Understanding Soil Acidity

Agricultural Bureau
of South Australia Inc.
PATHWAY TO IMPROVEMENT

CARING FOR OUR COUNTRY

Government of South Australia
Department of Environment and Natural Resources

"The nation that destroys its soil, destroys itself"

Franklin D Roosevelt

Understanding soil acidity

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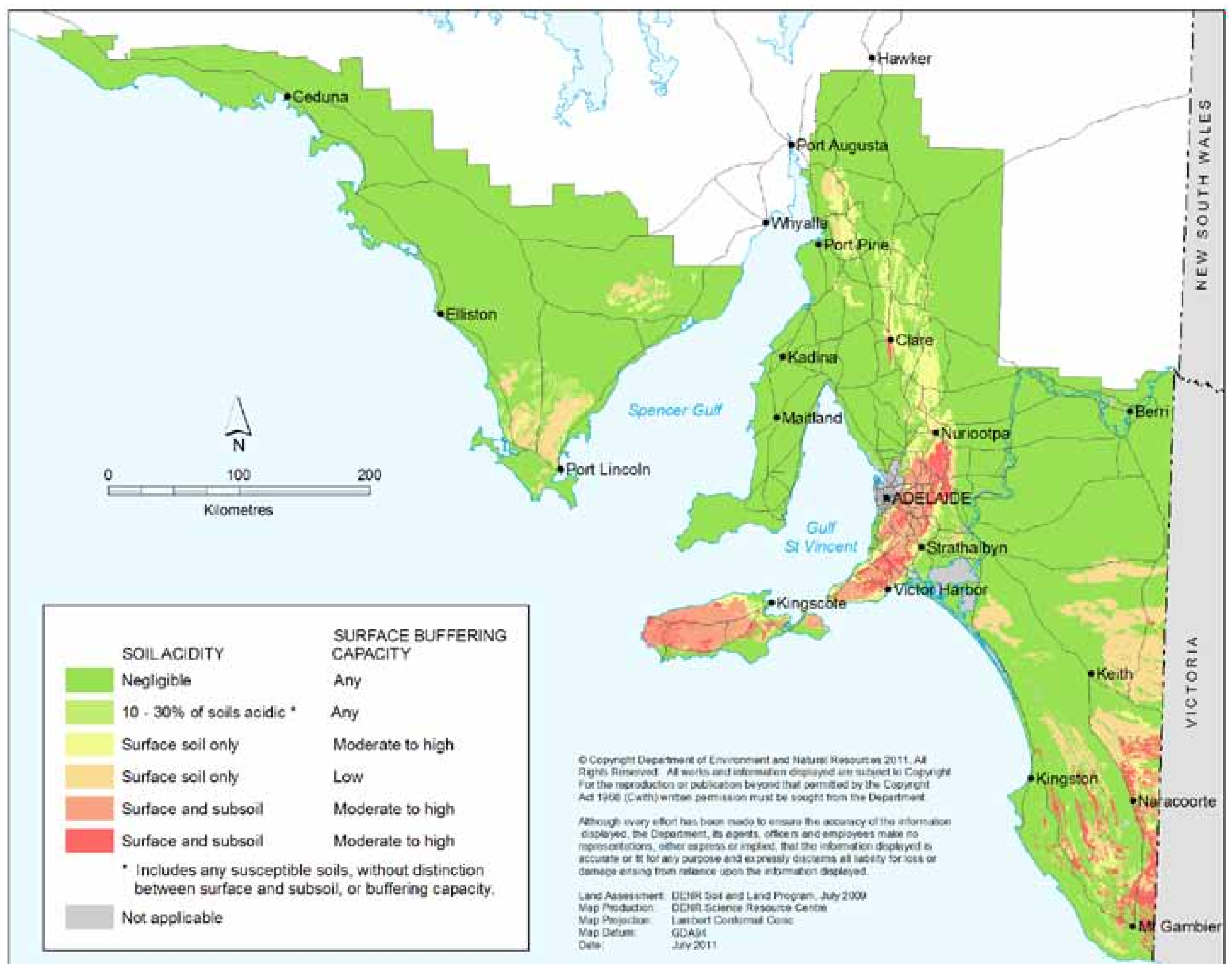


Classes are based on an interpretation of soil landscape map units. Acidity varies within soil classes (depending on management practice and climate), and within mapping units (which often include a complex of soils). Rankings are made according to pH measurements and extrapolation between similar environments. All land which is known to be acidic, or is similar to land known to be acidic is classified accordingly, regardless of land use or management. The acidity of each component of a mapping unit is assessed. The units are then classified according to the acidity of the most "at risk" component, provided that it accounts for more than 30% of the area of the map unit. Limited occurrences of acidic soils (i.e, account for 10-30% of the area of the map unit) are indicated as an additional class. Classes take account of both surface and subsoil (ie deeper than 30 cm) acidity, and the buffering capacity of the surface soil (buffering capacity is an indication of the soil's capacity to resist acidification).

Prepared by Rural Solutions SA, updated July 2011.

RURAL SOLUTIONS SA

Government of South Australia

What is soil acidity?

Soil acidity is a condition of the soil where there are excess hydrogen ions present. It is measured using the pH scale. pH is a measure of the acidity (the amount of hydrogen ions) in a solution. It is a negative logarithmic scale measuring from 0-14, where 7 is neutral (exact balance of H^+ and OH^- ions in the solution). A number lower than 7 indicates acidity (high H^+ ions), and numbers higher than 7 indicate alkalinity (low H^+ ions). As it is a logarithmic scale, a pH of 6 is 10 times more acidic than a pH of 7, and a pH of 5 is 100 times more acidic than 7.

Soil acidity is a severe soil degradation problem that can greatly reduce the production potential of crops and pastures. Soil acidification is a natural phenomenon and is also an inevitable consequence of productive farming systems. Productive agriculture increases the concentration of hydrogen ions in soil, which acidify the soil.

A significant problem for South Australia

There are more than 2.5 million hectares in SA that are susceptible to the risk of soil acidification. Many of these areas have been affected by soil acidity due to land management practices particularly in the more productive agricultural areas.

As soil acidity occurs slowly, production losses may not be noticed in the early stages. While acidity remains in the topsoil, it is simply treated with lime.

If acidity is not treated, it will affect the subsurface and subsoil, where it is then much more costly, slow and difficult to treat.

'Ball park' target soil pH Levels	$CaCl_2$
Dryland cropping	5.5
Extensive grazing	5.0 – 5.5
Intensive grazing	5.5
Vines / Olives	5.5 – 6.5
Apples	5.5 – 6.5
Intensive Vegetables	5.5 – 6.5
Potatoes	5.0 – 6.0

Soil pH can be measured two ways either pH in water or pH in calcium chloride ($CaCl_2$). Calcium chloride is the preferred method for measuring pH in neutral to acid soils. It is generally 0.5 – 1.2 units below soil pH in water.

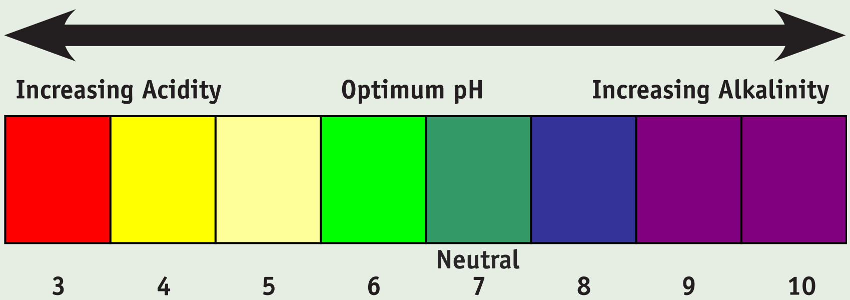
The importance of soil pH

Soil pH levels do not usually directly affect plants until levels are extreme. Most of the detrimental effects of acidity are due to the impacts of soil pH on the availability of plant nutrients.

In acid soils **aluminium** becomes increasingly available leading to toxic conditions. Some plants, such as phalaris and lucerne, are especially susceptible to aluminium toxicity and overall production can be severely reduced.

As soil pH moves either side of neutral **manganese** levels are also dramatically affected. As the soil becomes more acidic, manganese toxicity can occur and at the other end of the scale as the soil becomes more alkaline, manganese deficiency can occur.

Phosphorus is also strongly influenced by soil pH levels. As the soil pH moves either side of neutral phosphorus becomes increasingly tied-up in the soil and less available for plant uptake.



TOO MUCH:
- aluminium
- manganese
- iron

NOT ENOUGH:
- magnesium
- calcium
- potassium
- phosphorous
- molybdenum

TOO MUCH:
- sodium
- boron

NOT ENOUGH:
- iron
- zinc
- manganese
- copper
- phosphorus

Major causes of soil acidity

1. Natural acidity

- Parent material (the nature of the rocks) from which soils are formed influences soil acidity. Soils formed on sandstone or granite are much more likely to have acidity problems.
- High rainfall regions are more prone to acidity as a greater amount of nutrient leaching occurs and these soils have more active microbes that are turning over organic matter faster.

2. Productive agriculture is a major factor that accelerates acidification in farming systems.

- Removal of alkaline products and other minerals from the farming system as produce (hay, grain, animal products) increases acidification.
- **Addition of nitrogen from fertilisers and legumes.** The high use of nitrogen in agricultural systems, whether by growing leguminous crops or pastures or by adding nitrogen based fertilisers, can accelerate soil acidification. The conversion of nitrogen in the soil from ammonium (NH_4^+) to nitrate (NO_3^-) releases two H^+ ions in the process.
- **Leaching of nitrate and other nutrients.** Once nitrogen is in the nitrate form it is prone to leaching accompanied by the positively charged ions such as, Ca^{2+}, Mg^{2+}, Na^+ and K^+ and this process leaves behind acidifying H^+ ions. This process is further accelerated in areas with higher rainfall or if irrigation occurs, as leaching increases, resulting in net acidification of the system. Sandy soils with less clay are more prone to leaching as they have a less cation exchange capacity (CEC), and less water holding capacity. Their lower CEC also means that there is less capacity of the soil to buffer the acidification processes by releasing other ions into the system, leading to more rapid acidification of these soils.
- **Organic matter accumulation.** Improved pastures, particularly annual pastures species, add organic matter to the soil. Organic matter in itself is acidic and its accumulation in the soil can lower soil pH.

Paddock indicators of soil acidity

Careful attention to crop and pasture performance can reveal early indications that pH has dropped too far.

These include:

Yields are falling

- Production is declining
- Declining water use efficiency
- Perennial plants are not persisting, in particular lucerne or phalaris
- Clover or medic growth is patchy

Acid-sensitive crops are struggling

- Poor establishment and growth of medics, lucerne, barely, canola, phalaris
- Uneven crop and pasture growth
- Crops are less competitive with grassy weeds

Soil health declines

- Poor plant vigour
- Poor nodulation of legumes
- Stunted root growth
- Slow organic matter breakdown and formation of surface organic mats due to reduced soil biological activity

The above signs are characteristics of acid soils but may also be related to other soil and nutritional problems. A soil pH test is required to confirm a soil acidity problem.

Appearance of soil acidity indicators means that productivity and profitability is already significantly affected. Lime treatments should begin before they appear.

Tolerance of plants to soil acidity

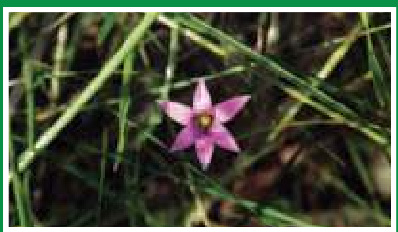
SPECIES	TOLERANCE
Canola, faba beans, lucerne, annual medics	Very sensitive
Barley, wheat, peas, phalaris	Sensitive
Lupins, wheat, sub-clover, cocksfoot, vetch, fescue, perennial ryegrass	Tolerant
Triticale, oats, serradella, lotus	Very Tolerant

Indicator Plants of Soil Acidity

These plants are more tolerant to elevated aluminium and iron levels

Sorrel

Fog Grass



Guildford Grass

Implications of soil acidity

As soils acidify, there are fewer choices of crops and pastures that will grow productively. Soil heath declines, activity of nitrogen fixing bacteria declines and nutrient imbalances can occur.

Soil acidity reduces farm productivity and long term sustainability by affecting many aspects of soil and plant health.

1. Increased soil toxicity

As soil pH ($CaCl_2$) drops below 5.0, toxic amounts of aluminium and manganese can be released into the soil solution. These are toxic to root growth and the soil biota.

Aluminium is a major concern. It is released into the soil solution from clay minerals as they break down under acidification.

Aluminium toxicity is a problem when soil tests indicate extractable Aluminium ($CaCl_2$) levels are 2 mg/kg or more (0.5 mg/kg or more for sensitive plants) or when exchangeable Aluminium is 5% or greater.

2. Reduced soil fertility

a. Decreased plant productivity
Favourable conditions for some weeds and reduced soil cover which can lead to soil erosion issues.

b. Nutrient Loss
In very acid soil, potassium, calcium and magnesium levels are usually low due to leaching and removal of products.

c. Stock health
Acid soils and low levels of magnesium can contribute to the risk of grass tetany (hypomagnesaemia).
Low levels of calcium can lead to milk fever (hypocalcaemia).

d. Phosphorus and molybdenum inefficiency
Phosphorus combines with free aluminium and iron released in acid soils to become less available to plants. Molybdenum is also less available.

e. Reduced microbial activity
Microbes that fix nitrogen or decompose organic matter are less active.

f. Declining land values
Loss of productive capacity due to acidity can affect land values.

3. Off-farm effects

- Decreased plant water use leading to increased recharge and dryland salinity.
- Increased pollution of groundwater and surface water due to leaching of nitrate and other nutrients.
- Increased risk of soil erosion and water pollution due to less soil cover.

Measuring Soil pH

Field Measurements

- Field pH kits are sold at most agricultural stores
- Provide a good indicator of soil pH levels
- Useful for monitoring soil pH levels

Laboratory Measurements

It is recommended that soil samples are sent to an accredited laboratory approximately every 5 years (less if your soils are predominantly sand) for an accurate soil pH test.

Soil pH can be measured in the laboratory by two methods:

1. pH Water
2. pH Calcium chloride ($CaCl_2$)

The reason for two tests

- pH (CaCl2) is less variable across seasons it is less influenced by soil salts and ions.
- pH (water) is standard on alkaline soils.
- pH (CaCl2) is generally more accurate on neutral to acid soils
- Difference between the two tests can range from 0.5 to 1.2pH units depending upon the soil being tested.

It is important to know which test was undertaken when calculating soil amendment (i.e. lime) application rates.

Sampling Soil

Best time to sample

We recommend that you carry out your soil testing over the summer months. Test results are more accurate when the soils are dry and often the best time to apply lime is just before the break of the season in autumn.

How to sample

1. Pick an area of uniform landscape i.e. flats or hill slope (as the soil texture is more likely to be the same).
2. Make certain that each collective sample is taken from soils of similar texture (e.g. clay, loam or sand) and from an area that has been managed the same.
3. Use a soil corer to collect the samples.
4. Collect soil samples with the soil corer (0-10 cm) along a fixed transect. This method allows for re-testing and better monitoring of changes in soil pH than random sampling.
5. Avoid areas such as sheep camps, headlands and access tracks.
6. Along the transect collect a minimum of 30 cores (the more cores taken the more reliable the sample).
7. Thoroughly mix the soil sample and take out a sub-sample to be sent to the laboratory.

Management of soil acidity

ACID SOILS MUST BE LIMED – Lime it or lose it

Lime reduces soil acidity

Lime (calcium carbonate) and other liming materials reduce acidity by neutralising the acid reaction in soils. The carbonate component of lime consumes hydrogen ions present in the soil solution and in doing so raises soil pH.

Prevention is best

Liming is the only cost effective way to manage low soil pH. It prevents loss of production and profitability in farming systems and reverses acidification

Liming is a capital investment in the farm business. Its true value should be seen in the losses prevented rather than responses to specific applications as with fertilisers.

Timing and frequency

Lime should be applied on the surface several months before sowing pasture or crops to allow time for the lime to react in the soil. Incorporation of the lime into the soil is recommended for the quickest results, as lime does not move readily down through the soil profile.

Frequency of applications should be determined by regular monitoring of pH. Soils should be tested every five years or so, more often for sandy soils and soils under irrigation.

Factors affecting liming frequency

1. Soil texture

Sandy soils usually require lime less often than clayey soils and at lower rates. Acidified clays are more expensive to reverse.

2. Rates of nitrogen fertilisation

High rates of ammonium fertilizers accelerate acidity.

3. Rate of produce removal

Hay and silage cuts and intensive cropping rotations remove more nutrients and so increase the rate of acidification.

4. Rate of lime applied

Higher rates can reduce the frequency of applications. Even spreading is essential. Caution: High application rates can induce manganese deficiencies where manganese status is marginal. Apply no more than 3 t/hectare of lime on sandy soils in one application.

5. Desired pH range

The lower the soil pH, the more lime is needed to meet target or ideal levels.

Lime sources, quality and effectiveness

Commonly used liming materials:

- **Agricultural lime**
  Crushed and sieved natural limestone is mainly calcium carbonate. It is safe, cheap and effective.
- **Lime sand**
  Lime sand is mined from natural deposits and is mainly calcium carbonate. It is safe and cheap but can be coarser and slower reacting than agricultural lime.
- **Dolomite**
  A mixture of calcium and magnesium carbonates. It is particularly valuable where magnesium is low.
- **By-product lime**
  This is a by-product from the production of soda ash. It contains mostly calcium carbonate, but with some calcium oxide and hydroxide.
- **Alkaline clays**
  Alkaline clays have a liming effect when applied to acid soils.

NOT GYPSUM!

Gypsum does not neutralise acidity. It is a moderately soluble form of calcium sulphate used as a soil conditioner to improve soil structure and overcome the problem of sodicity.

Lime response trial at the Waite Institute, showing the impact of lime on pasture production. Photo courtesy of K. Bond

Elements of lime quality:

Neutralising value (NV)

- This is a measure of purity of the product compared to calcium carbonate. By setting the NV of pure calcium carbonate to 100, a comparative value of other liming materials can be calculated.
- Good liming materials should have a NV greater then 80 – i.e. more than 80% as effective as pure calcium carbonate.

Particle size

- The finer the liming material, the quicker it will react with the soil, but the more difficult it is to spread accurately.
- A mixture of coarse and fine particles will overcome spreading difficulties but the coarse particles will react more slowly.
- Particles greater than 0.25 mm are inefficient in raising pH quickly.

Effectiveness of lime

- Liming materials only react slowly in the soil because they have low solubility with water.
- Incorporation of lime with small particle size and high neutralising value will give quickest response. Fine lime is not so critical in preventing any further decline in pH.
- Soil moisture is required for the lime-soil reaction.
- Surface-applied lime reacts more slowly than lime that has been incorporated.

Lime budgeting

Comparing lime products

The calculations opposite are useful to use when selecting liming materials. The cheapest is not necessarily the most cost-effective.

Cost of the Product ($/t) =
Cost of lime at the pit + freight + spreading cost

Effective Cost of Product ($/t) =

$$\frac{\text{Cost of product} \times 100}{\text{Neutralising value}}$$

Fineness of the material should also be taken into account. A high proportion with particle size less than 0.25 mm is preferred.

Sourcing Lime

To identify appropriate lime suppliers, contact:

- Local rural merchants
- Local NRM Board offices
- Rural Solutions SA consultants
- Check the yellow pages and online

Calculating lime rates

Decisions on the rate of lime required to correct soil acidity will depend on factors such as:

- The existing and target soil pH
- Subsurface or subsoil acidity issues
- Soil texture
- Lime quality
- Risks associated with over liming (low manganese levels)

Lime Requirement (t/ha) =
(Target pH – current pH) x Soil Texture Factor

Surface soil texture factors

Loam to clay loam	4
Sandy loam	3
Sand	2

Reduce rates by 25% if organic matter is low.
Seek advice if attempting to raise pH by more than one unit with a single lime application

Caution

- Over-liming may induce some trace element deficiencies in plants, particularly manganese. This can be corrected with applications of foliar manganese fertilisers.
- Over-liming may increase the risk of copper deficiency in ruminants.
- Uneven spreading may cause patches of over-liming.
- It may take several years to reverse the effects of over-liming.
- High rates of lime can increase the risk of root disease take-all, if it is present.

Acid soils CAN be managed

Liming for the future

Liming programs for soils vulnerable to acidification should be integrated into routine paddock management planning

Prevention is best

- Measure soil pH **NOW** to determine existing pH
- Monitor soil pH in each paddock every few years
- Apply lime in regular maintenance doses to maintain an ideal pH
- Encourage strong and deep root growth
- Grow deep-rooted perennials in pasture situations to recycle nutrients
- Balance fertiliser applications with plant requirements
- Feed hay back into cut paddocks to recycle removed nutrients
- Rotate stock holding areas to re-distribute nutrients

Lime being broadcast onto a cultivated paddock

Three different liming products with varying particle sizes

The key points

- Soil acidification is an increasingly important problem.
- Acid soils can significantly reduce production and profitability before paddock symptoms are noticed.
- Monitor changes in soil pH by regular soil testing.
- Danger levels for soil pH are for crops when soil pH ($CaCl_2$) is less than 5.5, and for pastures when pH ($CaCl_2$) is less than 5.0.
- Prevention is better than cure – regular lime applications!
- The most effective liming sources have a high neutralising value and have a high proportion of material with a particle size below 0.25 mm.
- More lime is required to raise soil pH in clays than in sands.
- Liming can induce manganese deficiency where soil manganese levels are marginal.
- If severe acidity is allowed to develop, irreversible damage to the soil can occur.

Lime acid soils to stay in business