# Nitrogen use efficiency indicators for the Australian cotton industry

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## AT A GLANCE…

- Terminology and definitions of nitrogen (N) use efficiency (NUE) across the different agricultural industries in Australia are not standardised. This makes it difficult to perform long-term industry-specific assessments of NUE, inform N management practices, and guide future R&D.
- Metrics used to measure NUE in Australian cotton systems were critically reviewed and used to define, describe and interpret guidelines for a suite of NUE indicators.
- The following NUE indicators are proposed: N utilisation efficiency (NUTE), N uptake efficiency (NUPE), Agronomic efficiency (AE), Partial factor productivity of applied N (PFPN), and Marginal return on applied fertiliser N (MRF).
- An NUE indicator framework for irrigated cotton systems was also proposed, which could be developed for, and applied to, other industries as data from the MPfN Program (*https://www.crdc.com.au/more-profit-nitrogen*) become available.

THE More Profit from Nitrogen (MPfN, *https://www.crdc.com.au/more-profit-nitrogen*) is a four-year cross-industry research program established to bring about increased farm profitability and reduced environmental impact by increasing nitrogen use efficiency (NUE), resulting in a reduction of the amount of N required to produce each unit of product for cotton, dairy, sugarcane and the tree crops of mango and cherry.

The 10 research projects of the program are financially supported by the Department of Agriculture, Water and the Environment (Australian Government) as part of its Rural Research and Development for Profit Program in collaboration with the Cotton Research and Development Corporation, Sugar Research Australia, Dairy Australia, and Horticulture Innovation Australia. The program is now in its final stages of research activity. For each of these industries, N is a significant input cost to producers and a substantial contributor to environmental footprints.

To achieve improved NUE, the MPfN Program aimed to expand the knowledge and understanding of:

- The interplay of soil, seasonal weather, and farm management factors for optimising N fertiliser formulation, rate, timing and placement across industries, farming regions, and irrigated and non-irrigated agriculture;

**TABLE 1: Comparison of proposed nitrogen (N) use efficiency (NUE) indicators for Australian agricultural systems**

| Proposed NUE indicator | Acronym | Focus | Factors affecting | Interpretation |
|---|---|---|---|---|
| Fertiliser N utilisation efficiency | *NUTE* | Productivity | Environmental and nutritional constraints to crop production; varietal/cultivar differences; general crop and soil husbandry. | Crop's ability to transform N taken-up from all sources into total biomass. |
| Fertiliser N uptake efficiency | *NUPE* | Productivity, Environmental | Environmental and nutritional constraints to crop production; varietal/cultivar differences; general crop and soil husbandry; off-site N losses. | Uptake per unit of N applied. If calculated by the difference method, proportion of N applied taken-up by the crop. |
| Agronomic efficiency of applied fertiliser N | *AE* | Productivity, Environmental | Environmental and nutritional constraints to crop production; varietal/cultivar differences; general crop and soil husbandry; off-site N losses. | Productivity per unit of N applied. If calculated by the difference method, then this shows net productivity per unit of N. |
| Partial factor productivity of applied N | *PFPN* | Productivity | Environmental and nutritional constraints to crop production; varietal/cultivar differences; general crop and soil husbandry; off-site N losses. Confounded by the contribution of soil N to crop N uptake and yield | Productivity per unit of N applied, but without account taken for yield that would have been produced with nil applied N fertiliser. |
| Marginal return on applied fertiliser N | *NRF* | Profitability | Relativity of fertiliser cost to product value (price ratio). | Economic return per unit of N applied |

- The contribution of mineralisation of soil organic matter (SOM) to the N budget of a crop or pasture; and,
- How enhanced efficiency fertiliser (EEF) formulations can better match a crop or pasture's specific N requirements.

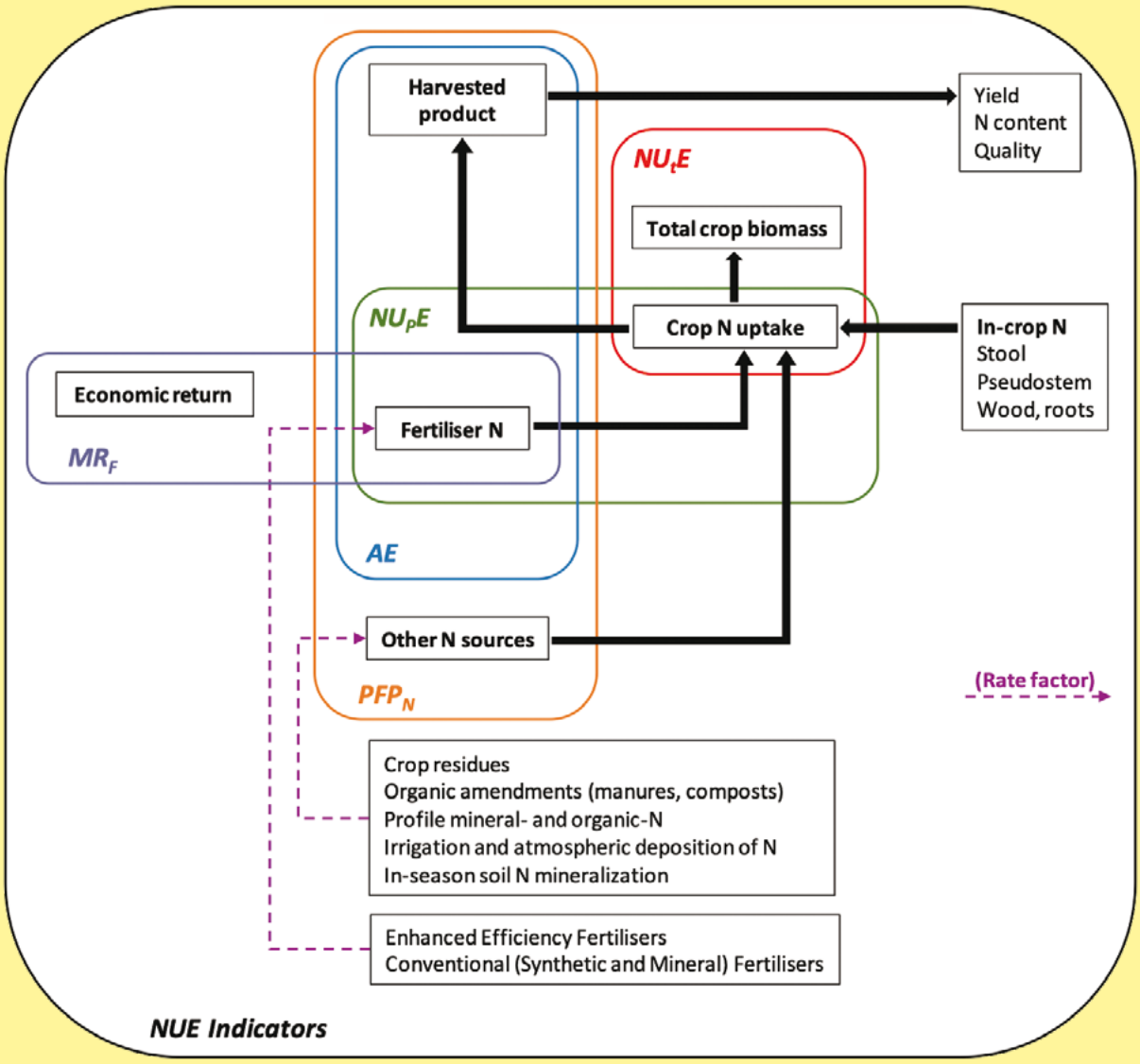
These formulations include controlled release fertilisers (e.g., polymer-coated urea), and slow release fertilisers such as those that contain urease or nitrification inhibitors.

## Nitrogen use efficiency

There are multiple ways that nitrogen (N) use efficiency (NUE) can be assessed. But at present there is no consensus as to how NUE should be calculated and reported across the different agricultural industries in Australia, which makes it difficult to communicate NUE data in a consistent manner. This variation in NUE terminology and definitions also makes it difficult to perform long-term industry-specific assessments of NUE, inform N management practices, and therefore guide future research and development needs focussed on N management.

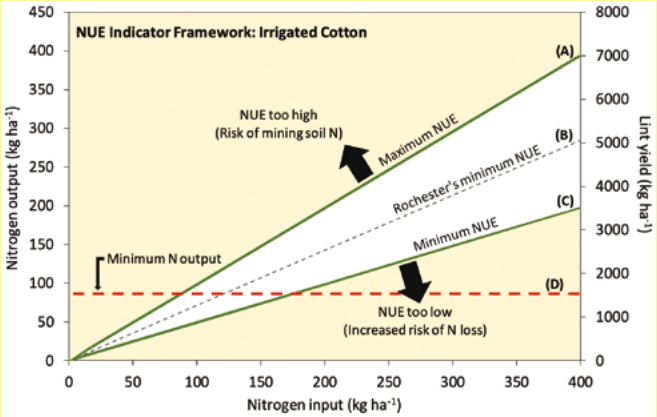
We reviewed and collated the various metrics used to measure NUE in order to define a suite of NUE indicators which can be applied across a range of crops, including cotton.

**FIGURE 1: The inter-relationship of the proposed NUE indicators**




AE: Agronomic efficiency of applied fertiliser N, NUPE: Fertiliser N uptake efficiency, NUTE: Fertiliser N utilisation efficiency, PFPN: Partial factor productivity of applied fertiliser N; MRF: Marginal return on applied fertiliser N.

**FIGURE 2: Conceptual diagram of the nitrogen (N) use efficiency (NUE) indicator framework for Australian irrigated cotton cropping systems**




- The slope of lines 'A' (maximum NUE) and 'C' (minimum NUE) represents the target NUE range;
- Line 'B' comprises the applied rate of a designated N fertiliser (in this case, urea) (x-axis) required to produce the designated yield of harvested product (right-hand y-axis) with the designated PFPN (the relationship between yield and N rate).
- Line 'D' denotes the desired minimum level of productivity (equally, the N output associated with such productivity level).

The most desirable outcome would be between lines 'A' and 'B'. The area below Line 'B' and above the minimum NUE line, 'D', represents outcomes where measures should be taken to improve NUE. These measures include improving fertiliser management practices through the '4Rs' (right product, right rate, right place, and right time) of Nutrient Stewardship and joint management of water and the soil biophysical environment.

The shaded yellow area above Line 'A' denotes unrealistically high NUE, that is, PFPN is higher than 100 per cent recovery of applied N fertiliser. Such a result occurs when N of soil or other origin contributes an appreciable proportion of N to the total biomass N.

For the yellow shaded area below the 50 per cent PFPN line (Line 'C'), there is an unacceptably high risk of N loss to the environment because the N application rate is not optimised for the cropping system.

Reports of the extent to which N is recovered depend on the adopted definition of NUE and whether crop yield, N uptake or other data are used. But it is generally agreed that a 'large' percentage recovery of applied N reflects an 'efficient' use of that N by the crop. Key factors affecting the efficient use of N from applied fertiliser are:

- Crop N demand and crop variety;
- SOM content and composition (which impact on the quantum of net N mineralisation/immobilisation);
- Plant availability of soil phosphorus (P) and potassium (K) (which may be sub-optimal and therefore confound the response to applied N); and,
- The soil biophysical environment (structure, compaction, water storage capacity and internal drainage; which may constrain root development and function, and affect soil and fertiliser N dynamics).

## NUE indicators

We have proposed the following NUE indicators:

- Fertiliser N utilisation efficiency (NUTE);
- Fertiliser N uptake efficiency (NUPE);
- Agronomic efficiency of applied fertiliser N (AE);
- Partial factor productivity of applied N (PFPN); and,
- Marginal return on applied fertiliser N (MRF).

The calculation, interpretation and usefulness of these NUE indicators are summarised in Table 1, and described more extensively in our recent research paper*. The inter-relationship of the proposed NUE indicators is shown in Figure 1.

## Indicator framework

An NUE indicator framework was adapted for Australian irrigated cotton cropping systems (Figure 2). This concept could be applied to other industries as more data from the MPfN program become available.

## Key conclusions

Case studies for irrigated cotton have reported values of NUPE (fertiliser N uptake efficiency) between 45 per cent (Queensland) and 62 per cent (New South Wales). Soil profile N plus in-season soil N mineralisation contributed between 150 and 190 kg N per hectare.

There appears to be potential to increase NUPE in irrigated cotton, and this may be possible through mitigation of N loss processes by:

- Addressing soil physical constraints;
- Changing to fertiliser forms better synchronised with crop N demand; and,
- Joint optimisation of water and N inputs.

Reducing N inputs without impacting productivity may be possible, and this approach (reduced N inputs) will also reduce the risk of N losses through processes such as denitrification and leaching.

The conceptual N use efficiency (NUE) framework proposed for irrigated cotton needs to be verified with more recent experimental data from the MPfN Program. The same conceptual approach could be also applied to other industries to establish NUE (as measured by PFPN) target ranges that are industry-specific.

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