Nitrogen Management that Maximizes Margins Improves Sustainability of Wheat Cropping

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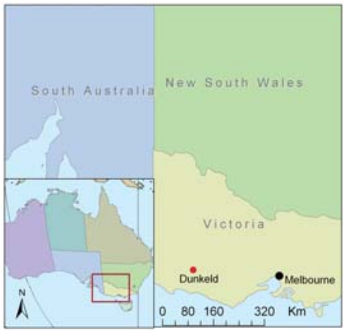
Flexible wheat cropping systems that maximize crop potential with minimal N application at sowing, were found to maximize both economic and environmental performance in southeastern Australia. A range of management combinations were used to estimate the impact of different combinations of initial soil N status and fertilizer strategies for wheat cropping in the Victorian high rainfall zone (Dunkeld, Victoria).



Nitrogen lost from cropped land can adversely affect receiving waters. As a result, cropping systems have been developed that increase grower earnings and reduce environmental impacts. In southeastern Australia sheep and cattle grazing lands are being converted to broad-acre, high rainfall (>550 mm) cropping. This land-use change has most likely increased N loss to surface waters from both conventional and raised-bed cropping systems. However, the most appropriate way of mitigating N loss from high rainfall cropping remains unclear.

For an earlier paper we developed a Bayesian Network to compare dissolved N loss from high rainfall cropping (Nash et al., 2010). The network combined subjective and objective information into a conceptually sound model that provided a transparent and logical linking of key management decisions to N loss including estimates of associated uncertainty. In this study we use a slightly modified Bayesian Network, the APSIM (Keating et al., 2003) crop production model, and gross margin analyses to investigate N loss risk, crop yields, and gross margins of wheat crops in the Dunkeld region of southeastern Australia. Crop production and water budgeting were modelled assuming similar sowing conditions each year for 120 years using climate data from 1889 to 2008. Those data were used: (a) to investigate relationships between environmental and economic objectives associated with N fertilizer use; and (b) to develop recommendations for managing N fertilizers used for growing wheat varieties with different growing season lengths where soils have different pre-sowing N fertility. The scenarios tested included a range of fertilizer application strategies with up-front and in-season applications (**Table 1**).

Table 1. Fertilizer management strategies used to compare economic and environmental attributes of wheat crops in the Dunkeld region.

	Fertilizer application			
	Sowing	GS31[a]	GS39[a]	Total
Management strategy[a]	- - - - - - - - - - - - - - kg N/ha - - - - - - - - - - - - - - -			
D0 0N	10	0	0	10
D0 25N	35	0	0	35
D0 50N	60	0	0	60
D0 100N	110	0	0	110
GS31 25N	10	25	0	35
GS31 50N	10	50	0	60
GS31 100N	10	100	0	110
GS39 25N	10	0	25	35
GS39 50N	10	0	50	60
GS39 100N	10	0	100	110
D0 25N GS31 25N	35	25	0	60
D0 50N GS31 50N	60	50	0	110
GS31 25N GS39 25N	10	25	25	60
GS31 50N GS39 50N	10	50	50	110

[a] D0 = Sowing, GS31 = Growth Stage 31, GS39 = Growth Stage 39 (Zadoks et al., 1974).

Abbreviations and notes: N = nitrogen.

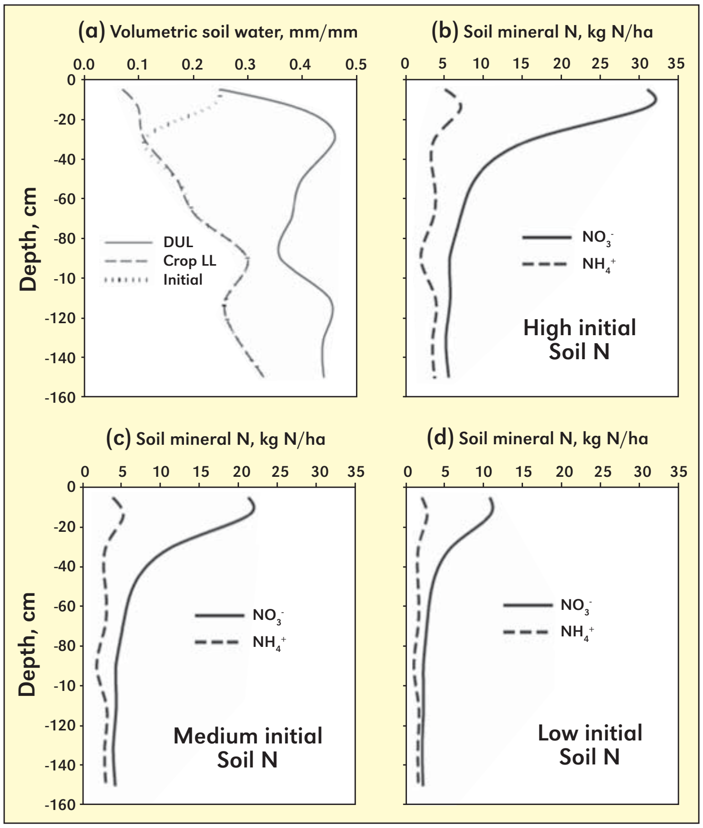


Figure 1. Initial soil water (a) and soil mineral N conditions (b-d) used for the simulations. High, Medium and Low initial soil mineral N conditions are shown in (b), (c) and (d), respectively. DUL = Drained Upper Limit (field capacity); Crop LL = Crop Lower Limit of water availability (permanent wilting point).

The environmental impact of the different management systems was estimated on the basis of dissolved N load. The Dissolved N Load Factor is a probability weighted outcome of N loss derived from the described Bayesian network, which considers a range of crop, site, weather and N management options (Nash et al. 2010). It is not a measure of the mass of N lost, but a small value indicates a lower probability of nutrient loss than a higher value. The Dissolved N Load Factor was estimated from the initial soil mineral N levels; Low, Medium and High (**Figure 1**), and fertilizer rates and timing. The study considered three varieties of wheat: "Silverstar®"(short season); "Chara®"(mid-length season), and; "Mackellar®" (long season).

Mackellar is a 'red' wheat and therefore used for animal feed, whereas Silverstar and Chara are potentially milling wheats. Because of differences in grain prices, returns from these three cultivars were different, although the impacts of N management on returns and dissolved N load were similar between the medium and long season wheats, but the modelling suggested that Dissolved N Load Factor was higher for the short season type Silverstar.

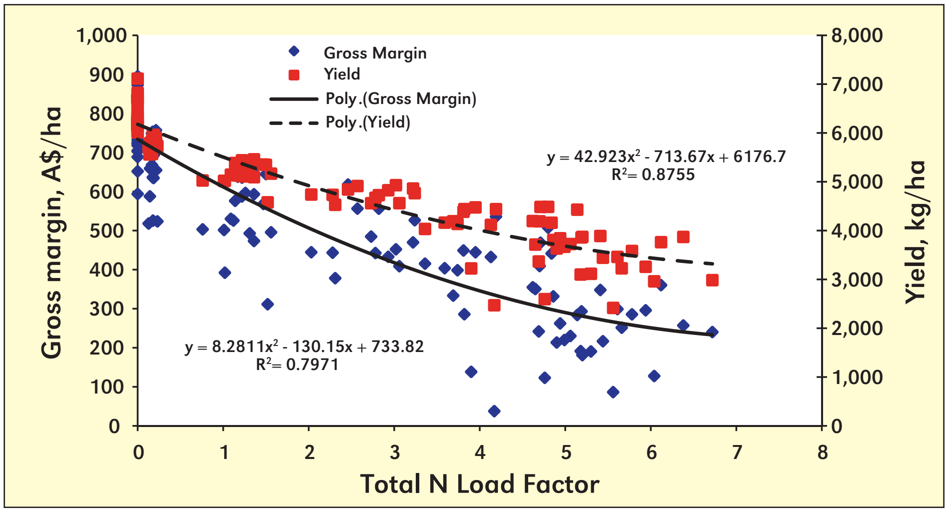


Figure 2. Plots of estimated average annual yields and gross margins against estimated environmental impact (Dissolved N Load Factor) from Dunkeld in southeastern Australia with data for the low initial soil N, 10 kg N/ha at sowing options.

Overall, irrespective of fertilizer application rates, crops grown on soils with higher initial N concentrations are generally higher yielding. Applied N, initial soil N and wheat variety affected gross margin estimates ($p = 0.001$). Overall gross margins increased with fertilizer application rate from A$264 to $444, $539, and $602/ha for the 10, 35, 60, and 110 kg N/ha application rates with strong linear ($p = 0.001$) and quadratic components ($p = 0.001$) to the relationship. The Dissolved N Load Factor decreased with increasing initial soil fertility (i.e., 4.0, 2.0 and 0.4 for the low, medium and high initial soil N, respectively) and with increasing applied N (4.4, 3.2, 2.2, and 1.0 for 10, 35, 60, and 110 kg N/ha, respectively).

These results imply that the reductions in drainage volumes from improved crop growth have a greater impact on N loss than the increased N concentrations resulting from the additional fertilizer N used to achieve that extra growth. This subsequently leads to a strong negative relationship between gross margins and the Dissolved N Load Factor (**Figure 2**). We subsequently calculated a Sustainability Rating by combining the Dissolved N Load Factor and gross margins, simply dividing the latter by the former, and developed a set of recommendations and conditional comments for likely cropping scenarios (**Table 2**).

Table 2. Analyses of gross margins and environmental performance for the wheat cultivar 'Chara' grown with different fertilizer application rates and fertilizer application strategies using data derived from APSIM modelling and the use of a cropping Bayesian Network.

Soil N	Total fertilizer N added, kg/ha	Gross margin, A$/ha	Dissolved N Load Factor (unit-less)	Sustainability Rating	Recommendation
Low	110	576	1.1	505	An additional 50 kg N/ha at sowing and an additional application (50 kg N/ha) at GS31[a]. SEE NOTE 1
Medium	50	750	0.2	>3000	Two post-sowing applications of fertilizer (25 kg N/ha) SEE NOTE 2
					OR
	110	780	0.0	>3000	Two post-sowing applications of fertilizer (50 kg N/ha).
High	50	873	0.0	>3000	Two post-sowing applications of fertilizer (25 kg N/ha). SEE NOTE 3

[a] GS31 = first node stage or Growth Stage 31 (Zadoks et al., 1974).

[1] This recommendation reflects the reduction in the volume of runoff (due to plant water use) that accompanies a productive crop.

[2] Rating based on maximum flexibility.

[3] This option provided the best overall flexibility, was within A$30/ha of the highest gross margin and low environmental risk.

This work suggests that flexible management of N fertilizers with the aim of maximizing gross margins will also lead to enhanced sustainability outcomes.

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References

Keating, B.A. et al. 2003. European Journal of Agronomy 18, 267-288.

Nash, D.M. et al. 2010. Journal of Environmental Quality 39, 1699-1710.

Zadoks, J.C. et al. 1974. Weed Research 14, 415-421.