Soil Fertility, Testing and Interpretation

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Abstract

Soil tests are a simple and inexpensive method of identifying the fertility status of particular paddocks or blocks on a farm. While some soil tests measure plant available nutrient reserves (e.g. Olsen P, sulphate S), others describe a basic soil characteristic (e.g. pH) or assess how a soil will react with added nutrients (e.g. CEC, P retention). Most laboratories offer a number of standard soil tests plus a range of optional extras. The critical importance of correct soil sampling procedure is discussed and examples given of the effect of sampling error on the results obtained. Because soil test results are naturally variable, trends in test levels over time are considered to be more accurate indicators of fertility status than are individual values obtained in a single year. The AgResearch "biological optimum" soil test levels for near-maximum pasture production are presented for each of the major soil categories (sedimentary, ash and pumice). The difference between biological optimum and economic optimum soil test levels is explained, and the role of the AgResearch fertiliser decision support models in the assessment of pastoral fertiliser requirements is briefly discussed.

Introduction

Soil fertility management begins with identification of which nutrient or nutrients are required to maintain or improve pasture or crop productivity. General information on the nutrient status of individual soil groups provides a useful preliminary indication of which nutrients are likely to be required. This is because the nutrient status of soils was originally, and to some extent still is, influenced by the composition of the soil parent material and the other soil forming factors.

Of course, once land is developed for agriculture, the application of fertilisers and other management practices inevitably change the nutrient status of the soil considerably. Different farms on the same soil, and even different paddocks on the same farm, therefore acquire a wide range of fertility levels. It is for this reason that we need simple and inexpensive methods of identifying the fertility status of particular paddocks or blocks on a farm. Soil testing is the most widely used of these methods.

Soil Testing

For most of us the term 'soil testing' means the measurement of plant available nutrient reserves in a soil, usually involving one or more chemical extractions. Typical examples include the tests for Olsen P, sulphate S, organic S, and the exchangeable (Quick Test) cations. Other tests describe a basic characteristic of the soil (e.g. pH, which is a measure of soil acidity) or assess ways in which the soil will react with added fertiliser nutrients (e.g. Anion Storage Capacity (P retention), CEC).

Soil tests are only useful if they have been 'calibrated' against pasture or crop growth. This involves conducting trials on a wide range of sites and in different years so that the relationship between pasture growth and soil test level for a particular nutrient can be determined. The calibration curve, as it is sometimes called, makes it possible to predict the likelihood of response to added nutrient at particular soil test levels.

Sampling Procedure

The most crucial step in the whole soil testing process is collecting the samples. I say 'crucial' because one of the greatest sources of 'error' in soil testing arises from natural soil variability and the difficulty of obtaining a representative sample. There are two main ways of minimising the effect of soil variability.

The first is to divide the farm into areas (or blocks) of similarity (based on soil type, topography, fertiliser history, etc), each of which should be sampled separately. As a general rule, it is better if a block sample is taken across several paddocks than from a single paddock representing that block. This is because individual paddocks vary in their soil test levels, especially on flat land, so a sample collected across several paddocks gives a better average for the whole block. On the other hand, it is appropriate to sample individual paddocks if the purpose is to identify a problem with a particular paddock or the paddock is to be tested prior to cropping, etc.

Having selected the block to be sampled, the second way of minimising variability is to avoid taking any soil cores from areas of atypical fertility such as stock camps, and around gateways, troughs and trees. These areas are often very fertile due to a long history of high dung and urine returns. In hill country in particular, stock camps which are not recognised as such are a major cause of erroneous soil test results. A useful rule of thumb when sampling hill country is to take samples from slopes only and, within a hill face, to only select spots for sampling which are of average slope (Figure 1).

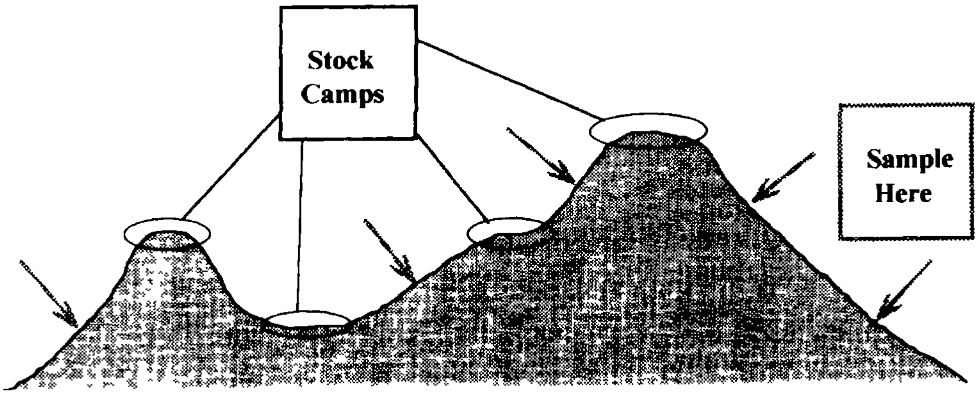

Figure 1. *Example of identification of stock camps, and the recommended sites for soil sampling designated by arrows*

The failure of inexperienced operators to recognise stock camps can greatly inflate soil test results, at least for P and K. During my first few years with Ravensdown, I re-sampled a number of hill country blocks after farmers had obtained surprisingly high Olsen P levels in samples they had collected themselves. Figure 2 shows the marked differences between some of these "farmer sampled" results (initial sample) and those for the same areas subsequently sampled by myself (second sample). Equally marked differences were found for potassium (Figure 3) but not for sulphur (Figures 4 and 5) or soil pH. These results clearly show the major effect that this type of sampling error can have on P and K soil test levels, emphasising the importance of not sampling any area remotely resembling a stock camp.

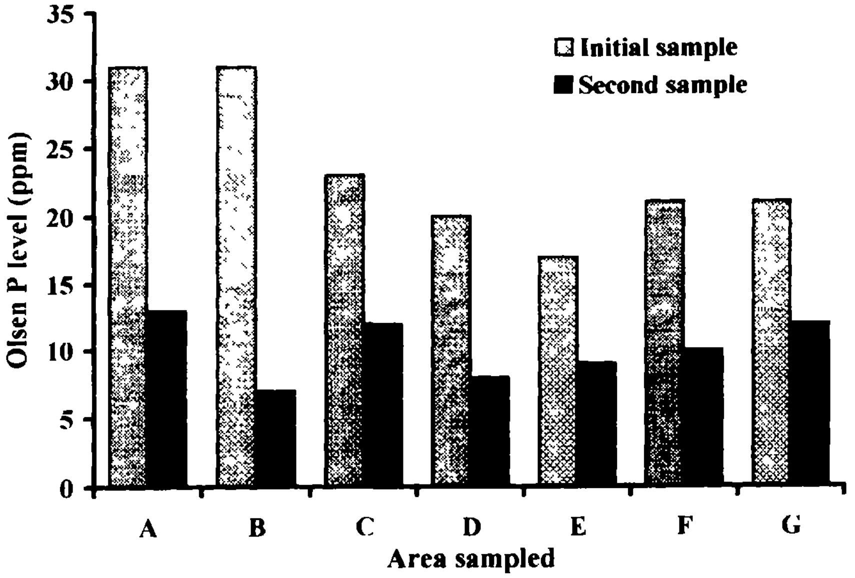

Figure 2. *Demonstration of sample variation on phosphorus The initial sample was collected by the farmer while the second was collected by an experienced soil scientist*

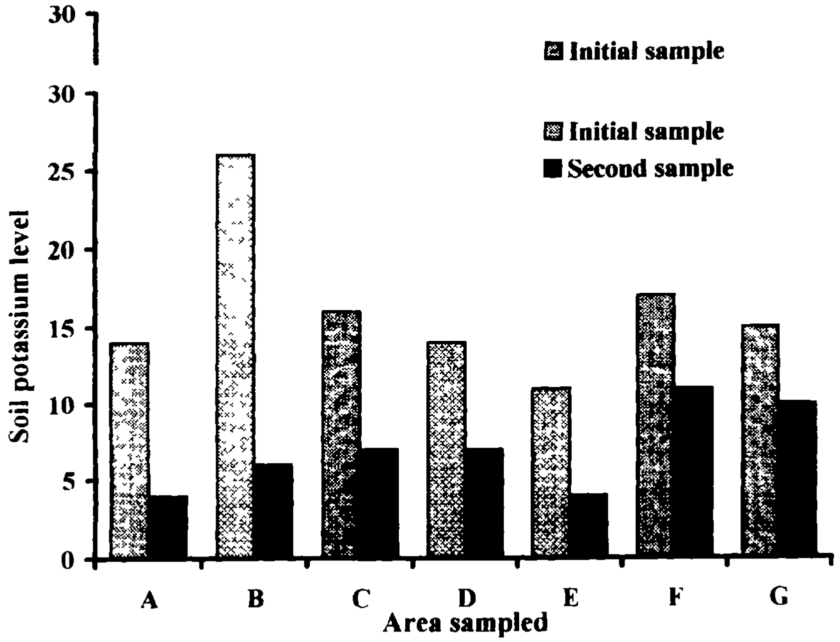

Figure 3. *Demonstration of sample variation on potassium The initial sample was collected by the farmer while the second was collected by an experienced soil scientist*

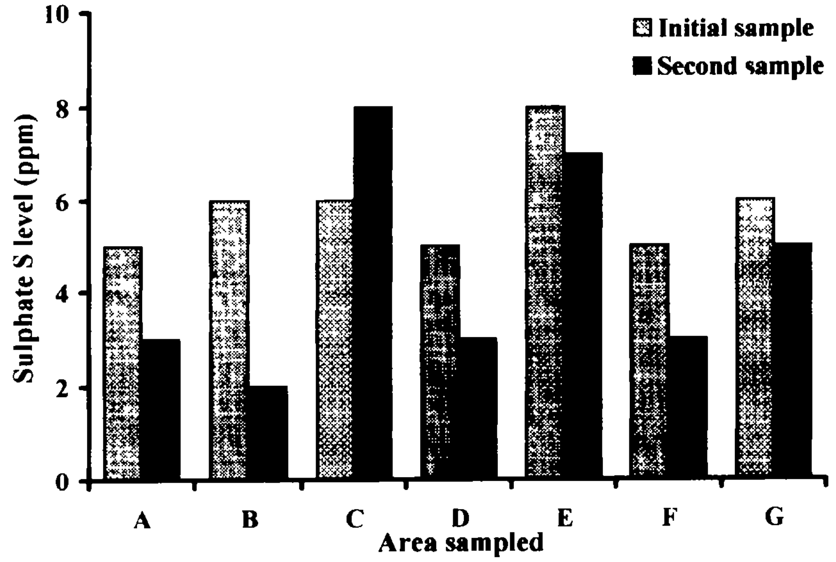

Figure 4. *Demonstration of sample variation on sulphate The initial sample was collected by the farmer while the second was collected by an experienced soil scientist*

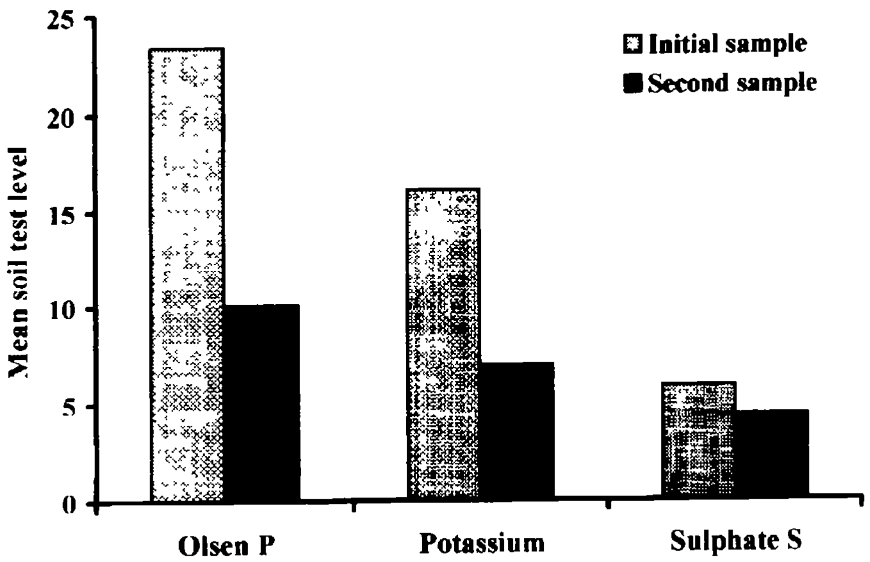

Figure 5. *Farm mean phosphate potassium and sulphate in samples collected by the farmer (initial sample) and an experienced soil scientist (second sample)*

One way of avoiding such problems is to set up carefully selected sampling transects with the assistance of an experienced operator. Samples can then be collected along the same transect line each time. Even greater precision may be possible through the use of a tape measure by sampling at fixed intervals, e.g. every 10 m, along the transect. This is the basis of a hill country soil sampling protocol developed by Ravensdown Fertiliser in conjunction with AgResearch.

On flat land there is less need to use sampling transects because paddocks are usually smaller and there is less spatial variability. Also permanent markers tend to be more of a nuisance in flat paddocks. For this reason it is probably best to use posts in existing fence lines as markers if a transect sampling system is used on flat land.

Since soil test levels may fluctuate depending on the time of year, it is preferable that sampling occurs at about the same time each year. Also, as much time as possible (preferably 6 months or more) should have elapsed since fertiliser or lime was last applied to the area being tested to ensure soil test levels have settled back to a stable level. Under dry conditions, applied fertiliser can continue to directly influence soil test results for several months.

Each soil sample, whether it be from a single paddock or a block comprised of several paddocks, should consist of at least 15 cores (this is the minimum). The Ravensdown hill country soil sampling protocol recommends taking 9 cores from each of three 100 m transects, giving a total of 27 cores per sample. Each transect would normally be in a different paddock of the same block.

Sampling to the correct depth is also important. Cores must be taken to a depth of 75 mm in pasture and 150 mm in arable land. Cores shorter than 75 mm will give high test results for pasture while longer cores will give low results. Although I prefer to remove excess herbage from the top of the cores, this is not essential as the weight of the herbage is small compared to the weight of the soil after the sample has been dried in the laboratory.

Once samples have been collected, they should be despatched promptly to the testing laboratory, or kept cool (preferably in a fridge during summer) until able to be despatched. Using the same testing laboratory each time will help to minimise analytical variation

Interpreting Results

Most commercial soil testing laboratories measure soil pH, Olsen P, sulphate S and the exchangeable cations (calcium, magnesium, potassium, sodium) as part of a standard soil test. Some also supply results for bulk density (not to be confused with field bulk density), cation exchange capacity (CEC), as well as % base saturation data. Optional "extras" usually include:

- Organic S – a measure of the long-term supply of S (recommended for pastoral samples).
- Resin P – an alternative test for available P, particularly in soils with a history of RPR use.
- Tetraphenyl Boron K (TBK) – a measure of the K supply including slowly-available reserves often prevalent in young and weakly weathered soils.
- Anion Storage Capacity (ASC) – a measure of the capacity of a soil to store nutrients such as P and S (previously referred to as phosphate retention).

Soil tests, like all biological measurements, are variable, some more so (e.g. those for K and S) than others (e.g. soil pH and tests for Ca and Mg). For this reason, the trends in soil test levels recorded over a number of years (see Figure 6 for an actual example) are generally regarded as more accurate indicators of the nutrient status of a block than are the individual values obtained in a single year. Soil test trends over time can also be related to farm or block productivity patterns over the same period

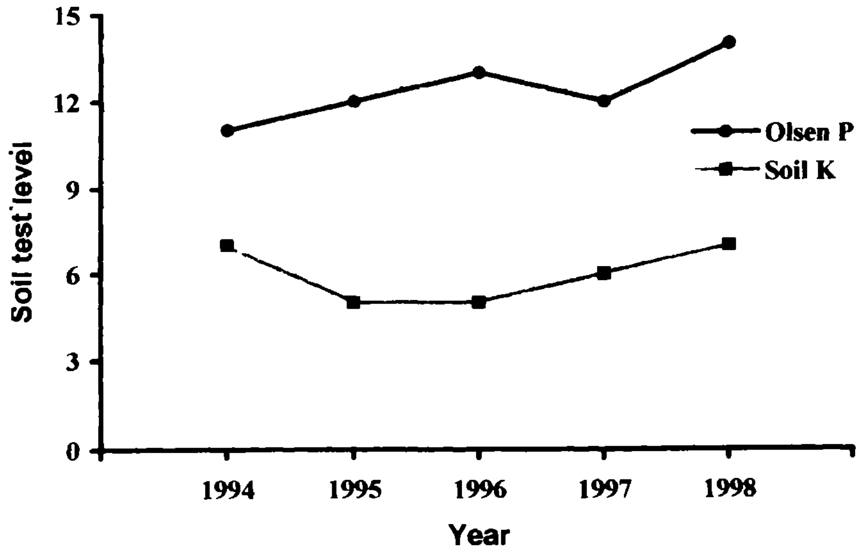

Figure 6. *Annual recording of soil elements to demonstrate trends which can be a useful aid to determining fertiliser application needs, as well as providing a more meaningful picture of soil element status*

Table 1 shows the range of values for near maximum pasture production for the tests most commonly used in making fertiliser recommendations. For some of the tests the range of values is different for different soils. Sedimentary soils include all those derived from sedimentary materials such as sandstone, mudstone, greywacke, recent alluvium and even wind-blown sand.

Table 1: AgResearch soil test ranges to achieve near maximum pasture production (adapted from Morton et al. 1994).

Soil Test	Soil Parent Material		
	Sedimentary	*Ash*	*Pumice*
pH	5.8-6.0	5.8-6.0	5.8-6.0
Olsen P	20-25	20-30	35-45
Sulphate S	10-12	10-12	10-12
Organic S	15-20	15-20	15-20
Quick Test K	5-7	6-8	6-8
Quick Test Mg	8-10	8-10	8-10

The soil test ranges shown in Table 1 are sometimes referred to as the "biological optimum" levels. For a particular nutrient, soils which test below the optimum range will generally respond to that nutrient providing other factors such as drainage, pasture species, management and other nutrients are not limiting. Conversely, in soils testing above the optimum range, nutrient deficiency is not significantly limiting pasture growth and responses are unlikely.

Although the soil test range required to achieve near maximum pasture production is given as a bench mark, this may not be economically relevant for all farms, especially in hill country. In general, as the gross farm income per hectare increases, the economic optimum soil test level comes closer to the biological optimum. However, even at low gross margins, modest rates of fertiliser use can be economic.

Fertiliser Requirements

AgResearch has recently released the latest version of it's computerised fertiliser decision support software which now includes models for lime and potassium in addition to phosphorus and sulphur. Using information applicable to a particular farm or blocks within a farm (Table 2), the models calculate nutrient requirements by estimating annual nutrient losses and non-fertiliser nutrient inputs. The lime model predicts responses to each of three rates of lime application.

Table 2: **Types of information required for generating nutrient recommendations using the AgResearch fertiliser decision support models.**

Soil group (e g sedimentary, ash, pumice)
Slope category (e g flat, rolling, easy hill, steep hill)
Soil test values (for Olsen P, organic S, Quick Test K, Quick Test Mg, soil pH)
K leaching rate (e g low, medium, high, very high)
Hay or silage yields
Stock class (e g sheep, sheep & beef, beef, intensive beef, deer, intensive deer)
Stocking rate
Gross margin per stock unit
Fertiliser nutrient and lime costs
Fertiliser spreading cost
Recent sulphur fertiliser history

The programme can create various scenarios, including "zero" (nil fertiliser), "maintenance" and "optimum". Maintenance in this case means maintaining the current production and soil test levels, whereas the optimum scenario uses economic information to determine the strategy which will maximise long run economic returns. This strategy first changes the fertility level to the optimal value (with capital inputs or by withholding fertiliser), then maintains fertility at this point.

The developers of the programme point out that it should not be used to provide black and white answers for a particular farm. This is because the relationships used in the models are based on measurements from relatively few experimental sites and it is unreasonable to expect that they will apply to every farm in the country given the large variability in soil and climate factors that exist. Instead the programme should be used together with specific farm factors and local knowledge to come up with a recommendation that should only be regarded as a starting point to be checked with on-farm monitoring and amended if necessary.

References

Morton, J , Roberts, A H.C., and Edmeades, D C. 1994 Fertiliser use on sheep and beef farms NZ FMRA 38 p