An informed approach to phosphorus (P) management in 2022

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Key Findings

- Opportunities are available for reformed phosphorus (P) rates under high fertiliser prices, but background knowledge is key.
- Gross margin analysis with phosphorus application rates is sensitive to soil available P, yield potential, fertiliser, and grain prices.
- On phosphorus responsive soil types, return from fertiliser (P) investment is normally greatest and most stable with cereal phases.

Why do the trial?

Fertiliser prices for phosphorus (P) inputs have more than doubled since those used at the start of the 2021 season and for a three-year rolling price average. Currently these high fertiliser prices are coupled with high grain prices which offsets potential decreases in partial gross margins but in the current global scenario there is high uncertainty if grain prices will hold until the end of 2022.

Higher inputs costs will naturally generate a mindset of simply reducing these input rates, but it is important to have background knowledge supporting these decisions so yield returns aren't compromised. Combined with high fertiliser prices there have been the observations that P replacement programs have been inadequate in meeting phosphorus demand in some soil types. This paper aims to outline gross margin scenarios under a range of fertiliser and grain prices which could be vastly different to those set up in previous seasons. Importantly the gross margin analysis will be performed using a range of different background P levels, soil type characteristics and yield potentials. Identification of likely paddock responsiveness and the variability in that response across the paddock is important. Several tools are available to assist with this determination which will be explained.

How was it done?

Through various research projects across the last 10 years both Agronomy Solutions and Trengove Consulting have managed over 50 replicated field trials across the broadacre regions of South Australia, with most of them being within the last 5 years (> 40). Most of these trials have assessed wheat and barley responses to P applications across a range of soil types. This dataset is highly valuable to assess gross margin scenarios under a range of conditions and the accuracy of various data layers in predicting P requirements.

In this article, we have used the P rate which is associated with the greatest partial gross margin (PGM) return when factoring in fertiliser prices and returns from grain yields. This is calculated by fitting grain yield response curves derived from the P rate trials. We have used this dataset to test the accuracy of various data layers in predicting PGM under current conditions and from the most accurate data layers looked at the effect of changing fertiliser to grain price ratios for expected 2022 scenarios. Determination of PGM has used recent price trends of MAP at $1250, Wheat (APW) at $400 and Barley (F1) at $295. This dataset is concentrated in the Yorke Peninsula and Mid-North regions of South Australia but is applicable to wider regions where soil types vary in alkalinity within paddocks driven by the presence of carbonates.

Results and discussion

Current soil P levels

Reviewing the large soil test database from project PROC9176604 reveals the overall P status of the broadacre cropping regions of SA and VIC. Over 1300 surface samples were collected in 2019 and 2020 with both Colwell P and DGT P levels placed in deficient, marginal, and sufficient categories (Table 1) based on published data (Moody 2007, Mason et al 2010). The PBI value for each site was used to determine a critical Colwell P position. Over half (52%) of sites were above critical DGT levels and as many as 73% of sites were sufficient in P using Colwell P. Using these soil test results to make a P recommendation for the sites sampled, shows that there are between 73% and 83% of sites that require < 10 kg P/ha to maximise yields. This proportion of sites is similar to what has been observed in the trial series associated with SAGIT project TC119 and TC221 discussed below.

Table 1: Soil P test results (Colwell P and DGT P) through the southern broadacre cropping region sampled in 2019 and 2020 placed in deficient, marginal, and sufficient categories with associated determinations of required P rates to maximise yields.

		Deficient		Marginal	Sufficient
		5 – 10 kg P/ha	> 10 kg P/ha	0 – 5 kg P ha	
Colwell P	Number of sites	72	218	68	970
	% Split	5	16	5	73
DGT P	Number of sites	163	367	113	685
	% Split	12	28	9	52

Site soil characteristics driving P responses

The intensive field trial dataset produced by Trengove Consulting from 2019 to 2021 (SAGIT projects TC119 and TC221), where 33 replicated field P response trials have been established on various soil type x NDVI/grain yield zones, is a powerful tool to test multiple data layers, including Colwell P and DGT P as discussed and other accessible data layers such as NDVI, pH and Yield. Of the 33 sites, 64% recorded non-significant (P≤0.05) responses to applied P (Table 1), leaving 12 with positive responses. Of these 12 responsive sites, at current prices the average P rate required to maximise PGM was 20 kg P/ha which highlights the continued importance of identification of P responsive soil types. Responsive soil types are characterised by soil pH ($CaCl_2$) between 7.5 – 7.8, higher PBI values (P retention) driven by the presence of soil carbonate and low comparative NDVI values (Table 2).

Table 2: Summary of soil characteristics averaged across the 12 responsive P sites compared to 21 non-responsive sites through Yorke Peninsula and Mid-North regions of SA. PGM was calculated based off MAP at $1250, Wheat (APW) at $400 and Barley (F1) at $295.

Response category	Number of sites	P rate at max PGM (kg/ha)	pH ($CaCl_2$)	Colwell P (mg/kg)	PBI	DGT P (ug/L)	Colwell P/PBI	pHnNDVI
Significant (0.05) (response to P)	12	20	7.56	28	91	26	0.42	9.3
Non-significant (0.05) (no response to P)	21	0.3	6.61	45	60	94	0.91	6.6

Relationships between the P rate at maximum PGM at each trial site and several data layers were used to find the layer(s) that most accurately predict P responsiveness at each site. Of the soil P tests, DGT P (R^2 = 0.72) was superior to Colwell P alone (R^2 = 0.44), at identifying sites where high P rates would produce high PGM's at current pricing and where reduction in P rates would not cause a decrease in PGM (data not presented). However, where Colwell P is combined with PBI (Colwell P divided by PBI) the Colwell P relationship improves to R^2 = 0.73, highlighting the importance of including PBI with Colwell P interpretation and measuring PBI at the same or similar intensity as Colwell P if that soil test is used for soil P mapping.

The most accurate combined data layer to provide a P rate requirement for max PGM was an index of the soil pH and NDVI at approximately GS30 (Figure 1). The index divides soil pH with the NDVI normalised to the paddock average. Areas that have high pH and low NDVI are typically highly P responsive, the level of response declines as pH decreases and historical NDVI at GS30 increases. The higher soil pH coupled with poor early vigour (low NDVI) occurs in the presence of soil carbonate, higher PBI values and lower residual P. The index is yet to be tested on soil types where high PBI is driven by other soil attributes such as Al or Fe, where there is a tendency of soil pH to be < 6 in these soils (e.g., Ferrosols on Kangaroo Island). For these areas a normalised NDVI index alone could be appropriate, or if pH is still an important factor, combining the data layers in a different index such as pH * nNDVI, where the lower values are more likely to be responsive to P however, this needs further investigation. A case study of a paddock associated with the SAGIT project TC221 using this method is presented later in this paper.

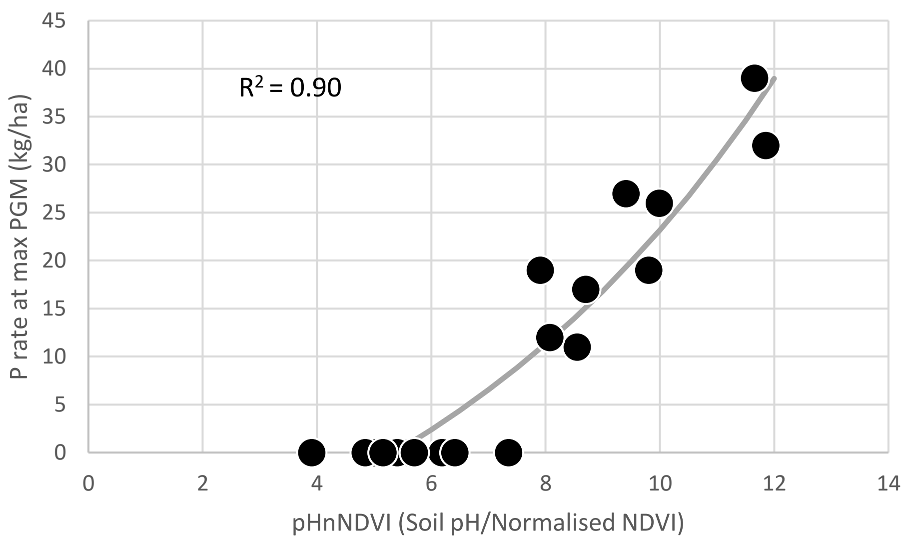


Figure 1: Relationship between the P rate associated with max PGM for P response trials (2019 – 2021) pHnNDVI.

Partial gross margin analysis for fluctuating fertiliser and grain prices

While there is some clarity with fertiliser prices for the 2022 season there is difficulty in predicting the grain price towards the end of 2022. At current grain prices the identification of P responsive sites still pays but what happens if grain prices fall? Using an accurate data layer (DGT P or pHnNDVI) we can present the influence of changing fertiliser and grain prices on optimal P rates for max PGM (Table 3). Based on 2021 fertiliser prices as a comparison and expected 2022 prices this analysis suggests economic P rates will be slightly less than half of that required in 2021.

Table 3: Sensitivity analysis of optimal P rates required for max PGM (kg/ha) for moving MAP prices at three decile grain prices (1, 5, 9) using either the pHnNDVI index or DGT P as a guide of deficiency (see figure 1). Grain price deciles from 2010 onwards, source: Mercado.

Decile 1 Grain prices: Wheat (APW1) - $214t, Barley (F1) - $165

MAP ($/t)	pHNNDVI					Soil DGT P				
	4	6	8	10	12	> 150	100	50	30	< 20
$500	0	3	11	19	28	0	4	16	28	40
$750	0	1	7	13	19	0	3	12	21	30
$1,000	0	1	5	10	14	0	2	9	16	24
$1,250	0	0	4	7	10	0	1	7	12	18
$1,500	0	0	3	5	7	0	1	5	9	13

Decile 5 Grain prices: Wheat (APW1) - $275t, Barley (F1) - $230

MAP ($/t)	pHNNDVI					Soil DGT P				
	4	6	8	10	12	> 150	100	50	30	< 20
$500	0	5	16	26	36	0	6	20	34	47
$750	0	2	10	18	25	0	4	15	26	38
$1,000	0	1	7	13	19	0	3	12	21	31
$1,250	0	1	6	10	15	0	2	10	18	25
$1,500	0	1	4	8	12	0	2	8	14	21

Decile 9 Grain prices: Wheat (APW1) - $332t, Barley (F1) - $293

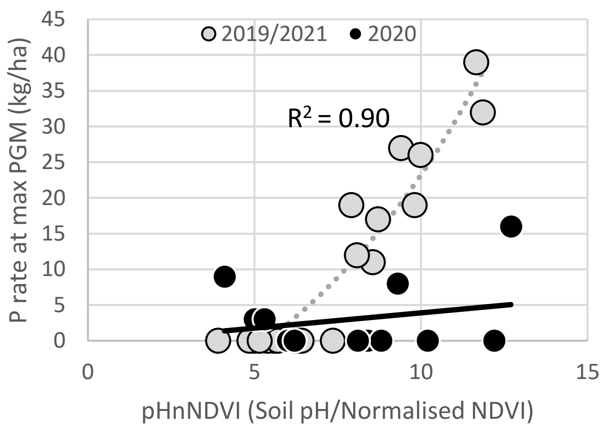
MAP ($/t)	pHNNDVI					Soil DGT P				
	4	6	8	10	12	> 150	100	50	30	< 20
$500	0	8	20	31	42	0	9	23	37	51
$750	0	3	12	21	31	0	5	18	31	44
$1,000	0	2	9	16	24	0	3	14	25	36
$1,250	0	1	7	13	19	0	3	12	22	31
$1,500	0	1	6	11	16	0	2	10	18	26

Opportunities for 2022 – time of sowing (TOS)

Recent SAGIT funded project (AS216) outlined the effect of TOS on P requirements through trials established on P responsive sites between 2017 and 2018 due to the prevalence of earlier sowing times. Results outlined that if adequate soil moisture was present in April for sowing, P rates can be reduced without any impact on yield.

This benefit reduced if there was either low moisture in April or sowing times moved to mid-May and beyond, with June sowing times producing linear but relatively flat uneconomic responses. Under high soil moisture and warm temperatures crop root systems develop effectively and therefore exploration of residual P is high, placing less reliance on fertiliser P inputs. Diffusion rates of P in these conditions are also optimised.

Data from Trengove Consulting supports this theory as the 2020 field trial data set, sown early May under good moisture revealed a lower pHnNDVI with optimal P rate relationship (Figure 2) compared to 2019 and 2021 with dryer conditions and later sowing (Table 4). This is a potential option for 2022 if wet conditions in April prevail.



Site	Year	Rainfall to May (mm)	Rainfall for April (mm)
Koolunga	2019	13	4.4
Bute	2019	9.1	3.2
Brinkworth	2020	180	64
Bute	2020	119	67
Kybunga	2020	154	78
Crystal Brook	2021	29	2.6
Spalding	2021	43	4.4
Hart	2021	42	10

Figure 2 (L) and Table 4 (R). Influence of high rainfall and high soil moisture at the 2020 sites compared to 2019 and 2021 and the impact of lower P requirements at P deficiency indices.

Case study

One paddock included in the trial series associated with the SAGIT project TC221 is located at Crystal Brook in the Mid-North of South Australia. This paddock was selected to evaluate the methodology of predicting P response using data layers and investigate a range of long-term P management strategies. Two data layers that are readily available were used to predict the P response at four sites in the paddock and P rate trials were established. The data layers used included, pH (calibrated to CaCl2) captured using a Veris pH mapping machine, taking approximately 8 samples per ha, and satellite imagery captured at approximately GS30 in a wheat crop in 2020 (Figure 3). These two data layers were used to calculate the pHNNDVI (as explained above) to identify four trial sites with different predicted P responsiveness. This process was repeated at a paddock at Hart and Spalding. A similar process was used in 2019 and 2020 to select sites to predict the P response across five paddocks.

At each of the four sites within each paddock, a P rate response trial was established with rates of P up to 90 kg/ha (409 kg MAP/ha). Very high rates of P are required to find the maximum yield on very high P demand sites. In the previous project the maximum rate was 50 kg P/ha, and some sites were still responding even at this level. At the site which was predicted to have the largest response a larger trial was established to investigate long-term (3 year) management strategies. This site included two treatments where 75 kg of P was broadcast in front of the seeder either as MAP or chicken litter, these treatments also had 15 kg P/ha as MAP applied in the furrow at seeding.

The grain yield response at each of the four sites in the paddock at Crystal Brook is shown in Table 5. The sites with low predicted P response (22 and 24) did not have any response to P fertiliser; the nil treatments produced the same amount of grain yield as the 90 kg P/ha treatments. At the site which was expected to have a moderate response there was also no response to P fertiliser. At this site there was significant variation in soil test results between replicates, with DGT-P soil test levels ranging from 38 in Replicate 1 up to 151 in Replicate 3. This level of variation explains why this site did not have a significant P response even though it was expected and highlights short scale variability that can be difficult to map and manage. At site 25, the most responsive site, significant yield responses were observed all the way up to 90 kg P/ha, indicating a highly P responsive soil. This is not to suggest that these rates were economic; for a current pricing scenario of $1,250/t for MAP and $295/t for barley, 32 kg P/ha (145 kg MAP) was required to maximise partial gross margin at site 25. The treatments that had 75 kg P/ha broadcast in front of the seeder followed by 15 kg P/ha below the seed, produced similar grain yield to the standard 90 kg P/ha applied below the seed. This suggests that the broadcast P was readily available. In previous trials this has not been the case, and this needs further investigation.

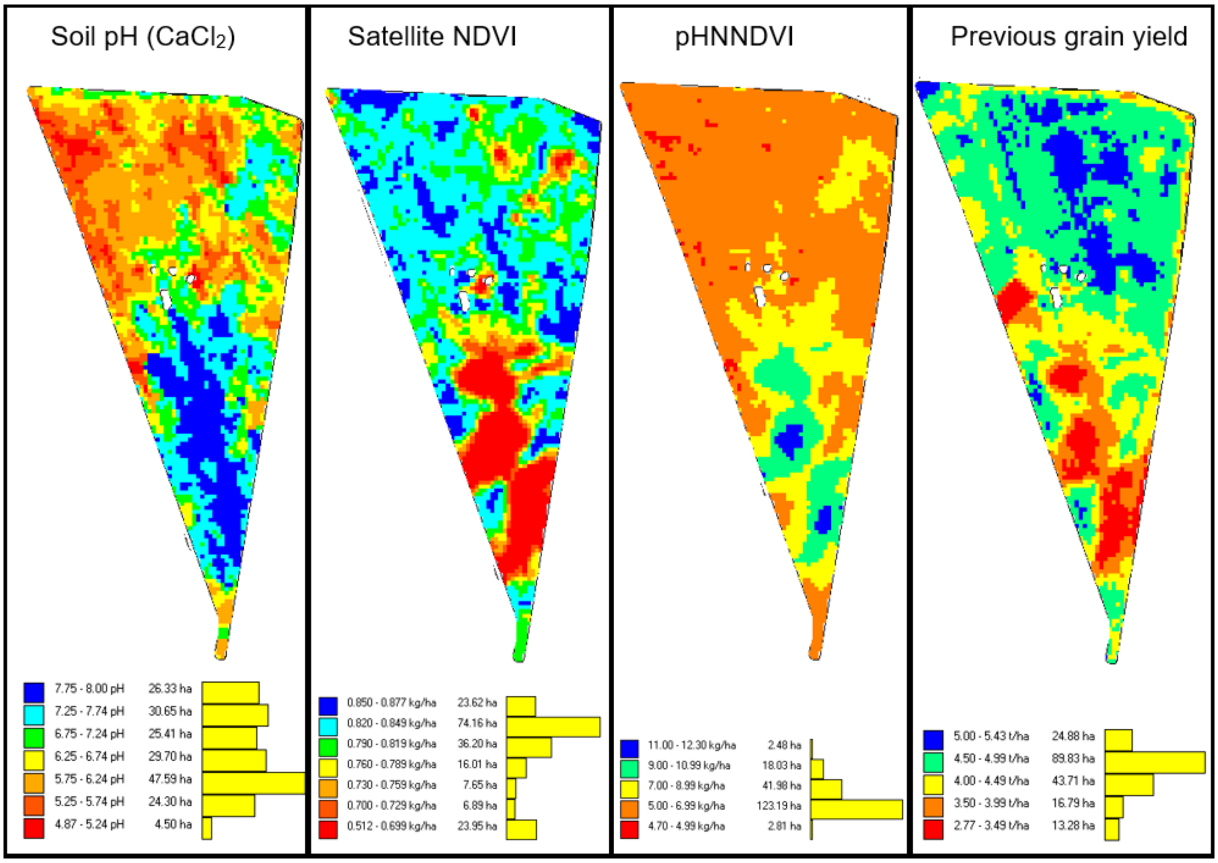


Figure 3. Soil pH, Satallite NDVI of wheat crop in 2020, approximately GS30, calculated pHNNDVI (pH / normalised NDVI) and historical grain yield for a paddock at Crystal Brook.

Table 5. Grain yield (t/ha) for the four P rate response trials at Crystal Brook in Compass barley in 2021, treatments with different letters are significantly different.

Site	22	23	24	25	
Expected response	Low	Moderate	Low	High	
P rate (kg/ha)					
0	2.70	4.32	3.98	2.71	f
7.5	2.47	4.36	3.83	3.41	e
15	2.77	4.44	3.78	3.84	d
22.5	2.51	4.38	3.58	4.10	c
30	2.56	4.35	3.64	4.22	c
50	2.94	4.44	3.65	4.54	b
90	2.73	4.31	3.54	4.74	a
CL				4.75	a
Spread MAP				4.75	a
P value	0.318	0.946	0.155	<0.001	

The yield data from the four trials in isolation is useful for measuring site specific responses within a paddock. But it becomes more powerful when a response curve is generated for each of the 33 sites, and these are put into a database to generate response curves based on the data layers used for site selection. From this database we can predict the P response based on pHNNDVI for each of the sites and use that data to generate partial gross margins. This can then be extrapolated to every point in a paddock to generate a P fertiliser application map.

The results from four modelled scenarios where high grain prices are coupled with a range in MAP prices and different fertiliser strategies are shown in Table 6. In Scenario 1 using MAP fertiliser price of $750/t, the optimum P rate ranges from 0 to 200 kg MAP/ha, averaging 44 kg/ha for the paddock. Increasing fertiliser price to $1,500/t in Scenario 2 reduces the average MAP rate to 24 kg/ha.

In some scenarios, we may prefer to ensure that all areas receive a minimum rate of starter fertiliser, rather than receiving nil in the areas that are predicted not to be P responsive. In Scenario 3 the minimum fertiliser rate is set to 20 kg MAP/ha, so that no zone receives less than this. This increases the average fertiliser rate for the paddock from 24 to 32 kg MAP/ha.

Scenario 4 is an example of a long-term strategy, where the minimum fertiliser rate for any given area is set by calculating P replacement based on the previous year's yield map. This strategy ensures P reserves are not being 'mined' on any soil, but being maintained on non-responsive soils, with higher rates still targeted to the P responsive soils. Each location receives whichever of the two rates is higher, the rate calculated from pHNNDVI or yield replacement. Scenario 4 increases the average rate to 90 kg MAP/ha, compared with 44 kg/ha in Scenario 1.

Given record high P fertiliser prices for 2022, Scenarios 2 and 3 provide an opportunity in this paddock for reducing average MAP fertiliser rates by 58 – 66 kg MAP/ha compared with Scenario 4, a saving of $87 – 99/ha.

Table 6. Results showing four modelled fertiliser strategies with a range of MAP prices.

Scenario	Grain price	MAP fertiliser price ($/t)	Min MAP fertiliser rate (kg/ha)	MAP fertiliser rate range (kg/ha)	Average MAP fertiliser rate calculated (kg/ha)
1	Decile 9	750	0	0 – 200	44
2	Decile 9	1500	0	0 – 130	24
3	Decile 9	1500	20	20 – 130	32
4	Decile 9	750	Replacement from previous yield	50 – 200	90

Conclusion

High P fertiliser price is currently slightly offset by high grain prices but with the uncertainty of these grain prices continuing into 2022, it is advised to revise P applications in 2022 due to significant impacts on optimal P rates required to maximise gross margins. Several data layers are available to assist with identifying areas where P rates can be safely cut back and those that will still return a profit with increased grain yields through adequate P applications.

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Photo. Soil testing rig.