CONCLUSION

Previous research trials have confirmed that the effects of Si on plants are primarily seen in times of stress (such as drought and heat). It can be inferred that no significant differences were seen between the treatment of Si and control (no Si) across all crop types, due to the extremely wet seasonal conditions, including flooding, across the sites. Extended stay-green phenotypes were observed in spring wheat, providing a reasonable indication of the positive effect of foliar Si application regardless of waterlogged conditions.

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IMPROVED DROUGHT RESILIENCE THROUGH OPTIMAL MANAGEMENT OF SOIL AND WATER

KEY POINTS

- **Diverse legume rotations may help build soil organic carbon.**
- **Early sowing of slower-maturing crops may lead to higher crop water use efficiency; this demonstration will commence in the region in 2023.**
- **Measuring residual mineral nitrogen will aid in preventing excess application, increase profitability, and decrease environmental losses.**
- **It is recommended to split deep nitrogen samples (for example 0-30cm and 30-60cm) to ascertain location of nitrogen in the soil profile.**

BACKGROUND

The project *Improved drought resilience through optimal management of soil and water* covers central and southern New South Wales regions with 12 demonstration sites.

The project is supported by Riverine Plains, through funding from the Australian Government's Future Drought Fund and the Grains Research and Development Corporation (GRDC).

The purpose of the project is to improve the management of natural capital through increased water use efficiency, soil organic carbon, and nitrogen utilisation, which, in-turn, is crucial to environmental and economic resilience in drought. These sites will focus on three strategies that have been proven previously, through the work of John Kirkegaard, in small scale field trials in New South Wales.

There were two sites in the Riverine Plains in 2022, with an additional site being added in 2023. Throughout the project, case studies and marketing collateral will be produced to ensure information is dispersed to encourage wider adoption across Australia. These will be promoted through the Vic Hub and the sNSW Hub and their farming systems groups.

FOCUS PADDOCK 1: DIVERSE ROTATIONS

AIM

To demonstrate how diverse legume rotations can fit into the modern farming system and potentially help build soil organic carbon.

METHOD

A host farmer from Howlong had two paddocks side-by-side to compare a non-legume and a legume rotation. In 2022, a paddock was sown half to wheat and half to faba beans. In 2023, the entire paddock will be sown to canola. Previously the paddock was in a wheat/canola rotation. The paddock can be irrigated by an overhead irrigator, but was not irrigated in 2022, due to the very high rainfall.

The following measurements were taking to identify the value of a diverse rotation:

- soil tests 0-30cm and 30-60cm, gravimetric soil water analysis, nitrogen content and organic carbon pre-sowing and post-harvest, GPS located on the same spot
- plant counts
- biomass counts at mid-pod fill
- nitrogen[15] (N15) analysis on faba beans and reference plants

Table 1. Mid-west paddock site details

	FABA BEANS	WHEAT
Variety	Amberley	Coota
Sowing date (beans)	22/04/2022	28/04/2022
Plant density (beans)	26 PLANTS/M2	NOT RECORDED
Starter Fertiliser	70KG/HA MAP	70KG/HA MAP
pH CaCl2 (0-30cm)	6.0	5.7
pH CaCl2 (30-60cm)	6.4	6.6
Colwell P mg/kg (0-30cm)	24	18
Colwell P mg/kg (30-60cm)	<5	<5
Rainfall (mm) Jan-March	258	258
Rainfall (mm) April - October	498	498

RESULTS AND DISCUSSION

Dry matter cuts, taken from the faba beans at mid-pod fill in October 2022 weighed 10.36tDM/ha. Subsamples from the faba bean dry matter cuts and a weed reference plant were also sent for N^{15} sampling to determine the amount of nitrogen fixation by the faba beans (data not available at time of publishing). The faba bean paddock yield of 0.98t/ha was dramatically down on expectations, due to severe waterlogging and disease. The wheat in the paddock was also affected by waterlogging yielded 2.5t/ha.

Soil properties taken before sowing and post-harvest at GPS locations indicated small increases in organic carbon (Table 3) However, the difference was potentially due to the different timing of the sampling. Carbon levels can fluctuate during the season and may not always be a legacy of the crop. Changes in soil organic carbon generally occur slowly over many seasons, and therefore can be difficult to detect in the short term. The soil moisture levels were converted from gravimetric to crop Plant Available Water (PAW) using bulk densities and soil lower limits for canola (pers. comm, Dunn M, 2023). Soil samples taken at 60cm depth in faba bean trials showed a decrease of PAW of 60.9mm, between sowing in May 2022 and post-harvest in January 2023. In contrast the wheat profile over the same depth and time period showed a decrease in PAW of 13.1mm. The higher stubble cover in the wheat may have reduced evaporative soil water loss between harvest and sampling.

Table 3. Soil properties faba beans, pre and post-sowing

	PRE-SOWING (17 MAY 2022)	POST-HARVEST (27/01/2023)
Organic carbon (% 0-30cm)	0.7	1.0
Organic carbon (% 30-60cm)	0.3	0.5
Soil moisture (PAWmm 0-30cm)*	36.1	1.9
Soil moisture (PAW mm 30-60cm)*	42.4	15.8
Total soil moisture (PAW mm 0-60cm)	78.5	17.6
Nitrogen (kgN/ha 0-30cm)	101.6	155.3
Nitrogen (kgN/ha 30-60cm)	20.6	77.4

*Note the pre-sowing soil moisture % is an air-dried soil moisture, while the post-harvest soil moisture was an oven dried soil moisture. The oven dried soil moisture may result in significantly drier soil, and the two cannot be compared.

Table 4. Soil properties wheat, pre and post-sowing

	PRE-SOWING (17 MAY 2022)	POST-HARVEST (27 JANUARY 2023)
Organic carbon (% 0-30cm)	0.9	1.1
Organic carbon (% 30-60cm)	0.4	0.5
Soil moisture (PAW mm 0-30cm)*	41.6	42.5
Soil moisture (PAW mm 30-60cm)*	61.8	47.8
Soil moisture (PAW mm 0-60cm)*	103.4	90.3
Nitrogen (kgN/ha 0-30cm)	94.1	152.6
Nitrogen (kgN/ha 30-60cm)	18.5	12.2

*Note the pre-sowing soil moisture % is an air-dried soil moisture, while the post-harvest soil moisture was an oven dried soil moisture. The oven dried soil moisture may result in significantly drier soil, and the two cannot be compared.

The deep nitrogen sampling pre-sowing showed the paddock had between 102 and 94kgN per hectare in the 0-30cm layer prior to sowing. The paddock was then sown to wheat on the west side and beans on the east side. After harvest, the nitrogen levels in the 0-30cm increased for both the beans (155kgN/ha) and the wheat (153kgN/ha).

The deep nitrogen sampling in the 30-60cm layer showed different trends for wheat and faba bean post-harvest. Prior to sowing, both sites had between 21kgN/ha and 18kgN/ha. Post-harvest, the nitrogen in the 30-60cm layer increased to 77kgN/ha in the faba beans and decreased to 12kgN/ha in the wheat.

The results show there is a total of 233kgN/ha following the bean crop and 165kgN/ha in the wheat crop, with most of the additional nitrogen in the beans being in the 30-60cm layer (Figure 1). Based on the rule of thumb of 80kgN/tonne to grow a canola crop, there is currently enough soil nitrogen following the wheat to grow a 2.1t/ha canola crop and enough nitrogen following faba bean crop to grow a 2.9t/ha canola crop.

The faba bean crop yielded poorly, so potentially the high levels of residual nitrogen are due to the failure of the crop and the residual is a combination of unused mineralised nitrogen and potential break down and mineralisation of the nitrogen rich crop root and shoot residue. The wheat crop also yielded below expectations, which may explain the high level of residual nitrogen in the top 30cm.

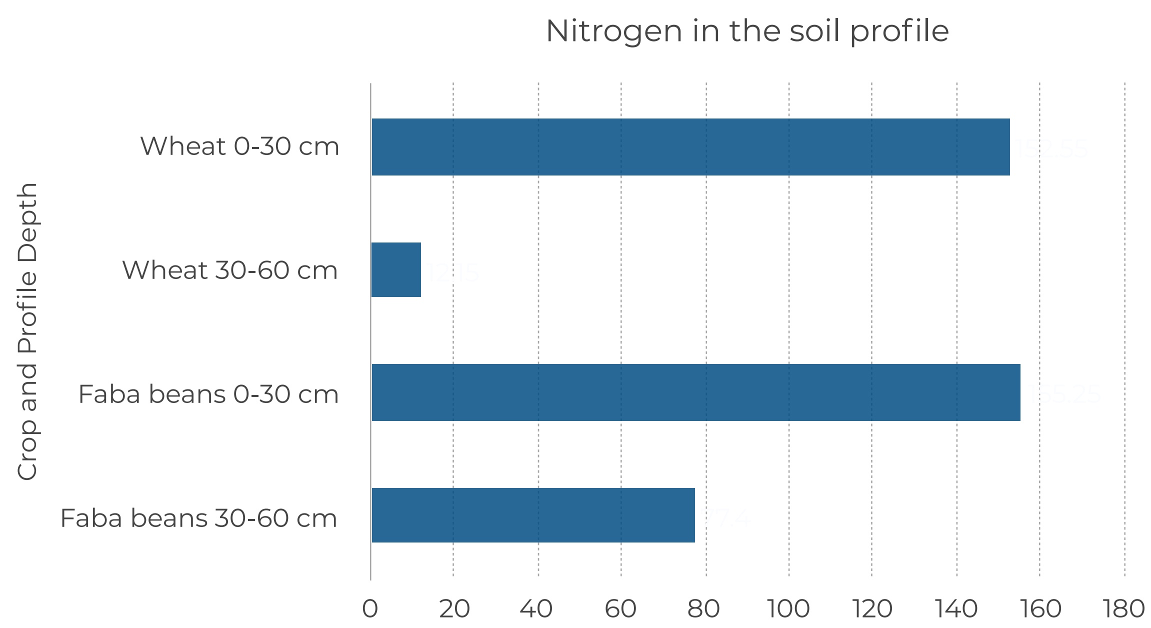

Figure 1. Kilograms of nitrogen per hectare remaining in the soil post-harvest (paddock sampled 27 January 2023.

CONCLUSION

Introducing diversity through a faba bean crop can increase the amount of nitrogen available to the following crop. In this year's demonstration, both the beans and the wheat succumbed to water logging and disease, which reduced the profitability of both crops. The higher levels of soil nitrogen measured after the failed faba bean crop is likely a result of unused mineral nitrogen and the breakdown and mineralisation of the crop residue. It is expected that the extra nitrogen in the faba bean crop will be available to the following crop later in the season, once the roots have penetrated below 30cm. The results suggest less soil water is available following the faba bean crop, which may limit the yield of the following canola crop, depending on the season.

FOCUS PADDOCK 2: NITROGEN BANKING

Table 5. Baragoola paddock site details

SOWING DATE	15 JUNE 2022		
Sowing rate and variety	Calibre/Rockstar Wheat @ 80kg/ha		
Starter fertiliser	70KG/HA MAP		
Total soil N to 70cm	166 KG/HA		
Average annual rainfall	571MM		
Actual annual rainfall	746MM		
Soil property	**0-10cm**	**10-40cm**	**40-70cm**
pH (CaCl2)	5.1	5.5	6.4
EC (dS/m)	0.11	0.07	0.04
Colwell P (mg/kg)	16	6	<5
PBI	39	47	83

AIM

To understand strategies of nitrogen banking versus application based on nitrogen demand, preventing excess application, increase profitability and decrease environmental losses.

METHOD

A farmer was identified who had sown wheat for the 2022 season. Pre-season soil samples were taken on 17 May 2022 to understand starting nitrogen, organic carbon and soil moisture. See Table 5 for pre-sowing soil test results and site details.

To gain understanding of crop establishment in each treatment, plant emergence counts, or tiller counts were taken early in the season.

Nitrogen was applied in the form of urea via a spreader in mid-September. The three treatments of nitrogen were calculated by Mathew Dunn from NSW Department of Primary Industries. Based on starting profile N of 166kg N/ha and additional 7kg N/ha (from MAP), the first two rates were calculated on decile 2 predicted yield and decile 7 predicted yield and final rate was an additional 120kg Urea/ha to understand how excess nitrogen can affect soil nitrogen stores, yield and profitability. See Table 6 for decile 2 and 7 calculations and Table 7 for applied fertiliser rates. The predicted yields have been determined from site modelling and the additional nitrogen required considers 40kg of nitrogen needed to grow 1t of wheat per ha.

Table 6. Nitrogen treatment calculations

TOTAL STARTING N KG N/HA (INCLUDING MONOAMMONIUM PHOSPHATE (MAP))	DECILE 2 PREDICTED YIELD T/HA	ADDITIONAL N REQUIRED FOR DECILE 2 KG N/HA	DECILE DECILE 7 PREDICTED YIELD T/HA 7 PREDICTED YIELD T/HA	ADDITIONAL N REQUIRED FOR DECILE 7 KG N/HA
173	5.2	35	6.5	87

Table 7. Urea rates

TREATMENTS	RECOMMENDED UREA RATE	APPLIED UREA RATE
Standard Rate	80kg/ha	75kg/ha
High Rate	180KG/HA	192KG/HA
Very High Rate	300KG/HA	319KG/HA

Biomass cuts were taken just prior to harvest on 15 December. The crop still had relatively high moisture and was harvested on 28 December once it had dried down. The biomass cuts were sent to NSW Department of Primary Industries in Wagga to have harvest index, yield estimates and seed protein estimates calculated. As mentioned above, post-harvest soil tests for total nitrogen, organic carbon and soil water content were taken in January 2023.

RESULTS AND DISCUSSION

A comparison of pre-sowing and post-harvest soil test results; organic carbon and soil moisture, are listed in Table 8. The comparison of total nitrogen values can be seen in Figure 3.

Table 8 Soil properties

PROPERTIES	PRE-SOWING 17 MAY 2022	POST-HARVEST – 75KG/HA UREA	POST-HARVEST – 192KG/HA UREA	POST-HARVEST – 319KG/HA UREA
Organic carbon % (0-10cm)	1.1	1.8	1.5	1.1
Organic carbon % (10-40cm)	0.3	0.5	0.3	0.3
Organic carbon % (40-70cm)	<0.2	0.2	0.2	<0.2
Soil moisture % (0-10cm)*	17.63	9.5	8.5	9.67
Soil moisture % (10-40cm)*	15.02	6.44	6.6	7.51
Soil moisture % (40-70cm)*	12.54	6.71	12.89	8.89
Soil moisture (PAW mm 0-10cm)*	14.5	1.7	0.2	2
Soil moisture (PAW mm 10-40cm)*	31.3	0	0	0
Soil moisture (PAW mm 40-70cm)*	12.7	0	14.2	0

*Note the pre-sowing soil moisture % is an air-dried soil moisture, while the post-harvest soil moisture was an oven dried soil moisture. The oven dried soil moisture results in significantly drier soil, and the two cannot be compared.

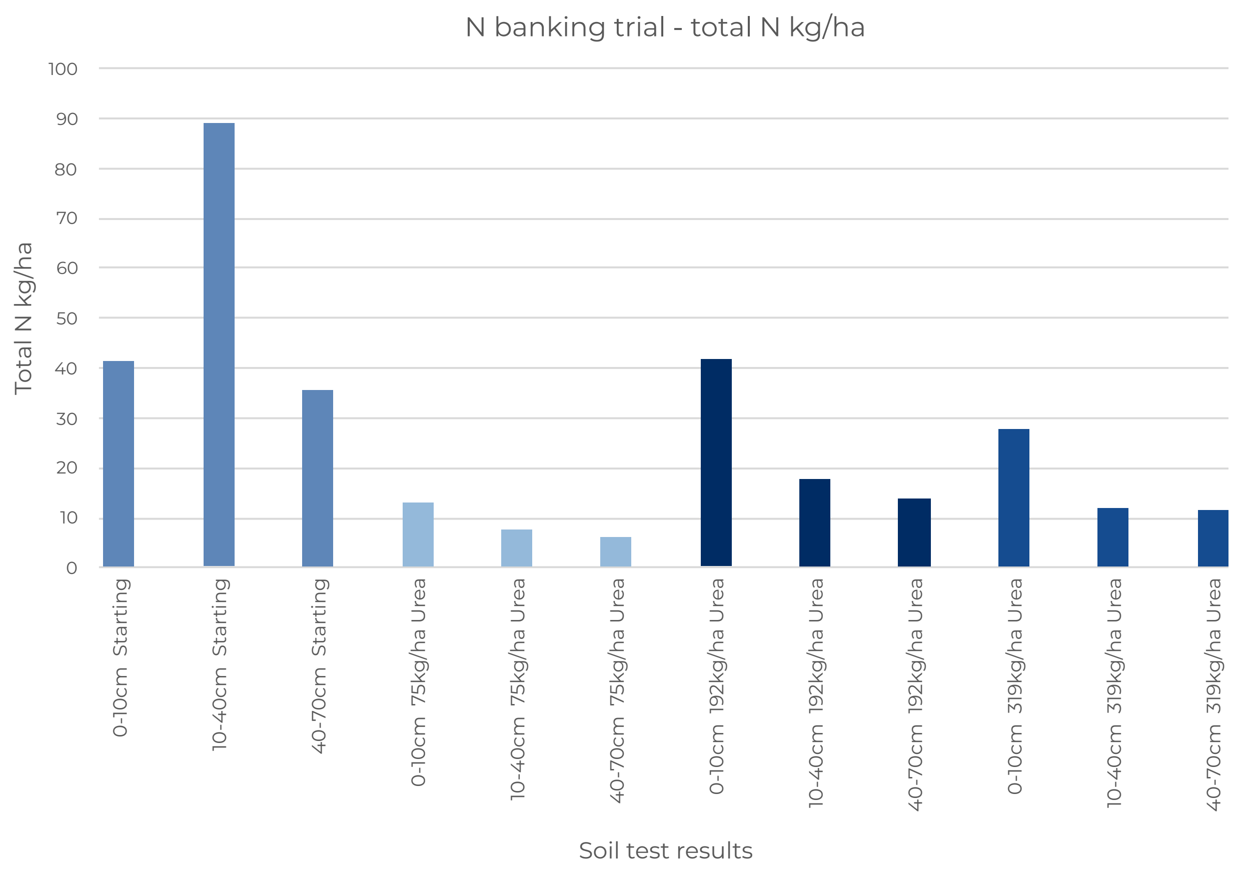

Figure 3. Nitrogen banking trial – total N kg/ha

The starting soil nitrogen results were taken in May 2022, with the paddock coming out of a canola crop in 2021. When comparing the soil tests of pre and post-harvest, we can see a large portion of soil nitrogen has been used up in the deeper parts of the soil profile, with the biggest change in the 10-40cm depth.

Organic carbon levels (Table 8) have remained the same or shown a very slight increase. This is likely due to fluctuation of carbon levels depending on timing of sampling as well as variation seen with post-harvest samples compared to the entire paddock sample pre-sowing. Changes in soil organic carbon generally occur slowly over many seasons and therefore can be difficult to detect in the short term.

The soil water sample for urea applied at 192kg/ha at 40-70cm looks to be an outlier. Across the majority of samples, soil-water content has decreased across all depths of the profile from pre-sowing to post-harvest. The samples do indicate that both the 192kg/ha and 319kg/ha urea treatments have increased soil water content across the profile compared to the 75kg/ha. However, it is very challenging to statistically prove this due to variability across the paddock. Plant available water (PAW) calculations were also completed across the samples, using information on soil type and crop type to assist with accuracy. PAW shows that the profile is extremely dry post-harvest for all three treatments, due to the above average rainfall at this site it is assumed that water was not necessarily a limiting factor in this crop, but has since been removed from the profile.

Harvest index cuts were taken prior to the machine harvest, demonstrating a relationship between nitrogen application with yield and protein content. These results are not statistical as the trial is not replicated. See comparison of dry matter, harvest index, grain yield and seed protein content in Table 9 and Figure 4.

Table 9. Harvest cuts results

UREA RATE	TOTAL DRY MATTER (T/HA)	HARVEST INDEX	GRAIN YIELD (T/HA AT 11% MOISTURE)	SEED PROTEIN (% AT 11% MOISTURE)
75kg/ha	8.1	0.41	3.76	12.5
190kg/ha	8.7	0.48	4.64	12.4
320kg/ha	9.2	0.45	4.68	13.4

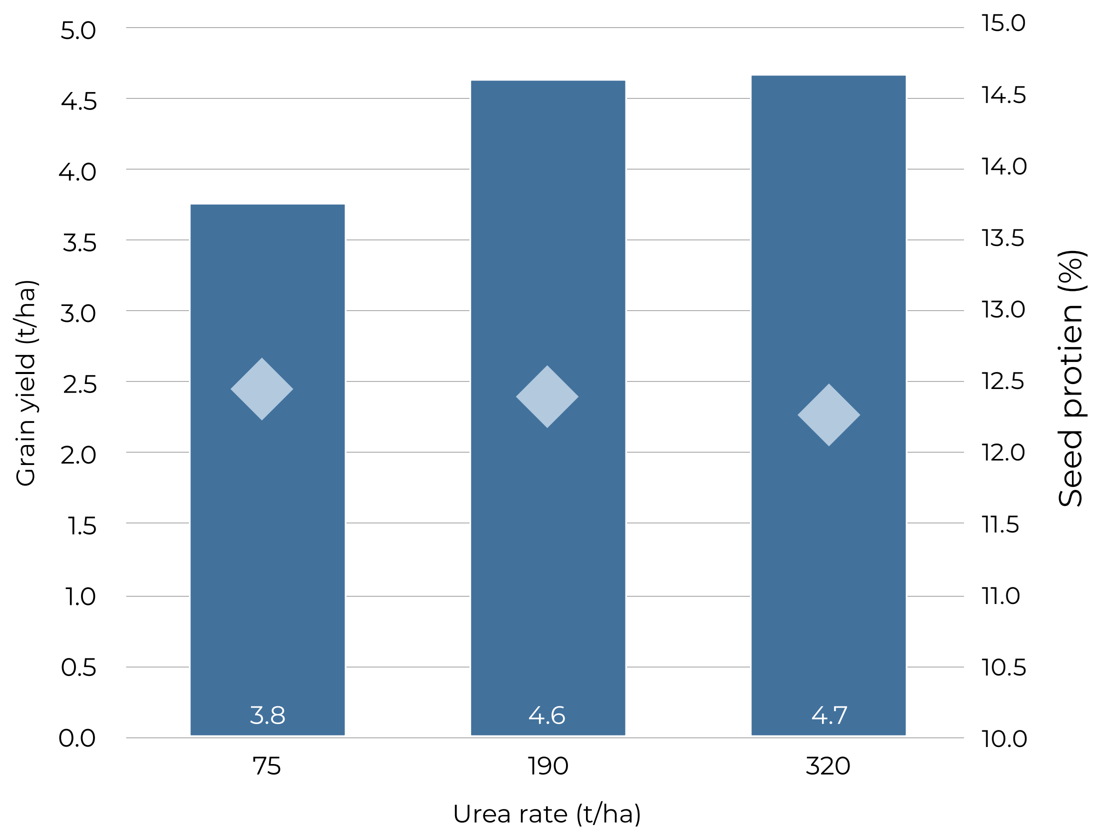

Figure 4. Harvest index cuts – yield and protein %

The yield for each treatment was below the predicted yield, as estimated prior to nitrogen application with modelling from data collected at the site, climate history and season predictions. The paddock suffered a high disease load of Rust, with Septoria coming in late and unfortunately the fungicides used were not able to control the severity and therefore a yield impact was seen. Increased nitrogen resulted in increased yield, with yield capped at the 190kg/ha urea treatment and only protein % increasing in the 320kg/ha urea treatment.

Normalised Difference Vegetation Index (NDVI) images and yield maps for the trial can be seen in Figures 5-7. These images indicate that the 320kg/ha urea treatment had increased the green area in September, compared to the other treatments, however by November it was equal to the 192kg/ha treatment. Yield for both of these was not different, however the images do indicate a lower yield for the 75kg/ha treatment. The images, particularly the yield map, shows a line within the paddock of low compared to high yield. This line coincides with the split of the two wheat varieties, Calibre and Rockstar and potentially highlights disease tolerance between the two.

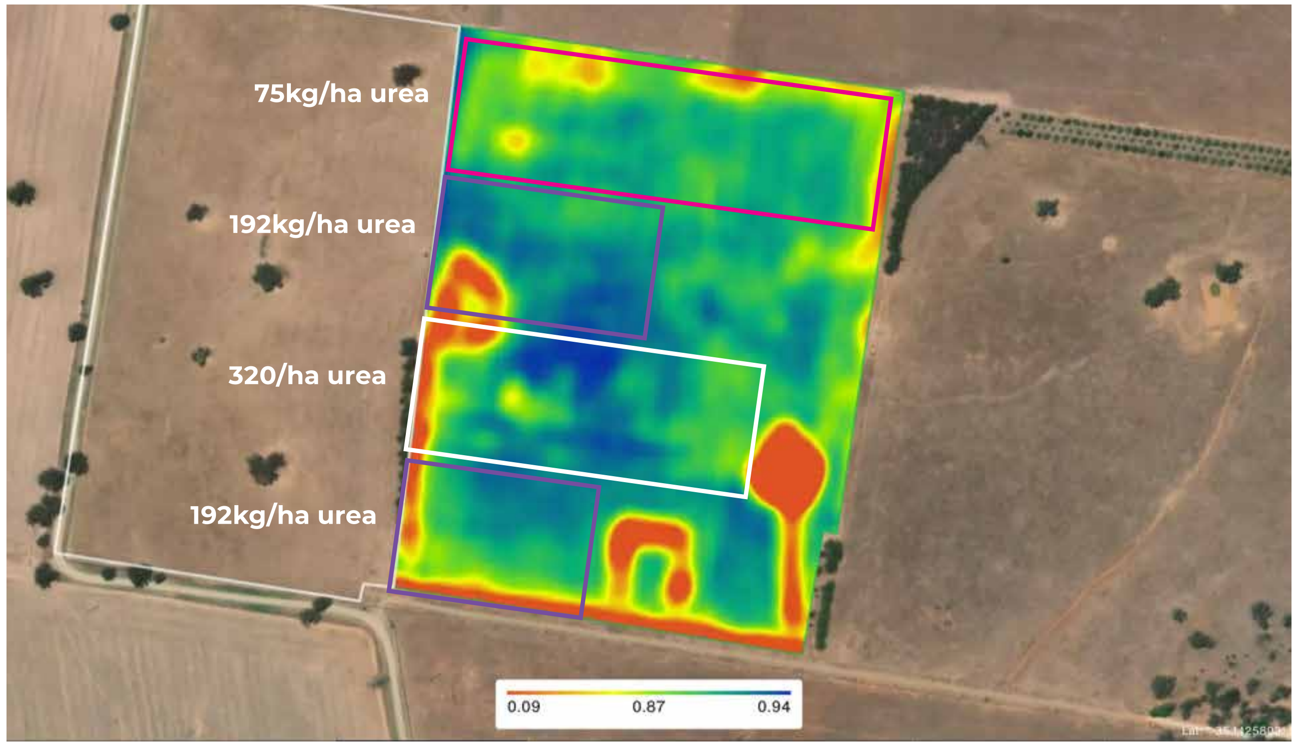

Figure 5. NDVI image 29 September 2022

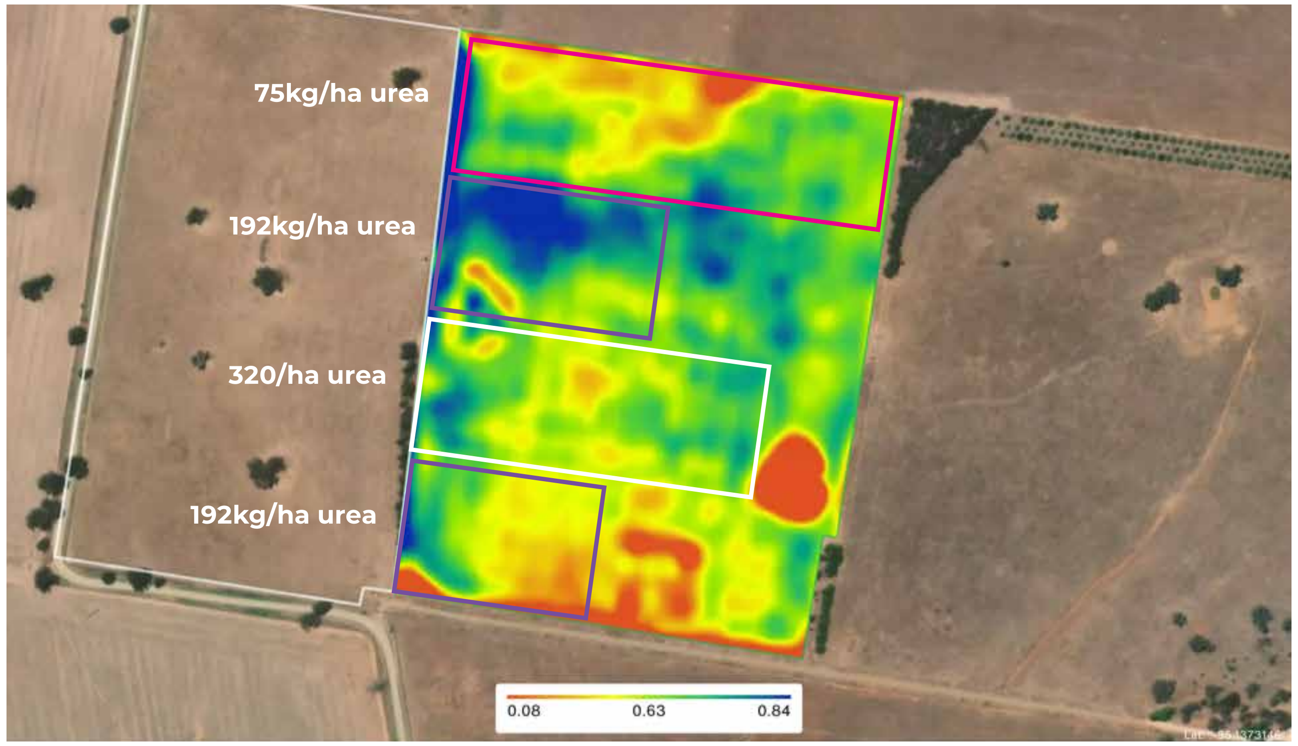

Figure 6. NDVI image 18 November 2022

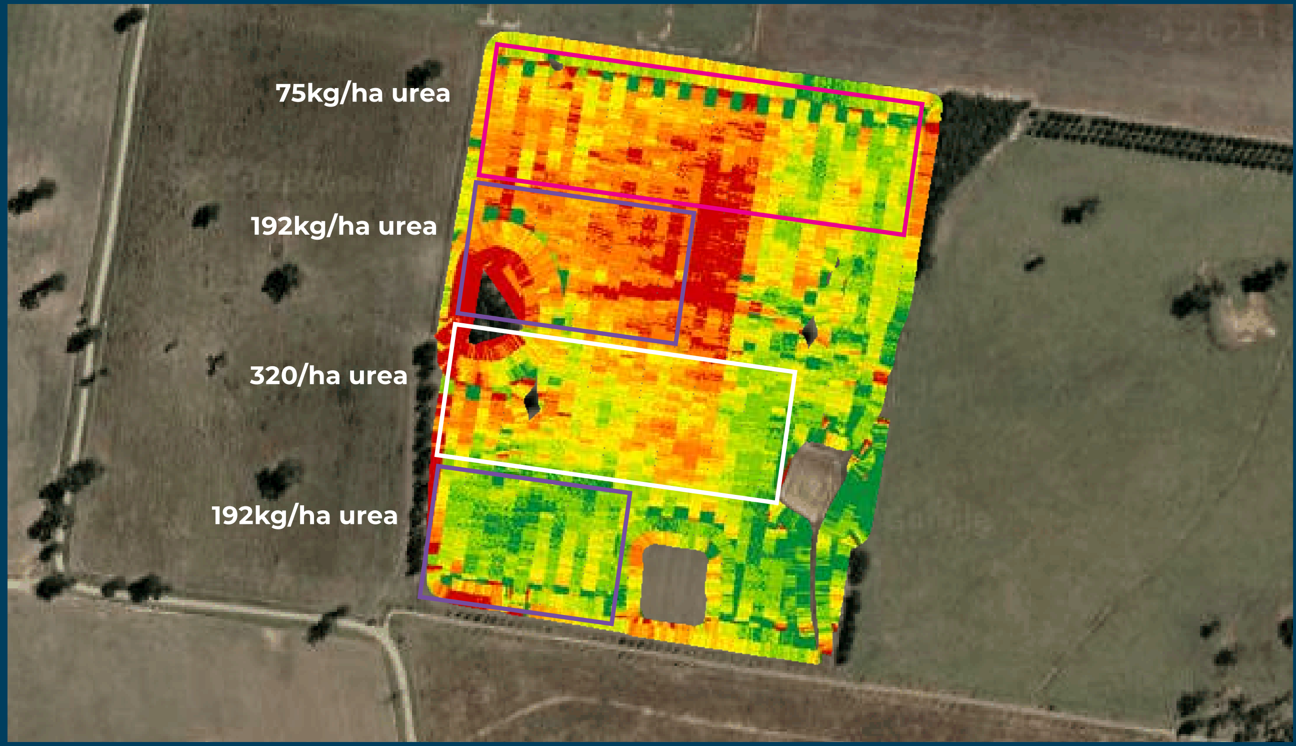

Figure 7. Yield map wheat paddock

For the economic analysis we assume there is a statistical difference between protein content (not proven) and the 190kg/ha urea rate is equivalent to H2 quality, and the 320kg/ha urea rate is equivalent to APH2 quality.

Sales at the GrainCorp Temora sub-station show that Hard Wheat grade 2 (H2) sales are at $390/t and APH2 are at $436/t. Urea prices fluctuated in 2022 depending on time of purchase, a price of $1,200/t is used for the below calculation.

Urea @ 190kg/ha: 4.6t/ha x $390 = $1794

Urea @ 320kg/ha: 4.7t/ha x $435 = $2045

An extra 130kg/ha of urea required to increase the rate, @ $1,200/t is an additional $156/ha

$2045 - $1794 - $156 = $95/ha profit for additional urea applied.

CONCLUSION

Increasing the supply of nutrients, including nitrogen, to the soil system will allow for microbial activity to continue to function. Over time it may allow for the maintenance or a slight increase in organic carbon content. It is not expected to see any real change in the system at this early stage. Increased soil water content is also a factor that can be impacted by the addition of nitrogen to the soil system. In this demonstration, yield was limited due to disease and did not reach predicted rates set in June. Water was not considered a limiting factor, however PAW is very low post-harvest. The highest nitrogen rate provided the highest yield and protein percentage, as expected, however post-harvest nitrogen stores were lower in the 320kg/ha urea treatment compared to the 190kg/ha urea treatment. This is likely due to a portion of nitrogen contributing to the increased protein content of 320kg/ha urea treatment yield and variation when testing in the paddock.

GLOSSARY

Bulk density: the volume of soil particles and pores among the particles, calculated as dry weight of soil divided by its volume.

Deciles: Rainfall deciles take the historic rainfall records at a location and sort into ten equal parts. Decile 1 are the years with lowest rainfall on record and decile 10 are the highest.

N15 plant analysis: A technique used to study the nitrogen cycle, providing more information on the conversions of one nitrogen compound to another.

pH in $CaCl_2$: pH measured in 0.01M CaCl1 solution instead of water is often preferred as it is less affected by soil electrolyte concentration and results in a more consistent measurement.

Plant available water: the maximum amount of water stored in the soil profile that is available for plant use.

Wilting point: the amount of water that is held so tightly by the soil that roots cannot absorb and therefore the plant will wilt.

Field capacity: the amount of soil water content held in soil after excess water has drained away, through gravity not through plants or evaporation.

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