Establishing the Australian Soil Assessment Program (ASAP)

Supporting Australia's sustainable future through improved knowledge of Australian soils and their responses to land management

A land of contrasts - canola growing at the foot of the Stirling Ranges, WA.

A report prepared by the National Committee on Soil and Terrain for the Soil Research, Development and Extension Reference Group

Executive summary

This report outlines:

- policy imperatives driving Australia's need for better soils understanding
- the value proposition for a new Australian Soil Assessment Program (ASAP)
- benefits that the new program will deliver
- seven streams of required, coordinated activity
- budget proposals.

Background

Soil is a finite resource. The rapidly increasing challenge to respond to competing demands for this resource creates a policy imperative not previously seen in Australia. Internationally, the United Nations has recognised this imperative by establishing the Global Soil Partnership[1], which will see a new set of soil-related initiatives to which Australia will need to respond.

Soil provides the foundation for food, fibre, feed and bio-fuel production and delivers a range of ecosystems services that benefits our society. It is a fundamental and strategic national asset, the sustainable development and management of which is essential for Australia's future prosperity.

Soil information – knowledge about soils and how they are performing – is essential. It forms an important input to public policy in crucial areas such as climate change mitigation, water management, agricultural productivity, biological diversity conservation, public health and national security.

Simply put, we must measure and monitor soil carefully and efficiently if we are to detect changes in quality and function. Most importantly, we must detect these changes sooner rather than later. Significantly, governments already recognise that improved grazing, forestry and crop management all play an important role in carbon sequestration. Soil knowledge is essential if we are to properly understand what soil condition change really means and what impact it has on our ecosystems.

Many sectors of the Australian economy, including agriculture, infrastructure development and nature conservation, use soil data. However, our current national soil information assets are largely unconsolidated, patchy and inadequate. Private industry generates a significant amount of soil data in some sectors but an integrated system for capturing and harmonising this data within public systems is required. The lack of a comprehensive, current and accessible national soil information infrastructure undermines Australia's capacity to identify and respond to risks and the effects of land use change and to identify critical pressure points.

A new Australian Soil Assessment Program (ASAP) would engage governments and the private sector in an effort to broaden the scope of the national soil information infrastructure. Different stakeholders, such as researchers, planners, policy makers and land managers need tailored soil and land information and a new ASAP is urgently required if Australia is to meet their needs. The availability of coordinated, standards-based, current and accessible soil data will reduce the cost of duplication and enhance outcomes for all end users.

1 http://www.fao.org/globalsoilpartnership/en/

ANZLIC, the Spatial Information Council's vision is that the '*economic growth, social and environmental interests of Australia … are underpinned by spatially referenced information that is* ***current, complete, accurate, affordable*** *and* ***accessible****; and is integrated in critical decision making.'*[2]

Consistently implementing national data standards and interoperability through the ASAP will support improved discoverability, access and usability of soil information. This in turn will promote greater collaboration across government agencies, industry, education, research and private sectors, ensuring that Australia has a credible and cost-effective national soil information infrastructure. It is well understood that *established roles in data stewardship and custodianship will realise greater integrity and confidence in the administration and delivery of authoritative…information*.[3]

Soil information is essential to determining the best long-term economic use of land and for managing financial and other risks associated with development and land use. The government's White Paper on Australia in the Asian Century[4] recognises soil as a major national asset driving agricultural productivity and supporting our desire to become a major food exporter.

Policy imperatives

Increasingly, public policy imperatives are driving the need to better understand our soils and to have relevant data and information readily available. Both government and industry are considering policies relating to:

- **Identification and Protection of Prime Agricultural Land** – ensuring, through the planning process, that the best agricultural lands remain available to produce food and fibre.
- **Registering Foreign Ownership of Agricultural Land** – evaluating the quality of agricultural land as an input to understanding the real impact of foreign ownership of agricultural land.
- **Carbon Sequestration in Soil** – long-term soil monitoring will improve what we understand about the effects of global warming, the carbon balance and potential carbon markets.
- **Natural Disaster Mitigation, Management and Recovery** – soil information is essential to understanding the water cycle: near real-time soil moisture information is vital to weather forecasting, flood monitoring, early warning on droughts and crop yield forecasting, among others.
- **Food Security** – there is growing demand to produce more food, fibre and bio-fuel with less arable land and declining water reserves. To respond to this demand, Australia must invest in soil research and development and greater cooperation across disciplines in order to improve its knowledge of and response to land management.

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2 http://www.anzlic.org.au/

3 National Location Strategy, Office of Spatial Policy (Principle 3)

4 http://asiancentury.dpmc.gov.au/

Value proposition

A nationally mandated and coordinated ASAP will provide **benefits of scale and coordination** across individual existing programs. This will reduce duplication and give greater trust in national soil information. Shared information will **improve accuracy and precision** by using consistent methodologies and standards while establishing a trusted ‘point of truth’ and identifying appropriate data management regimes.

A cooperative soil program is an **opportunity to maximise the value of soil data collection** while providing a mechanism for bringing all soils data into a national soil information infrastructure. A strategic focus on soil will enable greater input to other integrated national information infrastructures. This will ensure that existing and potential stakeholders will have greater access to and use of soil data. A national soils program will *increase governments’ knowledge, capacity and capability in acquiring, managing and delivering information.*[5]

Soil monitoring will **support evidence-based decision making for agriculture** to increase sustainable crop yields and quality. Furthermore, soil moisture monitoring is fundamental to hydrological, biological and biochemical processes, as well as being a fundamental climate variable.

Soil erosion has contributed to a decline of more than 10 million hectares a year world-wide. This places added pressure on soil resources for increased production to **meet the demands of a rapidly growing population**. The White Paper on the Asian Century noted that the world’s soil must support at least a 70% increase in food production by 2050, which will be a considerable challenge for Australia where only 9% of the landmass is arable. High quality soil information is required to guide resource use and allocation decisions that will allow us to meet this need without degrading the resource base.

Soil information is essential to **determining the best long-term economic use of land**. The government’s White Paper on the Asian Century also recognised **soil as a major national asset** driving agricultural productivity and supporting our desire to become a major exporter of food.

Soil biodiversity has **significant economic value**. The European Commission estimated that the world economic benefits of soil biodiversity are in the order of $US1.5 trillion per annum[6].

The ASAP will facilitate **better soil management** and generate potential benefits to Australia worth at least $2 billion per annum by 2020. These benefits arise primarily from increases in agricultural productivity. The gross value of Australian farm production is in excess of $41 billion per annum; better soil management could add 5 – 10% value to farm production each year.

A national soil program will provide an opportunity for improved benefits and costs of land resource assessment activities in Australia to produce an estimated benefit to cost ratio of >10:1 and up to 44:1 on selected case studies. The program will also **help to avoid costs** in other soil dependent industries (potentially hundreds of millions of dollars per year) and equally large societal and ecosystem service benefits associated with better soil and land management.

[5] National Location Strategy, Office of Spatial Policy (Principle 7)

[6] European Commission, The soil is alive: total economic benefits of soil biodiversity, Convention on Biological Diversity (22 May 2008)

The value of soil data lies in its **reliability and currency**. Failure to appropriately fund fundamental soil data capture and ongoing research will diminish trust in the available information, which will lead to an increase in costs due to duplication, data inconsistencies, no standards, poor discoverability and little or no interoperability. This would be a profound loss to the national economy.

Australia's **investment in soil information lags behind** other OECD countries and is currently mapped at a scale that is below international standards: Australia's investment in soil mapping is nine times less than that of other OECD countries.

Recommendations

The new ASAP will formalise the current collaborative model and build on existing soil information and research activities to deliver a strong, coordinated national approach. It will provide an on-going soil data capture, monitoring, forecasting and reporting system for Australia. The National Committee on Soil and Terrain recommends the following steps:

1. Establish a mandate for the cooperative national approach currently facilitated through the Australian Collaborative Land Evaluation Program (ACLEP), for the collection, sharing, monitoring and analysis of soil data that will implement consistent soil data standards to support interoperability, optimise access, reduce costs, remove duplication and improve data quality.
2. Provide strong national leadership and coordination to develop an integrated soil information system, building on the Australian Soil Resource information System (ASRIS) that will support government and industry programs and feed into a wider national environmental information infrastructure.
3. Provide prioritised and statistically-based soil data capture and long-term monitoring that enables the identification of and response to high-priority uses. Monitoring must be part of long-term ecological research and reporting.
4. Engage with all stakeholders, including the private sector, to improve efficiencies, knowledge, standards, data availability and cooperation to build a trusted source of truth for nationally consistent soil data.
5. Further develop existing initiatives aimed at providing an infrastructure for web-based delivery of standardised soil information.
6. Build soil information that serves to fulfil Australia's objective of becoming a major exporter of food. Take advantage of new technologies to capture and analyse soil data to build knowledge to support climate change adaptations and identify new opportunities.

Proposal

Secure annual funding to provide:

Coordination and user engagement	$6.8 million
Soil data collection, survey and assessment	$38.0million
Monitoring and forecasting	$20.0 million
Information systems	$11.2 million
Support facilities	$14.7 million
Research and development	$9.0 million
(International engagement)	($9.0 million)
TOTAL	**$99.7 million**

An indicative ongoing annual investment of $99.7m is required to support the six streams of nationally coordinated and integrated activity as summarised above. While a minor portion of this may come from better coordination of current soil research and development expenditure (estimated at $124m per year[7]), a significant new investment is needed to revitalise and upgrade the Australian national soil information infrastructure. An additional annual investment of $9m would support Australia's international engagement and leadership opportunities.

[7] Department of Agriculture, Fisheries and Forestry (2011). A stocktake of Australia's current investment in soils research, development and extension: A snapshot for 2010-11. Soils Research, Development and Extension Working Group.

1. Introduction

There is growing national and global acknowledgement that soil resources are important, finite and require careful management to ensure food security and maintain essential ecosystem services. Effective management is dependent on reliable information on soil resources and in particular, an understanding of how different soils respond to various forms of land use and management and changes in environmental conditions.

This report has been prepared as an input to the reform process in agricultural research, development and extension managed by the Primary Industries Standing Committee (the PISC cross-sectoral Soil RD&E Strategy). The terms of reference were:

- Establish the value proposition for a National Soil Assessment Program.
- Priority areas: the current coverage, resolution and availability of profile data for major land uses across Australia will be assessed to provide a basis for Program costs, agreeing priority locations for mapping.
- Analytical facilities and soil archives: identify the likely data streams that will be produced through the Program and the resulting demand on laboratory facilities for soil analysis (biological, chemical and physical) and the soil archives needed to support the proposed Program.
- Data management, analysis and web-based delivery: make a preliminary assessment of the level and type of investment needed to provide the expertise and facilities for analysing, managing and delivering the data sets which will be generated by a national soil survey.
- Improving data accessibility: provide advice on improving the collection, management and accessibility of soil information collected through government and non-government organisations, including the private sector, which could be shared to improve soil monitoring and land management; identify potential issues relating to privacy, data-sharing, intellectual property, access and use of data by third parties, badging and version control, and solutions to address them.
- Research and development: identify the issues and funding required to improve the methods for soil mapping, monitoring and forecasting to build the soil knowledge base for sustainable land use and management.
- User engagement and education: examine and report on the approaches to be used and the cost of the soil extension services which need to be associated with the survey program to maximise the utility of soil information.
- Costs: provide an estimate of the costs of the above components for a 10 year period.

This report is the result of an extensive consultation process that culminated in a national workshop held in Canberra in December 2012.

This report also provides input to the work of Australia's newly appointed Advocate for Soil Health, the former Governor-General, Major General Michael Jeffery. It outlines a set of options for enhancing the Australian Soil Assessment Program along with seven proposed streams of activity.

We begin with an important caveat. Most of this report focuses on the agricultural and pastoral lands of Australia. However, soil information is beneficial for land management and planning decisions in other industries and for different purposes. Some of the most significant include:

- land-use planning
- mapping and managing acid sulfate soils in coastal environments
- determining the location of corrosive and expansive soils to ensure appropriate engineering design and location of major infrastructure
- understanding the characteristics of soils to ensure successful rehabilitation of areas used for mining and waste-disposal
- setting environmental baselines for contaminants and implementing effective rehabilitation practices for contaminated lands
- contributing to scientific knowledge on landscape processes (e.g. for soil science, hydrology, ecology, geomorphology, exploration geoscience, and the earth-system sciences more generally).

This report does not provide a detailed analysis of information needs for these purposes although the scope and estimated costs of the proposed programs have been framed with these broader applications in mind. Although poorly documented, anecdotal reports suggest that the returns on investment into soil information for these purposes are extremely large. For example, completely avoidable problems such as optic-fibre cable breakages due to expansive soils, exposure of acid sulfate soils in sensitive environments, or poor location of urban developments on unsuitable soils are known to have associated costs in the order of tens of millions of dollars for each failure.

In this report, soil assessment is therefore considered within a broader landscape context. This integrated approach has a strong basis in theory and practice and it builds on the best elements of natural resource planning and management. Furthermore, the survey and monitoring systems needed for agricultural soil assessment are virtually the same as those needed for all forms of soil assessment.

1.1 Background – the need for soil information

Soil is a finite resource. The rapidly increasing challenge to respond to competing demands for this resource creates a policy imperative not previously seen in Australia. Internationally, the United Nations has recognised this imperative by establishing the Global Soil Partnership[8], which will see a new set of soil-related initiatives to which Australia will need to respond.

Soil provides the foundation for food, fibre, feed and bio-fuel production and delivers a range of ecosystems services that benefits our society. It is a fundamental and strategic national asset, the sustainable development and management of which is essential for Australia's future prosperity.

Soil information – knowledge about soils and how they are performing – is essential. It forms an important input to public policy in crucial areas such as climate change mitigation, water

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management, agricultural productivity, biological diversity conservation, public health and national security.

Simply put, we must measure and monitor soil carefully and efficiently if we are to detect changes in quality and function. Most importantly, we must detect these changes sooner rather than later. Significantly, governments already recognise that improved grazing, forestry and crop management all play an important role in carbon sequestration. Soil knowledge is essential if we are to properly understand what soil condition change really means and what impact it has on our ecosystems.

Many sectors of the Australian economy, including agriculture, infrastructure development and nature conservation, use soil data. However, our current national soil information assets are largely unconsolidated, patchy and inadequate. Private industry generates a significant amount of soil data in some sectors but an integrated system for capturing and harmonising this data within public systems is required. The lack of a comprehensive, current and accessible national soil information infrastructure undermines Australia's capacity to identify and respond to risks and the effects of land use change and to identify critical pressure points.

A new Australian Soil Assessment Program (ASAP) would engage governments and the private sector in an effort to broaden the scope of the national soil information infrastructure. Different stakeholders, such as researchers, planners, policy makers and land managers need tailored soil and land information and a new ASAP is urgently required if Australia is to meet their needs. The availability of coordinated, standards-based, current and accessible soil data will reduce the cost of duplication and enhance outcomes for all end users.

ANZLIC, the Spatial Information Council's vision is that the '*economic growth, social and environmental interests of Australia … are underpinned by spatially referenced information that is* ***current, complete, accurate, affordable*** *and* ***accessible****; and is integrated in critical decision making.'*[9]

Consistently implementing national data standards and interoperability through the ASAP will support improved discoverability, access and usability of soil information. This in turn will promote greater collaboration across government agencies, industry, education, research and private sectors, ensuring that Australia has a credible and cost-effective national soil information infrastructure. It is well understood that *established roles in data stewardship and custodianship will realise greater integrity and confidence in the administration and delivery of authoritative…information*.[10]

Soil information is essential to determining the best long-term economic use of land and for managing financial and other risks associated with development and land use. The government's White Paper on Australia in the Asian Century[11] recognises soil as a major national asset driving agricultural productivity and supporting our desire to become a major food exporter.

9 http://www.anzlic.org.au/

10 National Location Strategy, Office of Spatial Policy (Principle 3)

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1.2 Policy imperatives

Increasingly, public policy imperatives are driving the need to better understand our soils and to have relevant data and information readily available. Both government and industry are considering policies relating to:

- **Identification and Protection of Prime Agricultural Land** – ensuring, through the planning process, that the best agricultural lands remain available to produce food and fibre.
- **Registering Foreign Ownership of Agricultural Land** – evaluating the quality of agricultural land as an input to understanding the real impact of foreign ownership of agricultural land.
- **Carbon Sequestration in Soil** – long-term soil monitoring will improve what we understand about the effects of global warming, the carbon balance and potential carbon markets.
- **Natural Disaster Mitigation, Management and Recovery** – soil information is essential to understanding the water cycle: near real-time soil moisture information is vital to weather forecasting, flood monitoring, early warning on droughts and crop yield forecasting, among others.
- **Food Security** – there is growing demand to produce more food, fibre and bio-fuel with less arable land and declining water reserves. To respond to this demand, Australia must invest in soil research and development and greater cooperation across disciplines in order to improve its knowledge of and response to land management.

These factors also contributed to the formation of the Australian Government's Working Group on Water, Soil and Food which reported to the Prime Minister in August 2012[12]. The report's message was clear.

- Australia recognises that soil and water resources must be protected from the global threats of climate change, land degradation and competing land use.
- Australia's natural resources are valuable but, in many cases, fragile assets, and preserving our soils and water for the future must be a priority.
- Greater coordination, across agencies and across levels of government, is needed to effectively respond to these international and national challenges.
- A critical part of the response to these challenges is recognising the public and private benefits from contributing to soil and water security, and providing incentives for cooperatively maintaining soil and water security in Australia.

The Working Group's recommendations emphasised the need for greater coordination, integration and communication. Sustainability policy was put forward as the new competition policy and a key finding was that '*soil information and integrative systems models are the immediate gap*'. More specifically:

> *'… soil data remains an obvious and critical gap that has been immediately identified by the Working Group, and the data gap is holding back all [government] strategies. Reliable systems models that integrate across the soil-water-food risk nexus are also absent and are*

[12] www.daff.gov.au/natural-resources/soils/working-group-on-water-soil-and-food

required to link social, economic and environmental dimensions to maximise the return on investment. Such models are essential to better define soil data strategies.'

Equally clear was the explicit recognition that Australia's future prosperity has close links to the management of our soil and water resources. This was summarised in the Australian Government's 2012 White Paper on Australia in the Asian Century[13].

'Australia's soil is a major national asset, driving our agricultural productivity and ability to be a net exporter of food. The potential for Australian agriculture to increase productivity growth while managing climate change and reducing greenhouse gas emissions will depend heavily on successful management of the soil resource base.'

With this context, The Prime Minister of Australia, the Hon Julia Gillard MP, stated in an address to the National Farmers Federation in October 2012[14] that:

'Soils are the very basis of our survival...

The condition of our soils must be a national priority …

Government departments, CSIRO and our rural RDCs must continue to take an integrated approach to ensure resources are used sustainably and that we target investment to the right areas.

We also need to engage better with our soil scientists to take advantage of new ideas and to provide the information that our farmers need to look after their soil.'

The occasion marked the appointment of former Governor-General Major General Michael Jeffery, as Australia's Advocate for Soil Health. His mission in 2013 is to provide strong leadership and advocacy on the importance of healthy soil and the benefits thereof for all Australians. He has four primary tasks:

- advocate that the healthy condition of our soils must be a national priority
- develop cross-sector soil research priorities and help secure adequate resources for development and extension
- work towards ensuring that existing and new soils research meets the needs of Australia's soil managers – farmers
- advocate for adequate knowledge and supporting systems to help farmers to actively build healthy soils.

The Australian Soil Assessment Program outlined in this report contributes directly to this mission. It provides a foundation for ensuring that Australians will be living within the natural limits of their soil resources.

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[13] http://asiancentury.dpmc.gov.au/

[14] http://www.pm.gov.au/press-office/speech-national-farmers-federation-national-congress

1.3 The proposal

A coordinated national investment of $99.7 million per year is proposed through an ongoing Australian Soil Assessment Program. The Program will build the national soil information infrastructure. A portion of the investment could come from reallocation of existing funds but a significant new investment is likely to be required. The current estimated national expenditure into soil research and development is around $124m (DAFF 2011), little of which provides routine soil data collection, monitoring, information management or national assessment and reporting.

The Program, delivered through seven integrated streams of activity, would be nationally coordinated and regionally delivered. The streams, their required resourcing and expected outcomes are summarised in the following table and detailed later in this report.

Table 1: Streams of activity, indicative budget and outcomes

Stream	Budget $m/yr	Outcomes
1. Coordination and user engagement	$6.8	Improved community understanding and implementation of sustainable soil management
2. Soil data collection, survey and assessment	$38.0	Improved national data sets, understanding of soil processes and knowledge of land management impacts
3. Monitoring and forecasting	$20.0	An ability to assess and forecast trends in soil condition
4. Information systems	$11.2	Discoverable, accessible and useable soil data and information
5. Support facilities	$14.7	Improved and coordinated physical infrastructure
6. Research and development	$9.0	New and innovative tools for efficient and effective data collection along with improved and applied understanding and knowledge
7. International engagement	Indicative cost of $9.0 not formally included in this proposal	Australia recognised as a world leader and provider of soil knowledge directed towards sustainable land management and food security, with a strong focus on SE Asia and the Pacific
TOTAL	**$99.7**	Sustainable use and management of a fundamental and critical national asset.

1.4 Value proposition

A nationally mandated and coordinated ASAP will provide **benefits of scale and coordination** across individual existing programs. This will reduce duplication and give greater trust in national soil information. Shared information will **improve accuracy and precision** by using consistent methodologies and standards while establishing a trusted 'point of truth' and identifying appropriate data management regimes.

A cooperative soil program is an **opportunity to maximise the value of soil data collection** while providing a mechanism for bringing all soils data into a national soil information infrastructure. A strategic focus on soil will enable greater input to other integrated national information infrastructures. This will ensure that existing and potential stakeholders will have greater access to and use of soil data. A national soils program will *increase governments' knowledge, capacity and capability in acquiring, managing and delivering information.*[15]

Soil monitoring will **support evidence-based decision making for agriculture** to increase sustainable crop yields and quality. Furthermore, soil moisture monitoring is fundamental to hydrological, biological and biochemical processes, as well as being a fundamental climate variable.

Soil erosion has contributed to a decline of more than 10 million hectares a year world-wide. This places added pressure on soil resources for increased production to **meet the demands of a rapidly growing population**. The White Paper on the Asian Century noted that the world's soil must support at least a 70% increase in food production by 2050, which will be a considerable challenge for Australia where only 9% of the landmass is arable. High quality soil information is required to guide resource use and allocation decisions that will allow us to meet this need without degrading the resource base.

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Soil biodiversity has **significant economic value**. The European Commission estimated that the world economic benefits of soil biodiversity are in the order of $US1.5 trillion per annum[16].

The ASAP will facilitate **better soil management** and generate potential benefits to Australia worth at least $2 billion per annum by 2020. These benefits arise primarily from increases in agricultural productivity. The gross value of Australian farm production is in excess of $41 billion per annum; better soil management could add 5 – 10% value to farm production each year.

A national soil program will provide an opportunity for improved benefits and costs of land resource assessment activities in Australia to produce an estimated benefit to cost ratio of >10:1 and up to 44:1 on selected case studies. The program will also **help to avoid costs** in other soil dependent industries (potentially hundreds of millions of dollars per year) and equally large societal and ecosystem service benefits associated with better soil and land management.

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[15] National Location Strategy, Office of Spatial Policy (Principle 7)

[16] European Commission, The soil is alive: total economic benefits of soil biodiversity, Convention on Biological Diversity (22 May 2008)

The value of soil data lies in its **reliability and currency**. Failure to appropriately fund fundamental soil data capture and ongoing research will diminish trust in the available information, which will lead to an increase in costs due to duplication, data inconsistencies, no standards, poor discoverability and little or no interoperability. This would be a profound loss to the national economy.

Australia's **investment in soil information lags behind** other OECD countries and is currently mapped at a scale that is below international standards: Australia's investment in soil mapping is nine times less than that of other OECD countries.

1.5 Global context

The proposed Australian Cooperative Soil Assessment Program is part of an emerging international movement to improve soil management and ensure soil security. A significant development in December 2012 was formal establishment of the Global Soil Partnership by the United Nations Food and Agriculture Organization (FAO). An Intergovernmental Technical Panel on Soils will be convened by July 2013 and a high priority is building an enduring and authoritative system to monitor the Earth's soil resources.[17] An appreciation of this global context is significant for program design and priority setting within Australia.

At a global scale, there is a qualitative appreciation of the pressures on soil resources but limited consistent evidence on their condition and trajectories of change. In short, the world's soils need to support at least a 70% increase in food production by 2050 (FAO, 2011) but some fundamental questions are yet to be answered. For example:

- Is there enough arable land with suitable soils to feed the world in coming decades?
- Are soil constraints partly responsible for the apparent yield plateau for major crops?
- Can changes to soil management have a significant impact on the seemingly unsustainable global demand for nutrients?
- Can changes to soil management have a significant impact on atmospheric concentrations of greenhouse gases without jeopardising other functions such as food and fibre production?
- Will the extent and rate of soil degradation threaten food security and the provision of ecosystem services in the coming decades?
- Can water-use efficiency be improved through better soil management in key regions facing water scarcity?
- How will climate change interact with the distribution of soils to produce new patterns of land use?

A comprehensive global view is needed to answer these questions. It is also needed to deal with the trans-national aspects of food security and soil degradation. Because of trade, most urbanised people are protected from local resource depletion. The area of land and water used to support a global citizen is scattered all over the planet. As a consequence, soil degradation and loss of production are not just local or national issues – they are genuinely international.

[17] www.fao.org/globalsoilpartnership/home/en/

Australian governments and industries have an interest in understanding how land use decisions in one district, country or region have consequences elsewhere. For example, in coming decades, soil management will have to change across large areas in Western Australia and Queensland if cropping is to continue because of soil acidification and nutrient decline, respectively. If these productive areas are lost from production then an increase in production has to occur somewhere else to maintain world food supplies. Well-intentioned policies affecting land use can also have perverse consequences in far-off locations. For example, policies for bio-fuel production in North America and Europe affect land use around the world (e.g. Laborde 2011).

Australia will also need to track changes in land condition to meet the reporting requirements of international conventions. For example, implementation of proposals such as the United Nations Convention to Combat Desertification (UNCCD) Sustainable Development Goal of Zero Net Land Degradation[18] would require a significant effort to monitor soil and landscape change. Private sector accreditation programs require similar information.

The above considerations highlight how soil data and information are needed for many purposes from local through to national and global scales. For efficiency, the systems of measurement and analysis need to be integrated across this hierarchy of scales so that data collected at lower levels feed through to analyses at the higher levels. The dramatic advances in web-based technology make the integration of local, national and global systems possible. However, data and information have to be collected and managed according to consistent standards to enable integrated analysis.

The implication for developers of improved soil information systems in Australia is that close engagement is needed with the emerging global standards and systems. There are excellent precedents in other domains (e.g. weather, oceans, land cover, terrain, seismic monitoring) but the task is large and it will require a sustained commitment and effective international engagement.

[18] www.unccd.int/Lists/SiteDocumentLibrary/Rio+20/UNCCD_PolicyBrief_ZeroNetLandDegradation.pdf

2. Soil knowledge – needs and priorities

2.1 Priorities for improved knowledge

2.1.1 Soil management

The initial soil management priorities for the Program are to provide the necessary knowledge to:

- improve the matching of farming-systems with soil types at the farm and landscape scale
- control soil acidification in pasture and cropping systems
- slow unsustainable rates of erosion by water and wind across a wide range of land uses, particularly in eastern and northern Australia
- alleviate constraints caused by soil compaction and damage to soil structure
- restore soil carbon
- ensure nutrient budgets are balanced and unproductive losses are minimised
- control salinity and improve water use efficiency
- understand and manage subsoil constraints.

An early task for the Program is to clearly define these priorities in terms of their economic significance, geographic distribution and environmental importance. The process of priority setting will require extensive consultation and budget review. It also requires a good understanding of current data holdings (see text boxes below).

2.1.2 Understanding soil change and improving landscape function

Better decision-making at all levels requires a framework for understanding the significance of soil change. The task is to assess whether landscapes are functioning effectively. In broad terms, the criteria for determining whether a landscape is being managed sustainably are:

- leakage of nutrients is low
- biological production is high relative to the potential limits set by climate
- levels of biodiversity within and above the soil are relatively high
- rainfall and applied water is efficiently captured and held within the root zone
- rates of soil erosion and deposition are low, with only small quantities being transferred out of the system
- contaminants are not introduced into the landscape and existing contaminants are not concentrated to levels that cause harm
- systems for producing food and fibre for human consumption do not rely on large net inputs of energy.

The Australian Soil Assessment Program will need to develop the survey, monitoring and forecasting tools to allow quantitative assessment of these criteria in order to generate the anticipated benefits of at least $2 billion per year by 2020.

2.1.3 Knowledge gaps

As noted earlier, the current soil survey coverage of Australia is patchy and incomplete. Likewise, the associated databases of soil profiles are out of date and soil mapping coverage does not match well with current challenges and priorities. Text Box 1 (*National soil data and information assets*) gives a general indication of the current availability of nationally consistent map and site data. Text Box 2 contains an analysis of the age of data and the implications for being able to monitor soil change.

2.1.4 The digital revolution

This revolution has affected almost every aspect of soil assessment. It is also leading to a reassessment of what soil knowledge is useful. Many factors are involved:

- There has been a huge increase in the amount of data that can now be collected through the use of proximal and remote sensing.
- Global positioning systems and online spatial information systems have completely changed how soil information is being collected, collated analysed and used (Minasny et al. 2012).
- Crowd-sourcing and information sharing applications in other domains have dramatically raised expectations of users who are seeking access to soil information. They expect it to be intuitive, easy to understand and available online via an integrated spatial information service (e.g. Google Earth).
- The diversity of information providers and users has increased.
- Data reuse has become the norm because of the ease of storage, access and automated presentation.
- Easy movement between scales is expected, both for the viewing and analysis of soil information.

The revolution in information technology depends fundamentally on the development and adherence to standards for data. This is particularly challenging for soil assessment because there has been a general retreat from developing and adhering to standards in recent decades. The reasons are complex but factors include the reduced emphasis on soil classification, reductions in funding for technical support, and the absence of a national soil agency with a formal mandate for developing and maintaining operational standards. The Australian Soil Assessment Program will have to promote the use of standards to take full advantage of the digital revolution.

Text Box 1 – National soil data and information assets

Figure 1 shows the coverage and scale of nationally consistent land resource maps held by the Australian Soil Resource Information System (ASRIS). Most maps are less detailed than 1:50 000 (darker colours) and only suitable for regional and national assessments rather than supporting local land planning or management decisions. Data gaps, evident in NSW and SA, represent missing data or an inability to collate data within the national system.

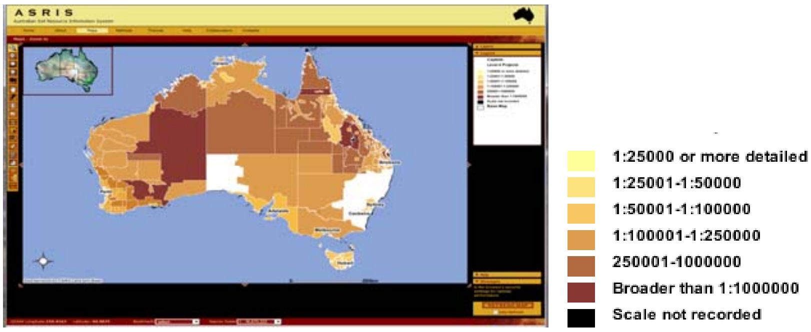
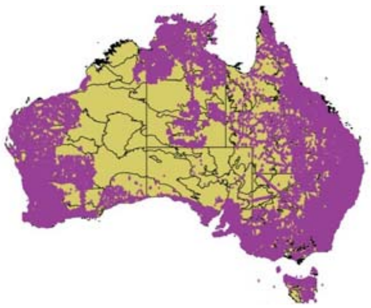


Figure 1: Scale of available soil and land resource maps across Australia.

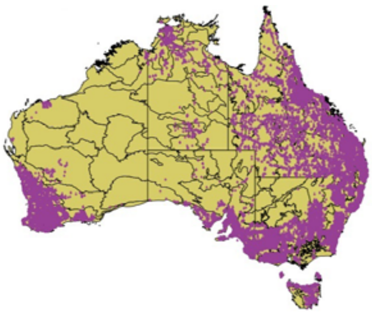
Ideally, Australian land planners, developers and managers would be supported by nationally consistent data at a resolution commensurate with the intensity of current and likely future land use. The intensive land management zones and populated coastal fringes of Australia require data at a fine resolution (grid size of 20–100m or cartographic scales of 1:25 000 or more detailed).

Site specific data are available for a number of locations across Australia. The Terrestrial Ecosystems Research Network (TERN) Soil and Landscape Grid Facility and the Australian Collaborative Land Evaluation Program (ACLEP), have worked with jurisdictional agencies to collate over 280 000 individual site records. This is an invaluable resource but there are many data gaps, particularly across the rangelands. Most sites have only been sampled once in 80 years and many are not fully characterized in terms of their soil physical, chemical and biological properties. Many sites lack analyses of the functional soil properties that are directly related to land management (e.g. carbon content, pH, nutrients, and water holding capacity).

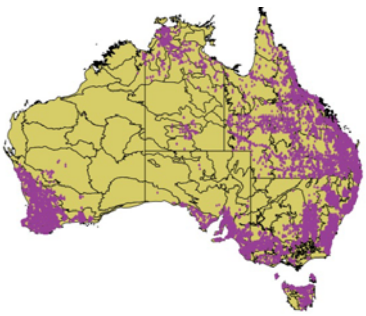
The figures below show the geographical spread of all sites (over 280 000); those with the basic measure of pH (approx. 65 000); those with the priority program measure of organic carbon (approx. 29 000); and those with the important though non-routine measure of bulk density (approx 1000). To monitor soil carbon stocks requires a measure of both organic carbon and bulk density so the small number of bulk density measurements limits the ability to map, monitor and forecast soil carbon dynamics.



All sites



pH



Organic Carbon

Bulk density

Text Box 2 – Temporal and land use coverage of soil data

Figure 1 shows the distribution of site data coloured by the decade in which it was collected. The majority of site data was collected between 1985 and 2000 (see graph) during the Decade of Landcare and following programs such as the National Action Plan for Salinity and Water Quality. A significant decline in the number of site data collected has occurred in the last 10 years. This has implications for our ability to analyse and report on the current condition of Australia's soil resources and the trend in impacts from land development and management.

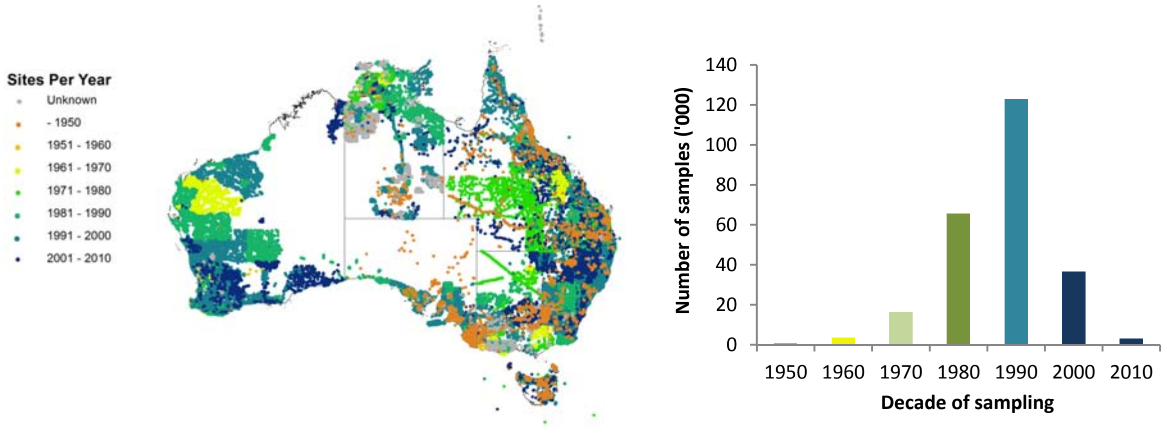


Figure 1: The national distribution of available site data and the decade of data collection

Very few soil data are available prior to the 1960s. As a result we have a relatively poor understanding of the pre-development baseline condition for most soils. Approximately 30% (about 100 000 sites) were collected prior to the mid 1980s, and over half (about 150 000 sites) were collected between 1985 and 2000. Less than 20% (about 50 000 sites) have been collected in the last decade, and nearly all sites have been sampled only once. There is no ability to monitor change in soil attributes or condition. This makes it difficult to detect and check changes caused by the intensification of land use or changes in land management.

Of the 280 000 sites available, nearly 50% (140 000 sites) have been collected from areas with low-intensity land-use (e.g. grazing of native vegetation). Just less than 10% of sites (about 26 000) are within the dry-land cropping areas and almost 20% (50 000 sites) are within more intensively managed modified pasture areas. Only 2.5% (7000 sites) are in the intensively managed horticultural regions. The remaining 10% (about 28 000 sites) are in areas used for nature conservation and forestry.

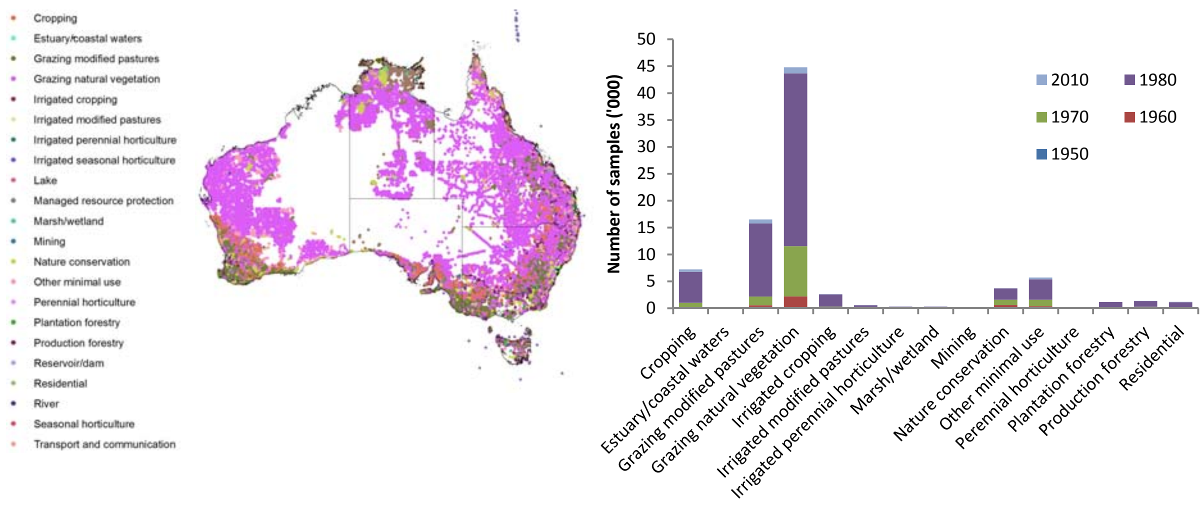


Figure 2: The national distribution of site data according to land use and year of data collection

The low numbers of sites in areas where management impacts on soils are likely to be greatest reduces our capacity to report on current soil condition.

2.2 What soil knowledge is useful?

2.2.1 Information for decision makers

The value of soil knowledge is largely dependent on the degree to which it improves our scientific understanding of how soils function, and whether it can change a decision maker's management choices. The latter is the primary focus of the Australian Soil Assessment Program. Pannell and Glenn (2000) provide useful guidance on how benefits can accrue from improved soil information. The key test is whether soil information reduces risks in decision making. A change in soil management, if it occurs, is the result of soil information *reducing the uncertainty about impacts of different strategies*. Several conclusions can be drawn from this simple principle:

- Land management options and perceptions of risk vary between farms and regions – the utility of information likewise varies.
- The gross value of information is zero if land management cannot change. The value is high if environmental or production outcomes are sensitive to management choices.
- If outcomes are sensitive to management choices then the optimal choice may be obvious. Conversely, the greater the uncertainty about factors controlling outcomes, the greater the value of information, provided it leads to a reduction in that uncertainty
- Information is beneficial when there is a close relationship between the soil factors and the payoff from different management options.

Thus there is a need for a clear understanding of the strategic roles of different types of information. This is underpinned by a base-level of consistent information on the distribution and condition of Australia's soil resources. Coordinated regional programs of mapping and monitoring then provide context for specific investigations to support tactical planning and management. These programs tend to be publicly funded, with the specific investigations mostly done by the private sector.

This arrangement is common in other domains. For example:

- Australia has a consistent coverage of topographic maps at several cartographic scales. There are also many topographic surveys and maps produced by consulting surveyors for specific projects (e.g. engineering, construction, mining, landscape planning)
- Weather and climate data are collected to support routine weather forecasting and preparation of seasonal outlooks. However, some applications require more detailed investigations or manipulation of data targeted to particular locations (e.g. aviation, air quality monitoring, boating) or audiences (e.g. weather apps, weather channels, web services).
- The public and private roles for geological investigations recognise the need for the former to provide the strategic and contextual information to guide the exploration efforts of mining companies.

Clear definition of public and private roles and their client groups will substantially improve the coordination of Australia's soil knowledge system. It is useful to start with a summary of the

differences between current regional programs of mapping and monitoring, and specific programs of work for tactical management.

2.2.2 Regional programs of mapping and monitoring

The accelerated program of regional land resource survey during the Decade of Landcare was the most significant mapping effort of recent years. All states dramatically expanded their soil and landscape mapping coverage and Western Australia and South Australia completed initial surveys across their agricultural lands during this time. They now have the benefit of a strategic overview of soil and land resources that is used for a wide range of planning and management purposes.

The most significant monitoring programs have been established during the last decade, particularly through funding from Caring for Our Country and several substantial state-based programs. Tasmania and New South Wales now have valuable baseline data on many of their most important soils and systems of land use.

These regional programs of mapping and monitoring have the following general characteristics:

- They are often designed to be used for a wide-range of purposes.
- Data are generally collected according to a set of well-established standards and systems for quality assurance (primarily the five Australian Soil and Land Survey Handbooks[19]).
- Scales of mapping were intended for regional planning purposes and are typically too broad (often 1:100 000 or coarser) for most decisions on practical soil management because soil variation at the paddock-scale cannot be resolved (this is in contrast to countries such as the United States where detailed soil survey data are available for more than 85% of the country at scales between 1:10 000 and 1:15 000).
- Those responsible for surveys are skilled professionals.
- Most of the data collected by the surveys are held and managed by public agencies and online access to some of this is possible through state and territory websites or via the Australian Soil Resource Information System.
- Some uses for the information are not known at the time of information collection but there is a rich history of the information being used in subsequent years for unanticipated purposes.
- The mapping programs in particular, provide valuable context and baseline information, substantially reducing costs for the more detailed tactical activities that are outlined below.
- Benefit-cost ratios are substantial (ACIL 1996, Sanders 2003).
- Good quality surveys continue to be used many decades after publication (e.g. CSIRO Land System Surveys).

[19] See http://www.clw.csiro.au/aclep/publications/handbooks.htm

2.2.3 Specific information for tactical management

Much larger quantities of soil data are collected every year during investigations designed to support tactical management decisions. The information is used for many purposes including answering well-defined questions on soil management (e.g. soil tests to determine application rates for fertilizers; assessments of soil structure to guide choice of tillage), routine compliance testing for various engineering and construction standards (e.g. geotechnical properties of soils, assessing site suitability for effluent management), environmental impact assessment (particularly for mining approvals and large developments), estimation of soil carbon stocks, and investigations into environmental problems (e.g. levels of contaminants and site remediation planning). These investigations have the following features.

- Most data are collected by the private sector and these activities are often either commissioned or mandated by government policy or regulation.
- Soils are often sampled according to predetermined fixed depths. Sampling is often restricted to less than 20 centimetres depth.
- Most data and information is used only once.
- More standards (including official Australian Standards) are used for sampling and measurement.
- Most data are held in private data bases or published in the grey literature with limited public access.
- A significant proportion of the information has commercial value and is intended to generate private benefit.
- Data collection is by highly skilled professions through to individuals with limited training and this is often reflected in the quality of data.

The scientific community also collects a significant amount of research data although much is not specific to tactical soil management. However, most of the features listed above apply equally to the resulting datasets and information systems.

2.2.4 Statement of user needs for soil data and information

A number of user reviews have been conducted over the years by various organisations to assess general and specific soil data needs (eg Hassall and Associates 1998, Michalski 2000, DPI 2010). The 2011 *ASRIS/ACLEP User Needs Analysis (*Auricht and Wood 2011) report demonstrates emphatically that a broad range of users demand soil and land resource information. Groups with a requirement for this information include the Australian, State and Territory governments, research organisations, regional catchment management bodies, resource information centres, community groups, educational and tertiary institutions, landholders and the private sector. Auricht and Wood (2011) identified the following among their main findings:

- Most users require information pertaining to key soil attributes delivered (current and proposed) by ASRIS. Information requirements that are currently not met by ASRIS occur with respect to soil moisture, nutrition, toxicity, biology and carbon.
- The ongoing collection of site data is considered essential.

- Users want an easily accessible source of nationally consistent, authoritative, trusted and well documented soil attributes available as downloadable datasets.

To capture a broad range of perspectives on current soil information needs, a short questionnaire was circulated to participants of the December 2012 national workshop hosted by the National Committee on Soil and Terrain. Participants were encouraged to circulate the questionnaire widely, to capture a variety of user group perspectives. Responses were received from approximately 20 organisations, representing agricultural extension services, agricultural industry, agricultural and environmental consultancy, researchers, modellers, the education and extension sector as well as a broad range of policy and government service providers. Responses are summarised according to user groups in Table 2. They highlight the need for:

- consistent national data at a fine resolution, particularly in areas of intensive land use
- data on soil functional attributes, including hydraulic properties (plant available water, hydraulic conductivity), particle size distribution, bulk density, carbon (total and fractions), microbial biomass, pH, nutrients (nitrogen (N), phosphorus (P), potassium(K)), toxicities and the presence of physical and chemical constraints to plant growth
- greater emphasis on characterising the subsoil (current data are frequently restricted to the upper profile and do not represent the full root zone)
- the ability to monitor changes in soil condition.

Table 2: Statement of specific user needs for soil data and information

User groups	Soil data and information needs that are not currently met	Benefits anticipated from this data and information
Farmers and other land managers	• Farm and paddock scale data for soil functional attributes, including hydraulic properties (plant available water, hydraulic conductivity), particle size distribution, bulk density, carbon (total and fractions), microbial biomass, pH, nutrients (NPK), toxicities → the presence of physical and chemical constraints to plant growth • The above information for subsoil • NRM staff and other extension providers with adequate skills and knowledge to aid in interpretation and use of soil data products • Technologies for rapid fine-scale spatial characterisation of soil properties (for integration with precision agriculture) • Data linking management practices with soil condition	• Improved land management planning and decision making, including adapting to climate change • Improved crop and pasture planning, matched to farm or paddock land capability • Improved in-season agronomic decisions and use of inputs • Broader uptake of precision agriculture (PA) • More effective planning and monitoring of soil improvement programs and effects of management practices. • Ability to better estimate yield probabilities • More informed sowing decisions • Enable local and regional comparisons of production and financial performance
Agricultural extension services	• A better science base in soil biology • Soil functional attributes: water holding capacity (WHC), compaction, bulk density, chemical constraints (salinity, toxicities, sodicity, pH, nutrient deficiencies) • The above information for subsoil • Technologies for rapid fine-scale spatial characterisation of soil properties (for integration with precision agriculture) • Technologies to enable farmers to play a larger role in collecting soil information on their own farms • Monitoring sites for adequate change detection	• To improve quality and relevance of extension, including promoting improved understanding of soil processes and to assist with practice change • To promote improved soil management to meet production and sustainability goals • Enables benchmarking, setting targets and monitoring change associated with management practice • To develop whole of farm soil management plans to improve farm profitability, reduce risk and ameliorate areas of degraded land • To target particular soil types/properties that can be economically modified or managed to improve productive capacity • Improved irrigation system selection, design and operation for best water use efficiency
Agricultural industry/companies	• Improvements in open data arrangements, including a framework for allowing privately collected data to be captured for public use • Straightforward access to a national soil database that is regularly updated from ongoing public and private surveys	• Improved provision of data and advice • Improved standards and accreditation, e.g. for fertilisers/plant nutrition • Better targeting and support for soil improvement plans • To promote a focus towards soil as an asset & to encourage investment • Improved planning for regions undergoing major change e.g. mining and coal seam gas (CSG) development, climate change adaptation
Researchers	• Datasets underpinning research are required at a national, regional and paddock scale • Up to date, consistent, comprehensive national soil data (including indicators of soil condition, functional data) in fine resolution • Subsoil (root zone) data • Data on soil hydraulic properties, including non-wetting characteristics, drainage, available	• To identify trends and determine appropriate research responses • Targeted research for improved soil management and condition • To develop and improve decision support and farming system analysis underpinning management • To predict production, resource use and

	water content (AWC) • Scale of variation and temporal changes to soil properties including contemporary nutrient levels and subsoil constraints (strength, pH, toxicity, salinity)	greenhouse gas emissions • To inform government, regional and local NRM planning and management • Production of more accurate and useful products and advice
Modellers	• High resolution spatial layers for key physical, chemical and biological attributes: pH, particle size distribution (esp. clay content), soil carbon (and carbon fractions), soil constraints to plant production, soil depth, soil hydraulic properties, erodibility • Improved information on soil-plant interactions • Surface rock cover (to improve erosion estimates)	• To validate and improve models, e.g. for soil carbon, water erosion, water quality, as well as farming systems models such as APSIM • To more accurately predict the effect of management practices • To inform catchment models and catchment decision making e.g. managing soil erosion and nutrient runoff in Great Barrier Reef catchments
Land development planners	• Up to date, accurate site data and modelled data • Consistent regional and national data • Site costs to ensure mooted developments obtain acceptable environmental standards	• Improved, detailed planning recommendations based on accurate assessment of land capability • To inform policy development • To more effectively train, accredit and audit land development planning advisors
Policy, government service providers	• Up to date regional and national data, with high resolution in intensive land use areas. • Improved soil data coverage in areas where current data is limited e.g. ACT, NT, NSW, Qld • Better understanding of the linkages between soil characteristics and: productivity, environmental risk • Local scale (1:50 000) information on provision of soil ecosystem services • Site data and up to date modelled data for soil carbon (total and fractions), pH (including subsoil), erodibility, hydraulic conductivity, plant available water, particle size distribution (esp. clay content), bulk density, nutrients (NPK), toxicities (including subsoil), soil depth, current water and wind erosion • The above information for subsoil • Soil landscape mapping at sufficient scale for regional planning purposes • Monitoring sites for adequate change detection • Technologies for rapid soil assessment • A better science base in soil biology, including understanding the role of soil biology in nutrient cycling, and the impacts of land management	• To improve policy development informing land management decisions and land use • To establish benchmarks for soil condition, and to evaluate trends in soil condition related to management practices • To improve land resource assessment, capability and suitability evaluation, including the identification of important agricultural land & expansion of irrigation areas • To better target, support, monitor and evaluate projects focussed on improved soil management • To set realistic resource condition targets at a catchment scale • Allow for improvements in productivity and natural resource condition • Enhanced understanding of and measurement of ecosystem services • To better inform the users of land resource information, including peri-urban planners, land valuators, strategic planners
Consulting sector	• Up to date regional and national data, with high resolution in intensive land use areas. • Interpreted products utilising current site data including functional data (esp. soil hydraulic properties)	• To improve land development and management advice, including site impact assessments, remediation planning and validation. • Improved standards and accreditation for nutrition advisors

2.3 Strengths of our current soil-knowledge system

Australia's expertise in soil management and land resource assessment is recognised internationally even though our operational systems for mapping and monitoring soils have many shortfalls. Our strengths include:

- A strong grass-roots movement committed to improve soil and land management. This builds on one of Australia's great achievements in natural resource management, the Landcare movement.
- Innovative agricultural industries that adopt new and improved systems for land management (e.g. grains, cotton, sugar, grazing and dairy).
- A strong research and development capacity in sustainable agriculture across a range of institutions, with clear international leadership in some aspects of soil science.
- State and territory survey agencies that adopt new technologies for soil resource assessment.
- A small but active private consulting industry with some companies having substantial international portfolios.
- A rich understanding of Australian soils and landscapes – the lasting legacy of more than 80 years of work by several generations of pedologists, geomorphologists, and land resource surveyors.

By international standards, Australian soil scientists have done a great job in collecting and reusing legacy data. A considerable proportion of the good quality regional mapping data collected over the last 50 years has either been entered into, or used to update, state, territory and national databases. #

3. Stream structure for the enhanced Australian Soil Assessment Program

The purpose of the Program is to support Australia's sustainable future through improved knowledge of Australian soils and their responses to land management. The Program will integrate existing soil knowledge-systems and improve access to data and information. The soil data infrastructure will be overhauled and augmented with targeted field surveys and monitoring activities. It will produce greatly improved decision-support systems leading to widespread improvements in practical soil management. By 2020, the seven streams of activity within the Program will generate annual benefits of at least $2 billion per year.

Stream 1: Coordination and user engagement

Purpose and outcomes

This cross-cutting stream provides the mechanisms for identifying and setting priorities for the other six streams including liaison with government, industry and community stakeholders. It coordinates Program activities and ensures delivery and reporting. The stream facilitates the national cooperative network required between all tiers of government, the private sector and community groups to support the national mandate for improved soil information delivery. The stream produces the extension and training outputs from the Program.

This stream would build on the established and effective arrangements under the current Australian Collaborative Land Evaluation Program (ACLEP).

Activities and outputs

The stream includes the following activities.

- Program leadership, strategic oversight and coordination of activities across the seven streams.
- Monitoring and evaluation of the seven streams and overall tracking of progress towards the Program goal of generating benefits of $2 billion per annum by 2020.
- User engagement via a diverse range of mechanisms to ensure relevance and effectiveness of the Program's outputs.
- Development and delivery of soil information products to key stakeholders (e.g. soil management manuals, web services, apps for mobile devices (e.g. SoilMapp and extensions), customised maps and interpretations).
- Education and training on soil assessment (e.g. specialised short-courses through to targeted extension activities in priority regions).

Capability requirements

A program management team with the necessary administrative support and coordination capability is needed. Specialists are needed for the various communication, education and extension activities. Most of these specialists will be located at the four primary bases (i.e. in addition to the technical teams associated with streams two and three (described in the following pages). This is necessary to ensure regional delivery and relevance.

Budget

Stream No.	No. of people	Labour cost @ $200,000 per unit	Operational cost
1	Program leadership (4) Monitoring & evaluation (3) User engagement (5) Communication (5) Training and education (2) Extension (8)	$5.8m	$1m
Total cost			**$6.8m**

#

Stream 2: Coordinated soil survey and assessment

Purpose and outcomes

Stream 2 delivers the essential soil inventory (soil characterisation, mapping, land resource assessment) and landscape understanding on which all other activities are based. It provides an improved soil data and information asset for Australia which can be analysed by and incorporated across a broad range of scientific, development and land management initiatives.

Activities and outputs

At least four primary field bases need to be established across Australia to ensure economies of scale. Each base will be the headquarters for approximately five survey teams which may or may not be co-located. In Western Australia, teams could be located in Perth and several regional centres (e.g. Kimberley, Albany). The northern Australian base could be in either Darwin or Townsville with teams located at these sites and further south (e.g. Central Queensland). The eastern Australian base is most strategically located in one of the major regional centres (e.g. Toowoomba, Armidale, Orange or Canberra). The south eastern base could be established in Tasmania with regional teams in Adelaide and Bendigo.

This stream provides:

- a consistent set of soil data and information products across Australia
- the spatial framework for soil assessment in Australia
- context for more detailed investigations required for specific purposes (primarily private-sector activities).

Capability requirements

Each primary base will be home to approximately five field teams. Each field team includes the following capabilities:

- field pedologist, field technical officer, base support staff
- drilling and coring machinery
- excavation equipment
- proximal sensing capability
- field computing support (tablet computers, high accuracy GPS, satellite phones)
- efficient access to digital environmental information (including digital terrain variables, time-series remote sensing, airborne geophysical data)
- remote area off-road capability (4WD, base camp facilities)
- sample processing and field laboratory capabilities
- map production and editing facilities.

Each of the four primary field bases will have appropriate backup and support facilities. Each will also have a senior pedologist responsible for quality control and survey methodology. Some bases will have staff responsible for interpretation, education and extension activities.

Field teams will be responsible for all aspects of field data collection and mapping. They would also provide measurement capabilities for the monitoring program.

Budget

Stream No.	No. of people	Labour cost @ $200,000 per unit	Operational cost
2	20 (4 bases x 5FTE) 80 (4x5 teams of 4FTE)	$20m	$8m $10m
Total cost			**$38m**

Stream 3: Monitoring and forecasting soil change

Purpose and outcomes

Decision makers need information on the baseline condition of soils along with guidance on rates of soil change and key thresholds. Determining rates of soil change is technically very demanding and it is only in recent years that countries have built robust systems (e.g. Japan, South Korea, France, Switzerland). At present, various lines of evidence are used to infer rates of soil change with information coming from several sources including:

- long-term monitoring sites (from simple plots through to complex field experiments)
- simulation modelling
- proxies (e.g. paired sites where space is substituted for time, or monitoring changes in land management rather than soil variables directly)
- narratives (e.g. historical accounts of soil condition)

The cost of soil monitoring is substantial. To be useful, programs of soil monitoring must have the following features.

- A clear purpose and close links to decision-making or a scientific purpose.
- A measurement network of representative sites.
- Complementary programs of mapping and simulation modelling. The latter are undertaken to assess whether soil change can be detected in a reasonable time.

Modelling should also be used to help determine where to locate monitoring sites and to specify the frequency of measurement. Modelling can also be used to help extrapolate results from monitoring sites.

Activities and outputs

Investment is required to support activities that ensure a balanced approach. These activities form the national monitoring system for soil condition, namely:

- community and landholder programs
- industry programs
- statistically-based soil monitoring for high-priority issues
- soil monitoring as part of long-term ecological research.

This stream will build on recent investments into soil monitoring including those through Caring for Our Country, the Terrestrial Ecosystem Research Network and several state programs. Comprehensive guidelines for establishing and maintaining local and national soil monitoring networks will have to be completed at the outset. The stream will then establish monitoring networks in priority regions where soil change is suspected to be occurring or likely to occur.

Capability requirements

The capability requirements for the stream will be shared with Stream 2 although specialist statistical expertise is essential.

Budget

Stream No.	No. of people	Labour cost @ $200,000 per unit	Operational cost
3	2 (national coordination) 48 (6 teams across 4 bases with 2 per team)	$0.4m $9.6m	$0.4m $9.6m
Total cost			**$20m**

Stream 4: Information systems and data management

Purpose and outcomes

Web-based delivery of soil information requires a significant new investment into the expertise and facilities for analysing and managing large and complex information resources. The Australian Soil Assessment Program can utilise several foundational investments into information technology. These include:

- The existing Australian Soil Resource Information System and several state soil information systems.
- Information system design (i.e. informatics and principles of interoperability) developed by the Water Information Research and Development Alliance (WIRADA – Bureau of Meteorology and CSIRO).
- The new high-resolution digital elevation model developed by CSIRO, Geoscience Australia (GA) and the Australian National University (ANU).
- Time-series remote sensing products (GA, CSIRO and state agencies (e.g. QLD)) partly funded by the National Collaborative Research Infrastructure Strategy (NCRIS) Terrestrial Ecosystem Research Network (TERN) facility for remote sensing (AusCover).
- Software and design principles for web-based delivery (based on products from the NCRIS Atlas of Living Australia (biodiversity) and system design from NCRIS AuScope (earth sciences).
- National computing infrastructure and related infrastructure developed through NCRIS and the lead agencies involved in scientific computing (particularly CSIRO, ANU, Bureau of Meteorology, GA).
- Coordination and facilities being developed through the National Plan for Environmental Information (NPEI, Bureau of Meteorology).
- Prototype national digital soil mapping systems developed through the NCRIS TERN soil facility.

These foundational investments are more than $100 million. The new investment for the Australian Soil Assessment Program will yield significant returns from these prior investments.

Activities and outputs

The key focus of this stream would be a major overhaul of the Australian Soil Resource Information System (ASRIS). This would include new software development (e.g. direct links to proximal sensors and laboratory information systems, improved interoperability, new web interfaces, apps for mobile devices) and a significant investment to support better systems for governance and data sharing. Part of the overhaul involves more effective integration of several state and territory soil information systems. This will reduce the number of stand-alone database systems and should result in a more integrated national system. Some larger state agencies may still run their own systems but the general principle is to move to a federated national system. This process would be facilitated through the PISC RD&E process and include an agreed cooperative model for managing the system.

Capability requirements

The teams require advanced skills in database management and the delivery of web services. Options for computing infrastructure need to be reviewed because of rapid technological advances. A cost-sharing model with a distributed national data facility is one potential model. The central facility will need a data coordinator, data manager, data base administrator, web service manager and GIS operator. The other distributed facilities will need a similar complement of skills.

Budget

Stream No.	No. of people	Labour cost @ $200,000 per unit	Operational cost
4	7 (national coordination) 24 (nodes of the federated national soil information system)	$1.4m $4.8m	$1.2m $3.8m
Total cost			**$11.2m**

Stream 5: Laboratories and the Australian soil archive

Many of the soil properties of interest to the Australian Soil Assessment Program have to be measured in an analytical laboratory. Examples of such properties include soil carbon, phosphorous, nitrogen and water holding capacity. Even the new methods for directly measuring soil properties in the field using proximal sensors (e.g. infrared spectroscopy) require calibration with measurements made in an analytical laboratory.

There are many advantages in having a single national analytical laboratory. It may also be feasible to have several national laboratories that specialise in particular sets of analytical methods (e.g. soil chemistry and mineralogy, soil physics, soil biology). Countries such as the United States centralised their analytical facilities many years ago and the benefits included:

- economies of scale and lower unit costs through automation and the utilisation of more advanced processing and measurement systems that can only be afforded in a large facility
- tight quality assurance because full-time analytical specialists manage processing systems that operate continuously
- improved accuracy and precision through the application of consistent methodology (small differences in analytical procedures between laboratories result in large measurement differences even for routine variables such as soil pH – this seriously undermines the value of national datasets when they are compiled from multiple sources).

The main disadvantage of a national analytical laboratory is the need for efficient systems for packaging and transporting soil specimens from the field to the laboratory, including procedures to ensure full compliance with quarantine regulations. The United States and French systems provide good models for Australia.

Several government agencies and a few private companies have laboratories that could become the focus for a single national analytical laboratory[20]. No single laboratory currently has the facilities to provide the full range of analytical services. Establishing a single national facility requires a significant capital investment, however, these costs will most likely be outweighed by savings even in the short term because small and relatively inefficient laboratories can be decommissioned.

An associated national facility is a soil archive. Australia's national soil archive is managed by CSIRO on behalf of all soil and land resource agencies across the country. It was been formed through the amalgamation of more than 10 regional or project archives. Several states manage their own archives. The national soil archive has been valuable for many applications including:

- calibration of new analytical methods
- production of new national maps based on new measurements on the tens of thousands of geo-referenced specimens held in the archive
- provision of soil material for research purposes (e.g. investigation of charcoal composition in Australia's main soil types)
- secure storage of soil specimens from baseline monitoring sites.

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[20] These are currently being reviewed as an input into the Soil RD&E Strategy by George Rayment.

Upgrading storage and processing facilities and further development of the associated links to the Australian Soil Resource Information System will generate significant returns for the ASAP. A key principle is to mandate that all soil specimens collected in the field programs are accurately geo-referenced and stored in the national soil archive with associated data being lodged in the Australian Soil Resource Information System.

Budget

Stream No.	No. of people	Labour cost @ $200,000 per unit	Operational cost
5	Service laboratory*		$8.7m
	15 (archive)	$3.0m	$6.0m
Total cost			**$14.7m**

* In this table, labour costs for the laboratory are included in the operational costs because the split will depend on the nature of the laboratory and the service agreements.

These estimates assume the following levels of survey and monitoring activity.

- Survey: Minimum of 10 000 sites per year from 20 teams doing five sites per day for 100 days per year. Five samples per site with 10% being analysed at $300 each. Total of $1.5m.
- Monitoring: Seven jurisdictions with eight regions containing 100 sites that each require 30 samples. Total of 168 000 samples. Ten percent are analysed individually with the rest bulked to generate 25 000 samples at $300 each. Total of $7.2m.
- Archiving: 75 000 samples requires fifteen archivists with each processing 5000 samples per year. Labour costs $3.0m. Operational costs include $30 per sample archive consumables and other operational expenses to $3.0m.

Stream 6: Research, development and training

Australia does not currently have an organised investment program to support the development of new methods for mapping, monitoring and forecasting soil condition from local to continental scales. However this field, along with research into the soil carbon cycle, is one of the most internationally active areas of research in soil science. Australia is a recognised leader, particularly through the achievements of The University of Sydney.

In recent years, most investment into new methods for mapping, monitoring and forecasting soil condition has come from CSIRO, the Australian Research Council and The University of Sydney. Various lines of funding through Caring for Our Country, the Rural Research and Development Corporations (especially GRDC's investments into precision agriculture), NCRIS and state-based investments have also been significant.

A more strategic and prioritised research and development program is needed and this is being addressed through the PISC RD&E process. Planning is also underway for a new CRC on soils. These matters are beyond the scope of this report. However, the Australian Soil Assessment Program needs to be able to either commission research or have its own researchers working on new methods for measurement, mapping and monitoring. The fields of proximal soil sensing and digital soil mapping are now producing revolutionary new ways to undertake soil assessment. The Program has to be in a position to quickly adopt these new technologies to ensure maximum return on investment.

Budget

The annual funding for the research stream is a minimum to ensure maintenance of core scientific capability. It only relates to research into methods for mapping, monitoring and forecasting soil condition. The total soil science budget for research is much larger.

Stream No.	No. of people	Labour cost @ $200,000 per unit	Operational cost
6	10 permanent researchers 5 postdoctoral positions 10 postgraduates	$5.0m	$4.0m
Total cost			**$9.0m**

Stream 7: International engagement and development assistance

The global context for soil use and management is changing. Some of the global challenges noted earlier along with the emergence of international activities such as the Global Soil Partnership means that Australia needs to have an efficient and effective mechanism for international engagement. The development of the global soil information system and new reporting requirements (e.g. the Sustainable Development Goal of Zero Net Land Degradation) are significant developments. It is in Australia's national interest to ensure that the international assessments of soil health are based on our best available data rather than outdated or incomplete data sets (as is the case now).

The first aspect of this stream's work will deal with international engagement on technical matters relating to soils. This will involve contributing to the development of international standards and ensuring that international proposals are feasible and applicable to our soils and landscapes.

The second aspect of the stream's work is to coordinate and contribute to the development assistance activities that focus on soil resources. A significant but fragmented effort is already being directed towards training and capability development in soil resource assessment in our region (e.g. Indonesia, Philippines) and further afield (e.g. West Africa). Several Australian universities are ready to provide postgraduate training and other short courses but coordination and liaison with our development partners is required before this can happen.

The soil management problems in our immediate region are large. They range from acidification and nutrient depletion of recently cleared soils through to loss of fertile soils due to urban expansion and unsustainable rates of erosion in upland areas. A cohesive and coordinated approach to these problems through Australia's development assistance program can improve livelihoods and increase food security. The scale and scope of this activity needs to be guided by the key Australian agencies (e.g. AusAID, ACIAR).

Australian soil and land resource specialists are highly regarded internationally. Investment in this stream will generate enduring benefits for Australia (e.g. education sector) and our region (food security, sustainable land management, poverty alleviation). Both are in Australia's national interest.

Budget

Stream No.	No. of people	Labour cost @ $200,000 per unit	Operational cost[1]
7	Technical standards and global soil information	$6.0m	$3.0m
	Education and training[2]		
	Development assistance projects[2]		
Total cost			**$9.0m**

[1] Although operating costs estimated for this stream, they have not been included in the Program funding summary as this work is outside the scope of the Terms of Reference.

[2] Funding for these activities is not estimated here. Large investments are made via AusAID and ACIAR budgets.

Total Program budget summary

A summary of the labour and operational costs for each stream

Stream No.	No. of people	Labour cost @ $200,000 per unit	Operational cost	Total
1.	Program leadership (4) Monitoring & evaluation (3) User engagement (5) Communication (5) Training and education (2) Extension (8)	$5.8m	$1.0m	$6.8m
2.	20 (4 bases x 5FTE) 80 (4x5 teams of 4FTE)	$20m	$8.0m $10m	$38.0m
3.	2 (national coordination) 48 (6 teams across 4 bases with 2 per team)	$0.4m $11.2	$0.4m $8.0m	$20.0m
4.	7 (national coordination) 24 (nodes of the federated national soil information system)	$1.0m $5.6m	$1.0m $3.6m	$11.2m
5.	Service laboratory 15 (archive)	 $3.0m	$8.7m $3.0m	$14.7m
6.	10 permanent researchers 5 postdoctoral positions 10 postgraduates	$5.0m	$4.0m	$9.0m
7.	Technical standards and global soil information	[$6.0m]	[$3.0m]	[$9.0m][1]
Grand Total				**$99.7m**

[1] Although costs are estimated for this stream, they have not been included in the Program funding summary as this work is outside the scope of the Terms of Reference.

4. Options for improving the return on investment

4.1 Issues

The strengths of Australia's soil-knowledge system are notable, the weaknesses are significant. Most reviews of the soil-knowledge system highlight the institutional complexity, inconsistency of technical methods, limited economies of scale, ineffective mechanisms for funding and lack of long-term strategy (e.g. Beckett and Bie 1976, Hallsworth 1978, McKenzie 1990, Campbell 2008, Wood and Auricht 2011). The reasons for these weaknesses are reasonably clear and they include:

- All levels of government need reliable information on soil resources but no single level of government or department has responsibility for collecting this information on behalf of other public sector agencies.
- Public and private interests in soil are large and overlapping but mechanisms for co-investment by public and private agencies have not been developed.
- Market failure in relation to the supply and demand of soil information is a significant and widespread problem. In the simplest case, beneficiaries of soil information do not pay for its collection and this reduces the pool of investment for new survey and monitoring programs.
- Partly as a result of the above, most soil survey and monitoring activities are currently funded through short-term government programs, private companies, individuals or in response to specific regulatory requirements (e.g. Environmental Impact Statements). These have not produced the enduring, accessible and broadly applicable information systems that are needed to meet the requirements of nearly all stakeholders.

4.2 Solutions

A formal and enduring mandate for soil resource assessment has to be developed. One mechanism to achieve this could be the incorporation, by legislation, of soil resource assessment activities into one or more agencies. This mandate is essential because of the long timeframes required to build the soil resource information base and to monitor soil change over several decades. It requires the same discipline and long-term institutional commitment that Australia has made for weather, climate and water resource data.

The new investment and institutional model has to focus on both public and private sector needs. In particular, ensuring better online access to the information that we already have is needed. This includes improving access to the large quantities of soil test data currently collected across Australia.

There are four broad institutional options. More detailed analysis will be necessary to estimate the costs and benefits of each option. The options are listed in order of the likely ease of administrating and implementing the Program to achieve the maximum return on investment. Option 1 should achieve the best return.

Option 1: Bureau of Soil Resources

Option 1 is creation of a new Bureau of Soil Resources modelled on the much larger Bureau of Meteorology and Australian Bureau of Statistics. The Bureau of Soil Resources would have a legislated charter to serve all levels of government and engage with private sector activities to maximise the net benefit for Australia. The Bureau would undertake most of the survey, monitoring and technical activities outlined above. It would have a workforce of technical specialists and significant capital assets (e.g. field survey capability, laboratories, computing infrastructure).

The Bureau of Soil Resources could be administered by an existing agency to minimise administrative costs. It would have a regional structure consistent with the streams of activity outlined above.

Option 2: Mandated program within an existing Australian Government agency

Option 2 is establishment of a legislated program within an existing Australian Government agency (e.g. DAFF). The Program would have a central management team that coordinated the activities outlined in this report. However, many of these activities would be contracted out to either state and territory agencies or the private sector. The balance between in-house technical work and externally contracted work would require careful management to avoid the loss of corporate knowledge and intellectual capital that can occur with such arrangements.

Option 3: Cooperative Centre for Soil Resource Assessment

Option 3 involves the formation of a new organisation with a business model and structure similar to current arrangements for Cooperative Research Centres. The legislation and agreements supporting such a centre would differ from that of a CRC because of the requirement for the organisation to be enduring. The arrangements for co-investment, for example, would need a more secure arrangement than the relatively short-term commitments required by CRCs.

Option 4: Status quo

Option 4 is to maintain the status quo with the proviso that a formal agreement is reached between governments, preferably via the Council of Australian Governments (COAG). This agreement would define responsibilities and cost-sharing arrangements. It would also appoint a lead organisation to run the Australian Soil Assessment Program.

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The report also builds on ideas from a national workshop of soil information specialists from government, academia, industry and the community held in Canberra in Dec 2012.

7. List of acronyms

ACLEP – Australian Collaborative Land Evaluation Program

ANU - Australian National University

APSIM - Agricultural Production Systems sIMulator

ASRIS – Australian Soil Resource Information System

AWC – available water content

COAG – Council of Australian Governments

CSG – coal seam gas

CSIRO – Commonwealth Scientific and Industrial Research Organisation

DAFF – Department of Agriculture, Fisheries and Forestry

FAO – Food and Agriculture Organisation of the United Nations

FTE – full time equivalent

GA – Geoscience Australia

NCRIS - National Collaborative Research Infrastructure Strategy

NPEI - National Plan for Environmental Information

NPK – nitrogen, phosphorus, potassium (plant nutrients)

PA – precision agriculture

PISC – Primary Industries Standing Committee

TERN - Terrestrial Ecosystems Research Network

UNCCD – United Nations Convention to Combat Desertification

WHC – water holding capacity

WIRADA – Water Information Research and Development Alliance