Soil Fertility – You can't manage what you don't measure

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Abstract: *The pH of many southern NSW soils under pastures has been reducing slowly due to nitrate leaching due to the addition of sub clover and increased product removal. Also, since the 1990s the amount of fertiliser applied to grazing pastures has declined. 252 soil samples from the South Coast, Southern Highlands and Southern Tablelands of NSW were tested for* pH_{cacl}*, Colwell phosphorus, sulphur (KCl40) and exchangeable potassium. The Southern Tablelands had the most soils with below optimum levels of pH (61%), phosphorus (56%), sulphur (65%) and potassium (33%). On the other hand, some of the South Coast and Southern Highlands soils had test levels in excess of the desirable amount (22% of phosphorus, 7% of sulphur and 26% of potassium tests). Farmers should be encouraged to regularly monitor their soils and apply adequate quantities of fertiliser to suit their enterprise.*

Key words: soil sampling, interpreting soil tests, soil nutrients, fertiliser

Introduction

Taking measurements and record keeping is not something new to farmers. The most commonly asked question after a rainfall event is "how much rain did you get?" Farmers will discuss calving and lambing percentages, weaning weights, numbers of wool or hay bales produced, recent prices at the sales yards. However, many farmers do not appear to have the skills to be able to match soil fertility to pasture production and animal needs. Farmers may not ask for help until there is an obvious problem with a pasture, their livestock or farm profitability. Since the introduction of sub clover and superphosphate in the 1920s (Bayley 1951), pH declines in the order of 5.2 to 4.2 over 50 years in soils in the Southern Tablelands have been recorded (Williams 1980). This has resulted in poor nodulation due to unsuitable pH for ryzobia, which has subsequently led to reduced pasture production and reduced survival of legumes (Hackney *et al* 2017, Norton *et al* 2019).

In addition, fertiliser use has been declining in the region, with many farms having no fertiliser applied for decades (Johnson 2012). Burns *et al.* (2014) reported a national downward trend in fertiliser application to pastures since the late 1990s except in the dairy industry. It was also reported that the majority of livestock producers from the wider population are making fertiliser decisions in the absence of soil test information. Problems caused by deficiencies as well as some complex interactions between nutrients are being recorded. This year producers in the Central and Southern tablelands experienced cattle losses due to grass tetany, a disorder that can be caused by an imbalance of potassium and magnesium in pastures (Watt 2021). Johnson and Watt (2011) reported phosphorus deficiency in cattle and Johnson (2012) investigated lameness and ill thrift in sheep grazing unfertilised, phosphorus deficient pastures in the Central and Southern Tablelands.

There are many tests available to provide information on the physical, structural and chemical properties of soils. These tests and the recommendations made from them have been developed following many decades of research. However, some farmers do not trust the results. In a survey conducted by Burns *et al* (2014) it was reported that 16% of the respondents "lacked confidence in the accuracy of soil tests".

Other forms of monitoring pastures and soils can be implemented. Soil pH test kits, nutrient budgets, fertiliser test strips or window plots and visual observations can all guide fertiliser use in the absence of soil tests. It should also be noted that relying on any of these techniques without soil testing may not provide reliable information to guide fertiliser use.

This paper investigates the degree and extent of low pH and nutrient deficiencies and excesses in soils that have resulted from the change of use of fertiliser and categorises the results from soil samples taken from the high rainfall zone (above 650mm) of eastern New South Wales. The suggested criteria for optimum, deficient and excessive nutrient levels are taken from the NSW DPI booklet *Fertilisers for Pastures* (Havilah *et al.* 2006) and as described by Gourley *et al.* (2019). I will also discuss the importance of nitrogen in pastures and how to reduce the impact of nitrate leaching on pH decline in soils.

Methods

Results from 252 soil tests from surface (0–10 cm) soils from farms in the South Coast (n=131), Southern Highlands (n=64) and Southern Tablelands (n=57) were evaluated. Samples are from various sources including natural resource management projects and private clients. There were a large variety of farms represented in this survey covering properties running a variety of livestock (sheep, cattle, goats and horses) and sizes from small holdings to large sheep, dairy and beef properties.

The soil samples were analysed at NATA accredited laboratories (NSW Department Primary Industries, Wollongbar or Nutrient Advantage, Werribee) measuring pH (1:5 Ca_{Cl}) and available nutrients phosphorus (Colwell), sulphur (KCl40) and potassium (exchangeable cation).

Results

pH

Table 1 shows the trend for a low pH is evident in the soils in the Southern Tablelands with 37% of samples having pH values below 4.5 compared to 7% on the South Coast and 16% in the Southern Highlands. The lowest value for pH in this data set was 4.0 for the Tablelands and Highlands soils and 4.4 on the coast. Only 8%, 5% and 16% of samples tested in the South Coast, Southern Highlands and Southern Tablelands respectively had pH values above 5.5.

Phosphorus (Colwell)

The proportion of soil tests with phosphorus results below the optimum level for pasture production is high for all regions (Table 2). The South Coast, Southern Highlands and Southern Tablelands recorded 42%, 34% and 56% of samples with a Colwell Phosphorus result below 30 mg P/ha. The lowest value measured in this study was less than 5 mg P/ha.

High phosphorus use was evident on the South Coast and Southern Highlands with 22 % of samples exceeding 100 mg P/kg. Of these, five samples on the South Coast and four in the Southern Highlands exceeded 300 mg P/ha. Only 2% of samples in the Southern Tablelands exceeded 100 mg P/ha, the highest value was 110 mg P/ha.

Sulphur

The proportion of tests with extractable sulphur levels below 5 mg S/kg were 6%, 19% and 37% for the samples in the South Coast, Southern Highlands and Southern Tablelands respectively. A further 28% of samples in the three regions had results between 5.1 and 8 mg S/kg with these soils requiring some input of a sulphur fertiliser (Table 3).

There were some extremely high (>100 mg S/kg) results from the South Coast which could indicate acid sulphate soils may be present deeper in the soil profile.

Potassium

Table 4 shows that one third of the soils tested in the Southern Tablelands were below the optimum level of 0.3 cmol (+) K/kg. Five percent of coastal soils and nine percent of soils in the Southern Highlands were found to have results below optimum.

A large proportion of soils had excessive potassium levels. On the South Coast 20% and the Southern Highlands 26% of soils had results above 1 cmol (+)/kg, with results as high as 3.4.

Discussion

Soil testing is a valuable tool to better manage pastures for the grazing industries. Farmers can be confident that the results from a soil test are accurate, as long as the soil used for testing is representative of the soil in their paddock. Samples taken accurately to 10 cm, while avoiding potential hotspots (camps, manure, around gates and water troughs and old fertiliser stockpiles) and tested at a NATA accredited laboratory, will provide an accurate measure of the nutrient levels in soil.

Interpretation of soil tests can be confusing for most land holders. Natural resource management courses such as Landscan and Five Easy Steps have been operating since the early 2000s. These courses have been designed to train farmers to interpret soil test and match soil fertility to production outcomes. These courses have had a positive response from farmers with many indicating they will change their fertiliser program in the future (Leech *et al.* 2021).

Once a nutrient deficiency is identified, the amount of fertiliser needed to raise the fertility of the soil to an optimum level can be calculated. Considerations such as cost, livestock and environmental safety, ease of application, availability of equipment or environmental limitations should be taken into account when choosing the product or products to be applied.

Application rates will depend on the properties of the soil (eg phosphorus buffer index or texture) or the intensity of the enterprise. The advice is usually based on bringing the soil fertility to the optimum level for almost maximum production of fertility responsive pasture species. However, these recommendations may not always suit the desired outcome. Pastures based on fertility-intolerant species such as Themeda triandra have a lower fertility requirement than improved pastures (Mitchell 2019). A low input, low output system may suit some farmers but this could lead to nutrient deficiencies in their livestock, so monitoring soil nutrient status should remain a priority.

Correcting pH requires the application of a liming product such as superfine lime. The amount will depend on soil texture. To raise the pH from 4.2 to 5.2, a light sandy soil requires 1.5 tonnes of lime / ha but a heavy clay will require 4 tonnes/ha to achieve the same outcome. Other products such as dolomite or sewage ash will also raise the pH of a soil.

Table 1: Frequency distribution and range of soil pH_{cacl} across different districts

	Soil pH_{cacl}					
District	**<4.5**	**4.5–4.8**	**4.9–5.1**	**5.2–5.4**	**>5.5**	**Range**
South Coast	7	33	34	18	8	4.0–6.2
Southern Highlands	16	38	36	20	5	4.4–5.6
Southern Tablelands	36	25	14	9	16	4.0–6.3

Table 2: Frequency distribution and range of Colwell Phosphorus across different districts

	Phosphorus (Colwell) **mg/kg**				
District	**<30**	**30–50**	**51–100**	**>100**	**Range**
South Coast	42	22	14	22	5.0–380
Southern Highlands	34	25	19	22	6.7–440
Southern Tablelands	56	25	17	2	7.8–110

Table 3: Frequency distribution and range of sulphur across different districts

	Sulphur (KCl40) **mg/kg**					
District	**<5**	**5–8**	**8.1–12**	**13–60**	**>60**	**Range**
South Coast	6	28	35	24	7	2.6–470
Southern Highlands	19	28	31	22	0	2.8–39
Southern Tablelands	37	28	19	16	0	2.5–23

Table 4: Frequency distribution and range of exchangeable potassium across different districts

	Extractable Potassium cmol(+)/kg					
District	**<0.2**	**0.2–0.3**	**0.31–0.6**	**0.61–1**	**>1**	**Range**
South Coast	1	5	47	27	20	0.18–2.8
Southern Highlands	2	7	41	24	26	0.18–3.4
Southern Tablelands	12	21	42	23	2	0.12–1.3

Nitrogen is one of the most important nutrients for pasture production but surface soil tests for are a poor indicator of nitrate levels. To avoid nitrogen being leached below the root zone, nitrogenous fertilisers need to be applied to moist soils to pastures that are actively growing.

There are three key strategies to ensure that pastures are supplied with nitrogen:

- No fertiliser, relying on pasture nitrogen being supplied from legumes. This method is suitable for low to moderate stocking rates.
- High fertiliser, used for high stocking rates such as dairy farms. Nitrogen is applied after every grazing or every second grazing while pasture is growing. This strategy is also useful if legume populations are low.
- Strategic fertiliser nitrogen use relies on pasture nitrogen being supplied from adequate legume populations when the soil temperature is above 10°C at 10 cm depth but fertiliser nitrogen is applied to fill short term feed gaps when the soil temperature is between 5 to 10°C.

Clover can contribute about 150 kg N/ha per year (Brogden and Miller 2017) if the soil has a pH is suitable for the rhizobia population and essential nutrients are in adequate quantities (Hackney *et al.* 2017). If choosing the high or strategic use of nitrogen fertiliser, it is important not to exceed 40 kg N/ha in each application, except when using an organic form of fertiliser, which releases nitrogen more slowly into the soil.

Nitrogen from fertilisers and clovers has an acidifying affect on soils, so monitoring soil pH is essential. Some nitrogenous fertilisers, such as ammonium sulphate and mono-ammonium phosphate (MAP), are more acidifying than others, for example urea and poultry litter, so this should be considered when choosing a fertiliser.

The optimum level of Colwell phosphorus is between 30 to 50 mg P / ha but this depends on the phosphorus buffer index (PBI) of the soil. Levels as high as 70 may be more suitable for very high production from nitrogen fertilised, irrigated soils. To correct soils deficient in phosphorus, application rates for soils with a PBI between 50 and 300 require about 20–40 kg P/ha to raise the Colwell test value by 10 units, which is equivalent to 230–460 kg superphosphate/ha.

Excessive phosphorus fertiliser application was evident in 22% of paddocks in the South Coast and Southern Highlands with values as high as 440 mg/kg Colwell P. These pastures do not require further phosphorus fertiliser until soil test levels drop to the optimum level.

The optimum result for the sulphur KCL40 soil test is between 8–12 mg S/kg, however a response to additional sulphur may not be evident if the result is between 5 to 8. More than 50% of paddocks tested in the Southern Tablelands were deficient in sulphur. These low sulphur levels appear to be linked to the reduction in the use of fertilisers containing sulphur, especially superphosphate. The application of 15 kg sulphur/ha is required on a sandy loam soil with an extractable sulphur (KCl40) test result less than 5 mg/kg, while 10 kg S/ha is required if the test is between 5 to 10 mg S/kg. Superphosphate applied at 145 kg/ha or 100 kg/ha gypsum will supply 15 kg S/ha.

Coastal soils with sulphur levels exceeding 100 mg/kg may require additional testing to determine if acid sulphate material is present. It is advisable to seek specialist advice when excessive sulphur is identified.

Soils most likely to be deficient in potassium are sandy and light textured and low in organic matter. A surprisingly high proportion of soils reported here were low in potassium. Removing product such as wool, hay or silage and the relocation of dung and urine to stock camps from the more productive parts of a paddock are all responsible for reducing potassium levels in soils.

An application of 60 kg of muriate of potash to a non-irrigated pasture is required to correct the deficiency of a soil with an exchangeable potassium soil test result below 0.2 cmol (+) /kg. Higher application rates are required for irrigated lucerne and dairy pastures and following hay and fodder conservation.

About one quarter of soils tested in the South Coast and Southern Highlands had high levels of potassium. Most of these came from dairies or former dairies in paddocks where animals have been yarded or following the use of dairy effluent and reclaimed sewage water. High potassium levels in pastures can cause animal health issues such as grass tetany and milk fever. Harvesting hay or silage will reduce soil potassium levels but monitoring potassium levels is essential if choosing this strategy.

To reduce the risk of high uptake of potassium by pastures and associated health disorders, avoid applying potassium fertilisers in early spring and at calving in seasonal herds. Split autumn and late spring applications are recommended in high rainfall areas or when high rates are applied. For best results apply potassium fertilisers to moist soils.

Conclusions

If graziers accurately sample their soils and monitor its fertility by regular testing, they will be able to apply the correct amount of fertiliser for their enterprise. This will have many benefits to productivity, animal health and the environment. Natural resource management programs such as the Landscan and Five Easy Steps program and more recently the Better Land Management Practices project are a valuable source of training for landholders to gain soil test interpretation skills. Farmers need to have confidence that consultants and resellers are providing accurate and relevant advice and recommend cost effective products that will provide the correct amount of nutrient to soils.

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