National Advocate for Soil Health

Second report to the Minister for Agriculture

January 2014

Executive summary

This second report to the Minister for Agriculture comprises two sections. Part one contains a set of soil research and development (R&D) priorities for use in the implementation of the National Soil Research, Development and Extension (RD&E) Strategy, as per the terms of reference for the Advocate for Soil Health. The soil RD&E strategy, developed over 2012–13 as part of the National Primary Industries RD&E Framework, aims to better coordinate our existing soil RD&E effort and target it in the national interest. As Advocate for Soil Health I have worked in collaboration with those developing the soil RD&E strategy, consulting widely with stakeholders and exploring common issues. A range of issues and opportunities outside of the RD&E spectrum have also been explored, and there has been a strong focus on providing leadership and advocacy on the importance of healthy soil. The two initiatives are complementary, and it is hoped that implementation of the soil RD&E strategy will provide an excellent mechanism through which to address a number of the issues raised here.

Research and development priorities were developed from feedback provided by a Consultative Group, whose expertise spans the Australian soil RD&E continuum. The priorities also incorporate ideas gathered from land managers, industry representatives, scientists and policy makers from across the country.

Research and development priorities were identified within four broad themes. The first theme, '*Quantification of our soil asset (data and mapping)*', recognises the pressing need for a national system for soil data collection and collation, and the development of techniques for rapid assessment of the soil resource. The second – '*Securing our soil asset*', considers landscape management issues and opportunities. The research priorities included here relate to maximising the full potential of our agricultural systems by identifying better land management practices, improving soil structure to enhance productive potential, and furthering understanding of how management impacts on soil biology and soil carbon.

Building technical understanding of the soil processes that underpin landscape processes is the focus of the third theme – '*Understanding our soil*'. Priorities within this theme capture soil

carbon transformations, hydrology, soil biology and nutrients (including nutrient use efficiency and the use of recycled nutrients and waste) and processes occurring at the soil-root interface.

The final theme, '*Soil at the interface*', recognises that soil processes are an integral part of broader ecosystem processes, and identifies priority areas for furthering our understanding of these interactions. These include: understanding greenhouse gas emissions from soil under different agricultural management practices, eutrophication and the impact of pesticides on non-target species, and the capture and storage of water in soil.

Part two of the report builds on the areas of interest identified in the first report, focussing on the broader aspects of landscape management, including the information needs of land managers, opportunities for international collaboration, and the professional development of soil scientists and natural resource managers. It also highlights the importance of the relationship between soil, water (hydrology) and biodiversity.

Part two also emphasises the importance of innovation, and of working to remove constraints to the adoption of sustainable and innovative land management practices. Australia's agricultural industries have a strong tradition of being innovative and adaptive to new challenges, and this has allowed them to be highly efficient and competitive in international markets. However, our soil must be seen as a key strategic asset underpinning all sustainable agricultural activity, and we must strive to pursue improved management practices to protect this asset for the long-term.

Improved understanding and management of non-agricultural lands is equally important, utilising the same principles of the integrated management of soil, water and biodiversity.

Implementation of the national soil RD&E strategy is due to commence in 2014. Continued cross-jurisdictional, cross-agency support of such an important initiative is essential, and will take up many of the issues raised in this report, and indeed in the first report to the Minister for Agriculture. The contents of both reports will form the basis of a progress report to the Prime Minister, which will be submitted in March 2014. The final report to the Prime Minister will build on previous reports and incorporate key strategic recommendations.

Contents

Introduction

'*The history of every nation is eventually written in the way in which it cares for its soil*'
– Franklin D. Roosevelt, statement on signing the US Soil Conservation and Domestic Allotment Act, 1936

This report draws together ideas gathered from farmers and other land managers, scientists and policy makers from across Australia. Extensive consultation with this diverse range of stakeholders stimulated avid and wide ranging discussion on the importance of soil and how it should best be managed for the benefit of all Australians. This consultation has affirmed the overarching principle that was put forward in the first report to the Minister for Agriculture on June 7 of this year, namely:

'Australia's soil, water and vegetation should be designated as key natural, national, strategic assets, to be managed accordingly and in an integrated way throughout the continent.'

This principle recognises the interdependence of soil, water and vegetation. Accordingly, the first report stressed the importance of considering soil in terms of the broader landscape, and taking a nationally coordinated approach to managing the whole system. The first report presented a summary of key issues identified, and an outline of areas to be further explored. Key drivers central to achieving progress on improving soil health in Australia were identified. These included national recognition of the importance of soil, the role of information and education in developing a skilled agricultural workforce, and opportunities to improve the way our soil research effort is focussed, analysed and delivered. These issues have been explored here in further detail.

This second report builds on the first and incorporates new ideas and information assembled during the past several months. These ideas have been explored in consultation with Australia's leading soil scientists and practitioners. An Expert Advisory Panel (EAP) comprising four leading soil scientists provided advice on specific soil topics, and commented on the various drafts. The EAP was further supported by a Consultative Group of some 21 leading experts in soil and landscape science and its application (see Appendix B).

The deliberations of both groups resulted in a set of cross-sectoral soil research and development priorities that were provided to the Reference Group for the development of the national cross-sector soil research, development and extension (RD&E) strategy for consideration. The soil strategy is being developed under the National Primary Industries RD&E Framework, and R&D priorities will be used to inform the implementation of that strategy from early 2014.

In addition to the collation of the ideas presented in this report, activity to date has focussed on raising awareness of the importance of best practice landscape management, in accordance with the mission of the Advocate role. As Advocate I have actively participated in numerous community forums and conferences, field visits and briefings with government agencies, to build on my understanding and to raise awareness of issues of soil and landscape management. A progress report will be provided to the Prime Minister in March 2014, and will incorporate interim findings. My final report to the Prime Minister in late 2014 will provide clear strategic direction for future national work in this area.

Part one: soil research and development priorities

Introduction

These soil research and development (R&D) priorities have been developed by the Advocate for Soil Health in consultation with the Expert Advisory Panel and Consultative Group (detailed in Appendix B). These priorities were provided to the Reference Group for the national cross-sector soil RD&E strategy for consideration in September 2013.

The R&D priorities are presented under four broad themes reflecting the soil R&D continuum. Some sub-themes are shared across themes.

1.1 Quantifying our soil asset (data and mapping)

Decisions made by land managers, whether farmers, or urban planners and policy makers, must be informed by sound scientific data. Current soil data coverage in Australia is inadequate and inconsistent – a variety of soil sampling methods, descriptors and parameters are currently used in each state and territory. A national approach to soil data collection, collation, analysis, dissemination, mapping and monitoring will enable the comparison of data, provide a basis for modelling and forecasting systems, and allow the identification and appropriate management of threats and opportunities.

Research priorities:

- **National protocol for soil analysis and data collation**: Research is needed to identify approaches that are most accurate and practical, and to mandate them as national protocols with flexibility to be updated as new methods are developed.
- **Soil testing techniques**: There is a need to support further development of rapid, cheap and accurate methods for soil assessment that can be used at the paddock and laboratory scale to better inform decisions of land managers. This should include the further development of proximal soil sensing methods (e.g. mid-infrared and near-infrared spectroscopy) and methods to measure the energy status of soil water which defines water uptake by plants and microbial activity in soil.
- **Soil mapping**: Further research is needed to improve the utility and efficiency of methods for digital soil mapping that links to specific soil functions. This research needs to include improved methods for remote sensing of landscapes, development of robust soil sampling systems for all conditions, and new ways of gathering, analysing and visualizing soil information via web-based technologies).

1.2 Securing our soil asset (landscape scale)

There is a growing global imperative to do more with less. Faced with challenges such as climate variability, increased competition for water and agricultural land resources to support a growing global population, Australia must play its part in ensuring that precious natural resources are managed in a sustainable way.

Research priorities:

- **Identifying and evaluating best practice**: Further research is needed to identify best practice and evaluate a range of systems and approaches to land management and to better understand their respective costs and benefits. Maximising the full potential of our systems, through better matching of agricultural land use to the variation in soil, weather and topography across the landscape will provide opportunities for increased production efficiency, better water use efficiency, and less negative environmental impacts.
- **Soil structure remediation and improvement**: There is a need to build upon existing research and develop improved management strategies for overcoming constraints to crop production both at the surface (e.g. non-wetting sands, hard setting soils) and subsurface (e.g. salinity, sodicity, compaction, acidity, nutrient availability). There are opportunities for soil structure remediation to be explored, including the manipulation of texture (adding clay to sandy soil), physical disturbance (e.g. deep ripping), addition to soil improvements (e.g. organic materials), greater use of green manure crops, ways to stimulate biological activity (e.g. earthworms, dung beetles), and the use of specific crops for 'biological drilling'.
- **Soil biology**: The effective management of soil biological processes is dependent on managing chemical and physical properties of the soil. Research focus is needed on understanding the impacts of organic and non-organic fertilisers, herbicides and pesticides on soil biota and biological processes over both the short and long term. This knowledge will allow us to more fully capture the benefits of soil biological processes.
- **Soil carbon maintenance and economics**: Within the constraints of climate, soil carbon levels are determined by the balance between carbon inputs and losses influenced by land management, soil type and nutrient availability. A focus is needed on understanding practices that should be used to maintain and increase soil carbon in different soil types, and to assess the economic viability of these practices. Further analysis is needed into the costs and efficacy of the generation and application of soil amendments to build soil carbon (e.g. composts, lignites and biochar) on multiple scales, to determine the suitability of these applications.

1.3 Understanding our soils (technical level)

A technical understanding of the processes at detailed scales that underpin activities at broader landscape scales is critical. This includes understanding, control and manipulation of soil carbon dynamics, soil-water interactions, and biological processes that optimise nutrient availability and the soil physical environment.

Research priorities:

- **Soil carbon dynamics**: There is a need to develop a thorough understanding of soil carbon transformations and stabilisation in the soil environment – for all soils and at depth. Additionally, there is a need for rapid, multi-sampling methods for soil carbon to be developed (e.g. MIR or similar rapid and on-the-fly methods). Modelling should also be used to predict how to sustain increased soil carbon under variable climates and land uses.
- **Hydrology**: To optimise the use of water resources, better understanding of soil-water interactions needs to include the impacts of water on soil chemistry and the three-dimensional movement of water in the landscape. There may be opportunities through modelling systems to better understand and predict soil water movement to quantify and predict bypass and lateral flows of water and solutes (including in cracking clay soils) that transport water and solutes to groundwater. Wetland servicing and riparian zone repair are critical to hydrological success.
- **Soil biology and nutrients**: A key area is the study of soil biology in the context of the soil physical and chemical environment. Further research is needed into understanding the links between soil biological processes and nutrient availability and cycling, and soil physical structure. This should include research into the mechanisms by which some biological amendments are effective and others are not. Understanding these processes could lead to a better appreciation of how biological processes can be manipulated to unlock nutrients, improve soil structure and suppress disease, and in so doing, reduce on-farm inputs.
- **Soil/root interface**: Further research is needed at the soil-root interface and on how the processes which take place there affect root growth, and ultimately agricultural productivity. There is a need to advance understanding of the role of plant roots on soil processes in the short-term (soil chemistry, hydrology, microbial diversity), and in the long-term (soil structure, soil formation), both directly (exudate chelation, physical perturbation, water distribution) and indirectly (biology of the rhizosphere). More research is also needed to understand soil-root interactions in deep subsoil, and to

explore how soils can be improved at depth (>30cm) so that the root zone of plants is optimised.

- **Nutrient efficiency**: Further research is needed to understand mechanisms of controlling the efficiency of major nutrient inputs such as nitrogen, phosphorus and potassium, and the full fate and consequence of the loss, retention and leaching of nutrients in agricultural landscapes. This will lead to the development of better ways to maximise the effectiveness of these inputs within the soil.
- **Recycled nutrients and waste**: Further research is needed into novel approaches of utilising organic 'waste' from cities and agricultural landscapes. This would necessitate a research focus on the broader environmental impacts of recycling nutrients, including the impacts on human health and soil condition in the long term.

1.4 Soil at the interface

Soil processes are an integral part of broader hydrological and ecological processes in terrestrial and aquatic systems. We need a better understanding of 'soil at the interface' to ensure appropriate and effective responses to environmental challenges such as those associated with agricultural land use, mining (e.g. impacts of fracking), eutrophication of waterways and near-shore marine environments (e.g. Great Barrier Reef), contamination (e.g. impacts of landfill, major chemical spills), and loss of biodiversity (e.g. impacts of clearing on soil biodiversity). This understanding will help secure soil as an essential asset to Australia's future.

Research priorities:

- **Environmental impacts**: A better understanding of the environmental impacts of agriculture can be gained by quantifying nutrient (carbon, nitrogen, phosphorus) cycles, greenhouse gas emissions and carbon sequestration potential associated with different agricultural practices. There is also scope for developing methods for measuring the emission of greenhouse gases from soil under different management practices, and in so doing, explore options for emission reduction.
- **Eutrophication**: The avoidance of negative impacts arising from agricultural practices including eutrophication of waterways and the impacts of pesticides and herbicides on non-target species requires further research.
- **Water capture and storage in soil**: How water can be more effectively captured and stored in soil so that optimal availability for plants is achieved should be investigated across soil types and farming practices. Minimising losses to evaporation and runoff by improving infiltration is of particular importance.

Part two: themes for future focus

2.1 Professional development of soil scientists

In concert with the trend seen in broader agricultural sciences, the number of students enrolling in soil science courses at a tertiary level has declined to critical levels. As a result we are seeing a serious lack of specialised graduates in soil science (and hydrology) available to meet employer demand. This problem seems to be compounded by a poor perception of both job security and opportunities for career progression.

Both of these factors are major considerations for students selecting a path of study, and for those already engaged in a professional career. Many of the positions available to soil scientists are short-term contracts reliant on competitive short-term project funding from RDCs or government. This restricts career development opportunities. So whilst there is an unmet demand for skilled soil and landscape scientists, our ability to attract young people to this discipline (and to retain them once they enter the workforce) is to some extent limited by the nature of the jobs available.

Adding to this problem, the soil science workforce is aging, and opportunities for mentoring and learning from experienced practitioners are becoming fewer. Many of our soil and land resource assessment experts were trained in the 1980s and 1990s by the strong cohort of senior soil scientists of that time. As these experts approach retirement age, and without adequate succession planning – including training and mentoring opportunities – we risk losing an invaluable knowledge and skill resource, assembled over decades. A major capability gap is developing, and unless addressed will inevitably limit our ability to address ongoing (and future) land management challenges.

It appears that this problem has been created in part by resourcing constraints and structural changes within government agencies, as well as the changing nature of industry roles, including the growth of private consultancy firms. It is worth noting that these changes bring with them a change in the type of knowledge and skills demanded by employers. Pleasingly, institutions delivering soil science education have recognised this shift, and teaching is evolving to better match the changing roles of soil science graduates. The 2012 report *A national soil science curriculum in response to the needs of students, academic staff, industry and the wider community*[1], is an important step in this evolution. The report explores options for a national

[1] Field, D, Koppi, T, Jarrett, L, McBratney, A, Abbott, L, Grant, C, Kopittke, P, Menzies, N and Weatherley, T, 2012, *A national soil science curriculum in response to the needs of students, academic staff, industry, and the wider community*, report to the Office for Learning and Teaching, Department of Industry, Innovation, Science, Research and Tertiary Education, available at olt.gov.au/project-national-soil-science-curriculum-sydney-2009.

approach to a curriculum that would produce work-ready graduates with interdisciplinary knowledge, skills and capabilities that are relevant to the needs of Australian employers and the constraints and challenges of the Australian environment. Field-focussed teaching is also essential and should be a priority.

There is a broad requirement to maintain and improve our national soil science expertise across the RD&E spectrum. Industry requires scientists with practical soil and landscape understanding, as well as highly developed quantitative skills. Our soil scientists also need to be adaptable, and able to communicate effectively. Training should reflect this industry need.

There is an opportunity to better utilise existing professional accreditation programs, to ensure that there is a consistent level of soil science (and related) expertise across the country. Such programs provide an ongoing learning framework for those delivering soil RD&E, and ensure that they have the skills and knowledge needed to deliver their work. Crucially, accreditation also provides confidence about the quality of the information being delivered.

The Certified Professional Soil Scientist[2] (CPSS) program administered by Soil Science Australia is a fine example. Soil science is a highly specialised field, and CPSS accreditation recognises the educational qualifications and the professional experience of a soil scientist. There are approximately 600 soil scientists across Australia with some level of CPSS accreditation. Such a program could be used by the universities as an accreditation goal for graduates. Greater uptake of accreditation would assist employers in selecting suitably qualified staff, and provide confidence to those seeking advice to inform decision making.

In short, to attract students to soil and landscape sciences, we need defined career paths and greater job certainty. A broader understanding of the importance of protecting and improving our soil resource, and the opportunities available within this discipline would also be useful. We should encourage the uptake of professional accreditation, either soil-specific (CPSS) or more broadly, to ensure that soil knowledge exchange is delivered by suitably qualified personnel.

2.2 Information needs for land management

Australia's soil is a key strategic asset, driving our agricultural productivity and providing essential ecosystem services. More effective management of this asset has the potential to deliver increased productivity and improved landscape health. The key to more effective management of the soil resource is the provision of up to date, fine scale soil information, including a better understanding of how particular soils respond to changes in land management and environmental conditions.

[2] www.cpss.com.au.

Soil properties are highly variable across the landscape. Improved understanding and quantification of this variability will allow for management decisions that better match the capability and limitations of the soil resource. Whilst there is much soil information available at larger scales across Australia, the interpretive value of the information available at the paddock scale is limited. It is clear that the information needs of land managers are not being met. The dearth of adequate soil data and information puts serious limitations on our ability to manage our agricultural land sustainably and profitably. As discussed in Section 1.1, decisions made by land managers, whether farmers, urban planners or policy makers, must be informed by sound scientific data, and adequate spatial information.

Whilst Australia has commendable expertise in this area, and has made significant progress on the collection of soil data in the past, most publically available soil data are too broad scale or too old to be used for decision making. Most land managers need paddock-scale information on which to base decisions, and this information needs to be presented in a clear and relevant manner, and communicated in an accessible format. The recently released *SoilMapp* tablet application, developed by CSIRO, is a great step in this direction.

An additional issue is that much of the older available data is focussed on soil classification, and does not report soil functional attributes, which are more relevant to management. Up to date, fine scale data on important attributes such as nutrient and carbon status, bulk density (which describes structure and compaction), water storage capacity and chemical constraints such as acidity, salinity and sodicity are essential. The effects of management decisions on all of these attributes, and the interactions between these attributes, add a further level of complexity to achieving effective landscape management.

Threats to soil function are apparent in some regions (e.g. acidification, nutrient deficit, soil erosion, declining carbon stocks), but accurate information on the extent and seriousness of these threats is lacking. This want for adequate soil data and information limits our ability to respond appropriately to threats, to the detriment of agricultural productivity and the health of our broader environment.

Our soil resource underpins our ability to meet looming challenges such as booming world populations and an associated demand for increased food production, and an increasingly uncertain climate. If we are to do this effectively, we must have up to date soil information at an appropriate scale. We should consider options for developing a public-private investment model for soil data and information that overcomes institutional barriers that prevent the right information being collected and shared for maximum benefits. This could include similar arrangements for soil mapping, focussed on the acquisition of relevant soil functional data. The

National Committee on Soil and Terrain are preparing a business case for such a model, to be considered during the implementation of the national soil RD&E strategy, which has recognised the importance of appropriate soil data and information.

To address the relatively low uptake of regular soil testing, we should investigate *why* farmers are not testing their soils. The costs associated with soil testing may be a deterrent, and if this is the case we should look at better communicating the benefits associated with regular soil testing. This should focus on the possible savings, such as a reduction in input costs, better targeting of problem areas, and the capacity to avoid long term threats to soil function that can be hugely expensive or impossible to reverse (e.g. severe acidification of the subsoil). Consideration should also be given to how we can capture the data collected by those landholders who do pay for testing. Whilst there is currently no obligation for private landholders to share their data, there would be many benefits associated with a national soil data system that incorporated such 'crowd-sourced' data.

Complementing this, there are opportunities to develop online applications that make complex soil information more relevant to land managers. This could include advice and options on how to address particular issues such as acidity and salinity. This issue is taken up further in the following section.

2.3 National approach – soil information and extension

It is apparent that whilst there is considerable effort underway to improve soil management, including via extension activities and the collection and collation of soil data, this effort is limited by a lack of national consistency, definition and coordination. We would benefit from a coordinated national response, beginning with a well defined high level national objective for soil and landscape management. A good example of such an objective is:

'*To restore and maintain an Australian landscape that is fit for purpose*.'

There appears to be a lack of understanding that healthy soils can only be achieved through the successful integrated management of soil, water and biodiversity. A national objective for soil and landscape management (such as that proposed above) would allow better understanding of this concept, and focus activity towards realising it.

As discussed in Section 2.2, appropriate soil data and information are crucial to facilitate efforts to better manage our soil and landscape. The idea that 'if you don't measure it, you can't manage it' certainly holds true in this respect. We need a national system for the collection of data, including sampling and testing methods and quality assurance. This would allow data to be more accurately compared between regions and perhaps even more importantly, over time. In short, the collection and collation of standardised information would improve our spatial and temporal interpretations, and the extension of research results. A vital outcome of long term soil data collection is the ability for scientists to use this information to monitor and forecast trends.

We should encourage the use of national standards for soil sampling, analyses, data collection and access, as well as support for and use of national facilities such as the open-access online Australian Soil Resource Information System (ASRIS) and the National Soil Archive. Both ASRIS and the National Soil Archive are administered by CSIRO through the Australian Collaborative Land Evaluation Program (ACLEP), which relies on partnerships with all state and territory agencies. Collecting data and maintaining a soil database can be expensive and require specialist expertise exceeding the resources available to the states. A collaborative national program such as ACLEP builds economies of scale and streamlines our efforts in this area. It is worth noting here that none of these activities operate with any formal mandate or legislative backing. This is in contrast to our arrangements for weather, climate, water and biological data, where there is a formal mandate for specified agencies to collect and manage data on behalf of the nation.

A stocktake of where repositories of soil information are presently held, what data remains relevant, where the shortfalls are and the priorities for meeting these shortfalls would be constructive. The National Committee on Soil and Terrain, which provides strategic oversight to ACLEP, have published national standards for the classification, collection and production of spatial data related to soil and terrain, and are well placed to progress the resolution of these soil information issues.

Effective extension of soil information to farmers and land managers is crucial. The extension paradigm has changed significantly in recent years, with a notable trend of declining government provision of individual to individual extension services. Recognising that the provision of extension services has traditionally been a state government role, a national mandate or coordinated service delivery system, such as centres of excellence, may be of value. New ways of communicating information to farmers should be explored, including interactive online repositories of information. The *SoilMapp* tablet application mentioned in Section 2.2 should be enhanced by filling in the data and information gaps, including by facilitating submission of data by users.

2.4 International opportunities

Australia is recognised as a world leader in soil science knowledge and management. Our soil scientists have played a large part in improving soil management throughout the developing world, and are actively involved in international initiatives related to soil science and management. Australian soil scientists are taking part in the Global Soil Partnership[3] (GSP), which was established by the United Nations Food and Agriculture Organization (FAO) to improve governance of the world's soil resources. We are also represented on the Intergovernmental Technical Panel on Soils, which provides expert advice to the GSP. Our technical expertise is also evident in our leadership role in the GlobalSoilMap[4] project, which is working to deliver a fine resolution digital soil map of the world. It is hoped that once complete the GlobalSoilMap will assist with better decision making in a range of important issues such as food security, climate change and environmental degradation.

There are significant benefits associated with sharing our expertise with other countries. For example, engaging with initiatives like the GSP maintains our commitment to international collaboration and coordination, and provides a vehicle for Australia to benefit from the international soil research effort. There are great opportunities for Australia to be active as a GSP partner, including in the sharing of our experience in natural resource management, and providing training and education for developing countries, where soil resources are critical. Australia has a lot to offer in terms of research capacity and expertise in hostile environments (e.g. low rainfall, low fertility, salinity and acidity), and we have a moral imperative to share this knowledge and skill to assist development and to address landscape degradation. Much of this knowledge and skill derives from our farmers, who are highly innovative and technologically sophisticated, and adept at meeting emerging challenges.

There are many bi-lateral arrangements between Australian and international agencies and collaborations on specific international projects. Projects funded by the Australian Centre for International Agricultural Research (ACIAR) are just one example. Engaging in international research partnerships and development projects presents mutual benefits, and we have established extensive networks with a proven history of collaboration.

There is an emerging international movement to improve soil management and ensure soil security. Australia has the expertise to be amongst the leaders in this movement. We should continue to show international leadership in improved land management, including through a movement towards data-driven decisions. Providing technical assistance in enhancing sustainability and food security should be a key focus of our aid program. We would benefit

[3] www.fao.org/globalsoilpartnership/en.
[4] www.globalsoilmap.net.

from increased support for Australia's ongoing participation in international research partnerships and structures, both public and private. Examples include the Consultative Group on International Agricultural Research, CGIAR. There is scope to further build international partnerships between universities, including through student exchange programs and the sharing of assessment techniques and expertise. We could also consider identifying international opportunities for Australian agricultural consulting businesses with soil expertise.

2.5 Constraints to adoption (management practices)

A large percentage of Australian soils are closely managed by farmers. The land management practices chosen by those farmers can have a crucial impact on the condition of our soils, and in turn on long-term productivity. Improving management practices can reduce soil loss through wind and water erosion, and slow rates of acidification and soil carbon decline. The condition of soil also contributes significantly to the quality of the ecosystem services a specific environment can provide. These services include cleaner air, improved water quality, reduced greenhouse gas emissions and the sustainable production of healthy food.[5]

Decisions to change management practices are influenced by a combination of financial, environmental and personal motivations, as well as the availability of easily accessed support systems.[6] However, the primary incentive for farmers to adopt improved land management practices is certainly financial – either through effect on yields and quality and the gross margins of the enterprise, or through positive impact on the value of the land asset. Likewise, farmers cite lack of funds as the major limiting factor in their ability to change management practices, followed by available time, workload and readily available advice on practice implementation. Therefore it is essential to assess potential land management practices in the context of their economic cost and impact. A good way to consider these issues is in the context of risk management and uncertainty, both of which are major considerations in the adoption of new management practices. The ability to manage risk (be it financial, technical, climatic, related to pest and diseases etc) is at the core of the whether adoption of new practices takes place.

[5] Cork, S, Eadie, L, Mele, P, Price, R and Yule, D, 2012, *The relationships between land management practices and soil condition and the quality of ecosystem services delivered from agricultural land in Australia*, prepared by Kiri-ganai Research for the Department of Agriculture, Canberra, September 2012, available at daff.gov.au/natural-resources/ecosystem-services/relationships-between-land-management-practices-soil-condition.

[6] Ecker, S, Thompson, L, Kancans, R, Stenekes, N & Mallawaarachchi, T 2012, *Drivers of practice change in land management in Australian agriculture*, ABARES report to client prepared for Sustainable Resource Management Division, Department of Agriculture, Canberra, December 2012. CC BY 3.0., available at daff.gov.au/__data/assets/pdf_file/0010/2235934/drivers-practice-change.pdf.

Drivers of change differ across industries, as do the preferred methods of accessing support for practice change. Regardless of industry, farmers need to be reminded of the importance of good soil management through media, through training and field days and through their advisors. A wide spectrum of providers plays an important role in supporting practice change. These providers range from grower groups and private consultants to Landcare and regional NRM facilitators and government programs. Grower groups have the sharing of information and the development of practical solutions at their core, and are becoming more and more active in this area. Learning and development through training courses, workshops, pilot trials and agribusiness initiatives are also key in influencing the decision to change.

Any approach to address constraints to the adoption of improved land management practices should understand that the most effective changes have traditionally been when there is both a profit and a sustainable agriculture driver. No-till farming systems are a good example. It follows that support for practice change through extension services, education or communication activities will be more effective if consideration is given to the different motivators (financial, environmental and personal). Further research in this area (for example through cost benefit analyses) to better convey the benefits and risks associated with practice change would be of great service. Communication would also be enhanced if preferred sources of information for each industry were identified and utilised. The national soil RD&E strategy will consider many of these issues and opportunities during its implementation phase, beginning in early 2014.

We should not forget the many opportunities to 'think outside the square' in addressing the issues raised here. Alternative approaches to farming are many, and should be given thorough consideration. This could begin by identifying which specific aspects of holistic/complete system farming are beneficial, and then analysing why they are successful and reinforcing that success. Also, given that the overriding motivator for practice change is financial, we could consider ways in which this pressure could be better managed. For example, regional bank attitudes to loans and debt servicing could be reviewed to take greater cognisance of on-farm sustainability, in addition to productivity.

2.6 Technology and innovation

Technological advances and innovation have underpinned much of our great progress in farming and land management in the past, and will inevitably play an even greater role into the future. This is particularly true as we search for ways to grapple with emerging challenges that will require us to increase production whilst reducing inputs, in the face of an increasingly uncertain climate. This needs to be done whilst also maintaining and improving the quality of the natural resource base.

As an example, we should build on and encourage the uptake of existing technology that allows more precise management, accounting for in-paddock variation in soil attributes and yield. This precision agriculture technology will assist cropping enterprises to reduce inputs, thereby reducing costs and minimising the loss of nutrients off farm, and the subsequent risk to the environment. For graziers in the rangelands, we should build on technology that allows them to better manage pasture biomass and improve herd structure. Supporting graziers to skilfully manage optimal stocking rates will help to build profitability, and to maintain long term viability.

Areas where innovative technology can assist land management include the areas of field-based sensing and analytics, rapid laboratory analytics, interactive applications, controlled traffic (including satellite guidance) and Unmanned Aerial Vehicles (UAVs). Developments in agricultural engineering, including new tillage equipment and irrigation infrastructure will also bring major benefits. On-farm innovations have always led the way and we should continue to take note of how our farmers are modifying their management practices and infrastructure. We should locate and encourage investment in novel technologies which have the potential for significant productivity gains. This should include scoping the technologies that have been successfully applied internationally.

We should also encourage innovations in the way we approach management. There are considerable opportunities for alternative management practices to boost soil health and sustainable land management outcomes. For example, pasture cropping (sowing annual crops into dormant native perennial pastures) looks to offer significant benefits for soil health. Climatic conditions and the availability of suitable pasture species may be a barrier to uptake of this practice in some parts of Australia, and further work is needed to examine how it can be applied to particular soil types or farming systems. Innovative grazing practices such as managed rotational or crash-grazing also appear to present benefits for soil and landscape condition, and ultimately for the productivity of the landscape. There are also opportunities to examine how alternative approaches to grazing management in the northern savannas can be used to reduce fuel loads and the associated risk of grass fires, which make a substantial contribution to carbon dioxide emissions. Similarly, we should continue to explore ways to better utilise organic wastes (which comprise the bulk of waste produced in urban centres) to improve soil condition, and to minimise greenhouse gas emissions.

We should look at the barriers to adoption of these innovative practices, and invest in further development of and communication about them. A process that streamlines the identification and evaluation of on-farm innovation (in both management practice and infrastructure), leading to more rapid uptake would be of great assistance in the move towards ‘best practice’.

2.7 Urban rural disconnect

In our increasingly urbanised society, people are becoming removed from agricultural food production processes and lack an appreciation of those maintaining the agricultural landscape on their behalf. Whilst it's our farmers who manage much of the landscape, all Australians benefit from their hard work. Therefore it is essential to reconnect urban Australia with its rural roots and to develop understanding and appreciation of the work done on farms, and of the importance of our land and soil resources. Part of this should be a greater appreciation of the role of farmers as 'environmental stewards', and an increased awareness about the geo-political importance of agriculture. Agriculture plays a role in all aspects of regional and global security.

There are many oblique benefits associated with resolving the urban-rural disconnect. For example, it may attract young people to careers in agriculture, and in doing so help to address the shortage of students enrolling in soil science units (discussed in Section 2.2). There is also some evidence to suggest that there are linkages between understanding where food comes from and healthier food choices, e.g. through community gardens projects. We should explore how to encourage the uptake of such projects, including school vegetable gardens and farm visits. There are also opportunities for the soil and landscape science community to more closely align with television shows such as Gardening Australia, and cooking shows that focus on how healthy food is produced.

Broad promotion of World Soil Day (5 December) should be encouraged, and we should prepare for the *International Year of Soils 2015,* which was proclaimed by FAO member countries in April 2013. This will serve as a platform for raising awareness on the importance of sustainable soil management as the basis for food systems, fuel and fibre production, essential ecosystem functions and better adaptation to climate change for present and future generations. Plans for the *International Year of Soils 2015* are currently being developed for consideration by the Global Soil Partnership.

2.8 Indigenous Australians

An estimated 20 per cent of the Australian continent is owned by Indigenous people, who have long-held cultural and traditional responsibilities for protecting and managing the land. There is a great, under-utilised opportunity to incorporate Indigenous knowledge into natural resource management, and into production systems.

One example of how this knowledge is beginning to be utilised is the Indigenous weather knowledge[7] project administered by the Bureau of Meteorology. This project recognises the

[7] www.bom.gov.au/iwk.

knowledge of weather and climate developed by Indigenous Australians over countless generations, and the complexity and diversity of weather over our continent.

There would be great value in an increased focus on natural resource management programs that target Indigenous Australians. We should share success stories such as the Northern Land Council, the Tiwi Land Council and Gundjehmi Aboriginal Corporation, who have worked with soil scientists to identify constraints and assess the suitability of land for agriculture. In particular we should engage with and utilise the specialist expertise of traditional land owners in the rangelands. There also exists significant potential in terms of employment and business opportunities for Indigenous Australians in an expanding grazing industry in Northern Australia.

2.9 Water in the landscape

Soil water is perhaps the key determinant of soil productivity. The amount of water in the soil is dependent on rainfall (or irrigation) and the water holding capacity of the soil. Climate change is causing increasing rainfall variability, making it more difficult to predict over the growing season. Forecasts suggest that this variability is likely to increase, with some regions becoming wetter, others drier, and extreme events more common. In this context, measuring and managing our soil water becomes particularly important. A large amount of the rain that falls on our soils is returned to the atmosphere through evaporation (up to 50 per cent on average in some parts of Australia), or lost from the system as runoff. We need to focus on how we can capture more water in our soil (by increasing infiltration and storage and reducing losses through runoff and evaporation) and how we can manage our agricultural systems to optimise the use of this water.

Farmers need to be supported as they adapt to a changing climate. Part of this support should include the information needed to better manage soil water. The water holding capacity of a soil is largely determined by its texture (the amount of clay, silt and sand) and its structure. Whilst it is difficult to alter the texture of a soil, management practices can have a significant impact on structure. A poorly structured or compacted soil will have only limited ability to capture and store water. Improving soil structure and increasing groundcover improves the infiltration, storage, availability and sustained supply of water from soil. Maintaining and building groundcover also reduces loss of water through evaporation and runoff, and improves the water holding capacity of a soil by building soil organic matter (which can hold up to twenty times its own weight in water). Better management of groundcover should therefore remain a high priority.

The long-term national intention should be for integrated monitoring and understanding of soil water, including forecasting responses to climate variability. This information will contribute to adaptive management and long-term productivity.

Groundwater represents a reliable water resource that can serve as a buffer against climate variability, and provide storage options that complement more conventional water stores. Australia's considerable expertise in groundwater hydrology should be tasked to investigate the opportunities for more effective use of near-surface groundwater systems to improve the productivity and resilience of Australia's farming landscapes. Any such investigation should however, fully appreciate that groundwater is part of the overall water system, and must be managed as an interconnected component and not in isolation from surface water.

Many of our important wetlands and river systems have been severely degraded since European settlement. We should continue to focus on the rehabilitation of these wetlands and riparian zones, which play a central role in maintaining and improving water quality. An important consideration in this process is farm runoff. Runoff can cause significant degradation in our waterways, by introducing large amounts of sediment, nutrients and sometimes pesticides. There are a number of land management practices that can be used to mitigate this risk and improve the quality of runoff. Maintaining groundcover will prevent the loss of topsoil and associated nutrients or contaminants. Timing of fertiliser or pesticide applications should also give consideration to short-term and mid-term rainfall forecasts. These sorts of practices are being promoted through programs such as Reef Rescue, which is targeting sugarcane farmers and graziers in the Great Barrier Reef catchments.

2.10 Regulatory burdens and inconsistencies

Rural businesses operate in a highly regulated environment, which can impose compliance costs or impede opportunities to innovate. Where appropriate, regulation can improve societal outcomes, but where it is unnecessarily burdensome, complex, redundant or duplicative, regulation hinders the productivity and profitability of Australia's rural industries. A recent report prepared by the Australian Bureau of Agricultural and Resource Economics and Sciences[8] found that around a quarter of federal agriculture regulations could be improved to reduce the burden for farmers. This is consistent with the Coalition Government's 2013 election commitment to reduce the regulatory burden for individuals and businesses by cutting red and green tape. We should ensure that effective soil management and on farm innovation are not unnecessarily constrained by regulatory requirements.

[8] Gibbs, C, Harris-Adams, K & Davidson, A, 2013, *Review of Selected Regulatory Burdens on Agriculture and Forestry Businesses*, ABARES (Report to client prepared for the Department of Agriculture's Agricultural Productivity Division), Canberra, November 2013, available at daff.gov.au/abares/publications.

Overlap, inconsistency and duplication in regulatory requirements and program priorities are not uncommon in our three-tier system of government. Soil and landscape types do not conform to these administrative boundaries. A single landscape unit such as a floodplain can cross multiple shires, NRM regions or state boundaries, and be subject to differing regulation, and differing management advice and support. These sorts of inconsistencies are confusing, place a burden on land managers, and can impede the sustainable management of our landscape. Better coordination and consistency would benefit land managers, and the long term health of our soil and landscapes.

Conclusions

Australia's soil, water and vegetation are key national strategic assets. Appropriate (and integrated) management of these assets is central to our continued national prosperity and the long term health of our landscape.

This report identifies a number of priorities for soil research and development, which will contribute to improved understanding and management of our vital soil resource. It also explores a number of themes focused on the broader aspects of landscape management, including the imperative requirement for soil information to support planning and decision making; constraints to the adoption of improved management practices and the need for effective extension; and the possibilities associated with uptake of technology and innovation.

The next report will be a progress report to the Prime Minister, in which the issues discussed here will be built on. These reports will inform the final report to the Prime Minister, where a number of strategic recommendations will be put forward for consideration by the government.

Appendix A – Meetings and events

The Advocate has continued to seek out opportunities for engaging with land managers, the general public and experts involved in natural resource management. Since the first report was submitted in June 2013, the Advocate has pursued the following activities:

- Meeting with representatives from Geoscience Australia to discuss their responsibilities in relation to soil, water and vegetation as well as the collection, storage, analysis and dissemination of geoscientific data, *10 May.*
- Visit to Victoria to speak with representatives from Corangamite CMA and Marcus Oldham College and visit several trial sites in the area, *13–14 May.*
- Meeting with representatives from Rural Industries Research and Development Corporation to discuss topics including the effects of climate change on agriculture productivity, developing northern Australia and improving Australia's soil mapping coverage and availability of data to the public, *12 July.*
- Meeting with members from Grain Research and Development Corporation to discuss broad acre farming methods and the resulting impacts on soil condition and water retention, *12 July.*
- Delivered the WA Boodja Soil Science lecture, hosted by the Soil Science Australia WA Branch, *5 September.*
- Meeting with representatives from the National Water Commission to discuss the role of the commission and water reform programs that have a bearing on soil or vegetation, *10 September.*
- Meetings with various stakeholders in Brisbane and Toowoomba to discuss topics including the role of soils in agriculture and access to soils information and education, *25–26 September*.
- Keynote address to the Queensland Landcare Conference on the topic of 'What is driving us?' and work to date in the role of Soil Advocate, *27 September*.
- Meeting with Murray-Darling Basin Authority senior executive staff to discuss the Basin Authority's role and how its work fits with other government agencies and the global environment, *3 October.*
- Second meeting with senior executive staff from the Bureau of Meteorology to discuss the work of the Bureau, especially their technological capabilities and the methods used to share their research and results with the public, *4 October.*
- Delivered a keynote address at the Australian Organics Recycling Association Speakers Event at the Hawkesbury Institute for the Environment, University of Western Sydney, *11 December.*

Appendix B – Expert Advisory Panel and Consultative Group

Expert Advisory Panel

Name	Affiliation/s
Prof Lynette Abbott	Winthrop Professor, School of Earth and Environment, Faculty of Natural and Agricultural Sciences, University of Western Australia
Dr Richard Doyle	President of Soil Science Australia Deputy Head of the School of Agricultural Science, University of Tasmania
Dr Neil McKenzie	Principal Research Scientist – CSIRO Land and Water (based in Montpellier, France)
Prof Iain Young	Professor of Environmental Biophysics Head of School of Environmental and Rural Sciences, University of New England Chair, Australian Council of Deans of Agriculture

Consultative Group

Name	Affiliation/s
Prof Paul Bertsch	Chief, CSIRO Land and Water
Dr Martin Blumenthal	Senior Manager Natural Resources, GRDC
Dr Michael Crawford	Deputy Executive Director - Future Farming Systems Research Division at Department of Environment and Primary Industries, Victoria
Dr Carole Hungerford	GP, specialising in nutritional and environmental medicine.
Mr Walter Jehne	Director, Healthy Soils Australia
Dr Gamini Keerthisinghe	Research Program Manager for Soil Management and Crop Nutrition Australian Centre for International Agricultural Research
Mr Matt Linnegar	CEO, National Farmers' Federation
The Hon Karlene Maywald	Chair, National Water Commission
Prof Alex McBratney	Professor of Soil Science, University of Sydney
Dr Mike McLaughlin	Professorial Research Fellow, University of Adelaide / CSIRO
A/Prof Pauline Mele	La Trobe University / Victorian Department of Environment and Primary Industries
Prof Neal Menzies	Dean of Agriculture, University of Queensland
Prof Ravi Naidu	Director, CRC for Contamination Assessment and Remediation of the Environment
Prof Steven Raine	Executive Director, Institute for Agriculture and the Environment, University of Southern Queensland
Emeritus Prof Alan Robson	University of Western Australia
Noel Schoknecht	Science Leader, Soils, Department of Agriculture and Food WA Chair, National Committee on Soil and Terrain
Dr Mark Stafford Smith	Science Director, CSIRO Climate Adaptation Flagship
Mike Stephens	National President, Australian Institute of Agricultural Science and Technology
Dr John White	Executive Director, Ignite Energy Resources
Dr Mary White AM	Palaeobotanist and author
Emeritus Prof Robert White	Melbourne University
Peter Wilson	Research Team Leader, National Soil Information, CSIRO