Modelling strategic nitrogen fertiliser decisions for Central Queensland farming systems

H.W. Cox[1] and F.C. Chudleigh[2]

[1]Department of Primary Industries, Biloela, Qld 4715
[2]Department of Primary Industries, Emerald, Qld. 4720

ABSTRACT

The cropping systems model, APSIM was used to simulate monoculture wheat, sorghum and opportunity-cropped wheat and sorghum for two districts in Central Queensland. Grain yield and protein distributions were produced from a factorial of three soil-fertility levels, three soil types and four nitrogen rates. Whole farm economic analysis for two example farms was applied to all scenarios. Soils of soil low plant available water-holding capacity (PAWC) greatly reduced the potential profitability of all scenarios including those with high N fertility. Low soil N fertility also reduced profitability but returns could be almost restored with N fertiliser. Tactical N application matching soil water and soil NO_3-N in a 1:1 ratio at sowing was the best practice. These scenarios detail production and economic effects of soil PAWC, different cropping systems, and various fertiliser strategies. Future application of these scenarios is dependent upon quantifying, within broad groups, the current soil N fertility status.

Key Words:

APSIM, tactical nitrogen fertiliser, farming systems,

INTRODUCTION

Central Queensland is a region with highly variable, summer-dominant rainfall. Summer rainfall can be of high intensity. Soils are predominantly cracking clays some of which can be shallow (Open Downs), or saline at depth (Brigalow types). These factors can limit soil water-holding capacity. Fertility of the Brigalow clays was high when initially cleared, but has subsequently declined. Farming commenced in the 1940s and historically, little N fertiliser has been applied. Garside *et al* (4) documented a decline in sorghum grain protein of >4 % after 25 years of cropping. In all years from 1984 to 1990, the proportion of wheat downgraded due to low protein was up to 65% and was greater than in any other Queensland region (5). Minimum tillage and opportunity farming systems are commonly used. This can place increased demands upon nitrogen fertility.

Growers can face dilemmas of variable rainfall, limited soil water storage capacity, declining soil fertility and unreliable returns for grain. Significant questions remain. When is it profitable to use N fertiliser? Is the potential production from the soil sufficient to justify N fertiliser? What is the best fertiliser strategy if it is needed? What cropping or pasture regime is most profitable?

MATERIALS AND METHODS

The systems simulation model, APSIM (version 1.5.5) was used to examine the yield and protein outcomes from dryland monoculture sorghum, monoculture wheat and opportunity cropping of sorghum and wheat under zero-till. Example farms modelled at Biloela and Capella were representative of the districts of the Dawson Callide and Central Highlands respectively.

The example soils had a PAWC of 100mm or 158mm for Biloela (depths 60 and 90cm respectively) or 90mm, 120mm or 150mm for Capella (depths of 60, 90 and 120cm respectively)(Table 1). Soil carbon and nitrogen levels were set to simulate soils of low, medium and high nitrogen fertility.

Simulated N fertiliser rates were 0, 50, 100 kg N/ha and a tactical N rate determined on the basis of a 1:1 ratio of soil water and available soil nitrate at sowing (3). Estimates of gross margin, return on assets, investment returns, and cash flow for each input combination were calculated. Harvest losses, insect, disease effects and weed competition, were excluded. Trends over the thirty-year periods in the production and economic indicators were calculated. For each district (example farm), a typical cost structure was used. Grain prices were held constant at 1998 prices including a sliding scale for protein and quality payments for wheat.

Table 1: Crop parameters for simulation runs

Parameter	Centre(PAWC mm)	Sorghum	Wheat
Sowing date	Biloela	15 Nov to 30 Jan	22 April to 8 July
	Capella	15 Sept to 30 Jan	22 April to 8 July
Sowing rain req't		25mm over 4 days	20mm over 4 days
Min. soil water at sowing; monoculture	Biloela (158/100)	80/50 mm	80/50mm
	Capella (90, 120, 150)	100mm	80mm
Min. soil water at sowing; opp. cropping	Biloela (158/100)	120/80mm	120/80mm
	Capella(90/120, 150)	100/120mm	100/120mm
Maturity length		Medium	Quick
Sowing density (pl/m^2)	Biloela	5	75
	Capella	7	100

RESULTS and DISCUSSION

APSIM produced appropriate yield and protein distributions for sorghum and wheat. The soil-nitrogen run-down curves and crop rotation scenarios were credible (data not shown). The modelled results indicated that the production and economic outcomes were influenced by; the water holding capacity of the soil, the inherent soil fertility, the climatic sequence and the cropping system chosen. Hence, the optimum quantity of applied fertiliser nitrogen fertiliser was affected by these factors.

Effect of soil PAWC on fertiliser strategy

N fertiliser application restored grain yield and protein levels similar to those of a high-nitrogen soil with medium to high-PAWC (Figure 1). N fertiliser application was not economic on high-N fertility soils of either high or low PAWC under any cropping system. On soils of low PAWC, continuous cropping exhibited high risk and low profitability (Table 2).

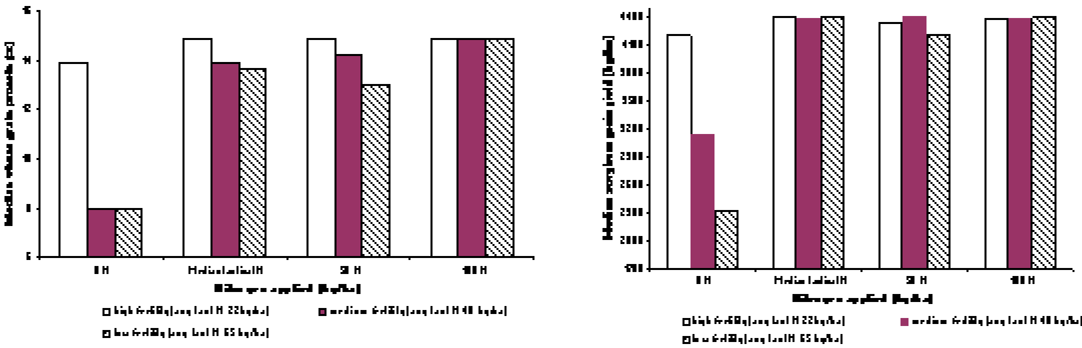

Figure 1: Effect of soil fertility and N fertiliser rate on a) sorghum grain yield, b) wheat grain protein for opportunity cropping in the Dawson/Callide

Table 2: Mean gross margins (GM) and return on assets (ROA) for low PAWC soils at Capella and Biloela for zero and tactical N fertiliser rates.

Centre	Capella (90mm PAWC)				Biloela (100mm PAWC)			
	Mean GM ($/ha/yr)		Median ROA (%)		Mean GM ($/ha/yr)		Median ROA (%)	
Fert. rate	0N	Tact N	0N	Tact N	0N	Tact N	0N	Tact N
			Low soil fertility					
Wheat	9	12	-12	-12	19	22	-10	-10
Sorghum	29	75	-12	-6	43	95	-8	-10
Opp. Crop	10	65	-12	-11	6	116	-13	-7
			Medium soil fertility					
Wheat	21	19	-12	-12	37	37	-9	-9
Sorghum	57	80	-7	-5	129	124	-8	-9
Opp. Crop	41	69	-9	-11	66	127	-8	-5

Tactical N rate

The tactical N rate varied between 0 and 130 kgN/ha and usually resulted in the best economic return. Further analysis showed that an N application rate for each crop equal to the average of the tactical N rate (Table 3) for each 30-year scenario would also give a similar return (data not shown). Turpin *et al* (6) reported a set N fertiliser rate as being the preferred option. The tactical N rate increased over time, compensating for the decline in soil nitrogen. It was also found that sorghum required a tactical N rate up to 50% less than wheat (Table 3). Further analysis has shown higher predicted N-mineralisation rates, lower denitrification for sorghum-dominated systems.

Table 3: Mean of the tactical N rates (kg/ha) for the various scenarios

System	Monoculture wheat			Monoculture sorghum			Opportunity Cropping		
Fertility	High	Medium	Low	High	Medium	Low	High	Medium	Low
PAWC					Capella				
150mm	33	55	65	16	35	44	36	54	62
120mm	25	45	55	12	30	42	30	47	55
90mm	11	25	33	9	23	31	19	33	41
					Biloela				
158mm	20	48	69	4	24	44	22	48	65
100mm	10	10	25	0	13	42	15	31	42

Trends in grain yield and protein over 30 years

The tactical N rate effectively and economically maintained wheat grain yields and grain protein (Figure 2). In this example, the mean of the tactical N rates was 40 kg/ha but increased from 20 to 50 kg/ha over the 30-year period. Hence, the N supply was better matched to the demand than that of the set rate of 50 kg/ha. Gross margins were maintained in a similar way by the tactical N rate.

a) b)

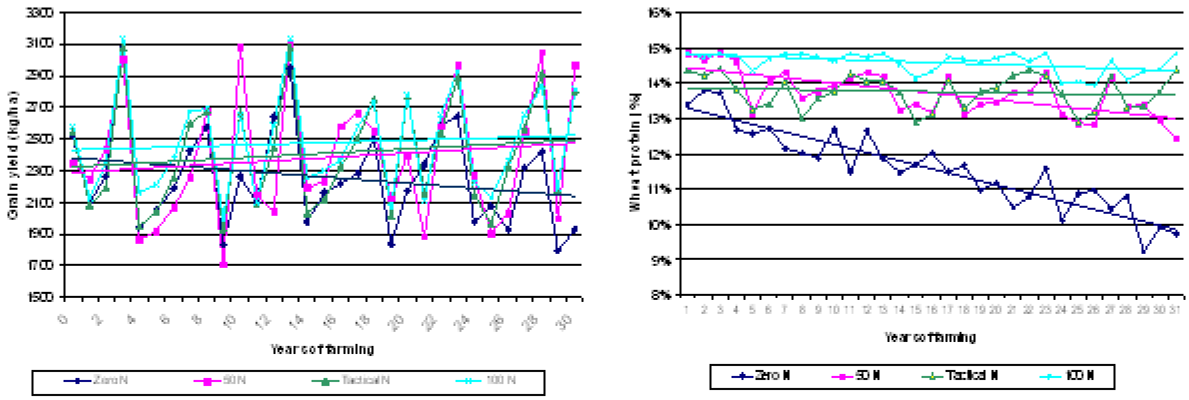

Figure 2: Trend of a) wheat grain yield and b) wheat grain protein over the mean of eight 30-year scenarios for a soil of medium N fertility and 158mm PAWC at Biloela.

Proportion of high-protein wheat produced with the tactical N rate

The tactical N rate typically produced 95% of grain protein results within ? 2% of 13%. This was similar to the result of Dalal *et al* (3). On high-PAWC soils, wheat protein of greater than 13% protein was achieved in 60 to 70% of years (Table 4). On low-PAWC soils, the proportion of high-protein wheat was lower, but as previously indicated these scenarios were relatively unprofitable.

Table 4: Percentage of outcomes with wheat grain protein > 13% using tactical N rate

District	Capella		Biloela	
Soil fertility	Low	Medium	Low	Medium
Mono wheat	68	70	70	70
Opportunity cropped wheat	55	60	70	70

Future work

The years producing the largest gross margins did not always coincide with the years that received the highest tactical N rates. This is because grain yield is significantly affected by in-crop rainfall. Dalal *et al* (3) reported the correlation between soil water at sowing and grain yield as 43%. The benefits of including climate forecasting prior to sowing will be tested. The Central Queensland cropping environment has variable rainfall, soils of lower PAWC and more opportunistic farming and hence may benefit significantly from climate forecasting. Controlled traffic farming may facilitate in-crop N application.

This modelling work has highlighted when N fertiliser may be profitable and when an alternative enterprise may be beneficial. To use these scenarios as an indicator of potential outcomes, the nitrogen fertility status of a paddock needs to be described. Wheat grain protein has been proposed as a measure of nitrogen sufficiency (4, 5). However, crops are often water-stressed in Central Queensland. This often inhibits the use of grain protein as an indicator. Age of cultivation is a general indicator (4) but is not a sufficiently accurate basis for a fertiliser strategy. Soil NO_3-N can vary widely over a fallow period, but when measured at sowing can assist the calculation of N fertiliser rate.

Dalal and Mayer (2) proposed that anaerobic mineralisable-N (0-0.3 m) and NO_3-N (0-0.6m) could be used as indicators of crop performance. It has also been suggested that 10% (range 5% to 15%) of total N could be a reasonable approximation of mineralisable-N (1). This factor may define of the N status of a paddock into the broad groups used in these modelling scenarios. If this is done, then these scenarios can provide insight into the potential production and the economic viability of N fertiliser strategies.

CONCLUSIONS

On a soil of high or medium PAWC, opportunity cropping, focussing on sorghum was the most profitable system. With soils of lower N fertility, N fertiliser was essential to restore production and gross margins. The modelled tactical N fertiliser rate was the most profitable strategy. However, the resultant N rates vary widely. High N rates could cause cash flow problems for the grower. An alternative option could be to apply a lower N basal rate follow by additional N during crop growth if required. The mean of the tactical N rates resulted in a similar economic outcome to the variable N rate. If the fertility status of the paddock could be broadly grouped, these scenarios would provide insight into a strategy for paddock use and N fertility management. Knowledge of soil PAWC was identified as essential to determining the potential profitability of a paddock or cropping system. Future work will evaluate other cropping systems, the effect of SOI and the value of in-crop N application.

REFERENCES

1. Dalal, R. C and Mayer, R. J (1986). *Aust. J. Soil Res.* **25**: 461-72.

2. Dalal, R. C and Mayer, R. J (1990). *Aust. J. Soil Res.* **28**: 563-75

3. Dalal, R. C., Strong, W.M., Weston, E.J., Cooper, J.E., and Thomas, G.A. (1997)

4. Aust. J. Exp. Agric. **37**, 351-7

5. Garside, A.L., Agnew, J. Chamberlain, H.J., Huf, S and Turnour, J. (1992) *Proceeedings 2nd Australian Sorghum Conference*. Gatton p311-315

6. Strong W.M., Armstrong. R.D., Best, E.K., Cahill, M.J., Cox, H.W., Dalal, R.C., Garside, A.L., Hibberd, D.E., Thompson, J.P. (1992). *Queensland Crop Production Conference*, Biloela, p69-84.

7. Turpin, J.E, Hayman P.T., Marcellos, H., and Freebairn, D.F. (1998). *Proceedings 9th Australian Agronomy Conference*, Wagga Wagga. pp 761-764