Australia
State of the Environment 2011

Assessments of status and trends in soil organic carbon workshop – summary notes

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Cover image

South Coast NRM region
Photo by Michael Marriott

Preface

This report was developed for the Department of Sustainability, Environment, Water, Population and Communities to help inform the Australia State of the Environment (SoE) 2011 report.

The Minister for Environment is required, under the *Environment Protection and Biodiversity Conservation Act 1999*, to table a report in Parliament every five years on the State of the Environment.

The Australia State of the Environment (SoE) 2011 report is a substantive, hardcopy report compiled by an independent committee appointed by the Minister for Environment. The report is an assessment of the current condition of the Australian environment, the pressures on it and the drivers of those pressures. It details management initiatives in place to address environmental concerns and the effectiveness of those initiatives.

The main purpose of SoE 2011 is to provide relevant and useful information on environmental issues to the public and decision-makers, in order to raise awareness and support more informed environmental management decisions that lead to more sustainable use and effective conservation of environmental assets.

The 2011 SoE report, commissioned technical reports and other supplementary products are available online at www.environment.gov.au/soe.

Introduction

A group of experts in soil carbon and land resource assessment met in Adelaide in March 2011 to provide input to the National State of the Environment Report. The meeting was convened to develop an assessment of the state and trends of soil carbon across Australia. The meeting was facilitated by Neil McKenzie and Mike Grundy from CSIRO and Rosemary Hook, an independent consultant.

The workshop attendees were briefed on the methods being used for the State of the Environment Report. Initial tasks included preparation of the grading statements and confirmation that the physiographic regions used in the Land Chapter were suitable for assessing soil carbon. The following grading statements were used with the percentage loss being relative to the pre-clearing or inferred pre-European condition.

- Very poor: Carbon stocks have decreased substantially (>70% loss).
- Poor: Carbon stocks have decreased (50–70% loss).
- Good: Carbon stocks have changed in some areas (30–50% loss).
- Very Good: Carbon stocks have either remained the same or increased (< 30% loss or increase).

The physiographic regions are based on landform and they form part of the Australian Soil Resource Information System (ASRIS).[1] The ASRIS mapping hierarchy divides Australia into three physiographic divisions, which are further subdivided into 23 provinces and 220 regions. These broad-scale mapping units have similar geological origins and a characteristic suite of soils and landforms. Even then, a diversity of soils and land management systems often occurs within each region. It is therefore only possible to reach general conclusions about the state of the soil for each region—there are always local exceptions.

This report has been compiled from the notes and completed proformas supplied by the experts in the weeks following the workshop. Only minor editorial changes have been made to ensure an accurate record of the original assessments. Some of the rating conventions in the published Land Chapter differ from those presented here because modifications to the system for representing uncertainty changed after the workshop. Note also that the assessments were mostly done by state or territory. Some physiographic regions cross state and territory borders and the assessments for the portion in each jurisdiction often differed. The final rating for such regions was based on the balance of evidence available. The ratings in this report have been retained in their primary form

This report provides assessments for every one of the 220 physiographic regions. The assessment table in the Land Chapter only provides ratings for regions where significant changes in soil carbon are occurring. The notes in the published assessment table are a summary of the longer notes presented below.

[1] www.asris.csiro.au

New South Wales

Greg Chapman and David Morand of the Soil Science Unit, Scientific Services Division, NSW Office of Environment and Heritage, Department of Premier and Cabinet

Comments:

Assessments of soil carbon grades and trends within the physiographic regions of NSW are based on data used in the Soils and Land Management section of the NSW State of Environment Report (2009) (http://www.environment.nsw.gov.au/soe/soe2009/chapter5/). These data were derived from measurements taken within specific soil monitoring units (SMUs) which were identified during the NSW Soil Monitoring Project (Chapman e*t al.,* 2011) on the basis of soil – landform combinations. Sites selected for measurement had land uses that were typical for the unit, as well as some measurements being taken in relatively undisturbed native vegetation sites so as to provide a comparison. SMUs were selected as being important units with Catchment Management Authority areas and were not considered in relation to the Physiographic Regions of Australia that are being used in the Australian State of Environment Report. Full details of the soil monitoring program in NSW can be found within Chapman *et al.* 2011 and Bowman *et al.* 2009.

The tables below indicate the SMUs that occur within a Physiographic Region where applicable as not all regions include one or more SMU. Ratings for each Physiographic Region are based on data derived from the SMUs within it, where these occur. It needs to be noted that land uses and soils assessed using the SMU data need not necessarily be those which are typical for a region.

Possible major future pressures to land values

No major future changes/pressures specifically identified

References associated with soil carbon in NSW:

Bowman G, Chapman GA, Murphy BW, Wilson BR, Jenkins BR, Koen T, Gray JM, Morand DT, Atkinson G, Murphy CL, Murrell A, Milford HB (2009). *Protocols for soil condition and land capability monitoring. New South Wales natural resource monitoring, evaluation and reporting program.* NSW Department of Environment and Climate Change. http://www.environment.nsw.gov.au/soils/soilsprotocols.pdf

Chapman GA, Gray JM, Murphy BW, Atkinson G, Leys J, Muller R, Peasley B, Wilson BR, Bowman G, McInnes-Clarke SK, Tulau MJ, Morand DTand Yang X. (in press 2011). Monitoring, Evaluation and Reporting of Soil Condition in NSW, 2008 Program. Office of Environment and Heritage, Department of Premier and Cabinet. NSW Government. Sydney.

Physiographic Region	Summary	Assessment Grade				Confidence in grade	Confidence in trend
		Very poor	Poor	Good	Very good		
Grey Range	Stony downs with gibber and predominantly Vertosol soils. Rangelands and conservation reserves. No soil carbon data available.		⊟			○	○
Bulloo Plain	Floodplain with Vertosols and Kandosols. Rangelands with extensive grazing. No soil carbon data are available, but an expected significant soil carbon loss as similar soils and land use to Paroo Plain		⊟			○	○
Paroo Plain	Sandplain with Red Kandosols and Arenic Rudosols. Rangelands with extensive grazing. 50% of the region covered by the Waanaring Sand Plain NSW SMU. Significant soil carbon loss presumably due to wind erosion.			↘		○	○
Warwick Lowland	Stony plains with mesas. Rangelands with extensive grazing. No soil carbon data available but expected to be similar to other rangeland regions.			↘		○	○
Warrego Plains	Floodplains, sandplains and claypans with Brown Vertosols and Brown Dermosols. Rangelands and opportunity cropping. Breewarrina Clay Grasslands SMU.		↘			◒	○
Nulty Springs Lowlands	Rolling downs and lowlands with predominantly Kandosols. Dry rangelands. No soil carbon data are available.		?				
Upper Darling Plains	Predominantly floodplains with Brown and Grey Vertosols. Rangelands in the west and cropping (including cotton) and grazing in the east. Includes the Breewarina Clay Plain SMU, within which significant loss of soil carbon has been measured under extensive grazing, but levels now thought stable. Cropping areas not monitored and assessed.			⊟		○	○
Charleville Tableland and Lightning Ridge Lowlands	Low sandy tablelands, stony plains and mesas. Dry rangelands with alkaline soils, mostly Kandosols. No soil carbon data available but likely to be similar to other rangeland soils.		⊟			○	○
Cunningham Slopes	Covers a wide range of parent materials (metasediments, sandstones and granites) and soils. Predominantly cropping and grazing. Mostly sandy topsoils exhibiting noticeable to significant declines in carbon. Partly			⊟		●	◒

	monitored in the Duri Hills, Bingara Rises and Warialda Sands SMUs.						
Tenterfield Plateau	Predominantly undulating granite plateau with some basalt cappings; mostly grazing, both modified and natural pastures, and conservation. Includes the Tenterfield Granites, part of the Bundara Granites, the Northern Tablelands Basalts and the eastern portion of the Inverell Basalts SMUS and, to the east, the Walcha Metasediments, Dorrigo-Comboyne Plateau and Granite Borderlands SMUs are included. Noticeable and, in the east, significant losses of soil carbon are evident. Variable land management but generally a declining trend predicted under current practices.			↘		◒	○
Clarence Fall	Dissected plateau margin on granites and metamorphic rocks and with a variety of soils. Mostly forestry, nature conservation or grazing natural pasture. Few monitoring data. Declines in soil carbon may be expected for areas with long grazing or logging and erosion histories but carbon levels now likely to be stable.			—		○	○
Clarence Lowlands	Coastal lowlands with a variety of soil types. Land uses including forestry, grazing, cropping and some nature conservation. Coincides with the Clarence Sodic Soil SMU and large portions of the North Coast Acid Sulphate Soils SMU. The Clarence Sodic Soils have deteriorated significantly in carbon levels and further deterioration is expected with current land management practices. North Coast Acid Sulphate Soils are expected to increase in carbon due to use of appropriate land management practices.		↘			●	◒
Toowoomba Plateau	Basaltic plateau with predominantly Ferrosols and Dermosols used mostly for grazing, perennial and seasonal horticulture and nature conservation. Includes the Alstonville Plateau and Casino Alluvials SMUs. There has been a widespread noticeable to locally significant decline in surface soil carbon mostly due to lack of effective erosion controls for macadamia and vegetable production on the Alstonville and Cudgen Plateaus. Land management is highly variable but generally thought to be resulting in a stable trend for soil carbon.	—				●	○
Nandewar Peaks	Dissected volcanics with mostly Chromosols and Dermosols. Contains small portions of the Inverell Basalts and Liverpool Plains Red Earth SMUs. Mostly forest or national park			?		○	○

	with grazing. Few soil carbon data but levels may have declined due to frequent burning.						
Cobar Plains	Sandy plains with predominantly extensively grazed Kandosols in the west; some nature conservation reserves. Sodosols and Chromosols in the east with cropping and grazing of modified and natural pastures. Almost entirely covered by the Girilambone Rises, the Cobar Peneplain Rises and the Cobar Peneplain Flats SMUs. Data from these SMUs show significant declines in soil carbon, probably mostly associated with erosion following previous overgrazing and aggressive tillage practices. Overgrazing by feral goats is expected to increase and lead to a continuing decline in soil carbon levels although land management is thought to be responding to the decline.			↘		◒	○
Lower Darling Plain	Floodplains on which well buffered Grey Vertosols predominate and with extensive grazing. Includes Lower Darling River Alluvials and Mid Darling River Coolibah SMUs. The few data available suggest a significant decline in soil carbon. Trend data is lacking but land management pressures have reduced.		—			○	○
Strezelecki Desert Plains	A variety of land systems. Soil Monitoring Unit is the Simpson Strezlecki Swales which is mostly national park with some grazing. Significant drop in soil carbon presumably due to over-grazing in the past. Trend is expected to be steady.		—			◒	○
Eyre Frome Plains	Sandy soils in dry rangelands with a history of over-grazing. No soil carbon data are available but further decline is not expected.		—			○	○
Barrier Ranges	Variable landscapes and soils including Red Vertosols on gibber and dune and swale systems. Rangelands with extensive grazing. Includes the Southern Barrier Ranges SMU and small areas of the Broken Hill Fans SMU. The limited data suggest that soil surface carbon has significantly declined in these units due to grazing and clearing pressures from Broken Hill.		↘			○	○
Warrumbungle Peaks	Mostly national park with sandy acid volcanic rocky soils used for grazing. No soil carbon data available but suspected carbon decline due to grazing pressures and fire management.		—			○	○
Mitchell Slopes	Western hills and slopes of the northern and central tablelands with a mix of parent materials, soil types and land uses including		—			●	○

	grazing both modified and natural pasture, cropping, production forestry and nature conservation. The large variability makes overall assessment difficult. Includes half the Binnaway Sandstones, Yeoval Chromosols, Molong Rise and Cowra Chromosols SMUs. Soil carbon has declined noticeably in most areas and markedly on soils with a long history of mixed farming. Widespread adoption of conservation farming practices is expected to prevent further declines or in some cases lead to improvements in soil carbon levels.						
Gunnedah Lowland	Predominantly self-mulching Vertosols used for cropping and Red Chromosols and Kandosols used for cropping and grazing. Includes Liverpool Plain Red Earths, Liverpool Black Plains and Liverpool Black Foot-slopes SMUs. There has been a significant decline in surface soil carbon. Intensive land use practices such as double cropping to ameliorate salinity are expected to further reduce soil carbon levels.		↘			○	○
Macleay Barrington Fall	Predominantly dissected plateau flank used for nature conservation and production forestry, some grazing. Includes parts of the Kempsey Hills, Wauchope Low Hills, North Coast Acid Sulphate Soils, Chichester Hills and Landsdowne Terrace SMUs. Few soil carbon data are available but previous forestry activities are suspected to have reduced carbon levels.			↘		○	○
Liverpool Barrington Plateaus	Dissected plateaus with high rainfall, very steep slopes and a variety of soil types. Land uses predominantly conservation, forestry and grazing. Includes the Chichester Hills SMU, though this area has not been sampled. Cleared and grazed areas are expected to have greatly diminished soil carbon compared to reference conditions.		?			○	○
Merriwa Plateau	Basalt plateau with Ferrosols and Vertosols that are mostly used for mixed farming. Coincides with the Merriwa Plateau SMU.				↗	●	◒
Goulburn Corridor	Hills and broad valley floors commonly with Kandosols and Sodosols. Includes the Muswellbrook Valley Floor and Goulburn River Valley SMUs. Noticeable to significant declines in soil carbon have been detected, but soil carbon values are expected to remain steady under current management.			–		●	◒

Hunter Valley	Low hills and undulating terrain with alluvial valleys and a variety of soils. Includes Hunter Valley Floodplains, Mined Areas and the Singleton Valley Floor SMUs. Soil carbon levels have dropped substantially in all three SMUs, presumably from erosion, a long history of intense land use and, in the case of Mined Areas SMU, soil profile removal. Soil carbon levels are expected to remain steady except in mined areas where management inputs may increase surface soil carbon levels.						
Ivanhoe Plain	Predominantly sandplains with Calcarosols but also Sodosols, Chromosols and Vertosols. Includes the Overnewton Flats, Arumpo Mallee Lands and the Border Mallee Lands SMUs. Monitoring indicates significant declines in soil carbon, presumably because of past overgrazing. Current practices would indicate a steady or improving trend.						
West-Turkey Plains	Rangeland plains with predominantly Calcarosols and some Chromosols. Encompasses the unsampled East Pooncarie Sands and the Southern Barrier Range Foot-slopes SMUs. No soil carbon data are available but levels likely to have declined as a result of past overgrazing.						
Riverine Plain	Predominantly alluvial sediments with Grey Vertosols and some Chromosols and Arenic Rudosols. Several important irrigation areas, extensive grazing and some dryland cropping particularly in the SE. Encompasses a number of SMUs with the Grey Box Plains, Boree Plains and Edward River Redgum Floodways in the east, and with the Moulamein Plain and the Lowbidgee Delta to the west. Soil carbon declines have been noticeable and tend to increase to the south. Levels are likely to be stable under land management activities in the Murrumbidgee catchment but could still be declining in the Murray catchment.						
Hume Slopes	Western hills and slopes of the central and southern tablelands with a large variety of landscapes and soils. Parna deposits with deep Red Kandosols and Chromosols also occur. Mostly mixed farming with grazing of modified and natural pastures more common in the SE. Numerous soil monitoring units which include the Ariah Park Plains, Wantabadgery Rises, part of the Murrumburrah-Harden Low Hills, and Murrumbidgee Alluvials, Yerong Creek Plains and the Coreinbob Low Hills.						

	Virtually all soils show indications of noticeable to significant declines in soil carbon. Land management practices are variable but generally not thought to be causing further soil carbon decline.						
Condobolin Plains	Predominantly alluvial plains with Sodosols and Vertosols used for cropping and grazing. SMUs include the Bland Riverine Plains and the Mid Lachlan Flood Plain. Limited evidence indicates that soil carbon levels have dropped substantially. Some concern that land management practices are falling short of sustainably managing soil carbon levels, leading to further declines.		↘			◒	○
Bathurst Tablelands	Tablelands of mixed geology and soils but Sodosols, Chromosols, and Kandosols common. Grazing of modified and natural pastures is the predominant land use. Includes the Central West Tablelands and Hill End Trough SMUs. The tablelands generally have a long history of agricultural land use resulting in significant declines in soil carbon, possibly exacerbated by the serious water erosion that has occurred in some areas. An increased awareness of soil carbon issues in land management should lead to an improving trend.		↗			◒	◒
Hawkesbury Shoalhaven Plateaus	Deeply dissected sandstone plateau with Kandosols prevalent. Predominantly managed within National Parks with minor pine production, grazing, horticulture and cropping. Significant urban development with most of Sydney included in this region and the Cumberland Lowland. Includes several small SMUs, namely the Somersby Plateau, Wolgan and Capertee Valley Floors, Cox's River Granites, Wingecarribee Hills, Mid Wollondilly Lands, Sydney Urban Fringe Bushland and the Moss Vale Plateau SMUs, with most monitoring focussing on agricultural land uses which represent perhaps less than 20% of the area. Available data indicate variable changes in soil carbon with greatest losses where land use has been intensive for long periods. In bushland there is a suspected net increase in soil carbon near the urban fringe due to nutrient addition and fire suppression, but carbon loss from most other areas associated with the fire management regime. It is thought that under all land uses soil carbon is not taken into account sufficiently to prevent further declines.			↘		○	○

Cumberland Lowland	Mostly urban and industrial land use but includes the Wianamatta Urban Fringe and Nepean River Alluvials SMUs, both of which have noticeable declines in soil carbon due to past practices. The trend towards increasingly intensive production is expected to cause further carbon decline.		↘			◒	◒
Werriwa Tablelands	Hills and plains commonly with Sodosols and Kandosol used mostly for grazing modified and natural pastures. Encompasses the Bungonia Tablelands and the Cullarin and Muringo-Bevandale Metasediments SMUs. Soil carbon decline has been slight. Given the mostly poor nature of the soils and variable management, carbon levels are expected to either remain steady or decrease.				↘	○	○
Tinderry Gourock Ranges	High hills commonly with Tenosols and Sodosols; land uses include production forestry and grazing. Includes the Braidwood Granites and Upper Shoalhaven Valley SMUs. The latter shows significant declines in surface soil carbon whilst the former has declined to a lesser degree. Land management is variable and likely to lead to further declines in the Shoalhaven Valley SMU but to stable levels on the Braidwood Granites.			—		◒	○
Monaro Fall	Deeply dissected and steeply sloping plateau margins and alluvial valleys; Dermosols common. Predominantly forested and managed for conservation and timber production but also significant areas of grazing. Includes the Ulladulla Coast and Bega Valley SMUs. Declines in soil carbon have been significant in both cases but improving land management is considered to be likely to increase soil carbon levels.			↗		◒	◒
Monaro Tableland	Undulating upland plains commonly with Dermosols and basalt derived Ferrosols. Used predominantly for grazing modified and natural pastures. Includes the Bombala Metasediments, Jindabyne Hills and Monaro Basalts SMUs. Monitoring for all three SMUs shows significant decreases in soil carbon. Land management practices indicate that soil carbon levels are expected to remain steady or slowly improve for the Monaro Basalts.			—		◒	◒
Australian Alps	Mostly high rainfall mountainous terrain with variable soils; used mostly for conservation. Grazing occurs in the lower hilly country in				—	◒	◒

	the north and east. Includes the Murrumbidgee Alps, Khancoban Granites and Tumbarumba Wet Granodiorites SMUs. All SMUs show slight to moderate deterioration in surface soil carbon, but current land management practices are generally thought to indicate a stable trend.						
East Victorian Uplands	A small part of this region occurs in NSW where grazing and production and plantation forestry are the main land uses. Also includes the Khancoban Granites and Tumbarumba Wet Granodiorites SMUs. Soil carbon as per Australian Alps.				⊟	◒	◒
Mallee Dunefields	Calcarosols are the predominant soil type, with the main land uses grazing and cropping. Includes Tooleybuck Mallee Sands, Lower Murray River Alluvials and Guthul Sand Plains SMUs. Significant decline in surface soil carbon has occurred due to past overgrazing but carbon levels are expected to generally remain steady under current land management practices.			⊟		○	◒
KEY **Grading Statements**	**Very poor:** Carbon stocks have decreased substantially (> 70 % loss).						
	Poor: Carbon stocks have decreased (50 – 70 % loss).						
	Good: Carbon stocks have changed in some areas (30 – 50 % loss).						
	Very Good: Carbon stocks have either remained the same or increased (< 30 % loss or increase).						
Indication of trend	↗ Improving ↘ Deteriorating ⊟ Stable ? Unknown						
Level of Confidence	○ Evidence and consensus too low to make an assessment ◒ Limited or low quality evidence but high consensus ● Adequate high quality evidence and high consensus						

At a glance… soil carbon

- Many topsoils in NSW are thought to have lost more than 30-50% of carbon compared with conditions at settlement, often associated with past erosion from over grazing, extensive tillage and, in some areas, considerable periods of agricultural use.
- Adoption of improved farming and grazing management practices is still not sufficient to halt soil carbon losses in many areas.

Victoria

Fiona Robertson, Victorian Department of Primary Industries and Bill Slattery, Department of Climate Change & Energy Efficiency with input from David Rees, Victorian Department of Primary Industries.

Physiographic Region	Summary	Assessment Grade				Confidence in grade	Confidence in trend
		Very poor	Poor	Good	Very good		
Australian Alps	Predominantly mountain terrain dominated by Dermosols, Rudosols, and Tenosols with minor but ecologically significant areas of Organosols. The major land use is nature conservation (1.1). Some previous high country grazing would have had an impact on soil carbon stocks since 1788, but the removal of grazing will be allowing these systems to stabilise. The impact of fires, particularly on peats, may result in an overall decline in soil carbon for this region.						
East Victorian Uplands	Predominantly hilly and mountainous terrain with minor valley flood plains; soils mainly Rudosols, Tenosols, and Dermosols, but Kurosols, Chromosols and Sodosols are also present. There are minor but ecologically significant areas of Podosols and Organosols. The eastern part of the region is dominated by native forests for nature conservation (1.1) with a smaller proportion (~30%) as production forestry (2.2) with previous grazing of the natural vegetation (2.1). Soil carbon relatively stable under native vegetation and some small decline under forest production and past grazing practices. Lower lying foothills in the west and south are mostly used for grazing natural (2.1) and modified pastures (3.2). These would have declined initially in soil carbon (<20%) but have stabilised over time. Urban and peri-urban areas in the west not assessed.						
Gippsland Plains	Depositional plains and fans dominated by Sodosols and Chromosols. There are minor areas of Podosols, Organosols, Rudosols (coastal dunefields typically under nature conservation), Vertosols (flood plains) and						

	Hydrosols. Land use is predominantly grazing of modified pasture (3.2) in extensive beef and sheep enterprises with minor but economically significant areas of more intensive higher input dairy enterprises, minor areas of cropping, irrigated horticulture and native forests for nature conservation (1.1) and production forestry (2.2). Soil carbon has generally declined and most likely stabilised under permanent pasture.						
South Victorian Uplands	*Eastern component* Dermosols are common in the Strzelecki ranges which have been predominantly cleared for grazing modified pastures (3.2) with sheep, and beef and dairy cattle; some production forestry (2.2), mainly pines. Significant areas of Ferrosols with grazing grazing modified pastures (3.2), often for dairy production; also seasonal horticulture. Sandy soils (commonly Sodosols and Podosols) in the southern Wilson's promontory and coastal areas are in national parks (1.1) or used for grazing modified pastures (2.2). Soil carbon in pasture lands has declined from 1788 (~40%) but it is likely that carbon levels have now stabilised under current practices. Areas of Organosols in the west near Melbourne have been drained and have lost considerable carbon, so much so that these soils are now classified as Humose Dermosols or Vertosols. *Western component* Dominated by the Otway Ranges with large forested areas. Some areas have been cleared for grazing modified pasture (3.2). Significant areas converted to pasture will have declined (<20%) in soil carbon since 1788, but are likely to have become stabilised more recently.			⊟		◒	◒
Indication of trend	↗ Improving ↘ Deteriorating ⊟ Stable ? Unknown						
Level of Confidence	○ Evidence and consensus too low to make an assessment ◒ Limited or low quality evidence but high consensus ● Adequate high quality evidence and high consensus						

Physiographic Region	Summary	Assessment Grade				Confidence in grade	Confidence in trend
		Very poor	Poor	Good	Very good		
Mallee dunefield	The Mallee is dominated by Calcarosols with Rudosols and Tenosols being sub-dominant. There are minor areas of Sodosols and Vertosols. Cropping (3.3), grazing modified pasture (3.2) and nature conservation (1.1) are the main land uses. Minor but economically significant areas of irrigated pastures (4.2) perennial horticulture (4.4) occur along the dunefields next to the Murray River. Soil carbon has declined substantially from 1788 (>50%) under cropping. Practices such as stubble retention and cover crop fallows are now practised and may have improved soil condition and be stabilising soil carbon, but in some areas soil carbon levels are probably still declining. Some irrigated pastures and perennial horticulture may exhibit less soil carbon loss due to increased biomass production. The large areas of nature conservation that previously have been grazed are now stabilised with respect to soil carbon. On balance the continuing decline in soil carbon under cropping systems would dominate the impact in this region.		↘			◒	◒
Wimmera Plain	The Wimmera plain comprises former beach ridges and aeolian and alluvial plains. The soils are mainly Vertosols and Sodosols, with Calcarosols and Tenosols being sub-dominant in the north. There are minor areas of Sodosols and Chromosols soils in the southwest. This region has been predominantly cropping (3.3) in rotation with grazing modified pasture (3.2) for wool for a long period of time. Initial decline in soil carbon would have been more buffered on the heavier soils that now most likely contain higher soil carbon levels than the lighter textured soils. A large area used for nature conservation (1.1) but likely to have been grazed in earlier years, will have declined initially in soil carbon and although rates of decline are likely to have stabilised more recently, carbon levels may still be declining. It is likely that changing farming practices to no till may reduce soil carbon loss in some areas, especially the heavier soils. Overall		↘			◒	◒

	however it was concluded that soil carbon is still likely to be declining in this region.						
West Victorian Uplands	The hills, slopes and plains of this region are dominated by Sodosols on sediments. There are significant areas of Dermosols on the southern slopes of the Central Highlands and Chromosols on the Dundas Tablelands. Minor but significant soils include Ferrosols, Rudosols, Podosols and Tenosols. Landuse is predominantly grazing modified annual pasture (3.2) with some cropping (3.3). Nature conservation (1.1) areas cover about 25% of the region. Minor but economically significant areas with Ferrosols surround the numerous volcanic cones and occur on the lava plains near Ballarat. These soils are used for potato production in rotation with beef grazing and field crops. Soil carbon would have declined with land clearing and may still be declining where cropping activities dominate, but may have stabilised in the permanent pasture regions.			⊖		◒	◒
Riverine Plains	The alluvial and colluvial Riverine Plains are dominated by Sodosols. Sub-dominant soils include Calcarosols and Vertosols and minor areas of Chromosols. Land use is predominantly irrigated agriculture in the central and eastern parts (irrigated pastures for dairy production and perennial horticulture which is mainly fruit with some vegetables and grapes). The western part is dominated by dry land cropping and grazing by sheep. In general soil carbon has declined in this region to low values, and is likely to be continuing to decline under dryland cropping systems although improved farming practices may halt this decline.		↘			◒	◒
Indication of trend	↗ Improving ↘ Deteriorating ⊖ Stable ? Unknown						
Level of Confidence	○ Evidence and consensus too low to make an assessment ◒ Limited or low quality evidence but high consensus ● Adequate high quality evidence and high consensus						

Physiographic Region	Summary	Assessment Grade				Confidence in grade	Confidence in trend
		Very poor	Poor	Good	Very good		
West Victorian Plains	This region consists mostly of lava plains with Sodosols and sub-dominant Chromosols and Vertosols, all characterised by poor drainage. There are minor areas of Hydrosols in the drainage depressions and Ferrosols on the volcanic cones. The less common sedimentary materials are characterised by Dermosols, Sodosols and Chromosols in the north and mainly Chromosols, Dermosols, Kurosols and Podosols in the south. The northern part is mostly used for grazing of modified annual pastures (3.2) for sheep and cattle with some cropping. The wetter southern coastal fringe is mainly used for grazing beef and dairy cattle on modified perennial pastures (3.2). There is a small area of plantation forestry (3.1) mostly blue gum and pine. Cropping and plantation forestry have recently expanded in area from a low base. In general soil carbon has declined (~50%) since 1788. There are areas of conversion from pasture to cropland that are probably declining in soil carbon together with the continuous cropping soils and areas of permanent pasture that may, in contrast, have stabilised.			↘		◒	◒
KEY **Grading Statements**	**Very poor:** Carbon stocks have decreased substantially (> 70 % loss).						
	Poor: Carbon stocks have decreased (50 – 70 % loss).						
	Good: Carbon stocks have changed in some areas (30 – 50 % loss).						
	Very Good: Carbon stocks have either remained the same or increased (< 30 % loss or increase).						
Indication of trend	↗ Improving ↘ Deteriorating — Stable ? Unknown						
Level of Confidence	○ Evidence and consensus too low to make an assessment ◒ Limited or low quality evidence but high consensus ● Adequate high quality evidence and high consensus						

At a glance… soil carbon
• Generally 30-70% loss of soil carbon in areas used for agricultural production. • Soil carbon now mostly stable in nature conservation areas, under grazing and some improved cropping practices. • Soil carbon levels still declining in many areas under cropping and in forested areas, may be declining due to changed fire regimes.

Tasmania

Bill Cotching, University of Tasmania

Comments

No specific comments

Possible major future pressures to land values

Increasing intensification of land use

References associated with soil carbon in Tasmania:

See tables

Assessment Component	Summary	Assessment Grade				Confidence in grade	Confidence in trend
		Very poor	Poor	Good	Very good		
Bass Coastal Platforms	Many drained swampy coastal plains (Hydrosols/Podosols) under dryland and irrigated grazing modified pasture plus sandy coastal dunes (Podosols) and quartzite/mudstone dominated hills (Organosols/Dermosols) in nature conservation reserves. Mostly high natural levels of soil carbon, apart from coastal dunes, all of which are stable and show little decline since settlement.						
Midlands Plain	Mostly sandy loams (Kurosols/ Chromosols/Sodosols/Tenosols) and clay loams (Dermosols) on weathered sediments under dryland grazing modified pastures and increasing areas of irrigated cropping; an increased intensity of cropping is resulting in a decline in soil carbon in some areas. Also dolerite/sedimentary/metamorphic rock hills (Dermosols/Kurosols) with native and modified pastures plus some production forestry which has stable soil carbon. Cotching WE, Kidd DB, 2010. Soil quality evaluation and the interaction with land use and soil order in Tasmania, Australia. *Agriculture, Ecosystems & Environment* **137**, 358-366 Cotching,WE and Lynch, S and Kidd, D, 2009. Dominant soil orders in Tasmania: distribution and selected properties. *Australian Journal of Soil Research*, **47** pp. 537–548. Cotching WE, Cooper J, Sparrow LA, McCorkell BE, Rowley W, 2001. Effects of agricultural management on Sodosols in northern Tasmania. *Australian Journal of Soil Research* **39**, 711–735. Cotching WE, Cooper J, Sparrow LA, McCorkell BE, Rowley W, 2002. Effects of agricultural management on Dermosols in northern Tasmania. *Australian Journal of Soil Research* **40**, 65–79. Cotching WE, Cooper J, Sparrow LA, McCorkell BE, Rowley W, 2002. Effects of agricultural management on Tenosols in northern Tasmania. *Australian Journal of Soil Research* **40**, 45–63.						

Lakes Plateau	Upland plateau on dolerite (Rudosols/Dermosols/Organosols) in nature conservation reserves where wildfire and grazing have initiated sheet erosion over large areas with very limited potential for recovery.						
West Tasmanian Ridges	Southern areas dominated by quartzite and conglomerate (shallow Organosols and Tenosols) in nature conservation reserves where a significant change to the fire regime since European colonisation has led to more frequent and/or hotter fires and combustion loss of Organosols in many places. These are near to their climatic limit of formation and recovery from loss is expected to be very slow and may be further reduced by expected climate change. Northern areas dominated by production forestry (Dermosols/Rudosols) with no potential for soil carbon sequestration.						
East Tasmanian Hills	Production and plantation forestry on soils derived from sedimentary rocks (Kurosols/Chromosols/Dermosols), dolerite (Dermosols/Ferrosols) and granite (Kurosols/Dermosols) with minor areas of declining carbon due to erosion. Irrigated cropping in the southeast (Sodosols/Kurosols/Vertosols) and northeast (Ferrosols) is resulting in a decline in soil carbon. Cotching WE, Cooper J, Sparrow LA, McCorkell BE, Rowley W, 2002. Effects of agricultural management on Vertosols in Tasmania. A*ustralian Journal of Soil Research* **40**, 1267–1286.						
North West Ramp	Irrigated cropping below 300 m altitude (Ferrosols) has resulted in 30 -50% reduction in soil carbon and associated soil health issues. Plantation forestry and grazing modified pastures (Ferrosols/ Dermosols on basalt/mudstone/granite) has had little impact on soil carbon levels. Parry-Jones J, 2010. The effect of agricultural land use on the soil carbon fractions of Red Ferrosols in North West Tasmania. Honours thesis for Graduate Diploma in Agricultural Science. Cotching WE, Sparrow LA, 2005. Changes over 8 years in soil organic carbon and pH on Ferrosols in northern Tasmania. Department of Primary Industries, Water and Environment.						
Bass Islands	Grazing modified pastures (Kurosols/Podosols/Hydrosols on King Island; Kurosols/Podosols/ Calcarosols on Flinders Island) with carbon						

	stocks showing little decline and stable.						
KEY **Grading Statements**	**Very poor:** Carbon stocks have decreased substantially (> 70 % loss).						
	Poor: Carbon stocks have decreased (50 – 70 % loss).						
	Good: Carbon stocks have changed in some areas (30 – 50 % loss).						
	Very Good: Carbon stocks have either remained the same or increased (< 30 % loss or increase).						
Indication of trend	↗ Improving ↘ Deteriorating — Stable ? Unknown						
Level of Confidence	○ Evidence and consensus too low to make an assessment ◒ Limited or low quality evidence but high consensus ● Adequate high quality evidence and high consensus						

South Australia

Jeff Baldock, CSIRO Land and Water with input from James Hall, South Australian Department of Environment and Natural Resources

Physiographic Region	Summary	Assessment Grade				Confidence in grade	Confidence in trend
		Very poor	Poor	Good	Very good		
Lincoln Hills	Predominantly dryland cropping (3.3) with smaller amounts of grazing of modified pastures (3.2) and natural vegetation (2.1) and nature conservation (1.1). Soils include ironstone soil, sands and loams over clays (duplex soils, mostly Sodosols), and shallow soils on rock and calcrete as well as calcareous loams and deep carbonate rich sands. More extensive declines in soil carbon would be expected under cropping but all lands should have now reached stable soil carbon values. Potential to increase soil carbon levels exists on the more productive heavier textured soils, as well as on sandier soils after modification with clay.			⊟		◒	◒
Ceduna Dunefield	Currently approximately equal areas of grazing natural vegetation (2.1) and dryland cropping (3.3) with smaller areas of grazing of modified pastures (3.2) and nature conservation (1.1). Soils are dominated equally by shallow loam on calcrete and highly calcareous sandy loams (Calcarosols), with smaller areas of deep siliceous or carbonate rich sands (often Tenosols). Declines in soil carbon due to cropping are expected but all lands should have reached stable soil carbon values. Potential to rebuild soil carbon levels is low due to low productivity of the region.			⊟		◒	◒
Eyre Dunefield	Predominant land use is dryland cropping (3.3), followed by grazing natural vegetation (2.1) and grazing modified pastures (3.2). Soils are predominantly calcareous loams (Calcarosols), loams and sands over clay (duplex soils, mostly Sodosols), siliceous sands (often Tenosols), and shallow soils on calcrete and rock. Declines in soil carbon due to cropping are expected but all lands should have reached stable soil carbon values. Potential to rebuild soil carbon levels could be expected on the more productive heavier textured soils, especially in areas with better rainfall, and on			⊟		◒	◒

	sandier soils after modification with clay.						
Gawler-Cleve Ranges	Current agricultural land use is almost all grazing natural vegetation (2.1). Soils are dominated by shallow loams (mostly Tenosols). Decline in soil carbon levels since settlement is likely in this low productivity region, with a low ability to be regenerated due to the low rainfalls.		⊟			○	○
Yorke Peninsula	Most of the region is used for dryland cropping (3.3) with the predominant soils calcareous loams (Calcarosols), hard loams over red clay (duplex soils, mostly Sodosols) and shallow soils on calcrete. Smaller areas of deep siliceous sands. The exception is in the south-west which has grazing natural vegetation (2.1) and conservation areas (1.1) on calcareous sands (deep carbonate-rich sands and shallow carbonate-rich sandy soils on calcrete).		⊟			◒	◒
Flinders-Lofty Ranges	The extent of this physiographic region makes characterization difficult. Although it encompasses most of the Adelaide Geosyncline and so constitutes a geological zone, land use and climate vary considerably giving three sub-regions: arid north, temperate central and cool-temperate south. In the north, soils are predominantly loams over red clay (mostly Sodosols), calcareous loam soils (Calcarosols) and shallow soils on rock, while in the central region soils are dominated by loams over clay (often Sodosols), gradational red soils and shallow soils on rock. In the south, soils are predominantly acidic loams over clay (mostly Chromosols), ironstone soils and shallow soils on rock. There are many other soil types in this region which has a long history of erosion in northern and central areas. The north is dominated by grazing of natural vegetation (2.1) and is likely to have lost soil carbon but levels have now stabilised. Dryland cropping (3.3) is predominant in the central areas with a significant area also devoted to vineyards. Soil carbon levels are lower than under native vegetation but most likely have stabilised given the long duration since cultivation was initiated. Agriculture in the south is predominantly grazing modified pastures (3.2) although high production horticulture (vineyards, orchards, vegetables) is also a significant land use. Soil carbon is likely to have been maintained or increased It is difficult to generalize the soil carbon status and trends across the region but overall a			⊟		◒	◒

	loss of soil carbon of 30-50% has been assigned, although generally losses have been greater than 50% in northern and central regions. As a move towards more intensive cropping practices is likely, a stable trend has been given. There should be good opportunity to increase soil carbon levels in central areas but little opportunity in the north. An overall assessment grade of poor with a constant trend has been defined.						
Torrens-Gulf Plains	Soils are dominated by calcareous loams (Calcarosols) and loams over clay (duplex soils, usually Sodosols or Chromosols) with significant areas of siliceous sands and shallow soils on calcrete in the south. Dryland cropping is predominant in the south, with some areas of high intensity vegetable production under irrigation; In the north land use is mostly grazing of natural vegetation. Soil carbon levels are likely to have declined significantly with little option for improvement except for the more productive and heavier soils.		⊟			◒	◒
West Turkey Plains	Approximately equal areas of shallow loams (Calcarosols) and crusty red duplex soils (Chromosols) used almost exclusively for grazing natural vegetation (3.2) with a small area of cropping (3.3) in the southwest. It is likely that soil carbon values have declined through the introduction of grazing, but the extent of loss would be low and stable values are now likely.				⊟	◒	◒
Ivanhoe Plains	This region is almost exclusively covered with calcareous earths (Calcarosols) with a sandy texture arranged in a dune/swale sequence. The dominant land uses are grazing native vegetation and nature conservation. The pasture component has declined in extent, leading to low, but stable, soil carbon values.		⊟			◒	◒
Mallee Dunefield	The main soils are calcareous loams (Calcarosols), siliceous sands (often Tenosols), shallow soils on calcrete, red sandy gradational soils, and sands and loams over clay (duplex soils, mostly Sodosols). Self-mulching cracking grey clays (Vertosols) and sodic duplex soils (Sodosols) are located along the Murray river valley. The major land use is cereal cropping (3.3) often in rotation with pastures (3.2) but tending towards a greater dominance of cropping. Significant areas of irrigated horticulture (vineyards, almonds and citrus) occur close to the Murray River. Inherently low soil carbon contents will have		⊟			◒	◒

	declined further with the introduction of agriculture. Given the low available rainfall, it is unlikely that significant gains in soil carbon can occur without irrigation or a strong move back to pastures.						
Coorong Plain	Mainly shallow soils on calcrete, calcareous loams (Calcarosols), deep siliceous sands (often Tenosols) and sands over clay (duplex soils, mostly Sodosols) with modified pastures (3.2) the predominant land use and some dryland cropping (3.3). Most soils are likely to have soil carbon contents close to native condition except possibly where dryland cropping is more common; in these areas soil carbon levels are likely to have declined significantly.			⊟		◒	◒
Wimmera Plain	Wide mixture of soil types including deep siliceous sands (some Podosols), sands and loams over clay (duplex soils, mostly Sodosols) and self-mulching cracking clays (Vertosols). The major land uses include dryland cropping and grazing of modified pastures along with some irrigationSoil carbon contents are likely to be little changed from pre-settlement levels and stable provided land use does not shift towards an introduction of cereals. Where pastures are irrigated for dairy, significant increases in soil carbon can be expected.				⊟	◒	◒
Millicent Plain	Wide mixture of soil types including shallow soils on calcrete, deep siliceous sands (often Tenosols), highly leached sand (Podosols), loams and sands over clay (duplex soils, often Sodosols) and cracking clays (Vertosols) as well as peat and other wet soils. The major land uses are grazing of modified pastures and plantation forestry with some dryland cropping and irrigation (dairy, vineyards, potatoes). Soil carbon contents are likely to be little changed from pre-settlement levels and stable provided land use does not shift towards an introduction of cereals. Where pastures are irrigated for dairy, significant increases in soil carbon can be expected.				⊟	◒	◒
Grouping of regions in central and northern SA	Olary Spur, Andamooka Tableland, Bunda Plateau, Gairdner Plain, Carlisle Plain, Oodnadatta Tablelands, Denison Ranges, Alberga Dunefield, Western Desert Ranges, Simpson Desert Dunefield, Diamantina Plain, Simpson Desert Plains, Eyre-Frome Plains, Strzelecki Desert Plains, Sturt Desert Plains, Innamincka Plains, Great Victoria Desert				⊟	◒	◒

	Dunes and Kulgera Hills. There is a diversity of landscapes and soils in central and northern SA regions, including plains with calcareous earths (Calcarosols) shallow loams (Tenosols, Calcarosols), crusty red duplex soils (Sodosols) deep and shallow sands (Tenosols, Rudosols) and minor cracking clays (Vertosols); desert dunefields with deep and shallow sands (Rudosols); tablelands with red duplex soils (Sodosols and Chromosols) and calcareous earths (Calcarosols); and ranges with red duplex soils (Sodosols). Land use includes nature conservation (1.1) and extensive grazing of the natural vegetation (2.1). There are also protected areas including areas for indigenous uses. There has been little to no investigation of the soil carbon in these regions. Levels are expected to be inherently low with generally little change since European settlement given the low land use pressures. There may, however, be some declines in carbon where disturbance has induced soil loss.						
KEY **Grading Statements**	**Very poor:** Carbon stocks have decreased substantially (> 70 % loss).						
	Poor: Carbon stocks have decreased (50 – 70 % loss).						
	Good: Carbon stocks have changed in some areas (30 – 50 % loss).						
	Very Good: Carbon stocks have either remained the same or increased (< 30 % loss or increase).						
Indication of trend	Improving; Deteriorating; Stable; Unknown						
Level of Confidence	○ Evidence and consensus too low to make an assessment; ◒ Limited or low quality evidence but high consensus; ● Adequate high quality evidence and high consensus						

Western Australia

Frances Hoyle, Department of Agriculture and Food, WA with input from Noel Schoknecht, Ted Griffin, David Bowran, Daniel Murphy, Paul Novelly, Phil Thomas, P-J Waddell

Comments

- Low starting point for soil organic carbon over large areas
- Upward and downward trends reflect nominal rates of change relative to a low starting point; i.e. the rate of any decline/increase is relative as it results from a relatively low base
- Major stress on up to 80% of the Western Australian landscape is associated with grazing pressure from introduced herbivores (uncontrolled feral grazing)

Possible major future pressures to land values

No specific changes noted

References associated with soil carbon in WA:

No specific references

Assessment Component	Summary	Assessment Grade				Confidence in grade	Confidence in trend
		Very poor	Poor	Good	Very good		
Warren-Denmark Slopes, Leeuwin Peninsula and Donnybrook Lowland	High rainfall and colder region with a range of soils. Intensive animal production (5.2), production forestry (2.2), nature conservation (1.1) and to the east, dryland cropping (3.3). Soil carbon levels maintained under forestry and nature conservation but at risk of declining in future due to declining rainfall. Increasing soil carbon under crop/pasture managed systems in the west due to reliable rainfall and high input systems.				—	◒	◒
Albany Esperance Sandplain	Sandplain with duplex soils, predominantly Sodosols. Current agricultural land use predominantly grazing (3.2) and cropping systems (3.3), with some perennial pasture (2.1) and production forestry (2.2). Significant nature conservation (1.1) area (30%). Relatively small declines in soil carbon from initial levels with positive trends for perennial systems; also positive trends in cropping due to nutrient inputs. Significant areas assessed to be good to very good and relatively stable. Constraints on soil carbon sequestration associated with steep rainfall gradient and/or low water holding capacity due to sandy soil textures, resulting in lower biomass production potential.				—	◒	◒
Salmon Gums Plain	Low rainfall region with higher clay soils e.g. loams, clay loams, clays (predominantly Sodosols). Predominantly cropping systems (3.3) in southern regions. Northern region agriculture. Possible constraints on future increases in soil carbon due to low biomass production potential which is exacerbated by a rising saline water table. Debatable whether there has been a decline in soil carbon even under cropping due to higher inputs of nutrients.			↘		◒	◒
Roe Plain, Coonana-Ragged Plateau, Bunda Plateau, Carlisle Plain	Plains with predominantly Calcarosols. Minimal use and grazing native vegetation. Shift from perennials to annuals? so possible future decline in soil carbon that could also be influenced by a possible increase in fire frequency. Nominal decline.			↘		◒	◒
Southern goldfields plateau	Plains with a range of soils including Kandosols, Tenosols, Sodosols and Calcarosols. Extensive grazing of native			↘		◒	◒

	vegetation (2.1) with significant nature conservation (1.1) areas. Soil carbon loss restricted to pastoral areas.						
Avon Plateau	A range of soils - sandplain to gravelly, loam and duplex soils (mostly Sodosols and Kandosols) - and medium to low rainfall. Predominantly cropping (3.3) and grazing 3.2), with the region producing approximately half the grain grown in WA. Recent nominal increases in soil carbon in topsoils due to reduced cultivation, residue retention and increased production efficiency; sandier textured soils may have experienced a decline. Declining subsoil carbon due to a change to annual based systems and loss of perenniality, leaving the system vulnerable to collapse. Although there are significant production constraints (e.g. due to soil acidity) the extensive area provides opportunity for carbon storage.			⊟		◒	◒
Northam Slopes	Loam soils (predominantly Sodosols and Chromosols) and reliable rainfall with agriculture dominated by cropping (3.3) and grazing systems (3.2). Similar comments to Avon Plateau with respect to soil carbon.			⊟		◒	◒
Darling Range	Almost exclusively Jarrah and Marree Forests growing on predominantly Tenosols. Negative pressure on soil carbon from dieback.				⊟	◒	◒
Swan Plain	Predominantly sandy soils (Podosols, some Kurosols and Chromosols) with intensive agricultural uses such as high and low input intensive animal production (3.2/4.2) and irrigated seasonal horticulture (4.5). The urbanized Perth region is included. The inherently low soil carbon levels are likely to have declined further under the intensively cultivated and managed horticultural systems, with a negative trend still in place. Irrigated modified pasture systems for dairy, however, may have localised increases in soil carbon with an upward/stable trend.			↘		◒	◒
Dandaragan Tablelands	Coastal nature conservation (1.1) areas on western edge and cropping (3.3) and grazing systems (3.2) dominant to the east. Steep rainfall gradient. Soils predominantly Tenosols and Chromosols with relatively stable soil carbon levels.			⊟		◒	◒
Greenough Hills	Reliable rainfall region with a range of soil types, though predominantly Chromosols. Dryland cropping (3.3). Erosion risk on lighter soils, but soil carbon about stable.			⊟		◒	◒

Woodramung Hills	Heavier loam and clay loam soils, predominantly Kandosols and Tenosols. Medium to low rainfall region dominated by low input cropping (3.3) and grazing (3.2). Eastern areas grading into the pastoral region. Likely drying trends have compounded effects of clearing and cropping on soil carbon.			↘		◒	◒
Murchison Plateau, Leemans Sandplain, Carnegie Hills, Glengarry Hills, Augustus Ranges, Yaringa Sandplain	Varied landscapes and soils with predominantly Tenosols and Sodosols. Extensive grazing of native vegetation (2.1) with significant nature conservation areas (1.1). Soil carbon linked to native vegetation biomass and likely to have declined in more heavily grazed areas; may be influenced in future by changing climate.		↘			○	◒
Shark Bay Peninsulas	Sandy soils, primarily Rudosols, Calcarosols and Tenosols in an area used for nature conservation (1.1).				—	◒	◒
Carnarvon Plain	Land use includes nature conservation (1.1), extensive grazing of natural vegetation (2.1) and intensive horticulture in a plains region with Sodosols, Tenosols and Hydrosols predominant. Episodic removal of surface soil carbon in horticultural areas on the flood plains (very small relative to total area).			↘		◒	◒
Grouping of hills and ranges in the Hamersley area	Kennedy Range, North West Cape Ridge, Hamersley Plateaus, Chichester Range, Nullagine Hills, Rudall Tablelands. Nature conservation, grazing native vegetation (ferals)				—	◒	◒
De Gray Lowlands, Onslow Plain, Yanrey-Cane Plain, Eighty Mile Plain	Predominantly plains and coastal dune systems, some low ranges; soils variable and including Sodosols, Vertosols, Tenosals and Calcarosols. Nature conservation (1.1) and extensive grazing (2.1) of native vegetation.			—		◒	◒
Great Sandy desert dunefield, Anketell Hills, Little Sandy Desert, Gibson Desert Plains, Great Victoria Desert Dunes, Western Desert Ranges	Sandy plains and dunes with areas of stony plains, stony rises, mesas, low tablelands and sandstone ranges. Soils predominantly Tenosols but also Rudosols and Kandosols. Grazing native vegetation with significant minimal use and nature conservation areas. Potential for nominal loss of soil carbon under increasing feral grazing pressure.				—	◒	◒
Stansmore Dunefield and Ranges, Sturt Creek Floodout, Tanami Sandplain and Tanami Sandplain and	Predominantly sandy soils (Rudosols and Tenosols, Kandosols) with some clays (Vertosols). Primarily a nature conservation (1.1) area, with some extensive grazing of native vegetation (2.1). Subject to feral grazing pressure which may lead to soil carbon				—	◒	◒

Ranges	decline.						
Dampier Tablelands	Low sandstone tableland with extensive sand sheets; soils predominantly Tenosols with some Kandosols. Mostly used for nature conservation (1.1) and for grazing native vegetation (2.1) with increasing grazing pressure effects on soil carbon.				⊖	◒	◒
Fitzroy Plains	Alluvial and estuarine plains with a range of soils including Kandosols, Tenosols and Vertosols. Extensive l grazing of native vegetation (2.1)			↘		◒	◒
Grouping of hills and ranges in the Kimberley	Fitzroy Ranges, Napier Limestone Ranges, Springvale Foothills, Halls Creek Ridges, Leopold Durack Ranges, Richenda Foothills, Kimberley Plateau and Couchman Uplands. Diverse landscapes with soils predominantly Tenosols, Rudosols and Ferrosols. Land use primarily nature conservation (1.1) and grazing of natural vegetation (2.1).				⊖	◒	◒
Top End Coastal Plain	Dissected lowlands with alluvial and estuarine plains. Soils predominantly Rudosols and coastal Hydrosols, however important areas of Vertosols and Kandosols. Mostly grazing natural vegetation (2.1) but the Ord River irrigation scheme has been developed on the Vertosols, with uses including irrigated cropping (4.3) and irrigated perennial (4.4) and seasonal (4.5) horticulture.??						
Fortescue valley	Alluvial valley with Kandosols, Vertosols, Sodosols and Calcarosols predominant.						
KEY **Grading Statements**	**Very poor:** Carbon stocks have decreased substantially (amount?). Ecosystem function is seriously affected.						
	Poor: Carbon stocks have decreased (amount?). Ecosystem function is adversely affected in some areas.						
	Good: Carbon stocks have changed in some areas. Ecosystem function is largely intact.						
	Very Good: Carbon stocks have either remained the same or increased.						
Indication of trend	↗ Improving ↘ Deteriorating ⊖ Stable ? Unknown						
Level of Confidence	○ Evidence and consensus too low to make an assessment ◒ Limited or low quality evidence but high consensus ● Adequate high quality evidence and high consensus						

The Northern Territory

Peter Wilson, Manager, National Soil Information, CSIRO Land and Water; formerly with the Conservation Commission of the NT with inputs from Jason Hill and Brian Lynch, NT Department of Natural Resources, Environment, the Arts and Sport

Comments and summary

- There are no long-term soil monitoring data in the NT.
- Termites may play an important role in carbon cycling within northern soil and impacts on these fauna are not assessed.
- Potential impacts from increased grazing pressures of feral and native animals due to increased stock watering-points, are unknown and not considered.
- Impacts from altered fire regimes across large areas are also not taken into account in these assessments.

Possible major future pressures to land values

> Increasing pressure for agricultural development in the north would be likely to impact on soil carbon values. (Law and Garnett, 2009)

References associated with soil carbon in the NT:

Chen, X., Hutley, L.B. and Eamus, D. (2005). Soil organic carbon content at a range of north Australian tropical savannas with contrasting site histories. *Plant and Soil* **268**: 161–171

Hancock, G.R., Martinez, C. and Wells, T. Modelling and Assessment of Soil Carbon Variability at the Point and Hillslope Scale. In *Oxley, L. and Kulasiri, D. (eds) MODSIM 2007 International Congress on Modelling and Simulation*. Modelling and Simulation Society of Australia and New Zealand, December 2007, pp.1743-1748. ISBN : 978-0-9758400-4-7.

Law, R. and Garnett, S.T. (2009). Understanding carbon in the Northern Territory: an analysis of future land use scenarios using the national carbon accounting tool. Report to the Tropical Savanna Management Cooperative Research Centre. School for Environmental Research, Charles Darwin University, Darwin.

Smith, S. and Hill, J. A draft report is in preparation with the title: Supporting Sustainable Development – Risks and Impacts of Plant Industries on Soil Carbon.

Physiographic Region	Summary	Assessment Grade				Confidence in grade	Confidence in trend
		Very poor	Poor	Good	Very good		
Gulf Fall and Gulf Coastal Lowlands	Mostly extensive grazing on shallow skeletal soils in undulating to steeply dissected country. Minor areas of alluvial and coastal plains. Relatively low grazing pressures with minor impact on inherently low soil carbon levels.				⊟	◒	◒
Sturt Plateau and Pine Creek Ridges	Mostly extensive grazing on shallow to moderately deep soils in undulating to flat plateau country. Relatively low grazing pressures with minor impact on inherently low soil carbon levels.				⊟	◒	◒
Ord-Victoria Plateaus	Mostly extensive grazing on shallow skeletal soils in undulating to steeply dissected country. Minor areas of alluvial and coastal plains. Relatively low grazing pressures with minor impact on inherently low soil carbon levels.				⊟	◒	◒
Arnhem Plateau and Arnhem Ridges	Rugged, rocky plateaus and ridges with minor sandy soils and limited development. Minimal impacts on inherently low soil carbon levels.				⊟	◒	◒
Top End Coastal Plain	Mostly low levels of development and impact throughout Arnhem Land and Kakadu National park coastal lowlands and floodplains. Extensive grazing and minor areas of more intensive land development and clearing around Darwin. Possible alteration of pre-European fire regimes but effects on soil carbon stores are largely unknown.				⊟	◒	◒
Daly Basin	Moderate to high intensity agricultural developments on small areas of better developed Red Kandosols. Largely extensive grazing in remaining areas with only minor occurrences of intensive stocking and pasture improvement. Small intensively managed areas likely to have a declining carbon trend.				↘	◒	◒
Whirlwind Plain and Birrundudu Plain	Extensive grazing on lowland plains with small areas of more intensive development on better clay soils and alluvial plains. Possibly minor decreases in soil carbon due to high seasonal stocking rates.				↘	◒	◒
Barkly Tablelands	Extensive grazing on broad, upland black clay plains. Some impacts on soil carbon in more pastorally important areas but generally more resilient soils.				↘	◒	◒

Southern Regions	Inland rangelands country including Tanami Sandplain and Ranges, Tanami Sandplain, Davenport Ranges, Sandover Sandplain, Redvers Dunefield, Macdonald Sandplain, Northern Alice Ranges, Northern Alice Plains, Tobermory Plain, Toko Plateaus, Central Ranges, Todd Plains, Simpson Desert Dunefield, Simpson Desert Plains, Western Desert Ranges, Great Sandy Desert Dunefield and the Amadeus Plains. Largely undeveloped with some areas of extensive grazing. Generally inherently low soil carbon levels that are likely to be decreasing in some pastorally important areas.				⊟	◒	◒
Indication of trend	↗ Improving ↘ Deteriorating ⊟ Stable ? Unknown						
Level of Confidence	○ Evidence and consensus too low to make an assessment ◒ Limited or low quality evidence but high consensus ● Adequate high quality evidence and high consensus						

At a glance… soil carbon

- Few data are available in the NT but most soils are thought to have lost less than 30% of carbon compared with conditions at time of settlement.
- Carbon levels are thought to be stable in most pastoral areas although the effects of grazing by feral animals and management fire regimes are unknown.
- Soil carbon levels are thought to be declining in areas of high grazing pressure and where there is more intense land use.

Queensland

Mike Grundy, CSIRO Land and Water, and Ram Dalal and Phil Moody, Queensland Department Environment & Resource Management

Comments

No specific comments

Risks to environmental values

None specifically identified

References associated with soil carbon in Queensland:

Dalal, R.C., Allen, D.E., Wanga, W.J., Reeves, S. and 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*, **112**: 133-139.

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Physiographic Region	Summary	Assessment Grade				Confidence in grade	Confidence in trend
		Very poor	Poor	Good	Very good		
Condamine Lowlands and Upper Darling Plains	High intensity cropping on Vertosols, sometimes with irrigation, has resulted in a loss of 70% soil carbon on Brigalow lands and of 50% soil carbon on basalt black soils (also Vertosols) since clearing but soil carbon levels are now stabilizing. Land management is moving to zero till and controlled traffic/ precision traffic so carbon trend may be slightly upwards. Reduced tillage causing increased stratification of organic carbon and organic nitrogen in these systems may lead to an increase in carbon in the surface 2 cms but it will take a prolonged period for changes to be detected in 0-10 cm layer. Less intensive rainfed cropping on Sodosols has resulted in similar soil carbon losses but the increased use of pulses in rotation and the potential increase in opportunity cropping as use of seasonal forecasts becomes more widespread, may result in an improved soil carbon trend. Areas with cattle grazing on improved pastures (mostly on Sodosols) were cleared later and have lost maybe 30-70% soil carbon since clearing; possible upward trend in soil carbon under shrub legumes. Light textured Rudosols and Dermosols, and sodic soils (Sodosols) used for horticulture had an immediate rapid decline in soil carbon in the 1950s, which then stabilized and now may be increasing under perennial tree crops and shrub legumes. Small area of national parks with little change in levels of soil carbon.		⊟			●	●
Charleville Tablelands	Brigalow with box and belah on Vertosols, Dermosols and some Sodosols, has been cleared for cattle grazing with some opportunity cropping; minimal sheep. Mulga with Kandosols and Chromosols variably cleared for cattle and some sheep over the last 25 years. Kandosols lost 50-70% soil carbon soon after clearing and cropping, but carbon levels now stable. Other soils may have had 30-70% loss since clearing, with areas cleared over last 10-15 years for pasture losing 30-50% of soil carbon; carbon levels probably now stable.			⊟		◒	◒

Physiographic Region	Summary	Assessment Grade				Confidence in grade	Confidence in trend
		Very poor	Poor	Good	Very good		
St George Plain, Warrego Plains, Maranoa Lowland and Lightning Ridge Lowland	Vertosols and Sodosols with irrigated and dryland cropping, have lost 30-50% of soil carbon but carbon levels are now stable after 30 years. Kandosols cleared for grazing cattle and sheep have also lost 30-50% of soil carbon, but the loss of soil carbon has been less than 30% on Sodosols, Vertosols and Dermosols with similar land use. Trends are now stable for all soils.			⊟		◒	◒
Taroom Hills	Mostly cleared for pasture for cattle over the last 40 years, with some small areas of cropping. Soils are Chromosols, Kandosols and Sodosols with small areas of Vertosols. Cropping areas have generally lost 30-50% of soil carbon and grazing lands 0-30%; trends are probably now stable.				⊟	◒	◒
Expedition scarplands, Connors Ranges, Carborough Ranges	Largely uncleared with little change to inherently low soil carbon levels.				⊟	◒	◒
Toowoomba Plateau	Long cleared Ferrosols on Tertiary basalt, used for cropping and pasture with increasing agroforestry. Soils have lost 70- 90% of carbon under cropping but now have a slow increase where land use is pasture or forestry.	↗				●	●
Bunya-Burnett Ranges	Most of the area is cleared grazing land with marginally improved pastures on Sodosols, with Kurosols and Kandosols. Few data but these areas probably have lost less than 30% soil carbon and levels are likely to be stable. Vertosols and Dermosols with intensive horticultural annual crops have lost 30-50% of soil carbon but are now stable. Some dairy and intensive cattle production on Ferrosols, Kandosols, Dermosols and Vertosols where carbon loss 0-30% but levels now stable.				⊟	◒	◒
Moreton Lowlands	Urbanised						
Maryborough Lowland	Podosols, Kandosols and Kurosols with pine plantations probably have a slow increase in soil carbon from an inherently low level. Kandosols, Dermosols, Hydrosols and		⊟			◒	◒

Physiographic Region	Summary	Assessment Grade				Confidence in grade	Confidence in trend
		Very poor	Poor	Good	Very good		
	Ferrosols used for sugar cane have had a 50-70% decline in soil carbon, but levels are now stable. Green cane trash blanketing may lead to an increase in carbon in the surface 2 cms but it is likely to take a prolonged period for changes to be detected in the 0-10 cm layer. Horticulture with both annual and tree crops on Dermosols and Ferrosols around Bundaberg has resulted in a 50-70% decline in soil carbon. Carbon now stable under small crops, but increasing under tree crops which are becoming more prevalent. There are few data but land with pastures and grazing on Sodosols and some Podosols probably have lost less than 30% of soil carbon which is now likely to be stable.						
Broadsound Plains	Land with inherently low fertility soils (Tenosols, Sodosols) cleared for grazing. Few data but maybe 50-70% loss of carbon following clearing but probably now with stable levels.		⊟			◒	◒
Townshend Ranges and Lowlands, Burdekin Hills and Lowlands	There has been no soil carbon decline associated with the Dermosols, Sodosols and Tenosols of the mountains with rainforest; levels are stable and inherently high in places. On the lowland plains with Hydrosols, Sodosols, Chromosols, Kandosols and Vertosols, soil carbon has declined by 50-70% under cropping but is now stable. Green cane trash blanketing may lead to an increase in carbon in the surface 2 cms but it will take a prolonged period for changes to be detected in the 0-10 cm layer.				⊟	◒	◒
Townsville Lowlands and Cairns Ranges	Irrigated and rainfed sugar production and horticulture on Vertosols, Sodosols, Hydrosols and Dermosols have resulted in a 50-70% loss of carbon but levels are now stable. Green cane trash blanketing in all areas except the Burdekin may lead to increase in carbon in the surface 2 cms but it will take a prolonged period for changes to be detected in 0-10 cm layer. The burnt cane system in the Burdekin is likely to prolong the period before any carbon increase. There were large decreases in soil carbon following clearing and grazing on coastal improved pastures, but carbon levels are now stable and as grazing is becoming less		⊟			●	●

Physiographic Region	Summary	Assessment Grade				Confidence in grade	Confidence in trend
		Very poor	Poor	Good	Very good		
	intensive, levels may be slowly increasing. Ponded pasture and aquaculture are small land uses for which no data are available.						
Hervey Tablelands, Alice Tableland, Scartwater Hills, Bulgonunna Tableland, Cotherstone Plateau, Drummond Uplands, Nogoa Scarplands and Buckland Plateau	Partially cleared grazing country with Kandosols, Chromosols and Sodosols. There are few data but soil carbon is likely to be declining where cleared recently, otherwise stable.			↘		◒	○
Atherton Tableland	A variety of land uses including improved nitrogen fertilized pastures on Ferrosols and Chromosols; intensive rainfed cropping on Ferrosols; irrigated tree crops (irrigated perennial horticulture); irrigated small crops (irrigated seasonal horticulture) on Ferrosols, Chromosols and Kandosols; and irrigated sugar on a range of soils including Sodosols. All areas with an immediate loss of 50-70 % of soil carbon at clearing but with soil carbon now increasing under pastures and tree crops and stable under rainfed crops and sugar; still decreasing under small crops.		↗			●	◒
Garnet Uplands	Recently intensified land use after clearing; there are few data but soil carbon is likely to have undergone significant loss and to still be declining		↘			◒	◒
All Cape and Gulf Regions	Torres High Islands, Jardine Uplands, Weipa Plateau, Meriuna Plain, Wenlock Uplands, Coleman Plateau, Holroyd Plains, Laura Plain, Cooktown Ranges, Palmerville Hills, Bullimba Plateau, Karumba Plain, Clara-Mitchell Plains, Gregory Range, Gilbert Hills, Newcastle Ranges, Einasleigh Plains, Gilberton Plateau, Wondoola Plain, Normanton Tableland, Donors Tableland, Armraynald Plain, Manangoora Plains, Gulf Fall and Isa Ridges. Extensive cattle grazing with minimal clearing on soils with inherently low carbon levels; little carbon loss and stable levels.				—	◒	◒
Burdekin Plateaus and Cape River	Grazing on Chromosols, Ferrosols and Dermosols, with clearing over 50 years ago. Losses of 50-70% soil carbon from		—			◒	◒

Physiographic Region	Summary	Assessment Grade				Confidence in grade	Confidence in trend
		Very poor	Poor	Good	Very good		
Plains	Chromosols, and 30-50% from Ferrosols and Dermosols though carbon levels now all stable.						
Belyando Plains	Grazing on extensively cleared Vertosols, Kandosols, Dermosols and Chromosols with buffel grass; smaller areas of rainfed opportunity cropping and irrigated cropping on Vertosols and Dermosols. Grazing areas have lost 30-50% carbon while cropping areas have lost 50-70%, but carbon levels are now stable throughout.				⊟	◒	◒
Mackenzie Dawson Lowlands	Rainfed opportunity cropping on Vertosols and Dermosols. These areas with a 30-50% loss of soil carbon, but levels now stable. Similar areas of extensively cleared grazing lands with buffel grass on Vertosols, Kandosols, Dermosols, Chromosols. Soil carbon losses of 50-70% but levels now stable. Small areas of irrigated cropping on Vertosols and Dermosols. These areas also with a 50-70% loss of soil carbon and with levels now stable.				⊟	◒	◒
Jericho Plain	Mostly cleared with extensive grazing; soil carbon losses of 30-50% but levels now stable.			⊟		◒	○
Winton Blackall Downs	Used for grazing but not generally cleared resulting in little soil carbon loss (< 30%) and stable levels.				⊟	◒	◒
Remaining southwest regions	Tobermory Plain, Boulia Downs, Eyre Creek Plain, Eromanga Lowlands, Whelen Lowlands, Diamantina Plain, Simpson Desert Dunefield, Diamantina Plain, Sturt Desert Plain, Cooper Plain, Strzelecki Desert Plains, Bulloo Plain, Paroo Plain Variable landscapes and soils; most regions with some extensive grazing. Few data available but expected soil carbon loss associated with overgrazing in the past but probably now mostly stable.			⊟		○	◒
Indication of trend	↗ Improving ↘ Deteriorating ⊟ Stable ? Unknown						

Physiographic Region	Summary	Assessment Grade				Confidence in grade	Confidence in trend
		Very poor	Poor	Good	Very good		
Level of Confidence	○ Evidence and consensus too low to make an assessment ◒ Limited or low quality evidence but high consensus ● Adequate high quality evidence and high consensus						