Setting investment and monitoring priorities for soil condition in Australia – a challenge to soil information collaboration

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Abstract
Sustainable food and fibre production from Australia's soils depends on informed management. Awareness of the consequences of modifying management actions must be linked with the state of the resource base. This must be implemented at all scales from farm management to national public policy. An analysis is described which spatially represented the key soil condition indicators pH and organic carbon. This involved an integration of intensity of the modifying processes, the resilience of the soil and present state of the indicators. A key to the success was the inter-agency collaboration both in data acquisition, knowledge of processes and validation of the products. These products are used to inform public investment in facilitating behaviour change and soil condition monitoring programs.

Key Words
pH, soil organic carbon, inter-agency collaboration, monitoring, soil resilience, modifying processes.

Introduction
Food and fibre production, particularly that using fuel, fertiliser and chemicals tends to modify the soil. To varying degrees, acidification, depletion of soil organic carbon (SOC), degradation such as wind and water erosion, and salinisation have been recognised for centuries. Large areas of land have been lost to food production and much is under continuing threat. In the context of an increase in world demand for food, sustainable management of the soil is an imperative. In documenting the condition of land, water and biodiversity resources, the National Land and Water Resources Audit (e.g. NLWRA 2001) noted that Australian soils have inherently low fertility and poor structure which leave them vulnerable to degradation. NLWRA recognised pH and SOC levels as key indicators of soil condition. Acidification and (in many soils) SOC decline are induced consequences of most agricultural systems and often limit productivity. Dolling *et al.* (2001) reported that about 20M ha of Australian agricultural land had surface pH below 4.8; a level sub-optimal for crop production.

In response to such degradation threats there has been significant private and public investment in education and amelioration. However, the effectiveness of this investment is unknown; there has been limited investment on monitoring the change in soil condition indicators and there is a clear demand to prioritise investment to areas where the most benefit can be obtained. The purpose of the exercise reported here was to prioritise geographic areas for investment under the Australian Government's Caring for Our Country program areas for investment (e.g. Anon 2008). This paper describes briefly the process used in identifying priority areas in Australia for investment to address declining pH and SOC (Baldock *et al.* 2009a, Wilson *et al.* 2009). It builds on a related program to monitor the pH and SOC in Australian soils (Baldock *et. al.* 2009b). The exercise illustrated both the utility of increasing collaboration of the custodial government agencies responsible for soil resource information (see Wilson 2010) and the value of the core of this collaboration: the Australian Soil Resource Information System (McKenzie *et al.* 2002). It also highlights some immediate needs.

Methods
A spatial modelling approach was adopted to simulate expected changes and the potential impacts of these changes on pH and SOC in different areas. This was achieved with a GIS analysis in a workshop with CSIRO and state agency scientists – using the best available national data on soil and land management. The analysis was on 5km pixels for the continent as a whole in the Multi-Criteria Analysis Shell (MCAS) (Anon 2009). The potential influences of changing climate was considered as a key long term issue but was seen as too uncertain to include in this near-future analysis.

The ASRIS national data was essential, however, the incomplete nature of the directly relevant spatial data (e.g. present pH, pH buffer capacity) meant that surrogates for some parameters were utilised. This also meant that parameters could not be quantitatively combined. Thus a series of weighted rankings were developed to simulate relativity between areas.

Results

pH

For pH, the priority areas for investment are those with high net input of hydrogen ions (H^+) (Net Acid Acidification Rate NAAR), low resistance to change (pH buffer capacity) and present values at or near critical (pH 5.5 – 4.5). Most agricultural land uses lead to acidification of the soil. Helyar and Porter (1989) identified the chemical processes involved. The NAAR can effectively be related to measures of production. Thus the NAAR map surface was estimated using a combined analysis of known measured acid addition rates of key land management practices, estimates of unmeasured practices and the spatial distribution of Australian Bureau of Statistics regional agricultural production statistics (MJ Webb in prep). Integrating this with a land use intensity interpretation (based on national catchment scale land use data) provided an acidification hazard map (Figure 1).

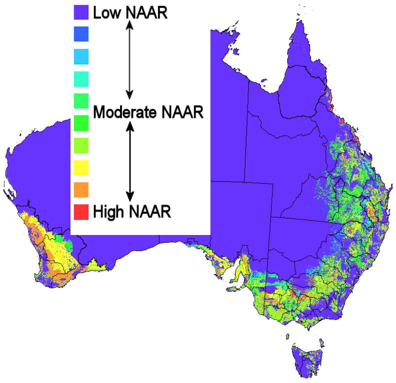

Figure 1. The Acidification Risk - an index of cumulative proton input.

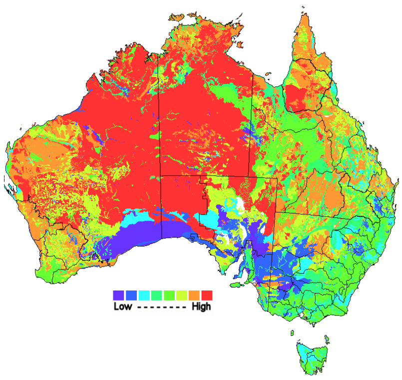

Figure 2. Index of soil "buffering.

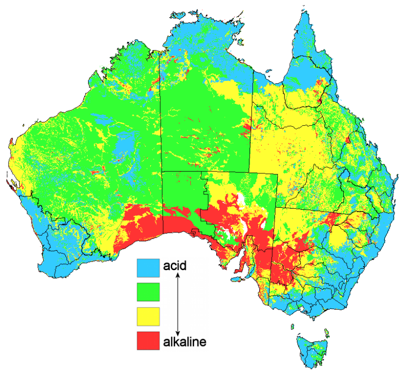

Figure 3. Index of present pH.

The resilience of the soil to absorb H^+ is related to the carbonate present and the pH buffer capacity, itself a function of SOC and clay content of the soil. The surfaces for these parameters were neither directly available nor complete. An index was developed using limited properties of soil units associated with the Atlas of Australian Soils mapping (McKenzie and Hook 1992, McKenzie *et. al.* 2000). The best available current pH (surface layer) available in ASRIS was incomplete. However, through a scaling exercise, the gaps were filled using properties of the Atlas mapping. This pH index map is shown in Figure 3. Figures 1 - 3 were combined to generate an acidification risk map (Figure 4.) This shows that areas with moderate to high agricultural intensity and low carbonate and buffering capacity are the most at risk to acidification.

Soil Organic Carbon (SOC)

For SOC, the priority areas for investment are those which have the highest potential to increase and retain SOC. This is attempting to meet the dual benefits of carbon sequestration and, in many areas, production benefits from increased SOC. It is noted, however, that increased SOC can exacerbate non-wetting problems in some areas. SOC in soil is largely the balance between plant production and SOC decomposition. Production is a function of moisture and nutrients. Decomposition is a function of microbial activity; influenced by moisture and temperature. In soils with high clay content, some SOC is physically inaccessible to the bacteria and is thus protected from decomposition. However, this protection is lost under crop systems. Thus, a complex array of map surfaces was needed to simulate this combination of factors. In general terms, areas with a significant loss of SOC through agriculture have capacity to support higher biomass production and to protect added carbon from decomposition and, therefore, have the highest potential for increased soil carbon.

The capacity of the current soil to hold more carbon can be related to the run down in SOC since the onset of European agricultural management (Figure 5). This was estimated by combining the length of time an area was cleared, how much of that time was in crop rather than in pasture and how much of the protection due to clay content has been lost.

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The potential for increased soil carbon input (Figure 6) is a function of harnessing unused effective rainfall and reducing crop/plant residue removal. Areas with equi-seasonal rainfall have the potential to increase production through incorporating perennials into the farming system. Reducing stocking rates (high off-take) also has the potential to increase soil carbon retained in the soil.

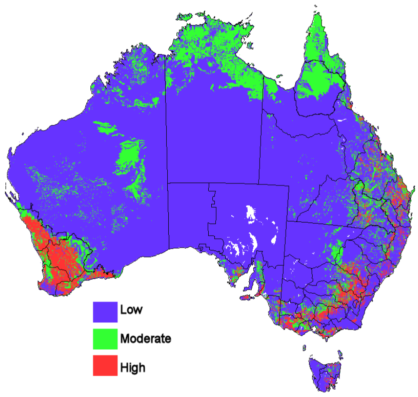

Figure 4. Acidification risk.

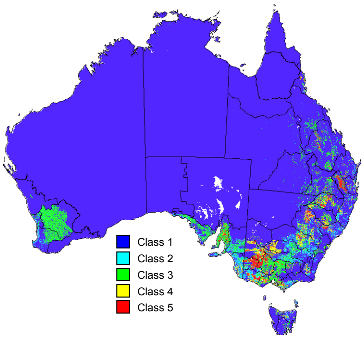

Figure 5. Capacity Index (store more SOC).

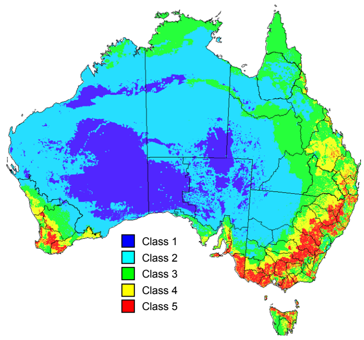

Figure 6. Carbon Gains Index (more carbon entering soil).

Microbial activity is controlled by moisture and temperature with highest activity being hot moist and lowest cold and dry. This is mitigated by the "protection" afforded by clay and exacerbated by the intensity of land use to provide an index of carbon losses (Figure 7.). The final interpretation of potential capability to produce and store more SOC (Figure 8) is a function of the capacity, the gains and losses. This shows that areas with highest land use intensity with clay soils and a long history of agricultural management had the highest potential to store more SOC relative to present. While it is not possible to validate these interpretations quantitatively, no glaring inconsistencies were identified during a review involving scientists from state agencies.

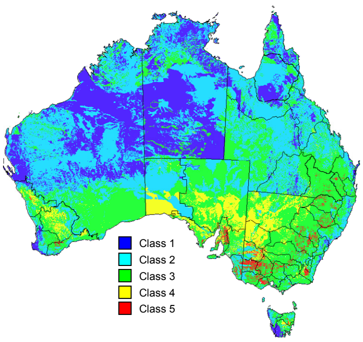

Figure 7. Carbon Losses Index.

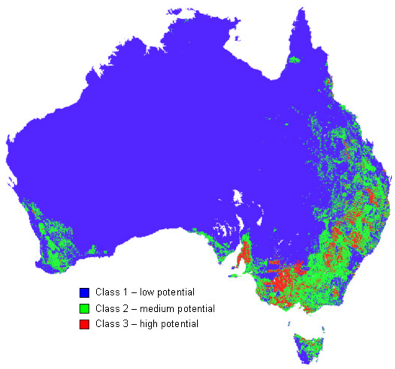

Figure 8. Potential Capability Index.

Some of the lessons

These analyses required a rapid response to national investment decisions in natural resource management improvement – and relied heavily on the 'readiness' of national datasets. Essential components of the analysis included spatial ASRIS soil attribute data (parameters needed to estimate pH buffering capacity, current soil pH, soil depth, clay content) as well as land use management data and the net acid addition rate. While there are significant gaps in these data – especially high quality, high resolution data - the clear challenge in the analysis was the need for current soil pH – and this can not be derived from the collation of legacy soil data. A soil attribute monitoring program is needed for these time sensitive attributes. In Australia, no such system is yet in place – although planning continues for its implementation.

For the carbon assessment, the national collection can't provide data on change over time in soil carbon due to a lack of sufficient temporal depth in the database, a substantial bias in the data against actively managed soils (samples taken from fence lines, reserves etc) and variable and unknown locational accuracy. These are ubiquitous problems in legacy data systems such as ASRIS. A convincing change analysis, therefore, was not possible. Better estimates will require a high level of interaction with time-series remote sensing and farm system modelling.

Conclusion

The inter-agency collaboration which has build ASRIS and maintains a national will for improving soil science enabled the rapid derivation of a national perspective for investment (Figures 4 and 8) from a patchy legacy data coverage. The modelling exercise demonstrated that despite dated and incomplete datasets, useful products can be generated in a workshop. This is possible both because the work in improving the capture and use of legacy data in ASRIS the ability of the collaborative model to assemble domain experts with sufficient knowledge of the data to reconcile disparate data and apply to the issue at hand. More detail on the analytical approach and the steps involved are in Baldock *et. al.* 2009a and Wilson *et al.* 2009. Higher quality inputs (e.g. current pH and SOC surfaces) will produce higher quality products; but these require a fresh approach to soil spatial data beyond the collation of legacy data. In particular, the integration of monitoring, modelling, remote sensing and spatial prediction are essential. The impetus for such programs is now building e.g. Baldock *et. al.* 2009b describe the development of a cost effective soil condition monitoring system which aims to concentrate on areas where change in these key soil condition indicators are greatest.

References

Anon (2008) Caring for Our Country Business Plan 2009-10. Australian Government http://www.nrm.gov.au/publications/books/pubs/business-plan.pdf.

Anon (2009) Multi-Criteria Analysis Shell (MCAS-S) for Spatial Decision Support, User Guide. Bureau of Rural Sciences. http://adl.brs.gov.au/mcass/docs/User_Guide.pdf.

McKenzie NJ, Hook J (1992) ‘Interpretations of the Atlas of Australian Soils’. Consulting Report to the Environmental Resources Information Network. Technical Report 94/1992. (CSIRO, Division of Soils: Canberra).

McKenzie NJ, Jacquier D, Ashton LJ, Cresswell HP (2000) ‘Estimating soil properties using the Atlas of Australian Soils’. Technical Report 11. (CSIRO, Land and Water: Canberra).

McKenzie NJ, Jacquier DW, Maschmedt DJ, Griffin EA, Brough DM (2005) ‘ASRIS Australian Soil Resource Information System, Technical specifications Version 1.5 October 2005’. (National Committee on Soil and Terrain Information).

Baldock J, Grundy M, Wilson P, Jacquier D, Griffin T, Chapman G, Hall J, Maschmedt D, Crawford D, Hill J and Kidd D (2009a) ‘Identification of areas within Australia with the potential to enhance soil carbon content’. (CSIRO Land and Water Science Report).

Baldock JA, Grundy MJ, Griffin EA, Webb MJ, Wong MTF and Broos K (2009b) ‘Building a foundation for soil condition assessment’. (CSIRO Land and Water Science Report).

Helyer K R and W M Porter (1989). Soil acidification, its measurement and the processes involved. In “Soil Acidity and Plant Growth”. (Ed AD Robson) pp. 61-101. (Academic Press: Australia).

Wilson P, Baldock J, Grundy M, Jacquier D, Griffin T, Moody P, Chapman G, Hall J, Maschmedt D, Crawford D, Hill J and Kidd D (2009) ‘Identification of land with a risk of acidification’. (CSIRO Land and Water Science Report).