Final report

Grazing system impact on livestock productivity, soil moisture and soil organic carbon

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Abstract

The project was established at ten producer participant demonstration sites in the New England and North West Slopes regions of Northern New South Wales. Participants shared livestock movement data, to investigate the impact of grazing management to pasture productivity, soil moisture and SOC levels.

Research has established that soil organic carbon (SOC) stocks can be improved through optimal pasture biomass production, but not the effect of grazing management on SOC accumulation.

The project compares changes to soil and pasture condition under a variety of high and low grazing management strategies.

NDVI sensors and soil moisture probes were deployed at all ten project sites. Their measurements were compared to yearly SOC test results and grazing management information.

The following key insights from the project include:

- SOC % levels are variable within project paddocks and across all project sites. This variability can be attributed to various factors including climate variability (rainfall & temperature in particular), organic matter input, soil microbiota, soil nutrient levels and soil types.
- The two participants with high density (DSE equivalents) rotational grazing management did experience SOC% increases (0.21% & 1.46%) respectively from 2020 to 2023.
- The limited duration of the project and low sampling density may have limited the ability to identify substantive SOC changes.
- The apparent consistency between annual rainfall pattern and soil moisture recordings for all properties
- Identification of the critical limits for plants available water (drained upper and lower crop limit, as expected align with soil type – participants were particularly interested in this.

The project did not find conclusive evidence linking grazing management to SOC changes, but as above, two sites may be able to attribute grazing management to SOC increases. A replicated trial with control zones is required to conclusively link grazing management intensity to SOC levels.

Further research should be conducted to confirm the relationship between the soil's moisture holding capacity and SOC changes. This could be due to the minor changes in SOC levels not being large enough to impact on plant available water.

All project participants found monitoring soil moisture levels useful. By linking up-to-date soil moisture levels to weather predictions this would be a useful management tool to make early farm management decisions, such as selling stock early if soil moisture is expected to limit pasture productivity.

Feedback from field days and field walks indicated core participants' knowledge and skills (%) increased from 64% in 2020 to 76% in 2024, while their confidence scores increased from 64% in 2020 to 76% in 2024. Observer participants, skills, knowledge, and confidence remained static at 56% to 60%.

Executive summary

Background

Soil and water management is fundamental to optimal pasture production. Effective utilisation of the seasonal feed base may provide an opportunity for residual pasture to build soil organic matter and thus improve water infiltration and water holding capacity, leading to improved livestock productivity, and over time, increase in soil organic carbon (SOC) stocks.

The main objective of the project was to determine whether there is an optimal blend of pasture production and feed base utilisation for improved livestock production and feed base utilisation for improved livestock productivity and increases in SOC levels.

The main target audience of the project are livestock producers in the New England region of New South Wales. Research results were shared to project participants and shared into the wider farming community, to provide evidence of how grazing best management practices can impact whole of farm carbon footprint.

Objectives

The objective of this project was to understand the inter-relationship between livestock management, pasture productivity, soil moisture and soil organic carbon levels. Although livestock productivity was not ascertained, soil moisture levels are related to pasture growth patterns, while a number of contributing factors meant that the variability in SOC % levels within and over the project sites indicated the difficulty in establishing any real relationship between soil organic carbon levels and soil moisture holding capacity.

Methodology

Ten demonstration sites were set-up in the New England region of New South Wales. Each site received a rain gauge, an NDVI sensor and two soil moisture probes. Soil samples were taken annually to determine soil organic carbon levels. Participants shared livestock movement data, to relate the impact of grazing management to pasture productivity, soil moisture and SOC levels.

Results/key insights

The project was set up in 2020 to discover the inter relationships within a grazing system of livestock productivity, soil moisture and soil organic carbon. Data collection and analysis as required under the project methodology has clearly indicated the complexity and scale of variability in assessing the results. The levels of variability in soil organic carbon % has been particularly challenging.

SOC % levels are variable within project paddocks and across all project sites. This variability can be attributed to factors including climate variability (rainfall & temperature in particular), organic matter input, soil microbiota, soil nutrient levels and soil types.

Project core participants and other producers have also expressed an interest in how they might adjust their farming activities to influence and mitigate the variability factors in sequestering additional soil organic carbon levels over their properties. Suggested areas and questions for producers may include investigation in future projects and could include:

- How can we change our herd/flock structure to influence pasture productivity and SOC% sequestration outcomes? Do we run less breeding stock?

- Do we change our grazing strategy from set stock to rotational grazing with “wire and water”?
- What new activities can we adopt to positively influence organic matter input, soil microbiota populations and soil nutrient levels and improvement in SOC% levels?
- Does pasture development and renovation translate into improvement in SOC% levels?
- Do we convert cropping paddocks to permanent pasture?

The relationship between soil organic carbon levels and soil moisture holding capacity can be better determined within a replicated trial plot scenario. Similarly, to confirm any relationship between livestock grazing intensity and soil organic carbon levels, a specific and controlled science-based project is also recommended.

Feedback surveys from producer participants and observers, indicate a real interest in soil organic carbon and the present and future relationship between SOC and productivity.

While the project findings are inconclusive, there are some genuine opportunities for further investigation and research to extend the hypothesis that improved SOC levels have positive impacts on soil moisture holding capacity and livestock production.

Benefits to industry

The project has confirmed a considerable number of factors that can be attributed to the variability in the sequestration of soil organic carbon in a pasture-based livestock enterprise. These factors include, climate variability, soil type, organic matter input, soil microbiota and soil nutrient levels.

The project has emphasised the usefulness of soil moisture monitoring to help producers make management decisions (when to buy livestock or feed, or when to sell livestock depending on soil moisture availability for pasture growth).

Field day feedback surveys over the course of the project have highlighted producers’ interest in gaining more skills and knowledge of the impacts of SOC in enhancing pasture and livestock production. Likewise, they are keen on gaining more skills in in-paddock pasture assessment and feed budgeting, to use when making grazing management decisions.

Future research and recommendations

Considering this project is a demonstration (PDS) project, there are now some exciting and encouraging prospects for implementing future research project(s) to evaluate the key findings, as described above. Primarily, the hypothesis will seek to conclusively relate grazing management to generating soil organic carbon, based on the results and the limited conclusions from this project.

Importantly, these research activities must be replicated plot trial design, with control zones and must address the variables producers are keen to understand, and they can have some influence upon. Producers will respond favourably to the opportunity to provide input into the project design and participation in the selection of new activities as part of new project.
Furthermore, it is recommended that such a project is conducted over a broad geographic area.

Considering the technology issues of utilising monitoring equipment for the current project, it is recommended that in future projects robust equipment is developed for long-term in-paddock use.

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1. Background

The Australian red meat industry is responsible for approximately 11% of greenhouse gas (GHG) emissions in Australia (Mayberry, 2024). The Australian Red Meat industry has the target to be carbon neutral by 2030, meaning there will be no net releases of GHGs into the atmosphere by that date. Increasing soil organic carbon (SOC) storage in soils (carbon sequestration) is viewed as a potential solution, with positive impacts on farm productivity.

Effective utilisation of the seasonal feed base resource through grazing management may provide an opportunity for residual pasture (herbage mass and ground cover) to build soil organic matter (Conant et al. 2017), improving water infiltration and water holding capacity (Lal, R 2020), in turn leading to improved livestock productivity and overall resilience of farming systems. In the Australian context, evidence so far has been mixed, with grazing management found to positively impact pasture productivity and groundcover but a lack of evidence linking grazing management to changes in SOC levels (McDonald et al. 2023). This lack of evidence is partly attributed to experimental design and one-off sampling (Debney and Lobry de Bruyn, 2024).

With an increase in demand for information and support of 'regenerative' agriculture practices, this project compared changes to soil and pasture condition under a variety of high and low intensity grazing management practices. Specifically, the project explored the impact grazing management on of pasture productivity and utilisation, on SOC levels, and on soil water holding capacity.

Ten trial sites were developed across the New England region. At each site, livestock management data was recorded, pasture production was observed, SOC levels were measured, and soil moisture levels were monitored. The aim was to determine the optimal blend of pasture production and feed base utilisation for improved livestock productivity and increases in SOC levels.

2. Objectives

Objective 1: Over five years this project will provide a comparison of pasture and resulting livestock production across twenty forty-hectare sites (two per site) using a high density / high inputs rotation and high density /low inputs grazing strategy.

- Achieved: timing and duration of pasture growth were compared between the different sites with differing grazing management strategies. However, each trial site was not separated into two 40-hectare sites with high and low input grazing strategies.

Objective 2: Develop a set of standard land and soil benchmarks across all treatments, and provide biannual progress reports, including progress against work plan, milestone deliverables and an aggregation summary of subsequent monitoring and evaluation findings as the project progresses, including the following objectives.

- Achieved: see the outcomes of the following objectives.

Objective 3: Measure change in plant available water (PAW) and water holding capacity (WHC) for all treatments and report the impact of each management practice/grazing system.

- Achieved: soil moisture thresholds were identified and monitored at each site

Objective 4: Measure change in soil organic carbon (SOC) under the above grazing systems and report on the impact of each management practice/grazing system, and the interrelationship with WHC.

- Achieved: SOC was measured and related to livestock management and soil water holding capacity

Objective 5: Measure and report on baseline pasture condition, species makeup, sward health and macrofauna of each demonstration site and compare the impact of grazing practices throughout the project.

- Achieved: baseline pasture species composition was assessed and macrofauna was counted and identified

Objective 6: Measure seasonal pasture mass (kg green DM/ha), estimate pasture quality and quantity, and provide an estimate of typical pasture growth rates expected for your pasture type/soil fertility/season, including any inputs.

- Achieved: pasture cuts and assessment conducted at two farms at 8-week intervals, in grazing exclusion cages. Furthermore, assessment of pasture biomass and composition at all remaining sites twice times a year.

Objective 7: Measure livestock production through live weigh gain (LWG) between the treatments throughout the project using an industry recognised method.

- Not achieved: livestock weight estimates were not shared by participants and insufficient pasture productivity data was available to use GrazFeed to model livestock productivity.

Objective 8: Participate in an MLA facilitated workshop and activities which will develop a carbon account for each participating farming system, using the approved MLA carbon accounting tool.

- Achieved: a workshop was organised for participants to build their carbon account, using the Sheep & Beef GHG Accounting Framework V2.4 (SB-GAFF).

Objective 9: Provide industry communication and engagement through targeted events, media events and technical reports that drives project participation, awareness, and wider adoption, as well as a final report outlining the outcomes of the program, including recommendations on best grazing management practices and their ability to increase soil profile carbon, pasture productivity and managements, and resulting livestock performance.

- Achieved: One field day open to the public and one field walk open to project participants only were organised each year (except during COVID-19 restrictions). A total of four case studies relating to the project was published in the MLA feedback magazine.

Objective 10: Provide evidence of how grazing best management practices can impact the whole of farm carbon footprint.

- Achieved: There was a lack of evidence showing that grazing management affected soil organic carbon levels. Impacts of livestock management (e.g. how many head to keep) were explored when using the Sheep and Beef GHG accounting framework for whole of farm carbon footprint impacts.

3. Methodology

3.1 Project site details

Ten producers located in the New England region of New South Wales participate in this project, located between Bingara, Guyra, Armidale, Walcha, and Ebor – see location map (Fig 1) below: All properties are primarily cattle and sheep production grazing operations – see Fig 2 below.

Figure 1: Participant site map

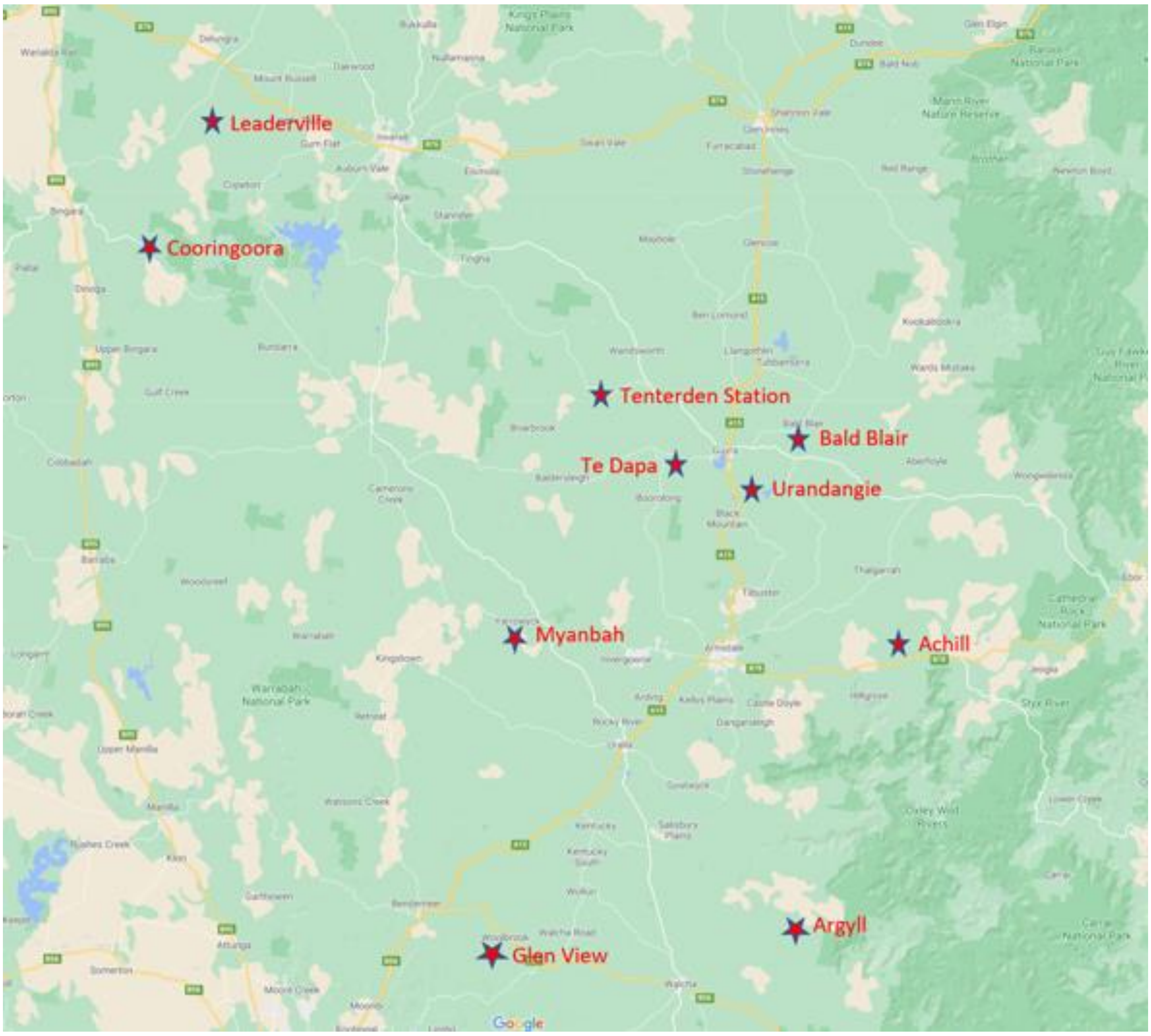


Table 1: Participant's site details

Property	Leaderville	Cooringoora	Tenterden Station
Participant(s)	Jorgensen family (Trevor, Colleen & Dane)	Ranald & Jane Munro	Rodney Neill & Jane Mactier
Project site area	112 ha	65 ha	96 ha
Livestock program	Brangus breeders	Breeding cattle & sheep	Trade cattle & prime lambs
Grazing strategies	Rotational	Rotational	Rotational

Property	Te Dapa	Bald Blair	Urandangie
Participant(s)	Andrew & Sarah Carruthers	Sam & Kirsty White	Bill & Jacqui Perrottet
Project site area	95 ha	115 ha	109 ha
Livestock program	Breeding cattle	Angus breeding herd and prime lambs	Breeding cattle, prime lambs & goats
Grazing strategies	Rotational	Rotational	High intensity rotational

Property	Myanbah	Achill	Argyll
Participant(s)	Hamish & Jess Webb	Charles & Dorianne Coventry	Gowen Family Estates (Joanne & Tracey)
Project site area	164 ha	76 ha	122 ha
Livestock program	Trade cattle & sheep	Breeding cattle & sheep	Breeding cattle
Grazing strategies	Rotational	Rotational	Rotational

Property	Glen View
Participant(s)	Gary & Rhonda Olrich
Project site area	82 ha
Livestock program	Breeding cattle & sheep
Grazing strategies	Rotational

As part of the project setup, paddocks were identified in consultation with the project participants and land and grazing management strategies were confirmed for the life of the project. As indicated in Fig 2 table, all participants allocated project site areas exceeding 40 ha. The number of paddocks selected at each site ranged from 2 to 6 paddocks per participant.

Considering this project is deemed a demonstration project, the controls for comparative assessment were provided by virtue of the range of number of paddocks per site and the geographic spread of the 10 project sites.

3.2 Soil testing

Annual soil samples were taken on each property, at the following depths (when it was possible to go to full depth):

- 0 – 10 cm
- 10 – 30 cm

- 30 – 60 cm, and
- 60 – 90 cm.

Figure 2: Soil sampling, Bald Blair June 2020

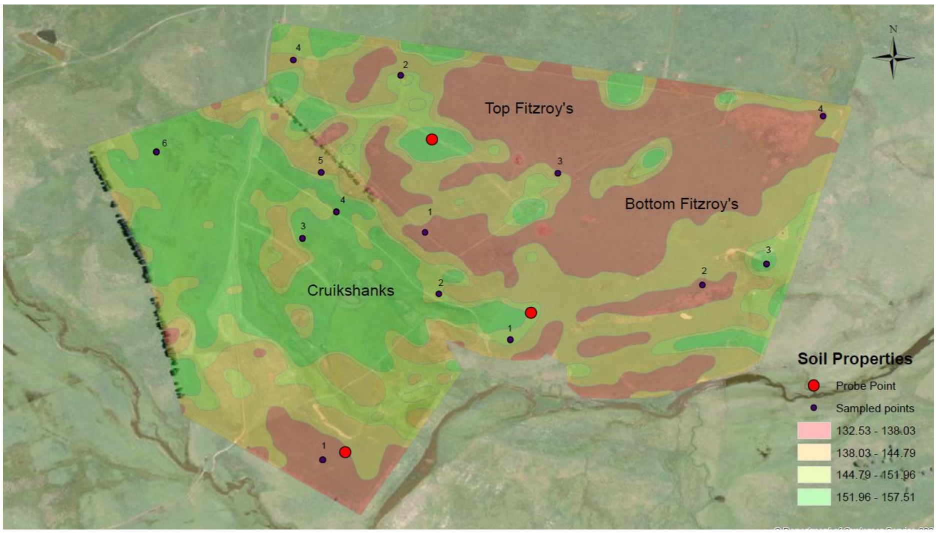
Baseline samples were extracted and analysed in 2020 between April – October, depending on when sampling site locations were determined across all ten demonstration sites. Soil sample sites were located with RTK GPS positioning (<10cm accuracy) at sites designated by EM38 soil conductivity zones - see details below. No subsequent annual soil samples were extracted in 2021 because of Covid-19 restrictions. In 2022 and 2023 the soil samples were extracted and analysed at the start of the growing season (September – October).

The location and number of soil samples were determined based on mapping of the properties with an EM38 (an electromagnetic induction device, Fig. 3), which measures the electrical conduction in the soil. The soil's electrical conductivity is dependent upon soil water content, soil cation content and clay content, as well as organic matter and soil depth. Maps generated by the EM38 were used to delineate soil 'zones' (different zones relative to each other) of low, mid, and high conductivity, in which soil sampling locations were located. If the EM38 map was more homogeneous, showing less variation, less soil samples were extracted, whereas if the maps showed more zonal differences, more soil samples were taken. Over all sites, at least three sample sites per zone were allocated.

Figure 3: Set-up used for measuring soil conductivity at Bald Blair with the EM38 device.

The soil samples were extracted with a hydraulic soil corer and the soil samples were sent to a soil testing laboratory with ASPAC and NATA accreditation for analysis (Eurofins-APAL in Adelaide). The soil samples were laboratory tested for soil organic carbon (Dumas % Total Organic Carbon), phosphorus (Colwell P mg/kg), and soil pH ($CaCl_2$) levels.

Figure 4: Soil conductivity map as result of mapping with EM38 device – see designated soil sample sites with suggested soil moisture probe sites as red dots (northern site selected).



Additionally, in June 2023 and in June 2024, a total of four soil samples were extracted on each property, with a hand auger. These samples were extracted to a depth of 0 – 10 cm and 10 – 30 cm and were analysed for carbon content only. The impetus for taking samples at these depths was to gather soil test data for percentage of total soil carbon at the prescribed depths as required under the Carbon Credits (Carbon Farming Initiative – Estimate of Soil Organic Carbon Sequestration using Measurement and Models) Methodology Determination 2021 methodology. Monitoring movements in soil carbon percentage during the life of the project were deemed useful in aligning the results with what is currently required under the carbon sequestration 2021 methodology. This sampling also aligned with the annual deep sampling in September/October to enable a comparison between soil organic carbon levels at the start and end of the pasture growing season.

3.2.1 Soil organic carbon (SOC)

In 2020, the standard method used for analysing soil organic carbon (SOC) was the Dumas dry combustion method. In 2021, no soil samples were extracted due to COVID-19 restrictions. In 2022, the Dumas method was no longer considered as the preferred industry standard test and the Walkley and Black (chromic acid wet oxidation) became the preferred method for measuring SOC.

Considering the requirement for the LECO method (dry combustion) to be used under the soil carbon sequestration 2021 methodology to identify SOC, this test was implemented in 2023 and 2024.

The different SOC analysis methods have different rates of carbon recovery (Conyers et al. 2011), making it difficult to compare the results between 2020, 2022, and 2023 with confidence. The adopted conversion factor from Walkely-Black to LECO was 1 (Skjemstad et al. 2000).

3.2.2 Soil phosphorus and soil pH

The soil samples taken annually were analysed for phosphorus levels and for pH, as these are two of the main factors limiting plant growth in the New England region.

The Colwell Phosphorus test was used to monitor phosphorus levels and the Phosphorus Buffer Index (PBI) for each paddock was determined in 2020. The critical value for optimal Colwell level (where pasture plants can achieve up to 95% of potential productivity) is based on PBI and sites within the project had critical values ranging from 25 mg/kg to 40 mg/kg.

All pH results were reported in calcium chloride ($CaCl_2$) rather than water. Critical pH levels were ideally set at a pH of 5.5. However, if pH levels were far from optimal, a pH of 5.2 was considered sufficient to sustain legume pasture plants. Lime application prescriptions are also dependent on ensuring annual application rates do not exceed 3 tonnes per hectare.

3.3 Soil moisture and rainfall monitoring

Each site received one rain gauge, which recorded rainfall every 15 minutes and had an accuracy of 0.2 mm rain (Fig. 5).

Figure 5: Rain gauge and solar panel installed at Myanbah.

To monitor soil moisture levels on-farm, at a depth of 20 - 30 cm and 50 - 60 cm in the soil, MP406 Standing wave Technology soil moisture sensors (https://ictinternational.com/product/mp406-soil-moisture-sensor/) were installed at one or two sites on each property. These sensors measure volumetric soil water content (volume of water per volume of soil, expressed in a percentage).

Considering 8 of the 10 project participants were prepared to install two sensor units, the positioning of the single units was strategically placed to represent average homogeneous soil types for the remaining 2 participants' paddocks within the project. The relative excessive cost for the equipment influenced the commitment to one unit only by the two participants.

Limits defining plant available water were visually identified on the soil moisture graph recorded during the first year after installation of the equipment:

- Drained upper limit is the amount of water held against gravity. This water only can be utilised from within the soil profile by plants or through direct evaporation. Visually, drained upper limits were identified on the soil moisture graphs after big rainfall events, at the point where moisture loss from the system starts to slow down.
- Crop lower limit is the minimal amount of water in the soil required for a plant not to wilt. This threshold depends on crop type and on soil type. Crop lower limits were visually identified when the soil lost no further moisture, after a small 'bump' in soil moisture, which is due to plants wilting and releasing the moisture held within plant tissue to the soil.

Plant available water is the water held in the soil profile, between the drained upper limit and the crop lower limit (Verburg et al., 2016). Knowing how much water is plant-available in the soil is a useful tool for making crop management decisions.

It was expected that increasing SOC levels will increase soil water holding capacity, as organic matter (of which roughly 58% is carbon) leads to soil aggregates and soil pores in a range of sizes: larger pores ensure water can get into the soil profile and smaller pores hold water tight enough to hold it against gravity but loosely enough for plant to be able to access it (Cates, 2020).

3.4 Pasture biomass measurements

3.4.1 Biomass cuts

Pasture biomass cuts occurred at 8-week intervals, at 2 project sites. These two sites were part of the MLA L.PDS.2000 project run concurrently with this project. Exclusion cages were set-up to ensure cattle could not access these pasture plots. Pasture was harvested with a mower, weighed, and a sub-sample was dried in an oven at 60°C for at least 72 hours, after which sub-sample dry weight was recorded.

Considering the size of the pasture cut plot (0.82 m2) and considering the proportion of each sample which was dried, pasture dry matter was calculated on a per hectare basis. From there, pasture growth rate since the last pasture cut was determined.

Fertiliser treatments were set-up in the pasture cages. Lime was applied to lift the pH to the critical level of 5.0, maintenance single superphosphate was applied to replace the amount of phosphorus exported by grazing livestock on a yearly basis, and the capital single superphosphate treatment was determined to lift the soil's Colwell phosphorus level above critical value (which was determined as >40 mg/kg based on PBI soil test results gathered from the baseline comprehensive soil tests for the paddock). The following treatments were applied:

- Control treatment without fertiliser or lime inputs,
- Lime treatment,
- Lime and maintenance rate single superphosphate treatment,
- Lime, maintenance, and capital single superphosphate treatment,
- Maintenance rate single superphosphate treatment, and
- Maintenance and capital rate single superphosphate treatment.

Figure 6: Pasture cut plots at Te Dapa.

3.4.2 NDVI monitoring

The Normalised Difference Vegetation Index (NDVI) is an index used to measure the normalised difference between red and near infrared light. It is a measure of plant greenness, correlated with chlorophyll content and leaf area, used to monitor plant health in the field. It is accepted that NDVI values above 0.2 represent pasture growth, NDVI values near 0 measure bare ground, and negative NDVI values represent water bodies.

NDVI can be used as a tool to monitor the timing of peak pasture yield and the length of the growing season. As such, it can be used as a tool to make management decisions, such as timing of restocking or monitoring the haying-off of pasture at the end of the growing season.

One Apogee NDVI Sensor (https://ictinternational.com/product/apogee-ndvi-sensors/) was installed on each site to locally measure photosynthetic active radiation and calculate NDVI on a patch of pasture situated 3 – 5 m from the selected probe sites, of an area of 1 – 3 m^2, depending on the angle at which the device was installed (Fig. 3). These sensors recorded NDVI every 15 minutes. The NDVI set-up consisted of a downward facing sensor, measuring reflected light, and an upward facing NDVI sensor, measuring incoming light. Collected data was available to participants and Precision Pastures personnel via a web-based dashboard.

Figure 7: Downward and upward facing Apogee NDVI sensors at Bald Blair.

3.4.2.1 NDVI value validation

A Greenseeker hand-held crop sensor (https://ww2.agriculture.trimble.com/product/greenseeker-handheld-crop-sensor/) was used to validated the readings taken by the Apogee NDVI sensors. Ten measurements of the same patch of pasture measured by the static NDVI telemeter were recorded with the hand-held Greenseeker (Fig. 8). When discrepancies were identified in the results between the two sensors, the Apogee sensors was sent-off to the manufacturers for repair and recalibration. In April & October 2023 and 2024, 10 pasture biomass cuts of a size of 0.5m^2 were taken around the probe sites to determine the relationship between NDVI and pasture biomass. Pasture cut fresh weight was recorded and a composite sub-sample of the 10 cuts was oven-dried to determine pasture dry matter.

Figure 8: Precision Pastures personnel using the hand-held Greenseeker crop sensor to measure NDVI in the paddock at Pointsfield, December 2022.

3.5 Macrofauna counts

Whilst macrofauna counts were not included in the 2020 baseline, it was considered by Precision Pastures personnel that this additional data would complement the results for other soil health attributes: especially movements in soil organic carbon.

In June 2023 and March 2024, macrofauna counts were conducted in 10 shovels-full of soil and the soil aggregates broken down on a flat surface and any life was counted. These counts were conducted at randomly selected sites within a radius of 10 m around the probe sites (Fig. 5). Soil macrofauna was monitored as it is strongly related to soil physical, chemical, and organic matter characteristics, and therefore is a metric for monitoring soil quality (Velasquez and Lavelle, 2019).

Figure 9: Macrofauna count performed by Precision Pastures personnel, at Glenview, June 2023.

3.6 Grazing strategies

All 10 participants conducted their paddock grazing strategies with a range of flexible rotational livestock movements approach. A highly intensive approach has been implemented at Urandangie where livestock were grazed at high DSE rates and moved frequently. Other participants moved livestock on an irregular basis without set stocking over extended periods of at least 6 months in duration.

All participants maintained minimum dry matter per hectare over grazed paddocks at greater than 1,000 kg/ha. Livestock were also withheld from paddocks if pastures were assessed to be at less than 3-4 leaf growth stager to maintain a balance between optimal pasture production and feed quality.

Grazing data was collected from all participants. The following information was recorded:

- Livestock date in and date out of paddock,
- Number of head,
- Livestock class,
- Estimated weight, and
- Estimated dry matter in pasture (kilograms dry matter per hectare).

The livestock class and weight information were used to calculate dry stock equivalent (DSE) using the conversion factors determined in the Prograze handbook (Graham, 2017).

For each participant, the DSE grazing days per hectare for the period January – November 2023 and December 2023 – May 2024 (grazing pressure), and the proportion of time a paddock was grazed was calculated, as this indicates how much rest-time a paddock received. Grazing intensity and rest times were compared between each of the project sites.

3.7 Project communication

A crucial component of the project has been the articulation of all associated activities along with regular reports of the progress against the project objectives during its 5-year term. These communication activities have involved reports and other project information extension to project participants, project observers and other livestock industry stakeholders.

The following activities were conducted as part of project communication:

- Case studies were published in the MLA feedback magazine,
- One field walk was organised yearly (available to project participants exclusively),
- One field day was organised yearly (open to anyone interested),
- A webpage promoting the project was created on the Precision Pastures website,
- Social media posts surrounding the project were published on the Precision Pastures Facebook and Instagram pages, and
- Summaries of the available data collected during the project was presented at various events.

4. Results

4.1 Project site descriptions

A total of 10 project participant sites were included in the project, with mostly one or two project paddocks – one had six paddocks. The sites showed a range of local soils and pasture types (see Table 2 and Fig 2) with paddock areas ranging from 17 ha to 70 ha. The sites were located between Bingara in the North West Slopes region and Walcha and Guyra in the Northern Tablelands region of New South Wales.

Existing paddock boundaries (without subdivision) were maintained for the life of the project.

Table 2: Characteristics of project site (location, rainfall, pastures and soil types).

Property	Average rainfall at closest BOM weather station (mm/year)	Main enterprise	Pasture and soils in project paddock 1	Pasture and soils in project paddock 2
Achill	664	Sheep breeding	Airstrip (17.5 ha) Black granite loam. 20 cm – Silty loam 50 cm – Silty loam Irrigated soybeans in 2020, then improved pasture with clover, plantain, ryegrass, fescue and chicory. The paddock is irrigated.	Sawpit (41.4 ha) Red granite loam. 20 cm - Silty loam 50 cm - Silty clay loam Native pasture consisting of wallaby grass, red grass, rat-tail fescue and pinrush.
Argyle	815	Cattle	Greenknob-Agris (74.2 ha) Black basalt. 20 cm - Loamy sand 50 cm – Loam Native pasture consisting of Phalaris, cocksfoot, pinrush and red grass, with many clovers.	Wattle (45.5 ha) Black-brown fine granite/trap. 20 cm - Silty loam 50 cm - Silty clay loam Native pasture consisting of phalaris, cocksfoot, pinrush and red grass.
Bald Blair	909	Angus stud and cattle	Top Fitzroy, Cruikshank's (70 ha) Black basalt 20 cm - Silty loam 50 cm - Silty clay loam Improved pasture mainly consisting of quantum fescue.	Gatwood (42 ha) Yellow-brown trap soil. Native pasture with wallaby grass, red grass and cocksfoot.

Property	Average rainfall at closest BOM weather station (mm/year)	Main enterprise	Pasture and soils in project paddock 1	Pasture and soils in project paddock 2
Cooringoora	741	Cattle	Creek Cultivation (40.8 ha) Red-brown alluvial sands 20 cm - Silty loam 50 cm - Clay loam Oats sown each year 2020 – 2023 and Lucerne sown in 2024.	Front (33.8 ha) 20 cm - Clay loam with floating rocks 50 cm – Clay loam with floating rocks Native pasture with lots of presence of red grass, wallaby grass and rat-tail fescue.
Glenview	782	Cattle and sheep	Top paddock (80 ha) Yellow-brown coarse granite. 20 cm - Loamy sand 50 cm - Silty clay loam Native pastures consisting mainly of wallaby grass, red grass, and phalaris.	Bottom paddock (85.4 ha) Yellow-brown coarse granite. 20 cm – Loamy sand 50 cm – Loam Native pastures consisting mainly of wallaby grass, red grass, and phalaris.
Leaderville	741	Cattle	Probe paddock (42.3 ha) Red vertosol 20 cm – Loam 50 cm – Clay Improved pasture with tropicals (Premier Digit grass, lucerne, clover and plantain).	Native paddock (45.7 ha) Red clay 20 cm – Clay loam 50 cm – Goes into Shale Native pasture consisting predominantly of Coolatai grass.

Property	Average rainfall at closest BOM weather station (mm/year)	Main enterprise	Pasture and soils in project paddock 1	Pasture and soils in project paddock 2
Myanbah	790	Cattle	Airstrip (22.7 ha) Grey-brown fine granite 20 cm – Loamy sand 50 cm – Loam Improved pasture consisting of plantain, chicory, Phalaris, brome grass and red and white clover, sown in 2022.	Centre Oats (63 ha) Grey/brown coarse granite 20 cm – Loamy 50 cm – Loam Native pasture, converted to oats in 2022 and sown with improved pasture species in 2023 (plantain, chicory, Phalaris, brome grass, red and white clover).
Pointsfield	777	Cattle and sheep	West Track (23.3 ha) Black/brown fine granite 20 cm - Loamy sand 50 cm - Loamy sand Improved pastures consisting mainly of fescue.	
Te Dapa	909	Cattle	Nancy's, Dam North, Dwyer's (65 ha) Brown fine granite 20 cm – Loamy sand 50 cm – Clay loam Improved pastures, sprayed and resown in 2022 and 2023 with Phalaris and cocksfoot and sown into oats in 2024.	Top One, Top Two (29.2 ha) Brown-grey fine granite 20 cm – Silty loam 50 cm – Silty clay loam Native pasture of quantum fescue, cocksfoot, red and white clover.

Property	Average rainfall at closest BOM weather station (mm/year)	Main enterprise	Pasture and soils in project paddock 1	Pasture and soils in project paddock 2
Tenterden	863	Cattle and sheep	Schoolhouse 1 (47 ha) Black basalt 20 cm – Silty loam 50 cm – Silty loam Improved pastures of fescue, perennial ryegrass, clover, and chicory.	Schoolhouse 2 (46 ha) Heavy red basalt. 20 cm – Silty clay 50 cm – Silty clay Improved pastures of fescue, perennial ryegrass, clover, and chicory.
Urandangie	909	Cattle, sheep, and goats	Black Hill (19.8 ha) Black basalt 20 cm – Loam 50 cm – Loam Improved pastures of quantum fescue, perennial ryegrass, lucerne, red and white clover, plantain and chicory.	Red Hill (81.5 ha) Red basalt 20 cm – Silty clay loam 50 cm - Silty clay loam Improved pastures of quantum fescue, perennial ryegrass, lucerne, red and white clover, plantain and chicory.

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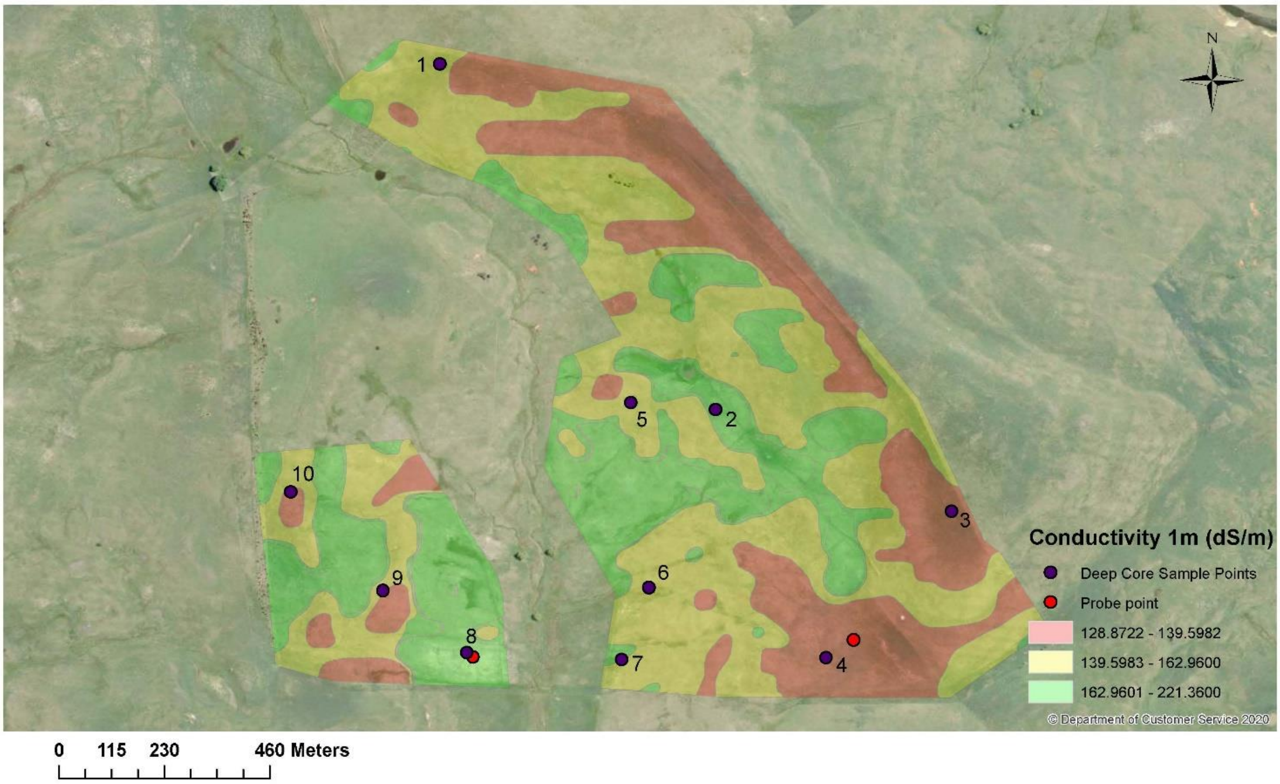
During the set-up stage of the project, while in consultation with the participants, it became clear that it was unfeasible to allocate two defined 40 ha sites, one site with a ‘high intensity / high input’ grazing strategy and one site with a ‘low intensity / low input’ grazing strategy on each property. This was because participants who adopted a ‘high intensity / high input’ grazing strategy were unable to provide comparative ‘low intensity / low input’ paddocks and similarly, participants with a ‘low intensity / low input’ grazing strategy were unable to facilitate the ‘high intensity / high input’ grazing strategy for the project. This meant that instead of comparing the impact of grazing strategies within one property, the impact of grazing management intensity was assessed between properties.

4.2 EM38 site characterisation

When recording soil conductivity to 1 m depth, conductivity values across the project sites ranged from 123 – 227 dS/m. The smallest range in conductivity measurements was observed at Achill (range of 11.3 dS/m), indicating more consistent soil types, soil moisture, and soil depth. At this property, both project paddocks had silty loam type soils. The largest range in conductivity values was found at Urandangie (range of 92.5 dS/m, Fig. 6), indicating more variable soil types. One project paddock had loamy soils, the second paddock has silty clay loam soils. Conductivity maps for all the project sites can be found in Appendix 8.1.

Figure 10: Conductivity recorded by the EM38 at 1 m soil depth at Urandangie, in August 2020. Red, orange, and green zones show low, medium, and high conductivity zones, respectively. Location of sampling sites (purple) and probe locations (red) are included.



Overall, the lowest conductivity values were identified at Argyle and Myanbah, sites with fine granite and coarse granite soil types, respectively. The low conductivity values were likely to be related to the low soil clay contents. The highest conductivity values identified at Urandangie and Tenterden, sites which both had black basalt soils, with high clay content.

Sampling sites were located to represent the variation in soil conductivity, as soil conductivity was used as a tool to determine soil type variability. Probe locations were selected together with project participants, based on the soil conductivity zones (Fig.10).

4.3 Soil test results

4.3.1 Baseline soil test results (2020)

4.3.1.1 Soil organic carbon (SOC)

The first round of soil tests were extracted at the end of September 2020. These were comprehensive soil tests giving information on phosphorus, pH and carbon (at all depths) (Table 2 for summary results). Complete soil results are located in Appendix 8.2.

Table 3: Average soil organic carbon (SOC) results in 2020, per property, with details on the number of samples analysed in brackets.

Property	Average SOC (0 – 10 cm, *Walkley-Black method)`	Average SOC (10 – 30 cm, *Dumas method)	Average SOC (30 – 60 cm, Dumas method)	Average SOC (60 – 90 cm, Dumas method)
Achill	4.10 (12)	1.17 (12)	0.43 (10)	0.31 (6)
Argyle	3.05 (16)	1.17 (16)	0.50 (15)	0.29 (14)
Bald Blair	3.97 (14)	1.79 (8)	0.72 (5)	0.37 (4)
Cooringoora	1.59 (12)	0.78 (12)	0.48 (12)	0.35 (11)
Glenview	1.73 (12)	0.39 (12)	0.25 (11)	0.25 (8)
Leaderville	1.65 (11)	1.13 (11)	0.50 (11)	0.31 (8)
Myanbah	1.22 (12)	0.44 (12)	0.32 (11)	0.25 (10)
Te Dapa	2.55 (18)	0.86 (18)	0.41 (18)	0.28 (17)
Tenterden	2.97 (9)	1.64 (9)	0.97 (9)	0.54 (8)
Urandangie	4.45 (10)	2.22 (10)	1.56 (6)	0.96 (4)

*Conversion factor W & B to Dumas is: 1

The number of samples taken usually decreased with depth, as it was not always possible to take soil samples until 90 cm soil depth, for example because of the presence of a hard compacted layer of clay or gravel. At Achill, Urandangie, and Blad Blair, it was possible to take samples to full depth at only 50%, 40%, and 29% of sites, respectively. At Achill and Bald Blair this was because of a rocky layer, whereas at Urandangie this was because of a hard clay pan.

Highest SOC levels at 0 - 10 cm depth were recorded at Achill, in the native, unimproved pasture (SOC levels ranging 3.91% - 5.96% under a red granite soil) and at Urandangie, in an improved pasture (SOC levels ranging 3.36% - 5.75%, red and black basalt soils). Lowest average carbon at 0 – 10 cm depth was found at Myanbah (ranging 0.69% - 1.49%, fine-coarse granite soils) followed by Glenview (ranging 1.36% - 2.88%, coarse granite soils). This was in line with expectations, as it is generally accepted that potential organic carbon storage depends on soil type, with generally higher carbon levels found in soils with higher clay content: the organic matter can become absorbed or coated with clay particles, making it difficult for soil microorganisms to decompose this organic matter (How much carbon can soil store). Myanbah and Glenview have more sandy soils, where microorganisms can more easily decompose the organic matter, leading to greater organic carbon losses.

The Urandangie SOC results also indicate relatively high SOC levels over the full soil profile. This could also be attributed to pastures performing at near to optimal production with minimal soil constraints as a benefit of a high inputs pasture management and high intensity grazing system.

4.3.1.2 Phosphorus and pH

When analysing the soil samples for organic carbon, the samples were also evaluated for Colwell phosphorus and pH ($CaCl_2$) levels (Table 3).

Averaged over each property, both pH and phosphorus levels were sub-optimal at Te Dapa, Archill and Myanbah, whereas both pH and phosphorus levels were optimal at Leaderville, Tenterden, Glenview and Urandangie. At Argyle pH levels were sub-optimal, whereas at Cooringoora phosphorus levels were sub-optimal.

The pH levels at Leaderville and Cooringoora are inherently high, or alkaline. On top of this, Leaderville has a regular phophorus fertiliser programme, with annual or bi-annual fertiliser applications.

Complete soil test results are available in Appendix 8.2.

Table 4: Average soil phosphorus and pH levels found on each property, at 0 – 10 cm depth (except at the Myanbah, where results are shown at 10 – 30 cm depth). Green cells show optimal pH and/or phosphorus levels. Blank cells show sub-optimal pH or phosphorus levels. For pH a threshold of 5.2 is used, whereas optimal phosphorus levels were determined individually for each property, based on the Phosphorus Buffering Index.

Property	Average pH ($CaCl_2$)	Phosphorus buffering index	Critical Colwell phosphorus (mg/kg)	Average Colwell phosphorus (mg/kg)
Achill	4.74	140	40	35.42
Argyle	4.60	57	30	41.69
Bald Blair	5.06	272	40	76.64
Cooringoora	5.45	78	35	33.17
Glenview	5.55	25	25	28.83
Leaderville	6.32	165	40	43.55
Myanbah	4.72	35	30	21.33
Te Dapa	4.70	78	35	34.06
Tenterden	5.35	294	40	83.22
Urandangie	5.25	249	40	127.60

4.3.2 Average yearly soil test results

A summary of average yearly soil test results for each property are presented in Table 5 (pH, Colwell phosphorus and SOC). While overall changes in SOC were not consistent between sites (meaning SOC levels fluctuated over the years), % changes in SOC from 2020 to 2024 results were as follows:

-0.61% to 1.45% (0-10 cm)

0.22% to 1.4% (10-30 cm)

-0.79% to 0.2% (30-60 cm)

The average change in SOC across all properties between 2020 – 2024 shows an increase in SOC at all three depths. This leads to question whether climatic conditions, fertiliser applications, pasture improvement or soil type rather than management impacts may have led to these changes (see table extension on P30). Pasture growth started later in spring 2023 compared to the previous years (see section 4.6.2).

Table 5: Average property pH, Colwell phosphorus (mg/kg) and soil organic carbon (SOC, %) levels, in 2020 (baseline), 2022, 2023 and 2024, with calculated change between 2022 and 2023. Red and green cells show decreasing and increasing levels respectively, from 2022 to 2023. Calculated % change between 2020 and 2024 appear on next page

Participant	Soil depth (cm)	pH (caCl2 direct)					Colwell P (mg/kg)					SOC (%)					
		2020	2022	2023	Change 2020 – 2023	Change 2022 – 2023	2020	2022	2023	Change 2020 – 2023	Change 2022 – 2023	2020	2022	2023	2024	Change 2020 – 2023	Change 2022 – 2023
Achill	0-10	4.74	5.12	4.99	0.25	-0.13	35.42	37.5	39.73	4.31	2.23	3.82	4.45	4.79	3.91	0.97	0.34
	10--30	4.8	5.08	4.92	0.12	-0.16	9	14.11	9.59	0.59	-4.52	1.14	1.8	1.22	2.26	0.08	-0.58
	30-60	4.6	5.07	4.89	0.29	-0.18		10	6.31		-3.69	0.42	0.98	0.27		-0.15	-0.71
Argyle	0-10	4.59	4.54	4.61	0.02	0.07	42.36	20.36	29.47	-12.89	9.11	3.05	2.32	3.35	2.47	0.3	1.03
	10--30	4.45	4.5	4.49	0.04	-0.01	11.73	9.21	11.74	0.01	2.53	1.17	1.09	0.96	1.64	-0.21	-0.13
	30-60	4.71	4.59	4.63	-0.08	0.04	34	6.83	9.33	-24.67	2.5	0.5	0.65	0.47		-0.03	-0.18
Bald Blair	0-10	5.06	5.07	5.06	0	-0.01	76.64	67.07	82.4	5.76	15.33	3.97	4.07	5.01	3.71	1.04	0.94
	10--30	5.35	5.14	5.27	-0.08	0.13	25.38	50.25	38.9	13.52	-11.35	1.79	2.9	2.09	3.19	0.3	-0.81
	30-60	5.82	5.21	5.7	-0.12	0.49	43.8	65.63	49.7	5.9	-15.93	0.72	2.04	0.66		-0.06	-1.38
Cooringoora	0-10		5.11	5.07		-0.04	33.17	24.33	31.12	-2.05	6.79	1.55	1.3	1.44	1.53	-0.11	0.14
	10--30	5.13	5.64	5.4	0.27	-0.24	7.67	30	17.68	10.01	-12.32	0.74	0.8	0.74	1.08	0	-0.06
	30-60	5.71	6.12	6	0.29	-0.12	7.33	37.25	23.14	15.81	-14.11	0.46	0.6	0.44		-0.02	-0.16
Glenview	0-10	5.55	5.36	5.46	-0.09	0.1	28.83	19.33	23.28	-5.55	3.95	1.73	1.38	1.52	1.12	-0.21	0.14
	10--30	5.71	5.48	5.51	-0.2	0.03	9.67	15.83	10.69	1.02	-5.14	0.38	0.42	0.33	0.6	-0.05	-0.09
	30-60	6.2	5.69	5.81	-0.39	0.12	25	18.2	15.64	-9.36	-2.56	0.25	0.26	0.21		-0.04	-0.05
Leaderville	0-10	6.32	6.3	6.31	-0.01	0.01	43.55	27.45	35.45	-8.1	8	1.65	1.72	2.01	1.87	0.36	0.29
	10--30	6.53	6.93	6.68	0.15	-0.25	30.91	11.57	18.2	-12.71	6.63	1.13	1.12	1.05	1.43	-0.08	-0.07
	30-60	7.14	7.31	7.23	0.09	-0.08	15.09	7.8	10.4	-4.69	2.6	0.5	0.61	0.7		0.2	0.09
	60-100	7.58	7.59	7.54	-0.04	-0.05	5.25	6	4.94	-0.31	-1.06	0.31	0.47	0.42		0.11	-0.05
Myanbah	0-10		5	4.96		-0.04			56.93	56.93	56.93	1.22	1.02	1.01	1.14	-0.21	-0.01
	10--30	4.56	4.69	4.75	0.19	0.06	21.64	26.33	25.77	4.13	-0.56	0.44	0.47	0.36	0.67	-0.08	-0.11
	30-60			5.69					10.07			0.32	0.24	0.22		-0.1	-0.02
Te Dapa	0-10	4.77	4.88	4.71	-0.06	-0.17	37.09	35.25	31.02	-6.07	-4.23	2.55	2.56	2.48	2.76	-0.07	-0.08
	10--30	4.67	4.85	4.73	0.06	-0.12	10.27	15.5	11.73	1.46	-3.77	0.86	1.18	0.8	1.47	-0.06	-0.38
	30-60		4.93	4.84		-0.09		10.88	8.07		-2.81	0.41	0.74	0.35		-0.06	-0.39
Tenterden	0-10	5.42	5.18	5.33	-0.09	0.15	88.25	52.75	75.25	-13	22.5	2.67	2.6	4.06	3.23	1.39	1.46
	10--30	5.6	5.54	5.6	0	0.06	55.88	33.13	41.33	-14.55	8.2	1.64	1.75	1.92	2.32	0.28	0.17
	30-60	6.22	5.91	6.18	-0.04	0.27	51.14	29.43	35.3	-15.84	5.87	0.97	1.28	0.99		0.02	-0.29
Urandangie	0-10	5.25	5.13	5.18	-0.07	0.05	127.6	105.1	114.47	-13.13	9.37	4.45	5.38	5.59	5.9	1.14	0.21
	10--30	5.66	5.5	5.66	0	0.16	42.7	54.9	48.53	5.83	-6.37	2.22	3.05	1.78	3.32	-0.44	-1.27
	30-60		5.63	6.07		0.44			40.44			1.56	1.84	0.77		-0.79	-1.07

Participant	Soil depth (cm)	% Change SOC												
		Change 2020 – 2024	% Change 20-24	Vol. W. Ave	Total AVE	Col P	pH	Fert	Past. Imp.	Soil Restraints	Soil Type	Rain Gauge	Moisture Probes	NDVI Sensor
Achill	0-10	0.09	2%	0%	5%	12%	5%	Yes	Yes	Yes	Trap / Granite	2	4	1
	10--30	1.12	98%	33%		7%	3%	Yes						
	30-60	-0.15	-36%	-18%			6%	Yes						
Argyle	0-10	-0.58	-19%	-3%	2%	-30%	0%	Yes		Yes	Trap / Granite	2	4	1
	10--30	0.47	40%	13%		0%	1%	Yes						
	30-60	-0.03	-6%	-3%		-73%	-2%	Yes						
Bald Blair	0-10	-0.26	-7%	-1%	7%	8%	0%	Yes		Yes	Black basalt	2	4	1
	10--30	1.4	78%	26%		53%	-1%	Yes						
	30-60	-0.06	-8%	-4%		13%	-2%	Yes						
Cooringoora	0-10	-0.02	-1%	0%	4%	-6%				Yes	Alluvial loam	1	2	1
	10--30	0.34	46%	15%		131%	5%							
	30-60	-0.02	-4%	-2%		216%	5%							
Glenview	0-10	-0.61	-35%	-6%	2%	-19%	-2%			Yes	Granite	2	4	1
	10--30	0.22	58%	19%		11%	-4%							
	30-60	-0.04	-16%	-8%		-37%	-6%							
Leaderville	0-10	0.22	13%	13%	11%	-19%	0%	Yes	Yes	Yes	Vertisol	1	2	1
	10--30	0.3	27%	5%		-41%	2%	Yes						
	30-60	0.2	40%	12%		-31%	1%	Yes						
	60-100	0.11	35%	14%		-6%	-1%	Yes						
Myanbah	0-10	-0.08	-7%	-1%	0%				Yes	Yes	Granite	2	4	1
	10--30	0.23	52%	17%		19%	4%		Yes					
	30-60	-0.1	-31%	-16%					Yes					
Te Dapa	0-10	0.21	8%	1%	6%	-16%	-1%			Yes	Granite	2	4	1
	10--30	0.61	71%	24%		14%	1%							
	30-60	-0.06	-15%	-7%										
Tenterden	0-10	0.56	21%	3%	6%	-15%	-2%	Yes			Basalt	2	4	1
	10--30	0.68	41%	14%		-26%	0%	Yes						
	30-60	0.02	2%	1%		-31%	-1%	Yes						
Urandangie	0-10	1.45	33%	5%	-1%	-10%	-1%	Yes			Basalt	2	4	1
	10--30	1.1	50%	17%		14%	0%	Yes						
	30-60	-0.79	-51%	-25%				Yes						

4.3.2.1 Achill

In Figures 11 to 13 below, Colwell Phosphorus, pH, and SOC levels in Achill's Airstrip and Sawpit paddocks from 2020 to 2023 are presented. The airstrip site is the improved and irrigated paddock at Achill. The application of starter fertiliser in 2021 led to increases in Colwell P and pH levels in 2022, which decreased in 2023. At the 0 – 10 cm depth, both pH and P levels were above critical in 2022 and 2023. The improvement of pH and P levels in 2022 were associated with an increase in carbon levels in the 0-10 cm layer, which then decreased again in 2023.

Sawpit is the unimproved pasture, where pin rush was growing as well as some native pasture species. There were no significant changes in either pH or Colwell P levels, which were sub-optimal at all soil depths for the duration of the project. Variance in C levels increased in the 0 – 10 cm layer, which was mainly related to high C levels recorded at sampling sites 6 and 8. Since cattle were grazing in the paddock when sampling in 2023, there is a possibility these topsoil samples contained some manure traces, even though these were avoided when sampling.

Figure 11: Soil Colwell phosphorus levels in Airstrip (a) and Sawpit (b), 2020 to 2023. The dashed horizontal red line shows the critical phosphorus value in both paddocks. Soil depths of 0 – 10 cm (layer 1), 10 – 30 cm (layer 2), 30 – 60 cm (layer 3) and 60 – 90 cm (layer 4).

a)

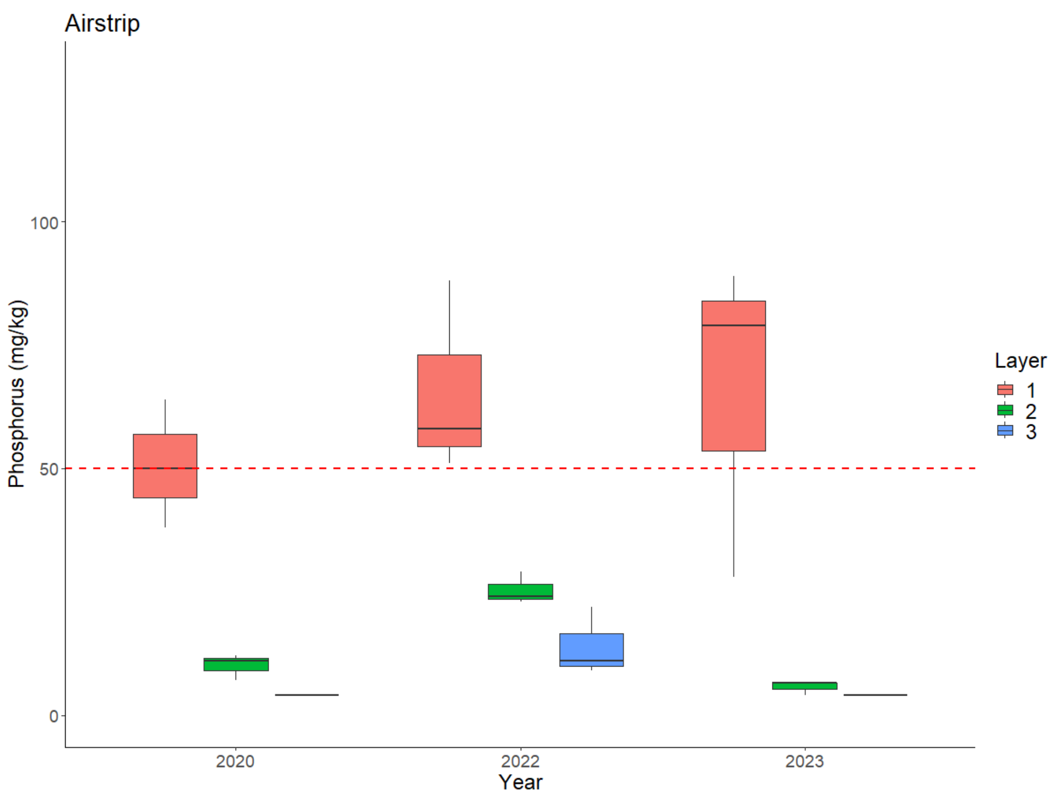


Figure 7, continued

b)

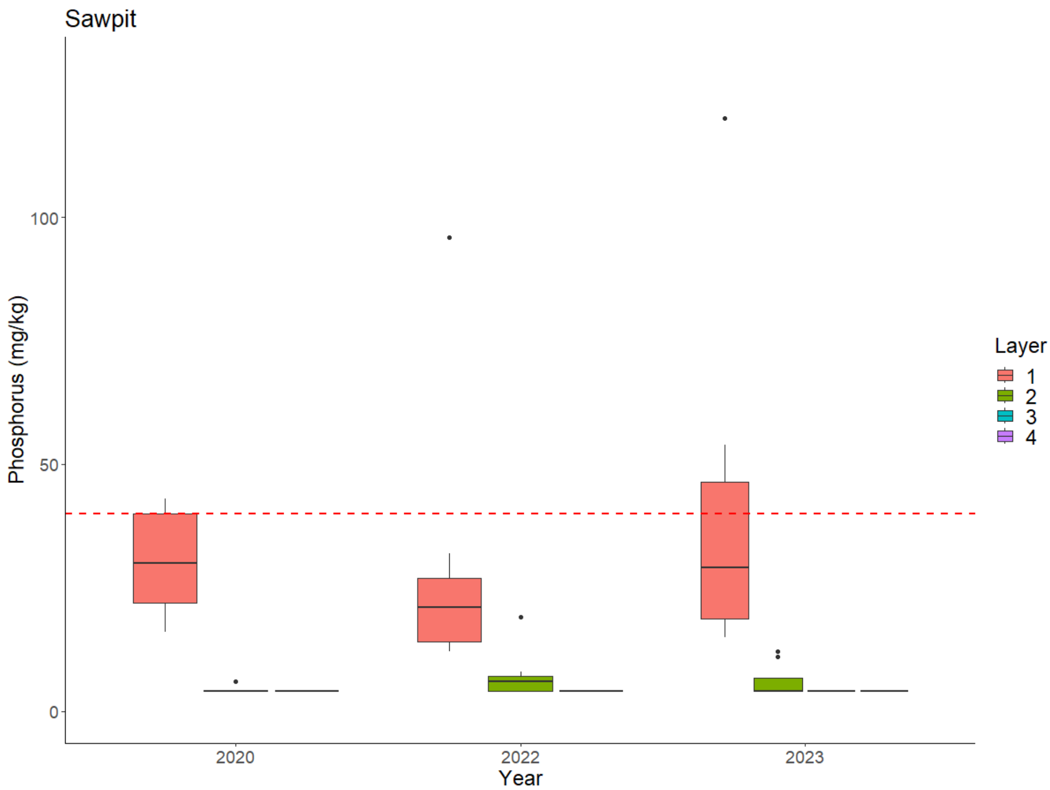
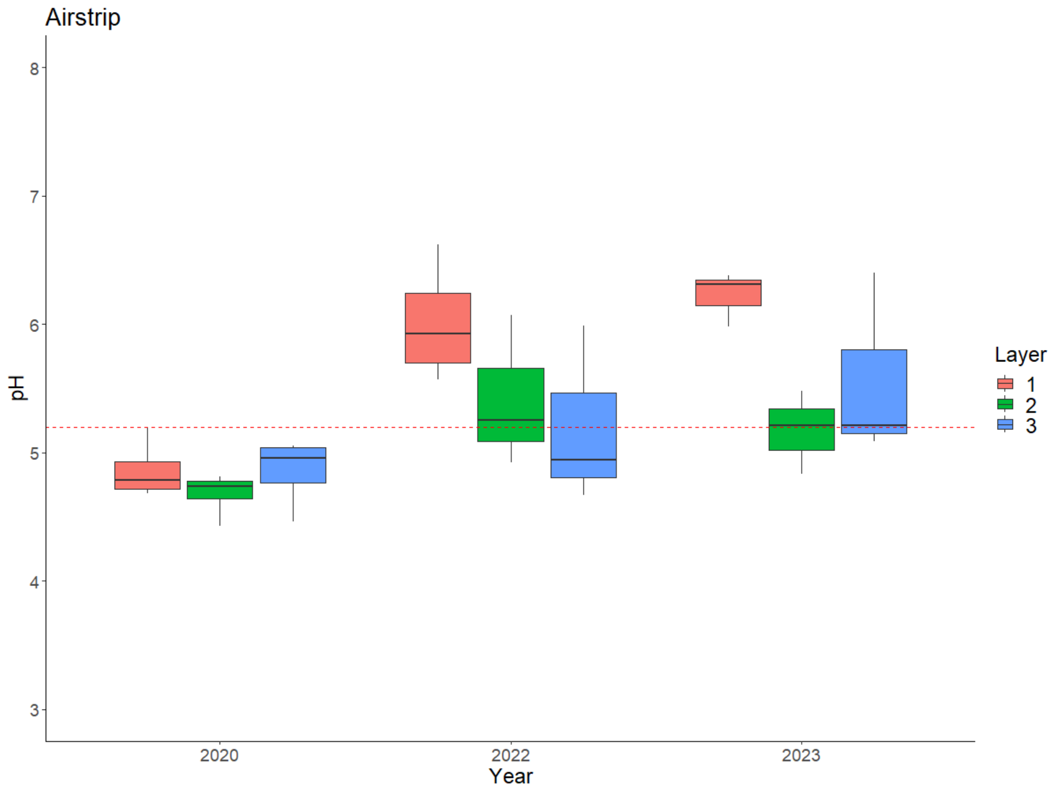


Figure 12: Soil pH at Airstrip (a) and Sawpit (b), 2020 – 2023. The dotted red line shows the critical pH value in each paddock (pH of 5.2). Soil depths of 0 – 10 cm (layer 1), 10 – 30 cm (layer 2), 30 – 60 cm (layer 3) and 60 – 90 cm (layer 4).

a)



b)

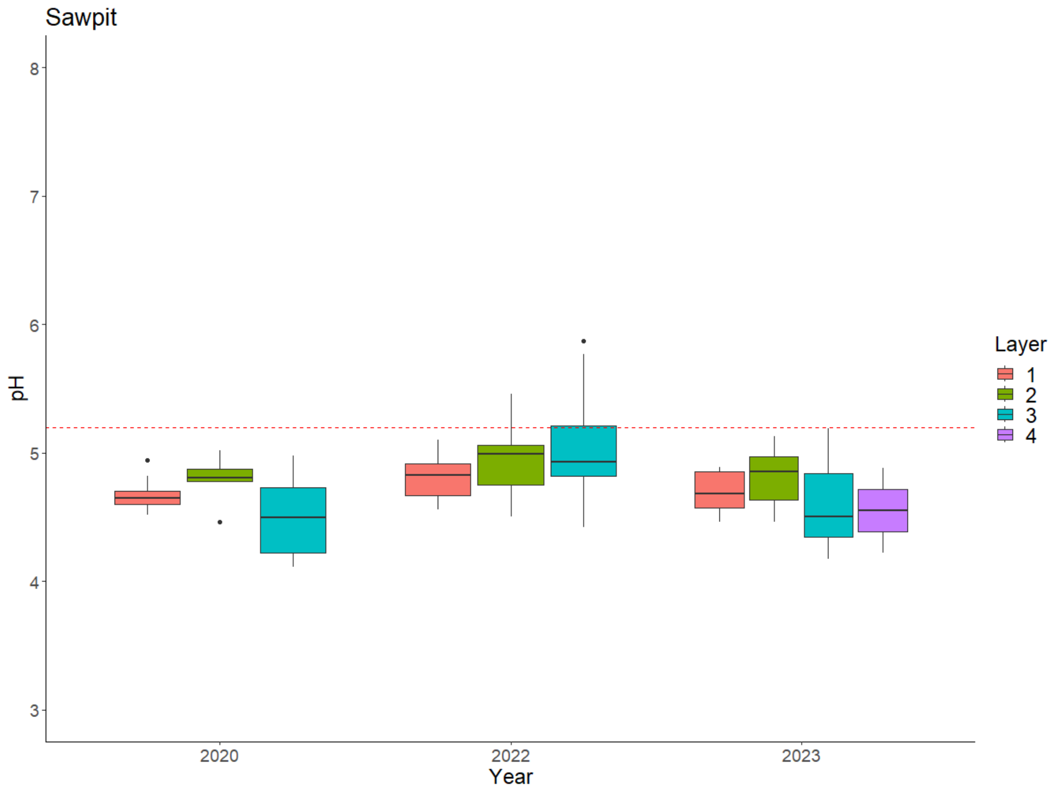
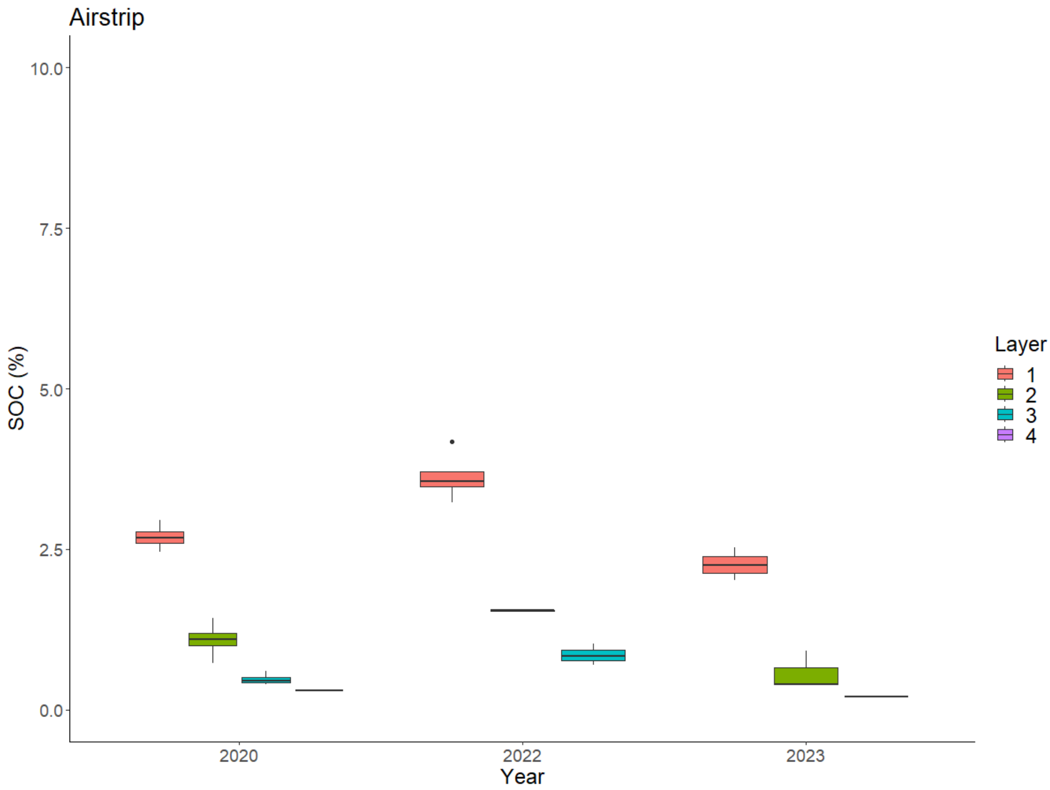
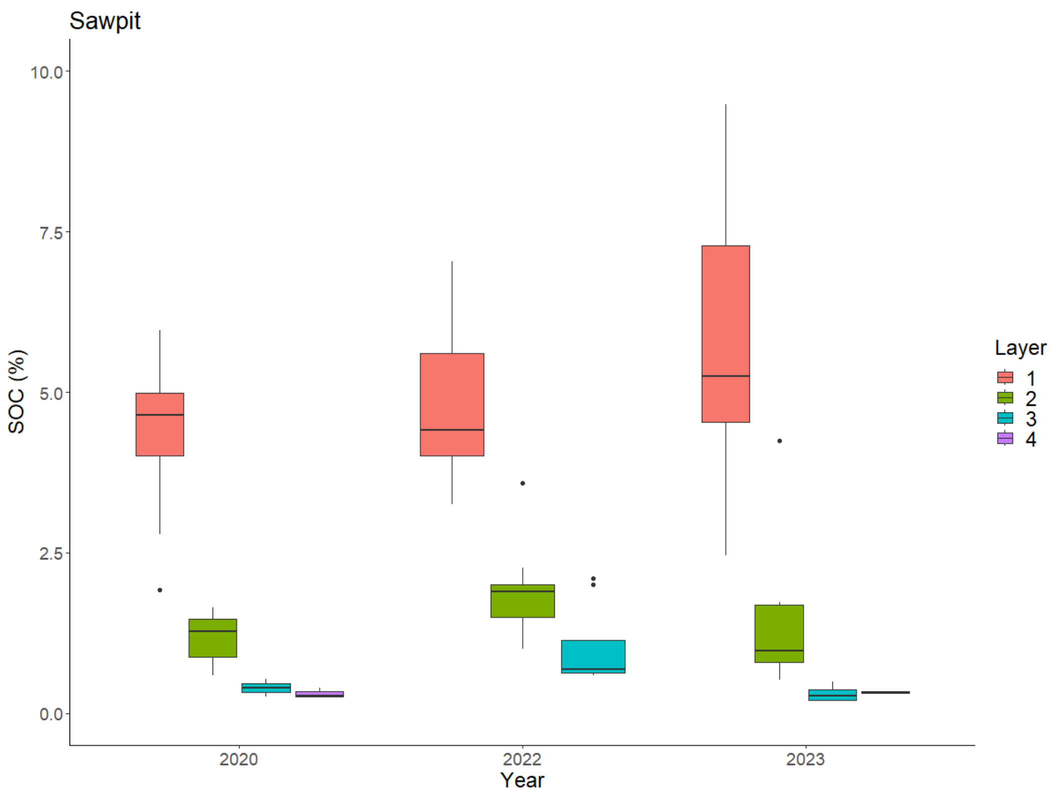


Figure 13: Soil organic carbon levels (%) in Airstrip (a) and Sawpit (b), at a soil depth of 0 – 10 cm (layer 1), 10 – 30 cm (layer 2), 30 – 60 cm (layer 3) and 60 – 90 cm (layer 4).

a)



b)



4.3.2.2 Argyle

At Greenknob site, phosphorus levels which were optimal in 2020 at 0 – 10 cm declined in 2022 to become sub-optimal but increased again in 2023 after single superphosphate application at 300kg/ha blanket rate (Fig. 14, a). Target Colwell P level is 35 mg/kg. Overall pH levels were sub-optimal (Fig. 15, a) and except for some slight variations in SOC levels in the top 0 – 10 cm, carbon levels slightly declined at depth (Fig. 16, a).

The Wattle paddock has unimproved pasture consisting of phalaris, cocksfoot, pin rush and red grass. Overall, phosphorus levels have declined over the years, and phosphorus levels also decline with soil depth (Fig. 14, b). No significant changes have occurred in pH levels, which were sub-optimal at all soil depths (Fig. 15, b). Soil organic carbon levels have not significantly changed either (Fig. 16, b).

Figure 14: Soil Colwell phosphorus levels in 2020, 2022 and 2023, classified per soil depth (0 – 10 cm = layer 1, 10 – 30 cm = layer 2, 30 – 60 cm = layer 3, 60 – 90 cm = layer 4, 90 – 120 cm = layer 5). The red dotted line shows the critical phosphorus value of 30 mg/kg.

a)

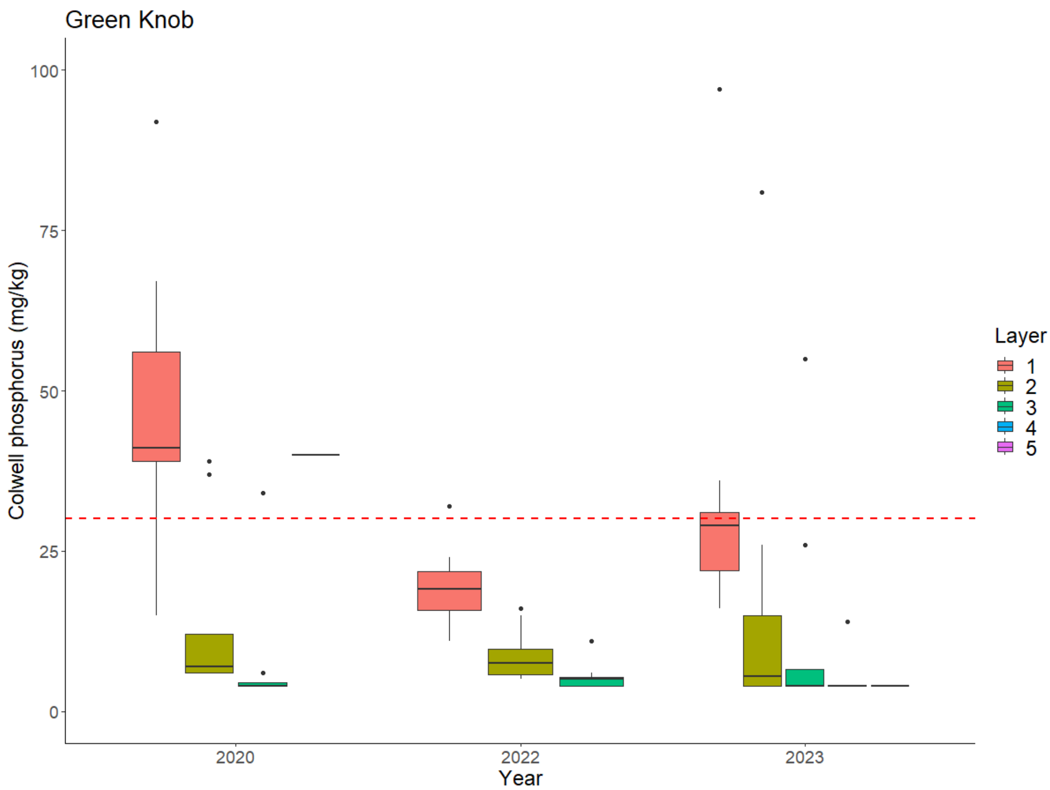


Figure 14, continued.

b)

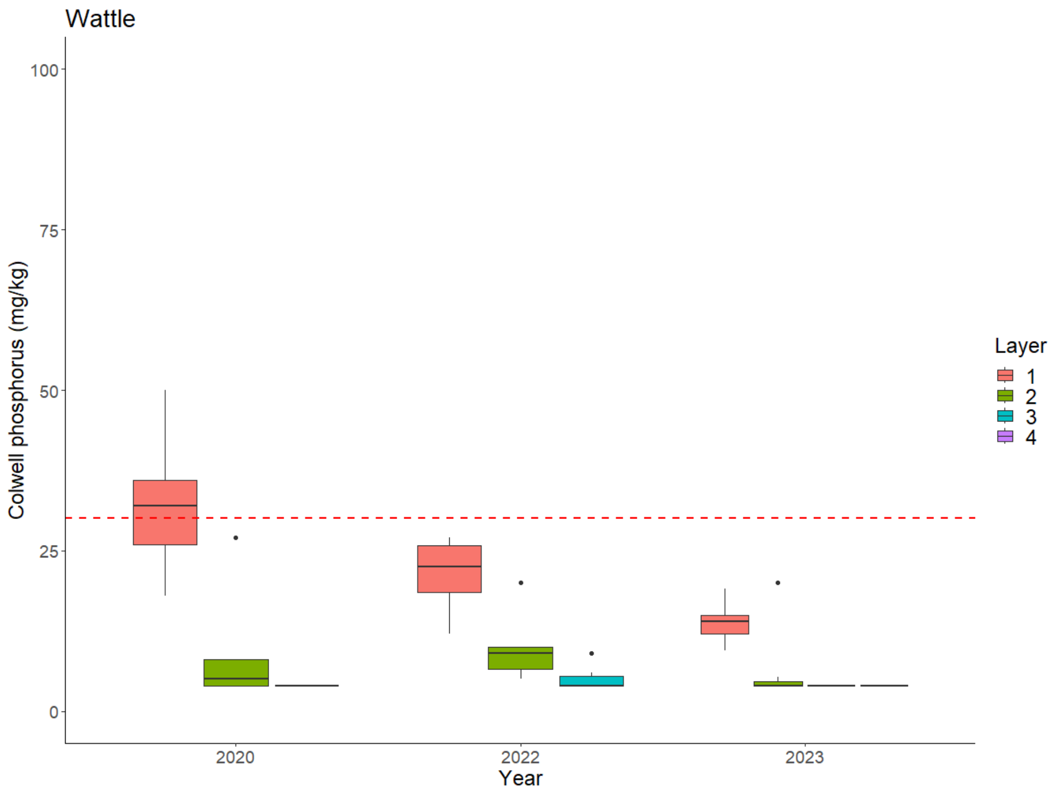
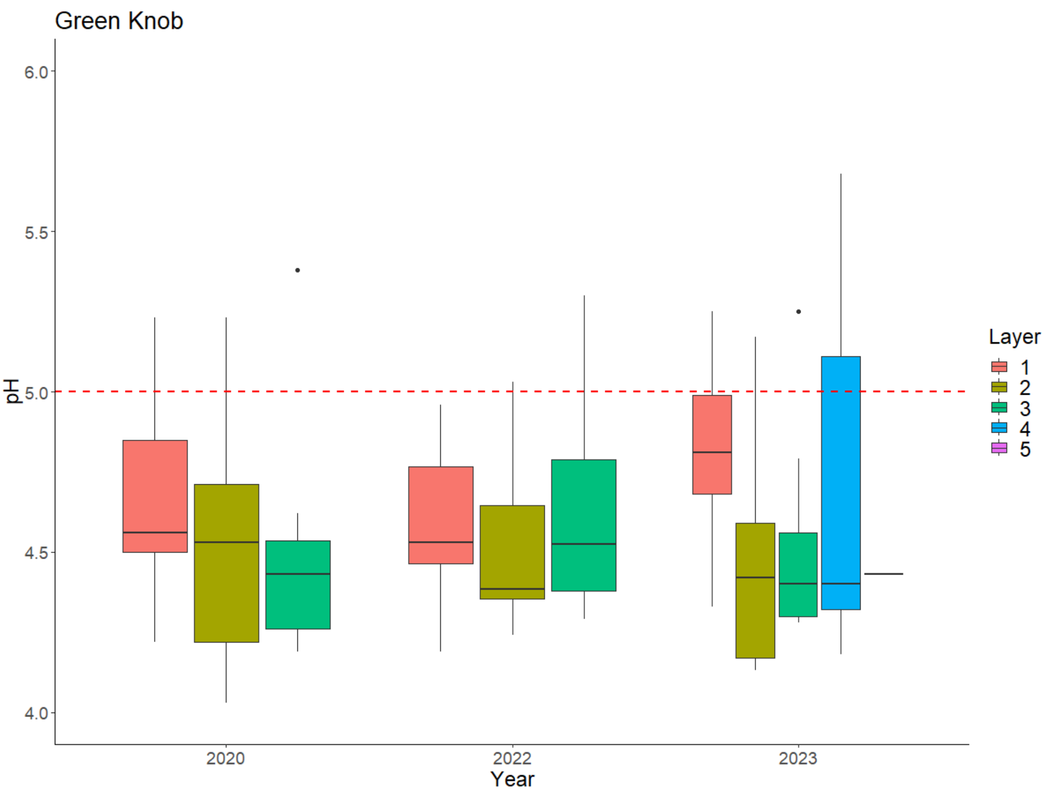


Figure 15: Soil pH in 2020, 2022 and 2023, classified per soil depth (0 – 10 cm = layer 1, 10 – 30 cm = layer 2, 30 – 60 cm = layer 3, 60 – 90 cm = layer 4, 90 – 120 cm = layer 5), at the Greenknob (a) and Wattle (b) paddocks at Argyle. The red dotted line shows the critical pH value of 5.0.

a)



b)

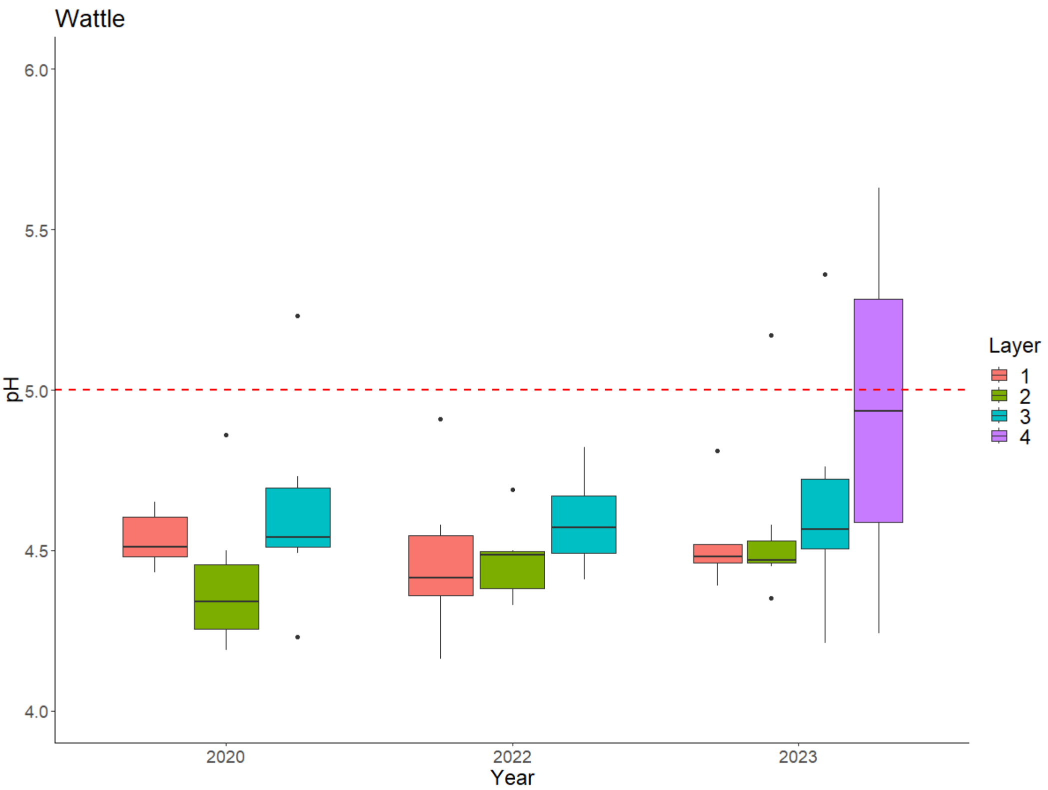
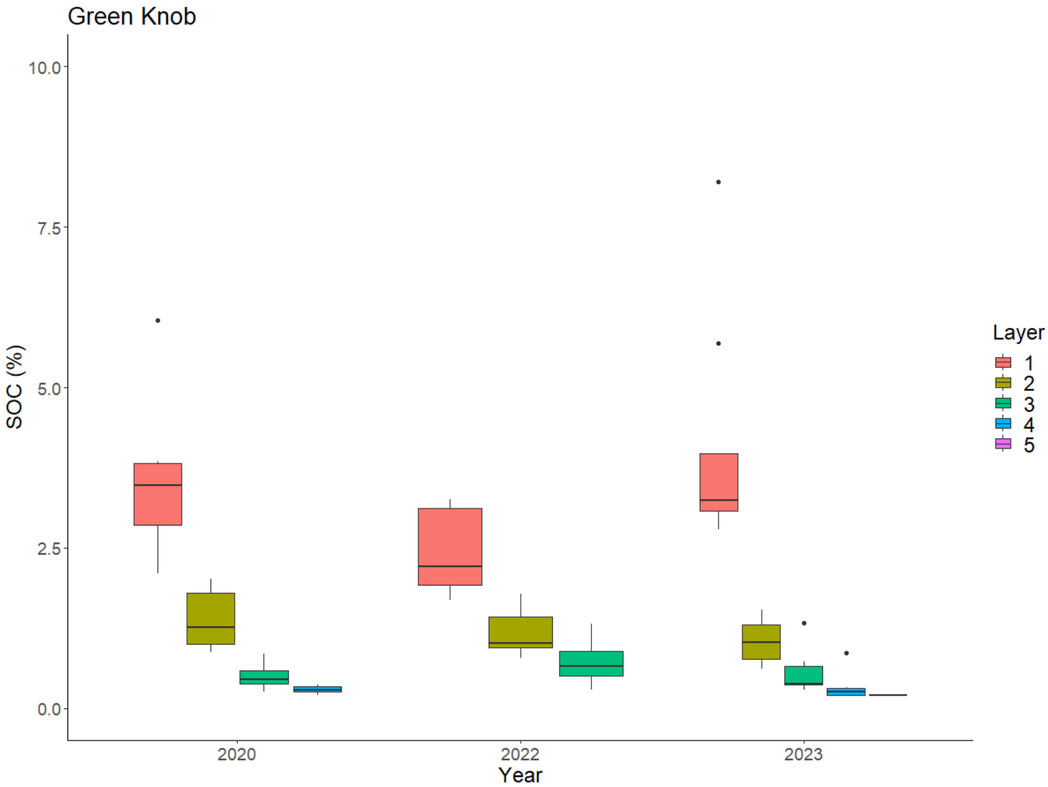
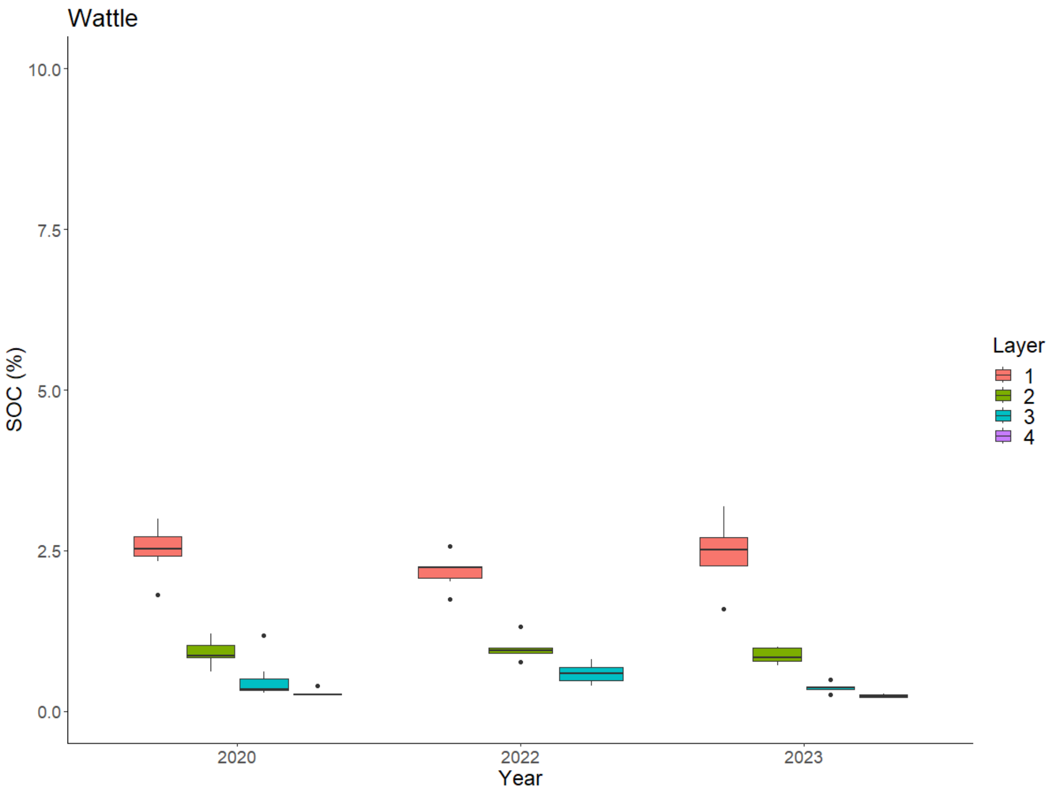


Figure 16: Soil organic carbon (%) in 2020, 2022 and 2023, classified per soil depth (0 – 10 cm = layer 1, 10 – 30 cm = layer 2, 30 – 60 cm = layer 3, 60 – 90 cm = layer 4, 90 – 120 cm = layer 5), in the Greenknob (a) and Wattle (b) paddocks at Argyle.

a)



b)



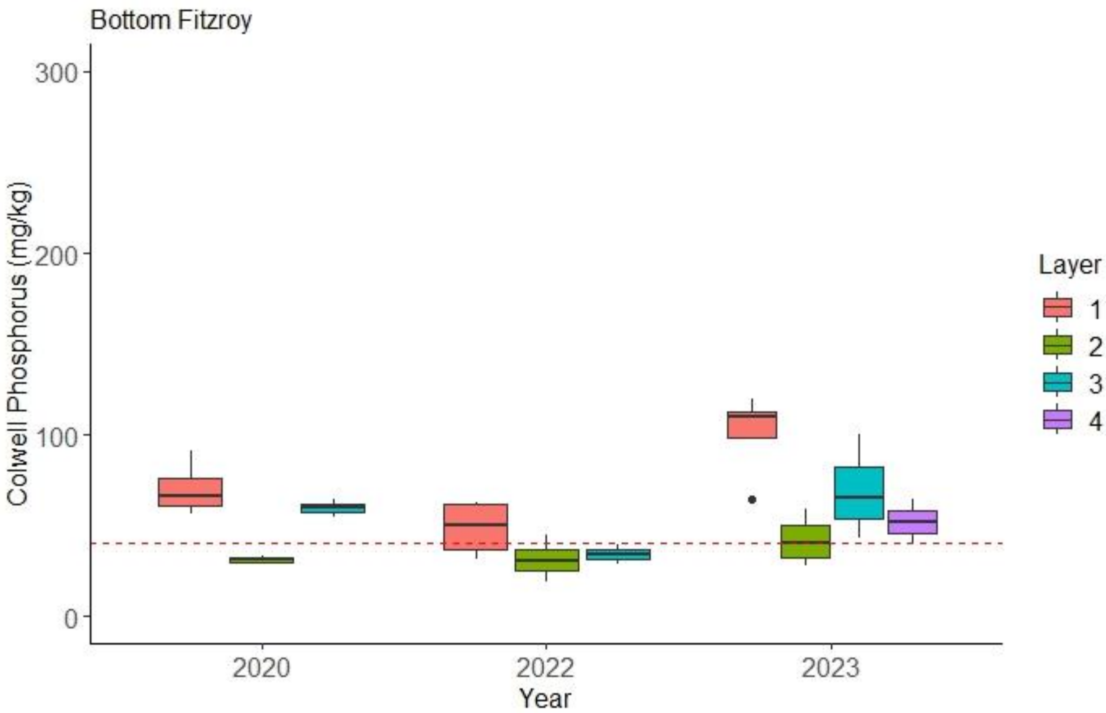
4.3.2.3 Bald Blair

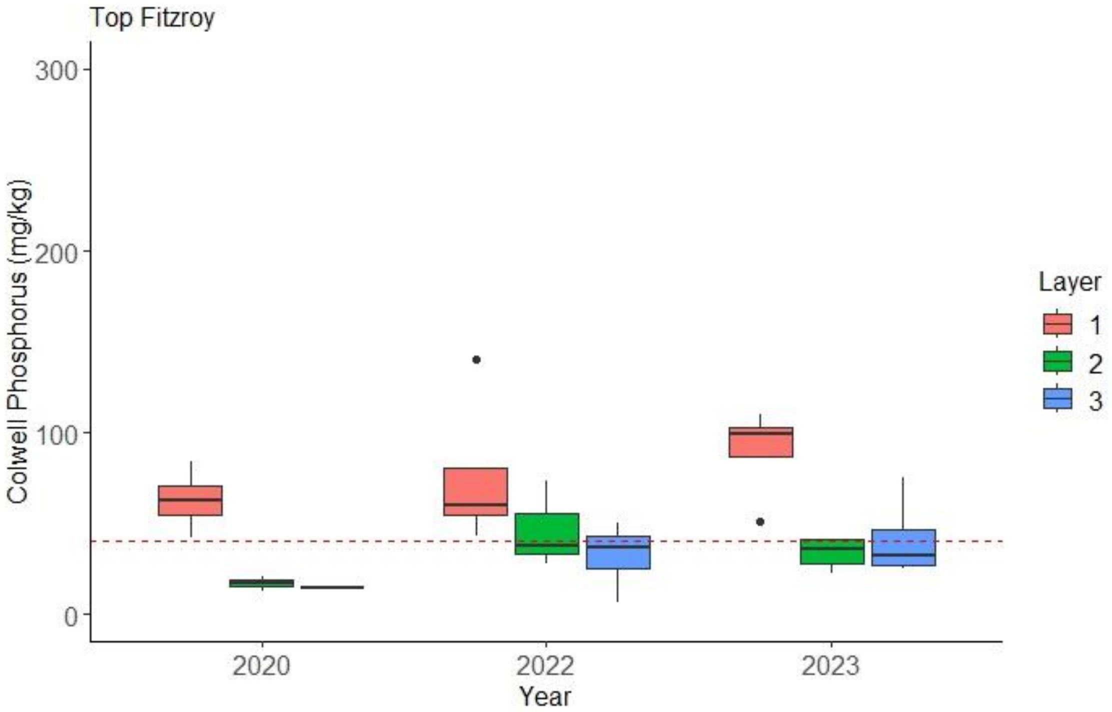
Although phosphorus levels slightly decreased from 2020 to 2022 in the top 10cm at Top Fitzroy and Cruickshanks, these levels were still above critical, and phosphorus levels in this layer increased in 2023 (Fig. 17) in all paddocks.

Average soil pH was below the critical value of 5.2 (Fig. 18) in the top 10 cm of soil in all paddocks, it was however above the critical value of 5.0 adopted for most remaining properties. Soil pH levels increased with soil depth.

SOC levels changed between 2022 and 2023, with an increase in carbon in the top 10 cm of soil and a decreased in carbon levels at depth (Fig. 19), in all paddocks.

Figure 17: Soil Colwell phosphorus levels (mg/kg) at Bald Blair (Bottom Fitzroy, Top Fitzroy and Cruickshanks paddocks) in 2020, 2022 and 2023. The layers represent the different soil depths: Layer 1 is 0 – 10 cm depth, Layer 2 is 10 – 30 cm depth, Layer 3 is 30 – 60 cm depth, Layer 4 is 60 – 90 cm depth and Layer 5 is 90 – 120 cm depth. The critical phosphorus value of 40 mg/kg is indicated by the red dotted line.




Top Fitzroy
Colwell Phosphorus (mg/kg)
300
200
100
0
2020
2022
2023
Year
Layer
1
2
3

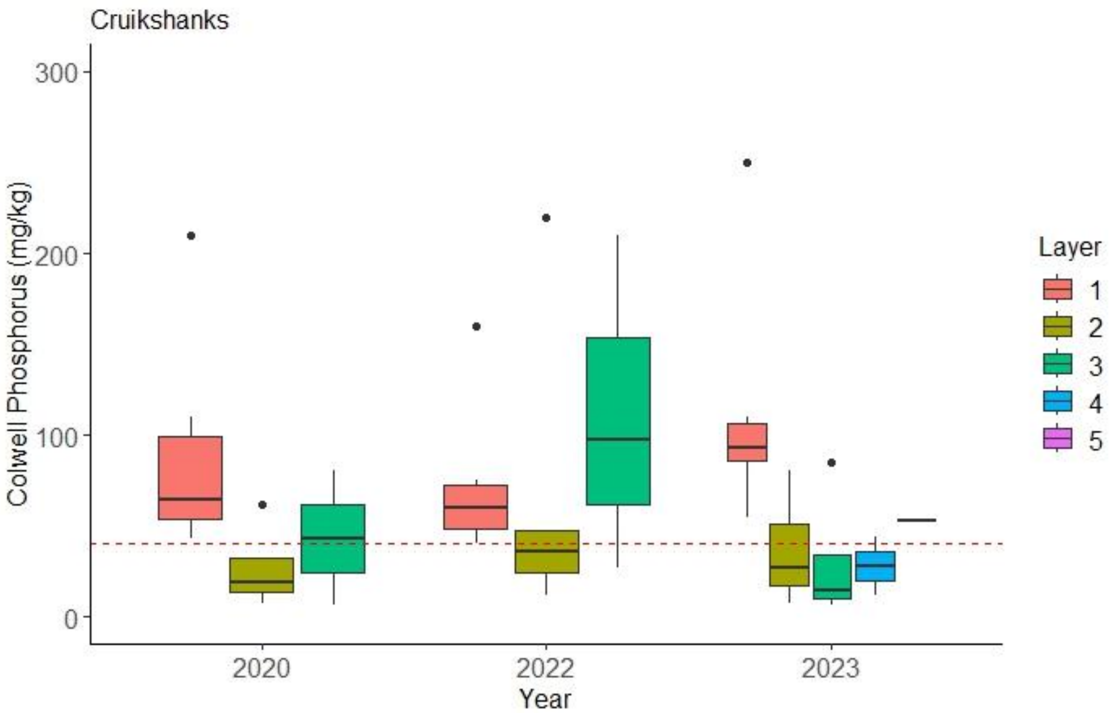
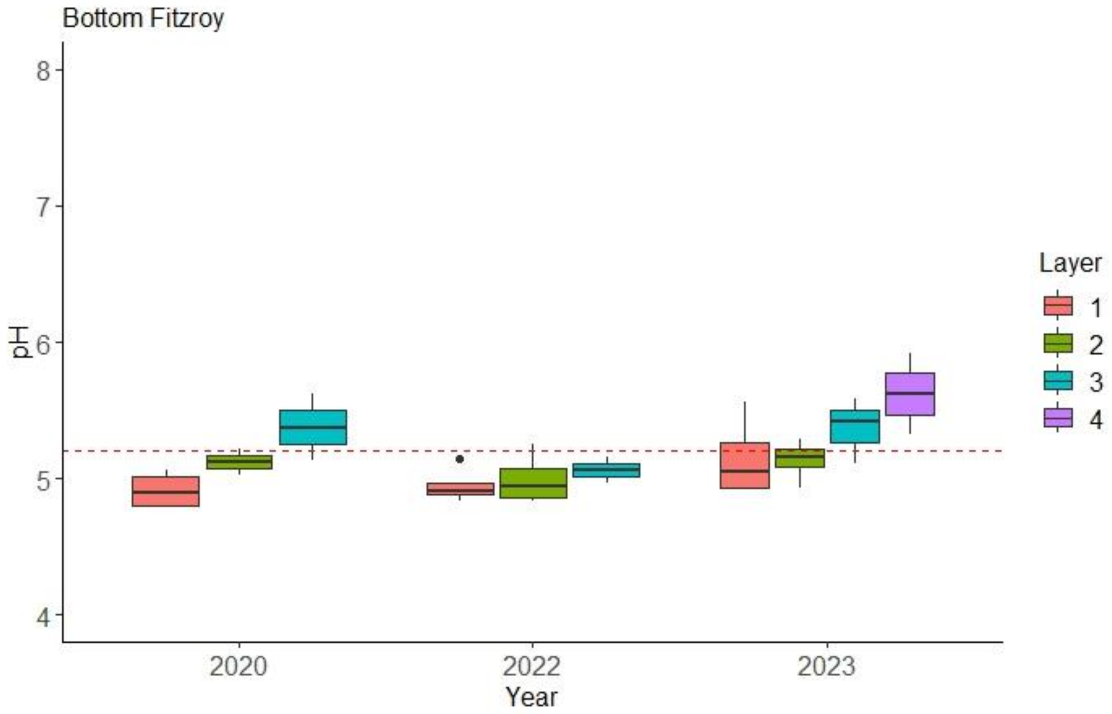
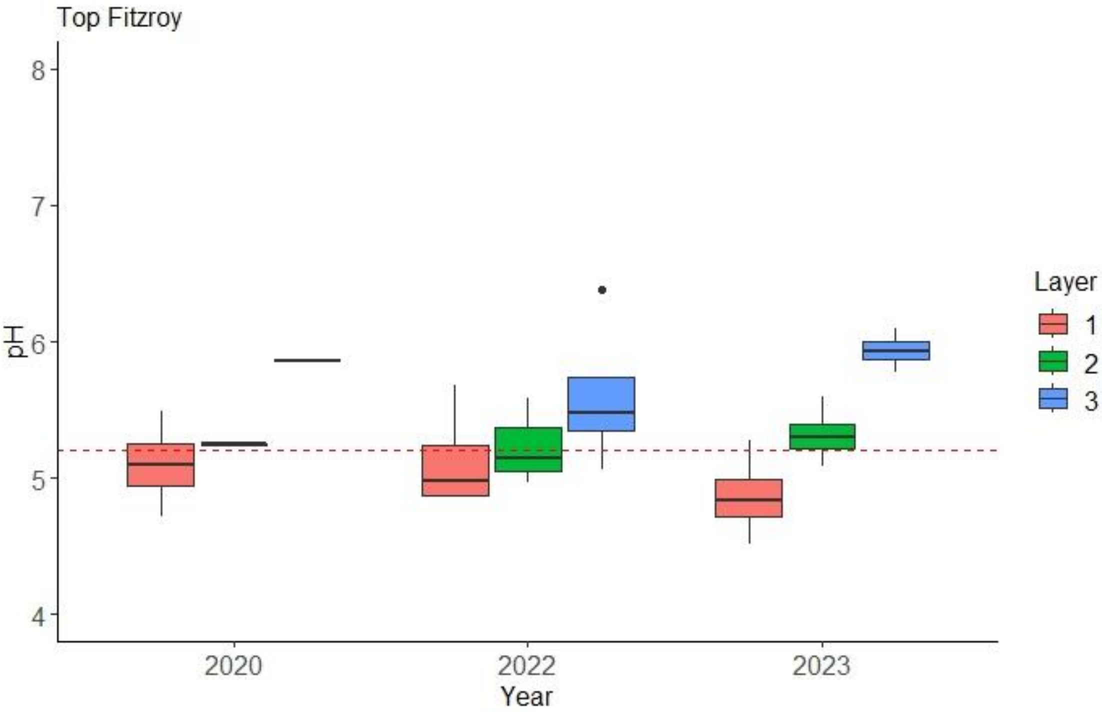

Cruikshanks
Colwell Phosphorus (mg/kg)
300
200
100
0
2020
2022
2023
Year
Layer
1
2
3
4
5

Figure 18: pH levels at Bald Blair (Bottom Fitzroy, Top Fitzroy and Cruickshanks paddocks) in 2020, 2022 and 2023. The layers represent the different soil depths: Layer 1 is 0 – 10 cm depth, Layer 2 is 10 – 30 cm depth, Layer 3 is 30 – 60 cm depth, Layer 4 is 60 – 90 cm depth and Layer 5 is 90 – 120 cm depth. The critical pH value of 5.2 is indicated by the red dotted line.




Top Fitzroy
8
7
6
5
4
pH
2020
2022
2023
Year
Layer
1
2
3

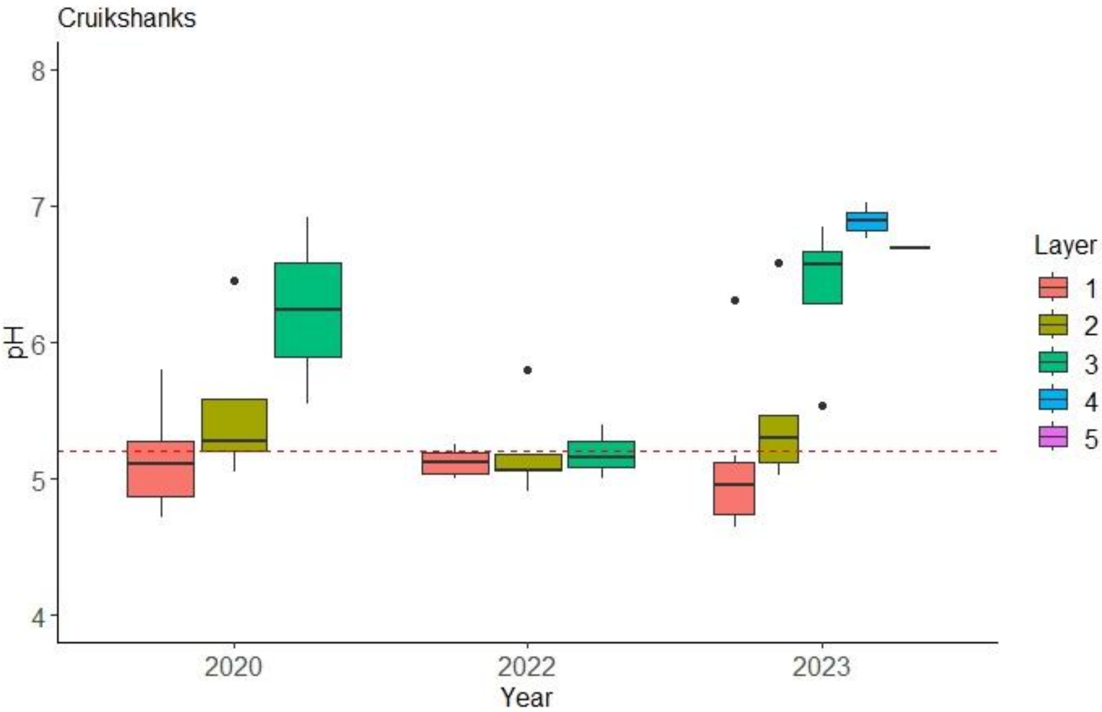
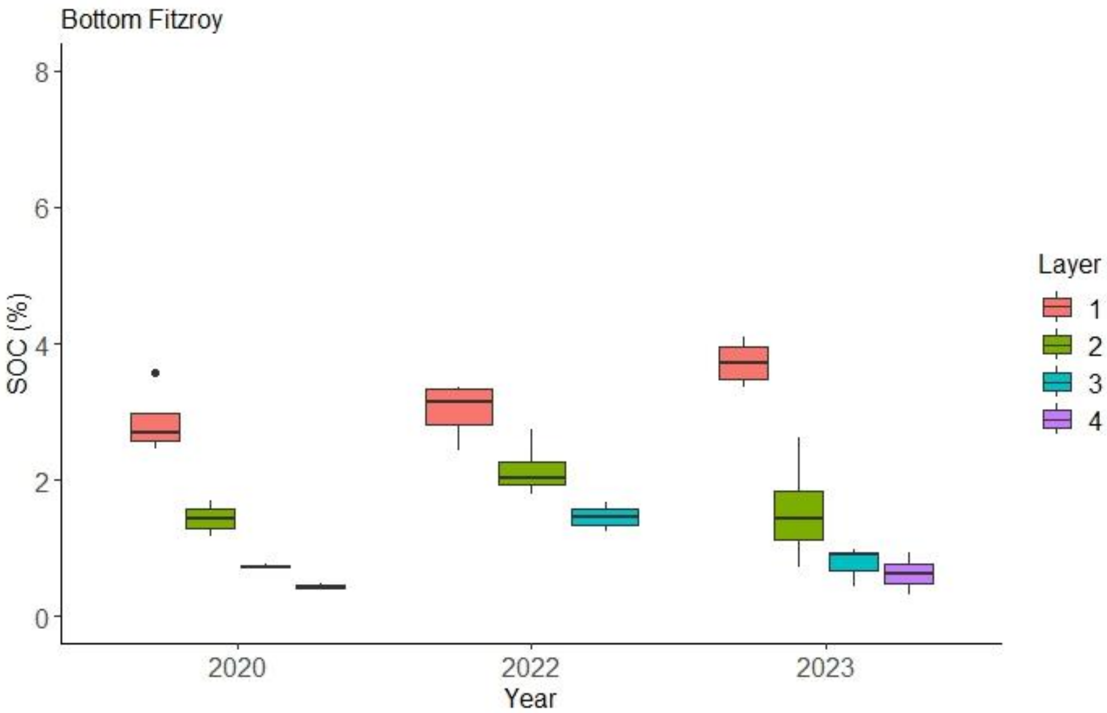
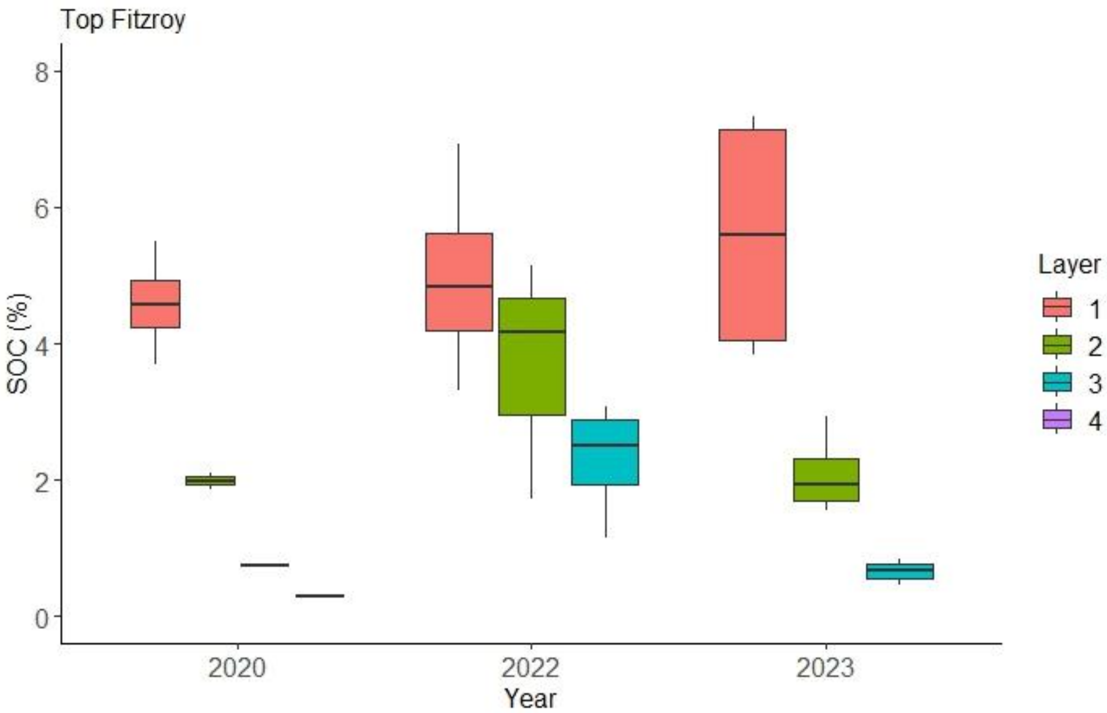
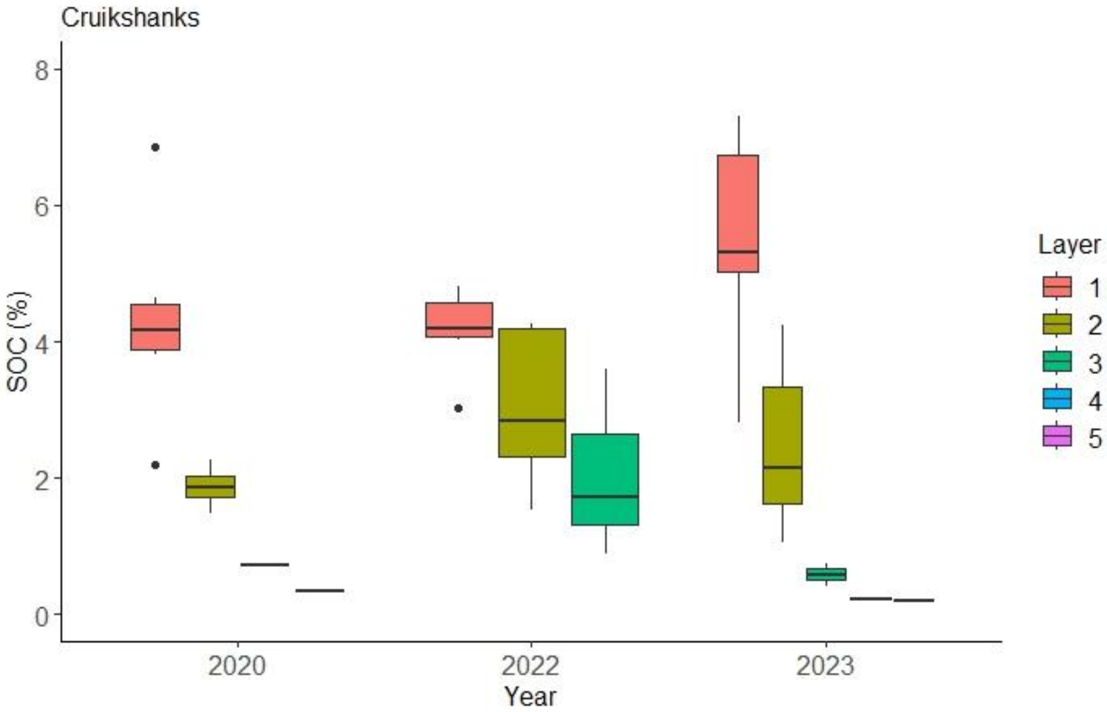

Cruikshanks
8
7
6
5
4
pH
2020
2022
2023
Year
Layer
1
2
3
4
5

Figure 19: SOC (%) levels at Bald Blair (Bottom Fitzroy, Top Fitzroy and Cruickshanks paddocks) in 2020, 2022 and 2023. The layers represent the different soil depths: Layer 1 is 0 – 10 cm depth, Layer 2 is 10 – 30 cm depth, Layer 3 is 30 – 60 cm depth, Layer 4 is 60 – 90 cm depth and Layer 5 is 90 – 120 cm depth.







4.3.2.4 Cooringoora

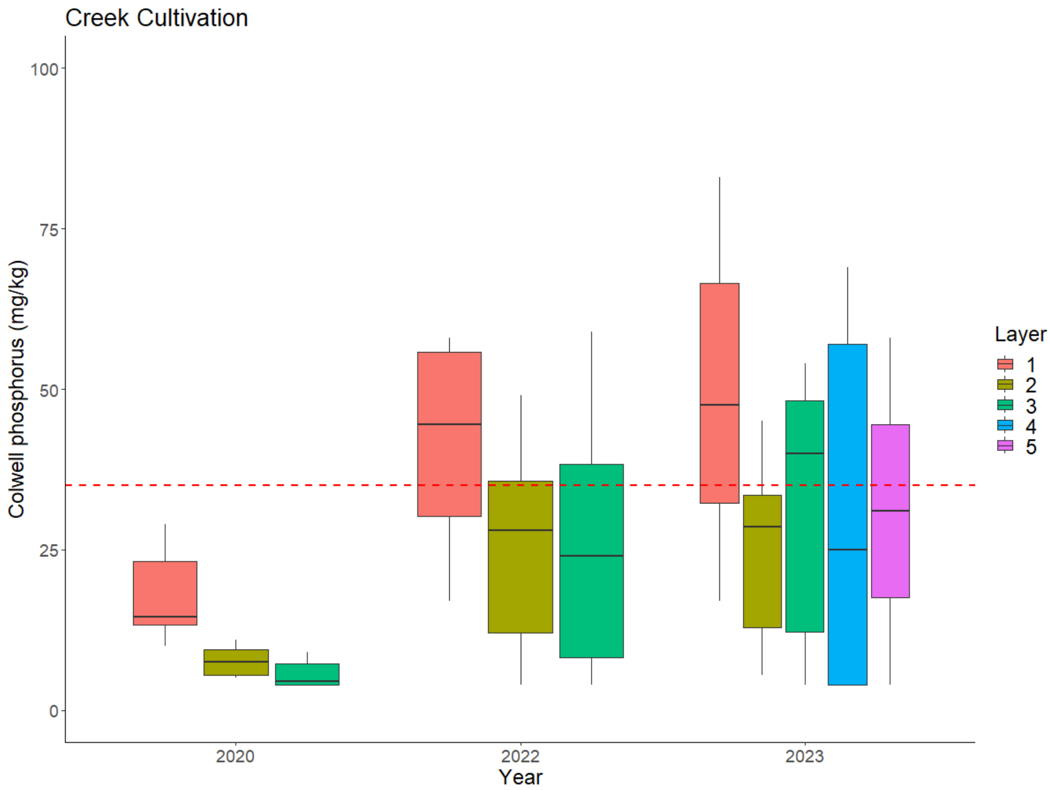
The demonstration paddocks at Cooringoora were the Creek Cultivation paddock, which has annually been resown with an oats crop and has received starter fertiliser, and the Front paddock, which has native pasture (including Coolatai grass, red grass and plains grass) growing and did not receive any fertiliser or lime during the trial period.

The Colwell phosphorus levels increased in Creek Cultivation to be optimal at 0 – 10 cm in 2022 and 2023 (Fig. 20, a). The pH levels were sub-optimal at 0 – 10 cm but increased with soil depth. SOC levels declined in the top 0 – 10 cm in 2022 and slightly increased in 2023 (Fig. 21, a). No significant changes occurred in deeper soil layers (Fig. 22, a).

In the Front paddock phosphorus levels declined to be sub-optimal at all soil depths in 2023 and no comparisons could be made in terms of pH levels as these were not taken at all depths each year (Fig. 20, b). In general, pH levels were not an issue in the Front paddock (Fig. 21, b). No significant changes occurred in carbon levels at any soil depth (Fig. 22, b).

Figure 20: Soil Colwell phosphorus levels (mg/kg) in 2020, 2022 and 2023 in the Creek Cultivation (a) and Front (b) paddocks at Cooringoora. Layer 1 = 0 – 10 cm depth, layer 2 = 10 – 30 cm depth, layer 3 = 30 – 60 cm depth, layer 4 = 60 – 90 cm depth, and layer 5 = 90 – 120 cm depth. The red dotted line shows the critical phosphorus value of 35 mg/kg.

a)



b)

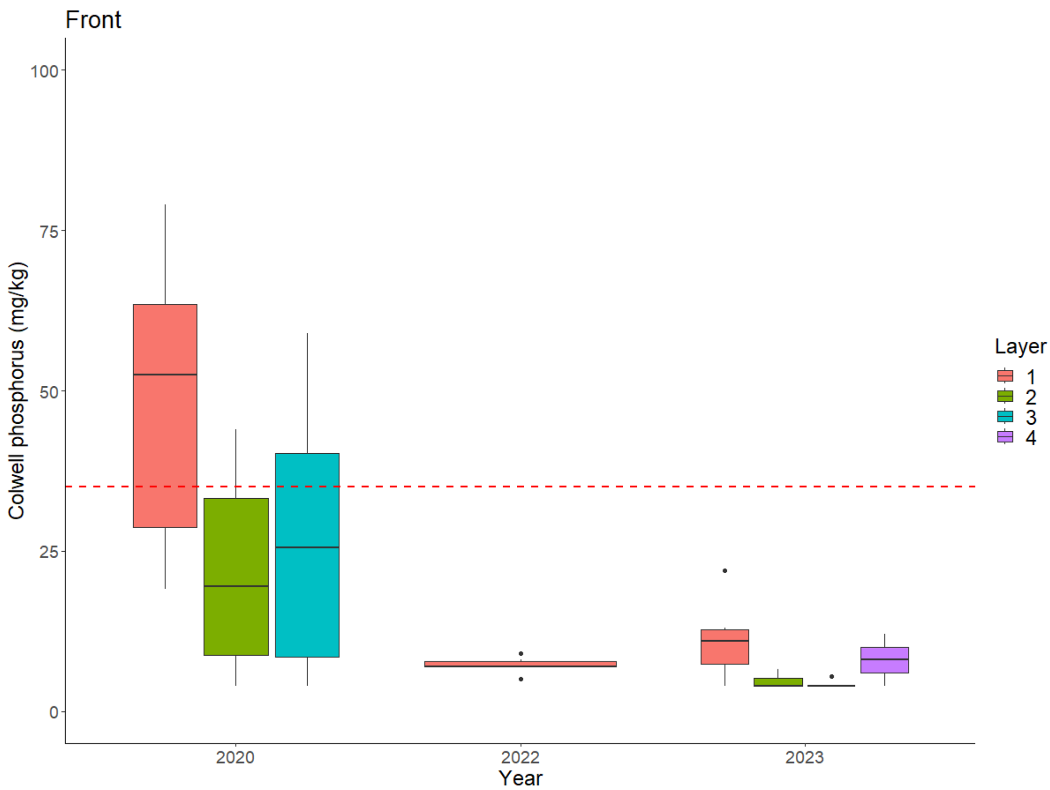
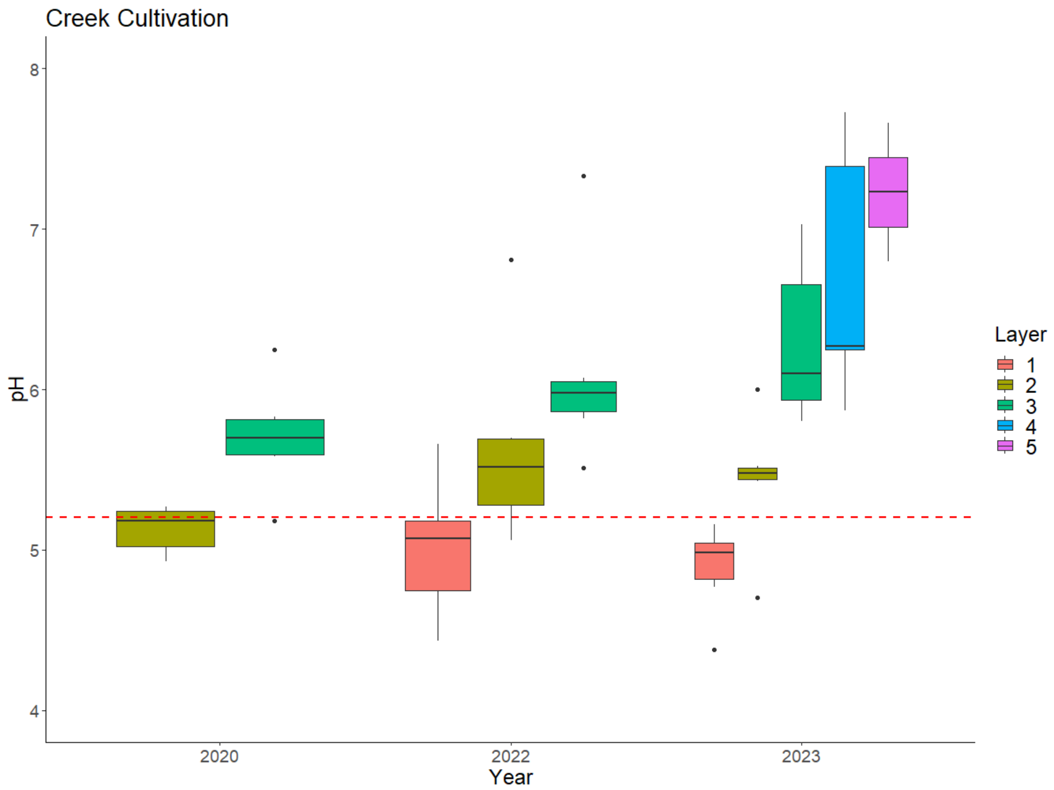


Figure 21: Soil pH levels in 2020, 2022 and 2023, in the Creek Cultivation (a) and Front (b) paddocks at Cooringoora. Layer 1 = 0 – 10 cm depth, layer 2 = 10 – 30 cm depth, layer 3 = 30 – 60 cm depth, layer 4 = 60 – 90 cm depth, and layer 5 = 90 – 120 cm depth. The red dotted line shows the critical pH value of 5.2.

a)



b)

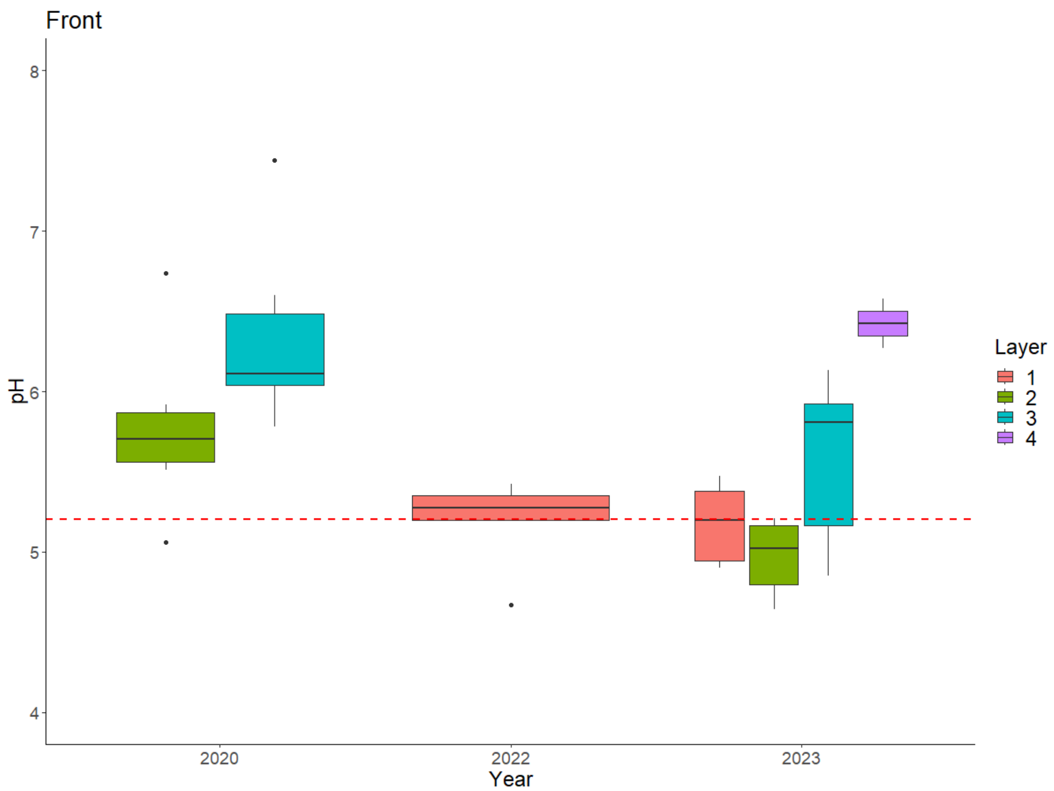
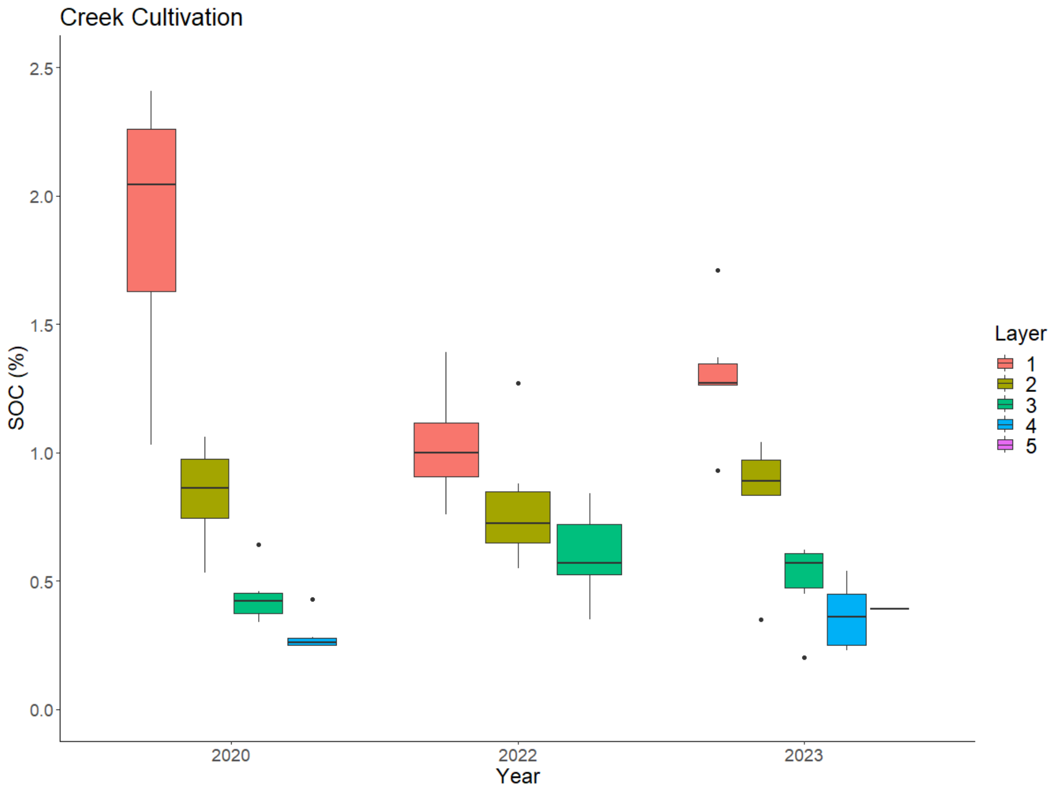
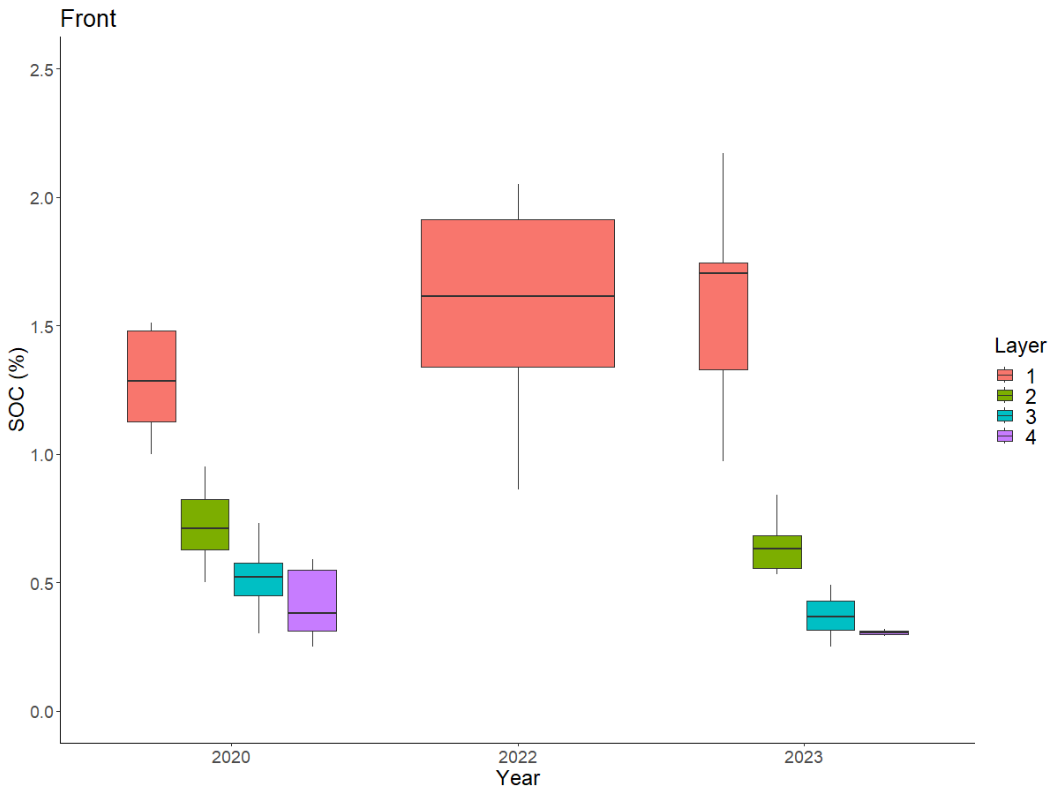


Figure 22: Soil organic carbon (%) in 2020, 2022 and 2023 in the Creek Cultivation (a) and Front (b) paddocks at Cooringoora. Layer 1 = 0 – 10 cm depth, layer 2 = 10 – 30 cm depth, layer 3 = 30 – 60 cm depth, layer 4 = 60 – 90 cm depth, and layer 5 = 90 – 120 cm depth.

a)



b)



4.3.2.5 Glenview

Overall, phosphorus levels were below optimal at every soil testing round and at every soil depth (Fig. 23), and a slight decline in pH levels occurred at every depth, over time (Fig. 24). SOC levels slightly decreased at 0 -10 cm in 2021, no meaningful change occurred in any other layer (Fig. 25).

Figure 23: Colwell phosphorus (mg/kg), at Glenview, in 2020, 2022 and 2023. Layer 1 is 0 – 10 cm depth, layer 2 is 10 – 30 cm depth, layer 3 is 30 – 60 cm depth and layer 4 is 60 – 90 cm depth. The red dotted line shows the critical phosphorus value of 25 mg/kg phosphorus.

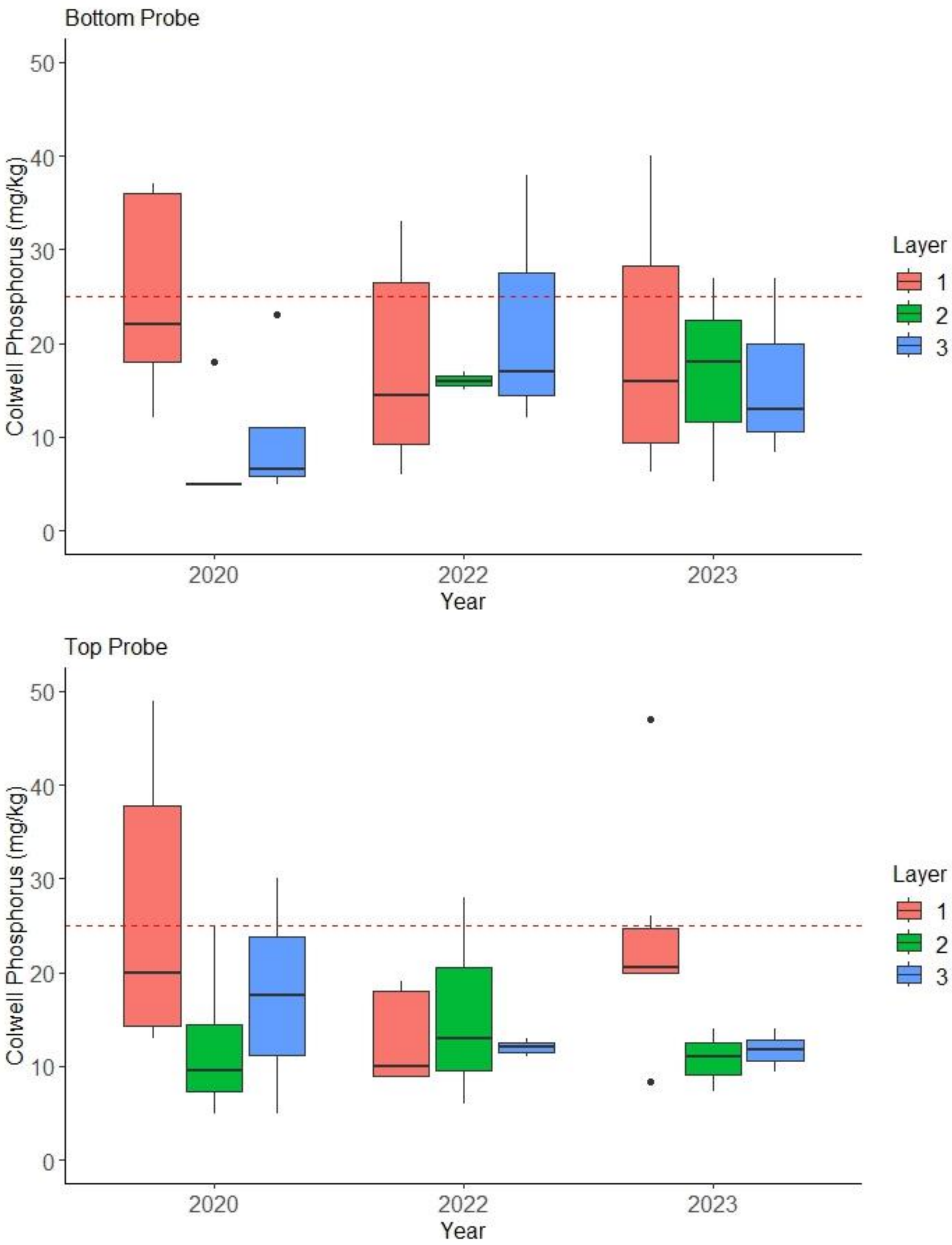
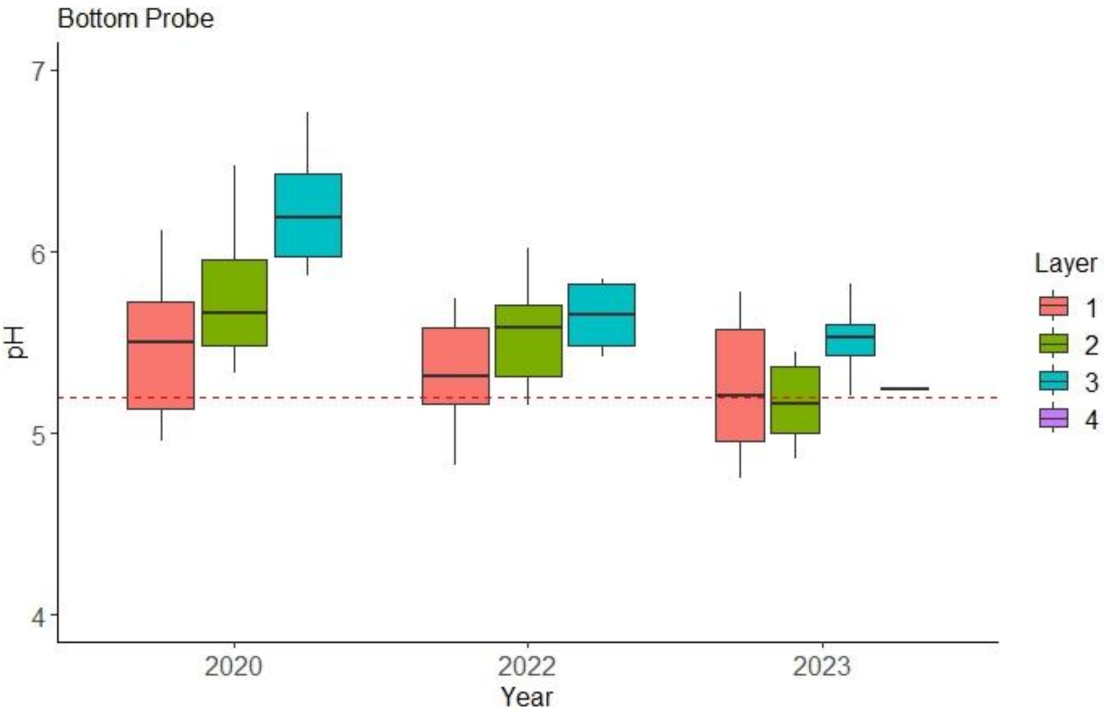


Figure 24: Soil pH levels at Glenview, in 2020, 2022 and 2023. Layer 1 is 0 – 10 cm depth, layer 2 is 10 – 30 cm depth, layer 3 is 30 – 60 cm depth and layer 4 is 60 – 90 cm depth. The red dotted line shows the critical pH value of 5.2 units.



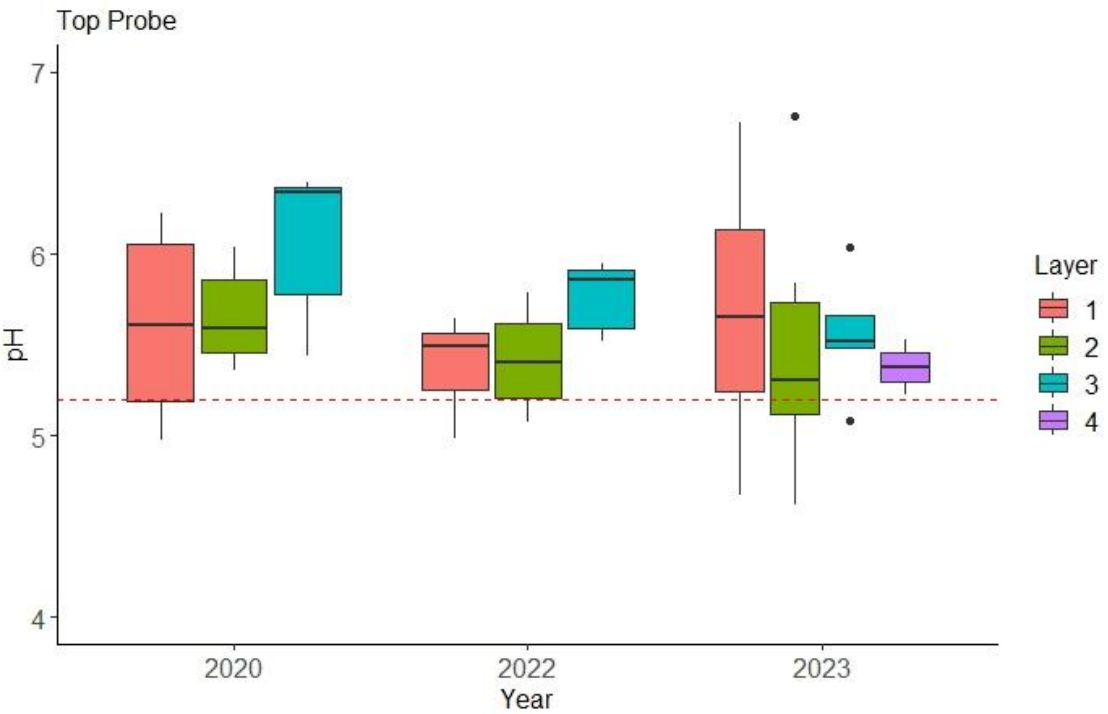
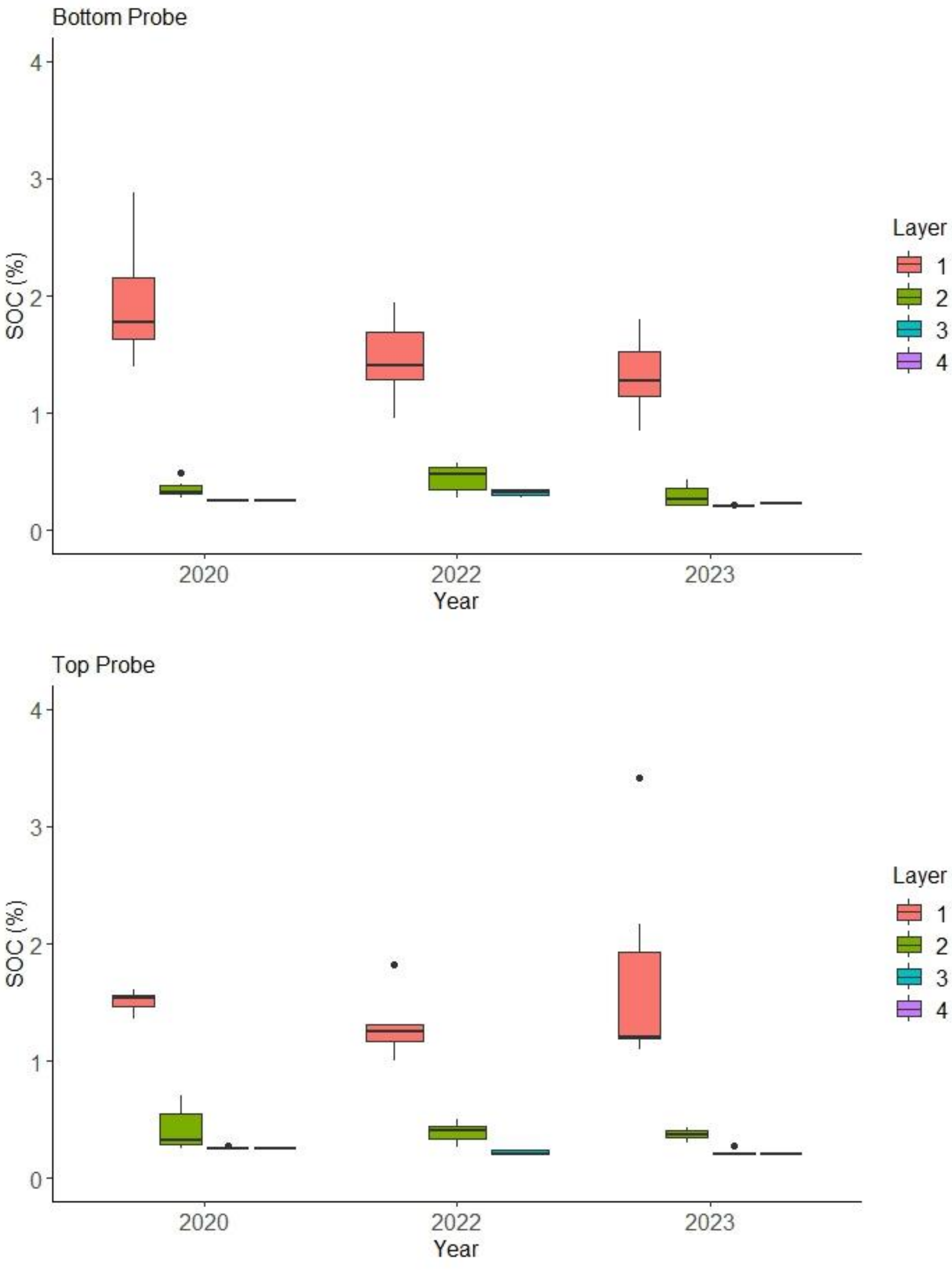


Figure 25: SOC (%) levels at Glenview, in 2020, 2022 and 2023. Layer 1 is 0 – 10 cm soil depth, layer 2 is 10 – 30 cm depth, layer 3 is 30 – 60 cm depth and layer 4 is 60 – 90 cm depth.



4.3.2.6 Leaderville

The pH levels were above critical and increasing with depth at all sample sites at Leaderville (Fig. 26). The application of starter fertiliser in 2020 and 2023 led to some sites being above critical value for Colwell phosphorus in the improved paddock, at 0 – 10 cm (Fig. 26), no notable changes in Colwell phosphorus levels occurred in the native, unfertilised paddock. In the native pasture, average carbon levels consistently increased at 0 – 10 cm and 30 – 60 cm depth (Fig. 28), in the improved Probe paddock, carbon levels decreased in 2022 at 0 – 10 cm and 10 – 30 cm depth but increased between 2020 and 2023 at 30 – 60 cm and 60 – 90 cm depth (Fig. 28). The increase of carbon levels at depth could be due to the transition from an annual cropping system to a permanent pasture with roots establishing at depth (including premier digit grass and lucerne).

Figure 26: Soil Colwell phosphorus (mg/kg) at Leaderville (improved and native paddocks) in 2020, 2022, 2023, classified by soil depth (0-10cm = layer 1, 10-30cm = layer 2, 30-60cm = layer 3, 60-90cm = layer 4, 90-120cm = layer 5). Critical phosphorus value of 40 mg/kg denoted by the dotted red line.

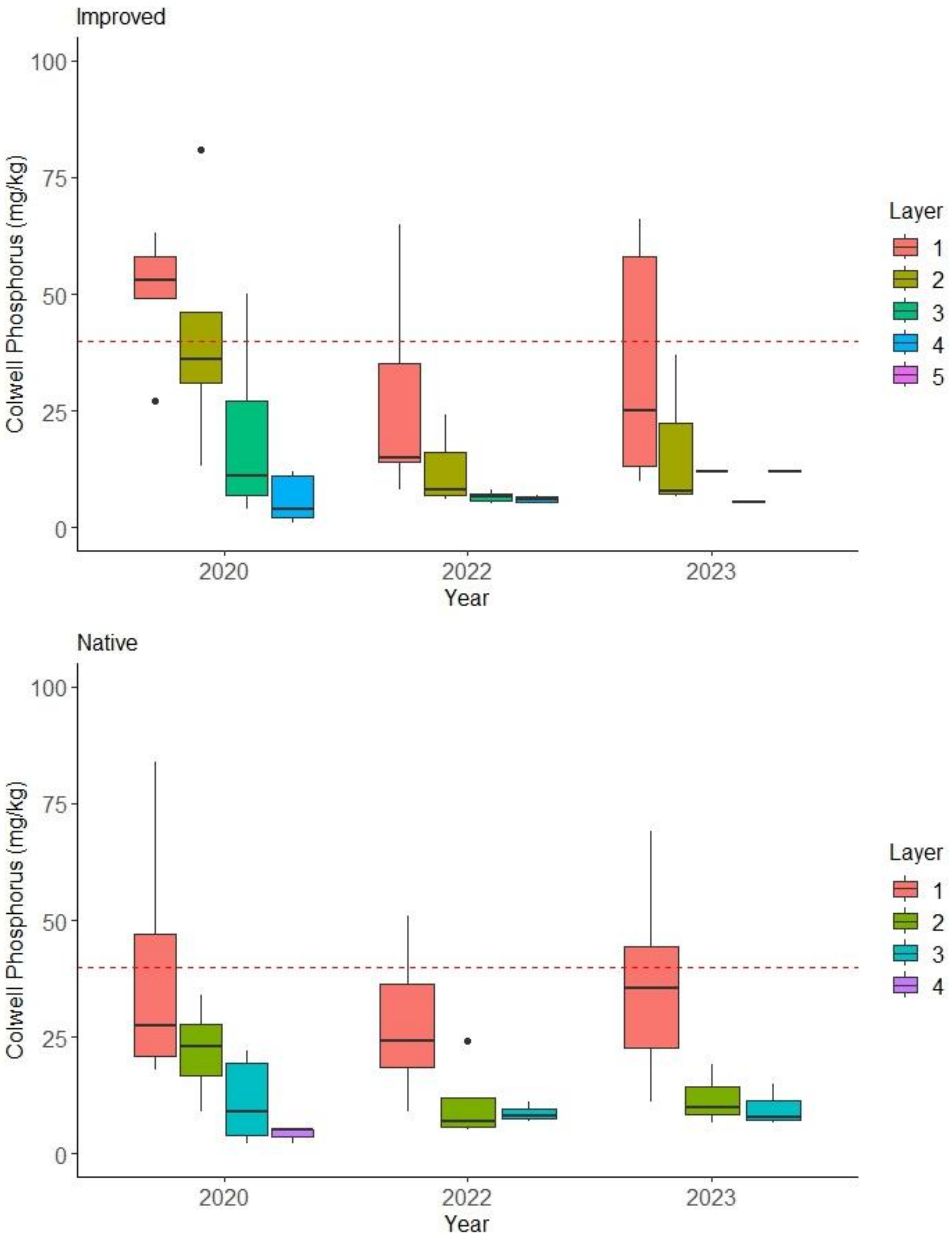


Figure 27: Soil pH at Leaderville (improved and native paddocks) in 2020, 2022, 2023, classified by soil depth (0-10cm = layer 1, 10-30cm = layer 2, 30-60cm = layer 3, 60-90cm = layer 4, 90-120cm = layer 5). Critical pH level of 5.2 units denoted by the dotted red line.

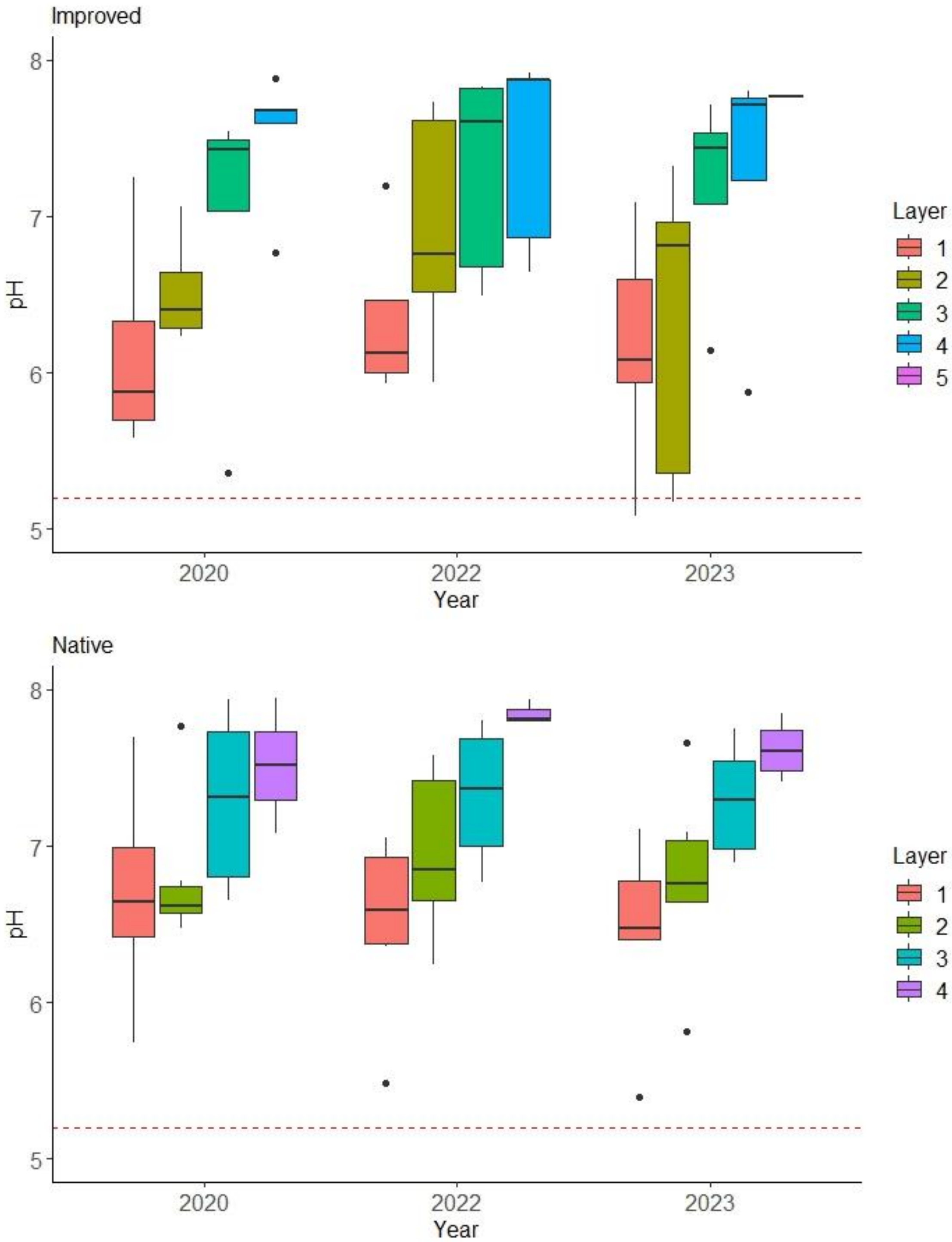
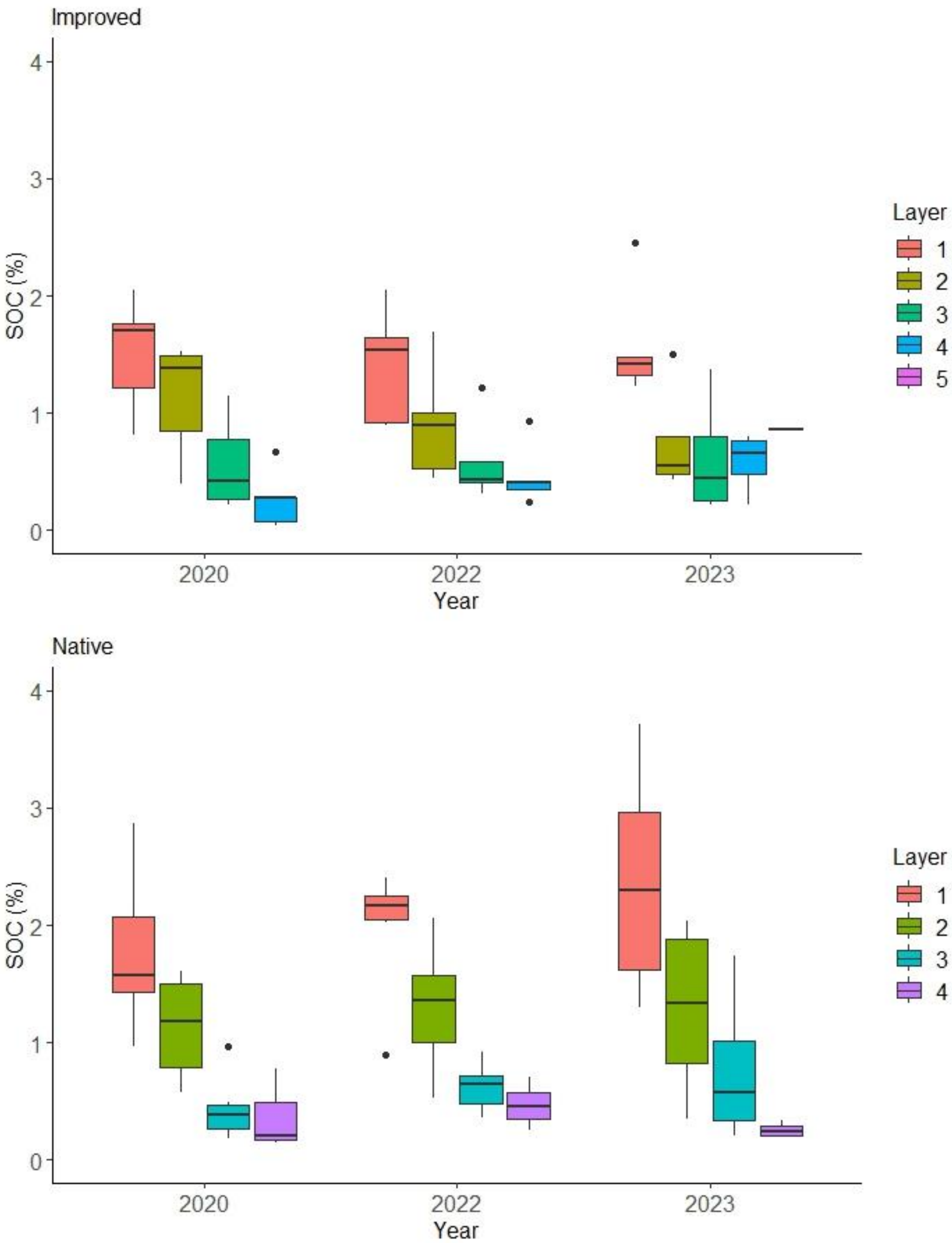


Figure 28: Soil organic carbon (%) at Leaderville (improved and native paddocks) in 2020, 2022, 2023, classified by soil depth (0-10cm = layer 1, 10-30cm = layer 2, 30-60cm = layer 3, 60-90cm = layer 4, 90-120cm = layer 5).



4.3.2.7 Myanbah

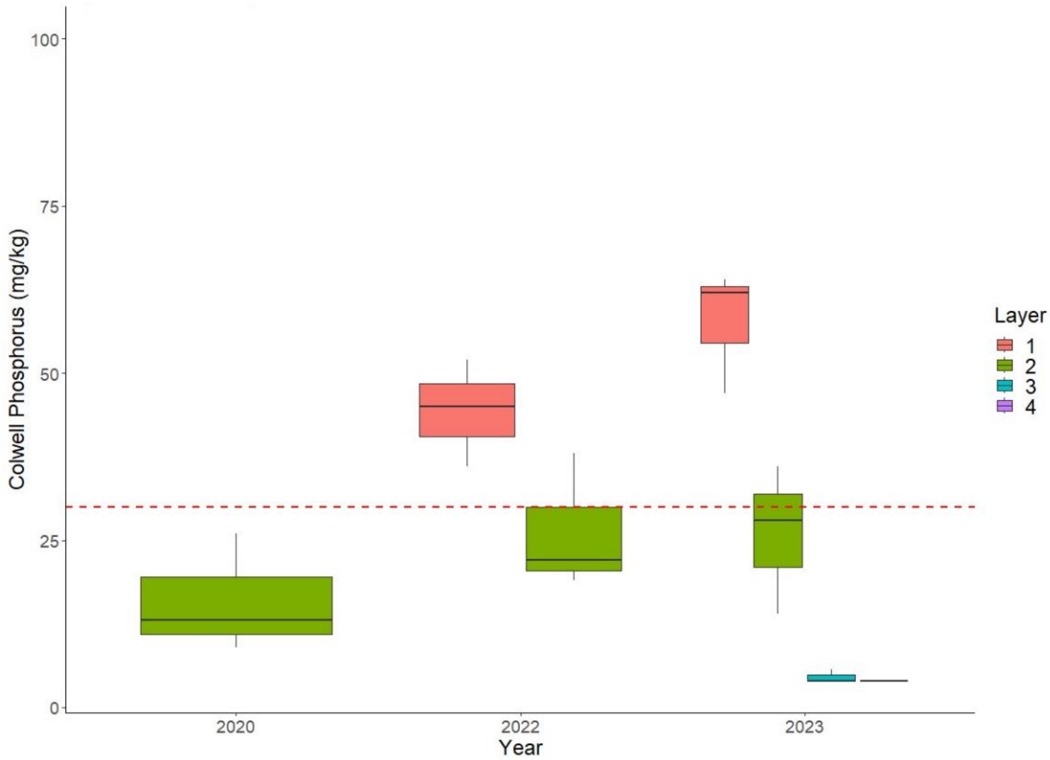
At Myanbah, the Airstrip paddock was an improved permanent pasture, whereas the Centre Oats paddock was planted with oats in 2022 and 2023, renovated into a permanent pasture (Phalaris, red & white clover, plantain), in 2024. Starter fertiliser was applied annually in the Centre Oats paddock.

Phosphorus levels increased in the Airstrip paddock in 2022 and 2023, compared to 2020 (Fig. 29, a). No changes occurred in pH levels, which stayed sub-optimal, due to the lack of lime application (Fig. 30, a). No major changes occurred in carbon levels in Airstrip, except for a slight decline in carbon levels in the top 10 cm in 2023 compared to 2022 (Fig. 31, a)).

Soil samples were not consistently extracted in the Centre Oats paddock, the only complete dataset for phosphorus, pH and SOC was taken in 2023 (Fig. 29, b, Fig. 30, b, and Fig. 31, b respectively).

Figure 29: Soil Colwell phosphorus (mg/kg) levels in 2020, 2022 and 2023 at the Airstrip (a) and Centre Oats (b) paddocks, classified by soil depth (0 – 10 cm = layer 1, 10 – 30 cm = layer 2, 30 – 60 cm = layer 3, 60 – 90 cm = layer 4). The red dotted line indicates the critical Phosphorus value of 30 mg/kg.

a)



b)

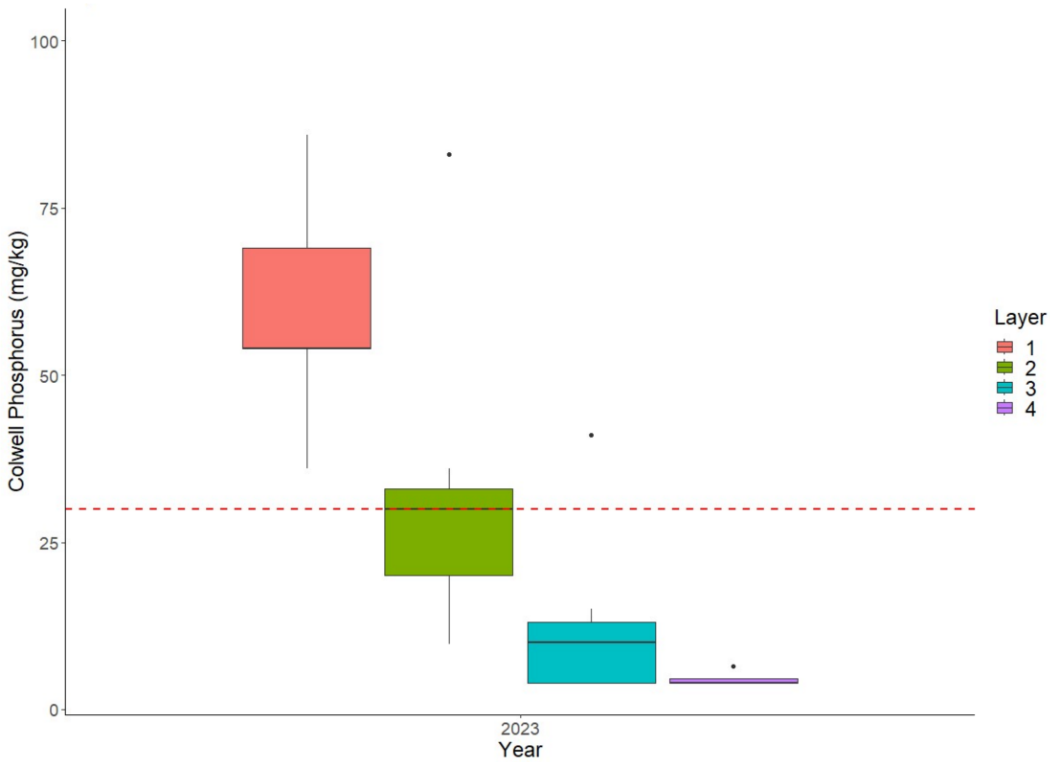
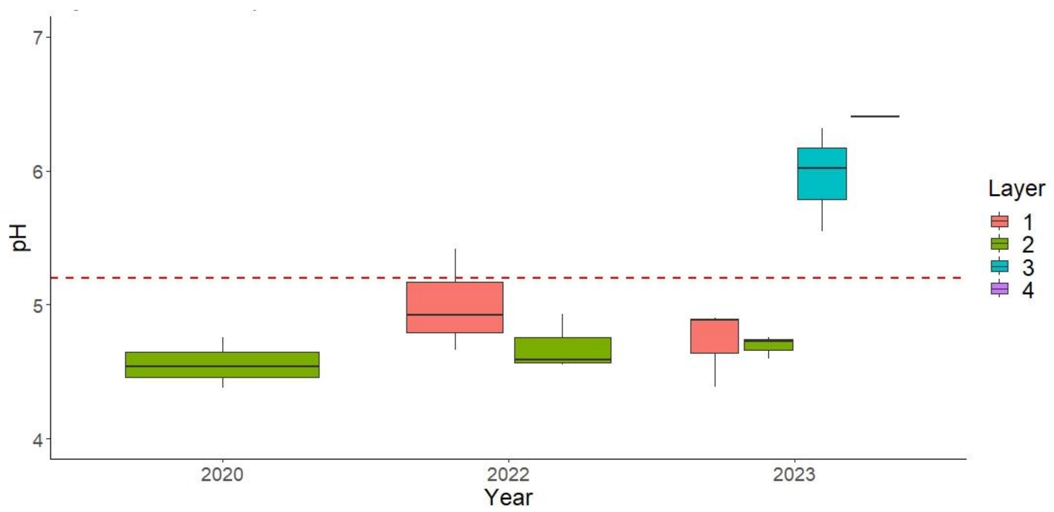


Figure 30: Soil pH in 2020, 2022 and 2023 in the Airstrip (a) and Centre Oats (b) paddock at Myanbah, classified by soil depth (0 – 10 cm = layer 1, 10 – 30 cm = layer 2, 30 – 60 cm = layer 3, 60 – 90 cm = layer 4). The red dotted line shows the critical pH value of 5.2.

a)



b)

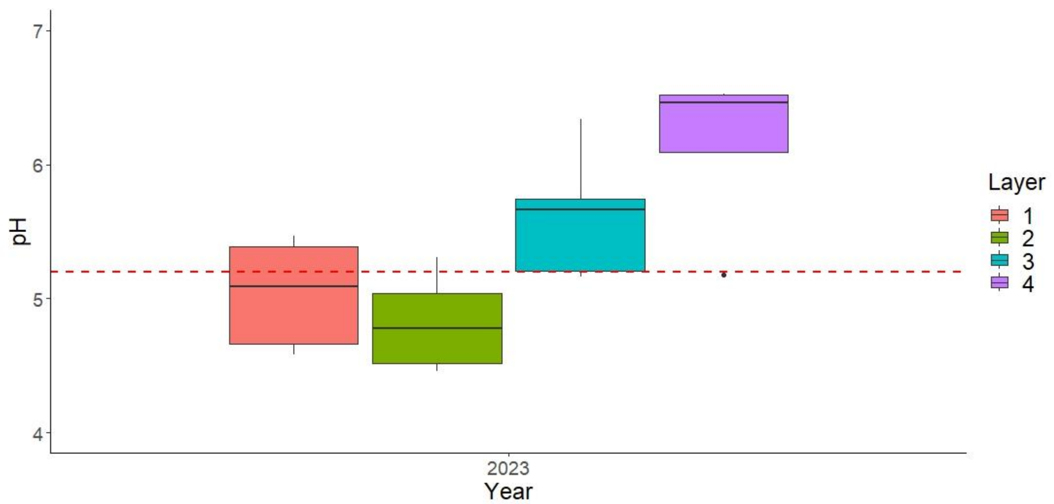
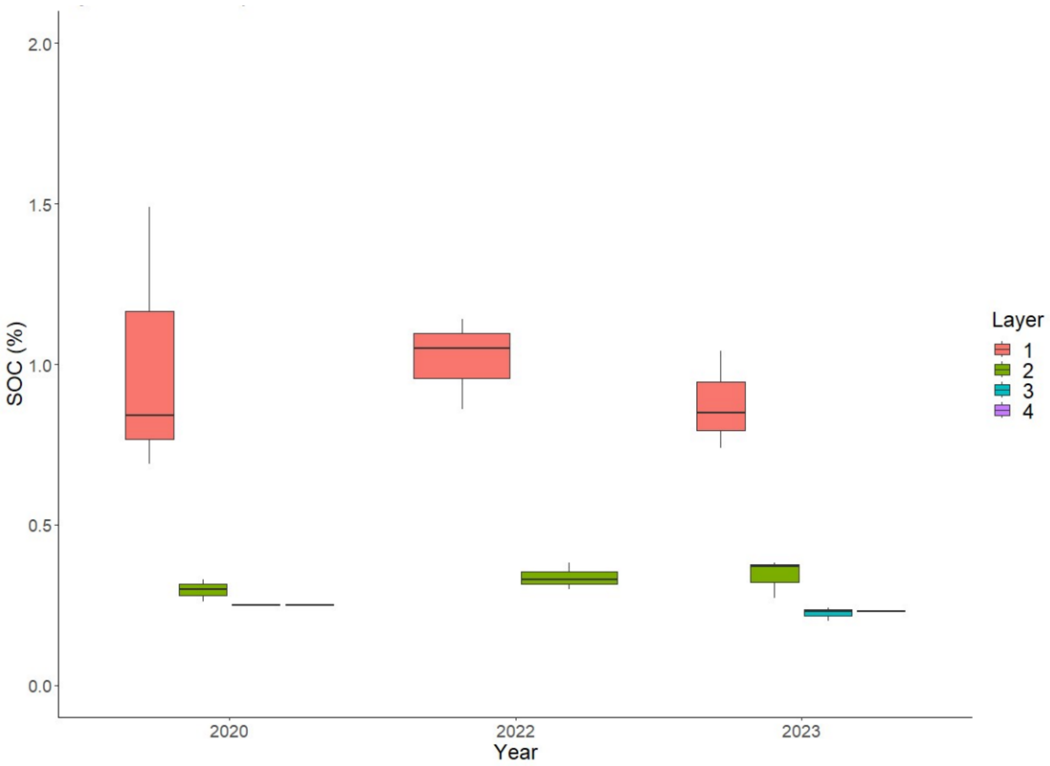
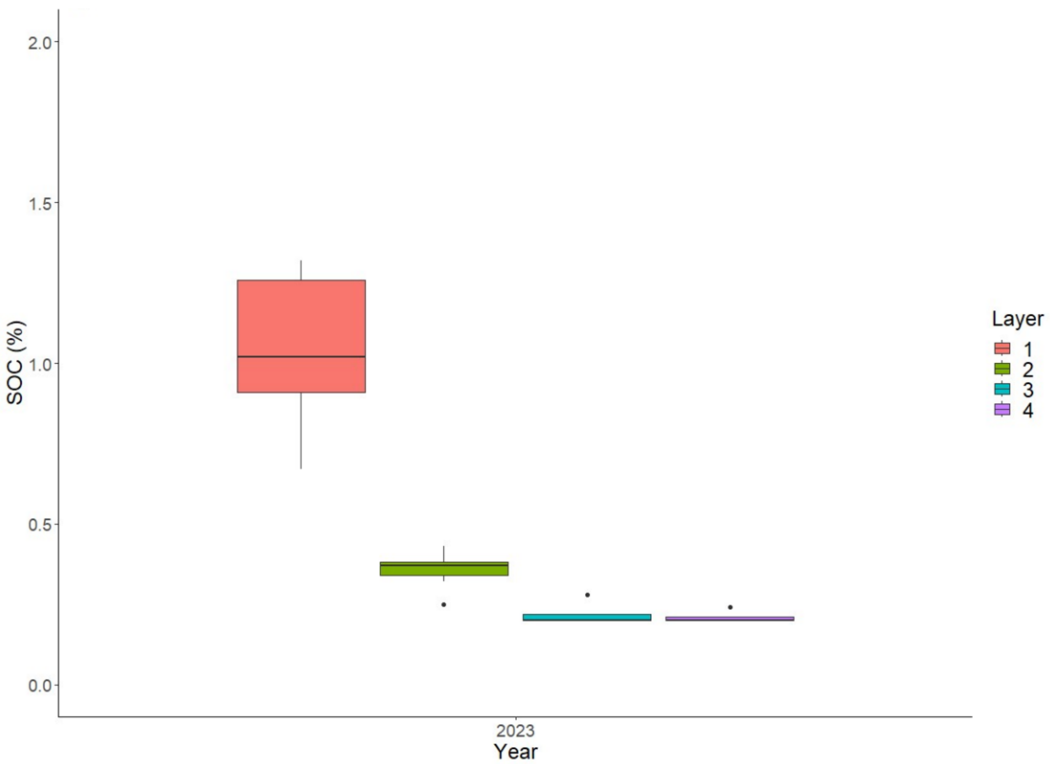


Figure 31: Soil organic carbon (%) in the Airstrip (a) and Centre oats (b) paddocks at Myanbah in 2020, 2022 and 2023, classified by soil depth (0 – 10 cm = layer 1, 10 – 30 cm = layer 2, 30 – 60 cm = layer 3, 60 – 90 cm = layer 4).

a)



b)



4.3.2.8 Te Dapa

In 2021 the Top 1 and Top 2 paddocks received X amount of phosphorus. No further phosphorus fertiliser or lime was applied at Te Dapa . These applications in Top 1 and Top 2 led to higher phosphorus (Fig. 32, d and e) and pH levels (Fig. 33, d and e) in the 0 – 10 cm and 10 – 30 cm soil layers in 2022, which declined in 2023.

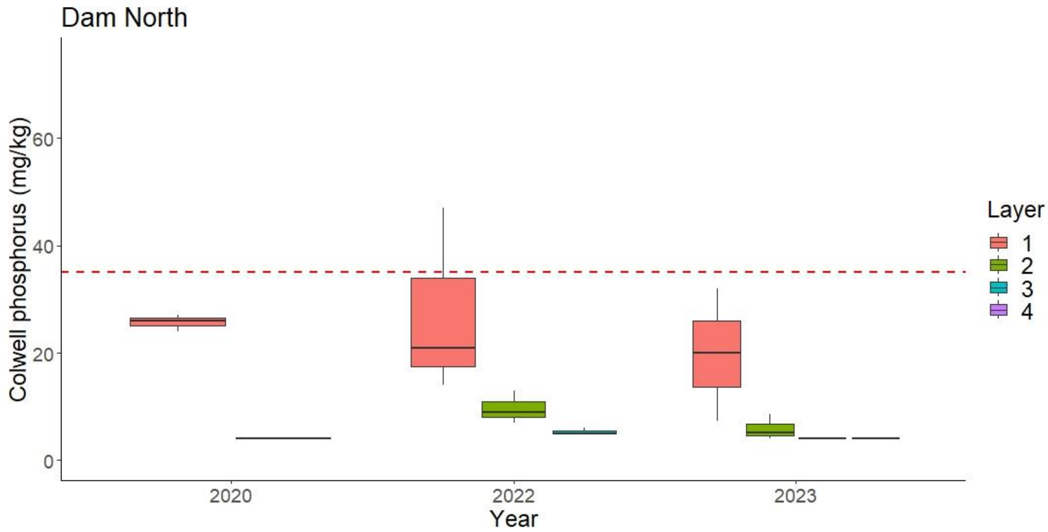
Except for Nancy's at 0 – 10 cm depth, the remaining paddocks were sub-optimal for phosphorus levels throughout the project, at all soil depths (Fig. 32). At Dwyers, 2 out of 6 soil samples were above optimal for soil phosphorus in the top 10 cm of soil in 2020, with only 1 sample above the threshold in 2024 (Fig. 32, a).

Except for the Top1 and Top2 paddock, most samples were sub-optimal in terms of pH, at a critical value of 5.0 (Fig. 33).

Dwyer's and Nancy's showed an overall decrease in SOC levels over time, at all depths (Fig. 34, b and c respectively). At Dam North, SOC slightly decreased in the top 10 cm in 2022, to increase in 2023. At the remaining depths SOC decreased (Fig. 34, a). In Top 1 and Top 2 no major changes in carbon occurred in the top 10 cm of soil between the years, a slight decline in carbon occurred in the 10 – 30 cm and 30 – 60 cm layers (Fig. 34, d and e respectively).

Figure 32: Soil Colwell phosphorus levels at the Dam North (a), Dwyers (b), Nancy's (c), Top 1 (d) and Top 2 (e) paddocks at Te Dapa, in 2020, 2022 and 2023. The dashed horizontal red line shows the critical Colwell phosphorus value of 35 mg/kg. Soil depths of 0 – 10 cm (layer 1), 10 – 30 cm (layer 2), 30 – 60 cm (layer 3) and 60 – 90 cm (layer 4) evaluated.

a)



b)

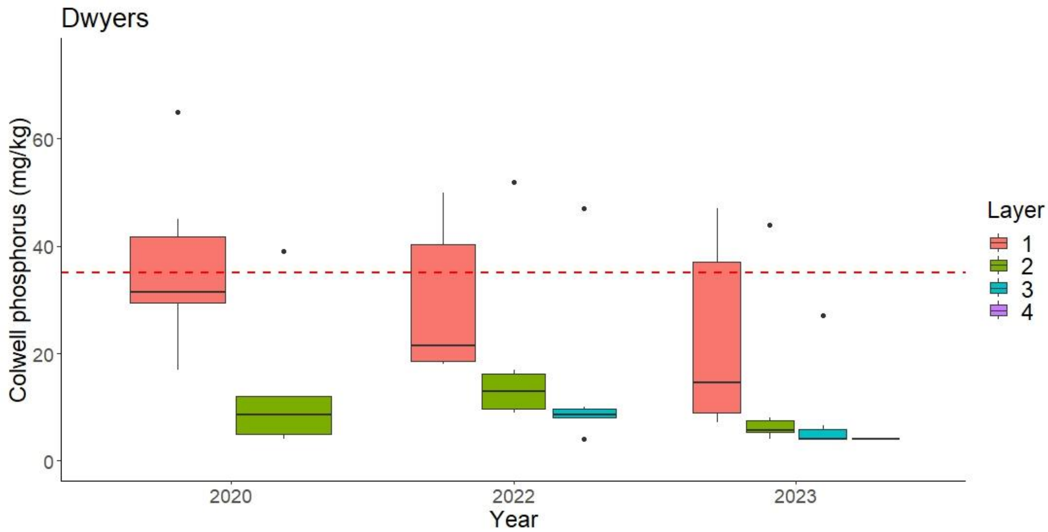
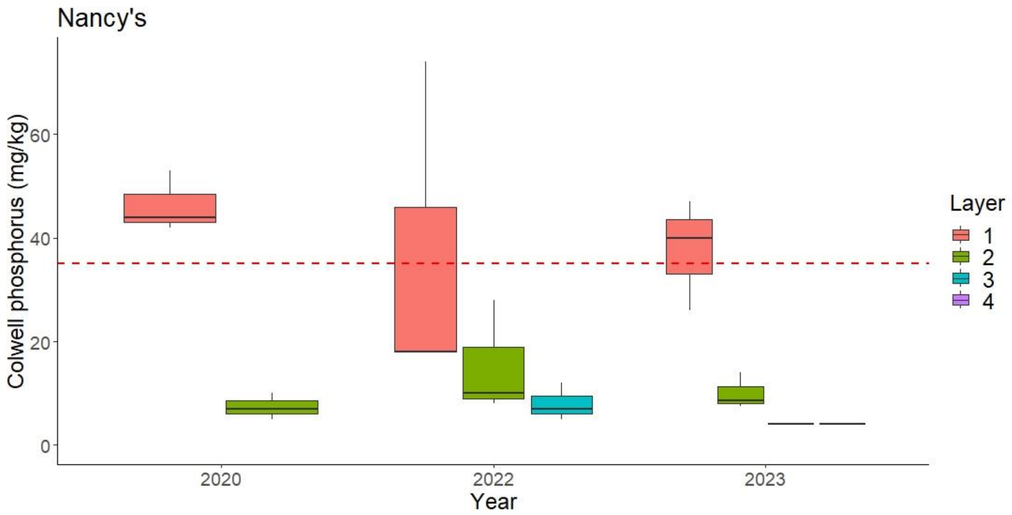
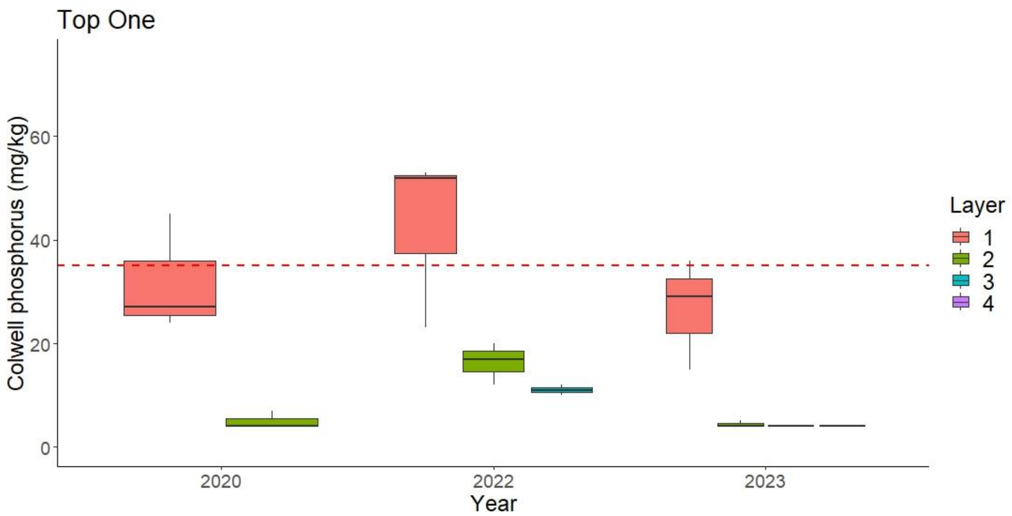


Figure 32, continued.

c)



d)



e)

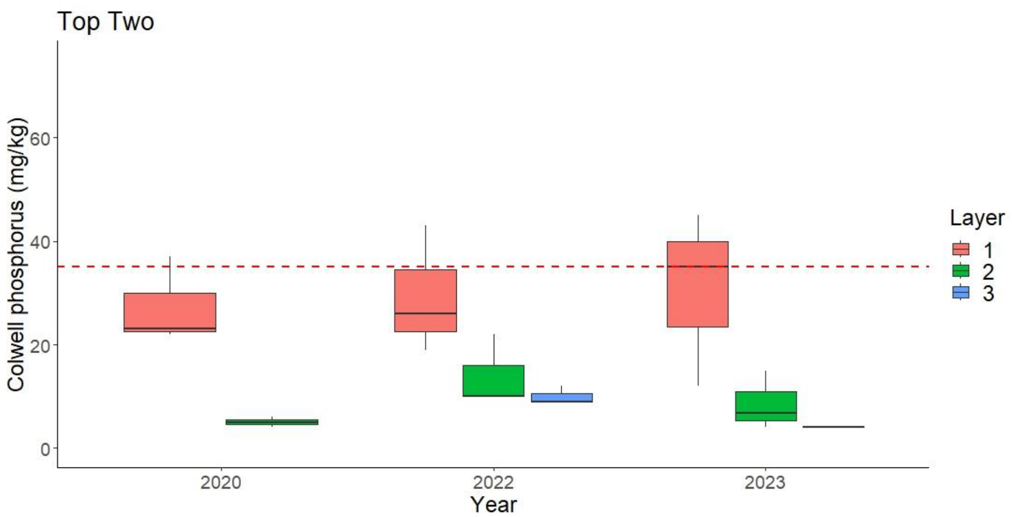
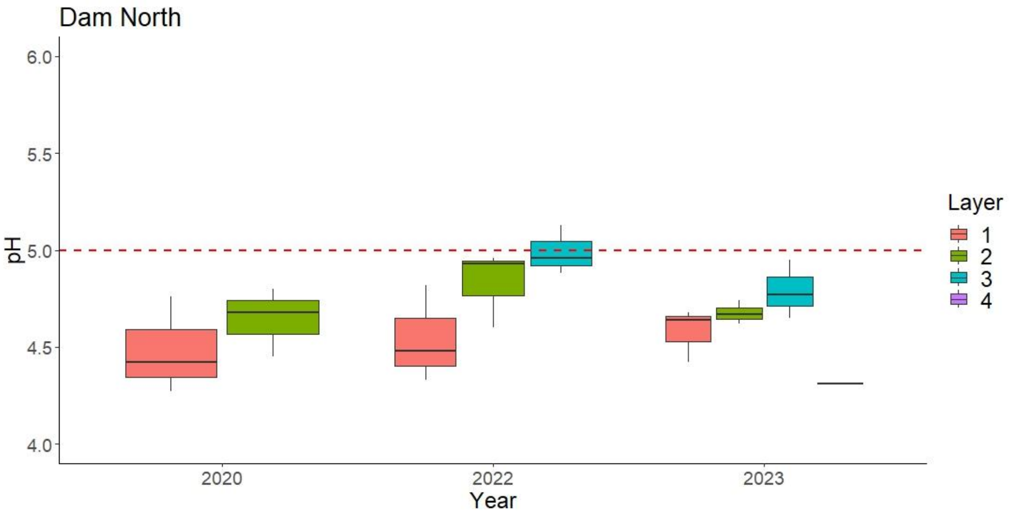


Figure 33: Soil pH at Te Dapa, 2020 – 2023, in the Dam North (a), Dwyers (b), Nancy's (c), Top 1 (d) and Top 2 (e) paddocks. The dotted red line shows the critical pH values of 5.0 units. Soil depths of 0 – 10 cm (layer 1), 10 – 30 cm (layer 2), 30 – 60 cm (layer 3) and 60 – 90 cm (layer 4).

a)



b)

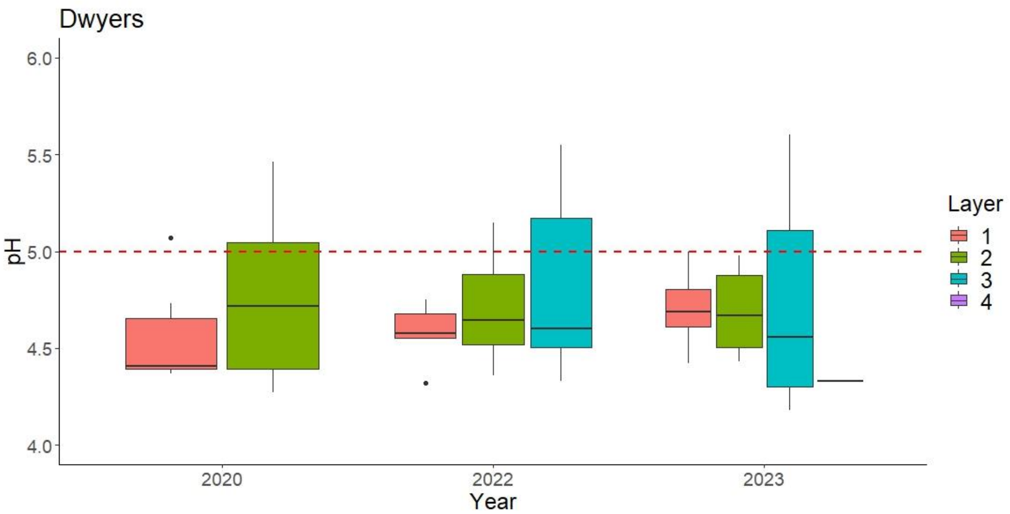
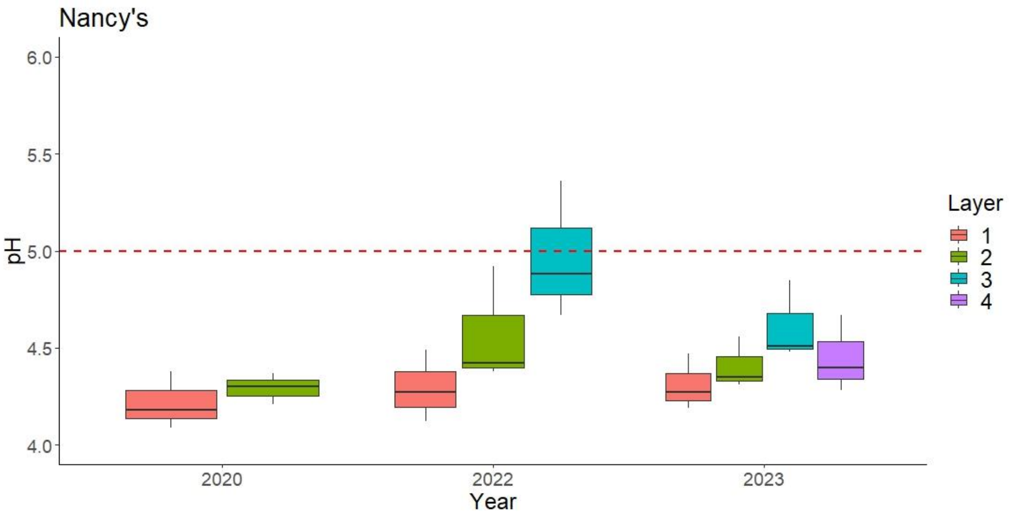
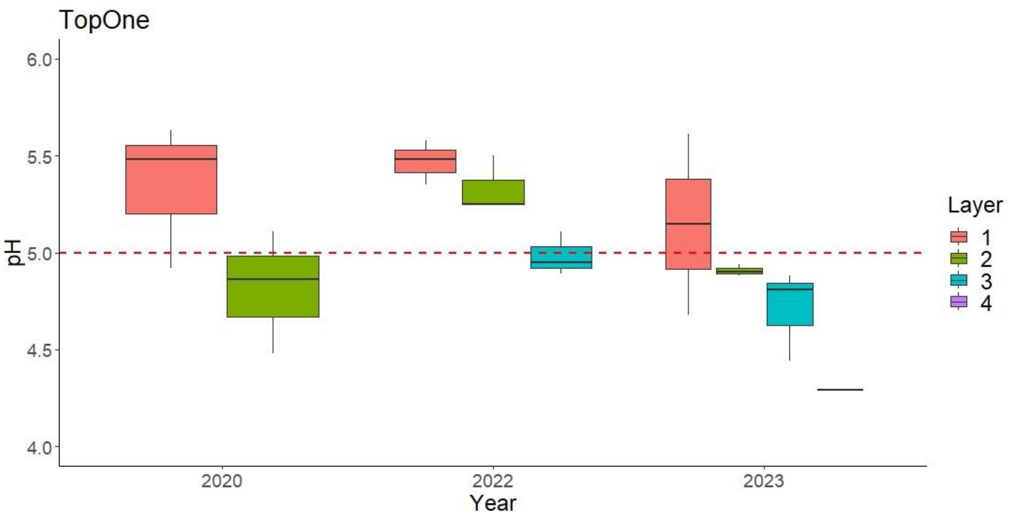


Figure 33, continued.

c)



d)



e)

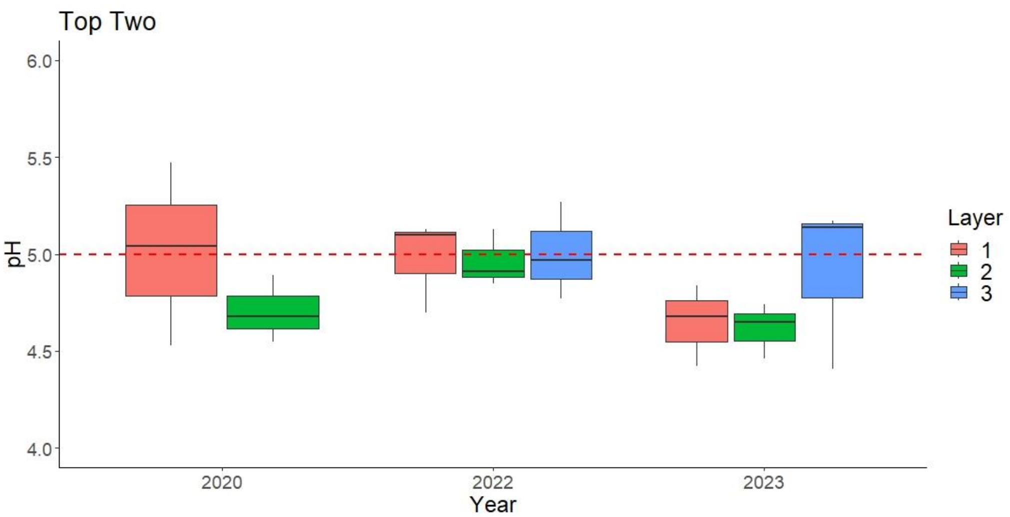
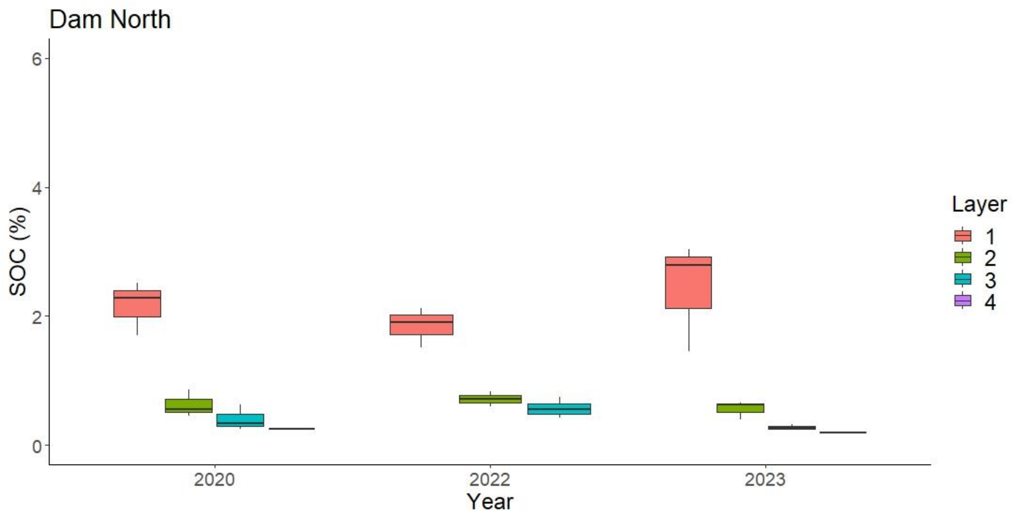


Figure 34: Soil organic carbon levels (%) at Te Dapa, in the Dam North (a), Dwyers (b), Nancy's (c), Top 1 (d) and Top 2 (e) paddocks, 2020, 2022 and 2023, at a soil depth of 0 – 10 cm (layer 1), 10 – 30 cm (layer 2), 30 – 60 cm (layer 3) and 60 – 90 cm (layer 4).

a)



b)

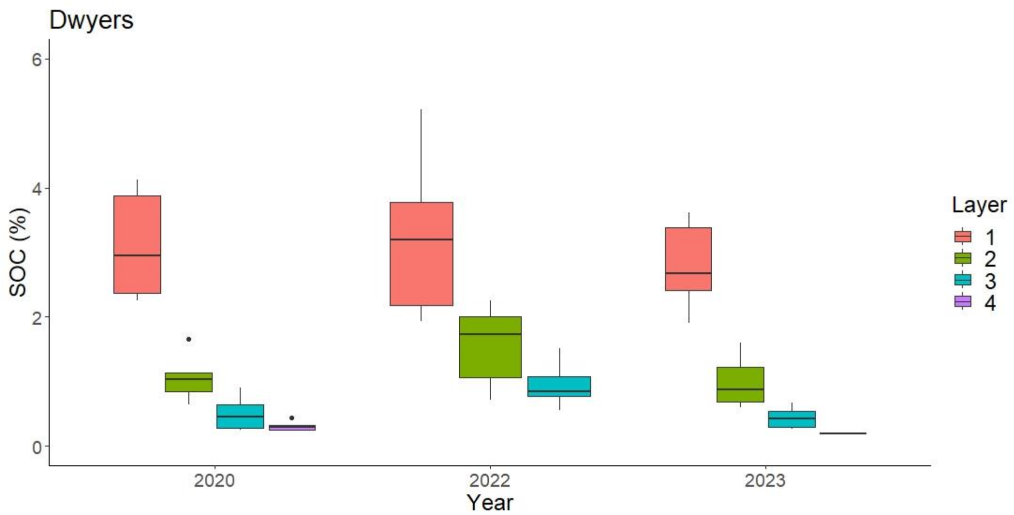
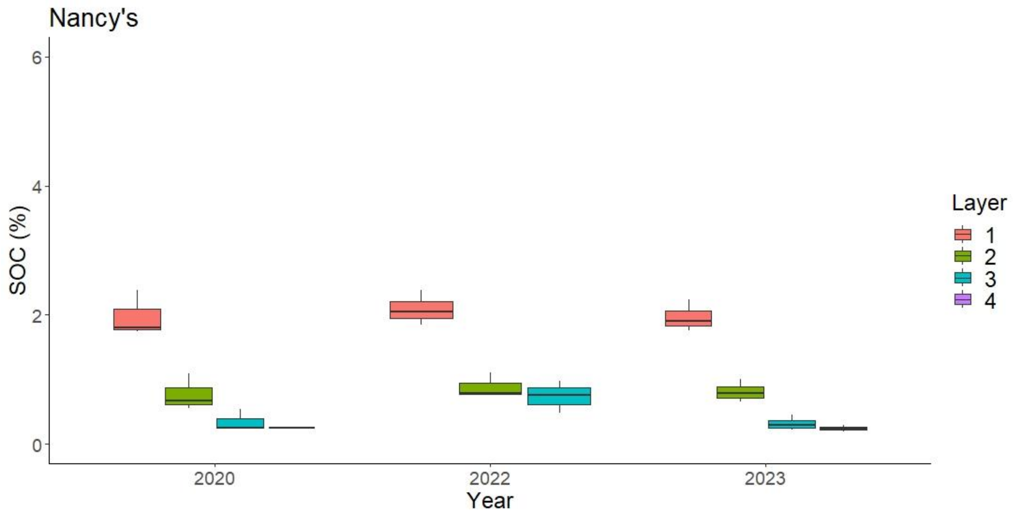
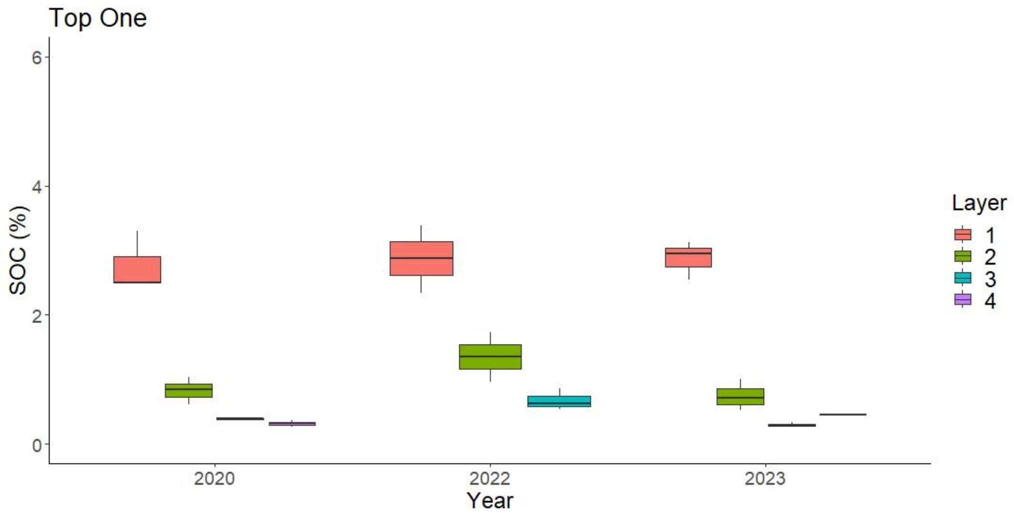


Figure 34, continued.

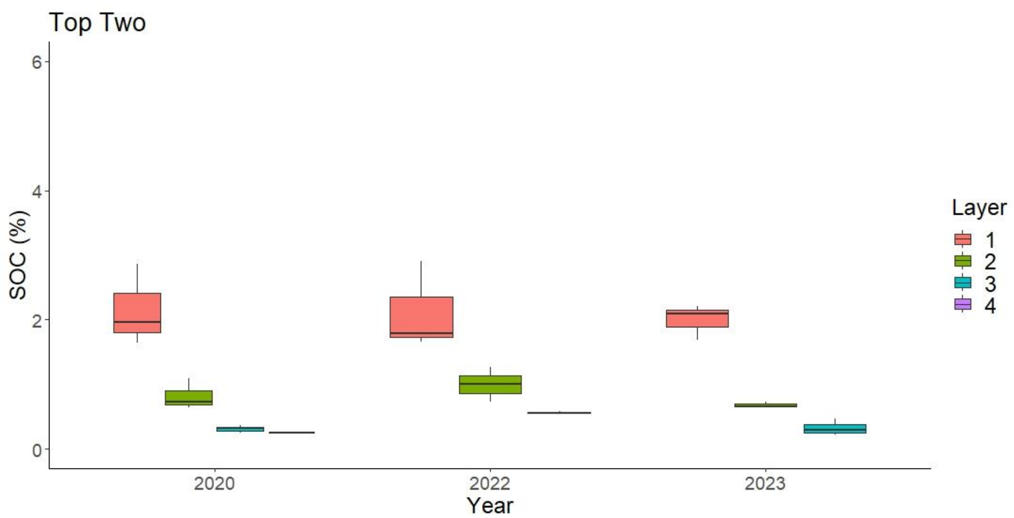
c)



d)



e)



4.3.2.9 Tenterden

Tenterden is one of the few properties where both phosphorus (Fig. 35) and pH levels (Fig. 36) were near to or above critical level at 0 – 10 cm and 10 – 30 cm for the entire duration of the project. The exception is in the Schoolhouse paddock, at 0 – 10 cm depth in 2022 and at 10 – 30 cm depth in 2022 and 2023. At depth, phosphorus levels declined over time, except for the increase in colwell phosphorus levels found in Schoolouse in 2023.

At 0 -10 cm, pH levels were slightly sub-optimal at most sites tested in 2022. The pH levels increased with soil depth (Fig. 36)

In the top 10 cm, carbon levels decreased slightly in 2022 but increased, on average, in 2023 (Fig. 37). At 10 – 30 cm, carbon levels increased over the years, whereas at 30 – 60 cm depth, they increased in 2022 to decrease in 2023 (Fig. 37).

Figure 35: Soil Colwell phosphorus results (mg/kg) at Tenterden (Church Quarry and Schoolhouse paddocks) in 2020, 2022 and 2023. The layers represent the different soil depths evaluated: layer 1 = 0 – 10 cm, layer 2 = 10 – 30 cm, layer 3 = 30 – 60 cm, layer 4 = 60 – 90 cm. The red dotted line shows the phosphorus critical level of 40 mg/kg.

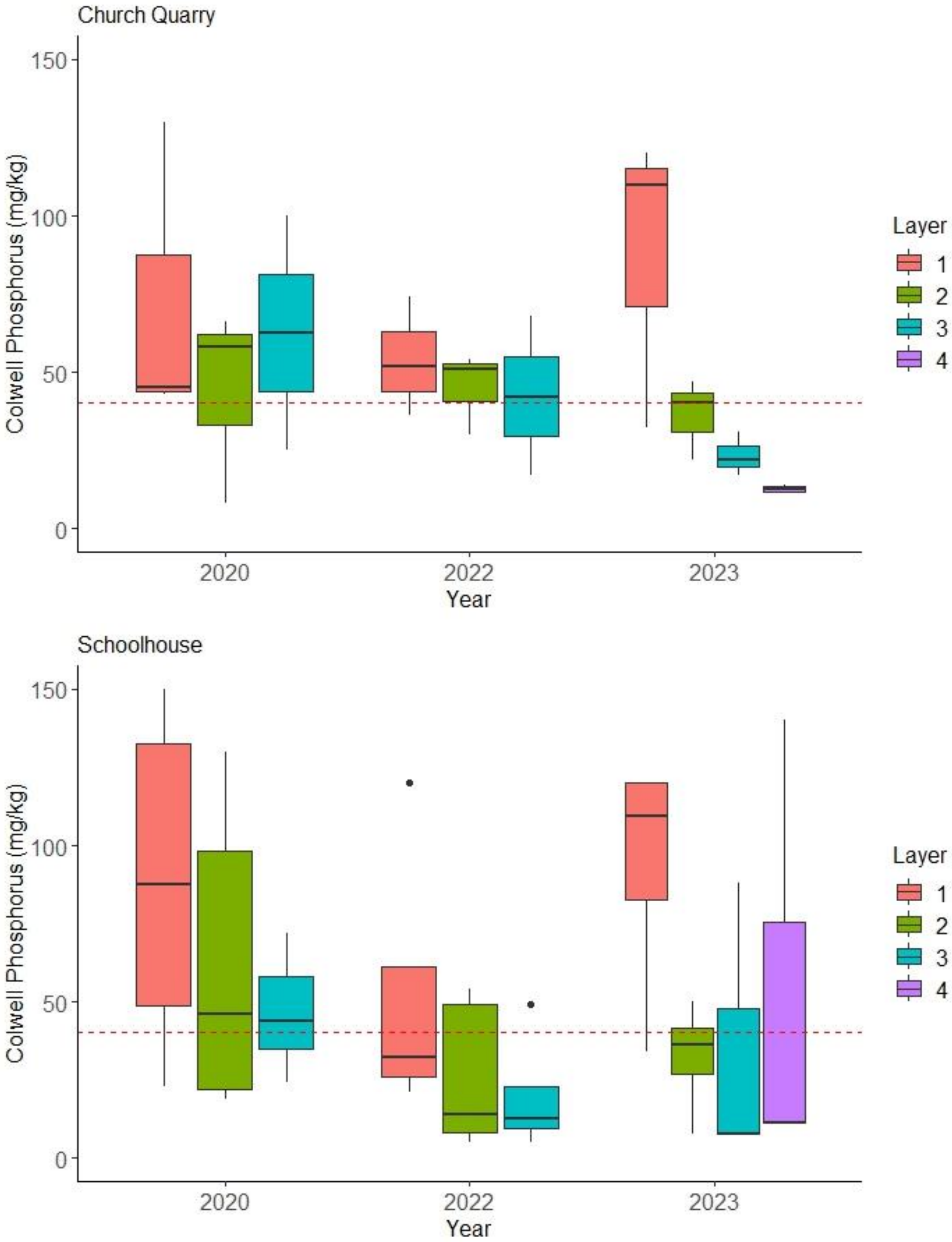
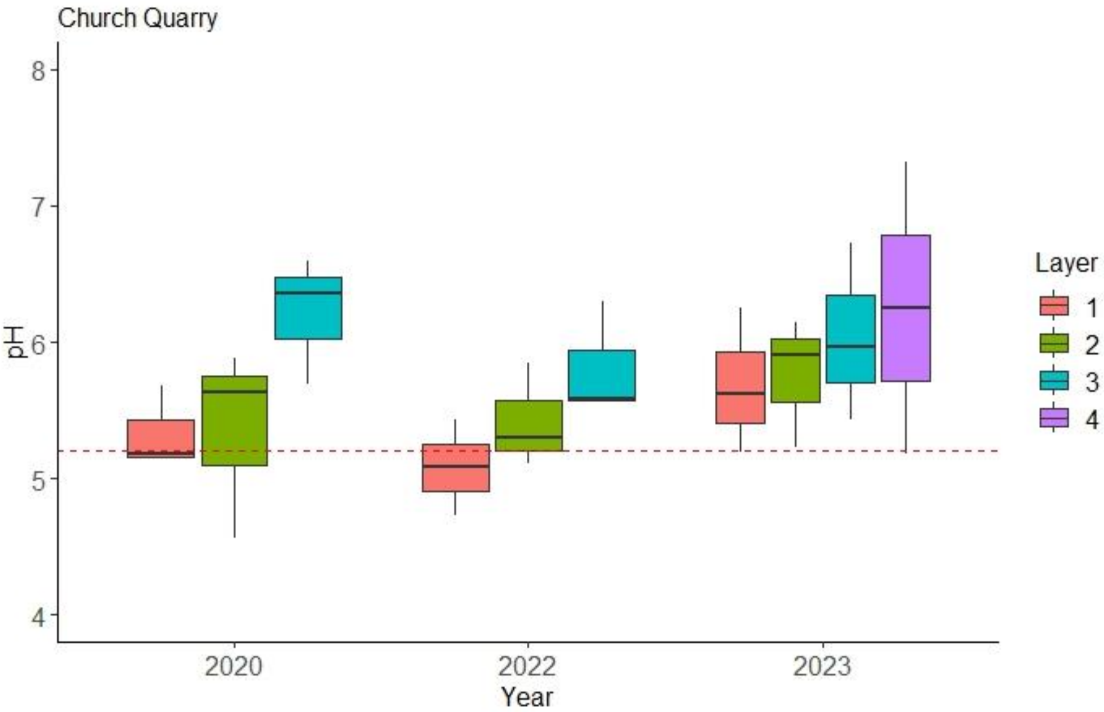


Figure 36: Soil pH results on Tenterden in 2020, 2022 and 2023. The layers represent the different soil depths evaluated: Layer 1 = 0 – 10 cm, layer 2 = 10 – 30 cm, layer 3 = 30 – 60 cm, layer 4 = 60 – 90 cm. The red dotted line shows the critical pH value of 5.2.



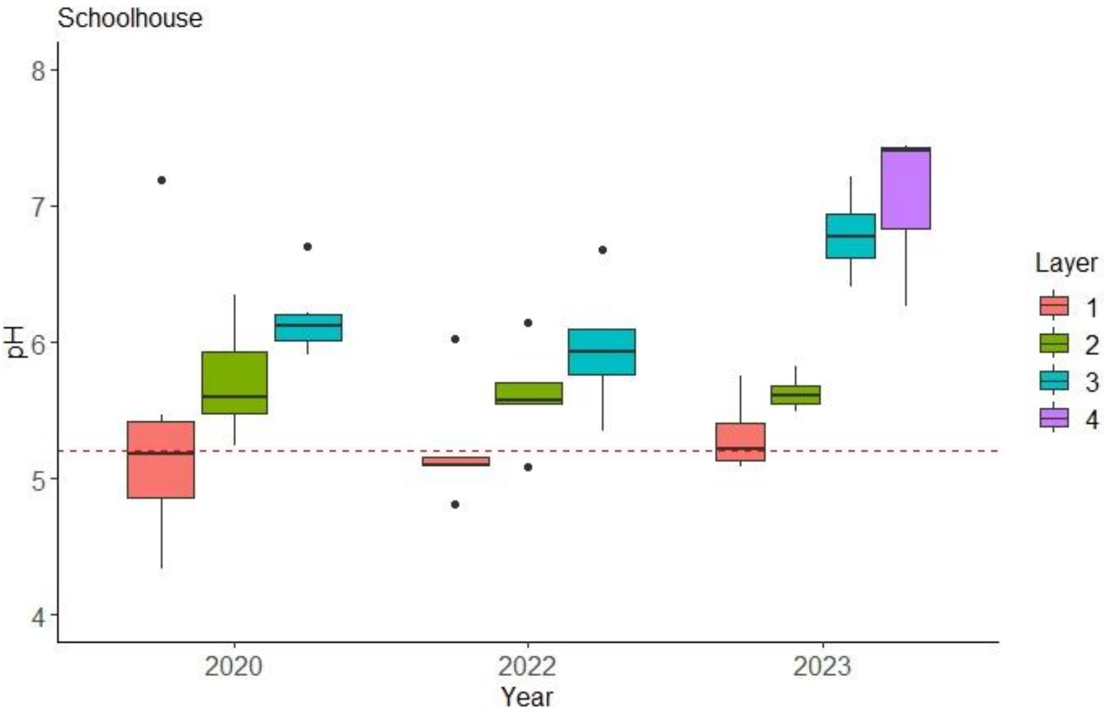
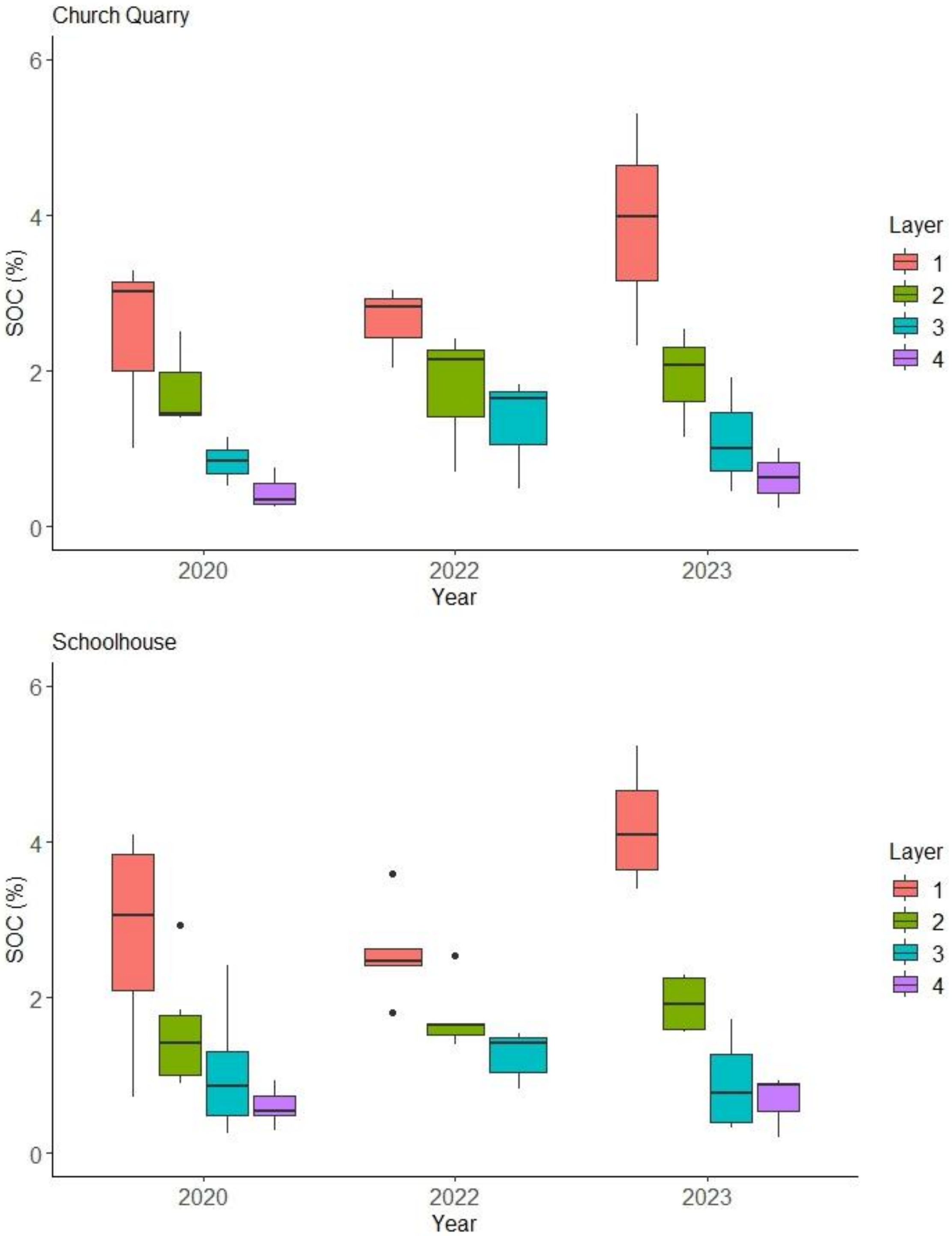


Figure 37: Soil organic carbon (%) results on Tenterden in 2020, 2022 and 2023. The layers represent the different soil depths evaluated: Layer 1 = 0 – 10 cm, layer 2 = 10 – 30 cm, layer 3 = 30 – 60 cm, layer 4 = 60 – 90 cm.



4.3.2.10 Urandangie

Soil phosphorus levels were above the critical level in the top 10 cm at Black Hill. Average soil phosphorus levels were slightly below optimal in Red Hill in 2022. In all remaining soil layers and in both paddocks, average soil phosphorus levels were close to optimal (Fig. 38).

In the top 10 cm of soil, on average, pH levels were above critical value in Black Hill in 2020 and decreased to become slightly below critical value in 2022 and 2023. In Red Hill. The opposite occurred, with the average soil phosphorus value increasing from being slightly below critical in 2022 to above critical value in 2022 and 2023 (Fig. 39). In all cases the average pH values were above a level of pH = 5, a critical value adopted for some of the remaining properties with very low soil pH value.

At 0 – 10 cm the average carbon levels increased from 2020 to 2022 in Black Hill, to come back down in 2023. In Red Hill, average soil carbon levels increased in 2022 and 2023, at the same soil depth (Fig. 40). In both paddocks, at 10 – 30 cm soil depth, average soil carbon levels increased in 2022 to decrease in 2023. At Black Hill, 2023 soil carbon levels at this depth were below the levels recorded in 2020 (Fig. 40)

Figure 38: Soil Colwell phosphorus levels (mg/kg) at Urandangie, in 2020, 2022 and 2023. The layers represent the different soil depths evaluated: layer 1= 0 – 10 cm depth, layer 2 = 10 – 30 cm depth, layer 3 = 30 – 60 cm depth, layer 4 = 60 – 90 cm depth and layer 5 = 90 – 120 cm depth. The red line shows the phosphorus critical values of 40 mg/kg phosphorus.

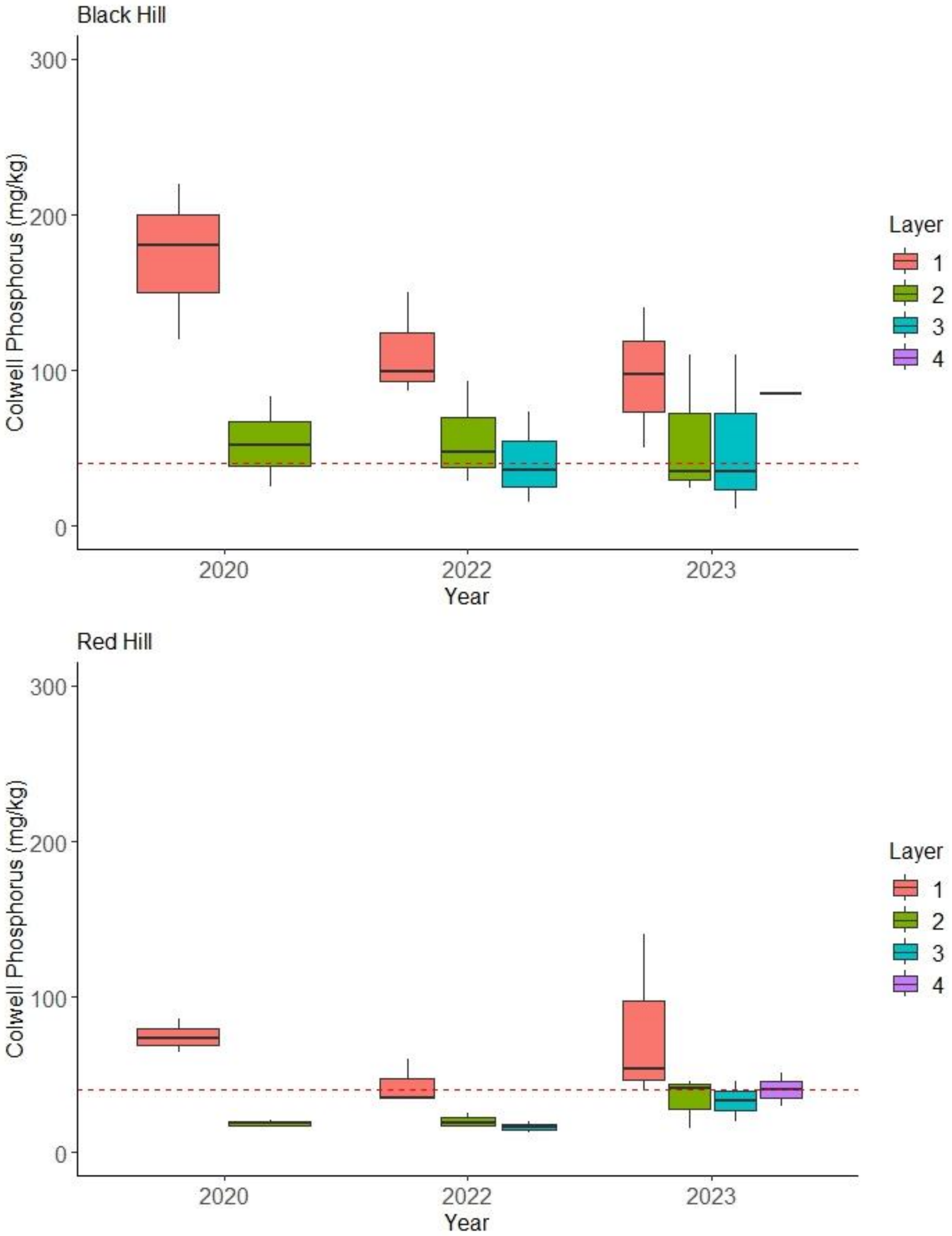
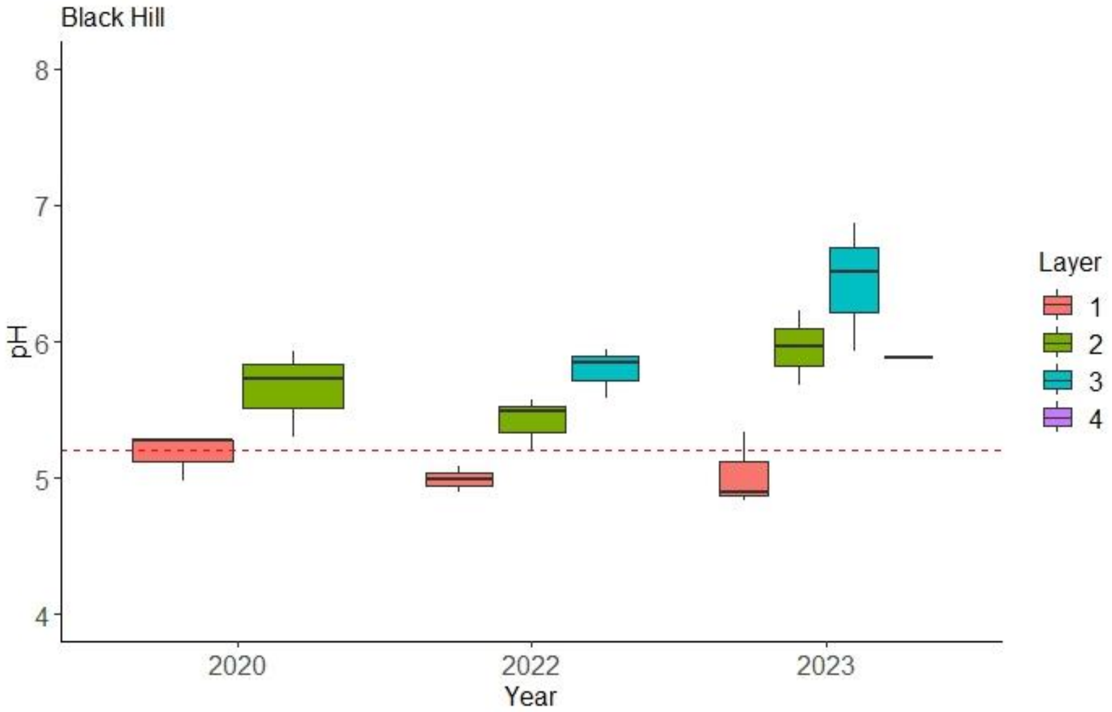


Figure 39: Soil pH at Urandangie, in 2020, 2022 and 2023. The layers represent the different soil depths evaluated: layer 1= 0 – 10 cm depth, layer 2 = 10 – 30 cm depth, layer 3 = 30 – 60 cm depth, layer 4 = 60 – 90 cm depth and layer 5 = 90 – 120 cm depth. The red line shows the pH critical values of 5.2 units.



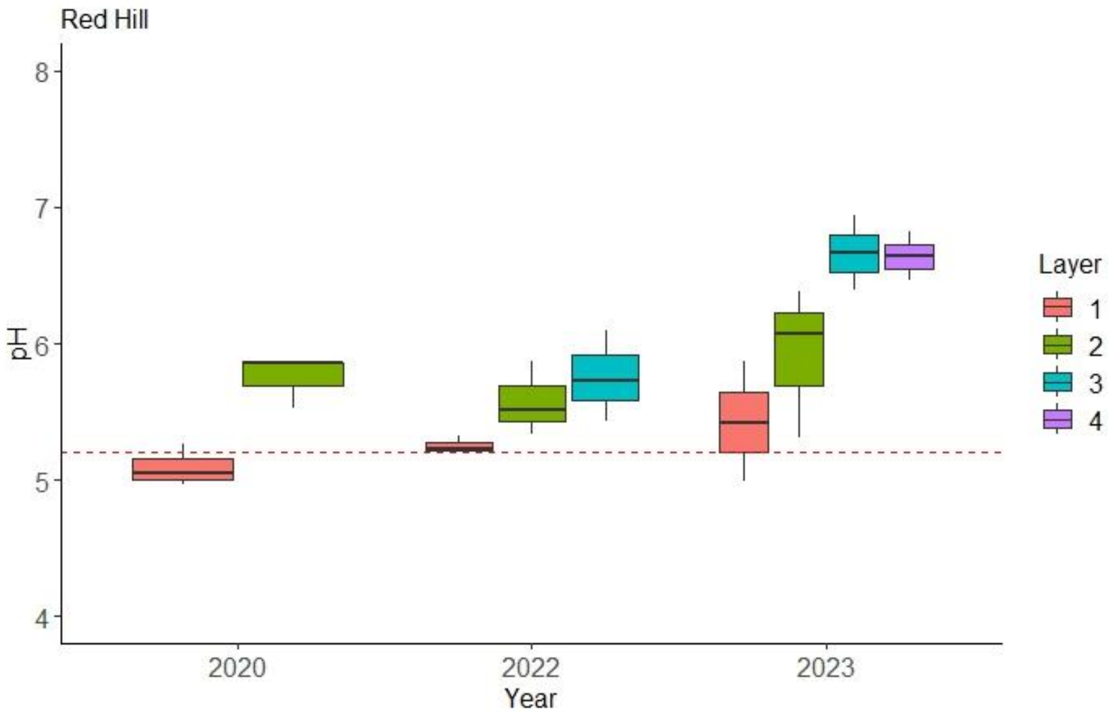
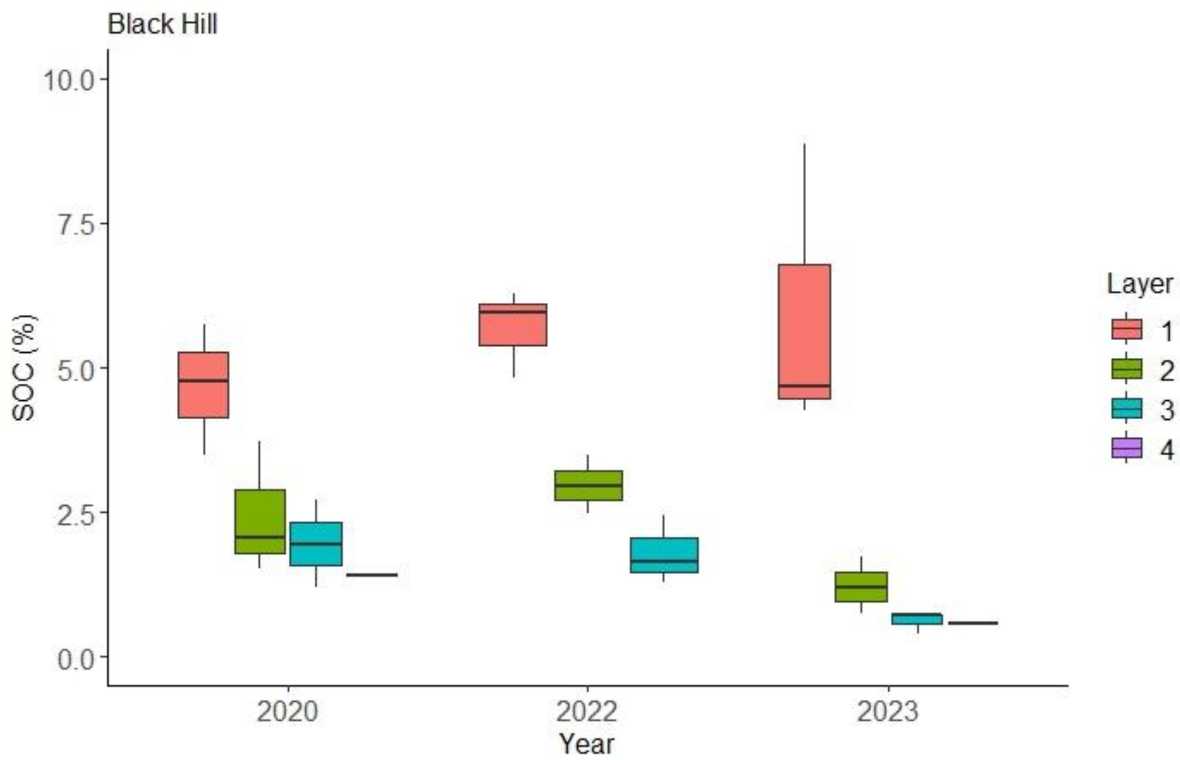
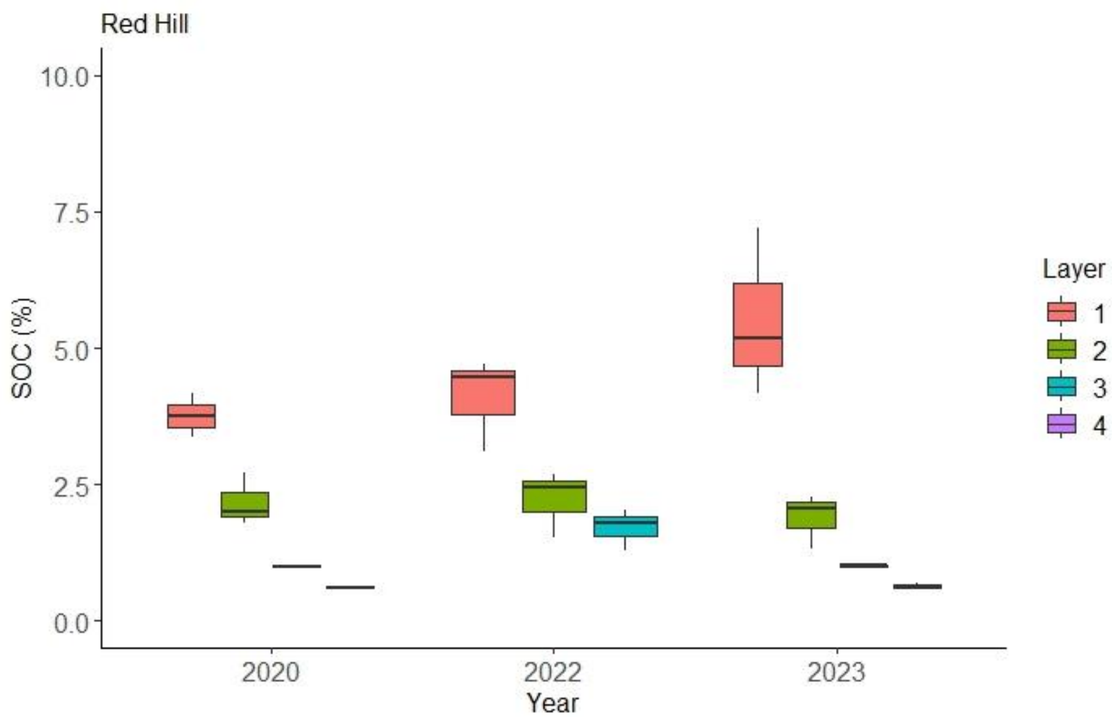


Figure 40: Soil organic carbon levels (%) at Urandangie, 2020, 2022 and 2023. The layers represent the different soil depths: layer 1= 0 – 10 cm depth, layer 2 = 10 – 30 cm depth, layer 3 = 30 – 60 cm depth, layer 4 = 60 – 90 cm depth and layer 5 = 90 – 120 cm depth.





4.3.3 Summary of soil test results

Ranges in SOC values across the properties were the greatest in the topsoil layer (0 – 10 cm) compared to the deeper soil layers (Table 7, example for Achill). This followed expectations as the organic matter input sources are located near the soil surface, and root density decreases with soil depth (Chan et al. 2010).

Table 6: Minimum, maximum, and range of soil organic carbon (SOC, %) values found at Achill, in 2020, 2022, and 2023.

Soil Depth (cm)	2020			2022			2023		
	Min	Max	Range	Min	Max	Range	Min	Max	Range
0 – 10	1.92	5.96	4.04	3.23	7.04	3.81	2.01	9.49	7.48
10 – 30	0.58	1.64	1.06	1	3.59	2.59	0.40	4.25	3.85
30 – 60	0.29	0.6	0.31	0.59	2.1	1.51	0.20	0.49	0.29
60 - 90	0.25	0.4	0.15				0.31	0.34	0.03

On a paddock average, the biggest increase in SOC between 2020 and 2023 was found at 1.38% at Schoolhouse, followed by 1.19% at Sawpit,1.17% at Cruickshanks and 1.13% at Urandangie, all at 0 – 10 cm soil depth. On a paddock average, the biggest decrease in SOC levels between 2020 and 2023 was found at Urandangie (0.79% decrease in SOC at 30 – 60 cm depth). The following biggest decreases were found at 0 – 10 cm depth (0.59% at Creek Cultivation, 0.50% at Pivot-Airstrip, and 0.31% at Dwyers). This means that the found variation in SOC levels over time were greatest in the top soil layer (0 – 10 cm), which can be explained by the following reasons. Firstly, SOC levels decrease with depth, meaning variation will naturally be smaller. Secondly, microbial density and activity are lower and more highly variable, reducing decomposition. Lastly, a greater fraction of the organic matter is in the microbial-associated organic matter fraction, also reducing the rate of decomposition (see Dynarski et al. 2020 for a review on the stability of SOC. The exception was the 0.79% decrease in SOC levels found at Urandangie at a depth of 30 – 60 cm (between 2020 and 2023), which was the highest decrease in SOC levels found throughout the trial. This was especially surprising since at this soil layer SOC levels went up on average 0.28% between 2020 to 2023, to then decrease by 1.07% between 2020 and 2023. We currently have no explanation for these results, since this was not due to the decrease in carbon at a limited number of sample sites, all individual sites declined in their carbon content (SOC range of 0.98 – 2.4% in 2020, 1.27% - 2.34% in 2022 and 0.4% - 1.02% in 2023).

No consistent changes in SOC were found related to increases or decreases in pH or soil phosphorus levels. This is related to:

- The climatic conditions during the project period; the 2018 – 2019 drought followed by three years of above average rainfall in 2020 – 2023, which would have had a considerable influence on plant production and thus the rate of SOC sequestration (Derner and Schuman, 2007). Climate impacts (temperature and rainfall) could explain why the similar trend of an average increase of SOC at 0 – 10 cm depth, with decreasing SOC at remaining soil depths occurred at 6/10 properties between 2022 and 2023.
- The lack of the ‘high input’ (treatment) and ‘low input’ (control) paddocks, which were meant to be set-up by the participants, made it impossible to determine carbon sequestration due to the high input treatment.

- The lack of set-up of these treatment and control paddocks also meant that there was no additional new activity implemented which was expected to significantly alter the SOC levels. The SOC levels are dependent on the organic matter input and output from the soil. Without an additional new activity leading to an increase in organic matter input, or a decrease in carbon respiration by soil microbiota, SOC levels are not expected to significantly change. When carbon projects are registered with the Australian government's ACCU Scheme, there is a need to implement either a new or activity, or a materially different activity, which is expected to lead to increased SOC levels (https://cer.gov.au/schemes/australian-carbon-credit-unit-scheme/accu-scheme-methods/estimating-soil-organic-carbon-sequestration-using-measurement-and-models-method).
- The use of different laboratory methods to determine carbon levels might have 'hidden' SOC changes, as the recovery of the amount of organic carbon in the samples could have been different over the years (see method section 3.2.1 for the explanation of the methods used for measuring SOC).
- The limited duration of the project and low sampling density of the project might have limited the ability to identify SOC changes. According to Paustian et al. (2019), when using a moderate sampling density, it takes at least 5 years to detect statistically significant cumulative SOC stock change of an annual SOC increase of 1%. Average carbon changes found under this project were usually below 1%. Accordingly, a more detailed sampling protocol was required to determine small changes in SOC levels and to be able to link these to property management. McDonald et al., 2023, explain 'a lack of statistical power of sampling designs have also been identified as potential sources contributing to the [soil organic carbon] variance in research studies'. Variation in carbon levels within a visually uniform field might be 20% (Robertson et al. 1997). Conant et al., 2002, also highlight 'small changes in soil C at a very fine scale, such as an individual farm or conglomeration of a few farms, can be detected with careful sampling'. The selection of 9 - 14 sampling sites on each property, for this demonstration project, was not sufficient to significantly detect SOC changes.

4.3.4 Soil organic carbon throughout the growing season

In June 2023 and June 2024, a total of four soil samples were extracted on each property and these samples were evaluated for SOC levels at 0 – 10 cm depth and 10 – 30 cm depth. These results were compared to the SOC levels found at these same sites in September-October 2022 and September-October 2023. The 2020 baseline SOC sampling was conducted in September 2020 only, no data was available for June 2020. (Appendix 8.3 for the full dataset).

When averaging SOC levels across all project properties, at 0 – 10 cm soil depth, carbon levels are higher at the start of spring, in September-October both years, compared to SOC levels at the start of winter (June)(Table 8). At 10 – 30 cm soil depth, highest carbon levels (when averaging for all properties) were identified in June 2024, followed by October 2022 and June 2023. Lowest carbon levels were identified in October 2023 (Table 8).

Table 7: Soil organic carbon (SOC) levels averaged for all properties, at 0 – 10 cm and 10 – 30 cm soil depth, at four dates. Four sample sites were monitored on each property (Appendix 8.3 for the full dataset).

Year	Month	SOC (%) 0 - 10 cm	SOC (%) 10 - 30 cm
2020	September - October	2.70	1.09
2022	September - October	2.71	1.45
2023	June	2.05	1.34
2023	September - October	2.90	1.06
2024	June	2.36	1.56

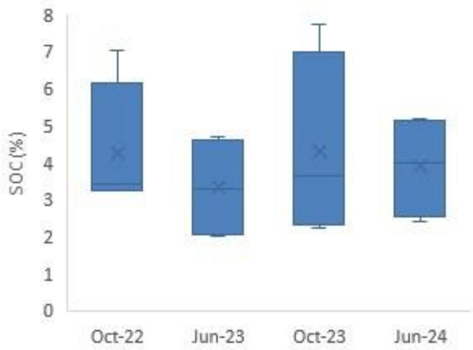
SOC levels fluctuate throughout the growing seasons, on each property. At 7/10 properties, SOC levels at 0 – 10 cm soil depth were on average higher early spring compared to winter (Fig. 36). The exceptions were:

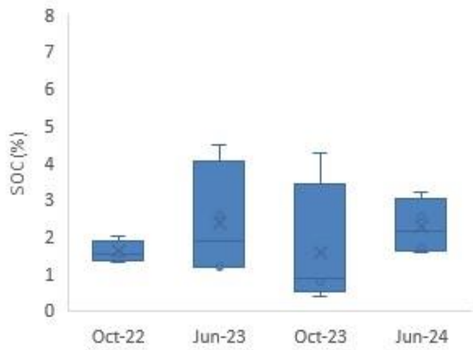
- Bald Blair, where average SOC levels did not show much change over the project period (SOC of 3.63%, 3.64%, 3.74% and 3.71% in September 2023, June 2023, October 2023 and June 2024, at 0 – 10 cm depth, respectively), however, the range in SOC levels found was greatest in June, compared to October.
- Myanbah, where the average SOC was slightly higher in June 2024 compared to October 2023 (average of 1.14% compared to 1.03% SOC).
- Tenterden, where the highest average SOC values were found in June compared to October in both years (SOC of 2.68%, 3.37%, 3.22% and 3.23% in September 2022, June 2023, September 2023, and June 2024, respectively).

Figure 41: Boxplots of soil organic carbon (%) levels recorded in October 2022, June 2023, October 2023, and June 2024, at each project property. Horizontal lines show medians and crosses show averages.

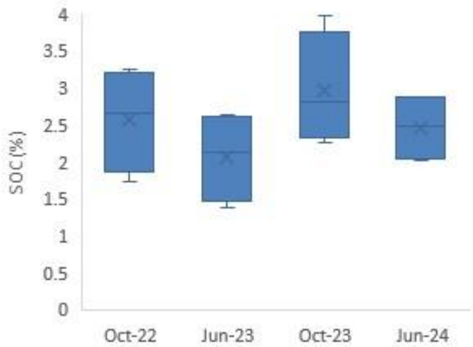
Property	0 – 10 cm soil depth	10 – 30 cm soil depth

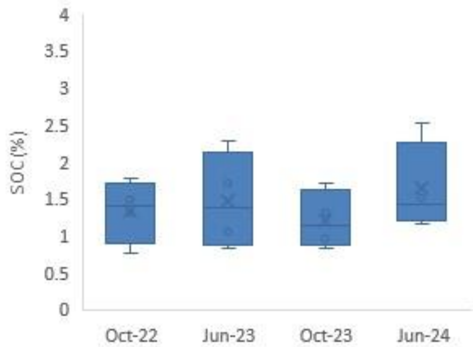
Achill



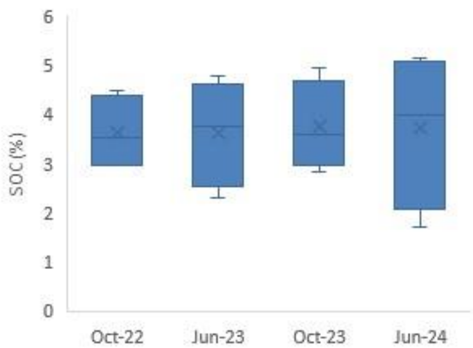


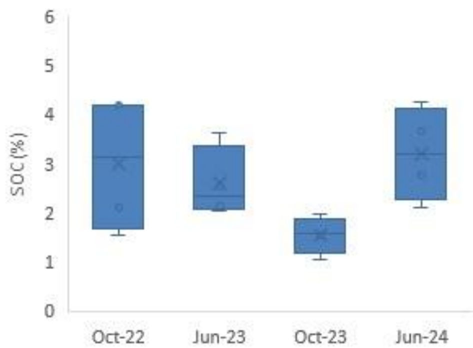
Argyle



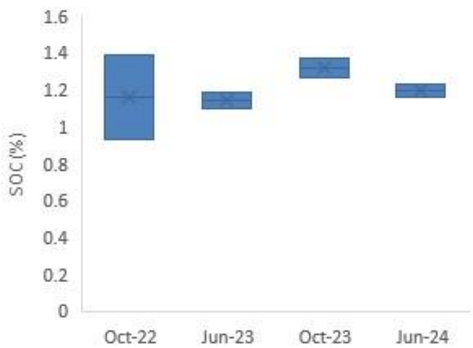


Bald Blair





Cooringoora



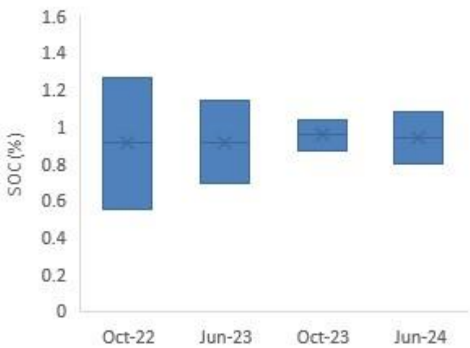


Figure 41, continued.

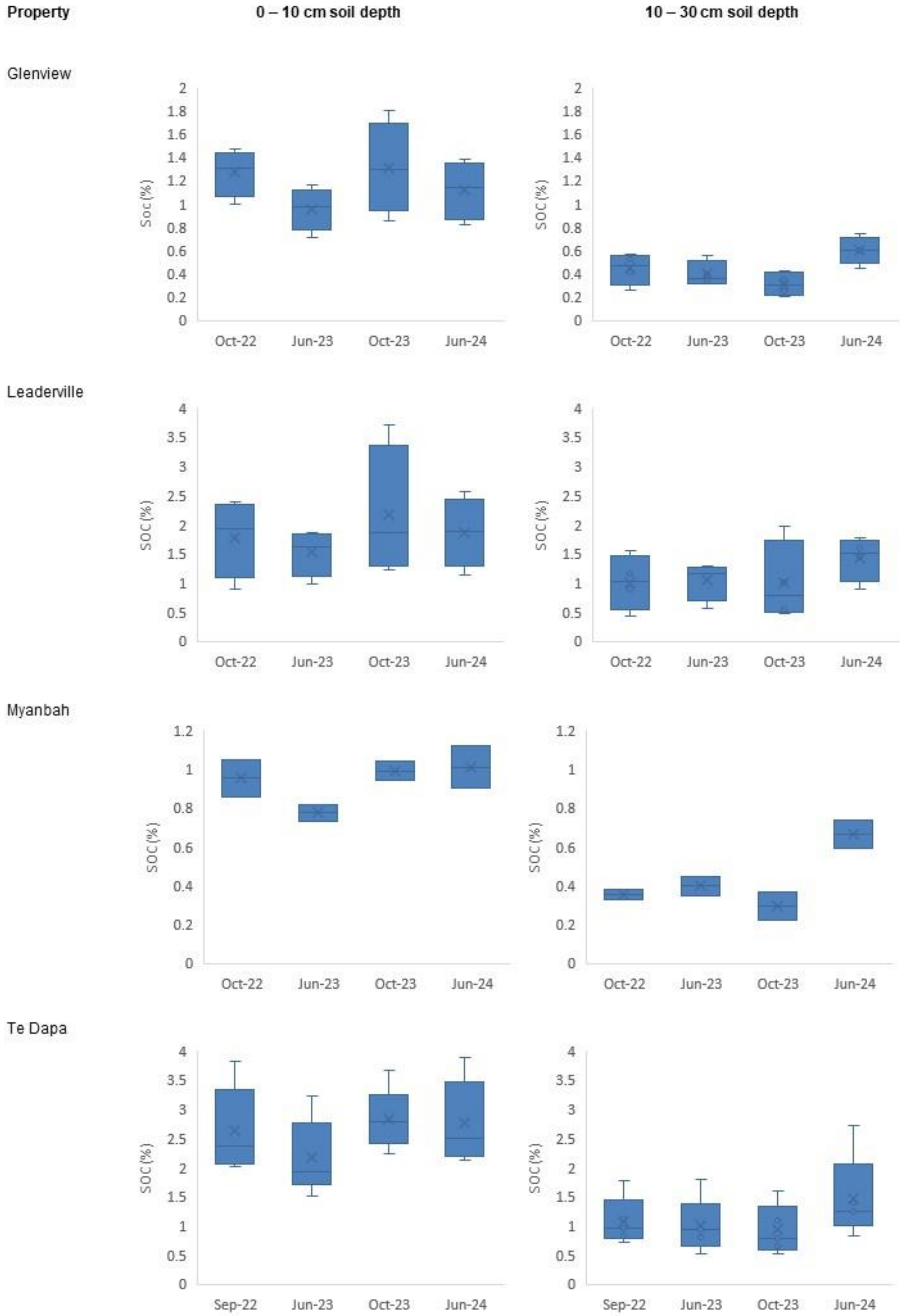
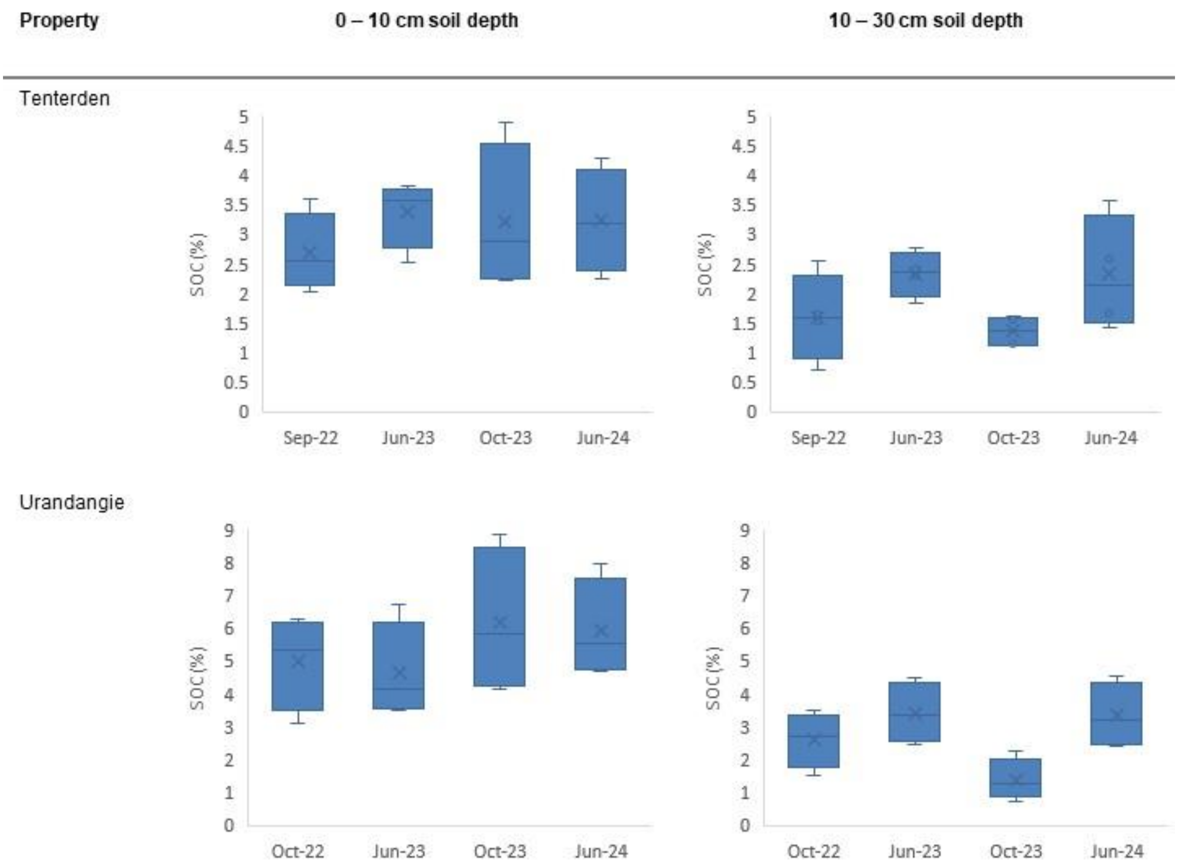


Figure 41, continued.



At a depth of 10 – 30 cm, 6/10 properties showed on average higher SOC levels at the end of winter compared to the start of spring (Fig.41). The exceptions were:

- Bald Blair, Glenview, and Te Dapa, where SOC levels decreased from October 2022 – October 2023, to increase in June 2024.
- Cooringoora, where there was not much change in average SOC levels overall (the average SOC levels ranged from 0.910% – 0.955%, or a total range of 0.045%).

SOC levels fluctuate throughout the year due to seasonal inputs of plant organic matter (residues, exudated, roots), or their decomposition (Franzluebbers, 1995). These seasonal changes also affect the microbial community firstly through changing climatic conditions (temperature, moisture) and indirectly through plant function (Stevenson et al. 2014). Results in a trial in the Pacific Northwest of the United States found 14% – 16% variation in the mean SOC content for a soil sampled monthly to a depth of 20 cm for 39 consecutive months (Wuest, 2014). In an Australian wheat-fallow system total carbon stocks in the top 10 cm decreased by 10% between early to mid-fallow (Wang et al. 2004), which reflected the impact of carbon inputs produced by the crop during a short growing season, decomposed during fallow.

The following hypothesis might explain the overall increase in SOC in the topsoil layer in June compared to October at 0 – 10 cm depth and the overall decrease in SOC at 10 – 30 cm depth between Winter – Spring:

- During winter, soil microbiota activity is suppressed, especially in the topsoil layer (0 – 10 cm) where soil temperatures are lower, meaning there is reduced decomposition of organic matter. At the same time, grazing events during this winter period could have led to trampling and incorporation of dead organic material, increasing SOC levels between June-October.

- Microbial activity continued for longer during winter at 10 – 30 cm depth, as soil temperatures would have been higher compared to 0 – 10 cm depth, leading to continued decomposition. Because rainfall started only after the soil sampling in October 2023, pasture growth had not yet taken off and there had been no replenishment of SOC at 10 – 30 cm depth, leading to lower carbon levels in October compared to June, on average.

Future research projects should be set-up to gain a better understanding of the seasonal fluctuations of SOC through time. The within season fluctuations in SOC levels could obscure the longer-term trends in SOC levels (Wuest, 2014): depending on when during the year samples are taken, and if samples are taken during different months each year, results could show a loss of carbon, when the overall trend is a gain, or the opposite could be true (Sanderman et al. 2010). Samples taken at one point in time are likely to have substantial but hidden measurement variability, making it difficult to compare SOC levels over time (Wuest, 2014). These implications should be considered when setting-up future trials.

4.4 Rainfall and soil moisture

Rainfall and soil moisture were monitored from the moment the equipment was installed during June to August 2020, and until 1st August 2024.

Highest total rainfall (1st July 2021 – 30th June 2024) was recorded at Glenview (near Walcha, 2,721 mm, Table 9) and lowest rainfall was recorded at Cooringoora (near Bingara, 1,853 mm). Overall, as is expected for this area, soil moisture levels were lowest at the end of winter and at the start of spring before the onset of the spring-summer rainfall.

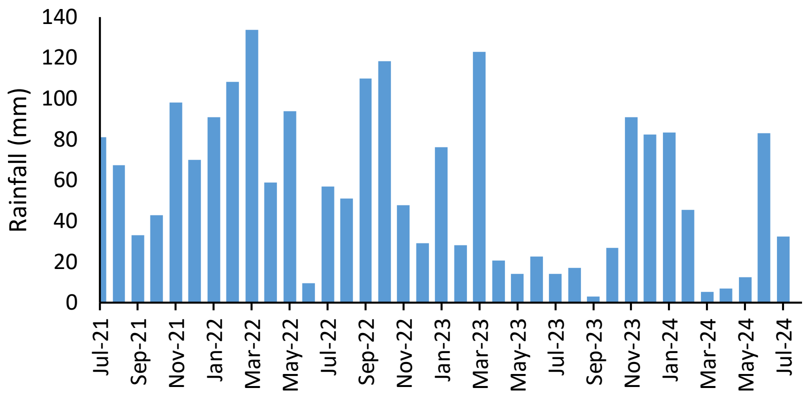
Table 8: Rainfall (mm) in the first and second halves of calendar years 2021 – 2024. Total rainfall 1st July 2021 - 30th June 2024 was calculated only if the rainfall data was complete.

	2021	2022		2023		2024	Total
Property	**July-Dec**	**Jan-June**	**July-Dec**	**Jan-June**	**July-Dec**	**Jan-June**	
Achill	426.4	491.2	367.8	301.2	177.2	420.8	2,184.6
Argyle	*	*	421.5	263.6	247.4	518.2	*
Bald Blair	390.5	495.4	406.7	284.8	234.4	*	*
Cooringoora	372.8	218.6	473.8	271	229.6	287.6	1,853.4
Glenview	496.4	505.9	544.2	380.2	382.8	412.4	2,721.9
Leaderville	630.0	394.2	386.7	306.4	313.2	377.8	2,408.3
Myanbah	101.0	396.2	316.6	163.2	*	*	*
Pointsfield	437.8	507.5	288.3	369.0	226.4	554.0	2,383.0
Tenterden	585.8	384.0	413.5	126.8	186.2	308.4	2,004.7
Urandangie	513.6	448.6	420.2	333.2	214.6	336.4	2,266.6

*Data corrupted due to hardware malfunction

The year 2022 was wet, with high rainfall from January – November. Rainfall was lower in autumn 2023 and was especially low the following winter (Table 9, Fig. 37). In 2023, spring rainfall started late, at the end of October, whereas in an 'average' year it would usually start early October.

Figure 42: Monthly rainfall at Bald Blair 1st July 2021 – 30th July 2024.

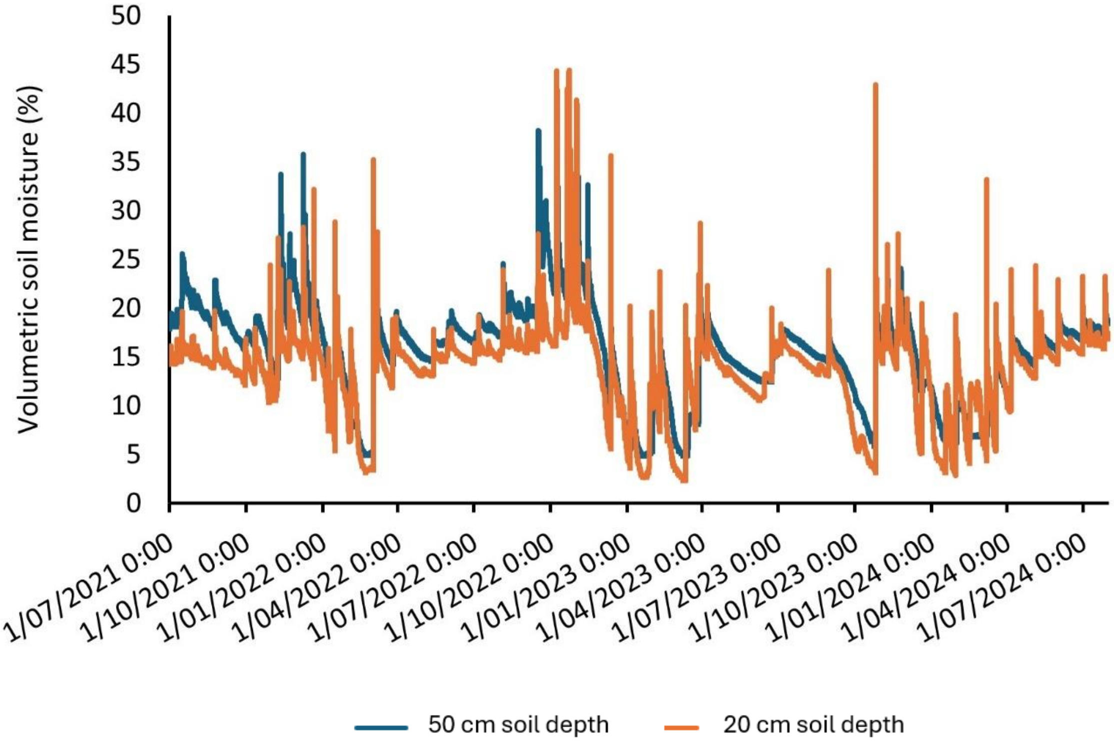


The rainfall patterns are reflected in the soil moisture recordings for all properties: the highest consistent soil moisture levels were reached between July 2021 and January 2022, and the consistently lowest soil moisture levels were reached between January 2023 – April 2023 or October 2023 - April 2024. The exception was the Achill Pivot paddock, which was irrigated, and soil moisture levels were therefore not only affected by weather but also by the irrigation schedule.

The identified critical limits for plant water availability (drained upper limit and crop lower limit, Table 10) did, as expected, align with soil type. For example, the drained upper limit at 20 cm soil depth at Creek Cultivation (Cooringoora) was set to 28% and the crop lower limit was found at 10%, these thresholds correspond to the soil type silt loam (Zotarelli et al., 2019), and the soil tests showed (section 1.1) this soil was indeed a silty loam. At the same site, the drained upper limit at 50 cm depth was identified at 38%, which is usually found in clay loams (Zotarelli et al., 2019). From the soil test results we know that this was indeed a clay-loam soil. Different soil types can be identified in the following way: more sandy soils have quick peaks in soil moisture after rainfall events and soil moisture levels decline rapidly. Soils with more clay will show longer lasting soil moisture peaks as these soils take longer to drain. The CLL and DUL thresholds are higher in soils with more clay compared to soils with more sand.

The difference between the appearance of the soil moisture graphs at 20 cm soil depth and 50 cm soil depth also gave an indication of the difference or similarity in soil types. For example, the shape of the soil moisture curves at 20 cm and 50 cm soil depth was similar at Glenview, the only difference being a slight lag in peak soil moisture levels at depth and a slightly higher soil moisture content overall at 50 cm depth (Fig. 38). The property has coarse granite soils, with at 20 cm a loamy sand and at 50 cm depth a loam type soil. At Bald Blair's Top Fitzroy probe site, however, there was more variation in soil moisture at 20cm depth (silty loam soil type) compared to soil moisture variation at 50 cm depth, with a clay loam soil type, which held on to water more strongly (Fig. 39). For the soil moisture graphs at all properties, see Appendix 8.4.

Figure 43: soil moisture at Glenview's Bottom Probe, 1st July 2021 to 30th June 2024.

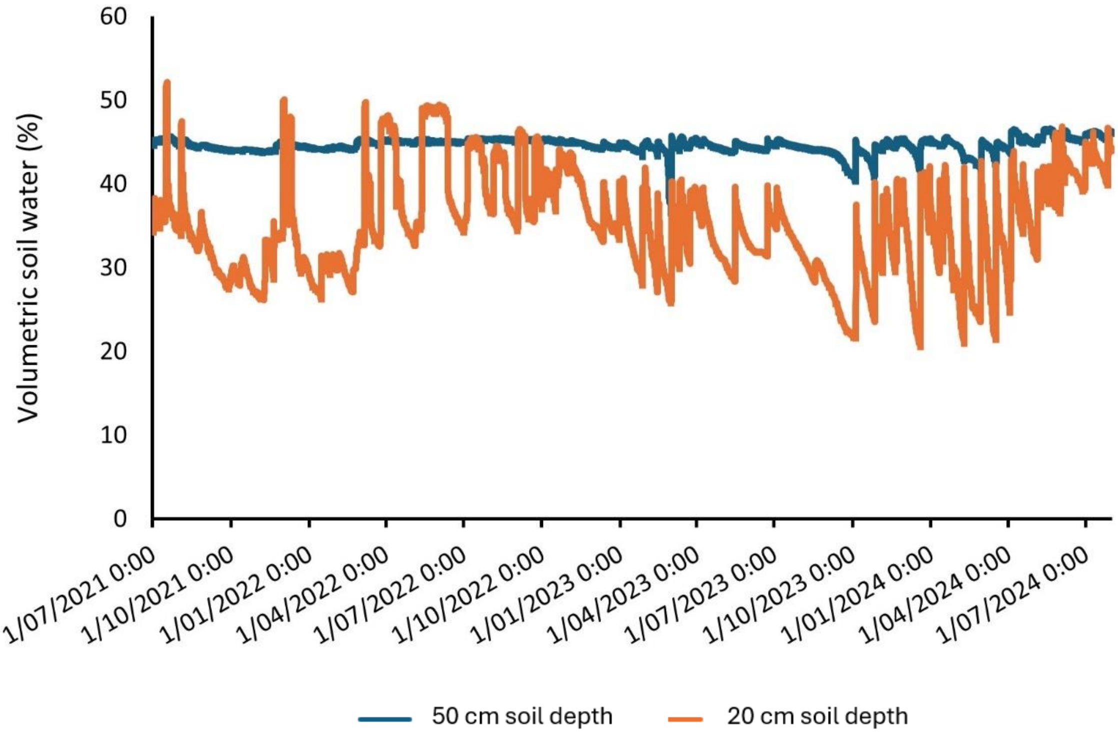


Drained upper limits were identified at all sites, at every soil depth (Table 9). Most of these were first identified between July 2021 – January 2022, due to high rainfall and associated high soil moisture levels during this period. In some cases, these thresholds were amended slightly fort wo reasons:

- heavier rainfall events leading to higher soil moisture levels than previously attained, and
- the timing of the soil moisture measurement. Measurements were taken every 15 minutes, and the timing of the measurement could have influenced how high soil moisture levels were.

Dry periods during the project were not sufficient to identify crop lower limits (CLLs) at each location, and the CLL is still lacking for 4/19 locations at 20 cm depth and 9/19 locations at 50 cm depth (Table 10). The sites at which the crop lower limits were not identified at 20 cm depth were heavy black and red basalt soils, which held onto soil moisture (e.g. Fig. 39 at 50 cm soil depth). The exception was the lack of identification of the crop lower limit at Glenview's Top Probe site, where the soil was a coarse granite type, however, a heavy clay layer occurs at depth. With increasing soil depth, less crop lower limits were found, due to the increase in soil clay content with depth at most soils (clay holds onto soil moisture more tightly), due to reduced water uptake by pasture whose majority of root bulk is found within the top 30 cm depth, and due to the lack of evaporation which does occur at the top soil layer. The fact that no crop lower limits were observed at depth at these 9 sites means these sites did not run out of plant available water over the duration of the project. Promoting deep root growth is therefore a crucial step towards mitigating drought impacts.

Figure 44: soil moisture at Bald Blair 's Top Fitzroy probe site, 1st July 2021 to 30th June 2024.



The method for determining plant available water capacity (the water content between the crop lower limits and drained upper limits) was reasonably accurate, with a confidence of about +-1% in volumetric soil water for the DUL and CLL thresholds. More precise DUL and CLL thresholds could be identified through a field experiment, this would however require a longer-term trial and would the right climatic conditions:

- To determine the DUL, an area should be slowly wetted and covered by plastic to avoid evaporation. The soil should then be allowed to drain and sampled for soil moisture and bulk density (Verburg et al. 2016),
- CLL can be determined opportunistically at the end of a very dry season or in a rainout shelter between crop flowering and sampling. This method however assumes the crop has explored all the water in the soil profile (Verburg et al. 2016).

Alternatively, the crop lower limits could have been measured in a laboratory setting, assuming an average CLL at 15 bar, by placing a soil sample on a pressure plate extractor (Foley, 2017). This method does give the CLL for a specific soil, however it does not determine the CLL for a specific soil and crop combination.

A change in DUL and CLL thresholds were expected over the experimental period, related to changes in SOC levels. The lack in change in DUL and CLL over the experimental period could be due to:

- A lack of accuracy with the visual method to determine slight changes in the CLL and DUL thresholds,
- The measured changes in SOC levels at individual sites at each moisture probe site ranged 0.23% - 2.25%. These limited changes in SOC might be too small and localised to significantly alter the CLL and DUL thresholds to a level where these are identifiable.

Minasny and McBratney (2018) explain a 1% increase in SOC, on average, lead to a 1.61% VSW increase in drained upper limit.

Table 9: Crop lower limits and drained upper limits (% volumetric soil water) identified at 20 cm and 50 cm soil depth. Orange cells indicate sites where these limits were not identified.

Property	Probe location	Crop lower limit (% VSW)		Drained upper limit (% VSW)	
		20 cm	50 cm	20 cm	50 cm
Achill	Sawpit	7.5		32.0	40.0
	Pivot	5.0	24.0	32.0	40.0
Argyle	Green Knob	15.0		45.0	42.0
	Wattle	7.5		33.0	31.0
Bald Blair	Top Fitzroy	22.0		38.0	45.0
	Gatwood	8.0	13.0	26.0	32.0
Cooringoora	Creek Cultivation	9.5	23.5	28.0	36.8
Glenview	Top Probe			43.0	38.0
	Bottom Probe	2.5	5.0	17.0	27.0
Leaderville	Leaderville	17.0	24.0	33.0	40.0
Myanbah	Airstrip	3.0		29.0	33.0
	Oats	7.5	19.0	27.0	39.0
Pointsfield	West Track	5.0	16.5	27.0	32.0
Te Dapa	Nancy's	2.6		30.0	34.0
	Top Two	5.0	24.0	38.0	40.0
Tenterden	Schoolhouse 1	34.0	27.0	42.0	43.0
	Schoolhouse 2		29.0	45.0	43.0
Urandangie	Red Hill			42.0	43.0
	Black Hill			42.0	45.0

For project participants, the moisture probe graphs were valuable for knowing at any time whether plant available water was, or might soon become, limiting. This information could then be used to decide when to destock or restock, or deciding if, when and what crops to sow. Participants also suggested that the knowledge of current soil moisture levels should be combined with weather predictions to be able to predict when crop lower limits might be reached. This would allow early decision making on stocking and crop management.

One suggestion made by participants was to combine rainfall data and soil moisture data to calculate rainfall infiltration and run-off. To be able to do this, more accurate rainfall data is needed, at a finer time-scale than 15-minute intervals.

The soil moisture probes were robust pieces of equipment: out of the 19 probes, only two broke down over the 5-year project period. More issues however occurred with the rain gauges which were subject to faults and damage. The rain gauges were damaged by livestock and birds, and the presence of dust, insects and spiders led to faulty readings. Additionally, most producers already had rain gauges. Based on conversations with and feedback from project participants, the main value for producers was to be able to compare rainfall near their house to rainfall in the project paddocks.

4.5 Macrofauna counts.

4.5.1 June 2023

From June 2023 it became clear to the Precision Pastures team that monitoring soil macrofauna activity at each site would provide further evidence of soil integrity and overall soil health.

The macrofauna found most often across all 10 demonstration sites were earthworms (juveniles and adults), white curl grubs, ants, and insects classified as 'grey moth larvae', as we were not sure what insect they were (Fig. 45).

Figure 45: Pictures of the macrofauna count activity performed in June 2023

Clump of soil for macro-fauna count

Sorting through soil to find macrofauna

Insect classified as 'grey moth larvae'

Earthworms and white curl grubs

The number of macrofauna, per class, found at each probe site is visible in Table 10. The numbers shown are the sum of all macrofauna found in the total of the 10 sampling sites, per property. If many ants were present in any one shovelful of dirt and the separate individuals could not be counted, the estimate of 100 ants was accepted.

Table 10: Macrofauna counts at all properties in June 2023. If there were too many ants to count individuals separately, their numbers were rounded-off to 100. The two lowest total fauna counts and the two highest total counts (excluding ants) are highlighted in orange and green respectively.

Property	Earthworm adult	Earthworm juvenile	Ants	Spiders	Centipede	Cockroach	Witchetty grub	Earwig	Caterpillar	Wireworm	Beetle	Larvae	Grey moth larvae	Cricket	Unidentified	Total (incl. ants)	Total (excl. ants)
Achill	0	1	3	1	0	0	22	0	0	1	0	0	1	0	0	29	26
Argyle	1	29	0	5	0	0	6	0	0	0	1	3	15	0	0	60	60
Bald Blair	1	3	100	3	3	0	1	0	2	0	0	5	53	0	0	171	71
Cooringoora	0	1	13	1	0	0	1	0	0	1	0	1	0	0	1	19	6
Glenview	4	13	100	2	1	1	9	7	1	4	0	0	0	0	1	143	43
Leaderville	0	0	7	2	0	0	0	0	0	0	2	0	0	0	1	12	5
Myanbah	0	5	0	0	0	0	0	0	0	1	0	0	0	0	0	6	6
Pointsfield	32	11	0	1	0	0	18	0	2	2	1	1	0	1	0	69	69
Te Dapa	55	4	0	0	0	0	21	0	0	1	1	0	0	0	0	82	82
Tenterden	1	0	0	2	0	0	1	0	0	0	1	0	0	0	0	5	5
Urandangie	0	5	1	4	6	0	0	0	2	1	1	0	13	0	0	33	32

Overall, the total number of macrofauna found was lower than was initially expected, which was related to the soil being dry at the time of count (start of June). The biggest number of earthworms was found at Argyle, Te Dapa and Pointsfield. The total number of macrofauna found was smallest at Tenterden and Myanbah, where we could not get full-depth soil samples because the ground was too hard. These were also the two sites with the lowest number of different species found (earthworms and wireworms at Myanbah, and earthworms, spiders, witchetty grubs and beetles at Tenterden).

The high number of macrofauna, especially earthworms, found at Te Dapa compared to the remaining properties was especially surprising, since there was limited green groundcover available (Fig. 46). The presence of dead organic matter on the soil's surface could have been an attractant to the macrofauna.

Figure 46: Groundcover around the NDVI probe site at Te Dapa, June 2023

4.5.2 February 2024

In February 2024, the macrofauna found most frequently were ants, white curl grubs, and larvae (which we could not identified further, Table 11).

At least 4 different types of macrofauna were found at each site. The greatest diversity of macrofauna types was identified at Te Dapa and Achill. This was unexpected on both accounts. At Achill a high number of macrofauna was found, even though the soil was very hard, and the shovel would not dig into the soil more than 5 – 10 cm. At Te Dapa, the probe site was covered mostly with dead vegetation and the new crop had not yet been sown. The soil was hard and dry. It is possible that the dead organic matter provided cover for the macrofauna. Better knowledge of species recognition could help in understanding the preferred habitat of different macrofauna species.

The most frequently occurring species were different in June 2023 compared to February 2024, because of the timing of the counts (winter in 2023 and autumn in 2024). For example, whereas Bald Blair had the highest fauna count (excluding ants) in June 2023, a substantial portion was made up of the ‘grey moth larvae’, of which we found only 1 at Te Dapa in February 2024. These larvae might not yet be present in the soil in autumn.

Te Dapa and Pointsfield had high fauna counts both times, Tenterden had the lowest fauna counts at both times.

No direct link was identified between the pasture composition, soil carbon, soil types, or grazing management and the soil macrofauna counts. This was partly related to soil conditions, as hard soils on some properties made it impossible to collect a full shovel of soil.

Table 11: Macrofauna counts at all properties in February 2024. If there were too many ants to count separate individuals, their numbers were rounded-off to 100. The two lowest total fauna counts, and the two highest total fauna counts (excluding ants) are highlighted in orange and green respectively.

Property	Earthworm adult	Earthworm juvenile	Ants	Spiders	Centipede	Cockroach	Curl grub	Earwig	Caterpillar	Wireworm	Beetle	Larvae	Grey moth larvae	Cricket	Unidentified	Total (incl. ants)	Total (excl. ants)
Achill	1	0	10	2	15	0	41	8	0	1	2	1	0	0	0	171	71
Argyle	5	5	11	0	0	0	5	6	0	0	0	1	0	1	0	34	23
Bald Blair	0	1	0	3	1	0	0	1	0	1	0	7	0	0	0	14	14
Cooringoora	0	0	30	4	0	0	13	0	0	0	6	0	0	0	0	313	13
Glenview	0	0	12	0	1	0	5	0	0	0	0	3	0	0	0	21	9
Leaderville	0	0	24	0	0	0	1	0	0	0	5	2	0	0	0	32	8
Myanbah	0	0	20	4	0	0	18	0	0	10	0	0	0	0	0	232	32
Pointsfield	5	2	27	1	2	0	68	4	0	1	0	0	0	0	0	110	83
Te Dapa	4	3	3	2	0	0	56	2	0	3	2	35	1	0	0	111	108
Tenterden	0	0	2	0	3	0	0	0	0	1	0	1	0	0	0	7	5
Urandangie	0	0	25	3	19	0	0	0	0	0	8	2	0	0	0	57	27

4.6 Pasture growth

Pasture growth was lowest at all sites between June and August, in winter, and highest between October and March each year. This aligns with low to no pasture growth in winter and highest pasture growth in spring and early summer, for temperate pasture species on the Northern Tablelands (Graham, 2017). Lowest pasture growth occurred between August – October 2023, aligned with the low rainfall period and lack of soil moisture for pasture growth in spring. Summer pasture growth rates at Pointsfield (pasture predominantly consisting of Phalaris) reached peaks of 30 – 60 kg DM/ha/day (Fig. 47), which is in line with the accepted rates of Phalaris and white clover pasture growth rates on the Northern Tablelands (averaging 40 – 60 kg DM/ha/day, Graham, 2017). Peak pasture growth rates measured in spring-summer at Te Dapa were between 20 – 50 kg DM/ha, which is in line with the accepted rate of native pasture growth on the Northern Tablelands (30 – 40 kg DM/ha/day, Graham, 2017, Fig. 48). Appendix 8.5 details recorded pasture growth rates at both sites.

No consistent, significant differences were identified in pasture growth rates between the fertiliser and lime treatments. This was because regular lime and fertiliser applications were not maintained adequately by the participants (no fertiliser was applied during the project period), meaning the phosphorus and pH levels in the plots were not reflective of the fertiliser and lime treatments.

Figure 47: Pasture growth rates (kg DM/ha) at the Pointsfield trial sites, April 2022 – June 2024.

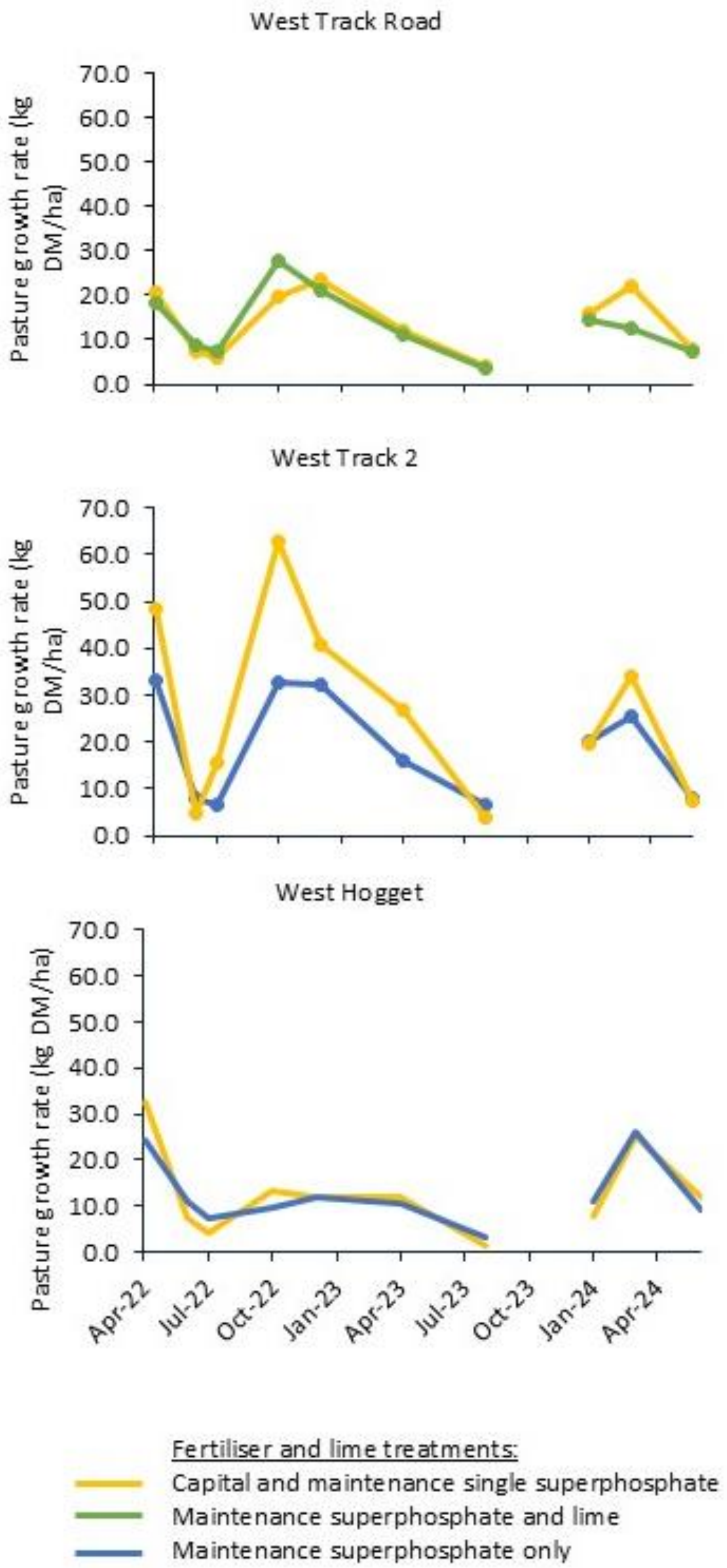
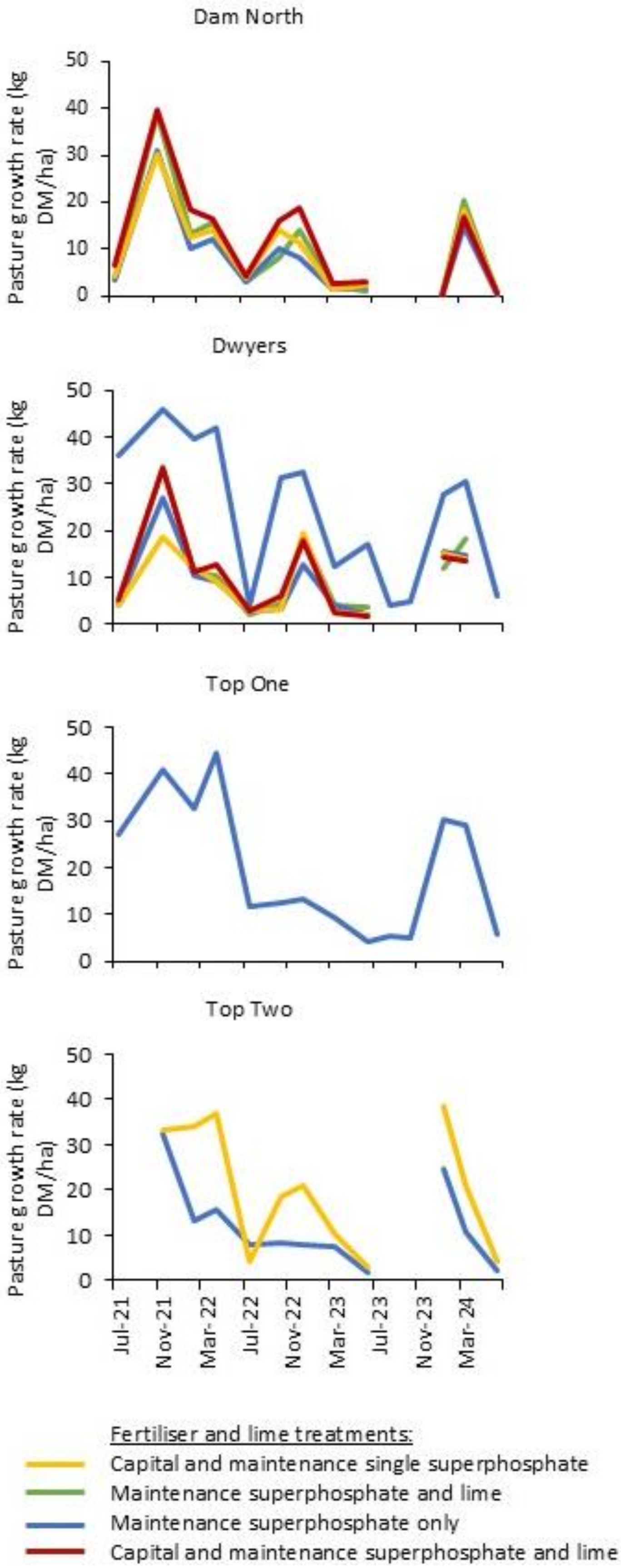


Figure 48: Pasture growth rates (kg DM/ha) at the Te Dapa trial sites, April 2022 – June 2023.

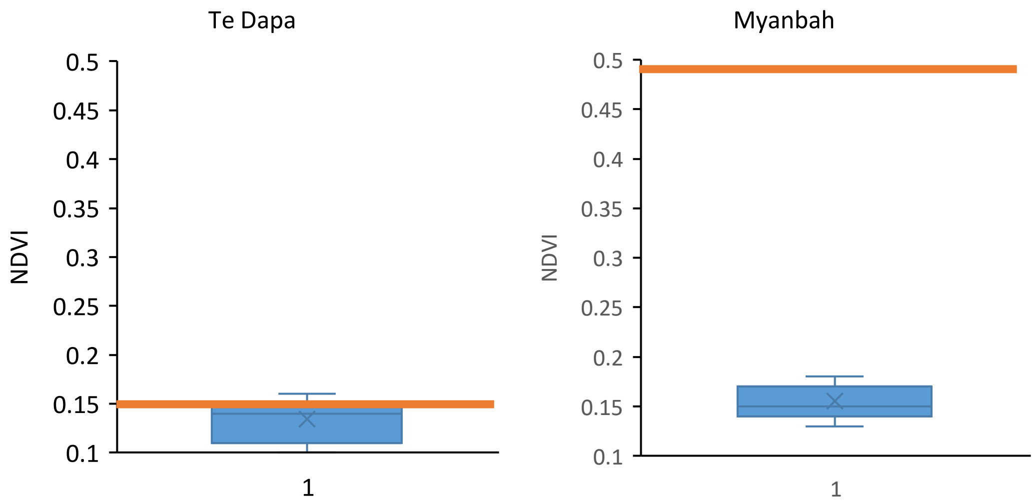


4.7 Normalised Difference Vegetation Index (NDVI)

4.7.1 NDVI validation

When comparing NDVI values recorded by the static NDVI telemeter and the hand-held Greenseeker, results were usually within the same range (Fig. 49). This method for cross-checking the validity of the measurements taken by the static NDVI telemeter highlighted four instances where the NDVI telemeters recorded faulty data. In these three cases, the equipment returned for repair and recalibration. The NDVI telemeters were not robust pieces of equipment and regularly broke down or stopped transmitting data. The cables were also prone to being damaged by cattle, even though the probes were surrounded by cattle panels to keep the livestock out. Appendix 8.6.1 shows the NDVI values recorded by the hand-held Greenseeker compared to the static NDVI telemeter.

Figure 49: Comparison of 10 hand-held Greenseeker NDVI measurements (blue box) and static NDVI radiotelemeter result (orange line) in September 2023, at Te Dapa (results from hand-held device and static telemeter align) and Myanbah (lack of correspondence between data collected by hand-held device and static device, showing erroneous recordings by the static NDVI telemeter).



4.7.2 NDVI throughout the growing season

NDVI values gave an indication of the start of the pasture growing season at each project site. Fig. 50 shows the NDVI values recorded at Achill (Sawpit), from 1st April 2021 – 30th September 2022. The steady increase in NDVI from the start of October 2021 (NDVI of 0.49 on the 1st of October) marks the start of the pasture's growing season. Peak NDVI values were recorded mid-January (NDVI of 0.77), to subsequently consistently decline starting the first of June (NDVI of 0.65) until the 1st of September (NDVI of 0.39).

Estimated start and end dates of each growing season, for each property, are recorded in Table 13. Associated NDVI graphs, for the period 1st July 2021 – 1st August 2024 are available for each property, in Appendix 8.6.2.

Figure 46 show groundcover at the Greenknob NDVI probe in June, August, and October 2023. Respective NDVI values recorded by the hand-held Greenseeker were 0.63 (green and actively growing pasture), 0.52 (less green pasture with more yellow and dead pasture), and 0.18 (some green pasture remaining, mostly yellow).

Figure 50: Median daily NDVI recorded at Achill, Sawpit, 1 April 2021 – 30th September 2022.

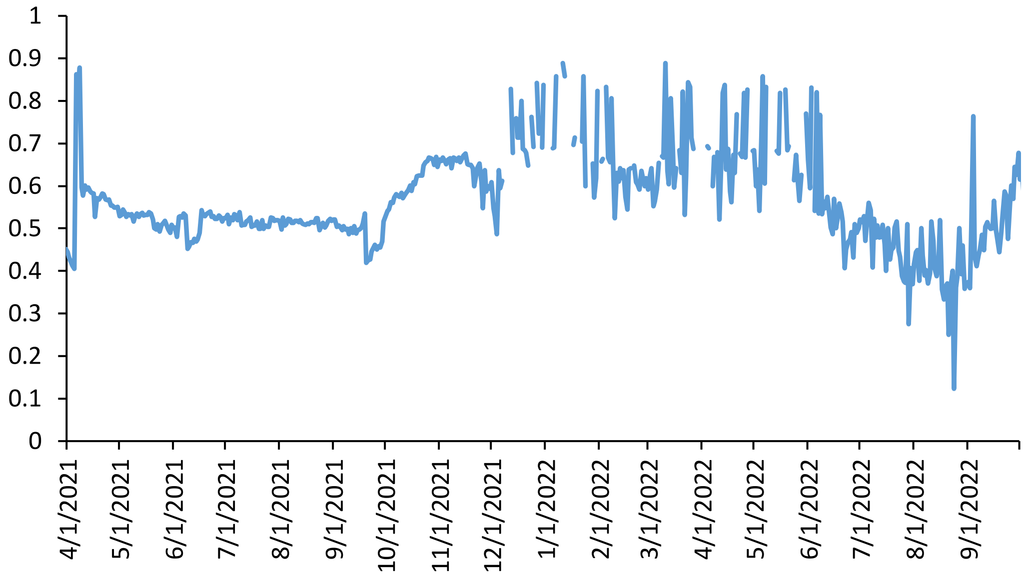


Figure 51: Groundcover around the NDVI probe at Achill, in April (left), August (centre) and October (right) 2023. Associated NDVI values were 0.63, 0.42 and 0.18, respectively.

At Cooringoora, oats were sown in March 2023, after spraying out of the paddock in January (Fig. 52). NDVI values were below 0.25 from January – March, showing the period of bare soil, then increased to 0.72 in April, after germination and during the oats' active growth phase.

Grazing is visible on the NDVI figure as a decrease in NDVI, as livestock graze the green, actively photosynthesizing leaves (Fig. 47). As all the project sites were grazed, it was sometimes impossible to extricate the grazing impact on NDVI from the seasonal and climatic impact of NDVI. The property with the clearest impact of grazing activities on NDVI is Leaderville, where frequent peaks and troughs are identified in the recorded NDVI values (Fig. 48). Peaks in NDVI were identified around an NDVI of 0.8 year-round, with grazing events reducing the NDVI to values to 0.2 – 0.4.

The start and duration of the growing season is dependent on the location of the property as well as the crop grown (Table 12). At all properties, pasture growth started between July (Bingara) to November (Armidale). The longest growing seasons were identified at Leaderville, where higher winter temperatures were less limiting for pasture growth and lucerne included in the pasture mixture started growing in winter, although slowly. The tropical grasses at this property started growing later in the season, around the mid-spring.

Figure 52: Daily median NDVI recorded at Cooringoora, 1st January 2023 – 31st December 2023.

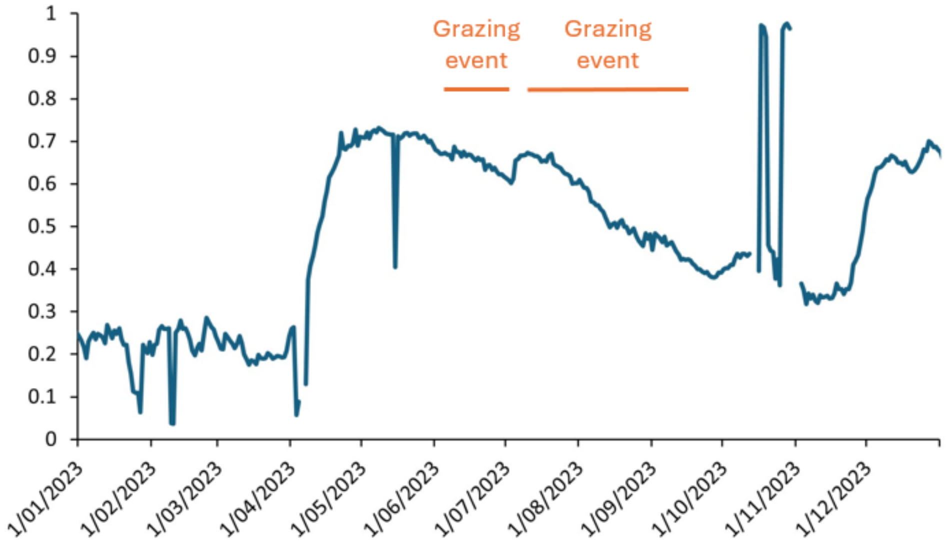
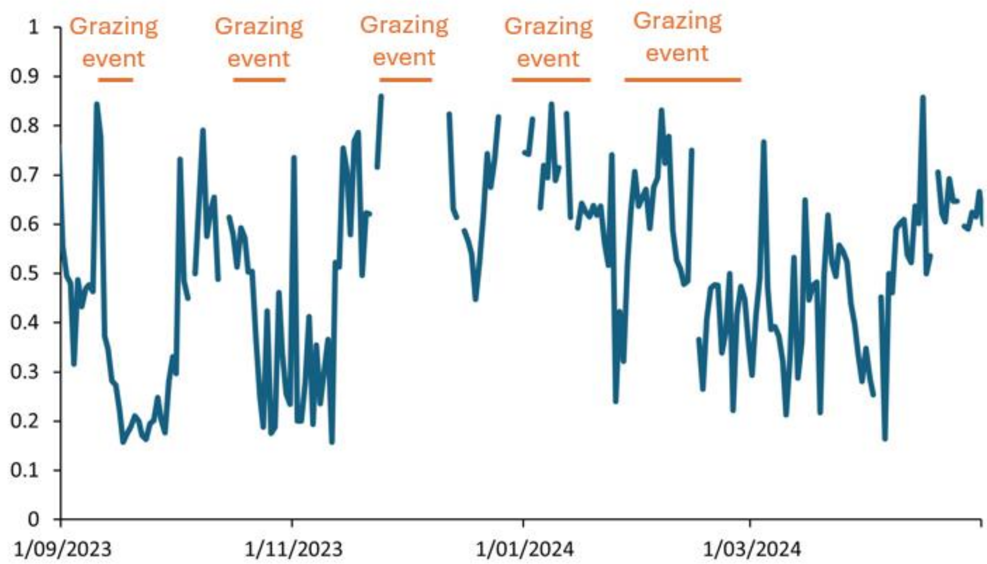


Figure 53: Daily median NDVI values recorded at Leaderville, 1st September 2023 – 30th April 2024.



The conversion from a permanent pasture (summer active) to oats (winter active) led to a year-round growing season at Cooringoora, from July 2022 to July 2023, with a period of bare soil (February-March 2023).

Whereas the growing season started around the same time in 2021 and 2022, the onset of rainfall later in the season delayed the onset of the growing season at Achill, Cooringoora, Glenview, and

Pointsfield in 2023. These four properties showed an average increase in SOC at 0 – 10 cm soil depth and a decrease at the remaining soil depths in September 2023, leading to the hypothesis that climatic conditions and plant growth stage might have led to these SOC results.

Table 12: Estimated growing season defined as the steady increase of NDVI after winter (NDVI value > 0.25), until the steady NDVI decline in winter. Dates are rounded-off to two weeks.

Property	2021 - 2022	2022 - 2023	2023 - 2024
Achill	1st Oct – 1st June	1st Sept – 15th May	1st Nov – 15th June
Argyle	Dashboard issues	Dashboard issues	Dashboard issues
Bald Blair	1st Sept – 15th May	1st Sept – 15th May	Equipment issues
Cooringoora	15th July – 15th May	15th July – 15th July	15th Nov – 15th May
Glenview	Dashboard issues	1st September – 15th May	1st November – 15th May
Leaderville	1st July – No clear end date	15th July – 1st May	1st July – 15th May
Myanbah	Dashboard issues	Dashboard issues	Equipment issues
Pointsfield	1st Aug – 1st June	1st Aug – 1st June	1st Nov – 15th May
Te Dapa	Sowing of permanent pasture – no success	Sowing of permanent pasture – no success	Equipment issues
Tenterden	1st Aug – 1st June	1st Aug – 1st June	1st Aug – 15th May
Urandangie	1st Sept – 1st June	1st Sept – 1st June	Equipment issues

The lack of data for some sites was due to either dashboard issues or equipment issues:

- Dashboard issues: an overload of data combined with outdated software leading to data loss.
- Equipment issues: these probes were returned to the supplier for recalibration and were therefore not recoding data during this period.

The equipment and dashboard issues highlight the trade-offs of working with the technology. Although providing a stream of data, the equipment issues led to extended periods when no data was recorded (as the broken probes had to be sent to the United States to be fixed). The software issues also demonstrate the speed at which the software got outdated (within the 5-year project period) and leads to question the viability of using the equipment on-farm.

4.7.3 Relationship between NDVI and crop biomass

NDVI indicates crop greenness rather than overall crop biomass, which is why there was no clear association between NDVI and pasture biomass found at the trial sites (the yellow biomass was not separated from the green biomass when taking pasture cuts and when weighing pasture biomass).

Figure 49 shows the NDVI and associated dry pasture weight of samples taken at Bald Blair between June 2023 and June 2024. Although there is no clear association between NDVI and pasture biomass at any of the sampling dates, the change in the pasture's growth phase is clearly visible when comparing the results over time:

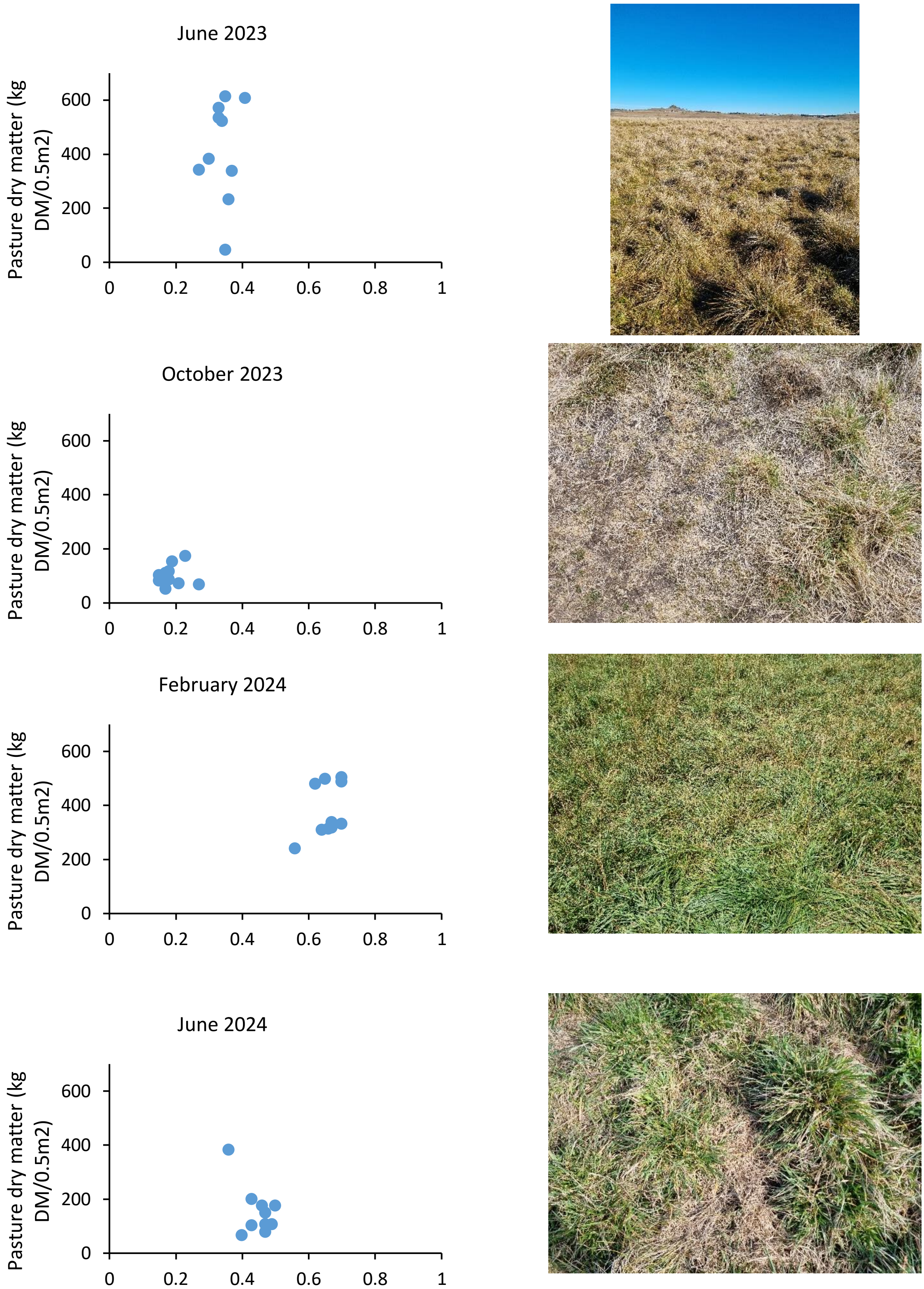
- In June 2023, pasture was mostly yellow, with only some limited green biomass (NDVI values recorded were low, between 0.27 – 0.41 but showed a broad range in pasture dry matter). Biomass was still high after the growing season.
- In October, because of lack of rainfall, the pasture was mostly yellow and pasture growth had not yet started-up (NDVI values were low, between 0.15 – 0.27 but the range in pasture biomass was also low). The pasture had been grazed over winter, reducing pasture biomass as compared to the start of winter.
- In February 2024, pasture was actively growing (NDVI values 0.56 – 0.7) and pasture biomass had accumulated over the growing season.
- In June, at the onset of winter, pasture growth has slowed (NDVI between 0.4 – 0.5) and due to grazing events, the dry matter biomass had decreased compared to February.

Appendix 8.6.3 details associated data for each property individually.

To understand the relationship between NDVI and pasture biomass at various times throughout the year, more frequent pasture samples should have been taken and the green pasture should have been separated from the yellow pasture when measuring pasture biomass. Taking pasture height measurements could also have improved the estimation of pasture biomass, as pasture height records have been identified to improve green dry biomass estimations compared to NDVI only (Andersson et al. 2017).

For future research projects, tools such as Pasture IO or Pasture Key, which use NDVI recorded by satellite to assess pasture growth and food on offer (at daily or weekly intervals) could be considered.

Figure. 54: NDVI and associated sample dry weight at Bald Blair in June 2023, October 2023, February 2024 and June 2024, with accompanying pictures of pasture.



4.7.4 Benefits and limitations of using static NDVI radio telemetres.

Malfunctions occurred with the NDVI telemeters after the devices had been installed in the paddocks for over 2 years. According to ICT International personnel (the equipment providers), this is the longest the equipment has been continuously used in the field. Usually, the equipment is used for short amounts of time, for short-term research trials only.

The telemeters were static and recorded NDVI in one area of the paddock only (roughly 1 – 3 m^2 depending on the angle of installation). There was no measure of how representative this limited measured area was compared to the remainder of the paddock. Livestock were also attracted to the exclusion cages the probes were in according to the participants this was often the first area the livestock visited, meaning it was the first area that was grazed. Livestock also camped around these probe sites, leading to a lack of pasture around the pasture exclusion cages at some sites (Fig. 55). As NDVI is reflective of green biomass, NDVI values will decline once the pasture starts yellowing / haying-off, even though there is still a bulk of dry feed available. An issue highlighted by several participants was therefore the difficulty in using the static NDVI data as a tool to determine when cattle should be moved into or out of a paddock (as this area is grazed first and there might still be green feed available in the remainder of the paddock). Alternative methods that could be explored in future projects are the use of satellite NDVI imagery to determine paddock-based pasture biomass or food on offer (e.g. use of paid services such as Pasture IO or Pasture Key). These measures are however less detailed, with a standard resolution of 10 m and an updated NDVI map approximately every 5 days (depending on the frequency of satellite fly over), compared to 15-minute, real-time data coming through with the static telemeter.

Figure 55: bare area around the probe cage at Urandangie because of livestock camping around the cage, February 2024.

4.8 Grazing management

4.8.1 Grazing pressure

There were difficulties in obtaining livestock movement data from all participants, as some participants did not record these movements. By the end of the project, out of the 11 participants, the following methods were used to track livestock movement:

- None – 2 participants
- Paper records – 4 participants
- Web-based application (such as Ag360, Maia grazing or Agriwebb) – 5 participants.

Following were reasons given for the lack of livestock movements:

- Change of farm manager,
- Issues with recording data on the application,
- We have not recorded livestock movement.

Table 14 shows grazing management data for the periods of January – November 2023 and for the period of December 2023 – April 2024. Appendix 8.7 contains the grazing management details for each property.

There was a broad range in grazing management strategies adopted by participants. The lowest intensity grazing management strategy (long grazing periods and low grazing pressure) was adopted at Myanbah (0.14 DSE/ha/day and the paddock being rested 57.3% of time). Between January 2023 and November 2023, cattle stayed in the paddock on average for 69 consecutive days, showing a slow rotation of livestock between paddocks.

The highest intensity grazing management strategy was adopted at Tenterden, with on average a grazing pressure of 33.5 DSE/ha/day and the paddock being rested 93.1% of the time. Livestock stayed in the paddock for 3 - 8 consecutive days before moving to the next paddock. This is an example of a high intensity, short duration grazing regime with longer rest periods.

Pointsfield and Bald Blair also adopted rotational grazing regimes with high intensity grazing and livestock staying in the paddocks for a duration of 1 – 10 days. Paddocks were grazed for less than 15% of the time. Urandangie is an example of where grazing management changed over time, with short duration, high intensity grazing between January – November 2023, and longer duration, with lower intensity grazing from December 2023 – April 2024.

Conversely, the grazing regime adopted at Argyle, Cooringoora and Glenview is lower intensity, longer duration with shorter resting periods.

Table 13: Grazing management at the project properties, 1st January 2023 – 30th November 2023 and 1st December 2023 – 30th April 2024.

Property	January – November 2023				December 2023 – April 2024					
	Average duration of grazing event (days)	Total DSE/ha	Total DSE/ha/day	Percentage time the paddock was grazed	Average duration of grazing event (days)	Total DSE/ha	Total DSE/ha/day	Percentage time the paddock was grazed	% SOC +/- (0-10 cm) Jan 23 to Nov 24	% SOC +/- (10-30 cm) Jan 23 to Nov 24
Achill	No grazing data for this reporting period				20	260.6	4.5	38.4	-0.54	0.46
Argyle	24	209.8	1.92	38.4	0	0.0	0.0	0.0	0.15	0.65
Bald Blair	7	149.2	3.93	11.4	8	23.2	2.9	5.3	-0.36	0.29
Cooringoora	25	51.8	0.32	27.0	123	8.7	0.1	81.5	0.27	0.28
Glenview	47	56.4	0.36	42.6	No grazing data for this reporting period				-0.26	0.18
Leaderville	No grazing data for this reporting period				18	184.0	5.1	24.8	0.15	0.31
Myanbah	69	20.9	0.14	42.9	29	4	0.1	19.2	0.15	0.2
Pointsfield	5	522.2	12.9	9.2	No grazing data for this reporting period				-	-
Tenterden	5	1,003.9	33.5	6.9	No grazing data for this reporting period				0.63	0.57
Urandangie	4	643.4	18.7	10.3	22.5	336.0	3.7	59.6	0.52	0.27

4.8.1.1 Grazing pressure and soil organic carbon

There may be a relationship between grazing strategy and SOC levels, as SOC % levels, on average, between January 2023 and November 2024 increased at 0 – 10 cm at Bald Blair, Cooringoora, Leaderville, Myanbah, Tenterden and Urandangie. All sites experienced SOC % levels increase at 10-30 cm during this period (see Table 13). The related grazing pressure from cattle and sheep during the January 23 to April 24 period over these sites does not appear to indicate any clear correlation between grazing pressure and movements in SOC %. All participants practice rotational grazing strategies where minimum 1,000 kg dry matter biomass levels are maintained and pastures are only grazed at greater than 4 leaf stage of growth. As evidenced in Table 5, Achill, Leaderville and Myanbah renovated the pastures at the sites during 2021.

These SOC outcomes may also be related to soils, climatic conditions, or other farm management factors, and at this stage it appears these aspects cannot be directly related to grazing management (as evidenced in this project).

These findings are in line with findings by McDonald et al. (2023), who reviewed literature on the impact of grazing management on SOC in Australia. No significant impacts of stocking intensity or stocking method on SOC were identified. This was evident by the presence of context specific characteristics, such as climate, soil type, pasture composition and management type, which might impact the response of SOC to grazing management (McSherry and Ritchie, 2002).

As noted in the conclusions section of this report, there would be clear benefits in conducting further science-based trials to test whether grazing management does impact SOC levels.

4.8.1.2 Grazing pressure and macrofauna counts.

Tenterden was the property with the lowest macrofauna counts but the highest grazing pressure. The macrofauna counts were low because of how hard the ground was on both visits, meaning less soil was extracted. The hard soil is due to the combination of the soil type being silty clays, with the high grazing pressure.

Macrofauna counts may not be related to SOC or grazing management.

4.8.2 Livestock weight gain

Although in some instances it was difficult to obtain livestock movement data from the participants, it was even more difficult to get livestock weight estimations. No livestock liveweight estimates were provided by the participants. The lack of weight estimates communicated with Precision Pastures personnel could be due to:

- Frequent paddock changes and the amount of work in estimating livestock weight,
- A participant's lack of confidence in their ability to assess livestock weight,
- Paddock movements conducted by someone else than the project participant (staff, family members), and therefore no record of the estimated weight, and
- Low importance of the visual weight assessment on the list of daily activities.

For future projects, ways around the lack of livestock weight estimates could be the following:

- Using in-paddock weighing equipment such as the Optiweigh system (https://www.optiweigh.com.au/, an in-paddock scale). This would require the participant to move the Optiweight along with livestock, and requires a substantial upfront cost, or

- Using phone apps, such as for example 'Agroninja beefie' (https://agroninja.com/) an app used to estimate cattle weight by taking a picture of stock. This does require the participants to regularly take pictures of their stock.

Having access to reliable livestock weight estimated could have provided an objective measure of the quality and amount of feed on offer, together with NDVI. Liveweight gain indicates the pasture provides a high-quality pasture, and livestock weight loss indicates either pasture quality or quantity is sub-optimal.

4.9 Communication

4.9.1 Field days and field walks

4.9.1.1 Year 2020

The field day and field walk events were merged into one event, which was originally planned for 2020 but was postponed until the 26th of February 2021 because of COVID-19.

The field day was conducted at Bald Blair. It introduced the project and showed results for the EM38 conductivity maps and baseline soil sampling. A total of 19 attendees were present, of which 9 were core participants.

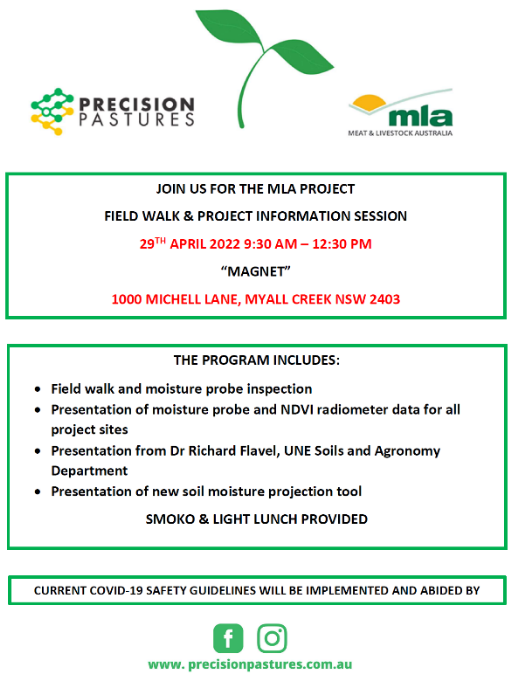
4.9.1.2 Year 2021

No events were organised in 2021 due to the incidence of COVID-19. No property visits or soil sampling occurred during this year.

4.9.1.3 Year 2022

In April 2022, a field walk was organised at Leaderville. Moisture probe and NDVI radiometer data was presented for all project sites and a field walk was organised for inspection of the moisture probe.

A presentation was delivered by Dr Richard Flavel (UNE Soils and Agronomy Department) on the interpretation of soil moisture data. John Barton, from Charton & Bang, demonstrated the used of the Microbiometer (https://microbiometer.com/) in testing the soil's microbial biomass and in testing the soil's fungal to bacterial ratio. There were 16 attendees, of whom 9 were core participants (from five different properties).



In November 2022, a field day was organised at Tenterden Church. Project findings were shared, and a presentation was held by Sarah Strachan (MLA Group Manager Adoption and Commercialisation) on the productivity imperatives in achieving carbon neutral by 20230. A total of 28 attendees were present, of which 7 were core participants from 6 different properties. Most of the discussion after the presentations was centred around the role of producers in attaining or working towards climate-neutral agriculture.

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14TH NOVEMBER 2022

WELCOME TO THE TENTERDEN MLA PROJECTS FIELD DAY

This field day provides an opportunity for both participating and observer producers to receive an annual update of the progress of the two MLA Producer Demonstration Site projects conducted by Precision Pastures.

The "Zoning up to optimise pasture production" project (MLA PDS project P.PSH.2000) commenced in 2020 at 5 sites across the New England. As a producer demonstration site, the purpose of the project is "to demonstrate the treatment of constraining soil nutrient deficiencies by zone at variable rate application (VRA) will provide optimal pasture yield, sustainable livestock production per hectare and profitable returns for livestock producers in the New England".

This project involves intensive grid-based soil sampling, soil zone mapping and variable rate application prescriptions for fertilizer and lime treatments. This project runs to 2025 and to this point there are some encouraging results from the project data in determining the production and financial benefits of "zoning up". An overview of this data will be presented today.

The "Grazing system impact on livestock productivity, soil moisture and soil organic carbon" (P.PSH.2005) completion date is April 2025 and is involves 10 core participants across the New England region. The project aims to establish the baseline data required to determine the optimal blend of pasture production and feedbase utilization for improved livestock productivity and increases in soil carbon levels. The project is co-funded by the MLA Donor company.

Since 2020, this project has been challenged by the covid restrictions and the wet soil conditions. Despite these, reasonable amounts of project relevant data have been collected. This data will be presented today with some interesting trends, particularly in relation to soil organic carbon.

Precision Pastures and MLA thank you for your attendance and we look forward to your feedback from the presentations.

MEAT & LIVESTOCK AUSTRALIA

4.9.1.4 Year 2023

In May 2023, a field walk was organised at Myanbah. Project findings were presented, and a discussion was held on how to best make use of the data collected through the project. A total of 8 attendees were present, of which 4 were core participants, from 3 different properties. All participants had access to the online dashboard collecting and presenting the project data (soil moisture, rainfall, NDVI), however most attendees did not regularly access this dashboard. For this reason, time was taken to step participants through the interpretation of all the data available on the dashboard.

A carbon accounting workshop was organised at the Catholic Chancery in Armidale in November 2023, to teach attendees on how to use the Sheep and Beef GHG Accounting framework (SB-GAF) to make a whole of farm carbon account for their own property. Ian Blackwood facilitated the workshop. Ian has a career of 30 years with NSW DPI as beef cattle officer and formed his own business in 2011, Industry Beef Consulting). The event was attended by 13 people, of whom four were core participants, from four different properties. One of the main feedback points given during and after the workshop, was the view that the models currently are highly reliant on 'estimates' for inputs (e.g. assessment of seasonal weights and growth rates) and the lack of rules on how to use the model to get consistent results. The need for a considerable amount of input data and the time-consuming nature was perceived to be a barrier to the use of the carbon accounting tools.

PRECISION PASTURES

mla MEAT & LIVESTOCK AUSTRALIA

Carbon Accounting Workshop

Learn how to prepare an initial carbon account for a grazing business

Topics:

- What is a carbon account?
- Why Is it important?
- How to build a carbon account?
- What do the outcomes mean?

Facilitator: Ian Blackwood, Industry Beef Consulting

16th November 2023

8:30am - 4:30pm

Lunch and morning tea provided

Location: *I'll double check room name* 3/131 Barney Street, Armidale NSW 2350

For catering purposes, please RSVP by Thursday 9th November, email: jori@precisionpastures.com.au or phone/text: 04 90 159 627

4.9.1.5 Year 2024

In May 2024, a field walk was organised at Urandangie. The event had two main areas of focus. The first was presenting project results and explaining how to make best use of the data collected throughout the project (presented by Precision Pastures personnel). The second part was presented by Jamie-Lee Edwards (UNE), who organised a workshop on how to assess pasture and feed availability in the paddock, and who held a presentation on the use of Ag360 as a tool to make feed budgets and get seasonal predictions of climatic conditions and pasture growth. The main goal of the field day was to give participants the tools to make well-informed, early farm management decisions around grazing. There was a total of 13 attendees, of whom seven were core participants. The discussion at the end of the field day highlighted the participant's interest in gaining more skills in pasture assessment and feed budgeting and attendees would have liked more time in the paddock to practice these skills. Furthermore, we found a divide between the participants actively checking the online dashboard which collects the project's data (soil moisture, rainfall, NDVI), comparing their results to that of other farms, or comparing their results this year compared to last year's results, and those participants who did not check or make use of the dashboard. Although most participants checked the data dashboard regularly at the start of the project, the interest waned for some participants, after a while. This was related to: technical issues meaning participants could not access data, participants changing phones/ computers and losing access to the dashboard, and dependent on how important the data was to the individual participant.

4.9.1.6 Year 2024

On 14th November 2024, a breakfast meeting was conducted in Armidale to present the final report for the project. The event was attended by a total 80 people including core and observer producers and was part of the National Agriculture Day event in Armidale. Milton Curkpatrick representing Precision Pastures, as project co-ordinator presented an overview of the objectives of the project, the methodology, the results and the key findings and insights from the project.

Event attendees also received a keynote address from Michael Crowley, Managing Director of MLA.

4.9.2 Other events

A sub-set of results from this project was presented at three other events:

- A seminar discussing the theme 'Soil carbon – What is it all about?" held in Dubbo, on the 24th of March 2023. A presentation "How to increase soil carbon in livestock production systems" was delivered to approximately 60 attendees.
- The Nature Based Solutions conference in Brisbane, 17th – 19th July 2023. The presentation topic "Soil organic carbon in grazing systems", was delivered to approximately 350 attendees.
- A presentation and Q&A session held in Rockhampton during Beef Week (5th – 11th May 2024), titled 'Challenging the quotes' was attended by approximately 50 industry stakeholders.

4.9.3 Case studies

Four case studies were published on the MLA website and/or in the MLA Feedback Magazine over the duration of the project.

In Autumn 2021, a case study was published on the MLA website on the White participants (https://www.mla.com.au/news-and-events/industry-news/the-right-stocking-rate-starts-with-a-soil-test/), on the advantage of soil testing. Through soil testing, a management plan was developed for fertiliser, gypsum, and lime. The use of a variable rate technology allowed the participants to apply exactly what was required in different areas. Soil testing allowed them to boost their carrying capacity by 25% because of the avoidance of pasture degradation.

In the Autumn 2023 MLA Feedback magazine (page 22), an article was published on this MLA MDC project and on the second MLA PDS project coordinated by Precision Pastures, highlighting SOC levels found in these two projects. One example included was the project site in Ebor, which showed an average increase of SOC levels over the project area of 0.31% annually, over two years. Carbon levels at the Ebor site are higher compared to carbon levels usually found on the Northern Tablelands, due to high rainfall and fertilise basalt soils, leading to many interactions after the publication of the article.

Also in the Autumn 2023 Feedback Magazine was the case study on the Olrich's (page 21), on improved grazing practices and more effective drenching to lower the barber's pole worm burden and provide better nutrition to livestock. Their involvement in the project is to discover whether or how these grazing and animal practices can be influenced by any relationship between soil, livestock production and soil organic carbon.

https://www.flipsnack.com/mlafeedback/meat-livestock-australia-feedback-magazine-autumn-2023/full-view.html /

A case study on Tenterden Station was published in the Winter 2024 MLA Feedback magazine (page 20). It focussed on the increase in livestock productivity achieved by adopting a rotational grazing system based on feed availability, ensuring year-round groundcover, thereby reducing erosion, and enhancing water infiltration on the property.

https://www.flipsnack.com/mlafeedback/meat-livestock-australia-feedback-magazine-winter-2024/full-view.html

4.9.4 Website

In 2023, a webpage dedicated to this MLA project was set-up on the Precision Pastures website (https://www.precisionpastures.com.au/services/research-and-development/). The web page contains the project titles, a summary, a client testimonial, and pictures. The Precision Pastures website also includes an events page, which contains a short description of the events, including the Field Walk Events organised by Precision Pastures (https://www.precisionpastures.com.au/mla-field-walk-pasture-assessment-and-feed-budgeting/).

Table 14: Half-yearly number of visitors on the Precision Pastures website (homepage and on the 'research and development' page).

Webpage	Jul-Dec 2021	Jan – June 2022	Jul – Dec 2022	Jan – June 2023	Jul – Dec 2023	Jan – June 2024	Jul – Nov 2024
Homepage	NA	NA	NA	793	893	835	1070
Research and Development page	NA	NA	NA	465	637	378	538

4.9.5 Social media

The Precision Pastures Facebook and Instagram social media pages were used to promote events, updates and findings related to this MLA project. This social media content schedule has been implemented to support a boost in social media engagement and to drive target audiences to program events, and resources in line with communications objectives. Social media presence increased over time, after the hiring of a Marketing and Communications Lead at the end of 2023 (Table 17). Between July 2021 and July 2024, the reach of Facebook has increased by 261,900 and the reach of Instagram has increased by 50,000.

Table 15: Precision Pastures social media analytics over the duration of the project.

Social media scores	July – Dec 2021	Jan – Dec 2022	Jan – Dec 2023	Jan – Nov 2024
Followers	+51	+170	+122	+123
Posts	20	31	37	88
Content interactions	160	681	764	1,300
Facebook reach	N/A	185,500	147,100	101,800
Instagram reach	N/A	38,300	23,100	7,200

In 2021, the best performing post was on variable rate fertiliser application used on Bald Blair (16th August). This led to a reach of 3,840 and 13 post interactions. In 2022 the most popular posts were a job advertisement and a post on the timing of soil carbon sampling and its influence on SOC levels (respective reach of 1,768 and 714, and 20 and 37 interactions). Best performing posts in 2023 were the promotion of the seminar held in Dubbo, on “Soil carbon – What is it all about” (reach of 1,198 and 10 interactions) and on the presence of Precision Pastures at the Nature Based Solutions conference in Brisbane (reach of 1,554 and 55 post interactions). In 2024, the best performing post was on the expansion of Precision Pastures into the Central West NSW (reach of 1,487 and 23 post interactions).

4.10 Monitoring, Evaluation and Reporting (MER)

4.10.1 Knowledge and skills

At the start of the project, participants were required to complete a pre-project survey, giving scores on knowledge and skill and on their confidence in understanding the inter-relationship between livestock productivity, soil moisture, and SOC. After each event, the attendees were required to give their post-event scores on the same topic.

While a target engagement number of 150 attendees was projected at the start of the project, actual respondents to the feedback surveys from the events were 10 core participants and 16 observer participants. This does not necessarily indicate a level of engagement below the initial target, especially considering attendees at the field days were generally reluctant to fill out survey forms and total attendances were more than 150 people.

Core Participants (10) manage 26,758 ha total area, total 9,410 head cattle and total 5,800 head sheep.

Observer Participants (16) manage 18,434 ha total area, total 8,173 head cattle and total 20,630 head sheep.

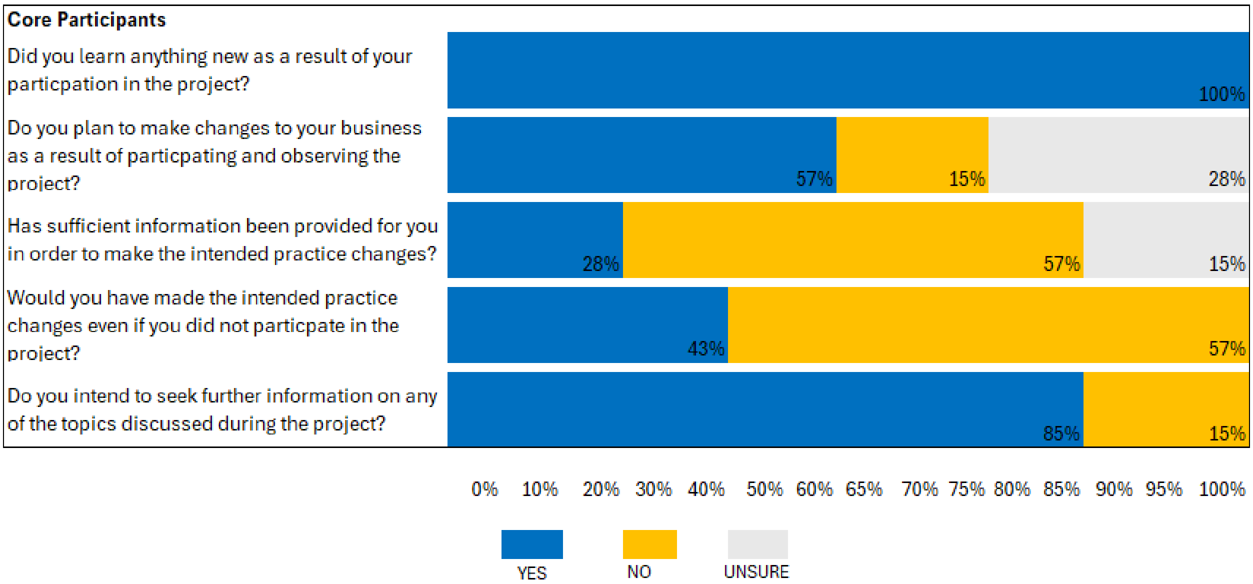
Appendix 8.8 contains the detailed feedback scores given per attendee.

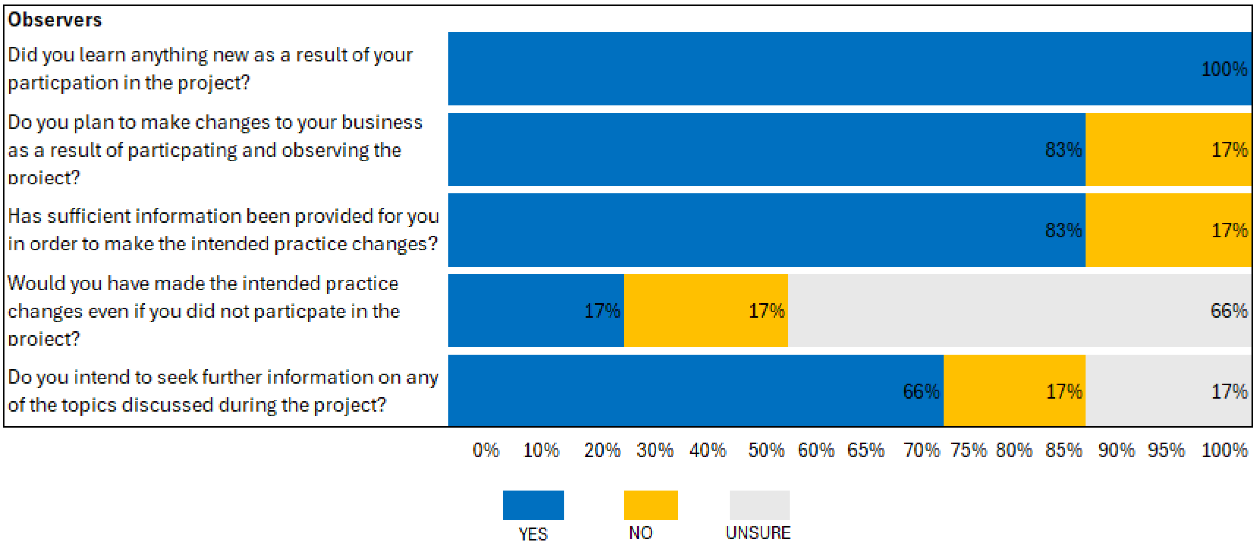
For both knowledge and skills and the confidence scores, results were the lowest at the start of the project. As illustrated in Table 16, there has been a positive uptake of the learnings from the project.

A small snapshot of experiences from core and observer participants included:

- *"Our experience with the project has reinforced that grazing management is a key to managing soil related constraints"*
- *"We are particularly interested in upskilling our team on grazing management"*
- *"Although we have attended a grazing clinic many years ago it's probably time for a refresher"*
- *"We would be interested in learning more about our carbon footprint"*
- *"Obtaining a correlation between production, soil moisture and SOC would help us with a more targeted management approach"*
- *"We need to know more about soil microbes and the influence of what we do above the ground"*
- *"If we don't measure it, we cannot change it"*

Table 16: Summary of core participants and observers' responses to their involvement in the project and project events, and the influence on practice change, the sufficiency of information and the desire to follow-up on topics presented during the life of the project.





4.10.2 Post - event evaluation

The project field days and forums were well attended over the five years duration of the project. Event feedback sheets completed by those who attended (including core and observer participants) these events indicated that the attendees consistently rated the events highly for both satisfaction and value. On average the satisfaction ratings from core participants for achieving greater skills and knowledge at 74% (range 64% in 2020 to 80% in 2024), while observer participants achieved improved from 64% in 2022 to 72% in 2024. Satisfaction ratings for achieving greater confidence for core participants ranged from 64% in 2020 to 81% in 2024. Observer participants satisfaction ratings for confidence levels remained static at ~60%.

Whilst skills and knowledge increased over the 5 years for both core participants and observers, it is understandable that the observer's confidence is static as they were not involved in the actual project.

A snapshot of experiences shared by attendees at the project events:

- Networking and sharing ideas and challenges was extremely valuable.
- Wonderful opportunity to explore the influence of grazing management on production, soil moisture and soil organic carbon although definite answers may be difficult to isolate due to variability.
- A general focus on grazing management and transition from set stocking to increase density and longer rest periods for pastures is a key learning.
- Measuring what we do is important to implement changes.
- Challenging constraints in the region are low soil pH (4.5-5 pH) and low Phosphorus.
- Increased knowledge and appreciation of the impact of soil microbes
- There is a lot more to learn about soil organic carbon and the practices to support its presence and stability.
- Although the technology is good to help guide us, visual assessments are still crucial to day-to-day management decisions.

- As an observer I have realised that I would like to be more involved as a participant next time
- Being involved has opened my mind to looking at diverse ways of supporting production.

5. Conclusion

5.1 Key findings

The project was set up in 2020 to discover the inter relationships within a grazing system of livestock productivity, soil moisture and soil organic carbon. Data collection and analysis as required under the project methodology has clearly indicated the complexity and scale of variability in assessing the results. The levels of variability in soil organic carbon % has been particularly challenging.

SOC % levels are variable within project paddocks and across all project sites. This variability could be attributed to factors including climate variability (rainfall & temperature in particular), organic matter input, soil microbiota, soil nutrient levels and soil types.

Project core participants and other producers did express an interest in how they might adjust their farming activities to influence and mitigate the variability factors in sequestering additional soil organic carbon levels over their properties.

Notwithstanding the above, following is a detailed outline of the key findings of this project:

- The most prevalent feedback from the carbon accounting workshop was the need for more guidelines or regulations to standardise the use of carbon accounting tools. The large amount of data and time-consuming nature of using the SB-GAF carbon accounting tool was identified as a barrier to the adoption. Furthermore, the participants criticised the use of 'estimates' as model inputs (e.g. using the estimated livestock seasonal liveweight, during a 'representative' year), which have a significant impact on the outcome of the carbon account.
- When setting-up a project, there is a need for more consultation with the participants during the pre-project planning process, to ensure the project aligns with participants' objectives and to ensure the intended project set-up fits within the participants' operations. For example, in this project, the participants who already adopted a high intensity / high input grazing system did not set a paddock apart with the low intensity / low input grazing system.
- In this project, no direct link was identified between macrofauna (count and species diversity) and grazing management strategy. Firstly, this was due to the counts being taken at various times of the year in 2023 and 2024, leading to the abundance of varied species. Secondly, the soil could not be extracted to full depth at each site, because of hard soils, meaning the sample sizes could not be compared. In the future, we advise

macrofauna counts be taken when the soil is warm, damp and with good pasture growth, making it easier to take full soil samples.

- The use of a static NDVI telemeter was advantageous as it allowed participants to see real-time NDVI in one delimited location on-farm. However, as this area was delimited (1 – 3 m^2), it was not representative of the remainder of the paddock because of preferential grazing near the probe location. This means that the information from the NDVI static telemeter could not reliably be used to make grazing management decisions. This led to the NDVI results being of least value to participants.
- Crop lower limits (the amount of water in the soil once plants have extracted all the water available to them, after which plants start wilting) could not be identified at 9/19 sites at a soil depth of 50 cm. This was related to these limits not being reached during the project and demonstrates the opportunity for using deep-rooted pasture species, which can access this soil moisture stored at depth and will help in maintaining plant production through dry periods.
- No changes in soil moisture holding capacity were identified during the project. This was related to:
    - The changes in SOC being too small to significantly affect the soil's water holding capacity, and
    - The visual method for identifying the drained upper limits and crop lower limits not being accurate enough to identify a change in drained upper limit or crop lower limit below 1%.
- A fair amount of technical equipment issues and software issues occurred during the project. This shows the need for the development of equipment which is not only suitable for short-term research trials but is also viable in a commercial setting and has a long lifespan. In terms of future demonstration projects, it highlights the need for a good support service from the equipment providers and/or manufactures, to help resolve issues when these occur.
- Fluctuations in carbon levels were identified between years and within years. This emphasizes the need to conduct soil sampling and measure carbon around the same time each year, with the plant/crop being in a similar stage of development to be able to make comparisons between years. The occurrence of a dry spring for example might delay the onset of plant activity and thereby delay the onset of carbon inputs into the soil. When taking soil samples, note should be recorded of the seasonal conditions and plant growth stages. See section 6 for more information.
- During this project, no relationship was identified between livestock grazing intensity and SOC levels because of the presence of many confounding factors (climate, soils, farm management, etc.) and because of the set-up of this project as a demonstration site. Explanation of the requirements to prove or debunk the relationship between SOC levels and grazing management intensity is provided in section 6 (Future research).

5.2 Benefits to industry

This project emphasized the usefulness of soil moisture monitoring to help producers make management decisions (when to buy livestock or feed, or when to sell livestock depending on soil moisture availability for pasture growth). To further expand the usefulness of this tool, it could be utilised with weather forecasts, to predict soil moisture movements. This would allow producers to make earlier grazing management decisions to ensure grazing stocking rates are matched to carrying capacity and feed availability to avoid overgrazing.

Although the static NDVI telemeter provide accurate NDVI readings for a small area within the paddock, greater value may be obtained by using satellite-recorded NDVI, which considers the entire paddock. This will give information on the evenness of pasture growth throughout the entire paddock. However, most services only offer updated NDVI readings every 5 days, indicating it cannot be utilised to make grazing management decisions on a smaller time scale.

Two main outcomes came from the field days. Firstly, producers emphasized their interest in gaining more skills in in-paddock pasture assessment and feed budgeting, to use when making grazing management decisions. This is an area of opportunity to up-skill producers, for example in upcoming projects. Secondly, the lack of rules around the use of carbon accounting tools and the time-consuming nature of using these tools was identified as barriers to their adoption. The use of what participants considered 'estimates' (for example seasonal weight gain for a specific livestock class, during a 'representative' year) and the large implication on the carbon account outcomes of these estimated made producers sceptical about the usefulness of the carbon accounting tools.

6. Future research and recommendations

No livestock weight estimates were provided by participants during this project. This project did not ask participants why they did not record livestock weight, which could be the topic of future research. Ways around getting livestock weight estimates from participants could be the following:

- Using an automated, in-paddock weighing system such as the Optiweigh (https://www.optiweigh.com.au/). It gives real-time cattle liveweight information and is stress-free for livestock. It does however require a substantial upfront cost for the purchase of the device, and it requires labour by the participant to move the scale along with the livestock to get continuous livestock weight estimates.
- The use of phone apps, such as for example 'Agroninja beefie' (https://agroninja.com/) could be considered. These apps give a livestock weight estimate based on breed, sex and age and based on a 3D photo of the livestock made with a mobile phone. This method is stress free for the livestock but requires producers to regularly take pictures of their livestock.

The moisture probes were robust compared to the remainder of the equipment installed in the paddocks. The information recorded by the moisture probes was also to value to participants to understand soil moisture movements over time and through the soil profile. To make the information more relevant in making short-term and long-term grazing management decisions, the real-time soil moisture information could be utilised with weather forecasts. This would make it possible to make statements such as "it will take X number of days before reaching the crop lower limit, it might be worth considering selling stock or buying feed", or "although soil moisture levels are low, rainfall is predicted and there is no need to consider selling stock or buying feed".

To get more value out of the static NDVI telemeters, more frequent pasture cuts may have been taken, with the sample being divided into green and dry biomass before drying and weighing. This would have allowed to determine seasonal relationships between NDVI and pasture growth, for each soil type and pasture species combination. Taking pasture height measurements could also have improved the estimation of pasture biomass based on NDVI, as pasture height records have been identified to improve green dry biomass estimates compared to NDVI only (Andersson et al. 2017). Linking NDVI to food on offer or pasture biomass would have made this measure more relevant for participants. For future projects, alternative ways of assessing NDVI could be considered as recording NDVI at one static point is not a reliable indicator for the remainder of the paddock (since livestock were attracted by the exclusion cage) and can therefore not reliably be used to make grazing management decisions. An alternative tool could be the use of satellite-derived NDVI data, which covers a paddock or property and measures NDVI on a 10 m grid cell. The frequency of the satellite overpass (usually 5 days) and the presence of clouds limiting NDVI readings are impediments to using this data for grazing management if a high intensity grazing management system is adopted where livestock are moved every couple of days.

Most equipment (except for the soil moisture probes) used in this project did not stand the test of time. There were regular hardware and software issues. There is a need for research and development into on-site monitoring equipment, which is robust, dependable, and viable, in a commercial setting.

This project found fluctuations in SOC levels throughout the year. There is limited knowledge of the topic, and it would be of value to get a better understanding of SOC levels throughout the year, at different soil depths, in cropping as well as in grazing systems.

To determine whether there is a relationship between grazing management intensity and SOC levels, a project consisting of a trial should be set-up, rather than a demonstration site. This project should have the following attributes:

- Set-up with treatment (grazing intensity and inputs) and control zones, to reduce the confounding factors of spatial heterogeneity (soils), farm management and climate, whilst also introducing new activities which should impact the carbon input and output balance,
- Adoption of one consistent method for analysing SOC in the laboratory, with the current preferred method being the LECO dry combustion method,
- Adoption of a more strategic and higher density soil sampling method, to increase the statistical power of the sampling design to be able to determine changes in SOC levels, and
- Set-up of a trial of longer duration, to have more time to monitor SOC changes.

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8. Appendix

8.1 EM38 conductivity maps

Conductivity maps made from the EM38 survey for all project sites are located in figures 51 – 61, below.

Figure 51: Conductivity map at Achill, project site 1, with soil sampling locations (red) and probe site location (green).

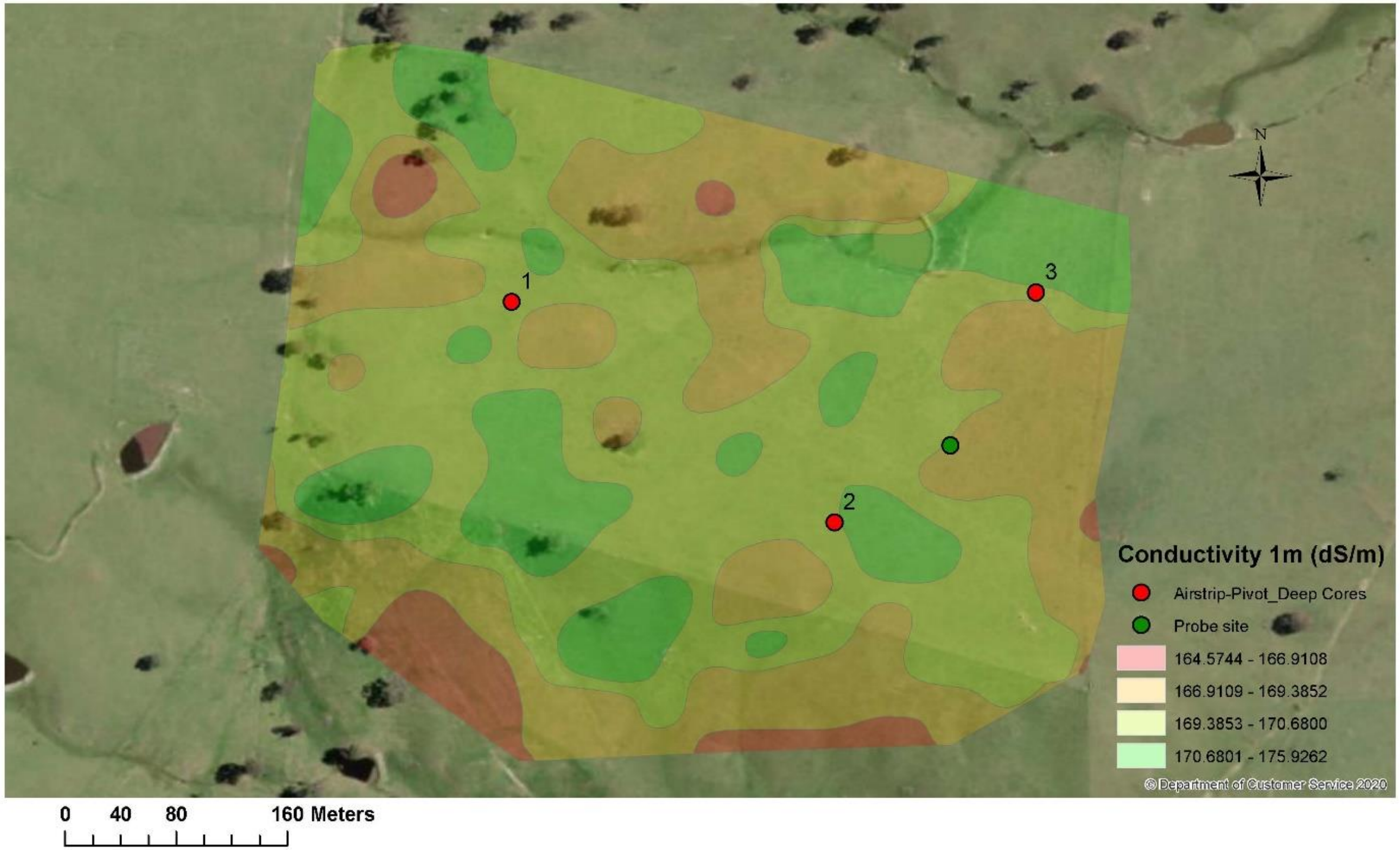


Figure 52: Conductivity map for Achill, project site 2, with soil sampling locations (green) and probe site location (red).

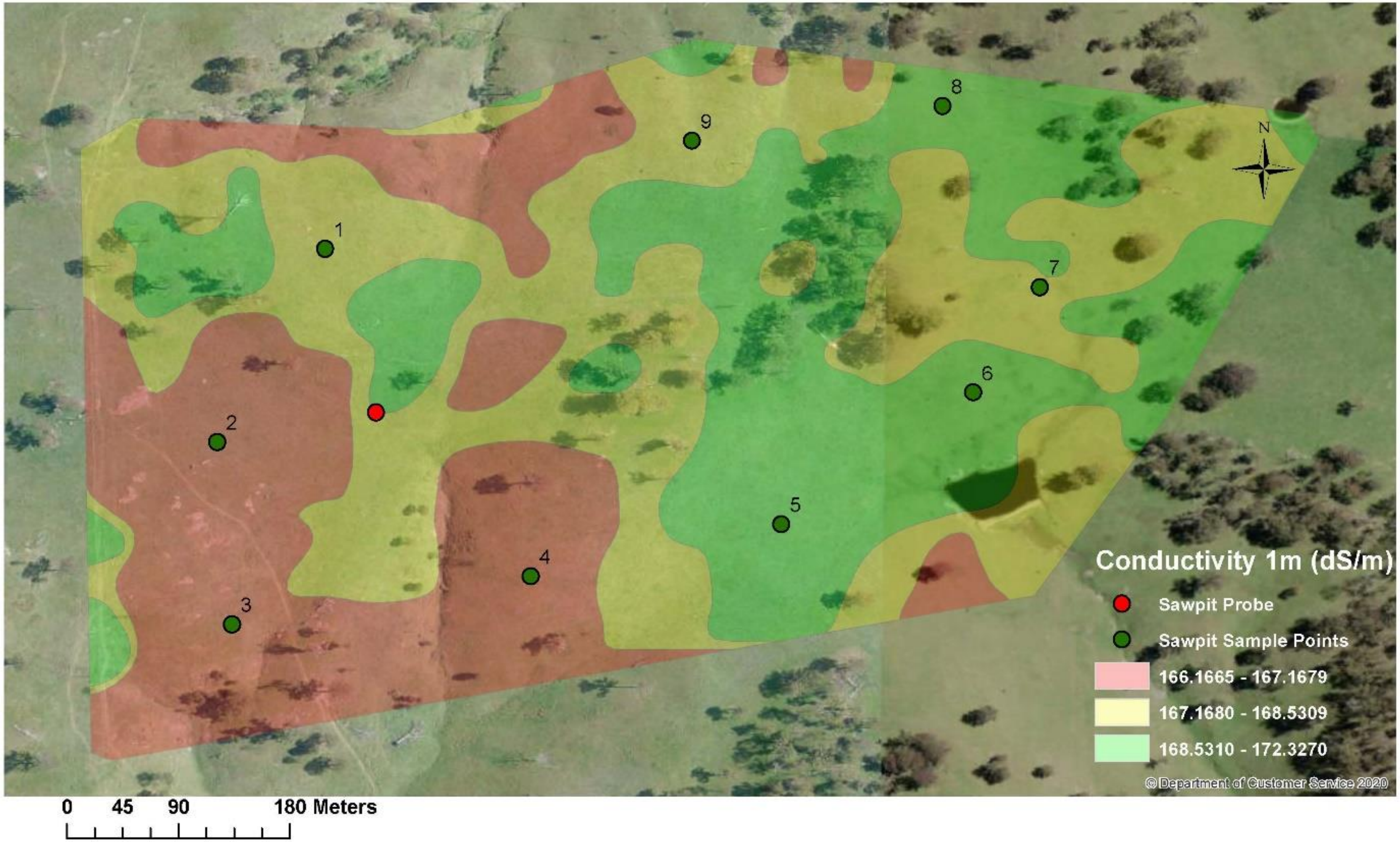


Figure 53: Conductivity map for Argyle, project site 1, with soil sampling locations (purple) and probe site location (green).

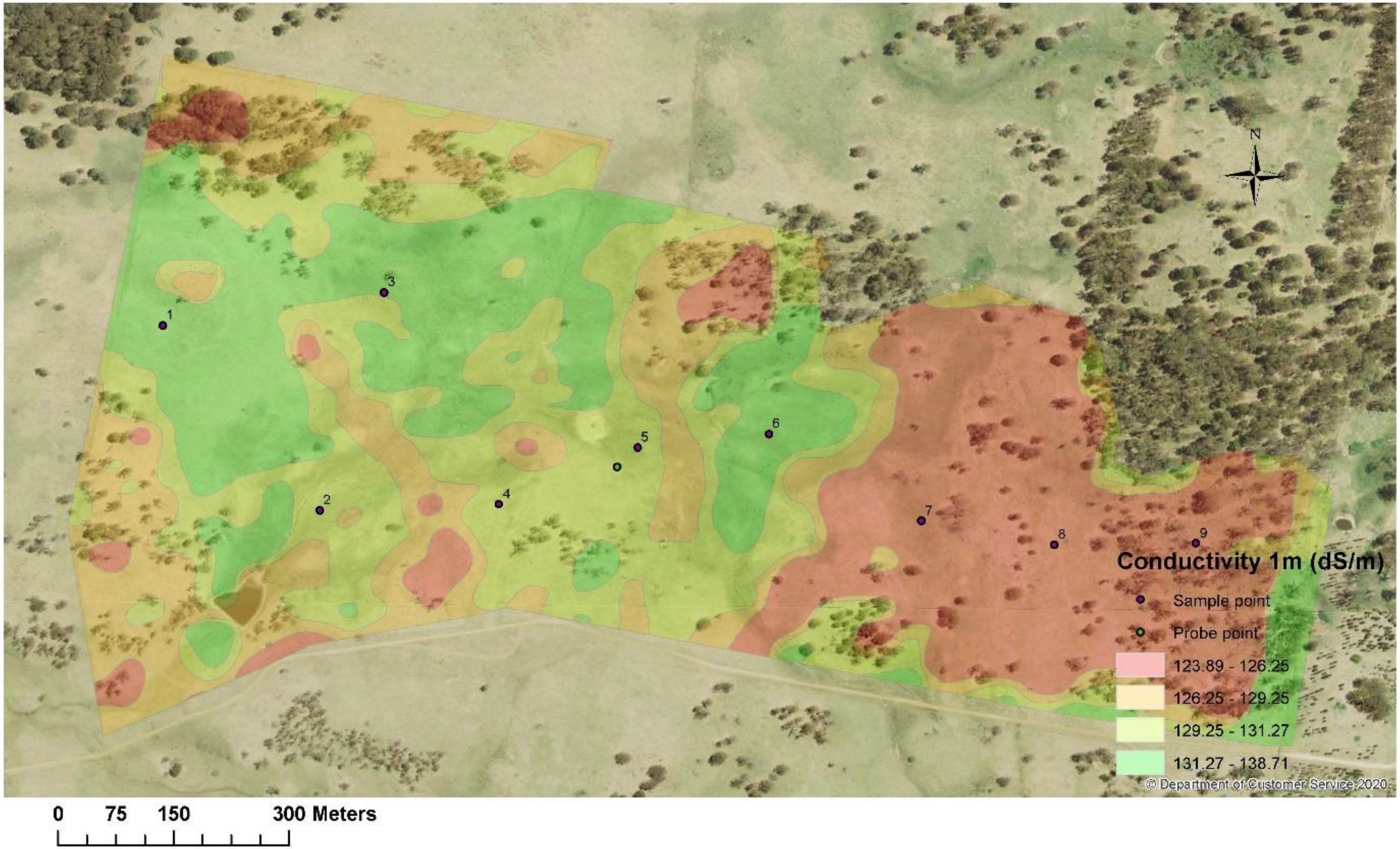


Figure 54: Conductivity map for Argyle, project site 2, with soil sampling sites (purple) and probe site location (green).

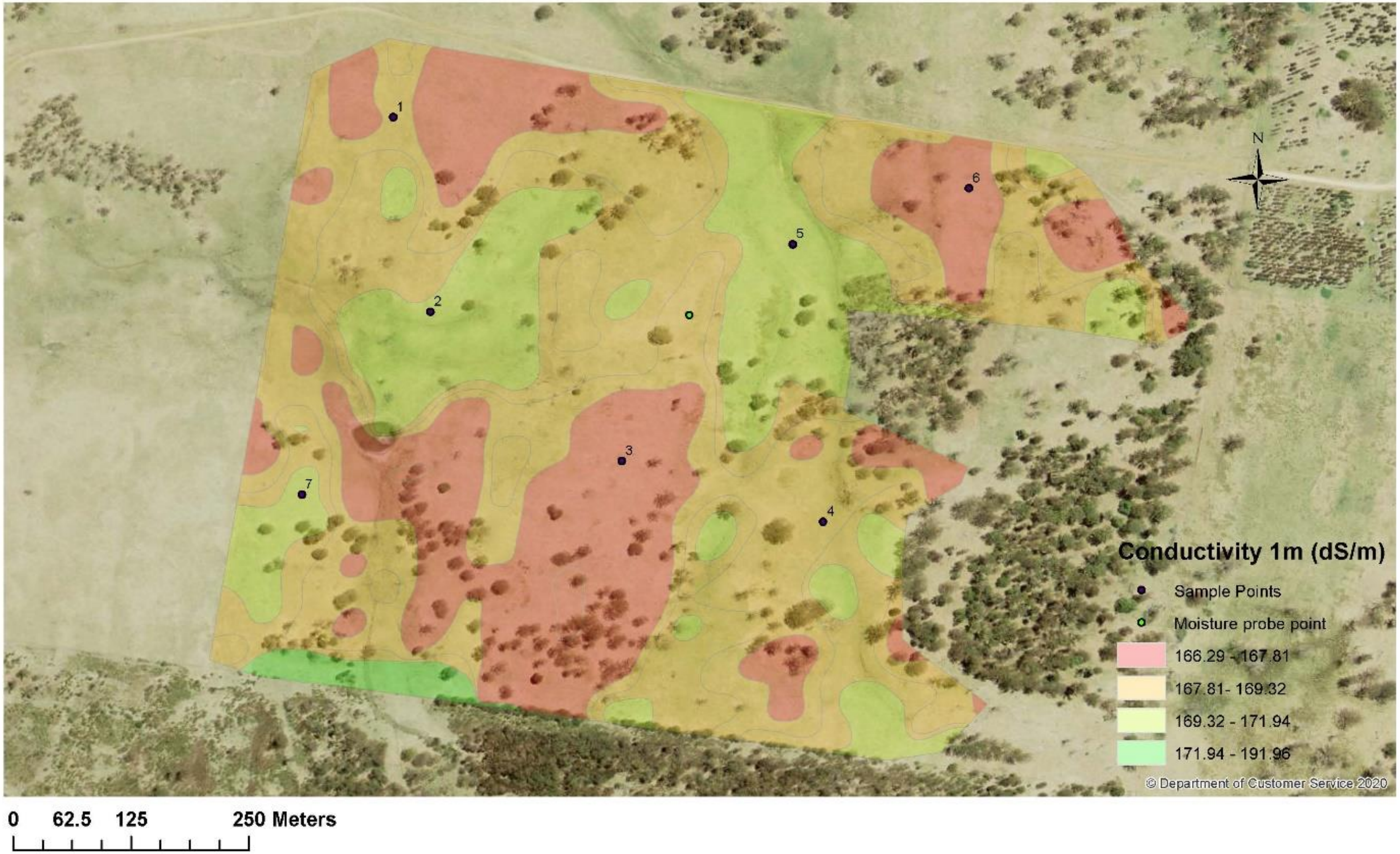


Figure 55: Conductivity map for Bald Blair, with soil sampling sites (purple) and probe site locations (red).

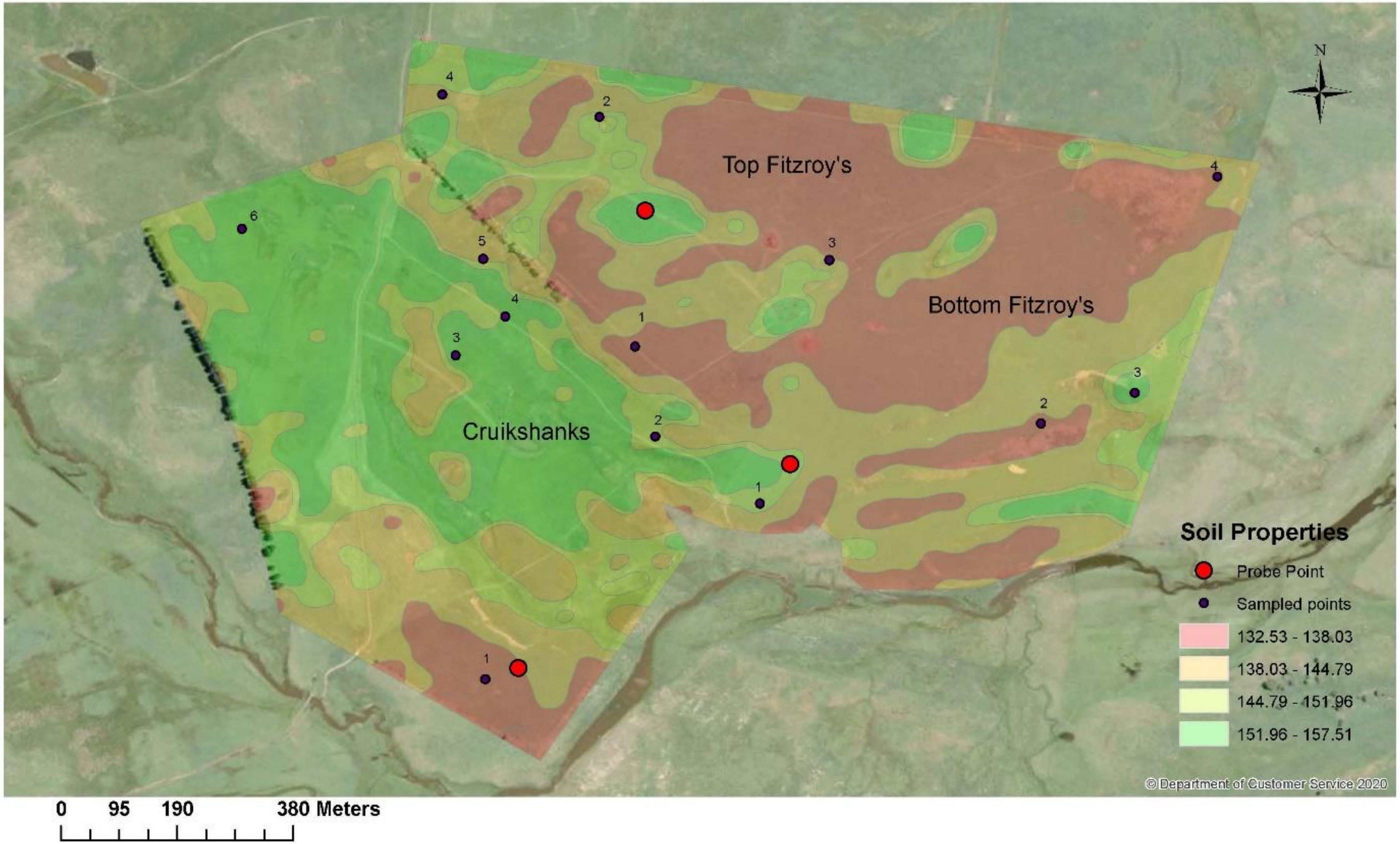


Figure 56: Conductivity map for Cooringoora, with soil sampling locations (purple) and probe site location (red).

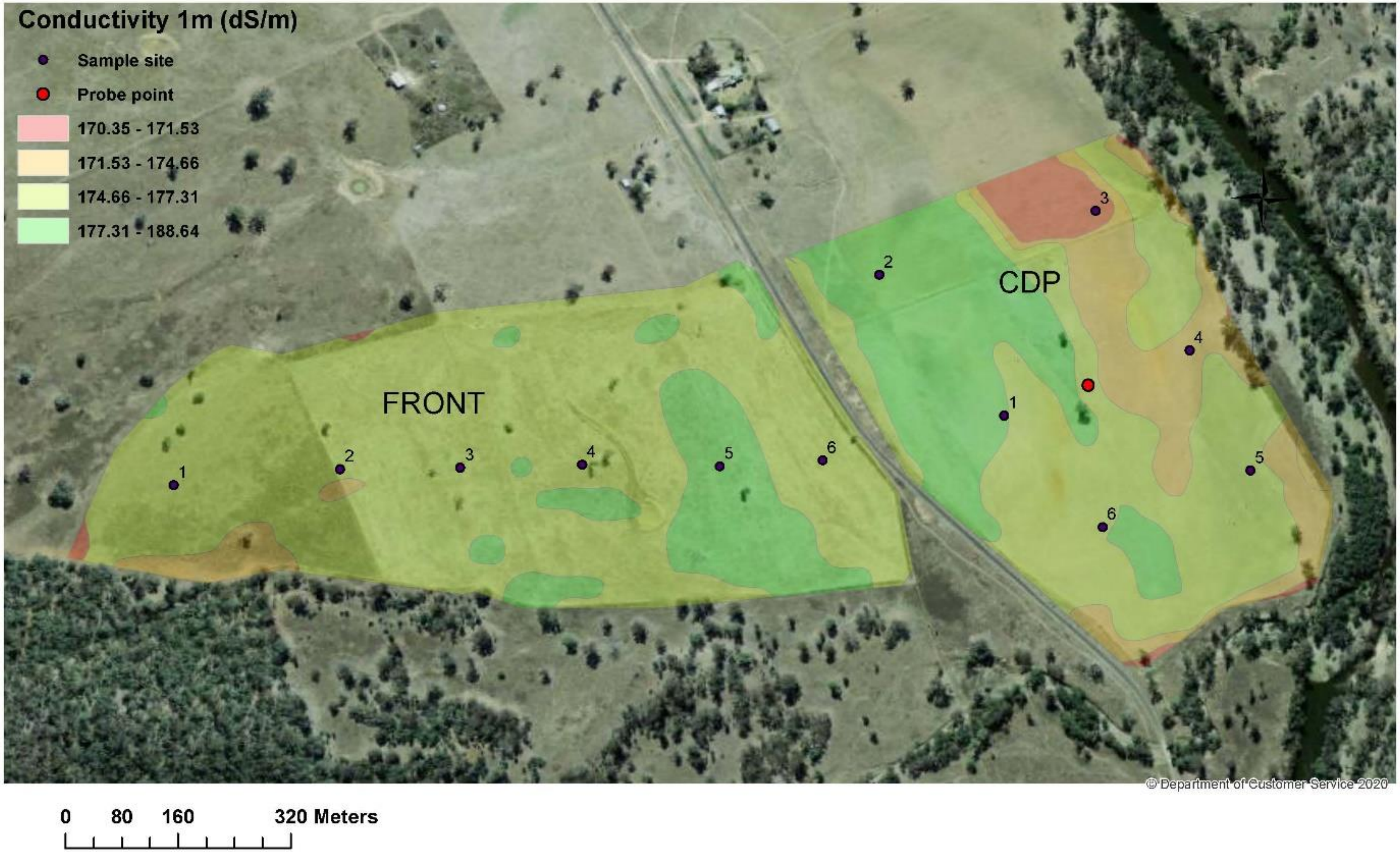


Figure 57: Conductivity map for Glenview, with soil sampling locations (purple) and probe site locations (green).

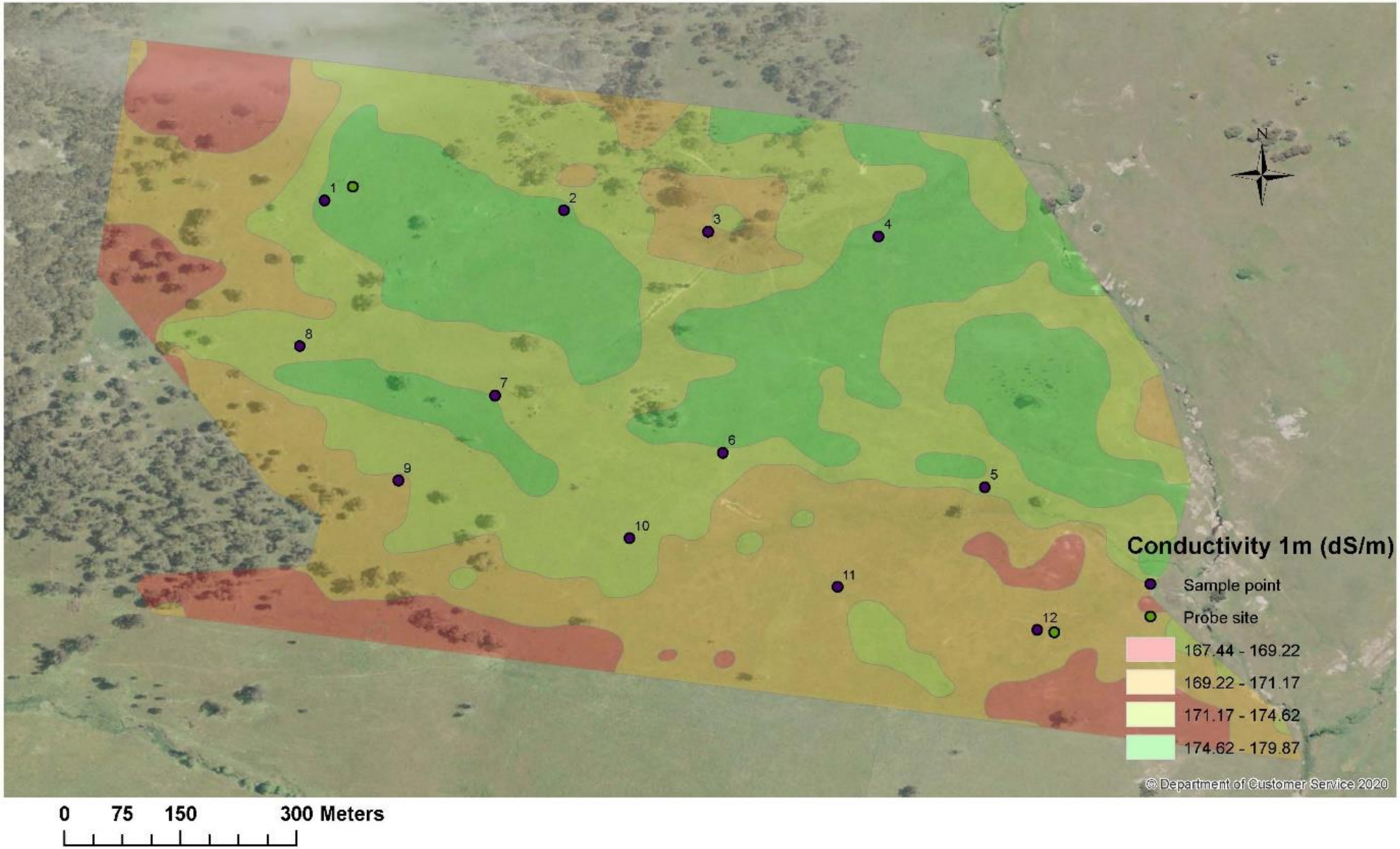


Figure 58: Conductivity map for Leaderville, with soil sampling locations (purple) and probe site locations (red).

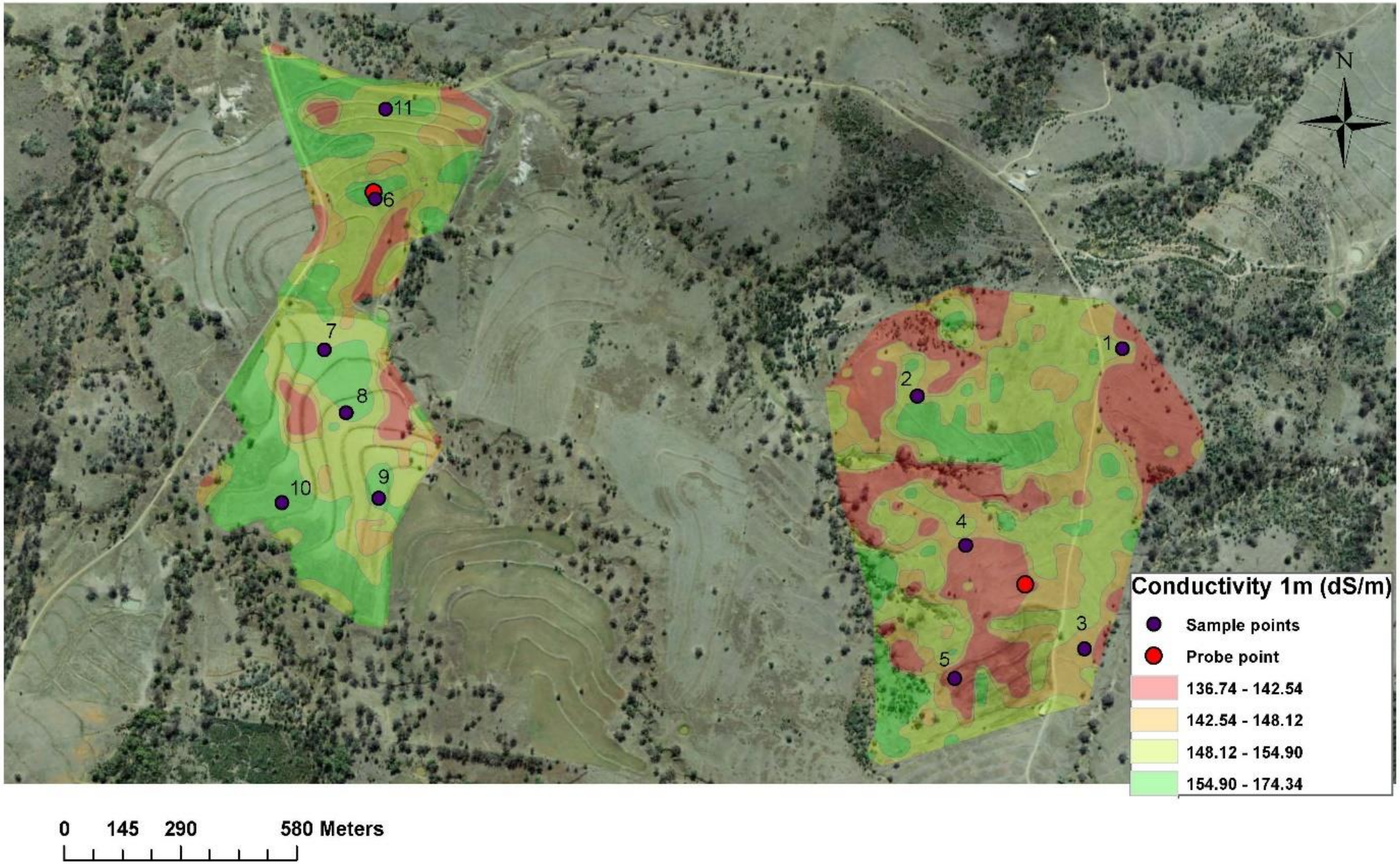


Figure 59: Conductivity map for Myanbah, with soil sampling locations (blue) and probe site locations (purple).

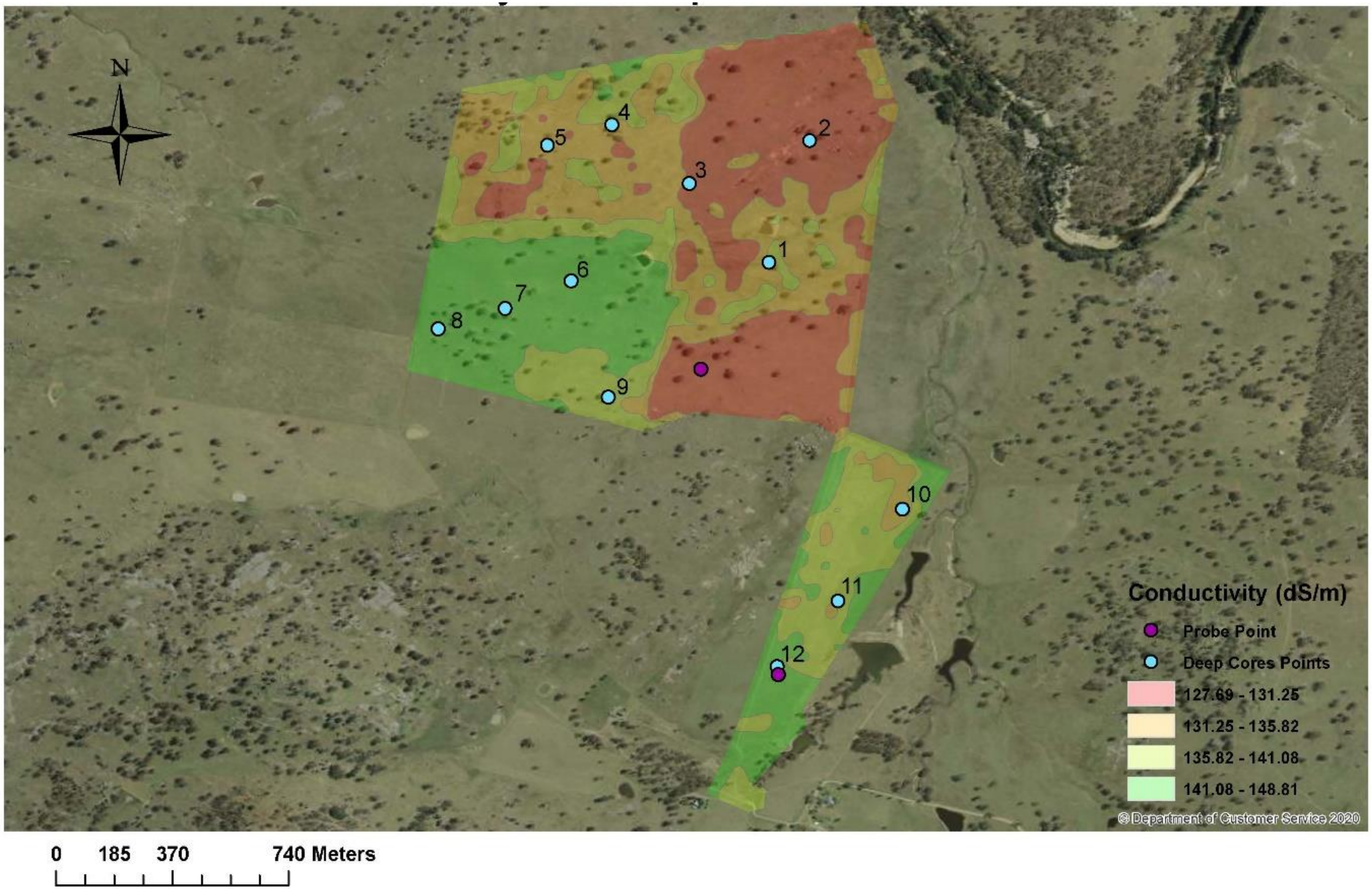


Figure 60: Conductivity map for Tenterden, with soil sampling locations (purple) and probe site locations (red).

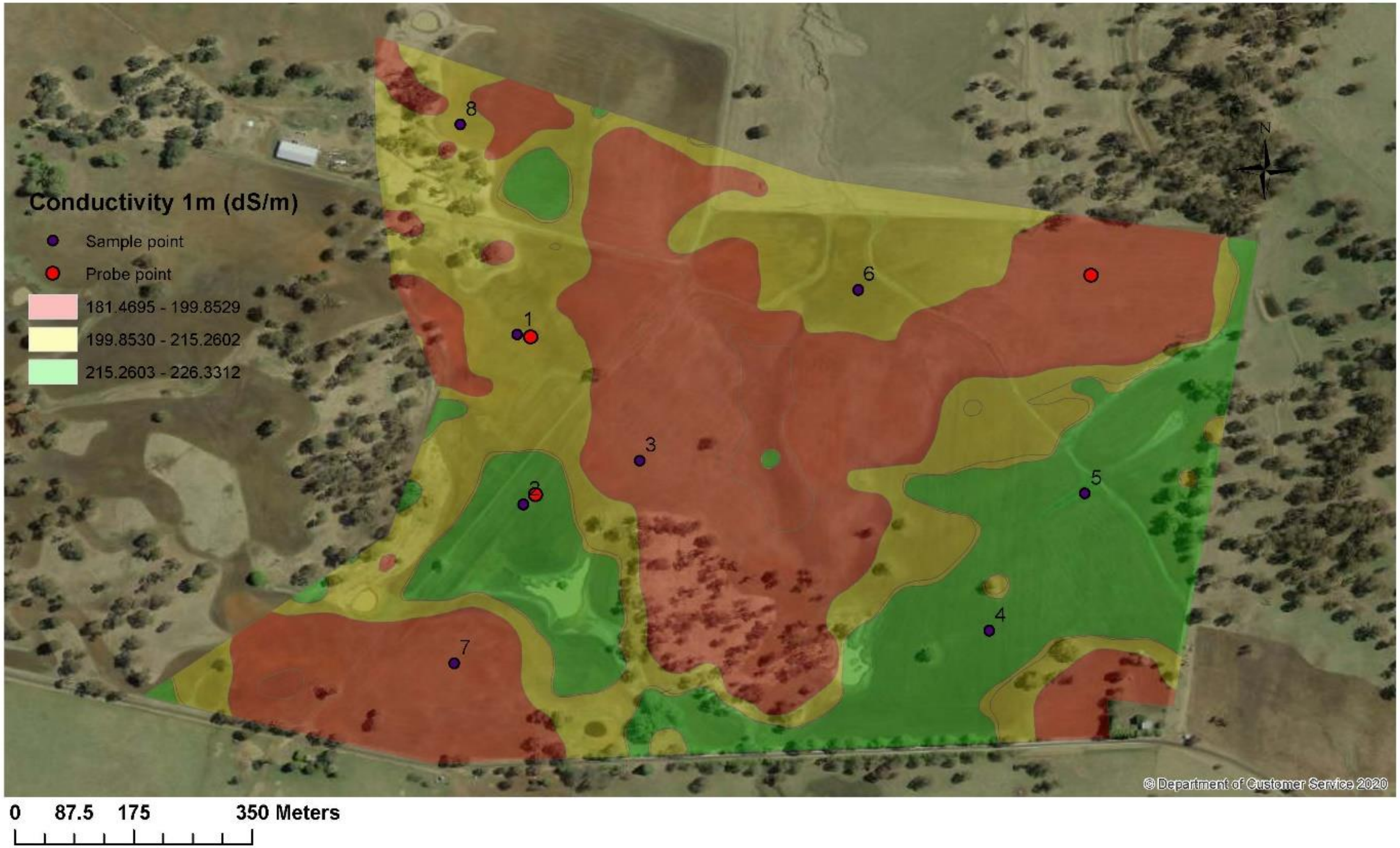
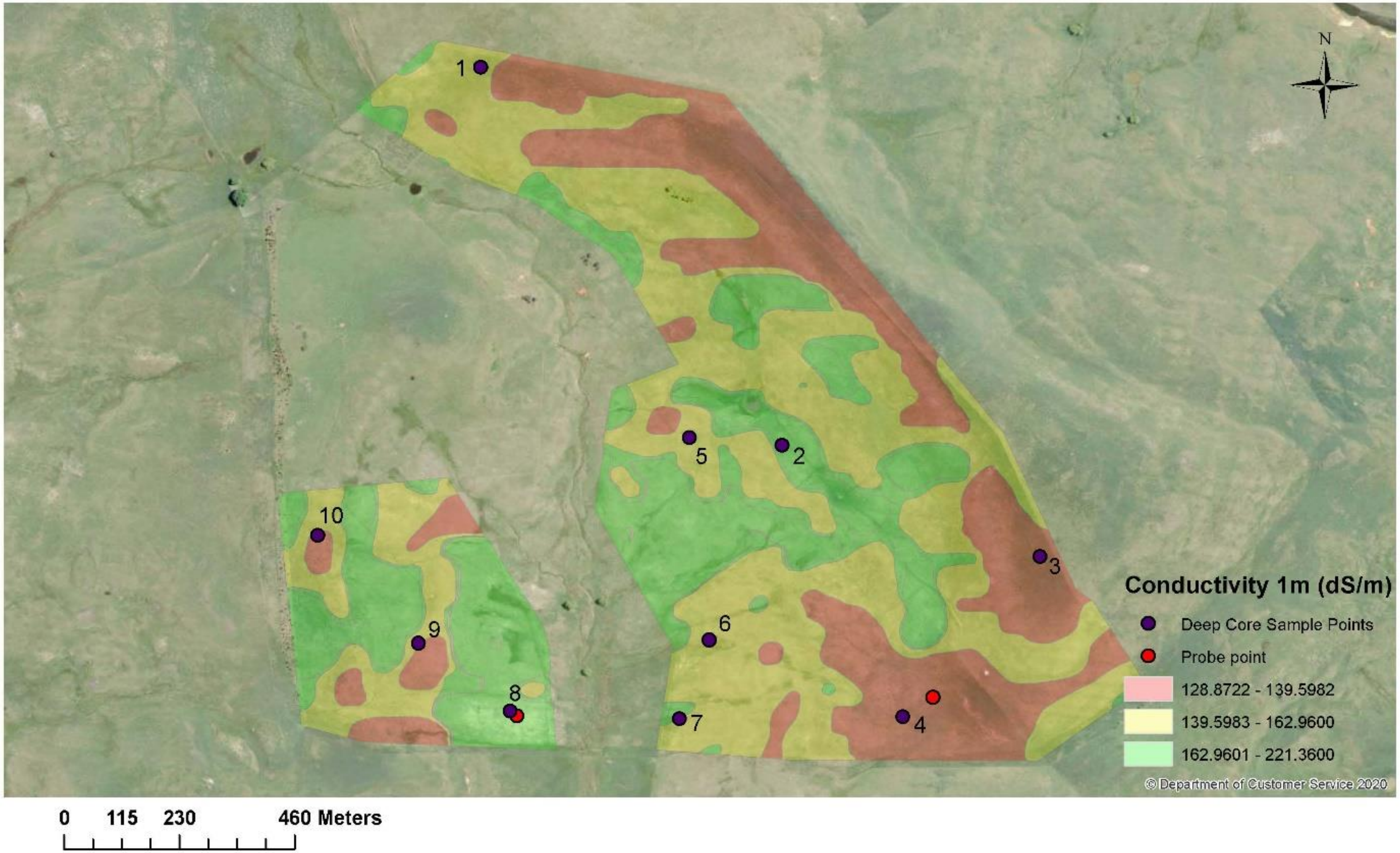


Figure 61: Conductivity map for Urandangie, with soil sampling locations (purple) and probe site locations (red).



8.2 Soil test results 2020 - 2023

Tables below (18 – 27) contain the results from soil testing conducted in 2020, 2022 and 2023, for each property. Several different laboratory methods for testing soil organic carbon were used (Walkley and Black (W&B), Dumas, LECO and Mid-infrared scanning).

Table 18: Soil test results for Achill, 2020 – 2023.

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Airstrip	Airstrip1	0-10	2020	October	4.84	38	2.63					
			2022	October	6.62	88	4.17					
			2023	October	6.31	89					2.55	2.01
		10-30	2020	October	4.77	11		0.73				
			2022	October	6.07	29	1.55					
			2023	October	5.21	6.5				0.4		
		30-60	2020	October	4.46	<5		0.43				
			2022	October	5.99	22	1.03					
			2023	October	5.09	<5.0				<0.20		
Airstrip	Airstrip2	0-10	2020	October	5.2	64	2.71					
			2022	October	5.57	58	3.23					
			2023	October	5.98	28			2.53			
		10-30	2020	October	4.71	12		1.08				
			2022	October	4.92	24	1.55					
			2023	October	4.83	6.5			0.91			
		30-60	2020	October	4.87	<5		0.39				
			2022	October	4.67	11	0.83					
			2023	October	5.21	<5.0				<0.20		

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Airstrip	Airstrip3	0-10	2020	October	4.68	50	2.95					
			2022	October	5.74	51	3.56					
			2023	October	6.38	79				2.25		
		10-30	2020	October	4.43	7		1.12				
			2022	October	5.25	23	1.52					
			2023	October	5.48	<5.0				0.4		
		30-60	2020	October	5.04	<5		0.6				
			2022	October	4.94	9	0.69					
			2023	October	6.4	<5.0			0.32	<0.20		
		60-90	2020	October				0.3				
Airstrip	AirstripProbe	0-10	2020	October	4.73	41	2.46					
		10-30	2020	October	4.81	15		1.43				
		30-60	2020	October	5.05	<5		0.47				
Racecourse	Racecourse01	0-10	2020	October	5.07	32	2.87					
		10-30	2020	October	5.23	6		1.13				
		30-60	2020	October	5.47	<5		0.49				
Sawpit	Sawpit01	0-10	2020	October	4.82	41	3.91					
			2022	October	4.6	12	4.42					
			2023	October	4.56	20				3.89		
			2020	October	4.84	<5		1.32				
			2022	October	4.84	<5	1.49					
		10-30	2023	October	4.96	<5.0			1.03			
		30-60	2020	October	4.11	<5		0.46				
			2022	October	4.89	<5	0.6					
			2023	October	4.78	<5.0			0.26	0.21		

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Sawpit	Sawpit01	60-90	2020	October				0.28				
Sawpit	Sawpit02	0-10	2020	October	4.71	28	4.71					
			2022	October	4.82	32	7.04					
			2023	October	4.58	44			7.73	7.16		
		10-30	2020	October	4.89	6		1.23				
			2022	October	4.74	7	2					
			2023	October	4.66	12			4.25			
		30-60	2022	October	4.81	<5	1.14					
			2023	October	4.9	<5.0			0.42	0.4		
		60-90	2023	October	4.88	<5.0			0.26	0.31		
Sawpit	Sawpit03	0-10	2020	October	4.64	22	4.29					
			2022	October	4.83	14	5.97					
		10-30	2020	October	5.02	<5		1.52				
			2022	October	4.99	<5	3.59					
		30-60	2020	October	4.98	<5		0.33				
			2022	October	5.04	<5	2					
Sawpit	Sawpit04	0-10	2020	October	4.65	43	4.57					
			2022	October	4.56	96	6.53					
			2023	October	4.46	54				5.34		
		10-30	2020	October	4.8	<5		1.07				
			2022	October	4.5	19	1.89					
			2023	October	4.46	5.3			1.16	0.8		
		30-60	2020	October	4.25	<5		0.46				
			2022	October	4.42	<5	0.68					
			2023	October	4.17	<5.0			0.31	<0.20		

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Sawpit	Sawpit04	60-90	2020	October				0.35				
Sawpit	Sawpit05	0-10	2020	October	4.94	16	1.92					
			2022	October	4.92	27	3.26					
			2023	October	4.75	23				4.75		
		10-30	2020	October	4.97	<5		0.58				
			2022	October	4.99	8	1.3					
			2023	October	4.99	<5.0				0.79		
		30-60	2020	October	4.85	<5		0.29				
			2022	October	4.93	<5	0.65					
			2023	October	4.5	<5.0				0.27		
Sawpit	Sawpit06	0-10	2020	October	4.61	30	5.62					
			2022	October	4.65	16	3.44					
			2023	October	4.87	35			10.3	9.49		
		10-30	2020	October	4.77	<5		1.49				
			2022	October	4.75	5	1					
			2023	October	4.78	<5.0			1.98	1.73		
		30-60	2020	October	4.69	<5		0.37				
			2022	October	4.82	<5	0.59					
		30-60	2023	October	4.29	<5.0			0.59	0.49		
		60-90	2020	October				0.2				
			2023	October	4.22	<5.0			0.36	0.34		
Sawpit	Sawpit07	0-10	2020	October	4.69	34	5					
			2022	October	5.08	23	4.37					
			2023	October	4.85	15				5.15		
		10-30	2020	October	4.8	<5		1.64				
			2022	October	5.06	6	2.27					

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Sawpit	Sawpit07	10-30	2023	October	5.13	<5.0				0.92		
		30-60	2020	October	4.14	<5		0.53				
			2022	October	5.21	<5	2.1					
			2023	October	5.19	<5.0			0.5	0.32		
		60-90	2020	October				0.26				
Sawpit	Sawpit08	0-10	2020	October	4.52	40	5.96					
			2022	October	4.91	21	3.89					
			2023	October	4.61	120			7.68			
		10-30	2020	October	4.77	<5		0.81				
			2022	October	5.41	6	1.57					
			2023	October	4.93	11			1.68			
		30-60	2020	October	4.59	<5		0.43				
			2022	October	5.77	<5	0.63					
		60-90	2020	October				0.4				
Sawpit	Sawpit09	0-10	2020	October	4.6	19	4.93					
			2022	October	5.1	12	4.39					
			2023	October	4.89	15				2.45		
		10-30	2020	October	4.81	<5		1.41				
			2022	October	5.46	<5	1.89					
			2023	October	4.56	<5.0			0.85	0.52		
		30-60	2022	October	5.87	<5	0.85					
			2023	October	4.4	<5.0			0.26	<0.20		
Sawpit	SawpitProbe	0-10	2020	October	4.53	18	2.78					
		10-30	2020	October	4.46	<5		0.6				
		30-60	2020	October	4.4	<5		0.25				

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Sawpit	SawpitProbe	60-90	2020	October				0.25				

Table 19: Soil test results for Argyle, 2020 – 2023.

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Greenknob	Greenknob1	0-10	2020	September	4.86	39	2.1					
			2023	October	4.94					2.78		
		10-30	2020	September	4.71	39		1				
			2023	October	4.24					1.02		
		30-60	2020	September	4.62	6		0.26				
			2023	October	4.3					0.37		
		60-90	2020	September				0.36				
			2023	October	5.68					<0.20		
Greenknob	Greenknob2	0-10	2020	September	4.22	39	3.85					
			2022	October	4.75	32	3.25					
			2023	October	5.21					3.97		
		10-30	2020	September	4.03	12		2.02				
			2022	October	5.03	16		1.78				
			2023	October	5.13				1.72	1.53		
		30-60	2020	September	4.45	<5		0.55				
			2022	October	5.3	11		1.31				
			2023	October	5.25				1.59	1.33		

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Greenknob	Greenknob2	60-90	2020	September				0.2				
			2023	October	5.34				0.52	0.86		
Greenknob	Greenknob3	0-10	2020	September	5.23	54	3.47					
			2022	October	4.42	18	1.96					
			2023	October	4.68					3.08		
		10-30	2020	September	5.23	37		1.79				
			2022	October	4.39	7		1.04				
			2023	October	4.16					0.96		
		30-60	2020	September	5.38	34		0.85				
			2022	October	4.37	5		0.7				
			2023	October	4.28					0.37		
		60-90	2020	September				0.33				
			2023	October	4.38				0.24	<0.20		
Greenknob	Greenknob4	0-10	2020	September	4.29	15	2.45					
			2022	October	4.48	11	1.69					
			2023	October	4.81					3.38		
		10-30	2020	September	4.22	6		0.89				
			2022	October	4.34	5		0.78				
			2023	October	4.17					0.61		
		30-60	2020	September	4.43	<5		0.47				
			2022	October	4.76	<5		0.29				
			2023	October	4.4				0.36	0.28		
		60-90	2020	September				0.28				
Greenknob	Greenknob5	0-10	2020	September	4.85	67	2.86					
			2022	October	4.54	15	2.36					

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Greenknob	Greenknob5	0-10	2023	October	4.33					3.24		
		10-30	2020	September	4.53	8		0.87				
			2022	October	4.36	5		0.98				
			2023	October	4.13					0.77		
		30-60	2020	September	4.32	<5		0.4				
			2022	October	4.38	<5		0.55				
			2023	October	4.33					0.34		
		60-90	2020	September		40		0.37				
			2023	October	4.42				0.23	0.29		
		90-100	2023	October	4.43				<0.20	<0.20		
Greenknob	Greenknob6	0-10	2020	September	4.51	40	3.82					
			2022	October	4.19	21	3.24					
			2023	October	4.78				5.78	5.69		
		10-30	2020	September	4.15	6		1.42				
			2022	October	4.24	8		1.4				
			2023	October	4.45					1.22		
		30-60	2020	September	4.2	<5		0.33				
			2022	October	4.38	5		0.86				
			2023	October	4.79					0.38		
		60-90	2020	September				0.2				
Greenknob	Greenknob7	0-10	2020	September	4.79	56	6.05					
			2022	October	4.52	16	3.08					
			2023	October	4.99				3.12	3.12		
		10-30	2020	September	4.72	7		1.91				
			2022	October	4.38	8		1.5				

Paddock	**Sample name**	**Soil depth**	**Year**	**Month**	**pH (CaCl2)**	**Colwell Phosphorus**	**Organic Carbon (W&B)**	**Dumas Total Carbon**	**LECO Total Carbon**	**MIR Total Carbon**	**LECO Total Organic Carbon**	**MIR Total Organic Carbon**
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Greenknob	Greenknob7	10-30	2023	October	4.59					1.31		
		30-60	2020	September	6.39	<5		0.44				
			2022	October	4.29	5		0.98				
			2023	October	4.28					0.66		
		60-90	2020	September				0.2				
			2023	October	4.18					0.32		
Greenkonb	Greenknob8	0-10	2020	September	4.5	41	3.51					
			2022	October	4.81	20	2.06					
			2023	October	4.37				8.21			
		10-30	2020	September	4.25	7		1.21				
			2022	October	4.57	6		0.95				
			2023	October	4.42					1.3		
		30-60	2020	September	4.19	<5		0.72				
			2022	October	4.67	<5		0.6				
			2023	October	4.47				0.88	0.72		
		60-97	2020	September				0.29				
Greenknob	Greenknob9	0-10	2020	September	4.56	92	3.14					
			2022	October	4.96	24	1.78					
			2023	October	5.25					2.93		
		10-30	2020	September	4.65	6		1.26				
			2022	October	4.87	15		0.94				
			2023	October	5.17				0.79	0.61		
		30-60	2022	October	4.87	6		0.36				
			2023	October	4.56				0.57	0.5		
		60-90	2023	October	4.3					0.23		

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Wattle	Wattle1	0-10	2020	September	4.65	37	2.33					
			2022	October	4.91	25	1.74					
			2023	October	4.48					2.51		
		10-30	2020	September	4.28	5		1.21				
			2022	October	4.5	8		0.76				
			2023	October	4.35					0.83		
		30-60	2020	September	4.23	<5		0.61				
			2022	October	4.41	<5		0.45				
			2023	October	4.21					0.25		
		60-90	2020	September				0.4				
			2023	October	4.24				0.27			
Wattle	Wattle2	0-10	2020	September	4.51	29	2.79					
			2022	October	4.35	26	2.23					
			2023	October	4.44					2.84		
		10-30	2020	September	4.23	8		0.89				
			2022	October	4.33	20		0.9				
			2023	October	4.45					0.77		
		30-60	2020	September	4.53	<5		0.32				
			2022	October	4.47	9		0.63				
			2023	October	4.52					0.35		
		60-90	2020	September				0.2				
Wattle	Wattle3	0-10	2020	September	4.6	18	1.81					
			2022	October	4.58	20	2.25					
			2023	October	4.81					2.26		
		10-30	2020	September	4.5	<5		0.86				
			2022	October	4.69	10		1.31				

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Wattle	Wattle3	10-30	2023	October	5.17					0.96		
		30-60	2020	September	5.23	<5		0.29				
			2022	October	4.82	6		0.8				
			2023	October	5.36					0.49		
		60-90	2020	September				0.2				
Wattle	Wattle4	0-10	2020	September	4.49	23	2.53					
			2022	October	4.16	27	2.56					
			2023	October	4.39				2.76	2.56		
		10-30	2020	September	4.86	<5		0.61				
			2022	October	4.35	10		0.97				
			2023	October	4.47					0.8		
		30-60	2020	September	4.49	<5		1.18				
			2022	October	4.7	<5		0.39				
			2023	October	4.76					0.38		
Wattle	Wattle5	0-10	2020	September	4.61	32	2.64					
			2022	October	4.39	18	2.24					
			2023	October	4.48					3.18		
		10-30	2020	September	4.41	<5		1.15				
			2022	October	4.49	6		0.99				
			2023	October	4.47					1		
		30-60	2020	September	4.66	<5		0.34				
			2022	October	4.56	<5		0.7				
			2023	October	4.5					0.37		
		60-90	2020	September				0.2				
			2023	October	5.63				<0.20	<0.20		

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Wattle	Wattle6	0-10	2020	September	4.43	50	2.99					
			2022	October	4.44	12	2.02					
			2023	October	4.52				2.72	2.28		
		10-30	2020	September	4.19	27		0.85				
			2022	October	4.48	5		0.93				
			2023	October	4.58					1		
		30-60	2020	September	4.73	<5		0.32				
			2022	October	4.58	<5		0.53				
		60-90	2020	September				0.2				
Wattle	Wattle7	0-10	2020	September	4.47	35	2.5					
			2023	October	4.52					1.59		
		10-30	2020	September	4.34	8		0.82				
			2023	October	4.48					0.71		
		30-60	2020	September	4.54	<5		0.4				
			2023	October	4.61					0.33		
		60-90	2020	September				0.27				

Table 20: Soil test results for Bald Blair, 2020 – 2023.

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Bottom Fitzroy	bottomFitzroy1	0-10	2020	August	5.06	62	2.46					
			2022	October	4.91	39	2.95					
			2023	October	4.92	64				3.36		
		10-30	2020	August	5.03	33		1.7				
			2022	October	4.87	27		2.09				
			2023	October	4.93	34				1.58		
		30-60	2020	August	5.13	55		0.76				
			2022	October	4.96	39		1.68				
			2023	October	5.11	100				0.98		
		60-90	2020	August				0.47				
			2023	October	5.32	64				0.92		
Bottom Fitzroy	bottomFitzroy2	0-10	2020	August	4.8	56	2.77					
			2022	October	4.84	63	3.36					
			2023	October	4.94	120				3.91		
		10-30	2022	October	5.25	45		1.96				
			2023	October	5.13	47				1.27		
		30-60	2023	October	5.42	43			0.68	0.9		
Bottom Fitzroy	bottomFitzroy3	0-10	2020	August	4.8	71	2.61					
			2022	October	5.14	31	2.44					
			2023	October	5.16	110			3.39	3.52		
		10-30	2020	August	5.22	29		1.16				
			2022	October	5.01	19		1.8				
			2023	October	5.29	28			0.93	0.72		

Paddock	**Sample name**	**Soil depth**	**Year**	**Month**	**pH (CaCl2)**	**Colwell Phosphorus**	**Organic Carbon (W&B)**	**Dumas Total Carbon**	**LECO Total Carbon**	**MIR Total Carbon**	**LECO Total Organic Carbon**	**MIR Total Organic Carbon**
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Bottom Fitzroy	bottomFitzroy3	30-60	2020	August	5.62	64		0.69				
			2022	October	5.15	29		1.23				
			2023	October	5.58	65			0.43			
		60-90	2020	August				0.38				
			2023	October	5.92	40			0.32			
Bottom Fitzroy	bottomFitzroy4	0-10	2020	August	4.99	91	3.57					
			2022	October	4.9	61	3.33					
			2023	October	5.56	110				4.09		
		10-30	2022	October	4.83	34		2.74				
			2023	October	5.19	59			2.99	2.61		
Cruikshanks	cruikshanks1	0-10	2020	August	5.27	65	2.2					
			2022	October	5.2	75	3.03					
			2023	October	4.96	84				2.82		
		10-30	2020	August	5.26	62		1.49				
			2022	October	5.18	47		1.53				
			2023	October	5.03	56			1.06	1.04		
		30-60	2020	August	5.55	80		0.71				
			2022	October	5.39	97		0.89				
			2023	October	5.54	85			0.64			
Cruikshanks	cruikshanks2	0-10	2020	August	4.94	63	4.65					
			2022	October	5.03	54	4.82					
			2023	October	4.94	91				5.38		
		10-30	2022	October	5.06	36		4.26				
			2023	October	5.1	37				3.67		
Cruikshanks	cruikshanks3	0-10	2020	August	4.84	110	4.11					
			2022	October	5	160	4.03					

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Cruikshanks	cruikshanks3	0-10	2023	October	4.65	110				4.96		
		10-30	2020	August	5.3	22		1.78				
			2022	October	5.06	220		4.19				
			2023	October	5.47	17				1.97		
		30-60	2022	October	5	210		3.59				
			2023	October	6.61	17			0.8	0.75		
Cruikshanks	cruikshanks4	0-10	2020	August	4.72	51	3.82					
			2022	October	5.25	40	4.19					
			2023	October	6.31	55				7.19		
		10-30	2020	August	5.05	16		1.96				
			2022	October	5.8	12		2.84				
			2023	October	6.58	7.7				2.34		
		30-60	2022	October	6.38	6		2.2				
			2023	October	6.84	11				0.41		
		60-90	2023	October	6.76	44			0.2	0.24		
		90-100	2023	October	6.69	53			<0.20			
Cruikshanks	cruikshanks5	0-10	2020	August	5.27	210	6.86					
			2022	October	5.18	66	4.7					
			2023	October	5.17	250			7.92	7.31		
		10-30	2023	October	5.16	80				4.23		
Cruikshanks	cruikshanks6	0-10	2020	August	5.8	43	4.24					
			2022	October	5.05	47	4.19					
			2023	October	4.68	95				5.25		
		10-30	2020	August	6.45	7	2.27					
			2022	October	4.91	24		2.32				

Paddock	**Sample name**	**Soil depth**	**Year**	**Month**	**pH (CaCl2)**	**Colwell Phosphorus**	**Organic Carbon (W&B)**	**Dumas Total Carbon**	**LECO Total Carbon**	**MIR Total Carbon**	**LECO Total Organic Carbon**	**MIR Total Organic Carbon**
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Cruikshanks	cruikshanks6	10-30	2023	October	5.43	17				1.51		
		30-60	2020	August	6.92	6		0.71				
			2022	October	5.16	27		1.72				
			2023	October	6.53	6.6				0.53		
		60-90	2020	August				0.33				
			2023	October	7.02	12			<0.20			
Top Fitzroy	topFitzroy1	0-10	2020	August	5.17	84	5.5					
			2022	October	5.09	59	5.17					
			2023	October	5.28	99				4.11		
		10-30	2023	October	5.33	41				2.09		
		30-60	2023	October	5.9	37			0.75			
Top Fitzroy	topFitzroy2	0-10	2020	August	5.49	59	4.43					
			2022	October	4.87	43	3.32					
			2023	October	4.9	100			7.44	7.33		
		10-30	2020	August	5.24	13		2.1				
			2022	October	5.14	28		1.72				
			2023	October	5.6	41				1.75		
		30-60	2020	August	5.86	14		0.73				
			2022	October	5.44	50		1.15				
			2023	October	6.09	75			0.29	0.46		
		60-90	2020	August				0.29				
Top Fitzroy	topFitzroy3	0-10	2020	August	5.02	42	3.68					
			2022	October	4.87	61	4.49					
			2023	October	4.78	51				3.83		
		10-30	2022	October	4.96	38		4.17				

Paddock	**Sample name**	**Soil depth**	**Year**	**Month**	**pH (CaCl2)**	**Colwell Phosphorus**	**Organic Carbon (W&B)**	**Dumas Total Carbon**	**LECO Total Carbon**	**MIR Total Carbon**	**LECO Total Organic Carbon**	**MIR Total Organic Carbon**
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Top Fitzroy	topFitzroy3	10-30	2023	October	5.26	30				1.54		
		30-60	2022	October	5.06	32		3.08				
			2023	October	5.77	25				0.84		
Top Fitzroy	topFitzroy4	0-10	2020	August	4.71	66	4.73					
			2022	October	5.68	140	6.92					
			2023	October	4.51	110			7.06	7.07		
		10-30	2020	August	5.26	21		1.87				
			2022	October	5.59	73		5.15				
			2023	October	5.09	22				2.94		
		30-60	2022	October	5.52	41		2.81				
			2023	October	5.97	28			0.57			

Table 21: Soil test results for Cooringoora, 2020 – 2023.

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
CDP	CDP1	0-10	2020	October		15	1.03					
			2022	October	5.66	28	1.07					
			2023	October	5.16	17				1.27		
		10-30	2020	October	5.25	11		0.96				
			2022	October	6.81	<5		0.7				
			2023	October	6	5.5				0.94		
		30-60	2020	October	6.25	9		0.46				
			2022	October	7.33	<5		0.54				
			2023	October	7.03	<5.0			0.45			
		60-90	2020	October				0.2				
			2023	October	7.39	<5.0				0.25		
CDP	CDP2	0-10	2020	October		13	1.86					
			2022	October	4.43	17	1.39					
			2023	October	4.38	32			1.37			
		10-30	2020	October	4.93	5		0.76				
			2022	October	5.06	7		0.55				
			2023	October	4.7	8.8			0.87	0.83		
		30-60	2020	October	5.58	<5		0.41				
			2022	October	5.82	<5		0.52				
			2023	October	6.8	<5.0				0.54		
		60-90	2020	October				0.28				
			2023	October	7.73	<5.0				0.45		
		90-100	2023	October	7.66	<5.0				0.39		

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
CDP	CDP3	0-10	2020	October		10	1.55					
			2022	October	4.67	37	0.76					
			2023	October	4.77	33				0.93		
		10-30	2020	October	5.21	8		0.53				
			2022	October	5.25	49		0.63				
			2023	October	5.52	45				0.35		
		30-60	2020	October	5.83	<5		0.43				
			2022	October	5.98	59		0.35				
			2023	October	6.22	43				<0.20		
		60-90	2020	October				0.2				
			2023	October	6.27	25				0.23		
CDP	CDP4	0-10	2020	October		29	2.27					
			2022	October	5.16	58	0.93					
			2023	October	4.95	68				1.27		
		10-30	2020	October	5.15	7		0.98				
			2022	October	5.37	29		1.27				
			2023	October	5.43	25			1.04			
		30-60	2020	October	5.63	<5		0.36				
			2022	October	5.51	21		0.84				
			2023	October	5.8	37			0.6			
		60-90	2020	October				0.27				
			2023	October	5.87	69			0.4	0.36		
CDP	CDP5	0-10	2020	October		26	2.41					
			2022	October	4.98	57	0.9					
			2023	October	5.02	83			1.24	1.26		
		10-30	2020	October	4.98	10		0.74				

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
CDP	CDP5	10-30	2022	October	5.7	27		0.75				
			2023	October	5.49	32				0.98		
		30-60	2020	October	5.18	8		0.34				
			2022	October	6.07	27		0.76				
			2023	October	5.98	54				0.61		
		60-90	2020	October				0.25				
			2023	October	6.25	57				0.54		
		90-100	2023	October	6.8	58				0.39		
CDP	CDP6	0-10	2020	October		14	2.23					
			2022	October	5.19	52	1.13					
			2023	October	5.05	62				1.71		
		10-30	2020	October	5.27	5		1.06				
			2022	October	5.66	38		0.88				
			2023	October	5.46	34				0.84		
		30-60	2020	October	5.76	5		0.64				
			2022	October	5.98	42		0.6				
			2023	October	5.92	50				0.62		
		60-90	2020	October				0.43				
Front	Front1	0-10	2020	October		19	1.51					
			2022	October	5.42	8	2.05					
			2023	October	4.91	9.9				1.75		
		10-30	2020	October	5.06	6		0.62				
			2023	October	4.64	<5.0				0.69		
		30-60	2020	October	6.6	<5		0.43				
			2023	October	4.96	<5.0			0.44	0.4		

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Front	Front1	60-90	2020	October				0.38				
Front	Front2	0-10	2020	October		52	1					
			2022	October	5.33	7	1.94					
			2023	October	5.34	22				2.17		
		10-30	2020	October	5.71	17		0.5				
			2023	October	4.74	6.6				0.84		
		30-60	2020	October	6.09	22		0.3				
			2023	October	4.85	5.5				0.44		
		60-90	2020	October				0.2				
Front	Front3	0-10	2020	October		21	1.51					
			2022	October	5.19	7	1.83					
			2023	October	4.9	13				1.68		
		10-30	2020	October	6.74	<5		0.65				
		30-60	2023	October	5.21	<5.0				0.53		
			2020	October	7.44	<5		0.5				
			2023	October	5.84	<5.0				0.31		
		60-100	2020	October				0.31				
Front	Front4	0-10	2020	October		53	1.18					
			2022	October	5.22	5	1.32					
			2023	October	5.47	<5.0				1.21		
		10-30	2020	October	5.92	22		0.84				
			2023	October	4.96	<5.0			0.52	0.54		
		30-60	2020	October	5.78	29		0.54				
			2023	October	5.78	<5.0			0.49			
Front	Front5	0-10	2020	October		67	1.11					

Paddock	**Sample name**	**Soil depth**	**Year**	**Month**	**pH (CaCl2)**	**Colwell Phosphorus**	**Organic Carbon (W&B)**	**Dumas Total Carbon**	**LECO Total Carbon**	**MIR Total Carbon**	**LECO Total Organic Carbon**	**MIR Total Organic Carbon**
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Front	Front5	0-10	2022	October	5.36	9	1.4					
			2023	October	5.39	12				1.73		
		10-30	2020	October	5.51	37		0.95				
			2023	October	5.08	<5.0				0.6		
		30-60	2020	October	6.13	44		0.73				
			2023	October	5.95	<5.0			0.26	0.25		
		60-90	2020	October				0.59				
			2023	October	6.58	<5.0				0.32		
Front	Front6	0-10	2020	October		79	1.39					
			2022	October	4.67	7	0.86					
			2023	October	5.05	6.6			1.02	0.97		
		10-30	2020	October	5.7	44		0.77				
			2023	October	5.19	5.5			0.66			
		30-60	2020	October	6.02	59		0.59				
			2023	October	6.13	<5.0				0.33		
		60-90	2020	October				0.55				
			2023	October	6.27	12				0.29		
Probe	Probe1	0-10	2020	October		76	1.51					
		10-30	2020	October	5.65	16		0.48				
		30-60	2020	October	6.06	23		0.33				
		60-90	2020	October				0.2				
Probe	Probe2	0-10	2020	October		54	1.12					
		10-30	2020	October	5.6	14		0.57				
		30-60	2020	October	5.76	13		0.44				
		60-90	2020	October				0.26				

Table 22: Soil test results for Glenview, 2020 – 2023.

Paddock	Sample name	Depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
DC	DC10	0-10	2020	September	5.75	12	1.89					
			2022	October	5.19	9	1.94					
			2023	October	5.65	6.2				1.29		
		10-30	2020	September	6.47	<5		0.49				
			2022	October	5.74	<5		0.32				
			2023	October	5.31	<5.0				0.28		
		30-60	2020	September	6.77	<5		0.2				
			2023	October	5.41	<5.0			<0.20	0.21		
		60-90	2020	September				0.2				
DC	DC11	0-10	2020	September	4.96	36	2.88					
			2022	October	5.43	19	1.76					
			2023	October	5.33	40				1.27		
		10-30	2020	September	5.33	5		0.32				
			2022	October	5.62	15		0.54				
			2023	October	5.39	18			0.34	0.21		
		30-60	2020	September	5.87	7		0.2				
			2022	October	5.81	38		0.35				
			2023	October	5.82	27			<0.20	<0.20		
		60-90	2020	September				0.2				
DC	DC12	0-10	2020	September	5.35	63	2.24					
			2022	October	5.63	33	1.27					
			2023	October	4.92	31				0.85		
		10-30	2020	September	5.53	5		0.4				

Paddock	**Sample name**	**Depth**	**Year**	**Month**	**pH (CaCl2)**	**Colwell Phosphorus**	**Organic Carbon (W&B)**	**Dumas Total Carbon**	**LECO Total Carbon**	**MIR Total Carbon**	**LECO Total Organic Carbon**	**MIR Total Organic Carbon**
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
DC	DC12	10-30	2022	October	5.55	17		0.53				
			2023	October	5	27				0.2		
		30-60	2020	September	6.2	6		0.2				
			2022	October	5.85	17		0.3				
			2023	October	5.56	13				<0.20		
		60-90	2020	September				0.2				
DC	DC1P	0-10	2020	September	6.22	49	1.61					
			2022	October	5.43	19	1					
			2023	October	5.73	20				1.21		
		10-30	2020	September	5.94	25		0.7				
			2022	October	5.64	6		0.26				
			2023	October	5.84	11				0.35		
		30-60	2020	September	6.34	97		0.27				
			2022	October	5.95	<5		0.2				
			2023	October	6.04	9.4				<0.20		
		60-90	2020	September				0.2				
DC	DC2	0-10	2020	September	5.89	15	1.56					
			2022	October	5.19	9	1.31					
			2023	October	6.72	21			3.69	3.42		
		10-30	2020	September	5.42	5		0.35				
			2022	October	5.19	<5		0.44				
			2023	October	6.76	<5.0				0.41		
		30-60	2020	September	6.39	<5		0.2				
			2022	October	5.52	<5		0.24				
		60-90	2020	September				0.2				

Paddock	Sample name	Depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
DC	DC3	0-10	2020	September	5.33	25	1.45					
			2022	October	5.64	18	1.16					
			2023	October	6.27	26				1.1		
		10-30	2020	September	6.04	8		0.29				
			2022	October	5.79	13		0.37				
			2023	October	5.19	7.3				0.35		
		30-60	2020	September	6.37	30		0.2				
			2022	October	5.86	11		0.2				
			2023	October	5.08	<5.0				0.22		
		60-90	2020	September				0.2				
DC	DC4	0-10	2020	September	6.11	13	1.55					
			2022	October	5.56	9	1.82					
			2023	October	4.67	20				2.17		
		10-30	2020	September	5.62	<5		0.28				
			2022	October	5.25	<5		0.5				
			2023	October	4.62	<5.0				0.38		
		30-60	2022	October	5.91	<5		0.2				
			2023	October	5.52	<5.0			0.24	<0.20		
		60-90	2023	October	5.22	<5.0				<0.20		
DC	DC5	0-10	2020	September	6.12	18	1.65					
			2022	October	4.82	10	1.47					
			2023	October	5.78	8.6				1.8		
		10-30	2020	September	5.47	5		0.33				
			2022	October	5.15	<5		0.57				
			2023	October	5.45	<5.0				0.43		

Paddock	Sample name	Depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
DC	DC5	30-60	2020	September	6.17	<5		0.2				
			2022	October	5.42	<5		0.34				
			2023	October	5.49	<5.0				<0.20		
		60-90	2020	September				0.2				
DC	DC6	0-10	2020	September	5.06	37	1.39					
			2022	October	5.74	6	0.95					
			2023	October	4.75	12				1.61		
		10-30	2020	September	5.79	18		0.28				
			2022	October	6.02	<5		0.28				
			2023	October	4.86	<5.0				0.38		
		30-60	2020	September	5.91	23		0.2				
			2023	October	5.21	<5.0				0.22		
		60-69	2023	October	5.24	<5.0				0.23		
DC	DC7	0-10	2020	September	5.14	14	1.36					
			2022	October	5.56	10	1.3					
			2023	October	5.57	8.3				1.19		
		10-30	2020	September	5.56	<5		0.2				
			2022	October	5.55	<5		0.33				
			2023	October	5.42	<5.0				0.43		
		30-60	2020	September	5.44	<5		0.2				
			2023	October	5.66	<5.0				0.27		
		60-90	2023	October	5.53	<5.0				0.2		
DC	DC8	0-10	2020	September	4.97	42	1.52					
			2022	October	4.98	61	1.2					
			2023	October	5.13	47				1.2		

Paddock	Sample name	Depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
DC	DC8	10-30	2020	September	5.36	11		0.62				
			2022	October	5.07	28		0.45				
			2023	October	5.09	14				0.3		
		30-60	2020	September	5.78	5		0.2				
			2022	October	5.59	13		0.24				
			2023	October	5.48	14			<0.20	<0.20		
DC	DC9P	0-10	2020	September	5.65	22	1.62					
			2022	October	5.15	29	1.35					
			2023	October	5.08	20			1.38	1.1		
		10-30	2020	September	6.01	5		0.31				
			2022	October	5.23	16		0.42				
			2023	October	5.01	5.3				0.25		
		30-60	2020	September	6.51	5		0.2				
			2022	October	5.5	12		0.28				
			2023	October	5.61	8.3				<0.20		
		60-90	2020	September				0.2				

Table 23: Soil test results for Leaderville, 2020 – 2023.

Paddock	SampleName	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Native	12	0-10	2020	April	7.05	18	2.2					
			2022	October	7.05	9	2.4					
			2023	October	6.86	11			2.29	2.11		
		10-30	2020	April	6.78	16	1.58					
			2022	October	7.58	<5		1.56				
			2023	October	7.66	<5.0				1.03	1.01	1.07
		30-60	2020	April	7.67	4	0.49					
			2022	October	7.71	<5		0.92				
			2023	October	7.75	<5.0				0.95	0.76	0.74
		60-90	2020	April	7.08	5	0.78					
			2022	October	7.81	<5		0.7				
			2023	October	7.85	<5.0				1.03	0.34	
Native	17	0-10	2020	April	7.7	26	1.42					
			2022	October	6.98	23	2.02					
			2023	October	7.11	20				1.83	1.52	1.45
		10-30	2020	April	7.77	19	1.27					
			2022	October	7.58	<5		0.95				
			2023	October	7.09	19			0.74			
		30-60	2020	April	7.94	4	0.41					
			2022	October	7.8	<5		0.64				
			2023	October	6.89	15			0.21			
		60-90	2020	April	8.02	5	0.2					
			2022	October	7.94	<5		0.45				

Paddock	SampleName	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Native	17	60-90	2023	October	7.5	<5.0				0.62	<0.25	
Native	18	0-10	2020	April	6.81	84	2.87					
			2022	October	6.36	40	2.12					
			2023	October	6.4	46				2.49		
		10-30	2020	April	6.64	34	1.1					
			2022	October	6.61	24						
			2023	October	6.66	9.9				1.61		
		30-60	2020	April	6.96	22	0.35					
			2022	October	6.77	11						
			2023	October	6.94	7.7			0.41			
Native	19	0-10	2020	April	6.4	53	1.67					
			2022	October	6.41	51	2.21					
			2023	October	6.52	69				3.71		
		10-30	2020	April	6.56	28	0.69					
			2022	October	6.77	6						
			2023	October	6.86	6.6				1.97		
		30-60	2020	April	6.75	14	0.18					
			2022	October	7.11	7						
			2023	October	7.48	<5.0					0.87	1.1
Native	20	0-10	2020	April	6.48	19	1.48					
			2022	October	6.77	25	2.27					
			2023	October	6.42	40				3.13		
		10-30	2020	April	6.47	27	1.61					
			2022	October	6.92	8						
			2023	October	6.64	<5.0				2.04		
		30-60	2020	April	6.65	21	0.97					

Paddock	SampleName	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Native	20	30-60	2022	October	6.96	8						
			2023	October	7.1	6.6				1.74		
		60-90	2023	October	7.41	<5.0					0.27	
Improved	21	0-10	2020	April	5.74	29	0.97					
			2022	October	5.48	17	0.9					
			2023	October	5.39	31				1.4		1.3
		10-30	2020	April	6.59	9	0.57					
			2022	October	6.24	5		0.53				
			2023	October	5.81	<5.0				0.35		
		30-60	2020	April	7.75	2	0.24					
			2022	October	7.63	<5		0.36				
			2023	October	7.57	<5.0					<0.25	0.31
		60-90	2020	April	7.95	2	0.14					
			2022	October	7.8	<5		<0.25				
			2023	October	7.71	<5.0					<0.25	<0.25
Improved	23	0-10	2020	April	5.74	63	0.81					
			2022	October	4.82	65	0.9					
			2023	October	5.94	66			1.46	1.32		
		10-30	2020	April	6.5	36	0.4					
			2022	October	5.94	24						
			2023	October	5.17	37				0.55		
		30-60	2020	April	7.54	11	0.22					
			2022	October	6.68	8						
			2023	October	6.14	12				0.22		
		60-90	2020	April	7.6	11	0.27					
			2022	October	6.87	5						

Paddock	SampleName	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Improved	23	60-90	2023	October	5.88	5.5				0.22		
Improved	24	0-10	2020	April	4.8	49	1.21					
			2022	October	6.03	15	0.92					
			2023	October	5.08	25				1.42		
		10-30	2020	April	4.9	81	1.38					
			2022	October	6.52	6						
			2023	October	5.36	6.6			0.58			0.43
		30-60	2020	April	5.36	50	0.78					
			2022	October	6.49	<5						
		60-90	2020	April	6.77	4	0.04					
			2022	October	6.64	7						
Improved	25	0-10	2020	April	7.25	27	1.76					
			2022	October	7.2	8	1.64					
			2023	October	7.09	9.9			1.61			1.23
		10-30	2020	April	7.06	13	0.85					
			2022	October	7.73	<5		0.89				
			2023	October	7.32	<5.0				0.48		
		30-60	2020	April	7.49	4	0.26					
			2022	October	7.82	<5		0.59				
			2023	October	7.71	<5.0				0.36		0.27
		60-90	2020	April	7.88	1	0.07					
			2022	October	7.87	<5		0.41				
			2023	October	7.8	<5.0			0.82	0.75		
Improved	26	0-10	2020	April	5.58	53	2.05					
			2022	October	5.93	14	1.54					
			2023	October	6.6	13				1.57		1.48

Paddock	**SampleName**	**Soil depth**	**Year**	**Month**	**pH (CaCl2)**	**Colwell Phosphorus**	**Organic Carbon (W&B)**	**Dumas Total Carbon**	**LECO Total Carbon**	**MIR Total Carbon**	**LECO Total Organic Carbon**	**MIR Total Organic Carbon**
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Improved	26	10-30	2020	April	6.23	31	1.49					
			2022	October	7.62	<5						
			2023	October	6.96	<5.0				0.8		
		30-60	2020	April	7.43	7	0.42					
			2022	October	7.83	<5		0.43				
			2023	October	7.39	<5.0			0.77	0.61		
		60-90	2020	April	7.69	2	0.28					
			2022	October	7.87	<5		0.35				
			2023	October	7.68	<5.0						0.56
Improved	27	0-10	2020	April	6.02	58	1.7					
			2022	October	6.22	35	2.05					
			2023	October	6.08	58				2.45		
		10-30	2020	April	6.31	46	1.52					
			2022	October	6.76	8						
			2023	October	6.81	7.7				1.5		
		30-60	2020	April	7.04	27	1.14					
			2022	October	7.61	5		1.21				
			2023	October	7.48	<5.0					1.38	1.37
		60-90	2020	April	7.68	12	0.67					
			2022	October	7.92	<5		0.93				
			2023	October	7.75	5.5				1.25	0.8	
		90-100	2023	October	7.77	12						0.86

Table 24: Soil test results for Myanbah, 2020 – 2023.

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Airstrip	Airstrip10	0-10	2022	October	4.66	36	1.14					
			2023	October	4.89	62			0.91	0.74		
		10-30	2022	October	4.55	19	0.3					
			2023	October	4.76	28				0.38		
		30-60	2023	October	5.55	5.7			<0.20	0.24		
Airstrip	Airstrip11	0-10	2022	October	5.42	45	1.05					
			2023	October	4.9	64				1.04		
		10-30	2022	October	4.59	38	0.38					
			2023	October	4.6	36				0.37		
		30-60	2023	October	6.02	<5.0			0.23			
		60-90	2023	October	6.4	<5.0				0.23		
Airstrip	Airstrip12	0-10	2022	October	4.92	52	0.86					
			2023	October	4.39	47			0.94	0.85		
		10-30	2022	October	4.93	22	0.33					
			2023	October	4.73	14			0.22	0.27		
		30-60	2023	October	6.32	<5.0			<0.20	<0.20		
Oats	Oats1	0-10	2023	October	4.6	36			1.33	1.11		
		0-30	2022	October				0.58				
		10-30	2023	October	5.31	17			0.46	0.38		
		30-60	2022	October				0.2				
			2023	October	5.66	15			0.39	0.28		
Oats	Oats2	0-10	2023	October	4.77	52			1.26			
		0-30	2022	October				0.85				

Paddock	**Sample name**	**Soil depth**	**Year**	**Month**	**pH (CaCl2)**	**Colwell Phosphorus**	**Organic Carbon (W&B)**	**Dumas Total Carbon**	**LECO Total Carbon**	**MIR Total Carbon**	**LECO Total Organic Carbon**	**MIR Total Organic Carbon**
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Oats	Oats2	10-30	2023	October	4.49	36			0.49	0.32		
		30-60	2023	October	5.43	10			0.27	<0.20		
		30-90	2022	October				0.41				
Oats	Oats3	0-10	2023	October	5.47	69				0.67		
		0-30	2022	October				0.32				
		10-30	2023	October	5.24	32				0.25		
		30-60	2023	October	5.16	11			0.21	0.2		
		30-90	2022	October				0.2				
		60-90	2023	October	5.18	6.4			0.23	0.24		
Oats	Oats4	0-10	2023	October	5.45	86				0.91		
		0-30	2022	October				0.65				
		10-30	2023	October	4.78	83				0.36		
		30-60	2023	October	5.97	41			0.33	<0.20		
		30-90	2022	October				0.2				
Oats	Oats5	0-10	2023	October	5.16	54				1.29		
		0-30	2022	October				0.49				
		10-30	2023	October	4.88	9.7			0.35	0.41		
		30-60	2023	October	6.34	<5.0				<0.20		
		30-90	2022	October				0.2				
		60-90	2023	October	6.4	<5.0				0.2		
Oats	Oats6	0-10	2023	October	5.39	77			1.57	1.32		
		0-30	2022	October				0.47				
		10-30	2023	October	4.46	22			0.41	0.43		
		30-60	2022	October				0.2				
			2023	October	5.21	<5.0			<0.20	0.22		

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Oats	Oats6	60-90	2023	October	6.53	<5.0				<0.20		
Oats	Oats7	0-10	2023	October	4.58	66			1.12	1.02		
		0-30	2022	October				0.2				
		10-30	2023	October	4.52	30			0.26	0.38		
		30-44	2023	October	5.2	<5.0			<0.20	0.22		
		30-82	2022	October				0.2				
Oats	Oats8	0-10	2023	October	4.66	54				0.83		
		0-30	2022	October				0.63				
		10-30	2023	October	4.73	33				0.34		
		30-60	2022	October				0.33				
			2023	October	5.74	13			0.2	<0.20		
Oats	Oats9	0-10	2023	October	5.09	54			1.27	1.02		
		10-30	2023	October	5.04	20			0.29	0.37		
		30-60	2023	October	5.68	5.1			<0.20	0.2		
		60-90	2023	October	6.52	<5.0			<0.20	<0.20		

Table 25: Soil test results for Te Dapa, 2020 – 2023.

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Dam North	DamNorth13	0-10	2021	October	4.46	18	2.21					
			2022	September	4.48	14	1.51					
			2023	October	4.42	7.3				1.46		
		10-30	2022	September	4.93	7		0.6				
			2023	October	4.74	5.1			0.42	0.4		
		30-60	2022	September	5.13	6		0.55				
			2023	October	4.77	<5.0				0.27		
Dam North	DamNorth5	0-10	2021	October	4.71	16	2.47					
			2022	September	4.33	47	2.12					
			2023	October	4.68	32				2.79		
		10-30	2022	September	4.6	13		0.83				
			2023	October	4.62	8.5			0.66	0.63		
		30-60	2022	September	4.96	5		0.42				
			2023	October	4.65	<5.0				0.24		
		60-90	2023	October	4.31	<5.0				<0.20		
Dam North	DamNorth7	0-10	2021	October	4.92	21	3.47					
			2022	September	4.82	21	1.91					
			2023	October	4.64	20				3.04		
		10-30	2022	September	4.96	9		0.72				
			2023	October	4.67	<5.0				0.66		
		30-60	2022	September	4.88	5		0.74				
			2023	October	4.95	<5.0				0.33		
Dwyers	Dwyers27	0-10	2021	October	4.61	44	4.46					

Paddock	**Sample name**	**Soil depth**	**Year**	**Month**	**pH (CaCl2)**	**Colwell Phosphorus**	**Organic Carbon (W&B)**	**Dumas Total Carbon**	**LECO Total Carbon**	**MIR Total Carbon**	**LECO Total Organic Carbon**	**MIR Total Organic Carbon**
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Dwyers	Dwyers27	0-10	2022	September	4.32	18	2.01					
			2023	October	5	43			3.67	3.56		
		10-30	2022	September	4.36	9		0.72				
			2023	October	4.98	8			1.09	1		
		30-60	2022	September	4.33	8		0.56				
			2023	October	4.69	<5.0			0.63	0.54		
Dwyers	Dwyers28	0-10	2021	October	4.48	15	2.67					
			2022	September	4.55	23	3.66					
			2023	October	4.65	8.7				2.39		
		10-30	2022	September	4.71	14		2.25				
			2023	October	4.43	5.6				0.66		
		30-60	2022	September	4.69	9		0.91				
			2023	October	4.18	<5.0				0.29		
		60-90	2023	October	4.33	<5.0				<0.20		
Dwyers	Dwyers29	0-10	2021	October	5.01	23	3.18					
			2022	September	4.56	18	1.94					
			2023	October	4.6	10			2.74	2.49		
		10-30	2022	September	4.94	9		0.85				
			2023	October	4.9	5.9				0.6		
		30-60	2022	September	5.55	<5		0.79				
			2023	October	5.25	<5.0				0.26		
Dwyers	Dwyers30	0-10	2021	October	4.43	27	3.34					
			2022	September	4.59	46	5.22					
			2023	October	4.73	19				3.62		
		10-30	2022	September	4.58	12		2.09				

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Dwyers	Dwyers30	10-30	2023	October	4.54	5.1				1.3		
		30-60	2022	September	4.5	8		1.13				
			2023	October	4.26	6.5				0.67		
Dwyers	Dwyers31	0-10	2021	October	4.28	27	2.63					
			2022	September	4.71	20	2.72					
			2023	October	4.42	7.2				1.91		
		10-30	2022	September	4.5	17		1.69				
			2023	October	4.49	<5.0				0.75		
		30-60	2022	September	4.51	10		0.76				
			2023	October	4.43	<5.0			0.29	0.32		
Dwyers	Dwyers32	0-10	2021	October	5.08	35	2.64					
			2022	September	4.75	50	3.82					
			2023	October	4.83	47			2.85			
		10-30	2022	September	5.15	52		1.77				
			2023	October	4.8	44				1.6		
		30-60	2022	September	5.33	47		1.52				
			2023	October	5.6	27			0.54			
Nancy	Nancy3	0-10	2021	October	4.55	41	2.85					
			2022	September	4.49	18	2.38					
			2023	October	4.47	26				2.24		
		10-30	2022	September	4.92	8		1.11				
			2023	October	4.56	7.5				0.79		
		30-60	2022	September	5.36	7		0.76				
			2023	October	4.85	<5.0				0.29		
		60-69	2023	October	4.28	<5.0			0.24			

Paddock	**Sample name**	**Soil depth**	**Year**	**Month**	**pH (CaCl2)**	**Colwell Phosphorus**	**Organic Carbon (W&B)**	**Dumas Total Carbon**	**LECO Total Carbon**	**MIR Total Carbon**	**LECO Total Organic Carbon**	**MIR Total Organic Carbon**
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Nancy	Nancy6	0-10	2021	October	4.25	58	2.24					
			2022	September	4.12	74	2.05					
			2023	October	4.27	47				1.9		
		10-30	2022	September	4.38	28		0.77				
			2023	October	4.31	8.6			1.01	1		
		30-60	2022	September	4.67	12		0.98				
			2023	October	4.51	<5.0			0.45			
		60-90	2023	October	4.67	<5.0				<0.20		
Nancy	Nancy8	0-10	2021	October	4.2	44	2.06					
			2022	September	4.27	18	1.84					
			2023	October	4.19	40				1.76		
		10-30	2022	September	4.42	10		0.79				
			2023	October	4.35	14				0.65		
		30-60	2022	September	4.88	5		0.48				
			2023	October	4.48	<5.0				0.22		
		60-90	2023	October	4.4	<5.0			0.28	0.29		
Top One	TopOne1	0-10	2021	October	5.62	53	2.84					
			2022	September	5.48	52	2.88					
			2023	October	5.61	36			2.6	2.55		
		10-30	2022	September	5.25	20		0.96				
			2023	October	4.88	5.2				0.53		
		30-60	2022	September	4.95	10		0.54				
			2023	October	4.81	<5.0				0.34		
		60-90	2023	October	4.29	<5.0			0.33	0.45		
Top One	TopOne10	0-10	2021	October	5.41	38	3.45					

Paddock	**Sample name**	**Soil depth**	**Year**	**Month**	**pH (CaCl2)**	**Colwell Phosphorus**	**Organic Carbon (W&B)**	**Dumas Total Carbon**	**LECO Total Carbon**	**MIR Total Carbon**	**LECO Total Organic Carbon**	**MIR Total Organic Carbon**
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Top One	TopOne10	0-10	2022	September	5.35	23	2.34					
			2023	October	5.15	29				3.12		
		10-30	2022	September	5.25	12		1.36				
			2023	October	4.94	<5.0			0.71	0.71		
		30-60	2022	September	4.89	11		0.63				
			2023	October	4.88	<5.0				0.28		
Top One	TopOne5	0-10	2021	October	5.63	53	3.63					
			2022	September	5.58	53	3.39					
			2023	October	4.68	15			3.17	2.95		
		10-30	2022	September	5.5	17		1.73				
			2023	October	4.9	<5.0				1		
		30-60	2022	September	5.11	12		0.86				
			2023	October	4.44	<5.0			0.3	0.27		
Top Two	TopTwo10	0-10	2021	October	6.14	31	1.95					
			2022	September	5.1	19	1.79					
			2023	October	4.84	35				2.1		
		10-30	2022	September	4.91	10		0.73				
			2023	October	4.65	6.8				0.66		
		30-60	2022	September	4.77	9		0.59				
			2023	October	4.41	<5.0			0.55	0.47		
Top Two	TopTwo12	0-10	2021	October	5.13	23	2.18					
			2022	September	5.13	26	1.66					
			2023	October	4.68	12				1.69		
		10-30	2022	September	4.85	10		1				
			2023	October	4.74	<5.0				0.65		

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Top Two	TopTwo12	30-60	2022	September	4.97	12		0.55				
			2023	October	5.14	<5.0				0.29		
Top Two	TopTwo8	0-10	2021	October	4.58	29	2.51					
			2022	September	4.7	43	2.91					
			2023	October	4.42	45			2.41	2.21		
		10-30	2022	September	5.13	22		1.27				
			2023	October	4.46	15				0.73		
		30-60	2022	September	5.27	9		0.56				
			2023	October	5.17	<5.0				0.22		

Table 26: Soil test results for Tenterden, 2020 – 2023.

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Schoolhouse	TDC1	0-10	2020	September	5.46	150	4.09					
			2022	September	5.15	32	2.47					
			2023	October	5.09	120			4.9	4.46		
		10-30	2020	September	5.63	98		2.93				
			2022	September	5.7	14		1.64				
			2023	October	5.64	50			1.61			
		30-60	2020	September	6.21	72		1.06				
			2022	September	5.93	11		1.42				

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Schoolhouse	TDC1	30-60	2023	October	6.41	88			0.43			
		60-90	2020	September				0.54				
			2023	October	6.26	140			<0.20			
Schoolhouse	TDC2	0-10	2020	September	5.18	130	3.28					
			2022	September	5.43	74	2.82					
			2023	October	5.62	110				3.98		
		10-30	2020	September	5.88	66		1.45				
			2022	September	5.84	51		2.14				
			2023	October	6.14	40				2.53		
		30-60	2020	September	6.6	25		1.14				
			2022	September	6.3	17		1.64				
			2023	October	6.73	17				1.01		
		60-90	2020	September				0.76				
			2023	October	7.32	14				1.01		
Schoolhouse	TDC3	0-10	2020	September	5.14	45	1					
			2022	September	4.73	36	2.04					
			2023	October	5.19	32			2.34	2.33		
		10-30	2020	September	4.56	58		2.5				
			2022	September	5.11	30		0.7				
			2023	October	5.23	22				1.15		
		30-60	2020	September	5.69	100		0.52				
			2022	September	5.57	42		0.48				
			2023	October	5.43	22				0.44		
		60-90	2020	September				0.34				
			2023	October	5.18	11			<0.20	0.24		

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Schoolhouse	TDC4	0-10	2020	September	5.28	110	3.96					
			2022	September	5.1	120	3.59					
			2023	October	5.75	34				3.4		
		10-30	2020	September	5.24	46		1.84				
			2022	September	5.09	54		2.54				
			2023	October	5.82	7.7				1.56		
		30-60	2020	September	6.06	24		1.38				
			2022	September	5.35	49		1.48				
			2023	October	6.69	<5.0			0.32			
		60-90	2020	September				0.93				
Schoolhouse	TDC5	0-10	2020	September	7.19	23	0.71					
			2022	September	6.02	61	1.8					
			2023	October	5.29	120				3.72		
		10-30	2020	September	6.35	19		1.55				
			2022	September	6.14	49		1.66				
			2023	October	5.49	33				2.29		
		30-60	2020	September	6	58		2.41				
			2022	September	6.68	14		1.54				
			2023	October	6.85	7.7				1.72		
		60-90	2020	September				0.74				
			2023	October	7.41	11						0.93
Schoolhouse	TDC6	0-10	2020	September	4.33	65	1.9					
			2022	September	5.1	26	2.62					
			2023	October	5.14	99				5.24		
		10-30	2020	September	5.45	22		0.89				

Paddock	Sample name	Soil depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Schoolhouse	TDC6	10-30	2022	September	5.57	8		1.52				
			2023	October	5.57	39			2.3	2.23		
		30-60	2020	September	6.17	44		0.42				
			2022	September	6.09	5		1.04				
			2023	October	7.21	7.7				1.11		
		60-90	2020	September				0.29				
			2023	October	7.44	11				0.87		
Schoolhouse	TDC7	0-10	2020	September	5.68	43	3.01					
			2022	September	5.08	52	3.04					
			2023	October	6.25	120				5.31		
		10-30	2020	September	5.63	8		1.4				
			2022	September	5.3	54		2.41				
			2023	October	5.9	47			2.07			
		30-60	2020	September	6.36	<5		0.84				
			2022	September	5.58	68		1.83				
		30-60	2023	October	5.97	31				1.91		
			2020	September				<0.25				
Schoolhouse	TDC8	0-10	2020	September	5.07	140	3.45					
			2022	September	4.81	21	2.42					
		10-30	2020	September	6.03	130		0.92				
			2022	September	5.55	5		1.4				
		30-60	2020	September	6.7	35		0.26				
			2022	September	5.76	<5		0.82				
Schoolhouse	TDC9	0-10	2020	September	4.78	43	2.67					
		10-30	2020	September	5.57	<5		1.28				

Paddock	**Sample name**	**Soil depth**	**Year**	**Month**	**pH (CaCl2)**	**Colwell Phosphorus**	**Organic Carbon (W&B)**	**Dumas Total Carbon**	**LECO Total Carbon**	**MIR Total Carbon**	**LECO Total Organic Carbon**	**MIR Total Organic Carbon**
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Schoolhouse	TDC9	30-60	2020	September	5.9	<5		0.66				

Table 27: Soil test results for Urandangie, 2020 – 2023.

Paddock	Sample name	Depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Project paddock	DC1	0-10	2020	June	6.05	270	5.48					
			2022	October	5.43	200	7.55					
			2023	October	5.08	240				7.07		
		10-30	2020	June	5.89	130		1.77				
			2022	October	5.71	140		3.89				
			2023	October	5.73	84				1.93		
		30-60	2022	October	6.02	89		1.99				
			2023	October	6.03	73			0.72	0.7		
		60-90	2023	October	6.2	29			0.28	0.34		
		90-100	2023	October	6.11	29			<0.20			
Project paddock	DC10	0-10	2020	June	5.28	120	3.48					
			2022	October	4.99	150	5.94					
			2023	October	4.89	97			4.5	4.67		
		10-30	2020	June	5.93	83		1.51				
			2022	October	5.19	93		3.48				
			2023	October	5.96	110			0.75			
		30-60	2020	June				1.19				
			2022	October	5.58	73		1.64				
			2023	October	5.93	110			0.4			
		60-90	2023	October	5.88	85				0.56		
Project paddock	DC2	0-10	2020	June	5.44	53	3.72					
			2022	October	4.98	74	5.07					

Paddock	Sample name	Depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Project paddock	DC2	0-10	2023	October	4.98	77				4.71		
		10-30	2020	June	5.55	14		1.82				
			2022	October	5.38	26		2.67				
			2023	October	5.36	29				2.47		
		30-60	2020	June				1.07				
			2022	October	5.66	9		1.82				
		60-90	2020	June				0.71				
Project paddock	DC3	0-10	2020	June	5.2	100	4.31					
			2022	October	5.17	220	6.66					
			2023	October	5.13	170			4			
		10-30	2020	June	5.8	49		1.71				
			2022	October	5.37	110		5.69				
			2023	October	5.87	68				1.72		
		30-60	2020	June				1.03				
			2022	October	5.75	49		1.78				
			2023	October	6.38	30				0.81		
Project paddock	DC4	0-10	2020	June	5.26	64	3.36					
			2022	October	5.23	34	4.71					
			2023	October	4.99	39			4.16			
		10-30	2020	June	5.86	16		1.79				
			2022	October	5.51	25		2.45				
			2023	October	5.31	41			1.32			
		30-60	2020	June				0.98				
			2022	October	5.43	16		1.79				
		60-90	2020	June				0.59				

Paddock	Sample name	Depth	Year	Month	pH (CaCl2)	Colwell Phosphorus	Organic Carbon (W&B)	Dumas Total Carbon	LECO Total Carbon	MIR Total Carbon	LECO Total Organic Carbon	MIR Total Organic Carbon
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Project paddock	DC5	0-10	2020	June	5.01	110	5.75					
			2022	October	4.96	92	5.21					
			2023	October	5.06	100			5.64	5.77		
		10-30	2020	June	5.18	18		3.12				
			2022	October	5.59	44		2.69				
			2023	October	5.61	28				2.37		
		30-60	2020	June				2.4				
			2022	October	5.49	54		2.34				
			2023	October	6.74	29				0.8		
		60-90	2020	June				1.15				
Project paddock	DC6	0-10	2020	June	4.96	73	3.75					
			2022	October	5.32	35	4.48					
			2023	October	5.87	54				5.17		
		10-30	2020	June	5.86	19		2.72				
			2022	October	5.87	16		2.69				
			2023	October	6.07	15				2.07		
		30-60	2022	October	6.1	13		2.03				
			2023	October	6.39	20				0.99		
		60-90	2023	October	6.46	30				0.57		
Project paddock	DC7	0-10	2020	June	5.05	86	4.18					
			2022	October	5.2	60	3.1					
			2023	October	5.42	140			7.2			
		10-30	2020	June	5.52	21		2.01				
			2022	October	5.34	19		1.52				
			2023	October	6.38	46				2.26		

Paddock	**Sample name**	**Depth**	**Year**	**Month**	**pH (CaCl2)**	**Colwell Phosphorus**	**Organic Carbon (W&B)**	**Dumas Total Carbon**	**LECO Total Carbon**	**MIR Total Carbon**	**LECO Total Organic Carbon**	**MIR Total Organic Carbon**
name	*name*	*cm*	*yyyy*	*name*		*mg/kg*	*%*	*%*	*%*	*%*	*%*	*%*
Project paddock	DC7	30-60	2022	October	5.73	20		1.29				
			2023	October	6.94	46				1.02		
		60-72	2023	October	6.82	51				0.69		
Project paddock	DC8	0-10	2020	June	5.27	220	5.74					
			2022	October	5.08	87	6.29					
			2023	October	5.34	140			8.88			
		10-30	2020	June	5.3	25		3.73				
			2022	October	5.57	29		2.94				
			2023	October	6.23	24				1.18		
		30-60	2020	June				2.71				
			2022	October	5.85	15		2.45				
			2023	October	6.87	11				0.72		
		60-90	2020	June				1.4				
Project paddock	DC9	0-10	2020	June	4.98	180	4.77					
			2022	October	4.89	99	4.82					
			2023	October	4.84	50				4.66	4.25	
		10-30	2020	June	5.73	52		2.05				
			2022	October	5.49	47		2.46				
			2023	October	5.68	35				1.74		
		30-60	2022	October	5.94	36		1.27				
			2023	October	6.51	35			0.72			

8.3 Soil test results June 2023 and June 2024

Table 28: Soil organic carbon (SOC, %) test results for each soil sampling site in September 2022, June 2023, September 2023 and June 2024.

Property *name*	**Paddock** *name*	**Sample name** *name*	**Soil depth** *cm*	**SOC (%)** *September 2022*	*June 2023*	*September 2023*	*June 2024*
Achill	Airstrip	Airstrip2	0 - 10	3.23	2.18	2.53	3.02
			10-30	1.55	1.19	0.91	1.71
	Airstrip	Airstrip3	0 - 10	3.56	2.03	2.25	2.4
			10-30	1.52	1.19	0.4	1.56
	Sawpit	Sawpit02	0 - 10	7.04	4.7	7.73	5.2
			10-30	2	2.57	4.25	3.21
		Sawpit05	0 - 10	3.26	4.41	4.75	5.01
			10-30	1.3	4.5	0.79	2.55
Argyle	Greenknob-Agris	Greenknob-Agris2	0 - 10	3.25	2.63	3.97	2.88
			10-30	1.78	2.28	1.72	2.52
		Greenknob-Agris7	0 - 10	3.08	2.55	3.12	2.84
			10-30	1.5	1.7	1.31	1.52
	Wattle	Wattle1	0 - 10	1.74	1.38	2.51	2.01
			10-30	0.76	0.82	0.83	1.15
		Wattle3	0 - 10	2.25	1.69	2.26	2.14
			10-30	1.31	1.04	0.96	1.35
Bald Blair	Bottom Fitzroy	bottomFitzroy1	0 - 10	2.95	3.3	3.36	1.72
			10-30	2.09	2.15	1.58	2.75
	Cruikshanks	cruikshanks1	0 - 10	3.03	2.29	2.82	3.15
			10-30	1.53	2.03	1.06	2.1
		cruikshanks3	0 - 10	4.03	4.19	4.96	5.16
			10-30	4.19	2.54	1.97	4.26

Property *name*	**Paddock** *name*	**Sample name** *name*	**Soil depth** *cm*	**SOC (%)** *September 2022*	*June 2023*	*September 2023*	*June 2024*
Bald Blair	Top Fitzroy	topFitzroy3	0 - 10	4.49	4.77	3.83	4.81
			10-30	4.17	3.64	1.54	3.66
Cooringoora	CDP	CDP2	0 - 10	1.39	1.19	1.37	1.16
			10-30	0.55	0.69	0.87	0.8
		CDP4	0 - 10	0.93	1.1	1.27	1.23
			10-30	1.27	1.14	1.04	1.08
	Front	Front3	0 - 10	1.83	1.5	1.68	2.04
			10-30	N/A	1.2	0.53	1.23
		Front5	0 - 10	1.4	1.38	1.73	1.67
			10-30	N/A	0.9	0.6	1.2
Glenview	DC	DC12	0 - 10	1.27	0.98	0.85	1.01
			10-30	0.53	0.56	0.2	0.6
		DC1P	0 - 10	1	0.97	1.21	1.27
			10-30	0.26	0.31	0.35	0.75
		DC5	0 - 10	1.47	1.16	1.8	0.82
			10-30	0.57	0.34	0.43	0.45
		DC9P	0 - 10	1.35	0.71	1.38	1.38
			10-30	0.42	0.39	0.25	0.61
Leaderville		Leaderville12	0 - 10	2.4	1.87	2.29	2.05
			10-30	1.56	1.22	1.01	1.59
		Leaderville19	0 - 10	2.21	1.76	3.71	2.57
			10-30	1.15	1.29	1.97	1.78
		Leaderville23	0 - 10	0.9	0.98	1.46	1.14
			10-30	0.44	0.57	0.55	0.89
		Leaderville25	0 - 10	1.64	1.5	1.23	1.71
			10-30	0.89	1.12	0.48	1.45

Property *name*	Paddock *name*	Sample name *name*	Soil depth *cm*	SOC (%) *September 2022*	*June 2023*	*September 2023*	*June 2024*
Myanbah	Airstrip	Airstrip11	0 - 10	1.05	0.82	1.04	1.12
			10-30	0.38	0.45	0.37	0.74
		Airstrip12	0 - 10	0.86	0.73	0.94	0.9
			10-30	0.33	0.35	0.22	0.59
	Centre Oats	Oats5	0 - 10	N/A	0.5	1.29	1.12
			10-30	N/A	1.13	0.41	0.64
		Oats8	0 - 10	N/A	1.28	0.83	1.43
			10-30	N/A	0.75	0.34	0.72
Te Dapa	Dam North	DamNorth5	0 - 10	2.12	1.94	2.79	2.14
			10-30	0.83	0.52	0.66	0.82
	Dwyers	Dwyers27	0 - 10	2.01	2.29	3.67	2.51
			10-30	0.72	0.95	1.09	1.17
		Dwyers32	0 - 10	3.82	3.24	2.85	3.89
			10-30	1.77	1.79	1.6	2.72
	Nancy’s	Nancy3	0 - 10	2.38	1.91	2.24	2.23
			10-30	1.11	0.8	0.79	1.25
	Top One	TopOne12	0 - 10	2.88	1.52	2.6	3.05
			10-30	0.96	0.97	0.53	1.41
Tenterden		TDC1	0 - 10	2.47	3.81	4.9	3.5
			10-30	1.64	2.77	1.61	2.59
		TDC3	0 - 10	2.04	3.64	2.34	2.24
			10-30	0.7	2.29	1.15	1.68
		TDC4	0 - 10	3.59	3.51	3.4	4.3
			10-30	2.54	2.41	1.56	3.57
		TDC6	0 - 10	2.62	2.52	2.23	2.87
			10-30	1.52	1.83	1.11	1.43

Property *name*	**Paddock** *name*	**Sample name** *name*	**Soil depth** *cm*	**SOC (%)** *September 2022*	*June 2023*	*September 2023*	*June 2024*
Urandangie		DC10	0 - 10	5.94	4.49	4.5	6.1
			10-30	3.48	3.77	0.75	3.82
		DC4	0 - 10	4.71	3.77	4.16	4.67
			10-30	2.45	2.89	1.32	2.58
		DC7	0 - 10	3.1	3.48	7.2	4.93
			10-30	1.52	2.46	2.26	2.42
		DC8	0 - 10	6.29	6.73	8.88	7.97
			10-30	2.94	4.51	1.18	4.54

8.4 Soil moisture monitoring

Figures 62 – 78 show the soil moisture results at all probe sites, for the project period of 1st July 2021 until the 30th July 2024.

Figure 62: Volumetric soil moisture at Achill, Airstrip, 1st July 2021 – 30th July 2024.

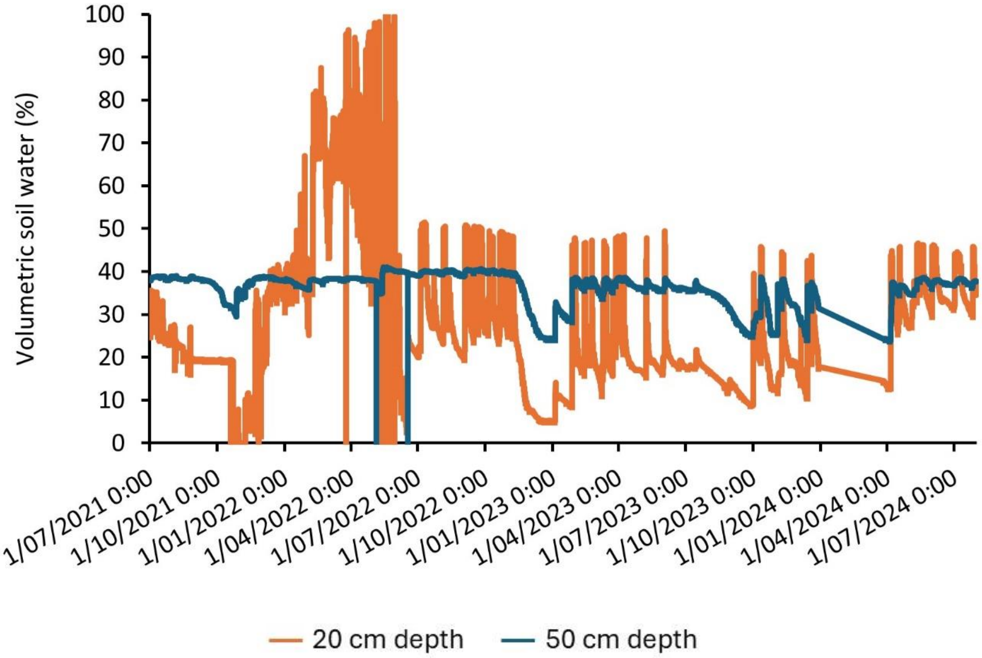


Figure 63: Volumetric soil moisture at Achill, Sawpit, 1st July 2021 – 30th July 2024.

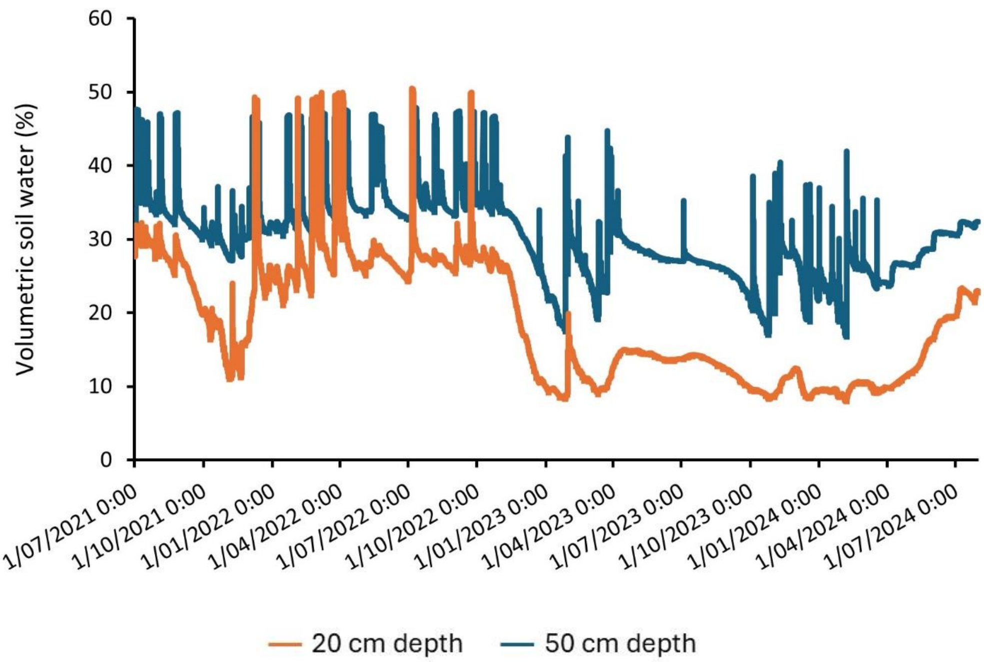


Figure 64: Volumetric soil moisture at Argyle, Greenknob, 1st July 2021 – 30th July 2024.

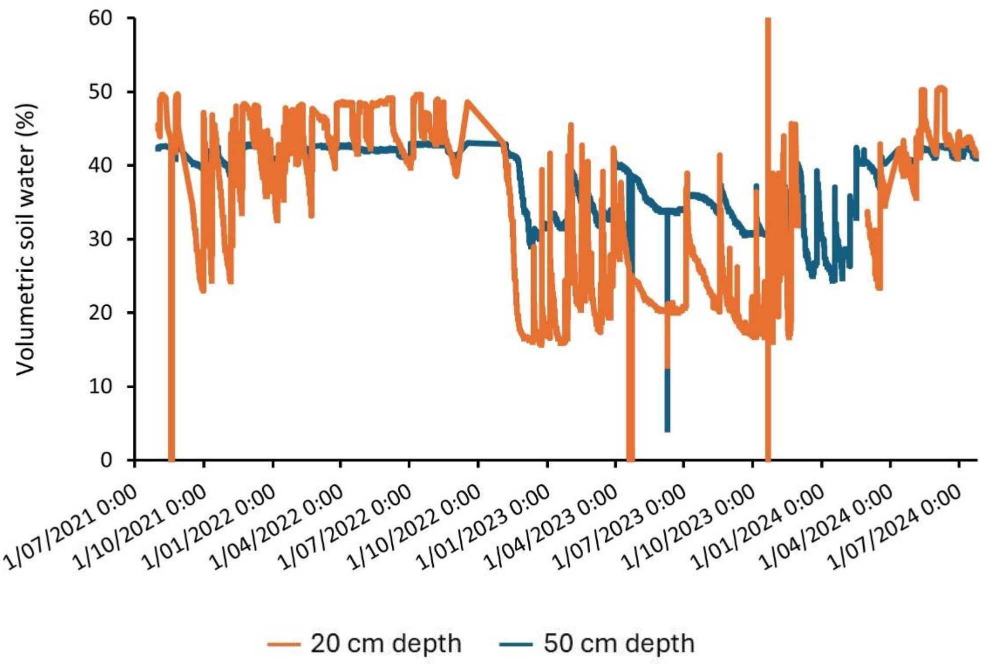


Figure 65: Volumetric soil moisture at Argyle, Wattle, 1st July 2021 – 30th July 2024.

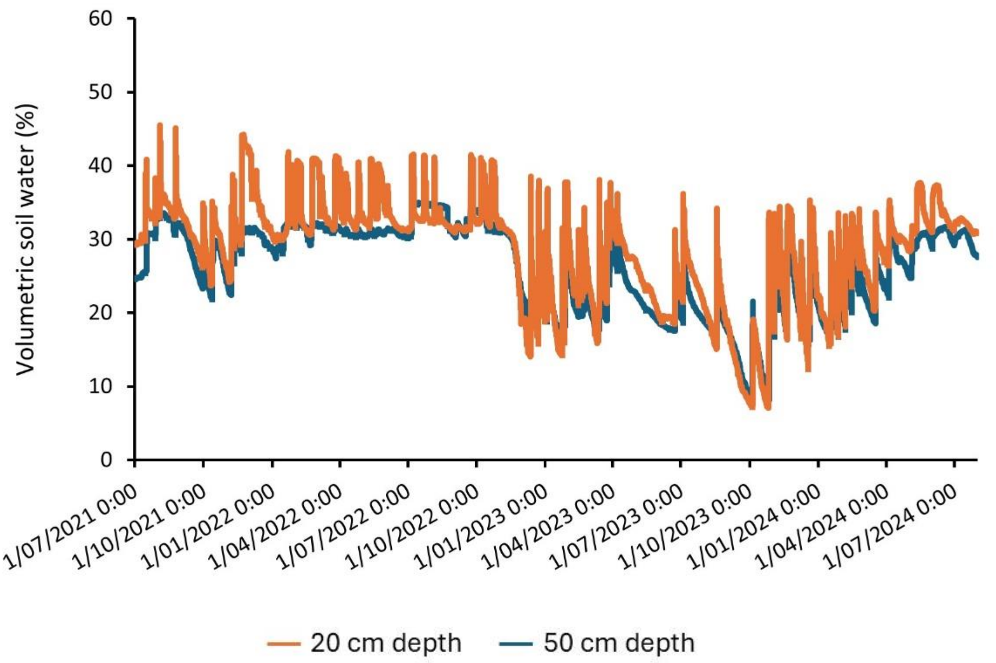


Figure 66: Volumetric soil moisture at Bald Blair, Gatwood, 1st July 2021 – 30th July 2024.

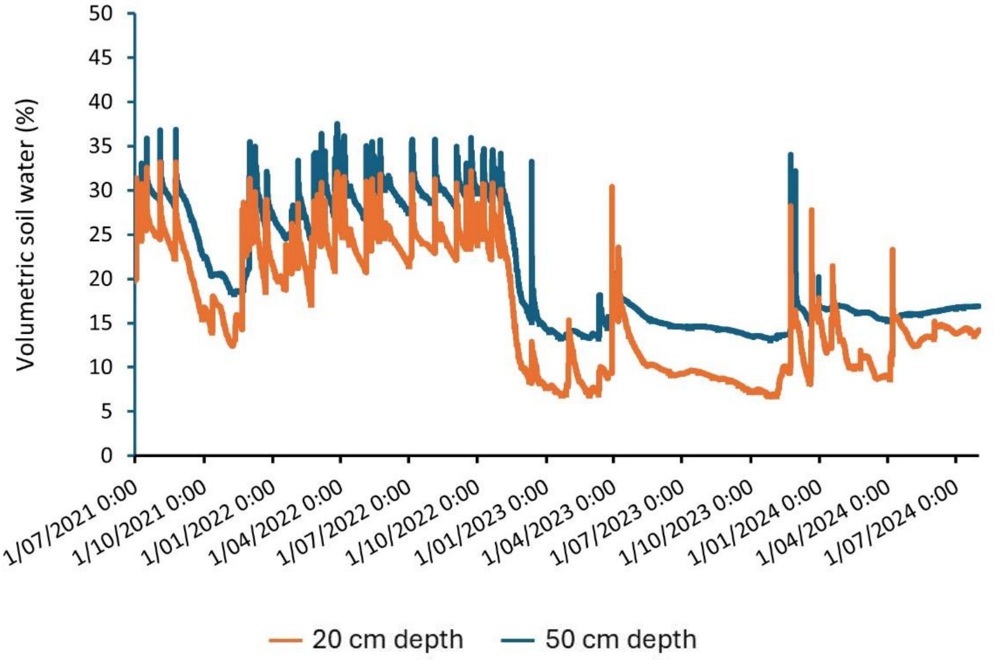


Figure 67: Volumetric soil moisture at Bald Blair, Top Fitzroy, 1st July 2021 – 30th July 2024.

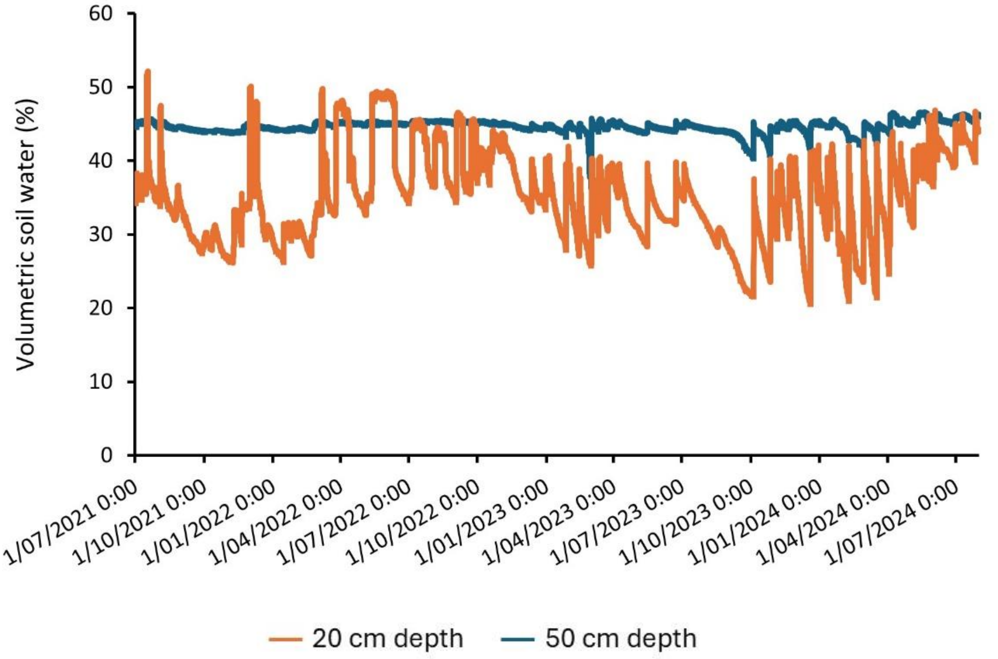


Figure 68: Volumetric soil moisture at Cooringoora, 1st July 2021 – 30th July 2024.

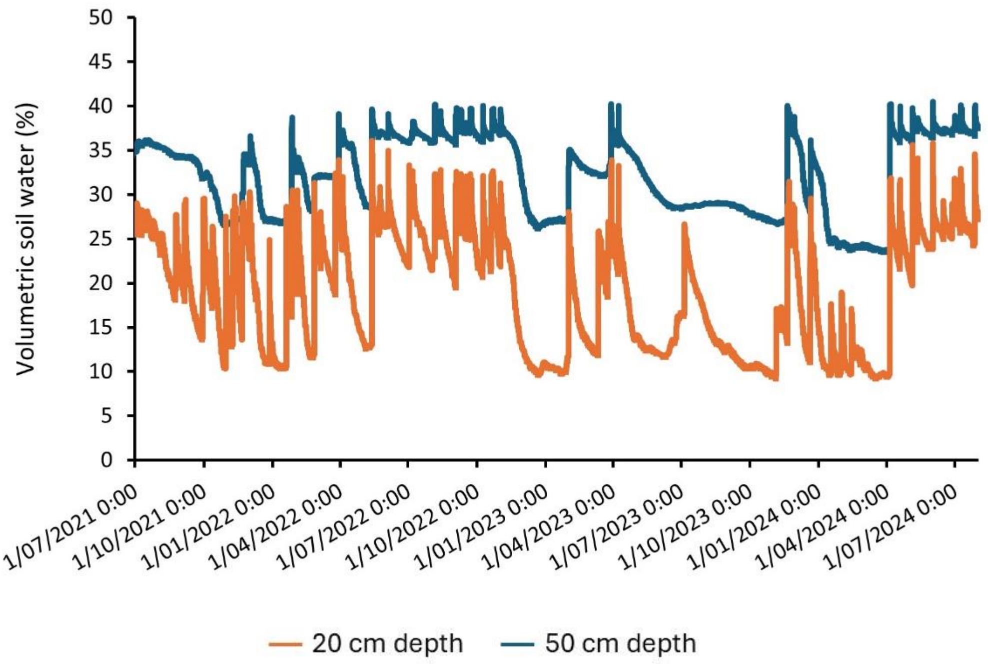


Figure 69: Volumetric soil moisture at Leaderville Probe, 1st July 2021 – 30th July 2024.

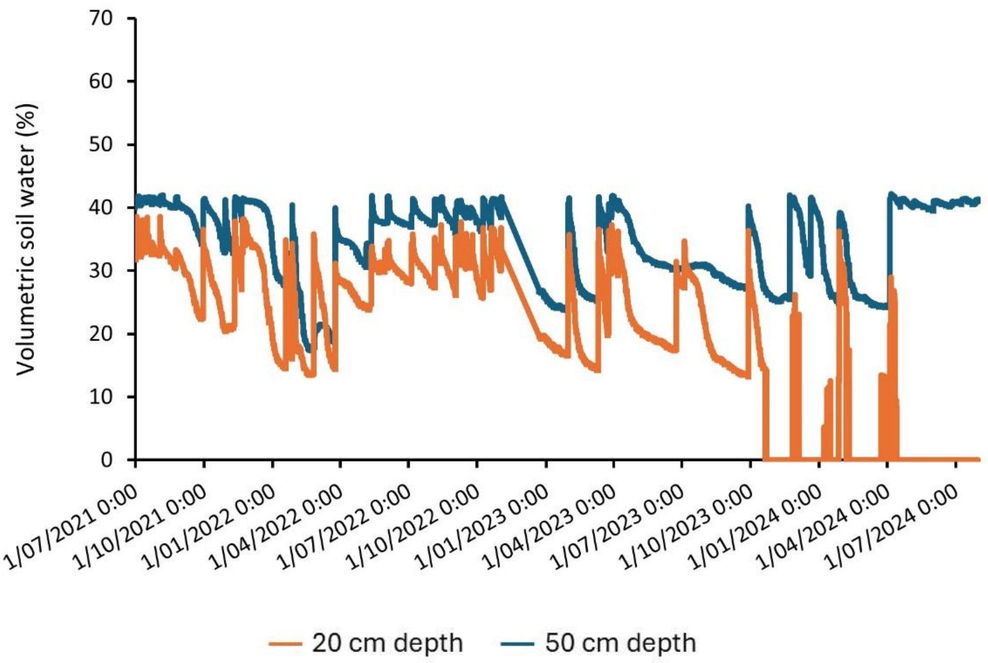


Figure 70: Volumetric soil moisture at Myanbah, Airstrip, 1st July 2021 – 30th July 2024.

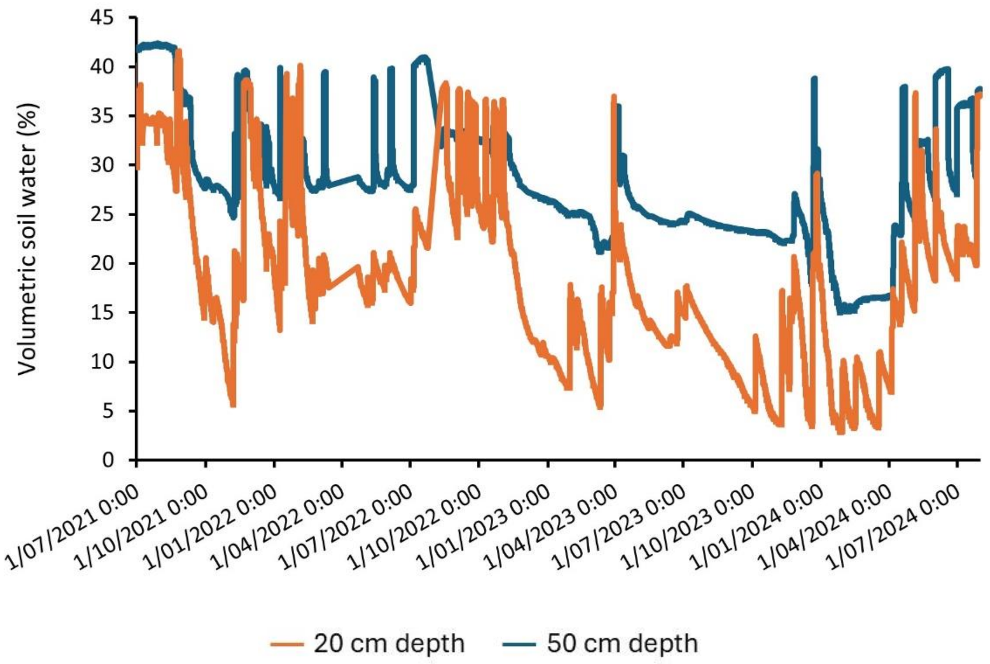


Figure 71: Volumetric soil moisture at Myanbah, Centre Oats, 1st July 2021 – 30th July 2024.

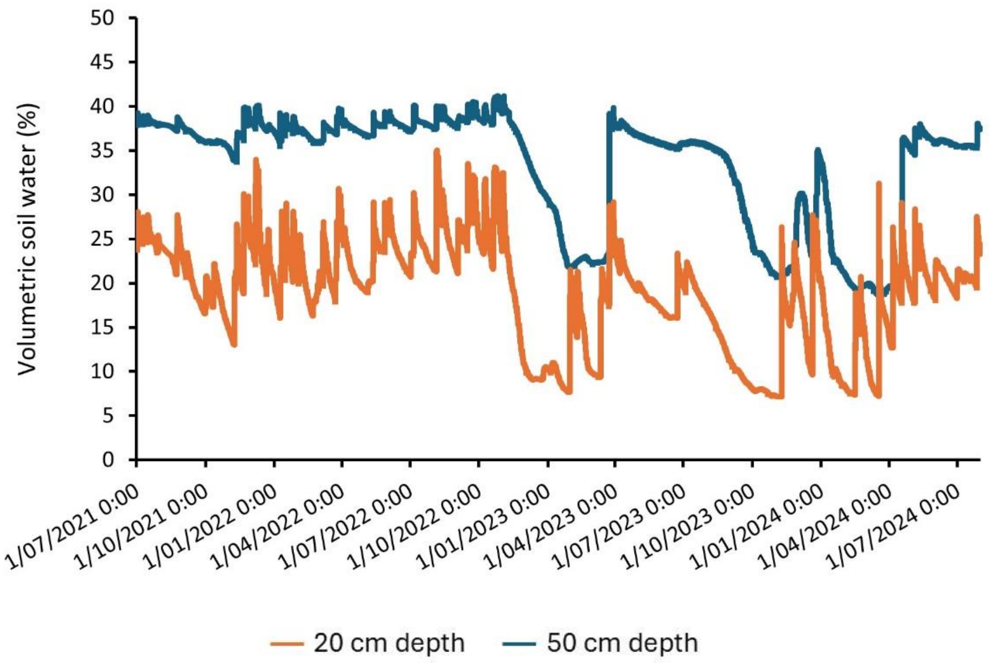


Figure 72: Volumetric soil moisture at Pointsfield, 1st July 2021 – 30th July 2024.

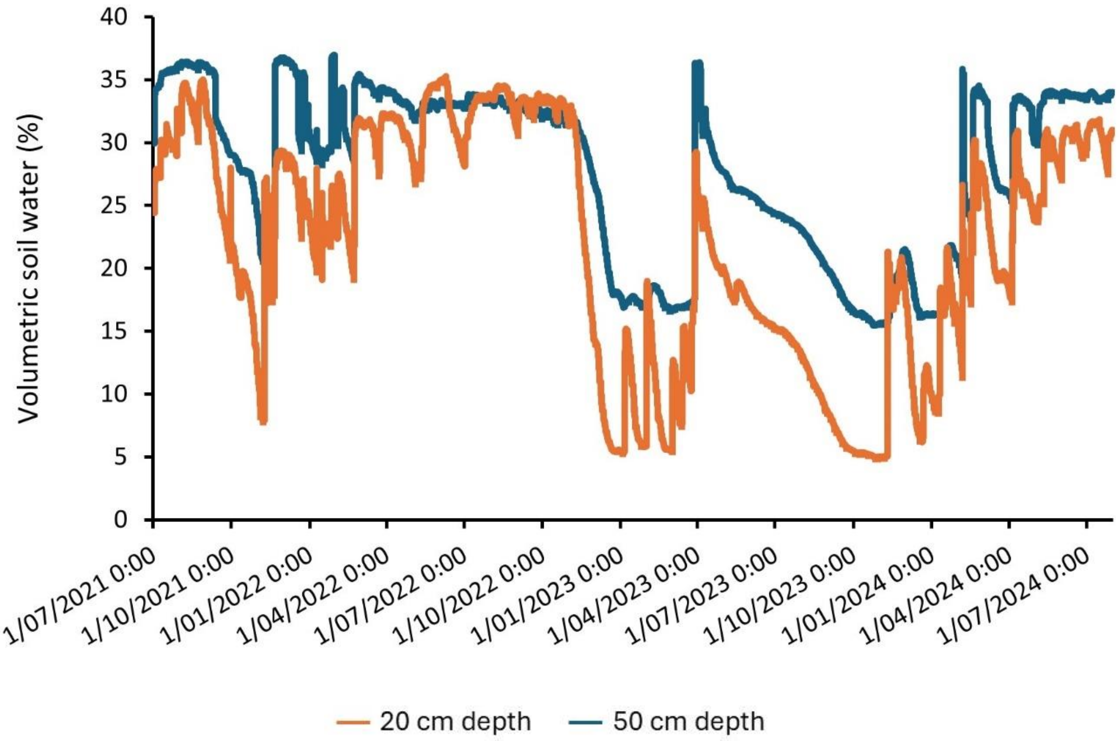


Figure 73: Volumetric soil moisture at Te Dapa, Nancy's, 1st July 2021 – 30th July 2024.

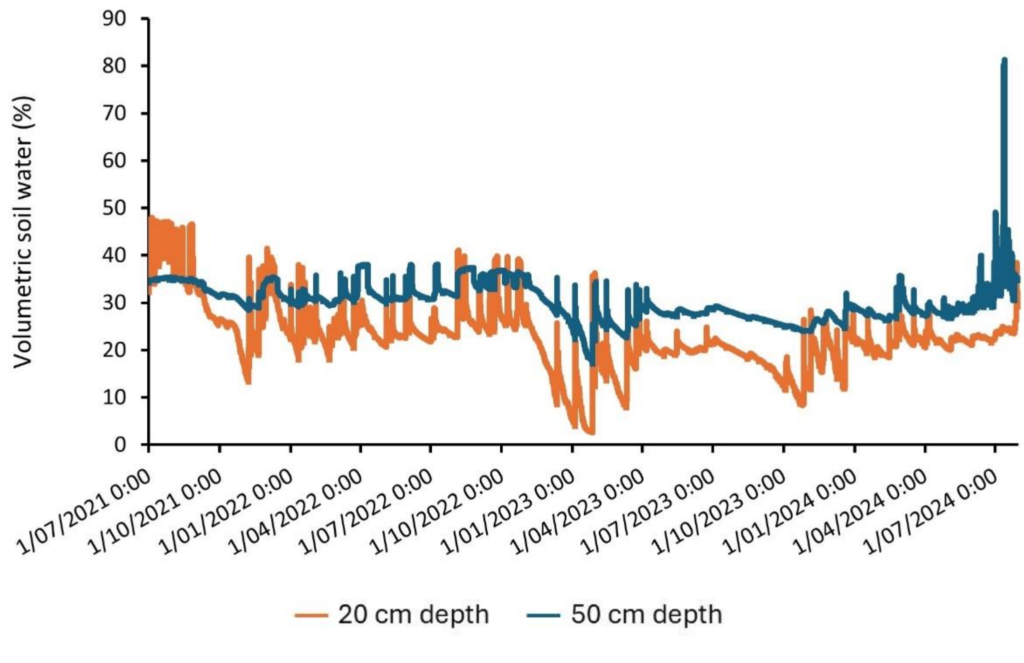


Figure 74: Volumetric soil moisture at Te Dapa, Top 2, 1st July 2021 – 30th July 2024.

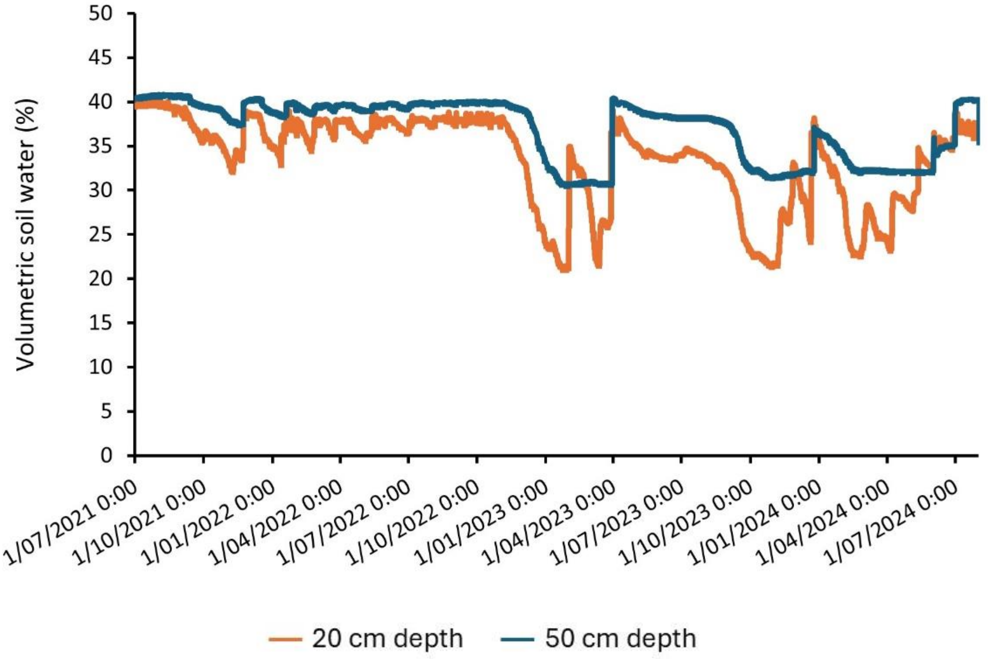


Figure 75: Volumetric soil moisture at Tenterden, Schoolhouse 1, 1st July 2021 – 30th July 2024.

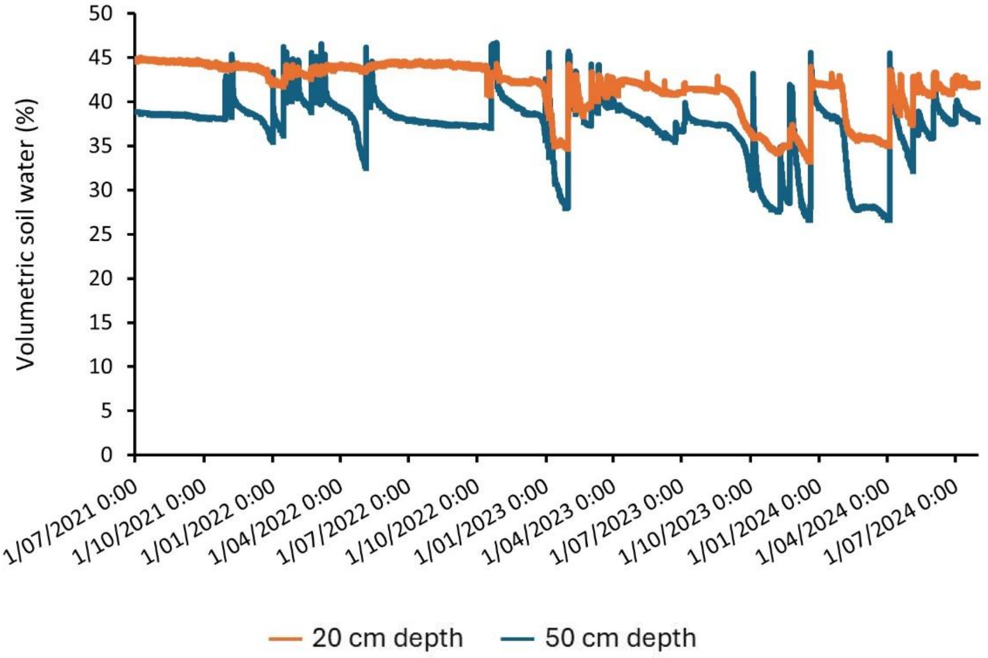


Figure 76: Volumetric soil moisture at Tenterden, Schoolhouse 2 Church Quarry, 1st July 2021 – 30th July 2024.

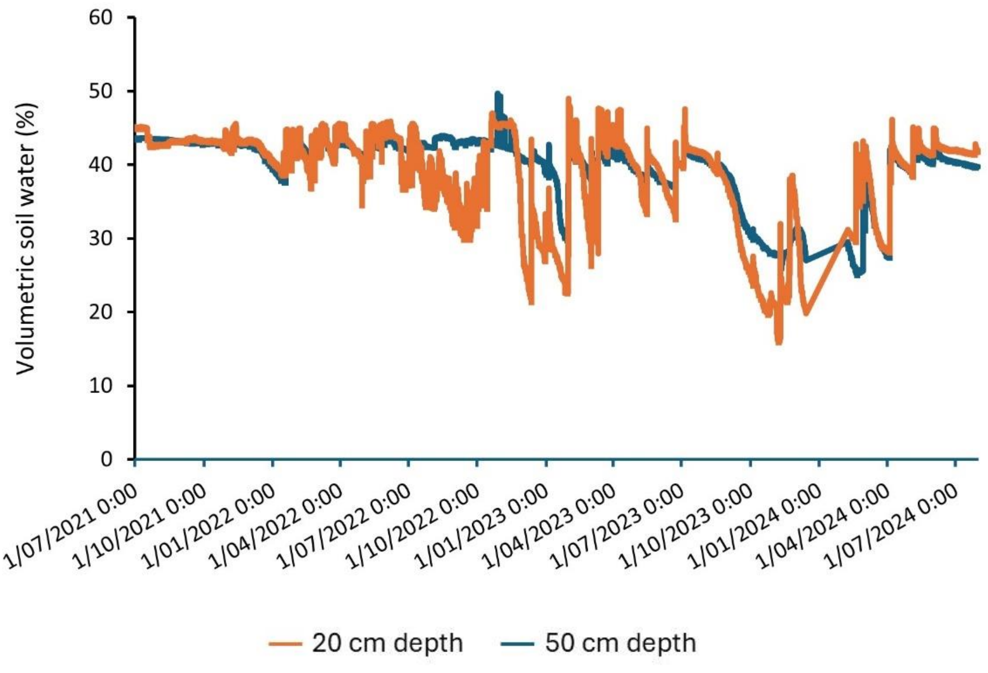


Figure 77: Volumetric soil moisture at Urandangie, Black Hill, 1st July 2021 – 30th July 2024.

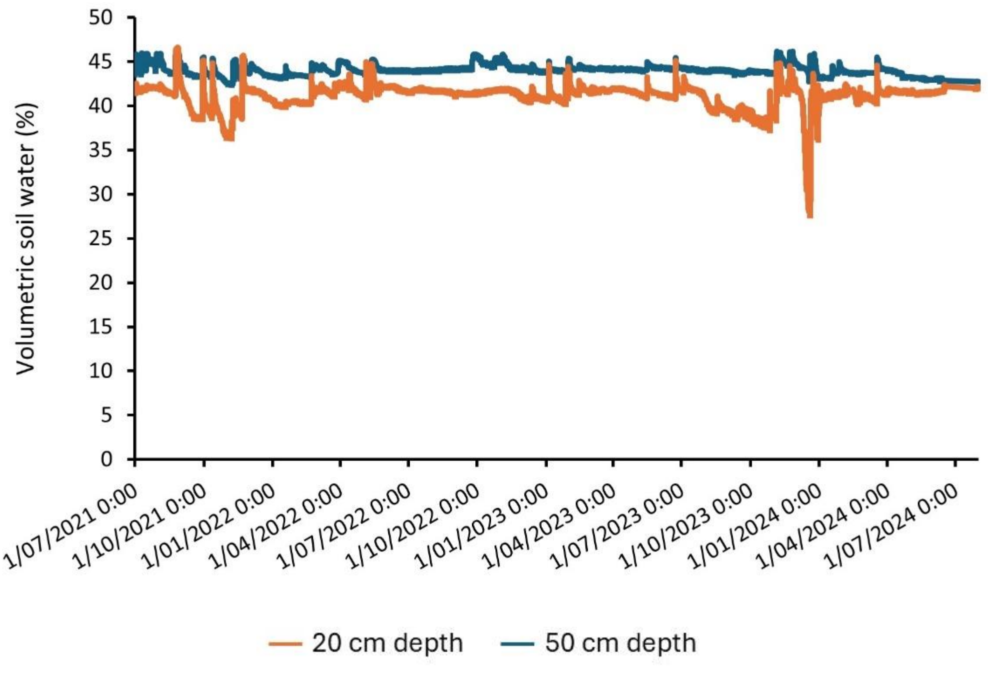
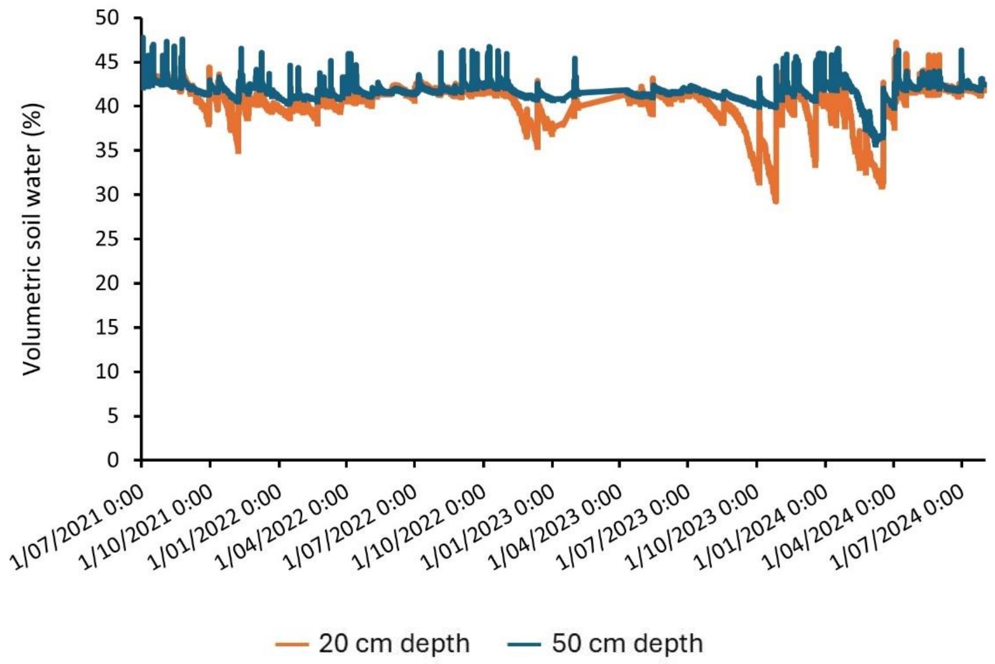


Figure 78: Volumetric soil moisture at Urandangie, Red Hill, 1st July 2021 – 30th July 2024.



8.5 Pasture growth rates

Table 29: Pasture growth rates (kg DM/ha) at Te Dapa, March 2021 – June 2024. Empty cells show pasture cages that divided into, no samples were taken. In phosphorus treatment, 'M' stands for 'maintenance rate', and 'C' stands for 'capital rate'.

Paddock	Phosphorus treatment	Lime treatment	Sampling month														
			Mar-21	Jul-21	Nov-21	Feb-22	Apr-22	Jul-22	Oct-22	Dec-22	Mar-23	Jun-23	Aug-23	Oct-23	Jan-24	Mar-24	Jun-24
Dwyers	M	No	57.4	36.1	46.1	39.7	42.0	4.0	31.4	32.4	12.1	17.0	4.1	4.8	27.9	30.5	5.9
	M	Yes	44.3	4.0	33.5	11.3	10.3	2.1	4.3	18.8	4.1	3.5			11.8	18.1	
	M	No	75.9	4.3	26.9	10.2	9.0	2.8	3.3	12.8	3.8	2.0			15.5	14.9	
	C+M	No	80.1	4.1	18.8	11.8	9.2	2.7	3.3	19.6	2.5	2.1			14.9	13.8	
	C+M	Yes	89.0	5.2	33.2	11.0	12.8	2.7	5.9	17.8	2.3	1.6			14.2	13.7	
Dam North	M	Yes	87.5	3.7	38.8	13.2	15.5	2.9	8.3	14.2	2.1	1.0			0.0	20.3	0.3
	M	No	46.4	3.4	31.2	9.9	12.0	3.0	9.9	8.2	1.3	1.9			0.0	14.9	0.3
	C+M	No	54.3	4.1	30.2	12.4	14.0	3.6	14.1	11.3	1.3	2.0			0.0	18.3	0.5
	C+M	Yes	94.2	6.6	39.6	18.2	16.5	4.1	16.0	18.8	2.6	3.2			0.0	16.6	0.7
Top Two	M	No	94.2		32.3	13.2	15.8	7.8	8.5	7.9	7.3	1.8			24.8	10.6	2.1
	C+M	No	138.8		33.4	34.2	36.9	4.2	18.5	20.8	10.2	3.2			38.6	21.1	4.3
Top One	M	No	58.2	27.2	41.0	32.6	44.7	11.7	12.4	13.4	9.3	4.3	5.3	4.8	30.4	29.3	5.7

Table 30: Pasture growth rates (kg DM/ha) at Pointsfield, June 2021 – June 2024. No samples extracted in October 2023 because not enough pasture biomass was available to harvest. In phosphorus treatment, 'M' stands for 'maintenance rate', and 'C' stands for 'capital rate'.

			Sampling month													
Paddock	Phosphorus treatment	Lime treatment	Jun-21	Nov-21	Feb-22	Apr-22	Jul-22	Oct-22	Dec-22	Apr-23	Jun-23	Aug-23	Oct-23	Jan-24	Mar-24	Jun-24
West Hogget	C+M	No	7.9	6.6	7.9	32.7	4.0	13.4	12.0	11.9	7.5	1.5		7.7	25.2	11.8
	M	No	8.1	7.4	7.5	24.2	7.1	9.6	12.1	10.6	10.8	3.2		11.0	25.9	9.0
West Track 2	M	Yes	11.1	6.7	7.5	33.3	6.3	32.9	32.3	16.0	7.7	6.7		20.0	25.6	7.8
	C+M	No	8.2	6.8	8.3	48.5	15.4	62.8	40.9	26.8	4.8	4.0		19.6	34.0	7.7
West Track Road	C+M	No	10.4	6.5	7.9	20.4	6.2	19.9	23.4	12.3	7.3	4.0		15.7	22.3	7.9
	M	Yes	6.5	6.6	7.4	18.3	7.6	27.5	21.0	11.0	8.7	3.8		14.3	12.4	7.4

8.6 NDVI results

8.6.1 NDVI validation

Table 31: NDVI values recorded with the hand-held Greenseeker device (10 measurements, averaged) compared to the NDVI recorded by the static NDVI telemeter. Cells highlighted in orange show a difference of more than 0.2 between the average Greenseeker NDVI and the static telemeter NDVI.

Date *dd/mm/yy*	Time *hh:mm*	Property *name*	Record *number*	Greenseeker NDVI *0 - 1*	Average Greenseeker NDVI *Average of 10 sites*	Static telemeter NDVI *0 - 1*
9/06/23	15:00	Glenview	1	0.26	0.213	1
			2	0.22		
			3	0.19		
			4	0.24		
			5	0.22		
			6	0.22		
			7	0.2		
			8	0.18		
			9	0.2		
			10	0.2		
6/06/23	10:00	Tenterden	1	0.45	0.374	0.367
			2	0.46		
			3	0.35		
			4	0.24		
			5	0.25		
			6	0.43		
			7	0.36		
			8	0.3		
			9	0.49		
			10	0.41		

Date *dd/mm/yy*	Time *hh:mm*	Property *name*	Record *number*	Greenseeker NDVI *0 - 1*	Average Greenseeker NDVI *Average of 10 sites*	Static telemeter NDVI *0 - 1*
5/06/23	13:51	Myanbah	1	0.54	0.44	0.776
			2	0.49		
			3	0.38		
			4	0.57		
			5	0.56		
			6	0.37		
			7	0.49		
			8	0.44		
			9	0.22		
			10	0.34		
7/06/23	9:45	Urandangie	1	0.33	0.374	-0.02
			2	0.37		
			3	0.31		
			4	0.44		
			5	0.38		
			6	0.41		
			7	0.44		
			8	0.34		
			9	0.33		
			10	0.39		
8/06/23	10:20	Leaderville	1	0.4	0.234	0.195
			2	0.19		
			3	0.23		
			4	0.17		
			5	0.17		
			6	0.16		
			7	0.23		

Date *dd/mm/yy*	Time *hh:mm*	Property *name*	Record *number*	Greenseeker NDVI *0 - 1*	Average Greenseeker NDVI *Average of 10 sites*	Static telemeter NDVI *0 - 1*
8/06/23	10:20	Leaderville	8	0.37		
			9	0.19		
			10	0.23		
7/06/23	14:00	Bald Blair	1	0.29	0.357	0.108
			2	0.3		
			3	0.36		
			4	0.36		
			5	0.41		
			6	0.41		
			7	0.33		
			8	0.41		
			9	0.38		
			10	0.32		
8/06/23	12:40	Cooringoora	Paddock had recently been resown, no groundcover present			
9/06/23	10:00	Argyle	1	0.52	0.488	Software malfunction
			2	0.49		
			3	0.53		
			4	0.5		
			5	0.44		
			6	0.49		
			7	0.47		
			8	0.5		
			9	0.45		
			10	0.49		
28/06/23	11:36	Te Dapa	1	0.24	0.273	0.156
			2	0.23		
			3	0.26		

Date *dd/mm/yy*	**Time** *hh:mm*	**Property** *name*	**Record** *number*	**Greenseeker NDVI** *0 - 1*	**Average Greenseeker NDVI** *Average of 10 sites*	**Static telemeter NDVI** *0 - 1*
28/06/23	11:36	Te Dapa	4	0.2		
			5	0.26		
			6	0.38		
			7	0.33		
			8	0.21		
			9	0.36		
			10	0.26		
27/06/23	11:25	Achill	1	0.25	0.239	0.245
			2	0.31		
			3	0.27		
			4	0.2		
			5	0.22		
			6	0.21		
			7	0.27		
			8	0.24		
			9	0.23		
			10	0.19		
27/06/23	14:07	Pointsfield	1	0.38	0.404	0.325
			2	0.47		
			3	0.52		
			4	0.42		
			5	0.39		
			6	0.33		
			7	0.3		
			8	0.37		
			9	0.42		
			10	0.44		

Date *dd/mm/yy*	Time *hh:mm*	Property *name*	Record *number*	Greenseeker NDVI *0 - 1*	Average Greenseeker NDVI *Average of 10 sites*	Static telemeter NDVI *0 - 1*
1/11/23	12:20	Te Dapa	1	0.13	0.155	0.176
			2	0.15		
			3	0.14		
			4	0.18		
			5	0.17		
			6	0.15		
			7	0.15		
			8	0.17		
			9	0.14		
			10	0.17		
31/10/23	13:45	Myanbah	1	0.16	0.134	0.842
			2	0.13		
			3	0.15		
			4	0.15		
			5	0.14		
			6	0.1		
			7	0.11		
			8	0.14		
			9	0.11		
			10	0.15		
17/10/23	15:10	Achill	1	0.14	0.173	0.245
			2	0.18		
			3	0.17		
			4	0.2		
			5	0.19		
			6	0.16		
			7	0.13		

Date *dd/mm/yy*	Time *hh:mm*	Property *name*	Record *number*	Greenseeker NDVI *0 - 1*	Average Greenseeker NDVI *Average of 10 sites*	Static telemeter NDVI *0 - 1*
17/10/23	15:10	Achill	8	0.21		
			9	0.19		
			10	0.16		
10/10/23	10:45	Urandangie	1	0.32	0.293	-0.058
			2	0.38		
			3	0.26		
			4	0.22		
			5	0.34		
			6	0.25		
			7	0.33		
			8	0.27		
			9	0.24		
			10	0.32		
12/10/23	10:30	Leaderville	1	0.34	0.293	0.462
			2	0.26		
			3	0.29		
			4	0.31		
			5	0.4		
			6	0.29		
			7	0.3		
			8	0.29		
			9	0.22		
			10	0.23		
11/10/23	14:40	Tenterden	1	0.26	0.267	0.307
			2	0.23		
			3	0.29		
			4	0.24		

Date *dd/mm/yy*	**Time** *hh:mm*	**Property** *name*	**Record** *number*	**Greenseeker NDVI** *0 - 1*	**Average Greenseeker NDVI** *Average of 10 sites*	**Static telemeter NDVI** *0 - 1*
11/10/23	14:40	Tenterden	5	0.23		
			6	0.39		
			7	0.29		
			8	0.33		
			9	0.2		
			10	0.21		
19/10/23	12:10	Glenview	1	0.17	0.212	0.147
			2	0.18		
			3	0.19		
			4	0.22		
			5	0.3		
			6	0.2		
			7	0.23		
			8	0.24		
			9	0.21		
			10	0.18		
18/10/23	13:30	Argyle	1	0.18	0.199	0.29
			2	0.21		
			3	0.21		
			4	0.19		
			5	0.18		
			6	0.17		
			7	0.24		
			8	0.23		
			9	0.2		
			10	0.18		
10/10/23	15:25	Bald Blair	1	0.18	0.159	-0.027

Date *dd/mm/yy*	**Time** *hh:mm*	**Property** *name*	**Record** *number*	**Greenseeker NDVI** *0 - 1*	**Average Greenseeker NDVI** *Average of 10 sites*	**Static telemeter NDVI** *0 - 1*
10/10/23	15:25	Bald Blair	2	0.12		
			3	0.16		
			4	0.16		
			5	0.16		
			6	0.17		
			7	0.19		
			8	0.15		
			9	0.13		
			10	0.17		
12/10/23	13:05	Cooringoora	1	0.15	0.15	0.369
			2	0.13		
			3	0.12		
			4	0.13		
			5	0.16		
			6	0.2		
			7	0.14		
			8	0.19		
			9	0.13		
			10	0.15		
6/02/24	9:00	Tenterden	1	0.62	0.595	0.62
			2	0.49		
			3	0.58		
			4	0.59		
			5	0.55		
			6	0.63		
			7	0.64		
			8	0.53		

Date *dd/mm/yy*	**Time** *hh:mm*	**Property** *name*	**Record** *number*	**Greenseeker NDVI** *0 - 1*	**Average Greenseeker NDVI** *Average of 10 sites*	**Static telemeter NDVI** *0 - 1*
6/02/24	9:00	Tenterden	9	0.67		
			10	0.65		
7/02/24	10:45	Pointsfield	1	0.56	0.56	0.68
			2	0.55		
			3	0.57		
			4	0.57		
			5	0.57		
			6	0.59		
			7	0.5		
			8	0.56		
			9	0.57		
			10	0.56		
7/02/24	13:00	Achill	1	0.6	0.549	0.66
			2	0.53		
			3	0.51		
			4	0.52		
			5	0.52		
			6	0.57		
			7	0.61		
			8	0.58		
			9	0.63		
			10	0.42		
8/02/24		Bald Blair				Probe being repaired
9/02/24		Myanbah				Probe being repaired
13/02/24	9:00	Te Dapa	1	0.15	0.151	0.16
			2	0.15		
			3	0.13		

Date *dd/mm/yy*	Time *hh:mm*	Property *name*	Record *number*	Greenseeker NDVI *0 - 1*	Average Greenseeker NDVI *Average of 10 sites*	Static telemeter NDVI *0 - 1*
13/02/24	9:00	Te Dapa	4	0.16		
			5	0.17		
			6	0.14		
			7	0.16		
			8	0.13		
			9	0.17		
			10	0.15		
13/02/24	11:30	Urandangie				Probe being repaired
14/02/24	8:45	Argyle	1	0.62	0.61	0.68
			2	0.62		
			3	0.59		
			4	0.62		
			5	0.67		
			6	0.41		
			7	0.64		
			8	0.63		
			9	0.67		
			10	0.63		
14/02/24	11:00	Glenview	1	0.28	0.346	0.42
			2	0.3		
			3	0.31		
			4	0.4		
			5	0.4		
			6	0.32		
			7	0.3		
			8	0.32		
			9	0.46		

Date *dd/mm/yy*	Time *hh:mm*	Property *name*	Record *number*	Greenseeker NDVI *0 - 1*	Average Greenseeker NDVI *Average of 10 sites*	Static telemeter NDVI *0 - 1*
14/2/24	11:00	Glenview	10	0.37		
15/02/24	11:00	Cooringoora	1	0.31	0.346	0.42
			2	0.38		
			3	0.4		
			4	0.34		
			5	0.35		
			6	0.39		
			7	0.4		
			8	0.33		
			9	0.42		
			10	0.35		
15/02/24	12:50	Leaderville	1	0.3	0.29	0.39
			2	0.28		
			3	0.34		
			4	0.24		
			5	0.19		
			6	0.33		
			7	0.32		
			8	0.32		
			9	0.28		
			10	0.3		
12/06/24	10:30	Tenterden	1	0.27	0.399	0.486
			2	0.55		
			3	0.42		
			4	0.44		
			5	0.49		
			6	0.36		

Date *dd/mm/yy*	Time *hh:mm*	Property *name*	Record *number*	Greenseeker NDVI *0 - 1*	Average Greenseeker NDVI *Average of 10 sites*	Static telemeter NDVI *0 - 1*
12/06/24	10:30	Tenterden	7	0.36		
			8	0.27		
			9	0.45		
			10	0.38		
19/06/24	10:02	Pointsfield	1	0.34	0.331	0.62
			2	0.33		
			3	0.31		
			4	0.34		
			5	0.32		
			6	0.36		
			7	0.31		
			8	0.31		
			9	0.35		
			10	0.34		
19/06/24	12:51	Achill	1	0.49	0.414	0.435
			2	0.43		
			3	0.41		
			4	0.34		
			5	0.41		
			6	0.44		
			7	0.41		
			8	0.42		
			9	0.42		
			10	0.37		
12/06/24	13:30	Bald Blair	1	0.41	0.417	0.58
			2	0.39		
			3	0.38		

Date *dd/mm/yy*	**Time** *hh:mm*	**Property** *name*	**Record** *number*	**Greenseeker NDVI** *0 - 1*	**Average Greenseeker NDVI** *Average of 10 sites*	**Static telemeter NDVI** *0 - 1*
12/06/24	13:30	Bald Blair	4	0.51		
			5	0.36		
			6	0.37		
			7	0.49		
			8	0.43		
			9	0.47		
			10	0.36		
28/05/24	9:30	Myanbah	1	0.46	0.496	0.43
			2	0.53		
			3	0.48		
			4	0.41		
			5	0.46		
			6	0.6		
			7	0.56		
			8	0.48		
			9	0.47		
			10	0.51		
21/06/24	11:00	Te Dapa	1	0.19	0.192	0.195
			2	0.19		
			3	0.18		
			4	0.2		
			5	0.23		
			6	0.2		
			7	0.19		
			8	0.18		
			9	0.19		
			10	0.17		

Date *dd/mm/yy*	Time *hh:mm*	Property *name*	Record *number*	Greenseeker NDVI *0 - 1*	Average Greenseeker NDVI *Average of 10 sites*	Static telemeter NDVI *0 - 1*
13/06/24	9:15	Urandangie	1	0.56	0.517	0.63
			2	0.43		
			3	0.53		
			4	0.5		
			5	0.61		
			6	0.5		
			7	0.53		
			8	0.52		
			9	0.45		
			10	0.54		
14/06/24	8:30	Argyle	1	0.51	0.487	0.557
			2	0.53		
			3	0.47		
			4	0.48		
			5	0.48		
			6	0.48		
			7	0.52		
			8	0.5		
			9	0.47		
			10	0.43		
14/06/24	11:45	Glenview	1	0.25	0.28	202
			2	0.33		
			3	0.37		
			4	0.23		
			5	0.28		
			6	0.17		
			7	0.26		

Date *dd/mm/yy*	Time *hh:mm*	Property *name*	Record *number*	Greenseeker NDVI *0 - 1*	Average Greenseeker NDVI *Average of 10 sites*	Static telemeter NDVI *0 - 1*
14/06/24	11:45	Glenview	8	0.32		
			9	0.37		
			10	0.22		
18/06/24	10:00	Cooringoora		Bare ground as paddock had just been resown		0.13
18/06/24	13:00	Leaderville	1	0.24	0.311	0.374
			2	0.27		
			3	0.3		
			4	0.36		
			5	0.33		
			6	0.32		
			7	0.23		
			8	0.39		
			9	0.3		
			10	0.37		

8.6.2 NDVI recorded during the project.

Following figures (Fig 79 – 89) show the daily median NDVI values recorded at each property, for the period 1st July 2021 – 1st August 2024.

Figure 79: Daily median NDVI recorded at Achill, 1st July 2021 – 1st August 2024.

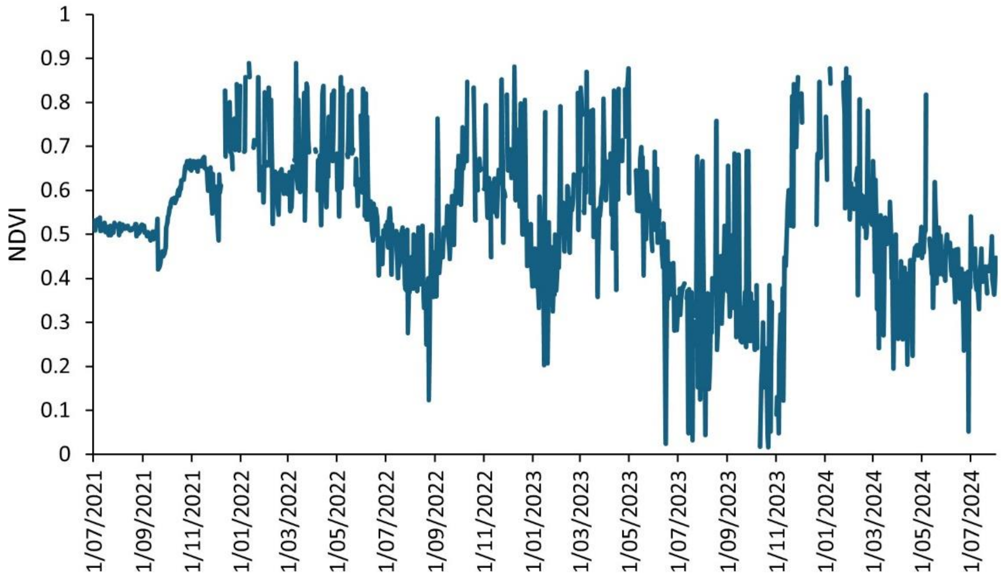


Figure 80: Daily median NDVI recorded at Argyle, 1st July 2021 – 1st August 2024. Because of software issues, no data available before the 25th March 2024.

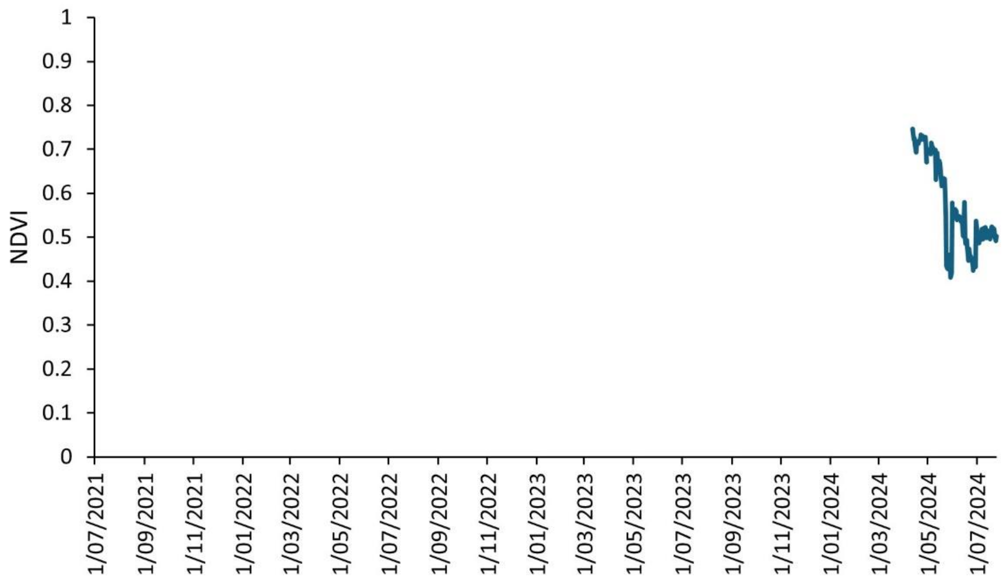


Figure 81: Daily median NDVI recorded at Bald Blair, 1st July 2021 – 1st August 2024.

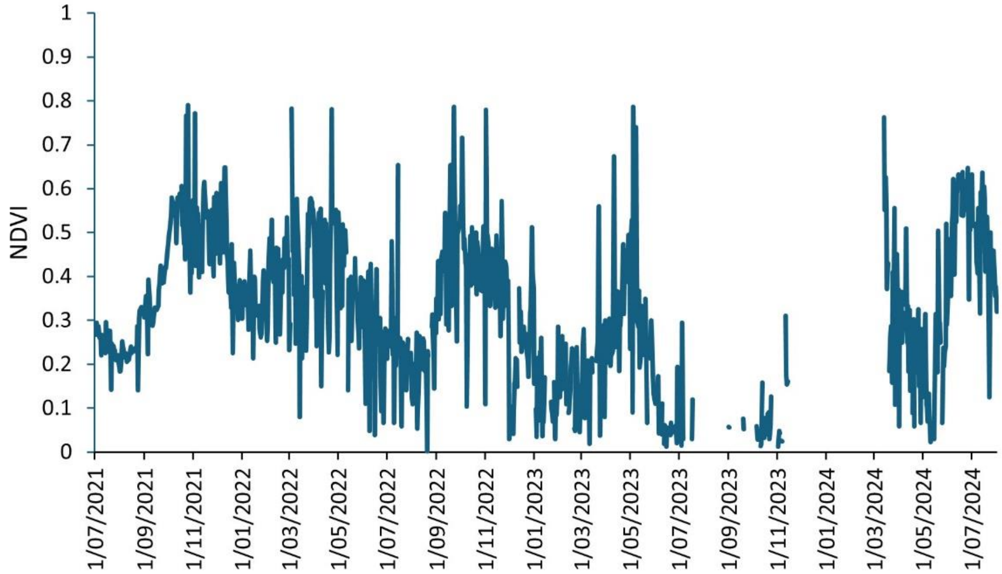


Figure 82: Daily median NDVI recorded at Cooringoora, 1st July 2021 – 1st August 2024.

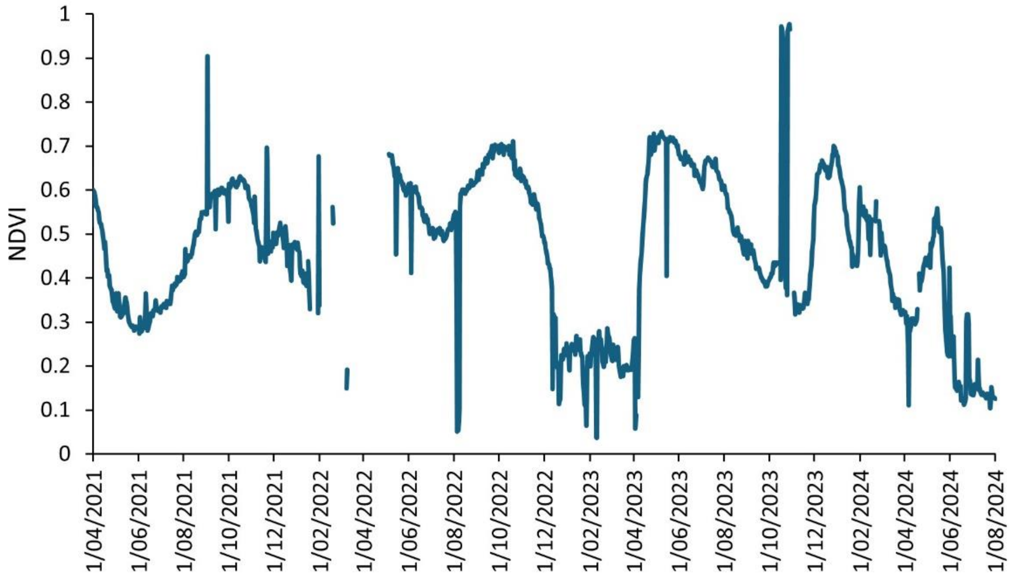


Figure 83: Daily median NDVI recorded at Glenview, 1st July 2021 – 1st August 2024.

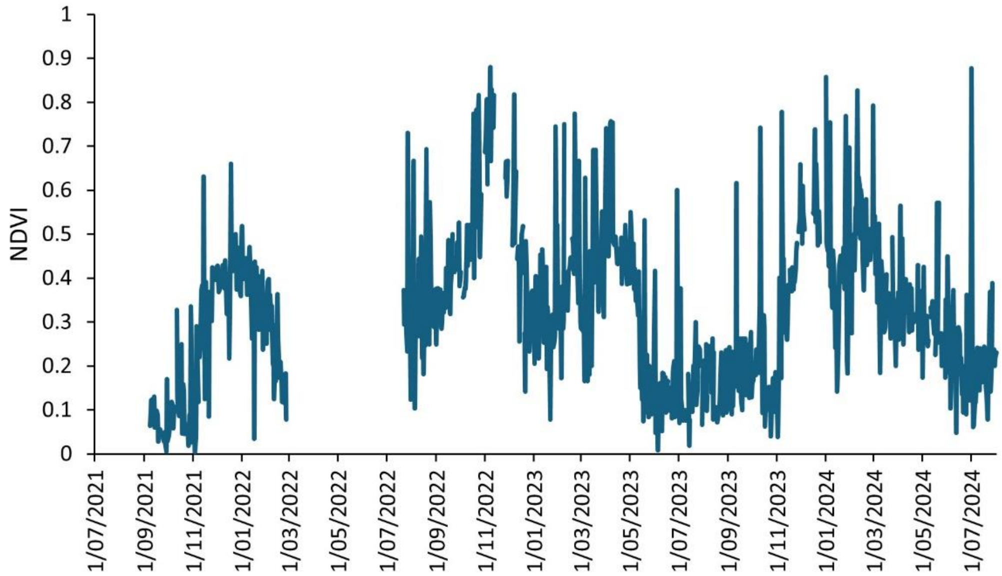


Figure 84: Daily median NDVI recorded at Leaderville, 1st July 2021 – 1st August 2024.

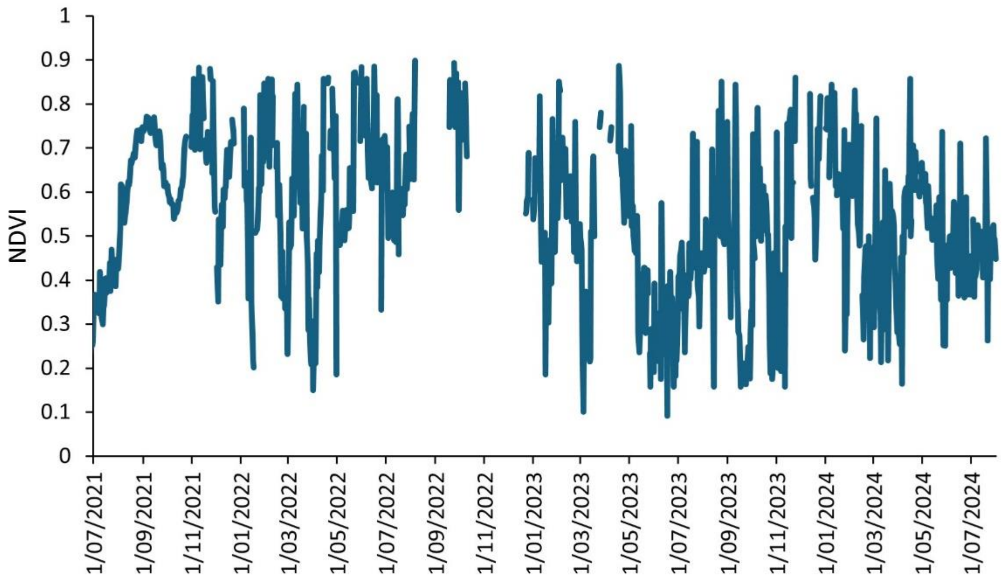


Figure 85: Daily median NDVI recorded at Myanbah, 1st July 2021 – 1st August 2024. NDVI telemeter issues occurred regularly, leading to data missing mid-2022, early 2023 and at the end of 2023.

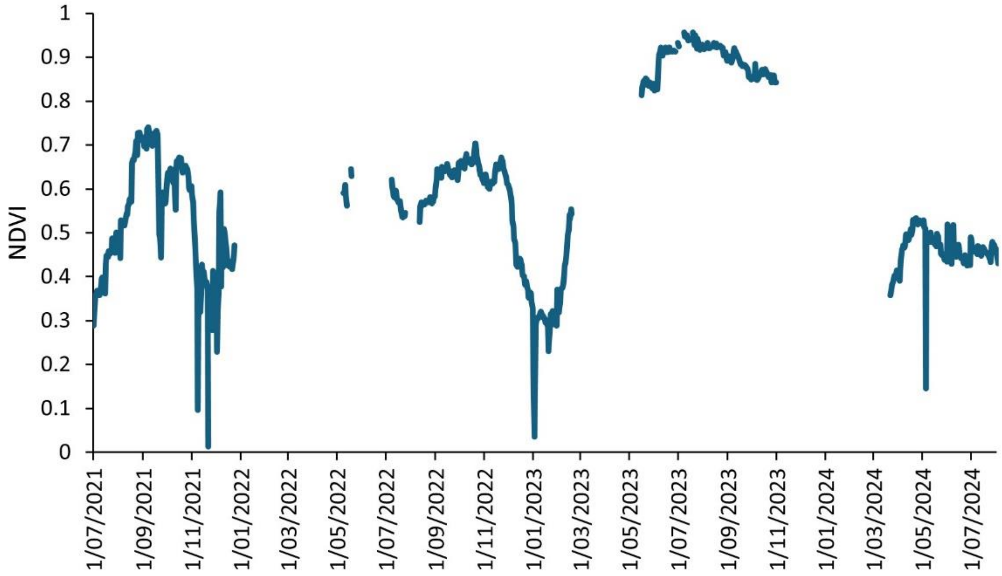


Figure 86: Daily median NDVI recorded at Pointfield, 1st July 2021 – 1st August 2024.

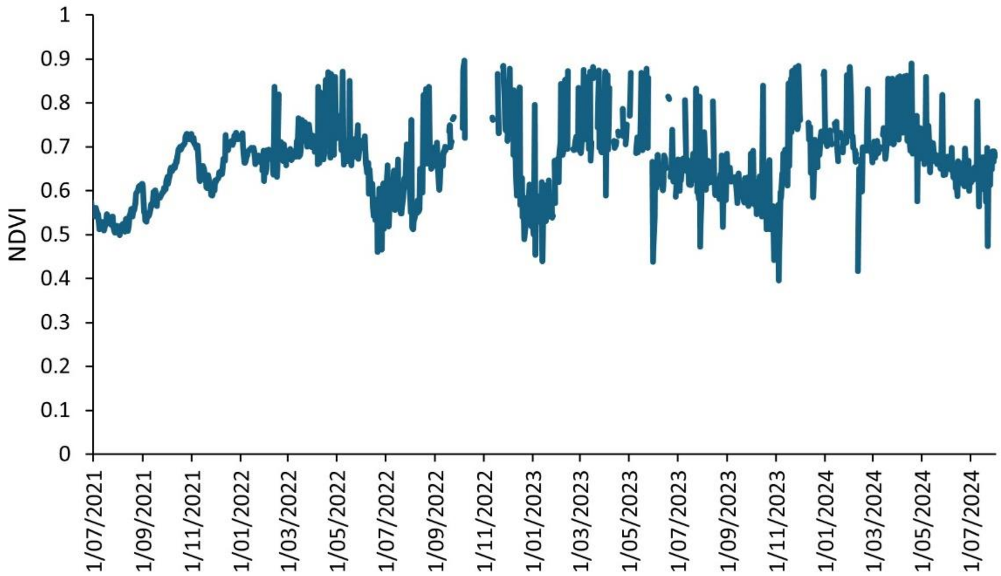


Figure 87: Daily median NDVI recorded at Te Dapa, 1st July 2021 – 1st August 2024. Due to dashboard issues, no data available after the 1st January 2022.

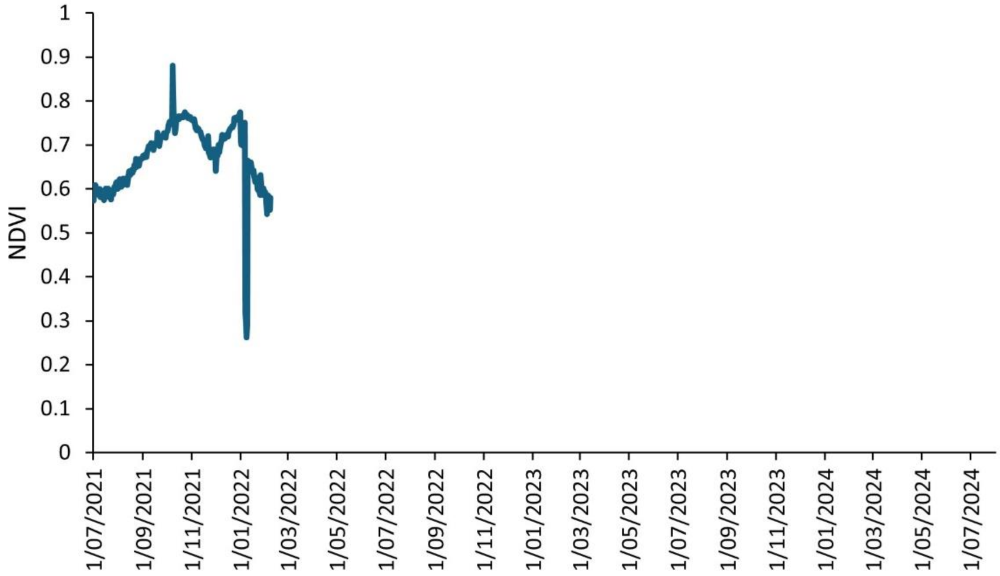


Figure 88: Daily median NDVI recorded at Tenterden, 1st July 2021 – 1st August 2024.

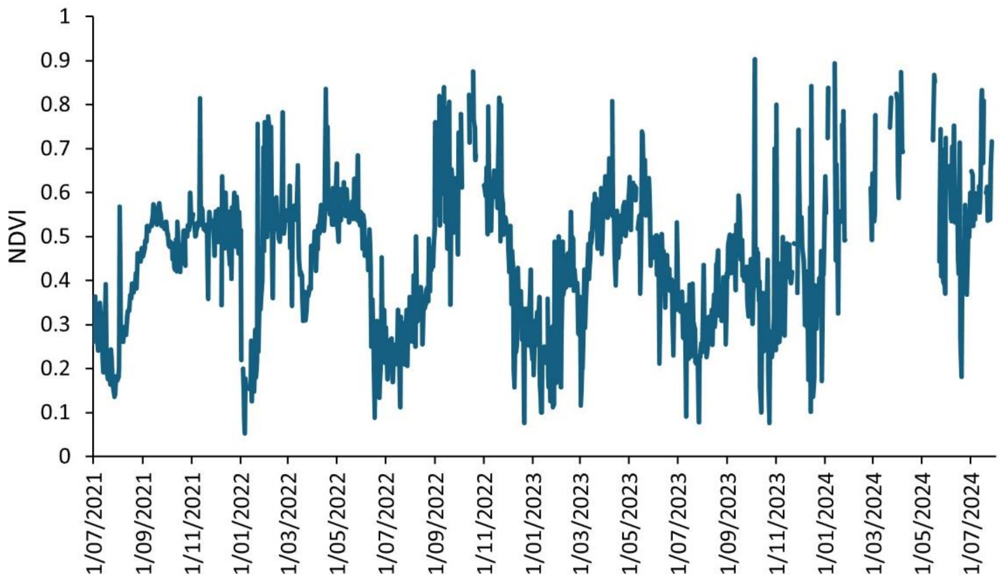
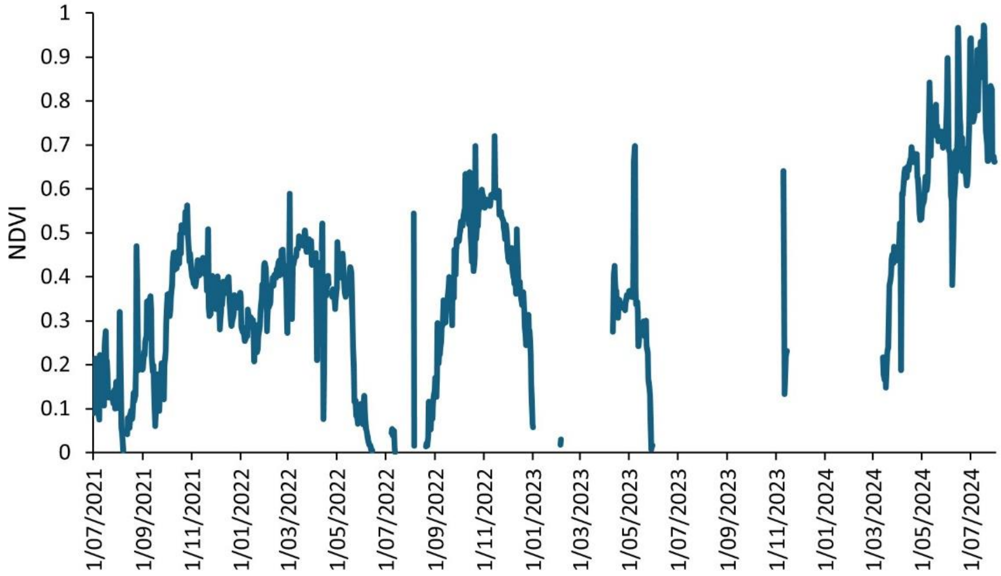


Figure 89: Daily median NDVI recorded at Urandangie, 1st July 2021 – 1st August 2024. Issues with the NDVI telemeter occurred early 2023, and from mid-2023 until the start of 2024.



8.6.3 NDVI compared to pasture biomass.

Table 32: Biomass weight of cut pasture (0.5 m²) and associated NDVI values. Fresh and dry weight of composite subsamples and calculated dry matter content.

Date	Property	NDVI	Sample wet weight (including bag)	Bag weight	Composite Subsample fresh weight (including bag)	Subsample bag weight	Composite Subsample dry weight (including bag)	Subsample dry matter content
dd/mm/yy	*name*	*0 - 1*	*g*	*g*	*g*	*g*	*g*	*%*
9/06/23	Glenview	0.2	242	8	100	8	77	75.0
		0.14	251	8				
		0.14	230	8				
		0.13	233	8				
		0.17	133	8				
		0.17	112	8				
		0.18	129	8				
		0.2	149	8				
		0.24	75	8				
		0.11	182	8				
6/06/23	Tenterden	0.62	152	8	100	8	39	33.7
		0.64	218	8				
		0.57	136	8				
		0.71	203	8				
		0.57	104	8				
		0.44	87	8				
		0.64	129	8				
		0.52	71	8				
		0.53	142	8				
		0.67	228	8				

Date	Property	NDVI	Sample wet weight (including bag)	Bag weight	Composite Subsample fresh weight (including bag)	Subsample bag weight	Composite Subsample dry weight (including bag)	Subsample dry matter content
dd/mm/yy	*name*	*0 - 1*	*g*	*g*	*g*	g	g	%
5/06/23	Myanbah	0.34	67	8	100	8	69	66.3
		0.43	46	8				
		0.44	30	8				
		0.36	223	8				
		0.33	227	8				
		0.45	128	8				
		0.39	72	8				
		0.38	105	8				
		0.36	111	8				
		0.33	239	8				
7/06/23	Urandangie	0.42	624	42	100	8	48	43.5
		0.47	423	42				
		0.32	387	42				
		0.47	410	42				
		0.4	407	42				
		0.33	295	42				
		0.5	438	42				
		0.33	260	42				
		0.39	135	42				
		0.35	296	42				
8/06/23	Leaderville	0.21	45	8	100	8	72	69.6
		0.25	152	8				
		0.19	32	8				
		0.38	88	8				
		0.2	56	8				

Date	Property	NDVI	Sample wet weight (including bag)	Bag weight	Composite Subsample fresh weight (including bag)	Subsample bag weight	Composite Subsample dry weight (including bag)	Subsample dry matter content
dd/mm/yy	*name*	*0 - 1*	*g*	*g*	*g*	g	g	%
8/06/23	Leaderville	0.23	58	8				
		0.5	71	8				
		0.3	245	8				
		0.16	50	8				
		0.18	238	8				
7/06/23	Bald Blair	0.35	45	8	100	8	58	54.3
		0.36	233	42				
		0.34	523	42				
		0.35	613	42				
		0.33	570	42				
		0.33	535	42				
		0.37	337	42				
		0.41	608	42				
		0.27	341	42				
		0.3	382	42				
8/06/23	Cooringoora	0.71	164	8	100	8	36	30.4
		0.7	229	8				
		0.68	337	8				
		0.74	482	8				
		0.74	505	8				
		0.75	364	8				
		0.71	529	8				
		0.63	387	8				
		0.73	360	8				
		0.72	381	8				

Date	Property	NDVI	Sample wet weight (including bag)	Bag weight	Composite Subsample fresh weight (including bag)	Subsample bag weight	Composite Subsample dry weight (including bag)	Subsample dry matter content
dd/mm/yy	*name*	*0 - 1*	*g*	*g*	*g*	g	g	%
9/06/23	Argyle	0.51	24	8	100	8	39	33.7
		0.47	97	8				
		0.54	40	8				
		0.53	138	8				
		0.42	181	8				
		0.51	12	8				
		0.5	11	8				
		0.51	71	8				
		0.47	209	8				
		0.64	165	8				
28/06/23	Te Dapa	0.31	40	8	100	8	89	88.0
		0.3	40	8				
		0.2	20	8				
		0.37	42	8				
		0.19	37	8				
		0.22	22	8				
		0.42	40	8				
		0.42	47	8				
		0.3	46	8				
		0.27	28	8				
27/06/23	Achill	Not enough biomass available to take pasture cuts						
27/06/23	Pointsfield	0.27	85	8		8		
		0.39	26	8				
		0.33	16	8				

Date	Property	NDVI	Sample wet weight (including bag)	Bag weight	Composite Subsample fresh weight (including bag)	Subsample bag weight	Composite Subsample dry weight (including bag)	Subsample dry matter content
dd/mm/yy	*name*	*0 - 1*	*g*	*g*	*g*	g	g	%
27/06/23	Pointsfield	0.31	53	8				
		0.35	14	8				
		0.28	24	8				
		0.35	93	8				
		0.31	16	8				
		0.27	47	8				
		0.44	12	8				
10/10/23	Urandangie	0.45	87	29	198	29	137	63.9
		0.49	209	29				
		0.55	223	29				
		0.32	147	29				
		0.29	157	29				
		0.27	93	29				
		0.3	121	29				
		0.41	177	29				
		0.36	182	29				
		0.31	108	29				
12/10/23	Leaderville	0.37	76	29	294	29	168	52.5
		0.61	116	29				
		0.41	141	29				
		0.54	164	29				
		0.31	59	29				
		0.45	115	29				
		0.29	71	29				
		0.51	145	29				

Date	Property	NDVI	Sample wet weight (including bag)	Bag weight	Composite Subsample fresh weight (including bag)	Subsample bag weight	Composite Subsample dry weight (including bag)	Subsample dry matter content
dd/mm/yy	*name*	*0 - 1*	*g*	*g*	*g*	g	g	%
12/10/23	Leaderville	0.42	106	29				
		0.51	132	29				
11/10/23	Tenterden	0.22	82	29	179	29	127	65.3
		0.3	74	29				
		0.23	73	29				
		0.28	165	29				
		0.22	115	29				
		0.25	162	29				
		0.36	109	29				
		0.28	162	29				
		0.25	62	29				
		0.3	73	29				
10/10/23	Bald Blair	0.18	117	29	150	29	129	82.6
		0.27	68	29				
		0.17	109	29				
		0.15	82	29				
		0.15	102	29				
		0.17	51	29				
		0.18	85	29				
		0.19	153	29				
		0.23	173	29				
		0.21	71	29				
6/02/24	Tenterden	0.45	132	25	101	25	68	56.6
		0.69	164	25				

Date	Property	NDVI	Sample wet weight (including bag)	Bag weight	Composite Subsample fresh weight (including bag)	Subsample bag weight	Composite Subsample dry weight (including bag)	Subsample dry matter content
dd/mm/yy	*name*	*0 - 1*	*g*	*g*	*g*	g	g	%
6/02/24	Tenterden	0.57	133	25				
		0.68	259	25				
		0.63	178	25				
		0.62	216	25				
		0.49	95	25				
		0.57	153	25				
		0.51	183	25				
		0.41	137	25				
7/02/24	Pointsfield	0.59	352	25	101	25	50	32.9
		0.53	81	25				
		0.49	137	25				
		0.55	138	25				
		0.61	206	25				
		0.55	148	25				
		0.57	148	25				
		0.5	147	25				
		0.62	352	25				
		0.49	251	25				
7/02/24	Achill	0.57	190	25	99	25	55	40.5
		0.63	138	25				
		0.52	77	25				
		0.5	220	25				
		0.6	260	25				
		0.49	174	25				
		0.48	98	25				

Date	Property	NDVI	Sample wet weight (including bag)	Bag weight	Composite Subsample fresh weight (including bag)	Subsample bag weight	Composite Subsample dry weight (including bag)	Subsample dry matter content
dd/mm/yy	*name*	*0 - 1*	*g*	*g*	*g*	g	g	%
7/2/24	Achill	0.45	77	25				
		0.57	218	25				
		0.52	81	25				
8/02/24	Bald Blair	0.65	522	25	96	25	53	39.4
		0.66	338	25				
		0.62	503	25				
		0.67	361	25				
		0.7	512	25				
		0.7	528	25				
		0.7	356	25				
		0.64	334	25				
		0.67	342	25				
		0.56	264	25				
9/02/24	Myanbah	0.35	128	25	103	25	63	48.7
		0.46	154	25				
		0.37	157	25				
		0.41	214	25				
		0.41	136	25				
		0.39	113	25				
		0.38	154	25				
		0.49	146	25				
		0.4	272	25				
		0.41	143	25				
13/02/24	Te Dapa	pasture sprayed-out, no biomass available for harvesting						

Date	Property	NDVI	Sample wet weight (including bag)	Bag weight	Composite Subsample fresh weight (including bag)	Subsample bag weight	Composite Subsample dry weight (including bag)	Subsample dry matter content
dd/mm/yy	*name*	*0 - 1*	*g*	*g*	*g*	g	g	%
13/02/24	Urandangie	0.6	373	25	349	25	177	46.9
		0.66	280	25				
		0.52	301	25				
		0.56	305	25				
		0.61	336	25				
		0.54	182	25				
		0.4	327	25				
		0.53	281	25				
		0.61	406	25				
		0.68	260	25				
14/02/24	Argyle	0.63	171	25	405	25	147	32.1
		0.72	198	25				
		0.67	518	25				
		0.64	187	25				
		0.63	175	25				
		0.67	236	25				
		0.65	389	25				
		0.73	211	25				
		0.68	120	25				
		0.72	180	25				
14/02/24	Glenview	0.36	71	25	237	25	155	61.3
		0.26	163	25				
		0.33	190	25				
		0.36	82	25				
		0.33	91	25				

Date	Property	NDVI	Sample wet weight (including bag)	Bag weight	Composite Subsample fresh weight (including bag)	Subsample bag weight	Composite Subsample dry weight (including bag)	Subsample dry matter content
dd/mm/yy	*name*	*0 - 1*	*g*	*g*	*g*	g	g	%
14/02/24	Glenview	0.3	74	25				
		0.33	66	25				
		0.3	126	25				
		0.34	106	25				
		0.34	91	25				
15/02/24	Cooringoora	0.43	265	25	137	25	80	49.1
		0.4	184	25				
		0.38	174	25				
		0.27	208	25				
		0.36	224	25				
		0.28	191	25				
		0.36	185	25				
		0.39	227	25				
		0.31	246	25				
		0.29	151	25				
15/02/24	Leaderville	0.35	168	25	101	25	80	72.4
		0.37	248	25				
		0.4	282	25				
		0.37	266	25				
		0.37	307	25				
		0.49	313	25				
		0.34	207	25				
		0.31	118	25				
		0.21	127	25				
		0.25	104	25				

Date	Property	NDVI	Sample wet weight (including bag)	Bag weight	Composite Subsample fresh weight (including bag)	Subsample bag weight	Composite Subsample dry weight (including bag)	Subsample dry matter content
dd/mm/yy	*name*	*0 - 1*	*g*	*g*	*g*	g	g	%
12/06/24	Tenterden	0.36	68	28	439	28	215	45.5
		0.27	42	28				
		0.37	95	28				
		0.45	95	28				
		0.43	117	28				
		0.27	120	28				
		0.41	40	28				
		0.43	39	28				
		0.31	37	28				
		0.36	56	28				
19/06/24	Pointsfield	0.38	68	28	155	28	89	48.0
		0.33	52	28				
		0.34	76	28				
		0.33	47	28				
		0.4	44	28				
		0.3	45	28				
		0.42	65	28				
		0.32	39	28				
		0.36	53	28				
		0.39	106	28				
19/06/24	Achill	0.39	38	28	78	28	67	78.0
		0.33	38	28				
		0.46	29	28				
		0.54	31	28				
		0.36	36	28				

Date	Property	NDVI	Sample wet weight (including bag)	Bag weight	Composite Subsample fresh weight (including bag)	Subsample bag weight	Composite Subsample dry weight (including bag)	Subsample dry matter content
dd/mm/yy	*name*	*0 - 1*	*g*	*g*	*g*	g	g	%
19/06/24	Achill	0.43	65	28				
		0.49	29	28				
		0.55	33	28				
		0.32	49	28				
		0.43	60	28				
12/06/24	Bald Blair	0.49	135	28	389	28	184	43.2
		0.43	132	28				
		0.43	228	28				
		0.47	178	28				
		0.47	106	28				
		0.36	412	28				
		0.47	135	28				
		0.46	205	28				
		0.5	204	28				
		0.4	94	28				
28/05/24	Myanbah	0.64	226	28	334	28	122	30.7
		0.46	161	28				
		0.61	239	28				
		0.5	156	28				
		0.44	152	28				
		0.53	130	28				
		0.43	145	28				
		0.43	118	28				
		0.55	189	28				
		0.6	318	28				

Date	Property	NDVI	Sample wet weight (including bag)	Bag weight	Composite Subsample fresh weight (including bag)	Subsample bag weight	Composite Subsample dry weight (including bag)	Subsample dry matter content
dd/mm/yy	*name*	*0 - 1*	*g*	*g*	*g*	g	g	%
21/06/24	Te Dapa	0.22	91	28	311	28	149	42.8
		0.25	93	28				
		0.2	89	28				
		0.2	115	28				
		0.29	158	28				
		0.7	93	28				
		0.19	124	28				
		0.21	146	28				
		0.3	68	28				
		0.22	135	28				
13/06/24	Urandangie	0.67	166	28	442	28	163	32.6
		0.54	260	28				
		0.63	267	28				
		0.65	127	28				
		0.65	153	28				
		0.64	234	28				
		0.56	148	28				
		0.45	224	28				
		0.68	253	28				
		0.49	77	28				
14/06/24	Argyle	0.52	100	28	276	28	104	30.6
		0.47	143	28				
		0.45	166	28				
		0.43	171	28				
		0.52	65	28				

Date	Property	NDVI	Sample wet weight (including bag)	Bag weight	Composite Subsample fresh weight (including bag)	Subsample bag weight	Composite Subsample dry weight (including bag)	Subsample dry matter content
dd/mm/yy	*name*	*0 - 1*	*g*	*g*	*g*	g	g	%
14/06/24	Argyle	0.47	188	28				
		0.43	472	28				
		0.47	315	28				
		0.52	216	28				
		0.53	106	28				
14/06/24	Glenview	0.22	52	28	143	28	114	74.8
		0.23	121	28				
		0.18	187	28				
		0.25	71	28				
		0.26	34	28				
		0.16	187	28				
		0.32	38	28				
		0.21	44	28				
		0.24	51	28				
		0.24	43	28				
18/06/24	Leaderville	0.36	93	28	252	28	166	61.6
		0.28	116	28				
		0.26	75	28				
		0.36	77	28				
		0.26	70	28				
		0.23	102	28				
		0.32	104	28				
		0.33	108	28				
		0.34	111	28				
		0.27	73	28				

Date	Property	NDVI	Sample wet weight (including bag)	Bag weight	Composite Subsample fresh weight (including bag)	Subsample bag weight	Composite Subsample dry weight (including bag)	Subsample dry matter content
dd/mm/yy	*name*	*0 - 1*	*g*	*g*	*g*	g	g	%
18/6/24	Cooringoora	No samples taken as lucern had just been sown and the soil was bare						

8.7 Grazing management strategies

Table 33: Grazing management adopted per project site, February 2023 – November 2023.

Stock Class	Grazing start	Grazing end	# days	# head	Area (ha)	DSE rating	DSE equivalent	Total DSE	Total DSE/ha	Total grazing days	Total DSE/ha/day	Rest days	Paddock rested (% time)
Bald Blair													
Bulls (600kg)	3/02/2023	10/02/2023	7	43	26	12.5	537.5	**3,878.6**	**149.2**	**38.0**	**3.93**	**264.0**	**86.8**
Bulls (650 kg)	27/03/2023	3/04/2023	7	49	26	12.9	632.1						
Bulls (350 kg)	7/07/2023	14/07/2023	7	126	26	8.4	1058.4						
Bulls (420 kg)	28/08/2023	4/09/2023	7	126	26	9.1	1146.6						
Cows and calves	24/09/2023	8/10/2023	10	60	26	8.4	504						
Cooringoora													
Angus cross cows	22/06/2023	14/07/2023	22	84	25	6.8	571.2	**1,296.1**	**51.8**	**161.0**	**0.32**	**141.0**	**46.4**
Angus calves	20/07/2023	25/09/2023	67	99	25	7.2	712.8						
Angus heifers	20/07/2023	26/09/2023	68	1	25	5.3	5.3						
Angus bulls	22/09/2023	26/09/2023	4	1	25	6.8	6.8						
Glenview													
Cows and calves	6/01/2023	20/01/2023	14	85	45	9	765	**2,538.5**	**56.4**	**142.0**	**0.40**	**160.0**	**52.6**
calves	6/01/2023	20/01/2023	14	82	45	5	410						
angus cows	18/04/2023	6/07/2023	79	71	45	8.5	603.5						
merino wethers	25/07/2023	12/09/2023	49	760	45	1	760						
Tenterden													
Xbred steers over 650 kg	17/01/2023	23/01/2023	6	209	24.7	10	2,090.00	**24,797.1**	**1,003.9**	**23.0**	**43.65**	**279.0**	**91.8**
cull cows	20/01/2023	23/01/2023	3	175	24.7	7.7	1,347.50						
Light cross bred steers under 530 kg	20/02/2023	25/02/2023	5	690	24.7	9	6,210.00						

Stock Class	Grazing start	Grazing end	# days	# head	Area (ha)	DSE rating	DSE equivalent	Total DSE	Total DSE/ha	Total grazing days	Total DSE/ha/day	Rest days	Paddock rested (% time)
Steers 500 - 580 kg	10/04/2023	14/04/2023	4	1082	24.7	7.8	8,439.60						
merino ewes	10/07/2023	14/07/2023	4	510	24.7	1	510						
weaners	19/07/2023	27/07/2023	8	1550	24.7	4	6,200.00						
Myanbah													
pregnant cows	19/04/2023	25/06/2023	67	41	26	8.4	344.4	**530.0**	**20.9**	**143.0**	**0.15**	**159.0**	**52.3**
bulls	12/07/2023	20/09/2023	70	6	26	12	72						
cattle	24/11/2023	30/11/2023	6	16	26	7.1	113.6						
Argyle													
cow + calf	5/01/2023	13/01/2023	8	230	37	9.7	2231	**7,761.6**	**209.8**	**109.0**	**1.92**	**193.0**	**63.5**
heifers	16/02/2023	23/02/2023	7	104	37	6.5	676						
heifers	14/03/2023	23/03/2023	9	104	37	6.7	696.8						
heifers	20/04/2023	27/04/2023	7	104	37	6.9	717.6						
cows	22/06/2023	30/06/2023	8	101	37	7.7	777.7						
cows	15/07/2023	28/07/2023	13	100	37	7.5	750						
cow + calf	1/09/2023	23/09/2023	22	85	37	9.5	807.5						
heifers	19/10/2023	8/11/2023	20	85	37	7	595						
heifers	15/11/2023	30/11/2023	15	85	37	6	510						
Urandangie													
yearling steers	9/02/2023	10/02/2023	1	137	10	6	822	**6,433.5**	**643.4**	**34.5**	**18.65**	**267.5**	**88.0**
yearling steers	11/02/2023	13/02/2023	2	105	10	6	630						
yearling steers	28/02/2023	1/03/2023	1.5	105	10	6	630						
yearling steers	9/03/2023	12/03/2023	3	105	10	6	630						
weaner steers	13/04/2023	18/04/2023	5	105	10	4.5	472.5						
weaner heifers	16/06/2023	20/06/2023	4	185	10	4	740						
weaner heifers	26/07/2023	1/08/2023	6	193	10	4	772						
weaner heifers	13/09/2023	23/09/2023	10	193	10	4.5	868.5						

Stock Class	Grazing start	Grazing end	# days	# head	Area (ha)	DSE rating	DSE equivalent	Total DSE	Total DSE/ha	Total grazing days	Total DSE/ha/day	Rest days	Paddock rested (% time)
weaner heifers	13/11/2023	15/11/2023	2	193	10	4.5	868.5						
Pointsfield													
older cows	17/04/2023	18/04/2023	1.2	N/A	23	Agriwebb	3,568.00	**12,010**	**522.2**	**35.2**	**14.84**	**266.8**	**87.76**
bought weaners	5/05/2023	10/05/2023	5.2	N/A	23	Agriwebb	804						
2021 steer calves / highland	5/05/2023	10/05/2023	5.9	N/A	23	Agriwebb	192						
feeder steers caroona	23/05/2023	26/05/2023	3.1	N/A	23	Agriwebb	525						
heavy Pardoo over 300	20/06/2023	23/06/2023	3	N/A	23	Agriwebb	983						
light wethers	18/07/2023	21/07/2023	3.1	N/A	23	Agriwebb	363						
joined heifers	30/07/2023	6/08/2023	7.9	N/A	23	Agriwebb	1,903.00						
older cows	16/11/2023	17/11/2023	1	N/A	23	Agriwebb	3,636.00						
Xbred rams	20/11/2023	30/11/2023	10	N/A	23	Agriwebb	36						

Table 34: Grazing management adopted per project site, December 2023 – May 2024.

Stock class (description)	Grazing start	Grazing end	# days	# head	Area (ha)	DSE rating	DSE equivalent	Total DSE	Total DSE/ha	Total grazing days	Total DSE/ha/day	Rest days	Paddock rested (% time)
Bald Blair													
Bulls	8/02/2024	16/02/2024	8	57	26	10.6	604.2	604.2	23.2	8.0	**2.9**	143	**94.7**
Cooringoora													
2021 Heifers	29/12/2023	30/04/2024	123	3	34	6.5	19.5	296.3	8.7	123.0	**0.1**	28	**18.5**
2022 steers	29/12/2023	30/04/2024	123	2		6.4	12.8						
2022 Heifers	29/12/2023	30/04/2024	123	44		6.0	264.0						
Myanbah													
Cattle	1/12/2024	30/12/2024	29	16	26	6.5	104.0	104	4	29	**0.1**	122	**80.8**
Urandangie													
Mixed breed steers	31/12/2023	22/01/2024	22	180	10	6.4	1152.0	3360	336	90	**3.7**	61	**40.4**
Angus steers	4/02/2024	14/02/2024	10	83		6.4	531.2						
Mixed breed steers	4/02/2024	14/02/2024	10	20		6.4	128.0						
Black baldy steers	4/02/2024	14/02/2024	10	40		6.4	256.0						
Angus steers	14/02/2024	13/03/2024	28	61		6.4	390.4						
Black baldy steers	31/03/2024	30/04/2024	30	54		6.4	345.6						
Mixed breed steers	31/03/2024	30/04/2024	30	48		6.4	307.2						
Angus steers	31/03/2024	30/04/2024	30	39		6.4	249.6						
Leaderville													

Stock class (description)	Grazing start	Grazing end	# days	# head	Area (ha)	DSE rating	DSE equivalent	Total DSE	Total DSE/ha	Total grazing days	Total DSE/ha/day	Rest days	Paddock rested (% time)
Mixed sex weaners	1/12/2024	17/12/2024	16	200	16.6	4.5	900.0	3054	184.0	36.0	**5.1**	115	**76.2**
Yearlings	1/12/2024	17/12/2024	16	60		6.0	360.0						
Heifers 450kg	1/01/2024	21/01/2024	20	130		6.9	897.0						
Heifers 450kg	5/02/2024	25/02/2024	20	130		6.9	897.0						
							Achill						
Cows, angus cross	6/01/2024	18/01/2024	12	97	20.7	7.1	688.7	5393.6	260.6	58.0	**4.5**	93.0	**61.6**
Angus calves	6/01/2024	18/01/2024	12	117		4.5	526.5						
Angus heifers	6/01/2024	18/01/2024	12	21		6.5	136.5						
Angus bulls	6/01/2024	18/01/2024	12	4		13.7	54.8						
Angus heifer weaners	15/03/2024	25/03/2024	10	50		5.4	270						
Angus cross cows	15/03/2024	25/03/2024	10	33		7.1	234.3						
Angus cows	15/03/2024	25/03/2024	10	40		7.1	284						
Angus hiefers	15/03/2024	25/03/2024	10	14		6.5	91						
Merino ewes	25/03/2024	30/04/2024	36	1887		1.3	2453.1						
Merino lambs	25/03/2024	30/04/2024	36	683		0.9	614.7						
Merino hogget ewe	25/03/2024	30/04/2024	36	40		1	40						
							Argyle						
None	N/A	N/A	0	0	37	0	0	0	0	0	**0**	0	**0**

8.8 Producer feedback scores

Tables 35 and 36 show the feedback scores given for the knowledge and skills section and for the confidence section, by core and observer participants respectively.

Table 35: Feedback scores (%) given by core producers, on 'knowledge and skills' and 'confidence', in November 2022, November 2023, April 2024, and November 2024.

Participant	Knowledge and skills						Confidence					
	Pre-Project (2020)	Nov-22	Nov-23	May-23	Apr-24	Nov-24	Pre-Project (2020)	Nov-22	Nov-23	May-23	Apr-24	Nov-24
1	80	64.3	60.7	80	NA	88	70	70	68	63	NA	80
2	76	53.5	85.7	76	NA	NA	80	80	90	56.6	NA	NA
3	48	78.6	78.6	64.2	64.3	84	40	100	64	80	76	60
4	28	78.6	78.9	71.4	71.4	84	80	70	74	76.6	70	80
5	76	53.6			NA	88	70	60			NA	40
6	32				NA	80	80				NA	70
7	64				57.1	52	60				82	30
8	76				NA	NA	60				NA	NA
9	68				85.7	60	50				66	60
10	92				78.6	100	50				88	50
Average	**64.0**	**65.7**	**76.0**	**79.4**	**71.4**	**79.5**	**64.0**	**76.0**	**74.0**	**69.1**	**76.4**	**67.4**

Table 36: Feedback scores (%) given by observer producers, on 'knowledge and skills' and 'confidence', in November 2022, November 2023, April 2024, and November 2024.

Participant	Knowledge and skills				Confidence			
	Nov-22	Nov-23	Apr-24	Nov-24	Nov-22	Nov-23	Apr-24	Nov-24
1	64.2	50	89		70	86	60	
2	46.4	50	79		70	38	86	
3	67.8	71.4	43		70	76	54	
4	64.2	39.3	64		30	26	62	
5	64.2	71.4	43		80	54	86	
6	57.1	71.4		75	50	28		60
7	89.3	78.6		90	50	88		90
8	46.4	42.9		60	20	72		90
9	50	60.7		50	70	58		30
10	78.6	14.3		75	80	32		70
11	71.4	64.3		90	70			60
12		89.3		65				30
				70				60
Average score	**63.6**	**58.6**	**63.6**	**71.8**	**60**	**55.8**	**69.6**	**70**