Soil Monitoring Program Workshop Report

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Contents

Summary

The vision of the National Soil Research, Development and Extension (RD&E) Strategy (2014) is to secure Australia's soil for profitable industries and healthy landscapes. In support of the vision, the strategy identified the need to improve systems for monitoring change in soil condition over time and for stakeholders to agree to national standards for the sharing, monitoring and analysis of soil data. In 2017, the National Soils Advocate pointed to the importance of soil data and soil information, including the ability to share and apply this information. More recently, preliminary consultation by the Australian Government for the development of the new National Soil Strategy identified the need for national soil monitoring program, including agreed standards and data collection.

Governments are not always involved in, or aware of all soil monitoring activities occurring across most states and territories. Research institutes and the private sector undertake monitoring for discrete purposes as well as jurisdiction-based state of the environment reporting or similar. Despite this wide interest, there is no single purpose for soil monitoring, nor a unified or agreed application of the data from a coordinated program, and subsequently there is no standardised approach to soil monitoring at a national level. Although episodic and detailed sampling and analysis of Australian soils has occurred over the past 100 years, this often related to specific projects, or was linked to short-term funding that did not permit the ongoing longitudinal studies required to understand changes in soils over time. As a consequence, gaps exist in the soil information necessary to support policy and reporting at national and international levels.

As part of the National Soil Strategy the Commonwealth Department of Agriculture, Water and the Environment commissioned VenturePro to assist with a consultation process in May and June 2020 to engage with key subject matter experts and better understand future soil monitoring requirements. This consultation took the form of a series of online workshops and a questionnaire which sought to capture a range of relevant perspectives and experiences.

There is strong interest across all government jurisdictions, and from others consulted during this process, to collaborate in designing and implementing a long-term, coordinated and federated, National Soil Monitoring Program (NSM Program) that complements work already undertaken by individual soil agencies, research institutes, industry and the private sector.

For a collaborative partnership approach to soil monitoring to be successful, jurisdictions indicated that the NSM Program would need a well-articulated purpose, and clear expected outcomes and value-add. These would act as drivers for the selection of soil monitoring sites as well as standardisation of soil data and soil analysis requirements. There is broad consensus about the preferred methodology to be applied, and a desire to ensure that where possible, any current soil monitoring is continued and integrated into a co-ordinated national program.

Consultation suggested that while there were several high-level risks to implementation of the proposed NSM Program, success would depend on bipartisan support for long-term commitment from the Commonwealth, together with states and territories, that accounted for the variable rates at which soils change as well as the different soil properties that would to be monitored to maximise the value from the program for key stakeholders. Another key success factor will be the ability of the Department and partners to leverage the linkages between soil

policy across a portfolio of interests and, across different Departments. The focus is on improving soil health for the purpose of increasing agriculture productivity, protecting environmental assets, increasing abatement of greenhouse gas emissions and ecosystem services, improving education, securing food and markets and demonstrating the value of soils through natural capital accounting.

In this context, further work is required to design, validate, cost and operationalise the envisaged NSM Program. To assist the Department of Agriculture, Water and Environment's workshop participants made the following recommendations:

Recommendation 1: That an ongoing and funded NSM Program be established to enable long-term monitoring of changes in the condition of Australian soil.

Recommendation 2: In the context of the Guiding Principles, that work is undertaken to confirm the proposed NSM Program purpose and demonstrate the value of its intended outcomes through development of use cases.

Recommendation 3: That a cost-benefit analysis be undertaken to better articulate the value proposition for the NSM Program and to assist in securing future co-partnering and funding.

Recommendation 4: That a Steering Committee and Community of Practice be established to further refine the proposed collaborative and federated NSM Program model and to oversee development of a sustainable operating model.

Recommendation 5: That program design for the NSM Program includes work to:

- develop criteria to identify suitable monitoring sites for inclusion
- confirm the suite of soil data relevant to the NSM Program
- define standards and protocols for data management (including access and sharing for multiple purposes), and
- confirm the preferred methodology.

Recommendation 6: That a health check of those monitoring sites identified for inclusion in the NSM Program be undertaken to better understand their operating status and to create a baseline.

Recommendation 7: That a staged implementation approach for the NSM Program be adopted to build capability and to ensure appropriate program design, consultation and governance can be put in place.

Recommendation 8: That following a decision about the design of the NSM Program, costings be developed for consideration by the Steering Committee; and subsequently that funding be secured to undertake further development and design of the NSM Program.

Recommendation 9: That an evaluation strategy be developed to support implementation and future funding for the NSM Program.

Recommendation 10: That a Risk Plan be developed for the NSM Program.

1 Introduction

Soil is a finite, complex and fragile natural resource that plays a critical role in primary production, carbon and water cycles, and supporting biodiversity. As such, soil resources and landscapes must be measured and monitored carefully and efficiently so that changes in quality and function can be detected and appropriately managed. Many sectors of the Australian economy, including agriculture, infrastructure development and nature conservation use soil data for planning and development and to ensure sustainable soil management practices.

Soil is a fundamental natural resource and its condition and use has a major impact on the economy and human health. Soil condition information is required to support critical decisions related to local, regional, national and international issues such as food security, environmental sustainability, carbon and greenhouse gas accounting, water availability and use (Grealish et al. 2011).

The National Soil Research, Development and Extension (RD&E) Strategy (2014) has a vision to secure Australia's soil for profitable industries and healthy landscapes (Appendix A). In support of this vision, the RD&E Strategy identifies the need to improve systems for monitoring change in soil properties over time, and seeks agreed national standards for soil data including sharing, monitoring and analysis.

On 18 July 2019, the Prime Minister made a commitment to a national focus on soil, based on a recommendation of the National Soils Advocate for a national soils policy outlined in his report – *Restore the Soil: Prosper the Nation* (National Soil Advocate, 2017). The development of a National Soil Strategy will be led by the Commonwealth Department of Agriculture, Water and Environment, but in collaboration with all states and territories, as agreed at the Agriculture Ministers Forum in October 2019. The Strategy is to be completed by June 2021. The National Soil RD&E Strategy developed in 2014, provides a strong foundation for the development of a National Soil Strategy. The Australian Government will engage with the Australian Soil Network to establish how the two strategies will work together.

Deficiencies in the national monitoring of soil condition adversely impact on various sectors where soil information is critical for informed decision making. These deficiencies also limit the capacity for reliable trend analysis and forecasting. As a result, calls for improved arrangements to achieve greater, more efficient access to soil information have continued since the release of the National Soil RD&E Strategy, with these analyses pointing to ongoing market and institutional factors affecting the provision of soil information (Grundy et al. 2015). Having a national NSM Program would enhance Australia's ability to appropriately monitor and forecast across a range of policy and operational settings where accurate and timely soil information is required and will be a key priority under the new National Soil Strategy.

1.1 Policy Imperatives

Increasingly, public policy imperatives drive the need to better understand our soils and to have relevant data and information readily available. Some of the policy imperatives for government and industry are outlined below. These linkages contribute to the mandate for an ongoing NSM Program. They also suggest possible future areas of collaboration across government, between tiers of government, and between government and partners in industry and academia.

1.1.1 Soil Health Security

Soil health security is motivated by sustainable development and is driven by the need to: secure food and fibre production that is not only productive, but profitable; preserves our biodiversity; and contributes to our water and climate sustainability (Bennett et al. 2019).

An emerging issue is the loss of agriculturally useful soil due to increased and expanding urbanisation, with urban and peri-urban development encroaching into agricultural green-fields and flood plains around our cities. This results in the alienation of highly productive and agricultural soil and a loss in productivity (Millar & Roots 2012).

1.1.2 Sustainable Food Production

The Australian Government has a goal to double agricultural production by 2030, and in 2019 the House of Representatives Standing Committee on Agriculture and Water Resources launched an inquiry into growing Australian agriculture to $100 billion by 2030. This could be seen as an economic opportunity that responds to global consumer demand and regional economic development expectations to produce greater quantity and quality of food, fibre and bio-fuel with less arable land and declining water reserves. To respond to this demand, it has been argued that 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 (NCST 2014).

Even so, in 2013, Australia's investment in soil information lagged behind other OECD countries and was below international standards. At that time, Australia's investment in soil mapping was nine times less than that of other OECD countries (NCST 2014).

Loss of high quality agricultural land over time due to urban and peri-urban expansion may also threaten the nation's ability to efficiently produce food on its most versatile and suitable soils. As a consequence, agriculture will be forced to produce food on poorer soils in less attractive climatic zones placing increased demands on water resources and potentially threatening the soil resource itself due to production demands exceeding the soil's capability.

1.1.3 Market Access

Australia has a deserved international reputation for high quality, safe, food production. In 2019 ABARES identified that the agricultural sector was 2.7 per cent of Australia's total gross domestic product (GDP) (Jackson et al. 2019). The gross value of Australian farm production in 2019, according to ABARES, was estimated to remain around $AU61 billion (Cameron et al. 2019). Data that assists supply chains, enables product traceability and supports reporting on the economic and environmental sustainability of our agricultural systems is central to Australia's continued access to, and competitiveness in global markets.

1.1.4 Environmental Sustainability and Ecosystem Services

In 2012-13, land accounted for 80 per cent of Australia's environmental assets and was estimated to be worth around $AU3860 billion (Williams 2015). Recognising the importance of soil health for Australia's future, the *State of the Environment Report* noted in 2011 that four trends (acidification, carbon decline, soil erosion and dryland salinity) were key threats to soil function having serious consequences, both economically and environmentally, for Australia (SoE Report 2011). The 2016 SoE Report confirmed that these pressures were continuing along

with the impact of climate-change, land-use change, habitat fragmentation and degradation and invasive species (SoE 2016).

Comprehensive, timely and accurate data about these matters (amongst others) underpin our knowledge of environmental sustainability and the potential to target relevant management intervention to areas of highest risk. For example, the FAO Global Soil Partnership Status of the World Soils Report identifies key threats to soil function (FAO 2015). Temporal soil information would enable monitoring and modelling of soil state and trend analysis and reporting of Australia's environmental sustainability. Such information will be vital to initiatives of natural capital accounting and for national reporting through the System of Environmental Economic Accounts. A comparator for Australia is the work undertaken in New Zealand by the Land Monitoring Forum where ecosystem services and natural capital accounting have been implemented (Mackay et al. 2013).

1.1.5 Meeting Australia's International Obligations

Progress on many of Australia's international trade, environmental, climate change and world heritage obligations are guided by policies that depend on comprehensive and reliable soil monitoring and forecasting capability. These include:

- United Nations Framework Convention on Climate Change (UNFCCC) reporting requirements including those related to the Kyoto Protocol and the Paris Agreement
- UN Convention on Biological Diversity (UNBCD) requirements for national reporting
- 2030 Agenda for Sustainable Development (particularly SDG 15.3)
- United Nations Convention to Combat Desertification (UNCCD) Sustainable Development Goal of Zero Net Land Degradation
- World Heritage Convention
- State of the Environment reporting
- Various voluntary agreements such as Intergovernmental Negotiating Committee on Desertification (INCD) and the Revised World Soil Charter and international reporting requirements under the Food and Agriculture Organization of the United Nations (FAO) Global Soil Partnership.

1.1.6 Innovation

Opportunities exist across government, and more broadly across the soil sector, to use soil data and soil information to foster innovation, for example greater implementation of precision agriculture (Barry et al. 2017). Investment in soil monitoring by governments will drive innovation that will benefit agricultural production. In turn, increased availability of soil information will foster innovation in the private sector and will inform better decision making and the allocation of private sector investment, and lead to increased economic output, both direct and indirect. For example, developing and applying advanced monitoring and remote and proximal sensing devices and data sources such as satellite sensing and high-tech observations (gliders, acoustic dopplers, infra-red spectrometers and soil moisture sensors) would provide a step change in quality and value from the standard tools and processes currently available.

1.1.7 Drought Resilience

The Australian Government is helping Australian agriculture to prepare for drought resilience and for future climate change and uncertainty through the *Future Drought Fund Act 2019*. This Act will provide $AU100 million annually to support Australian farmers and communities (DAWE 2019). National soil monitoring will help Australian farmers to better prepare for future droughts by understanding the ability of their soils to hold moisture and show resilience under long term dry conditions.

1.1.8 Prioritising, Monitoring and Evaluating Public Investment

The Australian Government, along with state and territory governments, make significant investments of public funds in activities related to soil management. It is important that these investments are well prioritised, well monitored and well evaluated. This relies on effective monitoring of soil condition to help identify priorities for investment, and to monitor changes over time as a result of investment.

More specifically, effective soil monitoring helps to identify soil conditions and constraints that could be limiting agricultural production or having a broader environmental impact and which could be addressed by targeted research and development, either with government investment or with industry investment.

1.2 Previous Attempts at National Soil Monitoring

Since 2010 there have been several attempts to design and implement a soil monitoring program nationally.

1.2.1 2010 Proposal

Baldock et al. argued in 2010 that it was not necessary to capture changes in soil condition at all sites nationally. Instead, a defined subset of prioritised sites in which temporal trends could be identified within regions would be desirable (Baldock et al. 2010). The report set out an approach to selecting regions, monitoring units and monitoring sites, along with sampling methodologies.

This report proposed a soil monitoring program that provided identification and assessment of soil variables such as Carbon and pH that exerted some level of control or influence over multiple soil properties, arguing that this would provide the greatest return on investment. The approach emphasised the need for reliable estimates of change in soil organic carbon and acidity (pH) across Australia. This would be possible if the monitoring program relied on a justified and well documented set of sampling and analytical protocols that could be used to provide reliable estimates of the soil properties being examined.

The 2010 proposal envisaged that a national monitoring program would be a collaborative initiative between CSIRO, the Federal Government and relevant state and territory agencies. It would extend current arrangements under the Australian Collaborative Land Evaluation Program (ACLEP) overseen by the National Committee on Soil and Terrain. A sub-committee of the NCST would oversee the operations of the program – with this governance and accompanying technical arrangements to be developed at the start of the operational phase.

1.2.2 2011 Proposal

The approach suggested by Grealish et al. (2011), built on the model of Baldock et al. (2010). Further refinements were made based on the Atlas of Australian Soils boundaries which provided improved spatial detail, consideration of the investment priority regions, and assessment by experts from each jurisdiction.

Grealish proposed that a national soil monitoring program would need to operate for no less than a decade and be on-going to enable longitudinal data to be obtained for analysis. To support this, a governance arrangement to address operational, privacy, intellectual property and cost sharing would require agreement between all jurisdictions. The proposal also identified roles for each jurisdictional representative, along with a national team to coordinate the proposed program, a central analytical laboratory, and an oversight committee comprised of data users, and members of the National Committee on Soil and Terrain (NCST).

1.2.3 2014 Proposal

A presentation was made to the NCST in 2014 about how to better manage soils in Australia. One component of this presentation dealt with soil monitoring. It was thought that some of the funding for soil monitoring would come from redirected and better coordinated activities already underway. Key features of the Australian Soil Assessment Program (ASAP) proposal, costed at $99.7 million, were seven streams:

- Stream 1: Coordination and user engagement
- Stream 2: Soil data collection, survey and assessment
- Stream 3: Monitoring and forecasting
- Stream 4: Information systems
- Stream 5: Support facilities
- Stream 6: Research and development
- Stream 7: International engagement (NCST 2014).

1.2.4 SCaRP

The Soil Carbon Research Program (SCaRP) was a nationally coordinated program of soil carbon research bringing together researchers from the CSIRO, universities and state government agencies. Funding was provided by the Australian Government's Climate Change Research Program as well as the Grains Research and Development Corporation (GRDC). The project commenced in April 2009 and concluded in June 2012 having coordinated 13 soil carbon research projects that together established a strong scientific basis for soil carbon measurement and accounting and for soil carbon enhancement (sequestration) (Rose, 2016).

1.2.5 TERN

The Terrestrial Ecosystems Research Network (TERN) measures key terrestrial ecosystem attributes over time from continental scale to field sites at hundreds of representative locations and openly provides model-ready data that enables researchers to detect and interpret changes in ecosystems. The aim of TERN AusPlots is to establish and maintain a national network of plots that enables consistent ecological assessment and ongoing monitoring of Australian ecosystems. As at November 2016, AusPlots had completed baseline assessments at over 550 plots across

the country. AusPlots collects a range of field data for integration with additional existing data sources and current knowledge. AusPlots undertakes in-situ surveillance monitoring to collect baseline data on soils and vegetation for use by the broader ecological and management community to:

- increase the understanding of the dynamics of plant species and soils
- progress knowledge on distribution, abundance and threats to ecosystems
- increase the knowledge of carbon and nutrient budgets of soils and vegetation
- input into DNA barcoding of Australian vegetation and soil communities
- determine the genetic and phylogenetic diversity, and biogeography of the continent
- assist in the field validation of remote sensing products
- assist state and federal agencies to meet monitoring and reporting obligations, and
- create a photographic reference of key Australian bioregions, enhance existing State photo reference libraries (TERN 2016).

1.3 Value Proposition for National Soil Monitoring

As these previous examples show, there has been a long-standing need to monitor Australia's soils, to understand their condition and the impacts of changes to that condition over time. With the 2019 Prime Ministerial announcement, the creation of the National Soil Advocate and work underway for a new National Soil Strategy led by the Commonwealth Department of Agriculture, Water and the Environment, there is an opportunity to use this renewed emphasis on soils to secure funds for a NSM Program.

In addition, the wide range of policy imperatives noted above provides evidence of the importance of soil and soil information across many areas of public policy as well as for Australia's future well-being. Over time, this body of information will contribute to the intrinsic value of the NSM Program as the utility of the information is better recognised and understood both across the policy spectrum but also by researchers and industry.

These factors provide a social license for progressing the NSM Program at this time.

Recommendation 1: That an ongoing and funded NSM Program be established to enable long-term monitoring of changes in the condition of Australian soil.

2 Consultation

An intensive consultation process in May and June 2020 engaged a range of subject matter experts and stakeholders to better understand future soil monitoring requirements. A key part of this work was to bring together stakeholders and soil experts to discuss policy drivers for a national NSM Program and to reach a consensus on priority outcomes, program options, potential stakeholder investments, and to identify linkages to other complementary work such as a possible National Soil Information Framework (NSIF) being considered by the Australian Soil Network (ASN). A list of stakeholders and experts invited to participate is at Appendix B.

2.1 Workshops

A series of workshops were scheduled in May and June 2020.

- **Friday 8 May** – To prepare for the three main workshops, an initial planning discussion occurred with a select group of experts, including those involved in the NSIF for the ASN. This discussion provided guidance about a questionnaire for workshop participants and the proposed workshops with the wider stakeholder group.
- **Thursday 14 May** – This was an introductory online workshop to describe the intent of the current project and gather initial input. This online workshop ensured participants understood the project, its timeline and intent. It provided an opportunity to ask any questions about the out-of-session work required prior to the online workshop on 22 May.
- **Friday 22 May** – This online workshop sought to build on the written out-of-session input. This online workshop:
  - explored the number and location of soil information sites;
  - identified the linkages between program outcomes, possible data, monitoring methodologies and site locations;
  - enabled participants to expand on any jurisdictional concerns/issues and the interest organisations/jurisdictions have in possible cost-sharing;
  - sought to identify a way forward, for example via a pilot site or sites.
- **Thursday 11 June** – This workshop sought feedback/validation on the draft Workshop Report and clarification of any issues that remained.

2.2 Questionnaire

Due to the complexity of the subject under consideration, and the use of exclusively online workshops, a questionnaire was developed to seek out-of-session views from proposed workshop participants and other stakeholders (Appendix C). These stakeholders included government, academia, industry and not-for-profit organisations. Questionnaire responses informed the online workshop discussions, and the contents of this Workshop Report.

2.3 Further Consultation

Those consulted during the current round of workshops were asked to identify any further stakeholders who might be relevant for future consultation, and co-design work as part of the implementation phase of an NSM Program. The list of suggested further stakeholders is at Appendix D.

3 Environmental Scan

3.1 Status of Current Soil Monitoring

As part of the consultation process, participants provided input to a high level environmental scan to better understand the current soil monitoring arrangements across Australia, and to identify what future requirements might be (Figure 1).

This scan identified that all jurisdictions have an interest in future soil monitoring, but that there are challenges to be addressed.

3.1.1 Challenges

The main challenges faced across those consulted included:

- a lack of ongoing funding and resources to enable the longitudinal sample collection needed to understand changes in soil over time,
- inability to access the full range of soil data available, since much of it is collected by private companies and individuals, and as such, is not available for assessment by others,
- some capability gaps because of fewer resources available,
- maintaining established collaborative arrangements across government agencies and between governments, research institutions and industry, and
- shifting or adapting existing soil monitoring programs to any future national standards.

3.2 Use of Soil Information

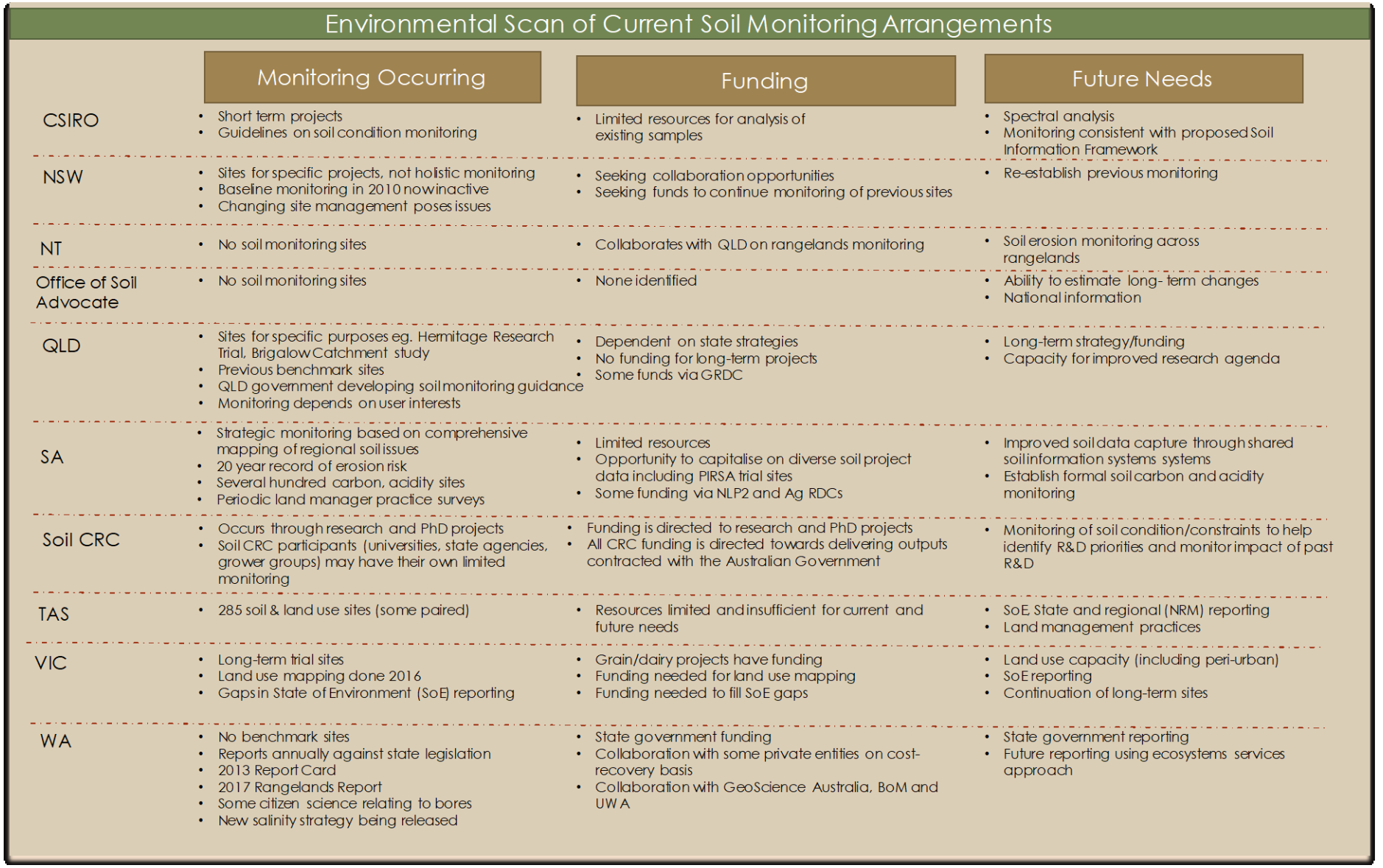
Participants (Appendix B) were asked to identify the purpose for, and frequency of, their access to soil data and soil information. Some participants sought input from other colleagues and networks to complete the questionnaire. From the responses provided, across jurisdictions and organisation types (government departments and agencies, academics, researchers, not-for profit organisations) participants reported that they used soil information for many purposes (Table 1). This list is not exhaustive, but does provide a high level indication of the importance of soil information across the sector. Further work could be done within the NSM Program to identify the primary users of soil information and to refine and document the purposes for which soil information is used.

Table 1: Soil Information Used

Activity	Usage
2030 Agenda for Sustainable Development (particularly SDG 15.3)	Used in an ongoing and occasional way by Newcastle University, CSIRO, Soils for Life, Soil CRC Used by WA for overseas Aid program but not for Australian work
Agricultural production	Used weekly or monthly by the majority of those consulted, Soil CRC uses daily

Activity	Usage
Contributing to scientific knowledge on landscape processes (e.g. for soil science, hydrology, ecology, geomorphology, exploration geoscience, and the earth-system sciences more generally)	Used weekly or monthly by all those consulted (Soil CRC uses daily as does WA government)
Determining the location of corrosive and expansive soils to ensure appropriate engineering design and location of major infrastructure	Used occasionally by the CSIRO, and researchers at the Soil CRC, occasionally by QLD government and twice per year by Victorian government.
Food and Agriculture Organization of the United Nations (FAO) Global Soil Partnership reporting	Used frequently by CSIRO, annually by Australian Government departments, occasionally by the Soil CRC and WA Government, once per year by the WheatbeltNRM
Intergovernmental Negotiating Committee on Desertification (INCD) reporting	Annually by Australian Government departments
Kyoto Protocol reporting	Used occasionally by CSIRO and annually by Australian Government departments
Land-use planning	Used weekly or monthly by many of those consulted, including the Soil CRC
Mapping and managing acid sulfate soils in coastal/inland environments	Used occasionally by Soil CRC, quarterly by some other researchers, and occasionally by CSIRO, WA Government and QLD Government
Paris Agreement reporting	Annually by Australian Government departments
Revised World Soil Charter reporting	Used rarely by CSIRO
Setting environmental baselines for contaminants and implementing effective rehabilitation practices for contaminated lands	Victoria is a lead agency on this topic, University of Newcastle uses monthly, the Soil CRC and NSW use infrequently
State of the Environment reporting	University of Newcastle uses monthly, Victoria, SA and WA uses once every 3 years, WheatbeltNRM uses annually and for longer reporting cycles, NSW and Soil CRC use rarely
Understanding the characteristics of soils to ensure successful rehabilitation of areas used for mining and waste-disposal	University of Newcastle uses monthly, NSW and WA governments use occasionally and Soil CRC uses rarely.
United Nations Convention on Biological Diversity (UNBCD reporting	Annually by Australian Government departments
United Nations Framework Convention on Climate Change (UNFCCC) reporting	Annually by Australian Government departments
World Heritage Convention reporting	Annually by Australian Government departments

Figure 1: Environmental Scan of Current Soil Monitoring Arrangements



4 Guiding Principles

In developing the NSM Program, including the various aspects of program design discussed later in this report, a series of guiding principles were identified by workshop participants. These are:

- A collaborative approach will be adopted to progress the NSM Program and to foster data sharing and improved knowledge about soil,
- As partners, the Commonwealth and all states/territories will be invited to participate in a Soils Monitoring Community of Practice,
- The NSM Program recognises and leverages existing soil data, soil monitoring programs and soil monitoring experience,
- The NSM Program is evidence-based and scientifically robust, guided by the best available scientific research and expert knowledge,
- The NSM Program will be implemented on a co-investment basis supported by agreements that foster success and future innovation,
- New, diverse funding streams and partners across the soil sector are secured to sustain outcomes,
- A long-term commitment, supported by a monitoring mind set will underpin the NSM Program,
- Outcomes will be clear and measurable, and
- Effective program management and evaluation will support future adaptation of the NSM Program.

5 Program Purpose and Outcomes

5.1 Purpose

All those consulted agreed that a clear statement of purpose was required for any NSM Program. Setting the parameters of the proposed program will assist with potential co-investment decisions from states/territories and others in the soil sector.

A possible purpose statement is:

The National Soil Monitoring Program provides a collaborative federated mechanism to deliver longitudinal soil information and assessments for improved decision-making, policy outcomes and research to drive the sustainable management of soils for all Australians.

5.2 Outcomes

The consultation identified that establishing a clear set of outcomes for a future NSM Program was an important and foundational piece of work. These outcomes would underpin program design, including:

- Sampling locations, sites and cycles
- Sampling standards that set out the samples to be collected and the timing/type of analysis required
- Sampling methodologies
- Program guidance and related tools.

5.2.1 Draft Outcomes

Noting that further work is required to validate and refine a set of possible NSM Program outcomes, the consultation identified the following outcomes (in rank order):

- Demonstrating the relationship between soil condition and land management practices, which will support on-farm decision making and government policy and program development at a national level,
- Identifying and developing a more robust approach to defining 'fit-for-purpose' activities that optimise the long-term, sustainable use of land,
- Improving understanding of the impact of drought, natural disasters and climate on soil health and productivity, including determining drought conditions and areas of need,
- Contributing to the development of new models to estimate and predict soil conditions, such as exploring options to utilise remote sensing technologies to help measure changes in soil carbon and other soil properties,
- Building soil monitoring capacity across sectors,
- Informing and supporting work relating to natural capital accounting,
- Improving information to support Australia's national and international reporting obligations (eg. greenhouse gas emissions under international obligations such as the

United Nations Framework Convention on Climate Change, soil carbon estimation for emissions reduction), and

- Improving understanding of Indigenous land management practices and how these contribute to soil health.

5.2.2 Potential Additional Outcomes

Consideration could also be given to high level outcomes that relate to better understanding of the soil biome as a whole as well as in discrete locations; to the practical and timely application of soil data to a variety of policy, agricultural and industry settings; to establishing a soil condition baseline; to better supporting decisions about the potential strategic purchase of key land parcels; and to enable soil/ecological investigations to rehabilitate with native ecosystems.

Further work will be required to test whether any of these suggestions could be included in the final group of NSM Program outcomes agreed.

5.2.3 Use Cases

Noting the policy connections for soil across government and the multifaceted interactions across the sector, work could be undertaken to prepare a series of targeted use cases that would provide rigor about the benefits expected from delivering the NSM Program outcomes. These use cases will assist further engagement with stakeholders and support future partnership and funding discussions.

Recommendation 2: In the context of the Guiding Principles, that work is undertaken to confirm the proposed NSM Program purpose and demonstrate the value of its intended outcomes through development of use cases.

5.3 Cost-Benefit Analysis

Having established the purpose and outcomes for the NSM Program, an important early piece of work will be a Cost-Benefit Analysis. The benefits identified in the use cases would inform the Cost-Benefit Analysis undertaken to:

- establish the value of the NSM Program to the Australian community,
- lay the foundation for later work that will be undertaken to evaluate the NSM Program, and
- support funding proposals to all levels of government (and potential investors outside of government).

Recommendation 3: That a cost-benefit analysis be undertaken to better articulate the value proposition for the NSM Program and to assist in securing future co-partnering and funding.

6 Model

A model for a future NSM Program (Figure 2) was developed with subject matter expert input. Building on the Guiding Principles, this model is designed with collaboration and scientific excellence as foundations.

6.1 Features of the Model

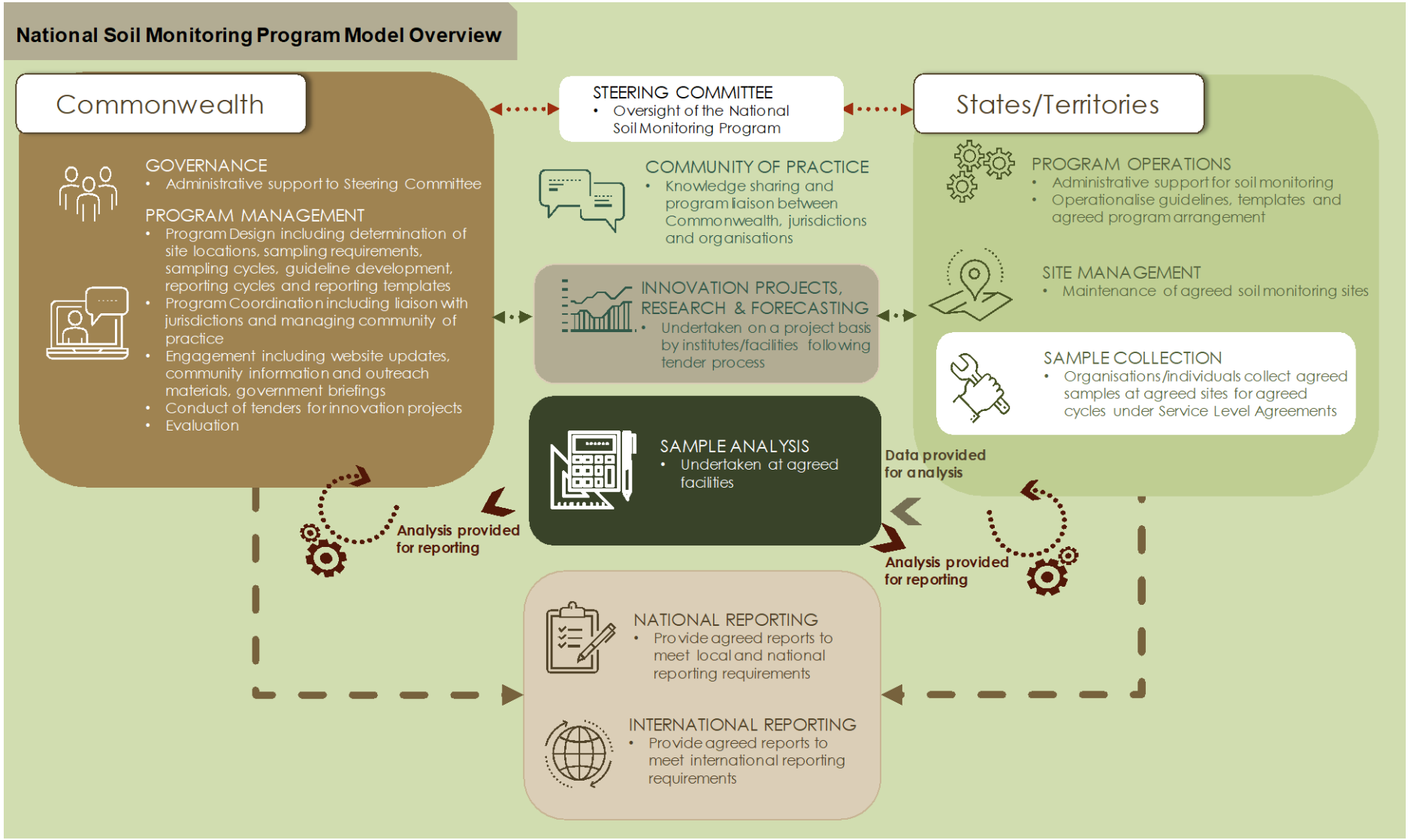
Key features of the model include:

- Program lead and oversight resting with the Commonwealth which provides overall funding with co-investment from states/territories,
- Establishment of a Steering Committee (drawing on subject matter experts and/or an existing entity such as the NCST or ASN),
- States and territories operationalise the NSM Program through agreements with the Commonwealth,
- Soil samples are collected according to service level agreements (either by technical staff employed by states and territories, and/or by individuals and organisations outside government on a fee for service basis),
- Use of existing accredited analytic laboratories for soil analysis,
- Use of enhanced state and national soil information systems to allow sharing, collation and analysis of standardised soil monitoring data,
- Reporting for key national and international requirements undertaken by the Commonwealth and states/territories using the information standardised via the NSM Program,
- A series of innovation projects initiated, funded and managed by the Commonwealth to improve soil monitoring,
- Establishment of a Community of Practice to support the NSM Program, and
- Ongoing engagement and outreach with the Australian community and soil information stakeholders, including across government policy areas with soil touchpoints.

It will be important to establish the Steering Committee as a priority so that it can take forward the necessary governance and decision-making about the NSM Program model and the related program design for it.

Early establishment of the proposed collaborative Community of Practice will provide further information to support the NSM Program's design and will strengthen stakeholder relationships.

Figure 2: A Model for a National Soil Monitoring Program



6.2 Soil Sample Collection Options - Pros and Cons

Participants identified that there was a need to have flexibility about who collected soil samples. This would enable jurisdictions to build on collection arrangements for projects already underway while allowing the NSM Program soil sample collection to evolve as new partnership and collaboration opportunities emerged. In practice this allows a hybrid of collection arrangements that are best suited to each jurisdiction. Jurisdictions would be able to seek new partnerships, provide additional funds and establish projects outside of, or alongside, the NSM Program. In situations where this additional sample collection by jurisdictions met the criteria and requirements for the NSM Program, they could be included in the Program.

Table 2 provides a summary of the pros and cons of collecting soil samples by in-house technical staff and through external fee for service arrangements.

Table 2: Pros and Cons of the Soil Sample Collection

	Option 1 Technicians within jurisdictions	Option 2 External Fee for Service approach
Pros	• Greater capacity to manage program activity, including collection and reporting • Soil data collection staff required by jurisdictions can increase regional employment • Soil collection staff can strengthen relationships between government and other elements of the soil sector • Greater flexibility within a single team to adapt priorities and respond to changing public policy needs for soil data	• Greater flexibility in partnership arrangements across the soil sector • Greater flexibility in potential future sites to be included in the NSM Program (i.e. some could be from the private sector) • Greater flexibility in managing the cyclical nature of soil data collection
Cons	• Employment of permanent staff may not meet the cyclical aspects of soil data collection • Investment is required in technical equipment and professional development	• A risk-managed compliance/quality assurance approach will be required to oversee data collection undertaken by external parties • Certifications of private operators may be required • A mechanism to manage payment and other administrative aspects of agreements with external parties will be required • Costs for collection may be higher • Remediation may be needed if organisations do not fulfil their soil sampling obligations

Recommendation 4: That a Steering Committee and Community of Practice be established to further refine the proposed collaborative and federated NSM Program model and to oversee development of a sustainable operating model.

7 Soil Information for the Future

The consensus view from those consulted was that while there was the potential for a wide range of soil attributes to be monitored, the decision about what would be mandated for the NSM Program will rely on the outcomes agreed for the Program. Development of these standards for data to be included in the NSM Program would form an important early piece of work.

Figure 3 provides an overview of the types of soil data considered useful by those consulted, and could be used as a starting point for further consideration following confirmation of the agreed NSM Program outcomes.

In addition, the subject matter experts consulted identified that, into the future, soil data has a multitude of potential purposes across policy areas, research and in relation to emerging technological advances that assist in collecting soil data, analysing soil data and forecasting on the basis of soil data. An example of the connections between soil data, information, product and policy layers for carbon is at Figure 4.

Noting this, the following issues would need to underpin any standards devised for the NSM Program:

- Meets best practice,
- Codified for long term monitoring,
- Deliver a broad suite of data that has applicability over time for a range of different purposes,
- Enable any necessary national and international reporting, and
- Have the potential to meet future innovation in research, data analysis, and community focus.

An expanded table of the soil data that could be considered for inclusion in the NSM Program, along with the purposes for which it is used, is at Appendix E. Further work would need to be undertaken in the Program Design stage of the NSM Program to refine this list and determine which data will be included. Data that is not include in the NSM Program could still be collected, analysed and funded by jurisdictions for their own purposes or projects.

Figure 3: Soil Data Mapped by High Level Categories to Potential Soil Monitoring Outcomes

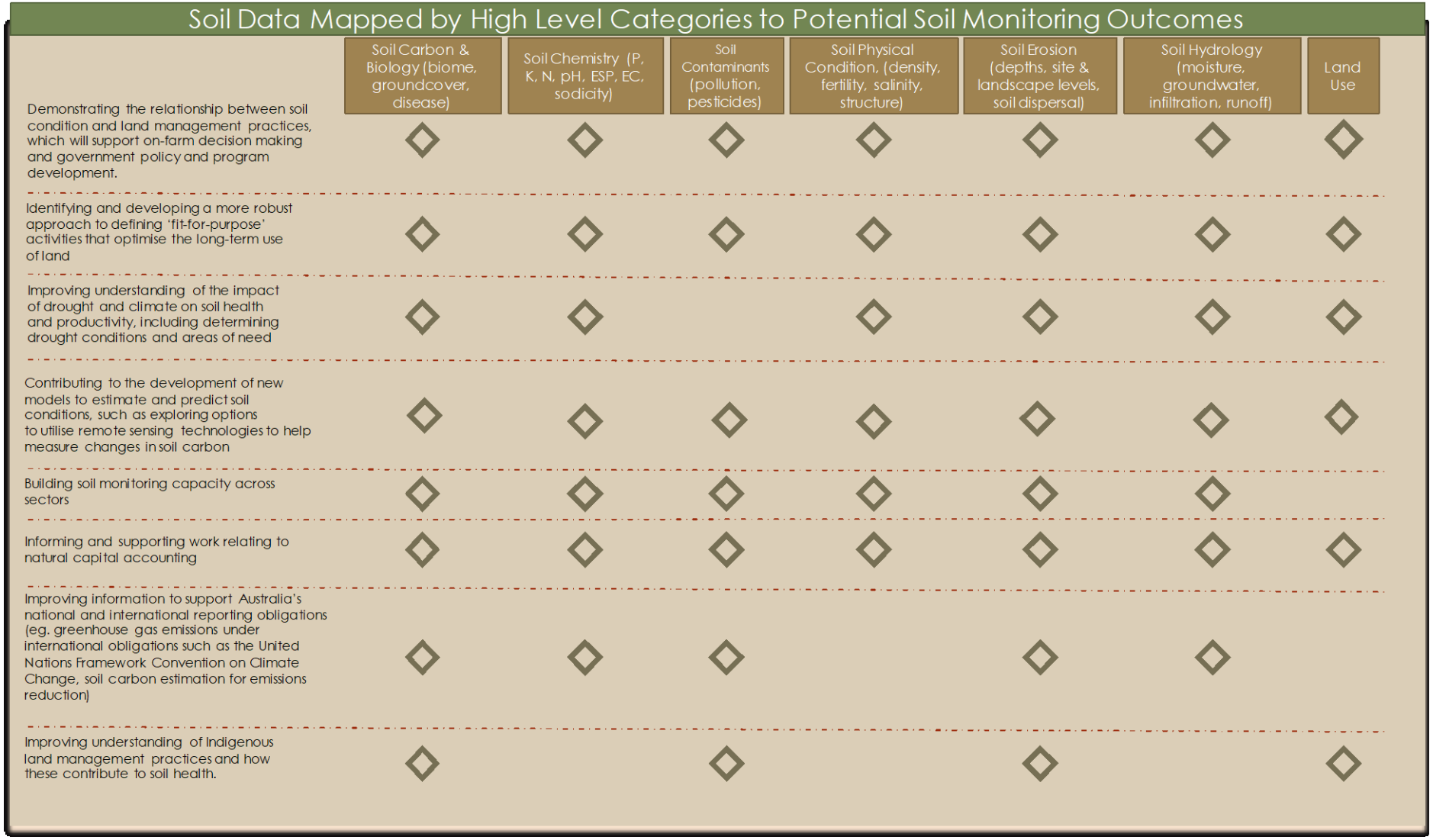
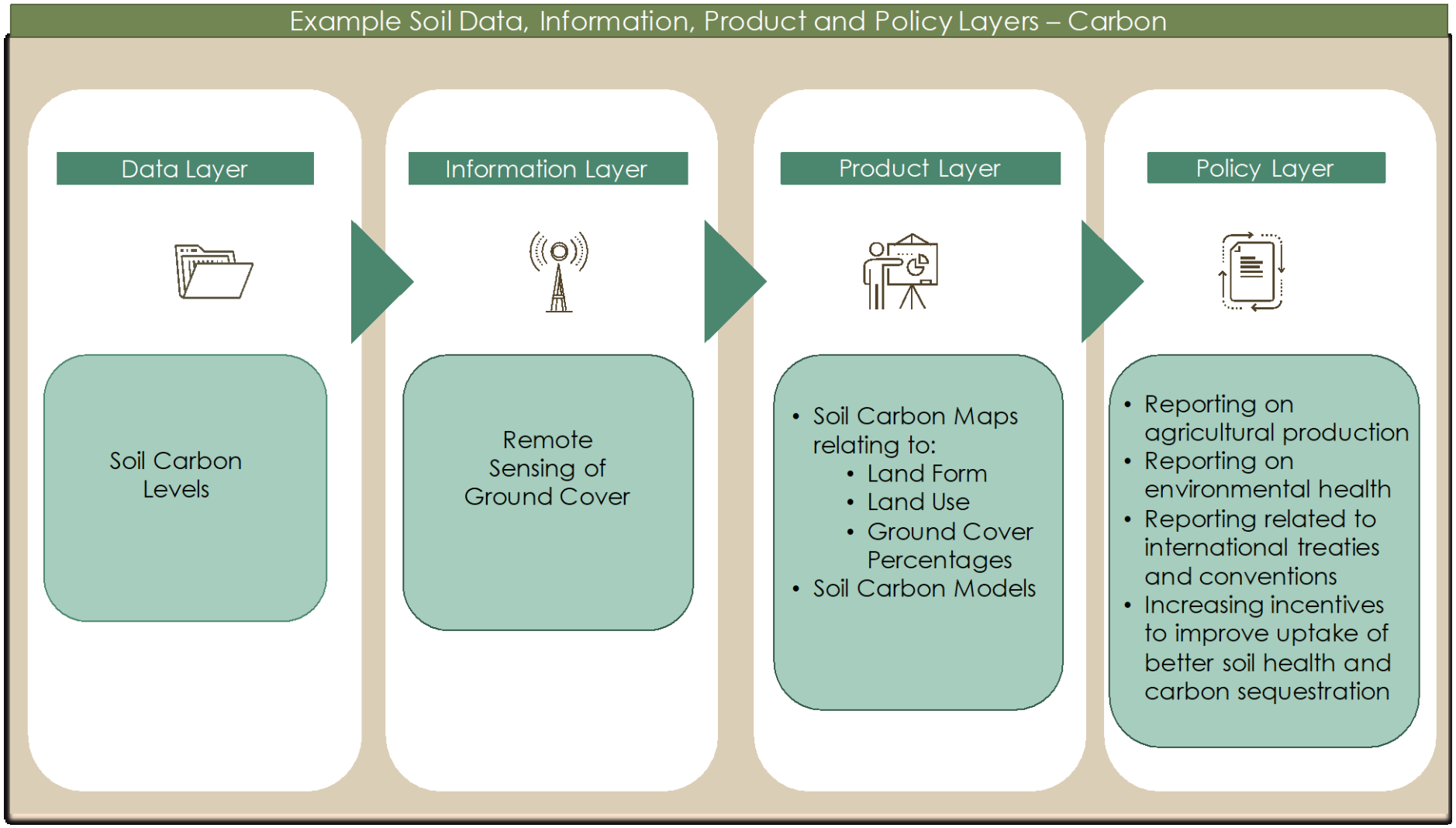


Figure 4: Example Soil Data, Information, Product and Policy Layers – Carbon



8 Sites

8.1 Definition of a Soil Monitoring Site

A soil monitoring site is a geographic location established to assess changing soil attributes statistically and spatially over time.

For the NSM Program, this means there is an expectation that a soil monitoring site will be used more than once to collect data that, when analysed, the data is able to be used for a wide range of purposes including research, forecasting, reporting, targeting of on-ground interventions, informing agricultural and other production, and contributing to planning and policies related to maintenance of the natural environment.

8.2 Types of Current Soil Sites

8.2.1 Soil Reference Sites

The NCST estimated that there were about 280,000 soil reference sites available in 2013. At that time nearly 50% (140,000 sites) related to areas with low-intensity land-use (e.g. grazing of native vegetation). Just less than 10% of sites (about 26,000) were within the dry-land cropping areas and almost 20% (50,000 sites) were within more intensively managed modified pasture areas. Only 2.5% (7,000 sites) were in the intensively managed horticultural regions. The remaining 10% (about 28,000 sites) were in areas used for nature conservation and forestry (NCST 2014). Participants in the current consultation suggested that these were likely to be single visit, single sample sites, which meant they would not necessarily be appropriate for the future NSM Program.

8.2.2 Private Sector Sites

Many sites are managed by private sector organisations. It is important to note that these private sector sites have been established for different purposes and collect data on different attributes using different methodologies that are not necessarily comparable or statistically representative of Australia's soils.

8.2.3 Monitoring Sites Overseen by Governments and Research Institutes

The current consultations identified that across Australia there are many sites that either have been, or could be, soil monitoring sites. These are overseen primarily by government departments and research institutes (Figure 5). The sites in Figure 5 include those used previously by SCaRP (most of which were visited only once), but since they are known sites which were used to obtain data about carbon, may be suitable for consideration as part of a future NSM Program.

8.3 Future Soil Monitoring Sites

The future location, purpose and number of sites is a significant issue for a national NSM Program. The subject matter experts consulted consider this to be a key feature of the program design which needs to be completed as an early piece of work by the NSM Program.

8.3.1 Location

Because it may not be possible (or feasible) to include all of the currently identified sites overseen by governments and research institutes, a set of criteria must be developed to ensure that any sites selected will meet the stated purpose and outcomes of the NSM Program. The view from the current consultation is that it is important to address the quality of future monitoring sites including their overall comprehensiveness, adequacy and representativeness. This will impact on decisions about the number and location of monitoring sites for the NSM Program.

Those consulted indicated that it would be necessary to develop a set of criteria to enable a health check of any sites agreed for inclusion. This would provide an assessment of their operational status and quality, as well as a baseline from which to operate the NSM Program.

Ideally, the totality of sites included in the NSM Program will:

- Include climate transects and ecological regions,
- Cover major land use, practices and management,
- Be co-located with other soil R&D where possible,
- Be paired with existing monitoring sites where possible,
- Be stratified (based on agroecological zone, and purpose-driven for these regions),
- Include a variety of soil landscapes and soil types, and
- Have appropriate number of sites across all jurisdictions.

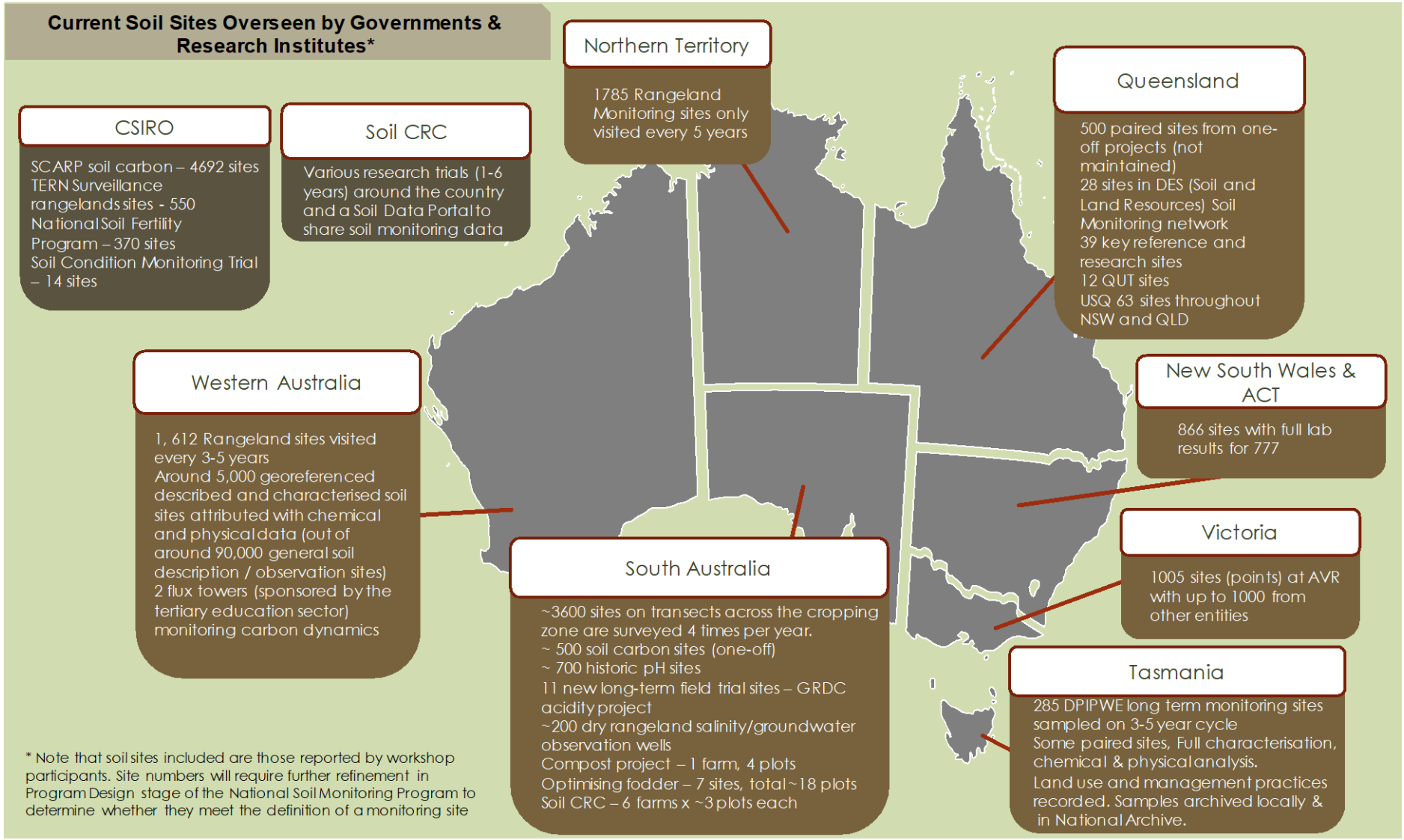
Participants suggested there was a need to ensure built-in redundancy for the sites chosen to allow for factors outside of the NSM Program's control such as the creation of dams or buildings on monitoring sites, or other changes that limited or precluded access to the site.

8.3.2 Tiered Approach

Within the context of the standards and protocols proposed to be developed for the NSM Program, it was suggested that sites be included on a tiered basis. Quality could be one of the criteria applied to allocate a tier to a site. Two tiers are envisaged:

- Tier 1: A high quality site that meets all of the data standards required, and will provide soil data to meet more than five core outcomes identified for the NSM Program. These would be considered 'super sites'.
- Tier 2: All remaining 'standard' sites that meet the criteria for inclusion in the NSM Program.

Figure 5: Current Soil Sites Overseen by Governments and Research Institutes



9 Methodology

The most appropriate methodology will depend on the purpose of the monitoring program. Participants pointed to several successful methodologies that had been used in the past, or were considered to be the standard approach by which a monitoring program should be measured.

An important consideration for the NSM Program is that some longitudinal studies currently being undertaken by jurisdictions will need to maintain their current methodologies to enable credible results to be obtained for the research already underway. In particular, Victoria noted that methodology and standards for currently monitored legacy sites and potential monitoring of other legacy sites, must follow the original soil sampling protocol irrespective of any national mandated protocol.

This does not necessarily preclude introducing a national NSM Program because some of the data already being collected may meet the future needs of the program as well as the initial research purpose. In addition, projects outside of the NSM Program approach, could continue providing those projects did not draw on monitoring program funds where only a tenuous link existed.

9.1 Consensus on Proposed Methodology

Although a number of different methodologies have been used for soil monitoring projects in the past, there was a general consensus amongst the subject matter experts consulted that the proposed NSM Program should rely on the methodology initially espoused by McKenzie (1991) and refined by others including Sanderman et al. (2011). This methodology has been modified and implemented across a range of projects over recent years (including SCaRP and by TERN) and has proven that, with minor adjustments as required, it provides a benchmark approach for soil sampling.

One participant suggested using the CSIRO Australian Soil and Land Survey Handbooks Series on soil chemical and soil physical methods and begin funding for a volume on soil biological assessment methods. A view put forward in the consultation was that the methodology should also include information from First Nations people about the condition of the landscape.

Recommendation 5: That program design for the NSM Program includes work to:

- Develop criteria to identify suitable monitoring sites for inclusion,
- Confirm the suite of soil data relevant to the NSM Program,
- Define standards and protocols for data management (including access and sharing for multiple purposes), and
- Confirm the preferred methodology.

Recommendation 6: That a health check of those monitoring sites identified for inclusion in the NSM Program be done to better understand their operating status and to create a baseline.

10 Implementation Approach

There was agreement from those consulted that implementation should be phased to ensure that critical governance and program design could occur to enable the NSM Program to be optimised for success. It will also enable further engagement by the Commonwealth with their state/territory counterparts and provide time for jurisdictions to prepare for implementation.

10.1 Staged Implementation

In the context of government funding cycles, it was proposed that a staged implementation approach would enable funding proposals to be developed that would deliver the initial stages of the NSM Program over a four-stage forward outlook (Figure 6). Details of Commonwealth responsibilities are outlined below.

10.1.1 Stage 1 Design and Planning – Commonwealth

- Develop/refine a governance structure for the project and establish a Steering Committee,
- Undertake collaborative program design (preferred model for implementation, confirming NSM Program purpose, objectives and intended outcomes, monitoring cycles, etc) and develop associated costings. While there will be some targeting of outcomes for the longevity of the program, the program design should also enable the data generated to be flexible for other purposes.
- Plan and undertake the user-centred design workshops/teleconferences needed to develop the technical aspects of program design. User-centred design is a key feature of modern systems approaches. It ensures that users are engaged throughout the design, development and implementation of projects.
- Develop agreed standards and guidelines
- Develop criteria for sites to be included in the NSM Program in preparation for the health check of sites to be included across jurisdictions,
- Develop reporting templates, service level agreement documents, and other tools,
- Establish a collaborative Community of Practice,
- Engage with jurisdictions (formally through Ministerial council and informally to design operational elements),
- Plan for implementation,
- Plan for tenders for innovation projects, and
- Conduct a Cost/Benefit analysis of soil monitoring.

10.1.2 Stage 2: Implementation – Commonwealth

- Program implementation (roll-out of guidelines, sampling cycles, sampling locations, sampling elements, storage arrangements, reporting tools and processes),
- Administrative support to Steering Committee and to Community of Practice,
- Conduct project tenders/approach to market, and

- Plan Program Evaluation.

10.1.3 Stage 3: Program Management – Commonwealth

- Establish on-going program management,
- On-going oversight of research projects,
- Administrative support to Steering Committee and to Community of Practice, and
- Conduct Program Evaluation.

10.1.4 Stage 4: Program Management and Planning for the Future – Commonwealth

All aspects of Stage 3 with the addition of planning for the next phase of the NSM Program and seeking funding from government/s as appropriate.

10.2 Maturity Model

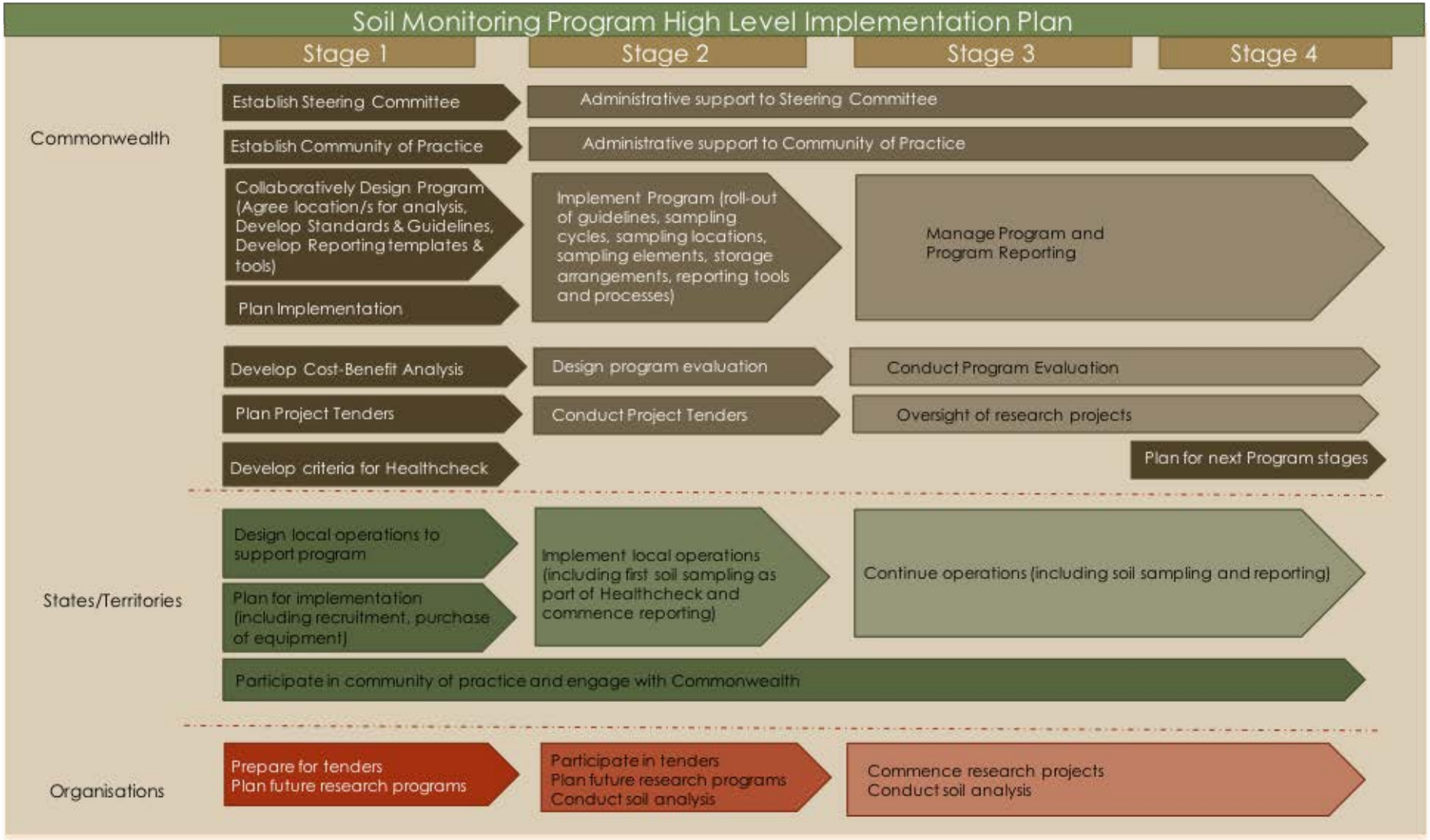
The Maturity Model developed to support implementation (Table 3) provides an overview of the capability delivered for the NSM Program.

Table 3: Maturity Model

Stage	Capability	
Stage 1 (Design and Planning)	• Program structure including key design elements and costings • Strengthened collaboration across jurisdictions • Tools and processes created to support program	• Detailed Implementation/Project Plan • Cost/Benefit analysis
Stage 2 (Implementation)-	• Program implementation • Strategic research program tenders • Coordinated sampling and analysis commenced	• Health check work underway towards a baseline • Evaluation strategy • Improved reporting
Stage 3 (Program Management)-	• Program management • Strategic research program underway • Evaluation possible	
Stage 4 (Program Management and Planning for the Future)- Features of Stage 3 as well as:	• Planning for future stages	

Recommendation 7: That a staged implementation approach for the NSM Program be adopted to build capability and to ensure appropriate program design, consultation and governance can be put in place.

Figure 6: Soil Monitoring Program High Level Implementation Plan



11 Funding

11.1 Jurisdictional Views on Partnering

There is a keen interest from all jurisdictions in collaborating and potentially co-investing to address mutual priorities and deliver the proposed NSM Program. It will be important for the Commonwealth to provide a clear shared purpose, value and scope for the Program to enable the NSM Program to be costed and for states/territories to determine how best to secure funding within their own program areas.

The consultation process identified that initial 'seed' funding of five years, ideally on a rolling 5-year basis would be desirable to initiate the NSM Program, providing that there was an in-principle agreement for ongoing funding to enable its operation to continue over the longer-term (10-20 years).

Consensus is that while jurisdictions and many research organisations are keen to be involved in operationalising the NSM Program, the Commonwealth, as the main user of nationally consistent soil data, should take the lead, including on funding.

Although there is wide support for a NSM Program, there is concern amongst the entire stakeholder group that they may be asked to undertake a particular project/activity but not be funded adequately to deliver. In this situation, stakeholders indicated they would prefer not to commence projects/activities. A summary of views provided by participants during the consultation is provided below.

11.1.1 New South Wales

In NSW there is an interest in a national NSM Program, although the funding envelope available will depend on what is asked of the state. NSW has a comprehensive state baseline across a number of programs, so their view is that for the national program to maximise value to NSW the national program should align as much as possible with existing programs and data.

11.1.2 Queensland

Queensland representatives indicated they would be interested in a strong and co-ordinated approach, particularly one based on collaboration. Within the state, there has been some discussion around economic stimulus opportunities. There is recognition within Queensland of the role soils have in the landscape and in resilience and environmental services. To this end, there are themes emerging in public policy around the role of soil and soil health in natural capital accounting (especially in relation to soil carbon) and soil security. It would be Cross-agency and policy support with formal strategic investment is required otherwise sites will not be maintained beyond the project life cycle. A clear and nationally consistent narrative about why Queensland should invest is necessary.

11.1.3 Victoria

In Victoria, there is an interest in soil monitoring for reporting by the Commissioner for the State of the Environment, Victorian Catchment Management Council and the Catchment Management Authorities. However, limited funding and the need for strategic and longer-term investment partnerships has resulted in a decline in resources for soil monitoring and analysis. There is strong guidance in Victoria about how investments are made, and the budget for the medium

term is limited. Funding proposals that speak to innovation, entrepreneurialism and regional development are more likely to succeed.

11.1.4 Tasmania

In Tasmania, DPIPWE is interested to participate in a National NSM Program, preferably to support and continue their current monitoring program and have this included in a national NSM Program. However, operational funding is required, and National NSM Program funding partnerships would most likely be matched 'in-kind'. Current Tasmanian monitoring sites are in the fourth round of sampling, on a five-yearly cycle. There would be a reluctance to include current monitoring sites if they were required to drastically alter sampling methodology to adapt to any national guidelines.

11.1.5 South Australia

South Australia is interested in participating in a long-term national soil monitoring program, however they could not implement this without additional resources. The state's current monitoring program is strategic and effective, based on limited resources and targeting of priority soil issues. Key overlapping SA and national priorities would include soil carbon and pH. If there is an opportunity to also collect and consider lower-tier, quality-flagged data from a broad range of soil projects across the wider landscape, we believe this would represent a more efficient use of existing funding, however this would require investment in improving soil information infrastructure. A further consideration for South Australia is that a NSM Program should deliver fit-for-purpose, interpretable data that meets the needs of jurisdictions and key end-users such as land managers. Commonwealth funding would ensure a more coordinated soil monitoring program involving all state government organisations working on soil initiatives, i.e. DEW, PIRSA, and the new Landscape SA regional groups. If there is an opportunity to collect information that could be used for monitoring, then on this basis, if it was possible to tap into all of the data collected across the government managed sites, this would be an attractive option for co-partnering. A further consideration for South Australia is avoiding an over-emphasis on academic and research activities, instead ensuring fit-for-purpose, practical, interpretable data where required to meet the needs of jurisdictions and end-users (e.g. farmers, land managers).

11.1.6 Western Australia

Western Australia is committed to producing an annual report on soil and landscape condition for the WA Commissioner for Soil and Land Conservation (guided by the *Soil and Land Conservation Act 1945*), and at infrequent intervals the WA government may produce a State of the Environment type report for the south west agricultural region and Pastoral Rangelands. However, there is an appetite for some sort of shared funding relationship, to ensure a consistent approach to regular soil condition monitoring of key attributes (e.g. soil quality condition of national significance) – a funding model that could perhaps be matched by the state 'in-kind'. Past programs have always been short term, so a model that is enshrined in a very long term commitment (rolling 5 to 10 year commitments – not 3 years) would be attractive and go a long way to encouraging the state to invest. WA would support co-funding a program to develop a more accurate carbon model that can feed into emissions reduction schemes.

11.1.7 Northern Territory

In the Northern Territory a soil monitoring program could be integrated with the pastoral rangeland monitoring program if the methodology was simple and practical. Soil monitoring

across the more intensive agricultural and horticultural areas could also be implemented through partnering with industry associations.

11.1.8 Australian Soil Network

The ASN would be keen to participate in a federated, collaborative model. This would align well with recent work they have commenced about a coordinated National Soil Information Framework (NSIF). There may be opportunities to draw on the expertise of the ASN to form part of the Steering Committee for the NSM Program.

11.1.9 Soil CRC

The Soil CRC has national and industry funding. A lot of the Soil CRC's monitoring and evaluation work will be looking at causality and attribution along with practice change. They are interested in collaboration with both the Commonwealth and the states/territories.

11.1.10 Other Research Institutions

Researchers at other institutions such as the University of Southern Queensland have indicated that they would be interested to assist the Government in the development of a NSM Program, and to support its implementation and stakeholder empowerment phases.

11.1.11 CSIRO

The CSIRO would be happy to work in collaboration. The organisation has national and international mandates that provides a driver to bring things together. Representatives indicated they would be interested in areas where innovation was a key feature (for example, a number of the subject matter experts were interested in development of remote and proximal sensing technologies to routinely assess the soil's capability and condition at both regional and local scales). A multi-use multi-purpose monitoring program that links to key public policy issues such as drought or biodiversity would be attractive for co-partnering.

11.1.12 Soil Knowledge Network

The NSW Soil Knowledge Network is a group of retired soil scientists interested in promoting soil education in the community. It would be able to provide limited on the ground support to monitoring programs and also provide invaluable information on landholder contacts relevant to soil types, climate and management systems proposed in the project. The Soil Knowledge Network would not able to provide direct funding.

11.1.13 Peak Bodies

Peak bodies have also shown an interest in partnering. For example, the Western Australian No-Tillage Farmers Association (WANTFA) is interested in soil monitoring but lacks funding. They would be interested in being consulted as the program is developed. Options could be explored with other peak bodies.

11.1.14 Soils for Life

Soils for Life indicated that the farming community they engage with would actively welcome the opportunity to participate in a national soil monitoring program. Key considerations include resources (suitably qualified people, funding) and access to appropriate facilities and equipment.

11.1.15 Industry

The contribution of the private sector needs to be considered. Some countries subsidise soil testing by private landholders as a means of cost sharing for data collection and ensuring that collected data enters a central repository. There is some appetite for having a suite of registered users who would undertake monitoring, or provide samples, under a Service Level Agreement.

Recommendation 8: That following a decision about the design of the NSM Program, costings be developed for consideration by the Steering Committee; and subsequently that funding be secured to undertake further development and design of the NSM Program.

12 Evaluation

Given the keen interest across all jurisdictions as well as the research, not-for-profit and industry elements of the soil sector, it will be important for a comprehensive evaluation plan to be developed for the NSM Program.

As foreshadowed in the models described earlier, this evaluation will require a baseline of information (provided by the Cost-Benefit Analysis) and underpin future funding proposals.

Being able to demonstrate that the NSM Program has added value over time, and that there has been a return on investment through a more systematic and coordinated approach to soil data collection, management and use, continual co-partnering is more likely. Governments will have greater confidence in the quality of the data being produced, and on the need for an ongoing funding arrangement that supports the longitudinal approach pertaining to soil monitoring.

Recommendation 9: That an evaluation strategy be developed to support implementation and future funding for the NSM Program.

13 Risks and Issues

13.1 Ongoing Issues in Soil Monitoring

In 2014, the NCST identified long-standing concern about the issues for future soil monitoring and management. These included: institutional complexity, inconsistency of technical methods, limited economies of scale, ineffective mechanisms for funding and lack of a long-term strategy (e.g. Beckett and Bie 1978, Hallsworth 1978, McKenzie 1991, Campbell 2006, Wood and Auricht 2011). The NCST pointed to a number of weaknesses that contributed to the deficiencies identified by previous reviews:

- 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.

The Committee considered that partly as a result of the above, most soil survey and monitoring activities remain 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 most stakeholders.

13.2 Current Risks

During the current consultation process, a series of high-level risks were identified for any future NSM Program. These include:

- Failure to adequately promote the necessary long-term nature of soil monitoring,
- Lack of bi-partisan support for soil monitoring as a fundamental aspect of Australia's future security and prosperity,
- Lack of awareness about the linkages between soil and key areas of public policy,
- Difficulty in measuring the value of soil due its complex and variable nature,
- Invalidating past soil monitoring data due to a shift to a different national consistent approach,
- Soils compete with other NRM issues, such as biodiversity, biosecurity and water,
- Failure to foster collaboration that builds on potential cross-portfolio and cross-jurisdictional policy linkages,
- Failure to secure long-term funding that enables an appropriate level of soil monitoring (which may extend over several decades),

- Inability to obtain priority for soil monitoring funds in a post-pandemic environment,
- Inadequate program management (including program design, establishment of governance arrangements, development of standards, guidelines, protocols and tools to support monitoring),
- Inadequate capability within the soil sector to undertake the necessary monitoring (including technical skills, research skills, forecasting skills, analysis and reporting skills, program management skills),
- Inadequate collaboration with potential industry (and other) partners,
- Failure to obtain high quality data,
- Failure of NSM Program governance (fraud, privacy breaches, conflict of interest, cyberattack), and
- Failure to clarify IP arising from soil monitoring.

These will require further assessment and incorporation into a Risk Plan for the NSM Program

Recommendation 10: That a Risk Plan be developed for the NSM Program.

Appendix A: National RD&E Strategy – Implementation Goals

Securing Australia's soil for profitable industries and healthy landscapes

	GOALS	OUTCOMES	ACTIONS
1	Improve effectiveness of co-investment to generate and apply new knowledge	Delivery of world-leading, innovative soil research by Australian scientists Joint identification of RD&E priorities Increased collaboration across organisations Sharing of knowledge Reduced duplication	Establish strategy implementation committee Establish topic-specific working groups Deliver annual soil RD&E forum Develop and review national soil RD&E priorities Facilitate networks and identify co-investment opportunities Communicate strategy activities and outcomes Monitor, evaluate, report and improve
2	Improve quality, availability and access to soil data and information	Maps of functional properties of soils at appropriate resolutions Improved systems for monitoring change in soil properties over time Improved ability to forecast future condition of soil Improved understanding of the condition of the resource base Improved decision-making at all levels	Undertake market research of user needs for soil data and information Establish a national, cooperative approach to collection, sharing, monitoring and analysis of soil data Agree to national standards for soil data including sharing, monitoring and analysis Develop integrated national soil information system, including improved web-based delivery of soil data and information Engage effectively with public and private sectors to better capture soil information and data
3	Improve communication and exchange of soil knowledge	Improved management of the soil resource by landholders Improved delivery of evidence-based information Improved knowledge exchange from researcher to farmer and back Improved knowledge of and engagement with soil experts Increased understanding of soil-related extension activities across Australia	Explore opportunities to use web-based technology to: • deliver credible information • communicate project level activities • establish register of expertise Improve delivery of soil information to extension providers, consultants, advisors and agribusiness professionals (e.g. through train-the-trainer type initiatives) Encourage uptake of accreditation (e.g. Certified Professional Soil Scientist) by extension providers, consultants, advisors and agribusiness professionals
4	Adopt a national approach to building future skills and capacity	Appropriate skills, capability and capacity to support current and future soil research, development and extension (RD&E) High quality education and training opportunities (tertiary and vocational) that meet needs of employers and soil managers Clear career pathways for soil science graduates Long-term support by industry to early career scientists (including through uptake of professional development programs)	Undertake national skills audit to map current and future expertise and capacity Continue developing a national soil science curriculum Develop a professional masters program in soil science Increase support for postgraduate scholarships and stipends Review existing soil related VET programs Explore development of online courses in soil science Recognise and promote training opportunities outside formal education system Encourage uptake of professional accreditation (e.g. CPSS)
5	Collaborate on development and use of physical infrastructure	Improved knowledge of physical infrastructure available in Australia for soil RD&E Collaboration, strategic investment in and development of new technology Nationally important assets (archives and field sites) protected Improved standards for collection and analysis of coil test results Improved interpretation and communication of soil test results Improved engagement with and capture of information from private laboratories	Establish a dispersed national soil archive Expand inter-laboratory soil testing proficiency programs Develop national standards for collection and analysis of soil samples Consider mechanisms to capture public and private soil data and information from analytical laboratories Maintain, collaborate and communicate work conducted on long-term field sites

Appendix B: Workshop Invitees

Organisation	Name
Commonwealth Department of Agriculture Water and the Environment	Troy Clarkson
	Nathan Sibley
	Claire Docherty
Commonwealth Department of Industry, Science, Energy and Resources	Alison Herbert
	Anna Whitton
CSIRO	Peter Wilson
Department of Planning, Industry and Environment (Environment, Energy and Science)	Emily Yip
	Brian Jenkins
NSW Department of Primary Industries	Warwick Dougherty
Northern Territory Department of Environment and Natural Resources	Jason Hill
Office of the Soil Advocate	Sue Bestow
Queensland Department of Environment and Science	Paul Lawrence
	Dan Brough
	Paul Harris
	Di Allen
Soil CRC	Michael Crawford
	Richard Doyle (& University of Tasmania)
South Australian Research and Development Institute, Primary Industries and Regions SA	Jim Cox
South Australia Department for Environment and Water	Tim Herrmann
	Craig Liddicoat
Tasmanian Department of Primary Industries , Parks, Water and the Environment	Darren Kidd
TERN Surveillance	Ben Sparrow
University of Queensland	Neal Menzies
Agriculture Victoria (Department of Jobs, Precincts and Regions)	Angela Avery
Victorian Department of Jobs, Precincts and Regions	Steve Williams
Department of Primary Industries and Regional Development, Western Australia	Tim Overheu

Appendix C: Questionnaire

Australian Government
Department of Agriculture, Water and the Environment

Soil Information Monitoring Questionnaire

You are invited to provide input to development of a future approach to monitoring soil nationally in Australia.

Soil condition information is essential for detecting changes in soil quality and function. It provides an important resource to inform public policy in targeted areas such as agricultural productivity, water management, drought resilience, climate change mitigation and adaptation, and biological diversity. This information is fundamental to reporting on a range of national and international obligations and underpins National Carbon Accounting.

The Department of Agriculture, Water and Environment recognises that across Australia, there are diverse stakeholders who gather, access, analyse, interpret and advise about soil information, whether this is in an academic, industry, not-for-profit, planning, agricultural, research or government setting. For this reason, we are seeking your views about future options for soil information monitoring.

There is an intent to ensure that Australia's soil monitoring approach is sustainable, resilient, more strategically focused and fit for purpose. Given the recent changes to many areas of our society, including the way Australians work and interact, there is an opportunity to reset arrangements for soil monitoring.

The attached questionnaire is an opportunity to provide your perspective on both current and potential future soil monitoring programs. To enable your views to be included, please return the questionnaire by **COB Wednesday 20 May 2020.**

1. Using a scale of 1-10 (1 being most important) please rank the importance of the potential National Soil Monitoring Program outcomes

It is envisaged a National Soil Monitoring Program would monitor a range of key soil health and condition parameters, including soil organic carbon, pH and nutrients, providing a number of potential benefits. Some potential program outcomes are identified below.

Potential Outcome	Rank
Building soil monitoring capacity across sectors	
Contributing to the development of new models to estimate soil conditions, such as exploring options to utilise remote sensing technologies to help measure changes in soil carbon	
Demonstrating the relationship between soil condition and land management practices, which will support on-farm decision making and government policy and program development	
Identifying areas where soils can potentially support increases in agriculture productivity	
Improving understanding of Indigenous land management practices and how these contribute to soil health	
Improved reporting of Australia's greenhouse gas emissions under international obligations such as the United Nations Framework Convention on Climate Change.	

Improved understanding of the impact of drought and climate on soil health and productivity, including determining drought conditions and areas of need
Informing the best long-term economic use of land; ensuring, where possible, the best agricultural land remains available to produce food and fibre
Informing and supporting work relating to natural capital accounting
Potential improvement of Emissions Reduction Fund (ERF) soil carbon methods through improved estimation methods

2. Is there an additional potential National Soil Monitoring Program outcome you would like to suggest?

3. In the past 12 months, have you used soil information for any of the following?

Activity	Yes/No	Frequency
2030 Agenda for Sustainable Development (particularly SDG 15.3)		
Agricultural production		
Contributing to scientific knowledge on landscape processes (e.g. for soil science, hydrology, ecology, geomorphology, exploration geoscience, and the earth-system sciences more generally		
Determining the location of corrosive and expansive soils to ensure appropriate engineering design and location of major infrastructure		
Food and Agriculture Organization of the United Nations (FAO) Global Soil Partnership reporting		
Intergovernmental Negotiating Committee on Desertification (INCD) reporting		
Kyoto Protocol reporting		
Land-use planning		
Mapping and managing acid sulphate soils in coastal environments		
Paris Agreement reporting		
Revised World Soil Charter reporting		
Setting environmental baselines for contaminants and implementing effective rehabilitation practices for contaminated lands		
State of the Environment reporting		
Understanding the characteristics of soils to ensure successful rehabilitation of areas used for mining and waste-disposal		
United Nations Convention on Biological Diversity (UNBCD reporting		
United Nations Framework Convention on Climate Change (UNFCCC) reporting		
World Heritage Convention reporting		

4. What type of soil information needs to be monitored and why?

Type of Soil Data	Purpose	Is it mandatory/desirable

5. How many soil monitoring sites do we have? (Please complete for your jurisdiction/organisation)

Jurisdiction/Organisation	Number of Soil Monitoring Sites

<insert State or jurisdiction>
Organisation (provide name)

6. What is the minimum number of soil monitoring sites needed for a credible national soil monitoring program? Where should these be and why?
7. How confident are you that this number of monitoring sites will provide the data needed to effectively support the soil monitoring program outcomes?
8. Current Soil Monitoring Site Details (please add more lines to the table if required)

Site Location/name	What soil properties are monitored	Which organisation monitors the site	Monitoring Frequency	How is the monitoring funded at this site

9. Are you aware of any current soil monitoring programs using a national methodology and standards, and if so is it worth expanding for a future monitoring program?
10. What would you recommend as an agreed national methodology and standards for soil monitoring?
11. How do you suggest this be developed nationally?
12. Are there any factors (e.g. monitoring site location) that would limit/prevent a national methodology/standards?
13. What is the current commitment and interest in your organisation/ jurisdiction for an on-going national soil monitoring program?
14. Are there any issues/showstoppers to a national approach, e.g. will it impact any current soil monitoring program?
15. Would there be an appetite in your organisation/jurisdiction for partnering and co-investment of a national soil monitoring program with the Australian Government, if so what would you need?
16. Using a scale of 1-10 (1 being most important) please rank the importance of the potential approaches to a future Soil Monitoring Program

Approach	**Rank**
Citizen science to process data	
Coordinated nationally consistent (federated) approach	
Conduct a pilot using an existing site	
Leverage/expand a current soil monitoring program	
Locate sites to support capacity building/research	
Locate sites to support regional employment	
Nationally coordinated (centralised) approach	
Partnering with Indigenous communities/other community organisations	
Payment for soil sample collection by non-government entities	
Registered providers of soil sites/samples	

17. Are there other stakeholders to engage with on soil monitoring, and if so, who are they?

Appendix D: Further Stakeholders

Stakeholder
ABS Environmental Economic Accounting
AgForce -pastoralists
AGnVET
Agribusines advisors
APPEA –represents the gas producers
ASSSI - Australian Society of Soil Science Inc
Australian Agricultural Institute
Banks and financial institutions
Catchment management authorities/catchment management councils
Conservation reserve managers (especially for baseline studies)
Consultants and advisory staff
Deans of Agriculture and DVC-Rs at regional and agriculture and forestry focused universities
DeltaAg (NSW)
Developing private markets for ecosystem services (including carbon and biodiversity)
Department of Foreign Affairs and Trade (DFAT)
Domestic and international advocates
Environment agencies
Farmers
Farming systems groups
Fertiliser manufacturers
Greening Australia
Greenpeace
Grower Groups - RDCs
Indigenous communities/First Nations peoples
Industry bodies
Industry sampling/testing facilities
International bodies (UNEP, UNDP)
Landcare
Landholders (small and large)
Local Councils (salinity/expansive soils)
Local Government Association of Queensland – peak representative body for local governments in Queensland
Mine rehabilitation managers
Not for profit organisations
National Farmers Federation
Natural Resource Management (NRM) organisations (national/regional)
Planners
Private agronomists
Queensland Department of Agriculture
Queensland Department of Environment and Science
Queensland Department of Natural Resources, Mines and Energy
Queensland natural resource management agencies
Queensland agriculture agencies
Queensland environment agencies
Queensland Farmers Federation
Queensland Resources Council –(re application of soil monitoring as part of licence approvals)
Researchers
Royal Geographical Society of Queensland
Royal Society of Queensland
Soils West
Superannuation investors
TAPG (Tasmanian Agricultural Productivity Group)
TFGA (Tasmanian Farmers and Graziers Association)
TIA (Tasmanian Institute for Agriculture)
UDIA – Urban Development Institute of Australia (Qld organisation)
UTAS (and other universities)
WWF

Appendix E: Soil Data Required

The information contained in this Appendix is compiled from responses to the questionnaire distributed during this consultation process. It will require simplification and consolidation as part of the program design for the NSM Program, along with a decision about which types of soil data will be mandatory.

Type of Soil Data	Purpose	Mandatory/Desirable
Acidity/ pH and at what depths (multiple depths up to 1.2 metres) (buffering capacity)	• Sustainable production: prevent subsoil acidification • Plant growth, soil biology • Agricultural production • Soil health/condition assessment and change, an amendment indicator • To provide a reference to measure trends • Acidity • Chemical reactions • Buffering and impediments • Indicator of fertility	Mandatory/Desirable
Acid sulphate soils	• Sustainability: off-site environmental impacts	Mandatory in specific cases
Aggregate stability	• Functional stability	Mandatory
Anions	• Chemical system balance	Mandatory
Biological activity of soil	• Measurement of soil health/soil biome and amendment indicator • Sustainability • Soil health and biome	Mandatory
Carbon/Organic carbon (to depth of 1.2 metres)/organic carbon pools	• Key indicator of soil health • National budgeting of greenhouse gas emissions • Farming/ To identify land with strong agricultural potential and where amendments may be necessary to meet soil potential • Environmental impacts • Index of soil health and Carbon accounting • Agricultural productivity • Soil structural and functional measure • Soil health indicator. Inorganic carbon provides context for interpreting nutrient availability and OC test results	Mandatory/Desirable
Chemistry such as CEC & CATNS and EC throughout the profile	• Soil health and change/To provide a reference to measure trends • Help to understand plant root growth issues • Productivity	Mandatory/Desirable

Type of Soil Data	Purpose	Mandatory/Desirable
	• Sustainability • Chemical stability	
Climate	• Soil water and temperature is a major driver of soil processes particularly soil biology and these factors need to be identified when promoting the widespread adoption of a management system.	Desirable
Contaminants & Pollutants (plastics, pesticides, other chemicals eg sulphuric acid – acid sulphate soils)	• Farming • Sustainable production: food security and market access • Measure change with practices/toxicity/accumulations over time • Steer urban residential development away from such areas.	Mandatory
Crop water use efficiency	• An integrated measure of soil-plant-management system performance, that informs overall soil capability / productive potential. Could be extended to pasture biomass.	Desirable
Degradation	• Agricultural productivity/ enhance downstream water quality e.g. GBR	Mandatory
Density	• Sustainable production • To provide a reference to measure trends • Soil carbon estimations • Compaction and relationship development to real-time soil monitoring • Change in soil porosity and indication of possible compaction	Mandatory/Desirable
Deposition/depth (site & landscape levels)	Soil gains	Mandatory for case studies
Disease	Profitability/sustainability	Desirable
Dispersal of soil in the air/ Dustwatch	Agricultural productivity, sustainability and environmental	Mandatory
Dynamic biological properties (site & landscape levels)	Soil condition & productivity	Mandatory for case studies
Dynamic chemical properties (site & landscape levels)	Soil condition & productivity	Mandatory for case studies
Dynamic physical properties (site & landscape levels)	Soil condition & productivity	Mandatory for case studies

Type of Soil Data	Purpose	Mandatory/Desirable
Erosion (site & landscape levels)/modelled erosion	• Soil losses • Provides an integrated and somewhat 'leading' indicator, and spatial data, to identify priority erosion hazard areas. In some • cases, particularly as forecasting models are now being developed, interventions may be possible before actual erosion occurs • Assessing loss of precious top soil resources, although this indicator is somewhat lagging (after erosion events have occurred).	Mandatory for case studies Mandatory for modelled erosion. Desirable for actual erosion (costly)
ESP (surface and sub surface)	• Agricultural productivity	Mandatory
Fertility	• Sustainability: productivity (on-site) and eutrophication (off-site)	Desirable
GHG sources in soils, e.g. soil C stocks	• Sustainability: manage GHG sources and sinks from soils	Desirable
Groundcover	• Surrogate for land management – already collected in many places • Strong surrogate for erosion, carbon, pH	Mandatory
Groundwater	• Salinity trends in some areas	Desirable
Landholder attitudes and management practices	• To understand trends, barriers, enablers, etc for improved soil management	Desirable
Land Use: Urbanisation/ Commodities	• Sustainability: food security and productivity • To provide information on what has been done at each site eg. cropping rotations, inputs that might affect soil condition or health • Need to show cause and effect of management on soil function change. Allows modelling of likely impacts and change in other areas or over time under similar or different management/use scenarios. Allows assessment of effectiveness of management practice change and other investments	Mandatory
Moisture/Plant available soil water	• Profitability/Sustainability • Drought Relief/Rainfed cropping • Soil water status	Desirable in rainfed cropping areas– EMI/moisture calibration needed

Type of Soil Data	Purpose	Mandatory/Desirable
Nitrogen (to depth of 1.2 metres)	• Sustainability, production, pollution • Index of soil health and Carbon accounting	Mandatory
Nutrients / Macro-Micronutrients to a depth of 1.2m	• Measurement of soil health and amendment indicator • Productivity • Nutrient supply • Measure changes with practices over time • Track maintenance of our natural resource for future productivity	Mandatory
Organic matter quantity	• Soil quality, nutrient delivery, Carbon sequestration • Best indicator for soil health (in relation to natural status and changes over time)	Mandatory
Organic matter chemistry (fractions, natural abundance isotopes)	• To allow much stronger prediction of Carbon stability and soil health for both (agro)ecosystem management and Carbon modelling for accounting purposes	Desirable
Phosphorous	• Soil health • A key indicator attribute for pasture productivity and livestock production	Mandatory
Potassium	• Soil health	Mandatory
Rangeland condition (vegetation, surface cover, soils, landscape erosion)	• WA Range Condition Monitoring System (WARMS)	Mandatory
Salinity	• Plant root growth • Agricultural production/ Sustainable production: prevent irreversible loss • Security of water resources • Impact on urban infrastructure • Environmental impacts •	Mandatory/Desirable
Saturated hydraulic conductivity	• Soil health	Mandatory
Sodicity	• Plant root growth • Agricultural production • Understanding water- and salt-balance responses to identify where changes to land use and management are needed	Mandatory/Desirable

Type of Soil Data	Purpose	Mandatory/Desirable
Soil biological, chemical and physical processes	• Interrelation with plant productivity (ground cover) • Productivity, sustainability and environmental • To provide an indication of soil health in terms of biological status – this can be expensive and highly variable based on recent climate • Assess impact of land use/management on change in soil function and on provision of ecosystem services. Assessment of natural capital value. Determine needs for management amelioration or remediation • Assess and compare microbial community composition, diversity and functional potential – for representative soil type / climate / land use combinations	Mandatory for Soil CRC case studies
Soil condition (site and landscape levels)	• Track change and trend in outcomes of adopting and implementing various land management practices • Agricultural productivity and environmental	Mandatory for case studies/Desirable
Soil Constraints (pH, non wetting, organic matter, compaction, carbon, nutrition)	• Profitability/sustainability	Desirable
Soil horizon depths, soil texture/structure throughout the profile	• Soil water, soil structure, aeration, organic matter improvement • Sustainability • Productivity	Mandatory
Soil hydrological properties (site and landscape levels)	• Soil condition & productivity, water use/ storage efficiency (ground cover and bare ground) • Dryland Salinity mapping and monitoring, bore monitoring	Mandatory for case studies
Soil Security	• An integrated Monitoring Approach: Capability and Condition intrinsically linked, Natural and economic capital parameters could be included in monitoring, as well as introduction of legislative and custodian impacts (codification) and connectivity – landowner knowledge and consequent management of each soil monitoring site. This approach will provide more insight than monitoring biophysical parameters alone, ie monitor other non-biophysical	Desirable

Type of Soil Data	Purpose	Mandatory/Desirable
	dimensions that will impact soil condition and overall security.	
Spatial distribution of soil types	• To inform possible changes and potential to detect change in response to land use management and land use change	Mandatory
Surface and sub surface Infiltration	• Water and air movement, plant root growth	Desirable
Time series data on soil characteristics	• To inform possible changes and potential for detect change in response to land use management and land use change	Mandatory/Desirable
Water and wind erosion	• Impact on sustainability of agricultural production • Security of water resources • Potential impact on infrastructure and human health	Mandatory

Glossary

Term	Definition
AAS	Atlas of Australian Soils
ABARES	Australian Bureau of Agricultural Resource Economics and Sciences
ACLEP	Australian Collaborative Land Evaluation Program
ASAP	Australian Soil Assessment Program
ASN	Australian Soil Network
co-investment	A shared funding arrangement
Community of Practice	An organised group of professional people who have a shared interest and who seek to improve their skills and learn from each other's experiences
co-partnering	A shared funding and operational responsibility
CSIRO	Commonwealth Scientific and Industrial Research Organisation
FAO	Food and Agriculture Organization of the United Nations
INCD	Intergovernmental Negotiating Committee on Desertification
NCST	National Committee on Soil and Terrain
NSIF	National Soil Information Framework
NSM Program	National Soil Monitoring Program
OECD	Organisation for Economic Cooperation and Development
SCaRP	Soil Carbon Research Program
SoE	State of the Environment
sustainability	The capacity for development that can be sustained into the future, within the capacity of the natural resource base. This includes encouraging sustainable agricultural and fishing practices which maintain and improve the natural resource base.
TERN	Terrestrial Ecosystem Research Network
UNBCD	UN Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNFCC	United Nations Framework Convention on Climate Change
WANTFA	Western Australian No-Tillage farmers Associations

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