MORE PROFIT FROM NITROGEN

Assessment of the relationship between the most economic rate of nitrogen and nitrogen use efficiency — *testing specific cotton, sugar, dairy and horticulture scenarios.*

About the research

The More Profit from Nitrogen Program (MPfN Program) was a five-year partnership (2016-2021) between the Australian cotton, dairy, sugar and horticulture industries. It was conducted to bring about increased farm profitability and reduced environmental impact by increasing nitrogen use efficiency (NUE), thereby, reducing the amount of applied nitrogen (N) required to produce each unit of product. Eleven research projects were delivered by nine organisations, involving forty-two field sites across Australia.

One of the knowledge outputs was a set of indicators determined for assessing, reporting and communicating upon NUE in Australian agricultural systems. A broad range of existing agronomic, environmental and economic NUE metrics were reviewed and applied to research project datasets of the MPfN Program to finalise the recommendations.

Background: economic indicators for NUE and a framework for determining the optimum NUE range

Understanding the economic perspective of NUE is important for agricultural industries when considering optimal N fertiliser products, placement, timing and rates of application to maximise returns and minimise environmental impacts.

The most economic rate of N (MERN) can be derived from the yield-to-N response relationship[1] by equating the first-order differential to the price ratio. Price ratio is equivalent to the break-even ratio, demonstrating the additional gain in profit for each additional unit of N applied. At this point, the economic return from N applied as fertiliser is maximised (Antille and Moody, 2021).

A generic NUE framework, originally developed by the EU Nitrogen Expert Panel (2015), was adapted for the Australian cotton and sugar (Antille and Moody, 2021) and dairy (de Klein et al., 2017) industries using available NUE datasets.

The slope of the wedge represents a range of desired NUE values; with lower values likely to exacerbate fertiliser N lost to the environment and higher values risking mining of soil N stocks and financial penalty due to loss of yield. Yield-to-N response relationships were developed from available industry and MPfN Program datasets to construct and test the proposed NUE frameworks.

PRIOR BACKGROUND FOR INDUSTRY

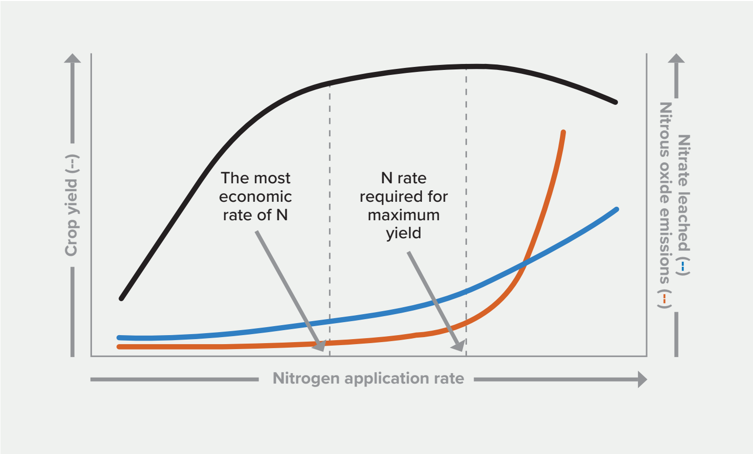
The aim of this case study was to apply key agronomic NUE indicators proposed through the eleventh MPfN Program project, *MPfN- Nitrogen use efficiency indicators for the Australian cotton, sugar, dairy and horticulture industries (RRDP1901)*, to assess their appropriateness as economic indicators in cross-sector productivity and profitability analysis.

Recommended prior reading: ANTILLE, D. L. & MOODY, P. W. (2021). *Nitrogen use efficiency indicators for the Australian cotton, grains, sugar, dairy and horticulture industries.* Environmental and Sustainability Indicators, 10, Article 100099. https://doi.org/10.1016/j.indic.2020.100099

KEY MESSAGES

- The most economic rate of nitrogen (MERN) is the point at which the economic return from N applied as fertiliser is maximised (the cost of any additional N is greater than the value of the extra crop yield produced).
- NUE is maximised by applying N fertiliser using application rate, timing and placement strategies that optimise plant uptake and minimise N loss (Figure 1). The application strategy for optimising NUE is most often also the most economic return from applied fertiliser N.

[1]This analysis assumes a quadratic-plateau relationship between yield and nitrogen applied. The derivation of MERN is discussed in detail in Antille and Moody (2021) (who also provide worked examples using data from Australian trials), based on an earlier work by James and Godwin (2003).



The cotton analysis in this case study used a large sample dataset (*n* = 306) from across several growing regions, sourced from the industry 'N-$mart database' (Visser and McClymont, 2021), which contains applied-N/yield results from field trials between 2010 and 2017; except for Darling Downs (2005-2016) and Bourke (2004-2014).

The sugar example analysed a sample dataset (*n* = 35) from Bell et al. (2014). The MERN values for cotton, sugar and dairy datasets were all able to be determined. For the MPfN Program horticultural tree crops of cherries and mangoes, a lack of yield response data resulted in marginal returns (AUD return/AUD cost of fertiliser) being determined only.

Figure 1. *Conceptual diagram showing a typical yield-to-nitrogen (N) response relationship (black curve), and the increased risk of N lost through leaching (blue curve) and nitrous oxide emissions (red curve) when a critical level of N applied as fertilizer is exceeded (modified from DEFRA, 2010).*

Analysis of farm level economic benefits

Table 1 presents optimal economic rates of applied N and corresponding yields for each industry with calculations based on the approach of Antille and Moody (2021), and (where data availability permits) how this relates to the NUE framework. This case study sought to source comprehensive Business as Usual (BAU) N practice datasets and established yield-to-N response curves. However, this was not necessarily complete or readily accessible for each industry. Best available sample studies and datasets were used to test the NUE framework and therefore may not represent industry-wide advice. Results vary according to context (soil type, climate, crop), and MERN varies according to price ratios at a given point in time (N fertiliser-to-crop/pasture product).

Table 1. *Most economic rate of nitrogen (MERN) and yield at the calculated most economic rate of N (^{Y}MERN), and interpretation of data in relation to the proposed industry specific NUE frameworks. Note that MERN values were calculated using a sub-set of industry data and therefore do not represent the average MERN for the industry.*

Industry	MERN	^{Y}MERN	Relationship between MERN and industry desired NUE range
[1]Sugar - Ratoon cane	178 kg N/ha/yr	118 Mg FW/ha	Within desired NUE range
[1]Sugar - Plant cane	136 kg N/ha/yr	118 Mg FW/ha	Within desired NUE range
[2]Cotton (furrow/flood irrigation)	234 kg N/ha/yr	2695 kg lint/ha (11.9 bales/ha)	Average MERN and that for each region are all within desired NUE range
[3]Dairy – annual ryegrass average seasonal response (Casino, NSW)	67 kg N/ha/ application	614 kg DM/ha/ application	Assuming 14 applications of N, the calculated MERN would deliver an average NUE that sits within the optimal range of the de Klein et al. (2017)'s framework. However, these data should be used with caution as the calculated optimum reflects specific year and site conditions and exceeds current BMP for N (range 20-50 kg N/ha per application (Fert$mart, 2021).
[3]Dairy – summer kikuyu average seasonal response (Casino, NSW)	42 kg N/ha/ application	615 kg DM/ha/ application	Assuming 14 applications of N, the calculated MERN would deliver an average NUE that sits outside (above) the optimal range of the de Klein et al. (2017)'s framework, suggesting under-application of N. However, in de Klein et al. (2017)'s work, the upper NUE limit is 40%. Should this upper limit be re-defined (e.g., 90%, as shown in the generic NUE framework), the average NUE would fall within the optimum range.

Data sources: [1]Bell et al. (2014), [2]Visser and McClymont (2021), [3]Rowlings et al. (2019).

For horticulture crop examples, the study found that limited data and no clear production N response prevented exploratory analysis and application of the NUE framework for cherries and mango crops (Revell 2021a-b). Results and discussion below summarises the average marginal return for the mango and cherry project trials as determined by Antille and Moody (2021).

Results and discussion

Sugar: Analysing the sample dataset showed the MERN falls within the suggested optimum NUE range for both plant and ratoon cane crops and aligns with industry BMP N rates. Datapoints outside (above) the desired optimum NUE range, suggest under-application of fertiliser N and financial penalties. At lower than optimum N application rates, there is still a significant and profitable yield response to increasing rates of N. Datapoints within the suggested optimum NUE range indicate that N inputs have been optimised. Datapoints that sit outside the optimal NUE range suggest over-application of fertiliser N, and therefore increased risk of N loss to the environment and financial penalty due to reduced economic return on applied fertiliser N (Figure 2, below).

Cotton: The analysis showed that except for one region (Macquarie), all calculated MERN values fall within the suggested optimum NUE range, as does the overall average MERN (Figure 2, below). Of the total number of datapoints (n = 296) used to generate region-specific yield-to-N response functions, 24% (n = 71) fell outside the optimum range (across all regions). Among those outside the optimum range, the NUE framework for cotton suggests that 25% (n = 18) were under-applied N and 75% (n = 53) over-applied. As indicated for the analysis of sugarcane data, under- and over-application of N will result in financial penalties and increased risk of soil N depletion or fertiliser N lost to the environment.

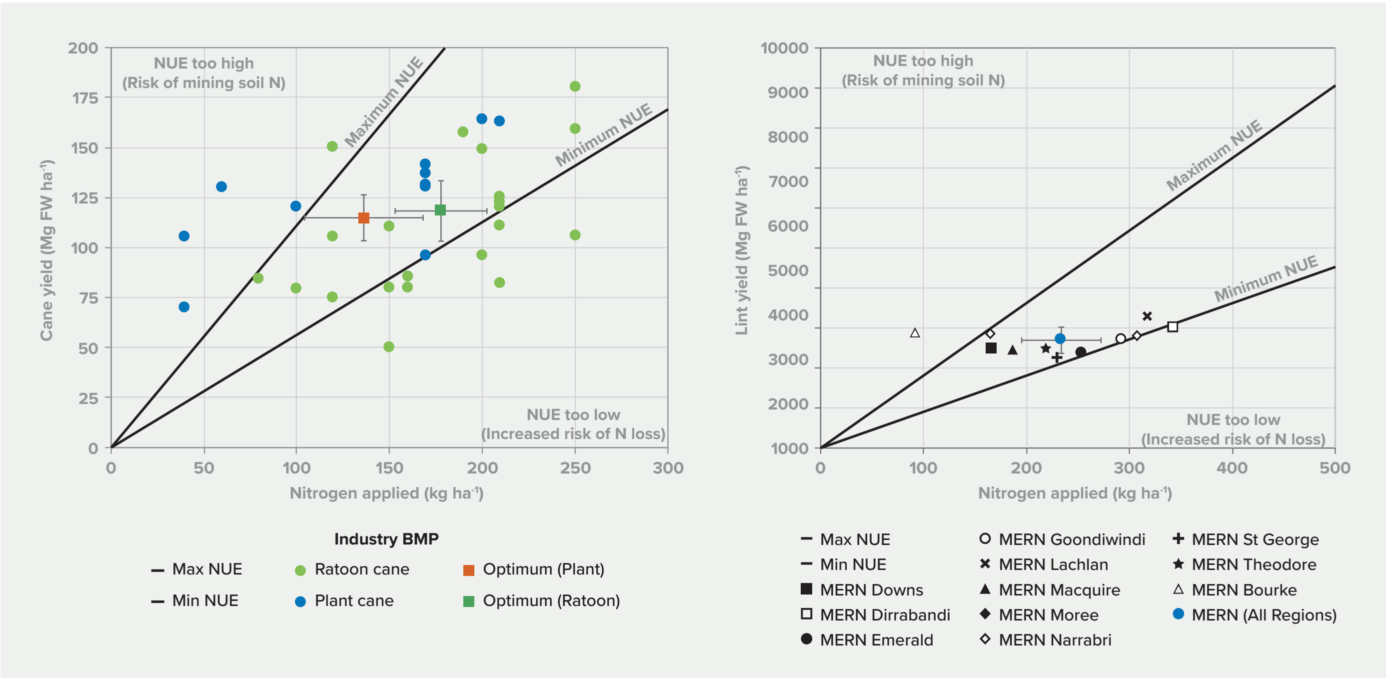


Figure 2. ***Plotting industry most economic rates of N (MERN) against suggested industry optimum N use efficiency (NUE) ranges for sugar (left) and cotton (right). The NUE framework is based on the EU Nitrogen Expert Panel (2015)'s indicator framework adapted by Antille and Moody (2021).*** *Nitrogen use efficiency is expressed as the partial factor productivity of applied fertiliser N. The difference between maximum and minimum NUE denotes the optimum (or target) NUE range. Error bars for average MERN values denote standard deviation (vertical for yield, horizontal for N rate). MERN values were calculated using a sub-set of industry data and therefore may not represent average MERN for the industry.*

Dairy: The analysis relied on MPfN Program data from the Casino NSW commercial dairy farm site (Revell, 2021b). This dairy region relies upon a summer kikuyu and winter annual ryegrass pasture system that is unique to NSW and Queensland. The MERN per seasonal application of N was calculated. Assuming 14 applications of N, the calculated MERN for annual ryegrass would deliver an average NUE that sits within the optimal range of the de Klein et al. (2017)'s framework. However, this data should be used with caution as the calculated optimum reflects specific year and site conditions and exceeds current BMP for N (range 20-50 kg N/ha per application). For kikuyu, the calculated MERN would deliver an average NUE that sits above the optimal range of the de Klein et al. (2017) framework, suggesting under-application of N. However, in de Klein et al. (2017)'s work, the upper NUE limit is 40%. Should this upper limit be increased, the average NUE would fall within the optimum range. Results are a function of the project data set used to generate the MERN (Casino, NSW site) and may also suggest more site-specific data is needed given the complexity of dairy systems (i.e., rain-fed, irrigated and variation between tropical and temperate pasture systems). This project acknowledged low yields for the season and noted yield responses ranging from flat (no response) to exponential, depending on conditions.

Horticulture: Average marginal returns ($ return/$ N cost) for mangoes and cherry production, based on MPfN Program data, vary significantly (between 3.2 and 129.8 for mangoes and cherry, respectively), mainly owing to different value of harvested product (Revell, 2021a). The MPfN mango and cherry projects found a lack of response to applied N. Measured over three seasons, there was no difference in yield or quality related to N application. The research recommended best practice N use at lower rates for the trial sites than current industry practice, presenting savings for growers and reduced risk of N loss. For example:

Mangoes: For an orchard density of 250 trees/ha, and a total crop of 20-30 Mg/ha (equivalent to a commercial crop of 12-18 Mg/ha), recommended application is 21-31 kg N/ha, compared to current practice of applying an average 35 kg N/ha, and up to 70 kg N/ha[2].

Cherries: For an orchard density of 1330 trees/ha, and a two-year average crop of 12 Mg/ha, research findings recommended an annual application rate of 91 kg N/ha for the research site. When compared to a current practice of 120 kg N/ha, a reduction in N fertiliser costs[3] of approximately $200/ha/year may be achieved.

Conclusions

The application strategy for optimising NUE is most often also the most economic return from applied fertiliser N. The most economic rate of MERN is site and year specific, and depends upon the price ratio. However, an average MERN calculated with historical data can be used with confidence to aid N decisions.

In relating a subset of project and industry derived yield-to-N response information to the Antille and Moody (2021) framework, the average MERN for sugar and cotton fall within the suggested optimum NUE ranges. For dairy, the MERN for annual ryegrass delivers an average NUE that sits within the optimal range of de Klein et al. (2017)'s framework, but for kikuyu the NUE sits above the optimal range. However, these results apply the de Klein et al. (2017) framework, which used a 40% upper NUE limit (lower than the EU framework range).

The NUE framework and the MERN analysis are promising tools for supporting farmer N application decisions, helping to communicate and improve NUE, deliver economic savings and reduced environmental impacts of N. With additional N and site-specific yield data, the NUE framework can be refined to confirm target NUE ranges for specific industries and potentially address regional and production differences.

[2]*Project case study: Optimising nutrient management for improved productivity and fruit quality in mangoes — Economic case study for the Northern Territory* *https://www.crdc.com.au/more-profit-nitrogen*
[3]*Project case study: Optimising nutrient management for improved productivity and fruit quality in cherries — Economic case study* *https://www.crdc.com.au/more-profit-nitrogen*

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MPfN Program Sugar research site

MPfN

FURTHER INFORMATION

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Visit www.crdc.com.au/more-profit-nitrogen

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