Fertiliser Association

Shaping profitable and sustainable farming

FERTILISER ASSOCIATION OF NEW ZEALAND

# Sampling Pastoral, Arable and Horticultural Soils

The principles and practices of soil sampling

Fertiliser Association

Shaping profitable and sustainable farming

**Published by the Fertiliser Association of New Zealand**
**e-mail : info@fertiliser.org.nz www.fertiliser.org.nz**

**Edited by J.D. Morton (MortonAg), A.H.C. Roberts (Ravensdown) and I.L. Power (Ballance Agri-Nutrients)**



**First published 2024**

**ISBN:**
Print: 978-1-7385804-2-2
Electronic: 978-1-7385804-3-9

Fertiliser Association
Shaping profitable and sustainable farming

# Contents

# Introduction

New Zealand soils do not contain all the nutrients essential for pasture and crop growth in sufficient plant available amounts to meet the productivity goals of land-based food production. Soil sampling is an essential first step in assessing the amounts of available major nutrients present in soils relative to those required by the plants.

Poor soil sampling will lead to misleading information on which to base subsequent fertilisation actions, which could result in a loss of productivity and profitability, and potentially have negative environmental impacts. Informed soil sampling protocols have been developed to account for spatial and temporal variability and to minimise the variability of soil testing associated with complex biological ecosystems and varying landscapes.

This booklet sets out to recommend soil sampling methods to ensure consistency in the approach. This consistency ensures valid comparison and interpretation of repeated sampling over time. Interpretation of soil test information and fertiliser recommendations arising from this are covered in a series of booklets found at: www.fertiliser.org.nz/Site/resources/tools.aspx

# 2. Assessing soil nutrient status

## Standard soil tests

There are literally hundreds of soil test methods used in research and commercial laboratories to measure nutrients in soils. However, the results from these methods are just numbers on a page unless they can be interpreted as a useful measure to inform soil nutrient management. The tests listed below have all been well calibrated against relative pasture and crop production under New Zealand soil, climate, and farming conditions.

Capital fertiliser inputs to increase soil nutrient status can be many times greater than maintenance inputs, especially if a rapid increase in soil nutrient status is required. Therefore, it is important to measure the existing soil nutrient status to assess whether a farm is in the development or maintenance phase. Soil testing, and consideration of fertiliser history, is the most accurate way to do this. The following soil tests are available from most New Zealand commercial laboratories and 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 (SO4-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).
- **Mineral Nitrogen (Min-N)** – measures nitrate-N and ammonium-N content of freshly collected soil. It represents the N immediately available to plants at the time of sampling.
- **Anaerobically Mineralisable Nitrogen (AMN)** – measure of N mineralised under specific laboratory conditions (anaerobic incubation at 40ºC for 7 days). It represents an estimate of nitrogen that will be potentially mineralised in the field throughout the season, which will depend on factors such as soil temperature and moisture.
- **Potentially mineralisable N (PMN)** – Potentially mineralisable N estimates the contribution to plant available N from mineralisation of organic matter and is well correlated with long term aerobic incubation studies. This test is increasingly replacing the AMN test.
- **Total Nitrogen (tN)** – this test measures the total N in the soil including mineral N and organic N. It is useful in determining the Carbon: Nitrogen ratio of soils.

The target ranges for these tests vary with soils and crops and are covered in a range of booklets which may be found at
https://www.fertiliser.org.nz/Site/resources/booklets.aspx

Note: Soil testing is not best suited for identifying trace element deficiencies in pasture plants and animals because of insufficient calibration and should be treated with caution. It is better to sample relevant plant and animal tissue to gain more insight into trace element status. For more information, see: Use of Trace Elements in New Zealand Pastoral Farming
https://www.fertiliser.org.nz/download/123583/fertusetraceelements.pdf

# 3. Sampling for standard soil tests

This chapter describes protocols for sampling soils for the standard soil tests conducted at commercial laboratories. Soil sampling for nitrogen and for contaminants have additional sampling considerations and handling requirements. These are addressed at the end of this section.

## 3.1 Pastoral farms

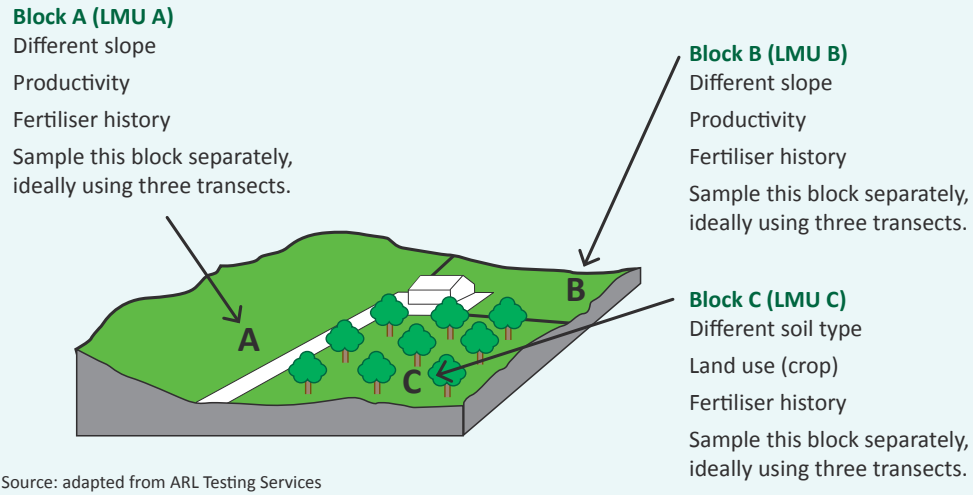
Fertiliser is a major item of discretionary expenditure on the farm, and so soil nutrient status should be monitored regularly. However, soil tests, like all biological measurements, are variable and therefore a single soil test taken at one point in time is of limited value.

Maximum advantage from soil analysis will be achieved by repeated testing over several years. In this way, a picture of trends in soil nutrient status of the farm is built up. The use of inexpensive handheld GPS units will assist in permanently identifying where soil samples are collected from, which will allow repeated sampling from the same sites each time. Taking samples 6 to 8 weeks prior to fertiliser application will allow the results of laboratory testing to be used to decide what and how much fertiliser should be applied.

### 3.1.1 Flat and rolling land

- Divide the farm into areas of similar soils, topography, management, forage type and fertiliser/lime history. These separated areas are termed land management units (LMUs) as shown in Figure 2.
- On dairy farms, effluent paddocks should be sampled as a separate LMU.

**Figure 2:** Sampling to cover different soils,slopes and management

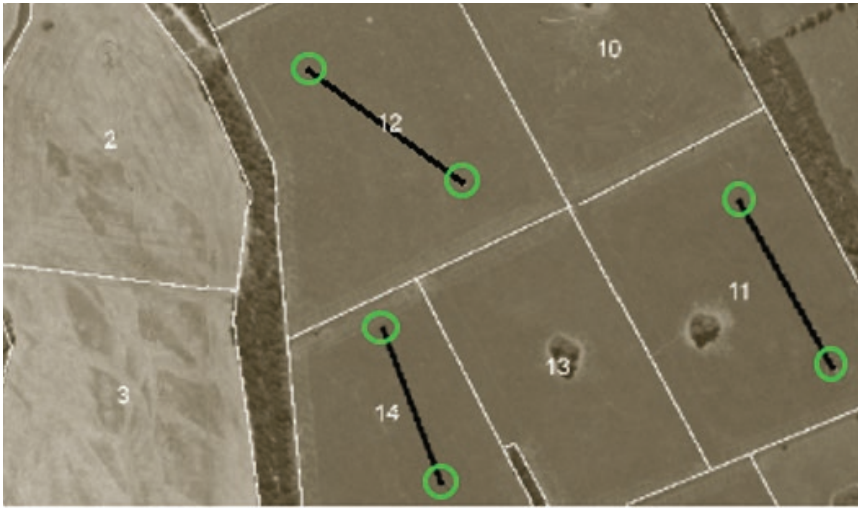



Source: adapted from ARL Testing Services

- If defining LMUs based on soil differences, the most accurate method is to use S-maps (https://smap.landcareresearch.co.nz/) or if unavailable for the area, use the Fundamental Soils Layer (https://soils.landcareresearch.co.nz/tools/fsl/maps-fsl).
- Set up sampling transects within each LMU avoiding gateways, fences, trees, hedges, excreta patches and water troughs. Ideally, at least three separate sampling transects should be set up, providing three soil analysis results for each LMU.

- Alternatively, if the farm is relatively uniform in topography and soil type, instead of identifying LMUs, set up 4-6 monitor paddocks and take one sampling transect across each monitor paddock.
- Capture the start and finish points of each transect using GPS (see Figure 3).
- For all pasture types including herbs such as plantain and chicory, collect a soil sample at 75 mm depth.
  (Except, if sampling to inform recommendations for lucerne, sample to 150 mm depth as the soil tests have been calibrated to allow for deeper rooting).
- Collect 15 or more cores, at 10 m spacing (and bulk cores into one sample bag) along each sampling transect.
- Sample every year for at least five years, to allow a trend to be established. Sampling can then be extended to every second or third year.
- Over successive years, sample in the same month each time, usually 6 - 8 weeks prior to applying fertiliser. The period from late autumn to early spring is a favourable time in which to sample as soil moisture content, which can affect soil test results, is more consistent between years.
- For each LMU, graph the average soil test results (and lowest and highest values). If monitor paddocks are used, there is one transect per monitor paddock, graph the average and the lowest and highest values for the monitor paddocks.
- Follow the soil test trends and compare to fertiliser application records, and then adjust fertiliser inputs accordingly.
- Do not sample for at least three months after application of P, K or S fertiliser or lime.
- If pasture tissue samples (representative of the livestock diet) are required, these can be collected from the same sampling transects.

**Figure 3:** Marked transects for three paddocks within a Land Management Unit of the farm.




### 3.1.2 Whole farm soil testing

Fertiliser is an expensive but necessary investment in pastoral, arable and horticultural enterprises. Soil nutrient testing is relatively inexpensive when compared to either potential increases in productivity or savings in expenditure through reduced or withheld fertiliser where it is not required.

Experience has shown there will be significant variability between LMUs and between paddocks within LMUs, despite similar fertiliser histories, even with regularly monitored, representative transects across multiple LMUs. On flat and rolling farms, in addition to routine transect or monitor paddock testing, it may be worthwhile considering sampling every paddock once every five years or so, (referred to as Whole Farm Soil Testing). This requires taking a transect sample from every paddock of the farm (including those paddocks with the regularly monitored transects). Often there will be significant numbers of paddocks below and above the target range even if the regular soil test monitoring transect results are all within the target ranges for the property. This is particularly so for soil Olsen P, soil pH and (to a lesser extent) soil Quick Test K.

Understanding the variability allows decisions to be made on a paddock scale (see Figure 4). This involves reducing or withholding either lime or P or K fertiliser, where soil test levels are above the target range, maintaining the levels for those paddocks within the target ranges and applying capital rates of P, and K fertiliser or lime on paddocks where soil Olsen P, Quick Test K or pH are below the target ranges. For example, for the farm shown in Figure 4, there were only four paddocks (shown in red) below the target range of Olsen P 20 - 30. Capital fertiliser was applied to those paddocks. Fertiliser was withheld from paddocks with high Olsen P (shown in orange) and maintenance fertiliser rates applied to the remainder (shown in green).

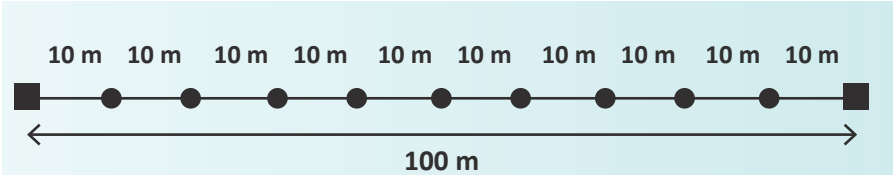
**Figure 4:** Soil Olsen P assessed for each paddock on a farm (Whole Farm Soil Testing)

### 3.1.3 Hill Country

Variability in soil nutrient status is greater in hill country, and so a modified sampling strategy is required compared to flat and rolling land.

- Divide the farm into areas of similar soils, topography, management, forage type and lime and fertiliser history. These are termed Land Management Units (LMUs).
- When LMUs are based on soil differences, then the most accurate method is to use S-maps (https://smap.landcareresearch.co.nz/) or if unavailable for the area, use the Fundamental Soils Layer (https://soils.landcareresearch.co.nz/tools/fsl/maps-fsl).
- Select three representative paddocks within each LMU and on each paddock select a typical mid-slope site across the dominant aspect. Mark out one 100 m or two 50 m long transects with permanent markers or GPS points at each end.
- Take one soil core (75 mm deep) every 10 m (see Figure 5).
- Bulk together all cores from each transect to provide one sample per paddock. The soil analysis results for each of the three monitor paddocks can be averaged to provide a single result for each LMU.
- When repeating sampling of transects in subsequent years, samples must be collected within a 30 cm radius of each 10 m mark on the transect (See Figure 6).
- Do not sample for at least three months after application of P, K or S fertiliser or lime.

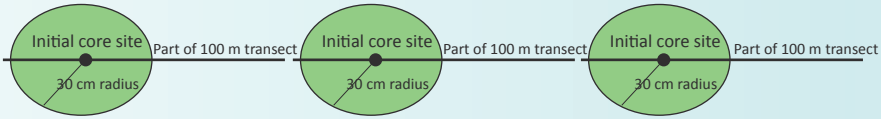
**Figure 5:** Hill country soil sampling protocol




(Marker pegs must be permanent and easily found, or plotted on GPS transects.)

**Figure 6:** Guide to selecting core sites for successive sampling along a transect

**When resampling take the sample core from within 30 cm of the original core**




- Using a 100 m tape measure or a 100 m rope with knots every 10 m will enable the soil testing personnel to achieve the accuracy required to sample each core within 30 cm of the original core.

## 3.2 Arable and fodder cropping farms

Arable farms are not generally divided into LMUs as with pastoral farms. It is much more common to sample each paddock and use this information to assist the fertiliser recommendations specific to the crop grown. Taking samples 6 to 8 weeks prior to fertiliser application will allow the results of laboratory testing to be used to decide what and how much fertiliser should be applied. For crops that are known to be pH sensitive, soil sampling for pH should be carried out 6-12 months before sowing to allow applied lime sufficient time to break down and increase soil pH.

Soil samples should be taken to 150 mm depth preferably before cultivation. Soil test target ranges for crops have been calibrated to this depth.

### 3.2.1 Transect sampling

Sampling cropping paddocks on farm:

- Identify transects, representative of the whole paddock, across cultivation lines using GPS, permanents markers of fenceposts.
- Avoid atypical areas e.g., fence lines, shelterbelts, gateways, troughs, irrigation runs.
- Use a 150 mm corer, as soil tests are calibrated to this depth, to account for cultivation of soil.
- Take 15 cores per transect and combine into one sample.
- Repeat sampling should take place at a similar time of year (preferably autumn/early winter for arable crops).
- Do not sample for at least three months after application of P, K or S fertiliser or lime.

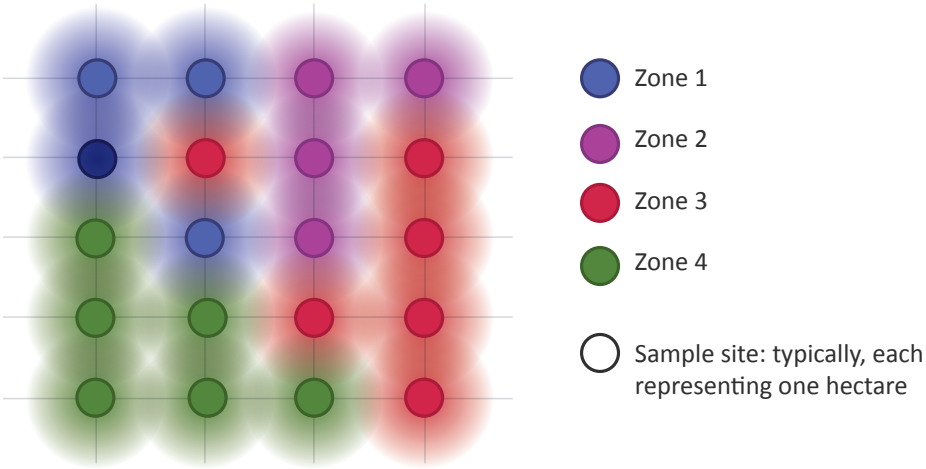
### 3.2.2 Grid sampling

Equipment which allows for precision planting and fertiliser application for crop production can be used to apply variable rates of nutrients and lime within a single paddock. To build a map of the within paddock variability, a grid sampling approach is best.

Soil sampling intensity is recommended at one sample per hectare.

- The soil sampling strategy should be exported onto a GPS unit to be used for locating sampling sites in the paddock.
- At least 15 soil cores should be taken on the circumference of a 10 m radius circle, around the GPS point (cluster sampling), and combined to give one sample per GPS point.
- The soil results are then processed to produce zones of different nutrient status or pH within paddocks (see Figure 7).

**Figure 7:** Example showing the zones developed following grid sampling.




### 3.2.3 Sampling for soil nitrogen

Soil nitrogen is mostly sampled and analysed for cropping land-use, with sampling at paddock scale. As per the cropping sampling protocols, take 12 - 15 cores per paddock in transects or grids. Keep away from gate areas, stock camps and suspected urine patches if sampling a mixed cropping enterprise.

- Sampling depth will depend on which soil N tests are to be undertaken.

- Typically sampling depth for Mineral N (Min-N) tests are at a range of depths, 0-150 mm, 0-300 mm or often to 600 mm.

- Typically sampling depths for Anaerobically Mineralisable N (AMN) tests and Total N tests for cropping are to 0-150 mm. The Potentially Mineralisable N (PMN) test is calibrated to 0-150 mm and 0-300 mm. Depth will depend on crop type.

- Samples should be frozen and placed into an insulated container to minimise mineralisation occurring in the sample while in transit to the laboratory.

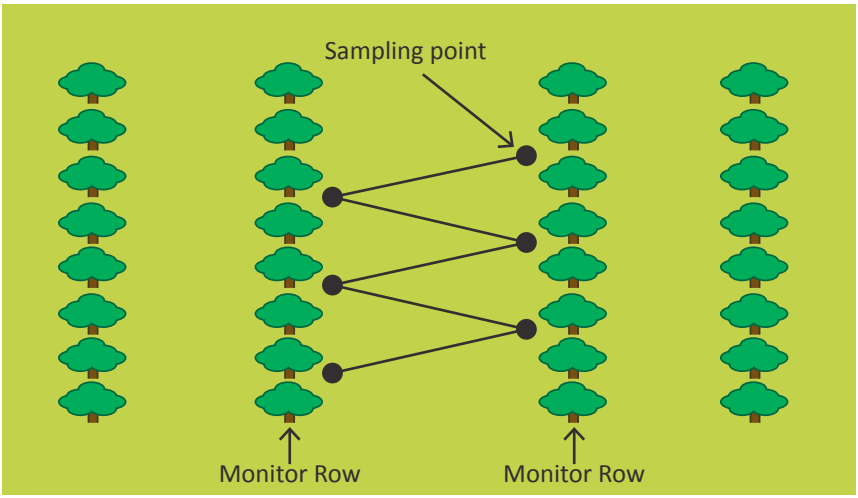
- Samples should arrive at the laboratory at less than 10°C, preferably in less than 48 hours.

## 3.3 Horticultural blocks

For permanent tree or vine blocks, soil sampling requires a slightly different pattern of sampling. In the case of horticultural blocks, a LMU will be based on the crop grown. Soil sampling should consider:

- Identifying monitor rows to be sampled for each LMU.
- Identifying representative transects within each pair of monitoring rows (see Figure 8).
- Soil samples should be taken using a 150 mm corer.
- Take 15 cores across each transect representing two monitor rows. Cores should taken within the dripline or root zone of the crop. The 15 cores taken across the transect should be combined for a single analysis (see Figure 8).
- Avoid atypical areas e.g., shelterbelts, gateways, irrigation runs.
- Repeat sampling at a similar time each year.
- Do not sample for at least three months after application of P, K or S fertiliser or lime.

**Figure 8:** Sampling for a permanent tree or vine block.




Source: adapted from ARL Testing Services

# 4. Soil sampling for contaminants

If assessing contaminant trace elements in soil, such as cadmium, it is important to ensure additional contamination is not inadvertently introduced to the soil sample. Therefore:

- Hands and materials used should be clean as they may contaminate sampling equipment.
- Stainless steel corers should be used. Materials which are galvanised or zinc plated risk contaminating samples.
- Do not sample old dump grounds and sites where chemicals may have spilled.
- Do not sample unrepresentative areas such as dung patches, stock campsites, fence lines, gateways, troughs, power pylons.
- Consider whether herbicide/pesticide spray areas should be treated as a separate block.
- For a screening sample on pastoral soils, sample to 75 mm. For cropping or horticultural soils sample to 150 mm depth.
- Do not sample for at least three months after application of P, K or S fertiliser or lime.

For more information on the 'Tiered Fertiliser Management System for Soil Cadmium' see: https://www.fertiliser.org.nz/Site/resources/tools.aspx

# 5. Assessing soil health or quality

Soils differ significantly in their soil chemical, physical and biological properties and the interactions between them are key to soil ecosystem function and health. This booklet concentrates mainly on measuring soil chemical properties because the methods are calibrated to pasture and crop production and any deficiencies can be rectified by the application of fertiliser nutrients and lime. However, if a soil is compacted through treading for example, then soil health or quality and hence plant growth will be reduced despite soil test levels being in the target range.

Optimum soil function relies on much more than just nutrients. Other observational or comparative measurements need to be made to fully establish the ecosystem functioning of our farmed soils.

There are many approaches which can be taken to assess soil health and there is no universally accepted methodology due to a diversity of landscapes and land uses in which they need to be applied.

The physical structure of the soil is important to allow water to percolate into and drain through the soil and allow gases such as nitrogen, oxygen and carbon dioxide to diffuse. The breakdown of soil structure e.g., through soil compaction, will detrimentally affect soil function and plant production and no quantity of nutrient additions will overcome this physical limitation. The soil needs to be physically remedied or managed differently after the cause has been identified to prevent reoccurrence.

The physical status of a soil is best monitored using the Visual Soil Assessment method field guides (Volumes 2 and 3)[1] where soil structure, porosity and texture are scored individually and summed to give an overall assessment of soil physical status.

[1] https://www.landcareresearch.co.nz/assets/Publications/VSA-Field-Guide-/VSA_Vol2.pdf
https://www.landcareresearch.co.nz/assets/Publications/VSA-Field-Guide-/VSA_Vol3.pdf

The soil provides a habitat for a wide diversity of organisms including microorganisms such as bacteria, fungi, viruses, archaea, nematodes, arthropods, and protozoa, through to macrofauna such as earthworms and other invertebrates. These organisms also contribute to a diversity of processes and functions that underpin the delivery of ecosystem services provided by the soil. Despite the importance of soil biology having long been recognised, there are still large gaps in our knowledge. While earthworm abundance and diversity of species and functional roles are used to indicate biological soil health, other indicators are also used overseas such as microbial respiration, insect pest abundance and plant disease risk. While genera and taxa of soil organisms can be measured including bacterial to fungal ratios there is little to no calibration, yet, of these against productive capacity and health of the soil.

## Notes

Fertiliser Association
Shaping profitable and sustainable farming

# Notes

## Notes

## Always work to the Four Rs


## 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), MAF Technology and latterly AgResearch, is gratefully recognised.

Fertiliser Association

Shaping profitable and sustainable farming