

## Understanding soil pH through dual-depth grid soil mapping

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### Key points

- Dual-depth (0–10cm, 10–20cm) grid soil sampling was used to map surface and subsoil pH across 45 properties and 2210ha of farmland in the eastern Riverina area of southern NSW.
- Soil sampling showed an average variation in pH of 0.8–1.0 pH units across a paddock in both the surface and sub-surface layers, with marked differences in soil pH between the two sampling depths.
- Exchangeable aluminium (Al) levels increased rapidly in the soil sample where pH was lower than 4.6, with minimal amounts of exchangeable aluminium detected where soil pH was greater than 4.6.

### Aim

This project aimed to reduce the erodibility of high-risk landscapes through an increase in the area of land planted to perennial pasture species, which are both more productive and more persistent when not constrained by acidity and aluminium toxicity.

To achieve this, the project aimed to increase awareness, knowledge and understanding of soil acidification and management options for topsoil and subsoil acidity. Traditional blanket-rate lime practices do not address the issue of increasing subsoil acidity, nor target areas where acidity is most severe, and the project explored dual-depth grid soil mapping in combination with variable rate lime application for more effective and longer-term management of soil acidification.

The project aims to increase the area of land planted to perennial pasture species, as well as increase the area of soil limed to at least pH 5.2 in the topsoil (0–10cm). Grass and legume-based pastures limed using tailored rates will be more productive as a result, with pasture legumes and their rhizobia able to supply more fixed nitrogen (N) for the benefit of the mixed sward.

Based on intensive soil sampling, the project aimed to develop property soil nutrient and liming plans that identify

the constraints, including soil acidity, that can influence the establishment and maintenance of perennial pasture systems. By ensuring that soil fertility and plant nutrition are understood and managed by the landholder, the focus can be on the prevention of soil erosion and the management of acidification.

### Background

Soil acidity affects 50 per cent of Australia's agricultural land and is a major constraint to pasture and crop productivity in areas of southern NSW with an annual rainfall of 550–800mm. Soil acidification is a natural process, which is driven by rainfall and accelerated by the removal of agricultural products, which are generally alkaline. Acidity is also affected by the balance of nitrogen in the system and influenced by the leaching of nitrates and the loss of nitrogen due to volatilisation or denitrification under waterlogged conditions.

Standard soil tests, taken at a depth of 0–10cm, provide a measure of soil pH in the surface root zone of crops and pastures. In these surface soils, the developing root systems of newly established pasture or crop species, as well as any soil rhizobia present, are exposed to soil pH and any associated toxicities, including aluminium toxicity. Soil pH can be inherently variable, both horizontally and vertically, in the profile and there has been a recent focus on the stratification of pH in the upper 20cm of the soil profile by soil scientists.

*Farming Smarter – a soils project for the next generation* is a five-year project. This project is supported by Riverina Local Land Services, through funding from the Australian Government's National Landcare Program. The project utilises precision agriculture (PA) techniques to identify the severity of soil acidity in a paddock and the range of in-paddock variation in soil pH.

This data will be used to provide guidance around the liming rates required to establish and maintain perennial pastures, as soil acidity can diminish nitrogen fixation by pasture legumes and acid-sensitive rhizobia. Soil acidity can also impact the root volume and rooting depth of pastures when constrained by aluminium and manganese toxicity, as well as affect plant nutrition when soil micronutrients, such as boron or zinc, become deficient at low pH. The dual-depth sampling process used in this project enables variable-rate lime application to be explored for managing the amelioration of acidity in both the top and sub-soil layers.



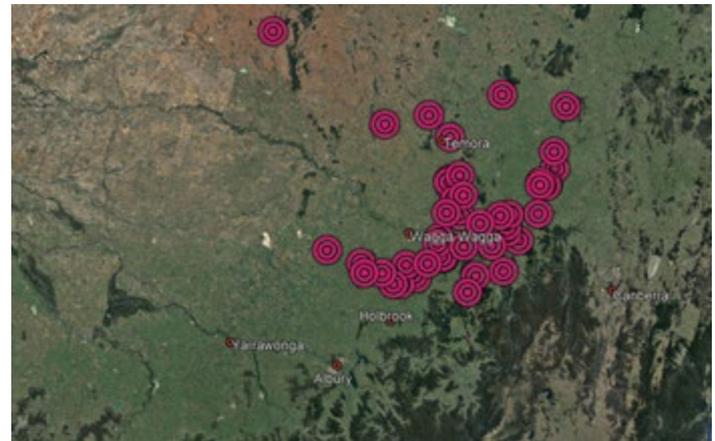
This article summarises the results of dual-depth soil sampling undertaken in the eastern Riverina area of southern NSW during autumn 2019 (year one of the project). Soil sampling was conducted across a range of paddocks used for mixed farming and selected for future perennial pasture establishment by the landholders.

This project recognises the value in having a better understanding of pH stratification in soils and focuses on understanding the variation in pH across the paddock, especially between the topsoil, which receives a surface application of lime, and the subsurface layer, which cannot be ameliorated until the acidity in the topsoil is saturated. By monitoring surface and subsurface acidity through dual-depth grid soil mapping, the project has taken a step towards increasing the knowledge and understanding of farmers and researchers in southern NSW, as well as improving the way acidification and re-acidification are managed. This will lead to increases in the efficiency in which we apply inputs of lime and fertiliser.

## Method

Dual-depth grid soil mapping was undertaken during autumn 2019 (year one of the five-year project). Samples were collected from 87 paddocks (across 45 farms), representing a total area of 2210 hectares of southern NSW farmland (Figure 1).

The grid soil sampling involved dividing each of the 87 paddocks into two-hectare grids, which were treated as individual units for soil sampling. The sampling process consisted of (a) creating digitised paddock boundaries and sampling plans; (b) the collection of GPS referenced samples (0–10cm, 10–20cm) by manual sampling, with eight sub-samples collected on a diagonal across each sampling grid; (c) sending of samples to an accredited laboratory to analyse pH (CaCl<sub>2</sub>) and exchangeable cations (calcium [Ca], magnesium [Mg], potassium [K] and sodium [Na]).



**FIGURE 1** Distribution of the project sampling sites across southern NSW

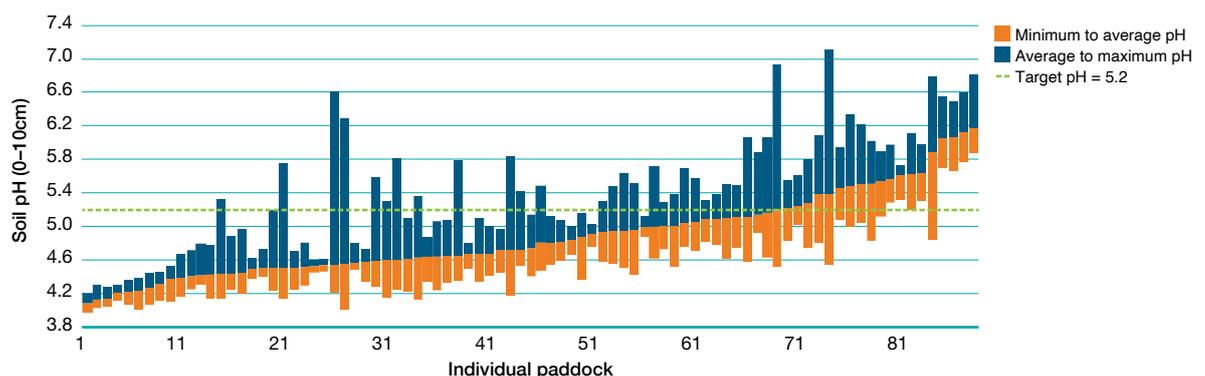
After initial results were received, further analysis was conducted for each property, with the two most acidic points selected for further analysis of exchangeable acidity (aluminium and hydrogen) in both the 0–10cm and 10–20cm layers.

## Results

Soil pH was highly variable across the 87 sampled paddocks. In the surface soil (depth 0–10cm), the average pH ranged from 4.1–6.2 (Figure 2). While 75 per cent of the sampled paddocks had an average surface soil pH of less than 5.2, 50 per cent of the paddocks had an average pH of below 4.8, placing them in the ‘highly acidic’ category.

There was significant variation between paddocks and within paddocks. The range in soil pH across a single paddock varied by 0.2–2.6 pH units, with an average range of 0.84 pH units.

In the sub-surface (10–20cm depth), average soil pH across the 87 paddocks ranged from pH 4.1–6.0, with individual paddocks measuring ranges from 0.2–2.9 pH units (average range of 0.99). Based on these average



**FIGURE 2** Soil pH at 0–10cm depth for 87 individual paddocks, shown as individual bars and ranked according to their average pH (intersection of the orange and blue lines)

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figures, the range and variability of the surface and sub-surface soils are reasonably consistent. However, soil pH data for the 10–20cm depth in Figure 3 (ranked according to surface soil pH) indicates there wasn't a consistent trend in the pH distribution between the surface and sub-surface layers. The exception to this was for the 15 most acidic surface soils (0–10cm), which were also consistently acidic in the sub-surface (10–20cm).

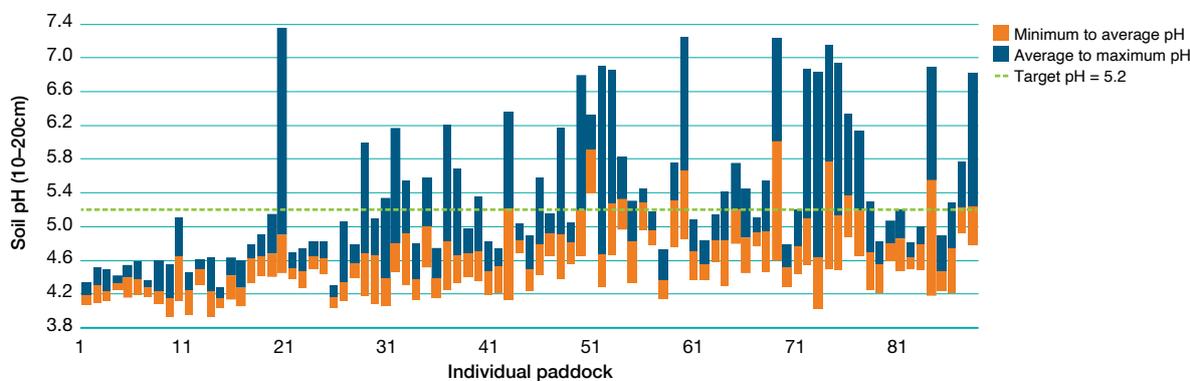
Paddock sampling occurred across a range of soil types and included a mix of cropping, pasture and mixed farming systems, however there were no obvious differences in soil acidity between soils with different land-uses. While the majority of paddocks sampled as part of this project had a history of lime application (at a rate of 2t/ha or greater), the combined effects of farming system, soil type, long-term rainfall patterns and long-term management practices is likely to be driving results.

One of the additional management challenges for acidic soils is the potential for increasing levels of exchangeable aluminium to amounts that are toxic for plant growth. The results from the 45 properties where exchangeable aluminium was measured (for the two most acidic points

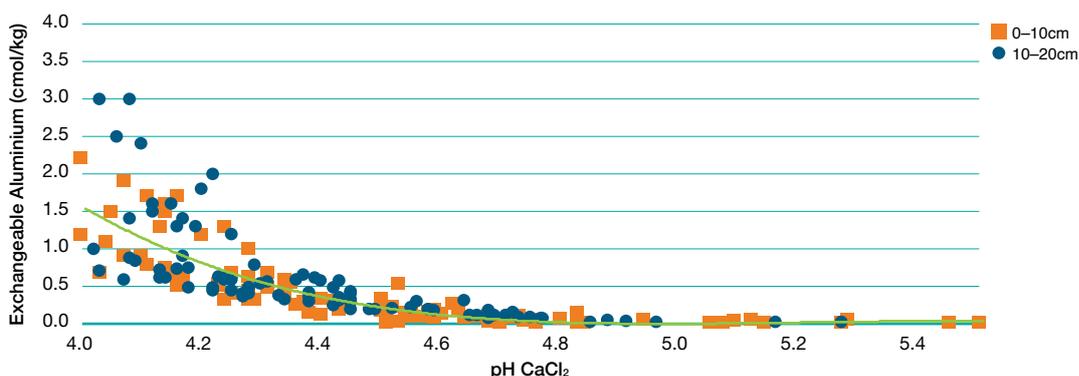
in each property), show a strong relationship between soil pH and exchangeable aluminium levels (Figure 4). This relationship is strong for both the surface and sub-surface layers, which is consistent with previous studies. These results show that minimal exchangeable aluminium was detected where soil pH was above 4.6, however where soil pH decreased below 4.6, exchangeable aluminium levels increased rapidly.

Based on the grid soil mapping results, three variable rate lime application scenarios were calculated to optimise lime inputs and ameliorate the soil profile. The first scenario involved ameliorating the 0–10cm layer to a target pH of 5.2, while the second involved ameliorating both the topsoil (0–10cm) and subsurface layer (10–20cm) to a target pH of 5.2. The third scenario was designed to achieve a longer-term aspirational goal and involved ameliorating the top 0–20cm to a target pH of 5.8 and maintaining pH above a benchmark figure of 5.5.

In order to ameliorate the top 0–10cm of the profile to the target pH of 5.2 using variable rate applications (scenario 1), an average lime rate of 1.3t/ha was required,



**FIGURE 3** 10–20cm soil pH across 87 paddocks shown as individual bars ranked in the same order as Figure 2 (average pH is the intersection of the orange and blue lines)



**FIGURE 4** The relationship between pH and exchangeable aluminium as measured at the two most acidic points on each property at 0–10cm depth and 10–20cm depth



with 10 per cent of paddocks receiving no lime and 10 per cent of paddocks requiring an average lime application rate in excess of the industry standard (2.5t/ha). Where the aim was to ameliorate to a depth of 20cm (scenario 2), higher rates of lime were required with an average paddock rate of 2.4t/ha and 40 per cent of paddocks requiring an application rate greater than 2.5t/ha. No analysis was conducted for scenario 3, as this is a longer-term goal which is unlikely to be achieved by a single application.

### Observations and comments

Soil pH was observed to be highly variable, both horizontally and vertically, within all paddocks tested as part of this project. The range in surface pH across paddocks averaged 0.8 pH units, while the range in sub-surface pH across paddocks and all two-hectare grids averaged one pH unit.

There was not a consistent correlation between the surface and sub-surface pH, due in part to the management and liming history of individual paddocks, as well as the history of product removed from each paddock. This highlights the value of dual-depth sampling when planning management actions such as amelioration (liming) or when considering acid-tolerant species for planting in an acidic topsoil (acid-tolerant species are still vulnerable to toxicities and deficiencies present in the more acidic 0–20cm layer).

When pH drops below 4.6, the levels of exchangeable aluminium were observed to increase. Low soil pH, accompanied by aluminium toxicity, creates a less favourable environment for pasture growth and rhizobial survival, which will reduce the amount of nitrogen fixed by legume pasture species. Pastures grown on acidic soils often also have a diminished root volume, will be more prone to weed invasion, more likely to encounter nutritional deficiencies and have a shorter life-span than pastures grown on higher pH soils.

There are economic and soil health benefits from placing lime more strategically in areas of highest need within the paddock. Tailoring the rate to achieve target pH values will reduce the severity of aluminium toxicity and arrest the re-acidification of the 0–10cm topsoil, as well as the ongoing acidification of the sub-surface 10–20cm layer.

Dual-depth grid soil mapping allows for more strategic use of lime in the short-term and long-term by targeting those areas that need it the most, allowing for the lime resource to be allocated more efficiently. Variable rate lime application strategies were developed for each paddock as a part of individual property management plans and delivered to landholders at workshops during June, 2019.

It is anticipated the property management plans, combined with variable rate lime strategies, will enable the successful establishment of perennial pastures to improve the quality and quantity of feed-on-offer and which will persist beyond the period it takes to recoup the establishment costs.

### Acknowledgements

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