A simple framework for profitable fertiliser use under risk and soil constraints

Amir Abadi[1] and Imma Farre[2]

[1] Centre for Crop Disease Management, Curtin University of Technology, Bentley, WA 6102, Australia
[2] Department of Agriculture and Food WA, 3 Baron-Hay Court, South Perth, WA 6151, imma.farre@agric.wa.gov.au

Abstract
Findings of a grower oriented research are presented, aimed at demonstrating a simple framework, with which growers can determine the fertiliser rates that maximises gross margins for wheat in Western Australia. The focus is on Economically Optimal Nutrient Rates (EONR), with emphasis on nitrogen use under different edaphic and agro-climatic conditions. Seasonal variability of price of nutrients and wheat are accounted for. Data from a decade of industry benchmarks are used to assess farmer practice in fertiliser use and the attendant yields and profits. It is shown that growers do adjust nutrient rates according to seasonal conditions and expected yields but not to the extent that may be expected when considering the large fluctuations in the price of nitrogen relative to wheat that have occurred in the last decade. Commodity statistics are used to estimate seasonal variation in the Break Even Ratio (BER) - the ratio of nutrient price to wheat price. It is shown that growers who inform themselves of yield response of their crops to a wider range of nutrient rates than those typically used, can increase their profitability by identifying EONRs that can be easily estimated using the N:Wheat price ratio, without the use of sophisticated computer models.

Key words
Wheat, nutrition, profitability, fertilizer rate, optimisation, decision support

Introduction
Fertilisers are one of the biggest cost items in the grower's annual budget (Planfarm-Bankwest 2008-2014). In the last decade the price of both Nitrogen (N) and Phosphorus (P) has varied substantially relative to price of wheat (ABARE 2013).

Yield response of wheat to N and P is usually demonstrated by a response curve that is depicted typically as a smooth, continuous curve exhibiting diminishing returns, which describes the causal relation between one or more nutrient and grain yield. Diminishing returns occurs when an additional unit of nutrient results in a less than proportionate increase in grain production (NAS 1961; Dillon 1968). Economically Optimum Nutrient Rate (EONR) is the rate of nutrient that results in a yield which maximises a crop's net return. This rate produces the Gross Margin (GM) maximizing grain yield, which is a function of grain yield, fertiliser rate and price of grain and fertiliser, among other factors. Consequently, the EONR occurs when marginal revenue (MR) from production of grain equals marginal cost (MC) of the nutrient applied. In other words, at the most profitable yield and nutrient rate, MR and MC are equal (Barnard and Nix 1976). This optimum is dependent on the price of nutrient in fertiliser relative to the price of grain, which is known as the Break Even Ratio (BER) (Sylvester-Bradley and Kindred 2009). The optimum N rate for wheat yield occurs at the point on the yield response curve where the slope of the curve equals the BER. This requires the estimation of marginal product for the nutrient (NAS 1961; Dillon 1968). Maximum financial returns for grain yield, and hence the optima for a nutrient such as N, are achieved at the rate of N where the slope of the yield response to N equals the ratio of price of N to price of wheat (Kindred *et al. 2007).*

In this paper, we acknowledge that adoption of an innovation is an economic process (Abadi et al. 2005) and thus suggest a simple method that growers can easily learn to estimate EONR prior to planting. For this method to be useful, the grower has to be aware of the yield response to the full array of N rates, from the lowest to very high rates. For simplicity, here, it is assumed that phosphate (P) use remains fixed and equal to the amount that will replace P exported by the previous crop.

Materials and Methods
Farm group statistics from industry benchmarks in Western Australia (WA) were compiled to assess recent farmer practices in fertiliser use and farm economic performance indicators for individual years for the period 2007 to 2013 (Planfarm-Bankwest 2008-2014). The single year data is ranked according to operating surplus/hectare/millimetre of growing season rainfall and grouped as top 25%, average and bottom 25%.

A sensitivity analysis was conducted using an economically optimising version of NPDecide, to determine profitable fertiliser use under different conditions. NPDecide and its various derivatives are used as decision support packages for fertiliser recommendations. The underlying model is based on an exponential wheat yield response function to N and P under different expected yields, N and P levels available in the soils and nutrient use efficiencies common in WA (Burgess *et al*. 1991; Robertson et al. 2008; Bowden *et al*. 2009). A grower can use an independent agronomist to obtain N response curves generated from a model like NPDecide or they can conduct strip trials on representative samples of soils and paddocks in different seasons, in order to understand the yield response of crops to N rates that are higher than or lower than rates typically applied. The purpose is to then use the response curve to estimate the marginal product of N use at different N rates.

The slope of the yield response curve to N at any point is the marginal product (MP) – indicating the change in wheat yield for each incremental increase in N rate. MP can then be used in conjunction with the ratio of N price to the price of wheat (Np:Wp or BER), to identify the N rate and attendant yield at which a crop is at its most profitable (EONR). The point on the response curve at which the slope equals the BER is the N rate that equals the EONR. Here we show samples of EONRs that have been estimated for wheat yield response curves to N, reflecting regional differences in expected yields and soil nutrient levels.

Results and Discussion

Current industry fertiliser use practices

Summarised farm group statistics from industry benchmarks (Planfarm-Bankwest 2008-2014) showed business performance indicators for top, average and bottom farmers in the Low Rainfall areas and Medium Rainfall areas of the WA wheat growing areas (Table 1). Data confirmed that farmers have certain ability to adjusted nutrient rates according to seasonal conditions and expected yield. For example, top farms in the medium rainfall areas varied their N use in the range of 35 to 55 kg/ha in the last seven seasons. Overall farmers adjusted nitrogen rates only by 18 to 40% around an average rate. Currently, at seeding, farmers apply that level of DAP that replaces the P for what was exported with last year’s crop. Then if the weather is conducive they may apply more N with liquid fertiliser or urea once in the low and medium rainfall zones and twice if the season is above average in the high rainfall zone.

Within a rainfall area, there were substantial differences in the level of wheat yield achieved which contributed substantially to the observed differences in farm operating surplus between top and bottom farms. Soil constraints such as acidity that affect the potential attainable yield in conjunction with finance constraints, limiting the expenditure in fertilisers, play a significant role in the low farm operating surplus, especially in bottom performing farms.

Table 1. Average and coefficient of variation (cv%) of business performance indicators for a sample of grain growers for seven season from 2007 to 2013. Business performance presented as Growing Season Rainfall (GSR), Nitrogen and Phosphorus use, wheat yield, operating expenses and farm operating surplus. Data presented for top, average and bottom farms in the low and medium rainfall areas of Western Australia.

Region	Low Rainfall (L1-L4)			Medium Rainfall (M1-M4)		
Business Performance	Top	Average	Bottom	Top	Average	Bottom
GSR (mm)	195 (21%)	191 (24%)	184 (28%)	234 (21%)	230 (24%)	224 (29%)
N Use (kg/ha)	33 (40%)	27 (31%)	24 (37%)	45 (23%)	41 (18%)	37 (31%)
P Use (kg/ha)	9 (27%)	7 (21%)	7 (29%)	10 (15%)	9 (13%)	8 (25%)
Wheat Yield (t/ha)	1.9 (39%)	1.5 (37%)	1.2 (40%)	2.4 (25%)	2.0 (28%)	1.6 (37%)
Operating Expenses ($/ha)	239 (27%)	211 (24%)	191 (28%)	325 (19%)	294 (18%)	270 (22%)
Farm Operating Surplus ($/ha)	213 (49%)	110 (73%)	19 (348%)	286 (44%)	159 (60%)	45 (170%)

Wheat yield response to nitrogen and Break Even Ratio (BER)

Values of BER for the period 2000 to 2015, using actual fertiliser and wheat prices in the different years were calculated for N in the fertiliser DAP and urea, and for P in DAP and super phosphate (Table 2). If we take N in urea as example, BER values were highest in 2008 and lowest in 2015. Assuming the wheat response curve to N is known, the EONR for 2008 would be the N applied at the point where the slope of response function is 7.7 and in 2015 the point where the slope is 2.9.

Wheat response curves to N applied for high and low expected yields in the low and medium rainfall areas of WA were generated using the optimising version of NPDecide (Figure 1) taking into account assumptions of attainable yields and available N and P in the soil and nutrient use efficiencies as described in Table 3. Given the April 2015 prices of $0.89/kg for N and $0.25/kg for wheat, the BER in April 2015 would be 3.56. The EONR can be obtained as the point on each curve where the slope of the curve equals 3.56. Under the stated assumptions, the EONR for the high and low yields in the low rainfall areas would be 70 and 60 kg/ha N respectively, and for the high and low yields in the medium rainfall areas would be 42 and 34 kg/ha N respectively (Fig. 1). These N rates that maximise GMs of crops result in yields of 1840, 1260, 2310 and 1440 kg/ha respectively, all of which are lower than the corresponding attainable yields of 2300, 1650, 2650 and 1900 kg/ha. It is important to note that these yields maximise gross margin and not gross revenues, which exclude cost of nitrogen). Generally, and in particular when N:Wheat price ratio is high, to maximise GM, grower accepts lower yields and lower gross revenues than would be the case at higher N rates.

In this paper, soil constraints that affect water use and nutrient use efficiency of crops are taken into account by adjusting the expected or attainable yield. Further research will be conducted into estimating the benefit-cost analysis of expenditure in ameliorating soil constraints as well as fertiliser rates.

Table 2. Values of Break Even Ratio (BER), ratio of price of nutrients and price of wheat, for the years 2000 to 2015. Nutrients (Nut) Nitrogen (N) in fertilisers DAP and Urea, and Phosphorus (P) in DAP and superphosphate. Numbers in bold indicate the maximum value observed and the underlined numbers are the lowest values.
Notes: a: Sources: ABARE, CSBP and Profarmer; b: nominal prices; c: nutrient prices in the compound fertiliser DAP was calculated by proportioning the total cost of the compound fertiliser to each of the constituent nutrients on the basis of the cost of each nutrient (in its cheapest form e.g. from a single nutrient fertiliser like urea for N) as a fraction of the cost of all nutrients in the compound.

Nut: Fertiliser	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
N: DAP	3.3	2.7	<u>2.7</u>	3.5	4.0	4.4	4.3	4.4	**7.6**	5.8	5.3	6.1	3.8	3.6	4.1	3.4
N: Urea	4.7	3.5	3.3	4.4	5.8	6.0	5.3	5.2	**7.7**	6.3	5.5	7.5	4.8	4.4	5.2	<u>2.9</u>
P: DAP	8.7	7.3	<u>7.1</u>	9.2	10.5	11.6	11.5	11.8	**20.2**	15.3	14.2	16.3	10.1	9.6	10.8	9.0
P: Sup. Phos.	11.3	<u>10.5</u>	10.9	13.2	14.5	14.6	12.6	13.7	**22.6**	21.0	17.8	19.9	13.9	13.2	14.5	12.0

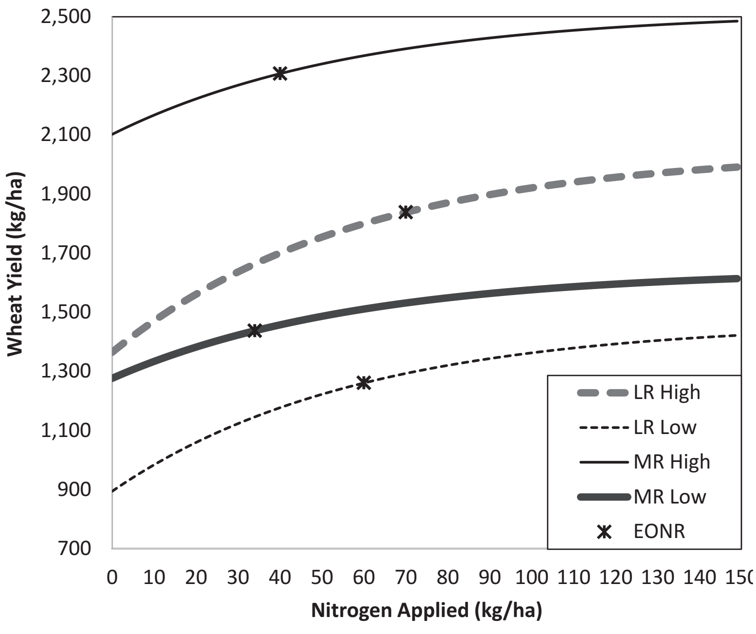

Fig 1. Wheat yield response to Nitrogen applied for High and Low expected yields in the low (LR) and medium (MR) rainfall areas of WA. Assumptions of expected yield and soil nutrient levels are shown in Table 3.

We recognise that there are constraints that may limit the extent to which grower can adjust the N rate. They include: knowledge resources of grower (access to timely, unbiased and expert advice), labour resources, financial resources, soil constraints (acidity, compaction) and diseases and pests (e.g. root nematodes) among others.

It is advisable that decisions concerning the most profitable quantity of fertiliser be made with knowledge of returns to investment in other parts of the farm business. Factors that may affect such decisions include level of equity limiting access to seasonal finance, other investment alternatives and whether the farmer is a lessee or an owner.

Table 3. Assumptions for expected (attainable) yield, available N and P in the soil and Non-fertiliser operating expenses for high and low yields in the low and medium rainfall areas. BER of 3.56 in Apr 2015. Values for soil responsiveness to added N and P are those typical of WA soils (Bill Bowden *pers comm*).

Variable	Unit	Low Rainfall GSR: 195 mm		Medium Rainfall GSR: 235 mm	
		High	Low	High	Low
Attainable Yield	kg/ha	2,300	1,650	2,650	1,900
Available N in Soil (top 10 cm)	kg/ha	55	47	90	75
Available P in Soil (top 10 cm)	kg/ha	11	11	15	10
Applied P - at seeding	kg/ha	6	6	10	8
Non-Fertiliser Operating Expenses (Opex)	$/ha	150	150	265	215
Economically Optimal N rate (EONR Apr 2015)	kg/ha	70	60	42	34
GM maximizing Yield	kg/ha	1,840	1,260	2,310	1,440
Gross Margin at EONR	$/ha	200	70	276	114

Conclusion

If a grower is aware of the current wheat yield response to a wide range of N rates on their own property, then the EONR can be easily estimated using the BER, without the use of computer models. Soil tests are necessary to provide an estimate of the soil nutrient supply and usual caveats apply about limiting factors, such as seasonal conditions, risk of dry finish and additional costs of splitting nutrient applications.

Acknowledgements

The authors gratefully acknowledge funding from GRDC's MPCNII initiative. Thanks also go to collaboration of subject matter experts: Doug Abrecht, Bill Bowden, Art Diggle, Chris Gazey, Wayne Pluske, Liam Ryan and Craig Scanlan.

References

Abadi Ghadim AK, Pannell DJ and Burton MP (2005). Risk, uncertainty and learning in adoption of a crop innovation. Agricultural Economics 33, 1–9.

ABARE (2013). Australian Farm Surveys Report 2013. Australian Bureau of Agricultural and Resource Economics, Canberra, ACT.

Barnard CS and Nix JS (1976). Basic Principles and Concepts. In Farm Planning and Control. Cambridge University Press.

Bowden JW, Pluske W and Lemon J (2009). Fertilising in a changing price environment. Crop Updates 2009. Perth.

Burgess SJ, Bowden JW and Diggle AJ (1991). NPDecide User's Guide: a Computer Program to help with Nitrogen and Phosphorus Fertiliser Decisions for Cereals. Department of Agriculture, Western Australia.

Dillon JL (1968). The Analysis of Response in Crop & Livestock Production. Pergamon Press Ltd (ed.), Oxford.

Kindred DR, Smith TC, Sylvester-Bradley R, Ginsberg D and Dyer CJ (2007). Optimising nitrogen applications for wheat grown for the biofuels market. HGCA project report No 417.

NAS (1961). Status and Methods of Research in Economic and Agronomic Aspects of Fertilizer Response and Use. Publication 918, National Academy of Sciences, National Research Council, Washington.

Planfarm-Bankwest (2008- 2014). Planfarm-Bankwest Benchmarks 2007/08 to 2013/14. in Planfarm Pty Ltd (ed.), Wembley, Western Australia.

Robertson MJ, Lyle G and Bowden JW (2008). Within-field variability of wheat yield and economic implications for spatially variable nutrient management. Field Crops Research 105, 211-220.

Sylvester-Bradley R and Kindred DR (2009). Analysing nitrogen responses of cereals to prioritize routes to the improvement of nitrogen use efficiency. Journal of Experimental Botany 60 (7), 1939-1951.