

Soil acidity and treatment in the Coorong and Tatiara District Council areas

The extent, causes and treatment

KEY POINTS

- Soil acidity is becoming an emerging and significant issue throughout the Coorong and Tatiara District Council areas having a major constraint on crop and pasture production.
- Soil acidity can affect sub-surface and sub-soils.
- Soil pH should be tested in paddocks on a regular basis at 5 cm increments to at least 15 cm.
- Soil acidity can be treated with the use of lime and / or soil modifications (such as ripping, delving, spading and clay spreading) provided that the underlying clay is alkaline.



Figure 1: Testing soil pH at a soil pit field day

Introduction

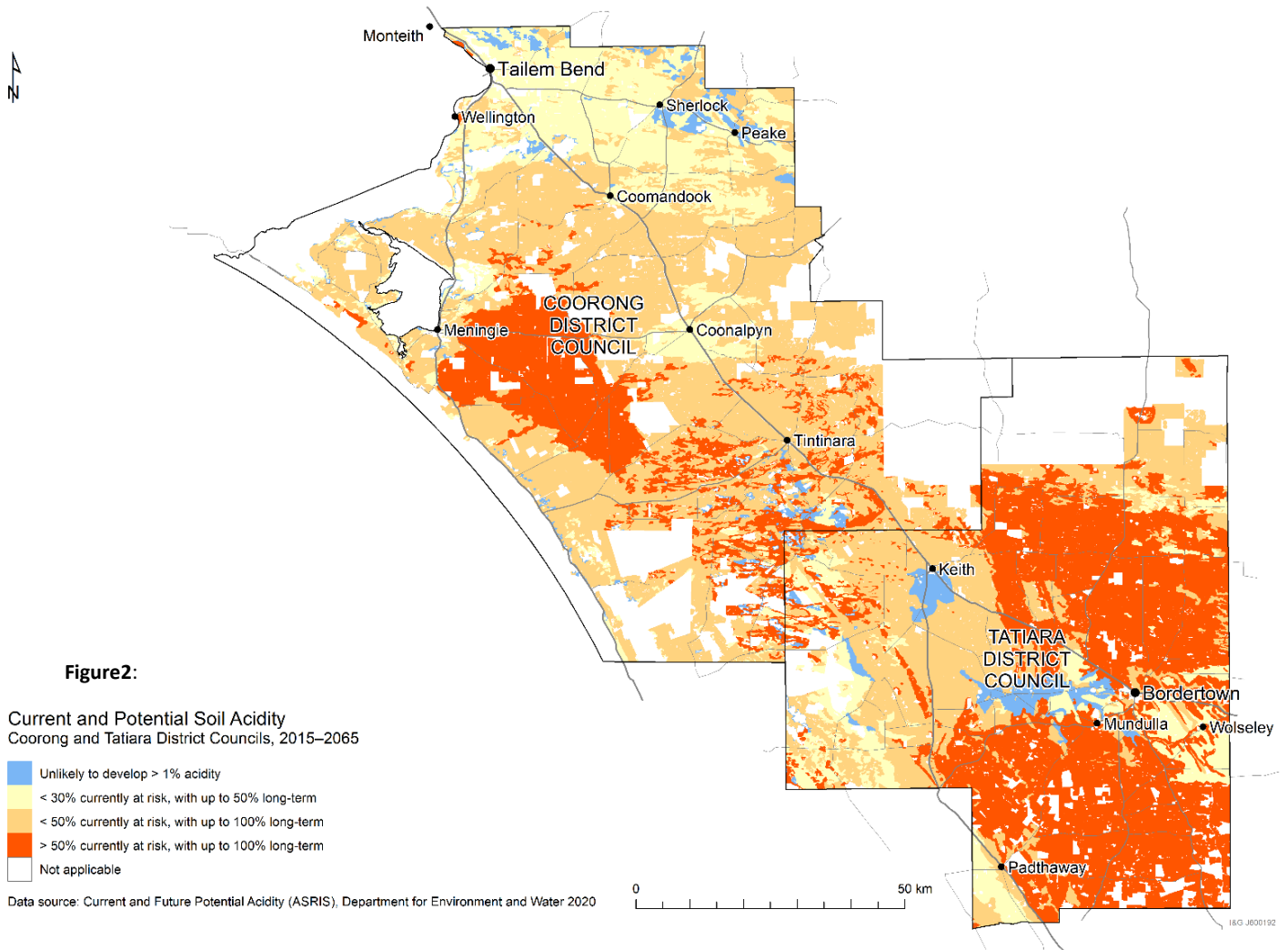
The Coorong and Tatiara District Council covers a combined area of 1.54 million hectares. It is a productive area of SA with a total value of annual agricultural production of more than \$490M (ABS, 2015-16).

Soil acidity (low soil pH) is becoming an emerging and significant problem throughout the area particularly on the sandy to sandy loam textured soils. It is a natural process but is accelerated with more productive and intensive farming practices.

When the soil falls below pH 5.5 (CaCl_2) the productivity of crops and pastures starts to decline.

The area currently acidic or likely to become acidic in the next few years is approximately 334,500 hectares or 35.6% of the agricultural area with an estimated production loss of \$5.3M.

It is estimated that a further 375,000 hectares of agricultural land in the area has the potential to become acidic over the next few decades assuming that the current farming practices continue and that soils are not adequately treated (Figure 2).



Lime and /or soil modifications such a ripping, delving, spading or clay spreading are options for the treatment of acid soils.

Cause and effect

Soil acidity is caused by a build-up of hydrogen ions throughout the soil due to:

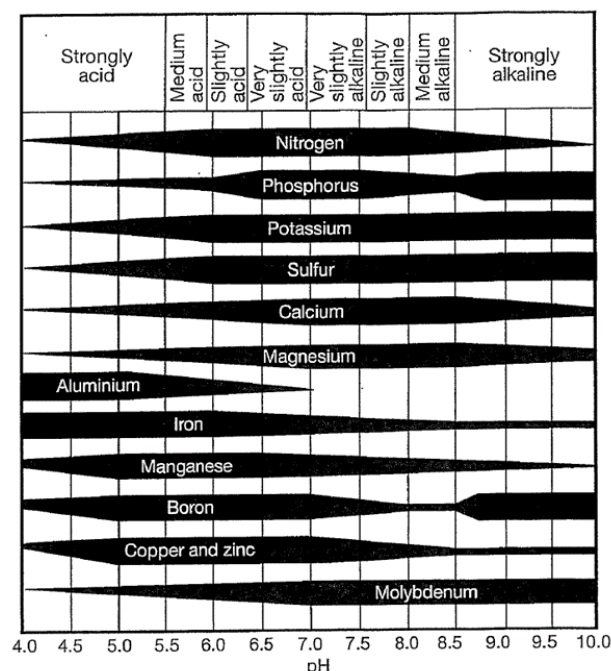
- the accumulation of organic matter;
- addition of ammonium-based nitrogen fertilisers;
- nitrate leaching; and
- the large removal of alkaline nutrients in plant and animal products.

Increase use of nitrogen fertiliser, higher yielding crops and more intensive cropping rotations have increased the rate of acidification throughout many areas of the Coorong and Tatiara District and has extended the areas where soils were not previously affected.

Fertiliser nitrogen applications generally accelerate acidification. Sulphate of ammonia (SOA) is three times more acidifying than urea, and one-and-a-half times as acidifying as diammonium phosphate (DAP) when compared per unit of nitrogen.

If soil acidity is not treated and when the soil pH falls below 5.5 (CaCl₂) then nutrients such as phosphorus, potassium, calcium, magnesium and molybdenum become less available to plants. Figure 3 shows the influence of pH on nutrient availability (pH water). The width of the bars indicates the availability of nutrients at different pH levels. The wider the bar the more available the nutrient is.

Figure 3: Influence of pH on nutrient availability (pH water) (Price, 2006)



Soil acidity can also reduce microbial activity including *Rhizobia* which is important for the nodulation of legumes. As the pH falls, toxic amounts of aluminium can be released into the soil, affecting root growth and plant development. Due to less availability of nutrients and toxic levels of aluminium then the productivity of crops and pastures start to decline, particularly for acid-sensitive plants resulting in a substantial economic loss.

Lucerne, lentils, annual medics, faba beans, canola and barley are all sensitive to acid soils. As the soils become more acidic then less sensitive crops may start to become affected. Table 1 shows the tolerance of crops and pastures to low soil pH.

Table 1: Tolerance of crops and pastures to soil acidity (low soil pH)

Very Sensitive	Sensitive	Tolerant	Highly tolerant
Lentils	Canola	Wheat*	Oats
Faba Beans	Phalaris	Sub-clover	Triticale
Chickpeas	Barley	Rye-grass	Lupins
Lucerne	Peas		Couch grass
Annual medics			
Durum wheat			
*Some wheat varieties can be sensitive while others can be tolerant. Wheat varieties that have some tolerance include: Wyalkatchem, Mace and Scepter.			

The symptoms of soil acidity show up as patchy un-even crop and pasture growth, yellowing of crops (Figure 4) poor nodulation of legumes and stunted root growth. If soil acidification is allowed to continue then it is likely that it will further decrease productivity and limit plant options to acid tolerant crops and pastures.

Acid tolerant weeds such as rye-grass and couch grass may dominant areas where soils are acidic.



Figure 4: Symptoms of low soil pH (pH 4.5 CaCl₂) on a lentil crop

If soil acidification continues then sub-surface and sub-soil layers can also be affected which are much more difficult and expensive to treat.

Where plants are affected there can also be reduced plant water use that can contribute to rising water tables and increased soil salinity. Where areas are left bare or partially bare then sandy areas can be prone to wind erosion.

Productive farming practices will continue to acidify the extent and severity of acidic land unless adequate on-going treatment such as liming and / or some form of soil modification is implemented.

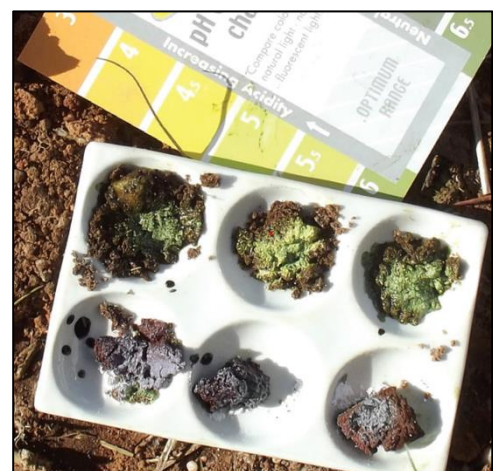
Soil sampling and testing

Soil pH can be measured in the field or in the laboratory.

Field testing kits (Figure 5) that can be purchased from agricultural stores are a useful guide for measuring soil pH levels. However, the result is an approximation of pH measured in soil water.

For a more precise test, soil samples should be sent to a soil laboratory and tested for pH in calcium chloride (CaCl₂).

Figure 5: Field testing kits can provide a guide for measuring in-field soil pH levels (Credit: Belinda Cay, Ag Communicators).



Soil sampling was traditionally carried out by taking twenty or so soil samples at a depth of 0-10 cm in a transect across the paddock and then the soil samples were sent to a laboratory.

Many soils are often stratified where they have a thin alkaline layer with an acid layer below. By sampling soils at 10 cm deep, often the severity of soil acidity was missed. When taking soil samples, it is now recommended to take depths at 0-5 cm increments to a depth of about 15 to 20 cm and then send these samples to a soil laboratory. When taking soil samples ensure that they are from a uniform area i.e. similar landscape and soil type.

On the laboratory test results you will notice that soil pH is measured by two methods i.e. in soil water or calcium chloride (CaCl_2). The optimum plant growth for pH (water) is between 6 and 8.5.

Soil pH (CaCl_2) is now the preferred method for testing soil pH as it gives a more accurate result in neutral to acid soils. However, it is about 0.8 pH units lower than pH (water). All lime recommendations are based on pH (CaCl_2).

For optimum crop and pasture production the soil pH (CaCl_2) in the top-soil should be 5.5 or greater.

Precision soil pH mapping by machines is a relatively new technology for measuring and mapping soil pH variation across paddocks. There are now a number of soil sampling machines that are commercially available. This includes the Veris® machines and quad bikes or ATV's with sampling units.

The Veris® machines can be towed with either a tractor or 4WD.

As they are towed across the paddock they take a sample on-the-go, measure the soil pH from direct contact and record its geographic position.

At a swath width of about 36 metres wide the machine samples about 8 to 10 points per hectare (Figure 6).



Figure 6: Veris® soil pH mapping machine

A number of organisations are now offering a soil sampling service where soil sampling units are mounted onto quad bikes or ATV's. Soil sampling is carried out on a pre-determined geo-referenced grid basis and due to cost-effectiveness is generally done on a one to two hectare grid. The soil is then sent to a laboratory for a range of soil analysis.

Once the data has been downloaded then soil pH maps can be produced. The maps often show a large spatial variability of soil pH and identify pH zones across paddocks (Figure 7). The soil pH maps show where lime should be targeted, and appropriate liming rates can be calculated for each zone.

By applying lime only where it is needed rather than a 'blanket' application results not only in improved soil pH conditions across the paddock but also helps to save costs.

Normalised Difference Vegetation Index (NDVI) maps (from satellites) that measure plant health and biomass as well as yield maps can also be used as a guide for acid soils. If the maps are showing low NDVI or low yield and if other issues such as diseases, nutritional problems, weeds, soil types and other constraints (shallow soils, rockiness etc) are eliminated then soil pH maybe the underlying cause.

Figure 7 & 8 shows the correlation between a soil pH map and NDVI map for beans. Where the soil pH is low then the beans are not growing as well.

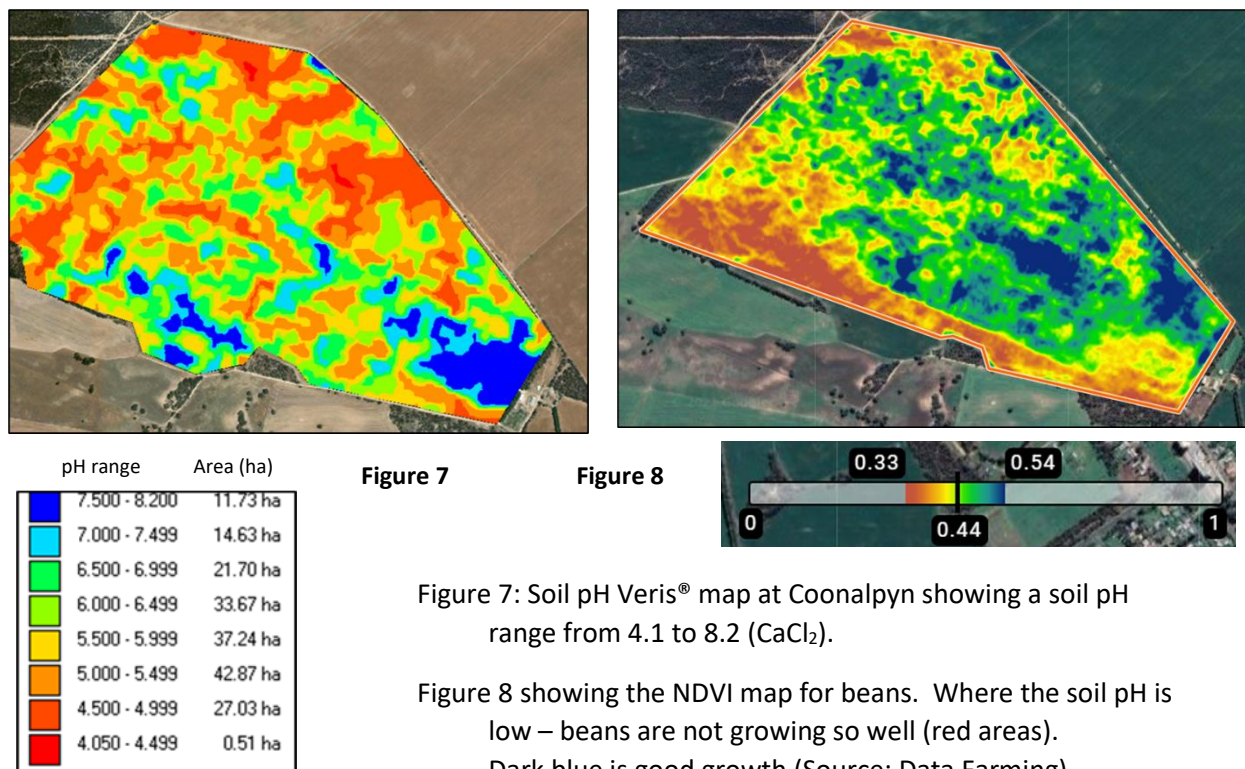


Figure 7: Soil pH Veris® map at Coonalpyn showing a soil pH range from 4.1 to 8.2 (CaCl₂).

Figure 8 showing the NDVI map for beans. Where the soil pH is low – beans are not growing so well (red areas). Dark blue is good growth (Source: Data Farming). August 2020

Yield penalty

When the soil pH falls below 5.5 (CaCl₂) then the yield of crop and pastures starts to decline. Table 2 and 3 show the estimated yield penalty for various crops and pastures with increasing soil acidity.

The data has been sourced from research trials, observations and pH vs yield maps.

Table 2: Estimated yield penalty for various crops with increasing soil acidity

Crop type	Production losses (tonnes per hectare)		
	Soil pH (CaCl ₂) 5.5 - 5.0	4.9 – 4.51	≤4.5
Wheat (Tolerant)	0	0.2	0.4
Barley	0.2	0.6	1.0
Peas	0.2	0.4	1.0
Lupins	0	0.2	0.4
Beans	0.2	0.6	1.2
Lentils	0.2	0.6	1.2
Hay	0.2	0.4	0.8
Canola	0.2	0.6	1.0
Other (oats / triticale)	0	0.2	0.4

Table 3: Estimated yield penalty for pastures with increasing soil acidity

Crop type	Production losses (tonnes per hectare)		
	Soil pH (CaCl ₂) 5.5 - 5.0	4.9 – 4.51	≤4.5
Acid sensitive (medic)	0.2	0.6	1.0 – 1.2
Acid tolerant (sub-clover)	0	0.2	0.4

Taking the area from each of the acidic ranges from the soil pH map (Figure 7) and multiplying this by the production losses (Table 2 or 3) and the current commodity price (\$/t) will provide an estimate of income lost, which can be quite substantial.

Treatment

Acid soils can be treated either with lime or with mechanical soil modifications provided that the underlying clay is alkaline.

Lime

Lime is used to neutralise soil acidification (Figure 9). The amount of lime required to treat acid soils depends on the initial soil pH, the target soil pH, soil texture and lime quality. To raise the soil pH by 1 unit requires 2 t/ha of lime for sandy soils; 3 t/ha of lime for sandy loams and 4 t/ha for loam to clay loam soils.

For example, if the current soil pH is 4.5 for a sandy soil then 2 tonnes of lime per hectare should raise the soil pH to a targeted level of pH 5.5 (CaCl₂). The lime requirement is based on pure lime or a Neutralising Value (NV) of 100%. If the material is less than this then higher rates of lime can be



used. For example, if you need to use 2 t/ha and the lime has a NV of 80% then $100/80 \times 2$ then 2.5 t/ha can be used.

The cost of lime per hectare depends on the lime quality (NV and particle size), freight costs, distance travelled from the lime source to the paddock and the application costs.

Figure 9: Applying lime

In the Coorong – Tatiara District Council area lime can be obtained from a number of sources.

Example

Assuming that a paddock with a sandy soil at Coonalpyn had a soil pH of 4.5 (CaCl₂) then the cost of the lime from the above sources to raise the soil pH to 5.5 (CaCl₂) taking into account the lime quality, freight, distance and spreading costs would vary from \$125 to \$184/ha.

As lime does not move quickly through the soil, mixing within the top-soil with tillage will improve its effectiveness. Lime may take up to two to three years to be fully effective.

Once the top-soil pH has been raised to pH 5.5 (CaCl₂) and assuming a rotation of wheat, barley, beans the pay-back period would be in the order 1.1 to 1.4 years. A maintenance rate of approximately 1 – 2 t/ha tonnes would be required about every 10 years.

A decision support tool for calculating lime application rates for acid soils and comparing the cost of lime from different lime suppliers for your paddock taking into account the cost of lime, lime quality, freight and distance has been developed by PIRSA. This is available from the web-site:

<https://acidsoilssa.com.au/>.

Soil Modification

There can be a range and a combination of machinery to modify soils to improve the soil pH both with and without lime. Ripping, delving or clay spreading are options for the treatment of acid soils by mixing alkaline clay through the top-soil. The pH of the sub-soil clay should be checked before using these methods.

Table 4 summarises some of the soil modification treatments, the estimated costs and the estimated pay-back periods. The pay-back period has been based on a wheat, barley, beans, wheat, barley, pasture rotation.

Table 4: Soil modification treatments for acid soils, approximate costs and pay-back periods

Tillage method	Summary	Approx. cost (\$/ha)	Approx. payback period (years)	Estimated time the treatment may last (years)
Deep Ripping	Deep Ripping results in minimal incorporation depending on the ripper tynes, however it can bring up some alkaline clay that can influence surface soil acidity provided that the clay is within 0.6 metres of the surface.	60 - 100	0.6 – 1.0	2-10
Spading	Mixes soil to a maximum working depth of 0.35 -0.4 metres. Can incorporate a range of surface spread amendments (e.g. lime, gypsum, organic matter, sub-soil clay and nutrients).	130	1.2	3-10
Delving and Incorporation	Delving is the use of wide tynes and bringing up alkaline clay from the lower part of the soil profile to the surface provided that the clay is within 0.6 metres of the surface. Once the clay is brought to the surface it requires incorporation into the surface soil (Figure 10).	300-450	1.9 – 2.3	10+
Clay Spreading and Incorporation	<p>If the clay is too deep in the profile for ripping or delving then clay spreading can be an option. Clay spreading is the removal of sub-soil clay from excavated soil pits, transporting it to the site and spreading it on the soil surface (Figure 11). The total distance from the clay pit must be considered in the total cost per hectare. If the distance is too far, the cost of transporting the clay to the site will prove un-economic.</p> <p>Clay spreading rates can vary from 150 to 250 t/ha with most farmers in the SE now using the higher rates, particularly in the higher rainfall areas. The alkaline clay on the surface will need to be fully incorporated. The cost depends on the machinery used, amount of clay applied per hectare, distance from the pits, the amount of over burden of material stockpiled and incorporation.</p>	500-800	2.5 – 4.0	Up to 20+

The pay-back period has focused primarily on treating acid soils but there are other benefits such as overcoming water repellent sands, reducing compaction, reducing erosion, improving soil structure and fertility and improving water holding capacity.



Figure 10: Delving



Figure 11: Clay spreading (Credit: Graham Gates)

Other machinery can include deep ripping with inclusion plates, off-set discs, one-way plough, mouldboard plough etc.

A recent innovation is the Bednar Terraland Ripper machine that is a combination of deep ripping and spading.

Other treatments that can improve soil pH include biochar, composts and manures but these are generally only used on small areas.

If alkaline irrigation water is used, then this can also have an alkalisising effect.

Summary

Soil acidity is becoming an emerging and significant problem throughout the Coorong and Tatiara District Council areas especially on the sandy to sandy loam textured soils and is having a detrimental effect on crop and pasture yields.

Both surface and sub-surface soils should be monitored on a regular basis, at about every five years to determine the soil pH.

Soil acidity can be prevented and treated through liming and / or soil modification methods.

References

Price G. (2006) *Australian Soil Fertility Manual* (Third Edition), Australian Fertiliser Federation and CSIRO.

Further information

Further information can be obtained from the web-site at: <https://acidsoilssa.com.au/>



National
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