Holbrook Landcare Network Soil Monitoring of Acid Soils Project

Key points

- Current liming practices are not addressing the current acidification rate.
- 86% of paddocks that have been limed in the last 5 years have pHCa levels above 5.0 in the surface but are moderately to severely acidic in the subsurface layers below 5 cm.
- Soil testing should be conducted around the same time of year in order to monitor changes in soil properties. This is necessary to minimise the natural variability that can occur between seasons in soil pH and exchangeable aluminium values.
- When monitoring trends in soil pH, sampling intervals of 5 cm to a depth of 20 cm are recommended.

Introduction

The aim of the 'Soils Monitoring of Acid Soils Project', funded by Murray Local Land Services, is to monitor changes in soil pH and fertility over time at selected sites across the Murray region and consider the management practices that have influenced these changes. This project is a follow on from the 2017 'Sub Clover Nodule Health Project' that collected baseline soil data and assessed the nodulation status of pasture legumes from 40 GPS located sites sampled in September 2017. In Mach 2020, 31 of these sites were resampled to monitor changes in soil properties. The nodulation status of legumes was not assessed in this project, due to the unfavourable seasonal conditions in 2019.

The 'Soils Monitoring of Acid Soil Project' is one of several acid soil related projects that sits under Holbrook Landcare Network's 'Acid Soils Program'. This program is investigating the extent and severity of acid soils.

Methodology

A total of 31 GPS located sites across 20 different farms between Burrumbuttock and Tumbarumba were sampled in March 2020. (Note - the sampling originally scheduled for spring 2019 was not achievable). Surface and subsurface soil samples were collected within a 10 m radius of the GPS point identified in 2017, using a 20 mm probe and bulked for 0 – 5, 5 – 10 and 10 – 20 cm depth intervals. The samples were analysed by CSBP Soil and Plant Laboratory for pH, electrical conductivity (EC), organic carbon (OC), phosphorus (P) and potassium (K), phosphorus buffering index (PBI), sulphur (S), nitrogen (N) and cation exchange capacity (CEC) as indicators of soil fertility.

Paddock management information was collected from landholders. Input information such as liming and fertiliser history and production outcome, such as grazing or hay cutting, was collected to gauge the effect that these factors may have on soil pH and fertility status.

Note: Financial constraints limited the sample depths collected for each site. The 10 – 20 cm depth interval was collectively sampled rather than the recommended 5 cm intervals of 10 – 15 and 15 – 20 cm. When monitoring trends in soil pH, sampling intervals of 5 cm to a depth of 20 cm are recommended.

Results

While it is possible to compare soil test results from individual paddocks taken in 2017 and 2020 for nutrients such as phosphorus, the 30-month re-sampling interval is too short to detect trends in other properties such as subsurface soil pH and organic carbon, which change very slowly over time.

Soil acidity and exchangeable aluminium

The 31 sites were grouped into soil pH categories based on the average pH of the subsurface layers within the depths from 5 – 20 cm.

Figure 1 shows that 45% of sites have severely acidic layers (pHCa < 4.5) at 5 – 20 cm, 48% are moderately acidic (pHCa 4.5-5.0) and only 7% are slightly acidic (pHCa >5.0) in the subsurface layers.
Of the same 31 sites in 2017, 26% of sites had severely acidic layers (pHCa < 4.5) at 5 – 20 cm, 58% were moderately acidic (pHCa 4.5 – 5.0) and 16% were slightly acidic (pHCa > 5.0) in the subsurface layers.

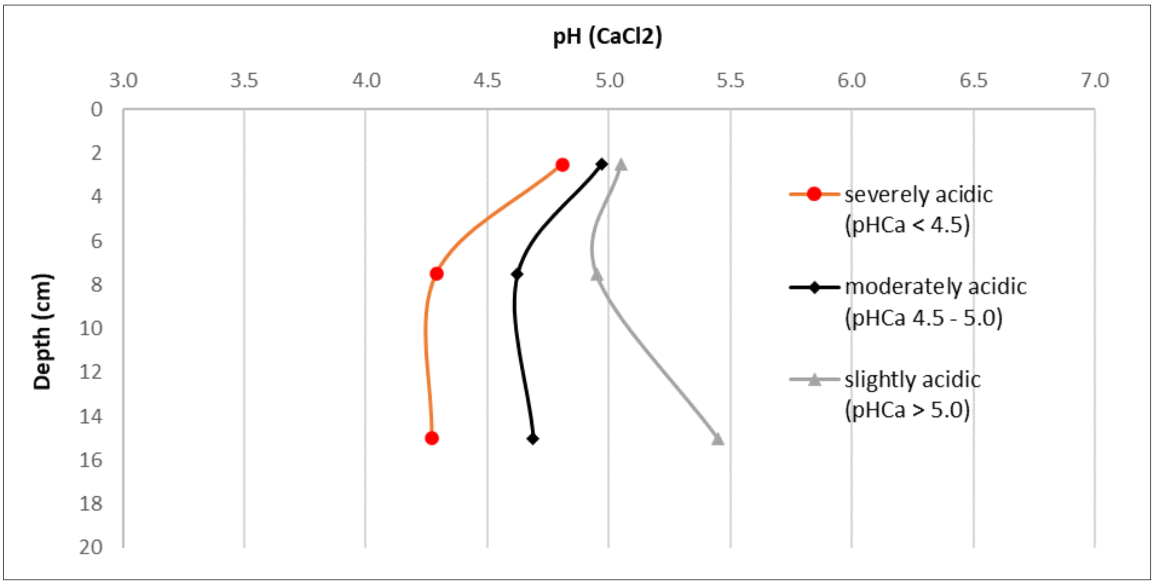

Figure 1. The average pH profiles of sites sampled in 2020, based on the pH categories: severely (pHCa < 4.5; n=14), moderately (pHCa 4.5 – 5.0; n=15) and slightly acidic (pHCa > 5.0; n=2).

Table 1 The average percent Exchangeable Aluminium in the soil profile for sites in each of the acid soil categories – severely, moderately and slightly acidic, based on pH in the 5 – 20 cm layers. The range in %Exch. Al values within each category is shown in brackets, above 2% being when there is an impact on plants growth

Depth (cm)	Average % Exchangeable Aluminium for severely acidic sites (pHCa < 4.5)	Average % Exchangeable Aluminium for moderately acidic sites (pHCa 4.5 – 5.0)	Average % Exchangeable Aluminium for slightly acidic sites (pHCa > 5.0)
0 – 5 cm	4.7 (0.2 - 14.3)	2.9 (0.2 – 30.4)	0.8 (0.4 – 1.2)
5 – 10 cm	15.2 (3.6 - 30.0)	6.6 (0.1 - 14.7)	1.7 (0.4 – 3.0)
10 – 20 cm	22.8 (10.0 - 45.3)	10.2 (0.6 – 34.1)	1.7 (1.4 – 2.1)

Liming

29 of the 31 sites have liming history, with 8 sites limed within the last 5 years, 16 sites limed more than 5 years ago, and 5 sites had never been limed. Liming history of the remaining 2 sites is unknown. Of the 7 sites limed within the last 5 years, 2 were incorporated with a speedtiller or scarifier to an estimated depth of 10 cm. These two paddocks were either going from pasture into crop, or from native pasture into improved pasture.

The sites sampled in 2020 were grouped into two groups on the basis of liming history to further investigate the effect lime is having on surface and subsurface layers.

- Group 1: Sites limed within the last 5 years (8 sites)
- Group 2: Sites that have never been limed (5 sites), and sites that were limed more than 5 years ago (16 sites).

Figure 2 shows that recent liming applications in the past 5 years have increased pH in the surface 0 – 5 cm layer but have had very little impact on soil pH further down the soil profile.

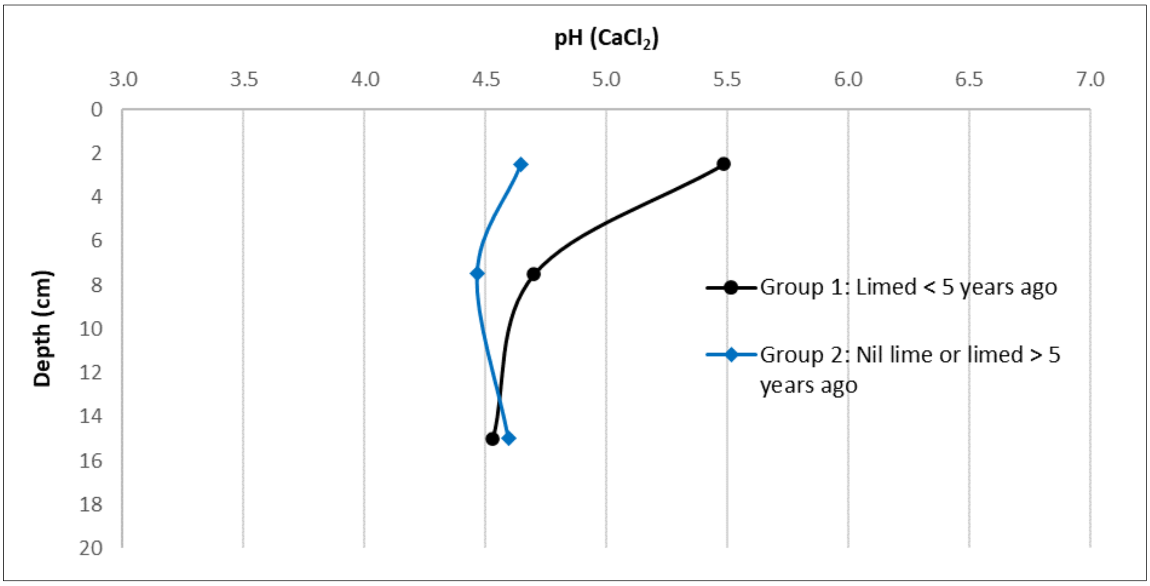

Figure 2 The mean pHCa of Group 1 (8 sites limed in the last 5 years) and Group 2 (21 sites that have received no lime or were limed more than 5 years ago).

Phosphorus (P)

Soil phosphorus levels were above critical values (>30 mg/kg P) in 74%of the paddocks (see Table 2). A comparison of critical P levels from the same 31 paddocks in 2017 shows that 3% more paddocks were above critical P levels compared to 2017.

Most paddocks containing below critical P values (<30 mg/kg P) in 2020 had received 2 or less applications of P fertiliser in the last 10 years. Interestingly, 2 paddocks below the critical P value had received annual applications >150 kg/ha of P fertiliser in the last 3 to 5 years.

Table 2 The mean phosphorus (P) levels of sites sampled in 2020.

Mean P (Colwell) (mg/kg)	All 31 sites	Sites with regular P fertiliser application n=24	Sites with ≤2 applications of P fertiliser in 10 years n=7
0 – 10 cm	53 (16 – 126)	57 (21 – 106)	32 (16 – 72)

Organic Carbon (OC)

Organic carbon (OC) for all sites averaged 2.3% and ranged between 1.4% and 3.7%. Average OC was 1.8% in the <600 mm rainfall zone, 2.4% in the 600 – 800 mm zone and 3.2% in the >800 mm zone. Compared to 2017, OC has decreased slightly in the <600 mm rainfall zone from 2.0% to 1.8%, and increased in the higher rainfall zones, although not significantly.

Table 3 The mean organic carbon % in each rainfall zone for 2017 and 2020 samples.

Rainfall Zone	2017	2020
<600 mm	2.0	1.8

600-800 mm	2.2	2.4
>800 mm	2.8	3.2

Discussion

Soil acidity and exchangeable aluminium

Subsurface acidity is common in soils of south eastern NSW. New management options to improve productivity and sustainability of these soils, including strategies to increase subsurface pH through more effective use of lime is one of the aims of Holbrook Landcare Network's 'Acid Soil Program'.

Soil pH is critical to plant health and soil function. Low pH reduces the productive potential of many crop and pasture species by reducing root growth and altering the availability and the plants' ability to access nutrients and water. As pH declines some nutrients become unavailable to plants, such as phosphorus and molybdenum, while other elements, such as aluminium and manganese can reach toxic levels.

The ideal target soil pH for most plant species is pHCa > 5.5 throughout the root zone, but particularly in the 0 – 20 cm surface layers, where up to 80% of the roots of most annual species are concentrated. The relatively small changes in soil pH is very important. Soil pH is measured on a log scale. This means that a pH of 5 is ten times more acidic than a pH of 6 and a pH of 4 is 100 times more acidic than a pH of 6.

Aluminium becomes available in the soil solution when soil pHCa is below 5.2 and increases rapidly in many soils as pHCa. falls below 4.8. As shown in Figure 3, aluminium stunts the root system, reduces root density and limits root hair development, minimising access to water and nutrients (P, K and Mg). Both low pH and levels of Exch. Al as low as 2% can reduce nodulation and nitrogen fixation by legumes.

Different plants show different levels of tolerance to aluminium. Of the crop and pasture species commonly grown in the NSW Southern Slopes and Tablelands, ryegrass, cocksfoot, oats and triticale are highly tolerant; sub clover, narrow-leaf lupin, some wheat varieties and established phalaris are tolerant; canola, albus lupin, some wheat varieties, barley, seedling phalaris and lucerne are sensitive; and pulse crops (faba bean, lentil, chickpea) are highly sensitive.

Figure 3. The effects of low pH and high aluminimum on root growth. The plant on the **left** is growing in soil that was not limed, **middle**: soil that was limed and incorporated, and **right**: soil that was limed and not incoprated.

The 2020 data shows that only 7% of paddocks have slightly acidic (pHCa >5.0) subsurface layers within the depths from 5 – 20 cm. This has declined from 16% in 2017 of the same 31 sites. Also, 45% of paddocks have severely acidic subsurface layers (pHCa < 4.5). This has increased from 26% of sites in 2017. The 30-month re-sampling interval is too short to accurately detect trends in subsurface soil pH and therefore it is recommended that future sampling is conducted in 5-10 years' time to accurately measure these trends. The timing of the sampling should also be addressed – the seasonal variation between sampling in 2017 and 2020 could explain some of this variation.

Liming

An effective liming program relies on the use of adequate rates of fine grade lime, of high neutralising value (NV), and a program of soil testing to guide liming frequency and application rate. Paddocks containing acidic surface and subsurface soils should be limed to increase pHCa to a target of 5.5. Research on soils of the NSW Southern Slopes has shown that by maintaining pH of the surface 0 – 10 cm layer above pHCa 5.5 will provide sufficient lime to neutralise the acid and raise pH in the surface soil and excess alkali from the applied lime to leach into deeper subsurface layers and slowly increase pH in those layers.

Lime that is topdressed moves very slowly into the subsurface layers, depending on soil type, rainfall and lime application rate. Based on research at a long-term NSW DPI research site near Tarcutta, the rate at which topdressed lime (alkali) moves down the soil profile is about 1 cm/year. Effective incorporation of the lime after spreading 'speeds up' the reaction of lime with the soil, to the depth of cultivation.

Two paddocks had been limed and incorporated in the past 5 years. In one of the paddocks that was incorporated with a scarifier the pH has increased in the surface 0 – 5 cm layer as expected but has not yet increased in the subsurface layers below. The most likely reason for this is that the depth of incorporation was shallower than anticipated. In the other paddock there was an unexplainable decrease in pH throughout the profile. This decrease could be due to a number of factors including: natural variability that can occur between seasons in soil pH, field sampling error or laboratory analysis error. It is recommended that these two sites are monitored in the future to measure the effect of incorporation.

A new monitoring site was established in 2020 as a 'paired site' for future monitoring. The new site was established in a limed strip within a pasture paddock that was applied at a rate 2.5 t/ha (not incorporated) in January 2019. The paddock has not been limed in the past and contains an existing site. Interpretation of the pHCa data from 2020 of the paired sites shows that the pHCa in the surface 0 – 5 cm layer of the limed site is approximately 1 pHCa unit higher than the unlimed site and approximately the same in the subsurface layers below, indicating that the lime has not moved far into the subsurface layers.

Manganese toxicity is an issue in many of the low pH soils of the region and is particularly important for those growing broad leaf plants, such as canola, lucerne and sub clover. However, it was not included in soil analyses for this project because, depending on temperature and soil moisture, the available manganese level in the soil varies widely from season to season making detection with soil testing difficult. Manganese levels usually peak over summer and autumn. Visual symptoms of manganese are common in canola in autumn, with yellowing of the leaves and reduced vigour, which tend to disappear as the available level fall in late autumn. Reduced vigour and yellowish or reddish leaf margins are symptoms of manganese toxicity in sub clover and lucerne, which are also likely to disappear late in autumn.

Phosphorus (P)

While this project focuses on acidic soils, it is important to also monitor other key nutrients. Phosphorus is essential for root growth and photosynthesis in plants. For rhizobia, it is essential for bacterial growth and for the conversion of atmospheric nitrogen to ammonia. Phosphorus is a major driver of plant growth (particularly of legumes) and unlike lime, commonly used P fertilisers are very soluble, and pasture will respond to applied fertiliser within months of topdressing.

The results of the 2020 sampling indicate that 74% of sites are above critical values, an increase of 3 percent since 2017 sampling. The majority of these paddocks have received between 100 and 200 kg/ha of super, MAP, or DAP every year.

The variability in soil P values highlights the importance of monitoring soil P levels and using critical P values to guide fertiliser inputs. For example, if P values are above critical values, farmers are wasting money and creating nutrient leakage by applying more P, and could rather divert the funds to fertilise paddocks low in P values, or towards acid soil management and lime inputs. On the other hand, as liming programs increase soil pH, it is important not to lose sight of P fertiliser requirements. At one of the 2020 sites 1 t/ha of lime topdressed onto a ryegrass/sub clover pasture raised the pHCa in the surface 0 – 5 cm from 4.5 to 5.2. However, the production of the pasture may be checked by marginal P levels, i.e. Colwell P value of 15 mg/kg.

Organic Carbon (OC)

Soil organic carbon (OC) is the carbon component of soil organic matter, with more than 50% concentrated in the shallow surface soil (0 – 5 cm). It is important for nutrient availability to plants, soil structure, and soil biological function. Soil OC levels change very slowly and are generally greater in higher rainfall areas due to increased plant growth, soil moisture and biological activity. A decline of OC levels was expected between 2017 and 2020 due to the exceptionally dry conditions over that time and potential loss from wind erosion. The trend in the decline in OC in the drier (<600 mm) rainfall zone between 2017 and 2020 may reflect this.

The increase in OC in the wetter (>600 mm) rainfall zones between 2017 and 2020 could be due to a number of factors including potentially higher localised rainfall in these areas over this period or grazing management that retained groundcover and minimised soil erosion losses. The pH at the majority of these sites decreased in the 0 – 5 and 5 – 10 cm layers, except for sites that were limed, and therefore it was expected that plant growth and OC would have also declined.

Sampling Method

In order to pick up the stratification in the subsurface layers, NSW DPI are recommending that the probe method of sampling be replaced by a 25cm core that can be cut at various depths. Contamination between layers could have been an issue with the results.

Conclusions and Recommendations

Recognising all the issues with the sampling in this project – the different seasons, the different depth intervals sampled and the equipment used for sampling, the results are indicating acidifying trends and the current liming application rates are not enough to address subsurface acidity. Paddocks that were limed in the last 5 years have pHCa levels above 5 in the surface but are moderately to severely acidic in the subsurface layers below 5 cm. The movement of lime down into subsurface layers can take several years' however. It is expected that sub clover nodulation health is also declining with acidifying soils.

It is recommended that future soil testing:

- Is conducted in another 2 years' time and every 5 years thereafter, to detect trends in soil properties such as subsurface soil pH and organic carbon, which change very slowly over time. This should be conducted in September in order to directly compare the results with the September 2017 data.
- Is assessed along with sub clover nodulation health to monitor if pH trends are impacting on sub clover nodulation health.
- Is sampled with a 25 mm diameter core and bulked for 0 – 5, 5 – 10, 10 – 15 and 15 – 20 cm depth intervals.

Key messages for Extension

- Seasonal variation in pH needs to be considered when testing
- Regular soil testing is important to make sure inputs are matched to requirements and that investment in one type of input is not wasted because the other is still a constraint on production.

We need more clarification from NSW DPI around the implications of the new recommendations for practical farm soil monitoring.