Soil acidity status report 2018

Prepared for the South Australian Murray-Darling Basin Natural Resources Management Region

Key points:

- **Soil acidity is increasing in the SAMDB region**
- **Estimated value of lost agricultural production in the SAMDB region due to acid soils is about $8.7M per year**
- **10% (272,000ha) of SAMDB's agricultural land has surface soil acidity (0-10cm)**
- **7% has sub-surface acidity (10-20cm)**
- **4% has sub-soil acidity (below 20-30cm)**
- **Further 26% (687,000 ha) of agricultural land could become acidic in next 10-50 years**
- **Last 10 years ave. lime use was 74% of estimated topsoil acidification rate**
- **Since 1998 lime use deficit has accumulated to about 60,000 tonnes, or about 0.3 tonnes per hectare of acid soil**
- **Estimated further 303,000 tonnes lime needed to raise pH_{Ca} of acidic topsoils above 5.5, and 40,000 tonnes lime for acidic subsurface soils**
- **Soil acidity will continue to increase unless lime use rates rise above 16,000 tonnes per year**

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Department of Environment, Water and Natural Resources

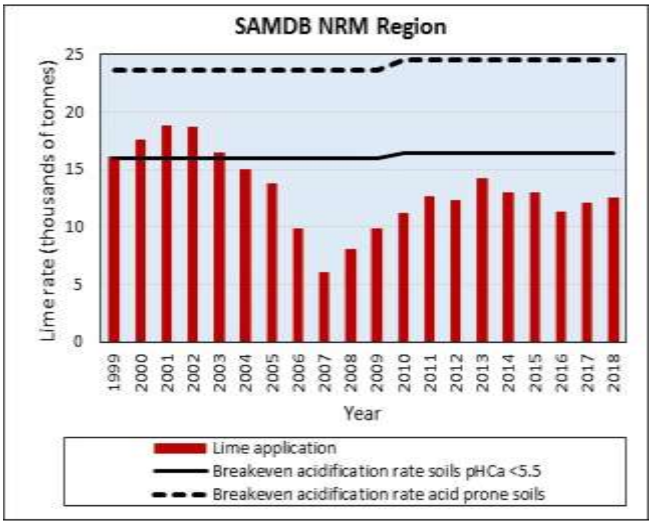
Summary (Soil acidity status report 2018 – SAMDB NRM Region)

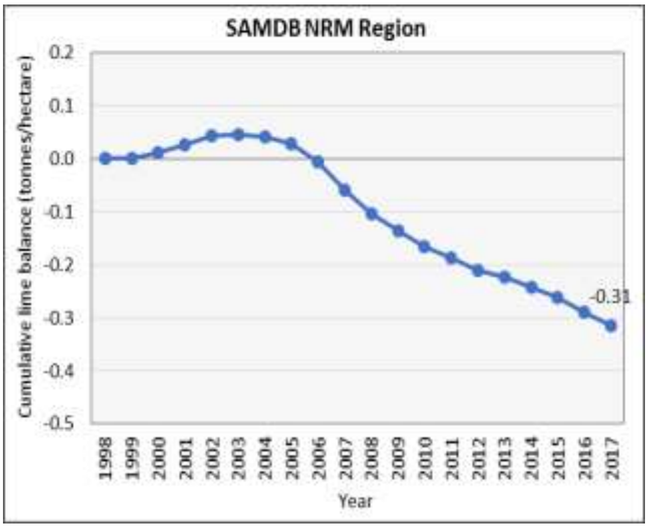
Extent and severity

- Approximately 10% (272,000ha) of the region's agricultural land has acidic surface soils (0-10cm depth). There are about 180,000 hectares (7%) with sub-surface acidity (approx. 10-20 cm), and 95,000 hectares (4%) with sub-soil acidity (below approx. 20-30 cm depth).
- A further 26% (687,000 ha) of cleared land in the SAMDB region has the potential to become acidic in the future, ie 10 – 50 year timeframe, particularly under more intensive and productive cropping systems, if not adequately treated by liming.
- In soil test data from monitoring sites in acid prone areas from 2008-09, 38% of topsoils, and 52% of sub-surface layers (10-20cms) were below a critical level of pH_{Ca} 5.0
- The soil pH testing has also shown that acidification (including subsoils) is occurring at a faster rate than previously measured, and that the area affected is expanding.
- The estimated value of lost agricultural production in the SAMDB region due to acid soils is approximately $8.7 million per year.

Lime requirement and lime use

Breakeven acidification rate on soils below pH_{Ca} 5.5	**16,000 tonnes/year**
Breakeven acidification rate on all acid prone soils	**24,000 tonnes/year**
'Catch-up' lime requirement for acid soils to reach pH_{Ca} 5.5/5.0	**343,000 tonnes**





- The revised estimate of the lime requirement to balance the breakeven annual acidification rate for surface soils below pH_{Ca} 5.5 on agricultural land in the SAMDB region is 16,000 tonnes of lime equivalent. Based on lime sales data, the estimated average annual lime use rate in the SAMDB region for the last 10 years was 12,000 tonnes, 74% of the breakeven rate. The estimated breakeven acidification rate on all acid prone soils is about 24,000 tonnes of lime per year.
- The estimated lime deficit that has accumulated since 1999 is about 61,000 tonnes of lime equivalent, or about 0.3 tonnes per hectare of acid soil.
- Not all other alkaline inputs (eg alkaline irrigation water) have been estimated but these would not be sufficient to make up the lime deficit
- Apart from lime required to treat annual soil acidification, approximately 343,000 tonnes of lime is needed to raise the pH of currently acidic soils to a productive level (pH5.5 surface/5.0

subsurface). This includes approximately 303,000 tonnes of lime for acidic topsoils and about 40,000 tonnes of lime to treat acidic subsurface soils (10-20cm).

South Australian Murray-Darling Basin NRM Plan targets

Resource Condition Target L1: Protect and improve soil and land to support the productive capacity and natural resources of the region by 2030

- **Based on available data and estimates of lime requirement, lime use rates are below the acidification rate and soil acidity is increasing.**

Awareness and knowledge of acidity

- Telephone surveys of landholders showed a good level of awareness of the soil acidity issue in the region, but there was less recognition of sub-surface acidity. There was a concerning level of misunderstanding of the causes of, and appropriate treatments for acid soils.
- Around one third of managers with acid soils don't regularly do soil tests, and 40-50% could not identify the critical pH range for acid soils.
- Most landholders (70%) with acid soils had sought information on managing acid soils, most commonly from consultants/advisors (45%).
- The main reasons given by landholders for not liming their acid soils are the perceived high cost of lime and the perceived lack of financial benefit from liming.

Future implications and strategies

- The area of land affected by acidity in the SAMDB region is likely to be increasing because of inadequate liming of acid prone soils
- Subsurface acidity is a developing issue which is harder to treat than topsoil acidity, and could continue to increase where surface acidity is not adequately treated.
- In some situations, irrigation with alkaline water may be an alternative 'treatment' for acidity, and in some areas there is also potential for claying with calcareous clay to be done to overcome acidity.
- To achieve the SAMBD NRM Plan targets relating to soil acidity, targeted programs are needed to achieve higher liming rates on acid prone soils, possibly involving landholders, the SAMDB NRM Board, DEW, PIRSA and farming industry and technology groups

Background information

1. Introduction

In SA's agricultural systems, acid soils are generally defined as having a pH_{Ca} (i.e. measured in calcium chloride) of less than 5.5.

Significant areas of agricultural land in the SAMDB region are prone to soil acidity (Section 2).

Natural soil acidification rates are accelerated by the growing and removal of agricultural products. Higher acidification rates occur in high rainfall areas, on sandy textured soils, and where there are high levels of production. Increased use of nitrogen fertiliser and higher yielding rotations have increased the rate of acidification and extended the areas where soils are now affected.
If soil acidity is not ameliorated by sufficient application of liming products, the consequences are:

- loss of production and financial returns, particularly for acid-sensitive plants
- progressive acidification of subsurface and subsoil layers, which are much more costly to ameliorate
- reduced uptake of soil water that can lead to rising water tables and increased soil salinity
- increased leaching of iron, aluminium and some other nutrients from the soil, potentially contaminating surface and ground water.

Acidic topsoils can be treated by the application of lime products, but acidic subsoils are more difficult and expensive to treat than the more easily accessible topsoil.

The estimated value of lost agricultural production in the SAMDB region due to acid soils is approximately $8.7 million per year (4.3M crops, $4.4M pastures. Statewide, this estimate is $83 million to $86 million. This estimation is based on current gross margins for crops and grazing enterprises in each region, using 2016 crop types by area and estimated yields (PIRSA). This takes into account cropping and grazing intensity, and uses available experimental yield loss data for crops and pasture species according to pH/acid soil sensitivity. The estimated area of acid soils by pH range in each region is used as per the estimation of 'catch-up' lime requirement in section 5.

The development of agricultural areas now affected by or prone to soil acidity has been recognised for some time in parts of the SAMDB NRM Region. The modern high production farm practices undertaken will continue to acidify these areas, and the extent of acidic land will increase unless adequate ongoing treatment is undertaken.

The SAMDB NRM Board has recognised soil acidity in their NRM Plan Strategic Plan 2014. The target which relates to acidity, under 'land' is:

Resource Condition Target L1

Protect and improve soil and land to support the productive capacity and natural resources of the region by 2030

Soil acidity is listed as a major threat to the 'land' asset class.

This document aims to give a summary of current status and trends in soil acidity on agricultural land in the SAMDB region, by presenting and discussing available data on land resource information, recent soil pH test data, survey data on landholders' awareness of and attitudes towards and treatment of acid soils. It also provides some strategies for addressing this issue.

2. Land resource summary

Data statistics and maps of the extent of acid prone soils in the SAMDB NRM Region have recently been revised, and are now in line with the Australian Soil Resource Information System (ASRIS).

In the SAMDB region, approximately 272,000 hectares of cleared agricultural land (10%) has surface soil acidity, which is about 13% of the acid soils in the state. An estimate of the current area of actual acid soils based on recent soil pH testing is given in section 3.

Figure 1 gives an indication of the estimated extent of areas of surface soil acidity (acid prone soils) which are acidic or imminently prone to becoming acidic, based on soil mapping data, and current climate and land use. Soil acidity in the SAMDB region occur along the eastern side of the Mt Lofty Ranges northwards to the hilly country around Hallett and Eudunda, in part of the southern Mallee, and in the Meningie and Strathalbyn areas.

In addition to surface acidity, there are about 180,000 hectares (7%) with sub-surface acidity (approx. 10-20 cm), and 95,000 hectares (4%) with subsoil acidity (below approx. 20-30 cm). These areas have higher rainfall and often support high value agricultural enterprises such as viticulture, dairy, horticulture, stud stock and high yielding broadacre crops.

It has been estimated that a large area (687,000 ha; 26% of cleared land) in the SAMDB Region has the potential to become acidic in the future, ie 10 – 50 year timeframe, assuming that current farming production practices continue and if these soils are not adequately treated by liming. This is about 29% of the area of soils with future acid potential in the state. A proportion of land over much of the southern Mallee area and Murray Plains south to the Lower Lakes area could potentially be affected (Figure 2). These areas are again in relatively higher rainfall areas, and hence are more productive. The harmful effects of soil acidity are more pronounced in these areas. Highly productive, intensive cropping or pasture systems with high nitrogen inputs cause the highest acidification rates so this land is most at risk of future acidification, even though the current soil pH may be close to neutral (e.g. pH_{Ca} 6 - 7). This will occur more quickly on soils with low pH buffering capacity (ie sandy textured soils). Newly developing acidity can appear in a patchy distribution that matches soil susceptibility to acidification. Areas irrigated with alkaline water are less likely to acidify.

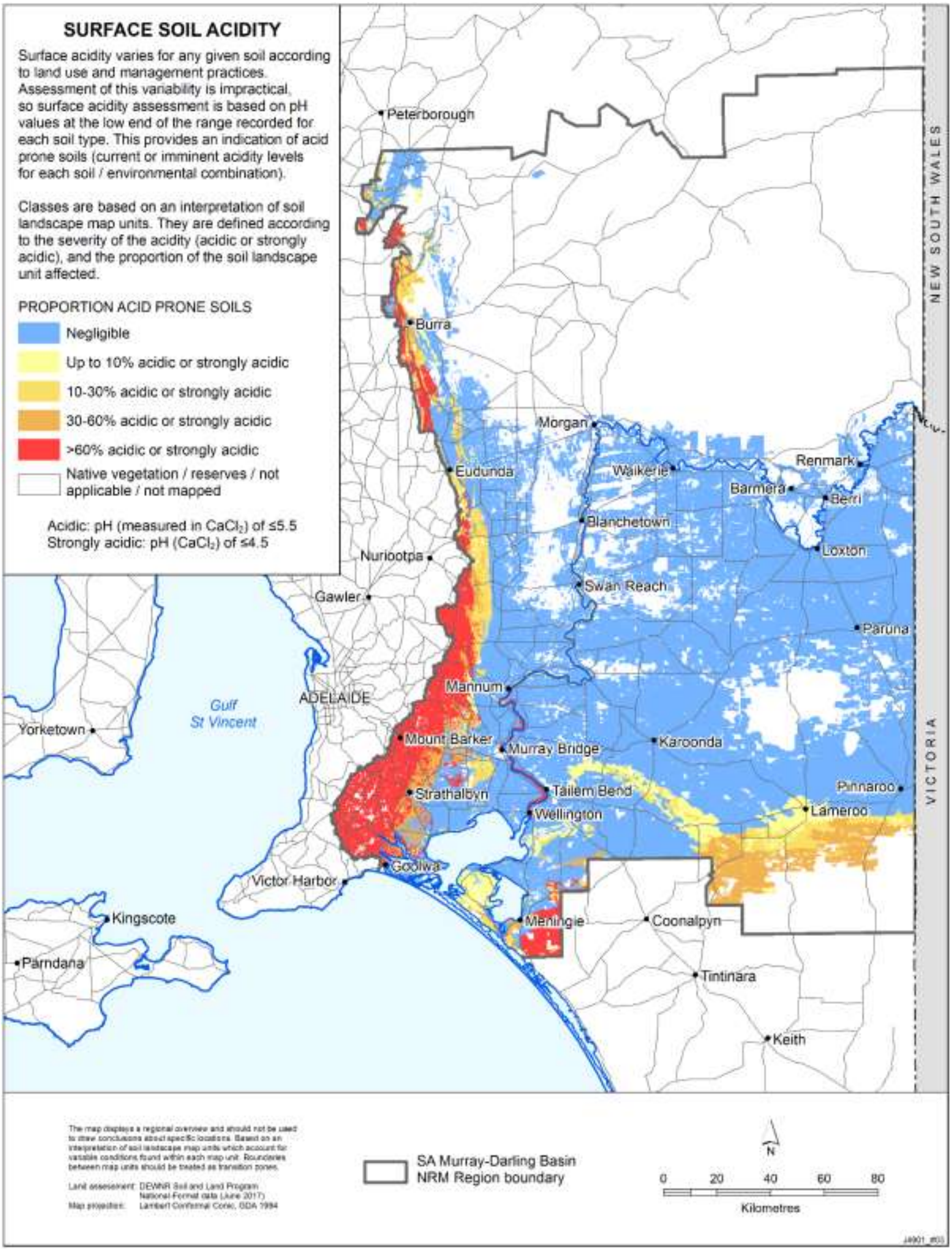


Figure 1 Estimated extent of surface soil acidity (acid prone soils) in the SAMDB NRM Region

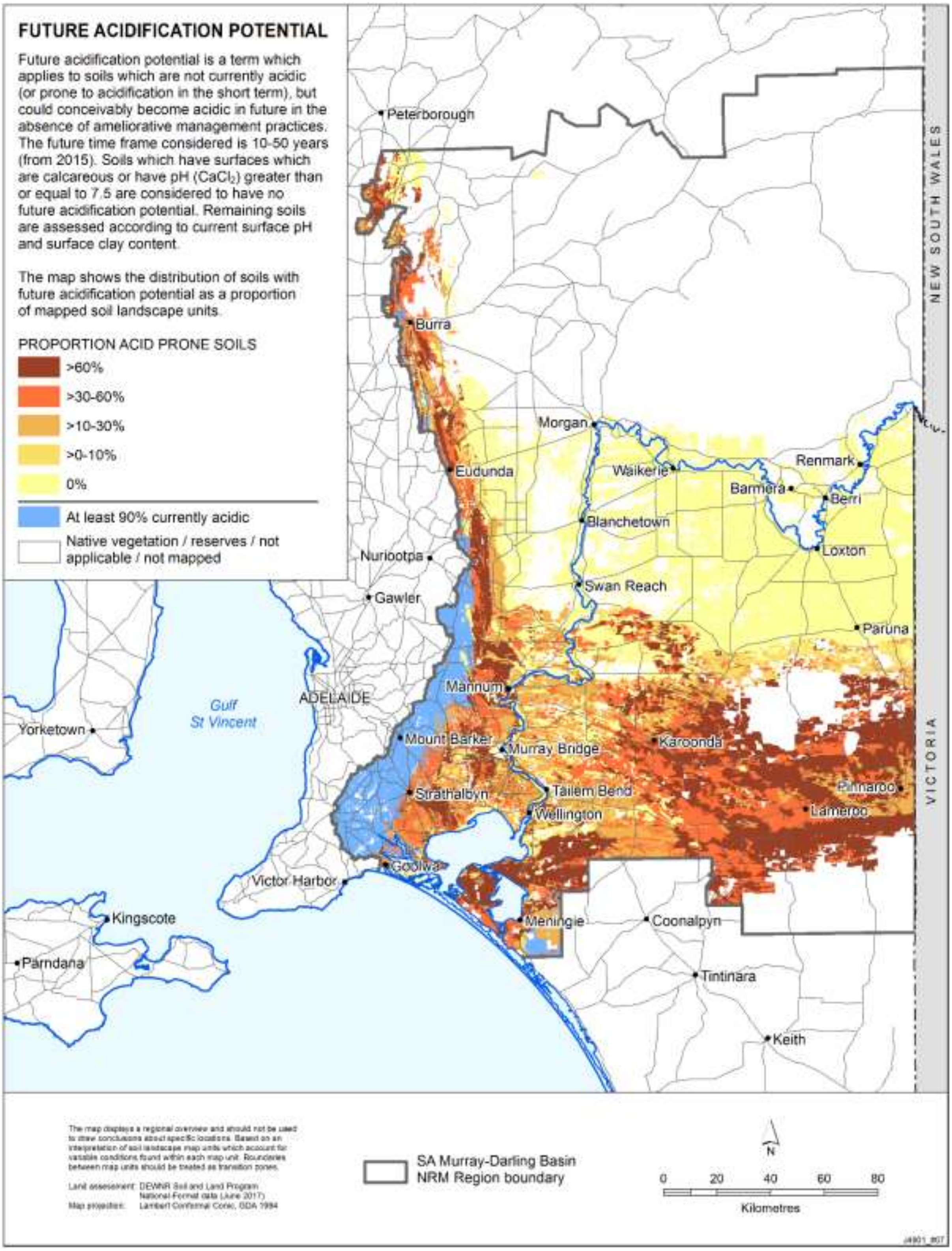


Figure 2 **Estimated area of soils with future acidification potential and existing acid prone surface soils in the SAMDB NRM Region**

3. Actual Soil Acidity Data

There are some relatively recent soil pH test data sets that help to show the current extent of actual acid soils in the SAMDB region.

Soil pH test data was collected in 2008-09 in the SAMDB region from 60 sites mostly in acid prone areas (surveillance, monitoring and Agricultural Bureau sites) as part of the former Caring for Our Country and DEWNR project 'Taking Action on Acid Soils'). Surveillance sites are designed for rapid surface measurements of pH using both test methods (H_20 and $CaCl_2$), whereas monitoring sites are selected as long term sites where soil pH changes are measured at different depth intervals (eg. 0-10, 10-20, 20-30cm) down the soil profile, and over time.

Summary data for these sites are given in Appendix 1. A representation of surface soil pH tests from this data set is shown in Figure 3, and sub-surface results in Figure 4.

This data indicated a significant proportion of acidic surface pH tests (36% with pH_{Ca} of less than 5.0) in these acid prone areas. It was particularly concerning that 52% of the samples had a sub-surface soil pH_{Ca} below 5.0., which highlights the increasing issue of sub-surface acidity.

This recent soil testing showed that the area affected by soil acidity is expanding outside of the areas previously recognised as acidic.

The soil pH testing at monitoring sites with high production cropping systems has also shown that acidification is occurring at a faster rate than previously measured (including subsoils).

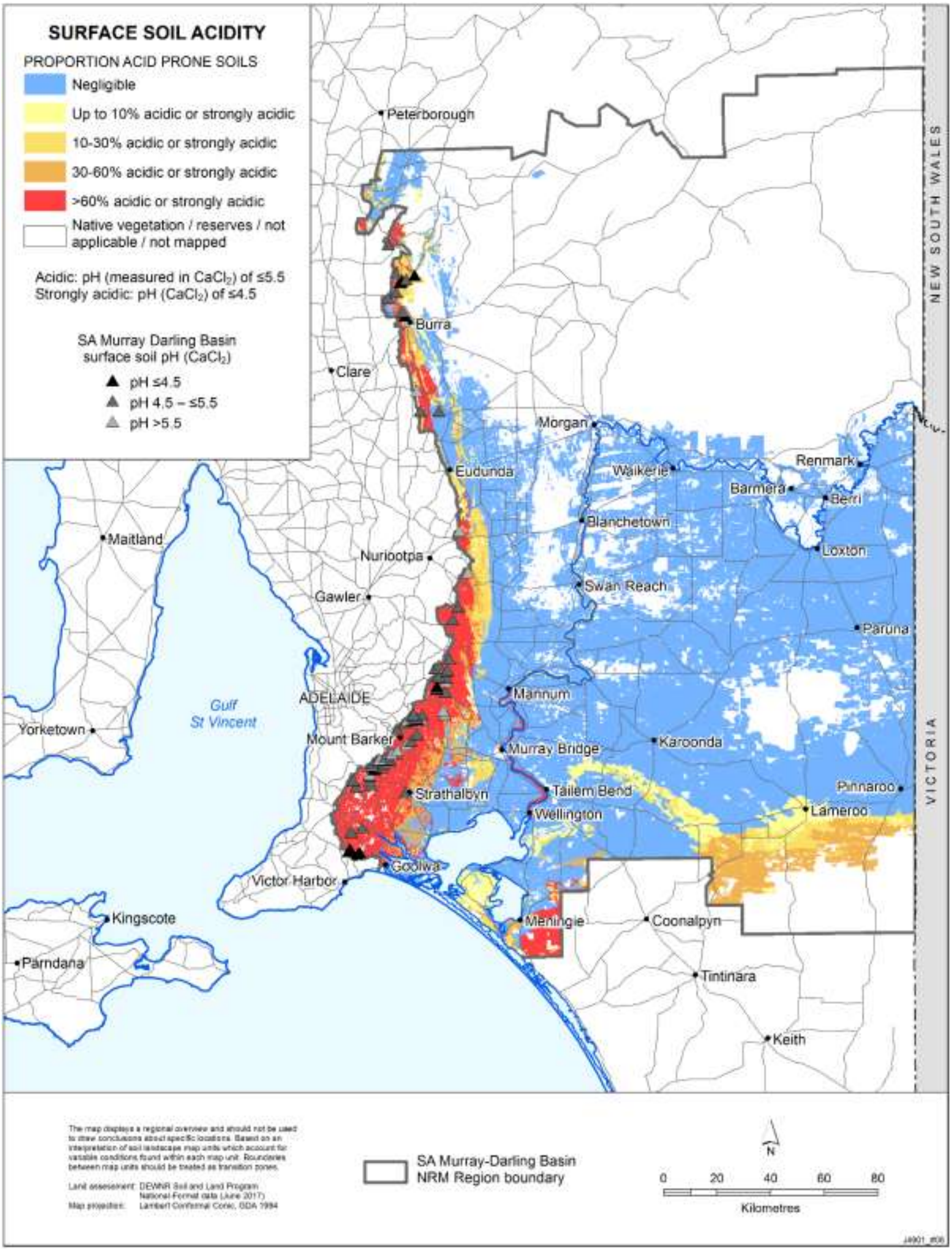


Figure 3. **Location of surface soil pH tests 2008-09 overlain on areas prone to surface soil acidity in the SAMDB region (most recent test result at each site shown)**

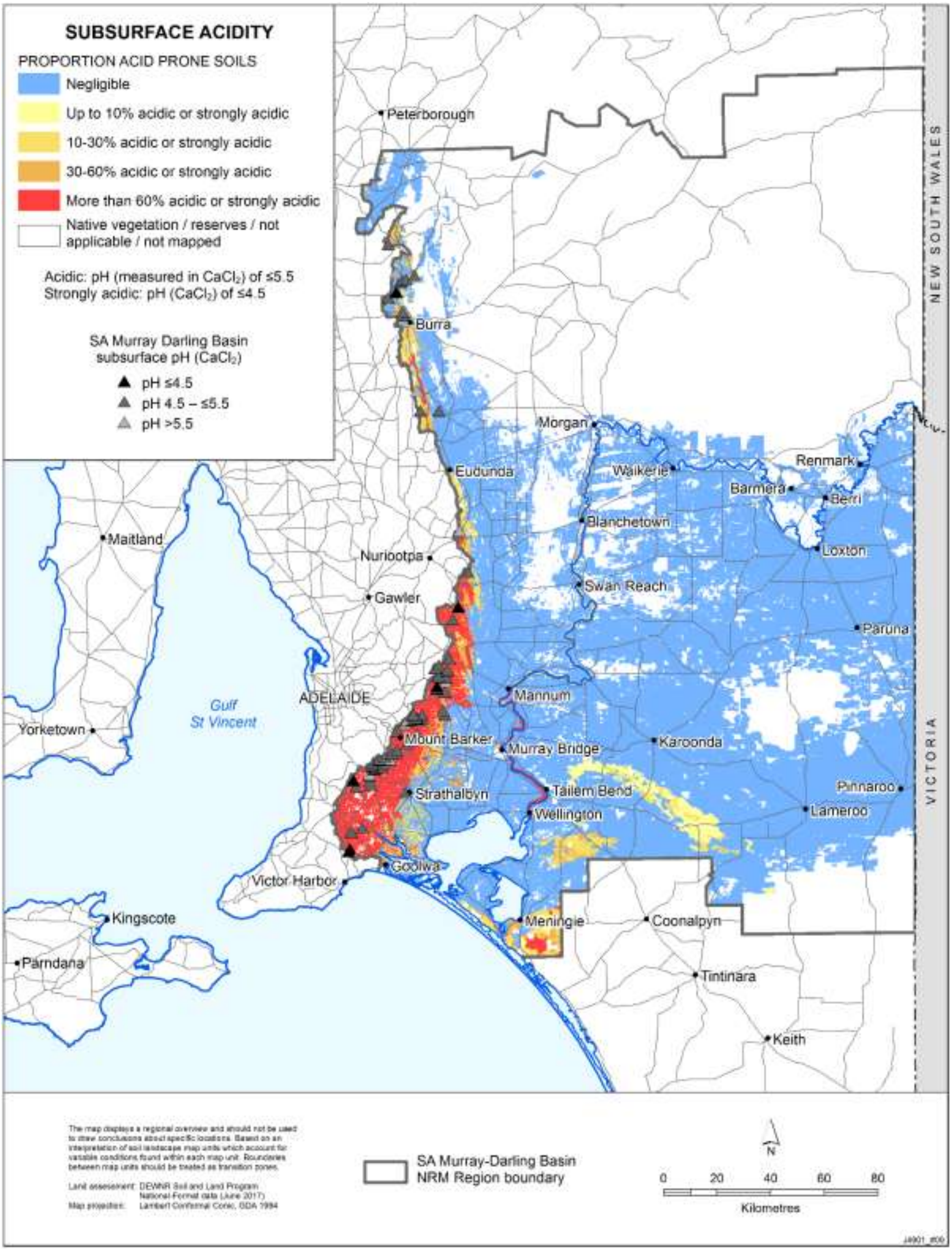


Figure 4. **Location of sub-surface soil pH tests 2008-09 overlain on areas prone to sub-surface soil acidity in the SAMDB region (most recent test result at each site shown)**

4. Knowledge, awareness and attitudes of landholders regarding soil acidity : Information relevant to the SAMDB NRM Region

DEW has commissioned a series of telephone surveys of agricultural land managers in SA (broadacre dryland cropping and livestock/dairy) between the years 2000 and 2017 to obtain data on land management practices they use, as well as their awareness and understanding of key soil and land management issues, including soil acidity.

About 15-25% of survey respondents stated they have acid soils on their property. About 35% of respondents with acid soils considered they also had sub-surface acidity on their property. This suggests that the sub-surface acidity issue is less well recognised among land managers, considering that about 70% of surface acid prone soils in the region are also prone to sub-surface acidity.

Around two thirds of respondents with acid soils do regular soil testing. It is a concern that about a third may not be aware of their soil pH levels and may not be treating acidity accordingly.

In recent surveys, only around 50 – 60% of managers with acid soils could correctly identify the critical soil pH for acidity in the range pH 4.5 – 6.0 (regardless of test method).

The land manager survey data also indicate there is some misunderstanding about the causes and treatments of soil acidity (Figure 5). For example, in the 2017 survey, nearly half of respondents mistakenly considered that gypsum could be used to treat soil acidity, and 59% wrongly thought that superphosphate was a direct cause of acidity. Nearly a third didn't consider that nitrogen fertiliser use and product removal from paddocks are causes of acidity. Results were similar in earlier surveys.

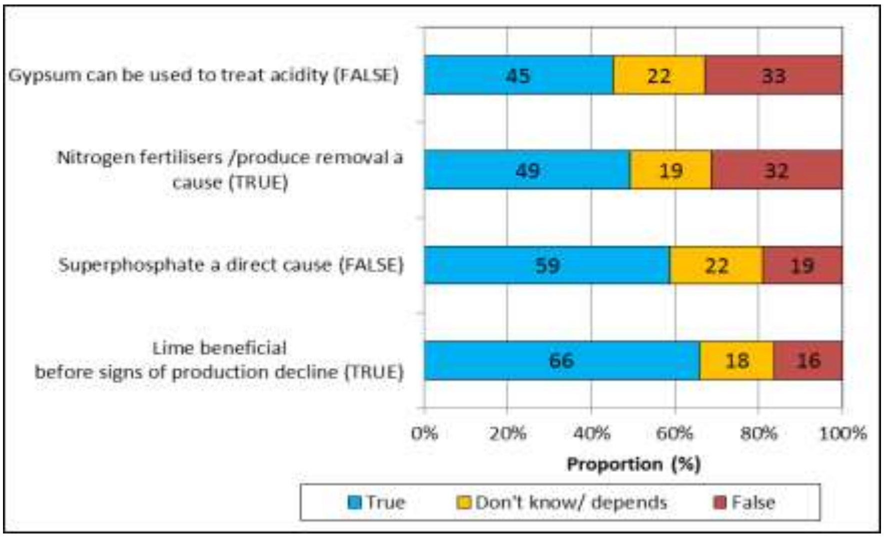


Figure 5. Proportion of true/false responses given to statements about causes and treatments of soil acidity, land managers with acid soils in the SAMDB region, 2017 survey

Around 70% of managers with acid soils said they have applied lime to some or all of this land. They were asked what prompted them to lime. About 60% of managers limed on the basis of soil pH test results, while about 40% did this on advice from consultants.

Approximately 70% of managers with acid soils have sought information on treating soil acidity. By far the most common source used was consultants/advisors (about 45%).

In the 2017 survey, about 36% of respondents with acid soils said they had used other treatments to manage acid soils, including acid tolerant plants (18%) and adapting fertiliser strategies (14%).

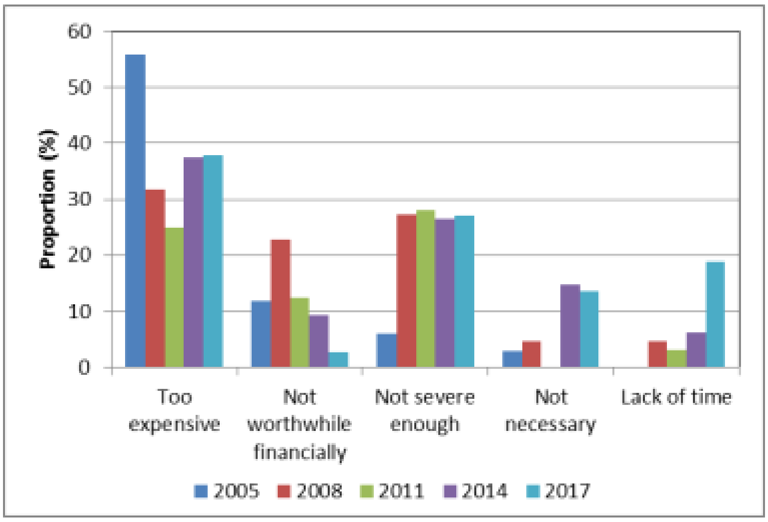


Figure 6. The most common reasons given for not liming by SAMDB landholders with acid soils

The main reasons that land managers gave for not liming acid soils were mainly related to cost or that they considered the acidity was not severe enough to warrant liming (Figure 6).

5. Treatment of Soil Acidity

Lime sales and estimated soil acidification rate

DEW collates data from lime resellers each year to estimate the amount of lime applied to ameliorate soil acidity on agricultural land within the SAMDB region. This lime sales data (tonnage) is compared to an estimation of the amount of lime that would be required to neutralise the annual acidification rate of soils.

The acidification rate is estimated from a number of parameters, including soil type, annual rainfall and the extent and intensity of the different agricultural production systems that contribute to soil acidification through removal of alkaline products in crops and pastures and the use of nitrogen fertilisers.

The annual acidification rate in the SAMDB region was recently revised, through a detailed re-assessment of land use data, farming systems and acidification rates, soil properties, and the results of surveillance and monitoring soil pH test data sampled from acid prone soil areas in 2008-09 (section 3). The potential extent that soil acidity in acid prone areas could be treated by claying with clay material containing free lime was estimated as part of this calculation. Estimated acidification rates for different land use categories is given in Appendix 2. The following data only applies to surface (0-10 cm) soil acidification. The additional amount of lime needed to treat sub-surface acidification has not been estimated.

(1) The estimated breakeven acidification rate on acidic soils, i.e. currently with a surface pH_{Ca} of less than 5.5.

This represents soils that are already acidic and currently need lime application to treat acidification, to avoid production loss and degradation of the soil resource. This is approximately 16,000 tonnes of lime equivalent per year, or about 91 kg lime per hectare per year on currently acidic soils.

(2) The estimated acidification rate on all acid prone soils.

This includes soils that are acidifying, but pH levels have not yet declined to 5.5. At this stage it would not be economic to apply lime to these soils. This is approximately 24,000 tonnes of lime equivalent per year, or about 91 kg lime per hectare per year on acid prone soils.

Figure 7 shows the SAMDB region acidification rate for current acid soils and all acid prone soils, with estimated average annual lime use since 1999. Lime use was highest around 2001 – 2002, but then declined to a low in 2007, before gradually increasing and then levelling off over the past few years. Over the last 10 years, average lime use was 74% of the estimated acidification rate for current acid soils (see table below).

There is a large gap between the breakeven acidification rate for all acid prone soils and the breakeven acidification rate for currently acidic soils, indicating that a further substantial area of soils are acidifying and will eventually require liming once they fall below pH_{Ca} 5.5.

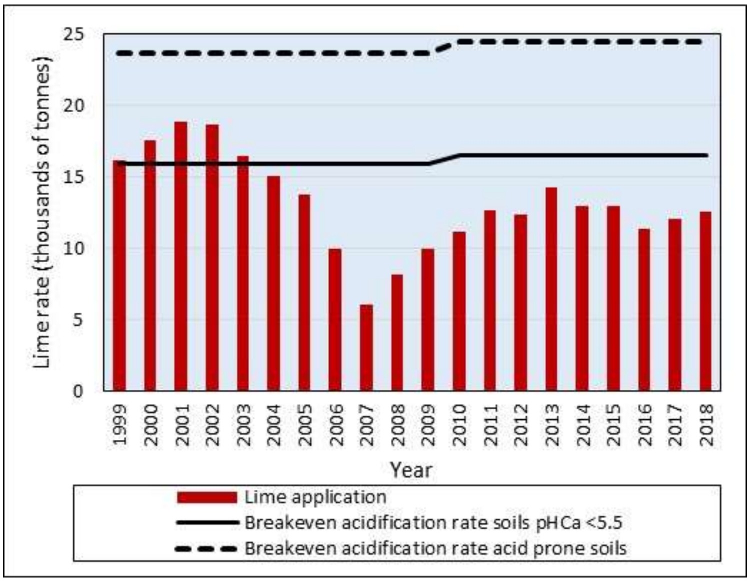


Figure 7. Estimated application of lime ('000 tonne) per year on agricultural land in the SAMDB region from 1999 to 2018 with the breakeven acidification rate for all acid prone soils and the breakeven acidification rate for currently acidic soils.

Note: Year on chart represents actual corresponding financial year (ie '2015' = 2014-15)

Slight change in estimated acidification rates in 2009 due to realignment of SAMDB NRM Region boundary (increase in area of acid soils)

Monitoring period ending 2018	Average lime use '000 t/y	Breakeven acidification rate acid soils '000 t/y	Average lime use % of breakeven
Last 5 years	12	16	75
Last 10 years	12	16	74
Last 20 years	13	16	80

Figure 8 shows the estimated net acidification, or cumulative lime deficit in the SAMDB region since the start of the lime sales data collection in 1999 (nominal baseline 1998 at zero). This is the yearly lime use minus the breakeven acidification rate on acid soils pH_{Ca} <5.5. Over this period the net acidification has accumulated to about 50 tonnes of lime equivalent, or about 0.3 tonnes per hectare of acid soil. The cumulative lime deficit prior to 1999 has not been estimated.

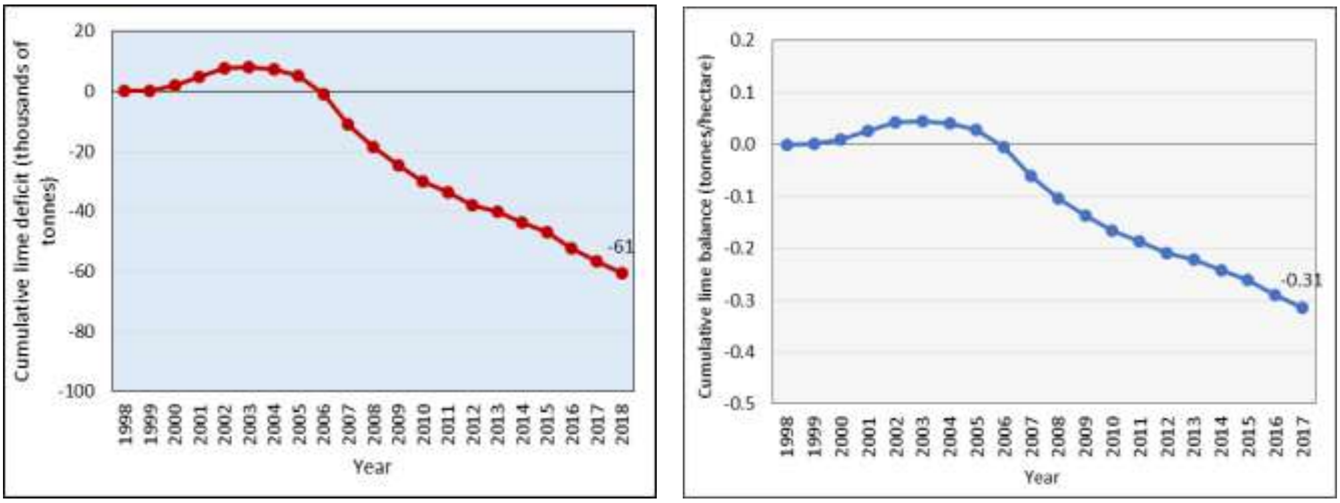


Figure 8. **Estimated net (accumulated) lime deficit in the SAMDB region since 1999: Left chart – thousands of tonnes of lime equivalent; Right chart – tonnes lime equivalent per hectare of acid soil pH_{Ca} <5.5, from 1998 to 2018.**

Lime needed to treat existing acid soils

In addition to the amount of lime required to treat the annual acidification rate, more lime needs to be applied to raise the pH of existing acidic soils to above the critical level for crop and pasture production. The extent and pH level of current acid soils (surface and subsurface) on agricultural land in the SAMDB region has been recently re-estimated based on the surveillance and monitoring site soil pH test data sampled in acid prone areas in 2008-09 (Section 3). The pH buffering capacity of soils in acid prone areas according to soil texture spatial data has also been incorporated into this estimate.

The 'catch-up' lime requirement to raise the pH of existing acid topsoils to pH_{Ca} 5.5 and subsurface soils to pH_{Ca} 5.0 for the SAMDB region is approximately 343,000 tonnes of lime. This includes about 303,000 tonnes of lime to raise the pH of all acidic topsoils, plus a further 40,000 tonnes of lime to ameliorate acidity in acidic subsurface soils (10-20cm depth).

The trend in insufficient annual lime application suggests that the area of soil acidity in the SAMDB region will continue increase in the future.

Other alkaline inputs such as application of other alkaline fertiliser forms, irrigation with alkaline water and areas modified by deposition of calcareous road dust are not expected to amount to a significant area in the higher rainfall areas of the SAMDB region. In the potentially acidic areas of the Southern Mallee, irrigation with alkaline water occurs on high value horticultural crops (eg. potatoes) although on relatively small areas of land.

Precision soil pH mapping of paddocks is being increasingly used in the region to enable lime rates to be targeted and varied according to pH variation within a paddock. This potentially improves the cost effectiveness of liming to treat acid soils.

A set of acid soils/liming calculator 'tools' for land managers has been recently developed through the DEW soil acidity program. These can be used to estimate the financial loss due to acid soils; the most cost effective lime source/rate options; and the longer term 'maintenance' lime requirement for any crop/pasture situation.

6. Summary of data

The results from the most current soil sampling pH data have highlighted that surface soil acidity is continuing to be an issue in parts of the SAMDB region, with some potential to spread. Subsurface soil acidity now occurs more frequently, and is an issue of concern. If surface soil acidity is left untreated there is potential for subsurface soil acidity to become a greater problem in the future.

From all the soil data collected through the surveillance, monitoring and Ag. Bureau sites, 38% of surface soil samples and 49% of sub-surface tests had a pH_{Ca} value of less than the critical value of 5.0.

Surveys of landholders with acid soils indicate some variability in awareness of acidity over time, partly related to the timing of active acidity programs. The cost of liming was the most commonly given reason for not applying lime to all acid soils. Annual lime applications are well below the estimated break-even acidification rate for the region and this highlights the need for more targeted programs to address this issue.

7. Climate change implications

The possible effect of climate change on soil acidification in the SAMDB NRM Region is difficult to predict because it would be influenced by what land use and land management changes might occur.

In general, indications are that climate change will cause a decline in annual rainfall and warmer temperatures.

In medium to low rainfall areas, this is likely to result in reduced soil acidification rates due to lower plant growth, less nitrogen fertiliser used and a smaller amount of product removal.

However, in higher rainfall grazing areas, soil acidification rates could increase, if there is a land use change to cropping where more nitrogen fertilisers and grain legumes are used; or if higher nitrogen inputs occur on pastures.

Conversely, if projected increases in summer rainfall encourage a greater amount of deeper rooted, non-legume perennial plants to be grown, this could increase nitrate uptake from the subsoil, reducing the leaching of nitrogen which causes soils to acidify.

Whatever changes to soil acidification may occur over time due to climate change, the current soil acidification issue is a high priority in acid prone areas in the SAMDB NRM Region which needs to be addressed to prevent it from worsening.

8. Links to state-wide soil acidity strategy

The issues and strategies described in this snapshot report relate to a state-wide draft strategy prepared by DEW “Strategy for Managing Soil Acidity on South Australia’s Agricultural Soils”.

The aim of this strategy is:

Degradation of South Australia’s agricultural soils by acidification is halted by restoring or maintaining soil pH to at least 5.0 (measured in $CaCl_2$).

9. Key Issues for Future programs

Key issues to address in future soil acidity programs in the SAMDB region are:

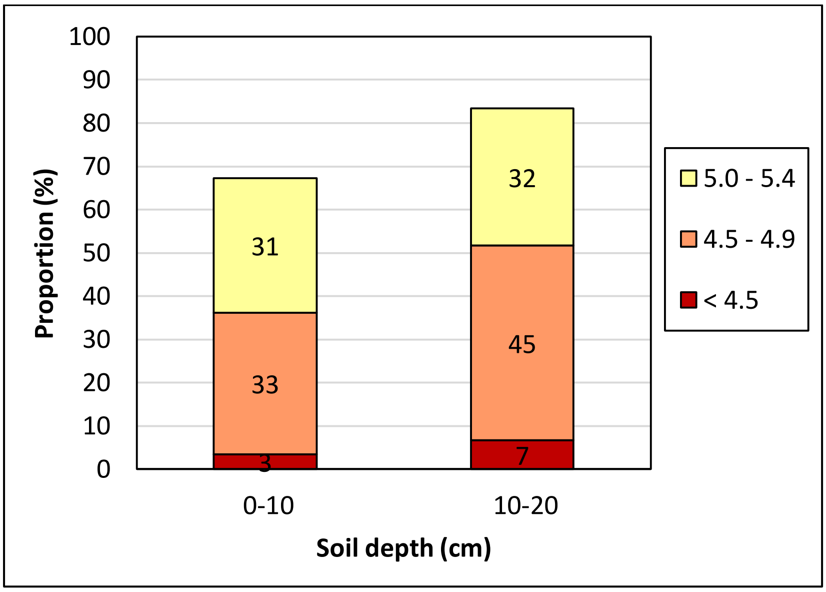
- Awareness - landholders need to be aware and informed of the issues linked to acid soils, critical pH, crop sensitivity
- Subsoil issues – subsoil/subsurface pH testing needs to be undertaken and encouraged because normal soil testing only assesses the surface soil layer, and once it develops, subsoil acidity is difficult to treat
- Paddock Variation- systems which allow mapping of paddock variation in pH have been recently evaluated and demonstrated so that liming treatments can be targeted to variation of pH within a paddock
- Cost benefit of treatment- while the cost of treating acid soils is relatively cheap compared to other parts of Australia, the cost benefit perception issue needs to be further addressed so landholders will recognise the longer term benefits of investing in adequate liming
- Some monitoring of 'alternative' treatments such as irrigation with alkaline water and claying with calcareous clay needs to be undertaken to see how long their benefits will last.

Appendix

Appendix 1. Soil pH test results

The following table and graph show results of 2008-09 soil pH sampling in the SAMDB region

Depth (cm)	No. of samples	% pHCa <4.5	% pHCa <5.0	% pHCa <5.5	Lowest pHCa	Highest pHCa	Mean pHCa
0-10	58	3	36	67	4.2	6.4	5.2
10-20	60	7	52	83	3.9	7.2	5.1



Appendix 2: Estimated acidification rates for land use types

Acidification rates based on available data for different land uses and intensities in the SAMDB region that were used to estimate the annual acidification rate.

Land use	Category / intensity	Acidification rate (kg/ha/y lime equiv)	Comments
Cropping	Continuous cropping	250	
	Intensive cropping	200	
	Cropping / Grazing	100	
Grazing	Intensive grazing	150	
	Good grazing	100	
	Extensive grazing	40	
	Non-arable grazing	30	
	Irrigated pasture	150	
Forestry		0	Limited data
Horticulture	Greenhouse	0	
	Annual	100	
	Fruit	100	
	Vines/ Olives	50	

Glossary

Acid prone soils - (or 'acid soils' based on soil characterisation survey data) soils that are currently or imminently prone to becoming acidic (next 5 – 10 years). The actual pH level for any soil depends on management (production intensity, liming history etc).

Future acidification potential – soils not currently acidic but have the potential to become acidic in the medium to long term (next 10 – 50 years). These are soils that are not calcareous and have a current estimated pHCa less than 7.5, and are likely to be acidifying over time under agricultural use.

Currently acidic soils – estimated to have current pH_{Ca} less than 5.5 based on recent (2008 - 2015) targeted soil testing programs as described in section 3.

Soil pH_{Ca} – soil pH measured using a standardised method of a suspension of 1:5 soil:0.01 molar calcium chloride solution (Rayment, GE & Higginson, FR 1992, *Australian Laboratory Handbook of Soil and Water Chemical Methods.* Inkata Press, Melbourne. (Australian Soil and Land Survey Handbook, vol 3)).