Five-Step Approach to Phosphorus Use on Clover-Based Pastures

By Robert Norton and Richard Simpson

A five-step approach involves soil testing, determining stocking rates based on the soil test values and the environment, calculating maintenance and capital P requirements to meet those stocking rates, determining if the strategy is profitable, and checking to ensure other limiting factors are addressed.

R. Norton/IPNI Image

Typical pastures in the southern grazing zones (400 to 600 mm annual rainfall) would be a sub-clover (inset image) and grass sward. Dependence on legumes means that N fertilizer is not commonly used in these semi-intensive pastoral systems.

The Australian pastoral industries can be divided into nine agroclimatic zones and within each there are different levels of grazing intensification with meat and wool sheep and/or beef cattle (**Figure 1**). The temperate and Mediterranean zones vary in terms of annual rainfall and species sown and are the main regions for semi-intensive and intensive sheep and cattle grazing. Grasses such as perennial ryegrass (*Lolium perenne*), cocksfoot or orchardgrass (*Dactylis glomerata*), and phalaris (*Phalaris aquatica*) represent a grade from wetter to drier areas, and these are replaced by annual ryegrass (*Lolium rigidum*) in the annual pasture zone. The grasses are complemented in mixed pastures with perennial legumes like white clover (*Trifolium repens*) in the wetter regions and subterranean (sub-) clover (*Trifolium subterraneum*) or medics (*Medicago* spp.) in the drier regions.

The development of Australia's improved pastures (currently 37 million ha) over the past 70 years has involved the introduction of productive and nutritious species along with applications of single superphosphate (SSP). The SSP (9% P, 11% S) is typically ground or aerially spread in the autumn and/or spring, and historically rates as high as 40 kg P/ha were used on what were inherently low-P soils. Liming, top-dressed K, additional S and Mo are also often applied as needed.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Mo = molybdenum.

For legume-based pastures, legume growth and persistence is particularly responsive to P availability, and this increases the amount of biological N fixation. As a consequence, P status largely drives pasture productivity, which enables stocking rates to be raised to improve farm profitability. To assist growers in making important fertilizer decisions, many years of science and industry-based research have been combined into a "Five Easy Steps" approach for managing soil P fertility in pastures. The aim is to improve profitability by appropriate SSP use on legume-based pastures grazed by sheep and cattle. A summary of this approach is presented here, while full details, including worked examples and a spreadsheet calculator, can be obtained from Simpson et al. (2009); the booklet and a related Microsoft Excel-based decision support tool can be downloaded from the link provided in the reference list.

Step 1: Soil test to assess current fertility

There are two common soil P tests for pastures in Australia

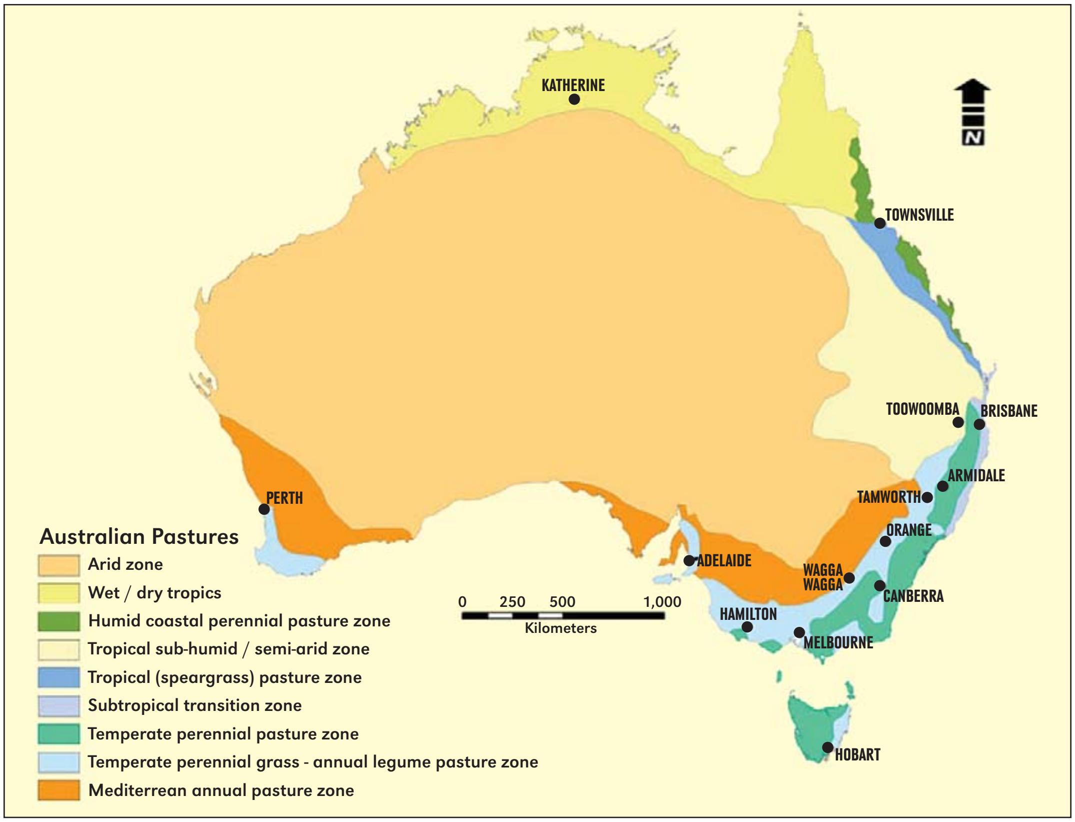

Figure 1. Pastures of Australia based on the limits to the adaptation of tropical and temperate pasture species (Wolfe, 2009).

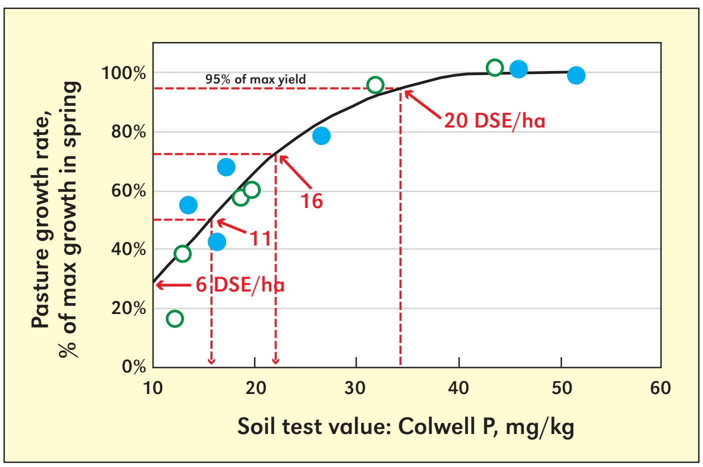

Figure 2. Combining soil P test values with pasture productivity to estimate likely stocking rates in an example where the potential carrying capacity is 20 DSE/ha. This example uses an unfertilized paddock with 6 DSE/ha and roughly equal increments in pasture yield and stocking rate with rising soil test values.

(Colwell-P and Olsen-P), both are bicarbonate extractions of different exposure times and soil solution concentrations, and each is well calibrated. A soil test value that indicates that a pasture should achieve about 95% of maximum yield is known as the "critical" soil test value. Critical values are reported as mg (extractable-P) per kg of dry soil. The critical value for the Olsen-P test is around 15 mg P/kg soil for clover-based pastures. However, the critical Colwell-P test value varies with the Phosphorus Buffering Index (PBI) of the soil. PBI is a measure of the P-sorbing capacity of the soil and it varies among soil types. A PBI of 100 indicates a critical Colwell P soil test value of around 32 mg P/kg to produce 95% of maximum pasture yield, whereas a soil with a PBI value of 200 will have a critical Colwell P soil test value of about 40 mg P/kg. The relationship between the PBI of different soils and their critical Colwell P values was determined in the Better Fertilizer Decisions for Grazed Pastures project (Gourley et al. 2007). The discussion here will be based on the Colwell-P test.

Step 2: Determine the target stocking rate

Raising soil fertility will produce more forage and allow more stock to be grazed up until the critical soil test value is achieved and some other environmental factor becomes limiting. The stocking rate— measured as Dry Sheep Equivalents (DSE) per hectare—is strongly related to rainfall and the length of the growing season. Grazing trials in southern Australia have demonstrated that with optimum soil fertility, stocking rates may vary from about 8 DSE/ha for a five-month season to about 20 DSE/ha for a nine-month season.

This information can be used to develop a stocking-rate function relative to Colwell-P soil test value. An example of this is given in **Figure 2** for a long season environment with an upper limit of 20 DSE/ha compared to an unfertilized stocking rate of 6 DSE/ha. This function does not necessarily mean that stocking rates should be increased to 20 DSE/ha as there are other factors to consider such as the availability and cost of additional stock. Stocking rate and its relationship to Colwell P varies with soil type, management system, pasture species and grazing management, so local knowledge is important in adapting this for farm use.

Step 3: Determine the best phosphorus rate

The amount of P to apply will differ if the aim is to either maintain or raise soil P fertility. Maintenance applications will consider exports of P from the paddocks (pastures) in animal products, losses in runoff, and P that accumulates in less available forms that can be adsorbed, precipitated and/or bound into resistant forms—sometimes collectively referred to as "fixed" P. **Table 1** gives a summary of the maintenance P required per DSE for different soil and animal loss factors across different pasture types and rainfall amounts.

These tables were developed as part of a long-term phosphate experiment conducted at The Pastoral and Veterinary Institute, Hamilton, Victoria (Cayley and Saul, 2001).

Phosphorus losses as adsorbed P in eroding soils, or as soluble P in runoff or leaching are of particular environmental concern, but on well managed pastures with good cover the amounts are usually small enough to be ignored for P-fertilizer budgeting purposes.

To achieve the higher stocking rates, the soil P level will need to be raised (**Figure 2**), and this amount is referred to as a capital application. For soils with PBI of 50 to 400, this is around 2.7 to 3.1 kg P/ha, respectively, above the maintenance rate to raise the Colwell P one soil test unit.

In the worked example shown, the objective of increasing the soil test level from 10 to 23 mg/kg would enable the stocking rate to be raised from 6 to 16 DSE/ha. This could be achieved by increasing P application from 5 kg P/ha/yr to 18.8 kg P/ha/yr over five years. After year 5, the capital amount would not need to be added, so the on-going maintenance application would be 13.4 kg P/ha. The combination of the maintenance and capital applications over the first few (5) years can then be economically evaluated in Step 4.

Step 4: Budgeting to check that the options are profitable

While a soil test and P budget will indicate that pasture production and stocking rate can be increased, it does not necessarily generate additional profit. But a cash flow budget can be developed to show the year by year consequences of this fertilizer plan. As part of this program, a spreadsheet calculator has been developed to assist growers to assess the implications of the extra costs of livestock and fertilizer on cash flow. In the first year of many fertilizer plans, there are often cash deficits due to the capital cost of the extra stock. Fertilizer price and stock returns have a large effect on the cumulative cash flow.

A worked example:

Pasture: 40% native perennial grasses, 60% annual grasses and subterranean clover (unimproved, low Animal Loss Factor)
Soil: Podzol, soil derived from granite
Phosphorus Buffering Index: 80
Colwell P: 10 mg P/kg
Average annual rainfall of 800 mm

Objective
To raise Colwell P to 23 mg P/kg and the stocking rate to 16 DSE/ha over 5 years (2.6 mg P/kg/yr, 2.0 DSE/ha/yr)

Capital P calculation
To raise Colwell P by 2 units with this PBI will require 2.7 x 2.6 kg P/ha above maintenance = 7.0 kg P/ha (A)

Maintenance P calculation (Table 1)
Prior to Year 1 = 0.84 kg P/DSE x 6 DSE/ha = 5.0 kg P/ha (B0)
In Year 1 = 0.84 kg P/DSE x 8.0 DSE/ha = 6.7 kg P/ha (B1)
In Year 5 = 0.84 kg P/DSE x 16.0 DSE/ha = 13.4 kg P/ha (B5)

Predicted annual applications to meet capital and maintenance demand (A + B)
Year 1 = 7.0 + 6.7 = 13.7 kg P/ha
Year 5 = 7.0 + 13.4 = 20.4 kg P/ha
On-going maintenance = 13.4 kg P/ha

Table 1. (A) Predicted P requirement per dry sheep equivalent (kg P/DSE) required for different soil loss factors based on soil types; (B) animal loss factors based on grazing intensity and landscape for different pastures with different average annual rainfall.

A. Predicted P requirement per dry sheep equivalent (kg P/DSE) for calculating maintenance P applications.

Soil type	Animal Loss Factor (based on B*)	Poor pasture, Annual rainfall, mm: 400	Poor 600	Poor 800	Improved pasture, Annual rainfall, mm: 400	Improved 600	Improved 800
Recent alluvials	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
Podzols, Clay loams	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
Acid Sands, Kraznozems other clays	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	1.10	1.11	1.19	1.06	1.19	1.31
	High	1.15	1.24	1.32	1.18	1.32	1.46

*B. Animal Loss Factors.

Intensive rotational grazing	Flat and rolling country (mostly <10°)	Very low
	Easy hills (mostly <25°)	Low
	Steep hills (one third of the paddock >35°)	Medium
Set stocked or intermittent grazing	Flat and rolling country	Low
	Easy hills	Medium
	Steep hills	High

Generally, paybacks become positive after 3 to 5 years and over time the improved pasture performance will enable higher stocking rates to be carried.

Step 5: Other things to consider before investing

Phosphorus is only one of the essential nutrients required by temperate legume-based pastures, although in many grazing areas it is the primary limitation. If the soil has additional nutrient limitations, such as K, Mo, or S, or if the soil pH is very low, then the responses to applied P can be held back by the other soil deficiencies. Soil tests are important tools for monitoring the nutrient supply for K and S. It is also important to remember to apply micronutrients at recommended intervals if they are required.

In most cases, an increasing P supply will increase the legume content of the pasture, which in turn increases soil N status and lifts productivity. Higher N status may also promote grass dominance. But these changes can be managed through grazing pressure. Rotational grazing and the use of well adapted forages will assist in maintaining desirable species balance and pasture quality.

While the Five Easy Steps approach was developed for clover-based pastures, the principles should apply to P management in any of the world's 3.5 billion ha of soil-pasture system where P has been identified as a limiting nutrient. BC

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