Final report

Enhancing grazing profitability through improving soil health

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Abstract

An immediate priority for the red meat industry is to develop methods of economically reaching net zero carbon emissions by 2030. This research seeks to better understand two approaches for increasing carbon sequestration levels in pastures.

A paired-site study of soil carbon stocks under C4 pastures sown with varying rates of the deep-rooted perennial legume, Progardes® desmanthus suggested that the presence of the legume improves soil carbon levels with a return on investment of 17%, 9% and 3% at the planting rates of 2kg/ha, 4kg/ha and 8kg/ha respectively. These results provide insight into an avenue of increased profitability for graziers and reduced net emissions for the red meat industry.

A further eleven trial sites comprised of two replicates each of three treatments – microbially diverse compost extract, minerals, and compost extract plus minerals – and two controls. Grazing yield was measured and at the conclusion of the trial, each site sampled for soil carbon and microbiological parameters. Drought and pasture dieback hampered the progress of the trial, and no significant results were found.

Executive summary

Background

An immediate priority for the red meat industry is to develop methods of economically, if not profitably, reaching net zero carbon emissions by 2030. One area of research seeks to better understand methods for increasing carbon sequestration levels in pastures.

Our research aimed to extend on preliminary findings of trials where different approaches resulted in an increase in soil carbon and productivity. This project consisted of two trials:

1. Field trial 1: To understand the effects of the incorporation of the legume Progardes® desmanthus on soil carbon at different seeding rates, and the associated return in investment when framed within a carbon trading scenario.
2. Field trial 2: To understand the effects of the application of a microbially diverse amendment on soil health, soil carbon, grazing yields and gross margins.

The outcomes of this research will inform graziers of methods which were found to be associated with an increase in pasture yield and/or soil carbon and profitability of grazing operations. As the trials were conducted at a paddock level rather than a plot or glasshouse level, results may be viewed by graziers as being more relevant, resulting in faster adoption and results for the red meat industry.

Objectives

- Develop a cost effective and environmentally responsible means of improving soil health and increasing soil carbon levels
- Engage a network of producers in improving soil health and further their understanding of business models involving soil carbon and investment in soil productivity
- Furthering understanding of linkages between various components of the soil health system to enhance sustainable development of the red meat industry
- Build leadership capacity in soil health and C research and adoption
- Achieve at least a 30% increase in carrying capacity at the farms included in the project.

The project achieved a number of objectives; however, circumstance such as drought and the Covid-19 pandemic meant the successful completion of other objectives was limited.

Methodology

Field trial 1: A site was selected where Progardes desmanthus had been planted into C4 perennial pastures in plots of 2kg/ha, 4kg/ha and 8kg/ha seven years earlier. Soil carbon levels in each plot were measured and compared to a control plot which had not been seeded with the desmanthus. A minimum of 10 soil cores were taken from each treatment and control plot to a depth of 120cm and analysed for soil carbon stocks as per the Australian Government's *Carbon Credits (Carbon Farming Initiative) (Sequestering Carbon in Soils in Grazing Systems) Methodology Determination 2014.* A cost benefit analysis was performed to understand the economic benefit of the treatment within the framework of trading the additional carbon sequestered on today's carbon market.

Field trial 2: Twenty-five trial sites were selected for the replicated cross-fence comparison of the impact of a microbially diverse compost extract only (B), minerals plus microbially diverse compost extract (MB), minerals only (M)) and no treatment (C) on grazing yield, microbial activity and diversity, and soil carbon. A soil microbial analysis (all paddocks) and mineral analysis (M and MB treatments) was conducted prior to treatment application and again at the completion of the trial four years later. Soil carbon (0-10cm) was also measured at the completion of the trial. Grazing yield was measured as stock days removed per hectare removed over a four-year period. The effect size was determined for each parameter and analysed for significance using a single-factor ANOVA. In the few cases where a statistically significant difference was found, a cost-benefit analysis was performed.

Results/key findings

The results of the research suggest that the incorporation of Progardes desmanthus legume into C4 perennial pastures, at rates of 2kg/ha, 4kg/ha and 8kg/ha may increase soil carbon sequestered. A planting rate of 2kg/ha showed the best return on investment at 17%pa when framed within the scenario that the additional carbon (less costs and statutory discounts) were traded on today's carbon market.

No conclusions could be drawn on the application of a microbially diverse compost extract to pastures and the effect on pasture yield, soil carbon or soil health. The results in all areas of the trial were significantly impacted by extended dry conditions and/or pasture dieback.

Benefits to industry

The incorporation of deep-rooted perennial legumes into C4 pastures can have numerous benefits to the red meat industry. Aside from the well-known productivity gains, the greater soil carbon stocks built over time provide the option to gain a return on investment by trading that additional soil carbon on the carbon market. Additionally, the adoption of this practice works towards the industry's goal of being carbon neutral by 2030.

Future research and recommendations

Repeated measurements of the Progardes trial area will provide insight into sequestration rates over time. Replicates of this trial in other areas will help understand if the results are repeatable in other environments. The results of this part of the research should be communicated to industry (along with other recognised benefits of the legume such as productivity gains) to raise awareness of the likelihood of this practice bolstering soil carbon stocks, improve adoptions and move the industry towards its carbon neutral goal.

Further research needs to be completed on the benefits (or otherwise) of microbially diverse amendments for pastures and soils. To ensure lack of moisture does not confound results, trials should be conducted in irrigated areas. Additionally, work should be done to understand the effectiveness of different methods of applying the amendments before extending the research back into an on-farm commercial scale.

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1. Background

The red meat industry is under the public spotlight regarding its carbon footprint, with 10% of Australia's greenhouse gas (GHG) emissions related to the production and processing of beef, lamb and goat meat (MLA, 2020). Therefore, establishing environmentally and economically effective methods of achieving carbon neutrality is of high priority.

The soil can act as a sink for, or source of, carbon emissions with the management of the resource determining whether carbon is emitted or sequestered (MLA, 2010). It is reported that traditional agricultural management practices such as cultivation and use of inorganic or synthetic fertilisers have resulted in depletion of soil carbon levels, soil fertility and overall soil health through the reduction of soil microbial activity and microbially-originated carbon stocks and the disruption of microbial food webs (Dick, 1992; Huber et al., 2008; Kuzykov, 2010). This leads to lowered yield and production, increased susceptibility to pests and disease, less resilience to climatic extremes and a greater reliance on inputs which, in turn, amounts to a pattern of declining profitability for grazing businesses.

Early research has shown that a method of soil management referred to as the biologically enhanced agricultural management (BEAM) method has resulted in an increase in both biomass production and soil carbon levels. This method is designed to optimize the growth and diversity of the soil microbial community and involves the use of small amounts of a microbially diverse, fungal dominant aerobic compost as a seed inoculant at planting to re-introduce or bolster soil microbial communities and raise fungi to bacteria ratio. In a 4.5 year trial of this method, soil carbon increased by 48.17t C/ha over the duration of the trial, or an average of 10.70t C/ha per year, along with a 5 times increase in above ground biomass when compared to a control plot. No fertilisers were used and the crops was irrigated as required throughout the trial (Johnson et al. 2015).

A hurdle in the use of a compost in broadscale grazing systems is the cost and practicality of sourcing and applying compost. A solution being used in broadscale cereal cropping systems is compost extract, which carries most of the biological benefits of the compost from which it is extracted, but less of the 'bulk'. When used in this manner, the amount of compost required is 3kg/ha (extracted to 100L of water). In broadacre cropping systems, fungal-dominant compost extract is used to coat seed before sowing and/or is direct drilled into the soil. It has been demonstrated on a Western Australian Wheat Belt farm that this practice has led to an increase 41.46% more soil carbon (to 30cm) than that in paddocks employing conventional means of cropping (Haggerty, pers. comm, 2017).

The replication of these effects on broadscale grazing systems would result in significant benefits to the red meat industry in respect to productivity, profitability and environmental goals. Therefore, an area of research in this project was to engage a network of graziers to trial the application of the BEAM approach in their grazing systems, and measure and compare changes in grazed yield, microbial activity and carbon stocks after several years.

Additionally, research has shown that under sowing C4 pastures with legumes can increase the rate of carbon sequestration. A study conducted by Fornara & Tillman (2008) showed that over a 12-year period, the incorporation of legumes into grassland savannah species increased soil carbon accumulation by 522% over that of monoculture plots of the same species. A further aim of our research was to understand if a similar result could be replicated, and if so, what planting rates of legume provided the greatest benefit to soil carbon and profitability.

Findings of this research will inform graziers and other industry stakeholders of strategies which result in increased pasture yield and carbon sequestration and the associated return on investment. Where the paddock-scale results are shown to be economically viable, results can be readily translated to the industry. Adoption of those practices which profitably increase yield and sequester carbon would likely follow and the resulting increase in revenue and decrease in net carbon emissions for the industry could be significant.

2. Objectives

While the project was successful in meeting some objectives, circumstances such as drought and the Covid-19 pandemic prohibited the achievement of others.

2.1 Develop cost effective and environmentally responsible means of improving soil health and increasing soil carbon levels

A preliminary paired-site study indicated that the incorporation of the tropical legume species *Progardes* d*esmanthus* into C4-grass pastures may positively impact soil carbon stocks, while separate field trials demonstrated few statistically significant differences in pasture yields between mineral and/or microbially diverse compost extract treatments when compared to untreated paddocks. It is unclear if this is due to consecutive low-rainfall years, pasture dieback or the treatments themselves.

2.2 Engage a network of producers in improving soil health and further their understanding of business models involving soil carbon and invest in soil productivity

There was good producer engagement in the early stages of the project; however, as drought took hold producer engagement waned, particularly in southern Queensland and NSW where many producers had withdrawn from the project by 2020. Those producers remaining in the project stayed engaged and showed great interest in exploring methods of increasing soil health and how improving soil carbon can fit into their business models. Border restrictions prevented on-farm engagement in NSW throughout 2020-21.

2.3 Furthering understanding of the linkages between components of the soil health system to enhance sustainable development of the red meat industry

The Progardes-pasture trial deepened our understanding of the impacts on soil carbon of under sowing legumes into C4 pastures and the flow-on effects on the sustainability of the red-meat industry.

The field trial resulted in a quite limited understanding of the impacts of mineral and biological amendments on soil health, however there were some valuable learnings around the costs and practicalities of treatment applications.

2.4 Build leadership capacity in soil health and carbon research and adoption

The project was successful in achieving this outcome, with the results of the legume-pasture trials catalysing further carbon research.

Many producers involved in the field trials gained confidence in their knowledge of soil health and continued to develop this knowledge and capacity within and beyond the project.

2.5 Achieve at least 30% increase in carrying capacity at the farms included in the project.

There were very few statistically significant increases in yield seen between treatments in any of the field trial sites. As the project commenced at the beginning of the 2017-2019 drought, it is unclear if this was due to treatments or environmental conditions.

3. Methodology

3.1 Field trial 1: Measurement of soil carbon in C4 pastures with and without Progardes desmanthus

A property between Tambo and Springsure in Queensland's Brigalow Belt was selected for this section of research. Pastures on the property were a mix of C4 pastures with large plots planted to 2kg, 4kg or 8kg of the deep-rooted perennial legume, Progardes® desmanthus seven years prior to sampling. A control paddock of the same C4 pasture type but without legumes was also selected.

3.1.1 Sampling design and sampling

Coring locations in the treatment and control paddocks were selected and GPS recorded during the sampling process. Twelve cores were taken from the control paddock, sixteen cores from the 2kg/ha Progardes pasture, 10 cores from the 4kg/ha Progardes pasture and 10 cores from the 8kg/ha Progardes pasture (Fig. 1).

At each location soil cores were extracted with a hydraulic coring rig (Fig. 2). Soil cores were 48mm in diameter and 1200mm deep.

Figure 1 - Treatment and control plots and sampling locations

Figure 2 - Extracting soil cores with a hydraulic coring rig

Each core was transferred to a cold room and stored below 4^0C until delivered to a NATA accredited lab for analysis.

3.1.2 Sample processing

Lab analysis for total carbon percentage and conversion to tonnes of carbon per hectare was per the Australian Government's *Carbon Credits (Carbon Farming Initiative) (Sequestering Carbon in Soils in Grazing Systems) Methodology Determination 2014.*

This method proved suitable for the purposes of this section of the research.

3.2 Field trial 2: Cross-fence comparison of the effect of a microbially diverse amendment on grazing yield and soil health

3.2.1 Selection of trial sites

Twenty-five on-farm trial sites were selected based on the following criteria:

a) Trial paddocks would be managed using time-controlled grazing techniques;
b) Each site had a minimum of eight suitable trial paddocks (uniform soil, land and pasture types, accessible for treatment application);
c) Accurate grazing charts would be in use by the land manager for yield monitoring in these paddocks;
d) Land managers of trial sites agreed to provide assistance to collect soil samples at beginning and end of project, and would be willing to provide photographs and commentary on notable happenings and things of interest;
e) Land managers of trial sites would apply treatments to trial sites as prescribed by RCS;
f) Land managers of trial sites would to participate in a learning group via online discussions and sharing of results.

Project sites were distributed throughout the eastern seaboard, from the Tropic of Capricorn in the north to the Southern Tablelands area in New South Wales (Fig. 3). The geographic spread was to both reduce the impact of natural events such as drought, flood or disease on the results of the project and, if all went well, to provide information on the impacts of the treatments across different climates and environments. However, due to the extreme drought conditions experienced by most of the east coast of Australia during 2018 and 2019, the border closures and regional travel restrictions associated with the Covid-19 pandemic, and pasture dieback, only seven project sites could be finalised (i.e. complete grazing data and soil samples) while another four were partially finalised (grazing data only).

Figure 3 – Field Trial 2 site locations

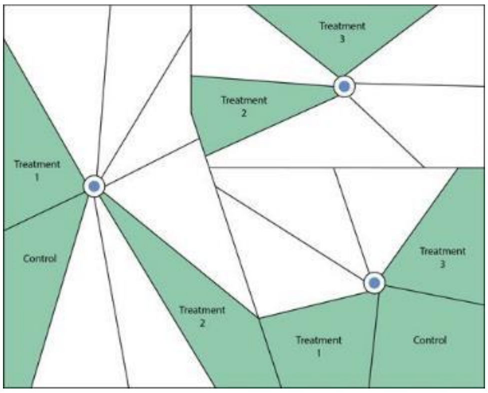
3.2.2 Paddock treatment type selection

Once suitable trial sites were selected, each site was visited by a project technician. Trial paddock suitability was assessed, and a trial treatment type allocated to each paddock. Compulsory trial treatment types were:

a) Compost extract (B)
b) Minerals (M)
c) Compost extract plus minerals (MB)
d) Control (C)

Two replications of each treatment type were required, therefore each trial site had (a minimum of) eight paddocks. Figure 4 provides an example of trial design.

Figure 4 – Example trial design



3.2.3 Soil sampling

After paddock appraisal and treatment type selection, soil samples were taken from each trial paddock. Three different soil samples were required:

3.2.3.1 Sampling for chemical analysis

To understand if mineral deficiencies were implicated in any potential responses, appropriate mineral treatment recommendations were made for M and MB treatment paddocks to balance soil minerals. Samples for chemical analysis were taken according to Lancaster (n.d.) to a depth of 100mm. The selected samples were sent to Southern Cross University's Environmental Analysis Laboratory (EAL) for analysis. The Albrecht/Reams plus totals and heavy metals analysis was performed on each soil sample.

Four years later at the completion of the field trials, soil was resampled for chemical analysis following the same procedure and transect as the baseline sampling round.

3.2.3.2 Sampling for biological analysis

A biological analysis was used as an indicator of soil health (along with soil carbon). A sub-sample for biological analysis was taken at the same time as that for chemical analysis (at both the commencement and completion of the trial). The biological sub-sample was placed into a freezer immediately post sampling then sent to Microbiology Laboratories Australia in a cold pack for analysis. The test performed on both the baseline and final samples was Microbe Wise Forecasta.

3.2.3.3 Sampling for RNA storage

In the baseline round, one sample from each paddock was taken for RNA storage. A small amount (approx. 2mL) of soil from the rhizosphere of a grass plant's roots was scraped into a vial containing 5mL of RNALater solution. The vial was sealed and placed into a -18°C freezer initially, then a -80°C freezer once one became available (approx. 4 months after sampling). These samples were to remain in storage until the end of the project and, if notable outcomes occurred in any particular paddock, a metatranscriptome analysis would be performed on both samples to provide insight into the difference in microbial community. As there were no notable results, no follow-up samples were taken for metatranscriptome analysis.

3.2.4 Photo monitoring

A suitable site was selected and GPS recorded in each trial paddock, and a photo taken of the pasture condition in that location at the beginning and end of the field trial.

3.2.5 Treatment recommendations

Based on results received from EAL, recommendations were made for treatment M and MB paddocks based on using 'soil friendly' soft fertilisers and catalytic amounts of trace minerals where required (see Appendix 8.1). Total and available limiting nutrients were considered, as was the accessibility of the trial site for equipment needed to apply the inputs and the availability of that equipment. For example, if the total nutrient level was adequate, but available nutrient level was low, small amounts of that nutrient were included in the recommendation (feed the biology, which will then access the unavailable nutrients and feed the plant). If the total level of nutrient showed to be lacking, then larger amounts of that nutrient was recommended (feed the plant). If the paddock was highly accessible, and the producer had equipment suitable for direct injection of the inputs, then input forms suitable for direct injection were recommended. If the paddocks were unsuitable for direct inject or the equipment wasn't available, input forms that were suitable for foliar application via a boomless spray unit may have been recommended, or, if the input requirements did not suit foliar application, a dry fertiliser blend was recommended for broadcast.

The biological input recommendation was standard across all trial sites, being 100L/ha compost extract (a metatranscriptome analysis showed the microbial diversity to be very similar to that used in Johnson et al., 2015), 200gm/ha Actpak biology activator, 3L/ha liquid fish emulsion and 2L/ha molasses. In some cases, for those paddocks receiving both compost extract plus minerals, the biological inputs may be mixed with the minerals, and in other cases the biological inputs were recommended to be applied separately to the minerals.

3.2.6 Soil amendments applied

For those properties which had suitable conditions to proceed with treatment application, inputs were applied as per recommendations. Biological inputs needed to be applied prior to rainfall to ensure incorporation into soil. As the trials commenced in the beginning of what was to become a severe drought, particularly in New South Wales, a large number of sites could not apply the treatments so were withdrawn from the trial.

3.2.7 Monitor trial paddocks

Trial sites were grazed as normal where possible (i.e. using time-controlled grazing method), and yields (SDH) recorded on grazing chart. Drought and pasture dieback affected the grazing on many sites, and therefore these sites (or individual paddocks in the case of dieback) were withdrawn from the trial.

3.2.8 Completion of field trials

In July of 2021, almost four years after the commencement of the field trials, the final grazing data was collected from those sites which were able to apply treatments and continue grazing throughout the drought. Of those sites, those which were accessible during Covid-19 travel restrictions were visited by a project technician, paddocks assess, soil sampled and sent for analysis, and final monitoring photos taken.

3.2.9 Analysis of data

The formulas used to calculate results are outlined below. Where statistical analysis was required, the Single Factor Analysis of Variance was used, and where a significant result was returned, paired sample t-tests were performed. See attached file named 'P.PSH.0918 – Field Trial 2 Data' for site yields, soil carbon levels, microbial indicators and statistical analysis.

3.2.9.1 Grazing yield

Grazing yield, or stock days per hectare removed (SDH) was calculated by landholders after each graze in each paddock, using Equation 1, below:

Equation 1 $$\mathrm{SDH} = \frac{\text{Total LSU in paddock} \times \text{number of days grazed}}{\text{paddock size (ha)}}$$

where LSU (large stock units) is calculated by following Equation 2:

Equation 2 $$LSU = number\ of\ each\ class\ of\ animal\ x\ AU\ rating\ for\ that\ class$$

AU (animal unit) ratings are as per Appendix 8.2.

The mean grazing yield for each treatment was calculated then compared to the mean of the control on each site, on a yearly and overall basis. The percent change in yield, or effect size, was calculated using Equation 3, below:

Equation 3 $$Effect\ size = \frac{(Mean\ of\ treatment - mean\ of\ control)}{Mean\ of\ control} \times 100\%$$

3.2.9.2 Soil carbon change

Where mineral analyses were performed, the Leco dry combustion method of analysis was used to determine total soil carbon. The percent change in soil carbon between baseline and final sampling was calculated using equation 4, below:

Equation 4 $$Effect\ size = \frac{(C\%\ final - C\%\ baseline)}{C\%\ baseline} \times 100\%$$

3.2.9.3 Estimate tonnes of soil carbon in top 10cm

To calculate tonnes of soil carbon from percent soil carbon, the bulk density and gravel content of the soil should be known. As these parameters were not measured in this part of the trial, a bulk density of 1.3 g/cm^3 and zero gravel content is assumed in both rounds of sampling. The calculation for estimating tonnes of soil carbon is found in Equation 5.

Equation 5 $$t\ C/ha = 10{,}000m^2 \times soil\ depth\ (m) \times bulk\ density\ (g/cm^3 \times carbon\ \%$$

3.2.9.4 Soil health change

Change in soil health was assessed by determining the change in a range of microbial indicators over the four-year span of the project (i.e. final result – baseline result).

4. Results

4.1 Field trial 1: Measurement of soil carbon in C4 pastures with and without Progardes desmanthus

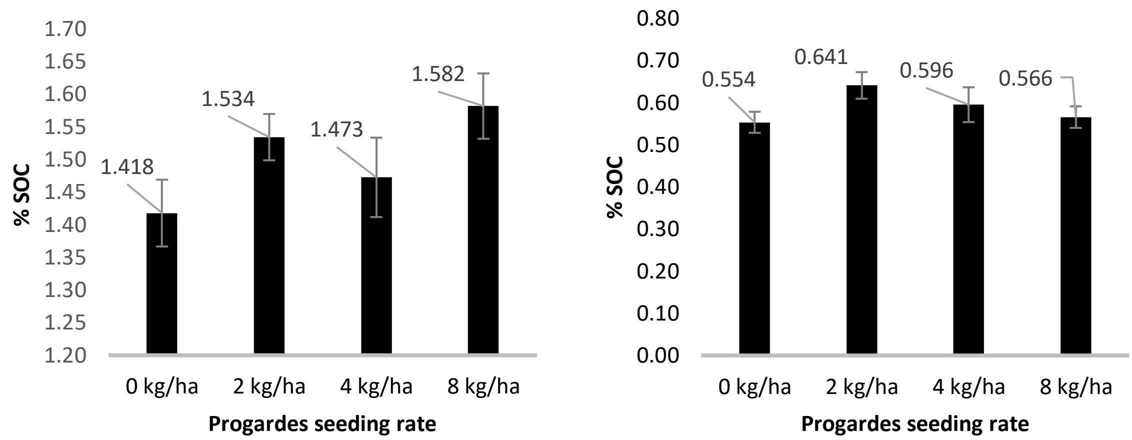
The trial area with the Progardes seeding rate had the highest carbon stock at 74.0 tonnes C/ha, 10.5 t/ha more than the control site which recorded 63.5 tonnes C/ha. The site with 2kg/ha Progardes recorded 7.4 tonnes C/ha more than the control, while the 4kg/ha Progardes site measure 8 t/ha more SOC than the control (Table 1). Much of the additional carbon was stored in the 0-30cm layer while the carbon stocks below 30cm were relatively consistent (Fig. 5).

Table 1 - Total SOC stock with different seeding rates

Seeding rate	0kg/ha (control)	2kg/ha	4kg/ha	8kg/ha
Tonnes C/ha	63.5	70.9	71.5	74.0

Figure 5 - % SOC for different seeding rates

(a) 0-30cm layer (b) >30cm



4.1.1 Cost-benefit analysis

A cost benefit analysis was run to compare the cost of seeding a pasture with Progardes desmanthus to the potential benefit gained if the landholder was to trade the additional credits on the carbon market. The cost of establishment was calculated in Table 2, below:

Table 2 - Cost of establishing Progardes desmanthus in pasture at different seeding rates

	Seeding rate		
	2kg/ha	**4kg/ha**	**8kg/ha**
Seed at $32/kg	$64	$128	$256
Seeding: spinner $25/ha	$25	$25	$25
Seed bed preparation: offsets	$40	$40	$40
TOTAL $/ha	**$129**	**$193**	**$321**

(Does not include cost of sucker control)

On November 2021, the Australian Broadcasting Corporation (2021) reported the Australian Carbon Credit spot price as $38.00. This is the assumed carbon credit price in this analysis. Carbon Link assumes carbon measurement costs and statutory discounts to be 50% of the net abatement of carbon. Using these assumptions, the return on investment can be seen in Table 3.

Table 3 - Return on investment in establishing Progardes desmanthus in pasture at different seeding rates

	Seeding rate			
	0kg/ha (control)	**2kg/ha**	**4kg/ha**	**8kg/ha**
Cost of establishment ($/ha)	0	$129	$193	$321
TOC (t/ha)	63.5	70.9	71.5	74
TOC above or below control (t/ha)	-	7.4	8	10.5
CO_2 e above or below control (t/ha)	-	27.16	29.36	38.54
Assumed carbon credits units	-	27	29	38
Gross value of additional soil carbon ($/ha)	-	$1,026	$1,102	$1,444
Net value after statuary discounts & costs ($/ha)		$513	$551	$722
Years established		7	7	7
Return on investment after 7 years ($/ha)	-	$384	$358	$401
Return on investment after 7 years (%)		298%	185%	125%
Net annualised carbon income ($/ha)		$73	$79	$103
Annualised return on investment (%)		**17%**	**9%**	**3%**

It can be seen in Table 3 that all seeding rates had a positive return on investment. The 2kg/ha seeding rate paddock resulted in the highest annualised return on investment.

4.2 Field trial 2: Cross-fence comparison of the effect of a microbially diverse amendment on grazing yield and soil health

4.2.1 Soil carbon response to application of mineral and/or biological amendments

Total soil carbon percentage measured in 2017 and 2021 can be found in Table 4. Those paddocks tested in both the baseline and final round were predominately those treated with mineral amendments (M; n=13) or mineral and biological amendments (MB; n=14). Sample sizes for biological amendments only (B; n=4) or the control paddocks (C; n=3) were small.

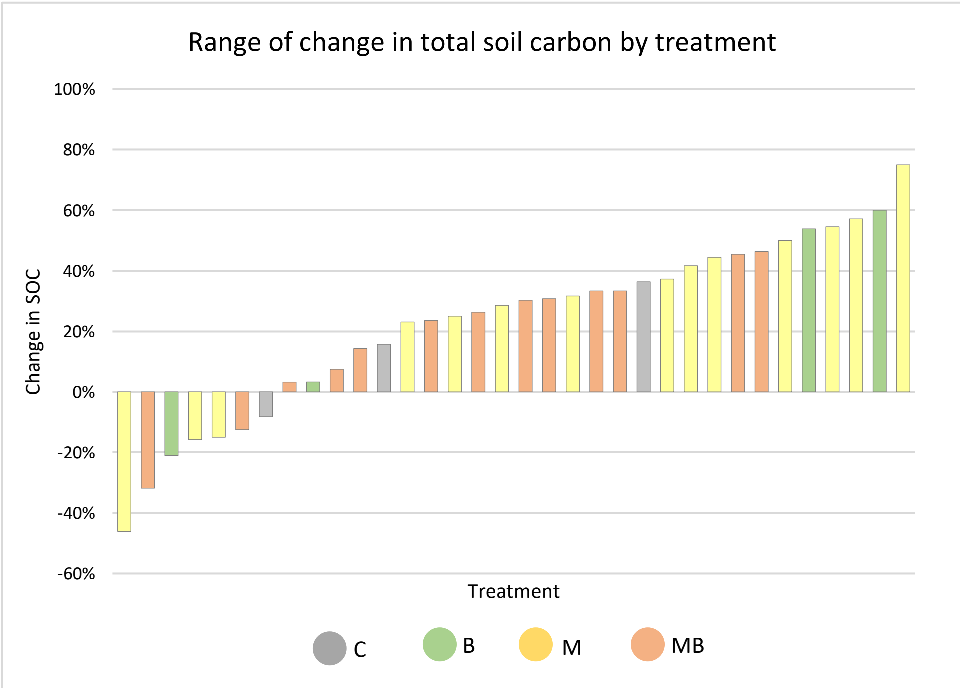
Table 4 - Total soil carbon in 2017 and 2021 (top 10cm, Leco)

Treatment	Site	Paddock	C % 2017	C % 2021	Effect size	t C/ha 2017	t C/ha 2021	t C/ha change
B	CO	WS4	0.76%	0.60%	-21%	9.88	7.8	-2.08
B	CO	6ME2	0.92%	0.95%	3%	11.96	12.35	0.39
B	CO	SL2	0.78%	1.20%	54%	10.14	15.6	5.46
B	MO	TR5	1.00%	1.60%	60%	13	20.8	7.8
C	CO	S1	0.73%	0.67%	-8%	9.49	8.71	-0.78
C	CO	6ME4	0.70%	0.81%	16%	9.1	10.53	1.43
C	MO	TR4	1.10%	1.50%	36%	14.3	19.5	5.2
M	CO	6ME1	1.54%	0.83%	-46%	20.02	10.79	-9.23
M	GL	L7	2.66%	2.24%	-16%	34.58	29.12	-5.46
M	WI	32	2.00%	1.70%	-15%	26	22.1	-3.9
M	MP	T5B	1.30%	1.60%	23%	16.9	20.8	3.9
M	BL	55	1.60%	2.00%	25%	20.8	26	5.2
M	WI	14A	1.40%	1.80%	29%	18.2	23.4	5.2
M	CO	WS1	0.60%	0.79%	32%	7.8	10.27	2.47
M	GL	L3	2.12%	2.91%	37%	27.56	37.83	10.27
M	MO	MR2	1.20%	1.70%	42%	15.6	22.1	6.5
M	BL	48	1.80%	2.60%	44%	23.4	33.8	10.4
M	CB	BPS4	1.40%	2.10%	50%	18.2	27.3	9.1
M	CB	BPN4	1.10%	1.70%	55%	14.3	22.1	7.8
M	MP	T5A	1.40%	2.20%	57%	18.2	28.6	10.4
MB	CO	WS3	1.10%	0.75%	-32%	14.3	9.75	-4.55
MB	MP	T4B	1.60%	1.40%	-13%	20.8	18.2	-2.6
MB	GL	L5	2.79%	2.88%	3%	36.27	37.44	1.17
MB	GL	L2	2.41%	2.59%	7%	31.33	33.67	2.34
MB	WI	15	1.40%	1.60%	14%	18.2	20.8	2.6
MB	BL	40	1.70%	2.10%	24%	22.1	27.3	5.2
MB	BL	54	1.90%	2.40%	26%	24.7	31.2	6.5
MB	CO	Y3	0.76%	0.99%	30%	9.88	12.87	2.99
MB	CB	BPS2	1.30%	1.70%	31%	16.9	22.1	5.2
MB	MO	MR1	0.90%	1.20%	33%	11.7	15.6	3.9
MB	WI	30	1.20%	1.60%	33%	15.6	20.8	5.2

MB	CB	BPN2	1.10%	1.60%	45%	14.3	20.8	6.5
MB	CO	SL3	0.82%	1.20%	46%	10.66	15.6	4.94
MB	MP	T4A	0.80%	1.40%	75%	10.4	18.2	7.8

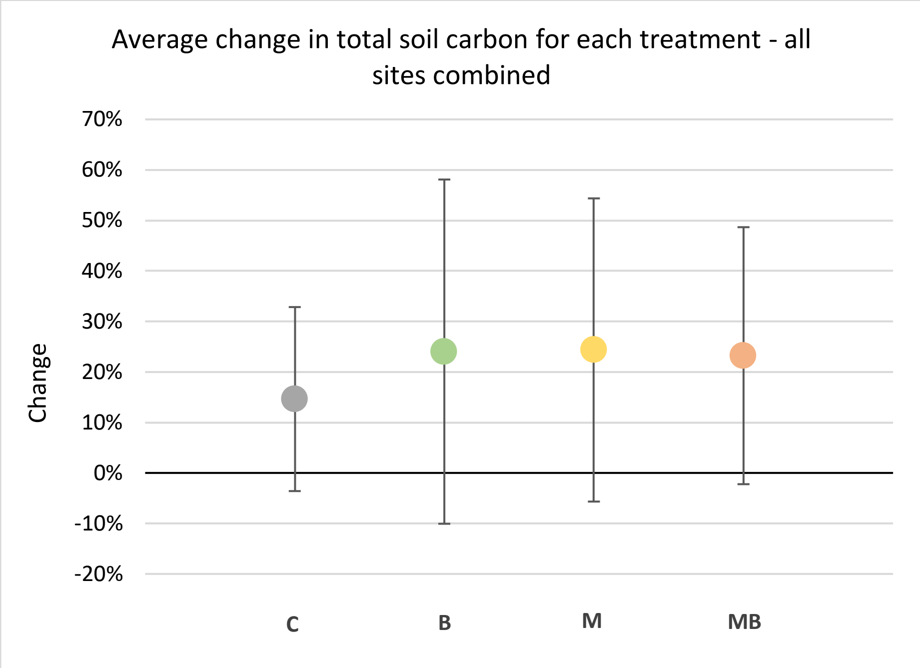
When the range of results were plotted on a graph, it appears that the greater changes in C% occur in those paddocks treated with either mineral or biological amendments rather than the two combined, as seen in Figure 6.

Figure 6 - Range of change in total soil carbon



The mean effect size and standard deviation of the control and each treatment (all sites combined) were calculated and plotted to compare C% change. Figure 7 suggests all treatments returned slightly higher change in C% than the control.

Figure 7 - Average change in C% (top 10cm)



However, variances are large for all treatments and control, and sample size small for C and B. A single factor ANOVA was run on the effect size between treatments and the control (all sites combined) and no significant differences were found ($p = 0.97$). Additionally, there were no statistically significant differences found between the control and/or treatments at the site level where $p < 0.05$, nor where there any statistically valid differences in carbon change between sites ($p = 0.12$).

Should a significant result have been returned, a cost benefit analysis would have been performed to understand the return on investment of applying a treatment and the value of the resulting increase in carbon, should the additional carbon stocks be traded on the carbon market. As no significant differences were found between controls and treatments, the potential return on investment could not be calculated.

4.2.2 Microbial indicator response to application of mineral and/or biological amendments

The change in soil microbial indicator and microbial group values between the initial and final samplings (for those sites which could be accessed during travel restrictions) was calculated, with an increase or decrease recorded for each paddock in Table 5 and Table 6. When the change was sorted by treatment, no patterns in the increase or decrease of those indicators could be seen (Table 5). This was verified by a single factor ANOVA of the overall microbial balance ($p = 0.98$) and total microorgansims ($p = 0.82$). Therefore, the trials have not been able to demonstrate an increase in microbial activity resulting from the application of biological amendments.

Table 5 - 2017 – 2021 change in soil microbial indicators and key microbe groups, sorted by treatment

			Microbial Soil Indicators							Key Microbe Groups																	
Treatment	Property	Paddock	Overall microbial balance	Nutrient solubilisation rate	Nutrient cycling rate	Disease resitance	Drought resistance	Nutrient accessibility	Residue breakdown rate	Total microorganisms	Total bacteria	Total fungi	Microbial diversity	Fungi:bacteria	Bacterial stress	Pseudomonas	Actinomycetes	Gram positive	Gram negative	Methane oxidisers	Sulphur reducers	True anaerobes	Protozoa	Mycorrhizal fungi
B	BL	53	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
B	BL	39	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
B	CB	BPN3	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
B	CB	BPS1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
B	CO	SL2	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↓	→	→	↑	↑	↑
B	CO	6ME2	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↓	↑	↑	↑	↓	→	→	↓	↑	↑
B	CO	WS4	↓	↑	↓	↓	↑	↑	↓	↑	↓	↑	↓	↑	↓	↓	↓	↓	↓	→	→	↓	↓	↑
B	GL	L4	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↓	↑	→	→	↓	↑	↑
B	GL	L6	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
B	MO	TR5	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
B	MO	BR1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
B	MP	T5C	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↓	↑	↑	→	→	↓	↑	↑
B	MP	T4D	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↓	↓	↑	→	→	↓	↑	↑
B	WI	32A33	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
B	WI	30A31	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
C	BL	52	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
C	BL	49	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
C	CB	BPN1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↓	↑	→	→	↑	↑	↑
C	CB	BPS3	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
C	CO	6ME4	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↓	↑	↓	↑	↓	↑	↓	→	→	↑	↑	↑
C	CO	S1	↓	↑	↓	↑	↑	↑	↓	↓	↓	↓	↓	↑	↓	↑	↓	↑	↓	→	→	↓	↓	↑
C	GL	L1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	→	→	↑	↑	↑
C	GL	L8	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↓	↑	→	→	↑	↑	↑
C	MO	TR4	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
C	MO	BR8	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
C	MP	T4C	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↓	↑	↑	↑	↑	→	→	↓	↑	↑
C	MP	T5D	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	→	↑	↑	↑	↑	→	→	↑	↑	↑
C	WI	15A16A	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
C	WI	33A3434A	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
M	BL	48	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
M	BL	55	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
M	CB	BPN4	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
M	CB	BPS4	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↓
M	CO	WS1	↓	↑	↓	↑	↑	↑	↑	↓	↓	↓	↓	↑	↓	↓	↑	↑	↓	→	→	↓	↓	↑
M	CO	6ME1	↓	↑	↓	↑	↑	↑	↓	↓	↓	↑	↓	↑	↓	↓	↓	↓	↓	→	→	↓	↓	↑
M	GL	L3	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	→	→	↑	↑	↑
M	GL	L7	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↓	↑	↓	↓	↓	→	→	↑	↑	↑
M	MO	MR2	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↓	↑	↑	→	→	↓	↑	↑
M	MO	MR4	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↓	↑	↓	↓	↓	→	→	↓	↑	↑
M	MP	T5A	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
M	MP	T5B	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
M	WI	14A	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
M	WI	32	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
MB	CO	SL3	↓	↑	↓	↑	↑	↑	↓	↑	↓	↑	↓	↑	↓	↓	↓	↓	↓	→	→	↓	↓	↑
MB	CO	WS3	↓	↑	↓	↓	↑	↑	↓	↓	↓	↓	↓	↑	↓	↓	↓	↓	↓	→	→	↓	↑	↑
MB	BL	54	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
MB	BL	40	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
MB	CB	BPN2	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
MB	CB	BPS2	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	→	↑
MB	CO	Y3	↓	↓	↓	↓	↓	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	→	→	↓	↓	↑
MB	GL	L2	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
MB	GL	L5	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↓	↑	→	→	↑	↑	↑
MB	MO	MR1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↓	↑	↑	→	→	↓	↑	↑
MB	MO	MR3	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↓	↑	↑	→	→	↓	↑	↑
MB	MP	T4A	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
MB	MP	T4B	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
MB	WI	30	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
MB	WI	15	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑

However, when the data was sorted by site, a pattern appeared which suggests that changes in soil microbial indicators, microbial groups, and therefore soil health are more likely due to environmental conditions and management, rather than treatments in this situation (Table 6). A statistically significant result for a single factor ANOVA of a number of indicators verified this pattern ($p < 0.05$).

Table 6 - 2017 – 2021 change in soil microbial indicators and key microbe groups – sorted by site.

			Microbial Soil Indicators							Key Microbe Groups														
Treatment	**Property**	Paddock	Overall microbial balance	Nutrient solubilisation rate	Nutrient cycling rate	Disease resitance	Drought resistance	Nutrient accessibility	Residue breakdown rate	Total microorganisms	Total bacteria	Total fungi	Microbial diversity	Fungi:bacteria	Bacterial stress	Pseudomonas	Actinomycetes	Gram positive	Gram negative	Methane oxidisers	Sulphur reducers	True anaerobes	Protozoa	Mycorrhizal fungi
B	**BL**	53	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
B	**BL**	39	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
C	**BL**	52	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
C	**BL**	49	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
M	**BL**	48	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
M	**BL**	55	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
MB	**BL**	54	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
MB	**BL**	40	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
B	**CB**	BPN3	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
B	**CB**	BPS1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
C	**CB**	BPN1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↓	↑	→	→	↑	↑	↑
C	**CB**	BPS3	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
M	**CB**	BPN4	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
M	**CB**	BPS4	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↓
MB	**CB**	BPN2	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
MB	**CB**	BPS2	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	→	↑
B	**CO**	SL2	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↓	→	→	↑	↑	↑
B	**CO**	6ME2	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↓	↑	↑	↑	↓	→	→	↓	↑	↑
B	**CO**	WS4	↓	↑	↓	↓	↑	↑	↓	↑	↓	↑	↓	↑	↓	↓	↓	↓	↓	→	→	↓	↓	↑
C	**CO**	6ME4	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↓	↑	↓	↑	↓	↑	↓	→	→	↑	↑	↑
C	**CO**	S1	↓	↑	↓	↑	↑	↑	↓	↓	↓	↓	↓	↑	↓	↑	↓	↑	↓	→	→	↓	↓	↑
MB	**CO**	SL3	↓	↑	↓	↑	↑	↑	↓	↑	↓	↑	↓	↑	↓	↓	↓	↓	↓	→	→	↓	↓	↑
M	**CO**	WS1	↓	↑	↓	↑	↑	↑	↑	↓	↓	↓	↓	↑	↓	↓	↑	↑	↓	→	→	↓	↓	↑
M	**CO**	6ME1	↓	↑	↓	↑	↑	↑	↓	↓	↓	↑	↓	↑	↓	↓	↓	↓	↓	→	→	↓	↓	↑
MB	**CO**	Y3	↓	↓	↓	↓	↓	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	→	→	↓	↓	↑
MB	**CO**	WS3	↓	↑	↓	↓	↑	↑	↓	↓	↓	↓	↓	↑	↓	↓	↓	↓	↓	→	→	↓	↑	↑
B	**GL**	L4	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↓	↑	→	→	↓	↑	↑
B	**GL**	L6	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
C	**GL**	L1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	→	→	↑	↑	↑
C	**GL**	L8	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↓	↑	→	→	↑	↑	↑
M	**GL**	L3	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	→	→	↑	↑	↑
M	**GL**	L7	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↓	↑	↓	↓	↓	→	→	↑	↑	↑
MB	**GL**	L2	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
MB	**GL**	L5	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↓	↑	→	→	↑	↑	↑
B	**MO**	TR5	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
B	**MO**	BR1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
C	**MO**	TR4	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
C	**MO**	BR8	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
M	**MO**	MR2	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↓	↑	↑	→	→	↓	↑	↑
M	**MO**	MR4	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↓	↑	↓	↓	↓	→	→	↓	↑	↑
MB	**MO**	MR1	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↓	↑	↑	→	→	↓	↑	↑
MB	**MO**	MR3	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↓	↑	↑	→	→	↓	↑	↑
B	**MP**	T5C	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↓	↑	↑	→	→	↓	↑	↑
B	**MP**	T4D	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↓	↓	↑	→	→	↓	↑	↑
C	**MP**	T4C	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↓	↑	↑	↑	↑	→	→	↓	↑	↑
C	**MP**	T5D	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	→	↑	↑	↑	↑	→	→	↑	↑	↑
M	**MP**	T5A	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
M	**MP**	T5B	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
MB	**MP**	T4A	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↑	↑	↑
MB	**MP**	T4B	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
B	**WI**	32A33	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
B	**WI**	30A31	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
C	**WI**	15A16A	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
C	**WI**	33A3434A	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
M	**WI**	14A	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
M	**WI**	32	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
MB	**WI**	30	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑
MB	**WI**	15	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	→	→	↓	↑	↑

Additionally, there were some differences between sites, but not between treatments, in the biomass of true anaerobes – sites BL, CB and GL saw a number of paddocks where the level of true anaerobes had increased, indicating these soils may have been somewhat anerobic at or just prior to the final sampling. It is interesting to note that the measured microbial diversity also decreased in a number of paddocks on both sites BL and CB. However, with the exception of site CO, microbial indicators had generally increased which may indicate an improvement in soil health on these properties.

4.2.3 Grazing yield response to application of mineral and/or biological amendments

The grazing yield from those sites where treatment application and grazing could occur (n=11) was analysed. The effect size of treatment means relative to control means for each property was calculated and is shown in Figure 8. A red star indicates a significant result.

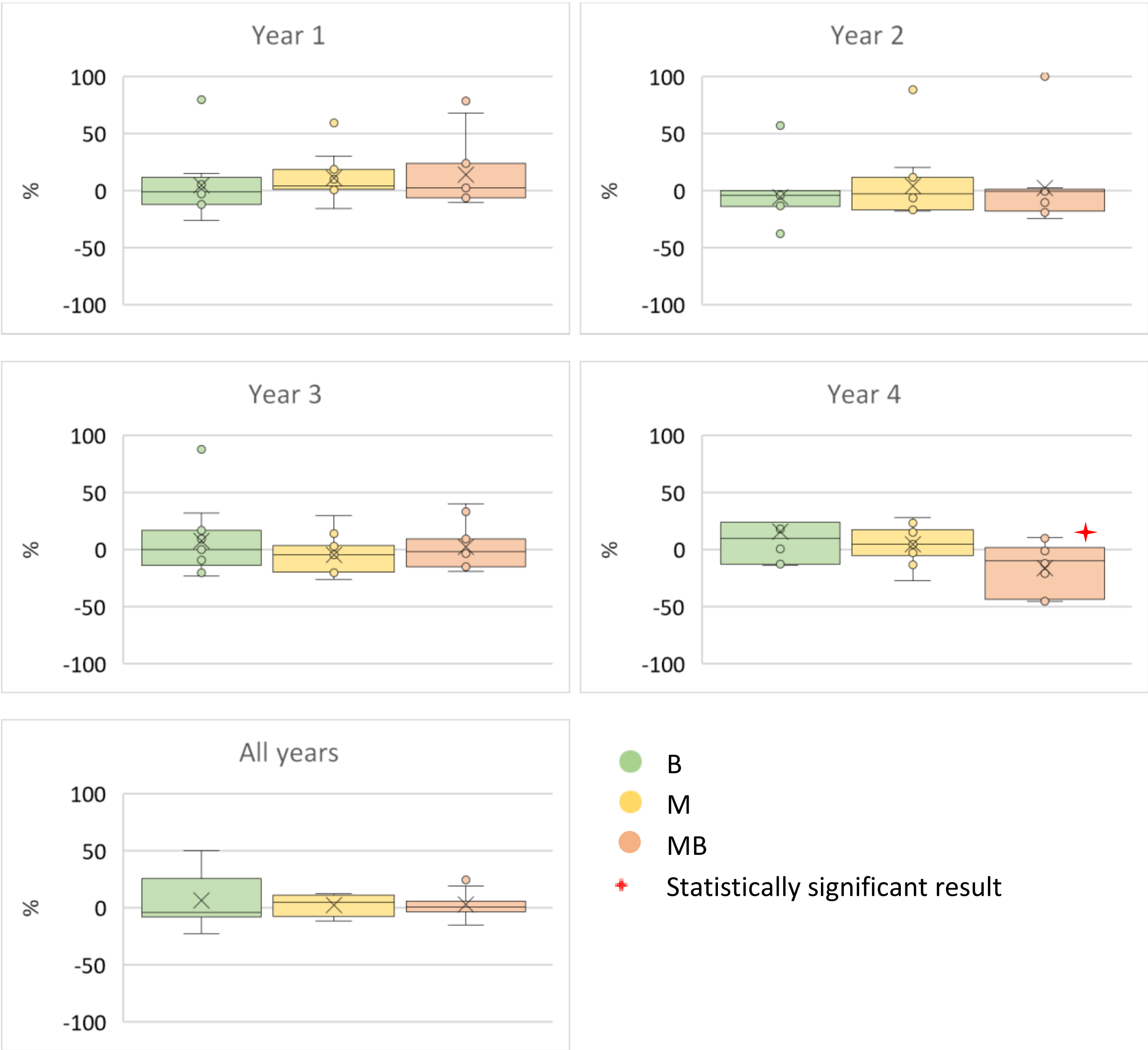
Figure 8 - Treatment mean yield relative to control mean yield – per site.

Only two statistically significant results were found. Site MO saw a significantly larger yield from those paddocks treated with MB in Year 2 (p = 0.018), while site CB saw a significantly larger yield from paddocks treated with B in Year 1 when compared to their controls (p = 0.09). These increases had dissipated by the following year. In the case of site MO, little rain fell in Year 1 after the mineral amendments were applied so it is possible that when a month of good rainfall occurred after the trial site had finished being grazed for the year, the response was captured in Year 2's grazing data instead of Year 1. However, no differences in grazing yield were noticeable 'on-the-ground'. Interestingly, those sites that showed a statistically significant response were the only two sites in Queensland that weren't badly affected by Pasture Dieback. It may therefore be that where pastures are healthy and free from disease, a response to the application of mineral and biological amendments may be seen if adequate rainfall occurs.

It may also be that an application of amendments need to be repeated every season for a response to be seen in each season. A cost benefit analysis of this, using the results from Site MO and Site CB can be found in Table 7 and Table 8 in section 4.2.4.

The mean yield for each treatment was also compared to the mean yield of the control using the combined data from all 11 sites. The results are shown in Figure 9.

Figure 9 - Treatment mean yield relative to control mean yield – all sites combined.



Year 4 was the only year where a statistically significant result occurred (p = 0.048). In this year, treatment MB yielded significantly less than the controls. It is unclear why this has occurred.

Visual records of the pasture condition were recorded prior to treatment application and again at the completion of the trial (where site visits could occur). All paddocks were in good condition at the start of the trials in 2017. The only differences that can be seen between the two photos are either seasonal or due to pasture dieback. No differences could be picked up due to treatment (see Appendix 8.3)

At Site DA, the compost extract was direct injected into the soil whereas all other sites, the extract was applied as a heavy-droplet spray. Within a few months after application, the producer at site DA noticed the B and MB paddocks to be ‘75mm higher and more vibrant green’ than the controls, as seen in Figure 10. Brix levels were reading higher on all treatment paddocks when compared to the control. This site entered a prolonged dry period shortly after and the visual effects were not picked up in grazing yield.

Figure 10 - Visual response to treatment B in direct injected paddock (B on LHS, C on RHS)

At site GL, a visual response was also seen in a Treatment B paddock compared to a Treatment M paddock. Figure 11 shows the paddock treated with compost extract only, while Figure 12 shows the pasture across a fence in a paddock treated with minerals only. Both paddocks had been managed the same way. The pasture in the Treatment B paddock is greener and denser than that in the Treatment M paddock. Again, this difference was not picked up in yield grazed.

Figure 11 - Paddock treated with Treatment B

Figure 12 - Paddock treated with Treatment M

4.2.4 Cost benefit analysis of grazing yield increase due to treatments

A cost benefit analysis of the statistically significant yield increases in Site MO and Site CB follows in Table 7 and Table 8 using a grazing yield gross margin of $1.20 per stock day (RCS ProfitProbe 2021 benchmark).

Table 7 - cost benefit analysis of grazing yield increase at Site MO, treatment MB, Year 2

COST BENEFIT		
Cost of MB treatment ($/ha)	$	315.28
Cost of MB application ($/ha)	$	37.69
Total cost ($/ha)	$	352.97
Average yield increase (SDH) - YEAR 2		51.6
Average gross margin/SD	$	1.20
Gross value of additional yield ($/ha)	$	61.92
Net return after costs	**-$**	**291.05**

TREATMENT COSTS		Cost per unit	Units required		Cost per product
TREATMENT B					
Compost (kg)	$	0.43	132	$	55.90
Actpak (kg)	$	34.50	8	$	272.55
Liquid fish (L)	$	3.50	119	$	414.75
Molasses (L)	$	2.50	79	$	197.50
Total cost of treatment				**$**	**940.70**
Treatment area - total hectares					**39.50**
Cost per hectare B				**$**	**23.82**

		Cost per unit	Units required		Cost per product
TREATMENT M					
Zinc Hepta Sulphate (kg)	$	1.80	42	$	76.14
Inkabor (kg)	$	2.80	42	$	118.44
Amino max (L)	$	8.80	22	$	189.20
Molybdenum (kg)	$	35.60	6	$	225.88
Copper Shuttle (L)	$	9.00	19	$	171.32
Liquid sea minerals (L)	$	3.10	63	$	196.70
Cloak wetter sticker (L)	$	9.00	6	$	57.11
Fertiliser blend (33% lime, 33% gypsum, 33%SRP) (kg)	$	0.89	12690	$	11,294.10
Total cost of treatment				**$**	**12,328.88**
Treatment area - total hectares					**42.30**
Cost per hectare M				**$**	**291.46**

		$/ha
TREATMENT MB		
Cost/ha Treatment B	$	23.82
Cost/ha Treatment M	$	291.46
Cost per hectare MB	**$**	**315.28**

APPLICATION COSTS	Cost per unit	Units required		Cost per product
Hire of unit (day)	1000	0.5	$	500.00
Labour (day)	500	0.5	$	250.00
Hectares treated - MB				19.9
Cost of application/ha			**$**	**37.69**

The application of the treatments prescribed for Site MO, treatment MB resulted in an average yield increase of 51.6 SDH in the year following application. However, the cost of these treatments and their application ($352.97/ha) greatly outweighed the value of additional yield ($61.92/ha) leading to a loss of $291.05 per hectare.

Table 8 - cost benefit analysis of grazing yield increase at Site CB, treatment B, Year 1

COST BENEFIT		
Cost of B treatment ($/ha)	$	23.55
Cost of B application ($/ha)	$	44.38
Total cost ($/ha)	$	67.93
Average yield increase (SDH) - YEAR 1		57.5
Average gross margin/SD	$	1.20
Gross value of additional yield ($/ha)	$	69.00
Net return after costs ($/ha)	**$**	**1.07**

TREATMENT COSTS	Cost per unit		Units required	Cost per product	
TREATMENT B					
Compost (kg)	$	0.50	116	$	57.75
Actpak (kg)	$	34.50	7	$	241.50
Liquid fish	$	4.50	105	$	472.50
Molasses	$	0.75	70	$	52.50
Total cost of treatment				**$**	**824.25**
Treatment area - total hectares					**35.00**
Cost per hectare B				**$**	**23.55**

APPLICATION COST	Cost per unit	Units required	Cost per product	
Hire of unit (day)	1000	0.5	$	500.00
Labour (day)	500	0.5	$	250.00
Hectares treated - B				16.9
Cost of application/ha			**$**	**44.38**

Where Treatment B was applied to paddocks on Site CB, a yield increase of 57.5 SDH was seen. The cost of the treatment and application ($67.93) was similar to the value of the increased yield ($69.00), returning just $1.07/ha.

5. Conclusion

The project made a significant preliminary advancement in the understanding of how a deep-rooted perennial legume such as Progardes desmanthus can influence soil carbon stocks.

However, due to the timing of Field Trial 2 coinciding with the severe drought affecting the east coast of Australia and pasture dieback in Queensland, it is unclear if the application of microbially diverse compost extract influences pasture yield, microbial activity or soil carbon. A yield response to the application of minerals would have been expected in a season that favoured pasture growth, even if that season was a number of years later; however, only one such response was recorded over eleven sites leading to the belief that the successive dry years and disease have confounded the results. Further research would need to be completed before any benefits or otherwise could be communicated to the wider industry.

5.1 Key findings

- The results of Field Trial 1 suggest that the presence of Progardes desmanthus legumes significantly increase SOC stocks, and a return on investment on 17%pa, where that additional carbon could be traded in today's carbon market, was estimated.
- The results of Field Trial 2 suggest that there was no influence on soil carbon or soil microbial activity of the application of a microbially diverse amendment, catalytic minerals, or both.

- There were very few statistically valid relationships found between treatments and grazing yield in Field Trial 2. The two site-specific results found to be statistically significant (Site MO, treatment MB, year 2; and Site CB, treatment B, year 1) were not visually noticed by the producer and the effect had dissipated the following year. When the grazing data from all sites were combined, there was a statistically valid decrease in yield in treatment MB in year 4. Where statistically valid results were found, a cost benefit analysis showed either a loss or near-zero return on investment.
- Early visual results from Field Trial 2 suggest there was a positive pasture response to the application of highly diverse compost extract. The visual response did not carry through to be picked up in grazed yield.
- Results of Field Trial 2 were likely confounded by successive dry years and pasture dieback.

5.2 Benefits to industry

5.2.1 Incorporation of perennial legumes into tropical pastures

Adding a deep-rooted perennial legume to C4 pastures is becoming a common practice throughout northern Australia due to the resulting increased pasture biomass and liveweight gain in animals grazing those pastures. The cost benefit analysis of the pasture-legume trial indicates further and significant scope for financial gain for red meat producers through the incorporation of Progardes desmanthus into C4 perennial pastures, with the results of this trial suggesting that at the recommended planting rate of 2kg/ha, the legume may substantially increase the amount of carbon sequestered in the soil, providing benefit to those producers wishing to trade in carbon markets. Additionally, this increase in carbon drawdown would move the red meat industry closer to its goal of becoming carbon neutral by 2030.

5.2.2 Application of microbially diverse compost extract to pastures

No benefits (or otherwise) to industry can be made around the application of microbially diverse compost extracts to grazing land at this stage, as the results of the trial were significantly affected by an extended dry period and pasture dieback.

6. Future research and recommendations

- Further rounds of soil carbon measurement in the Field Trial 1 sites will bolster the initial evidence around how legume species influence soil carbon stocks. Additionally, repeated samplings will provide an insight into the rate of soil carbon sequestration over time at different planting rates of Progardes desmanthus compared to pastures with no legume.
- Additional Progardes desmanthus sites should be established in other areas to help understand if these results are repeatable in different soil types and climates.
- The practice of incorporating legumes such as Progardes desmanthus into C4 pastures can be considered an economical and eligible activity for those producers wishing to become involved in a soil carbon project under the Australian Government's emission reduction fund. Communication of the results of this part of the research would provide graziers in northern Australia with confidence around this practice's likelihood of boosting carbon sequestration, potentially leading to increased adoption. RCS communicates these results at schools and workshops for red meat producers in relevant areas and, where eligible and suitable, recommends this practice as a new activity within the land management strategy of northern graziers registering soil carbon projects.

- Further research needs to be conducted on applying microbially diverse compost extract to pastures and the effect on soil microbial activity, soil carbon and pasture yield. Recommendations for further research include:
    - Perform a trial similar to Field Trial 2 on an irrigated pasture or fodder crop, to establish benefits of the application of microbially diverse amendments when moisture is not a limiting factor.
    - Studies to better understand the effectiveness of different methods for applying microbial amendments to soil would help inform larger scale, on-farm research and application. Direct injection, incorporation by irrigation or of use very heavy water rates per hectare are suggested methods for compost extract application, while inoculating seed with a compost slurry is another technique being used.
    - Further work is needed to understand how regularly microbial amendments need to be applied to pastures for production gains to be seen.

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8. Appendix

8.1 Treatment recommendations for Field Trial 2

8.1.1 Site MO

Paddock treatment	Recipe
Minerals only	**SPREAD:** A blend of one-third calcium, one-third gypsum and one-third soft rock phosphate at a rate of 300kg/ha **FOLIAR SPRAY** Mix: • 1L/ha Amino Max (nitrogen) • 1kg/ha zinc hepta sulphate • 1kg/ha Inkabor (boron) • 0.5L/ha Copper shuttle • 0.15kg/ha molybdenum • 1.5L/ha liquid sea minerals • 0.15L/ha Cloak spray oil • Water as required (min 100L/ha) and apply to pasture.
Minerals plus biology	**SPREAD:** A blend of 33% calcium, 33% gypsum and 33% soft rock phosphate at a rate of 300kg/ha **FOLIAR SPRAY** Mix: • 1L/ha Amino Max (nitrogen) • 1kg/ha zinc hepta sulphate • 1kg/ha Inkabor (boron) • 0.5L/ha Copper shuttle • 0.15kg/ha molybdenum • 1.5L/ha liquid sea minerals • 0.15L/ha Cloak spray oil • 100L/ha compost extract • 200gm/ha ActPak biology activator • 3L/ha liquid fish • 2L/ha molasses • Water as required (min 100L/ha) and apply to pasture.
Biology only	**FOLIAR SPRAY** Mix: • 100L/ha compost extract • 200gm/ha ActPak biology activator • 3L/ha liquid fish • 2L/ha molasses • Water as required (depending on the spray rate of your unit)
Control	No treatments on these paddocks for the duration of the trial.

8.1.2 Site GL

Paddock treatment	Recipe
Minerals only	FOLIAR SPRAY #1 Mix and apply: • OzGyp @100kg/ha • Zinc hepta sulphate @ 1kg/ha • Copper Shuttle @ 0.5L/ha • Inkabor (boron) @1kg/ha • Molybdenum @ 0.15kg/ha • Liquid sea minerals @ 1.5L/ha • Cloak spray oil @ 150mL/ha • Water (minimum 100L/ha) FOLIAR SPRAY #2 Mix and apply: • OzCal @ 100kg/ha • Water (as required)
Minerals plus biology	FOLIAR SPRAY #1 Mix and apply: • OzGyp @100kg/ha • Zinc hepta sulphate @ 1kg/ha • Copper Shuttle @ 0.5L/ha • Inkabor (boron) @1kg/ha • Molybdenum @ 0.15kg/ha • Liquid sea minerals @ 1.5L/ha • Cloak spray oil @ 150mL/ha • Water (minimum 100L/ha) FOLIAR SPRAY #2 Mix and apply: • OzCal @ 100kg/ha • Water (as required) FOLIAR SPRAY #3 Mix and apply: • Compost extract @ 100L/ha • Actpak biology activator @ 200gm/ha • Liquid fish emulsion @ 3L/ha • Molasses @ 2L/ha • Water, if required

Biology only	FOLIAR SPRAY Mix and apply: • Compost extract @ 100L/ha • Actpak biology activator @ 200gm/ha • Liquid fish emulsion @ 3L/ha • Molasses @ 2L/ha
Control	No treatments on these paddocks for the duration of the trial.

8.1.3 Site BL

Paddock treatment	Recipe
Minerals only	**SPREAD:** • 100kg/ha OzGyp **FOLIAR SPRAY** Mix and apply: • Zinc hepta sulphate @ 1kg/ha • Copper Shuttle @ 0.5L/ha • Inkabor (boron) @1kg/ha • Molybdenum @ 0.15kg/ha • Liquid sea minerals @ 1.5L/ha • Cloak spray oil @ 150mL/ha • Water (minimum 100L/ha)
Minerals plus biology	**SPREAD:** • 100kg/ha OzGyp **FOLIAR SPRAY** Mix and apply: • Zinc hepta sulphate @ 1kg/ha • Copper Shuttle @ 0.5L/ha • Inkabor (boron) @1kg/ha • Molybdenum @ 0.15kg/ha • Liquid sea minerals @ 1.5L/ha • Cloak spray oil @ 150mL/ha • Compost extract @ 100L/ha • Actpak biology activator @ 200gm/ha • Liquid fish emulsion @ 3L/ha • Molasses @ 2L/ha • Water, if required
Biology only	

	FOLIAR SPRAY Mix and apply: • Compost extract @ 100L/ha • Actpak biology activator @ 200gm/ha • Liquid fish emulsion @ 3L/ha • Molasses @ 2L/ha
Control	No treatments on these paddocks for the duration of the trial.

8.1.4 Site WI

Paddock treatment	Recipe
Minerals only	**SPREAD:** • 230kg/ha ECOGROWTH BLEND 11 (44% soft rock phosphate, 44% ultra-fine lime, 8% potassium sulphate, 4% elemental sulphur) **FOLIAR SPRAY** Mix and apply: • Zinc hepta sulphate @ 1kg/ha • Copper Shuttle @ 0.5L/ha • Inkabor (boron) @1kg/ha • Molybdenum @ 0.15kg/ha • Liquid sea minerals @ 1.5L/ha • Cloak spray oil @ 150mL/ha • Water (minimum 100L/ha)
Minerals plus biology	**SPREAD:** • 230kg/ha ECOGROWTH BLEND 11 (44% soft rock phosphate, 44% ultra-fine lime, 8% potassium sulphate, 4% elemental sulphur) **FOLIAR SPRAY** Mix and apply: • Zinc hepta sulphate @ 1kg/ha • Copper Shuttle @ 0.5L/ha • Inkabor (boron) @1kg/ha • Molybdenum @ 0.15kg/ha • Liquid sea minerals @ 1.5L/ha • Cloak spray oil @ 150mL/ha • Compost extract @ 100L/ha • Actpak biology activator @ 200gm/ha • Liquid fish emulsion @ 3L/ha • Molasses @ 2L/ha
Biology only	**FOLIAR SPRAY** Mix and apply: • Compost extract @ 100L/ha • Actpak biology activator @ 200gm/ha • Liquid fish emulsion @ 3L/ha • Molasses @ 2L/ha
Control	No treatments on these paddocks for the duration of the trial.

8.1.5 Site MP

<table>
<tr><th>Paddock treatment</th><th>Recipe</th></tr>
<tr><td>Minerals only</td><td>FOLIAR SPRAY #1
Mix and apply:
Sulphate of ammonia @ 50kg/ha
Water (minimum 100L/ha)
FOLIAR SPRAY #2
Mix and apply:
Zinc hepta sulphate @ 1kg/ha
Copper Shuttle @ 0.5L/ha
Inkabor (boron) @1kg/ha
Molybdenum @ 0.15kg/ha
Water (minimum 100L/ha)</td></tr>
<tr><td>Minerals plus biology</td><td>FOLIAR SPRAY #1
Mix and apply:
Sulphate of ammonia @ 50kg/ha
Water (minimum 100L/ha)
FOLIAR SPRAY #2
Mix and apply:
Zinc hepta sulphate @ 1kg/ha
Copper Shuttle @ 0.5L/ha
Inkabor (boron) @1kg/ha
Molybdenum @ 0.15kg/ha
Compost extract @ 100L/ha
Actpak biology activator @ 200gm/ha
Liquid fish emulsion @ 3L/ha
Molasses @ 2L/ha</td></tr>
<tr><td>Biology only</td><td>FOLIAR SPRAY
Mix:
100L compost extract
200gm ActPak biology activator
3L liquid fish
2L molasses
and apply at a rate of 100L/ha</td></tr>
<tr><td>Control</td><td>No treatments on these paddocks for the duration of the trial.</td></tr>
</table>

8.1.6 Site CB

<table>
<tr><th>Paddock treatment</th><th>Recipe</th></tr>
<tr><td>Minerals only</td><td>SPREAD

240kg/ha CB BLEND (Soft rock phosphate 42%, Ultrafine lime 42%, Potassium sulphate 8%, Elemental sulphur 4%, Zinc sulphate 1%, Copper sulfate 1%, Etidot 67 (boron) 1%, Sodium molybdate 0.5%, Sodium molybdate - trace amount)</td></tr>
<tr><td>Minerals plus biology</td><td>SPREAD

240kg/ha CB BLEND (Soft rock phosphate 42%, Ultrafine lime 42%, Potassium sulphate 8%, Elemental sulphur 4%, Zinc sulphate 1%, Copper sulfate 1%, Etidot 67 (boron) 1%, Sodium molybdate 0.5%, Sodium molybdate - trace amount)

FOLIAR SPRAY

Mix and apply:
Compost extract @ 100L/ha
Actpak biology activator @ 200gm/ha
Liquid fish emulsion @ 3L/ha
Molasses @ 2L/ha
Water, if required</td></tr>
<tr><td>Biology only</td><td>FOLIAR SPRAY

Mix and apply:
Compost extract @ 100L/ha
Actpak biology activator @ 200gm/ha
Liquid fish emulsion @ 3L/ha
Molasses @ 2L/ha</td></tr>
<tr><td>Control</td><td>No treatments on these paddocks for the duration of the trial.</td></tr>
</table>

8.1.7 Site FF

Paddock treatment	Recipe
Minerals only	**SPREAD:** ECOGROWTH BLEND 5 @ 100kg/ha – this is custom blend of 65% soft rock phosphate, 32% ultra-fine lime and small amounts of zinc, copper, boron, molybdenum and cobalt.
Minerals plus biology	**SPREAD:** ECOGROWTH BLEND 5 @ 100kg/ha – this is custom blend of 65% soft rock phosphate, 32% ultra-fine lime and small amounts of zinc, copper, boron, molybdenum and cobalt. **FOLIAR SPRAY:** Mix: • 100L compost extract • 200gm ActPak biology activator • 3L liquid fish • 2L molasses and apply at a rate of 100L/ha
Biology only	**FOLIAR SPRAY** Mix: • 100L compost extract • 200gm ActPak biology activator • 3L liquid fish • 2L molasses and apply at a rate of 100L/ha
Control	No treatments on these paddocks for the duration of the trial.

8.1.8 Site CO

<table>
<tr><th>Paddock treatment</th><th>Recipe</th></tr>
<tr><td>Minerals only</td><td>1. SPREAD:
• Guano @ 80kg/ha

2. FOLIAR SPRAY #1
Mix:
• Magnesium sulphate @ 10kg/ha
• Ultra-fine lime @ 100kg/ha
• Water
and apply.

3. FOLIAR SPRAY #2
Mix:
• Zinc Hepta Sulphate @ 1kg/ha
• Inkabor (boron) @ 1kg/ha
• Amino Max (nitrogen) @ 0.5L/ha
• Molybdenum @ 0.15kg/ha
• Copper Shuttle @ 0.5L/ha
• Cloak spray oil @ 0.15L/ha
• Water
and apply.</td></tr>
<tr><td>Minerals plus biology</td><td>1. SPREAD:
• Guano @ 80kg/ha

2. FOLIAR SPRAY #1
Mix:
• Magnesium sulphate @ 10kg/ha
• Ultra-fine lime @ 100kg/ha
• Water
and apply.

3. FOLIAR SPRAY #2

Mix:
• Zinc Hepta Sulphate @ 1kg/ha
• Inkabor (boron) @ 1kg/ha
• Amino Max (nitrogen) @ 0.5L/ha
• Molybdenum @ 0.15kg/ha
• Copper Shuttle @ 0.5L/ha
• Cloak spray oil @ 0.15L/ha
• Compost extract @ 100L/ha
• ActPak biology activator @ 200g/ha
• Liquid fish @ 3L/ha** We can look at increasing this rate to increase the nitrogen levels in the soil
• Molasses @ 2L/ha</td></tr>
</table>

	and apply.
Biology only	**FOLIAR SPRAY** Mix: • 100L compost extract • 200gm ActPak biology activator • 3L liquid fish** We can look at increasing this rate to increase the nitrogen levels in the soil • 2L molasses and apply at a rate of 100L/ha
Biology only – no fish or activation products	**FOLIAR SPRAY** • Apply compost extract only at a rate of 100L/ha
Humus compost blended with minerals	**SPREAD:** • Humus compost and mineral blend as per YLAD Living Soils recommendations.
Control	No treatments on these paddocks for the duration of the trial.

8.1.9 Site CH

Paddock treatment	Recipe
Minerals only	**SPREAD:** CH BLEND @ 200kg/ha – this is a custom blend of 50% sulphate of potash and 50% soft rock phosphate. **FOLIAR SPRAY** Mix: • 1kg Zinc hepta sulphate • 1kg Inkabor (boron) • 0.5L Amino Max (nitrogen) • 2L Phos-life (highly available P) • 0.15kg Molybdenum • 0.5L Copper Shuttle • 150mL Cloak spray oil • 100L water and apply at a rate of 100L/ha
Minerals plus biology	**SPREAD:** CH BLEND @ 200kg/ha – this is a custom blend of 50% sulphate of potash and 50% soft rock phosphate. **FOLIAR SPRAY** Mix: • 100L compost extract • 200gm ActPak biology activator • 3L liquid fish • 2L molasses • 1kg Zinc hepta sulphate • 1kg Inkabor (boron) • 0.5L Amino Max (nitrogen) • 2L Phos-life (highly available P) • 0.15kg Molybdenum • 0.5L Copper Shuttle • 150mL Cloak spray oil • 100L water and apply at a rate of 100L/ha
Biology only	**FOLIAR SPRAY** Mix: • 100L compost extract • 200gm ActPak biology activator • 3L liquid fish • 2L molasses and apply at a rate of 100L/ha

Control	No treatments on these paddocks for the duration of the trial.

8.1.10 Site WM

Paddock treatment	Recipe
Minerals only	**FOLIAR SPRAY** Mix: • 1kg Zinc hepta sulphate • 1kg Inkabor • 0.5L Copper Shuttle • 150mL Cloak spray oil • 100L water and apply at a rate of 100L/ha
Minerals plus biology	**FOLIAR SPRAY** Mix: • 100L compost extract • 200gm ActPak biology activator • 3L liquid fish • 2L molasses • 1kg Zinc hepta sulphate • 1kg Inkabor • 0.5L Copper Shuttle • 150mL Cloak spray oil and apply at a rate of 100L/ha
Biology only	**FOLIAR SPRAY** Mix: • 100L compost extract • 200gm ActPak biology activator • 3L liquid fish • 2L molasses and apply at a rate of 100L/ha
Control	No treatments on these paddocks for the duration of the trial.

8.1.11 Site DA

Paddock treatment	Recipe
Highway ESM and Finch South (MINERALS ONLY)	**FOLIAR SPRAY** Mix and apply: • OzGyp @ 100kg/ha • OzCal @ 100kg/ha • Zinc hepta sulphate @ 1kg/ha • Inkabor (boron) @1kg/ha • Amino Max (nitrogen) @ 0.5L/ha • Molybdenum @ 0.15kg/ha • Liquid Sea Minerals @ 1.5L/ha • Cloak spray oil @ 150mL/ha • Water
Finch South Middle (MINERALS PLUS BIOLOGY)	**SPREAD:** • 200kg guano **FOLIAR SPRAY** Mix and apply: • OzGyp @ 100kg/ha • OzCal @ 100kg/ha • Zinc hepta sulphate @ 1kg/ha • Inkabor (boron) @1kg/ha • Amino Max (nitrogen) @ 0.5L/ha • Molybdenum @ 0.15kg/ha Liquid Sea Minerals @ 1.5L/ha • Cloak spray oil @ 150mL/ha • Compost extract @ 100L/ha • ActPak biology activator @ 200gm/ha • Liquid Fish @ 3L/ha • 2L/ha molasses • Water if required.
Highway ENM (MINERALS PLUS BIOLOGY)	**FOLIAR SPRAY** Mix and apply: • OzGyp @ 100kg/ha • OzCal @ 100kg/ha • Zinc hepta sulphate @ 1kg/ha • Inkabor (boron) @1kg/ha • Amino Max (nitrogen) @ 0.5L/ha • Molybdenum @ 0.15kg/ha • Liquid Sea Minerals @ 1.5L/ha • Cloak spray oil @ 150mL/ha • Compost extract @ 100L/ha • ActPak biology activator @ 200gm/ha • Liquid Fish @ 3L/ha • 2L/ha molasses

	• Water if required.
Highway EN and Finch NM (BIOLOGY ONLY)	**FOLIAR SPRAY** Mix: • 100L compost extract • 200gm ActPak biology activator • 3L liquid fish • 2L molasses and apply at a rate of 100L/ha
Highway ES and Finch N (CONTROL)	No treatments on these paddocks for the duration of the trial.

8.2 Standard animal unit tables – cattle

LSU ratings for cattle (1 LSU = approx. 450 steer with no LWG) (1 LSU = 6.9 DSE)

Table 1 – Breeding cattle

Liveweight (Kg)	Dry Cows		Pregnant Cows (3rd Trimester only)		Lactating Cows (Cow + calf unit)	
	DSE's	LSU's	DSE's	LSU's	DSE's	LSU's
350	6.14	0.89	7.24	1.05	12.00	1.74
400	6.38	0.94	7.52	1.09	13.40	1.94
450	6.89	0.99	8.15	1.18	14.78	2.14
500	7.09	1.03	8.37	1.21	15.18	2.20
550	7.73	1.12	9.01	1.30	16.49	2.39
600	8.37	1.21	9.65	1.40	17.81	2.58
650	9.01	1.31	10.29	1.49	19.03	2.76
700	9.65	1.40	10.98	1.59	20.26	2.94
750	10.31	1.49	11.60	1.68	21.46	3.11
800	10.96	1.59	12.36	1.79	22.69	3.29
850	11.62	1.68	12.91	1.87	24.12	3.49
900	12.28	1.78	13.58	1.97	25.13	3.64

Table 2 – Feeder cattle

Liveweight (Kgs)	Steer/Replacement Heifer Growth Rate							
	0 Kg/day		0.5 Kg/day		1.0 Kg/day		1.5 Kg/day	
	DSE	LSU	DSE	LSU	DSE	LSU	DSE	LSU
200	3.25	0.47	5.27	0.76	6.79	0.98	8.25	1.19
250	4.67	0.67	6.35	0.92	8.05	1.16	9.13	1.32
300	5.44	0.78	7.32	1.06	9.24	1.33	10.01	1.45
350	6.14	0.88	8.43	1.22	10.69	1.55	10.89	1.57
400	6.65	0.96	9.09	1.32	11.41	1.65	11.77	1.70
450	7.27	1.05	9.72	1.40	12.09	1.75	12.65	1.83
500	7.73	1.12	10.26	1.48	12.71	1.84	13.53	1.96
550	8.03	1.16	10.65	1.54	13.15	1.90	14.41	2.08
600	8.72	1.26	11.32	1.64	13.82	2.00	15.78	2.29
650	9.41	1.36	11.98	1.73	14.49	2.10	16.16	2.34
700	10.11	1.46	12.64	1.83	15.17	2.19	17.04	2.47
750	10.80	1.56	13.31	1.92	15.84	2.29	18.80	2.72

Developed in conjunction with NSW Agriculture Department (Allan Bell) 1992.

8.3 Monitoring point photos

8.3.1 Site MO

B - MO TR5

NOVEMBER 2017

JULY 2021

B - MO BR1

NOVEMBER 2017

JULY 2021

C - MO TR4

NOVEMBER 2017

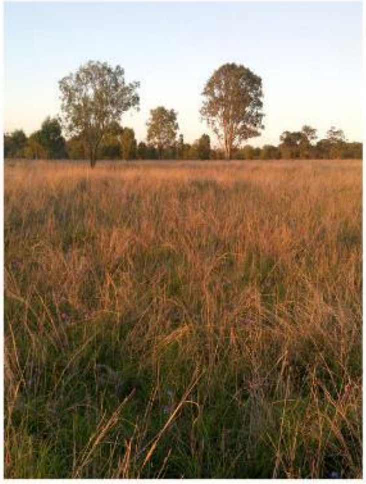
JULY 2021

C - MO BR8

NOVEMBER 2017

JULY 2021

M - MO MR2



NOVEMBER 2017

JULY 2021

M - MO MR4

NOVEMBER 2017

JULY 2021

MB - MO MR3

NOVEMBER 2017

JULY 2021

MB - MO MR1

NOVEMBER 2017

JULY 2021

8.3.2 Site BL

B - BL53

NOVEMBER 2017

AUGUST 2021

B - BL39

NOVEMBER 2017

AUGUST 2021

C - BL52

NOVEMBER 2017

AUGUST 2021

C - BL49

NOVEMBER 2017

AUGUST 2021

M - BL55

NOVEMBER 2017

AUGUST 2021

M - BL48

NOVEMBER 2017

AUGUST 2021

MB - BL54

NOVEMBER 2017

AUGUST 2021

MB - BL40

NOVEMBER 2017

AUGUST 2021

8.3.3 Site WI

B - WI32A33

NOVEMBER 2017

AUGUST 2021

B - WI30A31

NOVEMBER 2017

AUGUST 2021

C - WI15A16A

NOVEMBER 2017

AUGUST 2021

C - WI33A3434A

NOVEMBER 2017

AUGUST 2021

M - WI14A

NOVEMBER 2017

AUGUST 2021

M - WI32

NOVEMBER 2017

AUGUST 2021

MB - WI15

NOVEMBER 2017

AUGUST 2021

MB - WI30

NOVEMBER 2017

AUGUST 2021

8.3.4 Site MP

MB - MPT4A

NOVEMBER 2017 | MAY 2019 | JULY 2021

M - MPT4B

NOVEMBER 2017 | MAY 2019 | JULY 2021

C - MPT4C

NOVEMBER 2017

MAY 2019

JULY 2021

B - MPT4D

NOVEMBER 2017

MAY 2019

JULY 2021

MB - MPT5A

NOVEMBER 2017 | MAY 2019 | JULY 2021

M - MPT5B

NOVEMBER 2017 | MAY 2019 | JULY 2021

B - MPT5C

NOVEMBER 2017 | MAY 2019 | JULY 2021

C - MPT5D

NOVEMBER 2017 | MAY 2019 | JULY 2021

8.3.5 Site CB

B - CB BPN3

NOVEMBER 2017

AUGUST 2021

B - CB BPS1

NOVEMBER 2017

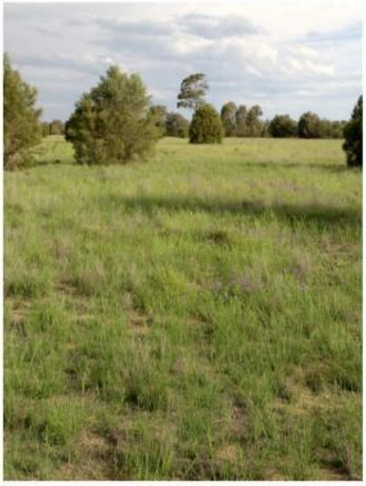
AUGUST 2021

C - CB BPN1

NOVEMBER 2017

AUGUST 2021

C - CB BPS3



NOVEMBER 2017

AUGUST 2021

M - CB BPN4

NOVEMBER 2017

AUGUST 2021

M - CB BPS4

NOVEMBER 2017

AUGUST 2021

MB - CB BPN2

NOVEMBER 2017

AUGUST 2021

MB - CB BPS2

NOVEMBER 2017

AUGUST 2021

8.3.6 Site CO

B - CO6ME2

NOVEMBER 2017

AUGUST 2021

B - COSL2

NOVEMBER 2017

AUGUST 2021

B - COWS4

NOVEMBER 2017

AUGUST 2021

M - CO6ME1

NOVEMBER 2017

AUGUST 2021

M - COWS1

NOVEMBER 2017

AUGUST 2021

MB - COY3

NOVEMBER 2017

AUGUST 2021

MB - COWS3

NOVEMBER 2017

AUGUST 2021

MB - COSL3

NOVEMBER 2017

AUGUST 2021

C - CO6ME4

NOVEMBER 2017

AUGUST 2021

C - COS1

NOVEMBER 2017

AUGUST 2021