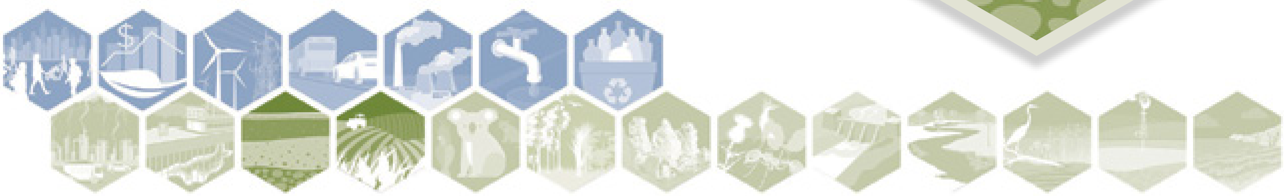
# 10 SOIL CONDITION



Soil resources in NSW are generally in a moderate condition, despite a broad decline in the condition of most soils since the arrival of European settlers. Some parts of the state are in poorer condition and display a significant loss of soil function.

Significant land degradation concerns are apparent across many areas of the state, with 74% of the 124 priority soil monitoring units selected for assessment being rated as poor or very poor for at least one soil degradation hazard.

On a statewide level, the loss of organic carbon and topsoil loss due to sheet erosion are responsible for the greatest loss of soil health and productivity. Topsoil loss due to wind erosion and salinity are also issues of concern.

Much of the change in soil health has occurred over longer timeframes, largely reflecting historic loss due to the lack of knowledge about managing soils sustainably in Australian conditions. More currently, the increasing intensity of land use, climate variability and extreme weather events represent greater risks to managing soil decline.

New conservation farming practices, such as reduced tillage, have helped to maintain soil condition generally, soil structure in particular, and to control erosion. The extent to which they improve the management of organic carbon levels and prevent acidification is less clear.

## NSW indicators

G Good  M Moderate  P Poor  U Unknown

| Indicator and status | | Environmental trend | Information availability |
|---|---|---|---|
| Topsoil loss (due to erosion) | M | Increasing impact | ✓✓ |
| Loss of organic carbon | M | Increasing impact | ✓✓ |
| Increase in salinity | M | Stable | ✓✓ |
| Change in soil pH (acidity) | M | Increasing impact | ✓✓ |
| Decline in soil structure | M | Stable | ✓✓ |

Notes: Terms and symbols used above are defined in About SoE 2015 at the front of the report.

The assessments of environmental trends in this theme are informed, in part, using information drawn from the related Theme 11: Sustainable land management, which describes ongoing pressures and short-term change.

## Context

Soils make a significant contribution to the economic and ecological prosperity of NSW. Healthy soils deliver essential ecosystem services, including: decomposition of organic matter, nutrient transformation, exchange and cycling, water infiltration, redistribution and filtering, along with climate regulation through carbon storage and cycling. They provide habitat for biota and support ecosystems and the primary production of food and resources.

Soil is essentially a non-renewable resource, as its formation is an extremely slow process that is beyond human timeframes (Bui et al. 2010; CofA 2014; Stockmann et al. 2014). Therefore, in order to maintain productivity and ecosystem services, soils must be managed sustainably. This theme describes the changes in soil condition relative to pre-European conditions that have occurred over the longer term (since European settlement) and as a result the soil degradation currently found in NSW.

The consequences of most types of soil degradation – such as soil loss from accelerated erosion, dryland and irrigation salinity, and subsoil acidity – are long-term and often either irreversible or difficult and costly to reverse. While some other forms of degradation, such as nutrient decline and surface soil acidification, may be remediated if addressed early, restoration is often expensive (Lockwood et al. 2003). In production landscapes, the application of best management practices can prevent or even reverse some lower levels of soil degradation.

## Status and trends

### Assessing the health of soil

Soil health is characterised by five key attributes or indicators of soil function: soil pH, soil carbon, soil structure, soil salinity and depth of topsoil.

In practice, soil health is often assessed by describing the extent of change or soil degradation that has occurred. In this analysis, seven change processes that relate to soil characteristics are recorded:

- change in soil pH (acidification)
- loss of soil carbon
- change in soil structure (compaction)
- increase in soil salinity (salinisation)
- loss of top soil through:
  - sheet erosion
  - gully erosion
  - wind erosion.

It should be noted that acid sulfate soils have been excluded from this description as they are not specifically a soil health issue.

There is a close relationship between the indicators of soil health and the soil change or degradation processes that result in loss of health, as described in Table 10.1.

The most recent systematic statewide assessment of NSW soil health commenced in 2008 under the NSW Natural Resources Monitoring, Evaluation and Reporting Strategy 2010–2015 (MER Strategy) (DECCW 2010). The monitoring program aimed to establish a baseline for soil condition in NSW and set up a permanent network of condition monitoring sites (Chapman et al. 2011).

As it was not feasible to monitor all soil types across the whole state, priority soil monitoring units (SMUs) were selected on the basis that they were broadly representative of regional conditions, but weighted towards areas considered to be of higher agricultural or ecological importance. Ten priority SMUs were identified in each of the 12 rural catchment management authority regions and four SMUs in the Sydney metropolitan area, for a total of 124 SMUs. The priority SMUs cover 280,000 square kilometres or 35% of NSW.

Up to 10 monitoring sites were established in each SMU. A program of soil data collection, with laboratory analysis, was undertaken at each site, together with the collection of land management data (see the related Theme 11: Sustainable land management). As the attributes of soil health and soil change processes can be quite variable in different naturally occurring soils, the health of each soil type was assessed as change relative to benchmark levels for the soil type, where it is still found substantially in its natural state.

A reanalysis of the original MER data was conducted in 2012 based on local land services (LLS) boundaries rather than catchment management authority (CMA) regions, using more complete and updated data (OEH 2014a). A total of 866 sites were surveyed, with full laboratory data available for 777 sites, with the

**Table 10.1: Relationship between soil health and soil degradation processes**

| Soil health indicator | Soil degradation process | Characteristics of soil condition and soil degradation processes |
|---|---|---|
| **Soil pH** | Acidification | Soil pH is an important chemical determinant of soil health. Most plants and crops grow best in soils that are slightly acidic to slightly alkaline, with many specific plants and crops being most productive in either slightly acidic or slightly alkaline soils. While both strongly acidic and strongly alkaline conditions are detrimental to plant growth, the main process of soil degradation is acidification. This is generally caused by intensification of land management with associated leaching processes, removal of soil nutrients and acidifying nitrogenous fertilisers.<br>Acidification reduces soil health and productivity and affects ecosystem function. |
| **Soil carbon** | Loss of organic carbon | Organic carbon is the main biological determinant of soil health by promoting soil nutrient recycling and improving soil structure. Organic carbon decline is generally a result of vegetation clearing and changes in land management leading to reduced replenishment of organic matter and greater losses to the atmosphere. |
| **Soil structure** | Soil structure decline | Soil structure refers to the arrangement of soil particles and voids. It governs soil water storage and movement and gas exchange and is the main physical determinant of soil condition. Soil structural condition is sensitive to land management practices. Soil compaction is caused by overworking wet or water-logged soils, use of heavy machinery, or excessive trampling by large animals. |
| **Soil salinity** | Salinisation | Soil salinity is the accumulation of salt on or near the ground surface due to rising water tables. It is caused by land-use changes that alter the hydrological balance in the landscape, such as clearing of vegetation, poor drainage and/or excessive levels of irrigation of crops or pastures with poor quality irrigation water, or in urban areas. An excessive level of salt is detrimental to plant growth and ecosystem processes. |
| **Depth of topsoil** | Topsoil loss due to erosion:<br>• sheet erosion<br>• gully erosion<br>• wind erosion | The topsoil layer is the soil stratum that supports most plant growth. It contains the majority of nutrients and organic matter available for plant growth. Its structure supports root development, along with the uptake of nutrients and water. Removal of the topsoil stratum reduces productivity and impacts on ecosystem functions.<br>Topsoil loss is caused by erosion processes – sheet, wind and gully erosion.<br>Sheet erosion is caused by rain splash and diffuse water flows during heavy or intense rainfall and flooding.<br>Gully erosion is the erosion of topsoil and subsoil by concentrated overland water flow in small localised areas of the landscape.<br>Wind erosion is caused by strong winds in dry conditions, where soils are bare or the ground layer of vegetation cover has been removed or thinned due to poor growing conditions, clearing or overgrazing. Many soils have eroded severely in the past to the extent that the topsoil has been completely removed. Off-site sediment and nutrient export affects water quality, aquatic ecosystem function and productivity. |

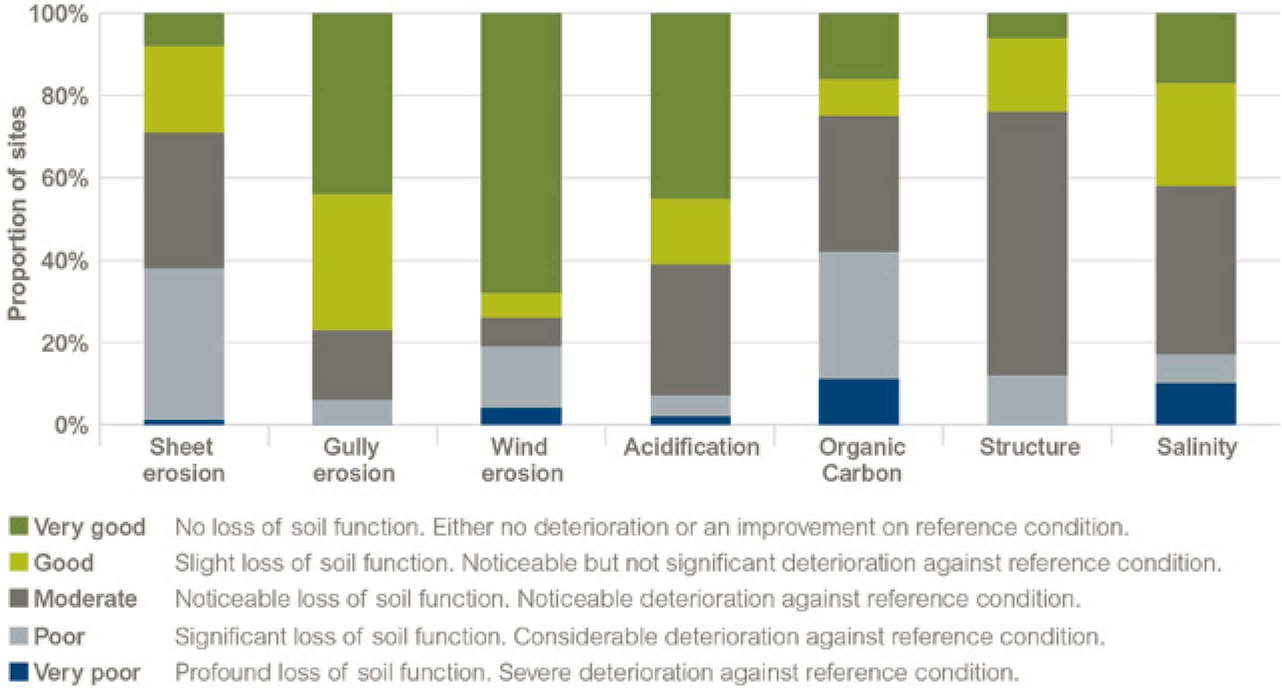
condition rating class determined for each of the seven soil degradation processes. A summary of the main findings is provided below.

The distribution of the condition classes for each soil degradation process for each SMU is depicted in Figure 10.1 (overleaf).

Figure 10.1 shows that, on a statewide basis, soils in NSW are assessed as being in moderate condition overall, but quite variable for different soil types. There has been a noticeable decline in the condition of most soils in NSW relative to their reference condition since the arrival of European settlers. As a result there has been a corresponding loss of soil function for ecosystem services and agricultural productivity.

However, it is evident that some parts of the state are in poorer condition overall, or display a significant loss of soil function due to some specific soil degradation processes. The percentages of SMUs in each LLS region that have poor or very poor ratings (i.e. where there

**Figure 10.1: Proportion of soil monitoring units in each soil condition rating class by soil degradation process**




Source: OEH 2014a

is significant or profound loss of soil function and where there is considerable or severe deterioration against reference condition) for each soil degradation process are shown in Table 10.2.

Of the 124 SMUs examined, 74% had poor or very poor ratings for at least one soil change process. It should be noted that the SMUs only cover 35% of the state but they are considered to be broadly representative of their respective regions and the state as a whole. A brief summary of the main issues resulting in loss of soil condition in NSW is given below, based on Table 10.2 and Figure 10.1.

### Organic carbon loss

Forty-one per cent of SMUs have ratings in the poor or very poor range. It is an issue broadly across the state and a significant concern (poor in 25% or more of SMUs) in seven of the 11 LLS regions.

### Topsoil loss through sheet erosion

Thirty-eight per cent of SMUs have ratings in the poor or worse range. It mainly affects central and coastal regions of NSW but is a significant concern (poor in 25% or more of SMUs) in 10 of the 11 LLS regions.

### Topsoil loss through wind erosion

Nineteen per cent of SMUs have ratings in the poor or worse range. It is a significant issue of concern in three of the western-most LLS regions.

### Increase in salinity

Seventeen per cent of SMUs and 15% of sites have ratings in the poor or worse range and it is a significant concern in four LLS regions.

Acidification, soil structure decline and topsoil loss due to gully erosion are issues affecting localised areas, with the results suggesting they are of significant concern in two or fewer LLS regions respectively.

The results suggest that, on a statewide basis, loss of organic carbon (41%) and topsoil loss due to sheet erosion (38%) are the two processes responsible for the greatest deterioration in soil condition over the longer term. Topsoil loss due to wind erosion (19%) and increased soil salinity (17%) are also issues of some concern. Acidification may however be more widespread than these results suggest, as it is believed to affect over half of Australia's agricultural soils (Wilson et al. 2009; ASoEC 2011).

**Table 10.2: Percentage of soil monitoring units in each local land service region where soil degradation processes are rated as poor or very poor**

| Local Land Service (LLS) region | Sheet erosion* | Gully erosion | Wind erosion | Acidity | Organic carbon | Structure | Salinity | SMUs with at least one process rated poor or very poor** |
|---|---|---|---|---|---|---|---|---|
| Central Tablelands | 47 | 13 | 0 | 0 | 40 | 0 | 47 | **73** |
| Central West | 26 | 4 | 4 | 0 | 19 | 13 | 22 | **61** |
| Greater Sydney | 50 | 0 | 0 | 43 | 57 | 0 | 30 | **90** |
| Hunter | 53 | 0 | 0 | 25 | 50 | 0 | 33 | **80** |
| Murray | 31 | 0 | 31 | 0 | 0 | 8 | 8 | **62** |
| North Coast | 80 | 20 | 0 | 22 | 56 | 0 | 0 | **100** |
| North West | 38 | 0 | 38 | 0 | 18 | 24 | 8 | **88** |
| Northern Tablelands | 67 | 8 | 17 | 11 | 33 | 11 | 0 | **83** |
| Riverina | 32 | 5 | 16 | 0 | 0 | 5 | 32 | **63** |
| South East | 76 | 9 | 0 | 18 | 59 | 0 | 24 | **88** |
| Western | 0 | 7 | 52 | 0 | 74 | 39 | 8 | **76** |
| **NSW (percentage of SMUs surveyed)** | **38** | **6** | **19** | **7** | **41** | **10** | **17** | **74** |
| **Ranking by severity of issue** | **2** | **7** | **3** | **6** | **1** | **5** | **4** | |

Source: OEH 2014a

Notes: *Indicates, for example, in Central Tablelands Local Land Service (LLS), 47% of soil monitoring units (SMUs) have sheet erosion rated as poor or very poor.

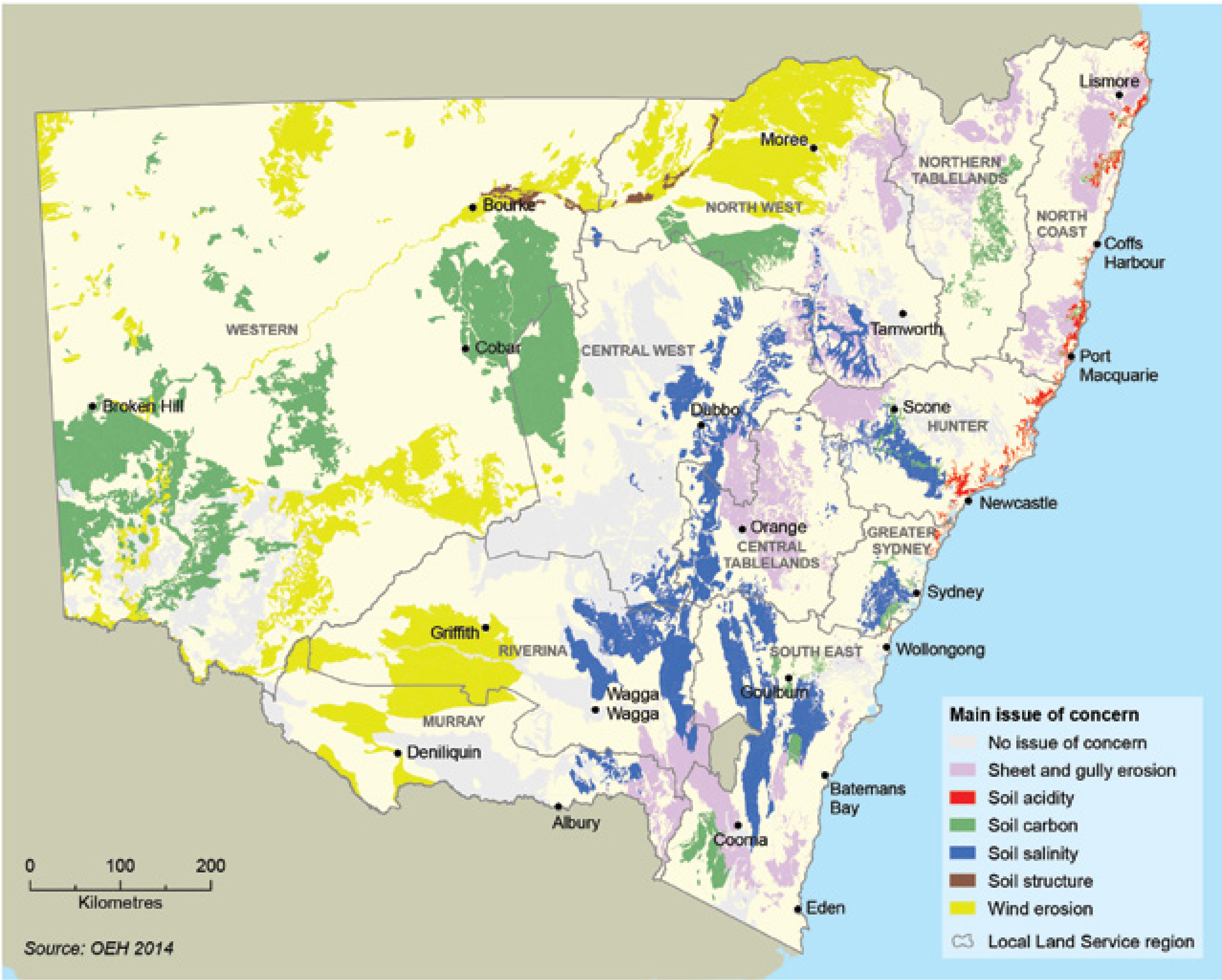
**Indicates, for example, in Central Tablelands LLS, 73% of SMUs are rated poor or very poor for one or more soil change processes.

Determining the levels of organic carbon in soil and the amount that has been lost is important, not only to assess and monitor soil health, but also to evaluate the potential for carbon sequestration in soil. Recent modelling (Gray et al. 2015) has estimated the amount of organic carbon in the top 30 centimetres of soil in NSW at 4.21 gigatonnes (Gt) prior to European settlement. Current stocks are lower suggesting that 530 million tonnes of soil organic carbon, or 12.6%, has been lost across the whole state. However, the study also found that the extent of soil organic carbon decline is highly dependent on the environmental land-use regime, with the greatest decline of 44.3 tonnes per hectare, constituting a 50% loss, occurring under a regime of regular cropping of soils with less siliceous (more mafic) parent materials in cooler (moist) conditions. Less intensive land uses, more siliceous parent materials and drier conditions were all factors contributing to a lesser decline in soil organic carbon.

The main soil health issues affecting SMUs where significant loss of soil function has occurred (identified by ratings of poor or very poor) are presented in Map 10.1 (overleaf). This map displays the main issues of concern for SMUs, and more than one issue may be significant. The map clearly shows that different soil decline processes are the dominant issues of concern in different parts of the state (further details based on the former CMA regions are presented in OEH 2014a).

The map does not necessarily indicate that the whole SMU is affected by the issue. The history of land use and land management will vary across any SMU, resulting in differing levels of change or deterioration in soil health. Much of the observed decline in the condition of NSW soils can be attributed to historic management approaches. Since the 1990s, there have been improvements in soil and land management, such as conservation farming and cell grazing, which have helped to minimise further loss of soil condition.

**Map 10.1: Main soil health issues within soil monitoring units**




## Pressures

### Unsustainable land management and land use

When European settlers first arrived in Australia they adopted traditional farming practices that had been developed to suit different soil profiles and different climate regimes in a different part of the world. Much of the soil degradation described in this theme is historic in nature and occurred before an understanding developed of how to manage soil sustainably in Australian conditions.

**The development of modern land management systems such as pasture rotation, conservation farming and no-till farming has halted the decline and in some instances reversed the loss in soil condition due to the impact of purely European land management practices. The extent to which soils are now being managed within their inherent capability given the current land use and the land management practices being conducted on them is described in the related** Theme 11: Sustainable land management.

### Climate variability

While soil may be managed sustainably with little risk of degradation during normal weather patterns, the unpredictability and variability of severe weather events can lead to conditions where the soil's capacity to cope is exceeded, leading to loss of soil condition and degradation. Climate change is expected to lead to more extreme weather events, increasing the challenge to manage for the variability in weather and possible drying conditions across much of NSW (Baldock et al. 2012; OEH 2014b), increasing the risk of some soil degradation hazards, particularly wind erosion and loss of soil carbon (Rengel 2011).

### Changed population and settlement patterns

Rising population in urban areas leads to more intensified land use. Increased demand for food at local, regional, national and international levels also leads to intensification in the use of productive land, increasing the risk of soil degradation. At the urban fringe highly productive land is coming under growing pressure to be converted to urban settlements, while population loss from rural areas reduces the capacity of managers to manage land effectively (see Appendix 2: Private landholder capacity to manage natural resources of SoE 2009 (DECCW 2009)).

### Economic factors

Declining farm profitability and poor international trading conditions, in particular a high exchange rate on the Australian dollar as experienced in the recent past, are also factors that may lead to an intensification of production activities, which may not be sustainable over the longer term.

## Responses

These responses are the same as those described for the related Theme 11: Sustainable land management.

### Legislation and policy framework

Important legislation providing for the protection and management of soil and lands in NSW includes the following.

The *Soil Conservation Act 1938* provides for the conservation of soil and farm water resources and the mitigation of erosion. It establishes the Soil Conservation Service, a state-owned soil conservation and environmental consulting business.

The *Native Vegetation Act 2003* regulates the clearing of native vegetation in NSW by outlining requirements for landowners when they clear native vegetation. Proposals for broadscale clearing of native vegetation must be assessed to determine whether this will improve or maintain environmental outcomes using the Environmental Outcomes Assessment Methodology (EOAM). This methodology establishes specific criteria for the assessment of impacts on land and soils when clearing is being considered.

Policy instruments supporting soil management include:

- the State Environmental Planning Policy (Rural Lands) 2008
- the Policy for Sustainable Agriculture in NSW (NSW Agriculture 1998).

### Programs

The performance monitoring system of the Soil Health Evidence Based Assessment (SHEBA) program (formerly SoilWatch) is used in many regions of NSW. It complements and supplements surveillance monitoring throughout the state.

Locally, the Landcare network contributes to integrated natural resource management at a grass-roots level. Nationally there are over 4000 Landcare groups and almost 2000 of these are registered in NSW. Groups are involved with a wide variety of land and water management issues, which can include soil erosion, streambank erosion, weed control, revegetation, degradation of the riparian zone, and farmland improvements. The projects and issues addressed by Landcare groups often assist in effective soil conservation by promoting the sustainable use of soils through education and community awareness programs.

The Soils Unit of NSW Department of Primary Industries (DPI Agriculture) has a large research and development program that develops technologies and management systems to maintain and enhance the physical, chemical and biological productivity of soils, protect the soils resource, build resilience and reduce environmental impacts. DPI Agriculture partners with local land services and private stakeholders to ensure research and development findings are delivered to industry.

The National Committee on Soil and Terrain coordinates and provides advice on soil and land assessment standards and policy. National protocols for monitoring soil acidification and soil carbon have been developed and published (Grealish et al. 2011).

The National Soil Research, Development and Extension Strategy (CofA 2014) will ensure soils research is targeted and collaborative and that research meets the needs of farmers and primary producers. There will also be better information and tools available on soil use and management.

The national strategy:

- provides an overview of soil research, development and extension (RD&E) in Australia, including challenges and drivers for soil RD&E
- considers current investment and capability in soil RD&E
- presents a future RD&E plan, including goals and strategic directions
- considers roles and responsibilities and co-investment
- provides a set of implementation actions.

The Carbon Farming Initiative (CFI) was replaced by the Emissions Reduction Fund (ERF) under the *Carbon Farming Initiative Amendment Act 2014*. The ERF has a number of elements that support sustainable management of soils. The CFI co-funded research under the 'Filling the Research Gap' program with the objective of identifying strategies to increase soil carbon and reduce nitrogenous greenhouse gases, increase productivity and potentially reduce soil acidification. The CFI also co-funded the 'Action on the Ground' program which focused on demonstrations by land managers to boost adoption of management techniques to increase carbon.

The ERF provides funding through a reverse auction mechanism that allows land managers proposing to sequester carbon to be financially rewarded for doing so. The first round of auctions in early 2015 resulted in 47 million tonnes of $CO_2$-e abatement (28 million tonnes of $CO_2$-e being contracted for sequestration and 19 million by other means).

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