

A GUIDE TO NUTRIENT BUDGETING

WHAT IS NUTRIENT BUDGETING?

WHY SHOULD I USE A NUTRIENT BUDGETING APPROACH?

HOW DO I ESTABLISH A NUTRIENT BUDGET?



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WHAT IS NUTRIENT BUDGETING?

Nutrient budgeting is a targeted approach to decide on fertiliser rates. In a nutshell, nutrient budgeting is using your farm (or paddock) rainfall data, soil test results and some simple calculations to determine an optimal fertiliser rate. A nutrient budgeting approach could be taken with any nutrient however the most used are nitrogen (N) and phosphorus (P). These are the two nutrients this guide will focus on.

WHY SHOULD I USE A NUTRIENT BUDGETING APPROACH?

- ✓ Match crop demand and fertiliser applications.
- ✓ Cost-savings on fertilisers.
- ✓ Maintain soil fertility.
- ✓ Reduce environmental risks.
- ✓ Better understand fertiliser recommendations made by advisors.
- ✓ Potential to use concepts in a variable rate application/precision ag system.

HOW DO I ESTABLISH A NUTRIENT BUDGET?

To establish a nutrient budget, you will need:

- A paddock soil test (ideally to at least 60 cm, split into several depth increments e.g. 0-10, 10-30 and 30-60 cm.)
- Long-term rainfall records.
- A fertiliser analysis (see below).
- A calculator.

The following information will guide you through the concepts and assumptions behind the nutrient-budgeting approach, and the steps to follow to calculate your own. The first section will focus on nitrogen, the second on phosphorus.

STEP 1: CALCULATE YIELD POTENTIAL

Calculations for this step are on page 4. It is useful to read the following information beforehand.

Determining your crop yield potential is the first step to estimating crop nutrient use. There are several ways to think about yield potential:

Potential yield: the best-case scenario. This assumes:

- Best variety grown with optimal agronomy,
- No pest, disease or other major stresses,
- Water is non-limiting.

Potential yield is only useful in very high-rainfall or irrigated systems and is not realistic in South Australian farming systems.

Water-limited yield: the potential yield (as above) taking into consideration the limitations of rainfall. This is a much more useful metric for South Australian farmers. This is commonly known as the French & Schulz equation. This guide uses an updated version of the French and Schulz equation (Harries *et al.* 2022).

Economic yield: the yield achieved by farmers when making economically optimal input decisions. This takes into consideration the law of diminishing returns. **Economic yield is calculated as 80% of water-limited yield.** Economic yield is what this guide will use for a nutrient-budgeting approach.

Farm yield: the yield your farm is achieving. A useful benchmark metric.

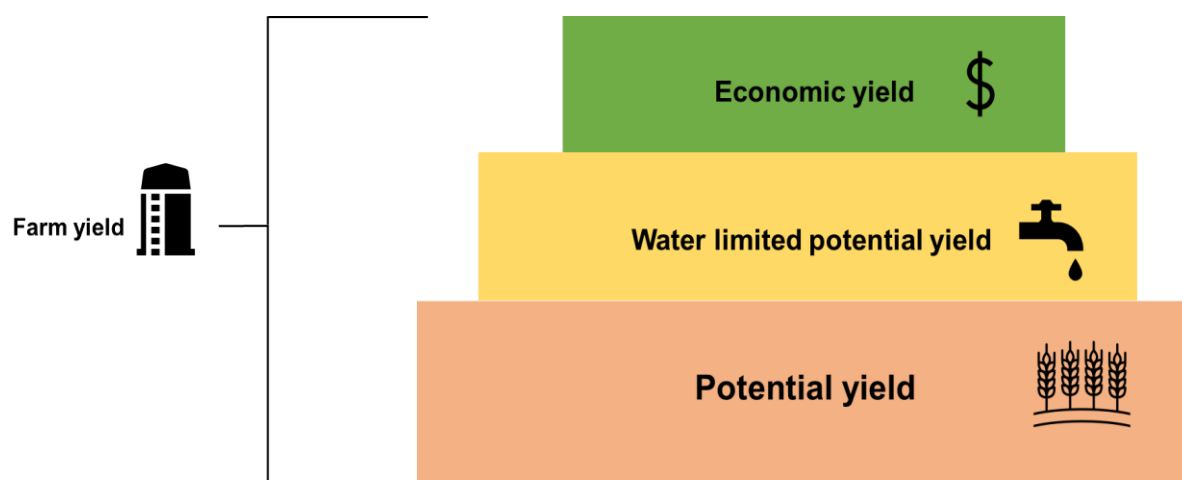


Figure 1. Potential, water-limited, economic and farm-yield.

Calculating yield potential:

You will need: Annual rainfall records.

1. Calculate water-use. Assuming 25% of rainfall during the summer period (Nov-Mar) and all the rain received during the growing season (Apr-Oct) is used by the crop:

$$\text{Water use} = (\text{total of Nov-Mar rainfall} \times 0.25) + (\text{total of Apr-Oct rainfall}).$$

2. Calculate water-limited yield (kg/ha)

$$\text{Wheat: } (\text{Water use} - 45) \times 25$$

$$\text{Barley: } (\text{Water use} - 50) \times 24$$

$$\text{Canola: } (\text{Water use} - 80) \times 15$$

3. Calculate economic yield (kg/ha).

$$\text{Economic yield} = \text{Water-limited yield} \times 0.8$$

Example (assuming a water use of 250 mm):

$$\text{Water-limited wheat yield} = (250 - 45) \times 25 = 5125 \text{ kg/ha (5.13 t/ha)}$$

$$\text{Economic yield} = (5125 \text{ kg/ha} \times 0.8) = 4100 \text{ kg/ha} = 4.1 \text{ t/ha}$$

STEP 2: CALCULATE NITROGEN DEMAND

You will need: your economic yield calculations.

Nitrogen demand varies with each crop, but there are some general rules of thumb for crop N requirement we can use:

Wheat: 40 kg N/ tonne grain

Barley: 35 kg N/ tonne grain

Canola: 80 kg N/ tonne grain

$$\text{Crop N demand} = \text{Economic yield} \times \text{crop N requirement}$$

Example: if our economic yield was 4.1 t/ha of wheat, the crop N demand is (4.1 t/ha x 40 kg N/tonne) = 164 kg N/ ha.

STEP 3: CALCULATE SOIL NITROGEN SUPPLY

You will need: a soil test result with nitrate-N, ammonium-N, organic carbon and a bulk density value.

From your soil test result you can calculate how much N is being supplied by your soil. This assumes the crop roots will make it to the depth of sampling (in this example, 60 cm).

What's in a soil test?

Nitrogen: There are two types of N which are reported in a soil test: nitrate and ammonium.

Both nitrate and ammonium are plant-available, however ammonium tends to be quite low on most soil tests. This is because ammonium is short-lived in the soil and rapidly turns into other forms of N (primarily nitrate). Often ammonium results will be reported as "<1.0 mg/kg". It is advisable to treat this as 0 mg/kg.

Bulk density: Measures the weight of soil within a known volume. This will be affected by soil type (sands are more densely packed than clays), and compaction due to soil constraints, spray tracks, etc.

To calculate available soil N:

Available soil N (kg/ha) =

total soil nitrate (mg/kg) + total soil ammonium (mg/kg) x soil bulk density (g/cm³) x depth (cm) ÷ 10

Example: if there is 30 mg/kg nitrate, 1.1 mg/kg ammonium and a bulk density of 1.3 g/cm³ in the topsoil (0-10 cm):

Available soil N = ((30 + 1.1) x 1.3) x 10 ÷ 10

= 40 kg/ha N

If there is 15 mg/kg nitrate, 1.0 mg/kg ammonium and a bulk density of 1.2 g/cm³ in the subsoil (10-30 cm):

Available soil N = ((15 + 1.0) x 1.2) x 20 ÷ 10

= 38 kg/ha N

Complete this step for all your sampled layers.

OPTIONAL:

Organic carbon is also mineralised throughout the growing season which releases nitrogen. This calculation is optional for this approach as it is purely an estimation. Mineralisation varies with seasonal conditions; for example, in hot and dry conditions very little N will be mineralised, whereas in warm and wet conditions a lot will be mineralised.

Mineralised N =

April-October rainfall (mm) x organic carbon (%) x 0.15 (kg N/ha)

Example: assuming a 0-10 cm carbon content of 0.95% and a GSR of 240 mm:

Mineralised N = $240 \times 0.95 \times 0.15 = 34 \text{ kg N/ha}$

The sum of available soil N in all your soil layers is how much N your soil can supply to the crop during the growing season.

STEP 4: CALCULATE NITROGEN GAP

You will need: your nitrogen demand and nitrogen supply calculations.

The nitrogen gap is the amount of N required by the crop to reach the economic yield which is not supplied by the soil.

N gap = Nitrogen demand (kg/ha) – Nitrogen supply (kg/ha)

Example: assuming a N demand of 164 kg/ha and a total soil supply of 110 kg/ha:

N gap = $(164 - 110) = 54 \text{ kg N/ha}$

STEP 5: CREATE A NUTRIENT BUDGET

You will need: your nitrogen gap and a fertiliser analysis.

Creating a nutrient budget is now simply calculating how much fertiliser you need to apply to close the nitrogen gap.

All fertilisers are required to have a nutrient analysis supplied. The nutrient analysis describes the content of nitrogen, phosphorus, potassium, sulfur and trace elements in the fertiliser. It is often written as N:P:K:S. For example, DAP has the following nutrient analysis:

Nitrogen: 18 %

Phosphorus: 20 %

Potassium: 0 %

Sulfur: 1.5 %

And the analysis would therefore be written as 18:20:0:1.5.

Some common fertiliser analyses are provided on page 11.

If you are unsure of what the nutrient analysis of your fertiliser is, contact the manufacturer or wherever you supply your fertilisers from.

To put together your nutrient budget, you need two calculations:

- Nutrient supplied (kg/ha) = Fertiliser rate (kg/ha) x fertiliser N analysis (%).

Example: if 80 kg/ha DAP is applied at seeding, total N applied is $(80 \times 0.18) = 14.4$ kg N/ha.

- Fertiliser required (kg/ha) = N gap (kg/ha) ÷ fertiliser N analysis (%).

Example: if the remaining N gap after seeding is 39 kg/ha and urea is used to supply this, total urea required = $(39 \div 0.46) = 84$ kg urea/ha

Use these calculations to compare your current fertiliser rates to what is required to close the N gap. Use this information to adjust your fertiliser rates as required. These steps can be used to find the most economical fertiliser rates for your farm.

STEP 6: MAINTAIN YOUR SOIL

Nitrogen builds up in soil through accumulation of organic carbon (plant residues, biomass) which has numerous other benefits for your soils (increased soil water holding capacity and infiltration, structural stability, nutrient retention and many more). Nitrogen can also be increased by incorporating legumes in the rotation. Consider the options available to you in your region.

Monitor your soil by regularly soil testing (approx. every 5 years if possible) and make sure to keep check on soil properties such as pH, salt levels, sodium and boron to keep on top of potential emerging constraints.

MANAGING SOIL PHOSPHORUS

You will need: a soil test with Colwell P and PBI values.

Note: Phosphorus budgets are based on the 0-10 cm soil test results only.

Soil phosphorus is essential for crop production and is one of the most challenging plant nutrients to manage. Phosphorus is easily “tied up” in the soil by clay particles, iron and calcium carbonate, and rapidly transforms from plant-available forms to unavailable forms.

STEP 1: ASSESS YOUR SOIL COLWELL P STATUS

Colwell P is the measure of plant-available and soil retained P used in SA. The degree to which phosphorus is tied up in a soil is described by the Phosphorus Buffering Index (PBI). A lower PBI means the soil does not tie up P readily and indicates leaching, and a high PBI means it will hold P very strongly. Therefore, a PBI test is necessary to interpret Colwell P values.

Below is a table of critical Colwell P values for a range of PBI values. Use this table to determine whether your Colwell P is adequate for your PBI value.

PBI Category		Critical Colwell P values (mg/kg) for PBI category
<15	Extremely low	20-24
15-35	Very very low	24-27
36-70	Very low	27-31
71-140	Low	31-36
141-280	Moderate	36-44
281-840	High	44-64
>840	Very high	n.a.

Source: Harding and Hughes 2022.

Example 1. If the soil has a PBI of 75, then the critical Colwell P value is ~31-36 mg/kg. If the soil has a measured Colwell P of 25 mg/kg, it is inadequate and needs to be increased by at least 6 mg/kg.

Example 2. If the soil has a measured Colwell P value of 33 mg/kg and a PBI of 55, the Colwell P is adequate.

From here, you can develop either a P replacement (maintenance) or P increasing strategy.

To develop a replacement strategy, follow the prompts in step 2 (below).

Note: Soil testing labs now offer DGT-P tests, which measures available P. This better mimics how much P can be used by the plant and can be a useful metric to interpret soil P results. However, it is expensive, requires interpretation and is not necessary for creating a nutrient budget. Consult your agronomist if interested in this test.

STEP 2: DETERMINE A PHOSPHORUS REPLACEMENT RATE

You will need the following values:

Crop removal of P (per tonne of grain):

Wheat: 3 kg

Barley: 3 kg

Canola: 6-7 kg

You will also need your fertiliser analysis.

1. Following step 4 from the Nitrogen Budgeting section, estimate how much P is going to be removed by the crop.

Example: if our economic yield was 4.1 t/ha, our P removal is $(4.1 \text{ t/ha} \times 3 \text{ kg/t}) = 12.3 \text{ kg P/ha removed}$.

2. Following step 5 from the Nitrogen Budgeting section, calculate the fertiliser rates required to replace the phosphorus used by the crop.

If your Colwell P value is low:

3. To account for a low Colwell P value, we need to add a “build up rate” of P – otherwise we run the risk of mining P, which becomes increasingly hard to manage. To do this we use our PBI to determine a “build up factor” which is the amount of extra P we need to add per unit increase of Colwell P.

The table below summarises what the build-up factor is for each PBI range.

PBI Value	PBI Class	P build up factor (kg/ha P required to increase Colwell-P by 1 mg/kg)
0-15	Extremely low	1.8
15-35	Very, very low	2.0
36-70	Very low	2.3
71-140	Low	2.6
141-280	Moderate	2.8
281-840	High	3.2
>840	Very high	>3.6

Source: Incitec Fertilisers via Smart Fertilisers.

Example: if the Colwell P needs to be increased by 6 mg/kg in a soil with a PBI of 75, the build-up rate required is $(2.6 \text{ kg/ha} \times 6) = 15.6 \text{ kg/ha P}$.

4. Following step 5 from the Nitrogen Budgeting section, calculate the fertiliser rates required to match the build-up rate.
5. Calculate your total P fertiliser requirement:

$$\text{Total P fertiliser requirement} = \text{Replacement rate (kg/ha)} + \text{"build up" rate (kg/ha)}$$

Note: if you have a high P value it can be economic to reduce P fertiliser rates for a season. However, this needs to be carefully monitored as prolonged mining of soil P can result in deficiencies.

Finally, consider follow-up sampling (0-10 cm) to monitor your P reserves – especially following seasons with higher-than-expected yields and/or biomass.

FURTHER INFORMATION

Table 1. Elemental composition of common fertilisers.

Fertiliser	Approximate percentage (%) of elements			
	Nitrogen	Phosphorus	Potassium	Sulfur
Urea	46	-	-	-
Ammonium nitrate	34	-	-	-
MAP	10-12	22	-	1-2
DAP	18	20	0	1.5
Single superphosphate	-	8.6	-	11
Double superphosphate	-	17-20	-	1-4
Ammonium sulfate	20-21	-	-	24
Calcium nitrate	15.5	-	-	-

Source: Harding and Hughes 2022.

Table 2. Critical soil P values for calcareous and non-calcareous soils.

	Soil phosphorus status (mg/kg) Colwell P				
	Very low	Low	Marginal	Adequate	High
Crops (non-calcareous soils)	<10	10-20	20-30	30-45	>45
Crops (calcareous soils)	<15	15-25	25-35	35-45	>45
Pastures	<10	10-18	18-25	25-45	>45

Source: Harding and Hughes 2022.

References:

Harding, A and Hughes, B 2022. *Understanding your soils and interpretation of soil tests*. PIRSA publication.

Hunt, J 2024. *Back to nitrogen basics – soil testing and nitrogen budgeting fundamentals*. GRDC Update Papers. <https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2024/02/back-to-nitrogen-basics-soil-testing-and-nitrogen-budgeting-fundamentals>

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