Precision soil management for pasture productivity

Case study farm: Coola Station

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
- 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 VRA in real pasture systems.

Focus farm: Coola Station

Tom and Hilary Ellis farm at Coola Station, a fifth-generation family farm with 150,000 dry sheep equivalents (DSEs) run across 9,000ha of heavy soils over limestone and flint rock near German Creek, SA.

The couple saw this project as an interesting way to learn about VR and what is required for their operation to target specific areas of deficiency.

"We know we have a problem here in SA with acidic soils and wanted to know whether we could combat the issue through using our own product; crushing our own lime and using lime with varying ENV (Effective Neutralising Value)," Tom said.

Method

At Coola Station, two pairs of neighbouring paddocks that were as similar as possible in terms of landscape and past management were selected as demonstration sites.

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. Several segmented soil samples (0–5,5–10,10–15,15–20cm) were also collected to determine whether there were any sub-surface acid throttles.

Based on these results, one paddock in each pair received a VR application of lime (aiming for a target pH of 5.5) and the other received a conventional blanket application of 3t/ha (Control). These high rates reflect the low ENV (34%) of the on-farm lime source used. The targets were decided by Tom and Hilary in consultation with the project team. 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 using AgriWebb livestock management software. 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 to 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 (conventional blanket rate) conditions.

Initial soil testing and variable rate applications

Initial grid soil sampling revealed variability in pH and soil nutrients across all paddocks. Only a selection of the maps of major soil characteristics from one paddock ('Clarkes') are shown in Figure 1 since the single pass of sampling generated a total of 16 maps per paddock. In this example:

- pH varied from 4.2 to 5.4 (average of 4.8)
- Exchangeable potassium K varied from 127 to 486 mg/kg (average 257 mg/kg)
- Olsen phosphorus P varied from 13 to 45 mg/kg (average 25 mg/kg)
- Sulphur S varied from 2 to 25 mg/kg (average 8 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 might return a result of 25 mg/kg, while east-west would be 34 mg/kg approx.

VR application maps were created for the treatment paddocks based on a combination of the pH and

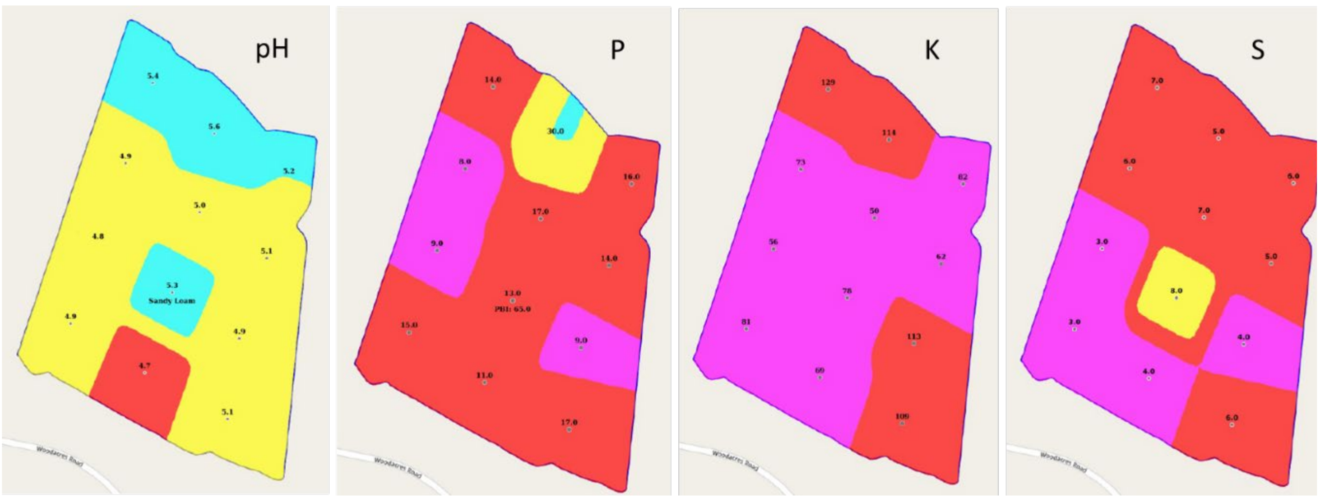

Figure 1: An example of the soil maps generated for each of the paddocks in the demonstration: pH, Olsen Phosphorus, exchangeable Potassium mg/kg, and Sulphur mg/kg. The different colour regions reflect different nutrient levels, with pink being lowest and blue highest. This degree of variability is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

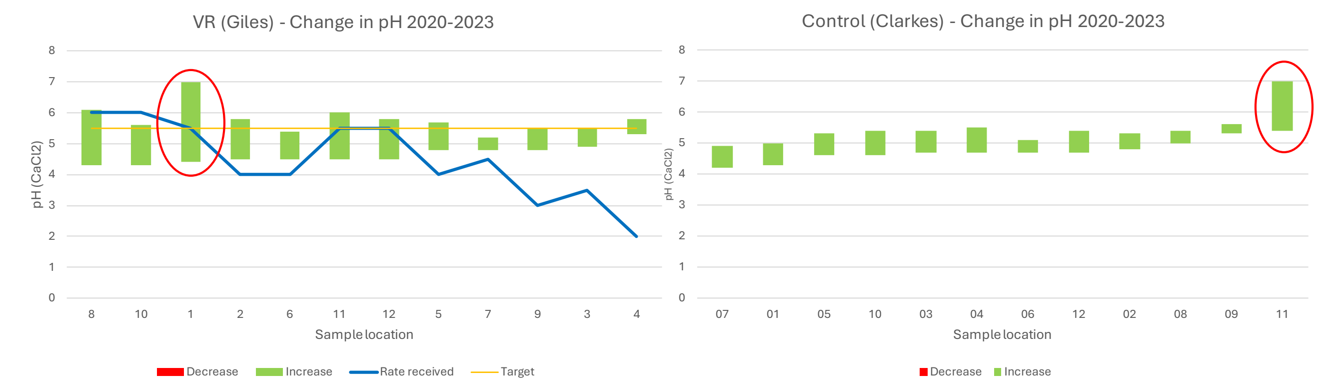

Figure 2: Change in Olsen P soil test 0-10cm between December 2020 and December 2022 for the first pair of paddocks. The VR paddock received a VR application of lime targeting a final pH of 5.5, and the control paddock received 3t/ha lime. Sampling locations are sorted in order of lowest to highest initial 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). Outliers removed from analysis are circled in red.

Cation Exchange Capacity (CEC) grid maps. VR and control applications occurred in March 2021.

Lime demonstration soil outcomes

Pair no.1 (Clarkes – Control, Giles - VR) were similar in December 2020 (Table 1). The control paddock had an average pH of 4.8, ranging from 4.2–5.4. The VR paddock had an average pH of 4.6, ranging from 4.3–5.3.

Although pair no. 2 (Duckhole – control, East Poonida – VR) shared a similar starting average pH, the VR paddock was twice as variable as the control paddock.

Return sampling detected some unusual changes at certain points in each paddock, (circled in Figure 2). A lime dump site location and adjacent gateway caused large jumps in pH at Giles point 1 and Clarkes point 11. In pair no. 2, Duckhole point 10 was affected by additional lime that was spread around a trough. East Poonida point 6 is the location of a limestone reef, and surface limestone appears to have biased on set of measurements more than the other.

Due to these outliers being affected by measurement errors or conditions unrelated to the lime application, they have been removed from the analysis in Table 1 and below.

By December 2023, conditions had improved on both pairs. Both VR paddocks increased to above the pH target of 5.5: Giles to 5.7, and East Poonida up to 6.0

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 Treatment		VR (Giles) Target 5.5	Control (Clarkes) 3t/ha
2020	Average	4.7	4.7
	CV%	6.4%	6.4%
	Range	1.00	1.10
2023	Average	5.7	5.3
	CV%	4.7%	4.0%
	Range	0.90	0.70
Change	Average	1.00	0.60
	CV%	-1.7%	-2.4%
	Range	-0.10	-0.40
	Average lime rate (treatment)	4.5 t/ha	3

pH ex outliers Treatment		VR (East Poonida) Target 5.5	Control (Duckhole) 3t/ha
2020	Average	4.8	4.6
	CV%	14.7%	7.1%
	Range	2.40	1.20
2023	Average	6.0	5.3
	CV%	6.2%	5.3%
	Range	1.30	0.70
Change	Average	1.20	0.70
	CV%	-8.5%	-1.8%
	Range	-1.10	-0.50
	Average lime rate (treatment)	4.4 t/ha	3

on average. This is likely due to the on-farm lime being more effective than predicted. By contrast, the control paddocks remained below the target with an average pH of 5.3 on each.

"Due to the nature of the soil, it will be very interesting to see how long the pH stays at these present levels," Tom says.

The variability in all paddocks also decreased, but the difference between VR and control paddocks was less consistent.

Figure 3: Change in Olsen P soil test 0-10cm between December 2020 and December 2022 for the second pair of paddocks.

In pair no. 2, the VR paddock experienced a large reduction in variability from a range of 2.4 units (CV 14.7%) down to a range of 1.3 units (CV 6.2%). The control paddock saw a smaller reduction (and had less variability to begin with) from a range of 1.2 (CV 7.1%) down to 0.7 units (CV5.3%).

In pair no. 1, however, variability reduced by slightly more on the control paddock (range 1.1 to 0.7, CV 6.4% to 4.0%) than the VR paddock (range 1.0 to 0.9, CV 6.4% to 4.7%). It may be that the VR application was not precise enough. This pair of paddocks were also the least variable paddocks in the demo: it could also simply be that greater initial variability is necessary for there to be a meaningful difference between treatments.

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. Unfortunately, there was too much variability in the TSDM data over time to draw meaningful conclusions about the effect that VR may have had on pasture growth.

AgriWebb records of DSE grazing days per paddock were also analysed, but gaps in the data record meant that there were nil grazing days for some paddocks over the duration of the PDS, although these paddocks were grazed during this period.

Consequently, the available data did not allow for an accurate comparison of pasture/livestock outcomes between treatments in this demonstration.

Tom didn't observe any visual differences between the paddocks but does note that the targeted paddocks were unimproved/10+ year pasture stands.

"I'd be interested to see what would have happened if they were under a recently improved pasture program," he said.

Cost/benefit analysis

As the data did not allow the project team to measure any differences 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 is limited to a comparison of costs between the VR and control treatments.

Table 2 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 etc. were held constant within each pair and are thus not included.

Table 2: 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
Clarkes	26	Control	3	$137.00	$1,079.00	$1,216.00	$46.77	Pair 1
Giles	25	VR	4.5	$775.31	$1,450.58	$2,225.89	$89.00	Pair 1
Duckhole	28	Control	3	$137.00	$1,148.72	$1,285.72	$46.45	Pair 2
East Poonida	28	VR	4.4	$878.23	$1,611.98	$2,490.21	$87.90	Pair 2

In this case study, the VR treatments were more expensive. This is due to both the greater initial cost of soil sampling, and the higher average rates of lime applied by VRA.

Next steps and conclusions

On these demonstration sites, the VR paddocks were generally more effective at reaching pH targets and were more effective at reducing variability when variability was higher to begin with. In the less variable pair of paddocks, variability actually reduced by slightly more on the control paddock.

The on-farm lime source used was more effective than predicted, leading to higher than necessary VR lime prescriptions. VR with more conservative rates may have succeeded in reaching targets, reducing variability, and had more comparable costs to the conventional blanket application, but as it was the VR applications were consistently more expensive. Other linked demonstration paddocks have indicated that cost savings from VR are more likely in paddocks where VR is able to reduce applications across large areas (i.e. where only some sections of the paddock are acidic, not all).

Soil variability can be introduced by both fixed (e.g. soil type, geological features) and more transient (e.g. animal movement, short- and long-term management decisions) factors (such as placement of lime dumps). This needs to be considered in the design of an effective variable rate strategy since this can lead to substantial changes unrelated to a soil's initial level of fertility.

While high frequency grid-based sampling approaches are far more effective at mapping variability than conventional soil sampling approaches, each data point is still at best an average of any remaining variability within the grid square. High degrees of variability that occur within a grid square (as with the limestone reef) can cause inconsistent results.

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.

Tom was very satisfied with the results and the improvement in pH using the on-farm lime source. He is considering a hybrid approach in the future: an initial blanket rate application of lime to raise the baseline pH, followed three years later with a VR application to manage the remaining variability. On these paddocks, now that pH is under control, he will shift focus to management of soil nutrients in general and phosphorus in particular.

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