Improved phosphorus prescription maps – beyond P replacement

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Key Findings

- Optimal phosphorus (P) applications for maximising gross margins differ within a paddock and have been linked to varying soil properties.
- Using the spatial data layers, soil pH and in season crop satellite imagery in a combined index has provided good prediction of P response and optimal P fertiliser rates.
- Benefits from targeting P responsive sites with high P rates can be observed in following seasons, indicating a long-term benefit and economic gain from this strategy.

Why do the trial?

The aim of this project is to increase the profitability derived from phosphorus (P) fertiliser applications. This will be achieved through increasing P fertiliser use efficiency by better understanding the spatial variability in P availability, demand and P response.

Map data layers that can infer spatial information on P uptake, soil tie up and response are becoming increasingly available, such as grain yield, soil pH, soil EC and NDVI. However, the best methodology for integrating these data for improving P rate calculations is unknown. The aim of this project is to better understand how these data layers can be integrated to produce variable rate P prescription maps that optimise P rates across variable paddocks.

This was achieved by analysing data layers (yield, soil pH, soil EC, NDVI) to identify the range in likely P response. This information was used to locate a series of P rate trials, in two paddocks in 2019 and three paddocks in 2020 in the Mid-North and Yorke Peninsula regions. The yield responses observed in these trials are being used to determine the relative importance or weighting that each data layer has on the rate calculation and inform the best method for integrating these data layers for calculating optimal P rates.

How was it done?

Predicted P response (low – very high) was estimated through analysis of historical satellite imagery and Veris pH data for five paddocks. Harvest yield maps were also used to check for ranges in grain yield. Based on these estimates, eight sites were selected in 2019 and a further 13 sites were selected in 2020 to cover a range of expected P response. Four sites were chosen in each of the paddocks near Bute in 2019 and 2020, Koolunga (2019) and Brinkworth (2020), and the paddock near Kybunga (2020) had five sites. The sites were chosen to cover the range in expected P response across each of the five paddocks.

An example of the map data layers used is shown in figure 1A and 1B for the 2019 Bute paddock. These data layers have been combined into a P sufficiency index (Figure 2), also being termed pHNNDVI in this report and is simply calculated by dividing soil pH by the normalised NDVI.

- pHNNDVI = soil pH/normalised NDVI

Based on this calculation, paddock zones with high soil pH and low NDVI have a high pHNNDVI value. These areas are predicted to have a higher P response than areas with low soil pH and high NDVI (low pHNNDVI).

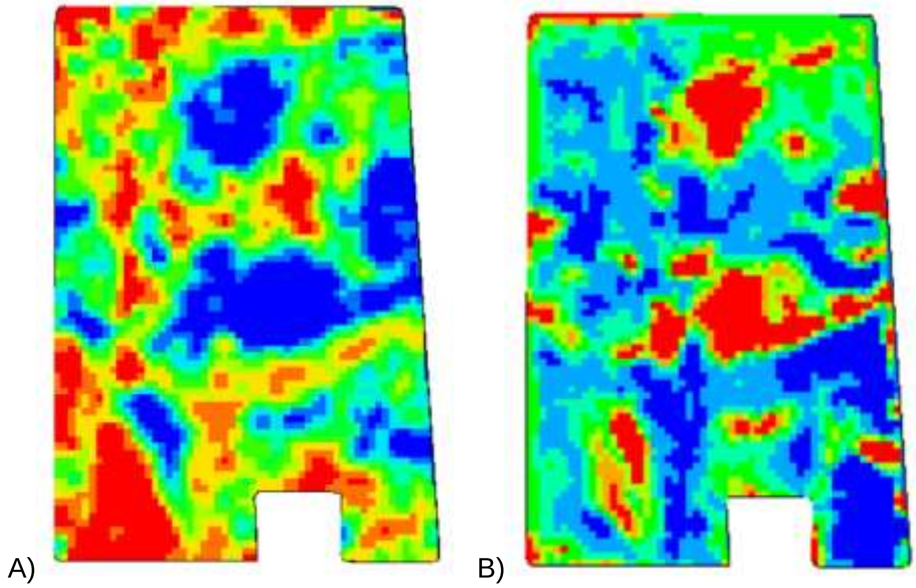

Figure 1. A) Soil pH CaCl2 and B) satellite NDVI for the trial paddock at Bute in 2019, warm colours represent low pH and NDVI values and cool colours represent high values.

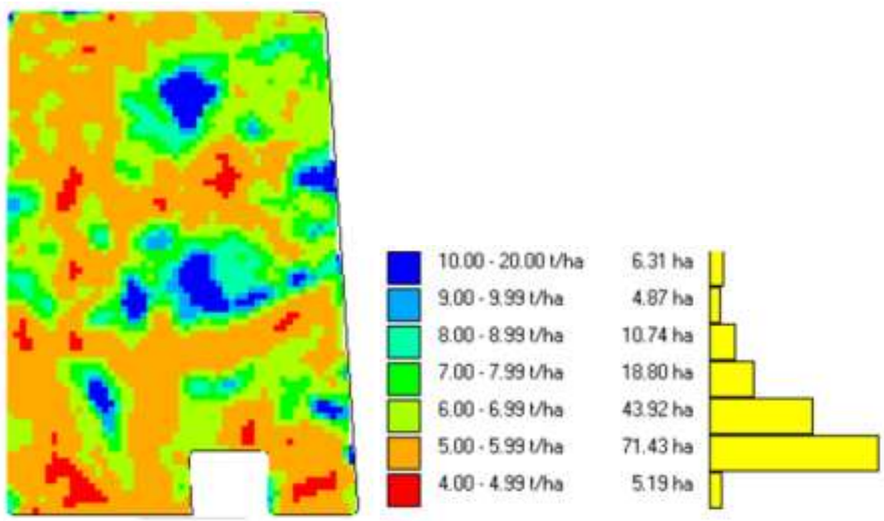

Figure 2. pHnNDVI derived from soil pH and satellite NDVI (shown in Figure 1) for the 2019 Bute trial paddock.

At each of the 21 sites selected, a P response trial was established using knife points and press wheels as a randomised complete block design with three replicates. Treatments included P rates of 0, 5, 10, 20, 30 and 50 kg P/ha (Table 2). Fertiliser was applied using MAP and nitrogen rates were matched between treatments using adjusted rates of urea. An additional treatment of 5 t/ha chicken litter was applied in trials in 2019 and 5 t/ha biosolids was applied to a treatment at Bute and Brinkworth in 2020. The entire paddock at Brinkworth was treated with biosolids at 3.5 t/ha in 2019.

Measurements throughout the season included soil tests (0-10 cm) for P levels (Table 1), Greenseeker NDVI, tissue tests on selected treatments and grain yield and quality. Grain samples were also retained and will be tested for P concentration to calculate P removal.

P rate for optimum grain yield for each site was calculated by generating a response curve (Exponential Rise to Max which generates the equation y = y0+a(1-exp(-b*x))) based on yield data for each site and then predicting the P rate that would achieve 90% of maximum yield. Partial gross margins (PGM) were then calculated from this data.

Table 1. Site descriptions and soil test results for 21 trial sites in five paddocks across NYP and Mid-North. Where descriptions of low-high are used, it is a relative reference compared to the paddock average.

Paddock	Site	Historical NDVI	Veris pH	Expected P response	Numerical expected response	DGT P	Colwell P	PBI	pH CaCl2
Koolunga 2019	**1**	Moderate	Alkaline	**High**	5	12	24	121	7.55
	2	Low	Alkaline	**High**	5	21	35	131	7.58
	3	High	Acid	**Moderate**	4	56	33	51	6.19
	4	Moderate	Neutral	**Low**	1	62	62	77	5.87
Bute 2019	**5**	Mod-High	Acid	**Low**	1	103	27	20	4.94
	6	Moderate	Neutral	**Moderate**	4	106	63	50	5.96
	7	Low	Alkaline	**High**	5	22	20	71	7.67
	8	Low	Alkaline	**High**	5	38	19	51	7.67
Brinkworth 2020	**9**	Low-med	High	**Moderate-high**	3	211	75	62	7.63
	10	Med-high	Moderate	**Low-moderate**	2	110	53	103	6.65
	11	Low	High	**High**	5	65	45	115	7.69
	12	High	Low	**Low**	1	186	94	63	6.22
Bute 2020	**13**	High cereal, med break	low/med	**Low**	1	180	33	23	5.75
	14	Low/high	high	**High**	5	46	38	68	7.82
	15	Medium/Low	medium	**Moderate**	4	107	67	92	6.11
	16	Low	high	**High**	5	68	37	105	7.63
Kybunga 2020	**17**	High	Neutral	**Moderate**	4	86	32	62	7.15
	18	Low	Alkaline	**High**	5	26	25	110	7.78
	19	Medium	Acidic	**Low**	1	142	23	28	6.99
	20	Medium	Alkaline	**High**	5	47	15	58	7.75
	21	Low	Strongly Alkaline	**Very high**	6	21	37	120	7.85

Table 2. Treatment list and application rates of MAP and urea for the 21 P trials in 2019 and 2020, chicken litter at sites in 2019 and biosolids applied at Brinkworth and Bute only in 2020.

Treatment	P rate (kg/ha)	MAP (kg/ha)	Urea (kg/ha)
1	0	0	49.4
2	5	22.7	44.5
3	10	45.5	39.5
4	20	90.9	29.7
5	30	136.4	19.8
6	50	227.3	0.0
7	Chicken litter in 2019 or Biosolids 2020 5t/ha	0	0

Results and Discussion

Table 3 shows expected P response, pHnNDVI value and the site average grain yields to demonstrate the production levels at each site. Site average yields range from 1.02 to 5.09 t/ha and P rate for optimum grain yield ranges from 0 kg P/ha to 55 kg P/ha P. It should be noted that there is no correlation between historical grain yield and P response for these 21 sites.

The relationships derived from the 21 P response trials conducted in 2019 and 2020 show that there is a useful correlation between the derived pHnNDVI and soil P availability measured with DGT (Figure 3). It also shows that in this dataset the pHnNDVI provides an improved correlation with optimum P rate than DGT P, indicating the methodology developed performed better than industry standard soil testing methodology. Both pHnNDVI and DGT P were far superior to Colwell P at these 21 sites (data not shown).

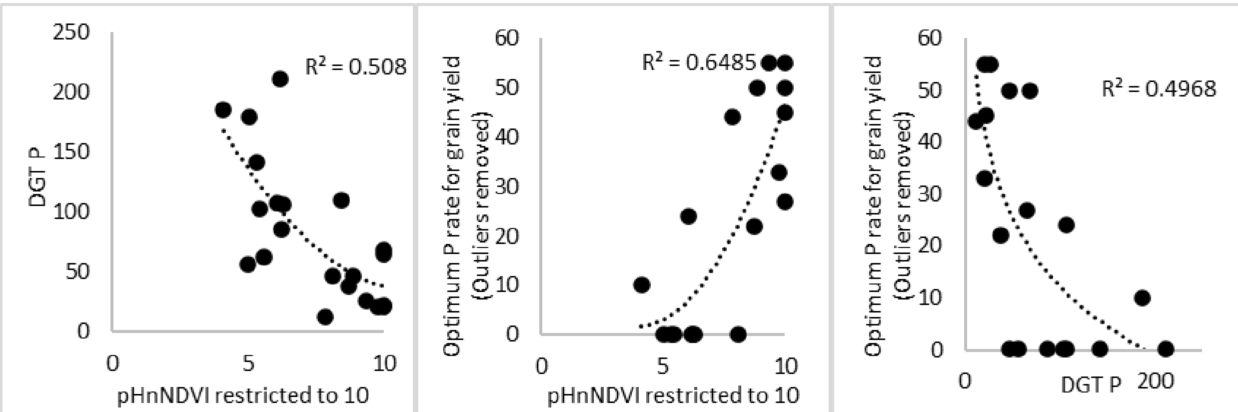

Figure 3: Relationship between pHnNDVI, DGT P and optimum P rate for grain yield derived from 21 P response sites in five paddocks in 2019 and 2020.

Optimal P rates at the P responsive sites increased PGM by up to $79/ha compared with returns from replacement P rates, with an average improvement in PGM of $41/ha. In the five focus paddocks assessed in this project (SAGIT TC119) the area of predicted high P response ranged from 16-40% of paddock area based on the derived P sufficiency index. Based on Trengove Consulting client data it is expected that these paddock areas of high P response would be representative of the region northern YP and western Mid-North where the trials were conducted. This represents a large area where economic gains could be achieved through improved P fertiliser strategies.

Longer-term economic response to P fertiliser is also sensitive to the accumulation or depletion of P over time and the crop response to changing soil P status in subsequent years. Three responsive trial sites established in 2019 at Bute and Koolunga were monitored again in 2020 when they were sown to lentil. Bute sites received 24 kg P/ha in 2020 and Koolunga 15 kg P/ha. At two of these sites lentil yield responses were measured in 2020 to P applied in 2019, with 50 kg P/ha treatments increasing lentil yield by 0.22 t/ha compared with untreated. These longer-term responses strengthen the economic case for higher P rates on responsive soils.

The highly responsive sites are responsive to extremely high P rates, up to 30-50 kg P/ha in many instances. However, these rates of P have not improved crop growth to the extent that these P deficient sites have the same vigour as the low response sites (using NDVI as a measure of vigour). For example, at Bute in 2020 sites 14 and 16 were P deficient and responsive to high rates on P. However, application of 50 kg P/ha at these sites did not increase NDVI to match NDVI of the untreated plots at the P sufficient, low response sites 13 and 15 (Figure 4). In addition, the long-term responses at sites from Bute and Koolunga described above indicate further long-term residual benefits of high P rate application. These results suggest that it is difficult to completely overcome low soil P status and severe P deficiency in a single year with fertiliser alone. It suggests that building soil fertility over time and increasing low soil P status will enable greater yields to be attained than fertiliser P can achieve in a single season.

A similar concept has emerged from hyper yielding trial sites in the high rainfall zone. That is, it is difficult to achieve high yields on low fertility sites where majority of the nutrient supply comes from fertiliser. Sites with high inherent fertility are required to achieve ‘hyper yields’. Similarities are evident with the P responses observed in this project, suggesting that building the baseline soil P status will build yield potential beyond what fertiliser P can attain in a single year.

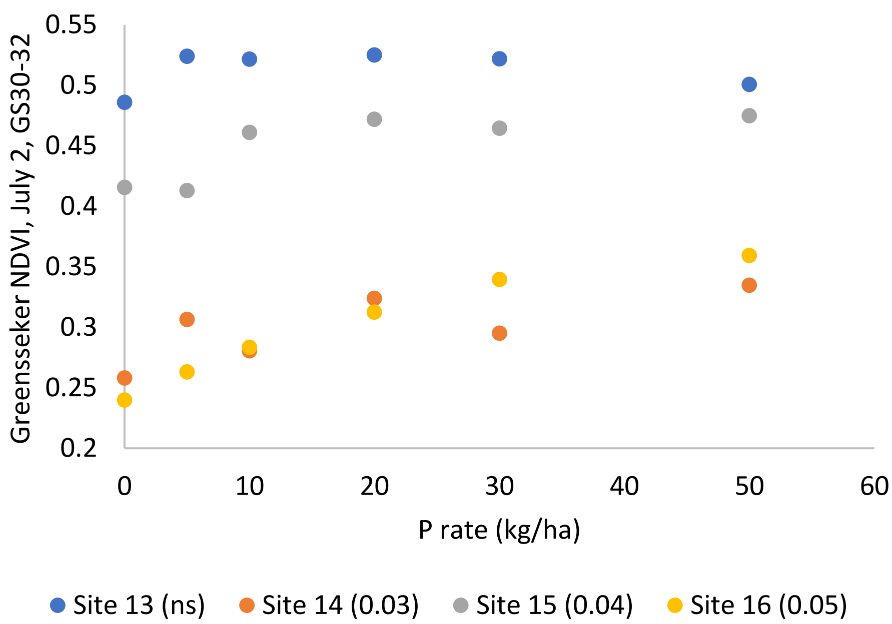

Figure 4. Greenseeker NDVI July 2, 2020 at Site 13 – 16 Bute P rate trials. LSD (P≤0.05) for each site is shown in brackets.

*Table 3. Expected P response, pHnNDVI, site average yield P rate for optimum grain yield and youngest emerge blade tissue P concentration (mg/kg) for P rate trials 2019 and 2020. The significance of grain yield response to P applications of each site is indicated by ** (P≤0.01), * (P≤0.05) and non-significant response (NS).*

Site	Expected P response	pH/ nNDVIi	Site average yield (t/ha)	Calculated optimum P rate for 90% grain yield (kg/ha)	Critical concentration of leaf tissue P met at P rate	Grain response to P
Site 1	High	7.9	2.07	44	50	**
Site 2	High	9.8	2.55	33	Not achieved	**
Site 3	Moderate	5.0	3.11	0	20	NS
Site 4	Low	5.6	2.65	*	10	NS
Site 5	Low	5.4	5.09	0	10	NS
Site 6	Moderate	6.3	4.64	0	0	NS
Site 7	High	10.0	4.08	45	50	**
Site 8	High	8.7	4.92	22	50	**
Site 9	Mod-high	8.4	2.16	50	#	NS
Site 10	Low-mod	6.1	3.27	0*	#	NS
Site 11	High	10.0	2.08	27	#	**
Site 12	Low	4.1	2.57	10	#	*
Site 13	Low	5.0	2.53	*	0	NS
Site 14	High	8.8	2.51	50	Not achieved	**
Site 15	Moderate	6.0	1.14	24	10	*
Site 16	High	10.0	1.02	50	50	**
Site 17	Moderate	6.2	2.34	0	50	NS
Site 18	High	9.3	2.16	55	Not achieved	**
Site 19	Low	5.3	3.80	0	20	NS
Site 20	High	8.1	3.02	0	Not achieved	NS
Site 21	Very high	10.0	2.09	55	Not achieved	**

** unable to predict optimum P rate for 90% yield for low level and non-significant responses*
 # leaf tissue samples not taken at these sites

Conclusions

Yield potential alone is not a good indicator of P requirement in this environment. When the data layers of pH and historical, early NDVI, are combined into a P sufficiency index, or pHnNDVI, the data can be used in parts of the Upper Yorke and Mid-North to predict P response as well as currently available soil tests. Adoption of this method of variable rate P application could lead to improved fertiliser use efficiency, increasing whole paddock grain yield outcomes for a given volume of fertiliser across the landscape. This would be achieved through greater grain yield production on underperforming, alkaline soil types. The advantage of using pH and satellite imagery for this purpose is that they can be measured cost effectively at higher resolution than traditional soil testing or grid sampling. If soil sampling is to be used for P rate recommendations then data from this project suggests that DGT-P should be used in preference to Colwell P in this environment as Colwell P had a poor relationship with optimal P rates in this data set.

It is important to note that this relationship will not fit in all situations and some knowledge of soil chemistry or ground truthing be conducted before decisions are made.

Acknowledgements

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