Australian Government

National Land & Water Resources Audit

An initiative of the Australian Government

SOIL CONDITION

INDICATOR HEADING

Soil condition

INDICATOR PROTOCOL

Soil acidification

Soil acidification

Endorsed

This protocol has been endorsed by the National Land and Water Resources Audit Advisory Council. Version 1 – December 2007. The indicators will need to be further developed as identified within the protocol.

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Status of indicator agreement

The National Land & Water Resources Audit (the Audit) coordinates the collation of data to support reporting on natural resource condition required under the National NRM Monitoring and Evaluation Framework (National M&E Framework).

The National M&E Framework identifies three requirements for monitoring natural resource condition:

- a set of resource condition indicators to measure progress toward the agreed national outcomes on a medium and long term basis
- a set of indicators for monitoring community and social processes relevant to or affected by NRM programs, as well as measures of the adoption of sustainable development and production techniques
- contextual data pertinent to the indicator being considered.

The Audit Advisory Council has agreed to a process for achieving a practical set of indicators under the National Monitoring and Evaluation Framework.

This process is to:

- obtain on-going **recommendations** from the relevant **National Coordination Committees** for each thematic area (including "Matters for Target") on appropriate indicators, protocols and information needs
- seek **endorsement** from the **Audit Advisory Council** that the indicators and protocols can be implemented at the national, state / territory and regional levels
- seek **agreement** from the Natural Resource Policies and Programs Committee (**NRPPC)** (or the Marine and Coastal Committee –**MACC-** for Estuarine, Coastal and Marine) that the indicators will be used and promoted by jurisdictions to underpin evaluations of NRM initiatives.

The NRPPC and MACC report to the Natural Resource Management Ministerial Council (NRMMC).

Indicator Protocol: Soil acidification

Matter for target:

Soil condition.

Indicator heading:

Soil condition.

Indicator name:

Soil acidification.

1. Definition

Soil pH is a measure of the acidity or alkalinity of the soil. It is the negative log of the hydrogen ion concentration on a scale of 1 to 14 where 7 is neutral, below 7 is increasingly acidic and above 7 is increasingly alkaline.

Soil acidification is a natural process which is generally accelerated by agriculture where the accumulation of hydrogen ions accompanies the removal of agricultural produce. The acidification rate, expressed as change in pH, is influenced by the buffering capacity of the soil. A good summary of soil acidification can be found in Fenton and Helyar (2000) or Lockwood *et al.* (2003).

2. Rationale

2.1 Why do we want to know it?

Soil acidity is a major land degradation issue facing much of Australia. It is important to know if it is being managed appropriately to avoid costly losses in production, negative implications for the environment and possibly restricted access to future markets for our agricultural produce.

Different crop species and even different cultivars have a pH range within which they are most comfortable; nutrient deficiencies and toxicities appear as the pH moves outside this range. Many Australian soils have a pH outside this range even in their natural state. The National Land & Water Resources Audit (2001) estimated that 50 million hectares of Australia's agricultural land are already experiencing impacts from soil acidity in surface layers and a further 23 million hectares in subsurface layers. This markedly affects yields.

Whether at a point, over a region or even nationally, the purpose of monitoring is to establish a baseline pH and observe trends over time with respect to that baseline. Often there will be a target pH and monitoring will measure progress towards that target.

The recommended measures of soil acidification are the:

- baseline pH
- change in pH over time
- estimated time to critical pH
- adoption of liming and other ameliorating land management practices.

2.2 Context in which it has been measured in national, state and regional resource management programs

This protocol refers to the regional scale monitoring of soil acidification at five-yearly intervals and over a period of at least 10 to 20 or more years. In some jurisdictions the NRM region itself will undertake the monitoring while in others a state agency will monitor on behalf of region(s). States and territories are expected to contribute to the Audit's soil acidification 'national report card'. The protocol applies most readily to crop and pasture land uses and would require modification for horticulture and other land uses.

3. Monitoring methodology

The overall approach is to show how the mean pH of a sampled population changes over time intervals of five years. Baseline pH (T_0) is easily measured and change in pH ($T_{0-}T_1$) is equally straightforward. To the degree that the sampling can represent certain soil, climate, land use and land management combinations then more subtle interpretations can be made of the data.

The estimated time to critical pH is a calculation which requires knowledge of soil buffering capacity, climate, land use and land management data.

The adoption of liming or other land management practices is determined by landholder interview.

3.1 Monitoring location selection

Monitoring baseline pH and change in pH over time is feasible for sites, paddocks, catchments and even NRM regions. Because it is relatively simple to sample for and measure pH, it is possible to take a large number of samples to determine populations and population trends.

The landscape is stratified into discrete monitoring and reporting units. Stratification is based on progressively more detailed soil mapping (such as the ASRIS levels of mapping), the imminence of reaching critical pH levels, plus climatic data and land use information. The number of sites within a unit depends on the area of that unit, its internal variability and possibly its significance in terms of agricultural production and provision of ecological services.

The number of samples (often around 10) at a site depends on the variability of the measured pH. A biometrician can determine the number of sites required for each monitoring and reporting unit and the number of samples to be taken at each site. Although this may be after the first round of sampling it will at least confirm that an adequate number of sites is included and allow rigorous statistical analysis.

Stratification and site selection accounting for within-site variability have received considerable attention in the literature (e.g. Grundy and Webb 1999; McKenzie *et al.* 2000, 2002a, 2002b).

Using the following formula it is possible to determine the variability at each site and the number of samples required at that site to achieve a chosen level of precision and confidence:

$$n = \frac{(\text{t value})^2 \, (\text{Sample Variance})}{(\text{Estimated sample mean}) \, (\text{Level of Precision})^2}$$

An essential element of monitoring soil acidification is that the point at which an observation is made is accurately recorded by GPS so that subsequent observations are made at that same point. This removes many random variables from the statistical analysis with the result that fewer sites are needed.

3.2 Monitoring frequency required

Because pH generally changes very slowly, five-year intervals are recommended for high risk areas and 10-year intervals for low risk areas. A number of five-year cycles may be required before any changes are confirmed. For operational reasons it is strongly recommended to sample a few of the monitoring and reporting units each year to avoid 'start up' overheads and facilitate training and quality control.

The pH should always be measured at the same time of the year to avoid seasonal effects and for the sake of economy, in combination with any other soil sampling practices in the region. Monitoring sites should be free of soil erosion or deposition.

3.3 Data measurement method

The minimum sampling requirement is 0–10 cm, 10–20 cm and 20–30 cm. However, 0–5 cm and 5–10 cm are preferred where possible and where there is a significant pH gradient. Sampling below 30 cm is required where there is evidence of acidification below that depth.

The sample is collected using a 50 mm diameter coring device with vertical sides to avoid bias of the sample towards surface material. The same device may be used for calculating bulk density if soil carbon is also being monitored.

The pH is measured in a 0.01 M $CaCl_2$ solution. Basic descriptions of each monitoring site should be made in terms of McDonald *et al.* (1990).

Information collected by landholder interview is used for estimating the adoption of lime as a land management practice over selected areas.

3.4 Data collation/calculation method

The list of attributes collected in the field and laboratory appears in Appendix 1. These definitions and acceptable values must be strictly adhered to for all surveys at all times if long term trends are to be extracted. Whether data are collected in field notebooks, a PDA (personal digital assistant or pocket computer) or field computer is a matter of choice.

The time to critical pH is estimated from predictive models such as that used in the Australian Agriculture Assessment (2001) and Moore (2004). This is possibly best estimated only for representative sites.

Information regarding use of liming as a land management practice can be difficult to collect and interpret. It can be useful at the individual paddock level for specific interpretations or at the very broad level to provide a general appreciation of changing farming practices.

3.5 Data storage and management

Institutional arrangements differ between jurisdictions and jurisdictions evolve, so great care must be taken not to corrupt or lose data, particularly given the initial cost involved in gathering and the fact that monitoring programmes may continue for some decades.

Normal 'best practices' apply for the storage and management of digital data. These include the appointment of a data custodian, satisfactory documentation (metadata) and off-site backup.

Under the terms of the National M&E Framework, all data must be placed in state soil data repositories and in turn uploaded to the national soil data repository known as ASRIS.

3.6 Data analysis and interpretation

Because the monitoring sites are selected to represent predetermined geophysical units, data are analysed logically and reported in relation to those units. For each monitoring and reporting unit the following results are expected:

- mean and standard deviation of pH at 'time zero' (T_0)
- mean and standard deviation of pH at second and subsequent samplings (T_1, T_2 … T_n)
- estimated time to critical pH
- use of liming as a land management practice at T_0 etc.

3.7 Reliability, validity and quality assurance

The key to quality assurance is to ensure that technical staff are adequately trained and all systems are in place and fully documented.

Specimens are to be collected and prepared according to McKenzie *et al.* (2002a), and analysed at an ASPAC and NATA-accredited laboratory according to the method of Rayment and Higginson (1992).

3.8 Metadata

Any metadata statements should be consistent with ANZLIC standards. See www.anzlic.org.au/policies.html

4. Reporting/information products

4.1 Audiences

NRM regional bodies monitor to learn whether their programmes are having an impact, for project accountability purposes and as a basis to establish funding priorities and develop policy; their time frame will be from within-season to a few years. (A few years may be too short a timeframe to detect change in well buffered soils or where the net acid addition rate is low. If this is the case then land management practices including lime applications become important, although these can vary widely from year to year.)

State, territory and federal jurisdictions are also interested in regional monitoring but their scope will be over several NRM regions, a state or even the entire nation. They will require a situation analysis, for example every five years.

4.2 Information products

Information products are the means of communication between the scientist and the audience. They are generally interpreted tables or maps showing indicator baseline condition and trend – as distinct from measured data - for each of the geographic units which had previously been established for monitoring and reporting purposes (Section 3.1). Information products often use 'traffic lights' to illustrate the baseline condition and the direction and degree of change.

- The basic information product is a map of the reporting unit showing the mean pH at $T_{0.}$
- Where time series information is available this can be colour coded (e.g. red, yellow, green and grey = no data) to show trends in mean pH. A histogram can convey the same shift in population mean.
- Graphs showing the trends in lime usage as a land management practice.

An example from the Gabby Quoi Quoi catchment in WA is shown in Figure 1.

The information products become increasingly valuable as it becomes possible to interpret the time series data for cause and effect.

Excellent examples of information products can be found at

http://nlwra.gov.au/Publications_and_Tools/Project_Reports/ then go to catchments to coast, wet tropics regional report card (April 2007)

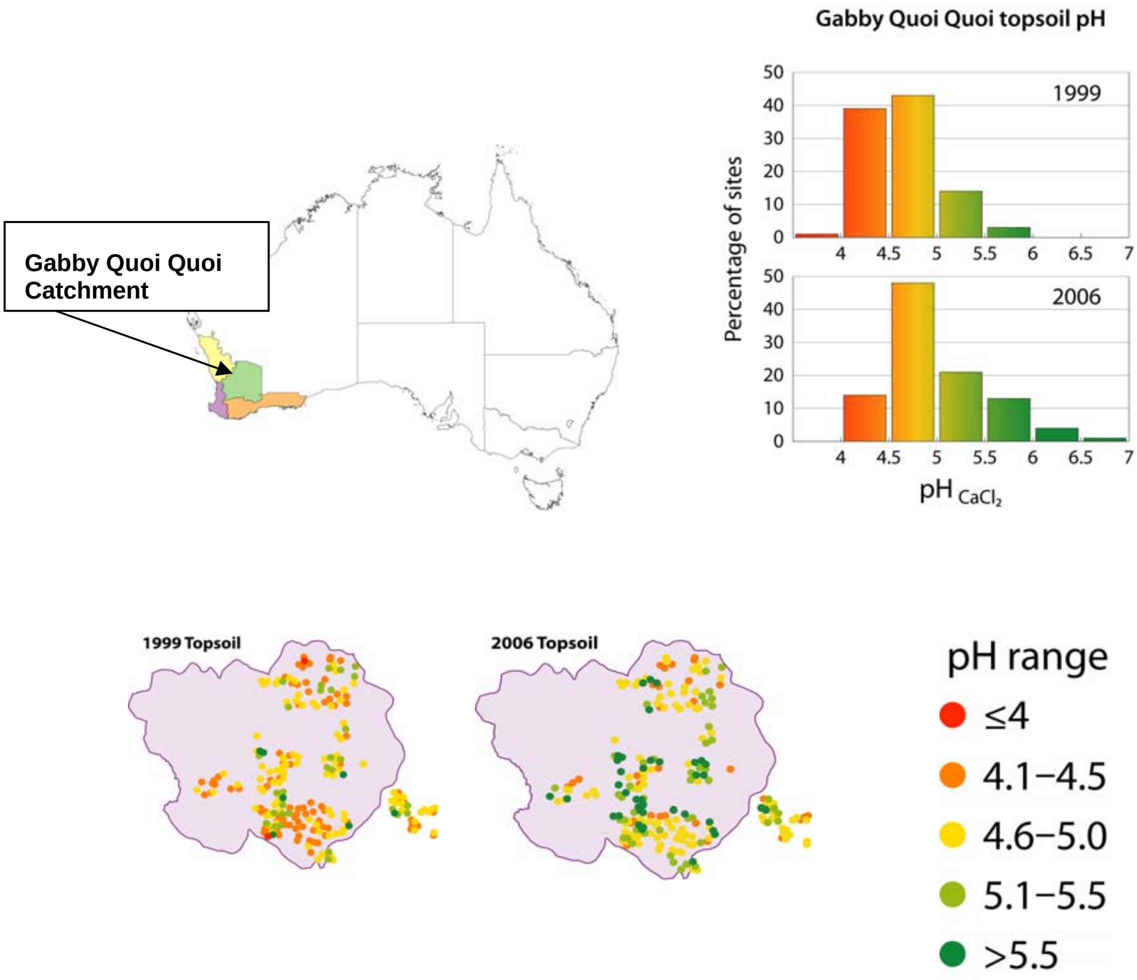

Figure 1: Example of information products showing topsoil pH (1999 baseline) and topsoil pH (2006) for Gabby Quoi Quoi Catchment

4.3 Confidentiality

Any data which could be attributed to an individual owner or property should be password protected.

There are no confidentiality issues associated with:

- primary data that have been collected wholly or partially with the use of public or project funds although to avoid misunderstanding the landholder should be made aware of how the data might be used
- data for which the landholder has given permission to use
- information products, i.e. data that have been aggregated or highly processed such that they cannot be attributed to an individual property or owner.

4.4 Data collation/calculation method

See Sections 3.6 and 4.2.

4.5 Data analysis, integration and interpretation information

See Sections 3.6 and 4.2.

For 'case histories' see Gazey *et al*. (2007), Chapman *et al.* (2007) available at www.nlwra.gov.au/.

4.6 Data access and storage

As with data, under the National M&E Framework, information products generated from NRM regional monitoring must be stored in a state-managed repository and from there uploaded into the NLWRA's Australian Resources Online (ARO) where it will be web-accessible.

4.7 Information product definition statement

Information products must have a statement outlining

- the type of product and product description
- why, when and by whom the product was produced
- product contents.

5. Current national activities

It is anticipated that a number of permanent monitoring sites will be established throughout Australia under the leadership of CSIRO Land and Water.

6. Future development

Consideration is being given to establishing a limited number of permanent monitoring sites (perhaps 20–30) in catchments representing the main agricultural, urban and forestry regions of Australia. A 'site' might be several tens of thousands of hectares, large enough to adequately represent interactions between land use and landscape processes. Depending on the site, any or all of the four soil condition indicators would be studied together with other indicators including nutrient contamination together with the impacts of changing land use.

Research and information gathered at these sites would contribute to a better understanding of the soil acidification process and provide data to calibrate and independently validate computer simulation models. Modelling requires contextual data and some improved contextual datasets of national extent would also be developed, including vegetation cover, land use and land management, climatic data, lime sales and applications. It is strongly recommended that a lime application question be part of the five-yearly Agricultural Census.

7. Links to other indicators

The protocol to stratify and sample soil pH is very similar to that of soil carbon. One of the most expensive parts of monitoring is gaining site access so there are economies to be achieved in combining pH and carbon sampling and analysis.

8. Further information

ASRIS (2007) Australian Soil Resource Information System website www.asris.csiro.au/index_ie.html (accessed May 2008)

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Fenton G, Helyar KR (2000) *Soil acidification.* In 'Soils: their properties and Management'. (Eds PEV Charman, BW Murphy) (Oxford University Press, Melbourne)

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Isbell RF (2002) 'The Australian Soil Classification,' revised edition. (CSIRO Publishing: Melbourne)

Lockwood PV, Wilson BR, Daniel H, Jones MJ (2003) 'Soil acidification and natural resource management directions for the future.' NSW Agriculture, Armidale.

McDonald RC, Isbell RF, Speight JG, Walker J, Hopkins MS (1990) 'Australian Soil and Land Survey Handbook', 2nd edition. (Inkata Press: Melbourne)

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9. Glossary

Glossary of terms

pH	A logarithmic scale from 0 to 14 of the H^+ concentration of a soil.
Soil acidification	The accumulation of H^+ ions in the soil which accompanies the extraction of bases and of agricultural produce.
Monitoring unit	A monitoring and reporting unit being the result of 'stratification' of the study area and representing a unique combination of soil, climate and land use or land management practices.
Sampling site	A georeferenced point within a monitoring and reporting unit where one or more samples are taken for analysis.

Acronyms

ACLUMP	Australian Collaborative Land Use Mapping Program
ANZLIC	Australian New Zealand Land Information Council
ASPAC	Australasian Soil and Plant Analysis Council
ASRIS	Australian Soil Resources Information System
NATA	National Association of Testing Authorities
NLWRA (the Audit)	National Land & Water Resources Audit
National M&E Framework	National Monitoring and Evaluation Framework
NRM (regional bodies)	Natural Resource Management (regional bodies); also known as CMAs or Catchment Management Authorities

Appendix 1

Attribute	Definition	Acceptable values
	Project and survey information	
Survey ID	Unique value, note that for monitoring purposes the same site might be visited on many occasions. The same survey ID will be used but the dates will be different in each case. Survey ID is always matched to a single survey name	Survey name and unique survey ID number
Surveyor ID	The principal field observer	Unique name
Date	Date of field sampling	dd/mm/yyyy
Soil/landscape map unit	Most detailed unit as determined from available mapping	
Land use	Land use at the time of observation classified according to ACLUMP	www.brs.gov.au/landuse
Land management practices	Land management practices at the time of observation classified according to ACLUMP	www.brs.gov.au/landuse
Rotational phases	Current rotation phase on the site f = cultivated fallow cf = chemical fallow p = pasture s = stubble c = cereal crop or any undetermined crop gl = grain legume crop ca = canola or other minor oilseed crop	f, cf, p, s, c, gl, ca
	Location Information	
Site ID	Three digit site number	###
Datum	Datum to which the GPS is set	GDA 94
Projection	Projection to which the GPS is set	UTM
Zone	Zone(s) within which the survey takes place	49–56
Site sampling pattern	An area of 25 m by 25 m or points or a radius of 4 m	Grid (g), radius (r)
SW corner coordinates	Eastings and northings in metres	6 & 7 numerals
Photo	Combination of project, site ID, date and file format	

	Observations	
Soil classification	As in the *Australian Soil Classification* or the state classification	
Interval 1 Depth pH Texture	 Depth in centimetres pH_{Ca} 1:5 soil:water As per McDonald (1990)	 0–5 cm, or 0–10 cm 0-14
Interval 2 Depth pH Texture	 As above	 10–20 cm
Interval 2 Depth pH Texture	 As above	 20–30 cm