N Bank, N Budget, N Balance – which is right for me?

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Take home message

- No N budgeting approach is perfect; each has its own set of pros and cons
- When adopting a method to assess likely fertiliser requirements, it is important to consider how it meets both your seasonal production and longer-term soil fertility goals
- Recording key inputs and outputs over time is crucial in tracking progress to improve productivity, N efficiency, soil fertility, and reducing risks associated with applying fertiliser nitrogen.

Background

In the mid-1990s, a significant shift in our understanding of nitrogen application rates occurred with the introduction of the seasonal N Budget in eastern Australia. This concept directly responded to the need for a more flexible determination of seasonal fertiliser N rate, pre-sowing. It represented a departure from the previous approach, where fertiliser N rates were primarily based on a regional fixed linear relationship with soil mineral N content, and fertiliser N was often less than 30% of the total crop N requirement. This evolution was driven by various factors, including the large quantities of soil mineral N in northern NSW and southeast Qld following the 1991–95 drought, changes in cropping practices, and improvements in yield potential.

The original N budget was born out of:

- Elevated soil mineral N contents in the soil in northern NSW and SE Qld following the 1991–95 drought
- Changes to cropping during the 1990s, which included 'hitting the wall' with soil OM decline and associated decline in mineralisable N in long-term continuous cropping systems
- A reduction in pasture leys that included legumes
- Improvement in yield potential from reduced soil disturbance in fallows
- Changes to wheat pricing that placed more emphasis on yield as the value driver
- Canola as a yield-boosting rotation crop with high nitrogen requirements, and
- Better adapted crop varieties with higher yield potential.

The net impact is a lower potential to mineralise N, higher levels of N removal in grain and lower N replacement from legumes.

Since then, many variants and simplifications of the original N budget have emerged. It's important for farmers and agricultural professionals to understand how these methods relate to making N decisions, their relationship to the crop N supply pools, and the pros and cons of the different methods. This understanding empowers you to make informed decisions and adapt these methods to your specific needs.

What's in everyday use?

A quick scan of publicly available information would tell you that 3 main methods are used pre-planting to determine the likely seasonal supplementary N requirement rate:

1. N balance (N removal in grain = N replacement in fertiliser and legumes)
2. N budget (estimate of potential yield and supply of N to reach potential economic yield)
3. N bank (N required for economic yield based on historic long-term rainfall and plant available soil water storage capacity).

The original N budget was based on five simple and commonly available input parameters: Target yield (TY), target grain protein (TP), protein to N conversion factor (PNF), nitrogen transfer efficiency (NTE) and soil mineral N content (SMN).

*Seasonal N deficit = (TY * TP * PNF ÷ NTE) – SMN*

From this equation, rules of thumb were created to simplify this even further to:

*Seasonal N deficit = (TY * crop factor) – SMN*
where the crop factor was 40 for wheat, 80 for canola, and 35 for barley.

Later variants of this basic N budget included further reduction of seasonal N requirement based on likely mineralised contribution from organic matter sources, from N mineralised between soil sampling for mineral N and harvest. A fundamental weakness of the N Budget is that it (i) requires and estimates future yield, which is often less than accurate, (ii) it is an annual budget and fertiliser N is usually taken up on a diminishing basis over 3 years and, (iii) it values all sources of N equally (single NTE for all sources), which has since been shown to be incorrect. For example, fertiliser N uptake efficiency in the year of application has been reported to vary from 0–40% preplant to 30–60% post-plant, while soil mineral N uptake efficiency has been quoted as being 4 times higher than fertiliser N (Daniel *et al.,* 2018; Armstrong *et al.,* 2021, Hunt & Wallace 2023).

A further issue with the N Budget's efficiency factor is the confusion about what it represents. In its original context, it was called NTE, representing the percentage of N in the grain available from all N sources. It represented two components: N uptake efficiency (NupE) and N utilisation efficiency (NutE) in a single number (Figure 1). Many papers published recently only report nitrogen uptake efficiency, which, if used in the original N budget equation instead of NTE, will over-estimate N available to the grain.

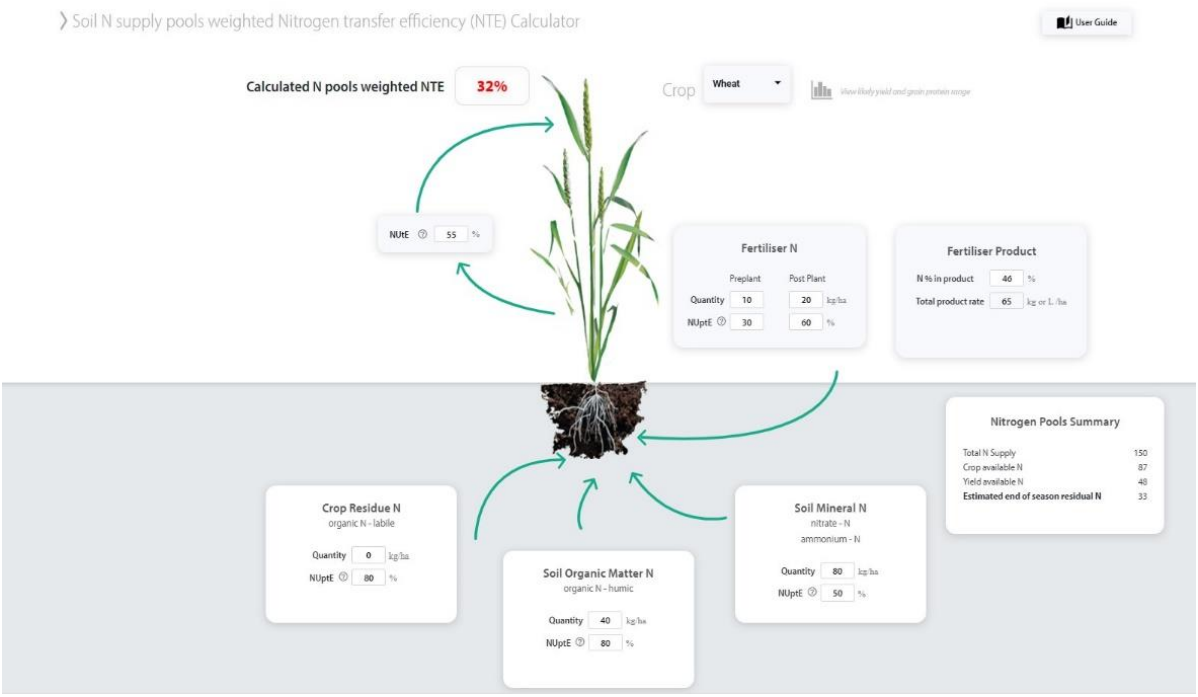

Figure 1. The main supply parameters of a nitrogen budget (Back Paddock Company)

More recent research has highlighted the further weakness of this and other methods that rely heavily on mineralised N to minimise seasonal N fertiliser rate. It is now recognised that N strategies that run a long-term net N crop cycle deficit and chronically low mineral N concentrations contribute to soil organic matter rundown and may be a limiting factor in building soil carbon stocks (Kirkby *et al.,* 2016). Where this occurs (N inputs are less than N exports in grain) over a long period, it reduces the N mineralisation potential of the soil. Long-term experiments such as those conducted by Dalal and Mayer (1986), Clarke and Russell (1976) and Heenan *et al.* (2004) estimate the N mineralisation potential halves in continuous cropping systems every 12 to 52 years. This decline means that future farming systems will be more dependent on fertiliser-based N unless changes to the system are implemented.

All soil nitrogen accessed by plants, at some point, cycles through to the plant available forms as ammonium, nitrite and nitrate, collectively referred to as mineral N. Typically, most mineral N is in the nitrate form. In these plant-available forms, mineral N is most vulnerable to loss (e.g., volatilisation, leaching, or denitrification). If the N form is organic, as either dead plant material or living or dead microbial biomass, it is protected from losses. Consequently, having high levels of organic N may be an advantage in scenarios where N losses are high and growers wish to be less dependent on fertiliser N inputs.

Fertiliser N is initially all mineral N and is, therefore, more vulnerable to loss. In the year of application, fertiliser N is often recovered in wheat at about 44% (+/- 11%, Vonk *et al.* 2022 and Angus and Grace 2017); however, it's not uncommon to have lower year one fertiliser recovery in wheat of 5 to 42% (Wallace *et al.* 2020). This doesn't necessarily mean high losses. Fertiliser N can be recovered in the years following application (Vonk *et al.* 2022). As much as 22% of fertiliser N can be recovered in the 2 to 3 years following the initial fertiliser N application (Vonk *et al.* 2022). This carried-over fertiliser N can be in different forms, including fertiliser N (i) consumed by microbes and re-mineralised, (ii) carried over as spared N (mineral N), and (iii) mineralised from the first-year and or second-year crop residues. Consequently, fertiliser

recovered over three to four years (66% +/- 15%) is higher than fertiliser recovery in year one (44% +/-) (Vonk *et al.* 2020), while fertiliser N losses in the review by Vonk (2022) averaged 34%.

N Balance, and more recently, N Banks, have been suggested as alternatives to strategically managing fertiliser N requirements. N balance tries to ensure N off-take in grain equals N inputs; however, it doesn't account for N losses, and consequently, it is referred to in the scientific literature as a partial N balance. The problem with the N balance approach is that you can only apply this in hindsight or using longer-term averages. If you use the latter, it will mean some years the paddock will be in negative N balance (under fertilising) and other years the paddock will have a positive balance (over fertilised), which over the longer term means it averages out to achieve N balance. This approach does not match high N demand years particularly well but does if followed, provide yield improvement opportunities compared with running a negative N balance – but it also increases risk.

N banking sets a target soil N requirement, which is the same every year for a given climate and soil systems based on long-term rainfall and PAW holding capacity of the soil. Dr James Hunt developed it to simplify decision-making, and testing to date shows that it is an effective N management strategy in southern cropping systems that simplifies the decision-making process. In this approach, the starting (early autumn) soil mineral N is subtracted from the N bank target to provide the fertiliser N input in kg/ha for the growing season. Because it tops up to a set target, it will also under and over-fertilise in some years but not to the same extent that occurs with the N balance approach.

Looking under the covers of how they relate to the N pool size and efficiency of crop access to the main N supply pools and the potential for OM decline, you could conclude that most are subject to a group of similar pros and cons as the original N budget method. So, when adopting a method to assess likely fertiliser requirements, it is important to consider how it meets both your seasonal production and longer-term soil fertility goals. Consistency and recording key inputs and outputs over time are keys to tracking progress to improve productivity, N efficiency, soil fertility, and reducing risks associated with applying fertiliser nitrogen.

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