Using grain protein maps to optimise nitrogen fertiliser to paddock scale nitrogen variability

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Key findings

- Wheat grain protein in 2022 showed a moderate correlation with soil available N pre-seeding in the following season at Bute and Redhill.
- The 2022 grain protein data was able to predict the in-paddock variability in fertiliser N requirement in the following crop at both experimental paddocks. However, there was a large variation between the paddocks despite having similar yield potentials. At 10% protein in 2022 the N fertiliser rate required to maximise partial gross margin (PGM) at Redhill was 125 kg N/ha compared to 61 kg N/ha at Bute.
- Crop N removal (combination of yield and protein) in 2022 had a strong relationship with N rate to optimise PGM in 2023 both Redhill and Bute.

Why do the trial?

In paddocks with significant spatial variation there is an opportunity to utilise data layers that can provide information at the site-specific level and aid nitrogen (N) decision making. The use of on combine protein analysers is becoming more common among grain growers. At harvest this technology allows growers to blend and segregate different grades of grain based on protein. However, the resulting grain protein maps also have the potential to assist N decision making by showing the spatial variation in protein (and therefore N) across a paddock. This variation can be used to assign zones and produce variable rate fertiliser maps.

The aims of this project are to increase the profitability derived from N fertiliser applications by:

- Examining the relationship between soil mineral N pre-seeding with grain yield and protein maps from the previous season.
- Examining the relationship between historical grain yield and protein maps, and the spatial variability of nitrogen response across paddocks in the Mid North and Yorke Peninsula.
- Provide information towards the potential for protein maps to create variable rate nitrogen application maps.

How was it done?

Paddock and trial site information

Two growers using standard yield monitors and retrofitted CropScan 3000H grain analysers were identified at Bute and Redhill. Wheat grain yield and protein maps from 2022 were analysed and one paddock per grower was selected for small scale field trials (Figure 1 and Figure 2).

Four sites per paddock were identified based on the 2022 data layers for small plot trials (Table 1). Each of the sites was predicted to have a different level of N fertiliser response based on historical crop performance. The 2022 grain yield and protein data from each of the selected trial sites are shown in Table 1. Soil available N for the Redhill site ranged from 38 – 56 kg N/ha and at Bute ranged from 31 – 56 kg N/ha. Organic carbon levels at both sites were low to moderate. There were no other constraints identified in the soil properties tested (data not shown).

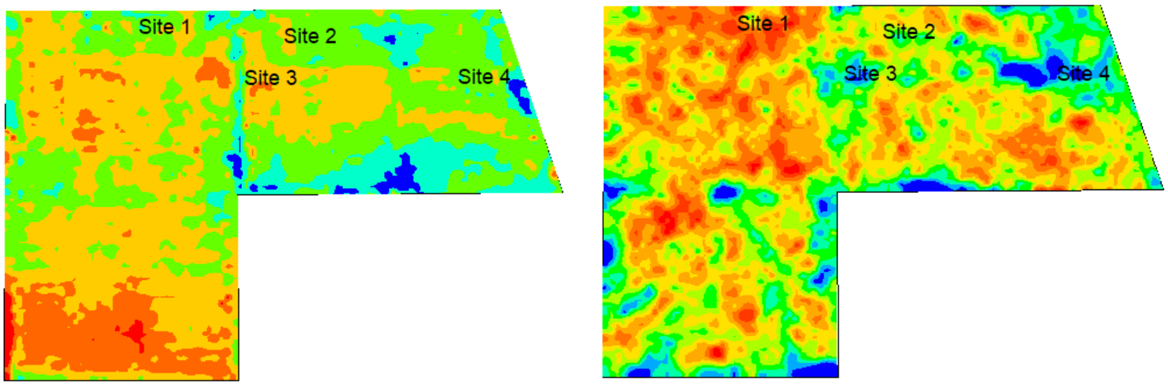

Figure 1. The 2022 Redhill paddock wheat yield map (left) and protein map (right).

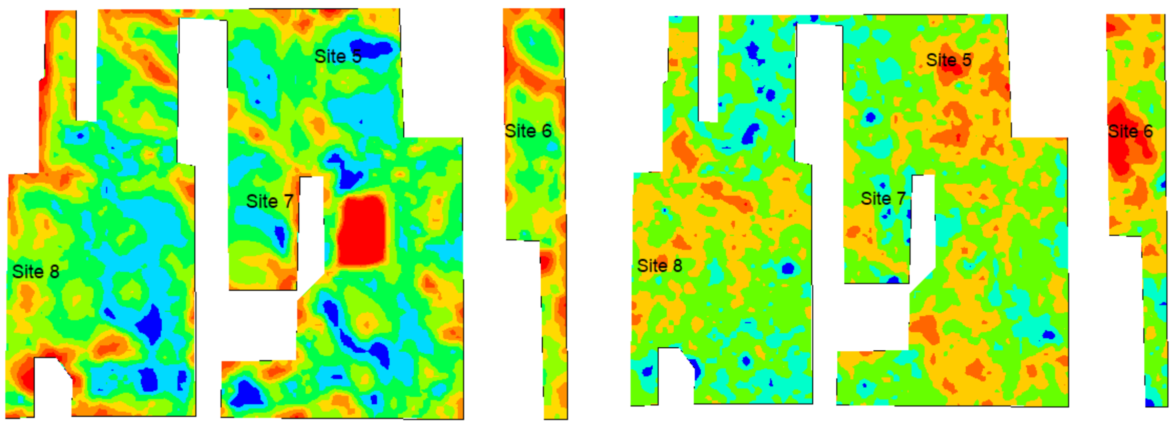

Figure 2. The 2022 Bute paddock wheat yield data (left) and protein map (right).

Table 1. Grain yield (2022), protein (2022), soil available N (sampled March 2023) and organic carbon for the small-scale plot trial locations.

N trial site	Location	Description*	2022 Wheat grain yield (t/ha)	2022 Grain yield (relative)	2022 Protein (%)	2022 Protein (relative)	Soil available N (0-100 cm)	Organic carbon (%)
1	Redhill	MYLP	5.6	1.02	9.8	0.93	38	1.3
2		MYMP	5.7	1.04	11.1	1.06	38	1.4
3		MYHP	5.3	0.96	11.3	1.07	49	1.3
4		HYHP	5.8	1.05	11.8	1.12	56	1.2
5	Bute	HYLP	7.9	1.11	9.7	0.91	31	0.9
6		MYLP	7.2	1.03	9.3	0.88	48	0.9
7		MYHP	7.0	1.01	11.3	1.06	56	1.0
8		MYMP	7.0	1.01	10.2	0.96	38	1.0

**Example MYLP = medium yield, low protein*

Nitrogen fertiliser rate plot trials

The trials were randomised complete block designs with three replicates. Plot dimensions were 1.5 m x 10 m. The N fertiliser response at each trial site was assessed with fertiliser rates of 0, 25, 50, 75, 100, 150 and 200 kg N/ha applied as urea early post emergent.

Trial management details for the individual sites are shown in Table 2. Plots were sown with a knife point press wheel system on 250 mm spacing. All plots were harvested for grain yield and grain quality was assessed. Grain yield and quality statistical analysis was performed using ANOVA and ASREML in R.

Yield potential was calculated = ((Rainfall (30% October to March) + April to October rainfall – 90 mm evaporation) * 25 kg/ha/mm). Previous October rainfall is generally not included in this calculation however, 2022 was an exceptionally wet season and it would be unwise to ignore it. Barley nitrogen requirement = (yield t/ha * 10% protein * 1.61) / 45% N use efficiency.

Table 2. Agronomic information for trial sites at Redhill and Bute in 2023.

Site	**Redhill**	**Bute**
Seeding date	May 15	May 16
Variety (Seeding rate)	Beast barley 80 kg/ha	Commodus CL barley 75 kg/ha
Starting fertiliser	MAP 100 kg/ha	MAP 100 kg/ha
N applications (Growth stage)	June 26 (GS 14)	June 26 (GS 14)
Harvest date	October 31	November 2

Nitrogen response curves were fit to the yield data for each site as a polynomial function. Predicted grain yield was then used to conduct partial gross margin (PGM) analysis to find the N rate at maximum PGM for each site.

Prices used in the PGM were $700/t for urea and $270/t for BAR1 barley. All treatments met and were assessed as BAR1 grade, despite some treatments reaching malt classification standards (currently Beast and Commodus CL are pending malt accreditation). The N rate at maximum PGM was then compared to historical yield and protein data.

Seasonal conditions

At both Redhill and Bute, the season started well with good seeding rains and a wet June. This was followed by a very dry spring (Figure 3). Well below average rainfall was received through July to October. October rainfall at Redhill was 5 mm and Bute 8.5 mm and this resulted in moisture stress prior to maturity at these sites. However, significant stored moisture was available for the crops throughout the growing season from the wet spring in 2022 (Figure 3).

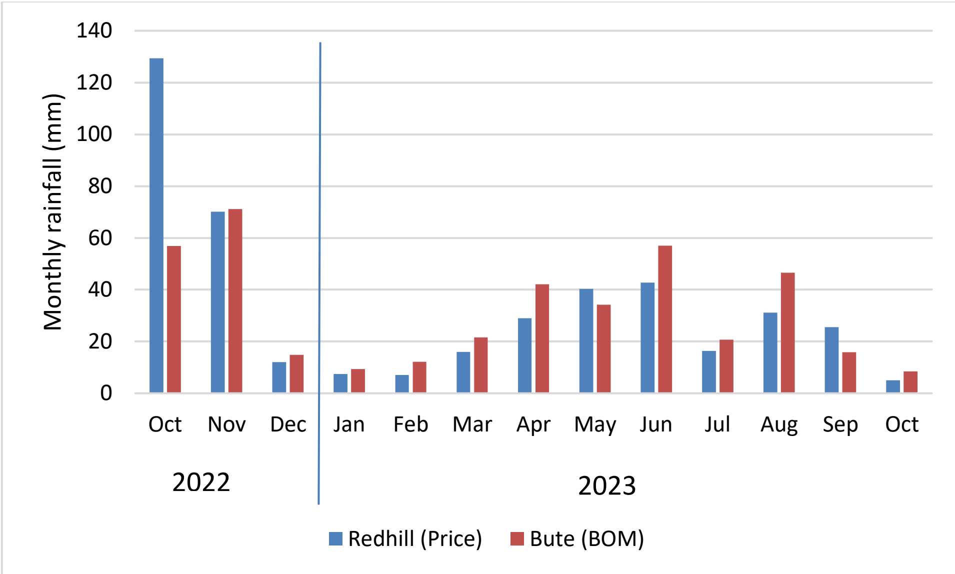

Figure 3. Monthly rainfall for Redhill and Bute from October 2022 to October 2023.

Results and discussion

Exploring the relationship between historical data layers and pre-seeding soil available N

Grain protein from the previous season had a moderate correlation to pre-seeding soil available N (Figure 4). At both the Redhill and Bute sites, as 2022 protein increased, soil available N measured in March the following season also increased. The rate of increase was similar for both sites at an average of 7.5 kg N/ha for each percent protein increase. The Bute sites were more variable and as a result had a weaker correlation compared to Redhill.

The 2022 grain yield and the combination of 2022 grain yield and protein (shown as N removal) did not have the same relationship between sites (Figure 4). At the Bute sites grain yield had a moderate correlation with soil available N compared to no relationship at Redhill. The opposite was observed between the two sites for N removal.

This data suggests grain protein can better describe the variation in soil available N compared to grain yield or N removal.

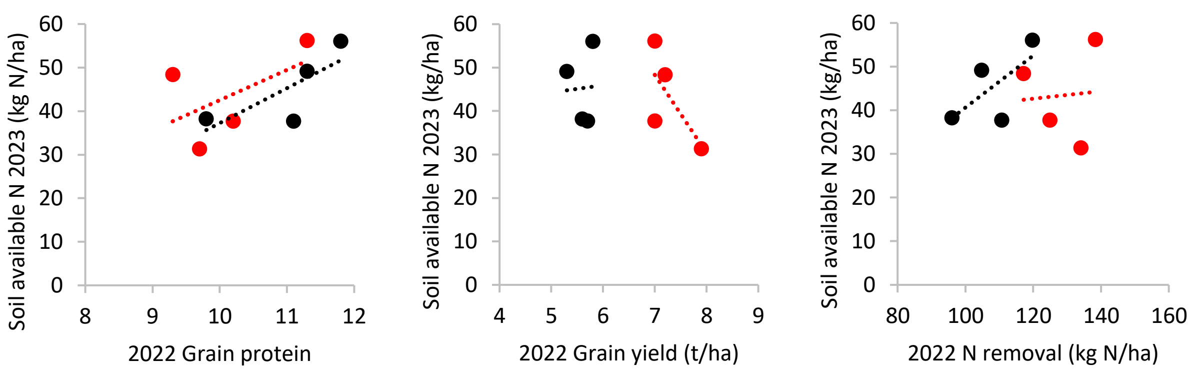

Figure 4. The relationship between 2022 protein (left), grain yield (mid) and N removal (right) and soil available N sampled March 2023 at Redhill (black) and Bute (red).

Protein – Redhill; $y = 8.01x - 42.89$, $R^2 = 0.59$, Bute; $y = 6.94x - 26.91$, $R^2 = 0.30$

Grain yield – Redhill; $y = 1.67x + 35.91$, $R^2 = 0.001$, Bute, $y = -18.00x + 174.37$, $R^2 = 0.49$,

N removal – Redhill; $y = 0.5952x - 18.909$, $R^2 = 0.4456$, Bute; $y = 0.0855x + 32.393$, $R^2 = 0.0054$.

Table 3. Grain yield, quality and N removal for eight N response trials at Redhill and Bute 2023. Within a row, numbers that share a common letter are statistically similar.

N rate (kg/ha)	**0**	**25**	**50**	**75**	**100**	**150**	**200**	***Pr (>F)***
Site 1 – MYLP								
Grain yield (t/ha)	3.4 d	4.0 c	4.4 b	5.0 a	5.0 a	5.3 a	5.3 a	*<0.001*
Protein (%)	8.7 f	9.2 ef	9.6 e	10.5 d	11.7 c	12.9 b	13.9 a	*<0.001*
Screenings (%)	0.3 b	0.2 b	0.2 b	0.2 b	0.2 b	0.3 b	0.6 a	*0.02*
N removal (kg/ha)	53g	65 f	74 e	92 d	102 c	119 b	128 a	*<0.001*
Site 2 – MYMP								
Grain yield (t/ha)	4.0 e	4.4 d	4.7 c	5.1 b	5.2 ab	5.2 ab	5.4 a	*<0.001*
Protein (%)	9.5 e	10.1 e	10.8 d	11.6 c	12.9 b	13.2 b	15.1 a	*<0.001*
Screenings (%)	0.2 b	0.3 b	0.3 b	0.3 b	0.2 b	0.4 b	0.6 a	*0.026*
N removal (kg/ha)	66 f	79 e	90 d	104 c	117 b	121 b	141 a	*<0.001*
Site 3 - MYHP								
Grain yield (t/ha)	3.8 d	4.3 c	4.5 bc	4.8 ab	4.9 a	5.1 a	5.2 a	*<0.001*
Protein (%)	9.8 e	10.1 de	10.9 d	12.0 c	13.1 b	13.6 b	14.7 a	*<0.001*
Screenings (%)	0.3 a	0.2 a	0.2 a	0.3 a	0.3 a	0.3 a	0.5 a	*0.151*
N removal (kg/ha)	64 e	76 de	85 d	101 c	113 bc	122 ab	134 a	*<0.001*
Site 4 – HYHP								
Grain yield (t/ha)	4.1 e	4.7 d	4.8 cd	5.0 bc	5.1 ab	5.3 a	5.1 ab	*<0.001*
Protein (%)	8.9 f	9.7 e	10.0 e	11.1 d	12.1 c	13.4 b	14.8 a	*<0.001*
Screenings (%)	0.6 a	0.3 a	0.2 a	0.3 a	0.5 a	0.5 a	1.0 a	*0.23*
N removal (kg/ha)	65 f	79 e	84 e	97 d	108 c	124 b	132 a	*<0.001*
Site 5 – HYLP								
Grain yield (t/ha)	3.7 d	4.2 c	4.5 b	4.6 ab	4.7 a	4.6 ab	4.5 b	*<0.001*
Protein (%)	8.7 e	9.1 de	9.5 d	10.5 c	10.7 c	12.6 b	14.4 a	*<0.001*
Screenings (%)	2.4 b	1.0 b	1.4 b	2.1 b	2.5 b	5.3 a	7.0 a	*0.002*
N removal (kg/ha)	56 f	67 e	74 d	84 c	89 c	101 b	113 a	*<0.001*
Site 6 – MYLP								
Grain yield (t/ha)	3.9 d	4.3 c	4.8 b	4.7 b	5.0 a	4.6 b	4.6 b	*<0.001*
Protein (%)	7.7 e	8.1 e	9.0 d	9.9 c	10.4 c	12.5 b	14.3 a	*<0.001*
Screenings (%)	0.6 d	0.6 d	0.9 d	2.1 c	2.1 c	4.9 b	8.4 a	*<0.001*
N removal (kg/ha)	52 g	61 f	75 e	81 d	91 c	101 b	115 a	*<0.001*
Site 7 – MYHP								
Grain yield (t/ha)	4.0 bc	4.1 abc	4.3 a	4.3 ab	4.3 a	4.0 c	3.9 c	*<0.001*
Protein (%)	9.7 d	10.5 d	11.9 c	12.2 c	12.5 c	14.6 b	16.0 a	*<0.001*
Screenings (%)	0.9 d	1.4 cd	2.8 bc	3.4 b	4.1 b	10.6 a	10.6 a	*0.151*
N removal (kg/ha)	69 d	75 d	90 c	92 bc	94 bc	102 ab	110 a	*<0.001*
Site 8 – MYMP								
Grain yield (t/ha)	4.1 d	4.5 c	4.7 ab	4.8 a	4.8 a	4.7 ab	4.6 bc	*<0.001*
Protein (%)	9.4 e	9.6 de	10.1 d	11 c	11.6 c	13.4 b	14.4 a	*<0.001*
Screenings (%)	0.9 d	1.0 d	1.4 d	2.5 cd	3.2 c	5.6 b	8.1 a	*<0.001*
N removal (kg/ha)	67 f	76 e	83 d	92 c	98 b	111 a	117 a	*<0.001*

General crop performance across the paddocks

Redhill grain yields were highly responsive to N at all sites, with responses ranging from 1.2 t/ha at Site 4 HYHP to 1.8 t/ha at site 1 MYLP, where maximum yield is compared with nil N applied (Table 3). Maximum barley grain yields were achieved with 75 kg N/ha or 100 kg N/ha across the four trial sites at Redhill. Grain quality was excellent with all samples testing < 1.0% screenings. Grain protein ranged from 8.7% to 14.8% and similar to grain yield was highly responsive to N fertiliser rate.

Maximum grain yields at Bute were slightly lower than at Redhill. The maximum yield at Redhill averaged 5.3 t/ha compared with 4.7 t/ha at Bute. Responses to N were also slightly lower, ranging from 0.3 t/ha at site 7 MYHP to 1.1 t/ha at site 5 HYLP. However, at Bute maximum grain yields were achieved from N fertiliser rates between 50 to 100 kg N/ha depending on the site. The low rainfall in September and October lead to moisture stress and haying off at some sites at high nitrogen rates (Table 3). This resulted in reduced grain yields and increased screenings at the highest N rates.

Grain quality was also more variable across the Bute paddock. The protein levels ranged from 7.7% to 16% and screening levels were higher in some treatments, up to 10.6%. Despite the moisture stress and resulting higher screenings the quality assessments meet BAR1 receival standards from all treatments and sites.

Partial gross margin analysis

<u>Historical protein to predict crop N response</u>

From the first season of results, there is evidence that historical protein can be used to indicate the variability in N demand for the current crop in a given paddock (Figure 5). At Redhill, as the 2022 protein increased the N rate to maximise PGM in 2023 reduced at a rate of 16 kg N/ha for each 1% protein increase. The response was steeper at Bute, where the N rate to maximise PGM reduced by 43 kg N/ha for every 1% increase in historical grain protein.

The absolute N requirement for a given historical protein varied between the two paddocks in 2023. At 10% protein in 2022 the N fertiliser rate required to maximise PGM at Redhill was 125 kg N/ha compared to 61 kg N/ha at Bute. The specific reason for the large difference in optimum N rates remains unclear from one season of results. The Redhill paddock produced higher maximum yields at 5.3t/ha compared with 4.7t/ha, but a 0.6t/ha increase in yield target should not increase optimum N rate by 64kg N/ha.

Fertiliser N requirements are affected by many factors including:

- Grain yield potential, both sites were predicted to have similar barley yield potentials and N requirements of 4.3 t/ha and 153 kg N/ha for Redhill and 4.8 t/ha and 163 kg N/ha for Bute.
- Soil available N pre-seeding was on average, slightly higher at Redhill (38 – 56 kg N/ha) compared to Bute (31 – 56 kg N/ha).
- Soil organic carbon levels (0-10 cm) were generally moderate to low in both paddocks. The Bute paddock is a sandy textured soil with organic carbon levels ranging from 0.9 – 1.0% indicating low potential for soil N mineralisation. At the Redhill paddock, the soil texture is loam to clay loam and the organic carbon values were higher ranging from 1.2 – 1.4% and therefore a higher potential for N mineralisation.

These factors suggest the Redhill site should have had more available N in the soil compared to Bute and therefore a lower N fertiliser requirement. However, the opposite was observed in the field and further investigation is required.

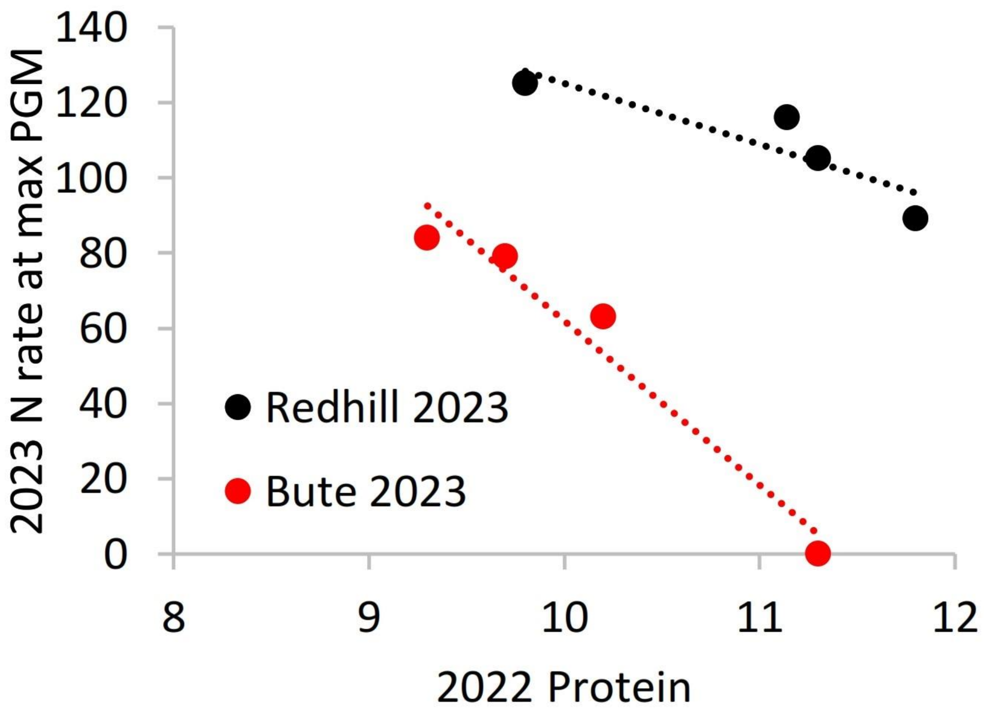

Figure 5. The 2022 protein and N rate required to maximise PGM in 2023 for Redhill and Bute.
Bute - y = -43.7x + 499, R^2 = 0.95, Redhill - y = -16.2x + 287, R^2 = 0.79

<u>Historical nitrogen removal to predict crop N response</u>

Using historical yield and protein data, the crop N removal from 2022 was calculated for each trial site (Table 1). The first season of trials show there is a strong relationship between the 2022 crop N removal and the 2023 fertiliser N requirement (Figure 6) and this relationship was similar for both the Redhill and Bute sites. As 2022 N removal increases, the N demand to achieve maximum PGM in 2023 was reduced. Where 2022 N removal reached 154 kg N/ha, no fertiliser N was required in the 2023 season to maximise PGM. In this instance all N from the following crop is being mined from soil reserves, which over time is expected to deplete organic matter reserves. When N removal reached 107 kg N/ha in 2022, N fertiliser rates that equal replacement were required to maximise PGM in the following season (Figure 6). Below this level of N removal, it was necessary to apply N fertiliser rates higher than removal to achieve maximum PGM. It is also expected applying higher fertiliser N rates than removal will result in an increase in soil available N going forward, as per the rationale behind N banking.

Using this methodology in practice suggests higher N fertiliser rates are required on low protein/low yielding areas of the paddock which may also increase the soil N bank. However, in high yielding/high protein areas of the paddock, soil N will be mined. If this strategy is used long-term it will result in a more spatially even N requirement across the paddock.

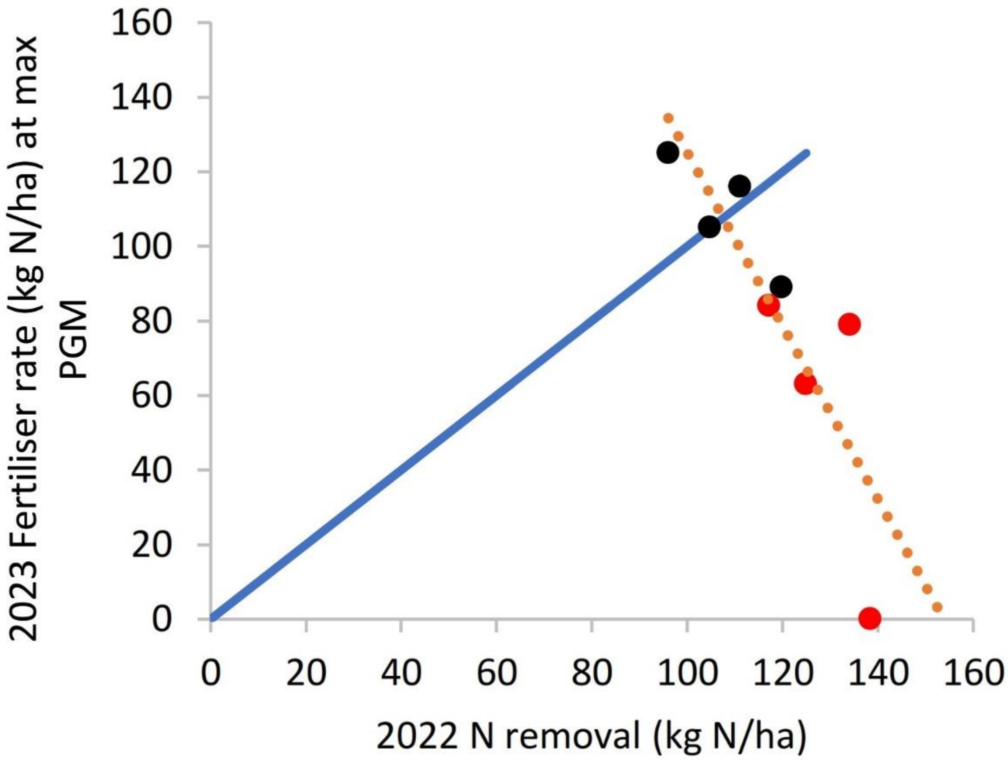

Figure 6. Crop N removal 2022 and N fertilise rate at maximum PGM 2023 for the Redhill (black circles) and Bute (red circles) trial sites, y = -2.32x + 358, R^2 = 0.72, the blue line shows where N removal = N applied.

Conclusions

Grain yield and protein maps collected in 2022 provided useful insight for understanding the variability in N response in the 2023 season. Protein data was more consistent at predicting soil available N and was useful in describing the variability in fertiliser N response in the following crop. The combination of 2022 yield and protein data into N removal produced a similar relationship with fertiliser N requirements for both paddocks. Further research is required across more paddocks and seasons to see if these relationships are maintained across a larger data set.

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