Precision soil management for pasture productivity

Case study farm: West Cuyuac

Introduction

Soil types, landscape, and management practices can all contribute to large differences 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 leads to variable pasture productivity and composition where some areas receive excessive nutrition and others are in deficit. Conventional approaches to spreading fertiliser at a uniform rate across a 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. Although there has been widespread adoption of VR in the cropping industry, uptake remains low in pastures. This demonstration 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: West Cuyuac

Richard and Sardie Edgar farm at West Cuyuac, Nareen, near Casterton in Victoria. West Cuyuac consists of around 6300 acres of mostly red gum country with sandy loam soils, including 1500 acres under development from forestry and only partially stocked. They currently run 13,000 ewes and 200 cattle and were aware of substantial variability in the way parts of their paddocks performed.

"I had been trying to improve the poorer performing parts of paddocks relative to other parts and thought than nutrient was the biggest issue", explains Rich.

Method

At West Cuyuac, 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. 8 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 one nutrient, and the other received a conventional blanket application (Control), with the target nutrients decided by Rich in consultation with his agronomist and the project team. Management within each pair was otherwise kept as identical as possible.

Throughout 2021 and 2022, Richard recorded all animal movements and other fertiliser applications 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 5 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 2022, 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 Test Results 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 are shown in Figure 1 since the single pass of sampling generated a total of 64 maps. In this example:

- pH varied from 4.7 to 5.6 (average of 5.1)
- Exchangeable potassium K varied from 50 to 120 mg/kg (average 85 mg/kg)
- Olsen phosphorus P varied from 8 to 30mg kg (average 14 mg/kg)
- Sulphur S varied from 2 to 8 mg/kg (average 5 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, K measured conventionally along a south-north transect would have returned a result of approximately 77 mg/kg, whilst east-west would be 62 mg/kg approx.

According to Rich, there was actually less variability than he initially thought there might be – but he found the maps very interesting and useful to decide what and where to target. Based on these results, Rich decided to target P on one pair of paddocks and K on the other.

"I consider P and K to be two of our most important nutrients," says Rich of this decision. "K is expensive so broad-brush spreading has always concerned me. I also know that parts of paddocks can be high in P whilst others are very low and plant growth is being restricted."

VR application maps were created for the treatment paddocks based on targets selected by Rich and his agronomist. In the P pair, the map aimed to achieve a target Olsen P of 18 mg/kg. In the K pair, a method based on K% of cations was used instead, which is

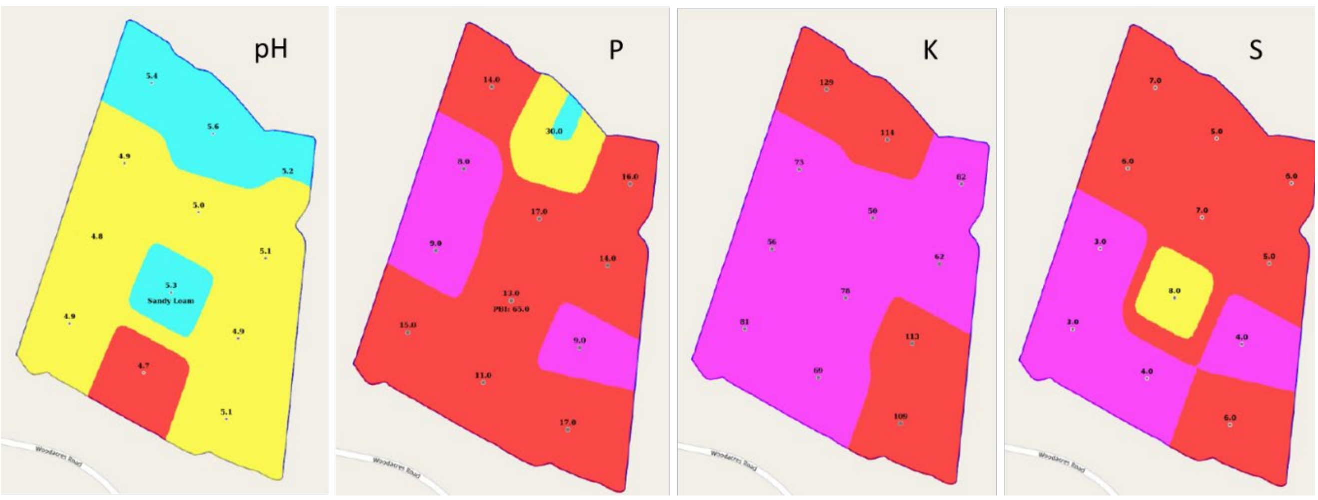


Figure 1: An example of the soil maps generated for each of the paddocks in the demonstration. The different colour regions reflect different nutrient levels, with pink being lowest and blue highest. All paddocks were highly variable.

discussed in greater detail below. At the same time the P control paddock received a blanket application of 18kg/ha P, and the K paddock 25kg/ha K. These applications occurred in May 2021.

VR P Demonstration Site

The paired paddocks that constituted the VR P demonstration site started with similar Olsen P levels and high variability in December 2020 (Table 1). By December 2022, the control paddock had only experienced a small increase in Olsen P (0.7 units) whilst the VR paddock had increased substantially (9.75) despite receiving a lower average P rate, suggesting that the VR application had been both more effective and efficient. However, the final average for the VR paddock was well above the target level of 15-18mg/kg Olsen P as a result of the farmer making a last-minute change to a blended fertilizer product with a higher P analysis (12.4% P) but still utilizing maps designed for SSP (8.8% P).

Table 1: Average Olsen P level (mg/kg) and CV% in initial and return sampling

Olsen P		VR (Wattle Corner)	Control (Colins)
2020	Average	11.5	13.8
	CV%	25%	28%
2022	Average	21.25	14.5
	CV%	27%	40%
Change	Average	9.75	0.7
	CV%	2%	12%
	Average P rate (treatment)	16.4	18

An important additional measure of success for a variable rate strategy is a reduction in variability across the paddock. In this case, both the VR and control paddock increased in variability as measured by the Coefficient of Variation (CV%). However, the control paddock became substantially more variable with an increase in CV% of 12%, whilst the VR paddock only increased by 2%. The VR application appears to have reduced the impact of factors that naturally increase nutrient variability in this system, such as animal movement, without totally removing variability from the system.

Figure 2 demonstrates the spatial impact of the two different strategies. In the VR paddock (figure 2a), areas with lower initial levels received a higher rate and tended to increase more than areas with higher initial levels. In the control paddock (figure 2b) no such tendency is observed.

There were no unusual changes to non-target soil characteristics. Calcium levels increased substantially in both paddocks alongside an increase in pH as a result of (uniform) lime applications. Potassium levels had also changed substantially between the two testing dates in line with ongoing farming operations.

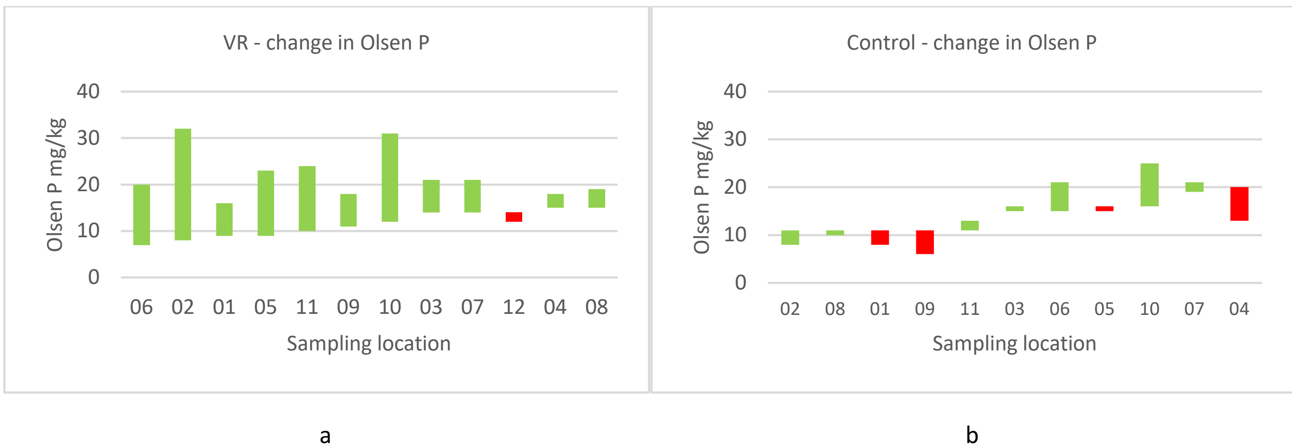


Figure 2: Change in Olsen P soil test 0-10cm between December 2020 and December 2022 for a) the treatment paddock, which received a VR Phosphorus application in May 2021 (average of 16.4 kg/ha P across the paddock), and the control paddock which received a uniform application of 18kg/ha P at the same time. 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.

VR K Demonstration Site

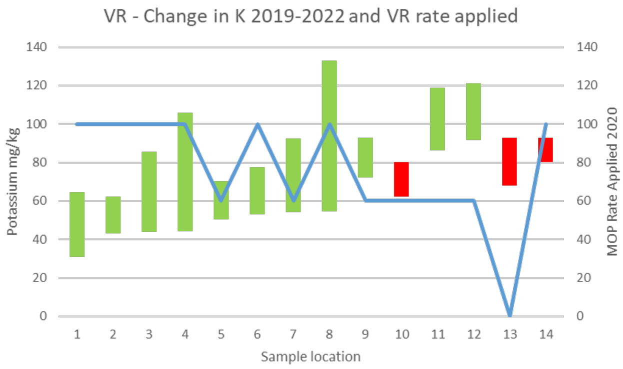
The paired paddocks that constituted the VR K demonstration site started with similar K levels and high variability in December 2020 (Table 2). By December 2022 the K level in both paddocks had increased – VR by 25 mg/kg to an average of 88.2 mg/kg, and control by 15 units to an average of 99.7 mg/kg. The greater increase in the VR paddock is not unexpected since the VR application averaged 38 kg/ha potassium compared to only 25 kg/ha on the control. However, the two paddocks diverged substantially when it came to variability: the control paddock became more variable (CV increased by 7%) where the VR paddock became less variable (CV decreased by 7%). The VR treatment was evidently more effective at managing K variability.

Table 2: Average Exchangeable K level (mg/kg) and CV% in initial and return sampling.

Exch K		VR (Dip)	Control (Isabellas)
2020	Average	63.64285714	84.7
	CV%	34%	30%
2022	Average	88.17857143	99.7
	CV%	27%	37%
Change	Average	24.53571429	15.0
	CV%	-7%	7%
	Average K rate (treatment)	37.85714286	25

Figure 2 demonstrates the spatial impact of the two different strategies. Of particular interest in this case is the approach used to determine the VR application rates on the VR paddock. The conventional method for determining rates uses soil test K in mg/kg as the basis for calculation. In this case, however, the demonstration site farmer and agronomist decided to use K % of cations as the primary input. This is a more unconventional approach (given that K % levels will also be affected by changes in the levels of other cations in solution) but one that had been used with previous success in the region on lighter, low cation exchange capacity soils.

Instead of targeting an actual K level in mg/kg that may be unrealistic, the K % of cations figure is used to determine which areas may have the capacity to hold more K and hence try to 'fill the bucket' instead. As a rule of thumb, if the K % cations was 3 %, it predicts a response and more fertiliser will be



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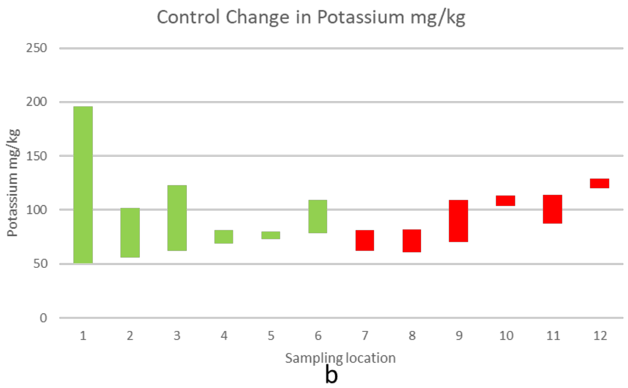

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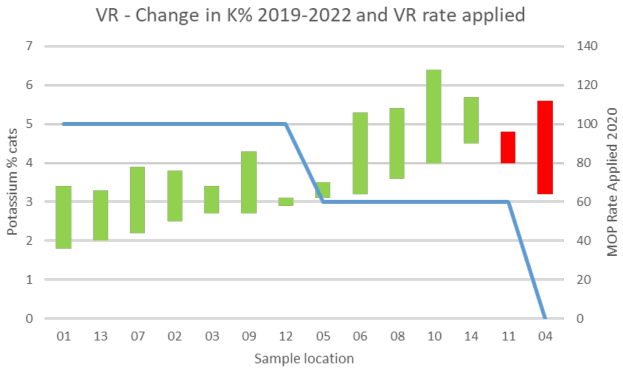

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% K		VR (Dip)	Control (Isabellas)
2020	Average	3.257142857	4.3
	CV%	34%	33%
2022	Average	4.192857143	5.5
	CV%	25%	27%
Change	Average	0.935714286	1.2
	CV%	-9%	-7%
	Average K rate (treatment)	37.85714286	25

d

Figure 3: Change in exchangeable K (2a, 2b), K as a percentage of cations in the VR paddock only (2c), and changes to average K as a percentage of cations and CV% (2d) for soil test 0-10cm between December 2020 and December 2022. Changes are displayed as per figure 1. The blue line on 2a, 2c, displays the variable rate applied at each point.

applied there, whereas when it is close to 5% the idea is that the soil bucket is full so any additional application would be of limited benefit. This approach is demonstrated by the blue line in figures 2a and 2c, which shows the rate applied at each point on the VR paddock: 2a in mg/kg, and 2c as a % of cations. The approach appears to have been successful and is worthy of further and more rigorous study to better understand it in comparison to a more conventional approach.

As with the VR P demonstration, there were no unexpected changes to non-target soil characteristics.

Pasture production

The recorded livestock movement data (date into paddock, out of paddock, mob size, DSE rating of mob, and paddock size) was summarised as DSE grazing days/ha/paddock for each month for analysis. This provides an indication of how paddock carrying capacity changed throughout the demonstration (Table 3).

Unfortunately, despite excellent quality data, monthly DSE grazing days/ha for each of the four paddocks was highly variable and there was no clear pattern of difference between VR and control.

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. As with the DSE measurements, data was highly variable (Figure 4). This is to be expected given both the impact of seasonal conditions and grazing, but it was further complicated by gaps in the data caused by cloudy conditions that blocked collection of satellite imagery during some winter months.

Table 3: Average annual DSE/ha. Monthly average DSE/ha was even more variable.

Paddock	Treatment	Average dse/ha from AgriWebb			
		2019	2020	2021	2022
Colins	Control	14.0	22.9	15.5	20.4
Wattle Corner	VR P	12.2	12.2	17.7	13.7
Dip	Control	14.1	12.0	18.6	15.7
Isabellas	VR K	22.0	11.1	32.9	19.0

There was no obvious or statistically significant difference (based on a paired-samples t-Test) in average monthly TSDM between control and VR paddocks throughout the demonstration. There was also no significant difference between the paddocks when data was split into pre- and post- VR spreading datasets. This is positive in the sense that the paired paddocks appear to have been very well chosen as extremely similar prior to any intervention, but also means that no substantial impact of VR on pasture growth was detected.

Since there was a measured change in soil nutrients, there are several factors which could explain a lack of measurable pasture response in the collected data:

- The limitations of using satellite data as a primary measurement. For example, there were gaps in

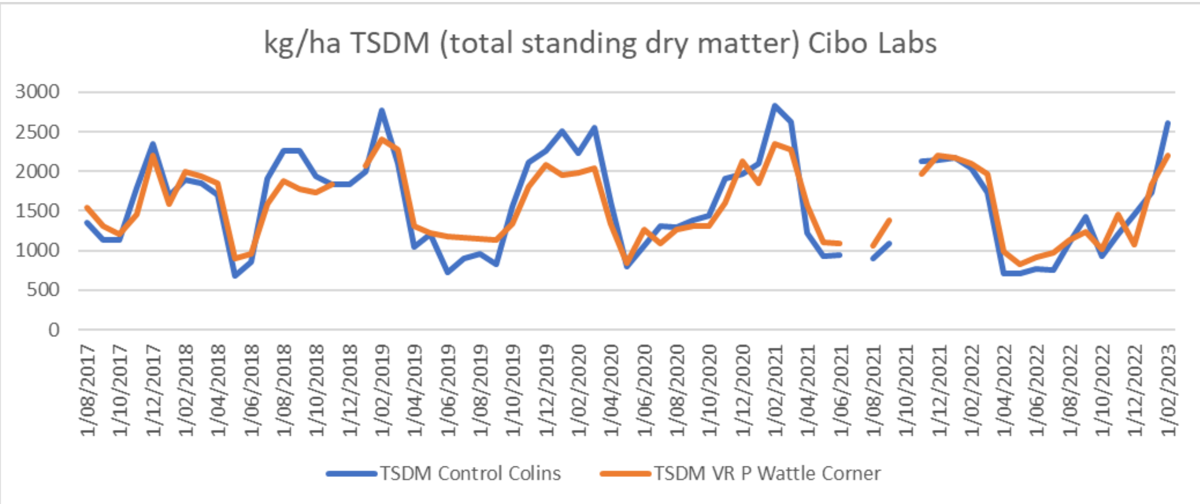

Figure 4: Monthly average Total Standing Dry Matter (TSDM) measurements from CiboLabs for the VR P paired paddocks. Spreading occurred in May 2021. There was no significant difference either before or after VR spreading occurred.

the data from cloud cover, and changes to pasture quality were unable to be measured. Further, it proved impossible to separate the effect of grazing pressure from any changes to pasture variability using this dataset.

- The DSE rating system only provides an estimate of animal requirements, not actual pasture intake. Actual metabolizable energy (ME) intake can be different to ME requirements which might mask some differences in pasture growth and quality.
- Supplemental feeding and other activities might have meant that grazing pressure was not always consistent between paddocks.
- Most importantly, P and K may not have been the most limiting soil nutrients, and hence there may have been no response because growth was still limited by other factors.

Visually Rich believes that there might have been some improvements in the VR paddocks: "I saw some improvement in pasture composition, with more clover in areas of the paddock that had been poorer performing. However, due to the amount of variables I was unable to establish any changes in carrying capacity. This is not to say they didn't occur but I believe we haven't got an accurate enough method of measurement."

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, this reduces the cost-benefit analysis to simply a comparison of costs between the VR and control treatments.

Table 4 outlines estimated fertilizer/ameliorant-related costs for each paddock, including any initial treatment applications and maintenance fertilizer since project commencement.

Costs were approximately $50 greater / ha for the variable rate treatment paddocks, due to both additional sampling costs and higher prescribed fertiliser rates.

Next steps and conclusions

This demonstration highlighted the extent of variability in pasture systems and the limitations of conventional soil sampling approaches to identify them. Positive changes in soil conditions resulted from variable rate P and K spreading, but despite some visual observations of improved pasture quality there was no measured change to pasture or animal condition. Consequently, based on this demonstration alone, an immediate financial benefit was not found.

However, Rich believes that it can still be a very valuable tool if used correctly. "Grid soil mapping gives you a great understanding of your farm soils and may be a useful tool for pasture selection, fence location and of course nutrient application," he explains. "I will continue to target low K areas of paddocks rather than blanket spreading and continue to investigate how VR and soil mapping can work in my system".

Rich also emphasizes that a different approach to benefits measurement may be needed in future trials: "My main observation is that we were unable to find an accurate measurement tool to establish the true benefit/cost of VR spreading. I believe Cibo Labs, Agriwebb data and the pasture cuts all lack the accuracy to give a definitive answer". A higher intensity approach than was possible in these paddocks may be needed.

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Table 4: Fertiliser and spreading-related costs for both pairs of paddocks, including initial treatment and maintenance applications.

Paddock	Area (ha)	Treatment	Total sampling cost ($)	Total capital input and spreading cost ($)	Total maintenance	Total treatment cost ($)	Total treatment cost ($/ha)	Note
Isabellas	24.1	Control	$137.00	$2,396.75	$3,285.79	$5,819.54	**$241.47**	Pair 1
Dip	26.9	VR K	$833.90	$3,219.66	$3,667.55	$7,721.11	**$287.03**	Pair 1
Colins	22.3	Control	$137.00	$1,584.42	$2,061.86	$3,783.27	**$169.65**	Pair 2
Wattle Corner	22.6	VR P	$700.60	$2,200.56	$2,089.60	$4,990.76	**$220.83**	Pair 2