Putting technology and science to the test to increase nitrogen use efficiency and environmental care

A Northern Agricultural Catchments Council farm demonstration

By Equii

Project ID: 1712-05-04

"Putting technology and science to the test to increase nitrogen use efficiency and environmental care" was delivered by The Trustee for Pluske Family Trust T/A Equii Pty Ltd. It was supported by NACC through funding from the Australian Government's National Landcare Program

1.0 AIM

The project addressed the important problem for the northern agricultural region of nitrogen (N) use efficiency. It aimed to demonstrate better use of the expensive input cost of fertiliser N by measuring increases in N use efficiency, with consequential decreases in potential harm to natural resources, through use of an integrated approach to N decisions.

The project helped address the issues of:

- financial sustainability of farming businesses through improved profits
- sustainability of the natural resource of soils upon which all farming businesses depend through better plant growth and less acidification as a consequence of reduced leaching of expensive fertiliser N
- reducing wastage of expensive, energy-hungry N fertiliser
- engagement, informing and capacity building of landholders in better N management to maximise sustainable agricultural and environmental care
- demonstration of the benefits of practice change for fertiliser N management.

2.0 BACKGROUND

In-season fertiliser N decisions are often the difference between positive and negative financial results for landholders in the NACC region so profitable use of fertiliser N is important for sustained land occupancy and beneficial land management. Fertiliser N accounts for about 25% of total variable costs for grain growers in the region so it is an expensive investment upon which good returns are needed.

Wasteful and expensive overuse of N fertiliser is damaging to the soil resource because when N leaches through the soil profile it acidifies the soil and increases potential damage to groundwater resources. Because of this, environmental care is synonymous with good fiscal use of N because wastage of expensive, energy-consuming N inputs is minimised.

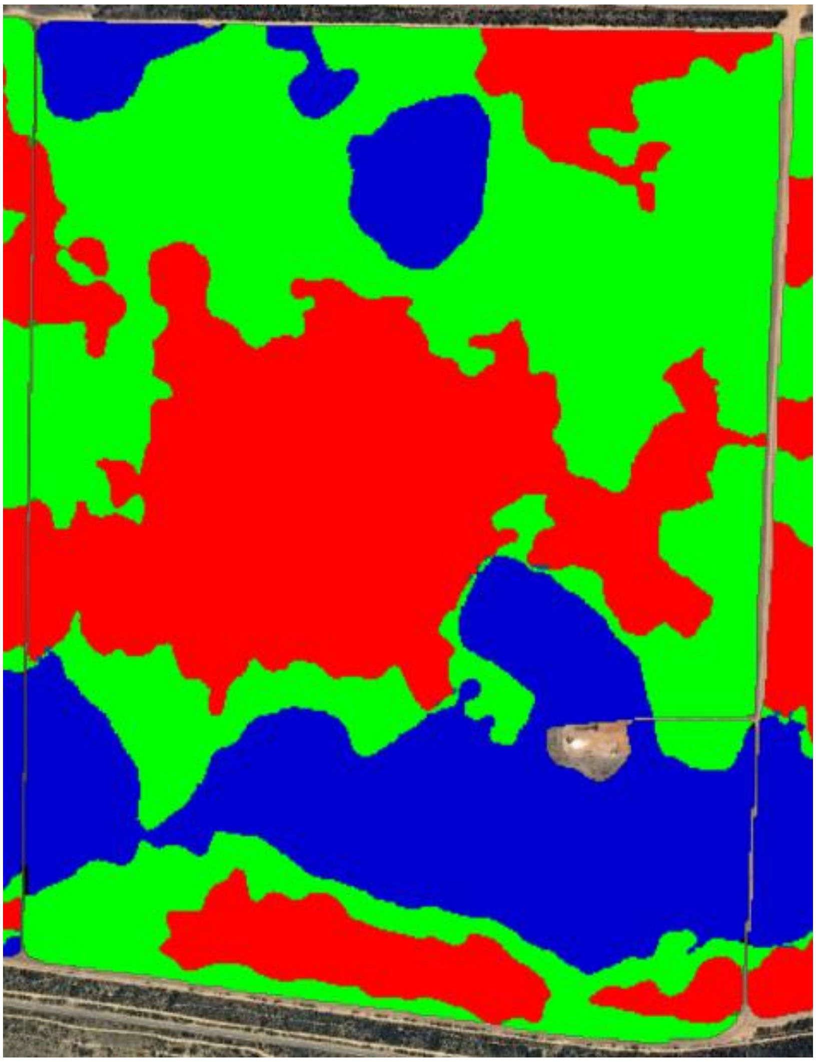
The project was the first largescale demonstration of an integrated approach to in-season N that links disparate data, proven science and spatial technologies to deliver a practical outcome which increases profits and environmental care for landholders. It utilised known spatial variability with temporal information to fine tune fertiliser N rates within a large area of crop as the challenging 2017 growing season revealed itself.

The approach for determining N rates bridges the gap between N demand and N supply with the most cost-effective rates of fertiliser N. It differs to historical techniques for N management like fertiliser company soil testing services and various decision supports (e.g. N Broadacre, DAFWA's SYN, NAVAIL and N calculators) because it focuses on estimating grain yield (the biggest determinant of N requirement) across large areas of farmland. Other methods are piecemeal in their approach and only deal with one small site or zone within one paddock at one time. They focus on small, measurable parts of the “N jigsaw” but are limited because they do not consider other, equally or more important parts of the jigsaw.

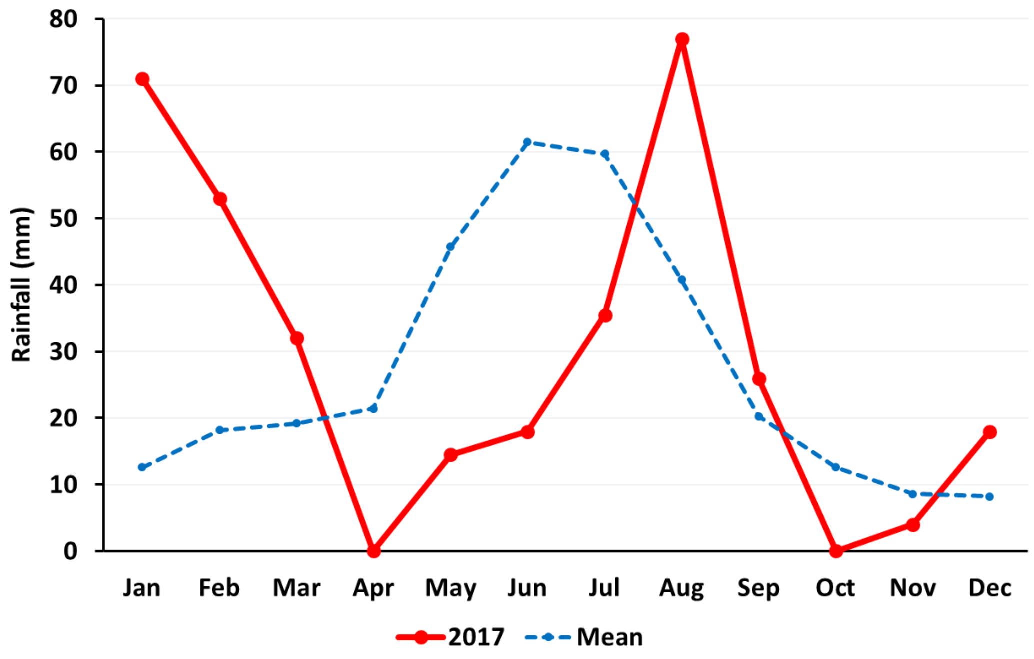
3.0 DEMONSTRATION SITE DETAILS

The project was located on Peter Freeman's Eradu property, Bundear Farms, approximately 55 km east of Geraldton on the Geraldton-Mount Magnet Road. It was conducted in the 2017 growing season.

The block was representative of the Eradu sandplain soils found in the area; predominantly deep yellow sands with zones of yellow sandy earths. Electromagnetic (EM), radiometric and historical yield maps were used to assist in determining management units/yield zones within the project site that corresponded to differences in soil type and depth. The map below shows these zones where red is low yield, green is medium yield and blue is high yield.



Average yearly rainfall at the site for the last decade is 316 mm. Total rainfall for 2017 was 349 mm with 156 mm of it received before the end of March (see rainfall chart below comparing average rainfall to 2017 rainfall). No rain was received at all in April and May/June rainfall was 75 mm less than average.



The unusual pattern of rainfall, especially the extremely dry period at and after the usual seeding period of April/May, meant yield expectations were low for most of the growing season. Good rainfall in late July and August was extremely unusual resulting in unexpected increases in yield expectations and unchartered conditions for predicting final yields upon which to base in-season fertiliser N rates.

The project site was managed by the grower, Peter Freeman, with agronomic and technical input support provided by Craig Topham of Agrarian Management.

Prior to seeding, Treflan (2 L/ha) and Logran (30 g/ha) herbicides were applied.

The site was dry-seeded by the grower with 70 kg/ha Ninja wheat on 9 May 2017.

Fertiliser nutrients applied at seeding were approximately 11 kg/ha of phosphorus, 12 kg/ha of potassium and 40 kg/ha of N. These were applied as

- 50 kg/ha ammonium sulphate fertiliser broadcast prior to seeding
- 50 L/ha liquid urea ammonium nitrate (UAN) fertiliser banded under the seed at seeding
- 75 - 85 kg/ha DAP fertiliser drilled at seeding
- 22 - 26 kg/ha muriate of potash fertiliser drilled at seeding.

The crop germinated on 25 May and the project's fertiliser N treatments (described below) were applied on 28 July.

4.0 METHOD

Standard in-season N management (St-N) was compared to optimum in-season nitrogen rates (Op-N) calculated using the approach that utilised:

- known spatial variability in yield (from historical yield maps)
- both spatial (across the block) and temporal (across years) information to forecast yields (the biggest determinant of N rates) in the different management units
- evidence-based predictions of fertiliser N responsiveness to bridge any gaps between N demand and N supply with the most cost-effective rates of fertiliser N
- in-season soil testing for mineral N.

The N rates calculated for St-N and Op-N for each of the three management units were compared in a trial within each management unit. Each trial consisted of four N rates and three replicates; a total of 36 plots within the project site. The trials were established on 28 July 2017, considerably later than originally anticipated because of the extremely dry start and poor season up to that time.

The poor start to the season meant St-N was different to what was planned pre-season, so fertiliser N rates were adjusted slightly to compare the prediction methods while also assessing overall N responsiveness. The N treatments were:

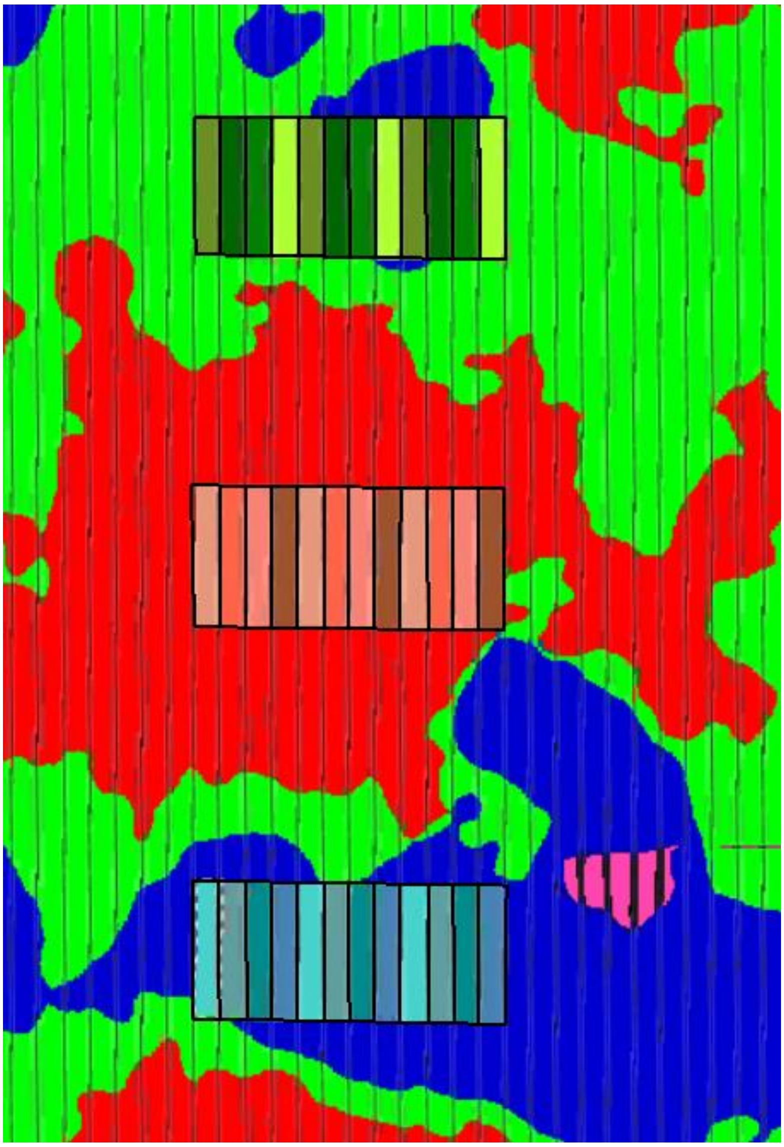
- Nil N
- St-N
- Op-N
- 1.5 x whichever of St-N and Op-N was highest (1.5 x max.)

The in-season N rates (and total N rates inclusive of N applied before and at seeding in parentheses) applied to each trial and their approximate costs are shown in the table below.

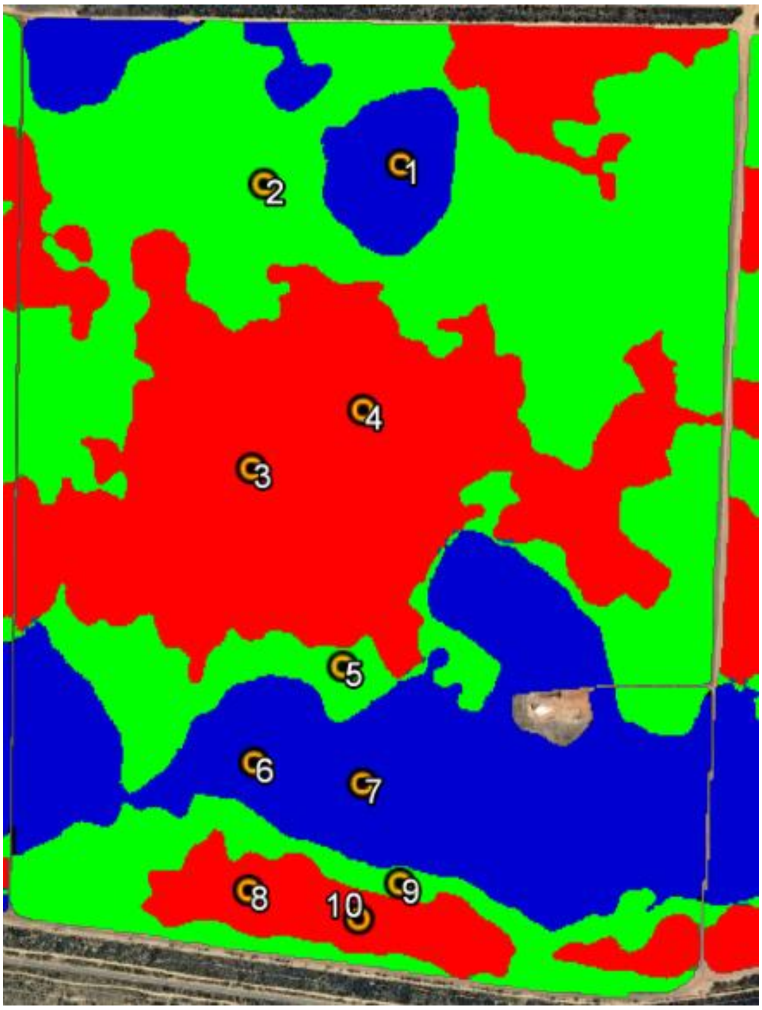
Management unit	**Expected yield (t/ha)**	**N treatment**	**Fertiliser N rate (kg/ha)**	**Treatment cost ($/ha)**
Low	1.9	Nil N	0 (40)	0.00
		Op-N	0 (40)	0.00
		St-N	15 (55)	16.50
		1.5 x max.	20 (60)	22.00
Medium	2.1	Nil N = Op-N	0 (40)	0.00
		-	10 (50)	11.00
		St-N	25 (65)	27.50
		1.5 x max.	40 (80)	44.00
High	2.5	Nil N	0 (40)	0.00
		Op-N	20 (60)	22.00
		St-N	40 (80)	44.00
		1.5 x max.	60 (100)	66.00

The N rate treatments were applied on 28 July as UAN liquid fertiliser by boomspray in 200 m long by 37 m wide plots (plots approx. 0.75 ha). The width of the plots ensured at least two complete harvester widths (14 m wide) could be used to measure plot yields at harvest.

The figure below shows where the plots were located within the management zones.



Before the start of the season, soil samples were collected from three depths (0 – 10 cm, 10 – 20 cm and 20 – 30 cm) at 10 sites (numbered 1 – 10 on the map below) on 14 December 2016 and analysed for standard soil tests. *All pre-season soil test results are shown at the end of the report.*



In-season soil tests for mineral N were collected from two depths (0 -10 cm and 10 – 30 cm) at the same 10 sites on 4 July 2017 and analysed for nitrate N and ammonium N. *These in-season mineral N soil test results are shown at the end of the report.*

On 4 July 2017plant tissue tests were also collected to gauge the adequacy of uptake of all nutrients including N. *The plant tissue test results are shown at the end of the report.*

Plant biomass of the growing wheat crop was gauged using NDVI (normalised difference vegetation index) sourced for 17 September. *The NDVI report is shown at the end of the report.*

Plots were harvested with a John Deere S680 harvester on 27 November 2017, much later than expected because of the late finish to the season. The harvest results were statistically analysed.

Grain protein was not measured, however the average grain protein concentration for the block was about 10.5% and all grain made the noodle segregation.

5.0 RESULTS

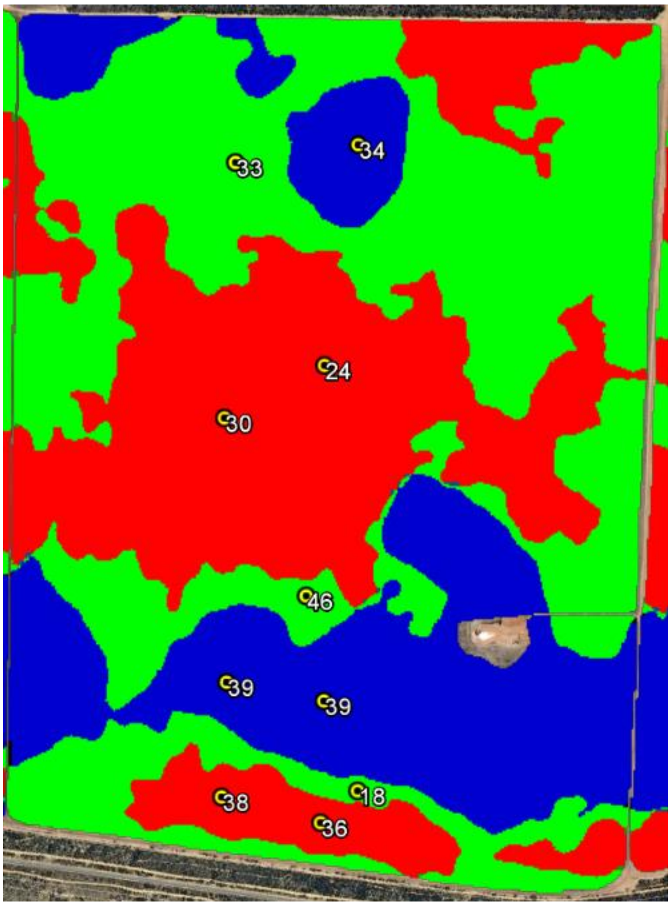
Pre-season soil tests

The soil samples collected on 16 December 2016 indicated:

- acidity was not a limitation to root growth down to 30 cm
- soil phosphorus levels (measured by the Colwell method) were high on low PBI's (phosphorus buffer index) indicating only starter fertiliser phosphorus was required for the 2017 crop. The DGT test for phosphorus (measured by the diffuse gradients in then films method) was also used to ascertain soil reserves. The DGT results were very high at all sites further suggesting a yield response to fresh fertiliser phosphorus was unlikely. "Insurance" fertiliser phosphorus was applied nonetheless
- soil potassium levels were marginal and crop growth and yield were likely to be adversely affected if fertiliser potassium was not applied
- organic carbon averaged 0.4% which is common for this soil type and region.

In-season soil tests for mineral N

The soil samples collected on 5 July 2017 and analysed for mineral N averaged 15 and 7 mg/kg in the 0 – 10 cm and 10 – 30 cm samples respectively. The is the equivalent of 35 – 40 kg N/ha which is a substantial amount for that time of the growing season, although not unexpected in this situation given the amount of fertiliser N applied before/at seeding, an absence of rains to leach mineral N and poor plant growth and uptake of N to this point in time. The quantities of mineral N in the top 30 cm of soil calculated from the soil tests are shown for the 10 sites in the map below. These results were considered when determining the Op-N rates for the trials in each management unit.



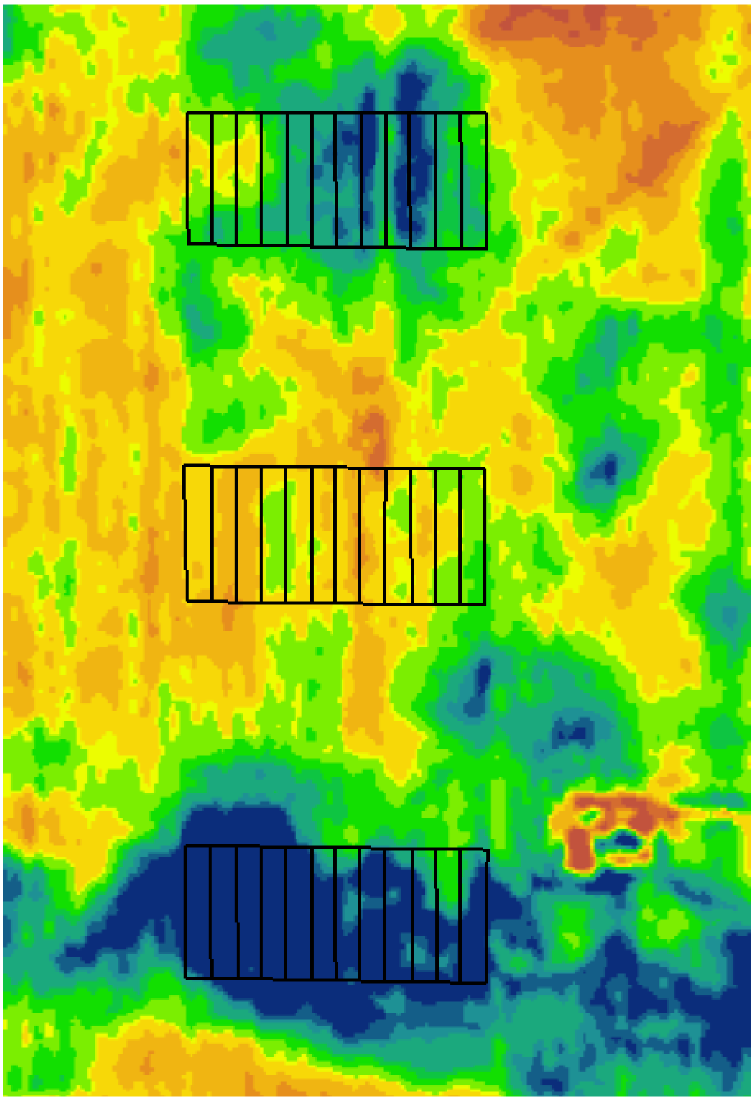
Plant tissue tests

Plant samples on 4 July 2017 indicated all nutrients were adequately supplied, including N up to that point of the season.

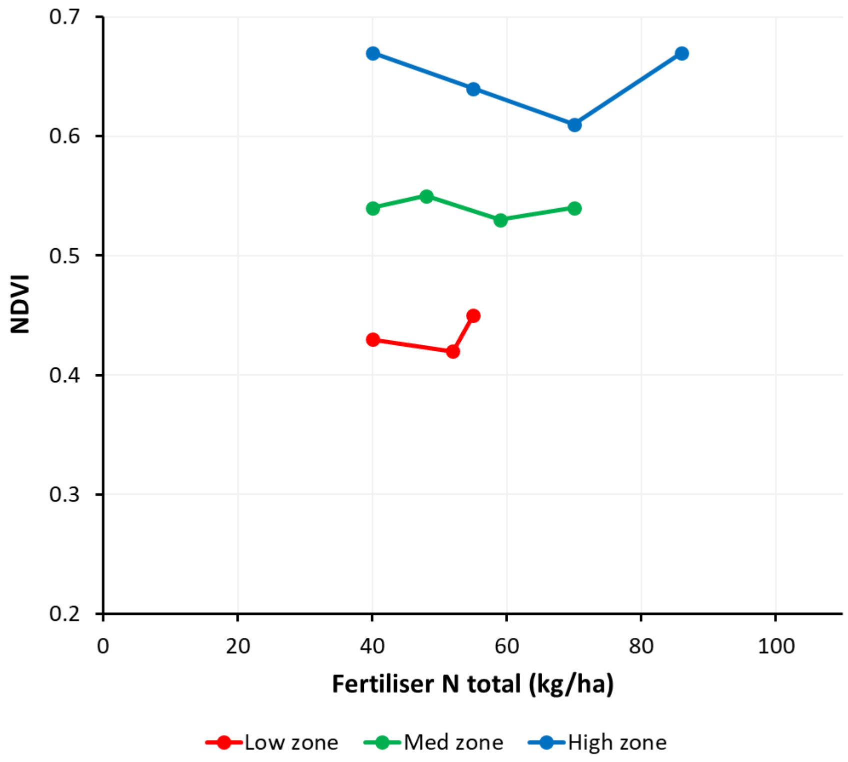
The soil and tissue tests, combined with good agronomy, good management and previous amelioration of soil compaction, acidity and non-wetting, gave confidence that responses to in-season N would not be constrained by other factors.

NDVI

The NDVI for 17 September 2017 (shown below) clearly showed there were differences in vegetation between the management units but suggested vegetation within management units was not influenced by the N treatments.



The analysis of the NDVI data (see graph below) confirmed this to be the case; the amount of vegetation reflected the yield potential of each yield zone and N treatment did not change the amount of vegetation within any zone.



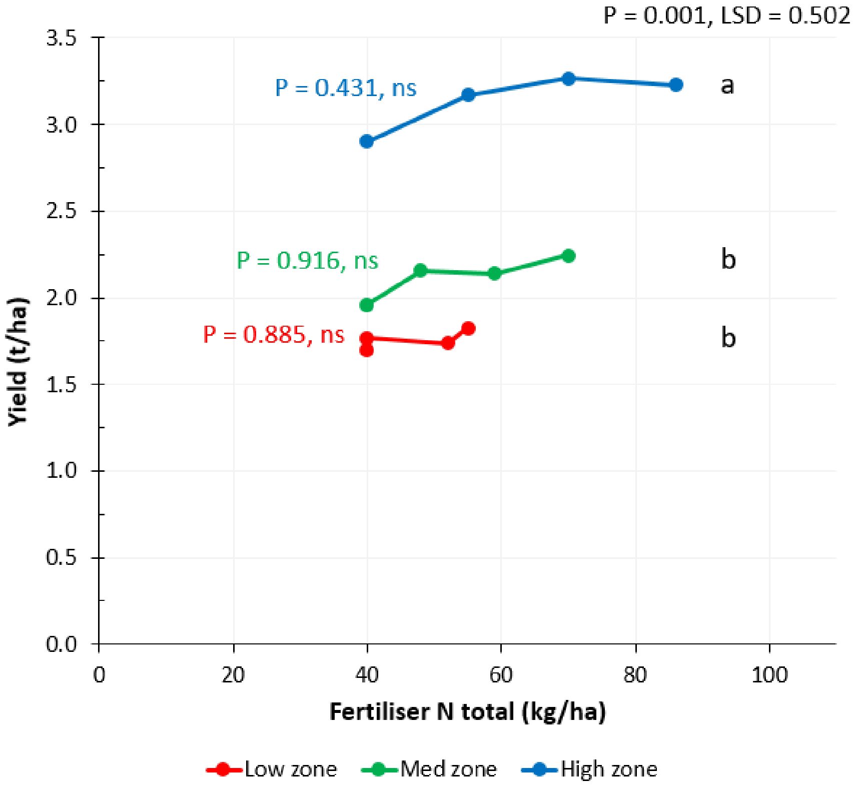
Harvest yield

Similar to the NDVI results, there were no differences in harvest yields between the N treatments in any of the management units (see results in the table and graph below). Harvest yield was significantly higher in the high yield zone than in the low and medium units (P = 0.001).

Yield did not respond to in-season N in any of management units, even though there was a slight but not statistically significant yield increase to N rate in the high management unit.

Management unit	N treatment	Fertiliser N rate (kg/ha)	Yield (t/ha)	Std. error
Low (b)	Nil N	0 (40)	1.70	0.22
P = 0.885, ns	Op-N	0 (40)	1.77	0.13
	St-N	15 (55)	1.74	0.17
	1.5 x max.	20 (60)	1.83	0.13
Medium (b)	Nil N = Op-N	0 (40)	1.96	0.20
P = 0.916, ns	-	10 (50)	2.16	0.36
	St-N	25 (65)	2.14	0.25
	1.5 x max.	40 (80)	2.24	0.33
High (a)	Nil N	0 (40)	2.90	0.16
P = 0.431, ns	Op-N	20 (60)	3.17	0.21
	St-N	40 (80)	3.27	0.11
	1.5 x max.	60 (100)	3.23	0.10

Management units with different letters are significantly different; P = 0.001, LSD = 0.502



Efficiency of in-season N

N use efficiency (NUE) is calculated by dividing the yield increase (over and above the yield from not applying any N) obtained from applying a given rate of N, divided by that rate of N. Given yields from applying in-season N did vary significantly from the Nil N treatment in any of the management unit trials, the NUE calculation and NUE comparisons are irrelevant for this project as NUE was 0 for all N treatments. Similarly, mass balance for N (which quantifies how much applied N ends up plants and grain) was the same for all N treatments as it was for the Nil N treatment because there were no significant differences in either biomass or yield. At this project site in 2017, any investment in in-season N was wasted.

6.0 CONCLUSION

In this project Op-N was more accurate than St-N for predicting in-season N rates because yield did not respond to N in any of the three management units within the project site. Even though St-N rates were calculated using lower yield expectations than were actually achieved (e.g. 2.5 t/ha rather than 3.1 t/ha in the high yield zone), the St-N rates were still too high. St-N rates would have been even more inappropriate if yield expectations in late July were accurate and would have resulted in up to 70 kg N/ha and $77/ha being wasted. At this project site in 2017 high in-season rates of N were wasted and were costly, both financially and environmentally.

The highest St-N rate of 40 kg/ha equated to a waste of $44/ha and, if that N was leached it would have costed another $2 – 3/ha in lime to negate the acidity it caused (the equivalent of about 150 kg/ha of lime that would be required to neutralise soil acidity caused by N leaching).

The 40 kg N/ha applied before and at seeding was enough to achieve final yields; yields that were very good given the unusual and unfavourable early seasonal conditions. The project was unable to ascertain if that 40 kg N/ha was too much, particularly in the low and medium management units. Ordinarily 40 kg N/ha would be considered as the “starter” N portion of the total N requirement which would be topped up in-season N. It would be rare to consider 40 kg N/ha to be sufficient for the whole season’s growth.

In this project in-season soil testing for N was an important piece of information for deciding appropriate in-season fertiliser N rates. The testing measured large quantities of plant-available N located near and beneath growing roots. It is likely this N and additional N mineralised from organic N in the soil when the soil was moist and warm in spring was sufficient to fuel the high yields that were ultimately achieved. While in-season testing of mineral N was useful at this site, this may not always be the case because if there is heavy rain after the testing measured N can leach below the root zone. For this reason there must be considered and careful interpretation of any in-season soil test results for mineral N.

In this project paddock variability had more impact on yield than N rate. Putting more effort into understanding paddock variability and causes thereof had more impact on yield and NUE than calculating N rates using historical approaches. It is clear paddock and seasonal variabilities have a huge impact on NUE and profitability of fertiliser N, which is what the new approach for determining Op-N considers.

7.0 ACKNOWLEDGMENTS

Equii acknowledges the funding and support of:

- NACC
- NLP
- Peter Freeman (Bundear Farms)
- Craig Topham (Agrarian Management)

NACC demonstration project (Bundear Farms): soil tests - 14 Dec 2017

Site	1	2	3	4	5	6	7	8	9	10
Lat	-28.673963	-28.674295	-28.679077	-28.678094	-28.682409	-28.684024	-28.684376	-28.686172	-28.686057	-28.686654
Lon	115.159065	115.156446	115.15621	115.158345	115.157956	115.156257	115.158333	115.156149	115.15905	115.158259
2018 Crop/Pasture	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat
2018 Expected Yield	2.8	2.2	1.8	1.8	2.2	2.8	2.8	1.8	2.2	1.8

VERY LOW | LOW | OK

pH ($CaCl_2$) 0-10cm	6.6	6.6	7.0	6.9	5.3	6.6	6.5	7.0	6.3	7.0
critical level	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
pH ($CaCl_2$) 10-20cm	6.0	6.0	6.9	6.9	4.8	6.2	5.5	6.3	5.8	6.4
critical level	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
pH ($CaCl_2$) 20-30cm	4.7	5.0	6.7	6.7	4.4	4.9	5.0	5.5	5.2	5.7
critical level	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Colwell-P (mg/kg) 0-10cm	8	16	14	16	15	16	14	15	8	20
critical level	14	21	17	17	22	22	13	15	16	16
PBI 0-10cm	1	11	8	7	6	9	1	5	4	7
Colwell-K (mg/kg) 0-10cm	39	25	28	37	45	42	28	25	29	27
critical level	106	92	82	82	92	108	107	82	91	82
DGT-P (ug/L) 0-10cm	72	105	85	98	96	87	105	123	83	147
Organic-C (%) 0-10cm	0.37	0.17	0.20	0.19	0.21	1.14	0.48	0.33	0.24	0.45

kg P/ha	8	3	1		5	4			11	
kg K/ha	23	26	20	15	14	22	29	22	23	21
t lime/ha					0.7					

NACC Demonstration Project

Samples collected 5 July 2017

Bundear Farms

Paddock	A Block	A Block	A Block	A Block	A Block	A Block	A Block	A Block	A Block	A Block
Site	**No 1**	**No 2**	**No 3**	**No 4**	**No 5**	**No 6**	**No 7**	**No 8**	**No 9**	**No 10**
Lat	-28.673963	-28.674295	-28.679077	-28.678094	-28.682409	-28.684024	-28.684376	-28.686172	-28.686057	-28.686654
Lon	115.159065	115.156446	115.15621	115.158345	115.157956	115.156257	115.158333	115.156149	115.15905	115.158259
Yield zone	High	Medium	Low	Low	Medium	High	High	Low	Medium	Low
Apal Lab ID (0 - 10 cm)	BJ028	BJ030	BJ032	BJ034	BJ036	BJ038	BJ040	BJ042	BJ044	BJ046
Apal Lab ID (10 - 30 cm)	BJ029	BJ031	BJ033	BJ035	BJ037	BJ039	BJ041	BJ043	BJ045	BJ047
NO3-N (mg/kg) (0 - 10 cm)	13.0	13.8	8.5	6.1	15.8	13.9	16.8	14.4	4.6	9.5
NH4-N (mg/kg) (0 - 10 cm)	2.3	3.3	1.7	4.3	4.8	2.8	3.5	2.7	2.3	5.1
NO3-N (mg/kg) (10 - 30 cm)	4.3	2.8	5.4	2.3	6.9	4.0	4.2	4.9	1.5	3.8
NH4-N (mg/kg) (10 - 30 cm)	2.1	2.4	1.9	2.5	1.8	3.9	1.8	2.4	2.5	4.0

NACC Demonstration Project

Samples collected 5 July 2017

Bundear Farms

Paddock	A Block	A Block
Site	**Site 7**	**Site 10**
Lat	-28.684376	-28.686654
Lon	115.158333	115.158259
Apal Lab ID	BK012	BK013
Crop	Wheat	Wheat
Plant part	Whole tops	Whole tops
Growth stage	Tillering	Tillering
Relative growth	Okay	Okay
Nitrogen (%)	4.71	5.36
critical level	3.5	3.5
Phosphorus (%)	0.35	0.46
critical level	0.27	0.27
Potassium (%)	3.02	3.24
critical level	2	2
Sulphur (%)	0.32	0.35
critical level	0.19	0.19
N:S ratio	7	9
critical level	7 - 17	7 - 17
Copper (mg/kg)	6.2	6.3
critical level	4.8	4.8
Zinc (mg/kg)	37	37
critical level	18	18
Manganese (mg/kg)	54	34
critical level	22 - 300	22 - 300
Boron (mg/kg)	3.3	2.6
critical level	1 - 55	1 - 55
Nitrate-nitrogen (mg/kg)	581	876
Calcium (%)	0.51	0.55
Magnesium (%)	0.22	0.18
Sodium (%)	0.03	0.02
Chloride (%)	2	1.9
Iron (mg/kg)	214	142
Cobalt (mg/kg)	<0.06	<0.06
Molybdenum (mg/kg)	<0.20	0.48
Aluminium (mg/kg)	288	108

VERY LOW	LOW	OKAY	TOO HIGH

Interpretation by EQUII

EQUII
making the complex simple

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REPORT
NDVI

Farmsat™ MAPPING APPLICATION

SEASON **2017-2018** CROP **OTHER**

Bundear Farm
VARIETY **NOT PROVIDED**
FIELD **ESSENTIAL**
SOWING DATE **25/04/2017**
AREA **214.4 HA**

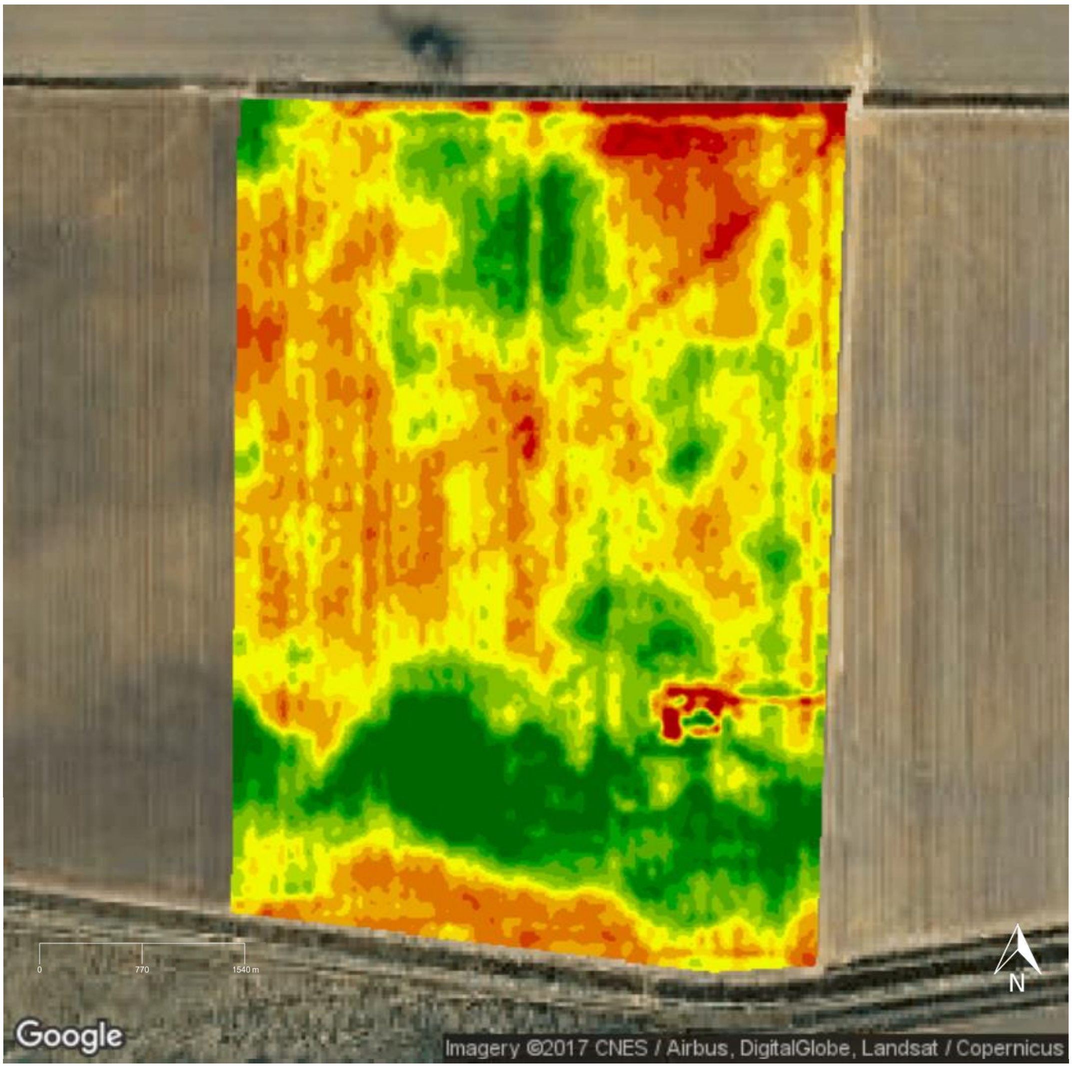

IMAGE DATE
13/09/2017

AVERAGE NDVI
0.48

Normalised Difference Vegetation Index (NDVI) is an indicator of crop vigor and crop development. Areas of high vegetation will have a higher NDVI reading and areas of low vegetation will have a lower NDVI reading. These maps have a scale of 0 to 1 and are created using the satellite images.

INDEX														
NDVI	0.12	0.33	0.36	0.38	0.41	0.44	0.46	0.49	0.51	0.54	0.57	0.59	0.62	0.75
AREA (HA)	1.5	2.6	4.4	19.9	40.4	30.6	34.9	15.7	18	13.4	7.4	10.8	14.7	
AREA (%)	0.7%	1.2%	2.1%	9.3%	18.8%	14.3%	16.3%	7.3%	8.4%	6.3%	3.5%	5%	6.9%	