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Collating and using Australian soil data - a process of aggregation or aggravation?

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Abstract
Soil and land resource data in Australia is captured and maintained by many jurisdictional agencies and individuals for many purposes. The Australian Collaborative Land Evaluation Program and the Australian Soil Resource Information System have tackled the challenge of collating consistent, standardised national soil data sets largely from legacy data. But how do we best simplify the complexity of soil data and provide appropriate useable data and information products for a wide range of users? Can we specify a minimum set of attributes and a spatio-temporal data model to satisfy more frequent and increasingly complex requests for soil data?

Key Words
Soil mapping, legacy data, aggregation, attributes, information products.

Introduction
Australian soil and land resource data have been captured over the last 70 years through a number of national approaches or regionally specific surveys. Data have been collected for a range of purposes, including scientific research and developing soil-landscape systems understanding, regional land resource inventory and characterisation, and local and site specific studies for particular development or management applications.

Soil and land resource data have been collected by a range of government and non-government organisations within individual jurisdictions and through multi-jurisdictional and nationally collaborative activities. Survey and analytical methods have varied between projects, and have advanced over time. This has resulted in a huge array of different and conceptually inconsistent legacy data. Some of these have been captured in digital information systems, but much remains in original hard copy formats or has been lost to science through inadequate desire, capacity or ability to properly manage historical data.

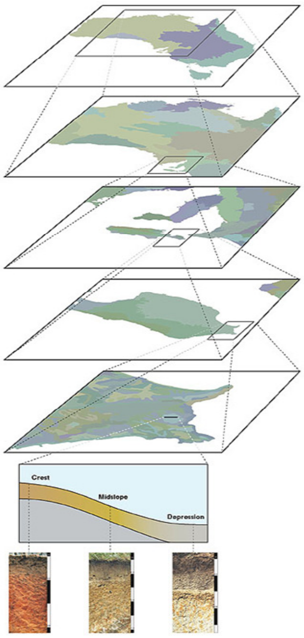
A strong, though relatively small, community of soil and land resource professionals exists within Australia. This is embodied in organisations such as the Australian Society of Soil Science Inc. (ASSSI) and through coordination mechanisms including the National Committee on Soil and Terrain (NCST). The latter supports the Australian Collaborative Land Evaluation Program (ACLEP) and activities to develop and promote standards such as the *Australian Soil and Land Survey Handbook* (National Committee on Soil and Terrain 2009) and *The Australian Soil Classification* (Isbell 2002). This effort is underpinned by an improving data and information infrastructure, and mechanisms for consistent national data collation, analysis and reporting such as the Australian Soil Resource Information System (ASRIS) (McKenzie *et al*. 2005).

Making soil data useful
Soils ain't soils. The processes of soil formation, interaction and modification are complex. The data collected to understand soil processes, describe their characteristics, map their distribution and model their interactions and alterations over time are complex. The systems developed to capture, manage, store, analyse and disseminate data and information on soils are also, therefore necessarily complex.

"Quick, give me a soil map!" is a common request issued by scientists, modellers, policy and decision makers to the gate keepers of soil information systems. "Sure - but which one?" is the common reply. This should be the start of a healthy conversation, exploring the complexities of soils and the data describing them and then, deciphering the user's specific needs, namely: the explicit soil characteristics required and their spatial and temporal representation. However, the conversation often ends in aggravation and frustration borne by data supplier and user alike due to poor user-needs articulation, and an inability by the custodian to supply the required attributes in the desired timeframe.

Aiming for "Utopia" - or striking a happy medium?

The ASRIS (www.asris.csiro.au) is underpinned by a hierarchy of mapping resolutions from broad national divisions (Level 1) through tract mapping of districts and systems (Level 4 to 5), to detailed site-based property and condition descriptions (Level 7) (Figure1). Adding to the spatial complexity is the data base recording of values for unmapped components within each of the mapped tracts and the use of a five layer functional depth model to accommodate variability of characteristics down the soil profile (Figure 2).



Level and tract name	Mapping window	Main attributes used for mapping	Typical uses for the information
Level 1 Division	30 km	Broad physiography (slope and relief)	Broad geographic context
Level 2 Province	10 km	Water balance, physiography	National natural resource policy
Level 3 Zone	3 km	Substrate lithology, water balance, physiography	Regional natural resource policy
Level 4 District	1 km	Groupings of geomorphically related systems	Catchment planning, location of new industries
Level 5 System	300 m	Local climate, relief, slope, lithology, drainage network, soil profile class	Catchment management, hydrological modelling, land conservation, infrastructure planning
Level 6 Facet	30 m	Slope, aspect, land curvature, soil profile class	Farm management, land-use planning, on-ground works
Level 7 Site	10 m	Soil properties, surface condition, microrelief	Precision agriculture, site development

Figure 1. ASRIS seven level spatial hierarchy (McKenzie *et al*. 2005)

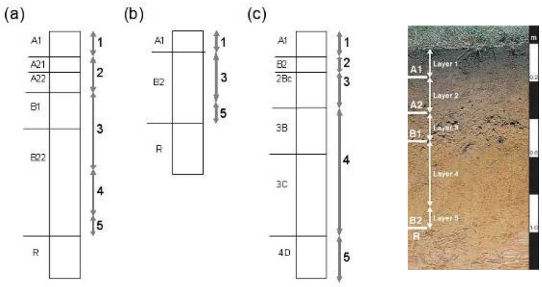


Figure 2. ASRIS five layer depth model (McKenzie *et al.* 2005)

A seemingly simple request for a soil map therefore, may result in a seemingly simple soil classification product, based on the dominant occurrence in non-homogeneous mapped entities, using conceptual or reference profile data which may not adequately or accurately represent the spatial, depth or temporal variation of soil characteristics at any actual point on the ground. Over simplification or over generalisation of the complex soils data can result in meaningless products or misrepresentation of the characteristics and the variability that may be essential to a particular modelling or management decision process. Striking a happy medium and producing a generic soil map can result in something not much more useful than a decorative picture.

On the other hand, the spatial and temporal complexity of soil characteristics cannot easily be summarised or visually represented. The specific data requirements for a particular modelling or decision making process need to be clearly and explicitly stated. Often this could result in a number of complex soil inputs that may not be able to be easily understood or assimilated into particular modelling or decision making processes. Aiming for "Utopia" therefore does not always satisfy users who often just want a simplified representation of the soil complexity, albeit at spatial and temporal resolutions that fulfil their specific needs. Users only want the attributes important to them, not necessarily the full complexity of the soil landscape system.

ASRIS aggregation products

The ASRIS web mapping interface provides a window into the complexity of data comprising Australia's national soil data collection. However, the interface does not provide access to all collated data and does not allow downloads of the data due to licensing limitations by some data contributors. In an effort to make at least some national soil data more readily accessible, the interface does provide visualisation and query of all available tract mapping at the various ASRIS levels. It also has aggregated representations of attribute values for a number of the commonly required soil properties for each of the five depth layers (Figure 3). However, many users of ASRIS are critical that they cannot find or use the data they want, and cannot easily understand the level/layer framework of ASRIS or the products presented - even in this simplified form.

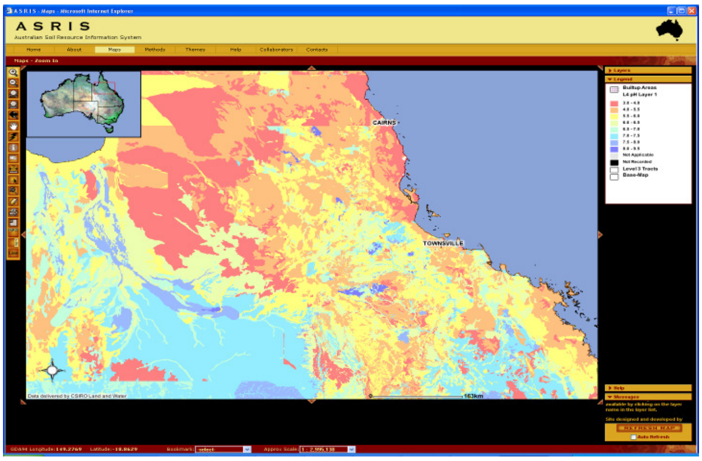


Figure 3. ASRIS Level 4 mapping showing dominant pH for layer 1

There are many methods by which component and depth data can be aggregated (Soil Data Viewer 5.2 User Guide - United States Department of Agriculture http://soildataviewer.nrcs.usda.gov/default.aspx). Generic ASRIS data views use dominant component or weighted average approaches. However many different views of the same data could be created using different aggregation approaches, and each may be more appropriate for a particular application. Aggregation of complex data using large national collations (such as ASRIS) can be computationally intensive, and may not lend themselves to on-the-fly, on-demand supply of requested data products. Additionally, regular updates or improvements to underlying data would necessitate lengthy re-creation of stored aggregation data sets.

New aggregated data products have recently been completed to support specific project requirements for carbon and acidification monitoring and prioritisation (Baldock *et al*. in prep, Baldock *et al*. 2009, Wilson *et al*. 2009a). The data have been aggregated both spatially and with depth to create 0-10 cm and 0-30 cm depth-slices using weighted averages. These products have been generated for parts of Australia using a 250 m cell sized representation to allow analytical computation within realistic project timeframes (Figure 4). These products provide another view of ASRIS data, which may or may not be useful inputs to other analyses.

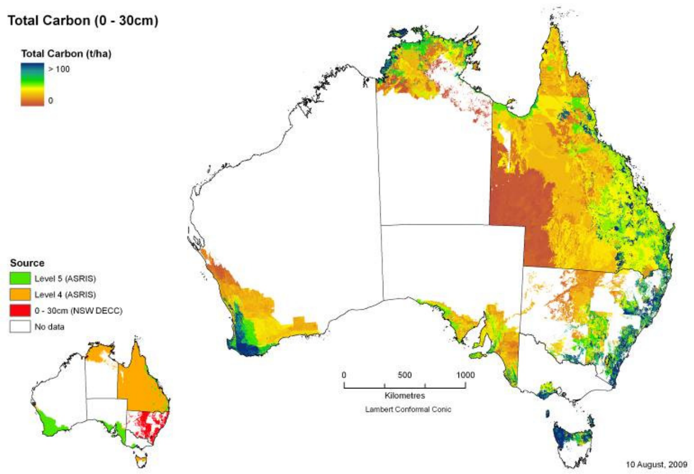


Figure 4. Spatial and layer aggregation of ASRIS data (Baldock *et al.* in prep)

Discussion

ASRIS supports the vision of making the best available soils data and information readily accessible and useable to a wide range of users. Current national data collations are now extensive and comprehensive enough to be useful inputs to many national and multi-jurisdictional analyses. A number of generic views of ASRIS data and project-specific aggregations, such as depth-weighted limitation values for agricultural land suitability assessment of northern Australia (Wilson *et al*. 2009b) have now been created, but the utility of these for other projects remains untested. The specific soil data needs of different analyses need to be well considered so that the right information products can be developed. Much angst can be generated if users do not understand the complexity of soils data, and cannot explicitly define the data inputs they require. Different aggregation processes and analytical methods (such as calculating values for individual un-mapped components then averaging, versus averaging components then calculating) can produce very different data products and therefore very different analytical results. The use of easily obtainable, over-simplified soil inputs will not result in appropriate representation of soil characteristic variability in modelling or decision-making processes, and therefore outputs and the decisions that ensue may be compromised.

Current discussions are focussed on creation of fine resolution data sets (e.g. 90 m continental grids, see www.globalsoilmap.net) with comprehensive depth models (e.g. attribute depth splines, see Bishop *et al*. 1999). While data sets in this format may be logical for better representation of the spatial, depth and temporal variability of soils, they may actually exacerbate analytical difficulties for different users due to the data volumes that will result. It is also questionable whether current computing capacity and software will allow ready use of such data models by many users. A short term solution will be to develop an agreed approach to grid representations of key soil attributes with explicit estimates of uncertainty and data quality. There is a need for soil scientists and information managers to work closely with soil data users to define the data requirements, and to build tools to assist flexible generation of products in a timely manner. The ACLEP will assist with this task, and also the promotion of information on soil and soil data complexities to the wider user community.

Conclusion

Users of soil data and information need to be adequately aware of the complexity of soil characteristics and their landscape interactions over space and time. Complex data required for soil description must be simplified to provide easily assimilated inputs into modelling and decision-making processes without losing the essential components of variability. Potentially, a set of standardised, aggregated soil characteristic data may be defined that could support a wide range of users needs. However, many users will require non-generic, project-specific inputs. Tools allowing flexible query and timely generation of appropriate data must be developed and made freely available. ACLEP will progress ongoing development of ASRIS national data and access tools to fulfil this need.

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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).

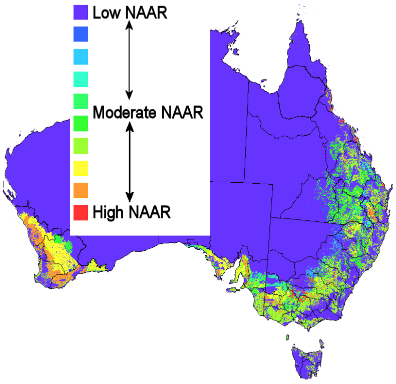

Figure 1. The Acidification Risk - an index of cumulative proton input.

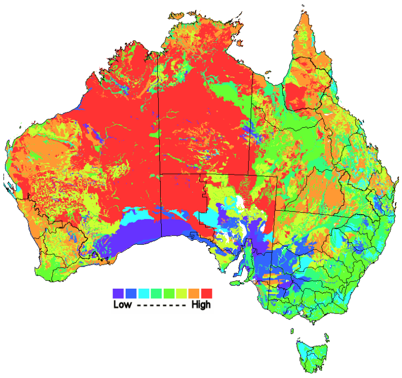

Figure 2. Index of soil “buffering.

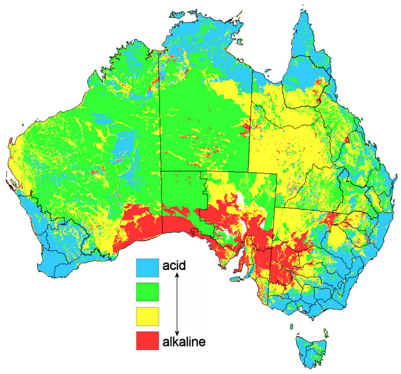

Figure 3. Index of present pH.

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.

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.

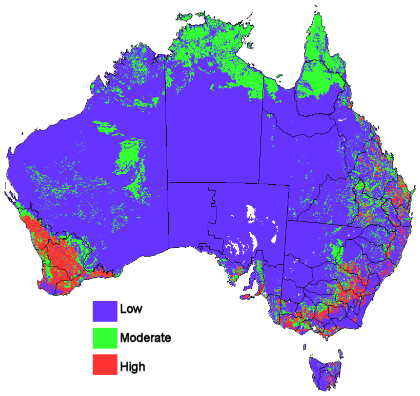

Figure 4. Acidification risk.

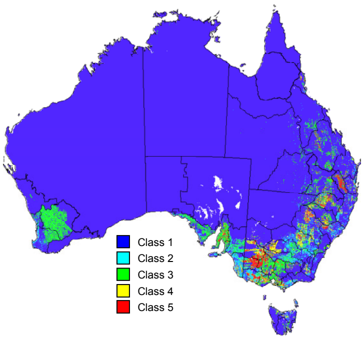

Figure 5. Capacity Index (store more SOC).

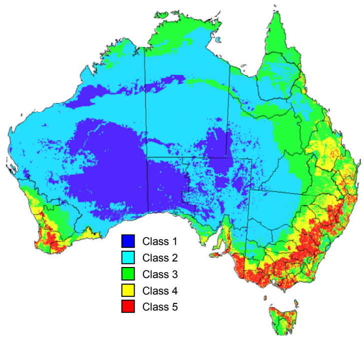

Figure 6. Carbon Gains Index (more carbon entering soil).

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.

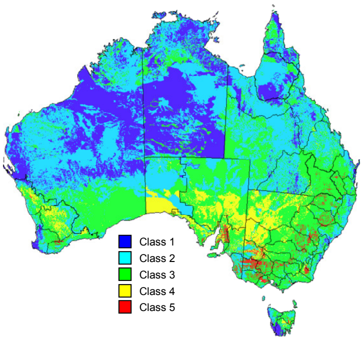

Figure 7. Carbon Losses Index.

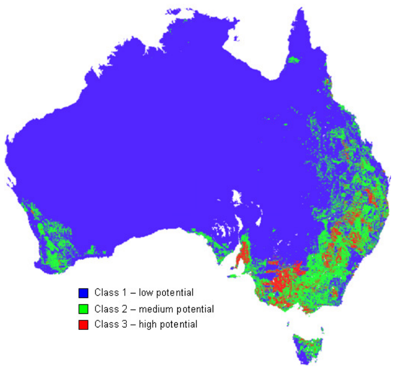

Figure 8. Potential Capability Index.

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.

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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.

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Soil policy development in Australia

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Abstract

In recent years, National and State investment in understanding and managing the Australian soil resource has declined despite the importance of soils in addressing key issues of our time, such as food security and climate change, and their crucial role as a key natural resource asset underpinning sustainable development.

The Australian Government, in partnership with the states and territories, is embarking on a process to bring soil-related issues into the public arena, to encourage debate, and to develop a long-term strategic national approach to the role of good soils management in addressing environmental and other issues. The time is ripe for a coherent, genuinely national focus on improving soil management to deliver benefits for consumers, for farmers, for rural communities and for the environment.

As a result of a public comment on a policy discussion paper on managing Australia's soils, several key areas that require national action have been indentified, including:

- a national strategic approach to manage future threats to the soil resource;
- increasing research and development on soil health;
- improving national soil related skills and knowledge;
- improving soil information and data management;
- improving education and extension capacities to support practice change; and
- improving public awareness of critical soil management issues.

Work is currently underway to align national actions with these needs. The presentation examines progress towards addressing these issues, and the influence that the soil science community can have on national soil policy and ultimately better environmental, economic and social outcomes that derive from more sustainable soil management and improved land stewardship.

Key Words

Soil policy, soil management.

Introduction

In all the debates around climate change and water scarcity, one of the most important elements has been missing from the discussion — the soil. Soil management is fundamental for food security, for water security and for storing carbon and reducing global greenhouse gas emissions, yet it has been largely ignored in the policy debate to date. Food, water and energy are finally being recognised as the most important national and international security issues, with the potential to affect far more people than terrorism.

Benign neglect would be a reasonable summary of the status quo in terms of the lack of any coherent national focus on soil management in Australia. Soil conservation extension services have been run down, the teaching of soils at tertiary levels has declined, soils monitoring programs are patchy and fragmented, like the overall soils information base, and we lack user-friendly tools for people to measure many soil parameters. We are unable to determine in a nationally consistent manner with any authority, whether the condition of our soils is improving or deteriorating. We accept without question the need for good economic data to inform economic policy decisions, yet we continue to under-invest in fundamental national data about natural resources like soil. While there is a strong demand for soils information, in most regions it is difficult to find people with the know-how to access and interpret existing information. Soils research is similarly fragmented and under-resourced and lacks the capacity to be generating the knowledge we will need to improve the management of Australian soils in even more challenging climatic conditions.

For the current generation, our challenge is to develop more sustainable ways of:
managing our soils in the face of environmental change and increasing demands upon soil resources;
restoring the productive capacity of degraded soils; and
putting in place robust and resilient systems of land use and management that prevent the further degradation of Australian soils and landscapes.

The Australian Government, in partnership with the states and territories through the National Committee on Soil and Terrain, is embarking on a process to air these issues in the public arena, to encourage debate, and to develop a long-term strategic national approach to the role of good soil management in addressing current the environmental issues. The time is ripe for a coherent, genuinely national focus on improving soil management, delivering benefits for consumers, for farmers, for rural communities and for the environment.

Internationally the importance of the land in supporting our future survival and prosperity is being increasingly realised, including the need for a soil management strategy to provide a clear purpose and direction for policy development and a framework to coordinate activities.

The need for a coordinated policy agenda to underpin the sustainable use of soils was clearly outlined in agenda 6 (Providing guidance to develop and implement national soil policies) of an International Union of Soil Sciences (IUSS) publication *A World Soils Agenda. Discussing International Actions for the Sustainable Use of Soils* (Hurni and Meyer 2002). International interest in policy frameworks continues. The Commission of the European Communities published a *Thematic Strategy for Soil Protection* in 2006 (2006a), with an associated impact assessment (Commission of the European Communities 2006b) and a proposal for the establishing of a framework for the protection of soil (Commission of the European Communities 2006c). Unfortunately this framework has yet to be implemented due to the complexities of gaining approval from the numerous member states. The importance of soil and improved soil management in mitigating climate change is increasingly realised, such as the *Review of existing information on the interrelations between soil and climate change* (Commission of the European Communities 2008).

Some jurisdictions within the Australian Federation have already begun working towards a "State Soil Policy". NSW, lead by the Department of Lands, has made considerable progress in this area with the publication of a draft soils framework titled *Looking forward, Acting now* (NSW State Soil Policy Working Group 2008).

This paper examines progress towards achieving an Australian national soil policy, and the expected benefits from this process.

Methods
As a first step a soil policy discussion paper was published in 2008 (available for download at www.clw.csiro.au/aclep/publications/reports.htm). Andrew Campbell of Triple Helix, a leading thinker in sustainable agriculture, was commissioned to prepare the report for the National Committee on Soil and Terrain (NCST). The discussion paper set the scene for the development of a national soil policy. It was partly based on the international work that preceded it, and on the NCST's and Andrew Campbell's vision of sustainable soil management in Australia.

The discussion paper, as well as raising key issues, puts forward a vision for the future and sets some core guiding principles that underpin the long-term sustainable management of the soil resource.

Managing the land so that we meet our current needs as well as proudly passing it on to future generations requires a significant and long-term commitment. The vision put forward in *Managing Australia's Soils: a policy discussion paper* sees Australian landscapes in which soil is conserved for its ecological values and the ecosystem services it provides, and soil health is enhanced for sustainable production. In this vision soil is just one component of an integrated and complementary natural resource system.

Underpinning this vision are ten guiding principles.
1. Soil is a crucial natural asset, and sustainable management and protection of the soil resource is fundamental to our future prosperity.
2. Degradation of our soil resource is an ongoing issue resulting in partial or total loss of productivity and

biodiversity (reducing capacity to provide ecosystem services from the land) and creating significant off-site impacts.

3. Prevention of soil degradation is nearly always substantially cheaper than the cost of restoration, and in most cases is a much better investment.
4. It is the responsibility of individuals, communities, industries and governments to not knowingly degrade soil and/or water resources.
5. Soil management and policy decisions at all levels should be based on the best available knowledge, and be evidence- and science-based.
6. Sustainable soil management is most likely to be achieved through integrated approaches to sustainable agriculture and natural resource management (NRM) where long term condition of the resource is built in as a core consideration.
7. Governments have a responsibility to provide an institutional framework that encourages and supports sustainable management and discourages unsustainable management of soil resources.
8. Industries that depend on the land have a responsibility to inform themselves about their impact on soil condition, and to promote and support sustainable soil management practices within their industry.
9. With the right to own, manage and use land and soil, landholders accept a duty of care to prevent soil degradation that affects others, and to implement management practices that maintain or improve soil condition and productive capacity.
10. Sustainable management of soil resources across the country requires coordination, cooperation and collaboration among all levels of government in partnership with industry, land managers and the community, regardless of land tenure.

Perhaps the most fundamental principle is the ninth – "*With the right to own, manage and use land and soil, landholders accept a duty of care to prevent soil degradation and to implement management practices that maintain or improve soil condition and productive capacity"*. As we all own land, either directly or indirectly, this duty of care role for the current generation to deliver to future generations the soil resource in as good or better condition than it is at present, should be a driving force behind our activities.

The discussion paper sets the framework for a way forward. It recommended actions in three core areas:
Rebuilding commitment
Rebuilding the knowledge base
Rebuilding capacity

The discussion paper was circulated for public comment, and 101 formal submissions were received. A summary of the submissions has been published (National Committee on Soil and Terrain 2009). The principal response from submissions demonstrated strong support for a strategic approach to soil management in Australia. The suggested mechanisms to achieve this approach were variable, with suggestions for a national soils policy and a national soil framework. There was a clear message that any approach should be integrated with other natural resource management issues such as water and vegetation management. The need for improved consideration of soil in wider debates on climate, biodiversity and future food security was identified.

Specific issues identified included:

- There was broad agreement on the need to build a case for strategic reinvestment in soils. Stakeholders saw a need for more research, particularly in the areas of soil biota, soil carbon, sustainability in soil management, and practice change.
- Stakeholders consistently identified the need for improved soils information including monitoring, collection, storage and access to data. The Australian Soil Resource Information System (ASRIS) was identified as a core national resource in need of on-going investment with recommendations that state based information should be linked to the website.
- The low level of community awareness and understanding of threats to soil resources and the long-term consequences of this was recognised.
- There is strong awareness of the growing lack of soils professionals with sufficient skills to interpret and apply soil information. Stakeholders stressed the need for specialist and local soils knowledge in the areas of soil classification and interpretation to support improved management practices leading to more sustainable use of soils.

- The lack of adequate people on the ground was frequently attributed to the ageing and retiring of soils specialists and the problems of universities being unable to maintain critical mass in soils courses. The lack of skilled soils people was also seen as a future threat to properly informed soils and land management policy development.
- Respondents identified a strong need to promote soils literacy through the NRM regional bodies. This would provide the opportunity to promote on-ground, local outcomes and to improve collaboration between landholders, NRM bodies and state / federal agencies.
- The issue of training, extension and communication as a key element in developing management practice change towards more sustainable soil management was strongly supported.

Key suggestions for a way forward from the submissions included:

- a national strategic approach to manage future threats to the national soil resource;
- increasing research and development on soil health;
- improving national soils skills and knowledge bases;
- improving soil information and data management;
- improving education and extension capacities to support practice change; and
- improving public awareness of critical soil management issues.

These issues have since been raised at a national governmental level, and actions are now in place to address them. An update of progress towards a national soils policy and related activities will be presented at the conference.

Conclusion

The need for improved management of our soil resource has been widely recognised. The challenge is to convert that need into public policy which improves soils management for the future benefit of all Australians. The paper charts our progress on that path.

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Soils of Northern Australia-potential food bowl or dust bowl?

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Abstract
There has been interest in developing the agricultural potential of northern Australia for many years. CSIRO, along with relevant Queensland, Northern Territory and Western Australian government agencies undertook an assessment of the suitability of soil and land resources for irrigated agriculture (Wilson *et al.,* 2009). Significant areas of potentially arable soils were identified independent of other limitations such as water availability, flooding, climate, land tenure and economic factors.
National and multi-jurisdictional assessments of soil and land resources are now possible due to ongoing efforts through the Australian Collaborative Land Evaluation Program (ACLEP) to collate the best available data into a consistent national format within the Australian Soil Resource Information System (ASRIS). Gaps in data coverage and attribution exist, and the scales and age of data in ASRIS still present significant issues. Better spatial and temporal coverage of data is required to support evidence based planning and policy decisions. Application of digital soil mapping techniques and remote and proximal sensing technologies will assist in developing an improved national soils information infrastructure.

Key Words
Land evaluation, suitability assessment, limitations, agricultural development.

Introduction
An understanding of the soil and land resources of northern Australia is fundamental to consideration of development options. Soil resources are available for development but they also underpin many landscape processes that provide a range of essential ecosystem services and functions. Thus the soil landscape is essential not only for sustainable agriculture but also to the functioning of water, nutrient and carbon cycles and for supporting the north's unique biodiversity.
Surveys of the soil resources have been conducted in the region over the past 70 years. The first attempt to assess the development potential of the Top End of Australia, was the "General Report on Survey of the Katherine-Darwin Region, 1946" by CSIRO (Christian and Stewart, 1953). With Queensland (Qld) and Western Australia (WA) populations predominantly in the south, few new northern land resource surveys have been conducted since such initial investigations. The Northern Territory (NT) with its population base in the north has generally invested more across the north and in key areas such as the Daly River Basin. Assessments have generally followed recurring periods of enthusiasm by governments over the past 60 years to develop key areas more intensely, but this has by and large not occurred.
This assessment of the north's potential suitability for agricultural development used a collation of the best available data, known as the Australian Soil Resource Information System (ASRIS). ASRIS provides a fundamental information base on which multi-jurisdictional and national land resource assessments can be made. However, data held within ASRIS has considerable gaps both in the extent and scales of mapping and the attribution available. In most locations, national assessments can be considered only as broadly indicative rather than a definitive statement on the soils' properties and their capability.
The study area covers over 120 million hectares of diverse and varied landscapes. Assessment of agricultural suitability is based only on the inherent properties or qualities of the soil and land resources themselves. Significant other limitations such as climate, flooding, water availability and tenure, legislative, social and cultural factors have not been taken into account. This study therefore identifies soil potentially suitable for irrigated crops and does not necessarily define useable land or priority areas for development.
Some general observations of the soils and lands across the north are:

- they are relatively intact with minimal impact from major developments
- they are ancient and generally have low levels of inherent fertility
- soil erosion rates are high even on moderately sloping land and levels of soil development are generally low, particularly on extensive rocky upland areas
- lowland plains are seasonally or annually inundated, often calcareous at depth, with some coastal

areas being potentially saline and containing sulfuric or sulfidic material
- many northern soils are acidic (pH below 6.0), gravelly (5-60%), and shallow (< 0.5m).

Developing a consistent suitability framework

This suitability assessment for agricultural development used the FAO Framework for Land Evaluation (FAO 1976) which includes:

- selecting a range of soil qualities (e.g. erosion hazard, water holding capacity, acidity etc) with potential to limit agricultural development and assessing for each soil type
- developing a suitability framework defining the level of limitation imposed by each soil landscape property on five classes of irrigated land use/crops, covering a range of establishment, management and harvest practices: including - annual crops, perennial crops, rice, forestry and improved pasture
- combining the previous stages to assess the limitations of a soil on a particular land use/crop type
- determining the overall suitability of each soil type from the most limiting land quality.

A consistent northern Australia suitability framework was developed from a collation of existing state and territory project based frameworks. The framework gives consideration to the soil landscape properties used by existing frameworks as well as an assessment of data availability and the degree to which specific qualities were likely to limit the chosen land use/crop types.

Data limitations

Soil landscape mapping data held within ASRIS are a collation of historic surveys undertaken at various scales, with different methodologies and different levels of attribution. To the extent possible, all data have been standardised to match the ASRIS Technical Specifications (McKenzie *et al.,* 2005) but issues remain with matching data between states and surveys. Numerous gaps in attribution also exist and these have been filled using surrogate measures where possible for this assessment. Missing data have impacts on the final suitability assessment, particularly where the land quality has a significant implication for the particular land use and may result in areas being “not assessed”. Figure 1 shows the survey scale of the ASRIS data used in this assessment. Note that most of the data is at reconnaissance scales of between 1:250,000 and 1:1,000,000.

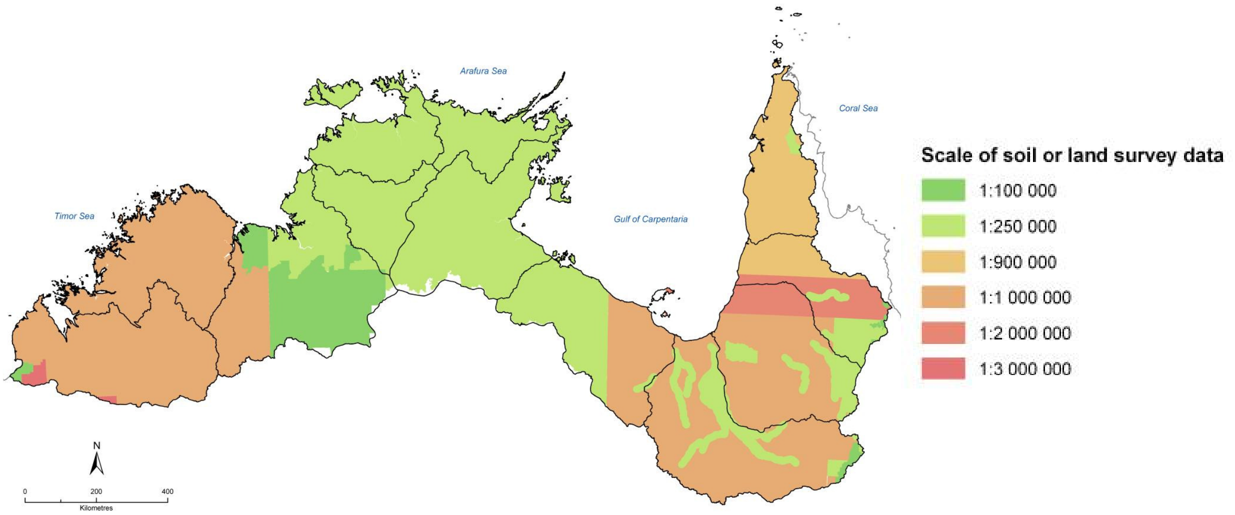

Figure 1. Mapping scales of ASRIS data used in this assessment.

Much of the broad scale mapping used for this study, shows the location of map units (polygons) that comprise a number of soil components which are described but not mapped. While this provides a better assessment of the suitability of individual soils, the specific location of these components is not defined. Development planning and on-ground land management would require data at scales of 1:50,000 or better. Such data exists for only small portions of the study area, particularly in the already developed WA Ord irrigation area and parts of the NT Daly River Basin, Mary River catchment and Darwin region.
Figure 2 shows the variability in intensity of land resource survey mapping across the study area. Note the more intensive surveys in the NT and Cape York (still considered to be reconnaissance scale) and the particularly broad nature of historic mapping in the QLD Gulf and WA Kimberley regions.

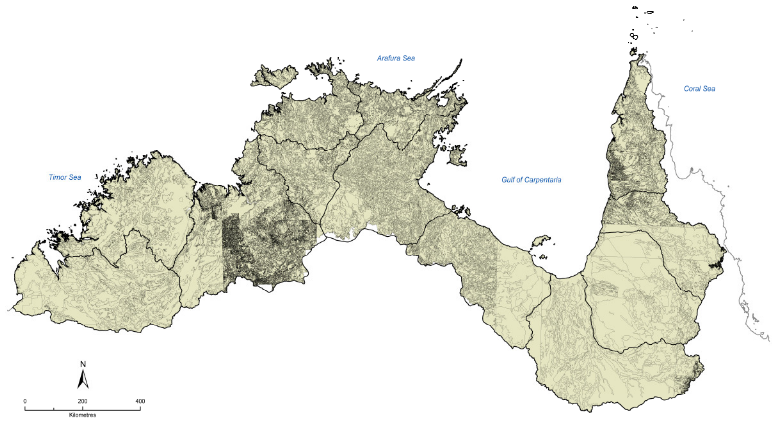

Figure 2. Variable intensity of mapping line work in the ASRIS data sets used in this assessment.

Results

The soils in the north of Australia are ancient and highly weathered. They have generally low base of fertility and poor resilience to impact - particularly compared to many southern Australian agricultural soils. Rates of soil formation are well below rates of soil loss, making the landscape inherently fragile. Extreme and variable climatic events including cyclones, extended wet season flooding and poor soil drainage, high intensity rainfall events, and annual extended dry seasons with high evaporation rates, often exacerbate the impacts of even small soil disturbances. Research, trials and other evidence have shown severe erosion can occur on relatively low slopes where erosion and sediment control measures and/or ground cover management has not been implemented with development (e.g. Robinson, 1976; Dilshad *et al.,* 1996). Some relatively large areas of soils suitable for irrigation do exist across northern Australia, particularly the Red Kandosols in the Fitzroy River region WA, the Red Kandosols of the Daly River Basin NT and some areas of Red and Brown Kandosols and Orthic Tenosols on Queensland's western Cape York (Figure 3). While the total area of arable soils across the study region may exceed 5-17 million hectares, it is dispersed across a vast landscape. The total area of soils identified as potentially suitable accounts for only 5-14% of the area assessed.

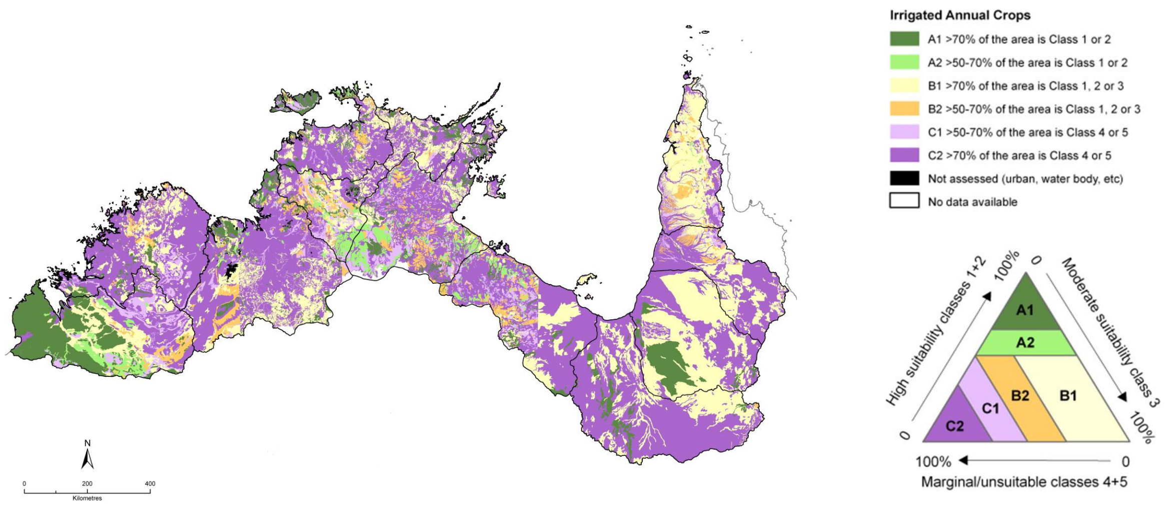

Figure 3. Example suitability map for irrigated annual crops.

The assessment of potentially suitable soils in this study has assumed an adequate availability of water and has not been constrained by existing or future land tenure. Similarly, climatic extremes and variability; regular extensive and prolonged flooding; seasonal inaccessibility; and low soil nutrition have not been considered in this irrigation suitability assessment due to limited data availability. These limitations may render a large proportion of the identified area unsuitable and therefore unusable for development. Therefore the area of suitable land identified is likely to be a maximum estimation rather than a minimum. In the context of the existing 30-60,000 hectares of agriculture in the region, the total potentially suitable area is very large. In the context of the 40-50 million hectares of agriculture already established across the southern states of Australia, it represents a significant potential addition to the national agricultural resource base.

Discussion

History has shown that the north is not an easily developed or commanded environment for intensive agricultural use (Christian and Stewart, 1953; Davidson, 1966). Agricultural developments in the WA Ord have been hampered by wet season accessibility, soil variability, low soil nutrients and increasing salinity issues. Agriculture in the NT Daly River Basin must be managed to reduce soil erosion events which can result from cultivation of even very low sloping land. Other significant management issues arise from soil qualities including - low water holding capacity, soils that require careful moisture management; sandy soils with high nutrient leaching potential resulting in leaky systems and off-site consequences; hard setting soils susceptible to surface sealing and crusting resulting in reduced infiltration rates and increased run-off and erosion. Lessons need to be learnt from history and at least new mistakes made!

Only limited information and understanding exists about the complex landscapes of the north and their sustainable development. Issues of landscape complexity and soil variability are likely to further reduce the areas of potentially useable land. However, this will only become apparent where more intensive soil and land survey is used to properly investigate areas at scales appropriate to development planning. Much of the area is surveyed at reconnaissance scales only (with limited field investigations and limited analytical data). As well, some poor data quality issues are known to exist, particularly in the older, broad scale surveys such as in the Queensland Gulf and the WA Kimberley/Fitzroy areas which may result in inaccurate assessment of agricultural potential.

The nationally collated ASRIS data base does provide a significant information base for large national and multi-jurisdictional assessments. However, gaps in data coverage and attribution exist and the scales and age of data in ASRIS still present significant issues. A multi-jurisdictional, collaborative effort was required to enable the required collation of consistent data for this assessment. Better spatial and temporal coverage of data are required to support evidence based planning and policy decisions. Future application of digital soil mapping techniques and improved remote and proximal sensing technologies will assist in developing an improved national soils information infrastructure.

Conclusion

Future agricultural development options for the north need to be planned wisely and be based on adequate and appropriate soil and land information. Scales of data must be commensurate with any intended intensification of soil and land resource use and the consequential impacts. Minimum scales of survey for proposed developments should be in the order of 1:50,000 with more intensive survey assisting final farm planning and design. A new generation of fine scale, soil attribute surfaces developed from technologically and scientifically advanced digital soil mapping processes will greatly assist and further progress the utility of the Australian Soil Resource Information System.

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