The on-going PA journey: The latest findings and recommendations

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Results summary

- Significant differences exist in the soil-moisture characteristics across paddocks giving a better insight into the drivers of variation in yield potential
- The use of historical yield maps will greatly assist variable rate phosphorus and nitrogen applications
- Farmers should keep using test strips to scrutinise the profitability of variable rate (VR) strategies
- Along with using other PA tools Yield map! Yield map! Yield map!

Introduction

Previously Riverine Plains has reported that significant differences in soil type and characteristics exist in many paddocks across the Riverine Plains area. These differences challenged the traditional practices of applying the same rates of inputs like lime, gypsum, nitrogen (N) and phosphorous (P) across whole paddocks. Instead, the concept that it is more appropriate to treat areas of paddocks according to their own unique characteristics as opposed to a grouped paddock average seemed to have a strong foundation.

During the completion of the last Riverine Plains project looking at PA in commercial cropping systems, some extra details have come to light regarding the drivers of yield variations within paddocks across the area, the overall economic potential of utilising variable rate strategies, and ideas more generally that are helping farmers take more sophisticated steps in their PA journey.

Soil moisture characteristics of zones

Three paddocks have been studied at Yarrawonga over a number of years. Included in this study has been the use of capacitance probes across different areas of the paddock that had been delineated into separate Potential Management Zones (PMZs) to investigate the soil moisture characteristics of these zones.

A total of nine probes were placed in Paddock 44, three on each of the different soil zones. One probe was placed in Paddock 49 (medium zone) and two probes in Paddock 46 (high and low zones). Moisture was monitored using Green Light Red Light (GLRL) soil moisture probes during the 2006, 2007 and 2008 winter crop growing seasons. The GLRL probes consist of five sensors, located at 20cm intervals down to one metre. Two short probes consisting of four sensors @ 10cm, 20cm, 30cm and 50cm were used on the light soils due to the restricted depth to bedrock.

During the three growing seasons the total soil moisture to 1m at the 1st July was greatest in the high conductivity zone with 242mm followed by the medium and low zones with 229mm and 201mm respectively. On average the low conductivity zone has 20% less total available water for the crop than Zone 2 (see Figure 1). This follows logic, as this zone has much less clay content — it generally exhibits topsoil overlaying a mix of soil and semi-broken down parent material.

However, changes in soil moisture from crop emergence to harvest indicate the low conductivity zone contributes 25mm per year to crop water use. The high conductivity contributes 11mm per year to crop water use, while the medium zone always had a surplus of 13mm per year. The surplus water in the medium zone during these three dry years indicates very poor crop water use on this soil type, suggesting rooting depth is limited by factors other than moisture.

The GLRL probes could account for the movement of each millimetre of rainfall down through the soil profile after a significant rainfall event, as illustrated in Table1. In each year the low conductivity zone showed movement to the greatest depth indicating its ability to wet-up quicker than the other two zones. The high conductivity zone always had the least amount of water at depth, thus requiring more moisture to become wet.

Table 1. Effect of rainfall events on soil moisture (mm) at various soil depths

RAINFALL EVENT	ZONE	20CM	40CM	60CM	80CM	100CM	TOTAL
15/7/2006	High	23.2	2.0	0.4	0.0		25.6
	Medium	21.6	2.2	0.4	0.0		24.2
	Low	9.6	6.4	3.4	1.6		21.0
5/7/2007	High	9.8	14.6	4.4	6.8	0.8	36.4
	Medium	3.6	8.4	18.0	6.0	0.0	30.4
	Low	6.0	8.0	4.0	8.4	4.0	30.4
10/7/2008 +	High	22.0	14.4	0.4	0.0		36.8
21/7/2008	Medium	22.0	7.2	0.6	0.0		29.8
	Low	17.6	12.4	1.6	0.0		31.6

Examination of the date of maximum moisture extraction shows that the date of maximum extraction in the low conductivity zone is always two weeks later than the other zones. This would suggest that this zone (zone 2) has greater root activity and thus more moisture availability leading to a higher yielding crop. In fact, looking at this another way, the low conductivity zone exhibited extraction about 20cm deeper than the other two zones during 2006, 2007 and 2008.

So, while the low conductivity zone holds less water, the water it does hold is much more available to the crop. During the recent dry years, the low conductivity zone has yielded well compared with the other zones. This can be explained by the superior utilisation of the little water that has fallen in this zone through deeper and longer extraction.

How much better is variable rate?

A protocol established by the University of Sydney, NSW has been used to lay out replicated trials using farmer-scale equipment to determine whether variable rate applications are better than uniform paddock rates. In each zone, a high and low rate was applied in replicated strips. Yield maps were then used to determine yield results from the high and low strips, and the middle paddock rate. Response curves could then be drawn for each zone, to reveal whether different zones responded differently to inputs, and thus to determine whether different zones had different optimum rates. During this research project such trials were run from 2005 to 2008 on five different paddocks.

Armed with this information, it is possible to compare the Gross Margin (GM) under standard management to the GM achievable under optimum-rate management. Where the GM of the standard management is less than the GM of optimum-rate management, the difference is termed a 'net wastage'. In the opposite scenario the difference would be a 'net gain'. The results of this analysis are shown in Table 2 for all the Yarrawonga phosphorus trials carried out in this project.

Table 2. Results of Gross Margin (GM) analysis comparisons between paddock average application of P fertiliser and that possible under optimum rate management.

YEAR	PADDOCK	SIZE (HA)	CROP	YIELD (T/HA)	NET WASTAGE ($/HA)	PROPORTION OF P FERTILISER COSTS (%)
2006	49	34	Wheat	1.8	50	85
2005	49	34	Barley	4.5	39	74
2005	46	39	Wheat	4.3	60	105
2006	46	39	Wheat	1.5	107	177
2008	46	39	Wheat	1.4	59	140
2006	4	55	Wheat	0.9	35	78
2007	4	55	Canola	0.5	18	53
2008	4	55	Wheat	1.2	26	40
2006	7	91	Wheat	1.1	60	154
2007	39	43	Canola	0.9	47	169
2008	39	43	Wheat	2.3	70	189
median		43			49	105

The results show that during the seasons there was always a 'net wastage' in all the paddocks, with a median wastage figure of $49/ha for phosphorus. This figure is a function of fertiliser costs and crop prices obtained in the specific year of each trial. The total net wastage for each trial was also compared to the total phosphorus fertiliser bill for the paddock average application. This provided an estimate of the wastage as a proportion of the phosphorus fertiliser costs for the year in which each trial was run. This is a simple way of standardising the wastage figures across the years. The median value of 105% suggests that the potential benefit to be gained by knowing more about the optimum rates of phosphorus fertiliser could be equal to the amount of money outlaid on phosphorus fertiliser across a number of seasons.

Obviously the seasons do impact on the yield results and the gross margin. The response functions for many of the PMZ across the trials were relatively flat. The 2006 to 2008 annual rainfall was in the lowest 10-20% of years recorded in Yarrawonga and the in-season rain remained well below average. These types of seasons would be expected to provide poor return to fertiliser outlay, and this is reflected in the low yields and high proportions of phosphorus fertiliser losses reported for these years in Table 1. However, even during 2005 where annual and in-season rainfall was above average, significant wastage in phosphorus fertiliser was documented in the two paddocks in the trial (Paddocks 46 and 49).

The Colwell soil P in the PMZ was monitored before sowing during a number of years across the trials. The average soil phosphorus level across the trials was 67mg/kg, with an average difference between PMZ in any paddock being 8mg/kg. The largest difference between PMZ was recorded in Paddock 46, which also recorded the greatest amount of soil phosphorus in each season. These high levels of soil phosphorus, along with the seasonal effect help explain the relatively flat responses to applied phosphorus, and therefore the continual ‘net wastage’ across the trials, even in above-average seasons.

What PA tools are useful?

Many Precision Agriculture (PA) tools and technologies are now available to growers. In previous work, EM 38 surveys have been proven to delineate soil-based zones that have genuine and important differences in soil characteristics. EM 38 zones have continued to be used as an important basis for zonal delineation in this project. They are a cost-effective tool, and allow all growers to implement zonal management, not just those with yield monitors.

However, in an ideal situation it is desirable to cluster a number of layers of spatial information together to come up with zonal maps. For example, Gamma radiometric images give a different view of the soil scape, while yield maps are a crucial record of levels of ultimate production that have been obtained from various parts of a paddock.

Other layers of information that are emerging include grain protein maps and ground-based crop imaging during the growing season. These technologies will be examined in detail in the latest project being carried out by Riverine Plains.

Growers need to decide how complex or how simple their PA decisions need to be, and what layers of information are required to make these decisions correctly.

Yield maps

<u>Phosphorous</u>

The construction of phosphorus-removal maps from previous year’s yield maps and soil fixation information can assist growers to improve the appropriateness of phosphorus allocation. This is an approach that is particularly relevant after drought-affected seasons. As was highlighted earlier, more phosphorus has generally been applied during recent years than has been removed through harvested grain. Moreover, yield variation within paddocks has still been apparent, giving weight to the case for varying phosphorus across paddocks in line with yield or phosphorus removal.

Figures 1 and 2 show zonal maps produced from yield maps from Paddock 33. Figure 5 is just based on the 2008 yield map, while Figure 6 is based on three yield maps (2006-2008). Both maps are relatively similar as all of these years were low-rainfall years. The zones are considered sensible, conforming to general topographical changes and changes in soil type across the landscape.

Figure 1. Three zones clustered from 2008 barley yield map, Paddock 33

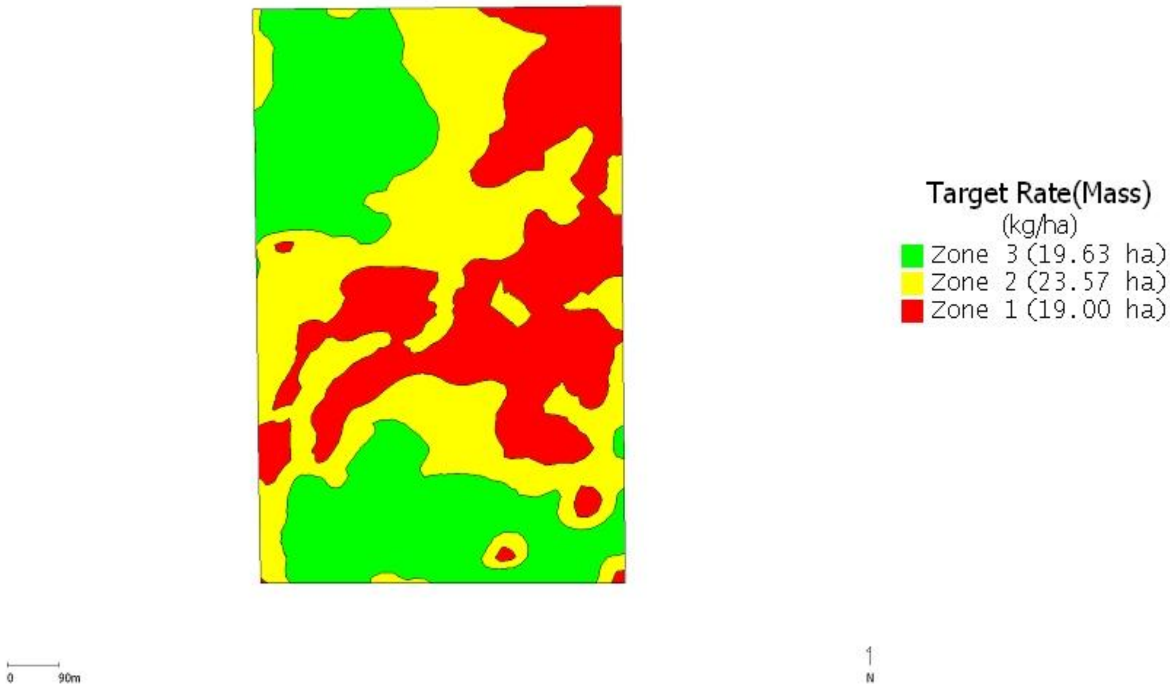

Figure 2. Three zones clustered from 2006, 2007 and 2008 yield maps, Paddock 33

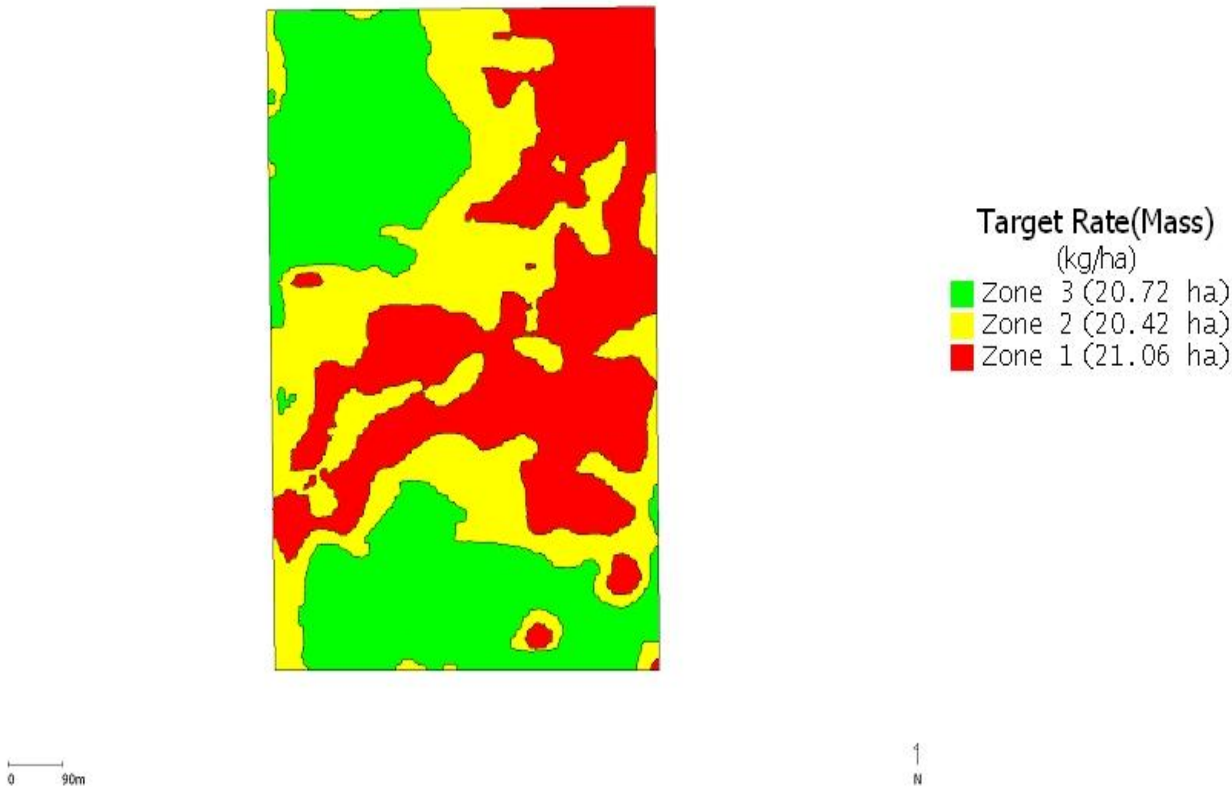

Table 3 shows the variation that has existed between zones in phosphorus removal in harvested grain for Paddock 33. Clearly huge variation occurs in phosphorus removal between years, depending on the overall yield trends between seasons. Good years, such as 2000, obviously see much larger general removal than do drought years.

There is also variation between zones. Interestingly, in very good years, there seems to be less variation. Intuitively enough consistent rain results in all zones performing well. However in other years, average or below, variation in phosphorus removal is quite significant, with changes in phosphorus removal of 1kg P/ha equating to 4.5 kg MAP/ha.

Table 3. P (kg/ha) removal from zones 2000-2008

		P removed in grain (kg/ha)		
		Zone 1	Zone 2	Zone 3
Zones based on all years	2000	21.6	22.47	22.6
	2006	3.7	4.2	5.1
	2007	2.8	4.8	7.3
	2008	9	10.4	13.3
Zones based on 2008	2000	21.8	22.4	22.6
	2006	3.7	4.2	5.1
	2007	3.8	4.9	7.2
	2008	9.2	10.4	13.2
Zones based on 2006-2008	2000	22	22.51	21.5
	2006	4.2	4.6	4.7
	2007	4.6	6.1	8
	2008	10.6	11.5	14.1
Zones based on yield and EM	2000	22.02	22.51	21.54
	2006	4.152	4.58	4.66
	2007	4.619	6.1	8.026
	2008	10.57	11.47	14.11

Correlations were carried out to determine which method of zoning is best in terms of delineating areas of similar yield and resultant phosphorus removal. The results are shown in Table 4. From this Table, the delineation zones based on yield maps are clearly superior at predicting phosphorus removal compared with the delineation of zones that incorporate EM results or zones based exclusively on EM results.

Table 4. Correlations between zonal averages and actual P removal

	Correlation with P removal
Three zones	0.786
Two zones	0.769
Three 06-08 zones	0.765
Yield X EM	0.319
EM38	-0.274

This is not to say that EM surveys are not useful. This has been confirmed by previous work. Moreover, in the previous Table (Table 6) it can be seen that P/ha removal in zones based on yield and EM are roughly the equivalent as the zones based only on yield. However, it is apparent that certain layers of spatial data are more beneficial than others for writing prescriptions for different inputs.

So, it is possible to further improve VR strategies by applying phosphorus according to phosphorus-removal maps. In fact, it may be possible to apply only the phosphorus removed and fixed in the following season due to current circumstances. However, a safer approach may be to simply vary the phosphorus prescribed from the average rate according to the percentage yield variation/phosphorus removal. This latter approach provides a buffer against under-fertilising, particularly in good years.

In fact, a retrospective investigation of phosphorus removal from historical yield maps has shown that while VR strategies based on the previous year's yield map are vastly superior to a blanket rate in reducing waste, in a good year the VR strategy would have resulted in under-fertilising although, this under-fertilising was much less than the waste from a blanket rate.

Nitrogen

As is the case in general agronomy, site-specific nitrogen prescriptions can be difficult to provide. While they have their limitations, many DSN tests have been taken in zones during the course of Riverine Plains' PA work with significant differences being frequently detected from DSN tests taken from zones based on an EM 38 survey.

In Paddock 44, changes in DSN values within zones have been consistent with N removed according to the previous year's yield map, giving credibility to the concept of taking DSN tests in zones. Furthermore, other work conducted by Riverine Plains has shown that the accuracy of DSN tests is significantly improved by taking cores in zones of a similar soil type.

Given the apparent strength however of the strategy of utilising yield maps in zoning, it would seem that it may be appropriate to either take DSN samples from consistently high, medium and low yielding areas as opposed to zones based on EM 38 alone. It is likely however that both technologies are still applicable for N, so taking DSN samples from yield zones that also correspond with the predominant soil variation in a paddock is recommended.

What to do on your own farm

Testing your own farm

As growers move into VR nitrogen and phosphorus strategies, it is important they continue ground truthing and checking their strategies with test strips. This approach is vital to avoid underfertilising. An approach to testing the benefits from VR strategies can be gleaned from this project.

After paddocks are zoned using the information that has been discussed, test strips of rates above and below the general zonal or paddock rate are applied in strips. A zero rate treatment should ideally be included in all trials, while the alternative treatments could be multiples of a grower's uniform application rate. Obviously placing zero rates in the paddock can cause some trepidation. The idea is to keep the size of the treatments small.

The design of the experiments should consider application equipment capability and size, spatial constraints due to management zone pattern and a desire to minimise the area/financial impact of the experiment. These type of experiments could be run using whole-paddock strips, but where VR technology is available, the application of these large plot experiments is easy.

The trials are best run for a number of seasons and crop types.

Moving beyond soil test results to write VR phosphorus prescriptions

There are a couple of ways to undertake this next step for phosphorus fertiliser management. In all cases it is conditional that any yield-limiting factors that can be ameliorated, are identified and treated first. It is also advisable to make these decisions in consultation with your local agronomist or adviser.

- Establish PMZ and paddock-scale experiments as described here. This option would provide the most detailed information for a farm but also takes a number of seasons to gather the data. Decisions on rates should be based on soil analysis within PMZ along with the measured response and consideration of the seasonal impacts.

- Establish PMZ as described here and set yield goals based on the average proportional differences between the PMZ from historical yield data. If one PMZ is expected to yield on average 30% less than another, then the yield goal for the season is set 30% lower in this PMZ. The baseline yield goal can be calculated as usual and required fertiliser rates established as usual.

- If soil sampling shows high Colwell P, the work here suggests an overall cutback in phosphorus fertiliser could be attempted. This can be achieved variably across a paddock by using:

  - Replacement based on removal calculated from previous season yield map, or an averaged removal map from a number of seasons.

  - Defining PMZ using whatever historical information available and altering application rates around the standard paddock average application. This scenario can provide a range of options for making the decision on rates, based on risk profile and local conditions. As an example, if a paddock is divided up into three PMZ, a risk-adverse option would be to set the application rate for the middle PMZ as the standard paddock average, and increase the rate on the higher PMZ and reduce it on the lower PMZ. This would most likely redistribute the same total amount of phosphorus fertiliser as traditionally applied. A bolder approach, which would reduce total phosphorus applied, would be to set the standard paddock average rate as the rate for the top PMZ and cut back proportionally in the lower PMZs. Numerous other variations are possible.

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