Accounting for mineralised nitrogen in crop nutrient budgeting to improve NUE and profit — case study

About the research

Sugar's sub-project of the MPfN Program, *Improved nitrogen use efficiency through accounting for deep soil and mineralisable Nitrogen (N) supply*, conducted its work under Activity 6 of the Program, with the key objective being to generate knowledge and understanding of the interplay of factors to optimise N formulation, rate and timing for the NSW industry. Two key outcomes of the research included:

- *Understanding the longer-term Potentially Mineralizable Nitrogen (PMN) of a soil to enable refinement of applied N additions.* In all likelihood this would allow greater transparency of marginal returns of applied N and fertiliser response; and
- *The supply of PMN from the soil varied, and while ammonium levels peaked at 14 days, nitrate levels continued to rise.* The SIX EASY STEPS (6ES[1]) program currently uses an N mineralisation index based on soil organic C (Walkley Black). Laboratory incubation studies (field capacity, 30^{O}C for two weeks) were used to estimate the amount of N available to the crop. These amounts are then discounted from the overall N requirement.

Analysis of farm level economic benefits

A farm level framework was developed to evaluate the economic and environmental potential of optimising N application using PMN testing to improve product budgeting and match N supply with plant nutrient demand. The analysis used a partial budget model to compare total N applied using the 6ES and the cost savings / emissions abatement from the additional N projections.

What is the PMN test and how is it derived?

N can be supplied to the crop through synthetic fertiliser and/or from existing stores of plant available nutrient in soil, as well as through PMN. The breakdown of organic material such as harvest residues (i.e. sugarcane trash) and soil organic matter releases plant available N to the crop, but the amounts added are currently difficult to incorporate into decision support tools, as predictive measurements of organic N contribution have not been available.

PMN can vary greatly within soils and locations. When summing the mineral N over the cropping season was investigated, researchers found the PMN over 300 days ranged between 100-560 kg N/ha. These soils are unique and undergo naturally accumulated organic matter. Analysis can be conducted with cores taken annually after harvest at a small additional cost. Figure 1 illustrates the calculations used from a large field data set to predict PMN.

[1] http://www.canegrowers.com.au/page/cane-to-coast/nutrient-management/six-easy-steps

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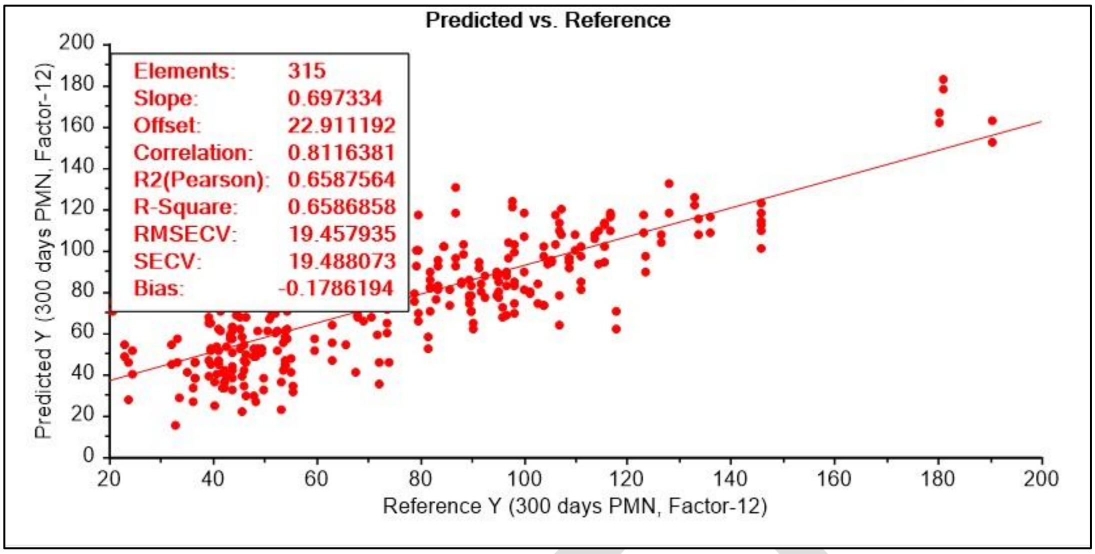

Figure 1 — Correlation model developed for 14, 56 and 300-day PMN.

Table 1 provides an example of a 40 ha field at Mackay employing PMN analysis in nutrient budgets. Research findings suggest a "10% reduction" in per ha applied N rate under most circumstances. Assuming baseline local recommendations from 6ES, an Emissions Factor (a coefficient which allows to convert activity data into GHG emissions) of 2% for irrigated sugarcane and valuing emissions at \$16 /t CO_2e, the combined environmental and economic impacts reveal an estimated \$558 field-scale net benefit.

Table 1 — Potential economic and environmental benefits of a 40 ha field at Mackay, employing PMN analysis in nutrient budgeting assuming a 10% reduction in N rate.

40 ha field	Soil testing costs	Nitrogen rate (plant and ratoon crops)	Difference (per field)	CO_2e abatement[2,3]	Total net benefit
SIX EASY STEPS for a soil with < 0.4% org C (Walkley and Black)	\$0	170 kg/ha	\$0	0 kg	\$0
Additional PMN test	-\$70	153 kg/ha	+\$558	4,053 kg	+\$1,040

The parameter values and assumptions of any economic model are subject to change and error. Sensitivity analysis, broadly defined, is the investigation of these potential changes and errors and their impacts on conclusions to be drawn from the model. Analysis was undertaken to test the sensitivity of the results to individual changes in fertiliser rates when considering PMN calculations and flow-on effects on nitrogen lost to the environment.

Table 2 shows the economic sensitivity results for N (in the form of Urea) and reduction in N rate using the aforementioned case study at Mackay, Qld. This assumes static CCS and yield and PMN enables a reduced applied N bounded by maximum and minimum market N values observed over the 10-year reference period. For example, when the PMN is high and applied N rate is 40% lower and the cost of urea is \$0.82/kg, the new N budget will achieve an estimated economic impact of \$56/ha. Provided that N price and PMN values make a positive contribution to the overall N budget outlined in the 6ES, the practice change should remain economical.

[2] http://www.cleanenergyregulator.gov.au/ERF/Auctions-results/march-2020
[3] https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg3-chapter8-1.pdf

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Table 2: Economic sensitivity results - Urea and reduced N rate from employing PMN calculations, $/ha economic impact at Mackay, Qld.

		Urea ($/kg)			
		\$0.51	**\$0.82**	**\$1.14**	**\$1.45**
Reduction in N rate %	**10%**	\$8.7	\$13.9	\$19.4	\$24.7
	20%	\$17.3	\$27.9	\$38.8	\$49.3
	30%	\$26.0	\$41.8	\$58.1	\$74.0
	40%	\$34.7	\$55.8	\$77.5	\$98.6

Table 3 shows the environmental sensitivity of results against business as usual when applying PMN testing that results in a reduced applied N rate. Research has found nitrous oxide emissions can grow exponentially under the right climatic conditions, hence 5% is sensitivity tested[4]. Similarly, in wet years, nitrate leaching through the profile can occur. A baseline of 10% and 20% is used, drawn from studies undertaken in broad acre irrigation[5]. The results show that if including PMN into crop nutrient budgeting resulted in a reduced applied rate of N, up to 1t/ha CO_2e may take place. Similarly, avoided deep-drainage as nitrates amounting to 14 kg/N/ha may occur under the scenarios tested.

Table 3: Environmental sensitivity results - value of avoided nitrous oxide emissions and nitrate leaching from using PMN in nutrient budgeting

		Avoided emissions (CO_2e / ha) and nitrate leaching (kg / N /ha)			
		Emissions Factor (kg N_2O ha)		Nitrate leaching (kg/N /ha)	
		2%	**5%**	**10%**	**20%**
Reduction in N rate %	**10%**	101.32	253.3	1.7	3.4
	20%	202.64	506.6	3.4	6.8
	30%	303.96	759.9	5.1	10.2
	40%	405.28	1,013.21	6.8	13.6

Figure 2 One metre soil core extraction using trailer mounted hydraulic soil core

[4] https://www.publish.csiro.au/sr/sr15314
[5] https://www.cottoninfo.com.au/sites/default/files/documents/Irrigation%20and%20N%20tour%20booklet%20-%20FINAL.pdf

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This analysis shows by employing PMN techniques in crop nitrogen budgeting alongside the 6ES, a more accurate appraisal can better utilise all sources of plant-available N, optimise fertiliser inputs and result in avoided losses of N to the environment. Where using PMN analysis results in lower applied N, both economic and environmental benefits eventuate through:

- Lower input costs from lower applied N;
- Reduced nitrous oxide emissions; and
- Reduced deep drainage losses from nitrate leaching.

For information on the MPfN research visit https://www.crdc.com.au/more-profit-nitrogen or contact Sugar Research Australia.

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