Technical information supporting the 2018 agricultural land (soil acidity) trend and condition report card

DEW Technical note 2018/30

Government of South Australia
Department for Environment and Water

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June, 2018

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ISBN 978-1-925668-73-5

Preferred way to cite this publication

DEW (2018). Technical information supporting the 2018 agricultural land (soil acidity) trend and condition report card. DEW Technical note 2018/30, Government of South Australia, Department for Environment and Water, Adelaide.

Download this document at https://data.environment.sa.gov.au

Consultation and acknowledgements

This document was prepared by Giles Forward, Tim Herrmann and Craig Meakin (DEW). Daniel Rogers (DEW) provided principal oversight throughout and technical review of this report. Improvements were made to this report and associated report card based on reviews by Colin Cichon, Ben Smith, Michelle Bald, Fi Taylor.

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Summary

This document describes the indicators, data sources, analysis methods and results used to develop this report and the associated report card. The reliability of data sources for their use in this context are also described.

1 Introduction

1.1 Soil acidity on agricultural land

Soil acidity is the second highest priority threat to the sustainable management of agricultural soils in South Australia. Approximately 2.0 million hectares of agricultural land (20%) are affected by soil acidity (acid-prone land). The estimated value of lost agricultural production in SA due to acid soils is approximately $85 million per year. Many soils in the higher rainfall areas of the state are naturally acidic.

Soil acidification can be significantly accelerated by agricultural practices including removal of grain, hay and livestock products from the paddock, use of ammonium-containing or ammonium-forming fertilisers, and leaching of nitrate nitrogen derived from legume plants or fertilisers. Increased levels of production lead to higher acidification rates. Sandy textured soils are at highest risk of acidification.

The consequences of untreated highly acid soils include:

- reduced growth and production of most agricultural plants
- reduced soil biological activity
- increased soil salinity due to increased drainage of rainfall to groundwater
- increased leaching of iron, aluminium and some nutrients leading to contamination of surface and ground water
- structural breakdown of the soil.

Surface soil acidity can be readily treated by application of liming products, but subsurface acidity is more difficult and expensive to treat. If acidic topsoils are not adequately treated over time, there is an increased risk of subsurface acidification. Acidity can also be ameliorated by incorporation of calcareous or alkaline clay or by use of alkaline irrigation water. The use of deeper rooted perennial plants and effective management of soil nitrogen can reduce the rate of acidification.

Soil acidification will continue to increase unless the level of remedial action is significantly improved.

1.2 Environmental trend and condition reporting

The Minister for Environment and Water under the *Natural Resources Management Act 2004* is required 'to keep the state and condition of the natural resources of the State under review'. Natural resource management report cards are produced as a primary means for undertaking this review. Previous environmental trend and condition report card releases reported against the targets in the South Australian Natural Resources Management Plan (Government of South Australia 2012b) using the broad process outlined in the NRM State and Condition Reporting Framework (Government of South Australia 2012a).

As the state natural resources management plan is currently under review, environmental report cards in early 2018 will instead inform the next South Australian State of the Environment Report (SOE) due out in 2018. Again, there is a legislative driver to guide the development of SOE reporting.

The *Environment Protection Act 1993*, which is the legislative driver to guide the development of SOE reporting, states that the SOE must:

- include an assessment of the condition of the major environmental resources of South Australia 112(3(a))
- include a specific assessment of the state of the River Murray, especially taking into account the Objectives for a Healthy River Murray under the *River Murray Act 2003* 112(3(ab))
- identify significant trends in environmental quality based on an analysis of indicators of environmental quality 112(3(b)).

Environmental trend and condition report cards will be used as the primary means to address these SOE requirements.

1.2.1 Environmental trend and condition report card continual improvement

Key documents guiding the content of South Australian environmental trend and condition report cards are:

- Trend and Condition Report Cards Summary Paper (DEWNR 2017)
- NRM State and Condition Reporting Framework (Government of South Australia 2012a).

Both of these documents reference a process of continual improvement in the way environmental trend and condition report cards are produced and communicated. A review based on key stakeholder feedback (O'Connor NRM 2015) indicated five key learnings (DEWNR 2017):

1. Environmental trend and condition are acknowledged as a useful communication tool. There is support for them to continue to be produced to highlight data gaps and reliability issues to a broad audience including: policy makers and investors; environmental managers; and the community
2. There are issues with data availability, access, consistency and transparency, which will need to be addressed and improved over time in future trend and condition report cards
3. Indicators or measures reported on were based on those outlined in the State NRM Plan. Not all of these are considered to be the most appropriate or relevant for those assets. These will be reviewed as part of the current State NRM Plan review and a set of agreed measures will be determined for future trend and condition report cards
4. Greater alignment of reporting relevant to project, regional, state, program and State of the Environment is seen as imperative
5. Better clarity is needed around target evaluation reporting, which should measure the impact or outcome of an investment at a project, regional, state or program scale. However the trend and condition reporting reflects the status of an environmental resource and its change based on impacts that affect its condition. In some cases, the same reporting can be used for both (e.g. soil erosion), and in others it cannot (e.g. threatened species).

As the process by which the environmental trend and condition report cards are produced evolves, there is an increased emphasis, in keeping with the Premier's digital by default declaration, on the use of open data and reproducibility. This is one key response to help address the second key learning outlined above. The report cards being produced to inform the 2018 State of the Environment Report are at varying stages along this route to open data and reproducibility.

2 Methods

2.1 Indicator

The indicator used to assess the trend in soil acidity is the 'cumulative lime balance'. This is the amount of lime used over time compared to the lime needed to neutralize the estimated rate of soil acidification (section 2.4.1).

The indicator used for soil acidity condition is the estimated proportion of acid-prone soils that are currently acidic (pH less than 5.5, Section 2.4.2).

2.2 Data sources

Department of Environment, Water and Natural Resources (DEWNR) – Soil and Land Information Framework; Soil acidification model; Annual lime sales data (1999 – 2017).

ABS, Australian Bureau of statistics. 7503.0 - Value of Agricultural Commodities Produced, Australia, 2015-16.

2.3 Data collection

DEW collects annual lime sales data (tonnage) from lime sellers in the state (since 1999) to estimate the amount of lime used on agricultural land in the six agricultural NRM regions (EP, N&Y, AMLR, KI, SAMDB, SE) and the state.

DEW conducted strategic soil pH testing on agricultural land within acid-prone areas in the six agricultural NRM regions (58 to 225 soil test samples 0-10cm per region; average 126 per region; total 757 tests) from 2008–15 to provide an estimate of the current extent and pH level of acidic soils.

The extent of acid-prone soils in SA is obtained from DEW's Soil and Land Information Framework.

2.4 Analysis

2.4.1 Trend

1. The 'cumulative lime balance' (lime deficit or lime surplus) is expressed as the amount of lime used, compared to the amount of lime required.

2. The amount of lime used is estimated from annual lime sales data collected from lime sellers in the state since 1999 (1998–99).

3. The amount of lime required is based on the estimated annual soil acidification rate of currently acidic soils on agricultural land in each region. The soil acidification rate is estimated from the extent of agricultural land uses/intensity and measured acidification rates, the extent of acid-prone surface soils in SA (Soil and Land Information Framework), and the extent of currently acidic topsoils (below pHCa 5.5) estimated from regional soil pH testing programs conducted from 2008–15.

4. Data were plotted along a yearly timeline to illustrate the progression in 'cumulative lime balance' (deficit or surplus) over time since 1998 (i.e. baseline year 1998 balance nominally assumed to be zero).

5. Ten-year trends are assessed by the 'cumulative lime balance' over the last 10 years of data (2006–07 to 2016–17). Trends are classified as stable, positive or negative if the cumulative lime balance (t/ha/y) was within +/-

10% of the annual acidification rate (AAR; t/ha/y), lime use surplus >10% of AAR, or lime use deficit >10% of the AAR, respectively (Table 2.1).

Table 2.1. Definition of trend classes used

Trend	Description	Threshold
Getting better	Over a scale relevant to tracking change in the indicator it is improving in status with good confidence	lime use surplus >10% of Annual Acidification Rate
Stable	Over a scale relevant to tracking change in the indicator it is neither improving or declining in status	lime use balance within ±10% of the Annual Acidification Rate
Getting worse	Over a scale relevant to tracking change in the indicator it is declining in status with good confidence	lime use deficit >10% of the Annual Acidification Rate
Unknown	Data are not available, or are not available at relevant temporal scales, to determine any trend in the status of this resource	
Not applicable	This indicator of the natural resource does not lend itself to being classified into one of the above trend classes	

2.4.2 Condition

1. Current soil condition is based on recent soil test data and soil attribute mapping data which are used to estimate the proportion of acid-prone agricultural land (in each region and the state) that currently has a surface pHCa of less than 5.5.

2. The condition scores for this report card are based on interpretation of estimates of the percentage of acid-prone land that is currently acidic with a pH less than 5.5. For example, <50% = Good, 50-75% = Fair, > 75% = Poor (Table 2.2).

Table 2.2. Definition of condition classes used

Condition	Condition Definition	Threshold
Very good	The natural resource is in a state that meets all environmental, economic and social expectations, based on this indicator. Thus, desirable function can be expected for all processes/services expected of this resource, now and into the future, even during times of stress (e.g. prolonged drought)	NA
Good	The natural resource is in a state that meets most environmental, economic and social expectations, based on this indicator. Thus, desirable function can be expected for only some processes/services expected of this resource, now and into the future, even during times of stress (e.g. prolonged drought)	<50% of acid-prone land with a pH of less than 5.5
Fair	The natural resource is in a state that does not meet some environmental, economic and social expectations, based on this indicator. Thus, desirable function cannot be expected from many processes/services expected of this resource, now and into the future, particularly during times of stress (e.g. prolonged drought)	50-75% of acid-prone land with a pH of less than 5.5
Poor	The natural resource is in a state that does not meet most environmental, economic and social expectations, based on this indicator. Thus, desirable function cannot be expected from most processes/services expected of this resource, now and into the future, particularly during times of stress (e.g. prolonged drought)	>75% of acid-prone land with a pH of less than 5.5

Unknown	Data are not available to determine the state of this natural resource, based on this indicator
Not applicable	This indicator of the natural resource does not lend itself to being classified into one of the above condition classes

2.4.3 Reliability

Information is scored for reliability based on the average of subjective scores (1 [worst] to 5 [best]) given for information currency, applicability, level of spatial representation and accuracy. Definitions guiding the application of these scores are provided in Table 2.3 for currency, Table 2.4 for applicability and Table 2.5 for spatial representation.

Table 2.3. Guides for applying information currency

Currency score	Criteria
1	Most recent information >10 years old
2	Most recent information up to 10 years old
3	Most recent information up to 7 years old
4	Most recent information up to 5 years old
5	Most recent information up to 3 years old

Table 2.4. Guides for applying information applicability

Applicability score	Criteria
1	Data are based on expert opinion of the measure
2	All data based on indirect indicators of the measure
3	Most data based on indirect indicators of the measure
4	Most data based on direct indicators of the measure
5	All data based on direct indicators of the measure

Table 2.5. Guides for applying spatial representation of information (sampling design)

Spatial score	Criteria
1	From an area that represents less than 5% the spatial distribution of the asset within the region/state or spatial representation unknown
2	From an area that represents less than 25% the spatial distribution of the asset within the region/state
3	From an area that represents less than half the spatial distribution of the asset within the region/state
4	From across the whole region/state (or whole distribution of asset within the region/state) using a sampling design that is not stratified
5	From across the whole region/state (or whole distribution of asset within the region/state) using a stratified sampling design

3 Results

3.1 Trend

A lime deficit (annual lime use compared to estimated acidification rate, as outlined in Section 2) has accumulated since 1998 in the state and all regions except for the AMLR NRM Region, which has a small lime surplus (Table 3.1, Figure 3.1).

The trend in cumulative lime balance was calculated from the last 10 years of data to 2017. In all regions and statewide, the 10 year trend was negative (i.e. increasing cumulative lime deficit). The annual average (negative) trend was greater than 10% of the estimated annual acidification rate in all regions and statewide so was rated as 'getting worse', as outlined in Section 2 (Table 3.2)

Table 3.1. Cumulative lime balance (deficit or surplus) since 1999 in tonnes per hectare

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
AMLR	0	0.04	0.07	0.11	0.16	0.20	0.22	0.23	0.23	0.19	0.16	0.16	0.14	0.13	0.13	0.14	0.14	0.11	0.11	0.09
EP	0	-0.14	-0.24	-0.32	-0.35	-0.39	-0.48	-0.62	-0.77	-0.89	-0.99	-1.09	-1.19	-1.31	-1.43	-1.55	-1.63	-1.70	-1.76	-1.61
KI	0	-0.02	0.00	-0.03	-0.04	-0.04	-0.10	-0.16	-0.20	-0.23	-0.24	-0.27	-0.31	-0.35	-0.38	-0.40	-0.39	-0.37	-0.39	-0.35
NY	0	-0.02	-0.04	-0.04	-0.03	-0.03	-0.05	-0.06	-0.15	-0.26	-0.29	-0.39	-0.48	-0.51	-0.58	-0.60	-0.67	-0.70	-0.71	-0.73
SAMDB	0	0.00	0.01	0.03	0.04	0.04	0.04	0.03	-0.01	-0.06	-0.10	-0.14	-0.17	-0.19	-0.21	-0.22	-0.24	-0.26	-0.29	-0.31
SE	0	-0.04	-0.07	-0.08	-0.08	-0.08	-0.05	-0.02	0.00	-0.01	-0.02	-0.01	-0.02	-0.03	-0.04	-0.06	-0.08	-0.10	-0.10	-0.12
State	0	-0.03	-0.05	-0.05	-0.05	-0.04	-0.05	-0.05	-0.08	-0.12	-0.15	-0.17	-0.20	-0.23	-0.26	-0.28	-0.31	-0.33	-0.35	-0.34

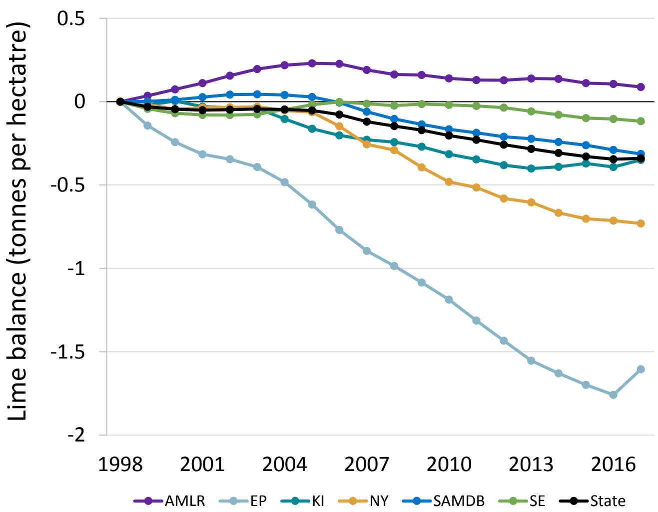

Figure 3.1. Cumulative lime balance (deficit or surplus) since 1999 in tonnes per hectare

Table 3.2. Trend in cumulative lime balance for last 10 years to 2017

	10 year cumulative lime balance (deficit) Kg/ha/y	Annual acidification rate kg/ha/y	Lime deficit % of annual acidification rate	Rating
AMLR	-10	96	-11	Getting worse
EP	-71	187	-38	Getting worse
KI	-12	91	-13	Getting worse
N&Y	-47	163	-29	Getting worse
SAMDB	-25	91	-28	Getting worse
SE	-11	65	-16	Getting worse
State	-22	97	-23	Getting worse

3.2 Condition

Condition scores were based on the proportion (%) of acid-prone land that has a current pHCa of less than 5.5, as set out in Section 2 (Table 2.2). Statewide, and in most NRM regions, the condition was allocated the score of 'fair' (50% - 75% area less than pHCa 5.5). For KI the score was 'poor' (>75% area less than pHCa 5.5, Table 3.3).

Table 3.3. Hectares of acid-prone soils, and estimated current proportion (%) with pHCa less than 5.5

	Acid-prone hectares	% pHCa <5.5	Rating
AMLR	256,000	60	Fair
EP	186,000	62	Fair
KI	162,000	97	Poor
N&Y	291,000	56	Fair
SAMDB	268,000	67	Fair
SE	871,000	68	Fair
State	2,033,000	67	Fair

3.3 Reliability

The overall reliability score for this report card is 4 based on Table 3.4.

Table 3.4. Information reliability scores for soil protection

Indicator	Applicability	Currency	Spatial	Reliability
Trend (cumulative lime use deficit)	4	5	4	4
Condition (% acidic soils)	3	5	4	4

3.3.1 Notes on reliability

Trend

The lime sales data converted to a lime deficit is a direct indicator, but the acidification rates estimation uses other data sources some of which are indirect; given applicability score of 4.

All data used for lime deficit is current <3 years old; given a score of 5.

Lime sales data represents 100% of the acid-prone area of all agricultural regions in the state but the recent soil pH test data is relatively limited within these areas; given overall score of 4.

Condition

Extent of acid-prone soils and the recent soil pH test data are collectively an indirect estimate of current soil acidity; given applicability score of 4.

Data used for condition is current <3 years old; given a score of 5.

Extent of acid-prone soils is high quality, recently revised data from the Soil and Land Information Framework; the soil pH test data sampled from the acid-prone areas in each region is a relatively small number of samples not fully randomized or stratified; given overall score of 4.

4 Discussion

4.1 Trend

Since 1999 when monitoring began, the statewide trend in soil acidity has been getting worse on agricultural soils in South Australia. The indicator is the 'cumulative lime balance' which is negative (deficit) because not enough lime is being applied to counteract soil acidification. The cumulative lime deficit has been steadily increasing in the state since 2005. This follows a relatively stable period from 1999 to 2005.

The lime deficit in all the agricultural NRM Regions has increased over the last 10 years, indicating a negative trend. Technically the AMLR region has a small lime 'surplus' but this has declined at a similar rate to the lime deficit in other regions. The slight 'improvement' in lime deficit in EP and KI regions in 2017 is encouraging but too little to indicate a reversal of this trend. A significant improvement in the 'lime deficit' would need to be sustained over many years to overcome the longer term negative trend.

This data indicates that overall, agricultural soils that are susceptible to acidity are becoming more acidic over time, and the area of acidic soils is increasing.

4.2 Condition

Soil acidity is rated as 'fair'. Approximately 67% of acid-prone soils in the agricultural areas in South Australia are currently acidic (pHCa less than 5.5), causing a decline in soil health and significant loss of agricultural productivity. The rated condition of acidity is 'fair' in most of the regions but 'poor' in Kangaroo Island, where nearly all acid-prone soils are currently acidic. The extent of acidic soils was probably considerable on KI prior to the start of agricultural use, so the proportional increase in acidity since then may in fact not be much different to that in the other regions.

The current condition assessment of soil acidity takes into account that some soils were already acidic before agricultural development but that acidity has increased considerably since then. The historic cumulative lime deficit from commencement of agricultural land use up to 1998 is likely to be significant, particularly for the more productive agricultural land use systems. This lime deficit has not yet been properly quantified.

The ongoing and future risks to mitigation of soil acidity on agricultural land in SA include:

- Ongoing availability of good quality, affordable lime in all districts
- Lime needs to be applied at locations where surface soils are acidifying to below critical pH levels for full productivity and where subsurface soils are acidifying, and at appropriate rates to overcome acidity
- Lime use rates need to increase in the future to counteract increasing levels of agricultural production (particularly cropping) and higher nitrogen fertiliser use rates, which are increasing acidification rates.

Targeted programs involving government and agricultural industry are underway to facilitate better treatment of acidic soils. Improved tools and technologies for soil testing and liming have been developed and are being adopted. A large increase in lime sold in 2017 on EP (and a smaller increase on KI) may be at least partly attributed to these programs.

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