Chapter 15
Nutrient Planning

CONTENTS

15 Nutrient Planning

15.1 Introduction

Responsible nutrient planning involves soil testing and nutrient budgeting to match the nutrients being applied with the actual farm nutrient requirements. The benefits of this approach include potential $ savings, increased productivity and a reduction in nutrients lost to the environment.

Nutrient planning follows the International Plant Nutrition Institute's 4Rs principles of applying the right source of nutrient, at the right rate, at the right time, and in right place.

To develop a nutrient plan, information is needed about existing soil fertility levels and farm production. The production level aims of the farmer also need to be considered to help determine soil nutrient targets.

Monitoring soil fertility trends in paddocks with soil testing is a key component of nutrient planning. By monitoring trends over time, the fertiliser program can be adjusted to match changing soil requirements.

Nutrient and soil fertility management is not an exact science. The figures used in this chapter are the best available at this point in time, but will change as more is discovered about nutrient management.

In this chapter the following key areas of nutrient planning are discussed:

- Factors affecting nutrient requirements
- Phases of farm development
    - The concept of maintenance and capital fertiliser
- Key tools for nutrient planning
    - Soil testing
    - Farm management zones
    - Nutrient mapping
- Setting target nutrient levels
- Nutrient budgeting to determine nutrient requirements
    - Maintenance nutrient requirements
- Capital nutrient requirements to boost fertility
- Prioritising nutrient applications on farm
- Monitoring soil nutrient status

15.2 Factors affecting nutrient requirements

To accurately plan for nutrient applications on a dairy farm the following must be taken into account:

- Soil type – different soil types either tie up or hold onto nutrients in different ways (see Chapter 4 for information on the physical and chemical properties of soil).
- Current soil nutrient status - affected by soil parent material, fertiliser history, climate, stage of farm development and management.
- The target soil nutrient levels you have set - for example, Olsen P of 20 mg/kg, Colwell K of 240 mg/kg (see Chapter 9.2.5 to 9.2.7).
- Nutrients bought in – grain, fodder, effluent applications.
- Nutrients removed – milk production, fodder conservation, cropping, stock sales.

As these factors are variable, nutrient requirements will vary from farm to farm, paddock to paddock and year to year. This will be discussed more in the sections on setting target nutrient levels, maintenance and capital requirements.

Nutrient planning is a vital part of the fertiliser planning process and should be reviewed on an annual basis.

15.3 Phases of farm development

Nutrients required will depend on the stage of development of the farm. In their natural state, most Australian soils have low levels of phosphorus (P) and sulphur (S) and, to a lesser extent, potassium (K). When converting land to a dairy farm, large inputs of nutrients may be required to raise the nutrient levels to adequate levels for pasture production. This is referred to as the **development phase** (Figure 15.1).

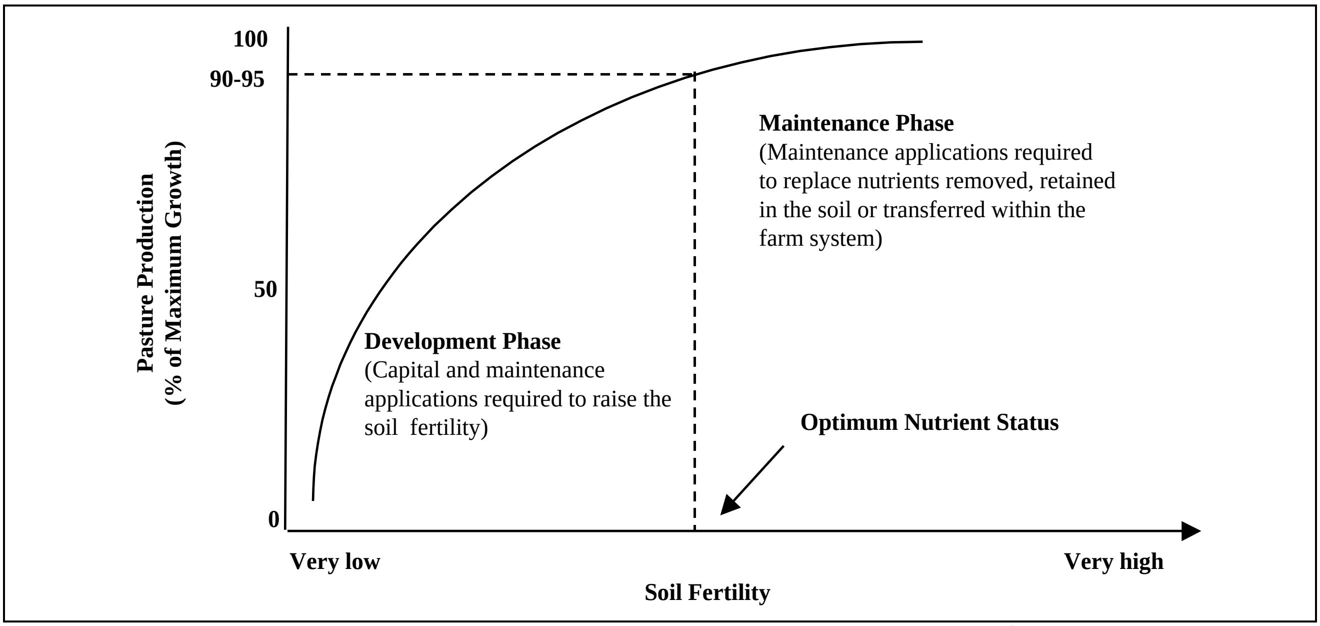


Figure 15.1 Development and maintenance phases of pasture production. *Source:* Adapted from Roberts A (1996) 'Farm for Profit' Conference Proceedings**.**

In the development phase, pasture response to nutrient applications will be high. For most dairy farmers, it is profitable to rapidly increase soil nutrient levels to the optimum, particularly P. Nutrients that are applied in excess of that required for maintenance (capital applications) raises the nutrient status of the soil.

Eventually, further increases in soil nutrient levels through capital applications will result in only very small increases in plant and animal production and the added nutrients provide no economic benefit. At this stage, optimum nutrient status has been reached and soil fertility is not limiting pasture production.

The optimum soil nutrient status on dairy farms is often regarded as being the point at which the production of existing pasture species is at 95% to 98% of potential. However, the economic optimum nutrient status may be lower on farms where pasture utilisation is low, product value is low or where seasonal production is not reliable.

When a soil reaches its optimum nutrient status, further applications of nutrients will be uneconomical and may increase risk of losses which pollute the environment (see Chapter 10.5). No further capital applications of fertiliser will be required. Such soils are referred to as being in the

maintenance phase (see Figure 15.1). Soils that are in the maintenance phase only require fertiliser applications that replace the nutrients that are removed from the soil through the farming operation.

So, to recap:
Nutrient applications are considered either as maintenance or capital applications.

- **Maintenance applications** keep the soil nutrient status at the same level while supporting pasture production.
- **Capital applications** increase soil fertility to a target level. Capital applications are the nutrients that are applied in **excess** of the maintenance requirement for any given production system.

> The concept of capital and maintenance applications is used to estimate farm nutrient requirements. If a maintenance application of nutrients is spread annually, assuming stocking rate and product removal do not alter greatly, soil fertility will remain at a similar level over time. If a capital application is made, soil fertility will increase over time.

15.4 Key tools for nutrient planning

There are a number of key tools that are considered essential to the nutrient planning process. Soil testing has been discussed in Chapter 8 and Chapter 9 and will assess the nutrient status of the soil in order to develop target levels, as well as to monitor the effect of previous nutrient applications. Nutrient mapping and farm management zones are relatively new key tools that are also necessary for effective nutrient planning.

15.4.1 Farm Management Zones

There are a large number of paddocks on a dairy farm and therefore it is often more practical to soil test in farm management zones (FMZ) than to soil test in every paddock. Ideally, when soil testing the farm, a representative soil sample would be taken from each FMZ.

Areas on the farm that could form separate FMZs include:

- Different soil types
    - Different soil types will likely have different phosphorus buffering indexes, resulting in different amounts of phosphorous necessary for maintenance and capital applications, may also have different baseline K and S and different leaching potential which may affect soil nutrient status
- Within those different soil types, different nutrient status
    - For example areas of low phosphorus or potassium versus high phosphorus or potassium
- Different management
    - Day or night paddocks; areas where fodder is regularly cut or fed out; where effluent has been spread; run-off blocks; problem paddocks.
- New and old irrigation areas

Initially a farm should be divided into six to seven FMZs. After soil testing it may be that two to three FMZs have quite similar results and can therefore be grouped together resulting in only four to five FMZs on the farm. Refer to Figure 15.2 for an example of an Australian dairy farm divided into management zones.

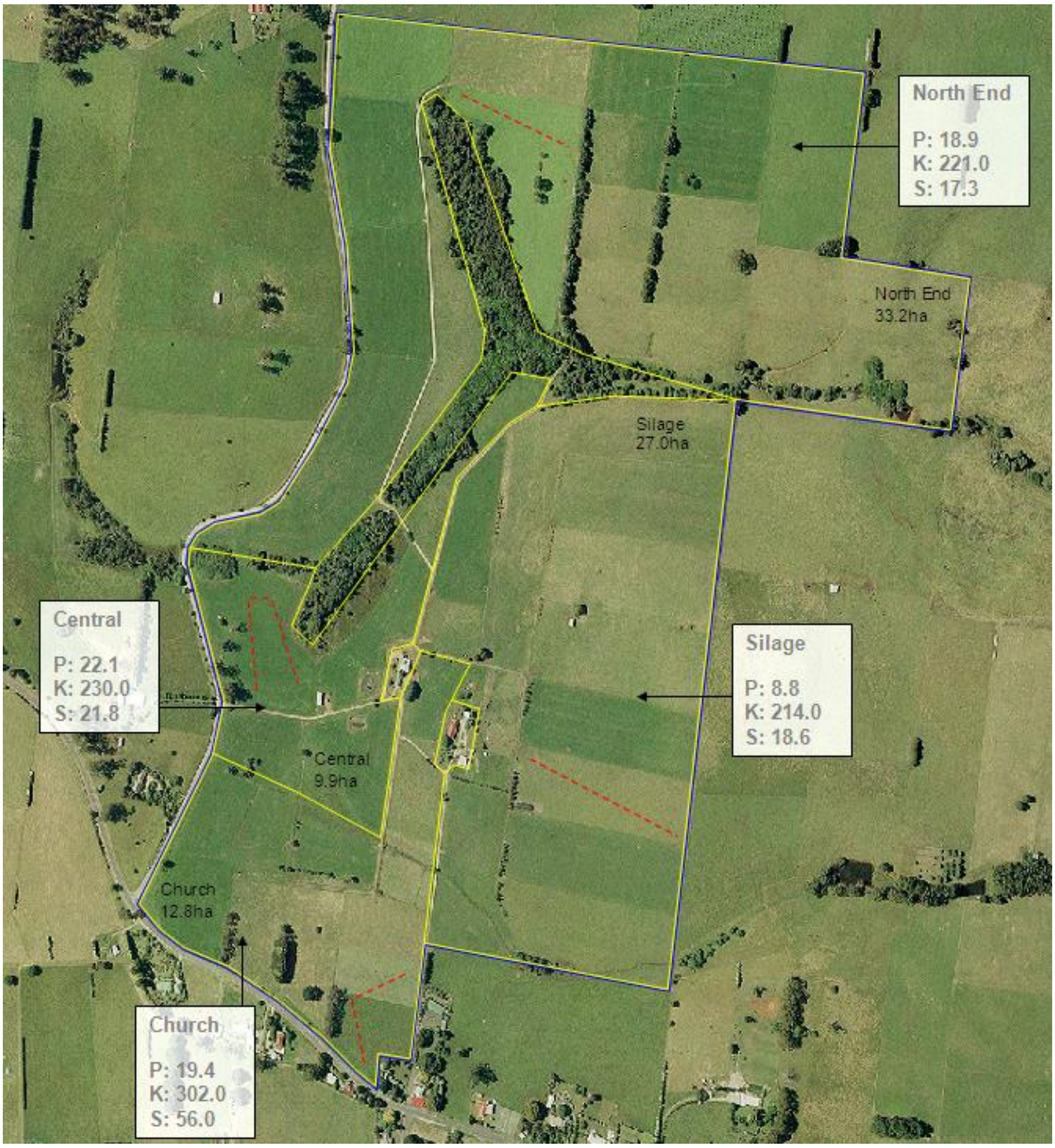


Figure 15.2 A map of an Australian dairy farm showing management areas. Red lines show were soil samples were taken, blue lines show the boundary, and the yellow line show the management areas**.**

The farm in figure 15.2 has been divided into four FMZs (North End, Central, Silage and Church). These areas correspond to different management areas and have been confirmed over a number of years with the aid of soil tests in other paddocks within the FMZs. Representative soil sampling is now used to monitor these areas. As you can see, the silage FMZ has a much lower P level than other areas of the farm and this will be a priority for fertiliser application. There is also high K and S levels in the Church FMZ, indicating potential to reduce or halt applications of these nutrients on these areas.

15.4.2 Nutrient Mapping

Nutrient mapping allows translation of soil tests into a visual representation of fertility across the farm. This assists with assessing variability across the paddocks on the farm. Colours are assigned to areas or paddocks depending on whether the nutrient level is low, marginal, good or excessive. Using nutrient mapping will allow quick visualisation of the variability within the farm and areas that have excessive nutrient levels, where consideration must be given to reducing inputs.

Nutrient maps can be as simple as using a farm map and highlighter pens to shade in different areas of fertility. Different colours are used to correspond to soil fertility guidelines and targets. Advisors may also assist in developing nutrient maps for the farm using different mapping programs. Nutrient maps can also help with grazing decisions on the farm. Areas with a lower nutrient status may not produce as much pasture dry matter as areas with good nutrient levels and this may influence how long and/or when these areas are grazed. This information can also aid in fodder conservation decisions; for example areas high in potassium should be identified and treated with caution as they can increase K levels in feed and therefore the risk of metabolic problems in livestock. Metabolic problems are discussed more in Chapter 3.

Nutrient maps are generally produced for phosphorus, potassium and sulphur. Some farms also produce maps for pH and salinity, as these can influence nutrient application decisions. Refer to Figure 15.3 for an example of a nutrient map on an Australian dairy farm.

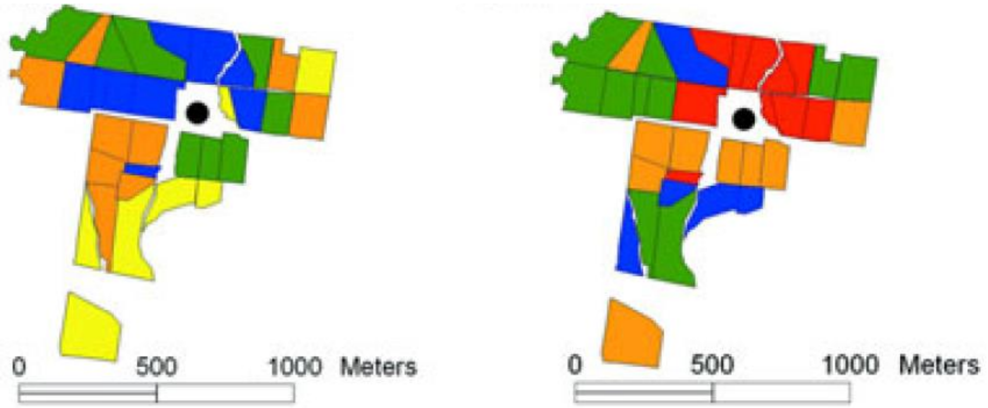


Figure 15.3 A nutrient map on an Australian dairy farm for Olsen P (left) and Colwell K (right). Red suggests very high, blue is high, green is adequate, orange is marginal and yellow is deficient nutrient P or K levels. *Source:* Gourley et al (2007).

Figure 15.3 illustrates how nutrient mapping can assist with nutrient decisions. P fertiliser will be a priority in the paddocks that are shaded yellow and orange and K fertiliser will be cut right back in the areas shaded red. The black dot in the figure is the dairy and as is often the case, K levels have built up close to the dairy where animals spend more time.

15.5 Setting target levels

It is important to set targets for the nutrients levels on a dairy farm – in particular phosphorus, potassium and sulphur. Setting targets will assist in determining whether the farm needs only a maintenance application or whether a capital application is required as well. Targets will be dependent on pasture species present, soil type and production levels.

The recommended target levels mentioned throughout this section are discussed in Chapter 9.2.5 to 9.2.7, ‘Interpreting soil and tissue tests’.

15.5.1 The effect of soil nutrient status on different pasture species

Pasture species have a big impact on potential pasture production. An unimproved pasture may have less than half the production of a well fertilised, improved pasture sown to perennial ryegrass and white clover.

Soil nutrient status and grazing management will each affect the botanical composition of a pasture. The application of nutrients alone may not always improve pasture productivity. Applying nutrients to an unimproved pasture will usually give a poorer dry matter response than applying nutrients to an improved pasture.

Figure 15.4 gives an indication of some of the temperate species likely to be present under various rainfall and soil fertility conditions. Higher soil fertility levels and higher rainfall conditions suit the improved species (for example, perennial ryegrass/white clover species). Low soil fertility levels and low rainfall conditions suit the unimproved species (for example, native grasses, sweet vernal, bent grass, and fog grass). Sub clover and paspalum are not included in this diagram because they have a wide range of rainfall and fertility tolerances.

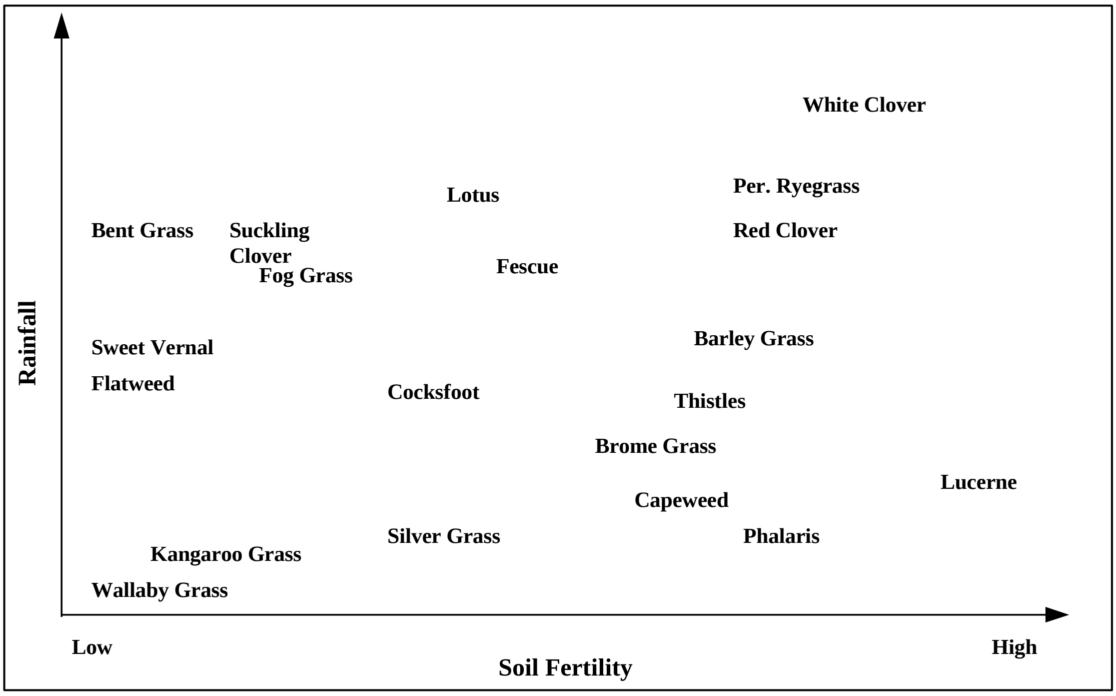


Figure 15.4 Rainfall and soil fertility requirements of a range of temperate weeds and pasture species. *Source:* Hill (1993).

15.5.2 Setting target levels for phosphorus, potassium and sulphur

The Olsen P test indicates the amount of phosphorus that is available to the plant in a soil and can therefore be compared across different soil types. The Colwell P test also measures available soil P as well as P that is less readily available to plants and will vary according to soil type. The optimum level of P when measured by the Colwell test will therefore be soil type dependent (see Chapter 9.2.5).

The Olsen P response curve in Figure 15.5 shows diminishing returns in pasture production as soil P level increases. This means there is a greater response to P applications at low Olsen P levels and that the response decreases at higher Olsen P levels.

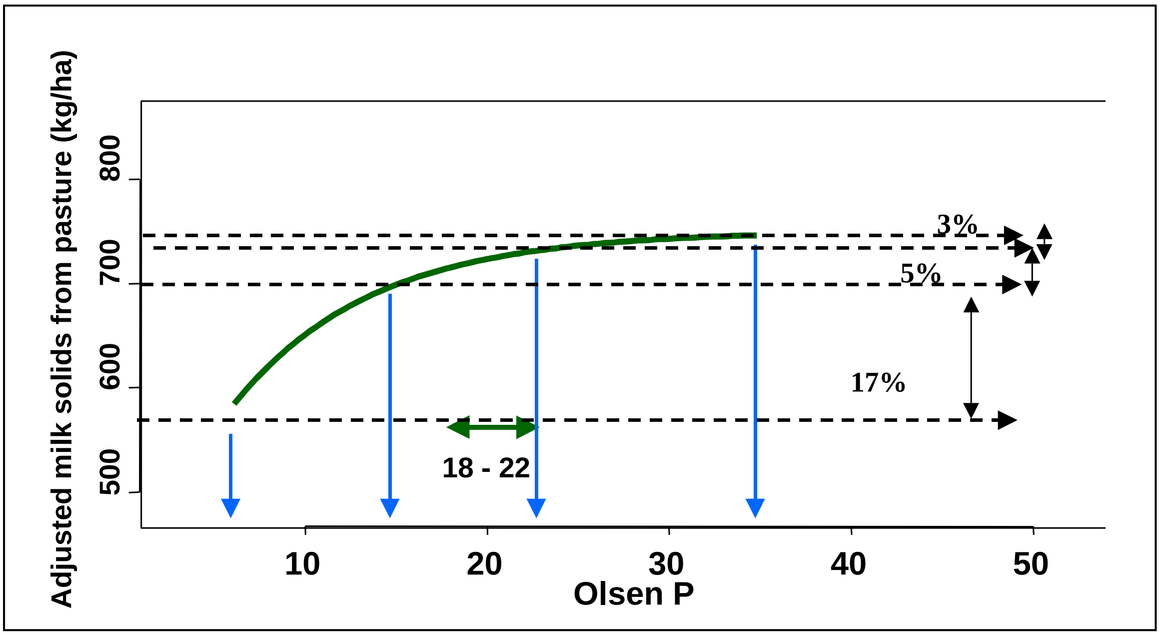


Figure 15.5 Relationship between soil Olsen P level and milk fat and protein responses to a range of Olsen P levels for soils sampled to a depth of 10cm. *Source:* DPI Phosphorus for Dairy Farms project.

The greatest response to applied P (17%) was at an Olsen P below 14, but a sizeable response (5%) still occurred from Olsen P 14. As can be seen from Figure 15.5, the response level above an Olsen P of 22 is only about 2%, and the response decreases further at the higher end of the range.

The ability of a soil to interact and hold on to phosphorus is referred to as a soil phosphorus buffering capacity. A soil with a high phosphorus buffering capacity requires a much greater application of P fertiliser (up to three times more) than a soil with a low phosphorus buffering capacity to give the same production result. The soil buffering capacity is measured on a soil test using the **phosphorus buffering index (PBI).**

Soils with high iron and aluminium levels, such as red volcanic soils (Ferrosols) and acidic peats, generally have a high PBI. Soils with a course texture, such as sandy loams, tend to have a low PBI. When P fertiliser is applied across a wide range of soil types at the same application rate, phosphorus requirements may not be met on some soils, whereas on others there may be a P loss to the environment due to oversupply.

A vital part of the nutrient planning process is to set P, K and S target levels for each of the FMZs on the farm. The DPI ‘Victorian Better Fertiliser Decisions’ project developed targets for Australian dairy soils – See the soil fertility guidelines for P, K and S in the following sections of Chapter 9:

- Phosphorus soil test target guidelines (Chapter 9.2.5.2)
- Potassium soil test target guidelines (Chapter 9.2.6)
- Sulphur soil test target guidelines (Chapter 9.2.7)

As mentioned in Chapter 9, ‘Interpreting Soil and Tissue Tests’, 95-98% of pasture performance compared to potential is considered adequate for a dairy farm system based on the latest recommendations from research. However each farm will need to set their own target levels for soil fertility. Farmers operating with levels higher than these suggested targets in their soils may decide to apply only maintenance levels of phosphorous fertiliser. The maintenance level of nutrient applied would be based on the target phosphorus level they are aiming to achieve. Another option is to cut back or to stop applying any fertiliser at all, but when doing this it is essential to monitor soil phosphorus levels annually. Once soil levels have fallen back to target levels, it is important to resume applying maintenance levels of nutrients, or the soil levels will continue to decline. This in turn would negatively affect pasture production and therefore milk production.

Phosphorus experiments undertaken on dairy farms in Western Australia between 2006 and 2010 as a part of the Greener Pastures Project (Bolland et al 2011), have also shown that no phosphorus fertiliser is required when soil test P is above the critical value for that soil. When soil test P is above the critical value for that soil, adding phosphorus fertiliser will have no effect on pasture production. The Green Pastures Project also showed the effect of applying no phosphorus fertiliser (Figure 15.6). The results highlighted that the rate of decline differ considerably depending on PBI of the soil and other factors. The soils with the lower PBI and lower critical Colwell P values tend to fall back quickly below critical values, whereas the higher PBI soils fell more slowly. Again the importance of monitoring fertility status with soil tests is highlighted.

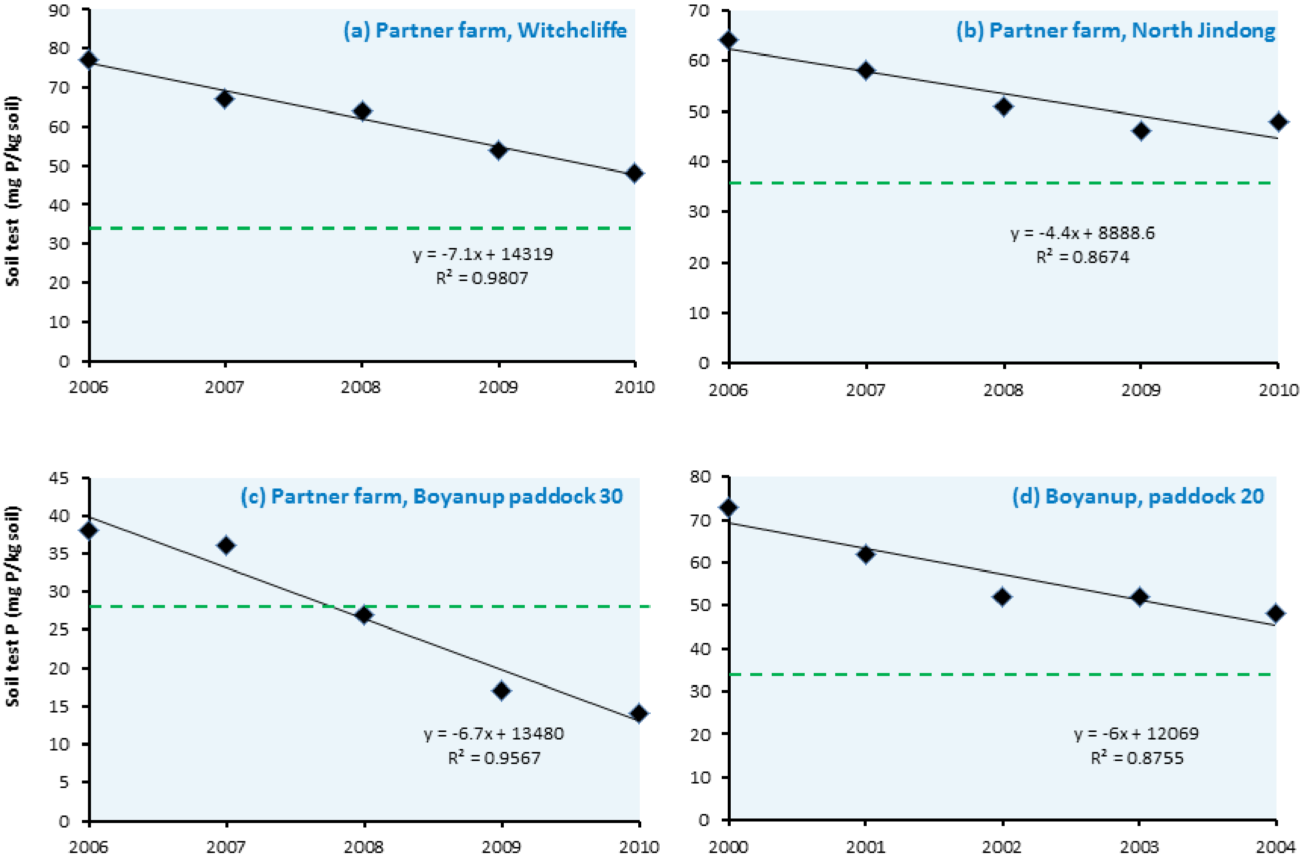


Figure 15.6 Colwell soil phosphorus test for the nil-P treatment of 4 experiments conducted in the dairy region of Western Australia. Critical soil test P values for each site are indicated by dotted lines – the critical value is for 95% of maximum pasture dry matter yield. *Source:* Adapted from Bolland et al (Feb 2011).

15.6 Nutrient budgeting to help determine nutrient application rates

Nutrient budgeting is a technique used to quantify or predict nutrient deficits or surpluses, either at a whole-farm or field scale, in an attempt to determine fertiliser requirements. It can improve nutrient use efficiency and reduce nutrient losses from agriculture. The approach discussed in this chapter is based on research led by Cameron Gourley from the Department of Environment and Primary Industries in Victoria. Gourley et al. 2007b discusses nutrient budgeting as an approach to improving nutrient management on Australian dairy farms.

Nutrients rates are always measured in kilograms of nutrients per hectare. This allows us to convert between kilograms of nutrient required/applied and the rate of fertiliser required/applied as discussed in Chapter 14. It also allows us to measure the nutrients coming and going, in a nutrient budget, on a per hectare basis.

A farm nutrient budget can be used to estimate the nutrients removed, or accumulated, for any area on the farm and this can be used to determine nutrient and therefore fertiliser requirements.

Nutrient budgets are often done on the effective milking area of the farm as it is easier to calculate the nutrients coming and going from this area. Farms with mixed production systems such as hay making, silage removal and cropping may require nutrient budgets prepared for each farm management zone.

Any imbalance between nutrient inputs (primarily as feed and fertiliser) and nutrient removals (in milk and livestock) can result in significant nutrient accumulation or depletion on dairy farms. Where there is nutrient accumulation this can represent both an opportunity cost and a threat to the environment.

15.6.1 Maintenance nutrient applications

The intent of a maintenance application is to keep the soil nutrient status at a steady level.

To determine the annual nutrient application required to meet the production goals of the farm the balance between the quantity of nutrients leaving the farm and the nutrients that are coming onto the farm must be considered. When more nutrients leave than are brought onto the farm the balance to be replaced is referred to as the **maintenance requirement**. In situations where more nutrient is coming onto an area of the farm than is being removed an excess of nutrients will develop and there is no maintenance requirement.

This method of calculating maintenance requirement is based on a nutrient budgeting approach and is currently recognised as the standard for calculating nutrient requirements on Australian dairy farms. The nutrient budgeting approach is a more accurate method across different production systems than the rules of thumb used in the past.

Nutrients enter and leave the soil and farm system via several pathways (see Figure 15.7). The question marks in the diagram indicate that the information is not readily or accurately known (such as the amount leached) or is highly variable (such as the distribution of manure and urine).

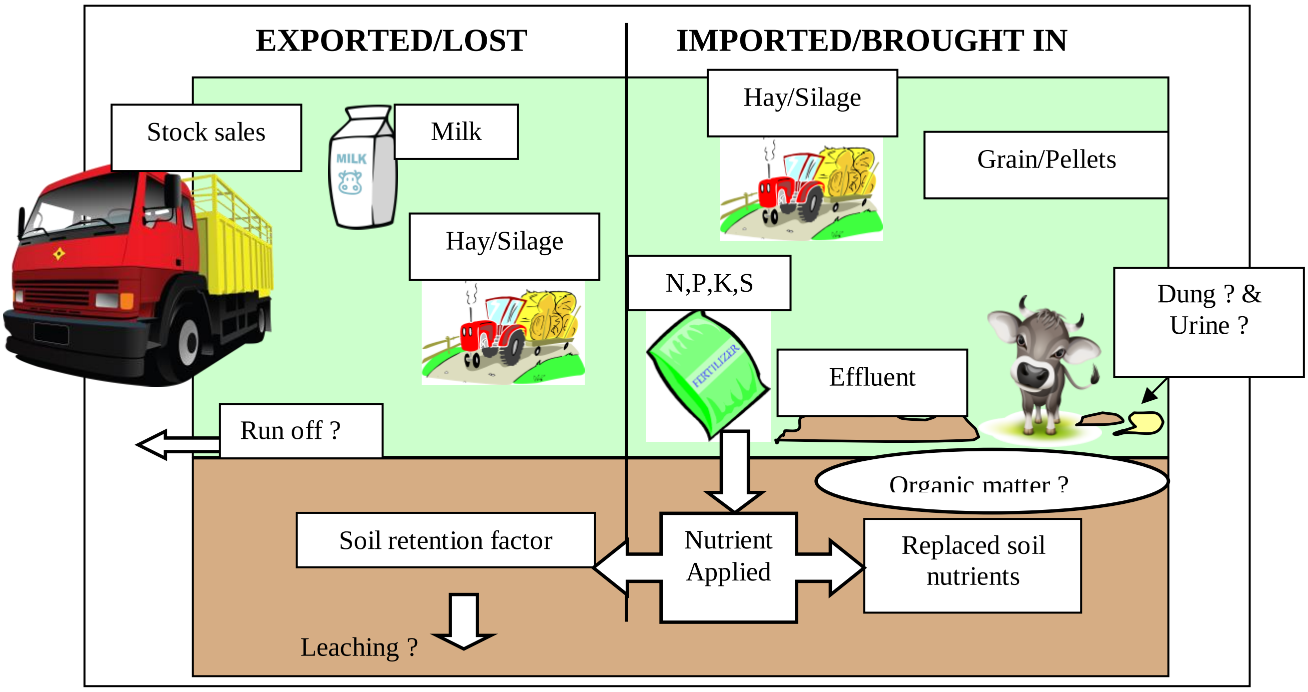


Figure 15.7 Major nutrient imports and exports in a dairy farming system

Losses include:

- Nutrients removed in milk and other animal products
- Nutrients sold or moved off farm as fodder
- Nutrients lost in dung and urine deposited on laneways and yards
- Soil losses, including leaching and nutrients held strongly or 'locked up' in the soil and its processes (commonly referred to as the **soil retention factor)**

Nutrients coming onto the farm include:

- Nutrients imported in feed (hay, silage, grain etc.)
- Nutrients returned in applied effluent

Nutrient budgeting allows you to determine the shortfall between losses and imports, which is the maintenance nutrient requirement. A simplified diagram of a nutrient budget is shown in Figure 15.8.

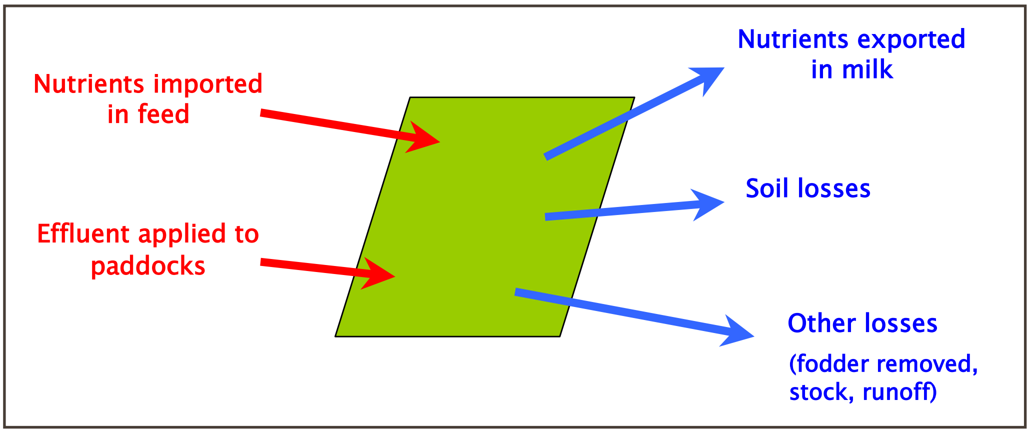


Figure 15.8 The nutrient imports and losses that determine the maintenance requirement

By calculating the amounts of imports and losses shown in Figure 15.8, the maintenance requirement of different areas of the farm can be determined as shown in the following equation:

Nutrients exported in milk + **Soil losses and other nutrient losses** - **Nutrients imported in feed and effluent** = **Maintenance requirement**

15.7 Calculating the maintenance requirement

In this section, we will focus on calculating the maintenance requirement of P for a certain area of the farm using example figures. The major exports and imports on a dairy farm are discussed to demonstrate the nutrient budgeting approach. Nutrient budgeting can also be done automatically by entering the figures into a nutrient budgeting program. This is often done with the assistance of an advisor who will have access to a nutrient budgeting program. It is however useful to know how the budgeted is calculated and the following sections work through how a nutrient budget is calculated.

The end of this chapter also has worksheets which demonstrate how the various components of a nutrient budget are worked out.

15.7.1 Calculating nutrient exports

15.7.1.1 Nutrients exported in milk

Every litre of milk that is exported off the farm removes a certain amount of P, K and S. We know that milk contains close to 0.1% P, so we can work out how many kg of P are exported from the farm. Assuming there is equal production from all areas of the farm (you could break the farm up into different areas of production), you can work out the kg of P exported per hectare.

Example

- Farm produces 1,000,000 litres of milk from 100 ha in one year
- 1,000,000 L divided by 100 ha = 10,000 L/ha
- 10,000 L/ha x 0.1% P = 10 kg P/ha

Therefore, we are removing **10 kg P/ha** from the farm in the form of milk.

15.7.1.2 Nutrients lost from dung and urine

This is a calculation from the ‘Phosphorus for Dairy Farms’ project to include when working out the maintenance fertiliser requirements for the farm. It makes an allowance for the nutrients lost in dung and urine while the cows are walking up the laneways and standing in the dairy yard. These nutrients are not being redistributed around the farm, unlike dung and urine in the paddocks.

You need to know the stocking rate of the farm. This is calculated by dividing the number of cows milked by the milking area of the farm. **The P lost from dung and urine in the laneways and dairy yard is estimated by multiplying the stocking rate by 0.8**.

Example:

- Farm milks 200 cows on 100 ha
- 200 cows divided by 100 ha = 2 cows/ha (stocking rate)
- 2 cows/ha times 0.8 = 1.6 kg P/ha

Therefore, the loss from dung and urine in the laneways and dairy yard is **1.6 kg P/ha**.

15.7.1.3 Soil retention factor

The soil retention factor accounts for losses within the soil structure in the case of P and accounts for leaching from the soil in the case of K and S. The ‘Phosphorus for Dairy Farms’ research illustrated conclusively that the maintenance application must also include a certain amount of P just to maintain the soil Olsen P level.

Each soil type has a different soil retention factor based on its physical and chemical make-up and its origin and weathering. Soils with a high PBI will remove P from the plant available pool more quickly and will have a higher soil retention factor.

A table of recommendations of P required to satisfy the soil retention factor has been developed and is now used to assist in making nutrient decisions (see Table 15.1 for recommendations based on Olsen P soil tests and Table 15.2 for Colwell P soil tests). Both the PBI and the current soil nutrient level affect the amount of P required to satisfy the soil retention factor. Therefore, areas of the farm that have different soil nutrient statuses and PBIs can have different total maintenance fertiliser requirements.

Table 15.1 Approximate amount of phosphorus required (kg/ha/yr) to satisfy the soil retention factor for a range of PBI values and Olsen P levels.

PBI Value	**Current Olsen P Level (mg/kg)**						
	2 to 4	**5 to 7**	**8 to 10**	**11 to 13**	**14 to 17**	**18 to 25**	**25 to 35**
0 to 50	0	3	6	8	9	10	10
50 to 100	0	5	10	15	18	20	20
100 to 200	0	6	13	20	23	25	25
200 to 400	0	7	15	22	26	28	28
400 to 600	0	8	16	24	28	30	30
Over 600	0	10	18	26	31	35	35

(**Source: Gourley and Burkitt pers. comm** - Adapted from Burkitt et al. 2002)

Example:
Table 15.1 shows that a soil with a PBI of 350 and an Olsen P of 16 would require around **26 kg P/ha** to satisfy the soil retention factor.

Figure 15.2 Approximate amount of phosphorus required (kg/ha/yr) to satisfy the soil retention factor for a range of PBI values and Colwell P levels

PBI Value	**Current Colwell P Level (mg/kg)**						
	10 to 15	**20 to 30**	**35 to 40**	**45 to 55**	**60 to 80**	**85 to 115**	**> 115**
0 to 50	1	4	6	8	9	10	10
50 to 100	2	7	10	14	18	20	20
100 to 300	2	8	12	15	20	22	23
300 to 400	2	9	14	18	22	25	25
400 to 600	5	11	17	22	28	31	32
Over 600	5	13	19	24	31	34	35

(Adapted from Accounting for Nutrients Fertiliser Budgeting tool www.accounting4nutrients.com.au)

Note that the amount of P required to satisfy the soil retention factor increases as Olsen and Colwell P increases. This is the opposite of what one might expect in that, as more P is available, one would think that less is needed for maintenance. Why is this so?

The fate of newly added nutrients is greatly affected by soil chemical and physical properties, the soil solution, soil temperature, soil moisture content, soil pH, amount of organic matter present, current soil nutrient status and other soil related factors, as well as by the amount of new nutrients added. The soil is complex and has ever changing soil reactions and fixation rates.

The increase in the amount of P required to satisfy the soil retention factor as Olsen and Colwell P increases is due to the high level of reactivity of freshly applied P and the substantial capacity of soil minerals to transform this P into less available forms – see Chapter 3.4.2. For any soil with a particular phosphorus buffering capacity (or PBI value), there appears to be a constant proportion of the applied P that is retained by the soil. Therefore, the greater the amounted added, the greater the amount retained, and therefore the greater the amount that needs to be replaced. A soil with a lower phosphorus buffering capacity (or PBI value) will retain a lower proportion of P than a higher PBI soil.

A table of recommendations for potassium and sulphur to satisfy the soil retention factor has also been developed to assist in making nutrient decisions (See Table 15.3). It is noted that there needs to be more research into this area.

Table 15.3 Approximate amount of potassium and sulphur (kg/ha/yr) required to satisfy the soil retention factor over a range of soil types

Soil type	Amount K to maintain present soil K levels	Amount S to maintain present soil S levels
Sand	25	12
Sandy loam	20	12
Sandy clay loam	15	12
Silty clay loam	15	12
Clay loam	15	12
Clay	10	12
Volcanic clay	10	12
Peat	10	12

(Adapted from Accounting for Nutrients Fertiliser Budgeting tool www.accounting4nutrients.com.au, and Cameron Gourley, DPI, Ellinbank, pers. com.)

15.7.1.4 Other losses

Nutrients are also removed in livestock leaving the farm, nutrient runoff, and fodder conserved and taken from the farm. These nutrient losses can be significant and are discussed further in the developing a nutrient budget worksheets at the end of this chapter.

For the example being worked through, assume that no fodder is removed from the farm, that other stock (for example young stock) are not on the area, and that nutrient runoff is minimised by best management practices.

15.7.2 Calculating nutrient imports

15.7.2.1 Nutrients imported in feed

Grain and fodder brought onto the farm contain a significant amount of nutrients. Both fodder and grain contain 3 kg of P per tonne of dry matter (DM). If we know how many tonnes of DM are fed over a certain area (tonnes DM/ha), we can work out the phosphorous imported onto the farm in brought in feed (see Appendix H, for nutrient contents of other feeds).

Example: 150 tonnes of grain and 100 tonnes of hay were imported and fed to animals on 100 ha

Grain: 150 tonnes divided by 100 ha = 1.5 tonne/ha
1.5 tonne/ha x 3 kg P/tonne DM = 4.5 kg P/ha

Hay: 100 tonnes divided by 100 ha = 1 tonne/ha
1 tonne/ha x 3 kg P/tonne DM = 3 kg P/ha

The total phosphorous imported in feed is therefore **7.5 kg P /ha**

It should be noted that the example above assumes the feed is spread evenly over the whole farm. In practice, there will be uneven distribution of nutrients over the farm both in terms of where the feeding out occurs and where the animals excrete the nutrients. Consider the issue of nutrient distribution when doing a nutrient budget. Regular soil testing will help identify issues associated with nutrient distribution.

15.7.2.2 Nutrients imported in effluent

The nutrients imported when effluent is applied must also be taken into account when calculating maintenance levels. Effluent is not actually imported to the farm, but is actually imported from the effluent system to the paddock. Depending on the concentration of nutrients and the rate of application, areas receiving effluent can have significant amounts of nutrients applied. If effluent has been applied to an area, the rate of nutrients can be determined using one of the worksheets in nutrient budget worksheets at the end of this chapter. (Also see Chapter 13, 'Using dairy effluent' for more information.)

For this example, assume that effluent isn't spread on the farm.

15.7.2.3 Calculating maintenance nutrient requirement

As mentioned, the nutrient budgeting approach takes into account the nutrients leaving the farm (exports and losses) and the nutrients that are coming onto the farm (imports). The shortfall between exports/losses and imports is the maintenance requirement, which is illustrated by this equation:

Nutrients exported in milk + **Soil losses and other nutrient losses** - **Nutrients imported in feed and effluent** = **Maintenance requirement**

Using the figures from the examples above, we can work out the phosphorous requirement for this particular area of the farm.

10 kg P/ha (milk) + **26 kg P/ha (soil retention) + 1.6 kg P (dung & urine loss)** - **7.5 kg P/ha (imported in feed)** = **30 kg P /ha**

Therefore, the maintenance requirement of **30 kg P/ha** is the amount that is required to maintain the current level of soil phosphorous. Similarly, we could calculate the maintenance requirement of K and S using the same approach.

Maintenance rates will vary between years because of farm management or production changes and climatic influences, such as wet weather (which increases nutrient leaching and runoff) or droughts (which reduce nutrient requirements). As always, monitoring soil tests over time will be important to validate P, K and S fertiliser application rates.

15.8 Capital nutrient applications

When nutrients are applied at a greater rate than that needed for maintenance, the soil fertility status of that particular nutrient rises. This is referred to as a **capital application.**

Soil type and PBI has a strong effect on the amount of applied nutrient required to lift soil fertility levels. The degree of fixation can vary. Nutrients may be strongly fixed, forming insoluble compounds, or may form more soluble compounds that can be slowly released back into the soil solution over time.

New Zealand experience has shown that it can take three to four years on some soil types before pastures fully respond to a high capital P application. Similar experience at Ellinbank on the Ferrosol soil indicates that up to two years may be required before the effects of the capital dressings are evident in terms of increased pasture growth and quality.

High P fixing soils have a high PBI, so they require large capital applications of P to raise the soil P level. Soils which contain large amounts of iron (Ferrosols) fix much of the P applied.

Sandy soil types are low P fixing and have a low PBI. In these soils, the majority of the applied P remains in the soil solution, and the remainder is held to the clay or organic matter. Sandy soils low in clay or organic matter are more susceptible to P leaching, however.

An increase in the soil nutrient status using a high capital application will occur more quickly on lighter soils, such as sands or loams, than on heavier-textured soils.

For capital P applications to be economical, pasture utilisation must be maximised. If the extra pasture grown as a result of higher P levels is not utilised, the investment in the capital application is wasted

15.8.1 The amount of capital Phosphorus required to raise the soil level by one unit

The amount of capital P required to raise the soil Olsen or Colwell P test by one unit (1 mg/kg) is variable and largely depends on the phosphorous buffering index (PBI) of the soil (see Table 15.4). Remember that this rate is in addition to the P applied to meet maintenance requirements. Soil texture can also be used as a guide for determining the amount of capital P required to raise the soil Olsen or Colwell P by one unit (where possible use the PBI figure which is more accurate).

Table 15.4 The approximate amount of capital P (kg/ha) required to raise soil Olsen or Colwell P by one unit (1 mg/kg) based on the soil type or PBI

Soil Type	PBI	Amount of P to raise Olsen P by 1 unit (kg/ha)	Amount of P to raise Colwell P by 1 unit (kg/ha)
Sand	0 to 50	6	2.2
Sandy loam	51 to 100	8	2.3
Sandy clay loam	101 to 300	9	2.5
Silty clay loam	101 to 300	9	2.5
Clay loam	301 to 400	10	2.8
Clay	401 to 500	11	3
Volcanic clay	501 to 600	13	3.2
Peat	Over 600	15	3.6

(Adapted from Accounting for Nutrients Fertiliser Budgeting tool www.accounting4nutrients.com.au)

This means that a soil with a PBI of 133 would require an application rate of 9 kg of P/ha to raise the soil Olsen P by one unit. The amount of capital P (kg P/ha) required to lift the Olsen or Colwell P to your target Olsen or Colwell P level on a particular soil can be calculated using the following formula:

Target Olsen P	-	Current Olsen P	=	Olsen P Units to be Added	x	Kg P/Unit of Olsen P	=	Capital P Application Rate (kg P/ha)
Target Colwell P	-	Current Colwell P	=	Colwell P Units to be Added	x	Kg P/Unit of Colwell P	=	Capital P Application Rate (kg P/ha)

Example: Your soil has a PBI value of 133 and an **Olsen** P of 12, and you would like to raise the soil fertility for P to an Olsen P of 20. You would calculate the estimated amount of capital P to apply as follows:

Target Olsen P	-	Current Olsen P	=	Olsen P Units to be Added	x	Kg P/Unit of Olsen P	=	Capital P Application Rate (kg P/ha)
20	-	**12**	=	**8**	x	**9**	=	**72 kg P/ha†**

†Equivalent to 818 kg (about 0.82 t) of single superphosphate per ha.

Example: Your soil has a PBI value of 133 and a **Colwell** P of 20, and you would like to raise the soil fertility for P to an Colwell P of 34. You would calculate the estimated amount of capital P to apply as follows:

Target Colwell P	-	Current Colwell P	=	Colwell P Units to be Added	x	Kg P/Unit of Colwell P	=	Capital P Application Rate (kg P/ha)
34	-	**20**	=	**14**	x	**2.5**	=	**35 kg P/ha**

Remember, **these are capital applications.** Therefore, they only become effective after the total maintenance requirement of the farming system and the soil has been satisfied. The decision would need to be made around how quickly this would be added (e.g. over one, two or three years)

15.8.2 The amount of capital Potassium and Sulphur required

Soil levels of potassium (K) and sulphur (S) can vary enormously due to factors other than soil type. Single superphosphate contains sulphur. Consequently, if single superphosphate is being applied regularly, sulphur deficiencies are less likely (although can occur on lighter soils). However, if high analysis fertilisers (e.g. triple super) or blends low in sulphur are used regularly, then extra sulphur may be required.

Potassium is fairly mobile in most soils. It is leached readily, particularly from lighter soil types and in extremely wet conditions. It is also removed in large amounts in hay, silage and fodder crops.

Table 15.5 The estimated amount of capital potassium (kg/ha) required to raise the soil level by one unit (1 mg/kg)

Soil Type	Potassium (kg K/Unit of K)
All soil types	2

(Adapted from Accounting for Nutrients Fertiliser Budgeting tool www.accounting4nutrients.com.au, and Cameron Gourley, DPI, Ellinbank, Pers. Com. 2013)

For example, to raise the level of potassium (K) by 30 units in a clay loam soil, approximately 60 kg/ha of K above that required for maintenance must be applied.

Research into yield responses to K have not been as extensive as for P, however the more commonly used K tests have a greater degree of field calibration. Because of the K buffering capacity of soils and many other influences on K concentration in the soil, K levels can vary throughout the year, and substantially from year to year. It is therefore important to monitor K regularly – See Chapter 9.2.6.1, ‘Tests for Available Potassium’.

Table 15.6 Estimated amount of capital sulphur (kg/ha) required based on soil test result

Sulphur soil test level (KCl 40 Test) (mg/kg)	Sulphur Required (kg/ha)
0 – 4	30
4 – 9	15
9 – 13	7
> 13	1

(Adapted from Accounting for Nutrients Fertiliser Budgeting tool www.accounting4nutrients.com.au, and Cameron Gourley, DPI, Ellinbank, Pers. Com. 2013)

For example, if soil testing indicates that the sulphur level is 5 mg/kg, then 15 kg/ha of sulphur should be applied in addition to maintenance.

Field-calibrated trials for sulphur are limited and there is insufficient research to quantify the amount of sulphur required to raise the sulphur levels by one unit. In addition to this, sulphur becomes less available in cold, wet conditions, and in these conditions responses to applied nitrogen are sometimes improved if some sulphur is applied at the same time (M. Bolland, Pers. Com. April 2013) – See Chapter 9.2.7.

15.9 Prioritising nutrient applications on farm

Whether the nutrient requirements of the farm will be fulfilled depends largely on the availability of money and the cost of nutrients. Sometimes these constraints mean that only part of the ideal nutrient plan can be implemented.

In that case, choices have to be made as to which part to implement now and which to implement later. Similarly, the choice may be between fertilising only part of the farm at the desired nutrient application rate and allowing the remainder to be unfertilised, or fertilising the entire farm at a lower rate.

If areas of the farm have recently been renovated, it is important to maintain nutrient application to these paddocks to ensure they do not become run down, as considerable dollars have already been invested in them.

Areas of the farm that have been cut for hay or silage also need special consideration. These paddocks will quickly deplete their stores of potassium in particular and may become infested with low producing grasses and flat weeds if potassium is not applied.

Part of the farms effluent management may be to pump out the ponds onto several paddocks throughout the year. These paddocks may not need additional applications of nutrients due to the high loads that may be being applied via the effluent.

It is up to the farm owner to decide on the nutrient level targets for the different Farm Management Zones on the farm. Once targets are reached, capital applications are no longer required and maintenance rates will be the most economic rate to apply. Soils with lower P levels should, under good management, reap larger economic benefits per unit of phosphorus applied compared to farms with higher P levels (see Figure 15.9).

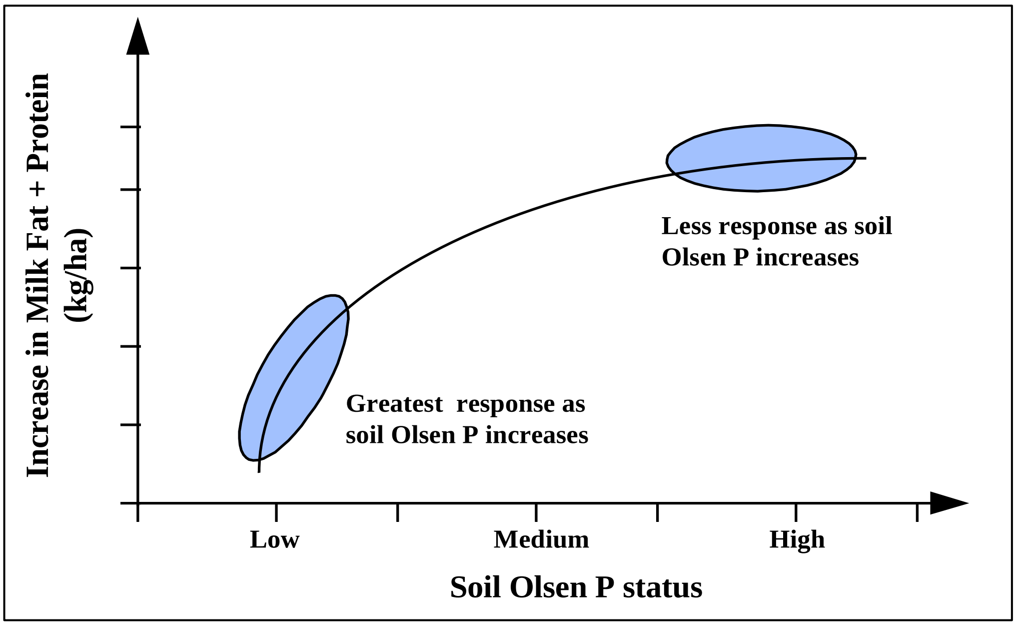


Figure 15.9 Relationship between soil Olsen P level and milk fat and protein responses to capital P applications

Figure 15.9 illustrates the principle of diminishing returns. This shows that fertiliser applied to increase the soil Olsen P level by one unit when the soil Olsen P levels are low will give a greater increase in production and financial return than fertiliser applied when the soil Olsen P levels are high. This same principle applies to all the nutrients required by plants.

In years where milk returns are high, capital applications may be applied to the paddocks with low P levels to prepare them for the sowing of improved pasture species or to improve the growth of existing improved species.

Factors affecting the nutrient requirements are constantly changing, and the soil fertility levels should be regularly monitored to make more informed, cost effective nutrient decisions.

Ideally, every paddock on the farm would be soil tested to determine the spatial distribution of each nutrient over the entire farm. This is very expensive, but research has shown that the cost is several times less than the savings that can be made.

15.10 Monitoring of soil nutrient status

An effective way to determine whether sufficient fertiliser is being applied to meet capital and maintenance requirements is to monitor soil fertility. Regular soil testing of Farm Management Zones, using correct sampling procedure, is vital to monitor your fertiliser program’s effect on soil fertility.

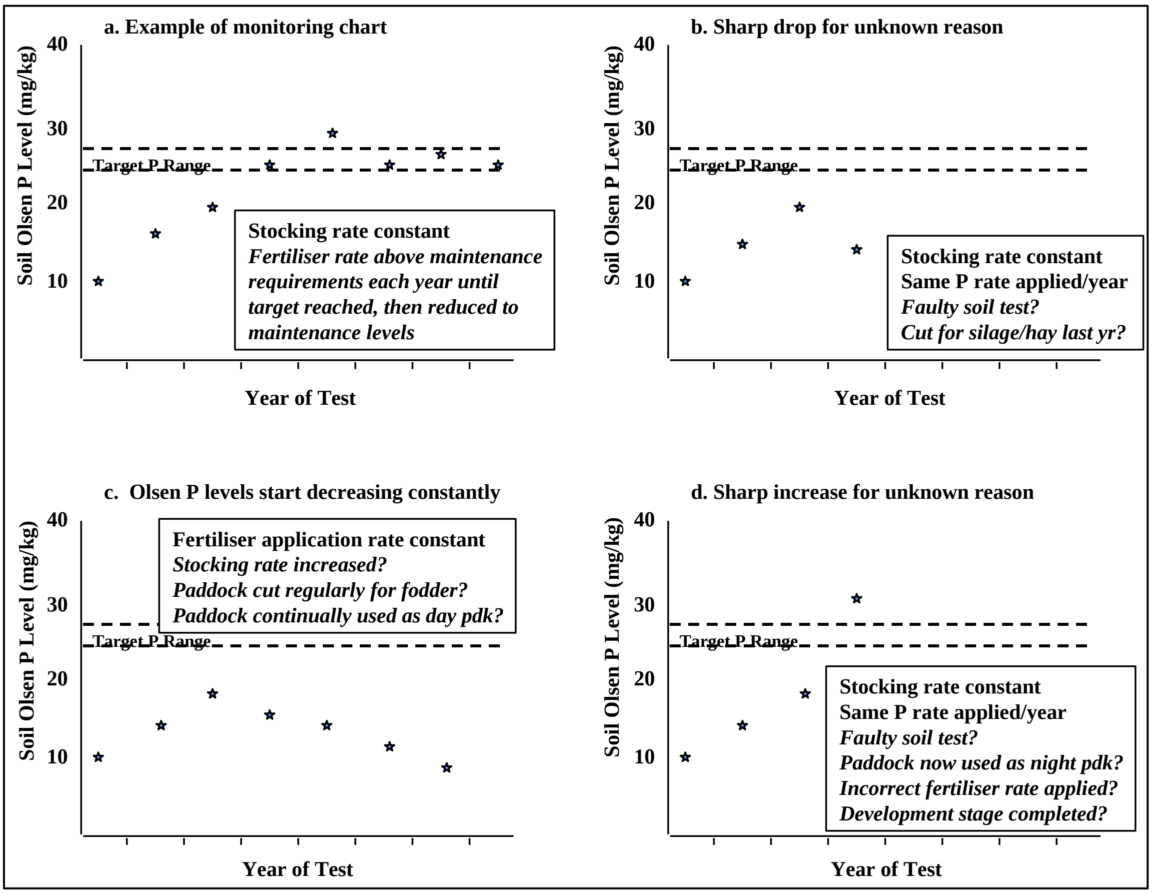
Two useful tools that can help to record results, monitor soil fertility trends, and make much more efficient fertiliser decisions are:

- Fertiliser monitor charts
- Computer software

15.10.1 Fertiliser monitor charts

Recording soil test results in the form of a graph (referred to as a **fertiliser monitor chart**) allows farmers to more easily identify or monitor the trend of the soil fertility in nominated areas on their farm over time. If fertiliser applications exceed the maintenance requirements, then the soil nutrient levels will increase. If applications are below the maintenance requirement, then the soil nutrient levels will decline. A sharp rise or fall in nutrient level may be the result of incorrect soil sampling, and may be ignored if the soil fertility trend has been steady and cow numbers and fertiliser applications have not altered substantially in that soil test period.

Figures 15.10a, b, c, and d show some examples of how to interpret soil Olsen P monitor charts. When trends on the fertiliser monitor chart are not what you expect, consider whether this is the result of management or environmental factors, such as the effect of applying effluent, feeding out in a sacrifice paddock rather than over a larger portion of the farm, or the effect of a very wet year on K and S.



a. Example of monitoring chart

Stocking rate constant
Fertiliser rate above maintenance requirements each year until target reached, then reduced to maintenance levels

b. Sharp drop for unknown reason

Stocking rate constant
Same P rate applied/year
Faulty soil test?
Cut for silage/hay last yr?

c. Olsen P levels start decreasing constantly

Fertiliser application rate constant
Stocking rate increased?
Paddock cut regularly for fodder?
Paddock continually used as day pdk?

d. Sharp increase for unknown reason

Stocking rate constant
Same P rate applied/year
Faulty soil test?
Paddock now used as night pdk?
Incorrect fertiliser rate applied?
Development stage completed?

Figure 15.10 Example fertiliser monitoring charts recording phosphorus levels and showing possible reasons for the interpretations

Figure 15.10a shows the soil Olsen P level rising steadily as capital applications above maintenance are applied and then levelling off when the target soil Olsen P level has been reached and maintenance application rates only are applied.

Figure 15.10b shows a sudden drop in the soil Olsen P level, even though the stocking rate and fertiliser application rates remained unchanged. It is unlikely that the soil Olsen P level would suddenly decline, and the drop may be due to a soil sampling or testing error. Sampling soon after a fodder crop has been removed and before the new season’s fertiliser is applied may result in a slight drop but not a drastic decrease in one year.

Figure 15.10c shows the soil Olsen P level steadily rising and then declining, even though the fertiliser application rates remained the same. The change in the soil fertility trend may be due to an increase in stocking rate, regular cutting of hay or silage, or nutrient transfer to elsewhere on the farm if the paddock is routinely used as a day paddock.

Figure 15.10d shows a steady rise in the soil Olsen P level towards the target P range and then a sharp rise. Again, this may be due to a soil sampling or testing error, paddock management changes, or application of an incorrect rate of fertiliser.

Make a graph for each nutrient or soil condition indicator you want to monitor, such as P, K, S, pH, and aluminium. You will need a set of these graphs for each area to be monitored on the farm.

15.10.2 Computer software

Many farm or herd management computer programs have sections which allow pasture and nutrient records to be kept. Alternatively fertiliser monitor charts can quickly be designed using spreadsheet software found on most computers.

15.11 Developing a nutrient budget for a dairy farm

15.11.1 Nutrient budgeting worksheets

The nutrient budgeting worksheets provide a guide to working through the process of calculating a whole farm nutrient budget. The worksheets take a whole-farm approach to nutrient management. Nutrient imports and exports are calculated over the entire milking area. Areas with different soil types and fertility levels should be treated differently; and where nutrient distribution is an issue, this should be taken into account.

Many advisors will be able to assist farmers with calculating nutrient budgets for the farm as a part of the fertiliser planning process. Often advisors will have spreadsheets or programs that will help process the numbers, and these spreadsheets and tools are based on information discussed in this chapter and on the following worksheets.

Nutrient Budget Worksheets

15.12 References

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