Australian Government

Department of Agriculture, Fisheries and Forestry

Research Project Summaries

Climate Change Research Program

Soil Carbon Research Program

Internet

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Overview

The *Climate Change Research Program* (CCRP), which ended on 30 June 2012, funded research projects and on-farm demonstrations to help prepare Australia's primary industries for climate change. Research focused on reducing greenhouse gas emissions, improving soil management and climate change adaptation, and involved projects that will lead to practical management solutions for farmers and industries.

Over four years the Australian Government invested $46.2 million in over 50 large scale collaborative research, development and demonstration projects. Total investment under the program was over $130 million and included contributions from research providers, industry groups, universities and state governments. A breakdown of the allocated government funding is below:

- Reducing Emissions from Livestock Research Program—$11.3 million
- Nitrous Oxide Research Program—$4.7 million
- Soil Carbon Research Program—$9.6 million
- National Biochar Initiative—$1.4 million
- Adaptation Research Program—$11.5 million
- Demonstration on-farm or by food processors—$7.7 million.

Research through the CCRP has increased our understanding of the sources of agricultural emissions and the potential for emission reduction and carbon sequestration. This information has underpinned the development of the first approved methodology under the *Carbon Farming Initiative* and has contributed valuable data for a number of methodologies currently under consideration. This will enable farmers to generate additional on-farm income through selling carbon offsets into domestic and international carbon markets.

Filling the Research Gap, part of the $429 million *Carbon Farming Futures Program* under the $1.7 billion Land Sector Package, is building on research undertaken through the CCRP. Research projects are targeting current gaps around abatement technologies and practices identified through the CCRP, and will continue to support the development of offset methodologies that land managers can use to participate in the *Carbon Farming Initiative*.

The following summaries highlight the key findings from soil carbon research undertaken through the CCRP as well as related projects being funded through Round 1 of *Filling the Research Gap*. This information should be used by potential applicants to guide applications in climate change research for agriculture under Round 2 of *Filling the Research Gap*.

Potential applicants are advised to contact the lead organisations for each project for further information and are encouraged to refer to the *Filling the Research Gap* Research Strategy (July 2012-June 2017).

Climate Change Research Program

Soil Carbon Research Program

Development of cost effective soil carbon analytical capability

Lead organisation
Commonwealth Science and Industrial Research Organisation (CSIRO)

Consortium member organisations
N/A

Objectives
- develop a cost-effective method for measuring the amount and composition of organic carbon in Australian agricultural soils
- provide measurements of soil carbon and its composition to the national soil carbon research projects for the samples collected from Australian agricultural regions.

Location
CSIRO Laboratory at Waite Campus, Adelaide

Key activities
Soils were collected across many agricultural regions of Australia as part of the Soil Carbon Research Program (SCRP). In excess of 4000 sites were sampled generating more than 20 000 soil samples. All soil samples had total carbon, organic carbon, and inorganic carbon analyses completed. Total nitrogen analyses were completed for approximately 50 per cent of the samples. A subset of samples were fractionated to determine the quantity of particulate, humus and resistant organic carbon present in the soils. All samples were analysed by a mid-infrared spectroscopy / partial least squares statistical analysis and calibration models were built to allow the prediction of the content and forms of carbon present in the soil.

Findings/Conclusions
A rapid method of analysing the content and composition of soil carbon was developed in this project which has the potential of making the laboratory analysis more cost-effective and lowering the cost of soil carbon measurement.

The laboratory based methodology used previously to divide soil organic carbon into its component fractions was successfully modified to reduce operator dependence, improve sample throughput, make it more transferable to other laboratories, and allow for the direct measurement of all fractions. Training was given to all SCRP partner organisations as well as several researchers and students from other organisations to build fractionation capacity across Australian soil laboratories.

The capability of mid-infrared spectroscopy combined with partial least squares regression analysis (MIR/PLSR) to predict the content of total carbon, organic carbon, inorganic carbon and total nitrogen for <2 mm soil samples has been conclusively demonstrated across the 20 195 samples analysed. Measurements for all four analytes can be obtained from a single finely ground sample rapidly and cost effectively. Pretreatment with acid to remove inorganic carbon is not required provided adequate calibration of the MIR instrumentation has occurred.

A ^{13}C nuclear magnetic resonance (NMR) approach to quantify the content of resistant organic carbon (ROC) present in a soil was developed. This key development supported the calibration of the MIR/PLSR.

Related projects funded under Round 1 of Filling the Research Gap

- Improved measurement and understanding of soil carbon and its fractions—CSIRO—Jonathan Sanderman. Funding of $165 000 ex GST
- A method for efficient and accurate project level soil organic carbon determination using in situ spectrophotometry and advanced spatial analysis—Geo Carbon Services Pty Ltd—James Schultz. Funding of $215 105 ex GST

Publications

1. Baldock, J & Keating, B 2010, 'Australia's National Soil Carbon Research Program', Presentation to *Federal Parliamentary Committee*, Canberra, ACT, 2 June.
2. Baldock, J 2011, 'The Science of Soil Carbon', *Department of Agriculture, Fisheries and Forestry Carbon Farming Initiative workshop*, Canberra, ACT, 8 March.
3. Baldock, J et. al. 2011, 'Soil Carbon Research Program and Soil Carbon Methodologies', *Carbon Farming Initiative Soils Workshop*, Canberra, ACT, 5 May.
4. Baldock, J et. al. 2011, 'Australian Context - State of Soil Science: Australian research activities with a focus on soil carbon and its impact on soil security', *Soil Security Meeting*, Washington DC, USA, 16 September.
5. Baldock, J & Sanderman, J 2011, 'Quantifying the chemical composition of soil organic carbon with solid-state ^{13}C NMR', Poster at *American Geophysical Union Meeting*, San Francisco, USA, 8 December.
6. Baldock, J & Viscarra Rossel, R 2012, 'Building soil carbon on farms: an information opportunity and challenge', *Soil Information Symposium*, Sydney, NSW, 16 April.

Further publications detailing the results of this research are in preparation and will be available.

Rapid measurements of soil bulk density

Lead organisation

Commonwealth Science and Industrial Research Organisation (CSIRO)

Consortium member organisations

N/A

Objectives

To develop a rapid method to measure soil bulk density

Location

Bruce E. Butler Laboratory, Black Mountain, Australian Capital Territory

Key activities

- calibrate an active gamma radiometric sensor to measure soil bulk density and test the stability of the calibrations over time
- quantify the repeatability of the sensor measurements

- compare conventionally measured bulk densities with active gamma measurements over a range of soils
- measure the effect of gravel on bulk density
- measure the effect of water on bulk densities measured using the gamma sensor
- use visible near–infrared (vis–NIR) spectroscopy to measure soil water to account for its effects on the measurements of bulk density.

Findings/Conclusions

- A rapid method to measure the bulk density of soil core samples was developed in this project.
- Soil bulk density is needed to convert organic carbon content (e.g. as per cent C) to stocks of carbon expressed as a mass of organic carbon per unit area (e.g. as Mg C ha-1). Current field methods to measure soil bulk density are slow and expensive to acquire accurate measurements.
- Pedotransfer functions (PTFs) to estimate soil bulk density from other soil properties (e.g. texture and organic matter) have been developed but these are imprecise and require the measurement of additional soil properties.

Results show that:

- measurements of density using the active gamma sensor are accurate and reproducible
- the active gamma sensor measures the apparent density of field-moist soil samples, not the bulk density. Therefore, the gamma measurements on field moist soil cores need corrections for water content
- vis–NIR spectra can be used to rapidly and accurately measure soil water. Estimates of soil water using vis–NIR spectra can be used to convert apparent density to soil bulk density
- gravel content has a marked effect on measurements of bulk density.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

Publications detailing the results of this research are in preparation.

Quantification of carbon input to soils under important perennial pasture systems in Australian agriculture—pulse labelling field studies in Western Australia

Lead organisation

Commonwealth Science and Industrial Research Organisation (CSIRO)

Consortium member organisations

N/A

Objectives

To quantify the allocation of carbon from photosynthesis below-ground and its movement into soil carbon fractions, under perennial grass pastures in the Western

Australian wheat belt, in order to define the potential for carbon sequestration in these systems.

Location
Perth, Western Australia

Key activities
This project utilised isotopic ^{14}C to quantify uptake of carbon via photosynthesis by perennial grass pastures, and its allocation into organic matter fractions below-ground. ^{14}C has a very low natural abundance that enables daily inputs of carbon to be traced within a large carbon pool. Hence the quantity of carbon distributed amongst root material (roots), particulate organic matter (POM) and humus (HUM) could be determined at both short and long time frames following plant feeds with carbon dioxide. This time-course of information could then be used for validating models that estimate changes in soil carbon.

The allocation below-ground of carbon captured by photosynthesis was measured at two sites in Western Australia; in spring and summer under Kikuyu near Gnowellen in the southern Western Australia wheat belt, and in spring only under Rhodes grass near Badgingarra in the northern wheat belt of Western Australia. The sites were managed under a minimal fertiliser regime. The stability of organic matter fractions below-ground was assessed over 12 months (spring and summer labelling of Kikuyu) and six months (spring labelling of Rhodes grass).

Findings/Conclusions
This project developed a sound methodological approach for quantifying carbon allocations into organic matter fractions in soils. The method is applicable to other systems and environments and provides a tool for determining more accurate estimates of carbon allocation below-ground under crops and pastures.

This project has developed novel information on the allocation of carbon from photosynthesis into soil organic matter fractions beneath two perennial grass pasture systems (Kikuyu and Rhodes grass) in Western Australia.

Under Kikuyu, between 13 per cent (spring label) and 10.8 per cent (summer label) of the total ^{14}C applied remained in the POM + HUM fractions at 0 - 70 cm depth after 12 months. Based on above-ground biomass production and relative allocations to each organic matter fraction, this was equivalent to net carbon allocations remaining in POM + HUM of 13.3 and 5.9 kg C/ha/day from spring and summer inputs respectively.

Extrapolation of these results from the Kikuyu field experiment using the GrassGro model suggests approximately one tonne of C/ha/year is possible in the POM + HUM fractions, but if the HUM fraction is regarded as the only stable fraction this reduces to just 160 kg C/ha/year.

In these experiments the isotopic signal for both POM and HUM was stable over 12 months, but further research is required to establish the stability of POM in the longer term.

Under Rhodes grass, approximately 11 per cent of the total ^{14}C applied was allocated into POM + HUM. However, the clumpy habit of Rhodes grass with large unpopulated areas separating individual plants in the paddock reduced the overall estimates of carbon sequestration in this system.

In all field experiments, decomposition of roots resulted in minimal transfer of carbon (<1 per cent) to POM and HUM, indicating that most of the carbon in roots was respired to the atmosphere.

Related projects funded under Round 1 of Filling the Research Gap

- The fate of above ground carbon inputs: a key process that is poorly understood—Queensland University of Technology—Richard Conant. Funding of $378 161 ex GST

Publications

1. Fillery, I, Roper, M & Jongepier, R 2011, 'Allocation into soil organic matter fractions of ^{14}C fixed by perennial-based pasture', *Australian Society of Soil Science Proceedings*, Busselton, Western Australia, 22 September.

Further publications detailing the results of this research are in preparation and will be available.

Variations in soil organic carbon on two soil types and six land-uses in the Murray Catchment, New South Wales, Australia

Lead organisation

Murray Catchment Management Authority, New South Wales

Consortium member organisations

N/A

Objectives

To investigate variations in Soil Organic Carbon (SOC) on some common soil types and land-uses in the New South Wales Murray Catchment, and to determine the relative impact of factors (land management and environmental) which may be influencing those variations.

Location

Sampling occurred within the New South Wales Murray Catchment, between the townships of Holbrook and Barham. A total of 100 sites were sampled in the 'Plains' region (on Duplex soils), and 100 sites were sampled in the 'Slopes' region (on Red Brown Earths).

Key activities

Soil samples were collected from a minimum of 25 paddocks within each of the following land-uses in the study area;

- Plains continuous cropping
- Plains rotational cropping
- Plains pasture
- Slopes mixed cropping

- Slopes introduced pasture
- Slopes voluntary pasture.

Ten soil cores were extracted within a 25 m x 25 m plot in each of the selected paddocks to a total depth of 30 cm. Paddock management information (tillage, stubble handling and grazing), was collected for each site via a land-holder interview and questionnaire process.

Samples were analysed for soil organic carbon (SOC) content and physio-chemical parameters including; bulk density, pH, electroconductivity (EC), cation exchange capacity (CEC), and phosphorus (P).

Findings/Conclusions

Key findings identified in the project included:

- Major land-uses accounted for 46 per cent of the variations in SOC within the study area; however the inclusion of climatic, topographic and soil physio-chemistry variables increased the explanation of variation to 72 per cent.
- There was an association between higher SOC stocks and pasture dominated land uses in the higher rainfall 'Slopes region'.
- No significant differences in SOC stocks were identified between the three land-uses of the low rainfall 'Plains region'.
- A strong inter-relationship was identified between low soil bulk densities and increased SOC per cent. This relationship was also linked to an association between SOC, pH and exchangeable aluminium in some land-uses.
- There were significant correlations between SOC and climatic variables within the 'Slopes introduced pasture' group, more so than with any of the other land-uses.
- A topographical position of between 7.5 - 10.3 per cent slope was identified in the Slopes region as having an association with increased SOC.
- There was a negative association between SOC and soil phosphorus and Slopes voluntary pasture group and a positive association between SOC and soil phosphorus in the Plains continuous cropping group.

Information collected from the project will be used at two levels;

- Low variations in SOC were identified within and between land-use groups in the Plains region, and higher variations identified in the Slopes region.
- Incorporation of climatic, topographic and soil phsyico-chemistry variables increased the predictability of SOC variation in the landscape.
- A large range of inter-related correlations were observed between soil chemistry variables and SOC, including soil pH, P, Al, Na, Ca, Mg, K and CEC, many of which require further interpretation.

Related projects funded under Round 1 of Filling the Research Gap

- Increasing soil carbon in eastern Australian farming systems: Linking management, nitrogen and productivity—Department of Primary Industries, Victoria—Fiona Robertson. Funding of $2 782 312 ex GST

Publications

Publications detailing the results of this research are in preparation.

Quantification of carbon input to soils under important perennial pasture systems used in Australian agriculture: C3/C4 transitions

Lead organisation
Commonwealth Science and Industrial Research Organisation (CSIRO)

Consortium member organisations
N/A

Objectives
To evaluate if the conversion of annual based pasture systems to subtropical perennial grasses increases soil organic carbon storage.

Location
Southern and Northern Agricultural Districts, Western Australia
Kangaroo Island and Fleurieu Peninsula, South Australia
Namoi Catchment, New South Wales

Key activities
In each region, a number of pairs of subtropical perennial and annual based pastures were identified and sampled. Sampling was conducted by collecting eight randomly located soil cores within a four hectare portion of each pasture. All samples were analysed for total organic carbon, total nitrogen and the stable carbon isotope ratio. One composite sample from each sampling depth per pasture was size fractionated and the size fractions were then analysed in a similar manner as the bulk soil samples.

Findings/Conclusions
This project developed sound scientific evidence that conversion of annual grass-based pastures to certain subtropical perennial grasses can lead to soil carbon sequestration in temperate climate zones.

Kikuyu-based pasture systems in the Southern Agricultural District of Western Australia, Kangaroo Island and the Fleurieu Peninsula of South Australia had greater soil organic carbon (SOC) stocks relative to annual based pastures. However, pastures sown to a combination of Panic and Rhodes grasses had SOC stocks that were no different than annual based pastures in the Northern Agricultural District of Western Australia,

The SOC difference between the kikuyu and annual pasture increased linearly with the age of the perennial pasture. Mean SOC sequestration rates under kikuyu were found to be 0.90 ± 0.25 and 0.26 ± 0.13 Mg C/ha/yr in Western Australia and South Australia, respectively.

- The response in kikuyu-based pastures relative to Panic/Rhodes and annual grass based systems was attributed to a combination of the spreading growth form and greater below ground carbon allocation of Kikuyu.
- Measurement of the stable carbon isotopic composition of SOC in these pastures indicated that where SOC has accumulated, the gains have been dominated by new SOC derived from the perennial vegetation and have been concentrated in the upper 10 cm of soil.

Related projects funded under Round 1 of Filling the Research Gap

- EverCrop® Carbon Plus: perennial forage plants in cropping systems to manage soil carbon—Future Farm Industries Cooperative Research Centre / NSW Department of Primary Industries—John McGrath. Funding of $1 000 000 ex GST
- Native perennial vegetation: Building stable soil carbon and farm resilience—CSIRO—Jonathan Sanderman. Funding of $350 000 ex GST

Publications

1. Macdonald, L & Sanderman, J 2011, 'Cycling the carbon and nutrient pathway: Making soil organic matter work', *The Grassland Society of South Australia Meeting*, Hamilton, Victoria, 2-3 June.
2. Sanderman, J, Roper, M, Macdonald, L, Maddern, T, Fillery, I & Baldock, J 2009, 'Soil carbon sequestration under perennial pastures in Western Australia: Isotopic evidence from C3-C4 vegetation shifts', *10th Australasian Environmental Isotope Conference*, Perth, Western Australia.

Further publications detailing the results of this research are in preparation and will be available.

The potential for agricultural management to increase soil carbon in NSW

Lead organisation

University of New England

Consortium member organisations

NSW Department of Primary Industries
NSW Office of Environment and Heritage

Objectives

- to assess the potential for agricultural land management practices (including emerging "carbon farming" practices) to influence soil carbon on cropping and grazing land in New South Wales agricultural systems.

Location

The project sampled the major agricultural regions of central and northern New South Wales, focusing on the central and northern tablelands, slopes and plains.

Key activities

A total of 800 sites were sampled. Site identification, sampling and sample processing and analyses were undertaken according to protocols agreed for the Soil Carbon Research Program (SCRP).

Findings/Conclusions

Impacts of land use on soil carbon are easily masked by natural factors. Variability in soil properties due to landscape heterogeneity and climate, have a larger influence on soil organic carbon (SOC) than management, making it difficult to detect differences due to management.

- cropped soils have lower soil carbon than pasture soils

- amongst grazed soils, the survey approach used for this study indicated limited influence of management (stock management, pasture improvement, pasture cropping) on total soil carbon
- similarly, amongst cropped sites, alternative management (tillage practice, organic amendments) appears to have had little impact on soil carbon stocks
- further analysis of the data may allow the identification of management impacts
- further data analysis is also required to assess the impacts of land management on the soil carbon fractions, so that long term impacts of soil carbon management can be predicted through modelling.

Central region

- Key drivers of SOC are climate and soil type, however management can affect SOC
- There was a strong negative relationship between soil carbon per mm of rainfall and silicon (Si) in cropping soils
- A high superphosphate strategy over the last 10 years, has improved soil phosphate but has not improved soil carbon in Tablelands grazing systems. High superphosphate sites were, however, still phosphate limited
- The data do not support the notion that soil carbon contents are higher under rotational grazing than conventional grazing systems
- Increasing cropping frequency decreases soil carbon
- The resolution of historical management data restricted the ability to make predictions of management impacts on soil carbon stocks. Land management surveys that focus more on specific management actions that may affect soil carbon stocks need to be developed.

Northern slopes and plains

- Soil carbon stock was higher in pasture systems compared to cropping systems in both the Chromosols and Vertosols
- Within the cropping systems surveyed, sites where minimum tillage was practiced instead of conventional tillage tended to have a greater stock of soil carbon, but this trend was not statistically significant in either soil type
- Though generally not statistically significant, pastures including tropical grass species tended to have lower soil carbon stocks than native pasture sites. This may be because tropical grass pastures have been introduced to renovate former cropping land
- Results from a randomised, replicated field experiment comparing native species (sown) with two introduced tropical grass pastures and lucerne, showed no effect of species type on soil carbon stocks after six years of well managed pasture production. While some other aspects of soil fertility had been influenced, potentially through the application of mineral fertiliser, and there were large differences in measured aboveground pasture biomass, the fact that the biomass was cut and removed from the site may have contributed to the lack of any discernible effects on soil carbon stocks.

Related projects funded under Round 1 of Filling the Research Gap

- Increasing soil carbon in eastern Australian farming systems: Linking management, nitrogen and productivity—Department of Primary Industries, Victoria—Fiona Robertson. Funding of $2 782 312 ex GST

Publications
Publications detailing the results of this research are in preparation.

Carbon sequestration in soil under no-till as affected by rainfall, soil type and cropping systems in Queensland

Lead organisation
Department of Science, Information Technology, Innovation and the Arts (formerly Department of Environment and Resource Management)

Consortium member organisations
Queensland Department of Agriculture, Fisheries and Forestry (formerly Department of Employment, Economic Development and Innovation)
Queensland Alliance for Agriculture and Food Innovation, University of Queensland

Objectives
- quantify the effect of rainfall, tillage and cropping systems on organic carbon stocks and organic carbon pools in cropping soils
- assess the effect of seasonal rainfall distribution and rainfall gradient on organic carbon stocks in no-till soils
- provide datasets to allow parameterisation of FullCAM to account for tillage under variable rainfall conditions.

Location
Queensland grain and sugarcane regions

Key activities
Soil sampling was conducted at over 200 sites throughout south east and central Queensland cropping regions and the Queensland sugarcane belt. These sites were selected so that they covered a range of:
- cropping systems, including summer and winter dominant grain cropping, and sugarcane
- annual rainfall (< 500 mm/yr to > 1950 mm/yr) and rainfall distributions (i.e. summer versus winter dominant)
- tillage and stubble management practices (ranging from no-till with stubble retention through to conventional tillage with stubble removal).

Soil samples collected from these sites have been measured for total organic carbon content and carbon fractions (particulate organic carbon, humus carbon and charcoal carbon). Analysis of various soil properties including pH, electrical conductivity and particle size analysis has also been performed.

Findings/Conclusions
Research findings indicate that there is no evidence of increases in soil organic carbon stocks in response to no-till management in Queensland grain or sugarcane growing regions.

However, no-till management does appear to have slower soil organic carbon loss and may be able to maintain stocks of organic carbon for longer periods following the input of organic carbon via pasture leys or green manure crops.

On a regional level, climatic variables (particularly the average vapour pressure deficit in the last five yrs), sand content and plant biomass production have had the most influence on the organic carbon stocks of the cropping soils sampled. Management would appear to have had minimal impact on a regional level. This is likely because of the low input nature of the crop-fallow management system used throughout Queensland, and the low use of management practices, such as pasture leys, capable of inputting significant quantities of organic carbon (especially via plant roots) into the soil.

Related projects funded under Round 1 of Filling the Research Gap

- Maintenance of soil organic carbon levels supporting grain production systems: The influence of management and environment on carbon and nitrogen turnover—Department of Agriculture and Food, Western Australia—Frances Hoyle. Funding of $1 009 884 ex GST
- Increasing soil carbon in eastern Australian farming systems: linking management, nitrogen and productivity—Department of Primary Industries, Victoria—Fiona Robertson. Funding of $2 782 312 ex GST

Publications

1. Dalal, R, Allen, D, Wang, W, Reeves, S & Gibson, I 2011, 'Organic carbon and total nitrogen stocks in a Vertisol following 40 years of no-tillage, crop residue retention and nitrogen fertilisation', *Soil and Tillage Research,* no. 112, pp. 133-139.
2. Dalal, R, Wang, W, Allen, D, Reeves, S & Menzies, N 2011, 'Soil nitrogen changes and nitrogen use efficiency under long-term no-till, residue management, and nitrogen fertilisation for cereal cropping', *Soil Science Society of America Journal*, no. 75, pp. 2251-2261.

Further publications detailing the results of this research are in preparation and will be available.

The pasture type and management affect on soil carbon stocks in grazing lands of northern Australia

Lead organisation

Department of Science, Information Technology, Innovation and the Arts (formerly Department of Environment and Resource Management)

Consortium member organisations

Queensland Department of Agriculture, Fisheries and Forestry (formerly Department of Employment, Economic Development and Innovation)

Objectives

- to quantify the effect of rainfall, soil type, pasture systems and pasture management on organic carbon stocks in grazing lands

- to estimate the soil carbon pools of total carbon stocks in grazing lands
- to provide a dataset to allow parameterisation of FullCAM to account for pasture management practices under variable rainfall and soil type conditions.

Location

Queensland and Northern Territory (Victoria River District)

Key activities

- Studies from the long-term pasture management trials and a range of grazing sites throughout Queensland were used to assess soil organic carbon (SOC) stocks.
- Detailed analyses of long-term trials were used to consider the role of fire management (frequency and intensity) and grazing management (pasture utilisation, exclusion from grazing and grazing intensity).
- Sites (98) across a range of commercial properties (plus the Wambiana grazing trial) throughout Queensland, representing a range of climate and soil-land types, were used to quantify SOC stocks, and explore the relationship(s) of SOC stock with grazing managements (broadly defined as continuous, cell, rotational and exclusion from grazing).
- At all sites, soil was sampled to 0.3 m depth (0.5 m depth at some long term trial sites).
- Sampling was undertaken according to Soil Carbon Research Program (SCRP) methodology, using the recommendation of Pringle et. al. (2010) whereby samples at each site were spread in a grid design with a random point of origin, then collected and stored separately for bulking in the laboratory.
- Additional management information, where available, was collected at the sites, including measured total standing dry matter, stocking rate, stock days per hectare, and related to SOC stocks.

Findings/Conclusions

Main project outcomes are:

- increased quantification of magnitude and variability of SOC stocks in northern Australian rangelands
- insight into key variables influencing SOC stocks in northern Australian rangelands (amount and variability of vegetation on the ground, local slope, annual rainfall, and ten-year average stocking rate)
- significant differences in SOC stock relating to pasture utilisation rate at a long-term trial site, which relates to measures of total standing dry matter and remote sensing information (NDVI). Pasture utilisation at 20 per cent provided the optimum SOC stock while at 80 per cent the SOC stocks were the lowest
- humus formed > 50 per cent of total SOC stock at the long-term pasture utilisation trial site and showed a similar trend to SOC stock in response to management
- the effect of grazing pressure at the Wambiana grazing trial was not statistically significant
- the effect of fire management at the Kidman Springs fire management trial was not statistically significant
- both sites had significant differences in SOC carbon levels between soil types
- further analysis on individual samples from the sites may provide a more sensitive test for the effect of management practices.

Related projects funded under Round 1 of Filling the Research Gap

- Understanding the influence of grazing pressure changes on soil organic carbon in the semi-arid rangelands of western NSW—NSW Department of Primary Industries—Graham Denney. Funding of $316 365 ex GST

Publications

1. Allen, D, Richards, A, Bray, S & Dalal, R 2011, 'Soil carbon - challenges of measurement, monitoring, modelling and management: a review', *Proceedings, Northern Beef Research Update Conference*, Darwin, pp. 87-93. <http://www.jkconnections.com.au/nabrc/activities_and_events/nbruc/august-2011-proceedings >
2. Dalal, R, Cowie, B, Allen, D & Yo, S 2011, 'Assessing carbon lability of particulate organic matter from $\delta^{13}C$ changes following land-use change from C3 native vegetation to C4 pasture', *Soil Research*, vol. 49, pp. 98-103.
3. Pringle, M, Allen, D, Dalal, R, Payne, J, O'Reagain, P & Marchant, B 2011, 'Soil carbon stock in the tropical rangelands of Australia: Effects of soil type and grazing pressure, and determination of sampling requirement', *Geoderma*, vol. 167-168, pp. 261-273.

Further publications detailing the results of this research are in preparation and will be available.

South Australian dry-land cropping

Lead organisation

Commonwealth Science and Industrial Research Organisation (CSIRO)

Consortium member organisations

Department of Environment and Natural Resources, South Australia

Objectives

- to identify land management strategies with the potential to change soil carbon content in red-brown earth soils of the mid-North and Eyre peninsula regions of South Australia
- to contribute to national approaches for developing rapid tools to predict soil carbon content.

Location

Mid-North and Eyre Peninsula, South Australia

Key activities

More than 900 soil samples were collected over two field campaigns (2010 and 2011) across the mid-North and Eyre Peninsula agricultural regions of South Australia. Samples were taken from 200 paddocks at three depths (0 - 10 cm, 10 - 20 cm, 20 - 30 cm) and analysed for total organic and inorganic carbon contents. Additional data was collected including climate data (rainfall, temperature), topographic data (elevation, slope, aspect etc), and 5 - 10 years of management data (e.g. crop type, tillage, stubble management, fertiliser additions, pasture rotation).

Findings/Conclusions

- In the mid-North agricultural region of South Australia, red-brown earth soils contained between 20.4 and 65.4 Mg/ha organic carbon in the top 30 cm, with overall average of 38 Mg/ha.
- In the Eyre Peninsula agricultural region of South Australia, red-brown earth soils contained between 16.1 and 67.4 Mg/ha organic carbon in the top 30 cm, with overall average of 31 Mg/ha.
- In general terms, there was a 2 Mg/ha increase in soil organic carbon (SOC) stocks for every 50 mm increase in rainfall across the 300 - 600 mm rainfall zone.
- A rule of thumb for the distribution of SOC within the top 30 cm of red-brown earth soils from the mid-North and Eyre Peninsula is for 50 per cent of the SOC stock to be in the top 10 cm and 75 - 80 per cent in the top 20 cm.
- Humus organic carbon was consistently the dominant soil organic carbon fraction in the sampled red-brown earth soils, accounting for approximately 45 per cent of carbon.
- Results indicated that no consistent effect of management could be measured above landscape variability.
- Variability in SOC stocks in red-brown earths was high and could be correlated with vapour pressure deficit above any other climatic, topographic or management variables.
- This suggests that the best approach to increase SOC stocks is to maximise plant productivity through addressing site specific limitations on plant growth.

Related projects funded under Round 1 of Filling the Research Gap

- Increasing soil carbon in eastern Australian farming systems: Linking management, nitrogen and productivity—Department of Primary Industries, Victoria—Fiona Robertson. Funding of $2 782 312 ex GST

Publications

1. Macdonald L, 2011, 'Soil carbon: function, management, measurement', paper presented at *Greening Australia Soil Carbon Workshop*, Murray Town, South Australia, 11 March.
2. Macdonald L, 2012, 'Soil carbon: measurement, function, management', paper presented at *Soil Quality Workshop*, Clare, South Australia, 19 June.
3. Macdonald L, 2011, 'Soil sampling', paper presented at *ASSI/ASPAC Soil Carbon Workshop*, University of Adelaide, 22 November.
4. Macdonald L, 2011, 'The National Soil Carbon Research Program: South Australian highlights', paper presented at *Mid-North Young Guns Workshop of Soil Carbon*, Clare, South Australia, 18 April.

Further publications detailing the results of this research are in preparation and will be available.

Soil organic carbon balances in Tasmanian agricultural systems

Lead organisation
Tasmanian Institute of Agriculture

Consortium member organisations
N/A

Objectives
- to determine current stocks of soil organic carbon in different soil types on agricultural land used for pasture and cropping
- to contribute data about soil organic carbon in Tasmania to the national Soil Carbon Research Program (SCRP) project in order to calibrate a more economical and efficient method of measuring soil organic carbon using mid-infrared (MIR) spectroscopy.

Location
Major agricultural zones of Tasmania

Key activities
There were two components of this study.

Component one involved investigating organic carbon levels in a range of soil types throughout the state. The samples came from four key soil groups: dark, cracking clay soils (Vertosols), brown, well structured soils (Dermosols), reddish brown, iron oxide rich soils (Ferrosols) and strong texture contrast soils (Chromosols/Sodosols/ Kurosols). For each soil order/group the samples were further split into two land uses, cropping and pasture. For each of these land uses, ten year land management records such as tillage, fertiliser application, crop type, periods of fallow etc were collected to determine impacts on soil carbon levels. Environmental data such as total and timing of rainfall, temperature, altitude and aspect were included in the monitoring.

Component two involved 25 long-term (13 years) field sites on red Ferrosols in northern Tasmania which were re-sampled. This sampling contributed to a long term study initiated by TIA-UTAS in 1997 and re-sampled in 2005 and 2010. The purpose of this study was to determine not only the change in total organic carbon (TOC) levels in pasture and cropping sites but also which carbon pools (either particulate organic carbon and/or humic carbon) are most affected by land use.

Findings/Conclusions
Soil order, rainfall and land use were all strong explanatory variables for differences in TOC, total nitrogen (TN) and bulk density (BD) in Tasmania. Cropping sites had 29 - 36 per cent less carbon in surface soils than pasture sites, they also had 2 - 16 per cent greater bulk densities. The difference between cropping and pasture was most pronounced in the top 0.1 m. Clay rich soils (Ferrosols and Vertosols) contained the greatest carbon stocks.

Land management effects on soil carbon were minor when compared to soil order, rainfall and land use. The number of years cropped and the number of years of conventional tillage had the most effect on soil carbon, i.e., both decreased soil carbon. The long term field trial component of the project, conducted on Ferrosols in the north of Tasmania showed that:

- Total organic carbon decreased with increasing years of cultivation. However, between 1997 and 2010, soil carbon levels did not decrease, nor did the ratio between carbon pools change, suggesting that, after many previous years of agricultural management, equilibrium may have been reached.
- Sites which had been predominantly used for pasture had higher organic carbon levels than cropped sites.
- Carbon associated with two soil particle size fractions (particulate organic matter and humus) which play different roles in the soil, was uniformly affected by land use.

Related projects funded under Round 1 of Filling the Research Gap

- Increasing soil carbon in eastern Australian farming systems: Linking management, nitrogen and productivity—Department of Primary Industries, Victoria—Fiona Robertson. Funding of $2 782 312 ex GST

Publications

1. Parry-Jones, J 2010, 'The effect of agricultural land use on the soil carbon fractions of Red Ferrosols in North West Tasmania', Honours thesis, School of Agricultural Science, University of Tasmania.
2. Parry-Jones, J, Oliver, G, White, E, Doyle, R, Cotching, B & Sparrow, L 2011, 'The effect of agricultural land use on the soil carbon fractions of Red Ferrosols in North West Tasmania', poster presented at the *Climate Change Research Program for Primary Industries Conference*, Melbourne, 15-17 February.
3. Scandrett, J, Oliver, G, Doyle, R & White, E 2010, 'Agricultural land use and soil carbon in Tasmania', poster presented at the *19th World Congress of Soil Science*, Brisbane, 1-6 August.
4. Sparrow, L, Cotching, W, Parry-Jones, J, Oliver, G, White, E & Doyle, R 2011, 'Changes in carbon and soil fertility in agricultural soils in Tasmania, Australia', paper presented at the *12th International Symposium on Soil and Plant Analysis*, Crete, June.

Further publications detailing the results of this research are in preparation and will be available.

Soil carbon in cropping and pasture systems of Victoria

Lead organisation

Department of Primary Industries, Victoria

Consortium member organisations

N/A

Objectives

To measure soil carbon stocks and composition in pasture and cropping systems of Victoria (dairy, beef, sheep and cereal production) and determine the influence of management in regions with varying climate and soil type.

Location

North-west, south-west, and south-east Victoria

Key activities

Soil carbon stocks were measured, using the standardised Soil Carbon Research Program (SCRP) methodology, at 861 sites; 602 on farms and 259 on established field trials. The farm sites were selected according to region, soil type, and management system, with approximately 25 representations of each region x soil x management combination. Average annual rainfall in the regions ranged from <300 mm to >1000 mm. The field trials included cropping systems comparing cultivation, stubble management and rotation treatments, and livestock systems comparing pasture type, fertiliser and grazing management treatments. The trials had been established for periods of between 5 and 94 years.

Findings/Conclusions

- Provisional results showed soil organic carbon stocks in the 0.3 m depth varied widely across the pasture and cropping systems of Victoria. Average total organic carbon stocks (0 - 0.3 m depth) in the regions were in the order: Mallee (15 Mg C/ha) < Northern Wimmera (29 Mg C/ha) < Southern Wimmera (33 Mg C/ha) < Northern and Southern Slopes (40 Mg C/ha) < Vic Volcanic Plains (65 Mg C/ha) < Eastern Plains (80 Mg C/ha) < Strzelecki Ranges (90 Mg C/ha) < Otways (165 Mg C/ha).
- Soil organic carbon stocks were strongly related to annual rainfall and the Enhanced Vegetation Index, highlighting the importance of water availability and plant production.
- Total organic carbon stocks varied with soil type in the order: Tenosol (8 Mg C/ha) < Calcarosol (26 Mg C/ha) < Sodosol (41 Mg C/ha) < Vertosol (48 Mg C/ha) < Chromosol (53 Mg C/ha) < Dermosol (106 Mg C/ha).
- Soil total organic carbon stocks varied with management in the order: continuous cropping (34 Mg C/ha) < crop—pasture rotation (45 Mg C/ha) < sheep/beef pasture (63 Mg C/ha) < dairy pasture (120 Mg C/ha).
- Results from the field trials showed that management practices such as fertiliser application, cultivation, stubble retention, crop rotations and grazing management had relatively small or no effects on soil organic carbon stocks.
- Carbon stocks were always greater in the 0 - 0.1 m depth than in the 0.1 - 0.2 and 0.2 - 0.3 m depths. The composition of the soil organic carbon stocks varied considerably, but averaged 24 per cent particulate carbon, 54 per cent humic carbon and 29 per cent resistant carbon.

Related projects funded under Round 1 of Filling the Research Gap

- Increasing soil carbon in eastern Australian farming systems: Linking management, nitrogen and productivity—Department of Primary Industries, Victoria—Fiona Robertson. Funding of $2 782 312 ex GST

Publications

A series of fact sheets explaining the research program and inviting farmers to participate were produced and distributed to farmers. Approximately 500 were distributed.

Further publications detailing the results of this research are in preparation and will be available.

Soil carbon storage in Western Australian soils

Lead organisation

The University of Western Australia

Consortium member organisations

Department of Agriculture and Food, Western Australia
Grower Group Alliance

Objectives

- measure soil organic carbon stocks, organic carbon pools and associated soil properties and land use histories required as input parameters for carbon models
- extend the coverage of the Western Australia soil benchmarking program and the associated www.soilquality.org.au database
- identify regions within the agricultural sector of Western Australia where maximal gains are to be made with respect to further capacity for carbon storage
- develop extension activities to inform growers and the wider agricultural sector of issues related to soil carbon research.

Location

Western Australia

Key activities

- Collect composite soil samples at 1005 geo-referenced sites in association with grower groups
- Measure bulk density, gravel and basic soil properties at each site to enable data integration into existing databases such as the Australian Soil Resource Information System (ASRIS)
- Examine soil carbon stocks from existing field trials
- Scan soils for MIR with a sub-set analysed for soil organic carbon pools
- Make all data derived from this project available to the CSIRO database, ASRIS database and www.soilquality.org.au web site
- Model an *attainable* equilibrium for carbon storage for each of the primary soil types using historical weather data and collected soil data as input variables
- Through comparison of actual and attainable soil organic carbon stocks identify regions where further carbon storage is likely
- Disseminate research findings to grower groups and the wider agricultural sector through workshop sessions.

Findings/Conclusions

- The minimum detectable differences in soil organic carbon stocks measured suggest they should be monitored on a decadal scale.
- Annual rates of change in soil organic carbon (0 - 0.3 m) were: 0.1 t C/ha for stubble retention compared to burning in a low rainfall environment, 0.2 t C/ha for clay addition to sandy soil, and 0.45 t C/ha under perennial pasture (>500 mm rainfall).
- Modelling suggested annual increases in soil organic carbon in the range 0 - 0.7 t C/ha were possible over the next 50 years in the higher rainfall areas of the Western Australian agricultural region. This means that rapid and large increases in *actual* soil organic carbon stocks are not likely in these soils.
- Comparison of *actual* soil organic carbon stocks to modelled *attainable* values indicated that there was further capacity for carbon sequestration in WA soils. However, this additional capacity was predominately in the subsoil with the surface layer (0 - 0.1 m) being at, or close to, carbon storage capacity. This means that management solutions need to focus on getting organic carbon into soil at depth. The benefit would be increased soil organic carbon storage and a deeper fertile soil layer.
- Perennial pasture systems showed regional differences. Soil organic carbon stocks were greater in the Kalgan region above that under annual pastures and cropped systems but not in the Esperance region. Both were sand plains—small differences in soil texture (clay content) were thought to be the reason for this difference. This means that there is a need for further work to better understand the soil types in which perennials are able to sequester more soil organic carbon.
- No difference was detected in soil organic carbon stocks calculated from conventional bulk density methods or a neutron density meter, suggesting the methods are interchangeable. The neutron density meter offers large gains in sampling efficiency for large sampling efforts such as required for regional soil organic carbon stock monitoring networks.

Related projects funded under Round 1 of Filling the Research Gap

- Increasing soil carbon in eastern Australian farming systems: Linking management, nitrogen and productivity—Department of Primary Industries, Victoria—Fiona Robertson. Funding of $2 782 312 ex GST

Publications

1. Carson, J, Wherrett, A, Hall, D & Murphy, D 2011, 'Carbon storage on the Esperance sand plain, Western Australia', Soil Quality Fact Sheet, <http://www.soilquality.org.au/factsheets/carbon-storage-on-the-esperance-sand-plain>
2. Holmes, K, Wherrett, A, Keating, A & Murphy, D 2011, 'Meeting bulk density sampling requirements efficiently to estimate soil carbon stocks', *Soil Research,* vol. 49, pp. 680-695.
3. Holmes, K 2011, 'Bulk density sampling requirements for estimating soil carbon stocks: How best to reduce sampling effort?', paper presented at the *Australian Society of Soil Science Conference*, Busselton, Western Australia, 23 August.
4. Murphy, D, Overheu, T, Wherrett, A, Holmes, K & Hoyle, F 2012, 'Carbon storage on the Albany sand plain, Western Australia', Soil Quality Fact Sheet, <http://www.soilquality.org.au/factsheets/carbon-storage-albany-sand-plain>

Further publications detailing the results of this research are in preparation and will be available.

Round 1 of Filling the Research Gap

Overview

Filling the Research Gap supports research into emerging abatement technologies, strategies and innovative management practices that reduce greenhouse gas emissions from the land sector, store soil carbon and enhance sustainable agricultural practices.

A total of 57 successful projects are being undertaken under Round 1 of the program. These projects share $47 million in Australian Government funding over the years 2011–12 to 30 June 2015 and are grouped into five sub-programs:

- National Livestock Methane Program
- National Agricultural Manure Management Program
- National Agricultural Nitrous Oxide Research Program
- National Soil Carbon Program
- National Agricultural Greenhouse Gas Modelling Program.

The following projects are been funded under Round 1 of *Filling the Research Gap* to participate in the National Soil Carbon Program and the National Agricultural Greenhouse Gas Modelling Program. Descriptions of all successful Round 1 projects are available at http://www.daff.gov.au/climatechange/carbonfarmingfutures/ftrg.

National Soil Carbon Program

Coordination of the National Soil Carbon Program / Soil carbon increase through rangeland restoration by facilitating native forest regrowth—

Department of Science, Information Technology, Innovation and the Arts—Ram Dalal. Funding of $1 500 000 ex GST

This project will coordinate and manage the soil carbon projects as a national program. In addition, it will also use standardised sampling and measurement methods in previously-cleared Queensland rangelands to quantify increases in carbon and carbon pools in soil and biomass under native forest regrowth up to 50 years old. Through modelling, the project will quantify the optimal soil carbon sequestration and pasture production for rangeland. The project will also contribute to developing a *Carbon Farming Initiative* methodology for managed forest regrowth for rangelands.

Environmental plantings for soil carbon sequestration on farms—CSIRO—

Keryn Paul. Funding of $1 000 000 ex GST

This national project will support the extension of the *Carbon Farming Initiative* (CFI) methodology for mixed-species environmental plantings to include carbon in soil. It will target agricultural-environmental planting sites for diverse climates and soil types and study how management of farmland with low opportunity costs affects soil carbon. The project aims to give land managers the required knowledge for CFI reforestation participation on marginal farm land.

Native perennial vegetation: Building stable soil carbon and farm resilience—CSIRO—Jonathan Sanderman. Funding of $350 000 ex GST

This project will quantify changes in soil carbon stocks and composition with the re-establishment of native perennial grasslands through adoption of rotational grazing and include measurement of soil carbon and its allocation to major fractions. The project aims to deliver the knowledge and tools needed for these extensive grazing systems to participate in the *Carbon Farming Initiative*.

Soil carbon benefits through reforestation in sub-tropical and tropical Australia—Queensland Department of Agriculture, Fisheries and Forestry—Tim Smith. Funding of $1 677 632 ex GST

This project will assess soil carbon sequestration under reforestation to enable accounting of full mitigation benefits (biomass and soil) and assist land managers to participate in Carbon Farming Initiative reforestation projects with increased confidence. It also will collect soil and biomass carbon data across hardwood, softwood, savannah and rainforest ecosystems in sub-tropical and tropical Australia to develop relationships of changes in soil carbon pools over time following reforestation of agricultural land. Finally, it will refine sampling protocols for improved measurement of soil carbon, develop a decision support calculator and provide economic case studies, enabling land managers to determine the feasibility of carbon farming through reforestation.

EverCrop® Carbon Plus: Perennial forage plants in cropping systems to manage soil carbon—Future Farm Industries Cooperative Research Centre / NSW Department of Primary Industries—John McGrath. Funding of $1 000 000 ex GST

This project will assess the role of perennial forage plants in improving the management of soil carbon in major cropping regions of southern Australia, provide data to improve soil carbon models and enhance farmers' decision making. It will use existing EverCrop® farming system and long term perennial forage trials to research if including deep rooted perennial forages into cropping systems can sustain or increase soil organic carbon relative to current annual based cropping systems.

Compost and biochar amendments for increased carbon sequestration, increased soil resilience and decreased greenhouse gas fluxes in tropical agricultural soils—James Cook University—Michael Bird. Funding of $1 000 000 ex GST

This project will trial compost, biochar and COMBI-mix (biochar mixed with organic waste prior to composting) soil amendments to North Queensland tropical agricultural soils. The trials will consist of business as usual, compost alone, biochar alone, COMBI-mix and compost mixed with biochar at a number of field sites. From the trials, the project will determine the impact of each on carbon sequestration, greenhouse gas fluxes and crop performance.

An assessment of the carbon sequestration potential of organic soil amendments—CSIRO—Mark Farrell. Funding of $802 797 ex GST

This project will quantify the relationship between the chemical composition of organic carbon and how it decomposes in a variety of potential soil organic amendments. Spectroscopic techniques will be used to measure carbon chemistry and long-term incubation experiments will quantify degradation dynamics. The data generated will be used to define the relationship between chemical composition and potential longevity / stability of different types of organic amendments in soil. The results of this analysis will be used within FullCAM (the model used to construct Australia's national greenhouse gas emissions account for the land sector) to provide consistency with Australia's national inventory and *Carbon Farming Initiative* methodologies.

Quantifying temporal variability of soil carbon—CSIRO—Jeff Baldock. Funding of $1 000 000 ex GST

This project will re-sample soil from 60 sites within the New South Wales Monitoring, Evaluation and Reporting (MER) program. Samples will also be collected from selected *National Agricultural Nitrous Oxide Research Program* field experiments to quantify the influence of applied management treatments on soil carbon stocks. Statistical analyses will quantify the magnitude and certainty of measured soil carbon stock changes. This project will support development of robust *Carbon Farming Initiative* methodologies

Improved measurement and understanding of soil carbon and its fractions—CSIRO—Jonathan Sanderman. Funding of $150 000 ex GST

This project will build on the research started in the *Soil Carbon Research Program* focused on developing techniques for rapidly and routinely measuring numerous soil properties at a lower cost. This research is to provide proof of concept to measure soil carbon fractions using visible near-infrared (vis-NIR) spectroscopy.

A method for efficient and accurate project level soil organic carbon determination using in situ spectrophotometry and advanced spatial analysis—Geo Carbon Services Pty Ltd—James Schultz. Funding of $195 550 ex GST

This project aims to demonstrate a commercially cost-efficient method to measure rangeland soil organic carbon (SOC) content and composition. The pilot project will be undertaken on 65 000 hectares of central Australian rangeland. It will utilise remote and ground based spectrometry, geospatial modelling using satellite derived soil with vegetation and landform indices to improve the basis for spatially stratifying soil types or land management zones to further improve sampling efficiency and confidence in SOC estimates.

Maintenance of soil organic carbon levels supporting grain production systems: The influence of management and environment on carbon and nitrogen turnover—Department of Agriculture and Food, Western Australia—Frances Hoyle. Funding of $1 009 884 ex GST

This project will investigate the stability of soil carbon under variable climate and management practices. Established research sites with different (or altered) soil organic carbon contents will be used to determine maximum soil carbon storage, the influence of carbon on critical soil functions and long-term viability of sequestering carbon as an emissions management practice. This evidence based approach combines field-based research with database analysis to provide information to landholders on beneficial/perverse outcomes associated with changing soil carbon levels in grain production systems. This will enable landowners to determine the profitability and risk of managing carbon from a sequestration versus production perspective.

Increasing soil carbon in eastern Australian farming systems: Linking management, nitrogen and productivity—Department of Primary Industries, Victoria—Fiona Robertson. Funding of $2 782 312 ex GST

This project will determine the effectiveness of a range of management practices for increasing soil carbon in cropping and pasture systems across eastern Australia, focusing on enhancing carbon input and permanence in key soil types and climatic zones. Soil carbon will be measured in farm paddocks and field trials. Simulation models, validated with measurement data will be used to extend experimental findings across eastern Australia. The project will support development of *Carbon Farming Initiative* methodologies to help landholders increase soil carbon and reduce greenhouse gas emissions.

Increasing carbon storage in alkaline sodic soils through improved productivity and greater organic carbon retention—The University of Adelaide—Glenn McDonald. Funding of $1 068 022 ex GST

This project will increase the present understanding of organic carbon accumulation in alkaline soils and improve farmers' capacity to store organic carbon. The project will identify options to increase storage of organic carbon in alkaline soils by studying the soil chemistry, surveying soil organic carbon on alkaline soils and conducting field experiments to ameliorate pH to improve carbon storage.

Understanding the influence of grazing pressure changes on soil organic carbon in the semi-arid rangelands of western NSW—NSW Department of Primary Industries—Graham Denney. Funding of $316 365 ex GST

This project will compare the carbon sink potential of alternative management activities in the southern semi-arid rangelands of southern Australia. A series of economic analyses of alternative grazing management strategies will be used to examine the relationships between agricultural productivity and profitability; soil organic carbon;

and natural resource change. With the cooperation of innovative landholders, case studies will provide a benchmark comparison for soil organic carbon (SOC) by contrasting the impacts of current best management practice against alternative (traditional) management practice. Current best management practice will be considered in terms of total grazing pressure, fencing and rotational grazing, while traditional management practice will be considered in terms of biodiversity, landscape function, and grazing intensity.

The fate of aboveground carbon inputs: A key process that is poorly understood—Queensland University of Technology—Richard Conant. Funding of $378 161 ex GST

This project aims to increase present understanding of surface carbon movement into the soil, improve soil carbon/nitrogen simulation models and work directly with soil carbon and nitrous oxide network modellers to provide greater certainty on the potential for reducing emissions. It will include site-based experimentation that complements other research on how management and climate affect carbon sequestration, nitrogen inputs to the soil and nitrous oxide emissions.

National Agricultural Greenhouse Gas Modelling Program

Potential soil carbon sequestration in Australian grain regions and its impact on soil productivity and greenhouse gas emissions—CSIRO—Enli Wang. Funding of $639 283 ex GST

This project will define soil organic carbon (SOC) sequestration potential and identify management practices that benefit both productivity and SOC stocks. It will use the farming systems model APSIM (Agricultural Production Systems Simulator), together with measurements to identify agricultural practices that increase SOC, quantify SOC sequestration potential across Australian grain regions, assess the vulnerability of sequestered carbon to subsequent changes in management and climate, and investigate the impacts of SOC change on carbon-nitrogen cycling, productivity and greenhouse gas emissions.

Facilitation of improvement in systems modelling capacity for Carbon Farming Futures—CSIRO—Andrew Moore. Funding of $629 816 ex GST

This project aims to eliminate any inconsistencies in modelling activities across *Filling the Research Gap* (FtRG). It will ensure that models are developed and applied consistently in FtRG, and that they embody the best scientific understanding of methane, nitrous oxide and soil carbon fluxes. A series of workshops and comparative studies will result in more robust and consistent abatement predictions and increased human capacity for modelling.

Whole farm systems analysis of greenhouse gas abatement options for the southern Australian grazing industries—The University of Melbourne—Richard Eckard. Funding of $537 902 ex GST

This project will conduct whole farm systems analysis of a range of nitrogen, carbon and energy efficiency and greenhouse gas abatement strategies for the dairy, sheep and southern beef industries. Each strategy will be analysed in a whole farm systems context, including methane, nitrous oxide, soil carbon, productivity plus the interactions between these. The outcomes from the project will be evaluated options: for reducing emissions intensity, improving farm profitability and/or further development into *Carbon Farming Initiative* offset methods.

The 'Biosphere' Graphic Element
The biosphere is relevant to the work we do and aligns with our mission—we work to sustain the way of life and prosperity for all Australians. We use this shape as a recognisable symbol across our collateral.

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