Soil condition surveillance monitoring for New South Wales

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Abstract
In 2007-2009 2,369 soil condition monitoring permanent sites were established or contributed towards a baseline to variously monitor soil carbon, structure, pH, salinity, coastal acid sulfate soils and sheet, gully and wind erosion across New South Wales, a state in South Eastern Australia (800,000 km^2). The background, design, site selection, field protocols and evaluation methods, results and reporting products are briefly described. The current NSW soil condition index is 3.7 where 5 represents natural or reference condition and a score of one indicates complete degradation. At least one indicator on average scores below 2.5at over half of the 124 soil monitoring reporting units. Soil carbon decline is most widespread; however other indicators are of particular regional and local concern. Next steps include dialogue with catchment managers and preparation for future monitoring.

Key Words
Monitoring, condition index, carbon, indicators.

Introduction
The State Plan (NSW Government 2008) lists thirteen Natural Resource Management Targets. The targets include an improvement in soil condition and an increase in the area of land managed within its capability by 2015. Catchment Management Authorities (CMAs) have prime responsibility for achieving the targets and the Natural Resources Commission is responsible for ensuring that CMA activities are directed towards the targets. The Department of Environment, Climate Change and Water (DECCW) is responsible for surveillance monitoring, evaluating and reporting on general progress towards the targets. CMAs are responsible for their own performance monitoring. Monitoring information along with soil and land use mapping and simulation models is intended to guide natural resource management decision making by the NSW government and CMAs. Soil condition is defined here as the ability of soil to deliver a range of essential ecosystem services, including habitat for soil biota, nutrient cycling, water retention and primary plant production and is difficult to directly measure. Indicators were chosen because they are relatively easily understood, can be readily and reliably measured to detect change over time, have well understood conceptual models, are readily scientifically assessed and reported, are relatively stable within monitoring time frames and can be influenced by land management. Pilot studies were conducted for the indicators, namely: sheet and rill erosion; gully erosion; wind erosion; soil carbon; soil acidity; soil salinity; soil structure and acid sulfate soils.

Methods
In 2008 a network of permanent sites and quadrants was established across 124 soil monitoring units to assist Catchment Management Authorities and the NSW with natural resource management decision making.

Monitoring Site Selection
Because sites are expensive and few, considerable attention was given to obtaining a data array which focussed across as much of the state as possible to provide a snap shot of soil condition, paying attention to areas where change is expected and needs to be monitored as well as utility for many future uses.
For placement of permanent quadrants site selection was by a three step stratification process.
1. Within each CMA, soil monitoring units (SMUs) were selected and prioritised for monitoring by CMA and DECCW soils staff, according to: their importance, areal extent, anticipated land use pressure and number of known soils issues. SMUs are typically groups of soil landscapes and in each major catchment region up to 10 of the highest priority SMUs were established for monitoring. SMUs were typically composed of groups of related soil landscape map units (Chapman and Atkinson 1998) or closest available equivalents.
2. Selection of land holder and land management actions. CMAs were asked to select landholders who were using typical land management practices on the two most extensive land use systems within each

SMU. Within each SMU five sites were established on each of the two most extensive land use systems and where possible additional sites were established on sites of least disturbance.
3. Location of long-term monitoring sites in the most typical areas of each SMU. Site selections were confined to extensive soil landscapes and the geographic centres of their most extensive facets. Where possible the sites were paired in close proximity across land uses, controlling for landscape variables such as slope position, aspect and soil type. The conceptual value of paired sites is outlined in Eldridge *et al.* (in press).

At each site a 25 by 25 metre quadrant was established. At least one nearby permanent site marker and the south western corner were geo-located using GPS. A Soil and Land Information System (SALIS) soil profile description was undertaken to at least 50cm in the south western corner and, where practical, a steel object buried to facilitate precise future relocation using a metal detector. Each quadrant was divided into one hundred 2.5 by 2.5 metre cells. Ten cells were chosen at random using a latin square design. Within each selected cell, soil under the most typical ground cover was sampled using a 50mm diameter tube. Specimens were taken at 0-5cm, 5-10cm, 10-20cm and 20-30cm according to detailed protocols (see DECCW, in press), Sample testing is underway at the DECCW Natural Resources Laboratory at Yanco for: pH in 0.01M $CaCl_2$, LECO Carbon, Bulk Density, and Electrical Conductivity (1:5 soil:water). Other tests, including pH buffering capacity are planned from soil profile samples. Work by Wilson *et al.* (in press) suggests that the sampling method adopted in the program, involving ten replicates within a 625 m^2 quadrant, provides an accuracy within 15 per cent of the true mean within 90 per cent of the time, at least for pH, carbon and bulk density. This is considered sufficient accuracy to determine change thresholds of 0.2 per cent carbon and 0.2 of a pH unit at more than 90 per cent of sites.

In all over thirty four thousand samples were collected to measure Carbon and pH; a modified version of the Visual Soil Assessment Shepherd (2000, 2007) and a further 1700 samples were used to assess soil structure at 850 characterised sites. Landholder surveys to both assess land management within capability (Gray *et. al,* in press), and to ascertain ground cover management practices for sheet erosion modelling were collected for 500 of the sites. In addition 128 detailed and 1200 broad-scale gully erosion sites; 40 acid sulfate soil sites; 23 dust particle sensors; eight detailed salinity study areas and thousands of mapped saline discharge sites were established or utilised. Sheet erosion and wind erosion were assessed using the Revised Universal Soil Loss Equation (Renard *et al.* 1997) and computational Environmental Management System (Shao *et al.* 1996) models.

Evaluation and Index Development
All thirteen natural resource management monitoring themes were requested to provide where possible condition ratings using a five class index, where class five represents reference condition and class one signifies complete degradation (Table 1). Consequentially a five class soil condition classification was developed for each indicator, for example as shown for soil acidity, in Table 2. Reference condition boundaries were determined for each SMU from literature review and undisturbed land use SALIS database values for the same soils within equivalent climates and parent material zones.   Functional threshold values were also used to define other class boundaries.
For each site each relevant indicator was allocated a condition class. Soil Condition Indexes were derived by averaging values for all sites within SMUs, CMAs and ultimately the state. Ratings of averaged values are shown in Table 2.

Table 1. Assignment of soil acidity condition ratings.

Soil acidity condition class	5	4	3	2	1
Soil acidification zone		expected natural pH for the zone			
a	>4.75	Not applicable	<4.75	<4.5	<4.1
b	>5.0	>5.0	<4.75	<4.5	<4.1
c	>5.3	<5.3	<4.75	<4.5	<4.1
d	>7-5.5	<5.5	<4.75	<4.5	<4.1
e	>7.1-5.8	<5.8	<4.75	<4.5	<4.1
Class boundaries Functional thresholds		mid point from 5 to 3 (noticeable decline)	Al soluble becomes soluble	Mn becomes soluble	Clay dissolution

Table 2. The NSW Soil Condition Index.

4.6 – 5.0	Very good	No loss of soil function. Either no deterioration or an improvement on reference condition.
3.6 – 4.5	Good	Slight loss of soil function. Noticeable but not significant deterioration against reference condition.
2.6 – 3.5	Fair	Noticeable loss of soil function. Noticeable deterioration against reference condition.
1.6 – 2.5	Poor	Significant loss of soil function. Considerable deterioration against reference condition.
<1.5	Very poor	Profound loss of soil function. Severe deterioration against reference condition.

Further details concerning the program are in Chapman *et. al* (in press).

Results

Laboratory testing is continuing, however preliminary results involving at least one soil core sampled from each site for carbon and pH were used to prepare the *NSW 2009 State of Environment Report* (DECCW, in prep). On a state wide basis, overall index for soils in NSW was assessed by MER as 3.7, indicating overall "fair" to "good' soil condition.   On average, there has been a noticeable and moderate decline in the condition of NSW soils relative to their condition in the natural "reference condition". This is interpreted as meaning that on average there has been a moderate loss of NSW soils to provide ecosystem services.

Some parts of the state and some particular soil condition indicators, however, have overall poorer condition, and a significant loss of soil function. These specific areas and indicators have lower soil condition indices, indicating "poor" or "very poor" condition, with a "significant" or "profound" loss of soil function and a substantial deterioration against the natural reference condition. The results suggest that on a state-wide basis, low organic carbon is the dominant issue of concern (see Figure 1), with organic carbon, soil structure sheet erosion, salinity, and soil acidity also being of significant concern.

Figure 1. Soil Carbon Condition for NSW

Organic carbon has been assessed as the most serious issue of concern across NSW. Its overall current condition is fair with an index of 3.2; and 29 (23%) of SMUs have indices at or below 2.5 (poor). It is a significant issue of concern in 5 of the 13 CMA regions. Preliminary analysis of SMU condition scores for the indicators suggests that there are three clusters of correlated condition scores: Sheet erosion, soil salinity and soil acidity are significantly positively correlated. As would be expected soil structure and soil carbon are significantly positively correlated. The negative correlation of wind erosion with both salinity and acidity is likely to be related to spatial factors.

Discussion and conclusions

The correlations of soil condition indicators appear to be linked spatially and relate to well established soil science and landscape processes and require further investigation. Identification of clusters of degraded soil indicators, or land sickness syndromes has implications for catchment planning, land management and monitoring program design. Whilst the soil condition index may be useful to compare soil condition with similarly scaled indexes from other themes, the process of averaging results in a central tendency which belies the fact that many sites are in poor or very poor condition.   We recommend a serial process of data investigation and dialogue with CMA decision makers to make best use of the information.

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