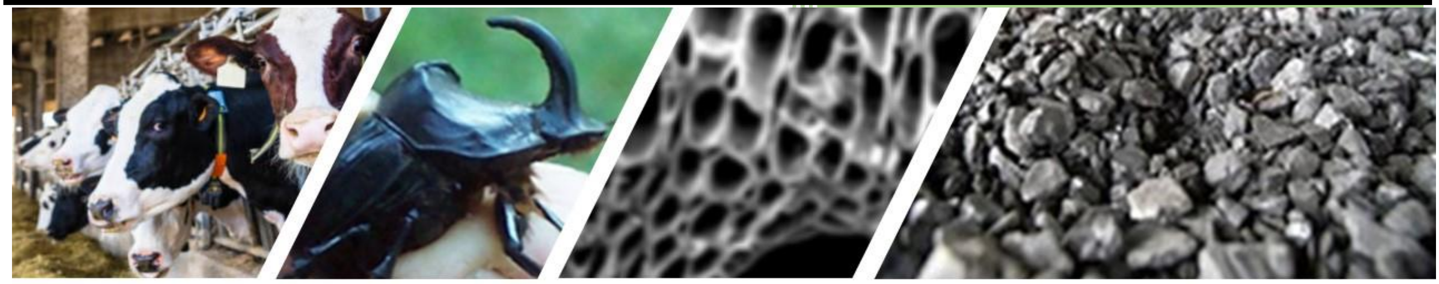
Biochar and Dung Beetles



A regenerative farming technique

Improving milk production, soil health and farm health

Australian Government
Department of Agriculture, Water and the Environment

Climate & Agricultural Support

Creation Care Pty Ltd

GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY

Goulburn Murray Landcare

SOFT AGRICULTURE
SUSTAINABLE ORGANIC FARMING TECHNIQUES

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A report for

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SMART FARMS SMALL GRANTS (Round 3) - Final Report

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Lewis Watson/Chris Blackberry
Mark Peterson
Craig Emmett
Richard Lazarotto
Wendy Sims
John Wright
Susan Wearden
Eamon Reeves
Jo Doolan
Karen Gamble

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Contents

Background

Farmers in the Goulburn Broken Catchment are subject to climate extremes. When this project began in 2020 the region was going through one of the worst droughts ever and the Murray River ceased to flow with the NSW arm cut off from the Victoria. The river was reduced to low or no flow in places across NSW irrigation allocations were at an all-time low and water and feed prices were high. Moving to 2022 Dartmouth dam upstream from the Goulburn Broken Catchment has overflown for the first time since 1956 and the region has experienced widespread flooding. Climate extremes coupled with volatility in water price significantly impacts on farm profitability in the region.

Biochar and activated carbon are a charcoal-like substance made by heating organic biomass (agricultural and forestry wastes) with very low oxygen. Biochar is special because of its many chemical properties, high surface area and ability to absorb moisture and nutrients. There are over 14 thousand published papers on biochar and its benefits to agriculture including and those describing its ability to support drought and climate resilience for agriculture. These papers are summarised in a meta analyses by Joseph et al 2021.

Biochar benefits reported by Joseph et al, 2021 include: improved soil health, and soil carbon, balanced pH, phosphorous availability, increased water availability, improved plant function and increased resilience to environmental stresses, increased animal productivity benefiting food, water and energy security. The paper reports on higher order use of biochar and the opportunity to feed through animals benefiting the animal, soil, pasture and water.

Some research trials on the Fleurieu Peninsula of SA using feeding biochar to dairy cattle and using dung beetles to burry biochar laden dung has provided great results to improve farm productivity and soil, plant and animal health. The results of the trials are reported by Rebbeck et al 2020 and Taherymoosavi et al 2022.

During the Fleurieu trial:

- Biochar was fed to dairy cows for a year at 150g/head/day
- There were statistically different increases in milk yield by 0.4 to 1.4 litres per head per day.
- Younger animals had a larger increase in milk yield likely due to rumen benefit
- Less fodder was fed
- A large increase in profit was recorded.
- The biochar laden dung contained more nutrients and minerals compared to non-biochar laden dung.
- There was evidence of improved soil and plant health as a result of the biochar laden dung being spread and across the paddock and buried by dung beetles.

A further report measuring the flow on benefit of burying the biochar laden dung can be found here with the main findings being:

- Large statistical benefits were found in biochar laden dung buried by dung beetles with improvements in soil mineral, soil carbon and pasture productivity.

The report concluded that farmers can use dung beetles to then bury the biochar laden dung through the soil profile to gain exacerbated benefits on soil health, soil mineral availability, soil carbon, plant minerals, plant feed test and plant biomass.

This project aimed to be a demonstration for farmers providing them with practical tools to increase production (by feeding biochar) and the corresponding soil health improvement tools (using dung beet les to bury the biochar laden dung). This project measured the benefits in soil carbon, and soil health, milk yield and animal health. It found and demonstrated similar results to the Fleurieu trial, although biochar was fed at a much smaller dosage.

The ongoing benefits of the dung beetles and biochar will continue to improve soil structure and soil water holding capacity and further increase farm productivity. The cascading benefit of using dung beetles and biochar over time continues to build giving farms increasing resilience to variable water availability and climate extremes, drawing down carbon and increasing productivity.

Project Aims

The project aimed to provide productive and sustainable use of soil and water and increase the viability of dairy farms by:

- Measuring or demonstrating the effectiveness of biochar as a feed additive in improving milk yield and quality and demonstrating the benefits on reducing mastitis and bloat
- Demonstrating the effectiveness of spring active dung beetles to bury biochar laden dung and improve and repair soil health and reducing methane and nitrous oxide emission from manure-by-manure burial.

Objectives:

Analyse the milk yield and quality changes, of feeding biochar at around 200gms/head/day on a property in the Goulburn Murray Catchment over a 6-month period and review results of a similar project in S.A.

Release spring active dung beetles on 10 farms and measure the soil health and pasture production improvement from dung beetles.

Methodology

This project was funded by federal government department of water agriculture and environment under a Smart Farms Grant. The project originated because dairy farmer Paul Stammers had purchased some Greenman biochar after hearing about associated Fleurieu biochar dairy projects discussed above. The project had aimed to measure the milk yield change at his dairy and then the soil and plant health across his property and 9 others who were to be provided dung beetles in the Goulburn Broken Shire. Shortly after the project received funding, Paul Stammers closed his dairy. This left the project without a dairy farmer to feed biochar and also no biochar (an in-kind contribution by the farmer).

The project manager contacted some suppliers asking if they could provide biochar for a minimum of 6 months to feed in a dairy. There were a number of companies contacted, however Soft Agriculture were the only company willing to provide the biochar for nothing.

The project manager also put a call out via the Goulburn Broken Landcare Group to a number of dairy producers in the Goulburn Broken shire asking for an expression of interest in dairy producers to:

1. Feed biochar to dairy cattle and
   Receive dung beetles.

Ten dairy farmers respond with interest in both feeding biochar and receiving a dung beetle colony. All 10 farmers were organic dairy farmers and an assessment process was conducted to look at their suitability to feed biochar with the following factors considered:

- Ability to mix biochar in the bail
- Ability to provide individual long term milk records
- Commitment to feeding for at least 6 months.

From the 10 farmers 3 were deemed suitable to feed biochar using the criteria

The project officer asked Soft Agriculture if they could supply to all 3 farmers, and they agreed. The project also needed to pay for the transport of the biochar from northern NSW to Shepparton (not originally budgeted. Due to this generous offer from Soft Agriculture (Mara Seeds) biochar was provided to all 3 farmers as shown in Table 1.

TABLE 1 FARMERS, QUANTITY OF BIOCHAR PROVIDED AND LONGEVITY OF FEEDING

Farmer Name	Address	Quantity of Biochar	How it was fed	Longevity
Chris Blackberry	713 McColl Road, Kyabram, Vic, 3620	1 tonne	Mixed at rex stockfeed in ration and fed in the bail	Lasted 3 months then resigned from the property and left the farm
Craig Emmett	12 Curr Rd, Stanhope, Vic 3623	1 tonne	Provided biochar to Rabar who attempted to make a biochar pellet with copper and zinc and bentonite and salt and acid buff, and molasses. It went mouldy so we added the biochar to the soil instead and measured differences.	Measured soil health instead
Richard Lazarotto	2137 Murray Valley Highway Cobram East	4 tonnes	Mixed at 50 gms/head/day fed at the bail to 200 Jersey Frisian cross dairy cows. Ration with barley, minerals and oil once at night.	Adds to feed primarily in spring. Still feeding with results discussed in this report.

Mark Peterson (organic) farmer provides crushed barley and wheat and dolomite in the bail with some oil in a feed dispenser. It didn't work out to feed biochar to his animals as the mixing was problematic at the dispenser. However Mark did sign his farm base lined for soil carbon by Agriprove and this occurred in Autumn of 2021. The farm has been signed up to the Australian Government Emission Reduction Fund (ERF).

Chris Blackberry an organic farmer only fed biochar in the dairy for 3 months until he resigned as farm manager, hence it was difficult to discern any differences from his milk data. However Chris Blackberry also signed up to have his farm base lined for soil carbon by Agriprove and this occurred in Autumn of 2021. The farm has been signed up to the Australian Government Emission Reduction Fund (ERF). Although Chris has left the farm, the baselining is inherited by the subsequent manager. If soil carbon is re measured by that manager and an improvement is found, they will receive a payback via the ERF.

Craig Emmet an organic farmer has 400 Frisian and Jersey cows . He is a flood irrigator with some dryland paddocks, and some flood irrigation paddocks. He tried to make a biochar pellet from the biochar to feed but it went mouldy so instead he spread the biochar onto a paddock containing fescue and clover that is flood irrigated. The project took some base measurements from the soil and plants and follow up soil measurements as described below. Craig Emmet also had his farm base lined for soil carbon by in kind support from Agriprove and this has been submitted to the ERF, and if he improves his soil carbon in the future will receive a payback.

Richard Lazarotto (RL), organic farmer**,** has 150 ha and has 120 milking cows being pure Frisians and pure Jersey plus Frisian x Jersey. All up he has 200 head of cattle on his farm Sixty percent of his calving occurs in the spring 40pc in the Autumn and 10pc in between. Richard started feeding biochar at just 50 grams/head per day mixed with 2kg/head/day of barley and wheat on about 20 Dec 2020 to the milking herd of 120 then stopped in Autumn March 2021. The barley and wheat feeding continued. He started feeding biochar again in Sept 2021 and stopped in Autumn. Again, started in Spring 2022 (Table 2).

The remainder of the feed is a grazing diet of rye grass and clover. Each cow consumes 20 – 25kg of pasture a day plus the 2kg of the grain supplement each at the bail. It was recommended to feed 150 grams of biochar however Richard started with 50 grams and found a benefit so never increased the rate. RL gains a premium price for protein and butter fat.

RL regularly herd tested for milk litres, fat and protein as well as mastitis. Milk samples sent to Numurkah Nu Genes (NNG) for testing. NNG provided milk test reports on a monthly basis and the results plotted in this report. The milk herd test conducted in December was done before biochar was fed. RLs historical milk data went back to April 2020. The aim was to compare historical milk data to milk data when biochar fed. The project team also regularly spoke with RL to discuss and report on other anecdotal findings.

TABLE 2 : BIOCHAR FEEDING MONTHS – RICHARD LAZAROTTO (B HIGHLIGHTED GREEN IS WHEN BIOCHAR WAS FED)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2020												B
2021	B	B							B	B	B	B
2022	B	B								B	B	B

In addition, initial soil and plant measurements described below and follow up soil tests were taken.

The 3 biochar feeding farms plus 7 additional farms were provided a colony of spring active dung beetles via Creation Care. Beetle species are pictured in figure 1. The farms and dung beetle types are shown in table 3.

FIGURE 1 ONTHOPHAGUS VACCA (VACCA) BEETLE LEFT AND RIGHT BUBUS BUBALUS (BUBALUS) DUNG BEETLE ON THE RIGHT

TABLE 3 FARM AND SPRING ACTIVE DUNG BEETLES PROVIDED BEING EITHER ONTHOPHAGUS VACCA (VACCA) BEETLE OR BUBUS BUBALUS (BUBALUS)

No.	Name	Location	Species
1	Lewis Watson / Chris Blackberry	Kyabram	Vacca
2	Craig Emmett	Stanhope	Vacca
3	John Wright	Lockington	Bubalus
4	Mark Peterson	Nathalia	Bubalus
5	Susan Wearden	Kyabram	Bubalus
6	Richard Lazzarotto	Cobram	Bubalus
7	Eamon Reeves	Dookie	Bubalus
8	Jo Doolan	Kyabram	Bubalus
9	Karen Gamble	Lockington	Bubalus
10	Wendy Sims	Lockington	Bubalus

Each farm had the opportunity to have soil tests, plant tissue tests, feed tests and microbial data taken from their property. There was not enough time to detect changes in soil, plant tissue, and feed test data as a result of the dung beetles, as a year and a half was needed to breed the dung beetles before release. However, baseline tests were necessary to then allow the farmers with support of the Goulburn Broken Catchment Management Authority (GBCMA) or the Goulburn Murray Landcare Group (GMLC) to follow up at a later date.

As Victoria had many lock downs due to Covid at the time tests were needed we sent the test packs out to farmers and reminded them via whats app and email to do their tests. We focused the testing on the farms that fed biochar being Chris Blackberry, Richard Lazarotto and Craig Emmet. We used the testing funding to do some additional more expensive soil health base lining. In addition 2 farmers registered their farms under the Australian Government ERF for soil carbon baselining via Agriprove (as discussed above). The tests that were carried out are shown in table 4 along with the dates the soil and plant tissue was collected for analyses.

TABLE 4: SOIL AND PLANT TISSUE TESTS CONDUCTED ON FARMS

Test Farmers	Microbial Soils	Plant Minerals	Feed Test	Soil Minerals	Soil Minerals	Farm Baselined for Soil Carbon ERF
Richard Lazarotto	22nd Nov 2020	22nd Nov 2020	22nd Nov 2020	22nd Nov 2020	10th Oct 2022	x
Craig Emmett	22nd Nov 2020	22nd Nov 2020	22nd Nov 2020	22nd Nov 2020	10th Oct 2022 (x2)	May 2021
Chris Blackberry	22nd Nov 2020	22nd Nov 2020	22nd Nov 2020	22nd Nov 2020	x	May 2021
Mark Peterson	x	x	x	x	x	May 2021

Plant and soil testing processes.

The following testing occurred using the following processes:

Soil samples were taken using a handheld soil corer. A total of 10 cores were taken from a transect across a chosen paddock sampling to 10cm. The cores were mixed up and then sub sampled to have one bag of soil sent for each farm. Soils were sent to soil carbon and mineral analyses to APAL and Microbiology Laboratories Australia for soil health.

Plant tissue samples were also taken at the same time that the soils were sampled and sent for analyses to APAL. 10 samples were cut to ground height across the paddock and sub sampled. They were split and half sent to APAL and the other sent to Agrifood feet test laboratories for feed test value.

The following tests were applied to the soil samples and plant tissue samples:

Soil mineral analyses from APAL laboratories; pH (water), P Colwell mg/kg, PBI, K (Colwell) mg/kg, S (KCl) mg/kg, organic Carbon %, ECw 1:5 µS/cm, CEC (standard cation exchange capacity – no prewash) meq/100g, % exchangeable Ca. % exchangeable Mg, % exchangeable K, % exchangeable Na, % exchangeable Al.

Plant mineral analyses by APAL laboratories; phosphorus (P) %, Nitrogen (N) %, Ammonium N %, potassium(K) %, sulphur (S) %, calcium (Ca) %. magnesium (Mg) %, sodium (Na)%, chloride (Cl) %, copper (Cu) mg/kg, zinc (Zn) mg/kg, manganese (Mn) mg/kg, molybdenum (Mo)mg/kg, cobalt (Co) mg/kg, boron (B) mg/kg, iron (Fe), mg/kg, aluminium (Al) mg/kg. NITROGEN: finely ground dry sample analysed by DUMAS method.
NITRATE NITROGEN: water extraction analysed by colorimetry. APAL in-house TMp-005/TMp-005PP,
MAJOR & TRACE ELEMENTS: microwave digestion and ICP-OES analysis. APAL in-house TMp-002/TMp-002PP
CHLORIDES: water extraction and potentiometric silver nitrate titrimetry. APAL in-house TMp-004/TMp-004PP

Feed Test parameters by Agrifood Feed test laboratories including metabolizable energy (ME), MJ/kg dm, digestibility (DMD) % digestibility of organic dry matter (DOMD) %, crude protein (CP) %, neutral detergent fibre (NDF) %, ADF %, dry matter (DM) %.

Key microbe groups from Microbial Laboratories Australia including total microorganisms, bacteria and fungi, microbial diversity, nutrient cycling rate, fungi: bacteria, bacterial stress and bacteria groups including pseudomonas, actinomycetes, gram positive bacteria, protozoa and mycorrhizal fungi (including VAM).

Microbiology laboratories Australia measures the soil indicators directly from the sample. It measures the amount of carbon dioxide (CO_2) emitted by microbes to calculate Microbial Activity. Plants can use the CO_2 emitted by soil microbes to overcome the often-limiting CO2 in the air around crops (Guntiñas *et al, 2013).* Having a good level of microbial activity in the soil not only helps soil processes but can improve crop growth. Molecular (DNA type) technology was used to analyse the unique cell membrane fingerprint of each microbe group to identify and quantify well known microbial groups essential to important soil processes.

Results

This report discusses the milk data findings from Richard Lazarotto plus presents the soil and plant data from the farmers and follow up soil carbon and mineral tests from 2 farms.

Rainfall

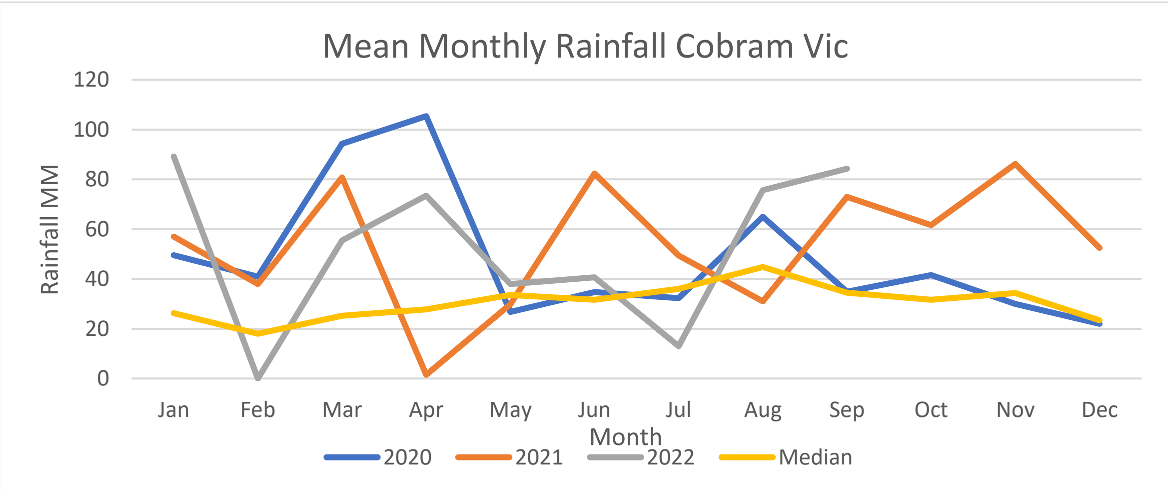


FIGURE 2 MEAN MONTHLY RAINFALL FOR 2020- 2022 COMPARED WITH THE MEDIAN AT COBRAM VIC NEAR RICHARD LAZAROTTOS (RL) FARM

The mean monthly rainfall at Cobram for 2020 shows that the median rainfall for 2020 from May onward resembled the long-term median more closely than 2021 and 2022. 2021 and 2022 were both La Nina years and had high spring rainfall. 2022 has since had flooding in the region. RL's farm was not flooded however the soil moisture profile is full, feed remained watery in 2022 until the time this report was written. As RL's farm is irrigated, it does remove some of the rainfall effect on pasture availability and soil impacts.

Performance of milk quality and quantity

Table 5 below repeated (table 2) shows when the biochar was fed and figure 3 demonstrates the corresponding average milk yield data. Note that biochar was fed in late December 2020 after the milk herd test so no effect will be shown in 2020.

TABLE 5: DATES BIOCHAR WAS FED AT RL PROPERTY (B IS WHEN FED)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2020												B
2021	B	B							B	B	B	B
2022	B	B								B	B	B

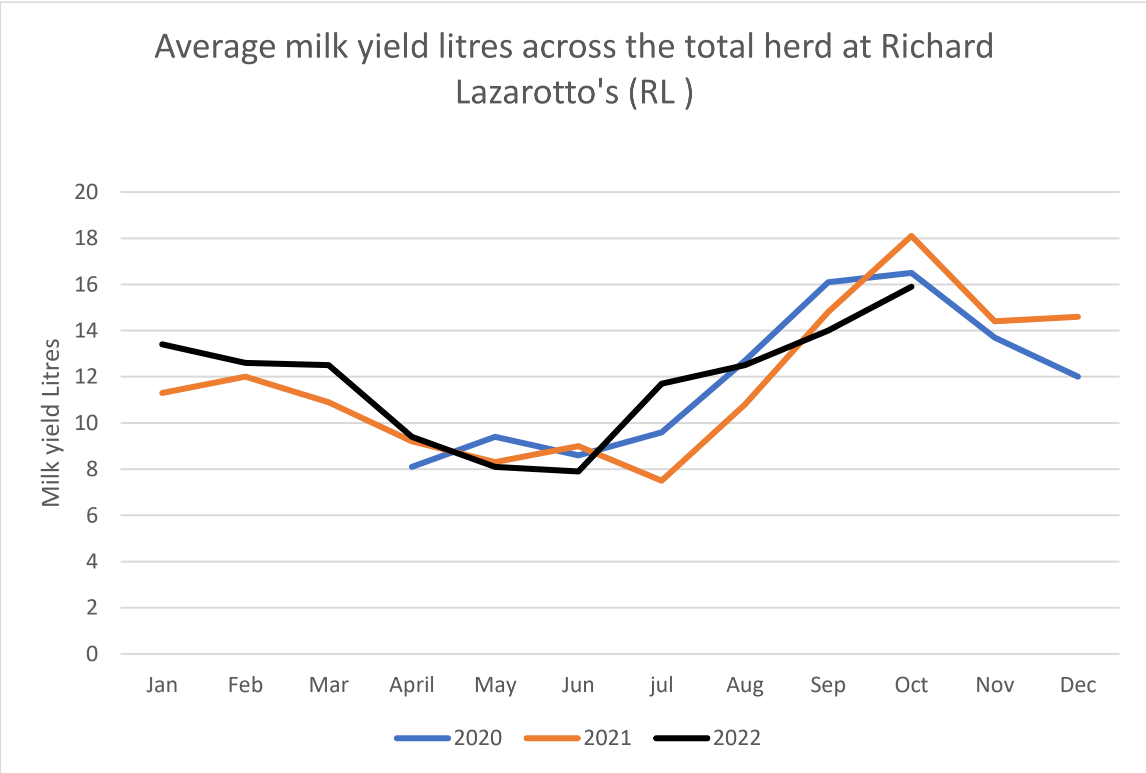


FIGURE 3: AVERAGE MONTLY MILK YIELD IN LITRES AT RICHARD LAZAROTTOS FARM FROM APRIL 2020 TO SEPT 2022.

Figure 3 shows that the average milk yield was higher in the months that biochar was fed. Biochar was fed in spring and summer of 2021 and 2022 and was not fed in 2020. In addition, in 2021 biochar was introduced earlier, this may have resulted in the spring peak of milk yield at the highest average ever produced by RL at 18.1 litres/head/day in October. It will be worthwhile to follow the milk yield data through until the end of the 2022 to see how the biochar continues to improve milk yield. RL will continue to herd test and feed biochar over summer. RL did report that he felt he was receiving around about the 1 litre per head per day increase in milk yield when he fed biochar. He also reported other improvements discussed below.

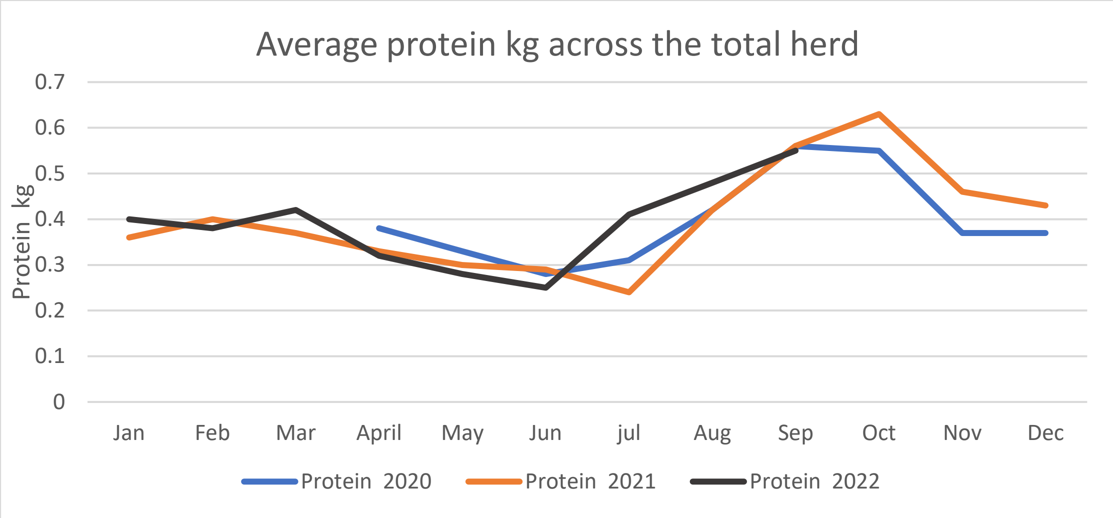


Figure 4 Average montly protien in KG at RLs farm from April 2020 to Sept 2022

Figure 4 demonstrates that protein appeared to be higher in 2021 compared with 2020 and is also trending that way in 2022. Some financial analyses are shown below.

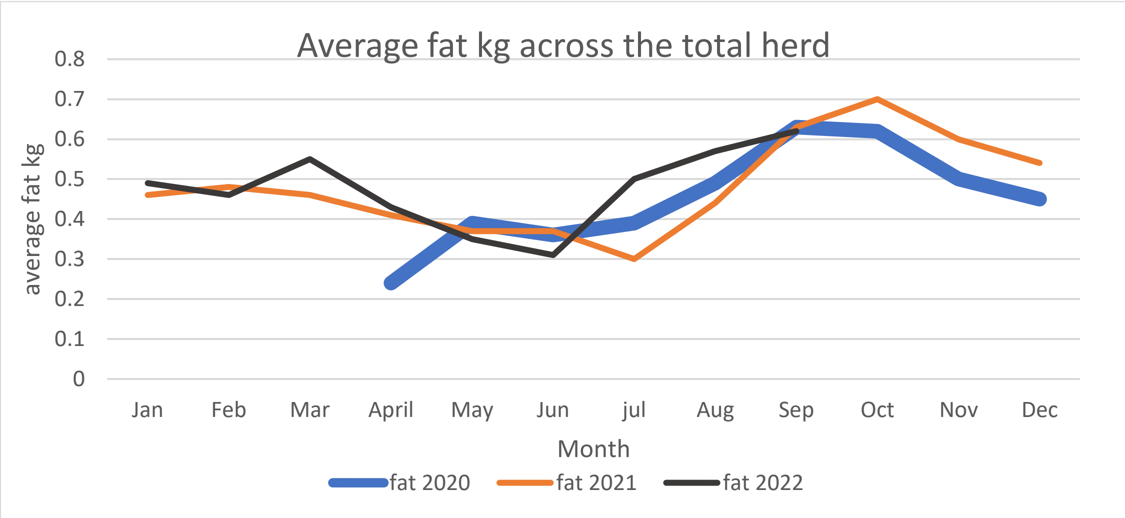


Figure 5 Average montly Milk Fat in litres at RLs farm from April 2020 to sept 2022

Figure 5 shows a similar trend in fat improvement in 2021 and 2022 compared with 2020. Although there is no data for Jan to March 2020.

Note that biochar was not in the diet of the animals at all in the winter months (table 5) and is only shown to see if there is any carry over effect of the biochar. It does appear that when biochar stops being fed Milk, fat and protein in yield does drop off.

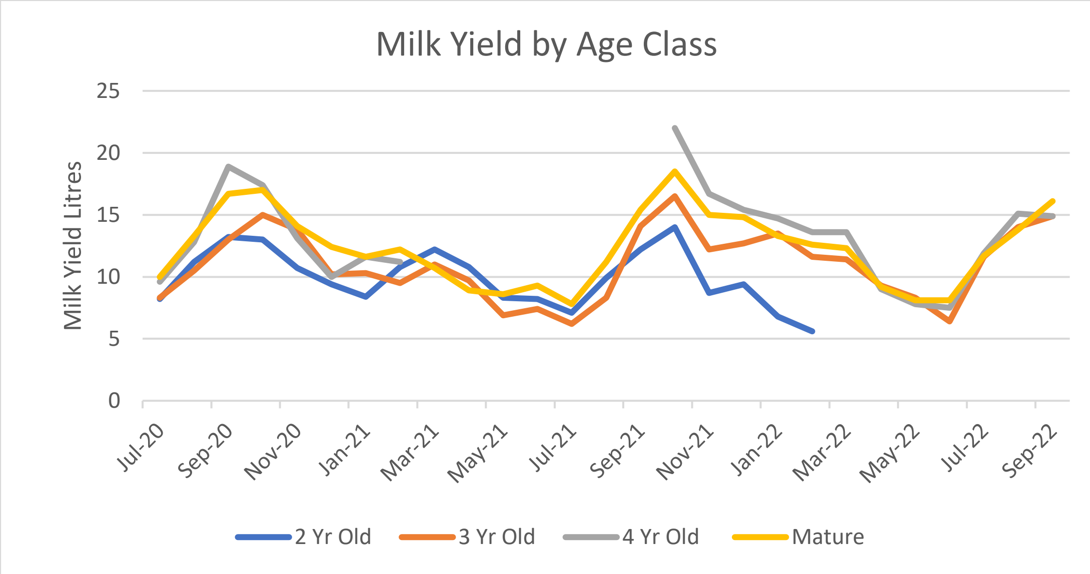


FIGURE 6 COMPARISON OF MILK YIELD BY AGE CLASS AT RL

Figure 6 shows the difference in milk yield by age class over time. Remembering that biochar was not fed in the winter months. If we compare Oct 2020 when biochar was not fed to Oct 2021 (Figure 7) there is a clear increase in milk yield across all age classes.

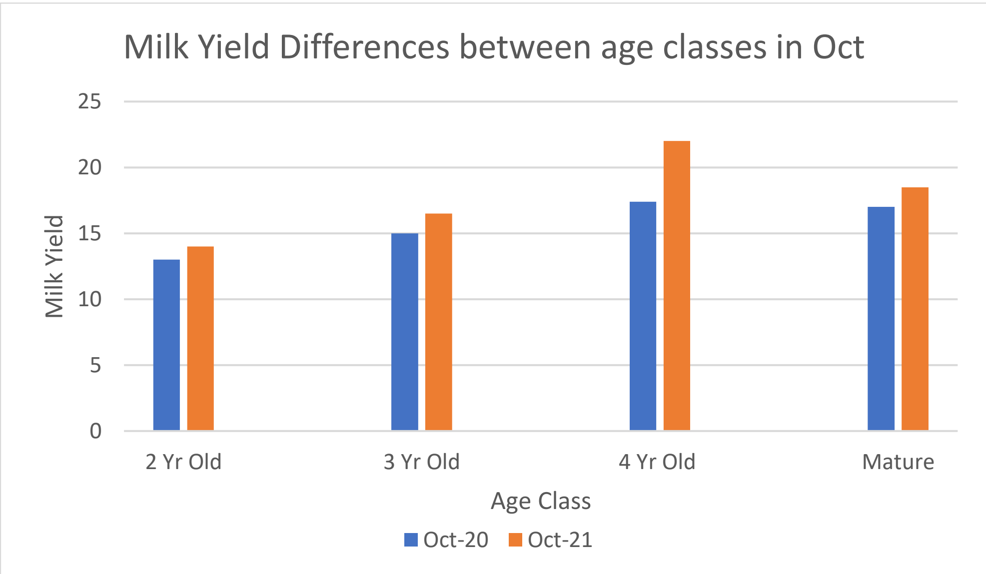


FIGURE 7 DIFFERENCE IN MILK YIELD BETWEEN AGE CLASSES IN OCT 2020 AND OCT 2021.

There are clear indications of increases in milk yield, fat and protein after feeding biochar. However, without statistical analyses we cannot be certain the effect is all due to biochar. There are other factors such as calving timing, feed quality and ambient temperature that can all impact on milk quality, however Richard Lazarotto reported the following observations:

- In spring at least 1 litre per head per day increase in milk yield
- Biochar effect continues for a while then drops off
- No more bloat (despite high protein)
- No occurrences of mastitis and usually is cases found.

- Fed less hay in winter, around 2 bales less
- $25 k/yr increase in profit approx.
- No acidic smell of cow dung so rumen more settled converting feed a lot better
- New young heifers look the best for a long time.
- At one point in Oct 2022 ran out of grain, so stopped feeding biochar and grain in the bale. Manure went very runny within 2 days. Once re introduced grain and biochar the manure was solid again.

Although we can not be certain that the increases were due to biochar, a similar research trial was completed on the Fleurieu was statistically analysed and found statistically significant increases in milk, fat and protein (Rebbeck et al 2020 and Taherymoosavi et al 2022). In the Fleurieu trial less fodder was also needed as a result of te biochar and similar observations were found. This trial achieved its aim of demonstrating biochar benefits. RL will continue to feed biochar and has interest from neighbouring farms to do the same.

Soil Health

Table 6 shows the microbiology test results from soil collected on the 22nd of November 2020 at Chris Blackberry, Richard Lazarotto and Craig Emmet's farm. As the dung beetles took a year and a half to rear, it was not intended during the lifetime of the smart farm project to go back and retest the soil health. However the Goulbourn Murray Catchment Management Authority is likely to follow these tests at a later date. In addition, Craig Emmett, Chris Blackberry and Mark Peterson all had their soil carbon baselined through Agriprove for the ERF as part of this project. Agriprove will re measure their soil carbon in a few years' time.

TABLE 6: MICROBIAL SOIL HEALTH INDICATORS TESTED BY AUSTRALIAN MICROBIOLOGY LABORATORIES. RED = TOO LOW, GREEN = HIGH BUT GOOD, GREY = TOO HIGH

Test Date 25th November 2020	Total Microorganisms	Bacteria	Fungi	microbial diversity	Fungi: Bacteri	Bacterial Stress	Psudomonas	Actinomycetes	Gram positive	Gram negative	True anerobes	prootzoa	Mycorrhizal fungi
	mg/kg	mg/kg	mg/kg	mg/kg	Ratio	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Craig Emmett	92.3	24.4	63.3	36.1	2.6	0.4	2.447	3.679	13.155	11.202	0.937	4.611	33.238
Richard Lazzarotto	84.7	27.1	53.4	39.4	2.0	0.4	3.572	4.163	14.844	12.303	0.901	4.159	22.464
Chris Blackberry	113.5	30.8	78.2	35.9	2.5	0.4	3.65	5.036	17.28	13.547	1.1	4.494	43.79
Normal	50	15	33.8	80	2:3	<0.5	1	1	4	11	<.005	1.3	10

Table 6 shows that the soil indicators for all 3 farms exceeded the normal levels in many cases. The biomass key desirable microbes were good for all samples, however with these microbial groups, nitrogen needs to be monitored as high amounts of nutrient may be kept by the microbes competing with the plants.

Protozoa levels were all above normal, likely due to the organic properties. Protozoa are important for nutrient transfer and cycling between soil trophic levels and can be sensitive to agrochemicals particularly herbicides. All 3 properties are organic with no chemicals used supporting protozoa abundance.

True anaerobes were elevated which indicates that the soil is prone to or had recently been waterlogged. The rainfall in November 2022 when the soil samples were taken was around the median, however all 3 soils were irrigated. This indicates there may be room for improved irrigation efficiencies.

Microbial diversity was fair but could do with more variants of microbes. The fungi to bacteria ratio was good for 2 of the 3 farmers. Richard Lazarotto could do with increasing bacteria amounts.

These results suggest that management practices should initially focus on building microbial diversity and bacteria for Richard.

It is suggested that the farmers re test periodically and concentrate on minimising true anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Plant tissue tests

TABLE 7 PLANT TISSUE TEST RESULTS FROM SAMPLES TAKEN ON NOV 2020 AT CRAIG EMMETT, CHRIS BLACKBERRY AND RICHARD LAZAROTTOS FARM

Sample Name	Nitrate - N	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sodium	Sulphur	Boron	Copper	Zinc	Molybdenum
	mg/kg	%	%	%	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg
Craig Emmett	30	2.83	0.46	2.69	0.369	0.32	0.53	0.33	14	7.3	25	0.73
Chris Blackberry	136	2.25	0.29	2.23	0.245	0.23	0.12	0.26	8.4	6.1	28	1.1
Richard Lazzaro	325	3.23	0.37	2.34	0.281	0.29	0.76	0.38	12	7.6	33	1.4
Normal		4-5	0.35-0.45	3.20-4.80	0.45-1	0.2-0.3	0.15-0.25	0.3-0.4	10-20	9-12	30-50	0.1-0.15
Normal Y or N		low	ok	low	low	ok	ok to excess	ok to low	low to ok	low	low to ok	low to excess

The plant tissue tests indicate that the Nitrogen and potassium in the plan tissue could be improved in all 3 samples. Copper Zinc and Molybdenum levels were low in Craig Emmett's samples as was Copper in Chris and Richards samples. Zinc was below normal in Chris Blackberrys sample. The Molybdenum levels high in all 3 samples. Richard Lazarotto had an increase in his soil heavy metal levels when retested in Oct of 2022 discussed below. This may well correspond to the plant tissue which at this stage is not re measured.

Feed test results

TABLE 8 FEED TEST RESULTS TAKEN FROM SAMPLES COLLECTED IN NOV 2020 FOR CRAIG EMMET, RICHARD LAZAROTTO AND CHRIS BLACKBERRY.

	Dry matter %	Moisture %	Crude Protein % of DM	Acid Detergent Fibre % of DM	Neutral Detergent Fibre % of DM	Digestibility DMD % of DM	Digestibility DOMD % of DM	ME Mj/kg DM	Fat % of DM	Ash % of DM
Craig Emmett Paddock	27.2	72.8	20.2	24.7	48.5	71.3	67.2	10.6	4.3	10.3
Richard Lazzarotto	24.8	75.2	19.2	25.4	50.3	70.7	66.7	10.5	3.8	12.2
Chris Blackberry	24.2	75.8	19.1	24.7	49.8	73	68.7	10.9	3.9	9.5
Ideal			16-18	<40	<40	80	60	12.1		

Plant samples were collected on the 22nd of November 2020. Rainfall was around the median when tests were taken. The crude protein in all 3 samples was very high indicating high levels of bloat could be a problem in dairy cows. However RL indicated that 2 cows survived bloat when fed biochar. The ME of the samples were lower than ideal for lactating animals but also perhaps an indicator of a season haying off rapidly in 2020.

NDF is slightly higher than ideal and means the animal needs to eat slightly more bulk for weight gain.

The ADF values are good. ADF is a measure of the plant components in forages that are the least digestible by livestock, including cellulose and lignin. ADF increases digestibility decreases, so forages with high ADF concentrations are typically lower in energy.

Pasture intake is determined largely by ME and pasture height then legume content. Pasture intake and pasture utilisation is best measured in terms of dry matter (dm). Differences in digestibility and ME are likely to be due to the ability of the soil to supply nutrients to the plants (Cayley et al, 2002).

The ash content of a feed is the inorganic portion which is not utilised by an animal. This is determined by heating a known weight of material at a very high temperature. The organic components (carbon, nitrogen, oxygen and hydrogen) are burned off and the residue is weighed to calculate ash. The ash contents (non-utilisable are relatively high in these samples).

Soil minerals before and after

Table 9 Soil minerals at Richard Lazarotto before biochar fed on 24th November 2020 then 2 years after on 10th Oct 2022

Richard Lazarotto – Irrigated intensive paddock (pit paddock) – Silty loam					
TESTS	**UNITS**	**24.11.2020 Pre-Biochar**	**10.10.22 Post Biochar**	**Desired Levels**	**More desirable range s=same, n=no & tick = yes.**
pH 1:5 water	pH units	7.61	7.3	6.5-7.5	√
pH CaCl2 (following 4A1)	pH units	6.98	6.84	5.5-6.5	√
Organic Carbon (W&B)	% (40°C)	4.88	6.03	0.9-1.8	√
Nitrate - N (2M KCl)	mg/kg	16	15	20-50	S
Ammonium - N (2M KCl)	mg/kg	4	4.4	2.0-1	√
Colwell Phosphorus	mg/kg	99	100	31-45	S
PBI + Col P		123	83	35-70	√
Colwell Potassium	mg/kg	820	790	150-220	√
KCl Sulfur (S)	mg/kg	47	31	8-20	√
Calcium (Ca) - AmmAc	mg/kg	1810	1840	1000-2000	√
Magnesium (Mg) - AmmAc	mg/kg	863	911	150-200	N
Potassium (K) - AmmAc	mg/kg	777	751	150-220	√
Sodium (Na) - AmmAc	mg/kg	584	403	15-120	√
Ca: Mg Ratio		1.3	1.2	2-8	N
K: Mg Ratio		0.28	0.26	0.1-0.5	S
GTRI		0.12	0.12	0.020-0.070	S
ECEC	cmol/kg	20.7	20.3	0.5-25	S
Calcium	%	43.7	45.1	60-80	S
Magnesium	%	34.4	36.8	10-20	N
Potassium	%	9.6	9.4	3-8	√
Sodium	%	12.3	8.6	5-6	√
Aluminium	%	0	0	0.5-10	S
Hydrogen	%	0	0	0.3-5	S
Salinity EC 1:5	dS/m	0.41	0.34	0.1-.5	√
Boron	mg/kg	1	1.6	0.5-2	N
Iron (Fe)	mg/kg	150	220	10-70	N
Manganese (Mn)	mg/kg	46	39	1-10	√
Copper (Cu)	mg/kg	2	2.8	0.5-1	N
Zinc (Zn)	mg/kg	8.3	11	0.5-1	N

Richard Lazarotto fed biochar to 120 cows on a 150-ha property. However he has 200 cows in total that graze on the property (some beef cattle). 200 cows do 5 tonne of dung in a day. Across a year this is 1825 tonnes of dung of wet weight dung equating to a spread rate of 12.1 tonnes/ha of manure. On RLs farm 120 cows were fed biochar for half of the year in both 2021 and 2022 (as biochar not fed in autumn and winter. 120 cows do 3 tonne of manure a day across half a year = 547 tonnes of wet weight dung across 150ha equating to 3.64 tonnes of bioactive manure x 2 yrs. When animals are fed biochar the dung becomes more bioactive and contains higher amounts of nutrients and minerals (Taherymoosavi, et al 2022). To summarise across 2 years at RLS farm, 24 tonnes/ha of manure would have been spread and 7.2 tonnes of this was bioactive. If buried by dung beetles one would suspect improvements in soil health, minerals and pasture productivity as found by other studies. If not buried you might expect, pasture fouling, and nutrient run off into waterways, which is a huge problem in NZ with the government charging a carbon tax in the near future in NZ.

Measuring the soil minerals and soi health gives a good indication of how the biochar in the manure has improved soil health and soil minerals. Especially when in the presence of dung beetles. RL does have good populations of winter and summer active dung beetles and did breed and release not yet active spring beetles through this project.

The below summarises his soil mineral results before and after feeding biochar which was spread across the farm in manure. The time between measurements was 1 year and 11 months. Rainfall in 2020 was around the median in spring, however in 2021 and 2022 it was well above the median. The paddock is irrigated so technically rainfall would make less of a difference to the readings of the soil.

Most soil mineral levels have increased to a more desirable range or remained within their desirable between 2020 and 2022 as shown by the symbol in the right-hand column of table 9. Potassium levels increased and the KCL sulphur in particular returned to a more desirable level.

The soil pH in particular also returned to a more desirable level. The soil organic carbon increased by 1.15%. When soil organic carbon increases so does soil water holding capacity and production. For every 1% increase in soil carbon through biochar addition, an extra 10 to 30 tonnes of water could be held in the soil (Bryant, 2015). On average, crop yield increases by 10% to 42% with biochar addition (Joseph et al 2021). Build soil organic carbon through negative priming by 3.8% (range −21% to 20%). A 1% increase in SOC in the top 30 cm of soil translates to sequestration of approximately 165 tCO2e per hectare, assuming bulk density of 1.5t Soil/m3 (Soil Carbon Industry Group, 2020). The benefits of increasing soil carbon by 1 % is summarised in table 10 below.

TABLE 10 BIOCHAR ADVANTAGES AND POTENTIAL BENEFITS

Advantage	Potential Benefits
Increase soil's capacity to hold water	For every 1% increase in soil carbon through biochar addition, an extra 10 to 30 tonnes of water could be held in the soil (Bryant, 2015).
Increase crop production	On average, crop yield increases by 10% to 42% with biochar addition (Joseph et al 2021).
Increase soil carbon levels	Build soil organic carbon through negative priming by 3.8% (range −21% to 20%). A 1% increase in SOC in the top 30 cm of soil translates to sequestration of approximately 165 tCO_2e per hectare, assuming bulk density of 1.5t Soil/m^3 *(Soil Carbon Industry Group, 2020)*.
Builds soil health	On average, biochar increases phosphorus availability in soil by a factor of 4.6
Reduce greenhouse gas emissions from soil	Reduce non-CO_2 greenhouse gas emissions from soil by 12%–50%

The Ammonium N is plant available N converted from organic N to NH4. Ammonium N is more resistant to loss through leaching and denitrification than nitrate N. Nitrate N is plant available N converted from NH4+to NO3 and is often more readily absorbed by plants. Ideally, there should be a moderate amount of conversion to optimise the benefits of both forms of N. The nitrate levels hardly changed between sampling dates, but the ammonium levels increased slightly. The Nitrate N levels are below the desirable, but the ammonium N is at desirable levels. This is typical of an organic system and encouraging to see some improvement. In addition, as more ammonium N less N oxide released to the atmosphere.

The level of heavy metals in the soil has increased including Boron, Copper, Zinc and Iron and in addition Magnesium increased. The levels of Iron, Copper and Zinc and Magnesium levels were above desirable levels and have increased more between sampling dates. There are papers published by Joseph et al 2021, that suggest that biochar binds these heavy metals and they will have no impact on the plant health and soil. However it would be interesting to measure the levels in the plant as table 7 showing the feed test results indicated that the heavy metal levels were too low in the plants. We need to remember with these results is that they are not statistically replicated and are purely for demonstration only.

TABLE 11 SOIL MINERALS AT CRAIG EMMET'S FARM BEFORE BIOCHAR WAS SPREAD ON THE SOIL THEN 2 YEARS AFTER ON THE SAME SOIL AND AT THE SAME TIME ON AN ADJACENT AREA WITH NO BIOCHAR.

Craig Emmett – Intensive Irrigated (paddock 22) – Silty Loam						
Tests	**Units**	**Pre-Biochar West 24 Nov 20**	**Non biochar East 10 Oct 22**	**Biochar West 10 Oct 22**	**Desired Levels**	**More desirable range s=same, n=no & tick = yes.**
pH 1:5 water	pH units	6.59	6.54	6.5	6.5-7.5	S
pH CaCl2 (following 4A1)	pH units	6.08	5.98	6.07	5.5-6.5	S
Organic Carbon (W&B)	% (40°C)	4.05	5.34	4.14	0.9-1.8	√ + N
Nitrate - N (2M KCl)	mg/kg	9.5	4.7	78	20-50	√
Ammonium - N (2M KCl)	mg/kg	3	4.5	18	2.0-1	√
Colwell Phosphorus	mg/kg	110	87	100	31-45	S +√
PBI + Col P		142	158	167	35-70	√
Colwell Potassium	mg/kg	550	530	590	150-220	√
KCl Sulfur (S)	mg/kg	46	20	28	8-20	√
Calcium (Ca) - AmmAc	mg/kg	1560	1360	1480	1000-2000	√
Magnesium (Mg) - AmmAc	mg/kg	681	759	792	150-200	N
Potassium (K) - AmmAc	mg/kg	434	414	500	150-220	√
Sodium (Na) - AmmAc	mg/kg	514	358	333	15-120	√
Ca:Mg Ratio		1.4	1.1	1.1	2-8	S
K:Mg Ratio		0.2	0.17	0.2	0.1-0.5	S
GTRI		0.08	0.08	0.09	0.020-0.070	S
ECEC	cmol/kg	16.8	15.7	16.6	0.5-25	S
Calcium	%	46.6	43.4	44.4	60-80	S
Magnesium	%	33.4	39.9	39.2	10-20	N
Potassium	%	6.6	6.8	7.7	3-8	√
Sodium	%	13.3	9.9	8.7	5-6	√
Aluminium	%	0	0	0	0.5-10	S
Hydrogen	%	0	0	0	0.3-5	S
Salinity EC 1:5	dS/m	0.42	0.22	0.36	0.1-.5	√
Boron	mg/kg	1.2	1.4	1.4	0.5-2	S
Iron (Fe)	mg/kg	310	410	380	10-70	√
Manganese (Mn)	mg/kg	30	39	36	1-10	√
Copper (Cu)	mg/kg	3.1	4.1	4	0.5-1	S
Zinc (Zn)	mg/kg	11	13	15	0.5-1	N

Craig Emmett made a biochar pellet out of biochar supplied to him at a local feed mill to feed within the dairy. Unfortunately, the pellet went mouldy. Biochar pellets have been made with some success at other manufacturers. However, it is thought that too much moisture may have been added and hence mould developed. Craig spread the biochar pellet onto soil as an alternative. The pellet contained roughly 50% biochar and was mixed with lime and salt. The pellet was spread across 3 ha at 200kg/ha. Hence the biochar would have been spread at 100kg/ha.

The soil tests at Craig Emmet's compare the same paddock pre and post biochar 2 years apart. In addition, they compare soil collected at the same time (Oct 22) on the biochar spread paddock and on an area in an adjacent paddock.

The soil tests show not much change in soil pH. However, the soil pH was at an optimum/desirable level. The soil organic carbon % increased from 2020 to 2022 by 1.5% however it did not appear to change much when the carbon was measured in the biochar spread area and the adjacent paddock. There could be soil factor, slight soil type differences between adjacent areas.

The Nitrate levels increased by about 70mg/kg and ammonium levels by 11 mg/kg on the biochar spread areas compared to the pre tested paddock and non-biochar adjacent paddock with the levels now well above the optimum. No inorganic N was spread to make this difference as the dairy is organic.

There was an increase in the plant buffering index, potassium levels, as well as Iron, salinity and manganese. The Sulphur levels also returned to a more desirable level as a result of spreading the biochar. The zinc and magnesium levels increased above normal levels..

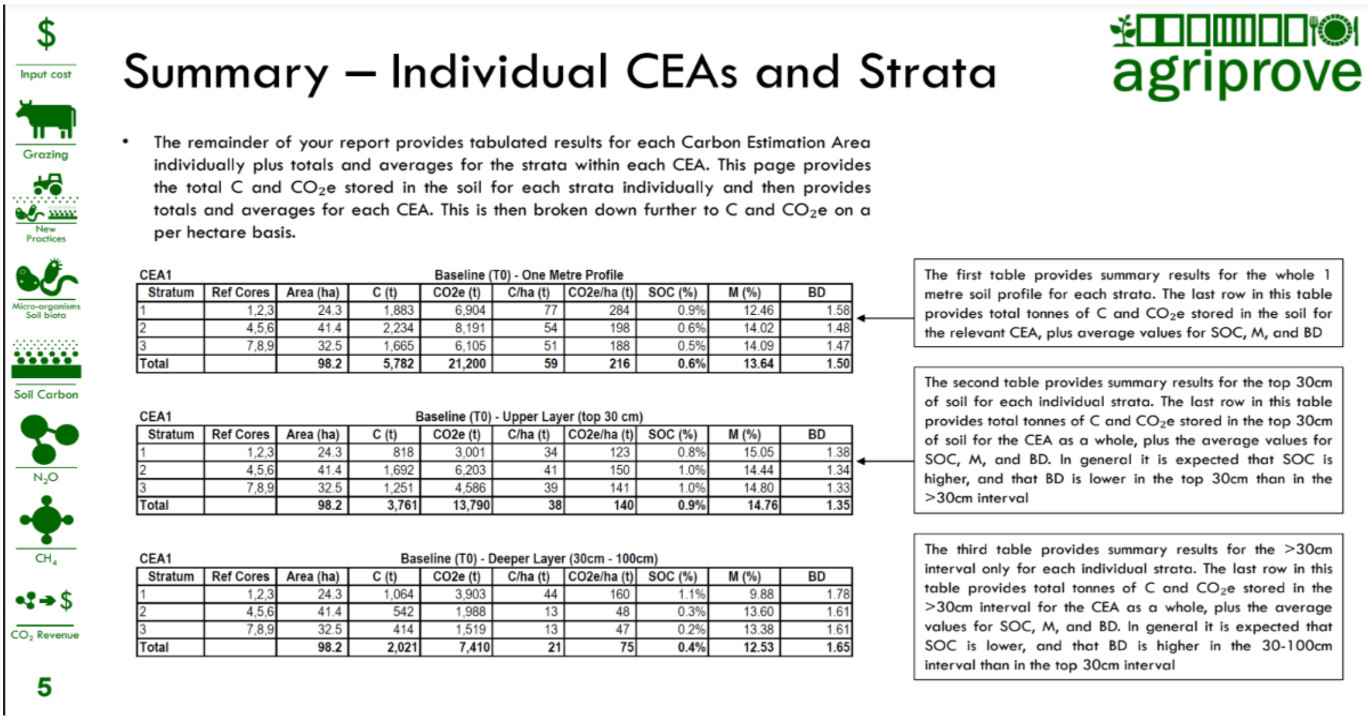
It appears on Craig Emmett's farm, biochar has had a similar positive effect on soil organic carbon (as shown in table 10) in addition to Nitrate and ammonium, potassium, sulphur and iron levels by spreading biochar on the soil.

Base lining Soil Carbon

As part of this project Agriprove provided some service for free soil carbon baselining and application to the Australian Government Emission Reduction Fund (ERF). 3 farmers had their soil carbon baselined including Craig Emmett, Mark Peterson and Chris Blackberry. The soil carbon baselining from Craig Emmett can be seen here. The agreements for Mark and Chris can be found here and they have chosen to keep their data private. Agriprove check every 3 months into how the 3 farmers are going and what they are doing to build their soil carbon. Agriprove will return back to do an audit when they deem there may be some measurable changes after a minimum of 2 years max of 5 years. Chris Blackberry has left his farm, however the baselining is transferable to the next farmer.

A summary of Craig Emmet's soil carbon baseline data is shown in figure 8

FIGURE 8 SUMMARY OF THE BASELINE SOIL CARBON DATA TAKEN AT CRAIG EMMETT'S BY AGRIPROVE



Summary – Individual CEAs and Strata

- The remainder of your report provides tabulated results for each Carbon Estimation Area individually plus totals and averages for the strata within each CEA. This page provides the total C and CO_2e stored in the soil for each strata individually and then provides totals and averages for each CEA. This is then broken down further to C and CO_2e on a per hectare basis.

CEA1 — Baseline (T0) - One Metre Profile

Stratum	Ref Cores	Area (ha)	C (t)	CO2e (t)	C/ha (t)	CO2e/ha (t)	SOC (%)	M (%)	BD
1	1,2,3	24.3	1,883	6,904	77	284	0.9%	12.46	1.58
2	4,5,6	41.4	2,234	8,191	54	198	0.6%	14.02	1.48
3	7,8,9	32.5	1,665	6,105	51	188	0.5%	14.09	1.47
Total		**98.2**	**5,782**	**21,200**	**59**	**216**	**0.6%**	**13.64**	**1.50**

The first table provides summary results for the whole 1 metre soil profile for each strata. The last row in this table provides total tonnes of C and CO_2e stored in the soil for the relevant CEA, plus average values for SOC, M, and BD

CEA1 — Baseline (T0) - Upper Layer (top 30 cm)

Stratum	Ref Cores	Area (ha)	C (t)	CO2e (t)	C/ha (t)	CO2e/ha (t)	SOC (%)	M (%)	BD
1	1,2,3	24.3	818	3,001	34	123	0.8%	15.05	1.38
2	4,5,6	41.4	1,692	6,203	41	150	1.0%	14.44	1.34
3	7,8,9	32.5	1,251	4,586	39	141	1.0%	14.80	1.33
Total		**98.2**	**3,761**	**13,790**	**38**	**140**	**0.9%**	**14.76**	**1.35**

The second table provides summary results for the top 30cm of soil for each individual strata. The last row in this table provides total tonnes of C and CO_2e stored in the top 30cm of soil for the CEA as a whole, plus the average values for SOC, M, and BD. In general it is expected that SOC is higher, and that BD is lower in the top 30cm than in the >30cm interval

CEA1 — Baseline (T0) - Deeper Layer (30cm - 100cm)

Stratum	Ref Cores	Area (ha)	C (t)	CO2e (t)	C/ha (t)	CO2e/ha (t)	SOC (%)	M (%)	BD
1	1,2,3	24.3	1,064	3,903	44	160	1.1%	9.88	1.78
2	4,5,6	41.4	542	1,988	13	48	0.3%	13.60	1.61
3	7,8,9	32.5	414	1,519	13	47	0.2%	13.38	1.61
Total		**98.2**	**2,021**	**7,410**	**21**	**75**	**0.4%**	**12.53**	**1.65**

The third table provides summary results for the >30cm interval only for each individual strata. The last row in this table provides total tonnes of C and CO_2e stored in the >30cm interval for the CEA as a whole, plus the average values for SOC, M, and BD. In general it is expected that SOC is lower, and that BD is higher in the 30-100cm interval than in the top 30cm interval

Farm economic benefits of biochar and dung beetles

As discussed above there was some evidence of increased soil carbon on Craig Emmet and Richard Lazaretto's farm. As an analogy, a 1% increase in SOC in the top 30 cm of soil translates to sequestration of approximately 165 tCO_2e per hectare, assuming bulk density of 1.5t Soil/m^3 *(Soil Carbon Industry Group, 2020)*. Meat and Livestock Australia report that microbes eat 90% of it and only 10% remains to contribute to the soil carbon pool, Time will tell and it will be important to understand this when Agriprove return to audit the soil carbon levels on Craig Emmett's, Mark Petersons and Chris Blackberrys farm. Under this assumption remaining is 16.5t/ha of CO2e remains as organic carbon with the current Australian Carbon Credit Unit (ACCU) sprot price at Oct 2022 reported by the clean energy regulator of $30/tonne, the payback to Craig and Richard using this analogy is 16.5 t CO_2e x $30 = $495/ha if this benefit continued down to 30 cm (only measured to 10cm).

However, Craig would need to minus the amount of carbon added via biochar. RL didn't base line but if he did , his biochar effect would not have to be accounted for as it was not applied to the soil it was fed through an animal.. The total payback using this analogy for RL = $495 x 150ha = $74250. RL already reported an increase in milk yield and a benefit of $25,000 per year. So across for the 2-year period this has doubled. Hence over 2 years he has gained $50,000 increase and for example an additional ERF benefit of $74,250 = $124,250 over 2 years. His soil productivity and farm productivity continues to build from the added biochar in a cascading way through the higher order use of biochar through the animal then through the dung beetle to the soil and then to the pasture and animal.

Dung Beetle Releases

There are no spring active dung beetle species established across southern Australia. This project gave the opportunity to do the first field testing in Victoria of the two new spring active species *Onthophagus Vacca* and *Bubus bubalus.* These species were established in on-farm dung beetle nurseries on 10 farms as shown in table 3 above.

Dung beetle nurseries were used because:

- These species are in short supply in Australia, so the numbers of beetles were not available for large-scale paddock releases.
- The nurseries enabled field testing of the site suitability of each species.
- Breeding beetles in farm nurseries enables farmers to learn about dung beetle rearing and will enable them to breed and spread dung beetles in the future.
- The nurseries were set up in spring 2020. Farmers were trained in feeding and management of the nurseries, which they did for one year, and in spring 2021 the farmers harvested the nurseries to obtain the number of beetles produced.

Vacca results

No beetles survived in the Vacca nursery at Craig Emmett's due to seepage from flood irrigation killing them all. This tells us, that while Vacca may well be suitable for the region, it would only be suitable in locations away from flood irrigation and levee banks.

The Vacca on Chris Blackberry's property was not harvested according to plan. There was good activity of the Vacca beetles on this property and there are likely to be ongoing survivors, but we just do not know the number of beetles produced because they were not harvested as Chris Blackberry was the lessee of the farm and left the farm.

Bubalus results

The results of the success of Bubalus dung beetle rearing are shown in figure 9 below.

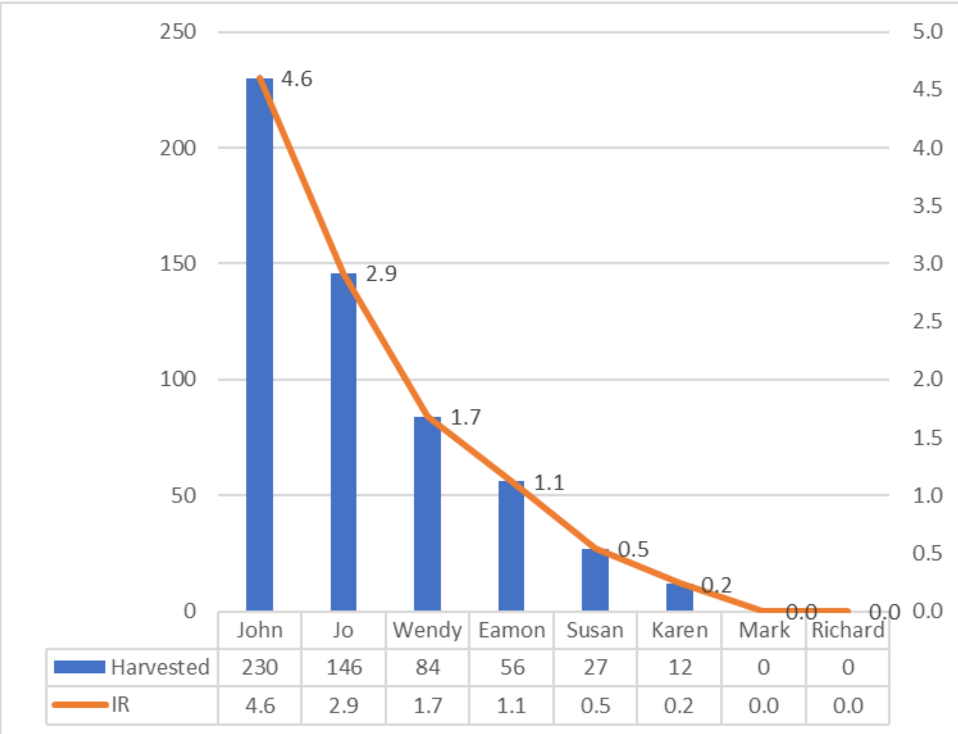


FIGURE 9 SUCCESS OF BUBALUS DUNG BEETLE REARING ON 8 PROPERTIES IN THE GOULBURN BROKEN CATCHMENT VIC.

The Bubalus nurseries started with 50 beetles so, for example, at John's property 230 beetles were produced, which is an Increase Ratio (IR) of 4.6. The IR varied from 4.6 to zero. The 0, 0.2 and 0.5 IRs occurred because of mice and flood damage and some other management variations.

The IR's of 1.1 and above were not as good as expected and were likely lower due to the rainfall distribution during the beetle breeding and development period. Figure 10 shows the actual rainfall recorded at farm sites and for April 2021 was between 1.5 to 5.4 mm, and in February 2021 five sites has zero to 1.4 mm. The red line on the graph shows the average annual rainfall at Montpellier in France, one of the origins of *Bubus bubalus*, is 36, 81 and 97 mm in Feb, Mar, Apr each year. It is highly likely that the low Feb and Apr rainfall in 2021 caused desiccation of the dung beetle broods in the soil, compared to what they would normally experience in locations like Montpellier. In a year of higher Feb to Apr rainfall it is likely the IR's would be higher than achieved in this work.

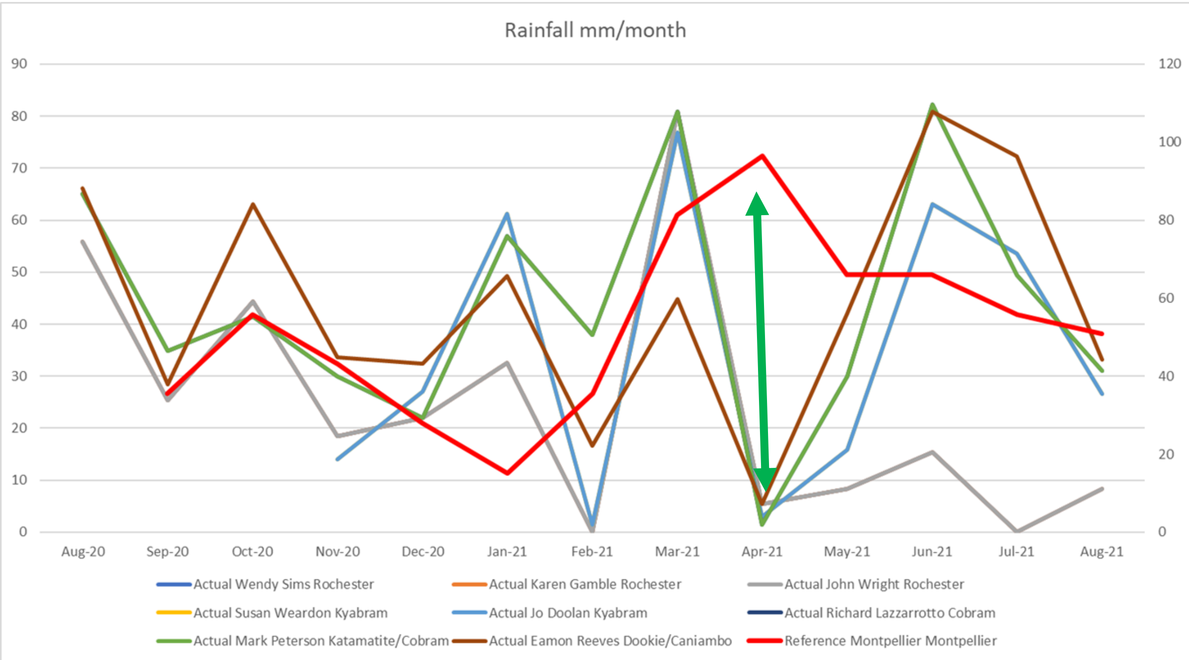


Figure 10 Rainfall in MM (X axis) at farmers sites whom had dung beetles in the Goulburn Broken Shire compared with Montpelier rainfall in France where Bubalus dung beetles originated.

However, even with likely mortality due to desiccation, the results of this work are promising. Note in table 12 below, that if the nurseries had been started with 100 or 140 beetles, instead of 50 beetles, at the achieved IR's would have been, at John's for example, 460 or 644 beetles after one year – which is enough for a paddock release of the beetles. Plus, the nurseries would have produced another crop of beetles in year 2 and year 3. Hence, multiple releases of 460 to 644 beetles would ensure a good establishment of beetles on a farm.

TABLE 12 BUBALIS DUNG BEETLE STARTER AND INCREASES AND PROJECTED INCREASES IF MORE BEETLES

Name	Harvested	IR	100 starter beetles	140 starter beetles
John	**230**	4.6	460.0	644
Jo	**146**	2.9	292.0	409
Wendy	**84**	1.7	168.0	235
Eamon	**56**	1.1	112.0	157
Susan	**27**	0.5	54.0	76
Karen	**12**	0.2	24.0	34
Mark	**0**	0.0	0.0	0
Richard	**0**	0.0	0.0	0

This work indicates that dung beetle nurseries can be used to establish *Bubas bubalus* on a farm when the nurseries are located where they will have good soil moisture during Feb to Apr – either from rainfall or from being in the damp spots on the farm – and when 100 to 140 starter beetles are used.

In spring 2021 Creation Care supplied extra Bubalus beetles to John, Jo and Carol (who took over one of the nurseries) so that they started 2021 with 140 breeding beetles. The results of the 2021 breeding are not known at the time of this report due to the harvest not being complete and also likely beetle death due to severe regional flooding during October 2022.

Demonstration and Extension

There has been a huge demonstration and extension effort on behalf of this project. The awareness numbers below depict actual numbers attending, or likely to read an article or watch a video. The knowledge numbers are 5 to 10% of the awareness numbers and the skill uptake is estimated as 5% from that. These demonstration and extension figures are shown in table 13.

TABLE 13 EXTENSION CARRIED OUT THROUGHOUT THIS PROJECT AND PROJECTED AWARENESS, KNOWLEDGE AND SKILL UPTAKE KNOWLEDGE

	Awareness numbers	Knowledge numbers	Skill/up take numbers
Social Media			
Climate & Agricultural Support Used Whats app to contact and discuss dung beetle issues and opportunities with farmers. This was a hugely successful medium with many photos shared, questions raised and problems solved. The pictures are shared are shown in this link	12	12	12
Twitter posts advertising workshops more widely	300	5	0
Multiple Linked In posts advertising benefits of biochar and dung beetles and advertising workshops	300	30	10
Newspaper Articles			
Article the local paper with Craig Emmett featured here	8000	80	10
ABC produced an article on biochar here Biochar industry fueled by agricultural waste expected to grow - ABC News	20000	4000	200
Newsletters sent out to data base			
A flier send out on dung beetles and soil carbon was produced and can be seen here and was emailed to climate & agricultural support Pty ltd data base of 500 plus workshop participants	500	100	12

A flier on assembly instructions on how to assemble a dung beetle nursery was sent to the 10 dung beetle nursery participants and can be seen here	500	100	12
A newsletter article was produced on how to transport dung beetles and can be seen here	500	100	5
Videos			
Landline ABC produced a national video on benefits of biochar for agriculture and can be seen here	200000	40000	2000
Goulburn Broken Shire produced a video on dung beetle harvest here	43	43	10
Goulburn Broken Shire produced a video on benefits of dung beetles here	43	43	10
A video presentation on biochar and dung beetles here shared by ANZBIG	150	30	2
A video produced from another project re shared via this project achieving more views here Biochar Dairy Trial and Farm Health Benefits - YouTube	1000	100	10
_**Webinars**			
March 21 presentations and participants can be viewed at https://drive.google.com/drive/folders/1zQ3O0sdJDaM10vY4utIc6WU_kWb_9MwQ?usp=sharing	85	17	0.85
Webinar on benefits of biochar and dung beetles 20th July 2021 with Melissa Rebbeck and Greg Dalton	60	20	6
Sept 21 presentation can be viewed here	50	10	0.5
Presentation on biochar and the circular economy for the Murray Darling Association at Albury can be seen here	150	30	1.5
Workshop final results Biochar – Dung Beetles Smart Farms Oct 2022	50	50	5
Other presentations and their videos can be seen here including a dung beetle and biochar working group discussion on the 8th Dec, 2020, 2 national presentations for ANZBIG on the 10th Dec 2021 and 11th Oct 2021. These were to update those with dung beetles on farms how to look after and also provide more detail on biochar element.	200	40	2
Total Numbers	**231943**	**44857**	**2261**

As a result of this project, it is estimated that 231,943 people were made aware of the benefits of biochar and dung beetles. The fact that Landline produced a video improved the outcomes of the extension. In addition 44857 people will now have improved knowledge of the benefits of biochar and dung beetles and 2261 are likely to change practices on farm or in their region as a result of this project.

The project had great numbers attend workshops and webinars held on line.

Summary and Conclusions.

The project achieved its aim of

- Measuring and demonstrating the effectiveness of biochar as a feed additive in improving milk yield and quality and demonstrating the benefits on reducing mastitis and bloat and
- Demonstrating the effectiveness of spring active dung beetles to bury biochar laden dung and improve and repair soil health.

This project demonstrated the benefits of biochar when fed to dairy cows in the Goulbourn Broken catchment of Victoria. It showed that around 1 litre per head per day increase in milk yield was achieved in spring and summer of 2021 and similar trends are being followed for 2022 compared to 2020 when biochar was not fed at a dairy. There was also an increase in fat and protein at the same dairy evident after feeding biochar. The farmer who persisted with biochar feeding over 2 years noticed an increase in his income of around $25,000 per financial year after feeding biochar

In addition to the improvement in milk yield and quality the farmer found

- No more bloat (despite high protein)
- No occurrences of mastitis and usually is cases found.
- Fed less hay in winter, around 2 bales less
- No acidic smell of cow dung so rumen more settled converting feed a lot better
- New young heifers look the best for a long time.

Dung beetles were reared on 10 farms in the Goulburn Broken Catchment of Victoria. There were varying levels of success with rearing and releasing these dung beetles with dung beetles likely to persist and populate on 5 of the 10 farms. These beetles will then infiltrate the district where properties have neighbouring cattle. Where less success occurred breeding and releasing dung beetles, flooding or over irrigation occurred or not enough rainfall late summer.

There was evidence of improved soil carbon and soil minerals in the soil as a result of feeding biochar through the animal. These results align with a fully replicated research trial completed by the same project manager (Rebbeck et al 2022) and a further dairy feeding study completed on the Fleurieu Peninsula (Taherymoosavi et al 2022).

The feeding biochar method to cattle and using dung beetles to bury the laden manure has been proven to reduce nitrous ox ide emissions which are 300x more potent than CO_2. This will also limit the excess nitrogen from running into nearby waterways which causes reduced water quality and can increase nutrient load and algal blooms especially in this study as many properties are very close to the Murray river.

Further work is required to demonstrate how fast manure burial by dung beetles can reduce nitrous oxide emissions. In addition, further work is required to show how biochar can reduce methane emissions by feeding it to cattle. However some evidence of methane reduction might be attributed to better feed conversion due to the reduction in the amount of fodder fed at the farm that persisted with biochar feeding. There are papers published that show the correlation between better feed conversion and methane reduction (Leng 2013).

This project will add a potential economic benefit to the region as biochar when fed to dairy cows has been demonstrated to improve production on farm by around 10pc per year. In the case of RL the benefit of both milk yield improvement and soil carbon payback was roughly $60,000 per year. In addition, once the dung beetles fully expand across the properties, they were reared on they will continue to improve soil health by returning nutrients and carbon to the soil; increasing water infiltration and holding capacity; and improving soil structure (reducing compaction) and improving pasture health and yield.

Further follow up work could occur to re measure the pasture tissue, feed test and soil health values on Richard Lazarotto and Craig Emmet's farm. Increased soil health through improved nutrient, carbon and water cycling has result in improved pasture production in similar studies. In addition, evidence provided by Doube and Marshall (2014) has shown that by using dung bee les to bury dung, less worm larvae are present on the soil surface resulting in less worms being ingested by cattle and a reduced need to worm cattle.

Three of the farms in this study had their soil carbon baselined and registered under the Emission Reduction Fund. They are likely to also have follow up auditing done with opportunities for farmers in the region to learn from their management practices. These results need to be treated with caution as they are not statistically replicated. This was a demonstration trial only.

It is estimated that at least 1000 other dairy farmers and farmers in the region and across the Australia became aware of the benefits of biochar and dung beetles with over 2000 farmers likely to change practice or advise to change practice.

This project could contribute greatly to the Australian Government pathway of 100 billion dollars in farmgate output by 2030.

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