Five easy steps

to ensure you are making money from superphosphate

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This booklet is relevant for the management of temperate legume-based pastures grazed by sheep and beef cattle on acid soils in southern Australia
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Disclaimer

Acknowledgements

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Contents

Why apply phosphorus fertiliser?

Phosphorus (P) is applied to Australian pastures because a majority of our soils have low P-availability for plant growth, and pasture growth is constrained by their P "deficiency". For legume-based pastures, improving P-availability boosts the legume content of the pasture and increases the amount of biological nitrogen fixation by the pasture system. Nitrogen is often the most limiting soil nutrient. Thus, P-fertiliser practise drives overall pasture productivity.

However, ultimately the objective of applying P is to lift or maintain stocking rate and consequently to improve profit per hectare.

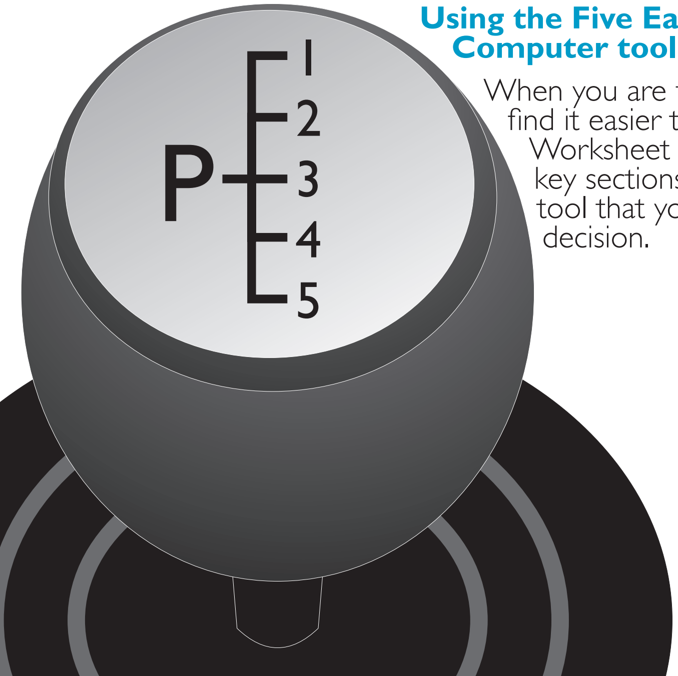
This booklet and the accompanying computer tool are intended to assist farmers in determining suitable levels for P-fertilisation of temperate pastures grazed by sheep and beef cattle on acid soils in southern Australia.

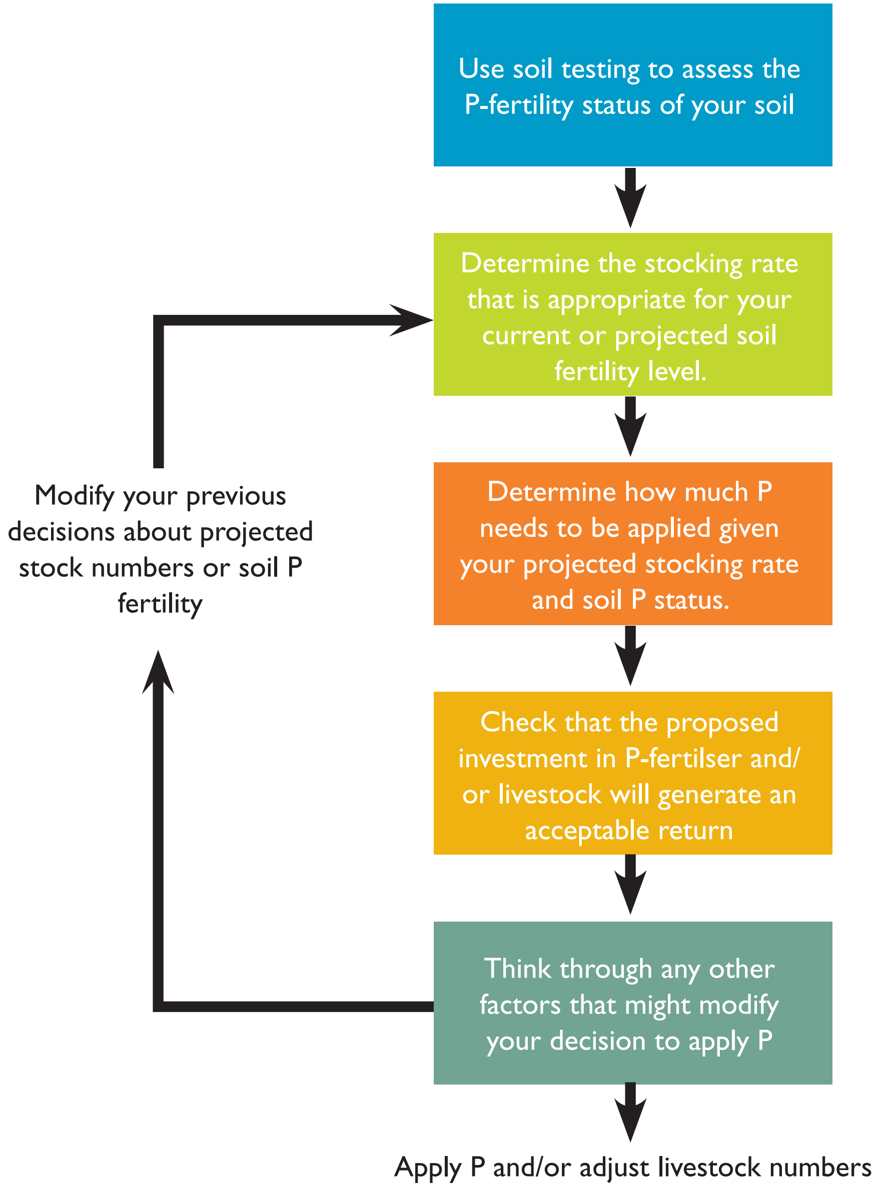
How to proceed

Each step is dealt with sequentially in this booklet. Work through each step in turn, as illustrated in the diagram.

Using the Five Easy Steps Worksheet and Computer tool

When you are familiar with the "Steps" you will find it easier to go directly to the Five Easy Step Worksheet (page 17). This directs you to the key sections of the booklet and computer tool that you need to reach a fertilizer decision.





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Step 1: Using a soil test to determine current soil fertility and your target for soil P management.

Soils always contain much more phosphorus (P) than is available to plants during the current growing season. Most of the P is in compounds that plants cannot use directly, is tightly bound to soil particles or in compounds that are only sparingly-soluble. The various soil tests that are used to assess whether fertiliser additions will result in more pasture growth all extract a small proportion of the total P in a soil; ideally a P-fraction that consistently indicates how much P is available for plant growth.

Because different soil P tests differ in the extraction solution used or the method of extraction, the number generated by each test may differ substantially. It is, therefore, important to be familiar with the test that you are using and the "critical" test value above which no further response to fertiliser application is likely.

This brochure deals only with interpretation of the Olsen extractable-P soil test (Olsen *et al.* 1954) and the Colwell extractable-P test (Colwell 1963) which are used widely in southern Australia. Both tests are applicable to acid soils but may not be suited to calcareous soils (e.g. Bertrand *et al.* 2003). The Colwell P test is an adaptation of the Olsen P test aimed at improving its reproducibility (Colwell 1963) but the cost of improved reproducibility was that soil test interpretation became soil-specific (Helyar and Spencer 1977).

Figure 1 shows the relationship between pasture yield and Olsen P over a wide range of soils. These data are interpreted to indicate that pasture will respond to fertiliser P application if the Olsen P soil test value is less than 15 mg P/kg soil, irrespective of soil type. Above this Olsen P value, pasture yield will not be increased markedly.

By contrast, interpretation of the Colwell P test is a two-step procedure because the critical P value of a soil varies with its Phosphorus Buffering Index (PBI) value (Figure 2). PBI is a measure of a soil's ability to readily sorb (bind) phosphate from soil solution (Burkitt *et al.* 2002; Burkitt *et al.* 2008). So for a fertiliser and grazing demonstration trial at Bookham, NSW where the soil had a PBI = 80, a critical Colwell P value of about 32 mg P/kg soil can be predicted from the PBI-critical Colwell relationship (Fig. 2). In fact, the results from an experiment examining the response of clover-rich pasture to P application at this site agree reasonably well with the critical Colwell value predicted using the site PBI (Fig. 3). This means that in this particular soil, pasture yield will be improved by applying P if the Colwell soil test is less than 32 mg P/kg, but will yield little extra pasture if the soil test value is greater than this value.

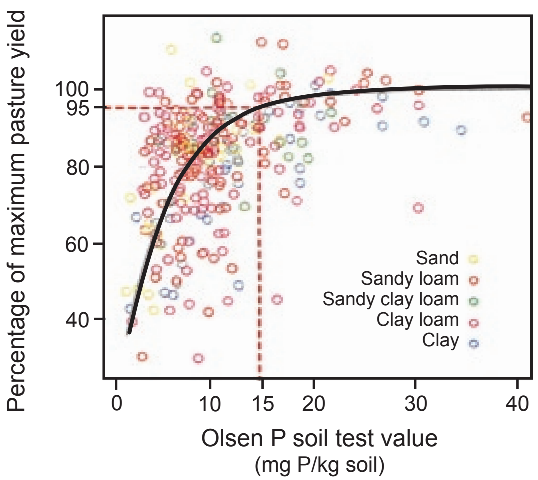


Figure 1: The relationship between percentage of maximum pasture yield and the Olsen P soil test value derived from experiments collated nationally by Gourley *et al.* (2007). The critical Olsen P soil test value at 95% of pasture production is 15 mg P/kg soil.

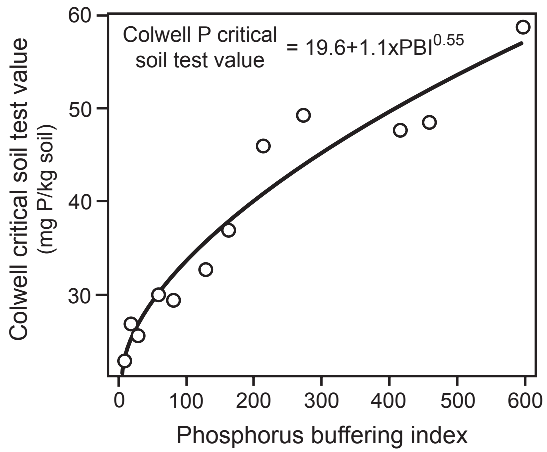


Figure 2: The relationship between critical Colwell P and the Phosphorus Buffering Index values of soil as derived from experiments collated nationally by Gourley *et al.* (2007). The critical Colwell P value is the soil test value predicted to produce 95% of pasture yield.

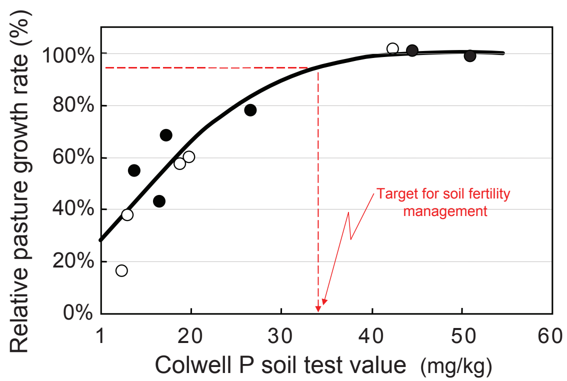
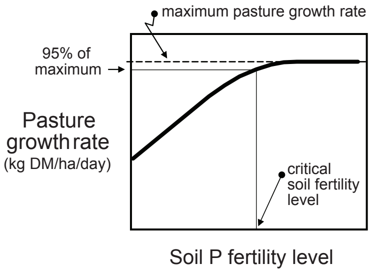


Figure 3: Response during spring of sub clover-rich pasture (clover = 60% of pasture dry matter) to soil P fertility in two separate years (○ 2002; ● 2003) at Bookham, NSW (Phosphorus Buffering Index for this soil = 80). The critical soil fertility level corresponding to 95% of maximum growth rate is indicated by the arrow.

Further information

When is a response to P expected and when is it not expected?

Pasture growing in P-deficient soil grows relatively slowly at a rate governed by the soil's ability to supply P to the pasture plants. Often this means that water-use efficiency (pasture grown per mm rainfall) will be relatively poor and productivity per hectare of land will be low. When P is applied, plant growth rate increases and more pasture is grown within each season. Consequently, more animals can be sustained per hectare. With fertiliser additions that lift soil P fertility a point will be reached where the soil can supply enough P for maximum pasture growth rates to be achieved. This is known as the "critical" soil fertility level and increasing soil P fertility above this point will not result in further increases in yield.



Many graziers complain that their pastures are no longer responding to P. There are a number of possible reasons why this might occur (not all good), but a good reason would be that soil fertility may have been built to the point where no further pasture response is expected. Then it may be possible to shift down to lower fertiliser application rates that maintain high pasture production without excess fertiliser use.

Another reason why a response to P may not be seen in a P-deficient soil can be the existence of another nutrient deficiency. In general it is expected that the most deficient nutrient in the soil will limit pasture growth rate. So if another nutrient is "more" deficient for plant growth than P, there will be little or no response to P applications. The nutrients that are most commonly the cause of such problems in southern Australia are sulphur, potassium and some micronutrients. The prevalence of these nutrient problems depends on your soil type and paddock history (see further discussion at Step 5: *Other things to think about before you invest*).

What is the Phosphorus Buffering Index test?

The Phosphorus Buffering Index (PBI) test is a relatively new, one-step test that has been adopted as the national standard method for measuring the P-sorbing capacity of soil. P-sorption is the process by which soluble P becomes adsorbed to clay minerals and/or precipitated in soil and it determines the partitioning of P between the solid and solution phases of the soil. This characteristic of the soil consequently influences the availability of P to plants and is therefore useful for interpreting some tests of plant-available P in soil. In particular, it allows prediction of the Colwell extractable-P value of a soil that corresponds with maximum pasture growth.

PBI is determined after measuring the amount of P that sorbs to 4 g of soil shaken gently for 17 hours at 25°C in 40 mls of 0.01M $CaCl_2$ solution which contains 4 mg of P in the form of KH_2PO_4 (Burkitt *et al.* 2002; Burkitt *et al.* 2008).

Which extractable-P test should I be using?

There are many extractable-P soil tests and all of them aim to be "dip-stick" type measures of the P that is available for plant growth and as such their objective is to be useful as a predictor of likely response to fertiliser P applications. Soil P tests can only be interpreted if you know the critical extractable-P value (i.e. the value above which further responses to fertiliser P are unlikely) of the test you are using for your particular soil. Some tests are not as reliable as others. Some extract particular forms of P better than other forms and may give differing results with different P fertilisers. Some return soil-dependent extractable-P values.

Most importantly, they often return different extractable-P values and this is why you must know the critical extractable-P value of the test you are using for your particular soil. If you are already using a particular soil test, it may not be a good idea to shift to a different test unless you have good evidence that it is a better test of plant-available P, and you know the critical P value of your soil with the new test.

What are the Olsen and Colwell tests?

Colwell P and Olsen P soil tests both use a bicarbonate solution (0.5 M $NaHCO_3$; pH 8.5) to extract phosphate from soil but differ in the time of extraction (Olsen: 30 min vs Colwell: 16h), and ratios of soil to extraction solution (Olsen: 2g soil/40 mls solution vs Colwell 0.5g soil/50 mls solution) (Rayment and Higginson 1992). Both are reported as mg (extractable-P) per kg of dry soil, but for any one soil the relative amount of P extracted by each test differs and the critical soil P value that is expected to indicate maximum plant growth also differs.

STEP
1

How to take soil tests properly

It is important to collect soil samples correctly to ensure a meaningful test result:

i. **Representative samples** – Establish monitor areas or transects that represent each of the major classes of land (land management units) across the farm. The objective is to adequately represent the differing areas of the farm that are to be fertilised whilst ensuring a reasonable soil testing load and expense. Using a soil corer, sample in the monitor area or along the transect in a systematic way and record the sampling interval and pattern used so that the sampling pattern can be replicated at later times. To ensure samples reflect the paddock as a whole, avoid stock camps, fence lines, water troughs, fertiliser dumps, burnt timber rows, wet gullies, gateways, tracks or dung patches and sample from different soil types separately.

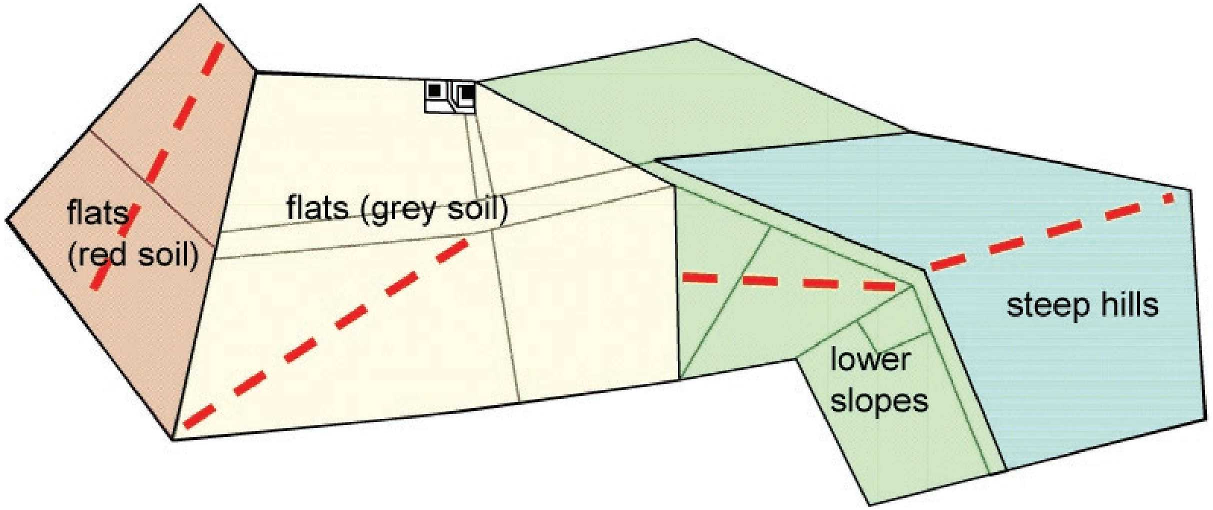
ii. **Mark the site** – Keep a record of the monitor area or transect for future testing. You may do this by noting where you started and finished and the route taken, by taking a series of GPS readings, etc.

iii. **Depth** – Extractable P is measured in topsoil samples using a soil sample depth of 10cm. P is typically more concentrated in the top few centimetres of soil so it is very important to obtain the full volume of soil to 10 cm depth to avoid biasing the concentration of P in the soil sample.

iv. **Sample number and handling** – Take a minimum of 30 soil cores along the transect or monitor area and combine to give a sample that is representative of the paddock. Send the sample to the testing laboratory promptly. Use an ASPAC-accredited laboratory to take advantage of the quality control that this accreditation represents.

v. **Timing** – Always sample at the same time every year. It is potentially feasible to take annual samples at any time of the year, but soil samples are most commonly taken in late spring. At this time soil is usually moist, but not wet, allowing soil cores to be taken quickly and easily. Moist soil holds together in the corer and this helps to ensure the sample is the full 10 cm depth. Never sample within the first few months after fertiliser application.

Soil testing: establish monitor paddocks or transects (▪▪▪▪) that represent the major classes of land, or land management units of the farm. The objective is to adequately represent the differing areas of the farm that are to be fertilised whilst ensuring a reasonable soil testing load. Retest the monitor areas annually. Over time you will be able to make decisions on the basis of the soil fertility trends that the data will reveal.



Step 2: What stocking rate?

The main reasons for applying P to pasture are to either increase, or to maintain stocking rate. Applying P without having extra stock to use the extra pasture grown may not be profitable. The extra stock that are needed may cost more than the fertiliser itself.

Predicting how many stock may be carried as soil fertility is lifted is often the most difficult task. Potential carrying capacity of a well-fertilised, temperate pasture is determined by the local climate, pasture type and soil conditions (particularly the water-holding capacity of the root zone). However, a dominant influence is the length of growing season.

Figure 4 shows relationships between potential carrying capacity (dry sheep equivalents/ha) and estimated average length of growing season from grazing trials run in south-eastern Australia (Saul and Kearney 2002). Upper and lower boundaries for potential carrying capacity were determined because smaller paddocks tended to carry more stock (most likely due to uneven pasture utilisation in larger paddocks).

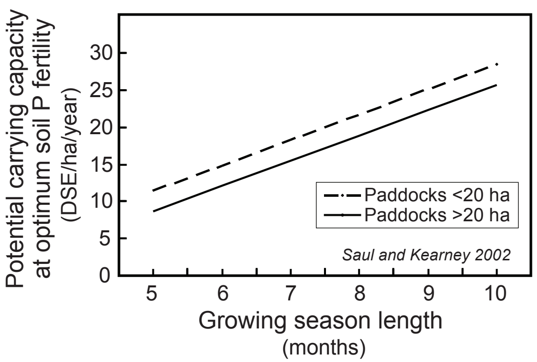


Figure 4: The relationship between potential carrying capacity of paddocks optimally fertilised with P (Olsen P = 15 mg/kg) and growing season length (Saul and Kearney 2002). Variation in growing season length alone was found to explain about 67% of the variation in carrying capacity of well-fertilised paddocks from various locations across south-eastern Australia.

How to use this information:

We will use the results of a grazing demonstration trial at Bookham, NSW (Graham 2006) to illustrate how it is now possible to estimate the soil fertility level that will give near maximum pasture production, and the potential carrying capacity of the site when operating at this level of soil fertility. The PBI of the soil at Bookham is 80.This indicates (Fig. 2) that the critical Colwell P soil test value is about 32 mg P/kg soil. We have already seen in Figure 3 that a pasture growth experiment at this site confirms this is correct. Average growing season length is estimated to be 7.5 months (opening rains about last week of April, pasture browning off first week of December). This indicates 17-20 DSE/ha may potentially be carried. The paddocks in the demonstration trial were under 20 ha in size so the upper estimate should apply. Unfertilised pasture at this site (Colwell P about 10 mg P/ha) carries 6 DSE/ha. These data provide upper and lower boundaries for soil fertility and stocking rate management and Figure 5 illustrates how to estimate the stock numbers that may be supported at intermediate levels of soil P fertility. The pasture growth response curve is taken from Figure 3. (In fact, the fertilised paddock in the demonstration trial carried 12-15 wethers/ha in good to average seasons with soil fertility (Colwell P) maintained just below 20 mg P/kg.)

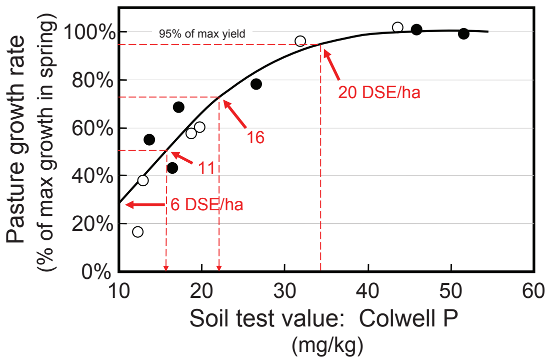


Figure 5: Combining information about the critical soil P level for near maximum pasture growth with potential carrying capacity sets an upper estimate for soil fertility and stocking rate management at about 20 DSE/ha. Knowledge of current soil fertility (10 mg P/kg) and stocking rate (6 DSE/ha) indicates the present position and together these pieces of information enable intermediate stocking rate and soil fertility positions to be estimated by assuming roughly equal increments in pasture yield and stocking rate.

What to do if you do not have access to relevant local fertiliser trial information:

Soil fertility and potential carrying capacity estimates can still be used in much the same way as in Figure 5 when you do not have access to pasture growth response information.

This is done by assuming a linear relationship between the stocking rate that can be sustained at your current soil fertility level and the critical P/potential carrying capacity position that you have predicted from soil PBI and growing season length for your site (e.g. Fig. 6). As pasture response relationships are often curvilinear (e.g. Fig. 5), this will most probably give a conservative estimate of the stock numbers that may be carried at each intermediate soil P fertility level (compare Colwell P levels predicted for each stocking rate from the actual pasture response function (Fig. 5) with those when the relationship between stocking rate and soil fertility is assumed to be linear (Fig. 6)).

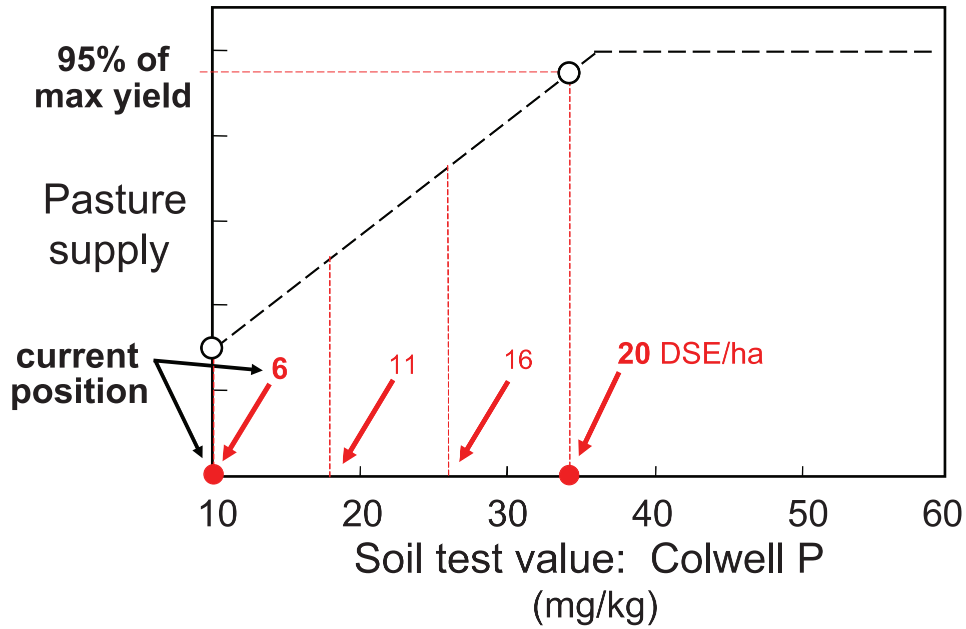


Figure 6: In many cases, the nature of the pasture-soil fertility response function for a site will not be known. However, it is still possible to estimate the critical soil P level and potential carrying capacity for the site. The current soil fertility and stocking rate can also be determined. This allows intermediate stocking rate and soil fertility positions to be estimated. This example assumes a linear increase in stocking rate with increase in soil fertility level.

Further information

How robust are the estimates of carrying capacity of adequately-fertilised pastures?

Estimating the carrying capacity of paddocks is the most difficult and least well-defined step in the process of planning a fertiliser investment. It is very important to understand the reliability and limitations of the estimate you make. Pitching too high will result in overstocked and degraded pastures and excessive supplementary feeding; too low will sacrifice income unnecessarily and may cause you to decide incorrectly against investing in fertiliser.

Some alternative ways to estimate potential carrying capacity:

Estimates based on average length of growing season

The method adopted in this booklet is based on the relationship measured between stocking rates achieved on fertilised pastures and growing season length at a number of locations throughout south-eastern Australia (Saul and Kearney 2002). In that study, variance in growing season length explained about 67% of the variance in the stocking rate. The association between growing season length and stocking rate is high but it should be remembered that about a third of the variance was associated with other undefined factors.The sorts of things that are likely to influence potential carrying capacity for a given length of growing season are pasture species, joining dates and other management actions, prevailing climate, soil type (conditions), etc. Potential carrying capacity estimates based on growing season length should, therefore, be treated as a guideline or starting point to which all other considerations of what constitutes sustainable carrying capacity are also applied.

Estimates based on average annual rainfall

There have been a number of attempts to relate potential stocking rate or pasture growth to either in-season or average annual rainfall. The most well known being that of French (1987) who found a linear relationship between potential stocking rate and annual rainfall (range 350-650 mm/year) for sites in South Australia:

sheep/ha = 1.3*(mm of annual rainfall – 250)/25

It is likely that this relationship holds for the environment in which it was formulated and in similar "Mediterranean" climates (mild wet winters and springs followed by hot, dry summers), but the estimates may not be applicable in other regions. For example, Saul and Kearney (2002) found that annual rainfall explained only about 48% of the variance in stocking rate in their study of sites across south-eastern Australia. Growing season length was thought to be a better predictor of carrying capacity than annual rainfall presumably because factors such as soil water-holding capacity, pasture type, topography and rainfall distribution are accounted for indirectly in the estimate of growing season length.

Local experience

In many districts either departmental or producer-initiated stocking rate trials have been conducted. These can be used to compare or 'ground truth' other estimators. Critical factors to consider are the length of the trial, soil fertility management and the seasonal conditions that applied. For example, a 3-year trial may give misleading information if the seasonal conditions were unusual. Also the enterprise type and the timing of reproduction need to be considered. If the time of lambing is radically different to your operation, this will have an impact on the number of ewes run and allowances for the differences will need to be made.

Paddock records on your own property can also give you a guide. Examine the performance of paddocks that have had a good history of fertiliser use; your records will enable you to compare the stocking rates achieved with potential stocking rate estimations by the other methods. It is not uncommon for the carrying capacity of paddocks to vary by up to 3-fold across a property. The aim is to increase the number of paddocks able to carry higher stock numbers sustainably.

Computer-based simulation models

Computer based models of grazing systems are now being used by a number of advisors to estimate potential stocking rates for districts and production systems. Discussing your plans with an advisor using this technology may also help you test your ideas.

Step 3: Determining the best P-application strategy.

How much P to apply

It is first necessary to decide if the aim is to increase soil P fertility over the coming year(s), or to maintain the current level of fertility by holding the paddock at about the same soil P test value.

To maintain soil P fertility

"Maintenance applications"- Enough P must be applied to cover export of P from the paddock in animal products, accumulation of P in animal camps, losses in runoff or water leaching to depth, and P that accumulates in soil because it has become tightly bound to soil particles, precipitated in sparingly-soluble compounds or bound in organic materials that resist degradation (sometimes referred to as "fixed" P).

Any amount of P loss in runoff or through leaching is of concern because it is environmentally undesirable, but the amounts are usually small enough that they can be ignored for P-fertiliser budgeting purposes. An exception to this can be leaching losses from sandy soils with very low P-sorption capacity.

To raise soil P fertility

"Capital applications"- The amount of P required to raise soil P levels is sometimes referred to as a "capital application." It is necessary to apply the amount of P needed for maintenance plus an extra amount of P to achieve an increase in the soil test value. The amounts of P required are influenced by the Phosphorus Buffering Index value of the soil (Table 1)

For example if the soil has a PBI=80 and the aim is to raise the Colwell soil test level by 2 mg P/kg soil over one year, it would be necessary to apply an extra

2 x 2.7 = 5.4 kg P/ha.

Calculating the amount of P required to maintain soil P fertility

A P-budgeting approach developed first for New Zealand pasture systems (Cornforth and Sinclair 1982) and adapted to Australian pastures (Cayley and Kearney 2000, Cayley and Quigley 2005) may be used. The budget recognises loss of P from the main grazing area of paddocks due to **soil** (P that is fixed, adsorbed, or leached) and **animals** (P transferred to camps and removed in products). Select the soil and animal loss factors appropriate to your paddock(s) from Table 2 and proceed to Table 3 to calculate the estimate of **kg P/DSE** required to maintain your current soil fertility level.

The amount of maintenance P to apply per hectare is calculated as:

kg P/ha = P/DSE x [average annual stocking rate (DSE/ha)]

Table 1. Estimates of the amounts of P/ha that need to be applied in excess of the maintenance P application to raise soil test values by 1 unit (mg P/kg soil) over the coming year. Note the confidence intervals associated with these estimates (derived from Burkitt *et al.* 2001; Burkitt *et al.* 2002).

PBI value of topsoil (0-10 cm depth)	50	100	200	300	400	500	600
Approximate amount of **extra P*** (in kg P/ha) needed to raise an Olsen soil test by about 1 unit (mg P/kg soil). (95% confidence interval)	8.6 (6.8-10.4)	9.0 (7.3-10.7)	9.8 (8.3-11.3)	10.6 (9.2-12.0)	11.5 (10.1-12.9)	12.3 (10.7-13.9)	13.1 (11.3-14.9)
Approximate amount of **extra P*** (in kg P/ha) needed to raise a Colwell soil test by about 1 unit (mg P/kg soil). (95% confidence interval)	2.7 (2.5-2.9)	2.7 (2.5-2.9)	2.9 (2.7-3.0)	3.0 (2.8-3.1)	3.1 (2.9-3.3)	3.2 (3.0-3.4)	3.4 (3.2-3.6)

* P in excess of the amount of "maintenance P" that must also be applied

STEP 3

Table 2: Loss factors for sheep or beef cattle (for calculating maintenance P applications)

(a) Soil loss factors	
Recent alluvial soils, low rainfall loams	low
Podzols, clay-loams (rainfall less than 900 mm), rendzinas	medium
Acid sands, krasnozems and other clays, organic soils	high

(b) Animal loss factors		
Intensive rotational grazing	Flat and rolling country (mostly less than 10°)	Very low
	Easy hills (mostly less than 25°)	low
	Steep hills (one third of paddock >35°)	medium
Set stocked or intermittent grazing	Flat and rolling country	low
	Easy hills	medium
	Steep hills	high

Table 3: Predicted kg P/DSE (*for calculating maintenance P applications*)

Soil Loss factor	Animal Loss factor	Poor pasture *Annual rainfall (mm)*			Improved pasture *(Annual rainfall mm)*		
		400	600	800	400	600	800
low	very low	0.42	0.45	0.48	0.43	0.48	0.53
	low	0.54	0.58	0.62	0.55	0.62	0.68
	medium	0.65	0.70	0.75	0.67	0.75	0.83
	high	0.77	0.83	0.89	0.80	0.89	0.98
medium	very low	0.61	0.65	0.70	0.63	0.70	0.77
	low	0.72	0.78	0.84	0.75	0.83	0.92
	medium	0.84	0.91	0.97	0.87	0.97	1.07
	high	0.96	1.03	1.11	0.99	1.11	1.22
high	very low	0.80	0.86	0.92	0.82	0.92	1.01
	low	0.91	0.98	1.05	0.94	1.05	1.16
	medium	1.01	1.11	1.19	1.06	1.19	1.31
	high	1.15	1.24	1.32	1.18	1.32	1.46

Soil definitions:

Alluvial soils: derived from river activity, usually well drained, more fertile than soils derived *in situ* from underlying rock

Loam: both friable and cohesive; when moist can be rolled into a ball but cannot be rolled out into a ribbon. Sand grains cannot be felt.

Clay loam: like a loam, but can be rolled into a ribbon that soon breaks up. Sand grains cannot be felt.

Clay: tough, plastic soil that can be rolled into a long ribbon when just dry enough not to be sticky.

Podzol: acidic sandy to clay loam topsoil with a change in texture (more clay) down the profile.

Rendzina: black to grey friable clay overlying soft limestone; neutral to alkaline reaction and a uniform profile.

Krasnozem: dark red-brown clay with very friable and stable crumb structure. The subsoil is a red clay, friable and very porous.

Organic soils: reclaimed swamps with mixed inorganic (clay) and organic materials.

Acid sands: sands are not cohesive and are coarse to touch, often high in organic matter with no change in texture to depth.

Definitions and qualifications:

Poor pasture is defined as pasture dominated by weedy species or native grasses as they are expected to have a lower yield and a lower carrying capacity than *improved pasture*.
1.0 DSE is equivalent to a 50 kg wether.

The effectiveness of rainfall will be less in soils with poor water-holding capacity so Cayley and Saul (2001) recommended considering using 100-200 mm rainfall less than average for shallow, sandy, stony, or badly structured soils.

Maintenance P calculation (Tables 2 and 3) is from Cayley and Quigley (2005) Phosphorus for sheep and beef pastures.

Worked example:

Location: Grazing Systems Demonstration Site, "Kia-Ora", Bookham, NSW

Average annual rainfall: 700 mm

Pasture: 40% native perennial grasses, 60% annual grasses & subterranean clover (Hill *et al.* 2004)

Soil: yellow kurosol (Isbell 1996) or yellow podzolic (Stace *et al.* 1968) soil derived from granite

Phosphorus Buffering Index *(PBI) of soil:* 80

Colwell extractable P before fertiliser application: 10 mg P/kg soil (see *Fig. 6*)

Soil fertility management objective: raise Colwell P to ~20 mg P/kg over 5yrs (see *Fig. 6*)

Stocking rate at start: 6 DSE/ha (6 merino wethers/ha)

Stock management objective: lift stock numbers by 1.4 DSE/ha/yr (1.4 wethers/ha/yr) (see *Fig. 6*)

STEP 3

Capital P calculation (using Table 1)

To raise Colwell P by 2 mg P/kg each year, this soil (PBI = 80) will require application of:

2.7 × 2 = 5.4 extra kg P/ha

Maintenance P calculation (using Table 2)

Maintenance P (kg P/ha) = P/DSE × [average annual stocking rate (DSE/ha)]

Pasture type: ***"unimproved"***

Soil loss factor: ***medium***

Animal loss factor: set stocked but small paddock and pasture utilisation, therefore, most like "intensive rotational grazing" with "rolling hill" topography ***= very low to low***

Maintenance P requirement prior to program: 0.675 *to* 0.81 × 6 DSE/ha = 4.1 *to* 4.9 kg P/ha

Maintenance P requirement in year 1: 0.675 *to* 0.81 × 7.4 DSE/ha = 5.0 *to* 6.0 kg P/ha

Maintenance P for year 5 of program: 0.675 *to* 0.81 × 13 DSE/ha = 8.8 *to* 10.5 kg P/ha

Predicted application rates: Application rate = maintenance rate + capital application rate

The calculation of P application rates for this example is shown in Table 4.

For single superphosphate which contains 9% P, the average P-application rate of 12.3-13.7 kg P/ha/year equates to annual applications of 137 to 152 kg superphosphate/ha over the 5 year period.

Table 4: Calculation of the predicted rates of P-fertiliser application to raise Colwell extractable P from 10 to 20 mg P/kg and stocking rate from 6 to 13 DSE/ha over 5 years at Bookham, NSW.

Year	1	2	3	4	5	**Average**
Planned stocking rate (DSE/ha)	7.4	8.8	10.2	11.6	13.0	
Capital P application to raise soil Colwell test level by 2 units per year (kg P/ha)	5.4	5.4	5.4	5.4	5.4	
Maintenance P application rate assuming 1.4 DSE/ha increase each year (kg P/ha)	5.0 - 6.0	5.9 - 7.1	6.9 - 8.3	7.8 - 9.4	8.8 - 10.5	
Predicted P application rate (kg P/ha)	10.4 - 11.4	11.3 - 12.5	12.3 - 13.7	13.2 - 14.8	14.2 - 15.9	**12.3 – 13.7** kg P/ha/year

What actually happened at the site featured in the worked example:

The Bookham site was managed without the benefit of these calculations and a total of 750 kg superphosphate was applied over a 5 year period from 1993 to 1998 as shown in Figure 7. Average application = 150 kg superphosphate/ha/year. We previously calculated (page 12) that somewhere between 137 to 152 kg superphosphate/ha would need to be applied each year for 5 years.

The soil test results were typically "noisy", but regular soil testing revealed that soil fertility was moving in the right direction and in 1998 a decision was made to maintain soil fertility ideally in the range: Colwell P = 20 - 25 mg/kg. This was not quite achieved, but soil fertility was successfully held just below a Colwell of 20 mg P/kg from 1999 to 2002 by applying an average of 86.3 kg superphosphate/ha/year. The estimate for maintenance calculated in the worked example for this site (8.8-10.5 kg P/ha) is a little higher than used in practice and equates to 98-117 kg superphosphate/ha/year.

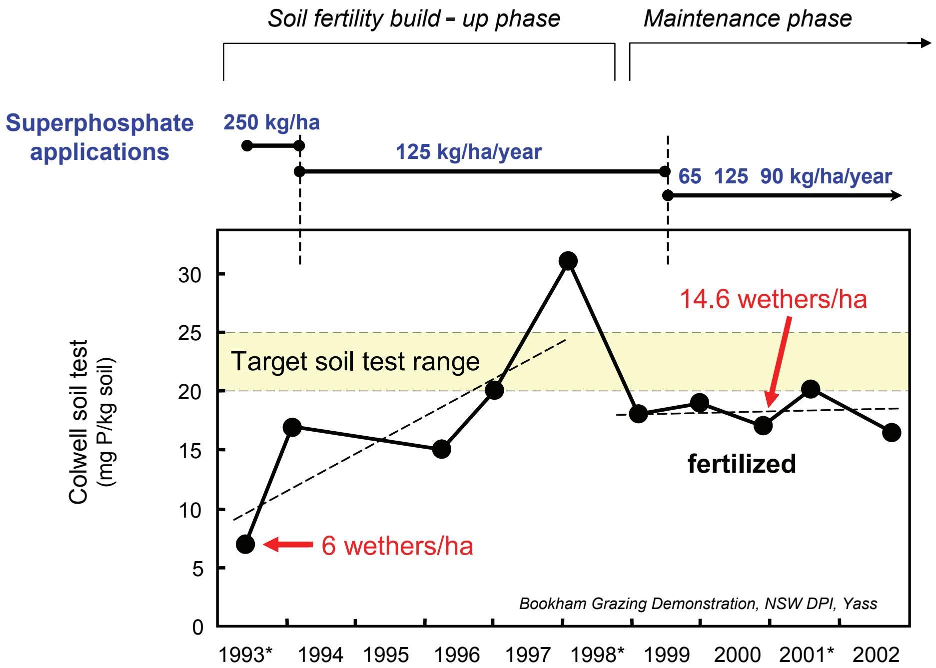


Figure 7: Fertiliser application history and results of annual soil testing in a Grazing Systems Demonstration at "Kia-Ora", Bookham, NSW. * indicates years in which superphosphate with molybdenum was applied.

STEP 3

Further information

The importance of regular (annual) soil testing

There are marked seasonal and annual fluctuations in the extractable-P content of soils which inevitably make soil testing data look "noisy". Within-season changes in the pool of extractable-P occur when fertiliser is applied, when rainfall stimulates mineralisation of organic matter, when drying events cause release of P from soil biomass, and are also a consequence of nutrient 'loss' into sparingly-available P compounds in the soil. Fluctuations between years occur because the amounts of P withdrawn from the pool of extractable-P in the soil vary with the prevailing weather conditions and the amounts of pasture grown and used in each season. Typical seasonal and yearly fluctuations in extractable P are illustrated in Figure 8.

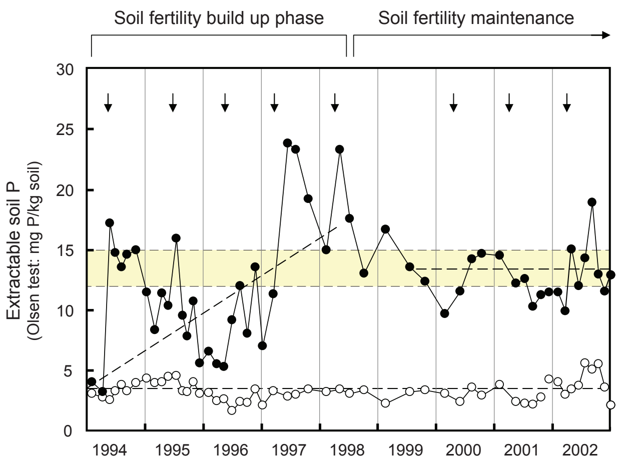


Figure 8: Results of very frequent soil testing in a soil fertility management experiment at Hall, ACT showing the marked seasonal and annual fluctuations in extractable-P that can be expected in a fertilised pasture (closed circles), but also in unfertilised pasture (open circles). Target range for soil fertility management in this experiment was an Olsen test range of 12-15 mg P/kg soil. Arrows indicate timing of fertiliser applications. CSIRO unpublished data.

Because it is not practical on farms to test paddocks more than once every year, it is important to take a few precautions when using soil tests to reduce unnecessary noise in the data and to ensure sensible interpretation of soil test information.

1. Take accurate soil samples
   If the soil is not sampled correctly the subsequent soil test results will be uninterpretable. Better not to have started! (See: How to take soil tests properly)

2. Sample a monitor area at the same time every year
   Sampling the same monitor area or transect and at the same time each year reduces variability due to spatial and seasonal variations in soil fertility.

3. Do not take samples within the first 2 months after fertilising
   Immediately after applying P-fertilisers there is often a useful, but transient spike in the availability of P (see Fig 8). Sampling soil during this spike in availability will give a misleading indication of soil fertility status.

4. Use data from a number of years to reveal the trends in soil fertility
   The most useful soil fertility data is that collected over a number of years because it allows the trends in soil fertility to be seen despite seasonal and annual fluctuations. In Figure 8 (experimental data with a very high frequency soil sampling) and Figure 7 (typical annual farm data), it is the trend lines (see dashed lines) that reveal the direction and rate of change in soil fertility.

   In the absence of a paddock's soil fertility history, decisions must be made using whatever soil test data is available, but over time decisions are made by taking account of the soil fertility trends that have developed.

Calculating and correcting fertiliser rates

Although calculation of the P-inputs required for both soil fertility build-up and maintenance are based on data from field trials, there are a number of reasons why, in the first instance, it is important to regard your calculated fertiliser rates as "ball park" estimates:

i. it is very easy to get animal or soil loss factors slightly wrong when classifying the attributes of a paddock or landscape.

ii. the confidence intervals around some of the estimates of the amounts of P required to lift soil fertility by one Olsen or Colwell unit are reasonably broad (Table 1)

iii. the calculations are for "average" seasons and could be either 'high' or 'low' depending on prevailing seasonal plant growth conditions.

iv. typical seasonal and yearly fluctuations in soil test results can often mean that initial assumptions about soil fertility are also only "ball park" estimates.

For all of these reasons, it is usually best to develop a soil fertility management schedule that will be followed over a number of years and to monitor it with annual soil testing. It is usually best not to react to any one soil test result, but to follow the soil fertility plan and allow soil test data to accumulate so that the trend in the data can be observed. A minimum of three years is often required. Over time, decisions are made by taking account of the soil fertility trends that have developed and sensible adjustments to fertiliser rates can then be made with the objective of also following the new rate until the trend in soil fertility change is understood.

STEP 3

As a guideline for practical soil test interpretation, it is sensible to assume that Colwell test results may be within ±2-3 mg P/kg and Olsen within ±1-1.5 mg P/kg of the true soil fertility level.

For the same reasons, after either estimating the target soil fertility level using an Olsen test or by interpreting the PBI test, a target range should be set (about 5 Colwell units, or 2-3 Olsen units wide) (for examples see Figs 7 & 8).

Droughts

Droughts present the main 'exception-to-the-rule' about not reacting to any one soil test once a soil fertility program is in place. Droughts are rarely predicted and the year's fertiliser application has often been spread by the time a dry season is apparent. In a drought, pasture does not grow to its full potential and dry soil conditions mean that soil chemical reactions are also not likely to proceed at the usual pace.

Under these conditions it is common to see higher than normal subsequent soil test results because plant-available P has been conserved in the dry seasonal conditions (Fig. 9).

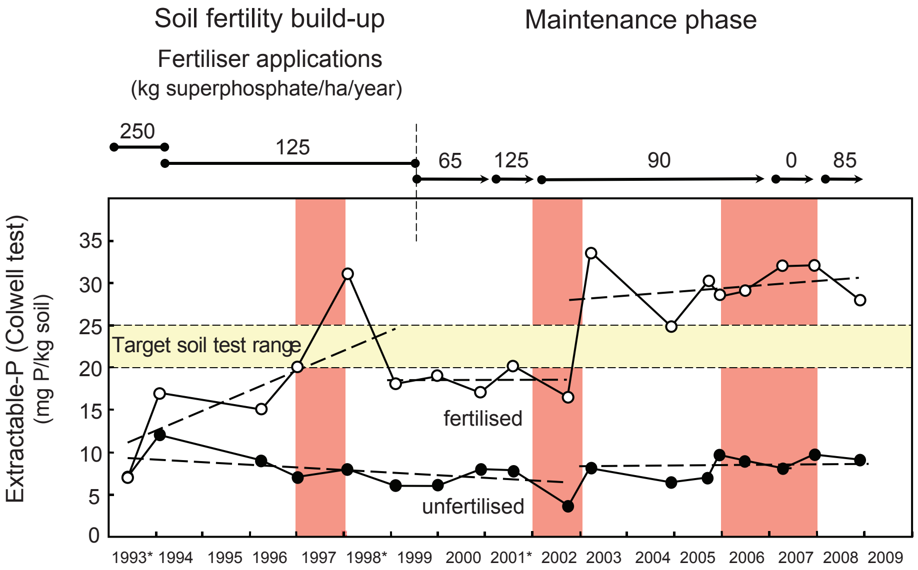


Figure 9: Fertiliser application history and results of annual soil testing in a Grazing Systems Demonstration at Bookham, NSW (e.g. Fig. 7), now extended to show years in which significant spring droughts occurred (pale red shading). Soil test results from an adjacent unfertilised paddock grazed continuously by 6 wethers/ha are also shown.

Elevated soil test numbers after drought are indicative of P conservation and can allow moderation of P-inputs without sacrificing the soil fertility plan and target. This can provide welcome cash-flow relief after a difficult period. After prolonged drought periods, stock numbers may also be well down and a complete revision of the soil fertility plan may be necessary.

When to review soil fertility management plans: about every three years and after droughts.

P Fertiliser Decisions

- If paddocks in their current state are supporting the current stocking rate (i.e. at the target P fertility level for the stock numbers being carried) then maintenance rates of P-fertiliser are required.
- If paddocks are well above their target P level then it is possible:

  a) to apply P-fertiliser at the maintenance rate to hold soil fertility, or

  b) to apply sub-maintenance rates of fertiliser or withhold fertiliser to allow soil fertility to decline to the target level.
- If soil fertility levels of paddocks across a farm are insufficient to support the livestock numbers held or planned, it is necessary to assess which paddocks are at or above their critical P level and hence at maximum production, and which paddocks may be fertilised to raise their productivity and thus support a higher stocking rate. Take account of paddock factors such as soil depth, shelter, pasture species and aspect in deciding which paddocks are selected for increased rates of fertiliser.

Under difficult financial circumstances it may be necessary to further fine tune the use of fertiliser across the farm. Under these circumstances within paddock assessments may allow less productive areas; i.e. westerly aspects, rocky and shallow soil depth areas, to be omitted from any fertiliser applications, hence improving the efficiency of the fertiliser that is to be applied. This action will cause these parts of the paddock to become less productive and so can not be a long term strategy unless the areas are to be withdrawn from the grazing area.

STEP 3

Table 5: Worksheet for planning the P requirements of pasture paddocks

Column 1	2	3	4	5		6	7		8		9	10	
Land management unit	Unit size	PBI	Optimum soil fertility target ~~Olsen test~~ Colwell test	Potential carrying capacity at optimum soil fertility		Current soil fertility test or estimate from trend ~~Olsen test~~ Colwell test	Estimated current carrying capacity given present soil fertility level.		Current livestock		Current stocking rate	Stocking rate planned for next year	Action
	ha		mg P/kg soil	DSE/ha	DSE/unit	mg P/kg soil	DSE/ha	DSE/unit	numbers /unit	DSE/unit	DSE/ha	DSE/ha	
Bookham grazing demonstration site	10	80	30-35[a]	20[b]	200	27[c]	17[d]	170	148 wethers	148	14.8	14.8	Apply maintenance P, or less to allow soil P to decline to target for current DSE/ha (i.e. Colwell P = 20-25 mg/kg
Totals for property													

[a] Use Figures 1 or 2

[b] Use Figure 4 or determine by local experience or other means

[c] In this example 2008 data (Fig. 9) is assumed to be current soil fertility

[d] Determined from Figure 6 and assumed to be a moderately conservative estimate

Five Easy Steps Work Sheet

This worksheet is intended to help you fill in Table 5 when assessing the fertiliser requirements of your paddocks. It directs you to the key sections of the Five Easy Steps technical booklet (left hand column) or the computer tool that accompanies it (right hand column) depending on whether you wish to follow a paper-based procedure, or to also use the computer tool. The Five Easy Steps booklet provides other important background material and examples of what has occurred at long term monitoring sites. Reading the whole booklet will give you a full understanding of the issues involved and the monitoring needed to review your decisions.

The key tasks for assessing the P-requirements of paddocks are as follows. Choose the method that is appropriate to you:

<table>
<tr><th>Paper-based method</th><th>Computer tool method</th></tr>
<tr><td colspan="2">1. Write the names and area of the land management units (LMU) of your farm in columns 1 and 2 of Table 5 (Worksheet for planning the P-requirements of pasture paddocks). A version of this Table suitable for photocopying can be found in Appendix 3 of the technical booklet.</td></tr>
<tr><td colspan="2">2. Using your soil test reports write the PBI (Phosphorous Buffering Index) of your LMU in column 3.</td></tr>
<tr><td>3. Calculate your optimum target P level.

Use Figure 1 (Olsen) or Figure 2 (Colwell), page 4 and your PBI to work out the target P level for near maximum pasture growth in each LMU. Write this in column 4. For practical management it is sensible to use this value to set a target soil test range (see: "Calculating and correcting fertiliser rates", page 14).</td><td>Calculate your optimum target P level.

At STEP 1 in the computer tool, select either an Olsen or Colwell soil test type, enter your current soil P test result and the PBI for your LMU. Also write the current soil P level for your LMU in column 6. Use a recent soil test to do this or, better still, estimate the value from a trend line developed using several years of testing (e.g. see Figures 7 & 8, pages13 and 14).

The target P level for near maximum pasture growth is displayed at the base of the page. Write this in column 4. For practical management it is sensible to use this value to set a target soil test range (see: "Calculating and correcting fertiliser rates", page 14).</td></tr>
<tr><td>4. Calculate your potential carrying capacity.

How many months of pasture growth do you get on average: _________. This could vary between your LMU's: e.g. hill country might be 6 weeks shorter than for valleys.

Use the number above and Figure 4, page 7 to calculate your potential carrying capacity. Think about whether you consider this predicted value is appropriate for your LMU. Write an appropriate carrying capacity value in column 5.

Multiply your LMU area by the DSE/ha figure in column 5 to give a DSE figure per LMU.</td><td>Calculate your potential carrying capacity.

At STEP 2 in the computer tool, enter the number of months of pasture growth that you get on average. This could vary between your LMU's: e.g. the pasture growth period for hill country might be 6 weeks shorter than for valleys. A predicted potential carrying capacity range is displayed in the cells outlined in green.

You are now required to specify the potential carrying capacity that you consider is appropriate for your LMU. This will be used for further calculations in the computer tool. Also write this number in column 5 of the planning worksheet.

Multiply your LMU area by the DSE/ha figure in column 5 to give a DSE figure per LMU.</td></tr>
</table>

5. Write in **column 6** the current soil P levels for your LMU. Use a recent (e.g. last year's) soil test to do this or, better still, estimate the value from a trend line developed using several years of testing (e.g. see Figures 7 & 8, pages 13 and 14).	N/A
6. Estimate the carrying capacity that is supported by your present soil fertility level and enter this value in **column 7**. To do this use the graph paper provided (Appendix 3) to first develop a graph relating soil P fertility and livestock carrying capacity for your LMU. (Use Figures 5 and 6, pages 7 and 8 of the booklet as a guide). On the graph, mark the maximum point for the LMU using the target P for near maximum pasture growth (**column 4**) and potential carrying capacity (**column 5**). Mark a minimum position from your knowledge of the P level of this country when unfertilised or at very low soil P fertility and the number of stock that it was able to carry (in DSE/ha) when at that soil fertility level. You may also wish to use other information. If you already know the sustainable carrying capacity of the LMU at its present level of soil fertility (**column 7**) use it and the current soil fertility level (**column 6**) to mark your present position. Over time you may be able mark several positions (carrying capacity vs soil fertility) on this graph. Draw a trend line through the points. If you do not already know the sustainable carrying capacity of the LMU at its present level of soil fertility, you may now estimate it from the graph and enter it in **column 7**. If you are planning to change the soil fertility level of this LMU, you can use the graph and your projected soil test value to estimate the carrying capacity of the LMU at the new level of soil fertility.	Estimate the carrying capacity that is supported by your present soil fertility level and enter this value in **column 7**. To do this you need to develop a graph relating soil P fertility and livestock carrying capacity at STEP 2. In the computer tool, you will have already specified the high soil fertility and carrying capacity end of the graph. You now need to specify the low soil fertility end of the graph and have two options for data entry. • If you know the P level of the LMU when unfertilised or at a low level of soil fertility and the corresponding number of stock that it was able to carry sustainably (in DSE/ha), enter these values. • If you know the carrying capacity of the LMU at its present level of soil fertility enter this value in DSE/ha. You need only specify one set of these values, but it is preferable to specify both. The computer tool will draw the graph preferentially using the lower soil fertility value unless you choose not to specify it. Figures 5 and 6 (pages 7 and 8 of the booklet) provide further information about the way you are being guided to develop the relationship between soil P fertility and the carrying capacity of your LMU. If you are planning to change the soil P fertility level of this LMU, the graph you have developed will be used by the computer tool to estimate the carrying capacity of the LMU at the new level of soil fertility. Alternatively, if you are targeting a particular level of soil P fertility, the graph will be used to estimate the livestock carrying capacity at that level of soil fertility.
7. Calculate your current stocking rate for the LMU in DSE/ha. This is recorded in **column 9**. If you do not know your DSE figure, record the number of animals in different classes in **column 8** and use the DSE table in Appendix 1 to work out your current stocking rate in DSE/ha for **column 9**.	Calculate your current stocking rate for the LMU in DSE/ha. This is recorded in **column 9**. If you do not know your DSE figure, record the number of animals in different classes in **column 8** and use the DSE table in Appendix 1 to work out your current stocking rate in DSE/ha for **column 9**. At STEP 2 in the computer tool, it is also necessary to specify your current stocking rate. This value is used as the starting point for the fertiliser plan.

<table>
<tr><td colspan="2">8. Are you planning to change your stocking rate/ha next year - either up or down? Write your planned number in column 10.</td></tr>
<tr><td colspan="2">9. Compare column 7 and column 10
If column 10 is greater than column 7 – this indicates your planned stocking rate is greater than your capacity to grow pasture.
Action: Using your carrying capacity vs soil P fertility graph as a guide, increase the soil P level to a level that can sustain the number of stock you anticipate carrying or reduce stock numbers. Reducing stock numbers could be done by moving stock to other LMU.
If column 10 is less than column 7 – this indicates you are running less stock than your estimated potential.
Action: Allow the soil P level to drop to a level that is appropriate for the stocking rate or increase stock number by buying or moving stock from other LMU.</td></tr>
<tr><td>10. Calculate your fertiliser rates.
Read the sections on pages 10, 11 and 12 of the booklet to understand how to use the fertiliser calculation tables. Based on the results from point 9 your possible actions are:
a. Maintain soil P level
Use Tables 2 and Table 3 (page 11) to estimate the amount of P to apply per DSE:
Record your answer ___________ kg P/DSE
Then multiply your kg P/DSE number by the stocking rate (column 10) to get the rate the rate of P that needs to be applied:
___________ kg P/ha
b. Increase soil P level
Use Table 1 (page 10). To estimate the extra P that needs to be applied in addition to the maintenance P rate to lift the soil P level.
Record your answer ___________ kg P/ha
You will then need to add points a and b to get the total amount of P to apply:
___________ kg P/ha
c. Allow soil P level to drop
This could be done by using no fertiliser for the coming year(s), or
by using a rate which is below the maintenance amount that was calculated in point b (using Tables 2 and 3).</td>
<td>Calculate your fertiliser rates.
Based on the results from point 9 your possible actions are to maintain the soil P level, increase soil P or allow the soil P level to drop.
Fertiliser rates are calculated at STEP 3 in the computer tool but the calculations also depend on key data having been entered previously into STEPS 1 & 2 as described above.
The tool will calculate the maintenance P and extra P for increase required for the fertiliser management plan that has been specified. It will also suggest an average amount of total P that may be applied during the period of increasing or decreasing soil P fertility that is planned. The maintenance rate of P application that applies to the final stocking rate should be applied thereafter.
You are required to enter the P concentration of the fertiliser that you will use and the tool will use this number to calculate the rate at which the fertiliser should be applied.
Note: Although the computer tool can indicate likely fertiliser rates for situations in which soil fertility is allowed to decline, it was not designed intentionally for this sort of application.</td></tr>
</table>

<table>
<tr><td>The worked example on page 12 of the booklet may help you work through these calculations.
To convert kg P/ha to kg/ha of fertiliser product, divide your figures in point 10 by the P concentration in your fertiliser product:
e.g. if my result at point 10 is 9 kg P/ha.
and
Product A has 8.8% of soluble P, so 9/ 0.088 = 102 kg /ha of product A
or
Product B has 1% of soluble P, so 9/0.01 = 900 kg/ha of product B</td><td></td></tr>
<tr><td colspan="2">11. Use the Cash Flow Budgeting Tool to examine the financial impacts of your decision (see STEP 4 of the computer tool).
The inputs required are described on page 24 of the booklet. Because fertiliser planning is a strategic (medium term) exercise, the cash flow budget extends beyond just next year's plans and requires you to think about where your business is headed. You may need to revisit the potential carrying capacity estimates for each LMU and to think about the timeframes over which you would like to implement your business plans. The cash flow tool will help you to estimate the likely profitability and business risk that is associated with your use of P-fertiliser.
The importance of the livestock gross margin that you will use is illustrated in Figure 12 on page 26. It is critical that you use relevant gross margins for your business. These results could cause a modification to your plans. In some cases the results might indicate that major changes to the grazing enterprises are required. These types of changes are outside the scope of this booklet and may require you to seek advice from appropriate professionals.
NOTE: the cash flow tool is not designed to handle situations in which stocking rates are reduced. This may be necessary if you are reducing soil P fertility. Reducing stock numbers releases capital and a different sort of financial analysis is needed. A 'partial budget tool for use when decreasing livestock carrying capacity' is provided separately and may be useful in this situation.</td></tr>
</table>

Step 4: Budgeting to check you will make money from your investment.

When soil test information indicates that you will be able to increase pasture production by applying P-fertiliser, it does not automatically follow that you will generate a profit. The extra pasture grown must be converted into a product that can be sold profitably and budgeting allows you to look at the potential return on your proposed investment in fertiliser. A cash flow budget can be used to show the year by year consequences of a fertiliser investment plan.

Cash flow budgeting for fertiliser applications expected to increase carrying capacity

Use the Cash Flow Budgeting Tool provided on the accompanying CD to examine the likely income and potential returns on investment when applying fertiliser to increase carrying capacity. A guide to the inputs required for the Cash Flow Tool is shown in Table 7.

A simple example of a cash flow analysis is also shown in Table 6. This example shows how the net cash results, annual differences in cash flow and the cumulative cash flow differences are calculated

Cash flow budgeting

Table 6 is a summary of a cash flow assessment of a plan to apply fertiliser to a native grass and subterranean clover-based pasture grazed by Merino wethers (some background details for the scenario are described in the 'worked example' [page 12] and the guide to the budgeting tool, [Table 7]). The pasture was already being fertilised to maintain the Colwell P level of the soil at about 17 mg P/kg with a carrying capacity of 10 DSE/ha. The cash flow budget was developed to test the idea that it would be worthwhile to increase soil P-fertility to 21 mg P/kg so that 13 DSE/ha may be carried.

In this example (Table 6), the annual net cash flow is initially negative due to outlays on both fertiliser and livestock. The cumulative cash flow position (which includes interest paid on debt) shows the time it takes to break even. Thereafter, the return on investment in this example is very favourable.

In fact, the first year(s) of many fertiliser plans initially results in cash deficits and unsatisfactory returns on extra livestock capital. This will be particularly evident when fertilising unfertilised paddocks and when fertiliser prices are high (e.g. Figs 10-12). However, the financial performance of the livestock enterprise will improve over time as carrying capacity is increased. Consequently, it is important to assess both the magnitude of the financial gains and how long it may take to return to positive cash flows.

Table 6: Summary of a cash flow assessment of applying fertiliser generated using the cash flow budgeting tool. The objective is to increase soil P-fertility over 2 years from 17 to 21 mg P/kg (Colwell test) and carrying capacity from 10 to 13 DSE/ha for a Merino wether enterprise grazing native grass and subterranean clover-based pasture at Bookham, NSW (for further details see the 'worked example', page 12 and the guide to the budgeting tool, Table 7). An average livestock gross margin ($22/DSE) is assumed. The maintenance fertiliser rate for the base position (10 DSE/ha) is 105 kg superphosphate/ha. The fertiliser is to be spread at 185 kg/ha to achieve the planned increase in soil fertility. From year 3, the enterprise will move to a new soil fertility maintenance phase with fertiliser inputs at 135 kg/ha.

Base Position (DSE/ha)	10					
(a) Livestock gross margin ($/ha)	220					
(b) Average cost of spreading fertiliser to maintain base position ($/ha)	48					
(c) Net cash result ($/ha) ***(=a-b)***	172					
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6+**
Projected Position (DSE/ha)	11.5	13.0	13.0	13.0	13.0	13.0
(d) Livestock gross margin ($/ha)	253	286	286	286	286	286
(e) Cost of spreading P-fertiliser ($/ha) (@ $400/tonne; spreading@ $5.70/ha)	80	80	60	60	60	60
(f) Cost of extra livestock (@ $40/DSE)	60	60	0	0	0	0
(g) Projected net cash result ($/ha) ***(=d-e-f)***	113	146	226	226	226	226
(h) Annual difference in cash flow due to fertiliser use ($/ha) ***(=g-c)***	-59	-26	54	54	54	54
(i) Cumulative cash flow difference including interest (@8%) on debt ($/ha)	-61	-91	-36	22	81	139+
(j) Internal rate of return (after 5 years)					49%	

STEP 4

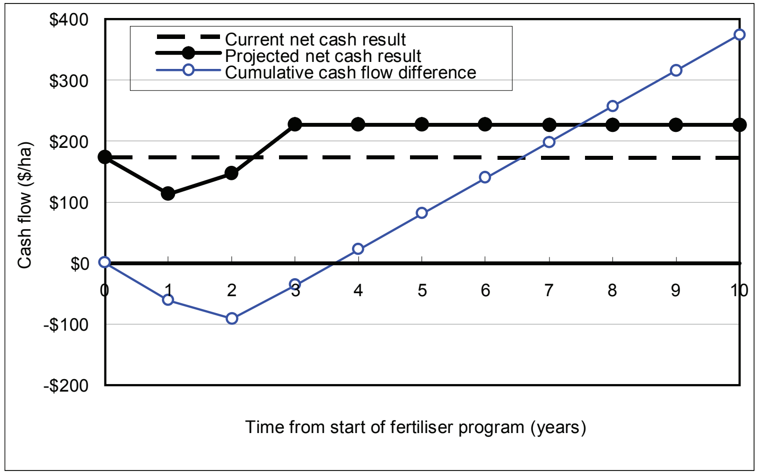
Table 7: Guide to the Cash Flow Budget Tool for fertiliser applications expected to increase livestock carrying capacity

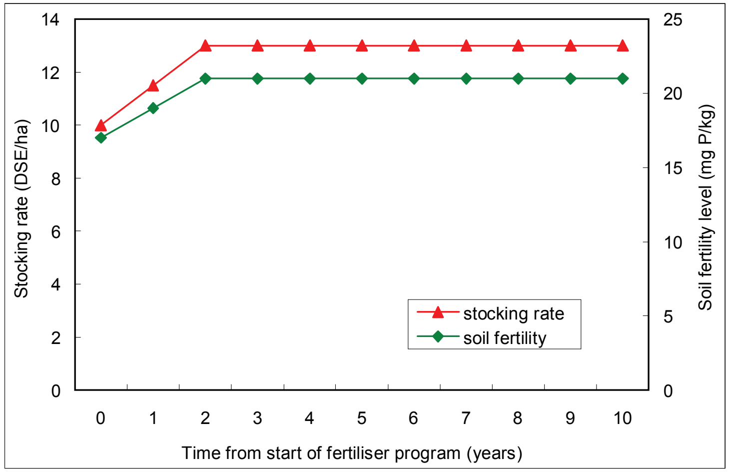
	Data entry (white cells)	Enter your values below	Results from your work on previous tabs
Step 1	Current soil Colwell P test (mg P/kg)	17	17
	Critical soil test level for near maximum pasture growth (mg P/kg)		32
Step 2	Stocking rate - current (DSE/ha)	10.0	10.0
	Potential carrying capacity with near optimal soil fertility (DSE/ha)		20.0
	Preferred target for soil P management (mg P/kg)	21	21
	Stocking rate - at preferred target for soil fertility management (DSE/ha)	13.0	13.0
Step 3	Timeframe - to achieve new soil fertility & stocking rate targets (years)	2	2
	Stocking rate - yearly increase (DSE/ha)	1.5	1.5
	Planned increase in soil P test (mg P/kg per year)	2.0	2.0
	Fertiliser rate needed to increase soil P at required rate (kg/ha/yr)	185	187
	Maintenance fertiliser rate at target carrying capacity (kg/ha/yr)	135	136
Step 4	Current fertiliser rate (kg fertiliser/ha)	105	
	Gross margin - current ($/DSE)	$22.00	
	Gross margin - projected ($/DSE)	$22.00	
	Capital cost of extra livestock ($/DSE)	$40.00	
	Fertiliser cost ($/tonne)	$400.00	
	Fertiliser spreading cost ($/ha)	$5.70	
	Interest on debt ($)	8.00%	
	Area of pasture (ha)	100	

Enter appropriate values into the white cells of the left column. The values arising from your responses on the previous tabs are shown in the coloured cells to the right.

Scroll down this page if you wish to see a complete 10-year cash flow budget spreadsheet for the current set of values.

You will probably want to try entering a range of different values to see how variations in fertiliser price, livestock cost and gross margins might affect the profitability of your enterprise. However, you need to remember that some of these values are **not independent** of one another. For example, changing the timeframe for achieving your fertility target will require altering the P application rate needed to attain that target. You will need to return to earlier Steps and revise your calculations there to help ensure your entries are realistic and consistent.





Internal rate of return: After 5 yrs: 49%
After 10 yrs: 48%

Year	0	1	2	3	4	5	6	7	8	9	10
Cash flow budget (current fertiliser regime)											
Stocking rate (DSE/ha)	10	10	10	10	10	10	10	10	10	10	10
Fertiliser rate (kg/ha)	105	105	105	105	105	105	105	105	105	105	105
Livestock gross margin income ($/specified area)	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22000
Fertiliser cost ($/specified area)	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4200
Fertiliser spreading cost ($/specified area)	570	570	570	570	570	570	570	570	570	570	570
Net cash result (current fertiliser regime) ($/specified area)*	**17,230**	**17,230**	**17,230**	**17,230**	**17,230**	**17,230**	**17,230**	**17,230**	**17,230**	**17,230**	**17230**
Net cash result (current fertiliser regime) ($/ha)	$172.30	$172.30	$172.30	$172.30	$172.30	$172.30	$172.30	$172.30	$172.30	$172.30	$172.30
Projected fertiliser option											
Stocking rate (DSE/ha)	10.0	11.5	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Fertiliser rate (kg/ha)	105	185	185	135	135	135	135	135	135	135	135.0
Expected soil P fertility level (mg P/kg soil)	17.0	19.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
Gross margin per head ($/DSE)	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00
Livestock gross margin income ($/specified area)	22,000	25,300	28,600	28,600	28,600	28,600	28,600	28,600	28,600	28,600	28600
Fertiliser cost ($/specified area)	4,200	7,400	7,400	5,400	5,400	5,400	5,400	5,400	5,400	5,400	5400
Fertiliser spreading cost ($/specified area)	570	570	570	570	570	570	570	570	570	570	570
Livestock purchase cost ($/specified area)		6,000	6,000	0	0	0	0	0	0	0	0
Net cash result (projected) ($/specified area)*	**17,230**	**11,330**	**14,630**	**22,630**	**22,630**	**22,630**	**22,630**	**22,630**	**22,630**	**22,630**	**22,630**
Net cash result (projected) ($/ha)	$172.30	$113.30	$146.30	$226.30	$226.30	$226.30	$226.30	$226.30	$226.30	$226.30	$226.30
Annual difference in cash flow due to fertiliser use ($/ha)	0	-5,900	-2,600	5,400	5,400	5,400	5,400	5,400	5,400	5,400	5,400
Cumulative cash flow position ($/specified area)		-5,900	-8,500	-3,100	2,300	7,700	13,100	18,500	23,900	29,300	34,700
Interest on cumulative cash flow ($/specified area)		-236	-595	-512	-73	394	864	1,333	1,803	2,272	2,742
Cumulative cash flow difference with interest ($/specified area)		**-6,136**	**-9,095**	**-3,612**	**2,227**	**8,094**	**13,964**	**19,833**	**25,703**	**31,572**	**37,442**
Cumulative cash flow differrence with interest ($/ha)	0	-$61.36	-$90.95	-$36.12	$22.27	$80.94	$139.64	$198.33	$257.03	$315.72	$374.42
Additional livestock capital ($/ha)		6,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000
Internal rate of return						49%					48%

*The net cash result in the case of the current program is the livestock gross margin income from the area less the fertiliser cost including spreading.
For the projected situation where stocking rate increases over time, the net cash result also includes the cost of livestock purchase.

STEP 4

Guide to the cash flow budget tool: explanation of inputs and outputs

Inputs

Stocking rates and carrying capacity: measured as dry sheep equivalents (DSE/ha). See Appendix 1. Carrying capacity at target soil fertility and yearly increase in carrying capacity are determined from the relationship between carrying capacity and soil fertility level which is developed as described in Steps 1 and 2 of this booklet.

Gross margins per DSE: are required for the current situation and for the situation after fertiliser and stocking rate adjustments have been made. These gross margins reflect production per head and are converted to per ha using the carrying capacity numbers. If carrying capacity is changing in line with change in pasture production (i.e. pasture utilisation is remaining about the same), differences in gross margin per head will be small (typical range: +$1 to -$2), most often a small decline in gross margin per DSE might be expected. The link http://www.dpi.nsw.gov.au/agriculture/farm-business/budgets/livestock gives a comprehensive outline of generic gross margins for various livestock enterprises. However, you are encouraged to complete your own gross margin estimate for greater accuracy. A gross margin template is provided (Appendix 2 and on the CD) to help you calculate the gross margin that applies to your operation.

Livestock costs: the capital cost of extra livestock required to convert the extra pasture into a saleable product can be greater than the fertiliser bill. The figure required is in $/DSE: e.g. merino ewe @$60/head equals $40/DSE when the DSE rating of a ewe is 1.5.

Fertiliser cost, application rates and spreading cost: the cost of fertiliser is not included in the gross margin per DSE because fertiliser cost is accounted for in these items. The current fertiliser rate is that used to maintain the current stocking rate and soil P fertility level. It can be determined from current practice and should be roughly consistent with the maintenance P-fertiliser application rate calculated from the current stocking rate using Tables 2 & 3. If these estimates are not roughly consistent think through the reasons why this may be the case. Difference may occur because your calculation of maintenance P is not appropriate for your situation and site or because actual rates of usage have been influenced by seasonal considerations, stocking rates etc.

Soil P test levels: are specified as mg P/kg soil and may be values derived from either Colwell or Olsen extractable P tests provided that the test method used is consistent with that used to specify the relationships between carrying capacity and soil P fertility, and fertiliser application rate and soil P fertility (Table 1). The planned annual increase in soil P fertility must be consistent with the rate of P-fertiliser application that is specified This is determined using Tables 1-3 as outlined in Step 3 of this booklet.

Interest on debt: this interest rate is used to calculate the cumulative cash flow position.

Area of pasture: the area to be fertilised.

Outputs

The tool is designed to assess applications of fertiliser intended to maintain or increase soil fertility and cannot handle situations in which soil fertility is allowed to decline. All outputs are determined automatically from the input information. Key outputs are graphed. The graphs of stocking rate and soil fertility level are used to check the expected production outcomes intended in the fertiliser investment plan.

Potential profitability: can be determined from the "projected net cash result".

Time for the investment plan to break even: can be determined from the "cumulative cash flow difference" which includes interest paid on debt. It is the time it takes for the cummulative cash flow difference to equal $0.

Internal rate of return: is calculated after 5 years and again after 10 years. The internal rate of return is the compound interest that could be charged on a project so that it breaks even at the end of the development period. If for example there is a 25% internal rate of return showing in year 5, it would mean that if you had to borrow for all of the development at 25% interest you would be just able to pay back the financier at the end of year 5 after you sold the additional stock that you had bought. Because you can currently borrow for much less than 25% it would indicate that the project was quite attractive. There are often many development opportunities on a property but as a guide in a low interest rate environment with a good outlook for the meat or wool product you are producing, you may consider that an internal rate of return of 12% may be sufficient to cover the risk. As the risk of the project increases because of factors such as climate variability, uncertainty of fertilizer prices or product prices, etc. you may require a higher return to justify the investment. Generally returns over 15-18% would be considered attractive. Remember in the financing, the loan principal also needs to be paid back as well as the interest and this requires a return significantly higher than the current interest rate in order to be able to meet the commitments.

Further information

How do investment plans and input costs influence return from a fertiliser investment?

The following examples show data generated using the Cash Flow Tool and illustrate some of the relationships between the key factors that affect the financial outcomes of a fertiliser investment.

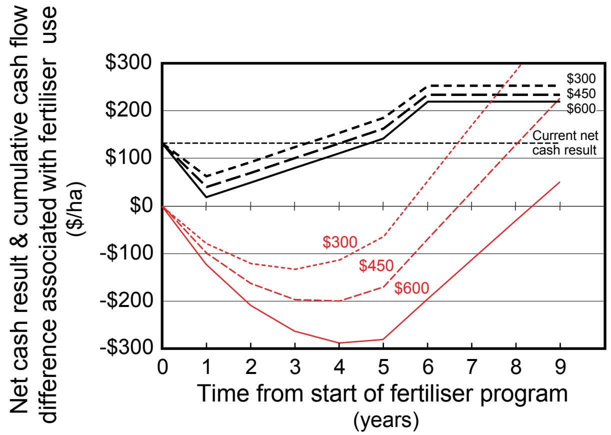
The analyses are based on the "worked example" shown earlier: a Merino wether enterprise at Bookham, NSW (page 12). The assumptions used in these examples, unless otherwise specified, are: P-fertiliser price = $400/tonne and spreading cost = $5.70/ha, the paddock is initially running 6 DSE/ha and has not been fertilised for many years, the P-fertiliser rate needed to raise Colwell soil test value by 2 mg P/kg soil and stocking rate by 1.4 DSE each year until targets are achieved = 145 kg fertiliser/ha, capital cost of livestock = $40/DSE. Three livestock gross margins were used, $17, $22 or $27 per DSE. This covered the range of gross margins seen typically in livestock enterprises in early 2009. Changing these assumptions will change the numbers, but not the trends.

Fertiliser price

Increases in fertiliser cost reduce profitability as shown in Figure 10. The cost of lifting soil fertility for a pasture that has not been fertilised is shown. Because the pasture was not being fertilised, the livestock enterprise has been slowly exploiting soil P reserves. The fertiliser plan to lift stocking rate and improve income per hectare must now cover both maintenance and capital fertiliser applications.

Higher fertiliser prices mean less profitability (see: net cash results [black lines]) and longer pay back periods (cumulative cash flow differences [red lines]). This can reduce the attractiveness of an investment substantially. At a fertiliser price of $600/tonne, it is expected to take between 8 and 9 years to break even compared with between 5 and 6 years when fertiliser price is $300/ tonne.

Figure 10: Impact of fertiliser prices ranging between $300/tonne and $600/tonne on additional profit per hectare (net cash results; black lines) and pay back periods (cumulative net cash differences which include interest on debt; red lines) for a Merino wether enterprise grazing previously unfertilised pasture at Bookham, NSW (for further details see the 'worked example', page 12).



REMEMBER: Fertiliser price is set by world markets and cannot be controlled on farm. If things are not looking rosy and you don't want to lie down and be run over by world prices take control of the things you can influence: (i) Fertiliser cost can be minimised by ensuring soil fertility management is on target for your soil and stock numbers. (ii) Focus on other variables that you can control directly (e.g. your livestock gross margin or stocking rate), and which also strongly influence the profitability of fertiliser decisions.

STEP 4

Capital cost of livestock

Cash flows are initially negative because of the investment that must be made in both fertiliser and livestock capital. Although it is commonly overlooked, the capital cost of livestock in a fertiliser investment is usually large (in the example shown here for theoretical sheep and beef enterprises [Fig. 11], it roughly equals, or exceeds the cost of the fertiliser). High livestock capital costs deepen the cash deficit experienced in the early years of the investment and lengthen the pay back period. Term loans could be used to finance the stock. This would reduce the peak debt, but would not change the break even time, and would decrease the profits until the loan was paid off. While cattle might have a higher capital cost, labour per DSE is lower so if the enterprise is run efficiently the reduced labour cost can offset the higher capital costs.

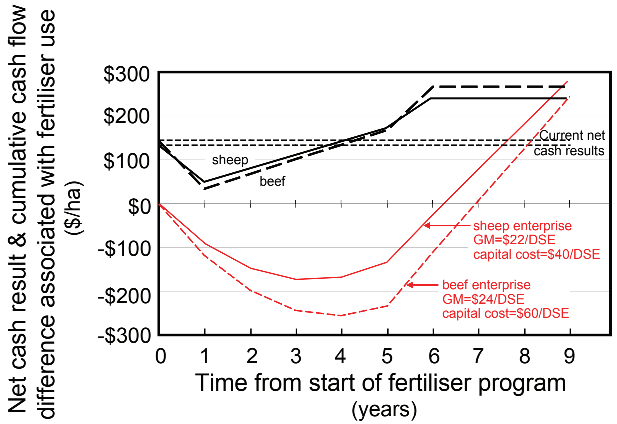


Figure 11. Comparison of the impact of livestock capital costs on the additional profit per hectare (net cash results; black lines), cash deficits and pay back periods (cumulative net cash differences which include interest on debt; red lines) for alternative livestock enterprises grazing previously unfertilised pasture at Bookham, NSW (for further details see the 'worked example', page 12). Fertiliser cost is $400/tonne.

Remember: the only way to pay for any pasture improvement is to increase the animal production from the area you have improved. This usually means that stocking rates have to be increased to improve the per hectare production. Part of pasture improvement is planning to increase the numbers of stock carried and you must ensure you have access to capital to pay for both the pasture improvement and the extra livestock necessary. Even if you plan to retain some of your own stock for this purpose, this is a loss of cash flow, because without the pasture improvement these stock would have been sold and would have created a cash flow. If access to capital is limited, it would be better to develop a smaller area ensuring there is still sufficient capital remaining to fully stock the improved area.

Gross margin per DSE

Roughly equivalent farms within districts often achieve substantially different gross margins per DSE. The major factor in these differences is the choice of livestock genotype and productivity. For example, the difference between the top 10% and bottom 10% of high accuracy teams from the Australia-wide Merino bloodline comparison (Atkins et al. 2007) was 19% or $6.34/dse. The range across the industry is greater than this because only major bloodlines are evaluated within the trials.

Figure 12 demonstrates the substantial impact that differences in gross margins/DSE have on the net cash result from a fertilizer investment

Profitability is higher and pay back periods are shorter for enterprises that run productive livestock. Enterprises that achieve high gross margins per DSE have a much greater chance of affording fertiliser that can lift overall profitability.

STEP 4

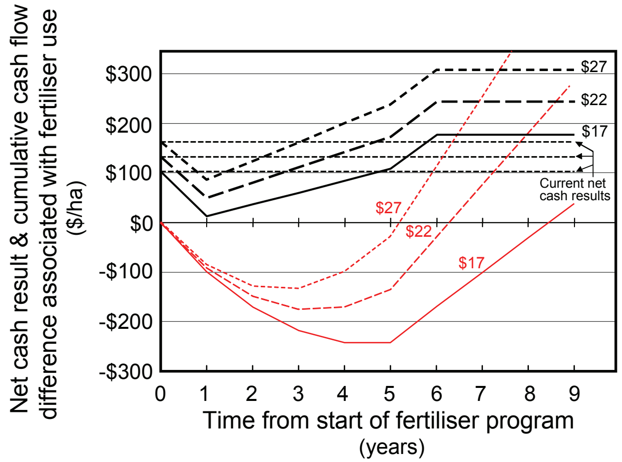


Figure 12: Impact of livestock gross margin on profitability (net cash results; black lines) and pay back periods (cumulative cash flow differences; red lines) may be expected by enterprises that achieve different gross margins/DSE. The example is the same as shown in Figure 10 and a fertiliser price of $400/tonne is assumed (for further details see the 'worked example', page 12).

Stocking rate

Your ability to increase carrying capacity will be limited by your soil type, pasture species, climate, *and your attitude*. Overly conservative stocking of pasture will reduce potential income from a fertiliser investment. However, it is important to ensure that stock numbers are increased in line with improving pasture availability and to do this without exceeding sustainable pasture utilisation boundaries.

Because stocking rate influences the net cash result profoundly, it is always valuable to question whether it is possible to lift stocking rate faster than "predicted" in any fertiliser investment plan. It should be remembered that although stocking rate calculations are based on the best current information, they are only estimates, assume average seasonal conditions and may have reasonably large confidence intervals. Anything outside of these assumptions may potentially be turned to financial advantage. For example, compare the positive cash flow consequences of adopting a slightly accelerated stocking policy so that the target stock numbers are achieved in 4 or 4.5 years (i.e. 2.0 or 1.7 DSE/ha/year increases, respectively) as opposed to 5 years (1.4 DSE/ha/year increase (Fig. 13) in the fertiliser investment plan that builds soil fertility and carrying capacity for a Merino wether enterprise at Bookham.

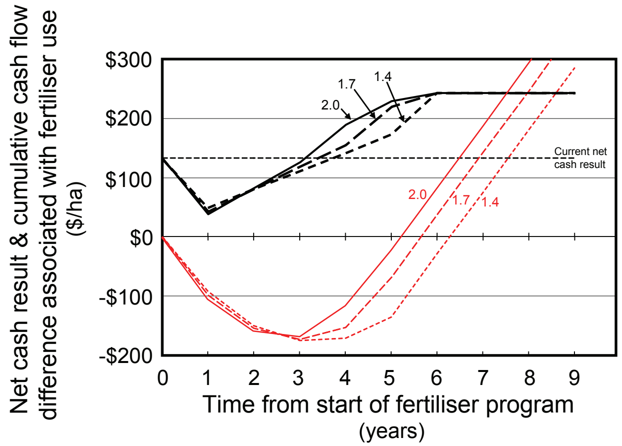


Figure 13. Potential impact of using an accelerated stocking policy as part of a fertiliser investment plan on the additional profit per hectare (net cash results; black lines) and pay back periods (cumulative net cash differences which include interest on debt; red lines) for a Merino wether enterprise grazing previously unfertilised pasture at Bookham, NSW (for further details see the 'worked example', page 12). Livestock gross margin is assumed to be $22/DSE and fertiliser cost is $400/tonne.

Caution: Whilst favourable seasonal conditions may easily support a more rapid increase in stock numbers, adverse seasons may make it more difficult to increase stock numbers.

Why does return on investment look so bad for fertiliser being applied to country that has not been fertilised previously, or not fertilised for a long time?

Partial budgets and early years of cash flow budgets for fertiliser applications to paddocks that are not already receiving fertiliser inevitably look less favourable than might be expected (e.g. compare example in Fig. 11 with the example in Tables 6 and 7). This is because P that is exported from unfertilised paddocks in animal products is being "mined" (i.e. not replaced) by a grazing enterprise that is not receiving maintenance P applications. When the decision is taken to increase soil fertility, the P-application rate must now cover the "maintenance-P" requirement of the soil and livestock numbers being run, and an extra allowance for "soil P increase".

This effectively means that the cash flow assessment of fertiliser application to an unfertilised paddock will also include the financial burden of prior P removal.

In cases where a fertiliser investment appears to be unattractive because it will take a long time to give an improved cash position, check the ability of your current enterprise to cover all business costs (overheads and debt). The current position might not be sustainable in the future and changes may need to be made. This could mean making major changes to your livestock enterprise before fertiliser use is considered.

STEP 4

Partial Budgets

Cash flow budgets are appropriate for assessing fertiliser investments because soil fertility plans usually extend over a number of years. Partial budgets can be also used to examine the extra income and potential return on investments and particularly shorter term investment plans.

A Partial Budget Tool is provided on the accompanying CD for assessing the impact of allowing carrying capacity to decline (Table 8). This will often mean that you are intending to also reduce soil P fertility. Such a decision results in capital being released and this tool compares the decline in income against the saving in fertiliser costs and the income from interest on the released capital.

Partial budgeting is technically irrelevant when examining the value of maintaining soil fertility because there is no change expected in either input costs or outputs. However, it is possible to check the income that is protected by maintaining soil fertility using the partial budget tool.

An example of this is shown in Table 8. This example is also based the scenario outlined in the "worked example" for a Merino wether enterprise at Bookham, NSW (page 12). A partial budget is developed assuming no fertiliser application for one year and the financial impacts of the consequent declines in soil fertility and carrying capacity that are expected to occur are assessed. In this case it would be counter-productive to stop maintenance fertiliser applications for this enterprise just because the fertiliser price had reached $400/tonne because a decline in income of about $35/ha would result.

Table 8: Partial budgeting for fertiliser applications expected to decrease livestock carrying capacity

Information required – inputs

Area being fertilised

Carrying capacity

Measured as dry sheep equivalents (DSE/ha)

(i) carrying capacity at current soil fertility level

(ii) carrying capacity if fertiliser strategy is applied

NOTE: carrying capacity has a major impact on the financial outcome. If uncertain use Step 2 calculation – what stocking rate?

Gross margins per DSE

Gross margin per DSE is required for the current situation and for the situation after fertiliser and stocking rate adjustments have been made. These gross margins reflect production per head and are converted to per ha using the carrying capacity numbers. If carrying capacity is changing in line with change in pasture production (i.e. pasture utilisation is remaining about the same), differences in gross margin per head will be small (typical range: +$1 to -$2), most often a small decline in gross margin per DSE might be expected.

A gross margin template is provided (Appendix 2) to help you work out your figures or you can access the template on the NSW DPI website: www.dpi.nsw.gov.au

Fertiliser cost, application rate and spreading cost

The cost of fertiliser is not included in the gross margin per DSE because fertiliser cost is accounted for in these items.

Livestock costs and interest rate for livestock capital

The figure required is in $/DSE: e.g. merino ewe @$60/head equals $40/DSE. If capital freed is used to pay off debt, generally the interest rate used would be the interest charged on the debt that is paid off. If the capital is to be used for external investment, use the interest rate earned on this.

Outputs

Gross margin income is given for the current and projected situations. This uses hectares, carrying capacity and gross margin from the inputs. The difference gives the decline in enterprise gross margin. The saving in fertiliser cost is calculated using hectares, price/tonne and current and projected application rates. Net income is calculated as gross margin income plus fertiliser saving. Livestock capital that is freed is calculated using hectares, carrying capacity difference and the livestock cost per DSE. Interest is earned on freed livestock capital using the specified interest rate. Resultant total income is the sum of the decline in enterprise gross margin income plus savings in fertiliser cost and interest earned on freed capital. It is reported as the total for the enterprise or as total income per ha.

Partial budget for fertiliser strategies expected to decrease livestock carrying capacit

Data entry (tan cells)		
Area of pasture	100	hectares
Carrying capacity (current)	11	DSE per ha
Carrying capacity (projected)	7	DSE per ha
Gross margin (current)	$22.00	per DSE
Gross margin with proposed fertiliser strategy	$22.00	per DSE
Cost of fertiliser	$400.00	per tonne
Fertiliser spreading cost	$5.70	per ha
Average annual fertiliser application (current)	90	kg/ha
Annual fertiliser application (proposed)	0	kg/ha
Capital cost of livestock	$40.00	per DSE
Interest rate for livestock capital freed	7%	
Partial Budget		
Livestock gross margin income (current)	$24,200	
Livestock gross margin income (projected)	$15,400	
Decrease in gross margin	-$8,800	
Cost of fertiliser (current)	$3,600	
Cost of fertilizer (proposed feriliser strategy)	$0	
Saving per annum in fertilize	$3,600	
Savings on spreading costs	$570	
Net result	-$4,630	
Livestock capital saving	$16,000	
Interest earned on capital saved	$1,120	
Result including interest saving	-$3,510	
Result per ha (including interest saving)	-$35	per ha

STEP 4

Step 5: Other things to think about before you invest

Other nutrients

This booklet deals primarily with managing the P-fertility of soils used for temperate, legume-based pastures. It has been assumed so far that the soils are only deficient in P and N. If a soil has an additional nutrient limitation for plant growth, the most deficient nutrient will be the primary limiting factor.

In such cases it is possible that the expected pasture growth response to P-fertiliser will not be realised (see Fig. 13). Money invested in P-fertiliser will not be entirely wasted, but it will be used very inefficiently. The expected carrying capacity will not be realised and profitability of the investment will be compromised.

It is important to be vigilant so that limiting nutrient situations are identified early. Common nutrient deficiencies are Mo (molybdenum) in acid soils, S (sulphur) and K (potassium). However, deficiencies of copper, boron, zinc and magnesium are also known to occur in particular soils across southern Australia.

Check local conditions with local advisors. Use soil testing to detect potential macronutrient deficiencies and plant testing to investigate potential micronutrient problems.

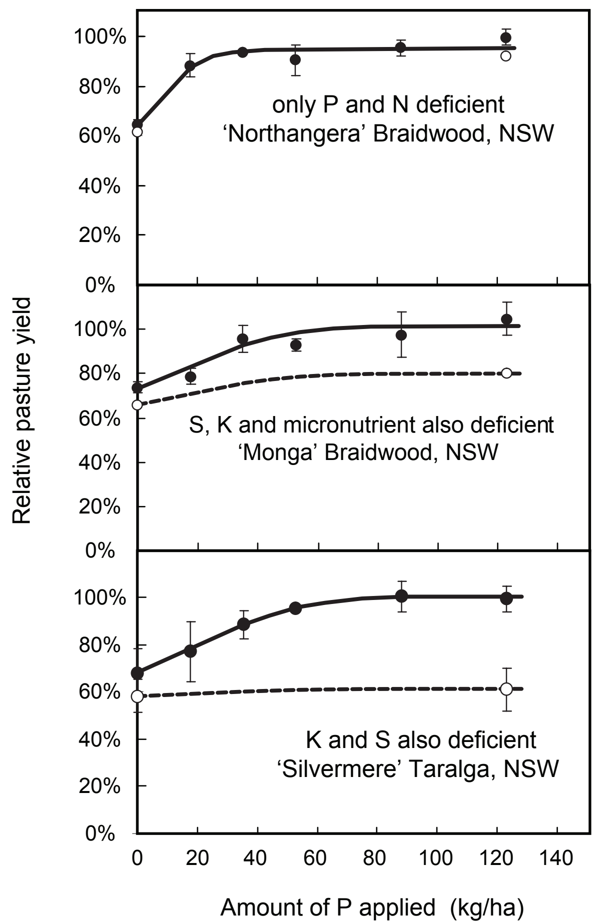


Figure 13: Response of sub clover-based pasture to increasing amounts of P applied along with a blanket application of other potentially-deficient nutrients other than N (closed circles) at three sites on the southern tablelands, NSW and P applied at the highest rate in the absence of the other nutrients (open circles). At two of the sites, nutrient deficiencies other than P will constrain the response to P-fertiliser unless corrected.

Some relevant critical soil test values

Table 9: Critical potassium: Colwell K soil test values (mg K/kg soil) for four soil texture classes that have been derived from a national data set by Gourley *et al.* (2007). (*NB: insufficient data available for definition of a response relationship for clay soils.*) More details can be found in the "Making better fertiliser decisions for grazed pastures in Australia" technical booklet at: www.asris.csiro.au

Soil texture	Critical K value [1]	Confidence interval [2]
Sand	126	109-142
Sandy loam	139	126-157
Sandy clay loam	143	127-173
Clay loam	161	151-182

[1] Soil test value (mg/kg) at 95% of predicted maximum pasture yield.
[2] 95% chance that this range covers the critical soil test value.

Table 10: Critical Sulphur: CPC (calcium phosphate plus charcoal) and KCl-40 (potassium chloride extract at 40°C for 3h) soil test values (mg S/kg soil) as derived from a national data set by Gourley *et al.* (2007). (*NB: Most soil S test data available nationally were from clay loam or sandy loam soils and it was not possible to test whether the soil S test – pasture response relationships differed between soil texture, states or regions.*) More details can be found in the "Making better fertiliser decisions for grazed pastures in Australia" technical booklet at: www.asris.csiro.au

Soil S test	Critical S value [1]	Confidence interval [2]
CPC	3	2-4
KCl-40	8	6-10

[1] Soil test value (mg/kg) at 95% of predicted maximum pasture yield.
[2] 95% chance that this range covers the critical soil test value.

Pasture composition and stability

When P-fertiliser is first applied to pasture growing in P-deficient soil, is it usual to see changes in the botanical composition which develop over a couple of seasons. The grassland often shifts from being relatively botanically diverse and slow growing to a less diverse but more productive pasture. The nature of the changes varies between grassland systems, environments and with previous interventions such as the sowing of exotic species. However, it is common to see an increase in productive annual and perennial species (including legumes which bring biologically-fixed N into the system) and a decrease in less productive, less competitive, diminutive and/or prostrate species. Feeding value of the pasture for livestock also improves. Changes in botanical composition are driven by the changing P and N status of the soil, but also by grazing pressure exerted by livestock (e.g. Fig. 14).

In many cases, pastures fertilised to achieve near-maximum productivity and livestock carrying capacity, approach botanical sustainability limits which are still relatively poorly understood. It is likely that the resilience of intensively-managed pasture systems depends on which plant species are present, on the presence of underlying problems such as soil acidity, salinity and drought, and is likely to also be influenced by paddock aspect and grazing management.

In some cases, the loss of key species can be very significant and may threaten the ability of the pasture system to maintain a high carrying capacity or to withstand droughts and other stresses. The costs of pasture renovation are very high and pay-back periods so long that significant loss of pasture composition and quality is generally unacceptable. Loss of key species, such as deep-rooted perennials, also has substantial potential costs for grazing system sustainability as they contribute significantly to high pasture yield, feedbase stability, pasture water balance (reduced leakiness), reduced nutrient leaching and reduced soil acidification.

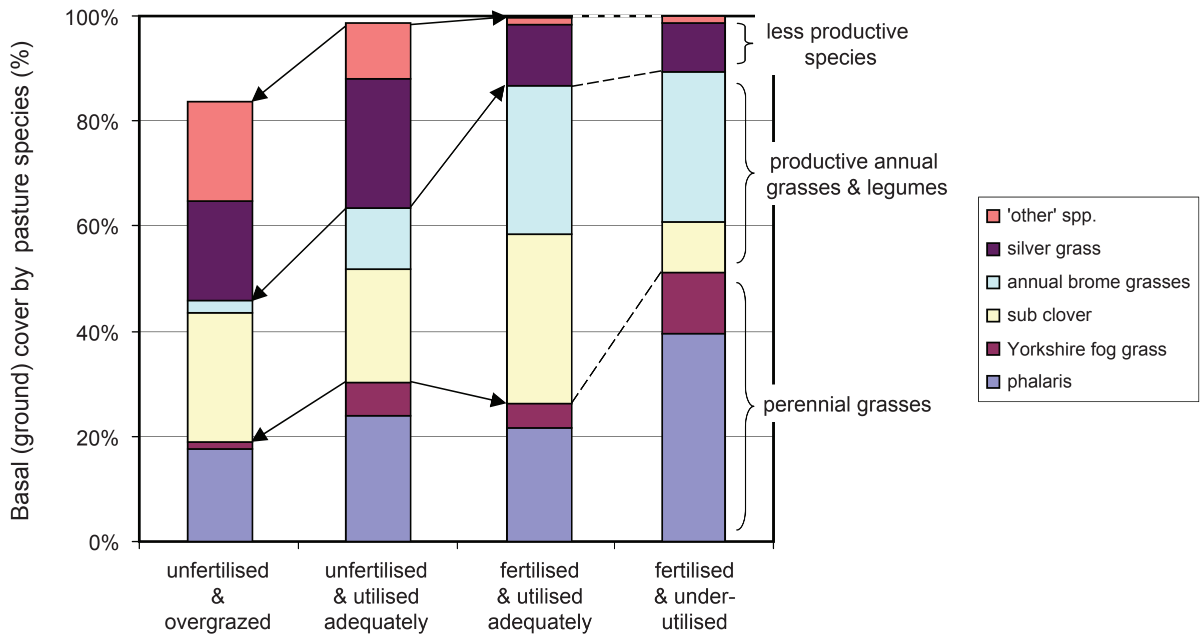


Figure 14: Changes in basal cover (effectively coverage of the ground surface; average for 1999-2001) by pasture species in an initially "degraded" phalaris and subterranean clover-based pasture on P-deficient soil (Olsen P = 4 mg P/kg; Colwell P equivalent = 8 mg P/kg) near Hall, ACT after annual applications of P-fertiliser and changed sheep grazing rates from 1994. Applications of P raised the soil P fertility to an Olsen P = 10-12 mg P/kg (Colwell equivalent about 20-24 mg P/kg). The 'unfertilised-overgrazed' and 'fertilised-adequately utilised' pasture systems were grazed continuously by 18 yearling Merino wethers/ha whilst the 'unfertilised-adequately utilised' and 'fertilised-under utilised' systems were grazed by 9 wethers/ha. Increase in bare ground was associated with low soil fertility and overgrazing, decline in the presence of less-productive species and increase in the more-productive species was associated with increased soil P fertility, and changes in perennial grass cover were associated mainly with grazing pressure (i.e. the combination of soil fertility and stocking rate). (redrawn from Hill *et al.* 2004)

STEP 5

Figure 15 shows a substantial change in the botanical composition of a wallaby grass pasture near Yass, NSW after application of superphosphate to lift productivity and stocking rate. Although the botanical changes observed in the intermediate fertiliser-stocking rate treatments are to be expected and are not dissimilar to the sorts of botanical change also expected in intensively-managed "improved" pastures, the concern for the native grass pasture system is potential loss of a perennial grass which cannot be re-sown at an affordable cost. Wallaby grass composition in the highest fertiliser and stocking rate treatment in this experiment appears to be even further compromised, but this treatment started with poorer wallaby grass cover and it is unclear whether intensive management was the real cause of the much lower final wallaby grass cover.

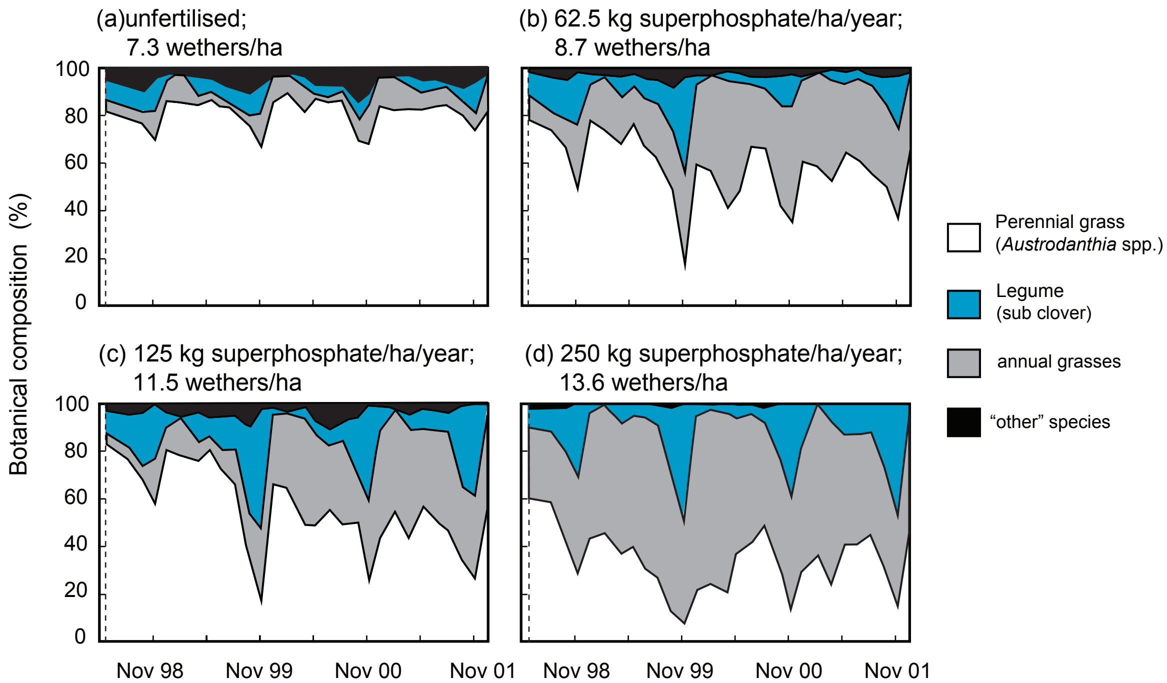


Figure 15: Changes in botanical composition of a wallaby grass pasture near Yass, NSW after annual applications of P-fertiliser and changed sheep grazing rates that commenced in 1998. High wallaby grass cover and low subterranean clover content was associated with low soil fertility, decline in wallaby grass occurred over the first few years concomitant with increase in annual grasses and clover species. Thereafter, botanical composition was relatively stable. (Bolger and Garden 2002)

Protect against degradation of the pasture resource base

Grazing management: Rotational, as opposed to continuous grazing, can help manage pasture persistence. In particular, cover by perennial species benefits from rotational grazing. Strategic resting (e.g. 4 weeks after opening rains, within a set stocked system) can also be beneficial for persistence, as can light stock pressure during a period of stress. However, resting strategies mean livestock pressures elsewhere may be higher, that supplementary feeding may be needed, or that you have destocked and all incur a cost. Understocking is costly and can also cause problems with pasture composition. The greatest pressure comes from stock numbers which exceed the pasture's carrying capacity regardless of the grazing method used.

Consider your pasture type and whether pushing to maximum soil fertility is desirable: Native pastures are often in parts of the landscape that can not be resown and seed is relatively expensive and hard to obtain, so it is more critical to ensure pasture persistence is maintained. For example, at the Bookham Grazing Demonstration site it was decided to aim at a target below the critical P level for maximum pasture growth to decrease the risk of annual grasses becoming dominant; i.e. a risk management strategy.

Dry periods: The higher your stocking rate the more critical it is to have a strategy in place to manage dry times. Increased P improves pasture growth when we have moisture, during extended dry periods the extra P is of less help. It is critical to manage the increased livestock pressure so as to avoid permanent damage to the pasture base.

Be vigilant, back-off the grazing pressure if necessary: Ground cover is your guide for action regarding the need for rest or a reduction in livestock numbers. Strategies could include the use of drought lots, the sale of stock, agistment or supplementary feeding.

STEP 5

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Appendix 1: DSE ratings for various classes of livestock.

Table 1. DSE ratings of livestock during the year.

Annual DSE ratings for livestock are required for estimating stocking rates and carrying capacity in the 5 Easy Steps worksheet and computer tool.

The figures immediately below are not necessarily the annual ratings that you will need but are supplied to help you calculate annual DSE ratings.

These DSE ratings are for the animal while it is in the listed category: e.g. for a 500 kg cow. While she is lactating the rating is 15.2 (cow and calf) but the cow might only lactate for 6 months. The categories that apply in the other 6 months of the year are a combination of late pregnant and dry.

'Pregnant' in sheep applies to the last month of pregnancy and in cattle to the last 3 months.

Some examples of whole-of-year enterprise ratings are on the next page (Table 2).

Mature wethers:
Scaling for wethers of different liveweights is the same as for dry, mature ewes.

Mature ewes					
Liveweight (kg)	Dry	Pregnant		Lactating	
		single	twin	single	twin
40	0.9	1.1	1.3	2.1	2.9
50	1.0	1.3	1.5	2.5	3.4
60	1.2	1.4	1.6	2.9	4.1

Growing lambs				
Liveweight (kg)	Growth rate (g/day)			
	50	100	150	200
20	0.6	0.8	1.0	1.2
30	0.9	1.1	1.3	1.5
40	1.0	1.3	1.5	1.65

Breeding cattle			
Liveweight (kg)	Dry	Pregnant	Lactating
350	6.0	7.0	12.3
400	6.5	7.7	13.7
450	6.9	8.2	14.8
500	7.1	8.4	15.2
550	7.7	9.0	16.5
600	8.4	9.7	17.3

Growing cattle			
Liveweight (kg)	Growth rate (kg/day)		
	0.5	1.0	1.5
200	5.3	6.8	8.3
250	6.4	8.1	9.7
300	7.3	9.2	11.1
350	8.4	10.6	12.9
400	9.1	11.4	13.7

Table 2. Examples of annual DSE ratings for whole enterprises.

For breeding enterprises, these ratings include the female, progeny and replacement females over a 12-month period.

Ewes

50 kg Merino ewe (fleece free and no gut fill)

Marking percentage	All progeny kept for 12 months	Wethers sold @ 5 months, ewe kept
105	2.3	2.1
95	2.2	2
85	2.1	1.93
75	2	1.86

70 kg first cross ewe (fleece free and no gut fill)

Marking percentage	All lambs sold at 8 months	All lambs sold at 12 months
125	2.73	2.96
115	2.62	2.86
105	2.54	2.76
95	2.46	2.66

Cows

500 kg cow for 12 months and calf for 6 months	11.4 dse
500 kg cow and calf for 12 months	15.0 dse

Trading steers in paddock for 12 months	9.0 dse
Trading steers in paddock for 6 months	4.5 dse

Examples

Example1: 1500 Merino ewes (50 kg liveweight) with 95% marking percentage.

1500 * 2.2 = 3300 DSE, which includes the ewes, lambs for 12 months and replacement hoggets.

If all these sheep were run on 450 ha, then the stocking rate is: 3300/450 = 8.25 DSE/ha

Example 2: Paddock running wethers for 6 months and traded lambs for 4 months.

Trading 800 lambs gained 20kg whilst grazing the 50 ha pasture paddock for 4 months.

Use the figures from Table 1: 30 kg is nearest to the average of the trade (in at 25 kg; out at 45 kg) and the average growth rate is about 180 g/head/day (estimate between the 150 and 200 g/head/day figures).

800 lambs *1.4 * 0.33 (only on the property for 4 months out of 12) = 370 DSE.

The stocking rate during the 4-month period is: 370/50 = 7.4 DSE/ha.

The paddock was spelled for 2 months (0 DSE) and then ran 200 wethers (55 kg liveweight) for 6 months: 200 wethers * 1.1 * 0.5 = 110 DSE.

The annual figure is: (370+110) = 480 DSE

And the annual stocking rate was: 489/50= 9.4 DSE/ha

Appendix 2: Livestock gross margin template examples

WOOL & LAMB GROSS MARGIN BUDGET

Enterprise:	**Wool or lamb enterprise**					
Enterprise Unit:	1,000	*18 um ewe*		1.9	DSE/animal	
Pasture:	*native*					
			Total DSE	1900	DSE	
INCOME:						**Total**
	Number sold			$ per head		
Livestock sales	177	*CFA ewes*		39		$6,956
	2	*CFA rams*		61		$122
	435	*weth weaners*		38		$16,530
	201	*ewe hoggets*		50		$10,050
	-			-		$0
Total	815	head				
	Kilograms sold (clean or greasy)			$ per kg (clean or greasy)		
Wool sales	6,000	*1177 ewes*	at 5.1 kg	7.10		$42,600
	70	*10 rams*	at 7 kg	6.79		$475
	1,450	*426 ewe lmb*	at 3.4 kg	6.40		$9,280
	360	*crutchings*		2.97		$1,069
	-			-		$0
Total	7,880	kg				
			A. Total Income:			$87,082
VARIABLE COSTS:	**Number**			**$**		
Replacements	2	rams @		900	per head	$1,800
	-	wethers @		-	per head	$0
	-	ewes @		-	per head	$0
Husbandry						
Drenching & vaccination	2,300	@		1.30	per head	$2,990
Dipping and jetting	1,800	@		2.00	per head	$3,600
Scanning	1,000	@		0.90	per head	$900
Mules & mark	900	@		3.75	per head	$3,375
Shearing	1,600	@		5.74	per head	$9,184
Crutching	1,800	@		0.85	per head	$1,530
Wool selling cost				4,000.00	in total	$4,000
Fodder and supplementary feeds						
Fodder crops				-	in total	$0
Feed: Hay, Grain etc				4,000	in total	$4,000
Pasture maintenance				5,500	in total	$5,500
Livestock selling costs	815	@		3.50	per head	$2,853
Commission on livestock sales				5.00	%	$1,683
Other cost				-	in total	$0
			B. Total Variable Costs:			$41,414

	GM including pasture cost	GM excluding pasture cost
GROSS MARGIN (A-B)	$45,668	$51,168
GROSS MARGIN/animal	$46	$51
GROSS MARGIN/DSE	$ 24.04	$ 26.93

BEEF CATTLE GROSS MARGIN BUDGET

Enterprise:	**Beef breeding enterprise**			
Enterprise Unit:	100 cows @	15.0	DSE per cow	
Pasture:	*enter pasture type*		Total DSE	1,500 DSE

INCOME:

Number sold		$ per head	Total
6	*Cows*	610	$3,660
-	*Calves*	-	$0
42	*Weaner Steers*	507	$21,294
21	*Weaner Heifers*	414	$8,694
-	*Steers*	-	$0
-	*Heifers*	-	$0
1	*Bulls*	1,033	$1,033
-	*Cull Repl Heifers*	-	$0
-	*Cull (for age) Cows*	-	$0
13	*OTHER*	610	$7,930
Total 83			

A. Total Income: $42,611

VARIABLE COSTS:

Replacements	1	bulls @	4,500	$/head	$4,500
	-	cows @	-	$/head	$0
	-	heifers @	-	$/head	$0
Livestock and vet costs.			1,036		$1,036
Ear tags	83	@	2.90		$241
Fodder crops			-		$0
Feed: Hay, Grain, Silage, Molasses etc			2,400		$2,400
Pasture maintenance			-		$0
Livestock selling cost			2,800		$2,800
Other cost (eg labour)			-		$0

B. Total Variable Costs: $10,977

	GM including pasture cost	GM excluding pasture cost
GROSS MARGIN (A-B)	$31,634	$31,634
GROSS MARGIN/COW	$316	$316
GROSS MARGIN/DSE	$ 21.09	$ 21.09

NSW DPI gross margin budgets for livestock are provided on the '5 Easy Step' CD and are available at www.dpi.nsw.gov.au/agriculture/farm-business/budgets

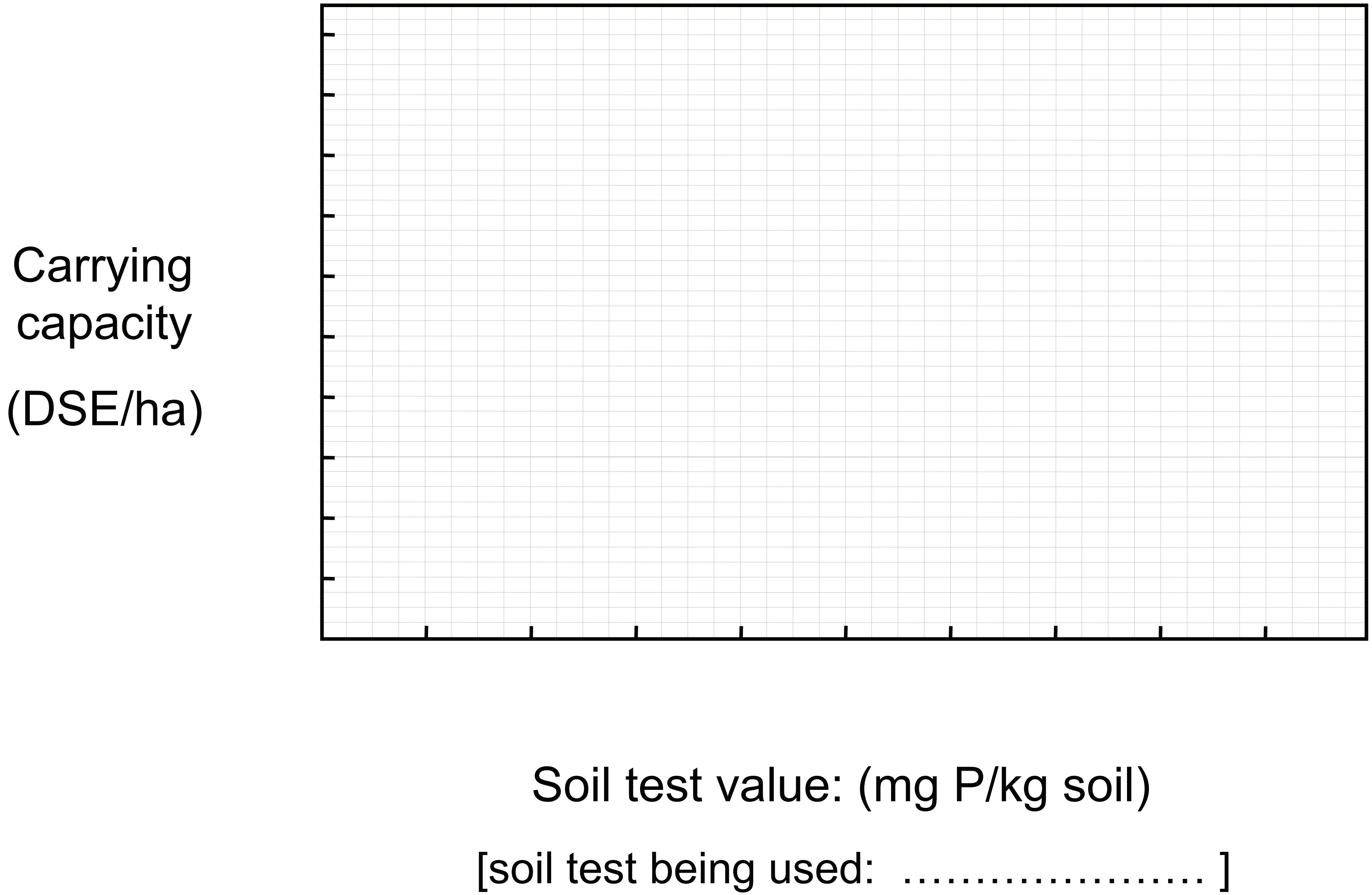
Individual budgets are provided in Portable Document Format (PDF).

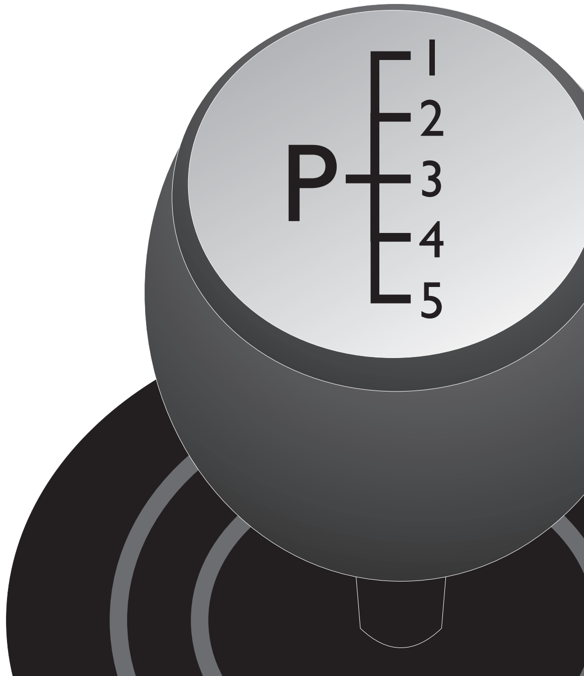
To read these files you need to have Adobe Acrobat Reader installed on your computer.

Appendix 3

Worksheet for planning the P-requirements of paddocks

Column 1	2	3	4	5		6	7		8		9	10	
Land management Unit	**Unit size**	**PBI**	**Optimum soil P target** (Colwell) (Olsen)	**Potential carrying capacity** at optimum soil P		**Current soil P level** (Colwell) (Olsen)	**Estimated current carrying capacity** given present soil P level		**Current livestock**		**Current stocking rate**	**Stocking rate planned for next year**	**Action**
	ha		mg P/kg soil	DSE/ ha	DSE/ unit	mg P/kg soil	DSE/ ha	DSE/ unit	Number & type/unit	DSE/unit	DSE/ha	DSE/ha	
Totals for property													


Carrying capacity
(DSE/ha)
Soil test value: (mg P/kg soil)
[soil test being used: …………………]



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