NEW

4.2 IMPROVING ACCURACY OF LIME RATE CALCULATIONS TO AMELIORATE SOIL ACIDITY

Australian Government | National Landcare Program | GRDC Grains Research & Development Corporation

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KEY MESSAGES

- Calculation of pH buffering capacity to predict lime requirements to achieve target pH were relatively accurate at standard rates but became more inaccurate at higher rates.
- There was some discrepancy between laboratory measurement of pH buffering capacity and the use of ped transfer functions to predict pH buffering capacity which should be further investigated.
- Soil pH change peaks one to two years after liming and then declines due to soil acidification and lime movement which should be considered in determining lime rates.
- Monitoring of pH change following liming is required to determine when re-liming is necessary.

Keywords: soil acidity, soil pH, lime, pH buffering capacity

BACKGROUND

Accurate calculations of lime requirements will help reach pH targets and remove soil constraints more quickly than relying on using rule of thumb applications such as 2.5 t/ha of lime applied occasionally or over a set period of time. Underestimation of target pH has implications for lime movement. Li et al (2019) found pH needed to be maintained above 5.5 at 0-10 cm depth to achieve lime movement into 10-20 cm depth. As soil characteristics vary, so does the amount of lime to reach targets due to the pH buffering capacity of the soil or its ability to resist change.

The general equation to calculate lime requirements is based on a desired pH change (Current pH – Target pH) and multiplied by pH Buffering Capacity (Equation 1).

Equation 1. *Lime Requirement*
= Desired pH change x pH Buffering Capacity

There are several ways to estimate pH Buffering Capacity (BC). Direct measurement which is offered by soil testing laboratories or through estimations by ped transfer functions based on correlation of soil characteristics to pH change.

Soil pH buffering is influenced by how much organic matter is in the soil but other related and influencing factors are clay content (mineralogy), exchangeable aluminium, pH, and cation exchange capacity.

In the economic calculator LimeAssist the following equation was used to predict pH Buffering Capacity (Equation 2). Other calculations use soil texture as a prediction factor.

Equation 2. *pH BC*
= [0.955 Organic Carbon % + 0.011 Clay %] x Bulk Density

In equation 2, the soil pH BC is expressed as the amount of lime (t/ha) estimated to raise the pH by 1 unit for soil depth 0-10 cm. For example to change soil pH from 5 to 6, knowing the BC then allows calculation of the lime requirement to reach desired pH change.

The percentage of Organic Carbon (OC) content of the soil is measured by the Walkley-Black method, clay content in the soil and bulk density (BD). This equation was developed in trials where lime application was incorporated (Aitken *et al*, 1990). Further discussion of this calculator, *Assumptions Underpinning LimeAssist Calculator* is on page 118.

The purpose of this paper is to report on the accuracy of using this method to estimate lime rates to achieve pH targets and to show how pH changes over time in response to liming from two trials at Mt Mercer and Skipton. These trials were set up as part of the project, "Building the resilience and profitability of cropping and grazing farmers in the high rainfall zone of Southern Australia," funded by Australian Government's National Landcare Program and GRDC.

METHOD

The Mt Mercer and Skipton trial sites were established in 2019. Soils were sampled within the trial site and sent to laboratories for analysis of different soil factors shown in Table 1. Bulk density was recorded based on the volume of soil taken from 10 locations from depths 0-10 cm. Together these soil factors were used to estimate soil pH buffering capacity.

Lime requirements were calculated based on required pH change and soil pH buffering capacity. These were then adjusted to account for reductions in lime purity based on Neutralising Value (NV). The lime used was applied in autumn 2019 from the Batesford lime quarry, with a NV of 85%. Different methods of lime application were compared, surface application with disturbance only from sowing or incorporation using a tyned scarifier to a depth of approximately 10 cm.

Table 1. *Soil characteristics and pH buffering capacity at 0-10 cm at Mt Mercer and Skipton trial sites*

Trial Site	Soil texture	Organic Carbon (%)	Clay content (%)	Bulk Density (g/cm³)	Estimated soil pH buffering capacity
Mt Mercer	Light clay loam	2.9%	30%	1.10	3.4 t/ha
Skipton	Silty loam	2.1%	18%	1.17	2.6 t/ha

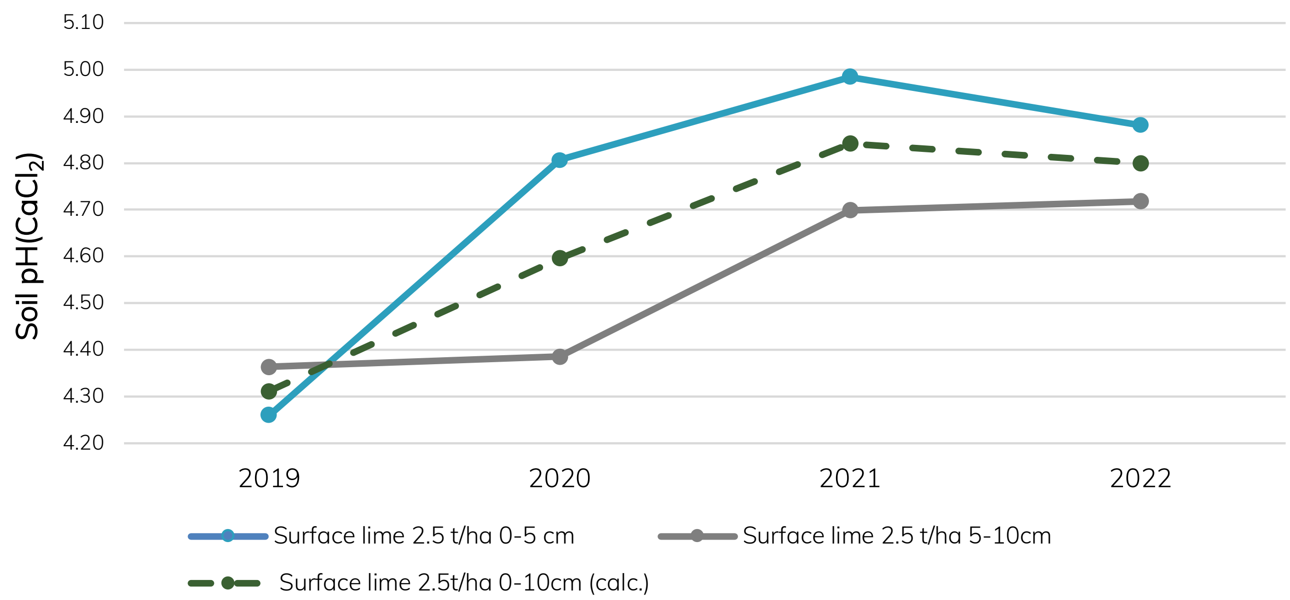

Figure 1. *Mt Mercer – Changes in measured pH at 0-5 cm and 5-10 cm and calculated combined change (0-10 cm) for surface applied lime which occurred over time.*

Four soil cores were taken annually within each treatment plot and divided into 5cm increments (0-5 and 5-10) and bulked together for pH testing by Apal laboratory from 2019 until 2022. The average pH of 0-5 cm and 5-10 cm was calculated to represent measurement of 0-10 cm soil pH to check accuracy of reaching pH target based on using pH buffering capacity to calculate lime rates.

RESULTS

Figures 1 and 2 show pH change over time from lime applications of standard farmer rates (2.5 t/ha) applied to the surface at Mt Mercer and Skipton respectively. The graphs show similar shapes, where the addition of lime increases pH, which peaks after either one or two years at the 0-10 cm depth and then starts to decline. Decline occurs because lime moves into the 5-10 cm depth and further acidification occurs. The graphs also show less pH change occurs at the 5-10 cm depth compared with the 0-5 cm, but it continues to slowly increase over time.

At standard liming practice the rate of 2.5 t/ha would be equivalent to 2.1 t/ha of pure lime based on the NV of 85%. Calculation of pHBC at Mt Mercer was 3.4 t/ha and 2.1 t/ha indicated that the pH should have increased by 0.6 pH unit to pH 4.9. The measured peak pH change achieved was 5.0 at 0-5 cm and the calculated change was 4.8 at 0-10 cm after two years (Figure 2).

The calculation of pHBC at Skipton was 2.6 t/ha, less than Mt Mercer because of reduced organic carbon and clay content. The pure lime rate was anticipated to increase pH by 0.8 units to 5.3. At Skipton the measured pH peaked at 5.6 at 0-5 cm and was calculated to reach 5.0 at 0–10 cm.

Therefore, the BC estimation was reasonably accurate at these two sites in predicting standard lime rates capable of achieving the desired pH change when surface applied under minimum tillage.

Figures 3 and 4 show pH change using higher rates of lime and compare incorporation methods to surface application.

The target pH change for the incorporated treatments at both sites was 5.2 at depths of 0-10 cm and 10-20 cm. At Mt Mercer the predicted lime rate to achieve this change was 4.9 t/ha after accounting for an NV of 85%. The calculated pH from combined depth of

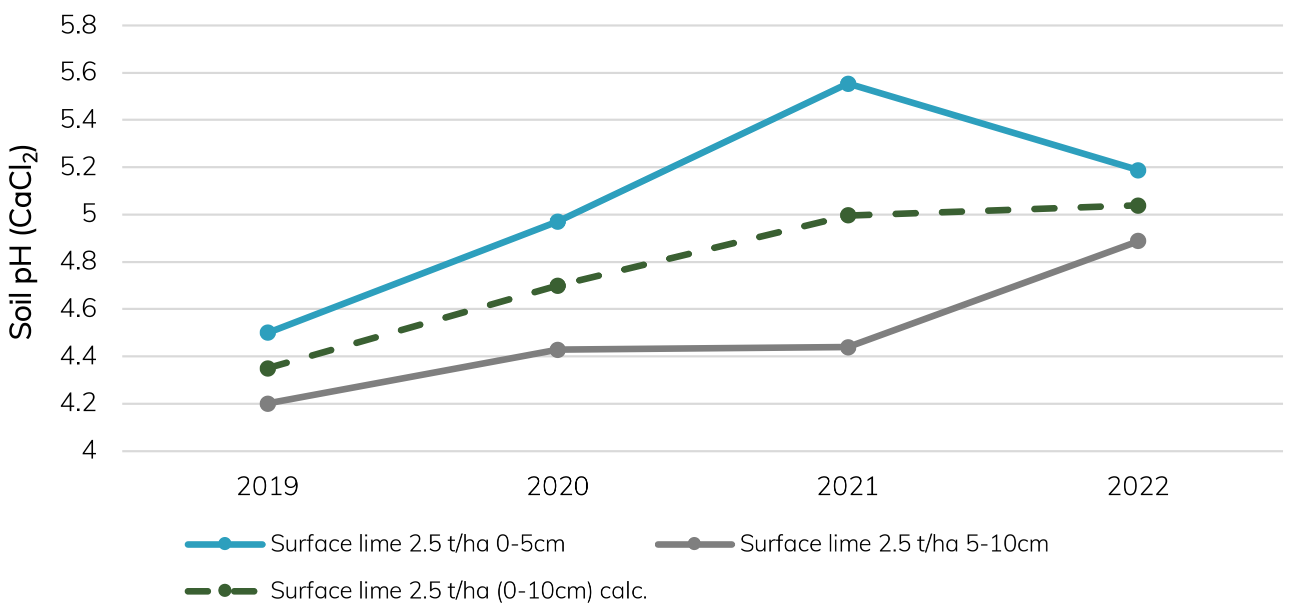

***Figure 2.** Skipton – Changes in measured pH at 0-5 cm and 5-10 cm and calculated combined change (0-10 cm) for surface applied lime which occurred over time.*

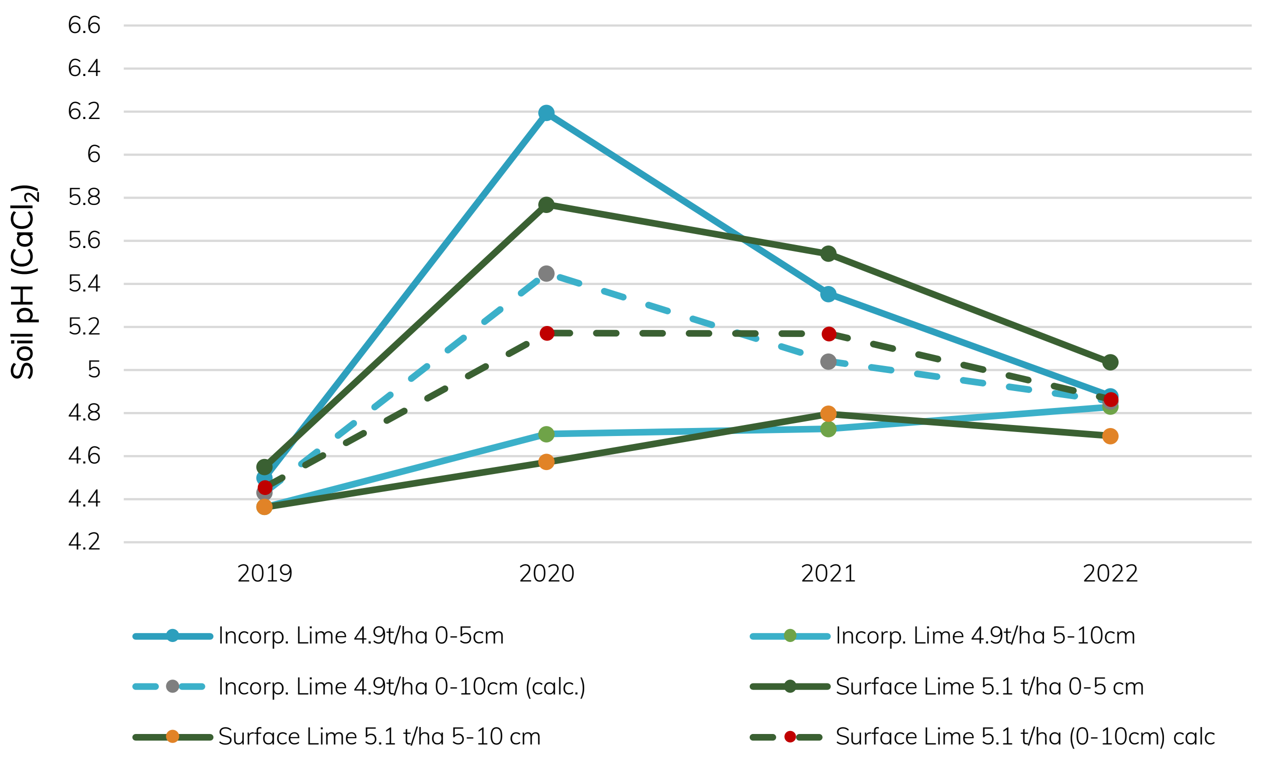

***Figure 3.** Mt Mercer – Changes in measured pH at 0-5 cm and 5-10 cm and calculated combined change (0-10 cm) for different treatments (incorporation (blue lines) and surface applied (green lines) which occurred over time.*

0-5cm and 5-10cm was 5.45 which shows this target has been slightly exceeded. Likewise at Skipton, the lime rate of 3.8 t/ha achieved a calculated peak pH change of 5.8 two years after lime application, which again was above the predicted target of 5.2 (Figures 3 and 4). This higher pH achieved at 0-10 cm was because lime was concentrated in 0-10 cm as there was no pH change after two years at the 10-20 cm soil depth for either depth (Table 2). Incorporation treatments were only able to mix soil and lime to depths of about 10 cm and then relied on lime movement into the underlying depths which is renowned for being slow.

At both sites, the surface application treatment had a pH target of 5.8. At Mt Mercer the lime rate of 5.1 t/ha achieved pH 5.8 at 0-5 cm but the calculated average for 0-10 cm was only 5.2. At Skipton with calculated lime rates of 4.5 t/ha to achieve the pH target of 5.8 the surface application pH peaked at pH 6.1 after two years and the calculated average for 0-10 cm was only 5.3. These results show that when higher lime rates were applied to the surface, the required target pH change at 0-10 cm was not achieved after three years and this is partly because lime becomes concentrated in the 0-5 cm depth and there is likely some undissolved lime present.

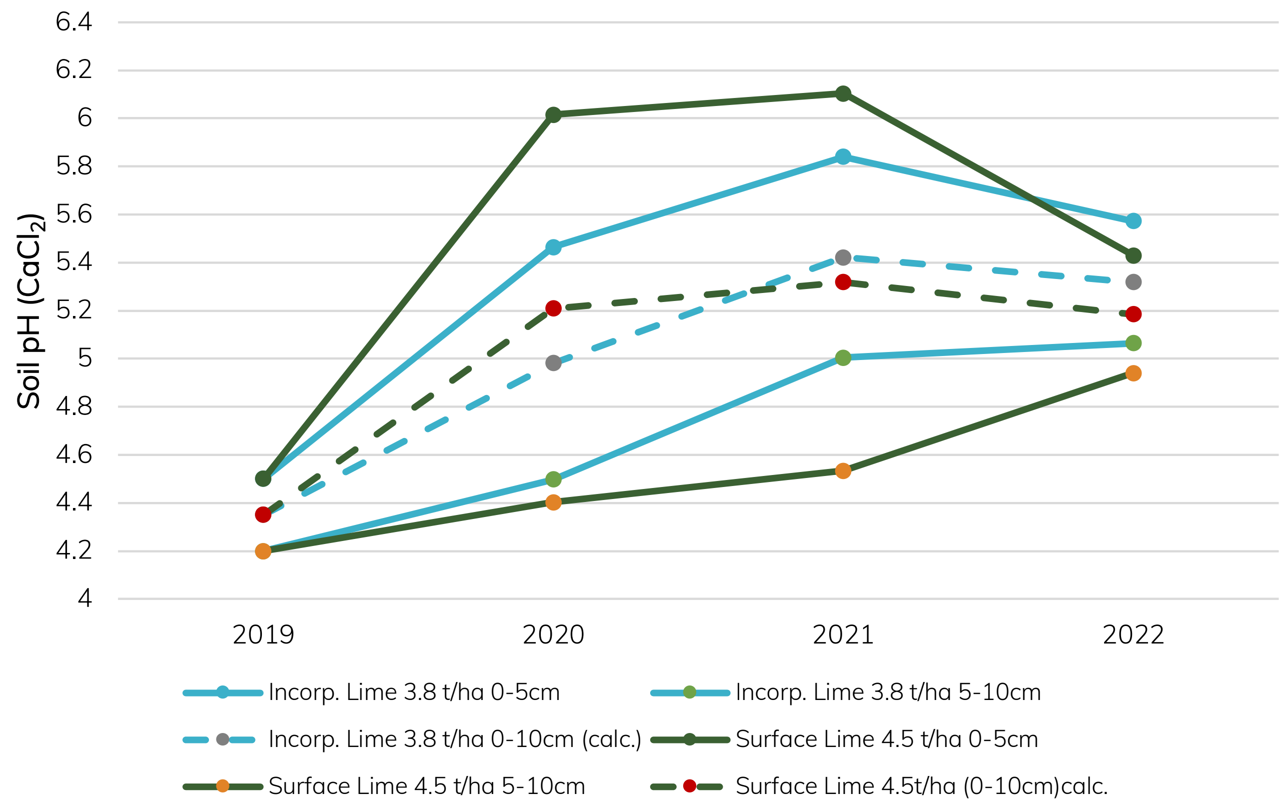

***Figure 4.** Skipton – Changes in measured pH at 0-5 cm and 5-10 cm and calculated combined change (0-10 cm) for different treatments (incorporation (blue lines) and surface applied (green lines) which occurred over time.*

***Table 2.** The change in pH at depths below 10 cm at Mt Mercer and Skipton sites under different treatments.*

Site	Treatment	2019 pH ($CaCl_2$) (10-20 cm)	2021 pH ($CaCl_2$) (10-15 cm)
	Standard lime 2.5 t/ha	4.44	4.45
Mt Mercer	Surface lime 5.1 t/ha	4.51	4.43
	Incorporated lime 4.9 t/ha	4.51	4.47
	Standard lime 2.5 t/ha	4.56	4.35
Skipton	Surface lime 4.5 t/ha	4.39	4.36
	Incorporated lime 3.8 t/ha	4.49	4.35

DISCUSSION

When the BC equation was developed, it was correlated to pH changes occurring under incorporated lime treatments. However, many farmers use minimal tillage. The trial results show that at standard lime rates (2.0 to 2.5 t/ha), the BC equation and resulting lime requirements calculated are reasonably accurate, but not when higher lime rates are used. This is because pH change becomes limited by lime solubility which slows at pH ($CaCl_2$) greater than 5.4 and stops at pH (6.3 or 6.4), or when soil becomes alkaline.

NSW DPI measured the pH buffering capacity at SFS subsoil acidity sites at Rokewood and Stawell, and their buffering capacities were much lower than what the ped transfer Equation 2 would have predicted. The measured pHBC at Rokewood was 0.7, 0.37 and 0.59 t/ha/10 cm/pH unit and at Stawell 0.92, 0.55 and 0.57 t/ha/10 cm/pH unit at depths 0-10 cm, 10-20 cm and 20-30 cm, respectively. Both soil types were light textured and sand/sandy loams. Monitoring of these sites found that the lime rates calculated were relatively accurate as target pH treatments were achieved at completion of trial

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when measured in 2022. This implies that more work on calculating or measuring accurate buffering capacities needs to occur.

Although the pHBC equation can be used to determine what lime rate is needed to reach a target pH, as Figures 1 to 4 show, pH will peak, but then start to fall. Therefore, additional lime would need to be added to the calculated amount to cover the pH drop from acidification and lime movement to maintain pH at the target pH. At the MASTER trial (Wagga Wagga), the pH falls were found to be 0.2, 0.15 and 0.1 pH unit/year for depths of 0-10 cm, 10-20 cm and 20-30 cm (Lie *et al*, 2019), and these were assumptions used to calculate required lime rates for Rokewood and Stawell.

Once soil acidity constraint is removed, maintenance liming needs to occur. If the trigger for re-liming is a pH of 5.5 then the lime application rates would not need to be calculated, but about 1 t/ha should be applied. It is generally uneconomic to apply rates less than 1 t/ha because of spreading costs and poor soil coverage of lime.

Despite pH being measured in a logarithmic scale which implies that less lime is required when pH is high (e.g. 5.5) compared to when it is low (e.g. 4.0/4.5), pH changes occur with near linearity from 4 to 6 pH ($CaCl_2$) with lime application (Brendan Scott, formerly NSW DPI, personal communication).

As there are many soil variables affecting lime rate calculations, monitoring changes in pH will be necessary to gauge when re-liming will need to occur.

ACKNOWLEDGEMENTS

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REFERENCES

Aitken RL, Moody PW and McKinley 1990. Lime requirement of acidic Queensland soils. I. Relationships between soil properties and pH Buffer capacity. Aust J Soil Res, 28, pp 695-701

Li GD, Conyers MK, Heylar KR, Lisle CJ, Poile GJ and Cullis BR (2019). Long-term surface application of lime ameilorates subsurface soil acidity in the mixed farming zone of south-eastern Australia. *Geoderma* 338, pp 236-246.