Fertiliser Association

Shaping profitable and sustainable farming

FERTILISER ASSOCIATION OF NEW ZEALAND

Fertiliser use on New Zealand Sheep and Beef Farms

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Published by the Fertiliser Association of New Zealand

Editors: Jeff Morton and Ants Roberts

For more information:
PO Box 11519, Manners Street Central, Wellington, New Zealand
04 473 6552
info@fertiliser.org.nz

www.fertiliser.org.nz

First Produced by New Zealand Fertiliser Manufacturers' Research Association Inc. and New Zealand Pastoral Agriculture Research Institute Ltd, 1994

Revised 1999
Reprinted 2004
Revised 2009
Reprinted 2012
Revised 2016
Reprinted 2018
Revised 2024

ISBN:
Print: 978-1-7385804-0-8
Electronic: 978-1-7385804-1-5

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Introduction

All farm systems are dependent on an adequate supply of essential nutrients, whether it is for cropping and horticulture or pasture for livestock. The role of fertiliser, along with other sources of nutrients such as crop residues, nitrogen (N) fixation, soil reserves, compost and effluent, is to help ensure adequate levels of essential nutrients are present for plant growth and animal health.

Our welfare and our nation's food and fibre production are intrinsically linked to our natural resources of soil and water. This booklet presents farmers with recommendations for fertiliser nutrient use in meat and wool production.

These recommendations are designed to sit alongside the Association's Code of Practice for Fertiliser Nutrient Management. The Code provides guidance on supplying the nutrients while avoiding and minimising the loss of those nutrients to the environment. The Code is available at:

www.fertiliser.org.nz

Efficient use of fertiliser requires that applications match plant needs as closely as possible, and that soil nutrient status is maintained by balancing nutrient input to nutrient removal.

The information presented in this booklet has been synthesised from a large volume of research on fertiliser nutrient requirements of sheep and beef farms. The information represents the average over a range of conditions. However, every farm is different and so some modifications may be required for individual farm conditions.

Use of forage crops is increasingly common on sheep and beef farms. Information on fertiliser use in forage crops is provided in the booklet: "Fertiliser use on New Zealand forage crops" at www.fertiliser.org.nz/site/resources/booklets.

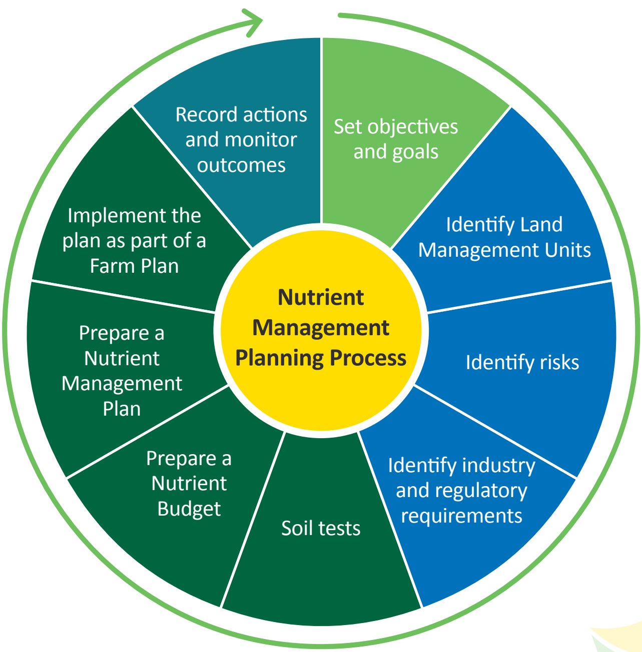
New Zealand's pasture-based livestock industry relies on a mix of pasture species which includes grasses, legumes, and herbs. Legumes require a high soil nutrient status in terms of phosphorus (P), potassium (K), sulphur (S) and trace elements. Lime use to manage soil pH is also essential. This booklet primarily focuses on the P, K and S requirements for maximising legume production and function. Once the required soil nutrient status has been achieved, on more intensive sheep and beef farms there may be a place for the tactical use of N fertiliser to meet short-term feed gaps.

We recommend that an experienced and certified nutrient management adviser or certified consultant with a good understanding of nutrient management tools and farming systems, is engaged to help formulate nutrient advice, whether as part of a nutrient plan or as part of a freshwater farm plan.

Nutrient budget and fertiliser nutrient management plans

Central to good fertiliser nutrient management is understanding the nutrient demands and nutrient cycles for your farm system.

Nutrient inputs and outputs should be documented in a nutrient budget. The actions and nutrient management requirements to achieve production goals and manage environmental risks should be clearly documented in a nutrient management plan which can be monitored and reviewed at the end of each production cycle.



Nutrient budget

This is a statement of the total nutrient inputs and outputs for a specific land area or management unit. A nutrient budget indicates where soil nutrient status is in decline, constant (i.e., at maintenance) or increasing. This nutrient budget could be based on modelled information using tools such as OverseerFM or estimates of stock requirements or crop removals, and soil test data. The nutrient budget should be reassessed when there is a significant change to the farm system and/or production goals, and/or where there is new soil testing information. The nutrient budget should address regional council and national regulations.

The information in a nutrient budget estimates the size of nutrient pools in the farm system, the risk of nutrient loss and the nutrient requirements for production. It also helps to inform fertiliser recommendations and development of a nutrient management plan.

When interpreting the results from nutrient budgets, keep in mind:

- Balances for P, K, S, magnesium (Mg) and calcium (Ca) should be checked against trends in soil test levels over time. For example, if P is in deficit, soil Olsen P levels should decline.
- A nutrient budget should inform where the current soil test levels for the farm are in relation to the appropriate target soil test ranges.
- N and P losses can impact on surface and groundwater quality and the Code of Practice should be carefully followed to minimise such risks. The Code is available at www.fertiliser.org.nz

Nutrient management plan

A nutrient management plan is a documented plan that describes how the major plant nutrients (N, P, K, S, and any others of importance) will be managed annually on a particular land management unit or farm. The purpose is to ensure farmers and growers get the best return from their spend on fertiliser and minimise nutrient losses, so adverse effects on the environment are mitigated.

It is anticipated that the nutrient management plan will be incorporated as part of the freshwater farm plan, which addresses the wider farm system.

Soils

From a practical agricultural point of view, there are two major groups of soils on which sheep and beef farming is carried out. These are:

Sedimentary soils: These soils have been derived from sedimentary material (greywacke, sandstone, mudstone) and include:

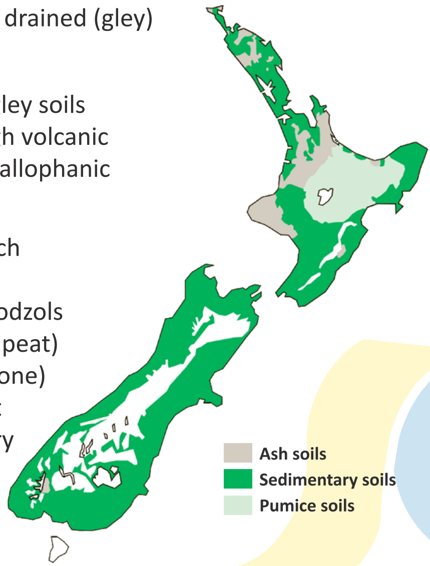
- **Brown soils** on terraces (Southland) and hill country (both North and South Island). Generally, these are well drained soils under moderate rainfall.
- **Pallic soils** are either poorly drained soils on terrace or rolling lands under moderate rainfall (Manawatu, South Otago) or free draining soils on terraces or rolling lands under low rainfall (Hawkes Bay, Wairarapa, Marlborough, Canterbury).

Other soil orders of lesser area include sands (Manawatu, Northland), recent soils (all regions) and podzol soils (Northland, West Coast, Golden Bay).

Volcanic soils:

- **Ash or allophanic soils** in Waikato and Taranaki, granular soils (Northland, Waikato) and the poorly drained (gley) soils formed from volcanic ash.
- **Pumice soils** on the Central Plateau and gley soils formed from pumice. These soils, although volcanic in origin, have different properties to the allophanic soils above.

Other soil orders for which there is less research information include sands (Manawatu and Northland), recent alluvial soils (all regions), podzols (Northland, West Coast, Golden Bay), organic (peat) soils (Waikato, Southland) and melanic (limestone) soils (North Otago). All these soils, except peat and podzols, can be categorised as sedimentary soils for the purposes of this booklet.

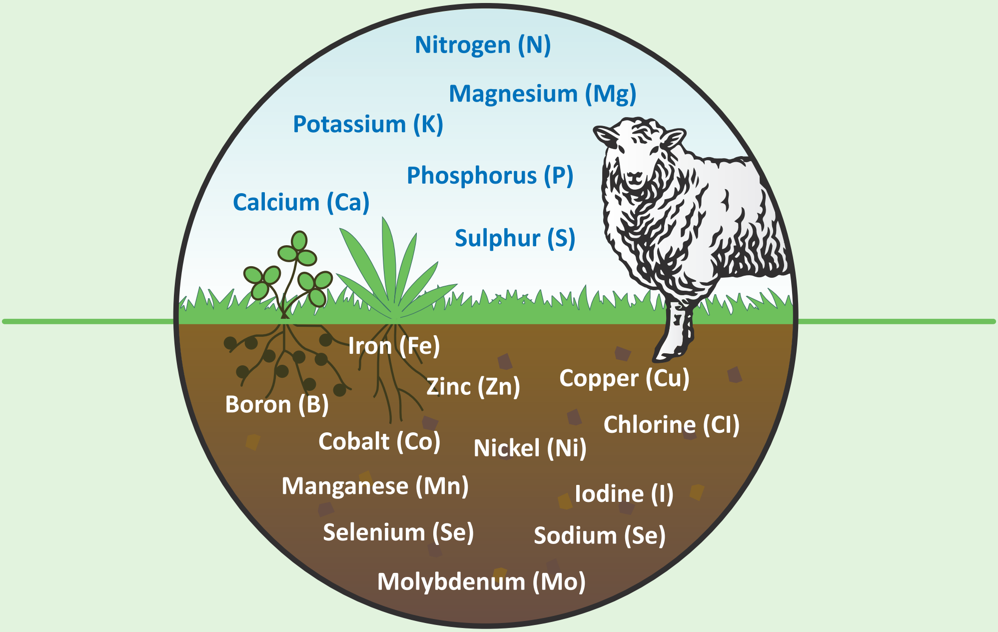


Detailed soil information is available from Manaaki Whenua at smap. smap.landcareresearch.co.nz

Essential elements in plants and animals

Major and minor elements are the fundamental nutrients which make up the building blocks of all plant and animal tissue. An adequate supply is necessary for growth and survival. There are 18 essential elements for plant and animal health.

Major and minor elements for plants and animals



There is no known function for sodium (Na), cobalt (Co) or selenium (Se) in plants, however Co plays an important role for N-fixing rhizobia in clover nodules.

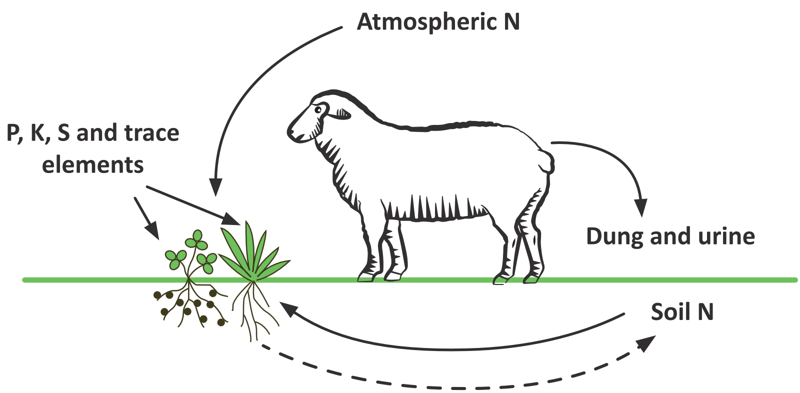
Sodium, Co and Se are important for animal health and nutrition.

Soil nutrient status of sheep and beef farms

Nutrient requirements of legume-based pastures

The legume, principally white clover, is the most important component in the New Zealand pastoral system. It supplies N that drives pasture production and provides high quality forage for meat and wool production.

Grazing animals eat the clover and return about half of the fixed N to the soil in dung and urine. Nitrogen also returns through death and decay of plant material. The N returned to the soil in this way adds to the soil N pool and becomes available to the grass in the pasture through the action of micro-organisms in the soil.

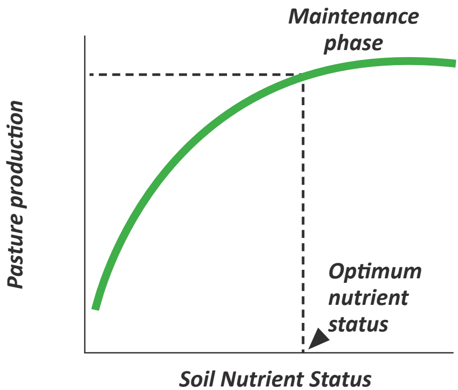


Fertiliser nutrients are applied to encourage white clover growth and N fixation. This N becomes plant available through dung and urine returned to the soil and through plant death and decay.

Phosphorus, K, S, trace elements and lime are essential for good legume growth and N fixation. On more intensively grazed pasture with high nutrient status, there are periods of the year when N fertilisers, used tactically, will increase pasture production and profitability.

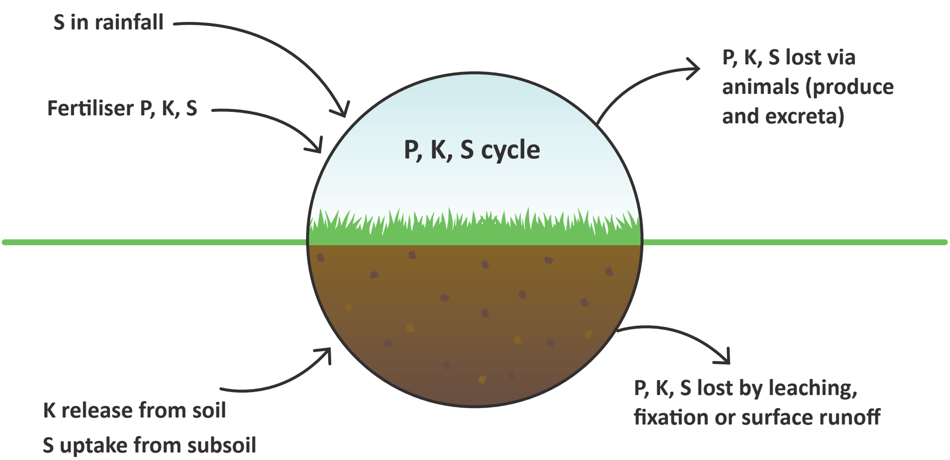
Building soil nutrient status

In the natural state, New Zealand soils have a low essential nutrient status for healthy and productive pasture and animals. When building soil nutrient status, capital inputs of fertiliser (and often lime), together with the passage of time and recycling of nutrients through the grazing animal, are required to build up soil nutrient reserves and organic matter. Pasture production and quality increases as the soil nutrient status increases through what is called the development phase. This development process may take many years.



Application of fertiliser builds up reserves of nutrients in both organic (i.e., as organic matter) and inorganic forms and hence total soil nutrient status increases. Initially pasture production increases rapidly as soil nutrient status increases during the development phase. When the maintenance phase is reached only small pasture growth increases result from large increases in soil nutrient status.

A farm with low soil nutrient status will require large inputs of nutrients to build soil nutrient reserves. Eventually, further increases in soil nutrient status will result in only relatively small increases in production. A soil nutrient status will be reached at which near maximum pasture production occurs. Farms at this stage of development can be regarded as being in the maintenance phase. Fertiliser is then required simply to replace the loss of nutrients from produce and livestock leaving the farm, from being transferred to camping spots by dung and urine deposits and from the inevitable losses of nutrients that occur in and from soils. At this stage, maintenance fertiliser application is required. The term maintenance refers specifically to the rate of fertiliser nutrient required to maintain the soil test at a constant level.



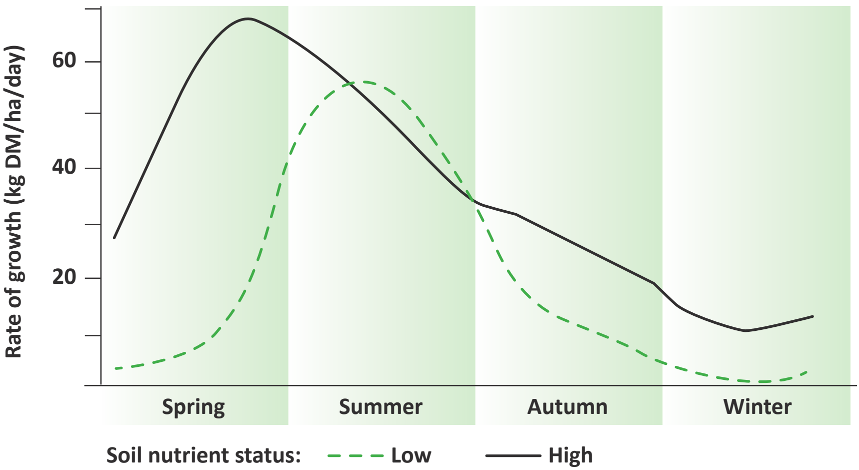
P, K and S cycles: Once soils have passed the capital development phase, lower maintenance applications are required to balance losses to maintain soil nutrient status.

Capital inputs of fertiliser nutrients or lime increase soil nutrient status or soil pH.

Maintenance inputs of fertiliser nutrients are defined as maintaining the current soil test levels by replacing the annual offtakes of nutrients from a farm.

The importance of soil nutrient status to pastoral farm systems

The use of fertiliser nutrient and lime inputs to develop soils to increase pasture production and quality affects the sort of livestock production systems you can run. Fertiliser and lime addition, as required, is one of the key factors in moving the annual pasture production curve from a low soil nutrient status, grass dominant system to a high nutrient status, ryegrass-legume based annual pasture production system.



In the diagram above, the two pasture production curves are from farms in the same environment with the same soil characteristics. The principal difference is that the Olsen P at the low nutrient status site (green dotted line) ranges from 5 to 10 while the high nutrient status site (dark solid line) had an Olsen P level between 20-30 (i.e., not limiting pasture production for this soil). All other nutrients and pH were adequate and similar between sites. The consequent increase in pasture production and quality between the low and high nutrient status production curves means that in the latter case more capital stock can be carried through winter, more stock can be carried throughout or finished during the rest of the year, the onset of calving/lambing can be earlier, and there is more opportunity to flush ewes for mating.

Assessing soil nutrient status

It is important to measure the existing soil nutrient status to assess nutrient requirements. Soil testing, and considering fertiliser history, is the only way to do this. The following soil tests are available from most commercial laboratories:

- pH, Olsen P, K, Mg, Ca, sulphate-S, organic-S, anion and cation storage capacity.

These soil tests are used for the following purposes:

- **pH** – a measure of soil acidity and hence a test for lime requirement.
- **Olsen P** – a measure of plant available P (mg/L or µg/g).
- **Quick Test K (QTK)** – a measure of plant available K (QTU, quick test units).
- **Quick Test Mg (QTMg)** – a measure of plant available Mg (QTU, quick test units).
- **Quick Test Ca (QTCa)** – a measure of plant available Ca (QTU, quick test units).
- **Sulphate-S (SO_4-S)** – a measure of the immediately plant available S (mg/kg or µg/g).
- **Organic-S (Org-S) or Total S** – a measure of the long-term supply of S (mg/kg or µg/g).
- **Reserve K or Tetraphenyl Boron K (TBK)** – a measure of K reserves in the soil (me/100 g).
- **Anion Storage Capacity (ASC)** – a measure of the capacity of a soil to store P and S (%).
- **Cation Storage Capacity (CSC)** – a measure of the capacity of a soil to store Ca, Mg, K and Na (me/100g). Also known as cation exchange capacity (CEC).

Refer to the booklet, 'Fertiliser Use on New Zealand Forage Crops' for guidance on assessing available soil N, if introducing a forage crop. See www.fertiliser.org.nz/site/resources/booklets

Soil Sampling

The best benefit from soil test information is achieved by regular testing over several years. Annual soil sampling is required to monitor an increase in soil nutrient levels from capital applications or to assist in determining maintenance requirements.

Once maintenance rates have been established, soil sampling should be undertaken at least once every two to three years. Taking samples six to eight weeks prior to fertiliser application will allow the results of laboratory testing to be used to decide what and how much fertiliser should be purchased. Refer to the booklet 'Sampling pastoral, arable and horticultural soils' for guidance on appropriate soil sampling procedures at www.fertiliser.org.nz/site/resources/booklets.

Soil test calibration curves

Soil tests are calibrated against pasture growth. This involves relating pasture growth to measured soil nutrient levels. Relative pasture production is used in these relationships. That is, production expressed as a percentage of the maximum. This allows data to be aggregated from different trials. The calibration curves have similar shapes, described by the term "diminishing returns" whereby increases in production become smaller with increasing soil test levels. Results from trials on a range of sites and years on a given soil order have produced calibration curves for the nutrients P, K, S, Mg and for pH.

The soil test calibration curves allow soil test values to be selected that will ensure pasture productivity is close to what is required for optimal economic return.

However, because of the variability in soil tests and the measurement of pasture production, there is no precise soil nutrient level that will guarantee a particular pasture production in all situations.

Variability (% error) of soil tests consists of spatial (space), temporal (time) and laboratory variability (error).

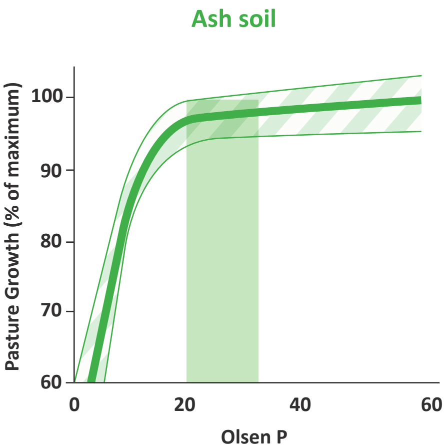
Soil test	Variability (% error)
pH	2-5
Ca	10-15
K	20-30
Mg	10-15
Olsen P	15-20
SO_4-S	20-40

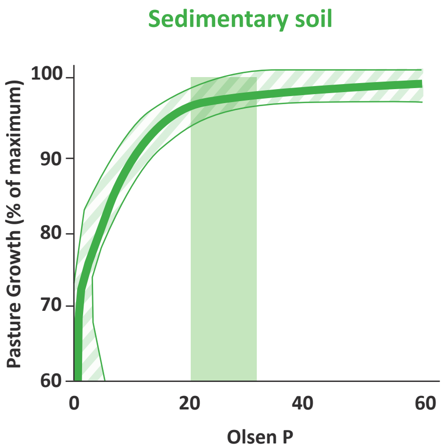
Target soil test ranges

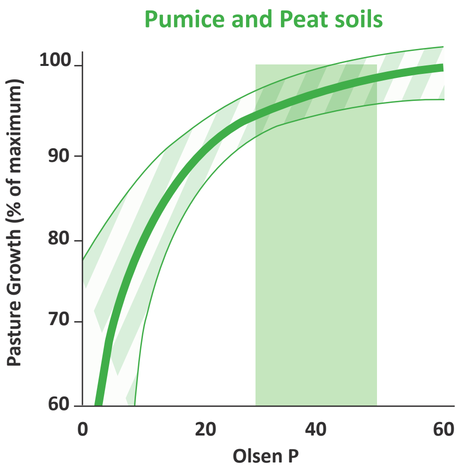
The target ranges given in this section of the booklet are a guide only. Target ranges for P, K, S and Mg encompass the soil nutrient levels which typically give at least 97% of relative pasture yield across all relevant trials. For P, which is the most expensive nutrient, where a farm should sit in relation to the target range will be based on economic and environmental considerations. Economic constraints will mean that many sheep and beef farms may operate below the soil target range with lower pasture production. For the other major nutrients, the general principle is to ensure that the nutrients are adequate i.e., for the farm's requirements, so as not to limit the pasture production response to P.

Soil Olsen P

The relationships between Olsen P and relative pasture production are different for the major soil groups of volcanic ash, sedimentary and pumice and peat soils. Calibration curves (bold centre line) are presented as graphs for each major soil group. The thinner curved lines beside the solid curve indicate there is a 95% probability that the relationship lies within this band. This also applies to the calibration curves for K and S.







The relationship between soil Olsen P and relative pasture production for ash, pumice and peat and sedimentary soils. The shaded boxes represent the target ranges.

Olsen P target ranges which will produce at least 97% of relative pasture production

Soil	Target Olsen P
Ash & Sedimentary	20-30
Pumice & Peat	35-45

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Environmental considerations

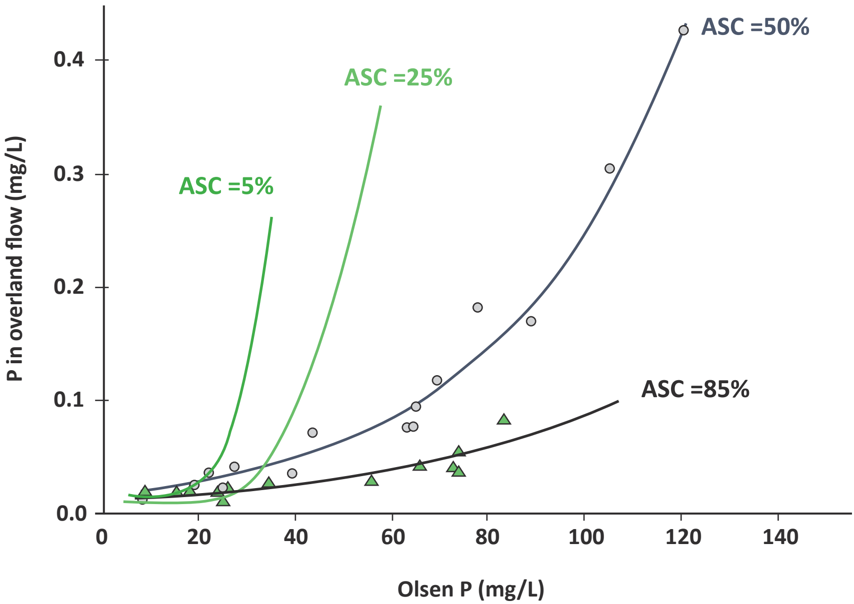
Careful consideration of where a farm sits in relation to the target Olsen P range is required. Each catchment will have identified contaminants that are priorities under the Freshwater Farm Plan regulations. Farmers and/or Certifiers will identify the specific farm risks that need to be managed. The Code of Practice for Fertiliser Nutrient Management will help identify ways to assist with fertiliser P management. The Code is available at www.fertiliser.org.nz

Research has shown that, where there are direct connections to surface water on farm, increasing soil P status has a correlation with instream P concentrations. Where instream P concentrations have been identified as an issue in the catchment context, a farm's Olsen P levels will need to take this into consideration.

Lowland soils

The key points relating to P losses from flat and rolling land are:

- P losses are generally small in well structured, well drained soils.
- Leaching of P can occur where there is drainage in soils with low anion storage capacity.
- Greater P losses occur from heavy textured soils because there is potentially more runoff from the compacted surface plus greater risk of stock damage and mole or pipe drainage allows greater transfer of dissolved, sediment and dung-P to surface waters.
- Most of the soil-derived P lost from a catchment is from within 5-10 m of streams or from mole or pipe drained soils.
- Consider the use of slower release P fertilisers (e.g., serpentine super, reactive phosphate rock) which can reduce direct fertiliser losses where this is applied in higher risk situations.
- P concentrations in overland flow increase as soil Olsen P levels increase, especially in soils with ASC less than 15%, where less P is bound to clay particles. This is illustrated in the following graph:



P loss accelerates with increasing Olsen P levels. The loss is influenced by the soil ASC. For lower ASC soils the P loss can be high even within the recommended Olsen P target range. For soils with ASC less than 15%, it is recommended to operate at the low end of the target range.

Hill country soils

The key points relating to P losses from hill country are:

Most P losses occur from relatively small near-stream areas (within 5-10 m) and within-paddock channel flows during a few storm events each year when runoff occurs.

The largest proportion of P loss is from P bound to soil particles from bank or slip erosion (high P concentration) or transport of soil particles in overland flow (low P concentration).

P losses increase with increased Olsen P (as above for lowland soils).

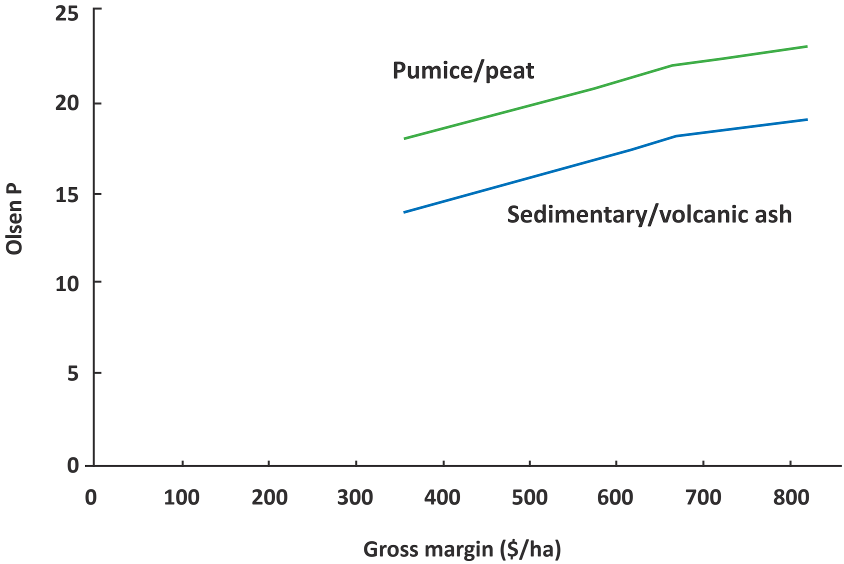
Consider the use of slower release P fertilisers (e.g., serpentine super, reactive phosphate rock) which can reduce direct fertiliser losses where this is applied in high-risk situations.

The Code of Practice for Fertiliser Nutrient Management will help identify ways to assist with fertiliser P management. The Code is available at www.fertiliser.org.nz

Economically optimal Olsen P levels

The economically optimum soil nutrient status is not necessarily the same as the target soil nutrient status. Sheep and beef farms will grow different amounts of pasture depending on topography, climate, pasture species, stocking rate and animal production goals and returns. Only the highly stocked (15 – 20 su/ha) and profitable finishing farms with favourable soils, climate and terrain will obtain economic benefit from achieving near-maximum pasture production. Many sheep and beef farms are breeding operations with some finishing livestock. They have varying proportions of hill country and seasonally variable rainfall. These farms are typically stocked at 8 – 10 su/ha and require less than near-maximum pasture production to optimise their financial returns. For an individual farm, econometric modelling for P, K, S and lime can be carried out to determine the economically optimal soil test ranges and the rates of fertiliser nutrients required to achieve or maintain them.

Whether or not higher soil Olsen P levels will result in an economic return will be determined primarily by the relationship between the cost of applied P and the gross margin per hectare. In the graph below economically optimum soil Olsen P has been calculated based on the longer-term average cost of fertiliser P ($3.75/kg P applied) across a range of gross margins (GM/ha) for both sedimentary/ash soils (blue line) and pumice/peat soils (green line).

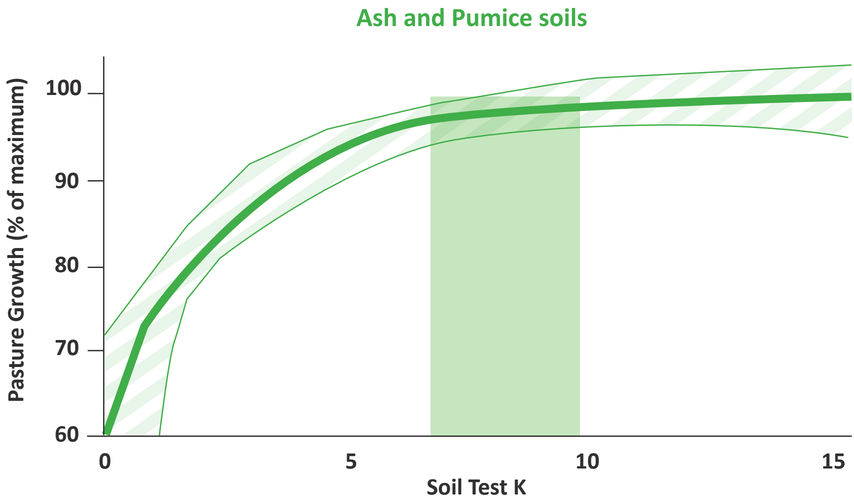


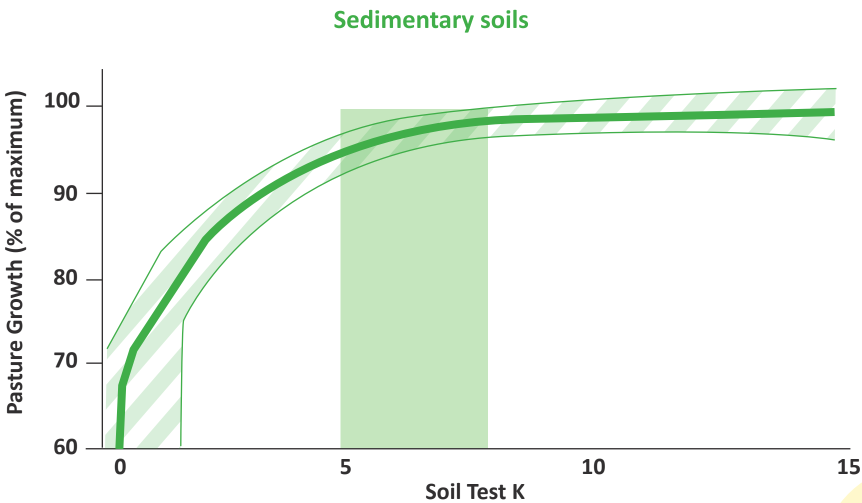
For many farms, the economic optimum will be less than the lower end of the target range. A qualified consultant can assist with the economic decision on whether the cost of additional fertiliser P to produce extra pasture is warranted based on production targets, fertiliser price, meat and wool returns and environmental risk.

The Code of Practice for Fertiliser Nutrient Management will help identify ways to assist with fertiliser P management. The Code is available at www.fertiliser.org.nz

Soil test K

Potassium, unlike P, is a nutrient which moves through the soil, and soil order differences are less important. A similar relationship between pasture production and soil test K applies across volcanic ash and pumice soils.





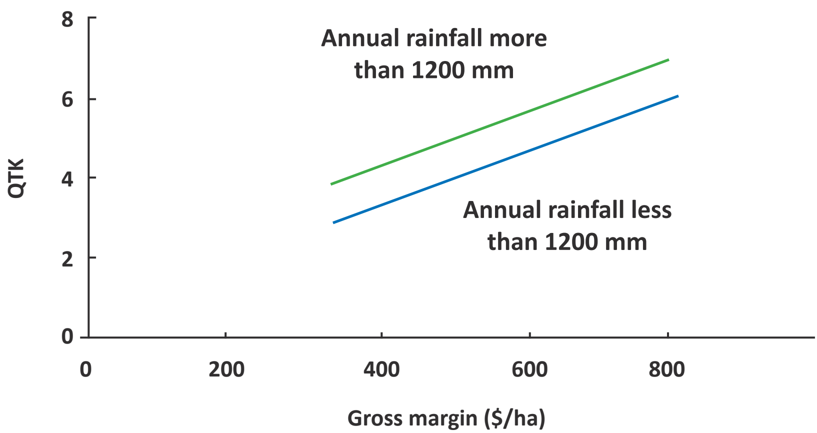
The relationship between soil Quick Test K and relative pasture production for ash, pumice and sedimentary soils. The shaded boxes represent the target ranges.

Soil Quick Test K target ranges which will produce at least 97% of relative pasture production.

Soil	Target ranges
Ash & Pumice	7-10
Sedimentary	5-8
Peat	5-7

Economically optimal K levels

Potassium is the second most expensive major nutrient supplied in fertiliser. In the graph below, an econometric model has been used to model the optimally economic level for soil QTK depending on an average fertiliser K price of $2.25/kg at different levels of gross margin (GM/ha).



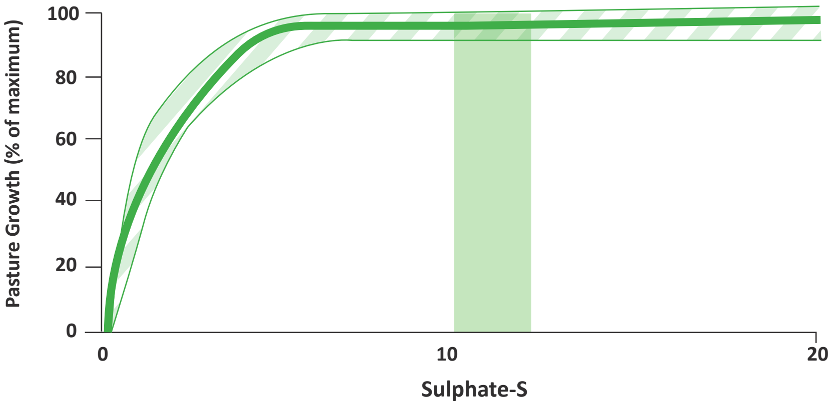
The figure shows the relationship between GM/ha and soil QTK at annual rainfall of less than 1200 mm (blue line) and greater than 1200 mm (green line).

This analysis suggests that it is economically justified for many farms to operate at less than the target range.

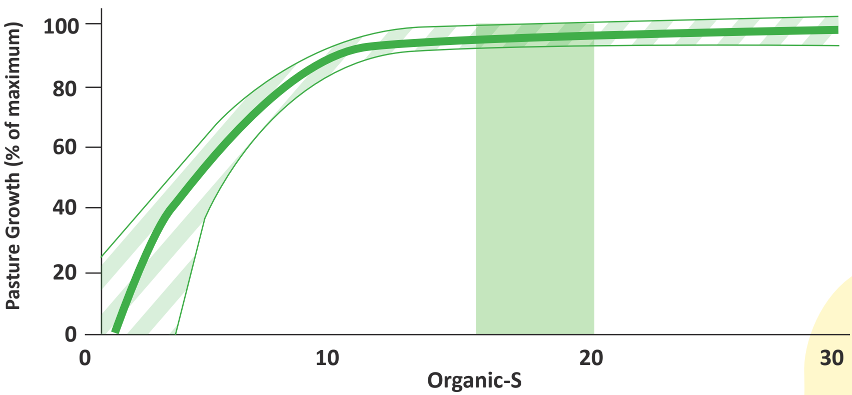
Soil test S

Sulphur is a nutrient which moves through most soils, and soil order differences are of lesser importance. There are three types of soil tests for S, one which measures immediately available S (sulphate-S) and the others which measure the slowly available S (organic-S) and total S. Analysis of trial data shows that a single relationship between pasture growth and soil test S applies to all soil orders.

All soil groups



All soil groups



The relationship between soil sulphate-S (ppm) or organic-S (ppm) and relative pasture production for all soil orders. The shaded boxes represent the target ranges.

Soil test S target ranges which will produce at least 97% of relative pasture production.

Soil	Target Ranges		
	Sulphate-S	Organic-S	Total-S
All soils	10-12	15-20	900-1000

Low levels of organic-S or total S indicate that there are low reserves of potentially plant available S in the soil and that an effective S fertiliser programme will be required to supply adequate S to the pasture. Adequate levels of organic-S and sulphate-S indicate that maintenance S fertiliser will be required to maintain soil S levels.

On some soils with low ASC, for example podzols and peats, it is very difficult to increase sulphate-S into the target ranges shown above. In these situations, annual rates of S to ensure adequate S supply should be applied.

Soil test Mg

Pasture production responses to magnesium (Mg) fertiliser are rare, except on some pumice soils especially if soil test Mg is less than 4-5. However, further increases in soil Mg levels result in higher pasture Mg concentrations. Ideal levels are 25-30 for animal health purposes, but even then, Mg supplementation of ewes, dairy and beef cows in the spring may be necessary if they are underfed.

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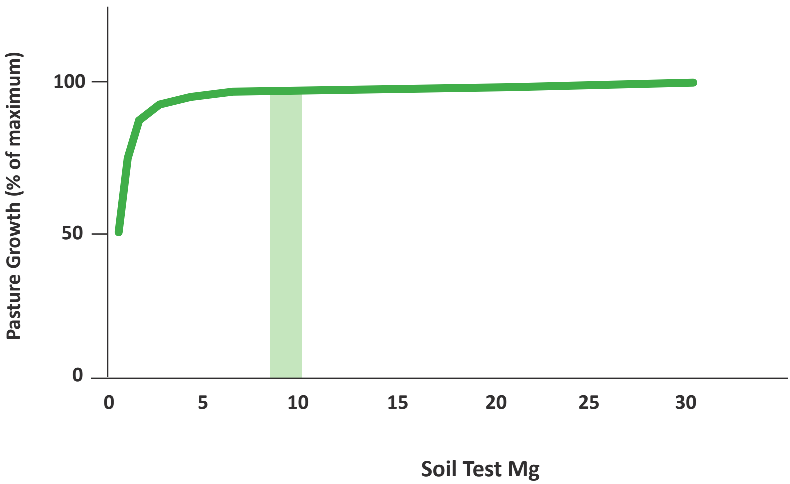


The relationship between quick test magnesium and relative pasture production for all soil orders.

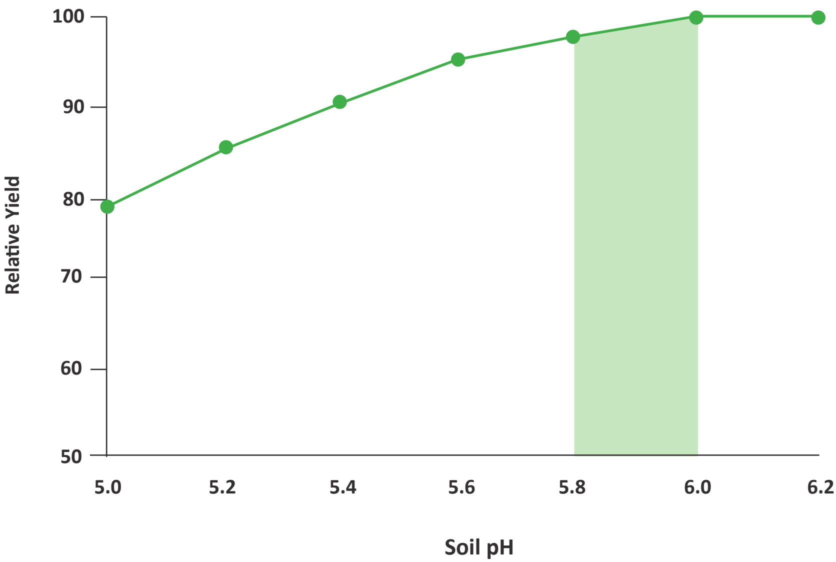
Soil test Mg target range which will produce at least 97% of relative pasture production.

Soil	Target range
All soils	8-10

Soil pH

Soil pH is important because it impacts on the availability of many soil nutrients as well as affecting soil microorganism activity. Lime is applied to increase soil pH. As the soil pH increases, the size of the response to lime decreases. Liming a soil with an initial pH 5.0 up to the target range will increase pasture production by 8-12%, depending on the rate of application. At pH levels of between 5.8-6.0, lime responses are small, indicating the target range has been reached. There is no benefit, in terms of pasture production, from liming soils to a pH greater than 6.0.

Peat soils are a special case. If the topsoil pH (at depth 0-75 mm) is already above pH 5, responses to liming will be quite small. Larger responses are likely at soil pH less than pH 5 in which case, liming is usually worthwhile for both pasture development and maintenance. For good pasture production a subsoil pH (75 to 150 mm) of at least 4.5 is best. Lime applied to the surface of peat soil does not move down to the subsoil, therefore lime should be incorporated into the subsoil to at least 150 mm depth.



The relationship between the pasture response and soil pH for mineral soils. The shaded box represents the target range.

Target soil pH levels which will produce at least 97% of relative pasture production.

Soil	Depth (mm)	Target soil pH
Ash, Sedimentary, Pumice	0-75	5.8-6.0
Peat	0-75 75-150	5.0-5.5 4.5-5.0

Target soil test ranges for New Zealand sheep and beef farms which will produce at least 97% of relative pasture production (and for Mg, animal health purposes):

Soil Test	Ash	Sedimentary	Pumice	Peat
Olsen P	20-30	20-30	35-45	35-45
Soil test K	7-10	5-8	7-10	5-7
Sulphate-S	10-12	10-12	10-12	10-12
Organic-S	15-20	15-20	15-20	15-20
Soil test Mg	pasture 8-10 animal 25-30	pasture 8-10 animal 25-30	pasture 8-10 animal 25-30	pasture 8-10 animal 25-30
pH	5.8-6.0	5.8-6.0	5.8-6.0	5.0-5.5 (0-75 mm) 4.5-5.0 (75-150 mm)

Raising soil nutrient status

If the decision is made to raise soil test levels and move up the pasture development/ maintenance curve, how is this done?

Increasing Olsen P

Field trials indicate that on sites where there has been a previous history of P application, the following rates of P, over and above those required to replace the annual losses from the farm, are required to raise Olsen P by 1 unit. Where pasture is established on more recently developed land, more capital P may be initially needed. It is more effective to apply a high rate of P over 1 or 2 years, than to apply the same amount of P over several years.

Amount of capital fertiliser P to raise Olsen P

Soil	Application rates (kg P/ha) to raise Olsen P by 1 unit	Average application rates (kg P/ha) to raise Olsen P by 1 unit	Average application expressed as superphosphate (kg/ha) to raise Olsen P by 1 unit
Ash	7-18	11	122
Pumice	4-15	7	78
Sedimentary	4-7	5	57
Peat	6-9	-	-

It should be noted that there may be a delay before Olsen P levels increase from capital P applications.

Increasing soil test K

Research data indicate that the following applications of K are required to increase the K soil test by 1 unit:

Amount of K (kg/ha) to raise the soil test K by 1 unit

Soil	Application rates (kg K/ha) to raise soil Quick Test K by 1 unit	Average application rates (kg K/ha) to raise soil Quick Test K by 1 unit	Average application expressed as potassium chloride (kg/ha) to raise soil Quick Test K by 1 unit
Ash	45-80	60	120
Pumice	35-60	45	90
Brown	35-60	50	100
Peat	35-60	45	90

Preventing soil S deficiency

Soil sulphate-S levels can only be increased over a long period of time on sedimentary and pumice soils because of their lower ASC values. There are no data available on the rates of S required to raise soil S test levels. However, trial results show that adequate S can be supplied with moderate inputs, even in situations where the deficiency is severe. Thus, where soil S levels are below the target ranges, near-maximum production can be obtained providing inputs of S are applied as follows:

Amount of fertiliser S (kg S/ha) to ensure an adequate supply of S

Soil	S application rates (kg S/ha) to ensure a deficiency does not occur.	Average S application rates (kg S/ha) to ensure a deficiency does not occur.	Average application as superphosphate (kg/ha) to ensure a deficiency does not occur.
Ash	20-30	25	235
Pumice	40-50	45	425
Sedimentary	30-40	35	330
Peat	20-40	30	285

Correcting soil Mg deficiency

Soils which are initially low in magnesium (QTMg <5) will require around 25 kg Mg/ha (45 kg magnesium oxide/ha) to eliminate pasture Mg deficiency. On average 7 kg Mg/ha will raise QTMg by 1 unit. Satisfying animal Mg requirements will require higher inputs (100 kg Mg/ha) initially, then followed by maintenance applications of 20-30 kg Mg/ha/yr.

Increasing soil pH

Lime is essential for good pasture establishment and maintenance. On ash, pumice and sedimentary soils the following guide applies:

1 tonne/ha of good quality limestone will raise soil pH by 0.1 unit to 75 mm depth.

Good quality limestone contains greater than 80% calcium carbonate and has been ground to the required fineness (50% with particle diameter < 0.5 mm and 90% less than 2 mm). If local limestones have lower calcium carbonate contents than 80%, then proportionately higher rates of lime will need to be applied to raise soil pH.

Peat soils should be limed according to the following:

Amount of lime (t/ha) to raise the soil pH by 1 unit on developed peats and peaty loams

Method of application	Soil Depth (mm)	Rate of Lime (t/ha)
Surface applied	0-75	9
Half surface applied and half incorporated	0-75	16
	75-150	34

Summary amounts of nutrients required to raise soil test by one unit

Parameter	Ash	Pumice	Sedimentary	Peat
Phosphorus (kg P/ha)	11	7	5	6-9
Potassium (kg K/ha)	60	45	50**	45
Sulphur* (kg S/ha)	25	45	35	30
Magnesium (kg Mg/ha)	7	7	7	7
Lime (t/ha)	10	10	10	***

* To ensure that deficiency does not occur
** Brown soils
***Depends on depth – see above or www.fertiliser.org.nz/resources/booklets

Maintaining soil nutrient status

The term 'maintenance' fertiliser requirement, as distinct from capital fertiliser requirement, refers to the amount of nutrients required to maintain the current soil test levels. Once target soil test levels have been achieved, how much fertiliser is required to maintain soil nutrient status? A modelled estimate based on pasture growth trials is provided below.

There is a wide variation in annual maintenance requirements between soil types and farming systems. The range of amounts of P, K and S required to maintain soil nutrient status for the appropriate soil test level at different stocking rates are:

Maintenance nutrient requirements (kg/ha) in relation to stocking rate

Stocking rate (su/ha)	Maintenance rate		
	P	K*	S
7	6-18	0-21	6-19
10	10-22	0-28	8-25
13	15-28	0-35	10-29
16	21-34	0-41	13-33
19	28-41	0-48	15-37
22	34-44	0-54	17-41

* K can be supplied by clay minerals on some sedimentary soils (e.g., recent, pallic soils) so there is no immediate requirement for K. In this situation, K reserves will become depleted over time and K fertiliser will be required in the future. Where hay and silage crops are removed an additional 15-20 kg K per tonne of dry matter should be applied on all soils.

Examples of maintenance requirements

In addition to stocking rate, maintenance nutrient requirements also vary according to other factors including soil type, topography, and rainfall. Some examples of maintenance requirements for different farming systems incorporating the above factors are shown below:

Location	Farm	SU/ ha	Soil	Topog-raphy	Rainfall mm/ year	P	K	S
						Kg/ha/yr		
Waikato	Beef/heifer grazing	22	Ash	Flat	1000	36	30	30
Waikato	Sheep/beef	16	Ash	Easy	1000	30	25	26
Central Plateau	Beef/heifer grazing	19	Pumice	Rolling	1200	34	26	30
Central Plateau	Sheep/beef	14	Pumice	Easy	1200	28	22	24
Hawkes Bay	Sheep/beef	13	Sedimentary	Rolling	1100	20	0	18
Wairarapa	Sheep/beef	10	Sedimentary	Steep	1100	18	0	17
Nth Canterbury	Sheep	8	Sedimentary	Steep	700	10	0	9
Mid Canterbury (irrigated)	Sheep	16	Sedimentary	Flat	1200	23	0	20
Southland	Sheep	15	Sedimentary	Flat	800	21	20	17
Southland	Deer	15	Sedimentary	Flat	800	21	20	17

The best procedure for farmers to determine the rate of nutrient required to maintain soil tests in the appropriate target range for their farm is to monitor soil test levels regularly. More precise farm-specific maintenance rates can be calculated from establishing trends in soil test levels over time. Once the trend in soil test level is neither rising nor falling this indicates that the rate of nutrient used is meeting maintenance requirements. At this stage soil sampling may be undertaken at least once every two to three years.

If these trends are not available, use the Maintenance Nutrient Calculator within OverseerFM Nutrient Budgets to estimate maintenance nutrient requirements. Alternatively, because production per hectare is related to stocking rate, a general rule-of-thumb for P, K and S can be stated as:

Apply 15-20 kg/ha superphosphate or equivalent per SU wintered.

Where K or elemental S is required, these should be added to the above e.g., 20-25 kg 15% potassic superphosphate or equivalent per SU wintered.

Once target soil test levels have been reached, maintenance fertiliser applications are appropriate.

Maintenance fertiliser rates can be calculated from nutrient losses, which are largely determined by soil test level and stocking rate.

Withholding fertiliser

Fertiliser is a major expense in most sheep and beef farm budgets and is often reduced during downturns in the farming economy. Serious consideration should be given to the following when re-examining the fertiliser budget:

- Completely withholding P fertiliser is an option if you are at or above the economically optimum soil nutrient levels for your farm and will avoid any possible effect to the long-term financial viability of your business. Remember that the application of other nutrients such as S and K, if required, should remain unchanged unless they too are above the optimum for your situation.
- If you are at or below the economically optimum soil nutrient levels, wherever possible, apply enough of the required nutrients to maintain your current soil nutrient status.
- If you are not able to apply full maintenance nutrient requirements due to financial constraints, then sub-maintenance rates will be much better than applying none. Remember that this mostly applies to P, not to the mobile nutrients such as S and K.
- A further option is to differentially apply fertiliser. You could extensively test all blocks or paddocks to determine areas of high and low soil nutrient status and redistribute your fertiliser applications to bring all areas together at the economic optimum soil nutrient levels.

Long term fertiliser trials

Over 7 years on the summer moist Ballantrae Hill Country Research Station, pasture production declined by 22% when no superphosphate was applied compared to 250 kg of superphosphate/ha/yr. At Winchmore Research Station under irrigated sheep grazing, annual pasture production (by year 4) was 54% lower when no fertiliser was applied compared with 188 kg of superphosphate/ha/yr. At Te Kuiti, despite moderate soil test levels, pasture and animal production decreased by the second year of withholding superphosphate (i.e., both P and S). By years 3 and 4 production had fallen by 20-30% and white clover content had decreased. At Whatawhata Hill Country Research Station, superphosphate was withheld from grazed farmlets previously treated with 200-300 kg/ha, and pasture production fell between 4 and 11% in the first two years, and animal grazing days declined by around 11 and 14% in years 1 and 2 of withholding. These results confirm that withholding fertiliser has a significant negative effect on productivity.

Timing of fertiliser application

The factors which determine the timing of nutrient application, and the need for single or split dressings, are:

- the rate at which the particular nutrient moves through the soil
- the ability of the soil to 'hold' the nutrient
- the amount of rainfall
- the texture of the soil
- managing for environmental risk

The Code of Practice for Fertiliser Nutrient Management addresses how environmental risks of fertiliser application can be managed.
(see: www.fertiliser.org.nz)

Phosphorus

When applying P fertiliser, the risk of P losses should be considered. The Code of Practice for Fertiliser Nutrient Management identifies risks such as erodible slopes, areas where nutrients applied could end up in drains or streams, and soils with low ASC.

Soil P moves relatively slowly through most soils, a consequence of its incorporation into organic matter and binding onto soil minerals. In general, there are very few leaching losses of P except on shallow soils with low ASC. Agronomically, timing is not important, however if the soil test levels are low and an immediate increase in production is required, the sooner fertiliser is applied the sooner there will be benefits. From an environmental point of view, applying soluble P fertilisers in months when there is a risk of high rainfall will increase the risk of P runoff. On dry hill country, there can be significant P loss in runoff from summer-applied fertiliser because of hydrophobic (water repellent) soil conditions reducing infiltration into the soil.

Application rates of greater than 100 kg P/ha (equivalent to 1.1 tonne superphosphate/ha) in a single application are not recommended. If capital inputs higher than this are required, then the dressing should be split. In low ASC soils (<15%), capital applications should also be split.

Peat and Podzol soils have low ASC because they have little mineral matter. There may be some advantages in splitting P dressings on these soils, especially at high application rates, but there is no experimental evidence to prove this.

Fluoride

To minimise the risk of fluoride poisoning, animals should not graze pastures where P fertiliser has been applied until at least 25 mm of rain has fallen to wash the fertiliser particles off the leaves and onto the soil.

Potassium

In contrast to P, potassium (K) moves quickly through the soil and leaching can occur. However, timing of application is only important where rainfall is high.

Ash and pumice soils with rainfall above 1500 mm and peat soils

Trial results show greater annual pasture production where K is applied in spring rather than autumn. However, there is no evidence to suggest that split applications are superior at typical rates of application (20-50 kg K/ha). However, when capital amounts are required (greater than 50 kg K/ha), it is advisable to split the application. The plant will take up less K and there will be fewer losses through the animal.

Ash and pumice soils with rainfall below 1500 mm

Under these circumstances, where normal K inputs are required (20-50 kg K/ha), spring or autumn applications are equally effective. For rates greater than 50 kg K/ha, a split application is recommended, applying equal amounts in autumn and spring.

Sedimentary soils

Trial results for a single application show greater annual pasture production where K is applied in spring rather than autumn. There is no evidence to suggest that split applications are superior at typical rates of application (30-60 kg K/ha).

For all soils

Avoid applying K before and during lambing/calving as it increases the risk of metabolic problems for pre-partum and lactating animals. Apply K after lambing/calving when clover growth is increasing. Ryegrass species are very efficient at extracting K from the soil in early spring and can usually grow to their potential without K fertiliser over that period.

Sulphur

Sulphate-S, the form present in superphosphate, is readily available to the plant and is fast moving through soils, whereas elemental-S must first be oxidised by soil microorganisms to sulphate-S before it is plant available. Elemental-S should be more effective than sulphate-S on soils with high rainfall and low ASC.

Sedimentary soils: (rainfall & irrigation >1500 mm)

A mix of sulphate-S (e.g., superphosphate, ammonium sulphate) and fine elemental-S (particle diameter < 500 µm) should be applied in spring, especially on stony free-draining soils and with grass-dominant pastures. Alternatively, split applications of sulphate-S can be made in August/ September and February.

Sedimentary soils (rainfall and irrigation <1500 mm)

For these sedimentary soils there is no difference, in terms of long-term pasture production, between sulphate-S and fine elemental-S. However, there is evidence that elemental-S will maintain more even pasture S concentrations.

Ash soils: free draining (ASC above 90%)

Trials on these soils show that neither form of S, nor the time of application, has any effect on pasture production. Either form of S can be used, irrespective of when the fertiliser is applied.

Ash soils: poorly drained (ASC below 90%)

For these soils there is no difference, in terms of long-term pasture production, between sulphate-S and fine elemental-S. However, there is evidence that elemental-S will maintain higher and more even pasture S concentrations.

Pumice and peat soils

The form of S to be used will depend on when the normal fertiliser application is made. Trial results on coarse textured pumice soils showed larger responses from fine elemental-S, than from sulphate-S when applied in the autumn, but there was no difference when applied in spring.

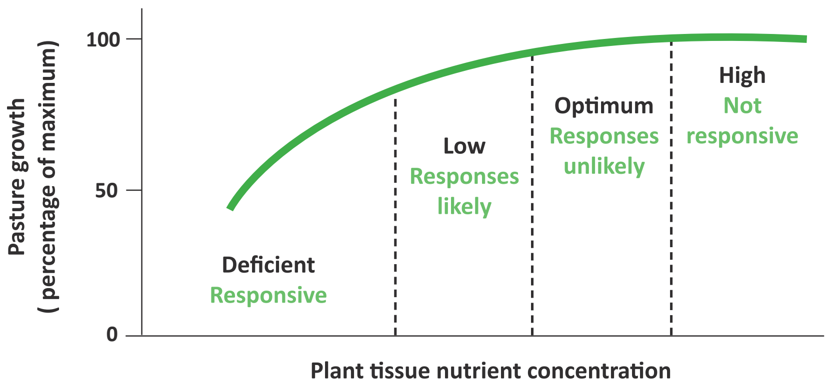
Pasture analysis

Pasture nutrient analysis is a useful back-up to soil testing. While soil testing determines available soil nutrient status, pasture analysis should be used to assess how much nutrient has been taken up from soil or a fertiliser application. Pasture analysis is also useful to check on trace element status.

Herbage samples whether mixed pasture (for general nutrients status for pasture growth and animal requirements), clover only for trace element deficiency diagnosis especially (see table below) or lucerne, should be taken from 3-4 paddocks in late spring, when climate is not limiting pasture growth rate and analysed for the major and or trace nutrients. If pasture concentrations are low, then more nutrient can be applied. Trace elements are present in small quantities in the soil making the relationship between soil level and plant and animal requirements hard to define. Soil tests do not accurately measure the amounts of trace elements available to pastures and animals but can indicate the build-up of a trace element in the soil after it is applied in fertiliser.

Pasture nutrient concentrations have been calibrated against pasture production, in the same manner as soil test levels. By relating pasture nutrient concentrations to yield, levels can be defined as either deficient (production responses will occur), low (responses may occur), optimum (responses unlikely) or high (responses will not occur).

Plant nutrient response



Care is needed when interpreting pasture analysis results, because nutrient levels in pasture are more variable than in soils. They are affected by pasture composition, time of year, stage of growth and soil moisture conditions. Professional advice should be sought before collecting samples and interpreting results.

Interpreting mixed pasture nutrient analysis for plant health.

Nutrient	Deficient	Low	Optimum	High
	(% of Dry Matter)			
N[1]	<4.0	4.0-4.7	4.7-5.5	>5.5
P	<0.30	0.30-0.34	0.35-0.40	>0.40
K	<2.0	2.0-2.4	2.5-3.0	>3.0
S	<0.25	0.25-0.27	0.28-0.35	>0.35
Mg	<0.15	0.15-0.17	0.18-0.22	>0.22
Ca	<0.25	0.25-0.29	0.30-0.50	>0.50
Nutrient	**Deficient**	**Low**	**Optimum**	**High**
	(Parts Per Million)			
Fe	<45	45-49	50-65	>65
Mn	<20	20-24	25-30	>30
Zn	<12	12-15	16-19	>19
Cu	<5	5	6-7	>7
B[2]	<13	13-14	15-16	>16
Mo[2]	<0.10	0.10-0.14	0.15-0.20	>0.20

[1] Optimum herbage N values will often not be achieved

[2] Clover only, NOT mixed pasture samples. For a Mo deficiency, clover N must also be below 4.5%.

In general, ash soils may be low in Co and Se, while pumice soils are typically deficient in Co and Se and low in Na. Boron may also be deficient for plant growth, particularly for lucerne or brassicas. Peat soils are typically deficient in copper (Cu), Se and molybdenum (Mo), although some peats are very high in Mo, and can be low in N.

Mixed pasture containing the optimum mineral contents given above will generally also supply animal requirements, provided the grazing animals are fully fed. The pasture nutrient concentrations given for these nutrients are to meet animal requirements, not pasture requirements:

Critical* pasture concentrations for mineral nutrition of a young sheep

Nutrient	Pasture Concentration
Na	0.11%
Cu[1]	5 ppm
Co	0.10 ppm
Se	0.03 ppm
I[2]	0.25 ppm

*Trace element levels must be above these levels to avoid clinical disorders. Trace element requirements for cattle are same except for Cu which should be 10 ppm.

[1] Depends on Mo and Fe concentrations. High Mo or Fe in feed can reduce Cu absorption: see correction of trace element deficiencies.

[2] 2 ppm I in pasture is recommended if feed contains goitrogens (e.g., forage kales, other brassicas).

Correction of trace element deficiencies

When trace-element deficiencies have been identified by herbage and/or animal liver tissue (or body fluid) analyses, they may be corrected by the addition of the required mineral(s) to the normal fertiliser application. Alternatively, some trace elements can be directly administered to animals. Apply fertiliser Mo only when both clover Mo and N is deficient (Mo <0.1 ppm, N < 4.5%). A response to fertiliser B will only be obtained from brassicas, lucerne and clover seed crops. When applying trace elements via fertiliser, this MUST be done in consultation with veterinary advice to adjust for other supplementation forms and avoid risk poisoning with Se particularly, and Cu.

Additional information can be found in Use of Trace Elements in New Zealand Pastoral Farming www.fertiliser.org.nz/site/resources/booklets

Trace element applications sufficient to overcome clinical deficiencies

Additive[1]	Timing	Rate	Frequency
Cobalt sulphate[2] (21% Co)[3]	Capital application in late spring	350 g/ha	Annually for 5-10 years
	Capital application in summer	240 g/ha	Annually for 5-10 years
	Maintenance in spring	60-100 g/ha	Annually
Copper sulphate[4] (25% Cu)	Capital application in autumn	5-10 kg/ha	Initially
	Maintenance application in autumn	5 kg/ha	Every 4-5 years
Sodium molybdate[5] (40% Mo)	Spring	50-100 g/ha	Every 4-5 years after testing clover
Selcote Ultra prills[6] (1% Se)	Spring or autumn	0.5-1 kg/ha	Annually
Selprill Double (2% Se)[6]	Spring or autumn	0.5 kg/ha	Annually
Sodium borate (15% B)	Spring	5-10 kg/ha	Initially
	Spring	5 kg/ha	Every 4-5 years

[1] Always check supplier's product specification for appropriate concentration and rate.

[2] Depends on soil Mn levels. If above 1 ppm, soil Mn can lower availability of soil Co.

[3] Where Granular Co (10% Co) is used, apply twice the rate.

[4] Effective where pasture Mo levels are less than 1 ppm. Where pasture Mo is greater than 1 ppm, animal supplementations can be more effective. Consult with veterinary advice to adjust for any other supplementation.

[5] Where granular Mo (10% Mo) is used, apply four times the rate.

[6] Application rates should not exceed 10 g/ha of selenium (as sodium selenate). Consult with veterinary advice to adjust for any other supplementation.

Nitrogen fertiliser for pasture

Regulatory controls on N fertiliser use

Regional council and national regulatory controls apply to N fertiliser use on pastoral farms. These must be understood and complied with. For example, the National Environment Standards for Freshwater Management 2020 regulations place a limit on 'synthetic' nitrogen fertiliser N, applied to pastoral land, at 190 kg N/ha/yr. This national regulation is in addition to any controls and regulations which are applied by regional councils.

The role of N fertiliser on pasture

Pasture legumes fix atmospheric N which drives pasture production. Maximising legume production and function requires an adequate soil nutrient status in terms of P, K, S, lime and trace elements. On more intensive pasture with high fertility status, there are periods of the year when N fertilisers, used tactically, will increase pasture production and profitability. N fertiliser is a management tool because it is a way of producing extra feed at times when animal feed requirements exceed pasture growth - in effect, N fertiliser is a form of 'supplementary feed'.

The key to profitable, tactical N use is to identify feed deficits early and apply N to increase pasture production to fill those deficit periods.

Seasonal responses

If pasture growth is being restricted by cold temperatures (i.e., below 6°C), waterlogged soils or dry conditions, then N responses will be limited. In general, pasture responses are largest and most reliable when the growth rate of pasture is greatest i.e., in mid-late spring in most regions. Autumn responses are generally smaller and less reliable than those in spring, while winter responses are lowest and the risk of direct loss of fertiliser N by leaching is greatest. Mid-to-late summer applications of N fertiliser are not recommended where low soil moisture limits growth. However good responses can occur on irrigated farms or regions which have reliable summer rainfall.

N and the environment

Where N fertilizer is used, it should be managed to ensure nitrate leaching is minimised. Nitrate leaching is minimised when there is rapid N uptake by actively growing pasture. This is obtained by not exceeding recommended application rates and applying N at the suggested times to match pasture and crop requirements. The greenhouse gas component of N fertiliser use on sheep and beef farms can be reduced by using products coated with inhibitors.

The Code of Practice for Fertiliser Nutrient Management provides clear, principle-based guidance on supplying nutrients, while at the same time avoiding or minimising losses to the environment. (See: www.fertiliser.org.nz)

Always work to the Four R's

Acknowledgments

The results in this booklet are based on comprehensive soil fertility and fertiliser research.

The work of field researchers, past and present, who have conducted field trials under the auspices of the Agricultural Research Division, MAF Technology and latterly AgResearch, is gratefully recognised.

Fertiliser Association

Shaping profitable and sustainable farming