'NBudget' – a nitrogen management tool for cropping systems

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Abstract

Effective management of plant-available nitrogen (N) by farmers will generally have beneficial productivity, economic and environmental consequences. The reality is that farmers may be unsure as to the nitrate levels in their soils at sowing and often make decisions about what crop to grow and how much fertiliser N to apply using little information relevant to nitrogen supply. Current extension information on N, including legume N_2 fixation, is often confusing, conflicting and inaccurate. With fertiliser N priced at about $1.50/kg, and with increasing pressure to reduce nitrous oxide (N_2O) emissions in the agricultural sector, farmers need to maximise N inputs from N_2-fixing legumes and to closely match fertiliser-N inputs to crop requirements.'NBudget' is an excel-based decision-support (DS) tool that will help farmers/advisers in Australia's northern grains region (northern NSW and southern Qld) estimate soil nitrate levels pre-sowing, set target yields and determine fertiliser N requirements for winter cereals and oilseeds. A major difference between 'NBudget' and other DS tools for N management is that soil testing for either nitrate, organic carbon or water is not required. Rather, 'NBudget' contains rule-of-thumb values and algorithms for estimating the net release or immobilisation of nitrate-N in the soil and for estimating N_2 fixation by a legume crop. Input data to generate the algorithms were derived from published and unpublished experiments conducted in the region during the past 30 years. Input data to run 'NBudget' are readily available to farmers. Details of the program are presented in this paper.

Key Words

Nitrogen budgeting, fertiliser N, legume N_2 fixation, WUE, N mineralisation

Introduction

Farmers in Australia's northern grains belt produce 20–25% of the nation's grain – principally wheat, barley, sorghum, chickpea, fababean and sunflower. All of the crops, except for the N_2-fixing legumes, chickpea and fababean, require nitrogen (N) to be supplied, either through the *in situ* mineralisation of soil humus and crop residues or from additional fertiliser N inputs. Matching the supply of N to crop demand remains a challenge for farmers as too little supply reduces crop yields and profits, while too much may result in substantial gaseous and/or leaching losses. Decision support (DS) tools to help farmers and their advisers make decisions about fertiliser N inputs have been developed and promoted during the past 15 years, from the relatively simple paper-based 'Nitrogen in 95/96', 'NITROGEN IN 96' and 'Nitrogen budgeting for winter cereals' to the more complex computer-based APSIM, WhopperCropper and Yield Prophet[?] (e.g. Lawrence et al. 2000; Carberry et al. 2009). All rely on a budgeting approach in which the supply of plant-available N for a paddock is determined prior to sowing together with the N demand, i.e. amount of N required to grow the crop (Marcellos and Felton 1994). The difference between N supply and demand is the shortfall that is met by fertiliser N inputs.

The amount of plant-available soil N is the sum of N mineralised or immobilised from fresh crop residues and animal manures, N left over (spared) from the previous crop and N mineralized from soil humus and partially decomposed (old) residues. Farmers use various techniques to determine plant-available soil N including deep coring for nitrate, calculating on the basis of soil organic carbon levels and back-calculating on the basis of previous yield x protein outputs, i.e. N replacement. However, farmers don't always estimate N supply with sufficient accuracy. Surveys of winter cropping paddocks in northern NSW during the past 15 years consistently showed large variations in soil nitrate at the end of the summer fallow and prior to sowing a winter crop. Ranges for two surveys were 17–315 kg nitrate-N/ha (survey in 1996 involving 70 paddocks) and 50–270 kg N/ha (2005–07, 21 paddocks) (GD Schwenke, pers. comm.; Elias 2009). Paddocks in the latter survey were intended to be sown to chickpea, a N_2-fixing legume that ideally should be grown in low nitrate soils (<50 kg nitrate-N/ha) to ensure nodulation and N_2 fixation are not suppressed. In a benchmarking study of 41 northern NSW durum crops during the 2007–08 winter seasons, N supply (measured soil nitrate plus fertiliser N applied after soil coring) at sowing ranged an astonishing 118–750 kg N/ha (L Serafin, unpublished data). Furthermore, grain proteins varied between 10.8% and 18.0% with the majority greater than 14.0%. Analysis of the complete data set revealed no relationship between N supply and either grain yield or protein contents. Clearly this degree of variability and disconnect between N supply and productivity would suggest an underlying, long-term uncertainty on the part of at least some of the farmers about soil nitrate levels.

‘NBudget’ – a tool for estimating pre-crop soil nitrate levels and fertiliser N inputs

‘NBudget’ is an excel-based decision-support (DS) tool that helps farmers/advisers in Australia’s northern grains belt (northern NSW and southern Qld) estimate soil nitrate levels pre-sowing, set target yields and determine fertiliser N requirements for winter cereals and oilseeds. There are 16 stations (locations) in the program, from Roma and St George in Qld to Dubbo in the central-west of NSW. A major difference between ‘NBudget’ and other DS tools for N management is that soil testing for either nitrate, organic carbon or water is not required. Rather, ‘NBudget’ contains rule-of-thumb values and algorithms for estimating the net release or immobilisation of nitrate-N in the soil and N_2 fixation by a legume crop. Input data to generate the rule-of-thumb values and algorithms were derived from published and unpublished experiments conducted principally by the farming systems and plant (N) nutrition programs of the NSW and Qld agricultural agencies during the past 30 years. Input data required to run ‘NBudget’ includes – location and description of the paddock as low, medium or high fertility, tillage practice, yield and protein level (for cereals) of the previous crop, fertiliser N applied to previous crop, assessment of crown rot risk and fallow rainfall or depth of wet soil.

Grouping the stations in ‘NBudget’ for estimating soil water, N mineralisation rates and soil nitrate

As stated above, there are 16 stations in ‘NBudget’, each with unique rainfall data. The stations are, however, assigned to one of three groupings for the purposes of estimating nitrate from simple paddock history and net N mineralisation during the pre-crop fallow and in-crop. The groupings are:

Group 1 – Dalby, Croppa Creek, Warialda, Inverell, Tamworth and Quirindi

Group 2 – Roma, Goondiwindi, Moree, Narrabri and Gunnedah

Group 3 – St George, Walgett, Coonamble, Coonabarrabran and Dubbo

Working through ‘NBudget’

There are five steps to work through to estimate yields and fertiliser N requirements for bread wheat, durum wheat, barley and canola and yields and N_2 fixation inputs for chickpea and fababean:

Site details – The station is selected from a drop-down list of 16 and property and paddock names inserted. Also selected from drop-down lists are the fertility status of the paddock (high, medium or low, according to the short description of each), soil type and tillage practice.

Two seasons ago – The program starts at this point. The user selects from the list the crop grown in the paddock the season before last. A rule-of-thumb estimate of soil nitrate at the start of last season is then shown (see below for additional explanation).

Last season – The user selects from a drop-down list the crop that was last grown in the paddock and inserts the yield, protein (in the case of bread wheat, durum and barley) and amount of fertiliser N applied. The program then provides an estimate of post-fallow soil nitrate, i.e. soil nitrate at the time that the farmer or adviser is making a decision about fertiliser N inputs for the coming cropping season. The other key value is post-fallow soil water, determined using either fallow rainfall records, depth of wet soil (push probe) or by other means, e.g Howwet?.

Crown rot assessment for current season – The expected level of crown rot is selected from the list. The yield loss for bread wheat, durum and barley is then calculated using default data from the NSW I&I Grain Pathology research program, Tamworth (S.Simpfendorfer, pers. comm.).

Targeting grain yields and proteins, fertiliser N – Expected grain yields for the coming season are calculated automatically using default water use efficiency (WUE) values after the user inserts the target grain proteins for the average season for bread wheat, durum and barley. Grain proteins for canola, chickpea and fababean are set at default levels. The fertiliser N requirements for bread wheat, durum, barley and canola and the amounts of N fixed by chickpea and fababean are then calculated together with residual (post-fallow) nitrate levels.

Rule-of-thumb estimate of sowing soil nitrate

The program essentially starts with an estimate of sowing soil nitrate for the previous season and, unlike other DS tools, does not rely on soil testing. Nitrate levels are variable across a paddock, which reduces the reliability of test values unless a relatively high number of cores are taken from each paddock (8–10). Deep coring for nitrate is also expensive and time-consuming. With 'NBudget', rule-of-thumb values, aggregated from published and unpublished data, were determined for particular scenarios. For example, the rule-of-thumb nitrate values for a no tillage paddock of medium fertility (history of good use of fertiliser N with cropping) at Moree are 18 kg N/ha after a double crop, 48 kg N/ha after low protein (N) wheat, 58 kg N/ha after moderate N wheat, 72 kg N/ha after N-fertilised canola, 77 kg N/ha after a pulse and 101 kg N/ha after a long fallow. Values for a cultivated paddock are about 30% higher.

Nitrogen mineralisation – humus and crop residues

Values are required for N mineralisation of soil humus and partially decomposed (old) residues during the fallow and in-crop. The nitrate-N released during both periods is used for crop growth. APSIM-generated values (J. Turpin, pers. comm.) for potential N mineralisation were modified to account for periods of low soil water, tillage, and environmental and soil fertility effects. For example, values for the same no tillage, medium fertility paddock at Moree are 17 kg N/ha for in-crop mineralisation, 53 kg N/ha for summer fallow mineralisation and 70 kg N/ha for long (winter-summer) fallow. Values for a cultivated paddock are about 30% higher.

With fresh crop residues, it is assumed that 65–70% of residue carbon (C) is respired during the post crop (summer) fallow with the remaining 30–35% locked into stable soil organic matter with a C:N ratio of 11:1 (Ladd 1987). Depending on the C:N ratio of the fresh residues, mineral N will either be released during the fallow, as with low C:N residues, or immobilised in the case of high C:N ratio residues. Residue C:N values are estimated by 'NBudget' based on grain proteins.

Fallow efficiency

Analysis of 12 site/years of data from the NSW I&I farming systems experiments at North Star in northern NSW, involving variations of crop, fertiliser N and tillage treatments (Felton et al. 1998; Marcellos et al. 1998), indicated average fallow efficiencies of 0.31 for no tillage and 0.28 for cultivated fallows. Fallow efficiency values were calculated as stored plant-available water (mm) to 1.2 m depth of soil at the end of the summer fallow divided by fallow rainfall. These efficiencies did not account for soil water at the start of the fallow. Real fallow efficiencies (actual water stored in the soil profile during the fallow divided by fallow rainfall) were, on average, 0.17 (no tillage) and 0.14 (cultivated). Both sets of fallow efficiencies are used in different ways in 'NBudget'.

Crop water use efficiency (WUE)

French and Schultz (1984) reported a maximum (potential) WUE value of 20 kg grain/mm plant-available water after 110 mm was subtracted to account for evaporation. More recent reports (e.g. Hochman et al. 2009) indicate that growers across a range of production regions and systems are achieving an average WUE of 15.2 kg grain/mm (with *x* intercept of 67 mm). As part of that study, scenario analysis using APSIM highlighted the importance of optimising plant density, sowing date and N supply for further improving WUE. Even with optimal agronomy, other factors reduce WUE, such as disease and pest damage, extremes of temperature and high vapour pressure deficits (VPDs) particularly during anthesis and post anthesis.

The WUE value for bread wheat in 'NBudget' was aggregated from a number of data sources and set at 12.5 kg grain/mm after subtracting 100 mm for evaporation. Grain yields for the other crops were calculated by multiplying the estimated wheat yields by constants – 1.10 for durum, 1.33 for barley, 0.50 for canola, 0.64 for chickpea and 0.80 for fababean. Durum has a higher WUE than bread wheat because of the higher N supply needed for the higher targeted grain proteins (13.0% for durum *versus* 11.5% for bread wheat). Barley has a higher WUE than both bread and durum wheats because its shorter growing season reduces exposure to increasing VPDs during spring.

Crop nitrogen use efficiency (NUE)

In this context, NUE describes the conversion of soil nitrate-N into grain N. As grain proteins increase, the efficiency declines and the amount of nitrate-N needed for each tonne of grain increases. Thus, the NUEs used in 'NBudget' for bread wheat/durum wheat are 0.52 for 11% protein, 0.47 for 12% protein and 0.43 for 13% protein. A high grain protein essentially denotes a crop well supplied with N but water stressed. Although 53 kg nitrate-N/ha needs to be available in the soil to produce each tonne of grain at 13% protein, just 23 kg N/ha ends up in the grain. The remainder is spared, i.e. not used by the crop, or returned to the soil as crop residues. The NUEs for barley are 0.62 for 10% protein, 0.57 for 11% protein and 0.53 for 12% protein. The differences between the NUEs for wheat and barley relate to the different grain moisture contents when describing grain proteins (12% for wheat and 0% for barley).

Chickpea and fababean N_2 fixation

Assuming a high level of nodulation and effective symbiosis, N_2 fixation is essentially determined by the growth (total biomass yield) of the legume and its utilisation of soil nitrate The higher the utilisation of soil nitrate, the lower the amount of N that the legume fixes. The percentage of legume nitrogen derived from N_2 fixation (%Ndfa) must first be determined before estimating total crop N fixed. Multivariate analysis of published and unpublished chickpea and fababean data (e.g. Doughton et al. 1993; Herridge et al. 1998) was used to develop algorithms describing relationships between %Ndfa, soil nitrate and grain yield. Grain yield was used as a surrogate for biomass yield because values for the former are readily available; in almost all situations, values for the latter are not (Herridge et al. 1998). In 'NBudget', the estimated %Ndfa values are then multiplied by estimated biomass yield to calculate total crop N fixed.

Where to now?

The intention is to validate 'NBudget' during the next 12–18 months using independent data sets sourced from northern NSW and southern Qld (GRDC project UNE00014). Once the accuracy of the program has been established, the intention then is to make it available to farmers and advisers in the region through an extension program. Written material will be released in conjunction with 'NBudget' that provides comprehensive details of the underlying assumptions. At this stage, the question remains as to whether the rule-of-thumb values for soil N mineralisation and nitrate status together with the empirical relationships that underpin ‘NBudget’ will provide sufficient accuracy for effective crop and fertiliser N management.

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