Economic and financial analysis of precision variable rate applications (VRA) of nitrogen

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Key points

- The use of variable-rate technology for nitrogen (VRT-nitrogen) application had mixed gross margin results given measured wheat yields, protein levels, calculated income and nitrogen costs in the nitrogen-rate trials undertaken at Yarrawonga and Dookie during 2017.
- Based on initial results at Yarrawonga and Dookie (using 19 and 13 years of wheat and canola yield responses to growing season rainfalls, respectively), the costs of conducting variable rate applications of nitrogen would require crop yields to increase by about 1%, or applied nitrogen costs to be reduced by at least 70%, before the approach breaks even over time.
- High overhead cost structures increase the risk of negative farm income. As VRT increases overhead costs, reviewing overall cost structures before adopting the technology is advisable.

Background

In 2017, wheat paddocks at Yarrawonga and Dookie each hosted nitrogen-rate experiments as part of the GRDC investment *Maintaining profitable farming systems in the Riverine Plains region* project. The trials were conducted on sub areas with low and high electromagnetic (EM38) conductivity. Based on results of these trials, measured wheat yields and protein content for each nitrogen-rate were available, allowing financial analysis for each experiment area to be completed. Using costs typical of the region, hypothetical farms were used to simulate financial risk for farms with high and low fixed costs.

Aims

To quantify the within-paddock variability of yields using records from paddocks in the Yarrawonga and Dookie areas and to quantify the impact of VRT-nitrogen on long-term, whole-farm financial risk.

Methods

For two farms at Yarrawonga and Dookie, farmer co-operators provided geo-referenced (harvester records) for wheat and canola yields, each from multiple paddocks over 19 and 13 crop years, respectively. The average yield of all wheat paddocks on a farm in a year was combined with growing season rainfall (GSR) data for that year, calculated from respective BOM monthly rainfall records for Yarrawonga and Dookie. In the case of wheat, 19 such data pairs could be assembled, while in case of canola 13 pairs of annual yield and GSR data were assembled, excluding two frost years. Quadratic functions were fitted to each of these data sets to show the relation of crop yield to GSR.

Using Charles Sturt University's (CSU) Spatial Data Analysis Network (SPAN), the geo-referenced yield records obtained over several years for the two paddocks were divided into grid areas of 90x90m (0.81ha). The grid areas were considered sufficiently large to serve as a basis for estimating the repeatability of yield categories (ie, highest quartile) over time and the correlations between crop yield and EM measures at different GSR levels.

In 2017, wheat paddocks at Yarrawonga and Dookie each hosted nitrogen-rate experiments in high and low electromagnetic (EM) zones. Based on these results, gross margins could be calculated for each experimental area considering local wheat and urea prices and assuming a 30% bonus for protein contents above 11.5%.

Farm financial risk can be expressed as the probability of a range of changes in cash flow measured over time. In this case, simulated 10-year cash books were prepared using locally valid variable, fixed and capital costs on two hypothetical farms. These costs included equipment replacement costs, based on typical machinery inventories and farmer-estimated timing of replacements. The additional costs of VRT equipment were estimated, with the assumption that all new machinery would be VRT-capable at the time of replacement.

Crop yields were simulated based on randomised 10-year historical sequences of GSR between 1960 and 2015, using wheat and canola responses to GSR. Annual gross income for each crop was calculated using these simulated yields, which were priced using randomised price sequences, based on recent historical weekly prices. The calculated cash flows included interest on the compounding cash balance, which included living costs



and income tax. This allowed calculation of the estimated change in the cash balance (similar to the bank balance) over each decade. @Risk software was used to record the change in this balance over 10,000 iterations (i.e. the 10-year cash balance was calculated 10,000 times using randomised price sequences), which allowed estimation of the probability of a range of these values, representing the risk profile for any scenario for a given farm. These indicate long-run probabilities of gains and losses.

Risk profiles were prepared for each farm before and after, including the cost of VRT given the assumption of 100% equity as starting positions.

Results

Calibrating VRT-nitrogen applications

Commonly-used benchmarks for calibrating VRT-nitrogen applications include EM38 measurements, long-term average yields and current normalised difference vegetation index (NDVI) measurements.

EM38 and yield

Several years of harvester yields and EM38 survey data summarised in 90x90m grid areas were available for the Yarrawonga and Dookie trial paddocks.

Overall, the highest EM38 levels were correlated with higher crop yields at low and medium GSR levels. In higher-rainfall seasons, crops can yield less in parts of the paddock with high EM38 than crops in the low EM parts of the paddock. Correspondingly, EM zoning can also indicate susceptibilities of high EM38 areas of the paddock to waterlogging in high-rainfall seasons and drought-proneness of low EM38 areas in drier seasons.

Gross margins of variable rate trials at Yarrawonga and Dookie, 2017

Gross margins for wheat yields measured in the 2017 variable rate trials at Yarrawonga and Dookie (*see Nitrogen response in different electromagnetic (EM) zones of the paddock* article, page 42) are presented in Table 1. These GM are based on wheat priced at $220/t, with a bonus of $30/t for protein above 11.5%, urea priced at $480/t and typical variable costs for these districts. The GM when nitrogen was applied at rates of 0, 40, 80, 120 and 160kg/ha and 40kg/ha as timed by NDVI are given for both the Yarrawonga (Farm 3) and Dookie (Farm 4) trials, along with results from both high and low EM38 plots on each farm.

During 2017, yield increased at both Yarrawonga (Farm 3) and Dookie (Farm 4), as total soil nitrogen (applied plus mineral nitrogen) increased (Figure 1).

The yield differences between trial paddocks are reflected in the GM (Figure 2), which is plotted against applied nitrogen rather than total soil nitrogen. There is high variability in yields between the trial sites, which makes these GM values difficult to interpret.

Yields at Yarrawonga were higher in the low EM38 zones compared with the high EM38 zones. At Dookie (Farm 4) this was reversed so the high EM38 zones yielded more than the low EM zones.

TABLE 1 Gross margins of different nitrogen application rates in high and low EM plots at Yarrawonga and Dookie

Applied nitrogen	Total nitrogen (soil + added N)	Yield	Protein*	Income#	Nitrogen cost^	Gross margin
kg/ha	kg/ha	t/ha	%	$/ha	$/ha	$/ha
Yarrawonga high EM						
0	129	5.7	9.3	1,254	0	932
40	169	6.4	10.2	1,408	19	1,067
80	209	5.8	10.5	1,276	38	916
120	249	6.2	11.5	1,394	58	1,014
160	289	6.3	11.6	1,416	77	1,017
NDVI 40	169	6.0	9.6	1,309	45	942
Yarrawonga low EM						
0	121	6.4	9.4	1,408	0	1,086
40	161	6.5	10.0	1,430	19	1,089
80	201	6.9	10.7	1,511	38	1,151
120	241	6.9	11.1	1,509	58	1,130
160	281	7.0	11.1	1,542	77	1,143
NDVI 40	161	6.8	11.8	1,485	45	1,118

Applied nitrogen	Total nitrogen (soil + added N)	Yield	Protein*	Income#	Nitrogen cost^	Gross margin
kg/ha	kg/ha	t/ha	%	$/ha	$/ha	$/ha
Dookie high EM						
0	206	3.6	10.2	792	0	470
40	246	3.8	10.5	829	19	488
80	286	4.4	11.6	998	38	638
120	326	4.6	11.5	1,040	58	660
160	366	4.4	12.5	1,002	77	604
NDVI 40	246	4.5	11.5	983	45	617
Dookie low EM						
0	182	3.3	11.9	756	0	434
40	222	3.4	13.5	771	19	430
80	262	3.3	14	745	38	385
120	302	3.8	14.7	866	58	486
160	342	3.7	14.1	853	77	454
NDVI 40	222	3.8	14.4	836	45	469

* Protein bonus of $30 for protein above 11.5%.
# Income based on wheat price of $220/t.
^ Nitrogen applied as urea at $480/t.

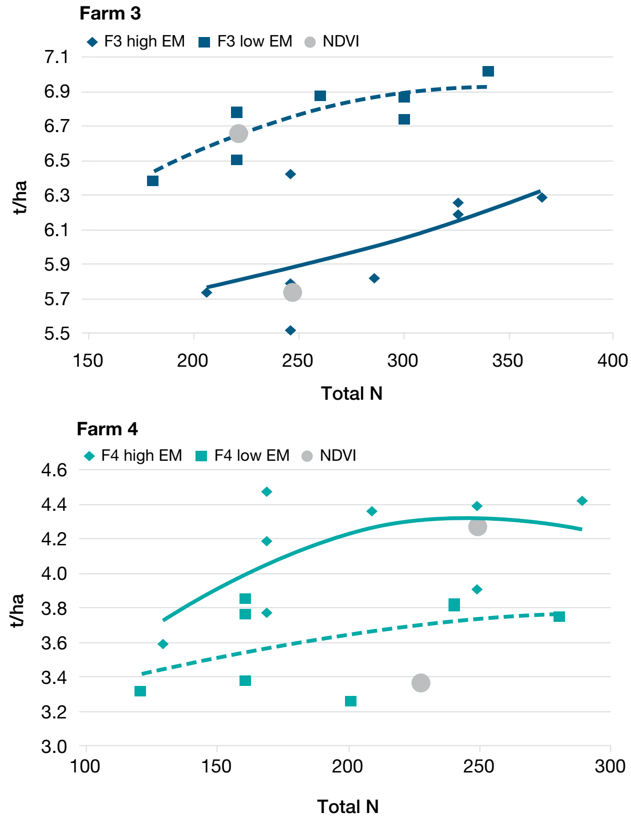

FIGURE 1 2017 trial wheat yield responses to nitrogen at the Yarrawonga (Farm 3) and Dookie (Farm 4) trial paddocks, in high and low EM plots , plotted against applied nitrogen, rather than total soil nitrogen

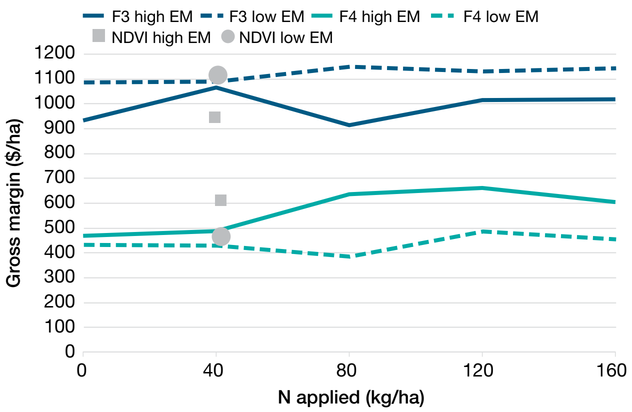

FIGURE 2 Wheat gross margins for 2017 at Yarrawonga (Farm 3) and Dookie (Farm 4)

Both EM zones at Yarrawonga had lower soil nitrogen compared with Dookie. There were yield responses to total nitrogen at Yarrawonga (Farm 3) for both EM levels, with the most economic total nitrogen rate for the high EM site 169 N (soil nitrogen — 129kg N/ha, applied nitrogen — 40kg N/ha. The most economic total nitrogen treatment for the low EM site was 201kg N/ha (soil nitrogen — 129kg N/ha, applied nitrogen — 80kg). Applying extra nitrogen to achieve protein was not economic at the high EM site.

Overall the yields at Dookie were lower than Yarrawonga, suggesting some in-season effect, which limited yields.

There were also yield responses to total nitrogen at Dookie. The most economic nitrogen rate for the high EM site was 326kg N (soil nitrogen — 206kg N/ha, applied nitrogen — 120kg N/ha), while the most economic rate for the low EM site was 302kg N (soil nitrogen — 182kg N, applied nitrogen — 120kg N/ha).

Where normalised difference vegetation index (NDVI) was used to determine nitrogen application rates, yield and GM was comparable to the other applied nitrogen treatments, with the exception of the high EM plots at Yarrawonga.

Retrospective assessments of 'most economic nitrogen rates' in a paddock in one season provide no guide to what will be 'most economic' in the future. It would be incorrect to extrapolate these particular GM results to paddocks in the district, given the extreme spatial and temporal variability of within-paddock crop yields.

Profitability — hypothetical farms with high and low fixed costs

Growers looking to implement variable rate nitrogen on a whole-farm basis need to consider the financial risk over time, which requires more than a single-year GM calculation. In the following example the farms shown are hypothetical but have been developed to show the full range of likely results that may be encountered in the region.

A short list of the considerations taken into account includes: randomly drawn 10-year historical rainfall sequences, yields, livestock GM from CSIRO (GrassGro model), prices (Geelong Port), costs (high and low fixed costs), debt (standardised at 100% equity), machinery replacement costs (calculated at expected changeover year), 10-year cash flows (including living costs, tax and interest) and change in cash (bank) balance over 10 years.

The distributions of probabilities of any change in bank balances over 10 years, given price and weather variations, define the 'risk profiles' of the two hypothetical farms. One of the hypothetical farms has high fixed costs and one with low fixed costs, starting with 100% equity, with and without VRT-nitrogen (Figure 3).

Comparisons of results for the high and low-cost farms are summarised in Table 2. The low-cost farm was the most viable, with zero risk of loss. This compares with a 40% risk of loss for the high-cost farm, which suggests this farm would not be viable with any debt.

Table 2 also shows that, based on the initial results for the Yarrawonga and Dookie areas, VRT-nitrogen needs to increase crop yields by less than 1%, or reduce costs



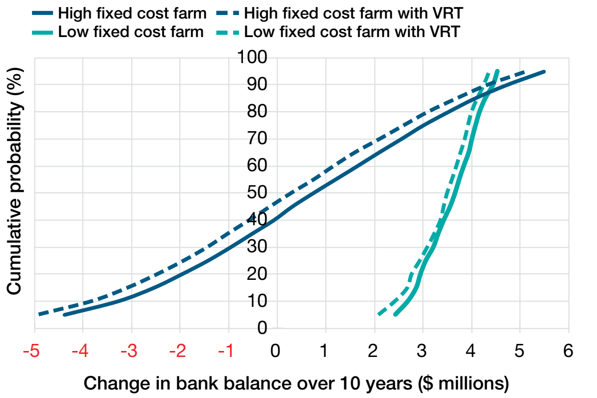

FIGURE 3 Probabilities of change in bank balances over 10 years, given price and weather variations, define the 'risk profiles' of two hypothetical farms with high and low fixed costs, starting with 100% equity with and without VRT-nitrogen application

Note: Indicated here are only the costs (without benefits) of VRT-nitrogen applications.

of nitrogen applied by at least 70%, before the approach breaks-even over time.

Acknowledgements

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References

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TABLE 2 Comparison of risk profiles

	High-cost farm		Low-cost farm	
	No VRT	With VRT	No VRT	With VRT
Initial cost of VRT		$30,963		$18,465
Cost after 10 years		$452,721		$181,744
Change in cash flow needed to cover cost of VRT				
Yield increase		0.30%		0.10%
Savings in nitrogen application cost		68%		70%
Risk of loss	41%	44%	0%	0%