Nitrogen use efficiency (NUE) and tools for farmer engagement: a good reason for being imprecise

Ashley Evans[1], Donna Lucas[2,] Dr Doris Blaesing[2]

[1] RM Consulting Group, PO Box 396, Penguin, Tasmania, 7310, http://www.rmcg.com.au, ashleyh@rmcg.com.au
[2] RM Consulting Group, PO Box 396, Penguin, Tasmania, 7310

Abstract
A nitrogen use efficiency (NUE%) calculator was developed to engage with cropping farmers and advisors on reducing nitrogen (N) losses from crop production.

The calculator utilises the 'partial nitrogen balance' (or 'output-input ratio') method to calculate NUE% for an individual crop, a rotation or a whole farm. It also enables estimating the monetary value of potentially unused mineral and organic nitrogen fertiliser.

Experience has demonstrated that both, farmers and advisors, are keen to engage with the tool due to its ease of use and the value of the results in supporting decisions on farm and monitoring NUE% over time. Farmers and advisors have used the calculator for a variety of reasons, including for verification of current best management practices, a means to assess whether or not fertiliser application is efficient and as a way to benchmark groups of producers in a region or groups growing a specific crop.

Calculating NUE% is a successful way to engage with cropping farmers and advisors. The review of nitrogen inputs, removal and costs, based on easily available data, proved an effective starting point for moving to more in-depth discussions about overall nitrogen, soil and crop management. This supported good planning and decision-making for farmers. In our experience, attempting a review of management practices with complex information and using assumptions where actual farm data is not available can disengage people.

Key Words
communication, extension, partial nutrient balance

Introduction
The method used in the described calculator for estimating NUE% on farms is the partial nutrient balance (also known as output-input ratio or removal to use ratio). This method calculates NUE% as follows:

$$\text{NUE\%} = \text{N removed} / \text{N applied} \times 100$$

Nitrogen sources taken into account include nitrogen from applied mineral and organic N, such as synthetic fertilisers, compost and soil amendments. The calculator does not take into account N fixed from legumes or mineralisation of organic matter. It also does not detail N loss pathways.

A high NUE% of >100% can indicate that more N is being removed than is being applied and the plants are accessing N from the organic pool or residual N from fertiliser applications to a preceding crop. It can also indicate that N is being accessed from sources not taken into account by the calculator, for example a green manure crop. It is important to establish the reason for a >100% NUE e.g. through discussion with the farmer and soil testing, as depleting the organic pool can result in N deficiencies at a later stage, if not replenished. This is particularly relevant from a crop rotation perspective.

A lower NUE%, e.g. <70-60% (depending on the crop) indicates that less N is being removed than has been applied; applied N is left in the soil and may be lost if not used by the next crop. If NUE% is low, it could indicate excessive use of fertilisers or issues with soil or crop health i.e. the crop has not grown to its potential due to lack of water, lack of other nutrients or pests and diseases, so that a standard fertiliser program provided too much N.

The tool and user guide are available online (Tas Farming Futures, 2014).

Approach

The NUE calculator was developed as an engagement tool to facilitate practice change on farms

The calculator was initially developed as an engagement tool as part of the Tas Farming Futures project (a three year carbon farming extension project funded by the Australian Government). It was developed to facilitate discussions about N losses, including N_2O losses by using easily available data from the farmer's own farm. We found that with other tools e.g. horticulture GHG calculators, if calculations were too complex or required numerous data inputs, people became disengaged. In most cases, the data required for complex tools was not available from standard farm records or were difficult to access by the farmer.

Therefore, a straightforward partial nutrient balance approach was adopted rather than more complex calculations that take into account pre- and post-crop soil available N, mineralisation rates (which are influenced by climatic factors, organic matter C:N ratios and the previous crop) and N losses (leaching, runoff, gaseous losses). Estimating these can be challenging, and therefore the results can be imprecise and vague. Farmers are also reluctant to use information based on estimates or data not originating from their own farm as a basis for making changes to management practices.

Crop N removal data and fertiliser N% data

The NUE% approach used relied on data that was easily recalled by farmers i.e. crop yield and nitrogen fertilisers used (type, rate and cost).

The calculator contains N removal data for the crops commonly grown in Tasmania, including poppies and pyrethrum. Users can add additional crops if required. The calculator was not designed for pasture-based enterprises. However, it does allow data entry for grazing of crop residues, which is common practice in Tasmania. It includes fertiliser N% data for a range of commonly used fertilisers and users can add additional products if required. Data for soil amendments, such as composts and animal manures were not included in the calculator due to the wide variation in nitrogen percentages in those products as well as mineralisation rates. However the user can add these N sources into the calculator if used on farm.

This partial nutrient balance approach has been proposed overseas as an agro-environmental indicator (Brentrup and Palliere, 2010) based on research.

NUE% can be calculated for individual crops, paddock rotation e.g. the NUE% for *x* years on a given paddock, or the whole farm i.e. the whole farm for a given year(s). It can be used to compare groups of farmers or regional practices. In addition, the calculator can provide an estimate of the monetary value of potentially unused nitrogen fertiliser.

Findings and discussion

Start with simple calculations

Starting with easy to access data and a straightforward concept meant that we could engage with farmers and their advisors with different background knowledge in a range of settings. The use of the NUE% calculator led to discussions about fertiliser types, amounts, timing of application and placement, as well as more complex N interactions including mineralisation rates, leaching, potential losses and risk factors (e.g. soil moisture, type of fertilisers and timing). It triggered the interest in monitoring more complex aspects of N management.

Working with farmers one-on-one to support decision-making

Nitrogen management can be a substantial portion of farm production costs and many producers in Tasmania are looking at ways to reduce this cost. The calculator proved to be a useful tool to engage with individual farmers as it provided data in the context of the farmer's own business. This enabled discussion, for example, about why the NUE % was low or high. Often the NUE% could be related to using fertilisers unsparingly, the effect of the previous crop (rotation) and/or the harvest indexes. Farmers, with the support of their advisers, were able to develop plans for nutrient and cost efficient nitrogen management. Actions included implementing soil and plant N monitoring, changing rotation or growing a green crop to capture unused N, using different fertiliser products or changing the rate and/or timing and/or placement of N fertiliser applications. For some farmers, the NUE% calculation confirmed that what they were already doing was sustainable. For some it led to a discussion of the effect of high N inputs or nutrient imbalances on crop health.

It was challenging to use the NUE calculator for seed crops e.g. vegetable seeds, because the harvest index is low, but the crop still requires sufficient N to grow. In this case the calculator was still useful for supporting discussion about N fertiliser management, crop nutrition, irrigation and soil management. It also highlighted the importance of considering the whole rotation and therefore considering available N before deciding on N fertiliser rates and timing.

Several farmers were surprised about the monetary value of potentially unused fertiliser. Although they were aware of income, costs and gross margin of each crop (they had good data on crop yields and gross margins), they had not considered the monetary value of potentially lost N. The NUE calculator provided them with a different way of assessing N fertiliser decisions.

Benchmarking groups
The ability to compare results within a group promoted discussions around the differences between farms and why those differences occurred. NUE% was calculated for 49 potato crops for Simplot Australia for the 2013/14 season. The calculations highlighted a wide range in NUE% (57% to > 100%). One interesting outcome of this was that regional differences in NUE% were found across Simplot's growing area. It was also noted that soil structure played an important role in many of the observed low efficiencies. It was concluded by the field officers that the tool could be used to support their fertiliser and soil management recommendations to producers, adding validity through numbers and in particular potential money saved. The ability to draw on locally relevant data was also useful for communications e.g. the 2013/14 Simplot potato crop data was utilised in an article on potato NUE%.

NUE% for individual crops
When considering individual crops e.g. a wheat crop grown in a particular year, the NUE% should be viewed with consideration of the harvest index as well as the previous crop. For example some crops may have a low NUE% because of a low harvest index (ratio of biomass removed via harvest to biomass left behind). In this situation a relatively large amount of reside is left on the paddock after crop harvest/removal. This residue provides organic matter for the soil, which will in turn provide N (and other nutrients) for the next crop, as it is broken down by soil microbes. The next crop should then have a relatively high NUE, so long as N fertiliser is not over-applied, because the crop can access mineralised N from the crop residues in the soil. This applies if the carbon to nitrogen ration (C:N) fosters mineralisation of organic matter i.e. is below 25.

The sustainable NUE% for a specific crop will depend on the type of crop, harvest index, the previous crop and how they fit into the rotation. The range of data from NUE% calculations for selected crops is shown in Table 1.

Table 1. NUE% data from Tasmanian crops.

Crop	Mean NUE %	Range	N
Poppies	47%	34 - 85%	11
Potatoes[a]	109%	57 – 233%	57
Wheat[b]	148%	53 - 271%	12

[a] excluding two crops grown following green manure crops 226% and 709%.
[b] excluding one crop with minimal N usage and NUE% >1000%

We found that NUE% can become less relevant at very low N fertiliser rates. For example, one farmer grew a 63t/ha potato crop with N applied of 44.5kg N/ha. In this case the NUE% was 709%; the previous crop was grass hay and prior to that a green manure crop. While this percentage is not very meaningful, is still highlights N efficiency. It allowed discussion with potato growers about: N management, harvest index, mineralisation rates and growing season/time and it illustrated N cycling and efficiency. Very low fertiliser rates can be correct/appropriate if they are part of a wider nutrient management plan but can be unsustainable if they lead to long-term soil mining.

NUE% for rotations or farming system
If the NUE% of a rotation or farming system is >100% there is a risk of mining soil N and reducing the soil N status. If the NUE% is low, this indicates that N is not being used by the crop and likely to be lost to the

environment especially if the soil is kept fallow for some time after harvest. All N losses represent an environmental risk as well as a cost to producers.

In general, partial nutrient balance NUE of 80-100% for a whole rotation/system is considered sustainable. This is taking into consideration factors such as N supplied through e.g. green manure crops. The range of data from 11 Tasmanian farms that calculated overall NUE was 67% to 159%. The farm with the highest NUE% had healthy soils, was using green manure crops in rotation with cash crops and nitrification inhibitors were also used. The tool can be utilised as a basis for discussions around N sources other than synthetic fertilisers.

Monitoring
NUE% for crops, paddocks, rotation or the whole farm can be monitored over time. This process is illustrated in figure 1. Monitoring NUE% allows an assessment of whether management practices have been effective and can also assist with identifying any emerging issues/trends.

Figure 1. Nitrogen management and monitoring cycle.

Conclusion

Starting with straightforward information, i.e. partial nutrient balance NUE%, before moving to more complex information/discussions encompassing mineralisation or N losses is effective for supporting farmer decision-making, and in turn increasing NUE sustainably. This is a good reason for neglecting complex N interactions with initial calculations. Starting with complex information is less effective in supporting the decision making process with farmers and advisers. NUE% can be easily calculated at a crop, rotation or whole farm scale. The NUE% data is useful for monitoring efficiency over time. This enables further fine-tuning of N management.

References

Brentrup, F and Palliere, C (2010) Nitrogen use efficiency as an agro-environmental indicator. OECD workshop "Agri-environmental indicators: lessons learned and future directions", 23-26 March 2010, Leysin, Switzerland. http://www.oecd.org/tad/sustainable-agriculture/44810448.pdf (accessed May 2016).

Tas Farming Futures (2014) Nitrogen Use Efficiency Calculator and User Guide, http://www.tasfarmingfutures.com.au