Long term effects of surface applied lime in the Woady Yaloak Catchment

September 2011

Part 1 - Retesting of SGS lime sites
About these notes

These notes have been prepared by Cam Nicholson, Nicon Rural Services for the Woady Yaloak Catchment Group. They are the first of three lime related activities being undertaken as part of a Caring for Our Country project to enhance biodiversity and soil conditions in the Woady Yaloak Catchment.

The notes describe the long term effects of liming on soil conditions from trials conducted in 1999 to 2002 as part of the Sustainable Grazing Systems (SGS) program. The second document will report on long term trends in soil condition, including pH, over a 20 year period based on previous and current farmer soil tests and land use. The third and final document will present the early response of new lime trials.

Disclaimer

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Executive summary

Eight paddock scale comparisons were established around Werneth in April 1999 as part of the Sustainable Grazing Systems (SGS) program. Different rates (at 3 sites) and different supplies of lime (at 3 sites) were applied and compared to a no lime area. Two sites only had one limed area compared to no lime. Rates varied from 1.25 t/ha to 5 t/ha. Lime was sourced from Kurdeez (K), Lara (L) and Green Valley (GV).

Sites were retested in August 2011 to examine the changes in soil pH and soil fertility. Four of the eight sites were in crop and four sites had received further applications of lime, including the areas not limed in 1999. The period between testing was drier than the long term average, including a severe drought.

The key finds were:

- **Soils have acidified since testing in 1999.** Of the four paddocks where no lime has been applied since 1999, the pH (CaCl$_2$) in the top 10 cm has dropped by 0.2 to 0.3 of a unit (falling from 4.7 to 4.5 or 4.4). This may appear small but given the logarithmic scale used to measure pH, the change represent approximately a doubling of hydrogen in the soil.

- **The pH (CaCl$_2$) of soils limed in 1999 are 0.2 to 0.5 of a unit greater (ie less acid) than the non limed areas.** However because the non limed areas have continued to acidify, a more meaningful comparison is with the pH of the non limed areas in 1999. Three of the four limed sites still remain higher than the pre liming levels when applied at 2.5 t/ha or 3.0 t/ha, suggesting liming has an effect for at least 10 years and possibly more.

- **There appears to be no obvious difference between the limes types (suppliers) when used at the same rates.**

- **Increased rates of lime reduce the acidity more than lower rates of lime (as expected).**

- **Liming maintained low levels of available (toxic) aluminium.** This means highly sensitive plant species would not be affected, whereas they would be on the non limed areas.

- **Available phosphorus (Olsen P) was not affected by liming.**

- **Organic carbon increased by between 0.15% and 0.32 % carbon over 11 years but cannot be attributed to the lime alone.** The accumulation may be a result of additional pasture growth, improve soil biological activity (fungi and bacteria) and farming practices.
Some concept around lime and pH

Describing soil acidity

Soil acidity (and alkalinity) is measured by pH. The \( p \) stands for potential and the \( H \) stands for hydrogen. It measures the amount of hydrogen (\( H^+ \)) in the soil. The more acid a soil, the more hydrogen in the soil. Alkaline soils contain less hydrogen.

All plants need hydrogen to enable them to absorb water and nutrients (called osmosis). Too much or too little hydrogen in the soil disrupts this process.

The measurement scale used for pH ranges from 0 to 14, with 7 considered neutral. Acid soils have a pH less than 7, alkaline soil greater than 7. To complicate matters, the pH numbers are presented on a logarithmic or multiplication scale. If we give a soil with a pH of 7 a value of 1, a soil with a pH of 6 has 10 times more hydrogen in the soil than a pH of 7 (not twice as much) and a soil with a pH of 5 has a 100 times more hydrogen in the soil than a pH of 7 (table 1). The amount of hydrogen in the soil doubles when pH drops from 5.0 to 4.7.

Table 1: Amount of soil hydrogen as pH declines

<table>
<thead>
<tr>
<th>pH (water)</th>
<th>Amount of hydrogen compared to pH 7.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.0</td>
<td>1</td>
</tr>
<tr>
<td>6.0</td>
<td>10</td>
</tr>
<tr>
<td>5.5</td>
<td>32</td>
</tr>
<tr>
<td>5.4</td>
<td>40</td>
</tr>
<tr>
<td>5.3</td>
<td>50</td>
</tr>
<tr>
<td>5.2</td>
<td>63</td>
</tr>
<tr>
<td>5.1</td>
<td>79</td>
</tr>
<tr>
<td>5.0</td>
<td>100</td>
</tr>
<tr>
<td>4.9</td>
<td>126</td>
</tr>
<tr>
<td>4.8</td>
<td>158</td>
</tr>
<tr>
<td>4.7</td>
<td>200</td>
</tr>
<tr>
<td>4.6</td>
<td>251</td>
</tr>
<tr>
<td>4.5</td>
<td>316</td>
</tr>
</tbody>
</table>

Measuring pH

The most common method of measuring soil pH is by mixing 1 part of oven dry soil with 5 parts of water. This represents the hydrogen the plants are exposed to in the soil. Unfortunately this fluctuates depending on the soil moisture and amount of salt in the soil. Research has shown this variation can be as much as 0.6 of a unit throughout the year, so it is not useful for making decisions about possible applications of lime.

An alternative test adds a chemical called calcium chloride (\( \text{CaCl}_2 \)) to the water sample. This removes the natural fluctuation, which means testing can occur and be compared at any
time of the year. The calcium chloride test is lower than the water test, usually by 0.7 units (although this will vary between 0.1 and 1.2 depending on the soil type).

**pH, aluminium and plant tolerance**

Many clay soils contain aluminium. Usually this aluminium is in a chemical form that is not toxic to plants. However if the pH falls below a certain level (more acid), the non toxic aluminium changes and can become toxic to some plants.

There is threshold bellow which the non toxic form of aluminium is rapidly converted to the toxic form. This is usually around a pH of 5.3 in water and 4.6 in CaCl$_2$.

Some plants are more sensitive to aluminium than others. Lucerne, phalaris, barley and canola are highly sensitive, followed by most clovers and wheat. Ryegrass and tall fescue are moderately tolerant with cocksfoot and oats highly tolerant.

**Measurements of soil aluminium**

Laboratories test for toxic aluminium in different ways. The most common methods and levels of various tolerances are listed (table 2).

**Table 2: Plant sensitivity to aluminium and corresponding levels for different analysis methods**

<table>
<thead>
<tr>
<th>Plant tolerance</th>
<th>Species</th>
<th>Aluminium (% of cations$^1$)</th>
<th>Aluminium (CaCl$_2$)</th>
<th>Aluminium (KCl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High sensitive</td>
<td>Lucerne, phalaris, barley, canola</td>
<td>2 - 8</td>
<td>0.5 - 2</td>
<td>15 - 30</td>
</tr>
<tr>
<td>Sensitive</td>
<td>Most clovers, wheat</td>
<td>8 - 12</td>
<td>2 - 4</td>
<td>30 - 50</td>
</tr>
<tr>
<td>Tolerant</td>
<td>Ryegrass, tall fescue</td>
<td>12 - 21</td>
<td>4 - 8</td>
<td>50 - 100</td>
</tr>
<tr>
<td>Highly tolerant</td>
<td>Cocksfoot, oats</td>
<td>21 - 30</td>
<td>8 - 13.5</td>
<td>&gt;100</td>
</tr>
</tbody>
</table>

*Source: Acid Soil Action*

**Lime and lime testing**

Lime is calcium carbonate (CaCO$_3$). When lime is applied to the soil, the carbonate (CO$_3$) reacts with the hydrogen (H$^+$) to produce carbon dioxide and water. Most limes are not very water soluble, so historically it is recommended to incorporate lime to increase the contact with the hydrogen in the soil. However limes from Southern Victoria are 'softer' and tend to partially dissolve in water. This means there is less need to incorporate these with cultivation or to have them ground finer.

Limes vary in the concentration of calcium carbonate. The purity of lime is referred to as the neutralising value (NV). A product must be above 60% calcium carbonate to be sold as lime in Victoria. The effective neutralising value (ENV) combines the purity of the limestone

$^1$ For salt levels between 0.07 and 0.23 dS/m
(NV) with the fineness of the limestone. This is a useful indicator of effectiveness for hard limestones but for the 'softer' limestones in Southern Victoria, ENV is less useful than the NV.

The Victorian Limestone Producers Association (VLPA) conduct voluntary tests of members products. The most recent results can be found at www.vlpa.asn.au/prodspecs
The trials

Eight paddock scale comparisons were established around Werneth (between Cressy and Rokewood) in April 1999 as part of the Sustainable Grazing Systems (SGS) program. The comparisons involved applying commercial quantities of surface applied lime to perennial pastures and comparing changes in soil condition, pasture production and pasture composition 20 months later. Different rates (at 3 sites) and different supplies of lime (at 3 sites) were applied and compared to a no lime area. Two sites only had one limed area compared to no lime. Rates varied from 1.25 t/ha to 5 t/ha. Lime was sourced from Kurdeez (K), Lara (L) and Green Valley (GV).

Since the completion of SGS, no further measurements had been taken at these sites. Four of the eight pasture sites have been cropped, three sites receiving at least one additional application of lime during the cropping phase (including the no lime areas). Four sites have remained in pasture and have not received any additional lime. Sites are identified in these notes by the original landowners name.

The depth of sampling varied. Some sites were sampled at 2.5 cm increments to provide a pH profile down to 10 cm. Other sites were sampled at 0 to 5 cm and 5 to 10 cm to examine any changes to soil fertility (0 to 5 cm reduces the dilution effect of the 5 - 10 cm layer which is commonly lower in fertility). A third group of samples were taken at 0 to 10 cm. Twenty samples were taken in each treatment and bulked together for analysis.

The trial sites were not replicated, the data set used in 2011 is small and different management has been applied at each site. The climatic conditions between 1999 and 2011 included a severe drought. The results need to be viewed with these variables in mind. Nevertheless the 2011 data does provide some insights into the effectiveness and longevity of lime in soils around Werneth. When combined with a more comprehensive study of soil condition in the Woady Yaloak Catchment (currently underway), the results should provide a better understanding of pH changes over time.

Discussion of the results are presented to answer a series of questions.

Natural / experimental variability

There is natural as well as sampling and laboratory variability in testing for soil pH. This needs to be taken into account when examining the changes over time. To highlight this variability, repeat samples taken on the same site at the same time often return a 0.1 or 0.2 difference in pH measurements. Therefore small difference between results may simply be due to natural variation or experimental error.
Question 1: How quickly is the soil acidifying?

There appears to be continuing acidification of the soil, even taking into account natural and experimental variability. The soil pH profiles of the no lime treatments at the four locations where lime has not be reapplied can be compared (figure 1).

![Keating - Soil pH (CaCl₂)](image)
![Lewis - Soil pH (CaCl₂)](image)
![Hirth - Soil pH (CaCl₂)](image)
![Bingley - Soil pH (CaCl₂)](image)

Figure 1: Changes in pH from 2000 to 2011 at 4 sites where no lime has been applied

While there is variability at each site, the change in pH (CaCl₂) down 0 to 10 cm is around 0.2 to 0.3 of a unit over 11 years (falling from 4.7 to 4.5 or 4.4). This may appear small but given the logarithmic scale used to measure pH the change represent approximately a doubling of hydrogen in the soil. The only variation to this trend is the Bingley site, where the pH has increased without liming. This site has been retested with a identical response measured, suggesting the initial measurement in September 2000 may be erroneous.
Question 2: How deep and quickly does surface applied lime move into the soil?

The pH profiles (at 2.5 cm increments) provide an illustration of the movement of lime into the soil. Data from the original SGS trials measured 16 months after application in 1999 shows a change in pH down to 10 cm without cultivation (figure 2). The greatest difference were measured in the top layers.

**Figure 2:** Changes in pH 16 months after surface application of 3 t/ha Kurdeez lime
**Question 3: How long does the lime last?**

The four no limed pasture strips provide evidence of the lasting effect of lime in the soil. In interpreting the results, consideration must be given to the on-going acidification of the no lime treatment which is used as a comparison. In other words the reference point (no lime applied) has also shifted during this time (refer back to question 1).

Direct comparison of the limed versus no lime areas suggest a reduction in acidity down the profile due to the application of lime (figure 3). The change in pH (CaCl$_2$) down 0 to 10 cm is 0.2 to 0.5 of a unit greater (ie less acid) due to the lime.

![Graphs showing soil pH changes](image)

**Figure 3:** Differences in pH for limed and non limed sites in Aug 2011. Note the rates and types of lime differ.
If the 2001 pH profile for no lime is used to compare to the 2011 results where lime has been applied, three of the four limed sites still remain higher than the 2001 pre liming levels when applied at 2.5 t/ha or 3.0 t/ha (figure 4). This would suggest the liming has an effect for at least 10 years and possibly more.

Figure 4: Differences in pH for the lime and no lime sites in Aug 2011 and no lime measurement in 2000.
Question 4: Is there a difference in lime rates?

Yes. It would appear increased rates of lime reduce the acidity more than lower rates (as expected). While only two sites than have not been limed since 1999 can be considered (and there is some variation at the higher rates of 2.5 t/ha and 5 t/ha), they are greater than the no lime and the lighter application rate of 1.25 t/ha (table 3).

Table 3: pH of soil in August 2011 (CaCl$_2$, 0 - 10 cm) at different rates of lime application

<table>
<thead>
<tr>
<th>Site</th>
<th>No lime</th>
<th>1.25 t/ha</th>
<th>2.5 t/ha</th>
<th>5.0 t/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keating</td>
<td>4.4</td>
<td>4.5 (+0.1)</td>
<td>4.8 (+0.4)</td>
<td>4.7 (+0.3)</td>
</tr>
<tr>
<td>Bingley</td>
<td>4.8</td>
<td>4.8 (+0.0)</td>
<td>5.1 (+0.3)</td>
<td>5.4 (+0.6)</td>
</tr>
</tbody>
</table>

Comparisons at the third site where different rates of lime were used in 1999 and then more lime reapplied have been confounded by cultivation and the different crops grown.
Question 5: Is there a difference in lime types?

Limes from three different suppliers were tested (Lara Aglime, Green Valley and Kurdeez) at three sites. There appears to be no obvious difference between the limes used (figure 5 and table 4). The higher pH results at the Missen and Caldow sites illustrates the effect of additional liming since 1999.

![Graphs showing soil pH at Marshall, Missen, and Caldow sites](image_url)

**Figure 5:** pH in Aug 2011 on sites limed with the same rate but different type of product (L = Lara, GV = Green Valley, K = Kurdeez)
Table 4: pH of soil in August 2011 (CaCl₂, 0 - 10 cm) of three different limes at the same rate of application

<table>
<thead>
<tr>
<th>Site</th>
<th>Rate</th>
<th>Lara Aglime</th>
<th>Green Valley</th>
<th>Kurdeez</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NV</td>
<td>80</td>
<td>91-94</td>
<td>93</td>
</tr>
<tr>
<td>Marshall</td>
<td>3.0 t/ha</td>
<td>4.5</td>
<td>4.6</td>
<td>4.5</td>
</tr>
<tr>
<td>Missen</td>
<td>3.5 t/ha</td>
<td>4.7</td>
<td>4.8</td>
<td>4.8</td>
</tr>
<tr>
<td>Caldow</td>
<td>3.0 t/ha</td>
<td>5.2</td>
<td>5.1</td>
<td>5.1</td>
</tr>
</tbody>
</table>
Question 6: What is the effect of multiple applications of lime?

Three of the eight sites have received additional lime since 1999, including the no lime areas. All areas have been cropped and will have had some soil disturbance and higher rates of fertiliser, especially nitrogen based products. This makes interpreting the results more difficult. Nevertheless the results suggest an interesting response when comparing the once only limed areas (ie were the nil treatment in 1999) with the multiple application sites and the time between liming. If using soil pH as a measure, the original no lime areas that are recently limed again (Autumn 2011) seem to have 'caught up' to the previously limed areas and now show similar pH profiles (figure 6).

![Missen - Soil pH (CaCl2)](image)

**Figure 6**: pH in Aug 2011 on sites limed in 1999 and again in 2011 (L = Lara, GV = Green Valley, K = Kurdeez)

The apparent 'confusion' may be a result of the reactions occurring in the soil immediately after the lime has been applied. The only pH profile where lime has been applied in 2006 shows a more predictable response (figure 7).
Figure 7: pH in Aug 2011 on sites limed in 1999 and again in 2006 (L = Lara, GV = Green Valley, K = Kurdeez)
Question 7: Does liming affect the availability of nutrients and other soil conditions?

Only the four non limed sites have been used in this comparison and all sites remain in pasture. Firstly liming does (as expected) dramatically reduce the available aluminium in the soil 11 years after application and drops to a level where it does not threaten sensitive plant species (figure 8).

![Al (% exch cations)](image)

**Figure 8: Available aluminium (as measured by exch cation %) in Aug 2011 on sites limed in 1999 and not limed**

The long term effect on available phosphorus (Olsen or Colwell) is inconclusive (figure 9). Measurements in 2001 would suggest a short term increase in available phosphorus occurs due to liming, however if this did occur it is highly likely this available nutrient has been used for plant growth or fixed in the soil. The one site where a large difference have been measured was subdivided in 2000 and over time different stock rates and fertiliser histories may have influenced the results.

![Olsen P (mg/kg)](image)

**Figure 9: Available phosphorus (as measured by Olsen P) in Aug 2011 on sites limed in 1999 and not limed**
Organic carbon increased by between 0.15% and 0.32 % carbon over 11 years at all four sites (figure 10). While this does not appear very large, the rates of accumulation are in line with CSIRO research for organic carbon. However carbon accumulation is a complex process and many other factors influence the rate of organic carbon build up and decline. The accumulation is a result of interactions between additional pasture growth, improve soil biological activity (fungi and bacteria), nutrient availability, other management practices and climatic conditions. In addition the error in testing soil organic carbon can be large. From this data it could not be concluded that liming increases organic carbon.

![Organic C (%)](image)

**Figure 10**: Organic carbon in Aug 2011 on sites limed in 1999 and not limed

**Acknowledgements**

The Woady Yaloak Catchment Project would like to thank the following farmers for agreeing to have follow up sampling of the SGS lime sites on their property.

- Tim Bingley
- Steve Butler
- Peter Hirth
- Nev Keating
- Ewan Lewis
- Troy Missen
- Andy Stephens