induction for Contractors	Online portion of induction completed on 5th May 2021. Soil sampling machine use instructions given by the Agronomist.	18/05/2021
6	Site identification	Identification and definition of probes, soil, and compactions test sites Review map; identify sites.	Sites for device deployment has been chosen and are available under Methods folder in a KML Folder… Revisit the document after the actual deployment. Influencing placement was tractor AB Lines (see pictures) length of cable and soil sampling cores.	18/05/2021
7	Soil compaction analysis	Engage with Agronomist to conduct soil compaction analysis to obtain reference compaction value	Agronomist had a manual penetrometer which identifies depth at which compaction layers may exist but doesn't generate an actual reading. Alefe contacted several companies and hired digital penetrometer to take measurements.	18/05/2021
8	Soil Tests	Engage with CSBP to conducted soil typing (soil tests) and collate results once available and provide to AxisTech	Alefe collected and marked up 1m soil core sample tubes on the 21st of May. Belinda processed soil core samples of the 25th of May and dropped them in to the Agronomist on the 26th of May. CSBP Sample order form was filled out and emailed to the Agronomist on 27th of May to accompany samples to the CSBP Lab.	27/05/2021
9	SMPs deployment	Deployment of soil moisture probes and establish connectivity	Alefe and Belinda installed Probes utilising the holes created by the soil sampling machine on 21st May. Sensors were attached on the 20th of May. Data setup was undertaken by AxisTech on the 21st. Data reading checked on the 26th. Belinda & Deon tampered the soil around all the probes to create better contact with the sensors on the 27th. Data readings rechecked all ok.	28/05/2021
10	Camera	Pre flight check of Camera connectivity and function in the planned paddock	Wes Showed Belinda how to put the components of the Camera together. Wes provided all the components for the set up of the second camera trailer. Overview of the camera app.	20/05/2021
11	Data Handout	Soil and tissue test result	Results were forwarded to AxisTech	08/06/2021
12	Tissue Tests	Coordinate the tissue testing on establish/existing crop	CSBP area manager collected 15 plants around each site and sent away for analysis.	14/06/2021
13	Camera Deployment	Deployment of camera to Two Tank paddocks	First Camera Installed – June 11th Second Camera installed – June 15th	15/06/2021
14	Collars	Reassemble and last minute check collar connectivity in preparation for deployment.	Belinda reassembled and checked with phone app	14/06/2021

15	Collar	Collar check	Collars were rechecked immediately prior to deployment 4 more collars were not functioning leaving 75 Collars.	14/06/2021
15	Devices	Collect and charge devices for data collection. Transfer weigh scales to yards	Scale head and wand programmed and charged. Scales moved to the yards	15/06/2021
16	Weights & CS	Collect Weights and Condition Scores on trial animals	Weights and condition score collection was delayed by 2 days due to bad weather	17/06/2021
17	Pre lamb treatment	Deployment of collars and pre lamb treatment (vaccinate ewes, etc animal welfare)	Delayed 2 days due to bad weather but completed on the 18th	18/06/2021
18	Sheep on paddock	Allocate animals to Two Tank Paddocks at the start of the project	Ewes were enclosed into Two Tanks Paddock at 11:55am	18/06/2021
19	Data Handout	Provide Annie with all data in accessible forms for tissue tests, soil tests, compaction tests, as well as any relevant data regarding devices installed, location and ID numbers.	EID/Collar Data – June 17th Soil Test data – June 8th Compaction data – June 16th Condition Scores – June 18th Weights – June 18th	18/06/2021
20	Animal Management	Belinda to monitor animals and ensure animal welfare standards	Cameras were set up on pre-set locations and Zoomed in by Belinda and Lucas and checked over the weekend. Belinda learnt how to playback footage. Lucas download footage to be saved to an external hard drive later. Belinda conducted checks at intervals during the day. Visiting the paddock when necessary	30/08/2021
21	Lambing starts	Expected period where ewes are expected to start lambing	First lamb was born on the 30th of June	07/07/2021
22	Sheep out of paddock	Remove animals from paddock and generate report on animals' distribution across the paddock (generate heat map)	Animals were removed from the paddock on the 22nd of August and collars were removed. However due to paddock availability management returned animals on the 23rd for a further 2 weeks. Heat map was generated in Power BI	22/07/2021
23	End of Collar data collection	Inform Annie data is no longer being collected for this trial	Belinda messaged Annie in Slack to inform of completion of data collection. Annie acknowledged on the 23rd	22/08/2021
24	Removal of Camera	Remove camera from paddock	Belinda and Deon removed cameras from paddock	23/08/2021
25	Soil compaction analysis	Engage with Agronomists again to conduct second soil compaction analysis at the same sites	Alefe collected soil compaction samples at the 5 sites using the same device hired the first time and the same methodology.	23/08/2021
26	Devices	Collect and charge Trutest devices for data collection	Belinda charged all devices ready for data collection the day before needed	22/08/2021
27	Weights & CS	Weigh and Condition Score Ewes as per animal ethics requirements	Belinda and Deon collected weights and CS scores of trial ewes	23/08/2021
28	Lamb Marking	Collect Data on Lambs & Survival rates	Data has been collected and submitted for analysis	30/09/2021
29	Device removal	Collars to be removed from Trial Ewes	Collars removed successfully no incidents involving collars recorded.	23/09/2021
30	Data Handout	To provide Annie with all remaining data	DNA results were received in December and uploaded for ingestion	30/12/2021
31	Harvest and yield map	Engage with Decipher to generate report on yield and biomass and generate maps. Once results available, provide to AxisTech	John Deere data uploaded into JD Data manager on January 12th informed AxisTech January 15th. Decipher biomass maps were created on January 20th and uploaded into slack	20/01/2022
32	PowerBI analysis and report	Conduct PowerBI analysis of all data and develop report; analyse compaction and animal distribution results with yield map generated during harvesting.	AxisTech undertook the analysis of data collected.	20/05/2022

Paddock History: Non-wetting sands that are common in the Esperance Port Zone coastal plains. Two tanks paddock at Yalabyn is no exception consisting of sand clay. The soil amelioration practise of Clayspreading has become common in the Esperance area to combat non wetting this was undertaken in Two tanks paddock in 2016. Clay was applied at two rates - Inner Zones 1 & 2, which were a deeper sand (>1m), received approximately 200 tonne to the hectare. Outer zones 1 & 2 (<1m), receiving 150 tonne to the hectare (Fig. 40). The affect of clayspreading is two fold, as it combats the non-wetting soils by improving moisture retention which allows plants to establish themselves and grow, which in turn improves soil nutrition and microbial activity. At the same time it changes the overall composition of the soil as you have incorporated clay particles into the top layer which were previously not there as indicated in the sample results (Fig. 41)

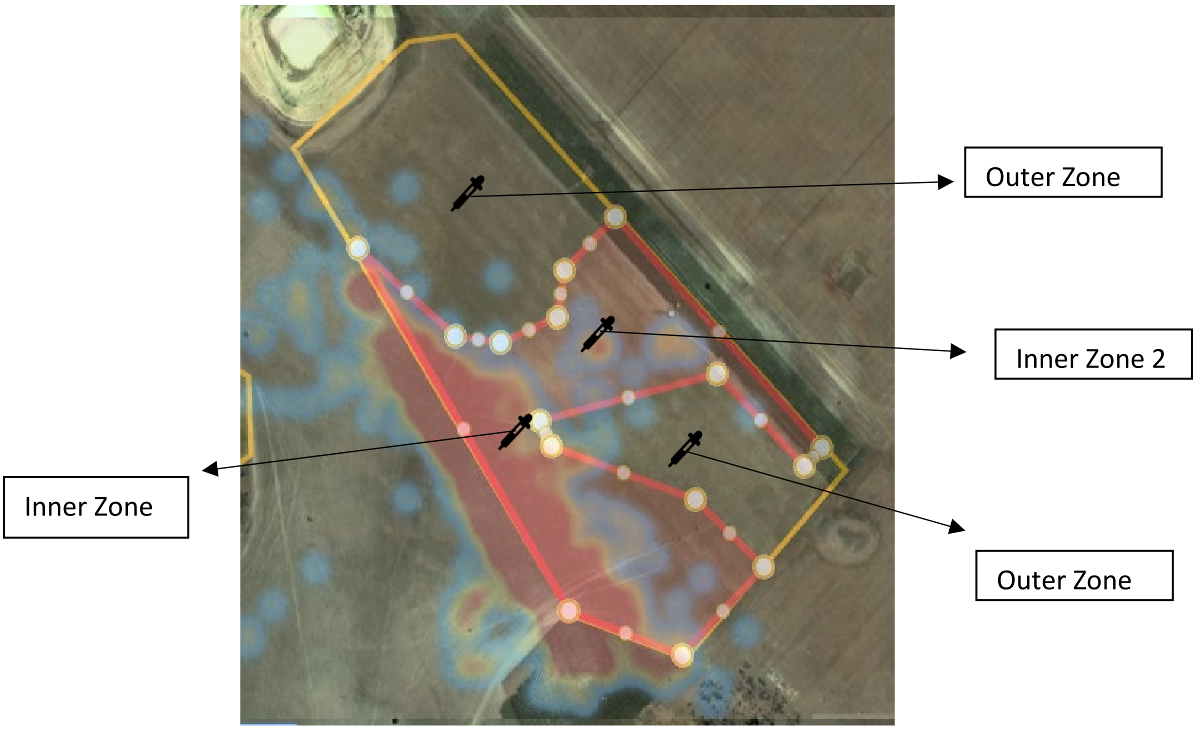


Figure 40 - Historical Clay Spreading Rates

Coolindown Farms

	Lab No	XZS21007	XZS21008	XZS21009
	Name	Site 1	Site 1	Site 1
	Code	SOILA063260	SOILA063278	SOILA063277
	Customer	Coolindown Farms	Coolindown Farms	Coolindown Farms
	Depth	10-30	30-50	60-80
Colour		GR	YWGR	YW
Gravel	%	0	0	0
Texture		1.5	1.5	1.5
Ammonium Nitrogen	mg/kg	1	< 1	< 1
Nitrate Nitrogen	mg/kg	8	7	4
Phosphorus Colwell	mg/kg	5	5	< 2
Potassium Colwell	mg/kg	17	15	18
Sulfur	mg/kg	2.6	5.5	1.7
Organic Carbon	%	0.11	0.32	< 0.05
Conductivity	dS/m	0.035	0.040	0.021
pH Level (CaCl2)		5.8	6.2	5.6
pH Level (H2O)		6.5	7.0	6.5
MIR% Clay	%	1.17	20.89	3.15
MIR% Sand	%	97.83	51.51	91.82
MIR% Silt	%	1.00	27.60	5.04

Figure 41 - Soil Sample Tests

This activity was run in parallel with Activity 1 and therefore the data used for collecting sheep movements to assess impacts on soil for this activity, is the same data collected in Activity 1, therefore the sheep and GPS device preparation is described in activity 1. A weather station was set up in the corner of the paddock to measure rainfall, windspeed and wind direction.

A soil coring machine was used to collect 3 replicate soil sample cores. A soil moisture probe was installed at each soil core testing site by using one of the core sample holes.

Figure 42 - Soil core samples

The cores were then measured and marked at 10-30cm, 30-50cm, 60-80cm and 80-100cm (Fig. 42). Tubes were then cut at the marked intervals and the sections were placed in separate buckets this was repeated until all 3 replicates were processed. The samples were then mixed, and the required testing amount placed into bags and labelled (Fig. 43 – 44). Buckets and gloves were washed between each sample.

Compaction tests were conducted in replicates of 3 at each core sample site using a Rimik CP300 (Appx. 8.6)

Figure 43 - Soil core samples mixed in buckets

Figure 44 - Soil sample bags

6.3 Results

The different data sets related to this activity have been collected and ingested into AxisStream. Analysis has commenced and some of the reports and visualisations that have been created are included in the figures and images below.

Note: Site 1 = SMP1 etc. in Fig. 47

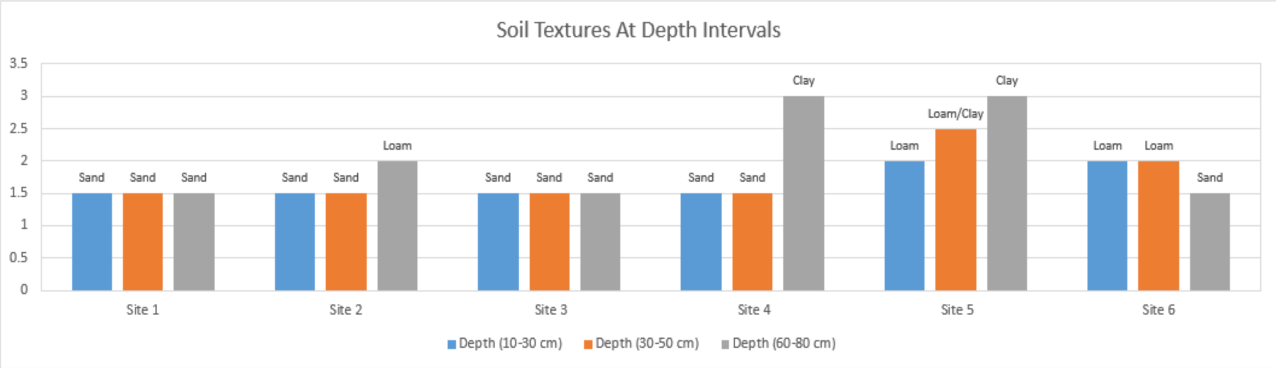


Figure 45 - Site Soil Textures at Depth Intervals

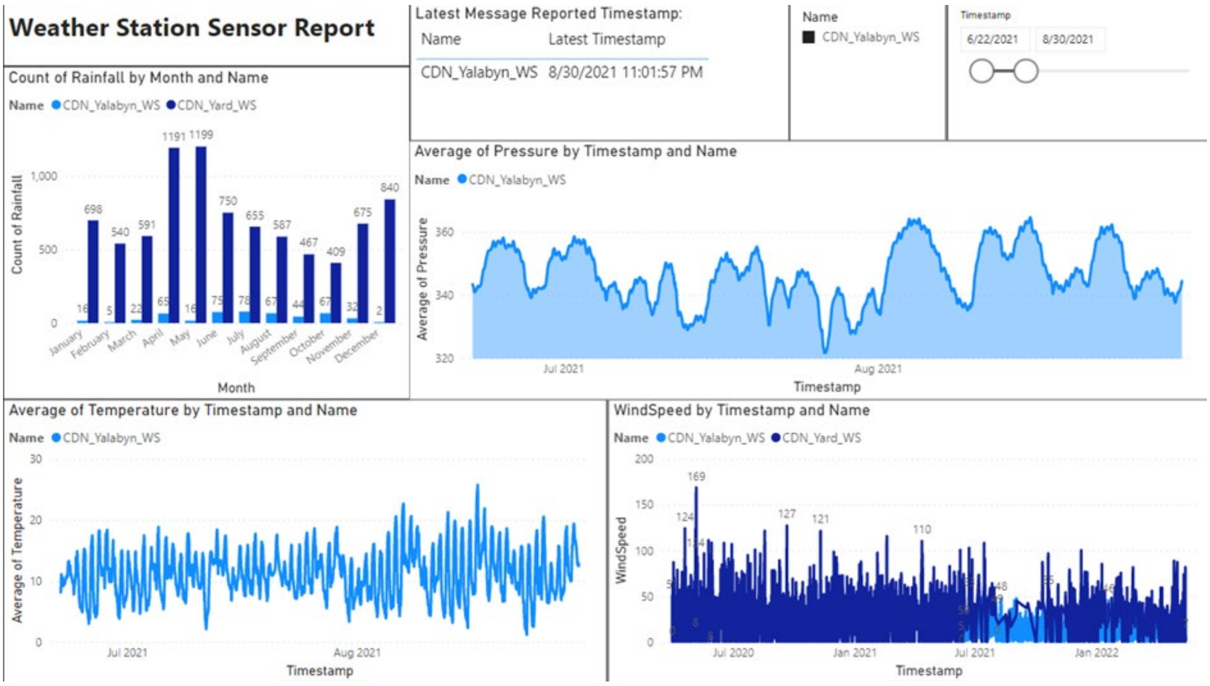


Figure 46 - Weather station report

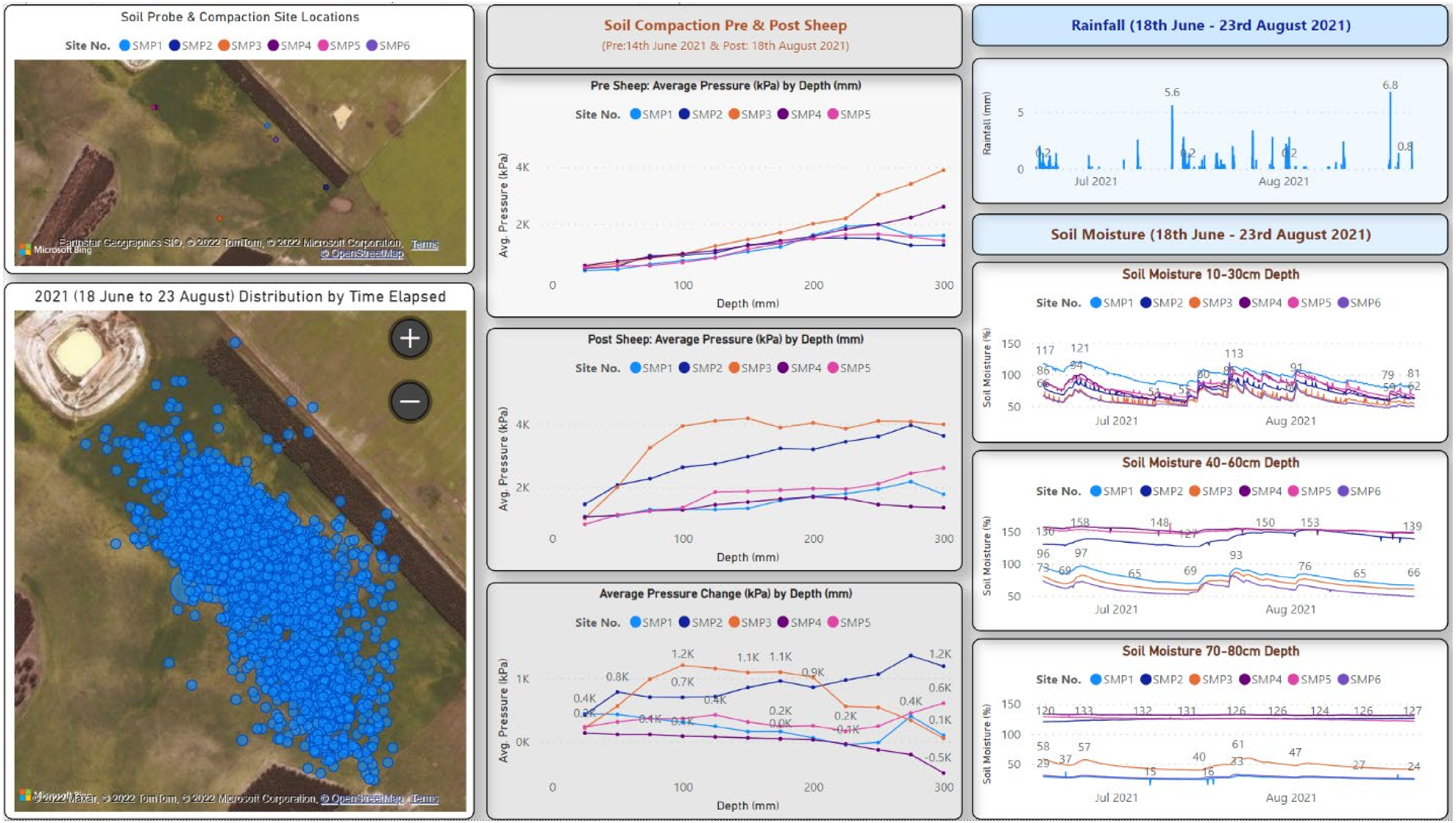


Figure 47 - Soil Moisture, Compaction, Rainfall and Animal Distribution Report 2021

6.4 Conclusion

Sheep in general have been found to have little impact on soil compaction at the surface level due to tillage practices, what impact they do have at a surface level results in minimal effect on yield. (Bell, L.W et al., 2011). These findings are reflected in the compaction results taken during this trial (Fig. 47), prior to sheep entering the paddock, where soil up to around 150mm depth where only small variations start to occur, when at 300mm depth SMP3 requires more than double the pressure to penetrate the soil compared to the other sites. This could be explained when considering the paddock history and noting that 10m from the paddock boundary where SMP3 site is located, as it was not deep ripped due to it being required to provide passage for vehicles. The GPS collar data shows that sheep were heavily concentrated around site SMP3, lightly visited SMP1 and almost completely avoided all the other sites where soil moisture probes and compaction tests were taken. The highest change in compaction post sheep in paddock, was at sites SMP2 and SMP3.

Coolindown Farms average yearly rainfall is approximately 500mm however in 2021 it experienced a slightly higher than average rainfall receiving 445mm by the 23rd of August with a total of 630mm for the year. Given that the sheep were not recorded or observed as being in or around SMP2, the other potential explanation for the increase in compaction is water. Looking at the results in soil tests site SMP2, SMP4 and SMP5 and the photos of the samples taken (Fig. 42) these sites all have a clay base that appears in the 80-100cm level. When looking at soil moisture probe readings, these 3 sites provided a consistently high soil moisture content at the 70-80cm depth. Interestingly, at the point in time where the 40-60cm depth reading reach their highest moisture content at these 3 sites, the soil moisture levels at 10-30cm depth begin to rise, suggesting that deep sand fills the soil profile with moisture from the bottom up. Given that water logging of plant roots causes nutrient deficiency that greatly impacts on yield (Steffens D. et al., 2005) the ability to observe soil water levels through probe data is highly beneficial, as it can't be seen by the eye at surface level. This means that counter measures, such as the application of fertilisers could applied in more timely fashion to counter the effects of water logging. (S.M. Nuruzzaman Manik et al., 2019)

The same however can't be said when looking at site SMP3 as the soil moisture levels at depth are much lower. Given that there is a sharp rise at the 30mm mark right through to the previously compacted deeper level this could actually be attributed to the extremely heavy sheep presence in this area. This then begs the question of whether IoT devices such as sheep collars and soil moisture probes could be used to map areas for precision deep ripping as opposed to blanket treating entire paddocks reducing costs in wages, fuel and overheads.

6.4.1 Key Findings

- Combination of sheep and water creates compaction at a deeper level in the soil.
- The use of IoT devices could potentially enable the ability to identify areas that would respond to amelioration or fertiliser applications.

6.4.2 Benefits to Industry

- Precision agriculture is set to accelerate with the increase in input costs to be able to utilise data from sheep activity to identify potential areas suitable for precision deep ripping and/or fertiliser applications.

6.4.3 Further research and recommendations

- Repeat of the Soil Amelioration activity with the addition of gridded measurements of soil compaction to more effectively look at the impact of sheep.
- Complete the same activity alongside another paddock with additional soil probes to assess potential correlation between soil types and soil moisture levels.
- Trial precision

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8. Appendix

8.1 Digitanimal Collar Spec Sheet

Digitanimal Collars Spec Sheet

AXISTECH DATA & DEVICES

digitanimal

AxisTech is a distributor of the Digitanimal collars which provides an animal's GPS location, heart rate and temperature so that their activity and well being can be monitored. The collars are suitable for both sheep and cattle and operate on the Sigfox network.

The devices are used with h a mobile app that you can download here.

Specifications	
Model	Digitanimal Collar
Housing	IP67 standard waterproof, light and ergonomic encapsulation, temperature probe that measures the surface temperature of the animal.
Power	18 months with Sigfox and 6 months with GSM
Connectivity	Current: Sigfox, GSM network

8.2 PTZ Camera Spec Sheet

AxisTech Solar PTZ Camera with Trailer Data Sheet

AXISTECH DATA & DEVICES

For this PTZ solution the camera is mounted to a mast on a trailer and powered by 195W solar panels with battery storage. This gives the flexibility to move the camera between a number of remote off the grid locations. Once on site the camera can be hoisted to a height of 5m.

The 4G Modem Router with Wi-Fi that has been installed within the trailer gives you the ability to remotely access the camera feed as providing a Wi-Fi hot spot to anyone out at the camera's location.

Specifications	
Camera Specs	· 1/2.8" 2Megapixel CMOS · Powerful 25x optical zoom · Starlight technology · Max. 50/60fps@1080P · Perimeter protection · Support PoE+ · IR distance up to 100m · SMD PLUS · IP66
Camera Dimensions	Φ160 mm × 295 mm (6.30" × 11.61") 3kg
Mast Dimensions	5m fully extended
Camera Power Supply	12VDC/PoE+ (802.at)
Solar Power Capacity	195W with battery backup
Connectivity	Industrial 4G Modem Router with WiFi
Storage	256GB (Micro SD Card)
Features	False alarm filtering: smart motion detection identifies humans and vehicles Alarms, events and tours: set up to receive notifications if certain events are detected between certain hours or in certain locations of the camera's view.

For more information on our devices, visit axistech.co or send us an email at info@axistech.co

8.3 Waterwatch Tank Level Sensor – Spec Sheet

Waterwatch T35 Tank Sensor Data Sheet

AXISTECH DATA & DEVICES

waterwatch

High accuracy radar sensor designed specifically to measure liquid levels in water tanks. Simple to install requiring just 4 self-tapping screws. A 50mm hole is required for concrete tanks.

Email and SMS alert notifications. Comes with a mobile app that you can download here.

Specifications	
Model	Waterwatch T35 Tank Sensor
Housing	Polycarbonate + PBT Waterproof and UV resistant Dimensions 130x130mm
Sensor	60GHz Radar sensor Measurement accuracy 0.2% Measurement range 0.15m to 3.5m Operating temperature: -40°C to +85°C
Power	Inbuilt Li battery 3 – 10 year battery life depending on connectivity and reporting rate
Connectivity	Current: Sigfox, 4G/LTE/CatM1/NB-IoT (5G ready)

8.4 Water Flow Meter – Spec Sheet

HC FLOW METER

Sensor: **Flow**

Detect, monitor, and report critical flow zone data via wired or wireless connection with this robust and simple-to-install flow sensor.

KEY BENEFITS

- Compatible with Hydrawise® enabled HC, HPC, Pro-HC, and HCC Controllers
- Provides station-level flow rates and totals
- Sends automatic alerts in the event of high-flow, low-flow, or unscheduled flow conditions
- Flow reports within Hydrawise Software can display total system water use and individual station water use for accurate water budgeting and tracking
- Robust brass construction with union fittings for easy installation and removal for winterisation
- Analogue dial on the face of the meter displays daily flow totals and a leak detector

OPERATING SPECIFICATIONS

- Scaled pulse output is pre-calibrated based on the size of the meter
- When wired directly to the controller, the meter must be installed with shielded, minimum 0.75 mm² wire, up to 300 m from the controller
- Accuracy: ± 2% of reading at recommended flow
- HC Flow Meter pressure loss chart
- Warranty period: 2 years

WIRELESS HC FLOW METER BENEFITS

- Add wireless communication to any HC Flow Meter (sensor sold separately)
- Send flow data wirelessly from the sensor to the controller, without the need to run wire or dig trenches

HC FLOW METER SPECIFICATIONS

	HC-075-FLOW-B (20 mm)	HC-100-FLOW-B (25 mm)	HC-150-FLOW-B (40 mm)	HC-200-FLOW-B (50 mm)
Minimum flow (l/min)	0.83	1.16	3.33	7.5
Maximum recommended flow (l/min)	60	110	250	400
Maximum flow rate (l/min)	80	130	330	500
Dial reading (m³)	1 pulse per 1 litre	1 pulse per 10 litres	1 pulse per 10 litres	1 pulse per 10 litres

WIRELESS HC FLOW METER OPERATING SPECIFICATIONS

- 152 m range (line of sight) from transmitter to receiver
- Communication frequency: 868 MHz for international use; 915 MHz for use in Australia/New Zealand
- Transmitter power supply: 3 AA batteries
- Receiver power supply: 24 VAC from host controller
- Warranty period: 2 years

HC-075-FLOW-B
(20 mm male BSP thread)
Height: 8 cm
Length: 23.2 cm
Depth: 8 cm
Weight: 0.9 kg

HC-150-FLOW-B
(40 mm male BSP thread)
Height: 16.2 cm
Length: 43.1 cm
Depth: 12.5 cm
Weight: 6.6 kg

HC-100-FLOW-B
(25 mm male BSP thread)
Height: 9.3 cm
Length: 26.2 cm
Depth: 8 cm
Weight: 1.4 kg

HC-200-FLOW-B
(50 mm male BSP thread)
Height: 16.2 cm
Length: 44.7 cm
Depth: 12.5 cm
Weight: 7.4 kg

SENSORS

WIRELESS HC FLOW METER

WIRELESS HC FLOW METER MODELS

Model	Description
W-HC-FLOW-INT	Wireless HC Flow Meter Kit, includes transmitter and receiver (international 868 MHz)
W-HC-FLOW-TR-INT	Wireless HC Flow Meter, transmitter only (international 868 MHz)
W-HC-FLOW-R-INT	Wireless HC Flow Meter, receiver only (international 868 MHz)
W-HC-FLOW-AU	Wireless HC Flow Meter Kit, includes transmitter and receiver (AU/NZ 915 MHz)
W-HC-FLOW-TR-AU	Wireless HC Flow Meter, transmitter only (AU/NZ 915 MHz)
W-HC-FLOW-R-AU	Wireless HC Flow Meter, receiver only (AU/NZ 915 MHz)
HC-075-FLOW-B	HC Flow Meter with 20 mm male BSP thread, m³ reading
HC-100-FLOW-B	HC Flow Meter with 25 mm male BSP thread, m³ reading
HC-150-FLOW-B	HC Flow Meter with 40 mm male BSP thread, m³ reading
HC-200-FLOW-B	HC Flow Meter with 50 mm male BSP thread, m³ reading

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8.5 Soil Moisture Probe – Spec Sheet

AxisTech Soil S95-EP Data Sheet

AXISTECH DATA & DEVICES

The EnviroPro soil probe provides capacitance-based soil moisture, temperature, and optional salinity monitoring and are available in 400, 800, 1200 and 1600mm depths.

Specifications	
Model	AxisTech Soil S95-EP
Sensors	Moisture sensor spacing: 10cm Diameter: 33.5mm +/-0.2mm Moisture resolution: 0.01% Accuracy: +/- 2% @ 0% VWC to 50% VWC Temperature resolution: 0.01°C Accuracy: +/- 1° @ 25°C Salinity resolution: 0.001dS/m Accuracy: +/- 5% @ 0-4dS/m at 10%-30% VWC
Power	Solar with Li battery backup
Connectivity	Current: Sigfox, 4G/LTE/CatM1/NB-IOT (5G ready) Pipeline: Satellite

Model	EC	Sensors	Depth (mm)
Soil S95-EP-04	No	4	400
Soil S95-EP-08	No	8	800
Soil S95-EP-12	No	12	1200
Soil S95-EP-16	No	16	1600
Soil S95-EPEC-04	Yes	4	400
Soil S95-EPEC-08	Yes	8	800
Soil S95-EPEC-12	Yes	12	1200
Soil S95-EPEC-16	Yes	16	1600

For more information on our devices, visit axistech.co or send us an email at info@axistech.co

8.6 Soil Compaction Reader Spec sheet

CP300 Instrument Features

rimik

The RIMIK CP300 is a mid level instrument capable of accurate and easy collection of cone-index data. The RIMIK CP300 is an essential tool for more intensive soil studies involving compaction, trafficability and moisture distribution.

The CP300 incorporates many of the features of the CP40II, but is limited to a 2 line non-graphical display, a 500 insertion memory and does not have GPS capability.

What it DOES offer is ultrasonic depth sensing, NiMh rechargeable batteries, internal logging and USB connectivity all in a small lightweight enclosure with stainless steel shaft and cone set. The shaft is the same two piece unit included in all current penetrometer models. The CP300 is stored in an easy to carry, durable fitted case.

The CP300 cone penetrometer is used to measure soil density and hardness where a research level study of the data is required. It measures and records cone index values up to 9800KPa based on the load required to force a cone through the soil. The instrument will record profile data to a maximum depth of 750mm at increments of 10 - 25mm. The instrument conforms to ASAE S313.3 feb99.

Up to 500 full depth insertions may be recorded and stored in memory. Profile results can be viewed on the LCD screen or downloaded to a computer or laptop via the serial port and with the use of RIMIK Penetrometer Reader Software.

This instrument can be user configured to operate in metric or imperial mode. The menu structure also allows the user to preselect any of four (4) depth intervals and to preselect any of six (6) cone sizes. Data can also be "Grouped" by nominating a group size (up to 500) prior to taking any set of insertions. The groups can be individually named.

Full profile data is output following each insertion via the USB port. With a wired connection to a device (e.g. laptop), the user can observe each insertion immediately in graphical format via a "Listen" function within the RIMIK Penetrometer Reader Software.

This instrument is designed for agronomists, soil scientists, engineers and research institutions and may be purchased with either or both the ASAE or EURO cone kits.

CP300 Software and Specifications:

- Windows 7® and above operating systems.
- Retrieve data from the instrument, saving in PDS format or export as a CSV.
- Display a number of graphs of grouped inserts with average and other defined lines.
- Manipulate graphical axes, scale and type as well as print the displayed information.
- Alter metadata and instrument parameters via the software.

Assembled Weight:	2.65kg	Resolution:	0.25kg (~20KPa)
Packed Weight including case:	4.4kg	Shaft size (diameter):	9.53mm
Assembled Dimensions:	431x1063x85mm	Maximum Insertion Depth:	750mm
Case Dimensions:	448x362x110mm	Interval Spacing:	10, 15, 20 or 25mm
Max 130mm² ASAE Cone Index:	7500kPa, 100kg	Memory Capacity:	500 insertions
Max 100mm² EURO Cone Index:	9800kPa, 100kg	Operating Temperature:	10 to 75°C
Cone Kit ASAE:	130 & 323mm²	Baud Rate/Download Speed:	9600bps
	@ 30° Face Angle	Screen resolution (characters):	2 x 16
Cone Kit EURO:	100, 200, 330 & 500mm²	Battery Life:	2400mAh
	@ 60° Face Angle		

8.7 Nulogic Plant tissues test results

NUlogic Analysis

Plant Sample Report

NUlogic | CSBP

Yalabyn - 2 Tanks

TRADING NAME:	Coolindown Farms
FARM:	Yalabyn
INTERPRETED ON:	30/06/2021
ACCREDITED ADVISOR:	Monica Field
PHONE:	0448 001 524
EMAIL:	monica@farmandgeneral.com.au
SAMPLE TYPE:	Plant
CROP / PASTURE:	Wheat
CRITERIA:	WHEAT - Whole Top Plants
ACCREDITATION:	FERTCARE

NUlogic Analysis

Plant Sample Report

NUlogic | CSBP

Interpreted Results

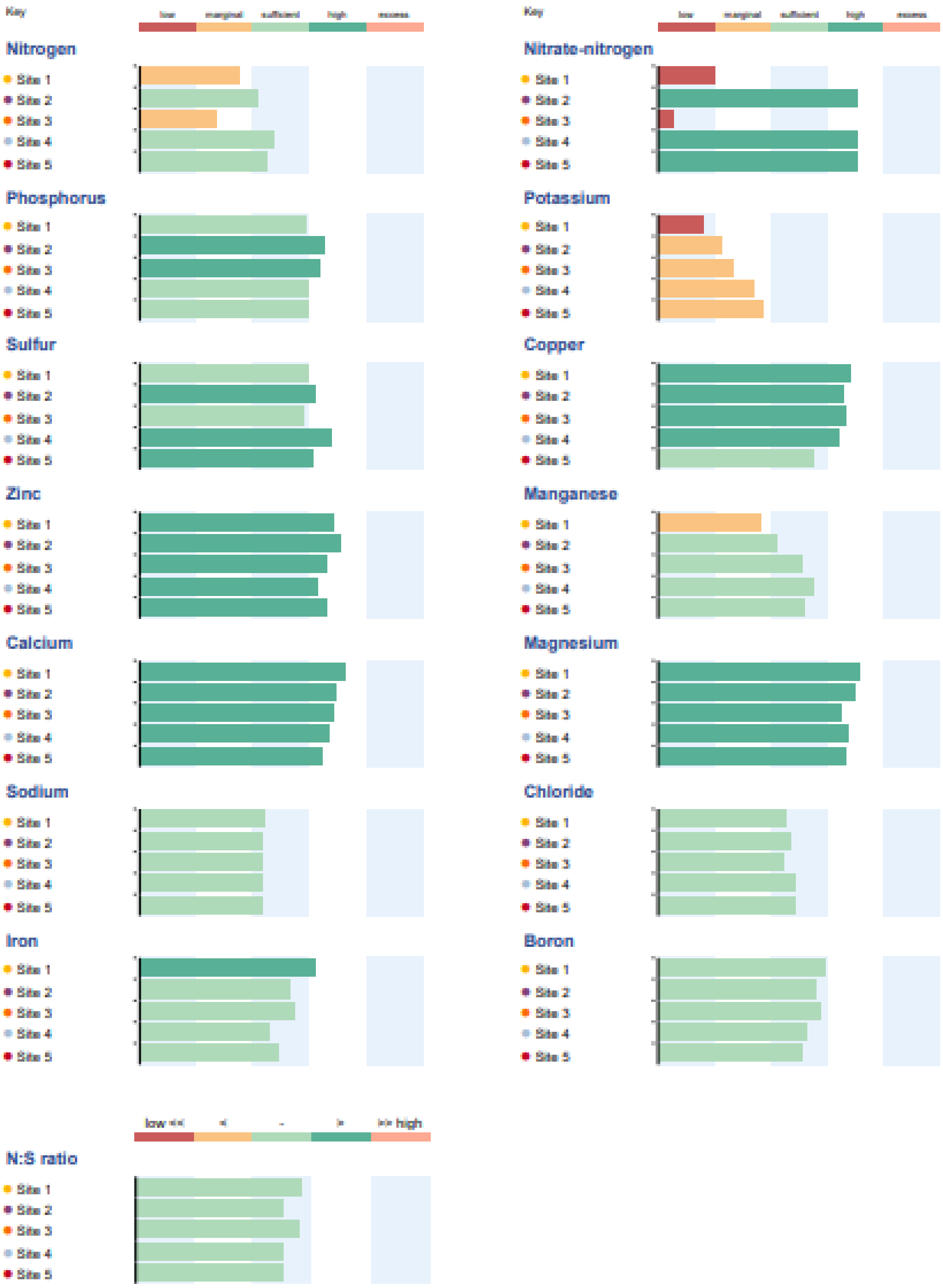
Paddock	2 Tanks (24.6 ha)	2 Tanks (24.6 ha)	2 Tanks (24.6 ha)	2 Tanks (24.6 ha)	2 Tanks (24.6 ha)
Site	Site 1	Site 2	Site 3	Site 4	Site 5
Lab Number	EFP21130	EFP21131	EFP21133	EFP21134	EFP21135
Plant Weight:	0.17g @ 32d	0.12g @ 32d	0.16g @ 32d	0.21g @ 32d	0.18g @ 32d
Total N [Leco] (%N) (9G2)	3.95 Marginal	5.29 Sufficient	3.96 Marginal	5.44 Sufficient	5.37 Sufficient
Nitrate-nitrogen (mg N/kg)	1714 Low	3660 High	450 Low	3878 High	3247 High
P (%P)	0.69 Sufficient	0.87 High	0.77 High	0.76 Sufficient	0.77 Sufficient
K (%K)	2.56 Low	3.41 Marginal	3.41 Marginal	4.43 Marginal	4.73 Marginal
S (%S)	0.31 Sufficient	0.37 High	0.30 Sufficient	0.40 High	0.37 High
N:S ratio	13 OK	14 OK	13 OK	14 OK	15 OK
Cu (mg Cu/kg)	5.9 High	5.8 High	5.1 High	5.3 High	3.3 Sufficient
Zn (mg Zn/kg)	33.1 High	38.2 High	30.3 High	31.0 High	33.9 High
Mn (mg Mn/kg)	22.8 Marginal	29.8 Sufficient	44.2 Sufficient	54.7 Sufficient	45.2 Sufficient
Ca (%Ca)	0.81 High	0.69 High	0.64 High	0.56 High	0.48 High
Mg (%Mg)	0.35 High	0.33 High	0.23 High	0.28 High	0.26 High
Na (%Na)	0.12 Sufficient	0.09 Sufficient	0.09 Sufficient	0.09 Sufficient	0.10 Sufficient
Cl (%Cl)	0.84 Sufficient	1.10 Sufficient	0.74 Sufficient	1.39 Sufficient	1.47 Sufficient
Fe (mg Fe/kg)	523.4 High	329.8 Sufficient	356.2 Sufficient	156.5 Sufficient	232.3 Sufficient
B (mg B/kg)	6.3 Sufficient	5.5 Sufficient	6.0 Sufficient	4.4 Sufficient	3.9 Sufficient

NUlogic Analysis

Plant Sample Report

NUlogic | CSBP

Interpreted Fuel Gauges



8.8 Stubble Analysis Report

Herewith are the results for the 9 x Wilson Wheat straw samples that were submitted for analysis.
ADF, DDM, ME, CP, WSC and NDF are all expressed on a Dry Matter (DM) i.e. Moisture-free basis.

Straw	Sample	% Dry Matter	% ADF	% DDM	MJ/Kg ME	% CP	% WSC	% NDF
1	Wilson 1 - 1	92.5	52.4	42.8	5.7	3.1	5.6	82.9
2	Wilson 1 - 2	92.5	52.5	42.6	5.7	1.1	9.2	81.6
3	Wilson 1 - 3	91.0	51.4	44.2	6.0	1.5	11.2	78.8
4	Wilson 2 - 1	75.3	50.1	41.6	5.5	3.6	5.7	78.7
5	Wilson 2 - 2	90.6	58.3	34.6	4.3	0.7	6.3	87.9
6	Wilson 2 - 3	90.4	49.2	43.6	5.9	1.5	7.6	78.4
7	Wilson 3 - 1	91.9	51.7	41.6	5.5	2.7	8.2	80.5
8	Wilson 3 - 2	91.6	56.8	36.1	4.6	0.8	7.5	86.5
9	Wilson 3 - 3	91.4	52.4	38.9	5.1	1.3	5.7	82.9

ADF = Acid Detergent Fibre - The residue that remains after extraction of plant material with an acid detergent solution. ADF gives an indication of the fibre material that may be indigestible to ruminants.

DDM = Digestible Dry Matter - The difference between the DM consumed and the DM excreted in the faeces, expressed as a percentage of the DM consumed. DDM is estimated by a laboratory procedure calibrated against DDM values for feedstuffs measured in feeding trials with live animals, usually sheep.

ME = Metabolisable Energy - The feed energy available to the animal to maintain body activity, growth and lactation etc. ME is calculated from DDM and is expressed as Mega Joules (MJ) per kg DM.

CP = Crude Protein - The amount of true protein and non-protein-nitrogen in a feed. Protein provides the basic building blocks of the body, the amino acids. CP is determined as Nitrogen content x 6.25.

WSC = Water Soluble Carbohydrates - The readily fermentable plant sugars that are extracted by water. For a hay or straw, moderate levels of WSC are desirable to enhance the acceptance by livestock.

NDF = Neutral Detergent Fibre - The residue remaining after extraction of plant material with a neutral detergent solution - mostly cell wall material that provides the "rumen fill" when roughages are eaten.

The ADF & NDF values are very high reflecting the high percentage of stem and limited leaf in the samples with 8/9 straws over 50.0% ADF and 6/9 above 80.0% NDF. These fibrous characteristics and the low WSCs with 8/9 straws below 10.0% have resulted in the very low DDM & ME values with 8/9 straws below 6.0 MJ/kg DM. The extreme is Straw 5 having the highest ADF & NDF values with a low WSC of 6.3% resulting in an ME of only 4.3 MJ/kg DM. In the case of Straw 3, the reasonable WSC of 11.2% appears to have helped lift its DDM & ME values. Although not reported, the "woodiness" or lignification of stem material can influence the effects of ADF & NDF on DDM & ME. The higher CP values possibly reflect some legume burr/seed present in some samples to lift the CP. However, the CP values are all well below the approx. 6.0% CP required in the diet DM to maintain a mature sheep. At these levels of CP and with the ME all well below the approx. 8.0 MJ ME/kg DM needed to maintain a mature sheep, these "composite samples" of Wheat straw couldn't maintain a mature sheep.

The question then is; how can sheep meet their CP and ME requirements for even maintenance when grazing the stubble paddocks from where these "composite samples" were taken?
Sheep have a great ability to select-out leaf components from the Stubble On Offer (SOO) and so what they eat will have a much higher Leaf:Stem ratio than the samples analyzed and consequently will be much higher in CP & ME. The leaf material selected will also be much lower in ADF and NDF than the stem material and so the sheep will be able to digest and eat more of this higher Nutritive Value (NV) leaf material. Amongst the numerous other factors that can influence how much DM the sheep can eat when grazing stubbles is the amount of SOO and the proportion of leaf to stem material within the SOO. The prior experience of the sheep grazing a stubble can also influence how quickly they learn to select-out the higher NV components – this can impact on the performance of weaners verses mature sheep during the first few weeks when they graze stubbles.

"You can not maintain a weaner, it is either dying or growing" - the outcome is largely determined by what you offer the weaner to eat.

Kind regards and best wishes,

Dr John T.B. Milton Director of ILS
Order of the Crown of Thailand, BAgrSci(Hons), PhD.
Please Note: Due care and attention is taken in providing these professional comments, but no responsibility is accepted for any inappropriate action taken in response to these comments.

8.9 Nutrient Value of Feedstuffs

Tables of nutrient values of feedstuffs

Most of these values have been extracted from data collected by Independent Lab Services, Perth, Western Australia, as reported in Bulletin 4473 '**The good food guide for sheep**'), with some values from other Australian departments (marked with *).

Dry matter, energy, protein and fibre content (dry matter basis) of cereals and pulses

Table 1 Dry matter, energy, protein and fibre content (dry matter basis) of cereals and pulses commonly fed to sheep. The average across the range of values tested in WA is shown in brackets.

Cereals and pulses	Dry matter (%)	Metabolisable energy (MJ/kgDM)	Crude protein (%)	Acid detergent fibre (%)
Wheat	91	12.4–13.3 (12.9)	7.5–15.0 (11.5)	2.5–4.5 (3.0)
Barley	91	11.6–12.2 (11.9)	7.0–13.0 (11.0)	7.0–9.5 (8.0)
Triticale	90	12.0–13.0 (12.5)	7.5–14.0 (11.0)	3.5–5.0 (4.0)
Oats	92	10.4–11.3 (10.7)	5.5–13.5 (9.0)	16.0–21.5 (18.5)
Narrow leaf lupins	92	13.1–14.1 (13.7)	27.0–42.0 (34.0)	17.5–23.0 (20.0)
Albus lupins	92	13.4–15.0 (14.0)	34.0–44.0 (38.0)	17.0–21.0 (19.0)
Peas	91	12.5–13.5 (13.0)	21.5–30.0 (25.5)	6.0–10.5 (9.0)
Vetch	91	12.4–13.2 (12.8)	26.0–34.5 (29.0)	7.5–9.5 (8.5)
Chick peas	91	12.0–13.0 (12.4)	18.0–24.0 (21.0)	12.0–16.0 (14.0)
Faba beans	90	12.4–13.2 (12.9)	22.0–30.0 (26.0)	7.5–9.5 (8.5)
Canola (>35% oil)	95	15.0–17.0 (16.0)	20.0–25.0 (22.0)	22.5–26.5 (24.0)

8.10 AEC Animal Ethics Agreement (AEC 21-6-25)

Title:	Efficacy of GPS tracking collars to measure the effect of distance travelled and sheep condition score on fertility in Merino/meat breeds in Western Australia	**AEC No:**	21-6-25

FORM A SIGNATORIES AND DECLARATIONS

Signatory and Declaration	Initial
Principal Investigator I understand my responsibilities as Principal Investigator in regard to the declaration outlined earlier in this section of this proposal/amendment; and will make all reasonable efforts to ensure that the activity is conducted and reported in accordance with the letter and spirit of that declaration.	Signature Print name: Belinda Lay Date: 28/12/2021
Responsible Director This proposal/amendment accurately represents the intended activity; and I confirm that the activity is aligned with Department priorities and I will ensure appropriate oversight of the activity.	Signature: NA Print name Date
RSU Manager *(if more than one RSU, to be signed by Manager of each RSU. PI to enter 'n/a.' if no RSU involved)* I am able to adequately resource the indicated elements of this proposal/amendment within RSU resourcing; I will ensure that staff advise the PI a soon as possible of any issue or concern related to stock or facilities involved in this activity	Signature: NA Print name Date
Veterinary Officer or other Officer (Product Integrity Project – Livestock Biosecurity) responsible for reviewing the declared veterinary chemical use *(PI to enter 'n/a.' if no chemical use)* This proposal/amendment contains all information required by me in regard to the use of chemicals in this activity	Signature: NA Print name Date
Biometrician This proposal/amendment meets the reduction requirements of the code.	Signature: NA Print name Date
Animal Welfare Officer I am satisfied with the animal welfare monitoring plan and auditing requirements of the proposed work; and an **appropriate Animal Welfare Monitor** will be assigned to undertake the necessary duties	Signature: NA Print name Date
Animal Research Committee Chair This proposal/amendment either has been, or does not need to be, endorsed/re-endorsed by the ARC	Signature: NA Print name Date
Animal Ethics Committee Chair This proposal/amendment has been endorsed/re-endorsed by the Animal Ethics Committee	Signature: Bruce Mullan (Digitally signed by Bruce Mullan Date: 2022.01.11 17:21:05 +08'00') Print name Date

Note: PI to enter 'n.a.' for each office for which the proposal/amendment has no impact. Signatures are not needed from these particular officers in regard to this particular proposal/amendment

8.11 Activity 3 - Data Supply Chain Scoping Study

Scoping Study: Supply Chain – Coolindown Farms

Project:	P.PSH. 1293 - MLA Using Devices & Data to Generate ROI's in a mixed farming enterprise
Written by:	Belinda Lay
Date:	7 October 2022
Version:	1.3

Coolindown Farms
856 Coolinup Road
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8.12 Activity 4 – Water Management Scoping Study

P.PSH.1293 - WATER MANAGEMENT SYSTEM - CONCEPTUAL FRAMEWORK V2.0

P.PSH. 1293: MLA Using Devices & Data to Generate ROI's in a mixed farming enterprise

Version: 2.0

Prepared By:

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