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Introduction

In previous work, it has been found 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 and phosphorus 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.

Additionally, it has been found that the variation in these soil factors in the Riverina and north-east Victoria (the Riverine Plains) at least tends to occur in large zones. Significant variation in large areas is highly manageable. Thus, it is possible to treat these areas or Potential Management Zone (PMZ) according to their own unique requirements in a process called zonal management.

In this process, paddocks are partitioned into areas of land identified as possessing relatively similar production attributes. The zones are separable by a difference in the average level of those production attributes. The PMZ for the Riverine Plains are typically built by combining crop yield maps, soil ECa (from EM38 surveys) or gamma radiometric maps and elevation maps using a statistical procedure to draw the boundaries.

The characteristics of each zone within a paddock can then be assessed. Inputs can then be applied according to each zones specific requirements instead of an average rate across a paddock.

Results from this project highlight the potential for improving winter cropping systems in the Riverine Plains area with zonal management, and shed some light on the best mix of tools and strategies to incorporate this system on commercial farms.

Project aim

The aim of this project was to explore the hypothesis that the establishment of PMZs within paddocks is useful for writing input prescriptions and identifying whether variable-rate (VR) application of phosphorus (P) fertiliser may be beneficial in the Riverine Plains region.

Riverine Plains Inc PA Project Team

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Project summary

In-paddock variation has been characterised, statistically proven and shown to be a robust and a common feature of the Riverine Plains landscape. The variability in crop growth resulting from variable soil attributes has been widely identified in the Riverine Plains. Trials examining the economics of variable rate nitrogen and phosphorus have frequently shown the potential benefit of the site-specific application of these inputs. The benefits come from reduced overfertilising and under-fertilising of areas according to underlying nutrient status and yield potential.

As a result, PA is being used commercially. In fact, in the results from a recent survey more than half of the respondents state they already use some form of PA. With regard to VR:

- 14% of respondents reported having yield maps and 9% used them. This is almost double the number that had used them three years ago (8% and 4%). About 60% intend to obtain yield maps in the future.
- Electromagnetic (EM) studies were being used by 3% of respondents three years ago. During 2008, 14% of respondents have had an EM study carried out.
- 59% (say 60%) of respondents intend to use EM studies in the future.
- Few respondents reported using VR technologies but a number (13%) had applied lime or gypsum at variable rates.
- 45% of respondents intend to use VR technology in the future.

In this project, the case for VR phosphorus has been proven, and ideas on incorporating such a strategy into commercial systems have been investigated. The combination of these two outcomes will help those intending to move into VR systems, and continue to increase the recognition of the potential of PA systems to improve gross margins in the Riverine Plains area.

Phosphorus

With specific reference to phosphorus, it is apparent that if Colwell soil phosphorus levels recorded here are 'typical', there is room for modifying future application rates of phosphorus fertiliser in the region. A reduction in overall average phosphorus fertiliser rates would appear to be justified to improve the gross margin of crop production. The next step of breaking paddocks into PMZs and establishing a VR application program will need to be examined on each farm. But from the results here, the clear majority of paddock seasons showed that applying at least two, and often three, different rates of phosphorus within a paddock would have been warranted to further improve the gross margin of crop production.

Nitrogen

Results from this project build on previous findings that gross margins can be improved by applying nitrogen variably across 2 or 3 zones.

Future PA work being conducted by Riverine Plains will focus on examining the usefulness of in-crop ground based sensing for refining nitrogen decisions. One approach may be to delineate nitrogen (N) zones based on a series of images. This work will also help growers deal with temporal variation and its implications for yield targets and subsequent nitrogen decisions.

Summary of major findings:

- Variable rate is happening commercially and there is money in it.
- Real differences in lime, gypsum, nitrogen and phosphorus requirements exist within paddocks.
- Yield maps along with other PA tools like EM38 are useful in zoning paddocks into areas of unique characteristics.
- When the individual requirements of zones are determined, inputs can be easily applied variably.
- The use of historical yield maps will significantly assist variable rate phosphorus and nitrogen applications.
- Test strips are a wise approach to testing the profitability of variable rate systems.
- Along with using other PA tools, Yield map! Yield map! Yield map!

Results and discussion

The potential for zonal management

A number paddocks at Yarrawonga, Victoria, were examined in detail from 2005 to 2008 (inclusive). Carrying on from a previous zonal management project, these paddocks were split into three zones according to results from an EM38 survey.

EM38 surveys measure apparent conductivity in the soil, predominantly to a depth of about 75 centimetres. These zones are referred to below, according to their relative apparent conductivity.

What differences exist in our paddocks?

Soil testing in zones

Replicated 0-10cm soil tests and 0-60cm Deep Soil Nitrogen (DSN) tests were taken within each zone, each year, across the paddocks. Additionally, capacitance probes measuring soil moisture were placed in zones in a replicated manner to assess each zone's soil moisture characteristics.

Table 1 shows some key soil test data from conductivity zones within Paddock 44. Clearly there are important differences between zones in all the parameters shown. These results raise two important points. Firstly, there are clearly genuine soil type differences within the same paddock. Secondly, differences in parameters that drive input decisions such as lime, gypsum, nitrogen and phosphorus are significant, directly demonstrating the potential for improving the allocation of inputs through zonal management.

Generally there is a strong correlation between the relative apparent conductivity measured in EM38 surveys and Cation Exchange Capacity (CEC), Exchangeable Sodium Percentage (ESP) and pH, where the high conductivity zone has a higher clay content and hence a higher CEC, higher ESP (requiring more gypsum) and higher pH (requiring less lime). This trend holds true across the other paddocks studied in this project, and indeed with farmer experience.

There are significant differences between zones when considering Colwell P and DSN results. In Paddock 44, the high conductivity zone generally has higher nitrogen levels, while the low conductivity zone generally has the lowest nitrogen levels. This result is replicated in the other project paddocks, however in general it is not possible to draw the same conclusions across whole farms, sub-catchments or whole catchments. So, parameters need to be tested within individual paddocks to determine differences. That is, it is not possible to draw general conclusions regarding phosphorus and nitrogen trends between zones so testing of zones within individual paddocks is required.

TABLE 1 Summary of some key 0-10cm soil test results for conductivity zones in Paddock 44

Parameter	Zone	2007	2006	2005	2004
Colwell P (mg/kg)	High conductivity	65	65	47	60
	Medium conductivity	77	78	81	73
	Low conductivity	80	84	80	68
DSN (mg/kg)	High conductivity	169	120	94	186
	Medium conductivity	60	88	86	150
	Low conductivity	74	117	83	86
pH	High conductivity	6.1	6.7	6.4	6.4
	Medium conductivity	5.8	5.7	5.9	5.7
	Low conductivity	5.9	6.0	5.8	5.7
CEC	High conductivity	22.8	22.1	25.2	24.0
	Medium conductivity	12.2	10.6	12.3	13.7
	Low conductivity	15.6	15.4	16.0	12.5
ESP (%)	High conductivity	5	5	3	4
	Medium conductivity	3	4	2	5
	Low conductivity	1	1	1	2

Soil moisture characteristics of 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 at 10cm, 20cm, 30cm and 50cm were used on the light soils due to the restricted depth to bedrock.

Data collected from the GLRL probes was used to investigate important aspects of the soil-moisture characteristics of the different conductivity zones. This determined if there were any significant differences that would potentially contribute to differing production potential between zones.

During the past 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 had 20% less total water than the high conductivity zone. This follows logic, as this zone has much less clay content — it generally exhibits topsoil overlaying a mix of soil and decomposing semi-broken down parent material.

The changes in soil moisture from emergence to harvest indicate that the low conductivity zone provided, on average, 25mm of stored soil water per year for crop water use. The high conductivity zone provided 11mm per year while the medium conductivity zone always had a surplus of 13mm per year. The surplus soil water in the medium conductivity zone during these three dry years indicates poor crop water use on this soil type. This suggests 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 Table 2. 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.

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 the low conductivity zone 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.

TABLE 2 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 + 21/7/2008	High	22.0	14.4	0.4	0.0		36.8
	Medium	22.0	7.2	0.6	0.0		29.8
	Low	17.6	12.4	1.6	0.0		31.6

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 ACPA at 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.

Nitrogen

Earlier work with nitrogen application highlighted the benefits of using historical information to build maps of PMZ and use these to help fine-tune required fertilizer rates. In work carried out on Paddock 44, it was shown across a number of years that different PMZs had different nitrogen responses and therefore required different nitrogen rates to maximise returns (see Table 3).

Figure 1 shows the varying yield response to applied nitrogen of three PMZs in Paddock 44 from work carried out in this project. Figure 2 combines applied nitrogen with underlying soil nitrogen in three PMZs. These figures further support the fact that individual PMZs have different responses to applied inputs, and also highlight the overarching in potential yield of zones, supporting the previous section on differences in water holding capacity of zones within paddocks.

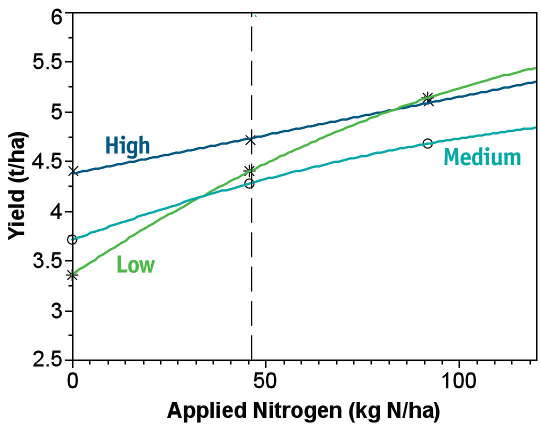

FIGURE 1 Applied nitrogen response functions for three zones for 2005 barley crop

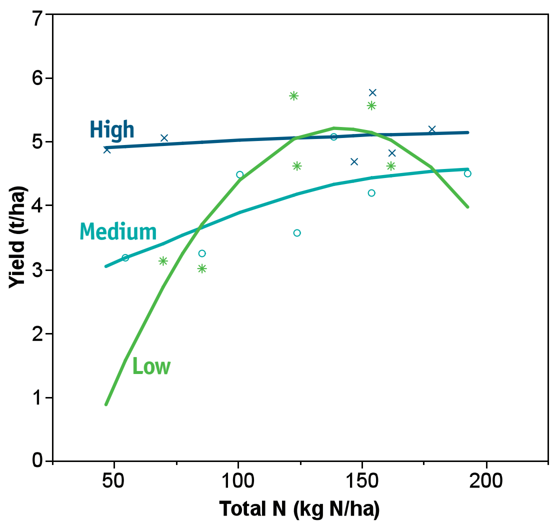

FIGURE 2 Total nitrogen response functions for three zones for 2005 barley crop

TABLE 3 Applied urea rates to achieve maximum return and maximum yield in Paddock 44 for 2003 and 2004

Zone	Pre-sowing DSN 2003	2003 urea rate to maximise returns (kg/ha)	2003 urea rate to maximise yield (kg/ha)	Pre-sowing DSN 2004	2004 urea rate to maximise returns (kg/ha)	2004 urea rate to maximise yield (kg/ha)
High	209	0	0	186	0	0
Medium	151	72	151	150	0	200
Low	99	169	237	89	0	0

Courtesy of Brett Whelan and James Taylor, ACPA, University of Sydney

Phosphorus

In Figure 3, a 55ha paddock (Paddock 4) was broken into two PMZs using the elevation, soil ECa (from an EM38 survey), total gamma emissions (from a gamma radiometric survey) and crop yield from 2006. These zones were used to carry out paddock-scale experiments with phosphorus to estimate if the response to phosphorus in each zone is actually different.

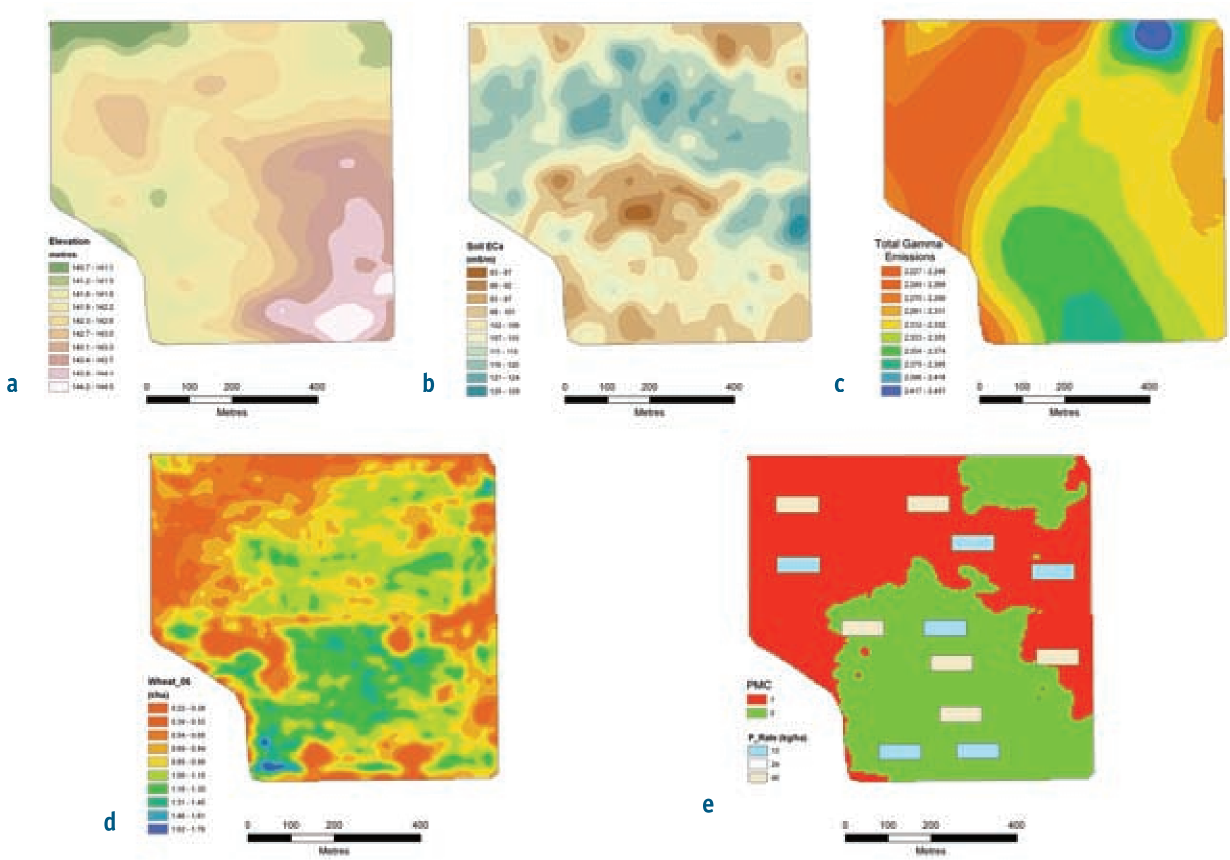

FIGURE 3 Data on Paddock 4 used to create potential management zones. (a) elevation (b) soil ECa (c) total gamma emissions (d) crop yield (e) management zones and a fertiliser response trial layout

The results from the 2006-2007-2008 seasons for Paddock 4 are shown in Figure 4. As can be seen, the optimum phosphorus application for the two zones is different, and while it shows changes with season and crop type, more phosphorus is consistently required in the medium conductivity zone. The amount required however, is less than the paddock average application in all seasons.

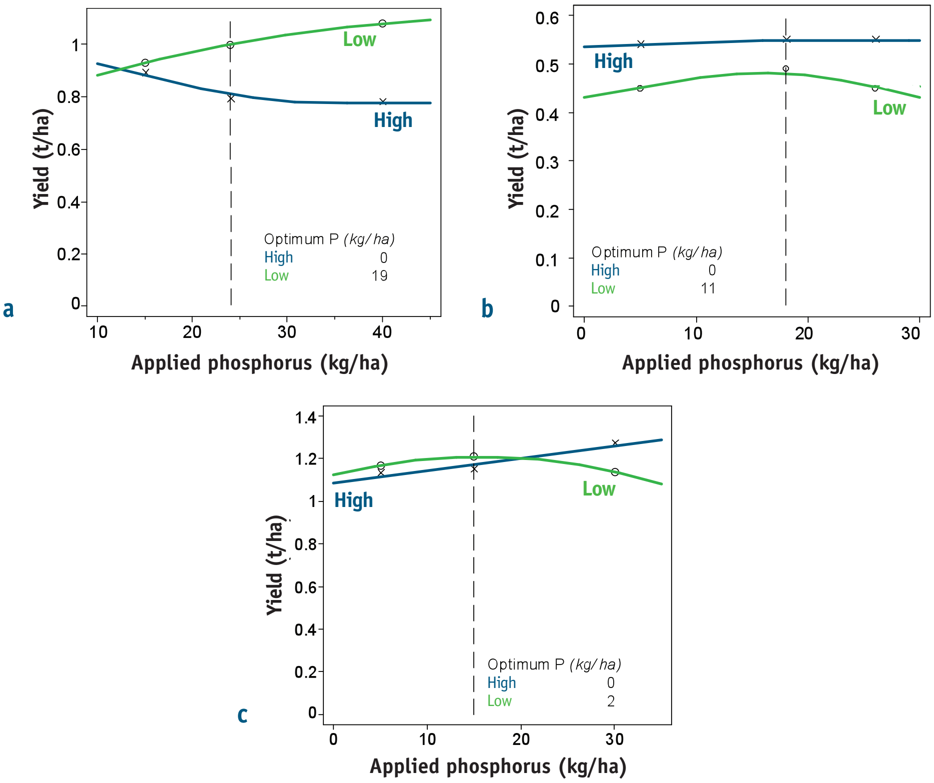

FIGURE 4 Phosphorus response results from Paddock 4 at Yarrawonga (a) 2006 wheat (b) 2007 canola (c) 2008 wheat

Note: The dashed line shows the paddock average application.

Armed with this information, it is possible to compare the gross margin under standard management to the gross margin achievable under optimum-rate management. The gross margin for each scenario is calculated by multiplying the yield by price and deducting the cost for the quantity of fertiliser applied.

Where the gross margin of the standard management is less than the gross margin 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 4 for all the Yarrawonga trials.

TABLE 4 Results of gross margin analysis comparisons between paddock average application of phosphorus fertiliser and that possible under optimum rate management

Paddock	Year	Size (ha)	Crop	Yield (t/ha)	Net wastage ($/ha)	Proportion of P fertiliser costs (%)*
49	2004	34	Wheat	1.8	50	85
49	2005	34	Barley	4.5	39	74
46	2005	39	Wheat	4.3	60	105
46	2007	39	Wheat	1.5	107	177
46	2008	39	Wheat	1.4	59	140
4	2006	55	Wheat	0.9	35	78
4	2007	55	Canola	0.5	18	53
4	2008	55	Wheat	1.2	26	40
7	2007	91	Wheat	1.1	60	154
39	2007	43	Canola	0.9	47	169
39	2008	43	Wheat	2.3	70	189
	Median	43			49	105

*Proportion of P fertiliser: Proportion of phosphorus fertiliser costs (%) = $\frac{\text{net wastage (\$)}}{\text{Phosphorus fertiliser bill (\$)}} \times 100$

The results show that over the seasons there was always a 'net wastage' in gross margin for all the paddocks, with a median wastage figure of $49/ha. This figure is a function of fertiliser costs and crop prices obtained in the specific year of each trial. To provide a simple way of standardising the wastage figures between the years, the total net wastage for each trial was compared with the total phosphorus fertiliser bill for the standard management application in that year. This was calculated as a ratio:

$$\text{Proportion of phosphorus fertiliser costs (\%)} = \frac{\text{net wastage (\$)}}{\text{Phosphorus fertiliser bill (\$)}} \times 100$$

This provided an estimate of the wastage as a proportion of the phosphorus input costs (i.e. the investment in fertiliser each year). The median value of 105% suggests that the potential financial benefit to be gained over a number of seasons by knowing more about the optimum rates of phosphorus fertiliser for a paddock could be at least equal to the amount of money outlaid on phosphorus fertiliser. So, for example, if the average phosphorus inputs were $40/ha/yr, then maximum improvements in gross margin of the same amount per year could be expected.

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. An assessment of the seasonal rainfall at Yarrawonga from 2004 to 2008 is shown in Table 5. 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 returns to fertiliser outlay, and this is reflected in the low yields and high proportions of phosphorus fertiliser losses reported for these years in Table 4. 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 (See Appendix). 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.

Using zonal management commercially

What PA tools are useful?

Many Precision Agriculture tools and technologies are now available to growers. In previous work, EM38 surveys have been proven to delineate soil-based zones that have genuine and important differences in soil characteristics. EM38 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.

As can be seen from Figure 3 (on page 6) however, it is desirable to cluster a number of layers of spatial information together to come up with zonal maps. 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.

TABLE 5 Annual and in-season rainfall for Yarrawonga

Year	Annual Rainfall (mm)	Percentile (%)	GSR (Jun-Nov) (mm)	Centile (%)
2004	365	20	251	70
2005	512	60	335	80
2006	217	10	131	30
2007	340	20	134	30
2008	320	10	168	40

Note: 10% is the lowest and 100% the highest percentile bands.

How are VR decisions made?

EM38 surveys

It is generally considered by the project team that EM38 surveys give the best maps for lime and gypsum prescriptions. Growers can apply their existing decision-making tools for lime and gypsum decisions to zones, as if they were individual paddocks. To this end, the following steps are appropriate for growers entering PA:

1. Carry out an EM38 survey of the paddock.
2. Validate EM survey and zones against elevation maps, yield maps, vegetation index maps (NDVI), other spatial data and grower knowledge.
3. Ground truth — topsoil and subsoil cores; presence of rock or gravel, depth to B Horizon, colour changes, compacted layers or plough pans, presence of plant roots.
4. Zone paddock/s (decide the number of zones after survey and ground truthing).
5. Develop VR lime and gypsum prescriptions based on zonal soil test results.
6. DSN test in zones.
7. Crop monitor in zones.
8. Yield map at harvest.

Variable nitrogen and phosphorus decisions can also be made by following the above protocol. While this approach is simplistic, if these are the existing tools being used by growers, then testing in zones will be an improvement compared to just testing whole paddocks.

Other areas of PA can be used however, to further improve nitrogen and phosphorus decisions. To this end, in this project we have invested some time in analysing how growers might best zone their paddocks for nitrogen and phosphorus prescriptions.

How good are yield maps?

Phosphorus

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, even in the recent droughts, giving weight to the case for varying phosphorus across paddocks in line with yield or phosphorus removal.

Figures 5 and 6 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.

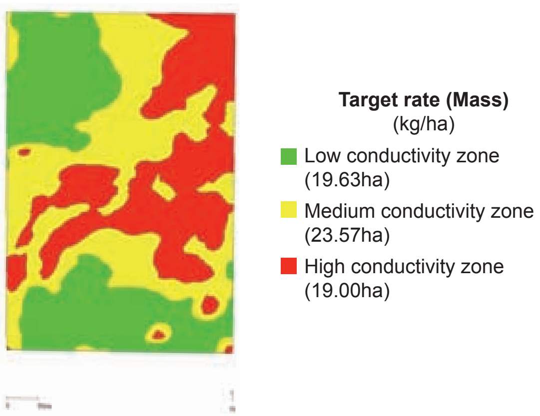

FIGURE 5 Three zones clustered from 2008 barley yield map, Paddock 33

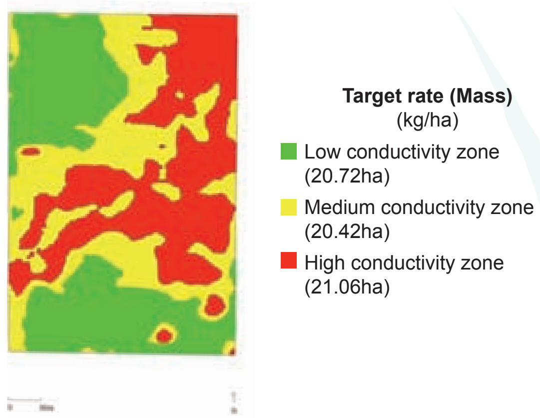

FIGURE 6 Three zones clustered from 2006, 2007 and 2008 yield maps, Paddock 33

Table 6 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 4.5kg MAP/ha.

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 7. From this table, the delineation zones based on yield maps are clearly superior at predicting phosphorus removal compared with the delineation of zones based exclusively on EM results.

TABLE 7 Correlations between zonal averages and actual phosphorus 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 Table 6 it can be seen that P/ha removal in zones based on yield and EM are roughly the equivalent to 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.

TABLE 6 Phosphorus removal from zones for 2000-2008

Conductivity zone		P removed in grain (kg/ha)		
		High	Medium	Low
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	9.0	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	22.0	22.51	21.5
	2006	4.2	4.6	4.7
	2007	4.6	6.1	8.0
	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

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 is vastly superior to a blanket rate in reducing waste, in a good year the VR strategy would have resulted in underfertilising. Although, this underfertilising 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 EM38 survey. An example of these results are shown in an earlier section of this report.

In Paddock 44, changes in DSN values within zones have been consistent with nitrogen 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 EM38 alone. It is likely however that both technologies are still applicable for nitrogen, 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

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 advisor.

- 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-averse 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 PMZ's. Numerous other variations are possible.

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 is 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 minimize 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.