Lime and liming – managing soil health

By Lisa Miller – Southern Farming Systems

Results at a glance…

- Liming to maintain good soil pH levels and avoiding yield losses is just as important as applying fertiliser.
- If growers let soil pH levels in the topsoil run-down (pH in CaCl2 < 5.0) they are at risk of creating soil acidity issues at depth which are harder and more expensive to treat.
- In general, not enough lime has been applied frequently enough to address acidification occurring within the whole soil profile, so soil test to depth and calculate lime requirements for 0–10 cm, 10–20 cm and 20–30 cm, not just the top 10 cm of soil.

Why do the trial?

SFS was fortunate to be involved in a soil acidity project in both crops and pastures which started in 2014 under a GRDC and federal government investment in South West Victoria.

We needed to improve our understanding of soil acidity management with particular regard to lime responses, soil acidity increases in the 10–20 cm layer, lime movement and lime quality.

From this research, better extension messages could be developed for local farmers and graziers.

What we found

Acidity affects plant and soil functions

Soil acidification is unavoidable in productive farming systems, and acidity eventually eats away profits, affecting chemical, biological and physical functions within soils and plants. This makes it difficult to diagnose acidity based on crop symptoms. But soil pH provides a good guide to which functions might be affected and the likely lime response as shown in Table 1.

Do not let soil pH run down

Our cars are serviced regularly so they run reliably and efficiently, and most people do not wait for their cars to break down and then have it fixed. The same applies to maintaining soils.

If topsoil pH is allowed to run down to less than 5.0 – which is common in grazing enterprises – significant production has probably been lost over the past five to eight years and possibly not noticed. More importantly, by letting the soil acidity form in the top 10 cm of soil, the acidity build-up results in leaching downwards of hydrogen ions and this allows soil acidity to increase at depths of 10 cm to 20 cm, where it becomes much more difficult and expensive to treat.

Lime is slowly soluble and often will not work straight away – it takes time to dissolve and move and so some ongoing yield losses will continue. If a subsoil acidity problem exists, lime with no

Table 1: Crop symptoms at different soil pH (measured in $CaCl_2$)

If the soil pH is:	
More than 5.5	There will be no problems from soil acidity affecting crop growth and yield, and there could be net movement of lime beyond 10 cm depth.
Less than 5.2	The effectiveness and numbers of rhizobia that fix nitrogen (N) on acid sensitive legumes (eg. lucerne and pulses, but not narrow-leafed lupin) are reduced. Liming increases the persistence and effectiveness of these rhizobia, and the amount of N fixed and grain produced of the sensitive legumes.
Less than 5.0	In addition to the effects above, there is a chance of molybdenum deficiency in legumes – check for local advice. Molybdenum is important in the synthesis of amino acids and proteins and a requirement for Rhizobium bacteria to fix atmospheric N.
Less than 4.8	In most soils, aluminium (Al) starts to precipitate from a harmless solid into a soluble form which is toxic to root growth. Aluminium tolerance among plant species varies. Reduced root growth means roots are unable to effectively explore soil for nutrients (particularly phosphorus and trace elements) and access stored subsoil water. Crop yield is reduced significantly. Reduction in root hairs occurs and so infection by rhizobia (nodulation of legumes) is severely affected.
Less than 4.5	The speed of N mineralisation processes (nitrification) slows significantly, resulting in decreased N supply. In most soils Al concentrations increase further and quickly become toxic to most pasture and crop species. There is a chance of molybdenum deficiency in cereals or canola, but check for local advice. The effectiveness of rhizobia in acid tolerant legumes, such as subclover, balansa and arrowleaf clover is reduced.
Less than 3.8	Soil can no longer buffer effectively against pH change and is overcome with acidity which breaks down clay minerals leaving only the sand component. Irreversible soil structural damage is done.

Source: Table adapted from Fenton, 2003.

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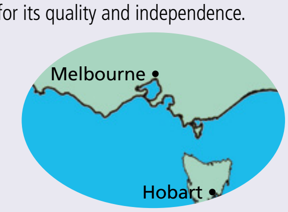
Region: Southern Farming Systems (SFS) was formed in 1995 by a group of farmers who came together to find ways of making farming in the higher rainfall zone (HRZ) more profitable. SFS has members in five branches; Geelong, Streatham, Hamilton, Gippsland and Tasmania. While SFS maintains strong partnerships with research and extension agencies and with agribusiness, the information provided to over 600 members, sponsors, supporters and students is highly valued for its quality and independence.



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Using good quality fine lime at the Rokewood site to ameliorate the acidity at 10 to 20 cm where the pH averaged 4.1.

incorporation will take five years or more to fix the acidity profile beyond 10 cm (depending upon soil type and rainfall), provided enough is applied to move downwards.

Maintaining good soil pH means yield responses to lime may not be immediately noticeable, but they will avoid ongoing acidification and yield declines. A soil pH increase will show that the lime is working and regular soil monitoring is recommended, particularly at 10–20 cm where there may be issues with subsurface acidity build-up.

Soil acidity eats away at yields

SFS replicated research trial data has been used to create lime response curves by calculating the percentage difference in yield of the control (un-limed plots) compared to limed plots for wheat and barley (see Figures 1 and 2). They show the yield reduction at different soil pH levels, especially in barley.

Most of the trial sites had acidity less than pH 4.5 in the topsoil plus acidity issues down to 15 cm or 20 cm. The moderate rates of lime applied and without any significant incorporation did not correct subsurface acidity at the sites and this probably reduced yield beyond what was measured.

NSW Agriculture broadcasting lime onto the soil surface at the Rokewood trial site.

Table 2: Rokewood subsoil acidity trial. Lupin response to liming treatments, 2018

Treatments	Treatment description	Lupin yield (t/ha)		Establishment counts (plants/m²)		Dry matter cuts at anthesis (kg DM/ha)	
Surface lime Incorporated	Surface liming 1.5t/ha incorporated into 0–10 cm with offset discs to bring pH to 5.5.	1.24	b	8.63	a	4084	b
Deep rip only	Surface liming 1 t/ha incorp. + deep rip. Ripped down to 30 cm, tines 50 cm apart.	1.36	b	6.73	b	4724	a
Deep lime	Surface liming 1 t/ha incorp. + deep rip + deep lime. Deep lime 1.5 t/ha placed between 8 to 25 cm (acid layer).	1.44	ab	9.07	a	4756	a
Lucerne pellet	Surface liming 1 t/ha incorp. and lucerne pellets 7.5 t/ha placed into acid band. (Rate based on providing the same amount of alkalinity). Contains 200 to 300 kg N/ha.	1.60	a	8.3	a	4983	a
LSD (P<0.05)		0.21		1.43		537	
CV (%)		7.46		8.72		5.8	

LSD – Least Significant Difference, CV – Coefficient of Variation

The responses are from surface applied South West soft rock lime [Neutralising Value (NV) 90 per cent, Effective Neutralising Value (ENV) 63 per cent] in 2014 with minimal tillage and incorporation.

These lime response curves will become even more robust with the collection of data points from 12 new trials SFS has set up in the high rainfall zone across Tasmania, south west Victoria, Gippsland and South Australia (supported by the National Landcare Program and GRDC).

We expect the responses to flatten out and become steady at pH levels above 5.0 for cereals and 5.5 for pulses.

With the collection of this additional data, lime response curves for canola and faba bean will also be generated.

Lime responses are difficult to predict

The lime responses can be variable as they are influenced by many factors such as:

Subsoil acidity

A trial at Rokewood is investigating subsoil acidity further including incorporating lime and organic amendment (lucerne pellets) to depth (see Table 2). The pH at this site was 5.1 at 0–10 cm, 4.1 at 10–20 cm and 4.7 at 20–30 cm. Relatively acid tolerant lupins were planted in the first year, but nonetheless it was apparent that the subsoil acidity resulted in a 672 kg per hectare reduction in biomass and a 200 kg per hectare yield loss (although yield difference was not significant).

Interestingly, the best response was with deep placement of lucerne pellets, producing an extra 399 kg per hectare biomass and 360 kg per hectare yield. Approximately a 20 per cent significant yield reduction in both wheat and barley was recorded at an acidity trial site near Cootamundra, NSW where the acidity constraint was at 10–30 cm depth.

Season

Acidity and aluminium toxicity reduce root growth which reduces the plant's ability to extract

Figure 1: Wheat yield responses to different soil pH levels, 2012–18

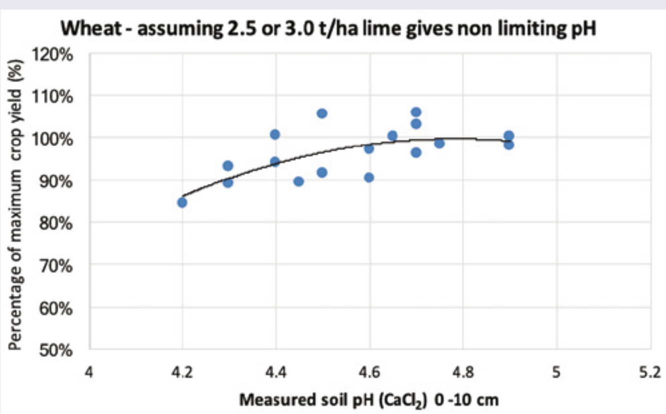

Figure 2: Barley yield responses to different soil pH levels, 2014–18

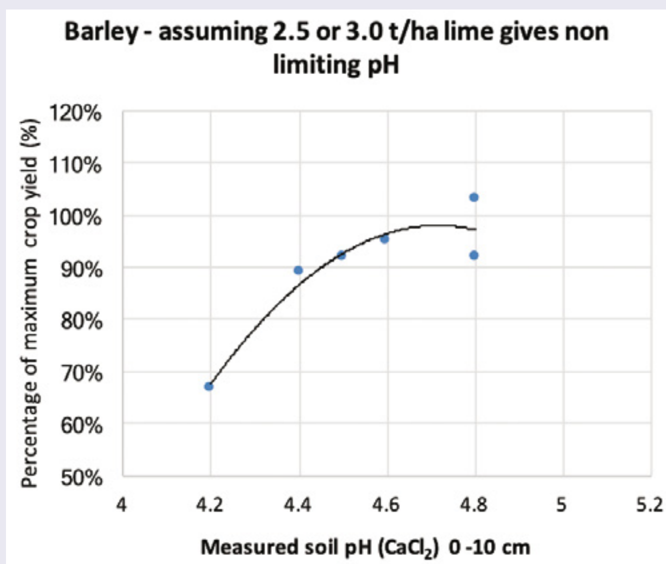

Table 3: Average annual acidification rate measured across Corangamite farming systems at different depths based on pH ($CaCl_2$) change over four years (2014–18)

System	Average annual acidification rate of the soil layers (*Application of kg pure lime/ha/year to counteract acidity)		
	0–10 cm	10–20 cm	20–30 cm
Cropping on clay loams	Average pH fall 0.05/year Lime equivalent 180 (Range 85-430)	Average pH fall 0.03/year Lime equivalent 100	Average pH fall 0.03/year Lime equivalent 100
Grazing on clay loams	Average pH fall 0.04/year Lime equivalent 138 (Range 85-345)	Average pH fall 0.01/year Lime equivalent 45	Average pH fall 0.02/year Lime equivalent 50
Hay cutting including lucerne on loams	Average pH fall 0.18/year Lime equivalent 350 (Range 300–400)	Average pH fall 0.09/year Lime equivalent 175	Average pH fall 0.12/year Lime equivalent 230

*Assuming 1 tonne of pure lime/ha lifts pH by 0.29 units in a clay loam and 0.5 in a loam.

soil moisture particularly in a dry finish to the season. But if there is ample soil moisture and the crop's nutritional needs are met, there may not be a significant lime response.

Organic carbon

High soil organic carbon (organic C more than 2%) appears to influence lime response by reducing the impact of aluminium solubility and toxicity.

Other soil constraints

If there are other soil constraints to production present, then a lime response may not be seen. This has been apparent in pasture trials in Southern Victoria where nutrient deficiencies over-rode lime responses.

Lime or fertiliser may not have shown significant differences when applied separately, but together they did. This indicates that lime is not a substitute for fertiliser – both are needed.

Other potential constraints may include compaction, waterlogging or sodicity.

Lime reaction

If you are looking for obvious responses in the first season following lime applications, you may be disappointed. Among this project's trials, there were only two with statistically significant lime responses in grain yield in the first year and that was when pH was low (pH 4.2 and 4.5) and acid sensitive crops were grown.

Lime needs acidity moisture and time to dissolve. Incorporated superfine lime has taken up to 18 months to fully dissolve. Surface applied lime without incorporation is likely to drive up soil pH in the top 1 cm to 6.0 or above where lime stops dissolving. Hence, the benefit of incorporation of some kind.

Acidification rates

If you are farming and removing plant and/or animal products from the paddock, then you are acidifying the soil. Soil acidification is caused by a number of processes, for example, as roots take up cations they release hydrogen ions to maintain charge balance.

Also, the cycling of nitrogen is particularly important, with the addition of urea or ammonium which is converted into nitrate and then leached beyond the rooting zone, leaving behind acidity.

If the agricultural system was closed (that is, products not removed and nitrate not leached), then acidification rates would be zero.

Analysis of trial results and monitoring of 100 un-limed paddocks mainly within the Corangamite catchment, showed that the rate of acidification varies according to the farming system and soil type (Table 3). The measured pH changes varied from 0.05 and 0.18 units per year depending upon the production system.

The decrease in soil pH at 10–20 cm and at 20–30 cm over the four-year period was also found to be highly significant. The equivalent amount of pure lime (100 per cent NV) required to neutralise the annual acidification rate was calculated from the reductions in pH over a four-year period.

Table 4: Acidifying effects of various farm enterprises in the greater than 500 mm per year rainfall zone

System	kg of lime/ha/year to balance acidification
Continuous grain cropping including grain legume	200 to 300
Grazed pastures	100 to 200
Lucerne hay	200 to 700

Adapted from Hollier, 1999.

Lime movement occurs if pH is kept above 5.5

Very few of the recent SFS trials saw lime movement beyond 10 cm because there was not enough time for it to move and because rates were not high enough to saturate the surface with alkalinity to allow it to leach. Any change in pH measured may have been through physical lime falling down cracks.

A lime trial run by NSW DPI from 1992 to 2010 (18 years) is one of a number of trials that only found subsoil amelioration when soil pH in the topsoil was kept above 5.5. Micro-fine lime was incorporated into the top 10 cm and soil pH maintained above 5.5 for the trial duration to counteract acidification and leaching.

After four years, lime had moved to 15 cm, but advanced no further for another four years (2004), but in 2010, lime was detected at 25 and 30 cm. Movement was about 1 cm per year.

Variation across the paddock and down the profile

The average paddock pH can be misleading when trying to make decisions about liming. To make informed decisions about liming, it is good to know what you are dealing with. The use of pH mapping or using yield maps to identify low production zones and then taking exploratory cores within them both have merit.

The Rokewood subsoil acidity site provides a good example of how soil acidity changes spatially and vertically down the soil profile. The Rokewood trial is 100 by 140 metres and the variation in soil pH is 2 units in the top 10 cm (Table 5).

Table 5: Average pH ($CaCl_2$) and Exchangeable Al results for the Rokewood trial site, 2017

Depth	Average soil pH	Range of soil pH	Average Al % of exchangeable cations
0–10 cm	5.11	4.1–6.1	2.75%
10–20 cm	4.10	3.8–4.4	19.33%
20–30 cm	4.71	4.1–5.5	3.41%
30–40 cm	5.76	4.8–7.1	0.09%

NSW Agriculture broadcasting lime onto the soil surface at the Rokewood trial site.

Doug Crawford, Ag Victoria, describes four considerations in relation to variable rate liming once the variability in soil pH is known. These are:

- No pH issues and therefore there is no need to lime.
- Marginal soil pH but maintenance liming is needed which can be applied by a blanket rate.
- There are distinct pH zones which make variable rate useful.
- There is too much variability but generally low pH, therefore it makes sense to apply a blanket rate of lime.

Doug describes pH mapping as an insurance policy to make sure lime is applied to where it is needed most and hence, is as cost-effective as possible. Some argue that the money spent on pH mapping (approximately $65 per hectare) is better spent on additional lime. Having pH maps allows you to identify zones that can be monitored in future, especially if subsoil acidity is likely.

Variation in soil pH across paddocks is caused by management and soil type which makes it hard to predict. Some examples include sheep stock camps, lime spreading inaccuracies, burnt canola swaths, trees and high production grain and hay areas.

Developing a lime program

Once the distribution of soil acidity is spatially and vertically understood, decisions can be made about where to lime, what rates are needed and how to apply the lime. Most growers and advisers only consider the 0–10 cm soil. Lime rates are rarely estimated based on treating acidity at all soil depths – 0–10 cm, 10–20 cm and 20–30 cm – which is why subsoil acidity develops.

Lime rates are determined by knowledge of the pH buffering capacity, which is chiefly influenced by the amount of organic carbon and then clay content. Below is a commonly used method for lime rate estimation which is available through Soil acidity monitoring tools (DPI, 2005) and appears in OptLime and Soil Amelioration calculators from WA. It calculates the amount of lime required to reach a target pH but to maintain it.

The target soil pH for the 0–10 cm is 5.5 to 6.0, if aiming to achieve lime movement or growing acid sensitive pulses, and pH 4.8 deeper in the soil to avoid Al toxicity.

Step 1. Pure lime requirement (t/ha)
= (Target pH – Current pH) ÷ Conversion factor

Divide the desired pH change by a conversion factor for different soil types:
0.26 for clay;
0.37 for clay loam;
0.47 for sandy clay loam;
0.57 for sandy loam; and,
0.67 for sand.

Step 2. Adjustment for organic matter (OM) – If the soil OM per cent is above 2 per cent, then add an extra 0.4 tonnes per hectare.

Note OM% = organic carbon % x 1.7.

Greater than 2 per cent OM content is likely in most pastures or crop pasture rotations.

Note the calculation is for pure lime which has 100 per cent NV and so lime rates will require adjustment depending on the NV per cent of the lime to be used.

Also, these calculations need repeating for each 10 cm soil layer as shown in the example in Table 6. The 10–20 cm and the 20–30 cm layer will be unlikely to contain OM content below 2 per cent so step 2 can be ignored.

Lime calculation rates for amelioration of acidity are estimates only and so it is important to monitor soil pH change after three or five years so that rates can be adjusted.

Too much lime?

Topdressing large amounts of lime without incorporation may cause micronutrient deficiencies (e.g. copper, zinc, boron and manganese) if these elements are already marginal, especially on poorly buffered sands. High rates of pure lime (NV 100 per cent) are thought to be in excess of 2 tonnes per hectare for a sand, 3 tonnes per hectare for a sandy loam or 4 tonnes per hectare for a loam or clay loam soil.

While these deficiencies can be overcome by the application of appropriate granular fertiliser or foliar sprays, if high rates of lime are required, it is best to split applications over a period of three or four years or incorporate the lime with a tine or disc implement.

Choosing a lime

Choosing a lime should be based on the most cost-effective product. Transport costs can be high so often, the cheapest lime is from the pits located closest to the farm. The price of lime tends to reflect the level of processing. But you need to know how effective the product is at neutralising acidity.

The typical costs of lime spread are about $40 to $50 per tonne depending upon the quality and transport distance.

- Purchase cost $18 to $30 per tonne for Victorian Ag lime.
- Cartage rate 10 cents per km.
- Spreading $8 per tonne.
- Variable rate spreading, extra $2 per hectare.

Most agricultural limestones are calcium carbonate and can be described as hard rock limes or soft rock limes. Explosives are needed to extract hard rock limes and need to be processed very finely so they react quickly in the soil, which add to the expense. Most of the limes in Victoria are soft rock excavated, crushed and then particles screened to less than 2 mm.

Purity, particle size and solubility

The main factors determining lime quality include purity (i.e. neutralising value NV) particle size distribution and solubility. Pure calcium carbonate (or pure limestone) has an NV of 100 per cent. The higher the NV, the purer the product. Lime products sold in Victoria commonly have an NV of 80 to 90 per cent. Some products can exceed 100 per cent if containing appreciable amounts of magnesium carbonate and/or burnt lime.

The finer a lime product is, the greater the surface area for the neutralising chemical reactions to occur. Therefore, a finer lime will reduce soil acidity more quickly than a coarser lime. The rate of lime dissolution is also affected by its solubility. Lime is regarded as being relatively insoluble, although this varies amongst different types.

NSW DPI compared the pH change of different lime types with the same average particle sizes and found that soft limes created 20 per cent greater pH change compared to a hard calcitic lime over a period of six to 12 months due to differences in solubility. Dolomites contain less soluble magnesium carbonate, and created 15 per cent less pH change compared to hard limes.

Effective Neutralising Value (ENV)

ENV is a calculation that allows for comparison of different liming materials by accounting for both the neutralising value of the lime and particle size. An ENV of a lime product is calculated based on the sum of its percentage of particle sizes (fine <0.3 mm, medium >0.3 mm to 0.85 mm and coarse >0.85 mm) which are discounted according to their potential reactiveness. Particle sizes of 5 mm are thought to take about 20 years to dissolve.

Table 7: Costs of soil acidity at the Bellarine trial site where soil pH was 4.2 (0–10 cm), 4.4 (10–20 cm) and 4.9 (20–30 cm) and lime applied at 3 t/ha

Year	Crop	Average yield of limed plots (t/ha)	Yield reduction compared to lime 3 t/ha	$Price/t of grain	$ Calculated cost of acidity
2014	Barley	3.0	1.0	$278	$275
2015	Canola	1.7	0.4	$531	$228
2016	Wheat	7.3	1.2	$200	$230
Total costs of acidity for 3 years					$734/ha

Table 6: The calculations of approximate lime rate required at the Rokewood trial

Depth	Average soil pH	Target	pH changed required	Soil type	Organic C %	Lime requirement (t/ha)
0–10 cm	5.11	5.8	0.7	Sandy loam	0.8	1.2
10–20 cm	4.10	4.8	0.7	Sandy loam	0.5	1.2
20–30 cm	4.71	4.8	0.1	Clay	0.6	0.3
Total pure lime requirement for soil pH recovery						**2.8**

A good quality lime from Victoria will have close to 50 per cent of its particle sizes less than 0.3 mm and very little above 0.85 mm and with good screening practices should contain no more than 5 per cent above 1 mm. Having up to date information on particle size distribution is important, even for soft rock limes.

Pelleted limes and liquid limes

There has been interest in the use of pellets containing super fine lime (20 to 40 µm) for ameliorating soil acidity, but the costs of these products are about $260 per tonne in bulk. Researchers in WA have reported that the lime pellets used in their trials acted like a good quality lime, and that it did not move horizontally in soils as was hoped, only vertically. There is interest in using these products in air seeders to place prilled lime into acidic layers at 10–20 cm at rates of 500 kg per hectare for two or three years and possibly in different orientations to maximise soil coverage.

Liquid lime sources are generally micro-fine calcium carbonate in suspension. In trials conducted by the Woady Yaloak catchment group, recommended rates of liquid limes were shown to be ineffective at creating pH change in comparison to standard rates of agricultural limes.

Profitability of liming

The profitability of liming is generally straightforward because many of the crops are acid sensitive, such as barley and pulses, and liming costs are often recouped within short time frames. Certainly, at one SFS trial, acidity cost was calculated to be $734 per hectare over the three-year period and liming (approx. $150 per hectare spread) paid for itself after the first year (see Table 7). This trial provides a good example of how liming can avoid yield losses from acidification.

Timing of lime application

Lime can be applied any time. Lime is normally applied in summer or early autumn to fit the farming schedule. Spring liming of pastures is beneficial to a following cropping rotation as there is time for the lime to start neutralising acidity, particularly if there is summer rainfall.

The factors which affect the time of liming are:

- Paddock trafficability.
- The need to apply lime six weeks prior to sowing to avoid inducing any micronutrient issues.
- Accessing lime, and ability to back-load lime after grain delivery to reduce transport costs.
- Wind erosion risks where the fine component of lime is lost from bare surfaces.

Growers in high rainfall zones often look to spread lime prior to burning stubble. Lime effectiveness is not adversely affected by burning. Agricultural limes are treated at 900°C in kilns to create burnt lime which makes it faster acting for use in the building and horticultural industries. A hot stubble burn might reach 500°C at most. But agronomists raise some concerns with spreading lime before burning stubble. These include:

- Spreading lime over heavy stubble may not give even coverage compared to spreading on bare paddocks. This may be a visual perception issue as the lime cannot be as easily seen amongst the stubble or could be valid if the spreading height was too low.
- Stubble does not seem to burn as well if lime is spread. This may be a factor if the lime was moist and covered stubble.

Soil pit discussions with Lisa Miller at SFS – Agrifocus field day on October 17, 2018.

Applying lime into paddocks with some stubble cover or prior to burning is likely to reduce losses from wind erosion. Timing application to coincide with rainfall or heavy dews can help wash the lime off any stubble and start to dissolve the lime.

To sum up

Acidification occurs in all farming systems where plant or animal products are removed, and liming will be necessary to neutralise it or else significant losses in yields will occur

Acidification is not just confined to the top 10 cm of soil and the emerging issue of acidity at 10–20 cm indicates that our liming practices (rates, frequencies and lack of incorporation) have been insufficient at addressing it. Therefore attention to the subsurface and subsoil through monitoring, the maintenance of good soil pH and generally incorporation of lime in low rainfall (<500 mm) or heavy clay soils is vital for protecting the soil asset.

This work is set to be expanded in a new GRDC and NLP Smart Farms project across the high rainfall zone in Tasmania, Gippsland and in southern South Australia.

The research undertaken as part of this project (SFS00026) is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC – SFS would like to thank them for their continued support. Other acknowledgments include the Australian government support through the Corangamite catchment management authority and through a Smart Farms grant. In addition, thank you to NSW DPI and Agriculture Victoria.

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Lime quality and testing PhD opportunity

A PhD opportunity investigating lime quality and developing new tests to reflect performance is now available through SFS.

Soil acidity is recognised as one of the major soil constraints to increased agricultural productivity in Australia. Lime is a key amendment to address the decline in soil pH. This project will explore and develop novel approaches to advance understanding of lime type, quality, variability and spreadability on performance under current farming systems and practices.

Lisa Miller from SFS – the farmer organisation leading the project – says an outcome of the PhD would be to have a way of testing lime quality that we are confident in and is commercially applicable. A reliable methodology will be developed to accurately compare different lime types.

This PhD offers the opportunity to work in the Centre for eResearch and Digital Innovation (CeRDI) at Federation University Australia.

The Victorian Lime Producers Association is a third partner in the project and represents the interests of Victorian limestone producers.

SFS and CeRDI are offering this industry-funded 3-year PhD scholarship in soil science at Federation University Australia's Mt Helen Campus in Ballarat. This is an excellent opportunity to be paid to undertake your PhD in an industry with excellent employment prospects. Further information see *www.seek.com.au*

This project sits within a broader project: *Building the resilience and profitability of cropping and grazing farmers in the high rainfall zone of Southern Australia*, funded by the Australian Government's National Landcare Program Phase Two.