Nitrogen fertiliser decisions – the good, the right and the risky

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Take home messages

- The 'right' N fertiliser decision maximises profit, replaces N taken out in grain plus any N lost from the soil, and minimises chances of losing money in any given year
- It is difficult to make the 'right' N decision every year, but 'good' decisions are relatively easy and are more likely to be 'right', particularly when reviewed over several years
- There are many ways of making 'good' N decisions that suit different decision-making preferences – pick one that suits you and use it
- Check that your 'good' decision-making system is 'right' in the short-term using grain protein, and in the long-term using a partial N balance.

Background

Risk is a term that has taken on many definitions but is commonly used to describe the chance of something negative happening. However, the more formal definition is that there is a range of outcomes associated with an action (both positive and negative), and that the probabilities of the different outcomes are known. This definition perfectly describes N fertiliser decisions in Australian cropping systems. When a decision is made about how much fertiliser N to apply to a crop and when, there is a range of possible outcomes in terms of the effect on yield, quality, logistics, labour and profit (some positive, some negative). The probabilities of these different outcomes can be estimated, based on soil tests for water and mineral N, and historic climate data, either using a complex tool like Yield Prophet® or simpler tool based on rainfall deciles like Yield Prophet Lite.

'Good' and 'right' decisions

Nitrogen decisions are a clear demonstration of the difference between 'good' and 'right' decision making. 'Right' or 'wrong' relates to the outcome of a decision. For this discussion, 'good' or 'bad' relates to the process of deciding. A 'good' decision is based on available evidence and information, with appreciation of both likelihood (probability) and consequences (outcomes) of any action that is taken (Nicholson 2019). A 'bad' decision is made in the absence of evidence and relies on assumptions and guesses. 'Good' decisions can be both right and wrong when reviewed in hindsight. Whether an N fertiliser decision is 'right' or 'wrong' largely depends on seasonal conditions following N application (rainfall, temperatures, etc.), which, in Australia, are highly variable. Whether an N decision is 'good' or 'bad' depends on the evidence used to make the decision, and if the performance of the decision-making process or system is reviewed and adjusted over the longer term.

How to make 'good' N fertiliser decisions

GRDC RiskWi$e has been evaluating different N fertiliser rate decision-making processes (Table 1) in a national network of field experiments. An emerging finding from this network of experiments is that there are lots of ways to make 'good' N decisions that use different sources of evidence, and that there are 'good' decision-making processes available that suit a broad range of decision-making preferences. Some of the decision-making processes in Table 1 are highly active and analytical and require a lot of input information and time on behalf of the decision maker, e.g. Yield Prophet or Replacement+Protein. Others, such as N banks or Financial, are more passive, require less information, and don't explicitly consider risk in the decision-making process, but an appreciation of risk is embedded in their derivation.

Table 1. The different N decision-making processes being evaluated in GRDC RiskWi$e. The methods evaluated at each site were chosen by local action research groups, so not all methods are included at all sites.

Decision-making process	Abbreviation	Description
Nil	NIL	Nil top-dressed N control. Starter fertiliser (for example, MAP) at sowing only.
District practice	DIS	N rate determined by local N decision-making process.
National average	NAT	National average N fertiliser rate (45kg N/ha) applied each season.
N Bank Conservative	NB_CON	25kg N/ha less than environment economic optimum.
N Bank Optimal Profit	NB_PRF	Environment economic optimum N bank target.
N Bank Optimal Yield	NB_YLD	25kg N/ha more than environment economic optimum.
Decile 1	YP_D1	Yield Prophet or Yield Prophet Lite assuming 100% probability or decile 1 rain for remainder of season (severe drought).
Decile 2-3	YP_D3	Yield Prophet or Yield Prophet Lite assuming 75% probability or decile 2–3 rain (moderate drought).
Decile 5	YP_D5	Yield Prophet or Yield Prophet Lite assuming 50% probability or decile 5 rain (median).
Decile 7-8	YP_D7	Yield Prophet or Yield Prophet Lite assuming 25% or decile 7–8 rain (favourable).
Forecast Responsive	YP_BOM	Yield Prophet or Yield Prophet Lite informed by Bureau of Meteorology 3-month seasonal climate forecast.
Financially Responsive	FIN	Apply as much N fertiliser as can be purchased with 8% of gross income from the previous season at current market value of urea.
Replacement	REP	Amount of N removed in grain applied as fertiliser N in the following season.
Replacement + Protein	REP_PRO	Replacement of N removed in grain +/- extra based on protein content of previous crop.
Replacement +30%	REP_HI	Apply N fertiliser equal to grain N offtake from previous season plus 30%.
Replacement -30%	REP_LO	Apply N fertiliser equal to grain N offtake from previous season minus 30%.
Enhanced fertilisers	EEF	N fertiliser is supplied with coatings to reduce losses (for example, urease inhibitors, polymers, nitrification inhibitors)
Manure	MAN	Proportion of N supplied through addition of manure of known N content

The difference between the GRDC RiskWi$e experiments and past N experiments is that they evaluate decision-making processes or systems rather than fixed rates, and that the treatments are applied to the same plots year after year, allowing effects to accumulate and long-term performance of different decision-making processes to be evaluated. This long-term approach has revealed that 'good' decisions are much more likely to be 'right' decisions when reviewed over more than one season, because both unused N and water carry-over to subsequent crops. Carry-over of N compensates for one-off over-fertilisation by reducing costs or boosting yield in subsequent seasons. Often N deficient crops don't extract all the available soil water, and this can compensate for one-off under-fertilisation by increasing yield in subsequent years. Reviewing performance over many seasons means that decision-making processes based on probability have a larger number of years to approach the probability distribution used to predict risk.

How to make 'right' N fertiliser decisions

In the analysis of the experiments, we use several criteria including profit, risk, water-use efficiency, environmental losses and maintenance of soil organic matter, to evaluate how 'right' different decision systems are. A key finding was that long-term yield and, to a lesser extent, profitability (gross margin) was largely explained by mean (long-term average) N rate (Figure 1 and Figure 2). Whilst different decision methods vary in how much N they recommend in a single year and this can result in a decision being 'right' or 'wrong' in that season, when considered over the long term, these annual differences even out. At most sites, gross margin has a weaker and flatter relationship with N rate (Figure 2) compared to grain yield. That is, decision-making systems can vary quite a bit in how much N they apply on average, but the mean gross margin is similar. Mean annual gross margins are roughly equivalent at mean annual N rates varying from 0 to 90kg N/ha at Bute, 40–90kg N/ha at Curyo, 80–160kg N/ha N at Dookie and 50–150kg N/ha at Griffith.

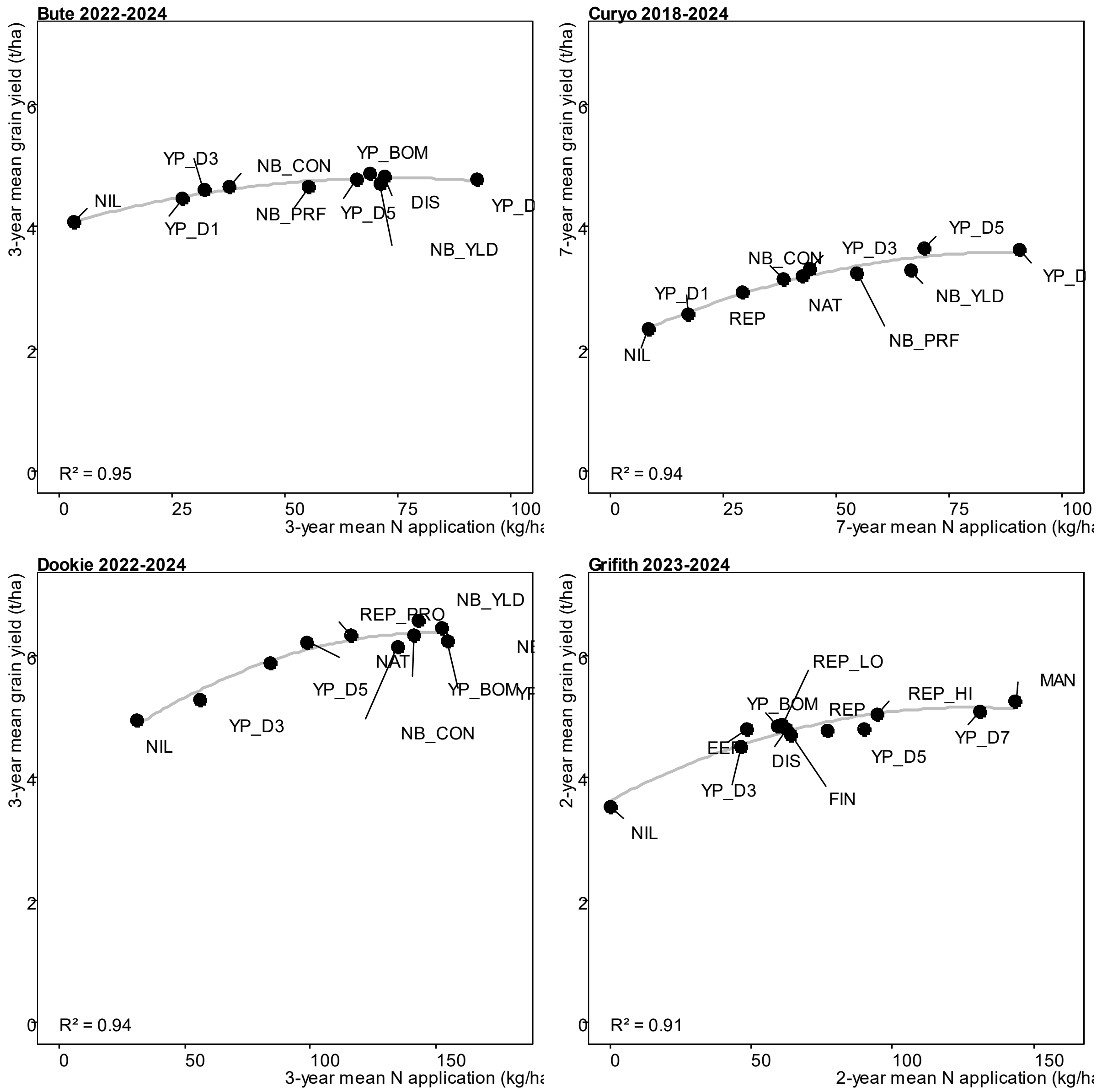

Figure 1. The relationship between mean annual N application and grain yield for a subset of four sites from the GRDC RiskWi$e network (Bute, Curyo, Dookie and Griffith). See Table 1 for a list of treatment abbreviations.

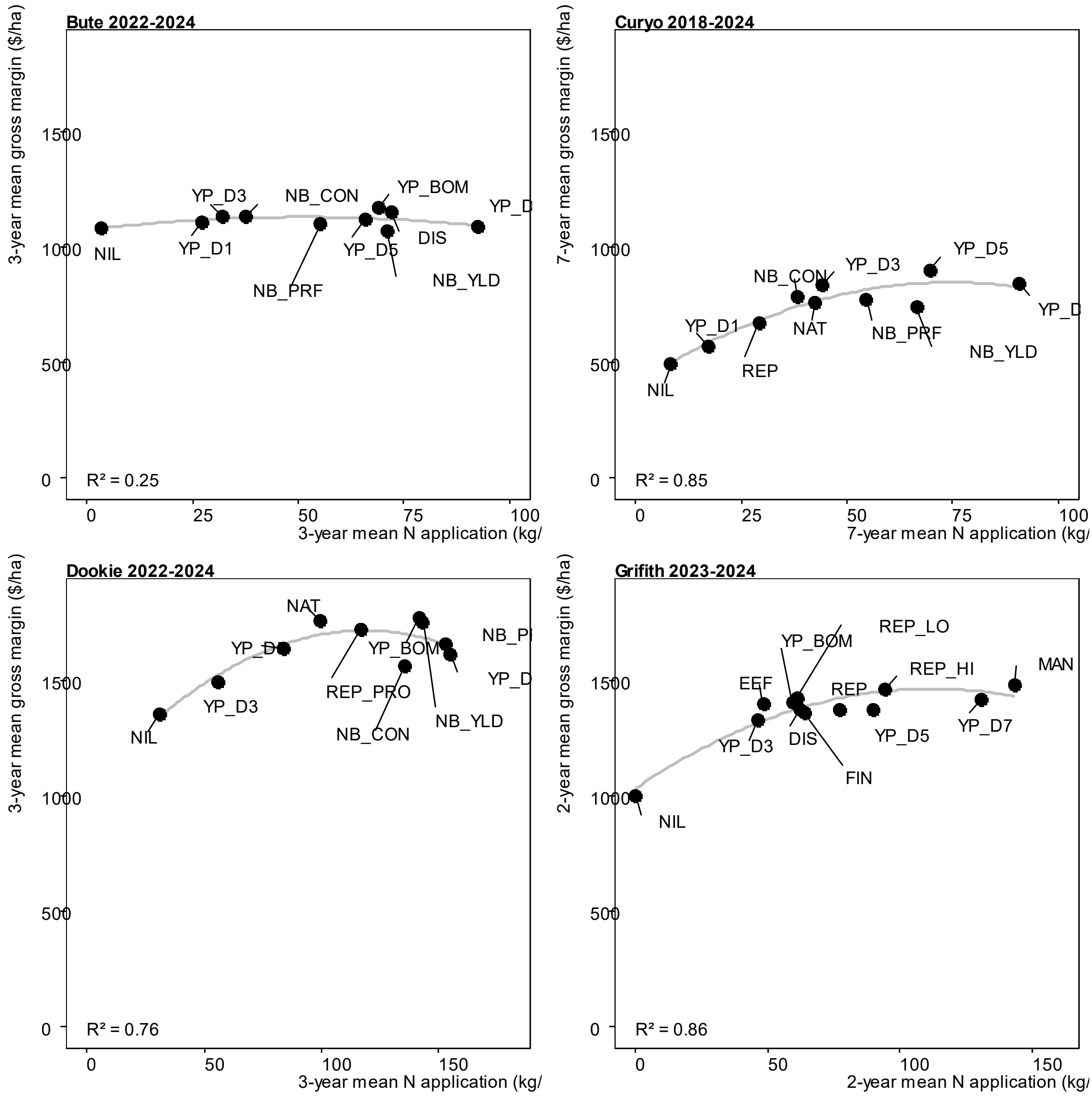

Figure 2. The relationship between mean annual N application and gross margin for a subset of four sites from the GRDC RiskWi$e network (Bute, Curyo, Dookie and Griffith). See Table 1 for a list of treatment abbreviations.

Despite the flat response, active evidence-based analytical systems, like Yield Prophet, that consider risk in their decision making, are consistently profitable (that is, 'right') at most sites, but more passive systems are often equally profitable, or not far behind. For example, at all sites YP_D5 and YP_BOM treatments frequently sat at the peak of the fitted curves, but NB_PRF or REP usually had similar mean N application rates and profit.

An implication of the finding that long-term average N rate explains >90% of variation in yield is that 'bad' decisions not based on evidence in the year of application can be 'right' if, over the long term, they achieve the average optimum N rate for a given environment. This means that very passive N decision-making processes (e.g. same N rate on every crop in every year) can also achieve close to maximum yield and profit, provided the outcome of the decision process are reviewed over the short and long term, to ensure the decision is 'right'. Reviewing and adjusting simplistic decisions in this way validates them with evidence, so even the simplest of decisions need to be evidence-based to be 'good'.

The simplest way of reviewing decision-making performance over the short term is by reviewing grain protein data. A consistent finding of the RiskWi$e experiments is that profit is maximised in cereals when grain protein is between 10 and 12% and, in canola, between 22 and 24%. If protein contents are lower than these ranges, crops were likely to be N deficient and didn't yield as well as they could have, which reduces gross income and profit. If they are higher than these ranges, more N was applied than necessary to achieve maximum yield, which increases variable costs, and, in some cases, excessive N reduces grain or oil yield, which reduces gross income.

Keep the system in balance

Given that a broad range of decision-making systems can deliver equivalent gross margins, how can we further evaluate decision-making systems to tell which systems are most 'right'? Partial N balance is an easy and powerful way for growers and advisers to evaluate how 'right' an N decision system has been over the longer term (>3 years). Partial N balance is the difference between major N inputs to the cropping system (fertiliser and legumes) and N exports in grain and hay. The term 'partial' is used because N losses, atmospheric deposition, non-rhizobial N fixation and animal export are not included because they are hard to estimate, tend to be relatively small, and cancel each other out. A cropping system which has higher N inputs in fertiliser and legumes than the N exported in the grain has a positive partial N balance. A system which has lower fertiliser and legume N inputs compared to grain export has a negative N balance and is mining soil organic N to maintain crop productivity. Mining soil organic N releases CO2 into the atmosphere, as soil organic matter mineralises and is not replaced due to N deficiency, limiting the formation of stable soil organic matter.

At all GRDC RiskWi$e field sites, there are N decision-making systems that are profitable but also maintain a neutral to slightly positive partial N balance (Figure 3). This means they generate N recommendations that put back what is taken out in grain and are unlikely to be mining soil organic N and emitting CO2. Maintaining soil organic matter also provides a buffer that reduces risk associated with N management decisions. This is illustrated by comparing N rate and gross margin in Figure 2 at Curyo (0.7% soil organic carbon from low rainfall, light soil texture and a long history of long fallowing) with Dookie (1.2% organic carbon from high rainfall, heavier soil texture and a long history of legume pastures). At Curyo, the Nil and low N treatments are substantially less profitable than YP_D5 because there is very little mineralisation in favourable seasons to support crop yield, and yield is reliant on getting N fertiliser decisions 'right'. At Dookie, the Nil and low N treatments are not as far behind YP_D5, because mineralisation is able to better support yields in favourable seasons, which means there is less pressure to get N decisions 'right' in every single year.

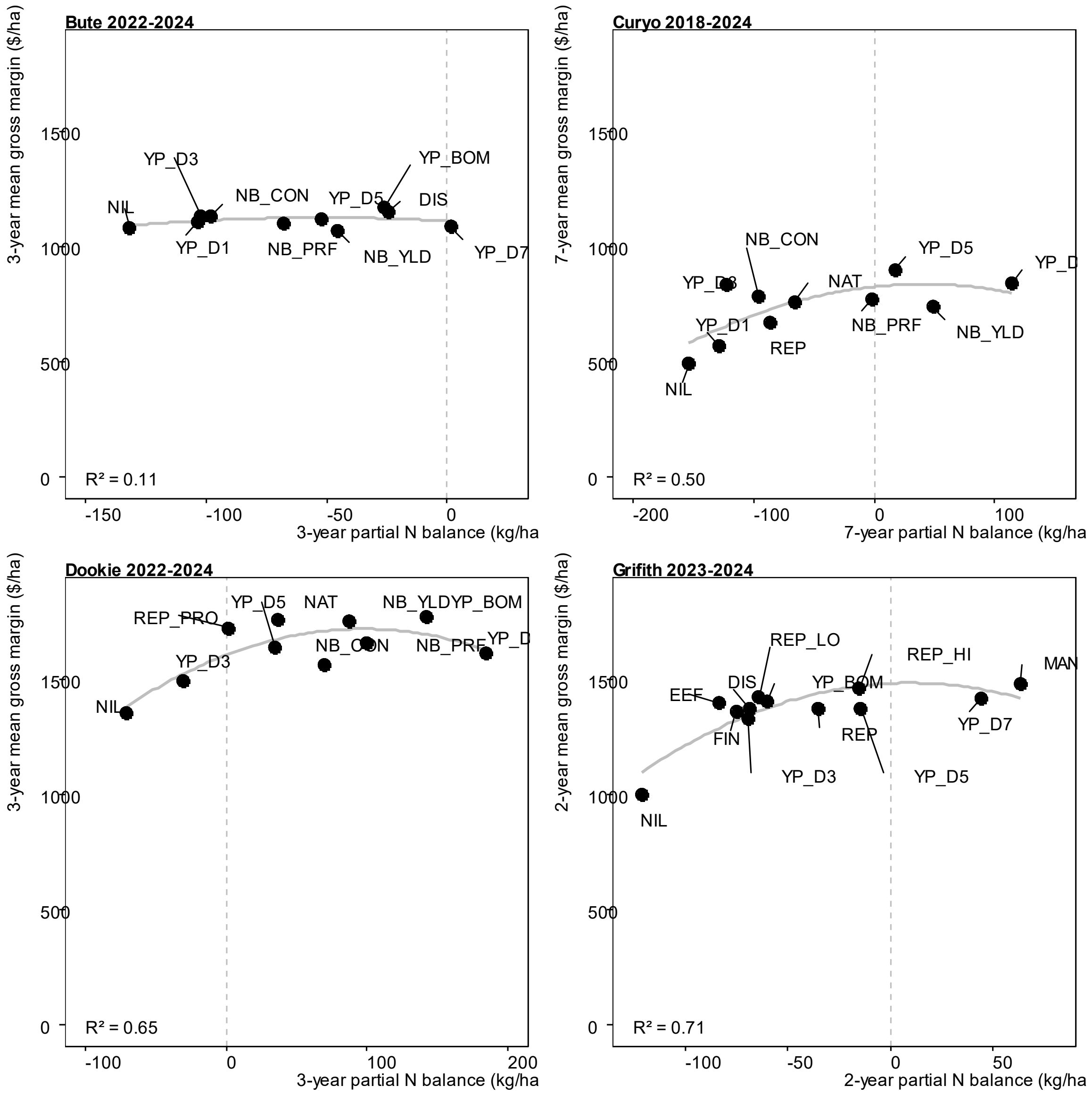

Figure 3. The relationship between partial N balance and gross margin for a subset of four sites from the GRDC RiskWi$e network (Bute, Curyo, Dookie and Griffith). See Table 1 for a list of treatment abbreviations.

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RiskWi$e – the National Risk Management Initiative https://research.csiro.au/riskwise/

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