Precision soil management for pasture productivity

Case study farm: Calcolat Creek

Introduction

Soil types, landscape and management practices all contribute to variability in soil nutrients and characteristics like soil acidity within a single paddock. The influence of livestock, who ingest nutrients in pasture in one area and deposit them in another as urine and faeces, can be particularly substantial. This can lead to variable pasture productivity and composition as some areas receive excessive nutrition and others are in deficit. Conventional approaches that spread fertiliser at a uniform rate across the whole paddock do not account for this.

Variable Rate (VR) technology is now commonplace in spreading machinery and allows the rate of fertilisers and ameliorants to vary across a single paddock to better match varying requirements. A successful VR strategy may aim to:

- distribute inputs more efficiently (i.e. match inputs to requirements)
- reduce or control variability within the paddock
- reach target critical values for key soil characteristics and nutrients in a more uniform manner
- grow more/better pasture and make more money.

Although there has been widespread adoption of VR in the cropping industry, uptake remains low in pastures. This project aimed to support adoption by providing a series of relevant case studies with detailed information on the cost and benefit of VR application in real pasture systems.

Focus farm: Calcolat Creek

Hugh and Laura Altschwager, in partnership with Hugh's parents, farm at Calcolat Creek in Tantanoola, SA. Calcolat Creek is a dryland prime lamb production system with soils dominated by black cracking clays and grey loams.

Hugh decided to participate in this Producer Demonstration Site (PDS) project after noticing a lack of consistency in pasture density and species composition in some paddocks.

"We guessed it may be due to soil acidity and were keen to undertake some grid testing," he explains. "We thought variable rate lime spreading could be a good strategy to reduce pH variability."

Method

Two pairs of neighbouring paddocks that were as similar as possible in terms of landscape and past management were selected.

In December 2020 all paddocks were grid soil sampled to create maps of multiple soil characteristics. This involved dividing each paddock into a series of 2ha grid squares. Eight soil subsamples at 0–10cm depth were taken on a transect across each grid square and then bulked together to create a representative sample for the square that was sent to an accredited soil laboratory. Every sample was tested for pH, Phosphorus (P), Potassium (K), sodium (Na), magnesium (Mg), Calcium (Ca), sulphur (S), cation exchange capacity (CEC) and various micronutrients.

Based on these results, one paddock in each pair received a VR application of lime (aiming for a target pH of 5.2), and the other received nil lime (control). These targets were decided by Hugh in consultation with the project team. This meant that there was no direct comparison between VR and conventional lime application on this property. However, the neighbouring property was also involved in the project and included two paddocks that received 3t/ha lime. Management within each pair was otherwise per standard practice and kept as identical as possible.

From 2021 through to the end of 2023, all animal movements and other fertiliser applications were recorded in a spreadsheet by Hugh. Cibo Labs' PastureKey service was used to monitor feed on offer (FOO). PastureKey uses satellite imagery, combined with a library of GPS-located observations of total standing dry matter (TSDM) and machine-learning algorithms, to estimate TSDM remotely every five days. Cibo Labs also provided pasture estimates dating back several years prior to project commencement as a 'baseline' measurement of paddock performance.

In December 2023, a second, final round of grid sampling was undertaken across all paddocks. This followed the original sampling plan (i.e. same grid locations, same depth 0–10cm) to enable a comparison of the actual changes in soil condition under the VR and control (nil lime) conditions.

Initial soil testing and variable rate applications

Initial grid soil sampling revealed substantial variability in pH and soil nutrients across all paddocks. Only a selection of the maps of major soil characteristics from one paddock ("Home 2") are shown in Figure 1 since the single pass of sampling generated a total of 64 maps. In this example:

- pH varied from 4.5 to 6.5 (average of 5.3)
- Exchangeable potassium K varied from 191 to 976 mg/kg (average 452 mg/kg)
- Olsen phosphorus P varied from 5.0 to 19 mg/kg (average 11.3 mg/kg)
- Sulphur S varied from 2 to 13 mg/kg (average 6.6 mg/kg).

These maps also illustrate the limitations of a conventional soil sampling approach using a transect to achieve a 'representative average' result. In this paddock, Olsen P measured conventionally along a south-north transect would have returned a result of approximately 14 mg/kg, while east-west would be 11 mg/kg approx.

"We were surprised at how acidic some areas had become and the overall high variability of pH in relatively small areas," Hugh said, which consolidated their decision to focus on VR lime.

VR application maps were created for the treatment paddocks based on a combination of the pH and Cation Exchange Capacity (CEC) grid maps. These applications occurred in April 2021.

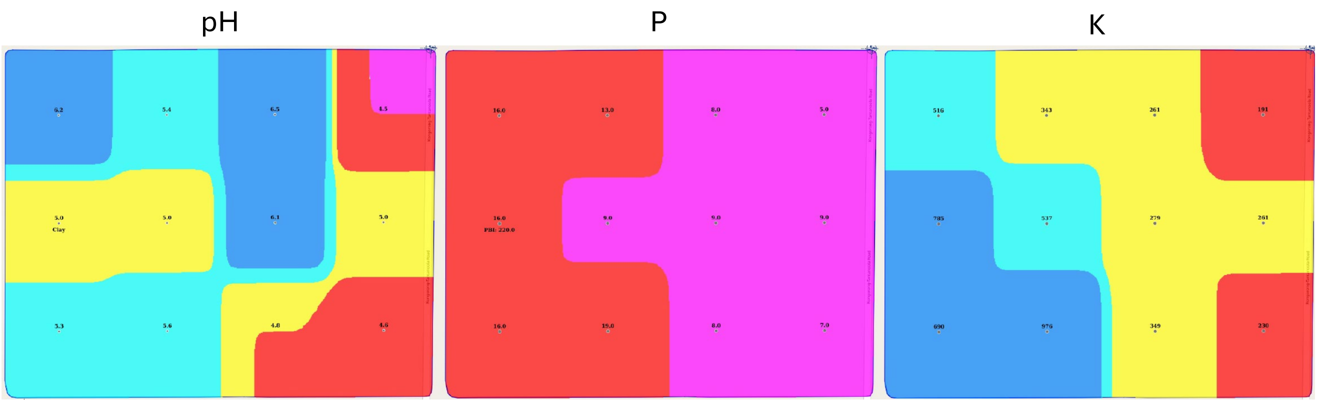

Figure 1: An example of the soil maps generated for each of the paddocks in the demonstration: pH, Olsen Phosphorus, and exchangeable Potassium mg/kg. The different colour regions reflect different nutrient levels, with pink being lowest and blue highest. This degree of variability is broadly representative of all paddocks in the demonstration.

Lime demonstration soil outcomes

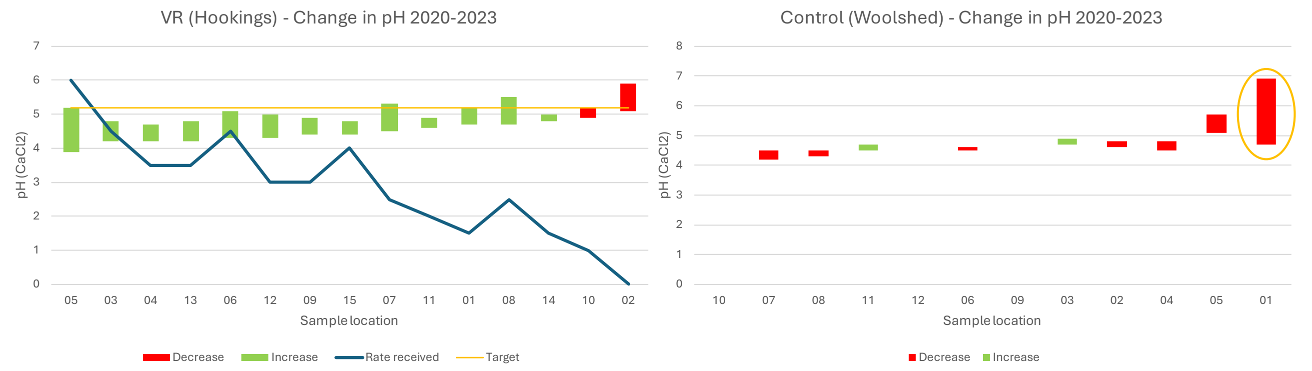

Figure 2: Change in Olsen P soil test 0-10cm between December 2020 and December 2022 for the first pair of paddocks. The VR paddock received a VR application of lime targeting a final pH of 5.2, and the control paddock received nil lime. Sampling locations are sorted in order of lowest to highest initial soil test result (and consequently highest to lowest VR P applications). Green bars indicate an increase in Olsen P between sampling dates at each point, with the bottom of the bar representing Dec 2020 and the top of the bar Dec 2022. Red bars indicate a decrease in Olsen P, with the top of the bar representing Dec 2020 and the bottom of the bar Dec 2022. The VR paddock also displays the rate received at each point (blue line) and the target pH (yellow line). An outlier removed from analysis is circled in yellow in the control paddock.

Pair no. 1 (Woolshed – Control, Hookings - VR) started in a similar position in December 2020 (Table 1). The VR paddock had an average pH of 4.6 (with a range of 0.8 units), and the control average 4.7 (range 0.9 units).

The paddocks behaved largely as expected with the exception of Woolshed – Point 01 location. An unreasonably large decline in pH was measured at this location (circled in Figure 2). It is more likely that this is due to sampling results being affected by the variety of watercourses and gravel bands that run through this section of the paddock than being a true measure of change. Consequently, this point was removed from the following analysis.

By December 2023 the VR paddock had converged towards the target (Figure 2). This is reflected in an increased average pH (5.0) and reduced variability. This average is, however, still below the target of 5.2. This may be due to acidification rates being greater than expected or allowed for in initial calculations (due to seasonal conditions or grazing), meaning there was insufficient time for lime to have full effect.

By contrast, the control paddock continued to acidify. The average pH fell slightly to 4.6, reflecting the ongoing natural process of acidification. The variability also decreased slightly (Table 1). Such a decrease in variability is often observed as a paddock reaches highly acidic pH.

Table 1: Average pH, coefficient of variation CV%, and range in initial and return sampling for pair no. 1 (top) and pair no. 2 (bottom)

pH ex outliers		**VR (Hookings)**	**Control (Woolshed)**
Treatment		**Target 5.2**	**Nil**
2020	**Average**	4.6	4.7
	CV%	10.7%	7.7%
	Range	2.00	1.30
2023	**Average**	5.0	4.6
	CV%	4.4%	5.6%
	Range	0.80	0.90
Change	**Average**	0.5	-0.10
	CV%	-6.3%	-0.02
	Range	-1.20	-0.40
	Average lime rate (treatment)	2.8 t/ha	0

pH		**VR (Home 2)**	**Control (Home 3)**
Treatment		**Target 5.2**	**Nil**
2020	**Average**	5.3	5.4
	CV%	12.2%	10.5%
	Range	2.0	2.00
2023	**Average**	5.4	5.6
	CV%	10.8%	10.4%
	Range	1.7	1.60
Change	**Average**	0.1	0.3
	CV%	-1.4%	0.1%
	Range	-0.30	-0.40
	Average lime rate (treatment)	1.5 t/ha	0

Pair no. 2 (Home 3 – Control, Home 2 – VR) were also very similar in 2020 (Table 1). The VR paddock had an average pH of 5.3 (range 2.0 units), and the control an average of 5.4 (range 2.0 units). Around half of the VR paddock was already above the 5.2 target and hence received no lime.

Surprisingly, return soil test results from December 2023 indicated that many of the points that had received no lime had nevertheless increased in pH – on both the variable rate and control paddock (Figure 3). These increases were also associated with increases in calcium and certain other characteristics.

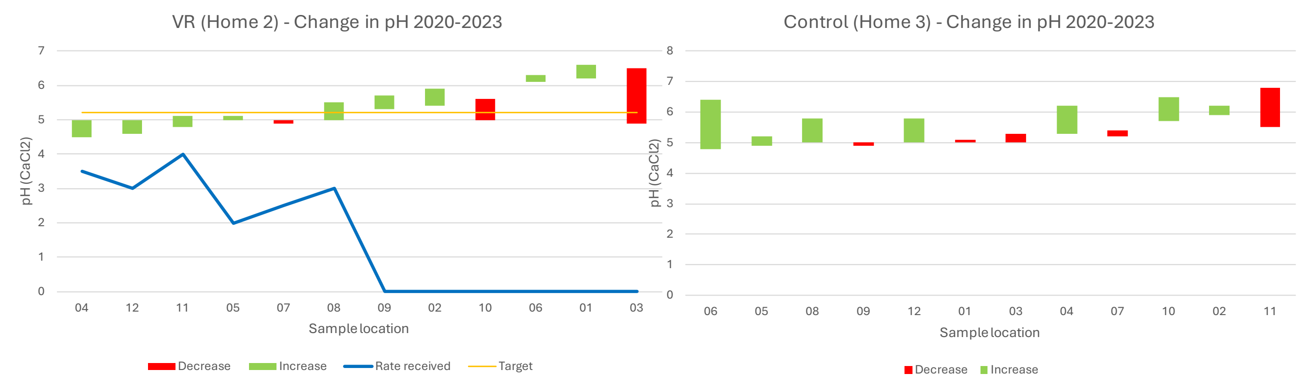

Figure 3: Change in Olsen P soil test 0-10cm between December 2020 and December 2022 for the second pair of paddocks. The VR paddock received a VR application of lime targeting a final pH of 5.2, and the control paddock received nil lime. Sampling locations are sorted in order of lowest to highest initial soil test result (and consequently highest to lowest VR P applications). Green bars indicate an increase in Olsen P between sampling dates at each point, with the bottom of the bar representing Dec 2020 and the top of the bar Dec 2022. Red bars indicate a decrease in Olsen P, with the top of the bar representing Dec 2020 and the bottom of the bar Dec 2022. The VR paddock also displays the rate received at each point (blue line) and the target pH (yellow line).

Further investigation revealed that this is likely due to physical movement of unincorporated lime and topsoil in surface water flows. Due to a watercourse that runs through these paddocks, up to half of the area can be flooded up to a foot deep during a wet winter, which occurred during the project. The flow is, generally, from the variable rate paddock into the control paddock. Many of the points that experienced unusual increases are locations where water collects and remains for more extended periods of time. A further factor may be infiltration by alkaline groundwater during these flood events.

Pasture production

Cibo Labs estimates of total standing pasture dry matter (TSDM, both dead and green) was summarised as monthly paddock average TSDM kg/ha for analysis. These were calculated back to 2017 prior to project commencement.

CSIRO GrazFeed was used to convert the recorded livestock data (date into paddock, out of paddock, mob size, livestock class) into monthly estimates of dry matter intake/ha. Pasture wastage was added and supplementary feed inputs deducted to calculate monthly and annual pasture utilisation and stocking rate (Table 2).

Unfortunately, there was too much variability in the TSDM data to draw meaningful conclusions about the effect that VR may have had on pasture growth. There was also no difference detected in pasture utilisation. However, Hugh did observe improvements in terms of pasture density, composition, residual dry feed and lamb weights turned off Hookings (VR).

Table 2: pasture used per month in kg/ha calculated using CSIRO GrazFeed for the Calcolat Creek demonstration paddocks. Measurements were not precise enough to determine whether there were any meaningful differences between paddocks.

		kg/ha dm utilised				dse/ha			
	Average	2021	2022	2023	average	2021	2022	2023	average
variable rate	**Hookings 1 (27ha)**	8353	8770	8876	**8666**	20.9	21.9	22.2	**22**
control	**Woolshed 1 north (28ha)**	8717	9569	9745	**9344**	21.8	23.9	24.4	**23**
variable rate	**Home 2 (25ha)**	6922	8364	5323	**6869**	17.3	20.9	13.3	**17**
control	**Home 3 (23ha)**	7826	6395	6822	**7014**	19.6	16.0	17.1	**18**

Table 3: Fertiliser and spreading-related costs for both pairs of paddocks.

Paddock	Area (ha)	Treatment	Average lime rate t/ha	Total sampling cost ($)	Total capital input and spreading cost ($)	Total treatment cost ($)	Total treatment cost ($/ha)	Note
Woolshed 1	28	Control	0	$137.00	$0.00	$137.00	$4.89	Pair 1
Hookings 1	27	Trt	2.8	$837.00	$2,435.40	$3,272.40	$121.20	Pair 1
Home 3	23	Control	0	$137.00	$0.00	$137.00	$5.96	Pair 2
Home 2	25	Trt	1.5	$775.00	$1,312.50	$2,087.50	$83.50	Pair 2

Cost/benefit analysis

Because there was no measurable difference in pasture production or carrying capacity, and since other useful measurements such as animal weight or pasture quality were unable to be taken, the cost-benefit analysis reduces to a comparison of costs between the VR and control treatments.

Table 3 summarises the costs associated with the initial applications of lime, including all expenses related to soil sampling, analysis, lime transport and spreading. Subsequent maintenance applications were held constant within each pair and are thus not included.

In this case study, the VR treatments were more expensive. This is due to both the greater initial cost of soil sampling, and because the control paddocks received nil lime. Compared to a hypothetical 2.5 t/ha blanket rate of lime, however, costs become more comparable, and approach parity between Home 3 and Home 2 due to the large area of Home 2 that did not require lime under the VR application.

Next steps and conclusions

Unfortunately, pasture availability, as well as pasture and livestock grazing days, recorded for this demonstration weren't sensitive enough to pick up differences arising from the different lime treatments applied. As a result, there were no measured benefits to offset the greater upfront cost of VRA. Cost savings are more likely in paddocks where VR is able to reduce applications across large areas, as in Home 2.

There are other useful lessons that can be drawn from the results:

First, that lime effectively ameliorates soil acidity, and un-limed paddocks will continue to acidify over time. Lime should be applied regularly to avoid the negative impacts of soil acidity on pasture growth.

Second, that VR lime may be able to reduce variability in soil pH. Although comments about effectiveness compared to conventional lime applications can't be made based on this demonstration site alone, Hugh was generally very pleased by the results of the VR application in Hookings 1. Results from other linked demonstration sites support that VR lime can often be more effective than conventional applications at reaching pH targets and managing variability.

Third, that ongoing sources of variability (animals, geography, etc) need to be considered when deciding what the most effective tool will be to manage paddock variability. Pair no. 2 may see more benefit from additional drainage works before VRA can make an impact. Hugh is considering incorporating future applications to also reduce potential movement in surface water flows.

Ultimately, a more intensive experimental design is necessary to pick up any changes to pasture, livestock and overall financial outcomes arising from different lime application strategies. However, Hugh remains committed to managing the variability in his paddocks. Due to the overall low pH observed in his soils, he is considering a hybrid strategy: an initial blanket rate application of lime to raise the average pH to a point where a subsequent VR application can address the remaining variability and deliver upfront cost benefits.

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