national carbon
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technical report no. 12

Pre-clearing Soil Carbon Levels in Australia

Adrian Webb (Editor)

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PRE-CLEARING SOIL CARBON LEVELS IN AUSTRALIA

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Webbnet Land Resource Services Pty Ltd

National Carbon Accounting System Technical Report No. 12

March 2002

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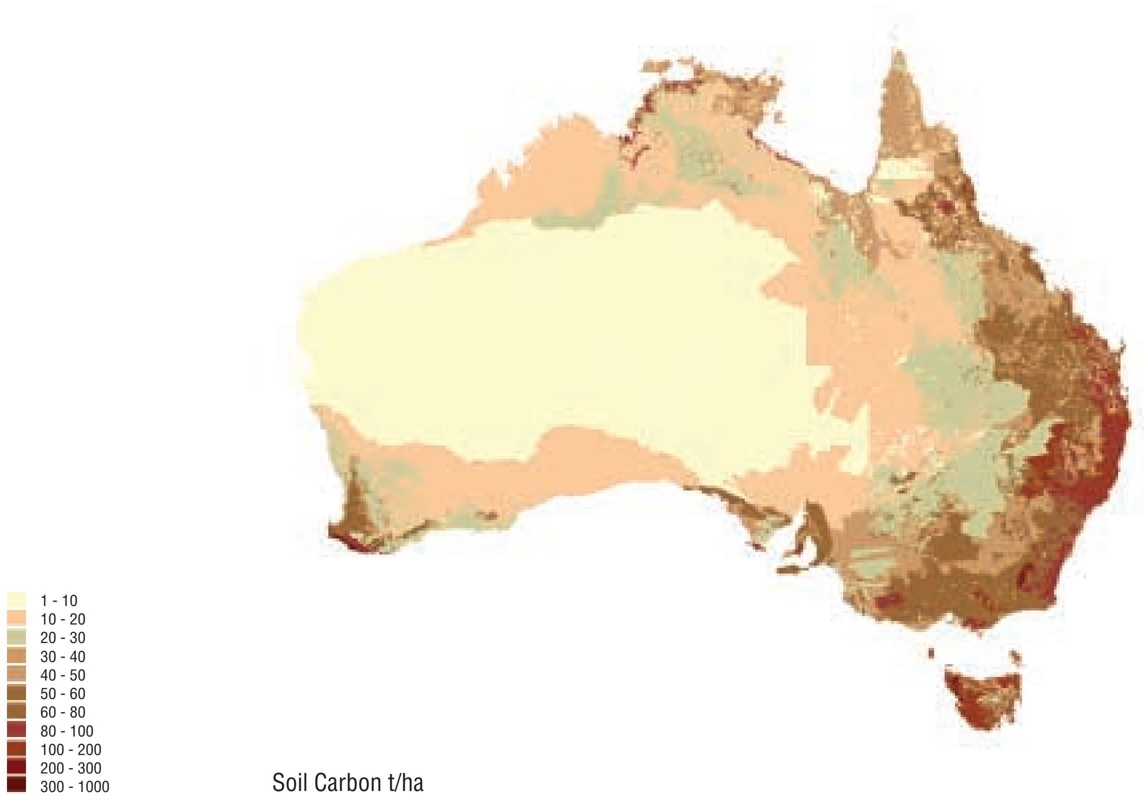
SUMMARY

A map of soil carbon in the top 30 cm of soil across Australia has been produced in collaboration with the State and Territory Governments and CSIRO using existing soil carbon and associated data.
An important input to modelling the soil carbon flux is the level of soil carbon prior to land use change, that is soil carbon in pre-cleared conditions. Estimated change due to the land use change is then modelled using climate, land management, land use and crop yield inputs. This soil carbon map is an input to the estimation of soil carbon change in Australia including the 1990 Baseline for the Land Use Change and Forestry components of the National Greenhouse Gas Inventory.

The map below shows the broad variability of soil carbon, some of which is clearly related to climate/landscape characteristics. Estimates of pre-clearing soil carbon levels in Australia range from < 10 to > 250 tonne (t) per hectare (ha) to 30 cm depth. This project has highlighted the value of soil site databases nationally, but also emphasised the deficiencies in them. A major requirement into the future for the National Carbon Accounting System will be to improve the quality of the site data and the ability to predict pre-disturbance soil carbon levels and the subsequent impacts of land use practices.



Soil Carbon t/ha

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1. INTRODUCTION

The flux in soil carbon associated with land use change is a key component of Australia's greenhouse gas balance. The Australian Greenhouse Office (AGO) is implementing a national approach to estimating soil carbon change due to land use activity involving modelling using the *Roth-C* soil carbon model. The collection and collation of information for the national program is stratified within the boundaries of the Interim Bio-geographic Regionalisation of Australia (IBRA Version 4, Thackway & Cresswell 1995). An important input to modelling the soil carbon flux is the level of soil carbon prior to land use change, that is soil carbon in pre-cleared conditions. The model is subsequently used to estimate change in soil carbon due to the land use change.

The AGO and its consultants have worked closely with key contacts in each State and Territory Government and CSIRO to derive pre-clearing soil carbon estimates for mapped soil units for each IBRA cell using existing readily available data. The approach allows for updating as new improved data become available. This report provides a collated spatial coverage of soil carbon within IBRA regions and a brief overview of the approach and findings for each of the States and the Northern Territory. The individual State and Territory reports are appended; they provide supporting documentation on the basis of decisions on aspects such as area of major soils, amalgamation of soil groups, and soil carbon estimation/allocation to spatial units.

2. APPROACH

There were two components to the approach used to provide estimates of soil carbon for spatial units across the IBRA regions. The main one involved the States and the Northern Territory providing estimates mainly for the agriculturally significant regions; and the second involved estimating default values for other IBRA regions based on expert judgement. The latter component was included essentially to provide a continental coverage in case some areas outside the agricultural regions showed evidence of land clearing. The modelling used in compiling the soil carbon flux estimates necessitated having default values for these areas. Information on climate and soil landscapes plus knowledge of soil carbon in neighbouring regions was used to guide expert judgement in establishing the default values where data was not directly available.

The approaches implemented across each State and Territory were essentially similar and required the linking of limited point source information to extensive spatial coverages of soil or land units. This involved two phases. One was the development of a spatial distribution of soils within each of the IBRA regions, with the objective of defining a few (< 10) spatial units. The second was to derive soil carbon contents for each of these soil units within each region. This exercise required judgements on similarity and importance of soils to support the spatial unit amalgamations required to arrive at the relatively few units per IBRA region.

2.1 SPATIAL SOIL COVERAGE

In all States and Territories there are soil survey coverages at a number of scales and these were evaluated to derive the most accurate coverage for each region. In some cases, this included high intensity surveys (> 1:50,000); at the other extreme, the only soil coverage is the Atlas of Australian Soils or broad scale Land System Mapping. For each coverage, the polygons were interpreted for major soils and then overlaid on the IBRA polygons. The end result was a patchwork of surveys of various scales within each IBRA region.

Since most soil mapping has been conducted to determine the spatial variation of soil types and a limited number of easily observable soil features, they are likely to have limitations as predictors of soil carbon variation. That limitation is likely to increase as scale broadens. Since Queensland is the State with the major areas of recently cleared land, and therefore likely to contribute most to the soil carbon flux, it was considered particularly important to use the finest scale polygon data available for any part of the State. Polygons of similar dominant soils were derived for the agricultural regions of Western Australia, South Australia, Tasmania, and the lands north of the Tanami Desert in the Northern Territory. In Queensland, New South Wales and Victoria a whole of State coverage was provided.

In Victoria, because of the lack of geo-located soil carbon information in the databases and readily available reports, the Geomorphic Units of Victoria were used as the spatial units, rather than the best level of scale available, generally as Land Systems Mapping. This has resulted in a coverage with less variation than would have occurred with larger scale mapping units supported by more site data.

To achieve the objective of having only the main soil units for each IBRA subdivision, several different models for aggregation were considered. The goal was to minimise the heterogeneity of the surface (upper 30 cm) properties of the soil units by describing only meaningful variability.

2.2 APPLICATION OF THE SITE DATA

The spatial estimation of soil carbon was derived by overlaying the site coverages on the soil/landscape polygons, and estimation of an average soil carbon level to 30 cm depth from available or derived data. The estimation and allocation of soil carbon contents generally involved two stages. Initially, a comprehensive ‘data search’ was conducted to determine the extent of existing chemical and physical information for uncleared sites required for calculating soil carbon contents. Organic carbon contents were determined for soil profiles then averaged for each of the Soil Orders, Principal Profile Forms or Groups within each IBRA region. Where site data were scarce or non-existent, data from similar soils in the same or neighbouring IBRA region were used. For example in the Northern Territory, where there was no information for a Soil Order, the value of another Soil Order was used and adjusted accordingly. This was often the case with Rudosols. The carbon contents of the Rudosols were generally determined from the Tenosols or Kandosols, with a reduction factor, to account for higher gravel contents. Where there was no information for an IBRA region then the values of the most appropriate adjacent region were used.

In each State, data were identified from the State databases. In some States additional data were collated from unpublished and published reports. Many of the later sites were not digital and significant time was spent in capturing these data. Where CSIRO data were available they were included, except in New South Wales.

There were a number of significant limitations in the data for the purpose. These included:

- general lack of bulk density measurements;
- paucity of measurements below 10 cm; and
- poor coverage of pre-clearing site data.

The distribution and numbers of soil sites with soil carbon data is shown in the individual distribution maps from each report. These maps reinforce the conclusion that there are relatively few site data in many areas.

While the extent of site data could not be improved without significant expenditure, a number of analytical approaches were adopted to deal with the lack of bulk density and organic carbon to depth and thus produce a set of sites with imputed values of carbon quantities per unit area. These are detailed in each of the separate reports. For example, in South Australia, bulk density for soils with little or no bulk density data were estimated using a pedotransfer function derived from the relationship of soil carbon (C) with bulk density (BD) on 35 South Australian pasture sites (Merry pers. comm.), using the equation:

$$BD = 1.608 - 0.0872\%C \ (r^2=0.46, n=105).$$

The data from the pedotransfer function were compared with those from a previous study by Skjemstad (pers. comm.) and the default set of McKenzie *et.al.* (2000), and a decision was made to accept the pedotransfer approach.

Soil organic carbon measurements are normally derived from combustion in a LECO furnace. The method historically used to derive soil carbon values for many sites was the Walkley and Black method that has evolved over time in the major laboratories and thus produced results that have varied over time. In a separate study implemented as part of the AGO soil carbon estimation program, the relationships between the Walkley Black method and the LECO method were examined through time across the major laboratories in each State. These relationships provide adjustment factors for the soil carbon values reported in each State to a LECO dry combustion standard (Skjemstad *et.al.* 2000).

3. OUTPUT

The spatial estimates of soil carbon will be an input to the estimation of the soil carbon change due to land use change in Australia. The map (Figure 1) shows the broad variability of soil carbon, some of which is clearly related to climate/landscape controls. Estimates of pre-clearing soil carbon levels in Australia range from < 10 t/ha to 30 cm depth in arid areas to > 250 t/ha to 30 cm depth in highland areas of the Southern Alps and Tasmania and coastal swamps.

Each State provided the spatial coverage of land units (soils) and site data underpinning the allocation of soil carbon values to spatial units. These have been joined at State boundaries and have resulted in a few "boundary" constraints/anomalies across State borders and where coverages of different scales or purpose abut each other. None were carried out specifically to provide a spatial soil carbon coverage. The result is a national coverage of land units with a nominal soil carbon value to 30 cm depth. The individual reports for each State and the Northern Territory are provided in the appendices. These should be referred to for the specific details of method and data availability employed in each State or Territory.

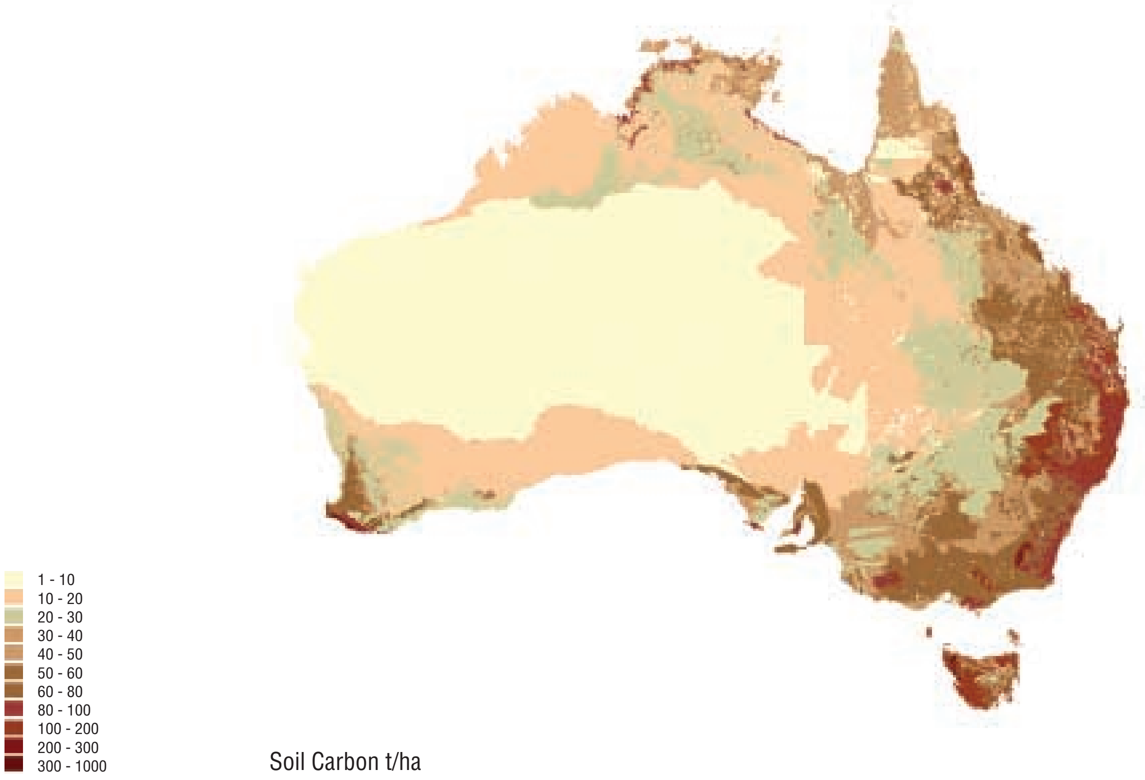

Figure 1. Soil carbon (t/ha $_{0\text{-}30\ cm}$) values for Australia.

Large areas of the agricultural zones of Australia have very low densities of observations, and the resultant spatial distribution needs to be treated with caution. This is particularly so for Victoria. This deficiency is exacerbated in areas where the only polygon mapping is the Atlas of Australian Soils or one of the broader Land System studies. In situations where there is a reasonable distribution of sites but the polygonal mapping is broad, the analysis has produced results which are on average accurate but which do not reflect local variation. Most State collaborators indicated that lack of geographic location information precluded the use of some site data.

Other limitations to the analyses arise from the nature of the input data. The site data came from a wide range of sources. Very few of them were collected with the spatial modelling of soil carbon as an aim. The quality of the soil site data used across the regions varies considerably. Soil carbon concentration data below the surface soil are rare and bulk density values are extremely rare. In many regions, the sampling was biased towards agriculturally significant soils, low sloping areas and areas with established agricultural land uses. This is not critical as these are the areas also subject to land use change. Similarly, the polygonal mapping was not intended to produce a surface of soil carbon when the various studies were compiled. The extent to which the polygons delineate soil carbon variation depends on the correlation between the mapped entities, such as soil type or land system and soil carbon.

The end result has been the compilation of a spatial coverage of soil carbon to 30 cm for Australia. In southern Australia most of the clearing for agriculture occurred prior to the period for which soil carbon fluxes are being estimated for the 1990 baseline. Therefore the requirement for accurate estimation of pre-cleared soil carbon is much less important than for those areas where more recent clearing has occurred over large areas.

In the non-agricultural zones of central, western and northern Australia, with minor land clearing, there is little requirement for accurate soil carbon estimates for the baseline estimation, and the default values are considered appropriate at this stage.

This current soil carbon coverage provides an initial basis for estimation of soil carbon change due to land use change, and to guide decisions on capturing more accurate spatial carbon coverages. This project has highlighted the value of soil site databases nationally, but also emphasised the deficiencies in them. A major requirement into the future for the National Carbon Accounting System will be to improve the quality of the site data and the ability to predict pre-disturbance soil carbon levels and subsequently model the impacts of land use practices. The known uncertainties identified in this work will assist quantitative analysis of uncertainty in the soil carbon change estimates.

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APPENDIX 1

PRE-CLEARING SOIL CARBON LEVELS IN WESTERN AUSTRALIA

Ted Griffin and Noel Schoknecht
(Natural Resource Management Agriculture Western Australia)

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1.1 BACKGROUND

This project is one of several related projects for the National Carbon Accounting System. Specifically, it provides an assessment of pre-disturbance soil carbon levels in Western Australia (WA).

1.2 OBJECTIVES

1. Identify the major soils in each IBRA cell in Western Australia and provide an estimated area of each major soil in each IBRA cell using the best available data;
2. Allocate soil carbon (kg/ha 0-30 cm depth) for the major soils in each IBRA cell and provide the data in a spatial context; and
3. Provide supporting documentation on the basis of decisions made in the allocation.

2. METHODS AND RESULTS

2.1 SPATIAL UNITS

2.1.1 IBRA Regions

The AGO chose the IBRA regions as the basic spatial unit by which to report organic carbon levels. An analysis of the reasoning for this is contained in the account of a workshop in 1999 (Webb 1999). For the agricultural areas of south-western Australia this provided 6 units (Figure 1).

Initial analysis of the soil composition in these areas showed them to be very heterogeneous. In itself this is not a problem except in so far as it might be a reflection of climatic variation. Since climate, especially rainfall, appears to be a major driver of the soil carbon levels it is appropriate to minimise this source of variation if possible.

A related project collating land use and management information, 1970 - 2000 (Griffin *et.al.* 2000) had a similar requirement and as the data generated from both projects would need to be consistent, it was decided to subdivide the IBRA regions.

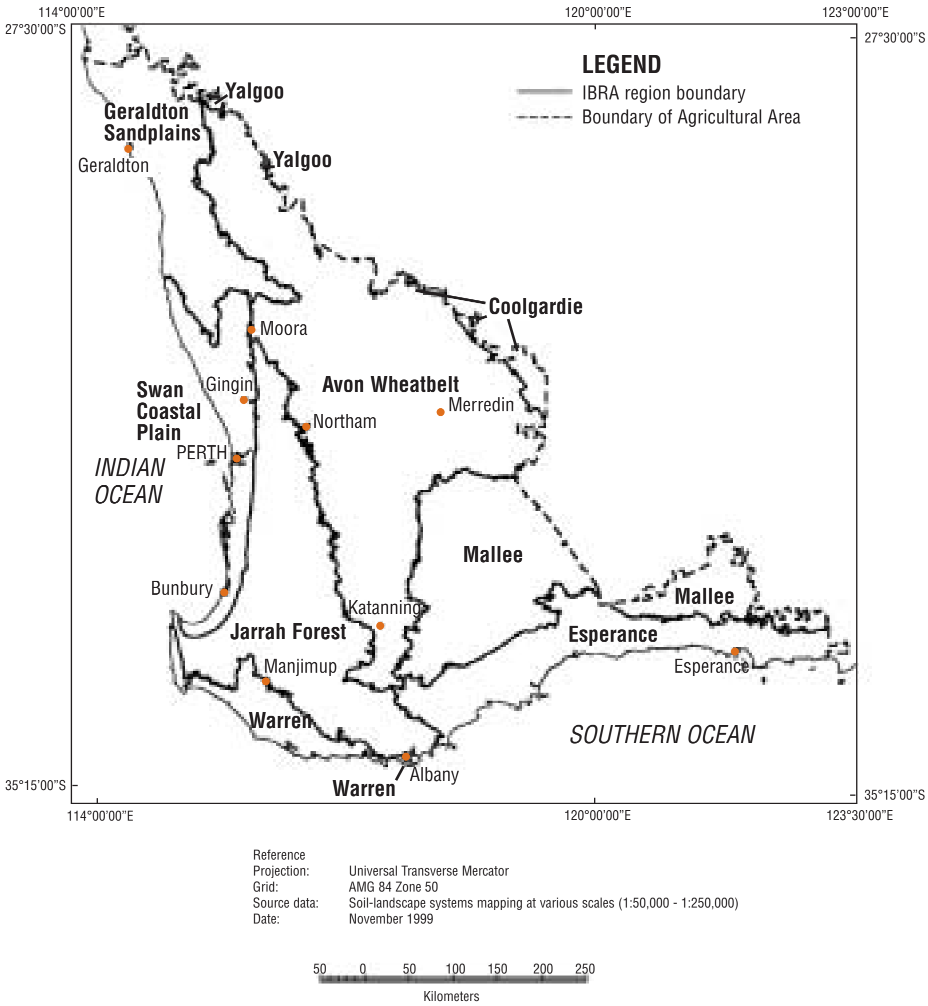

Figure 1. IBRA regions in south-western Australia.

2.1.2 Subdivisions of IBRA Regions

Webb (1999) argues that IBRA regions are surrogates of climatic regions. The six IBRA regions in south-western Australia are broadly Mediterranean types. However, this area contains significant rainfall gradients which has been the basis for a regionalisation for crop recommendations (Figure 2).

These figures broadly endorse IBRA regions as climate surrogates. However, the Avon wheatbelt in particular and a few others have significant gradients that would merit recognition. It is also recognised that subdividing for climate, in addition to being a better predictor of organic carbon, reduces the heterogeneity of the soil (and land uses) within the reporting units. The challenge is what to use as the basis for this subdivision as rainfall isohyets are effectively arbitrary.

CVT Key

1	North	VH	Very High - >750 mm average annual rainfall
2	North Central	H	High - 450 - 750 mm (where there is a VH region)
3	Central	H	High - > 750 mm (where there is no VH region)
4	South Central	M	Medium - 325 - 450 mm
5	South	L	Low - < 325 mm

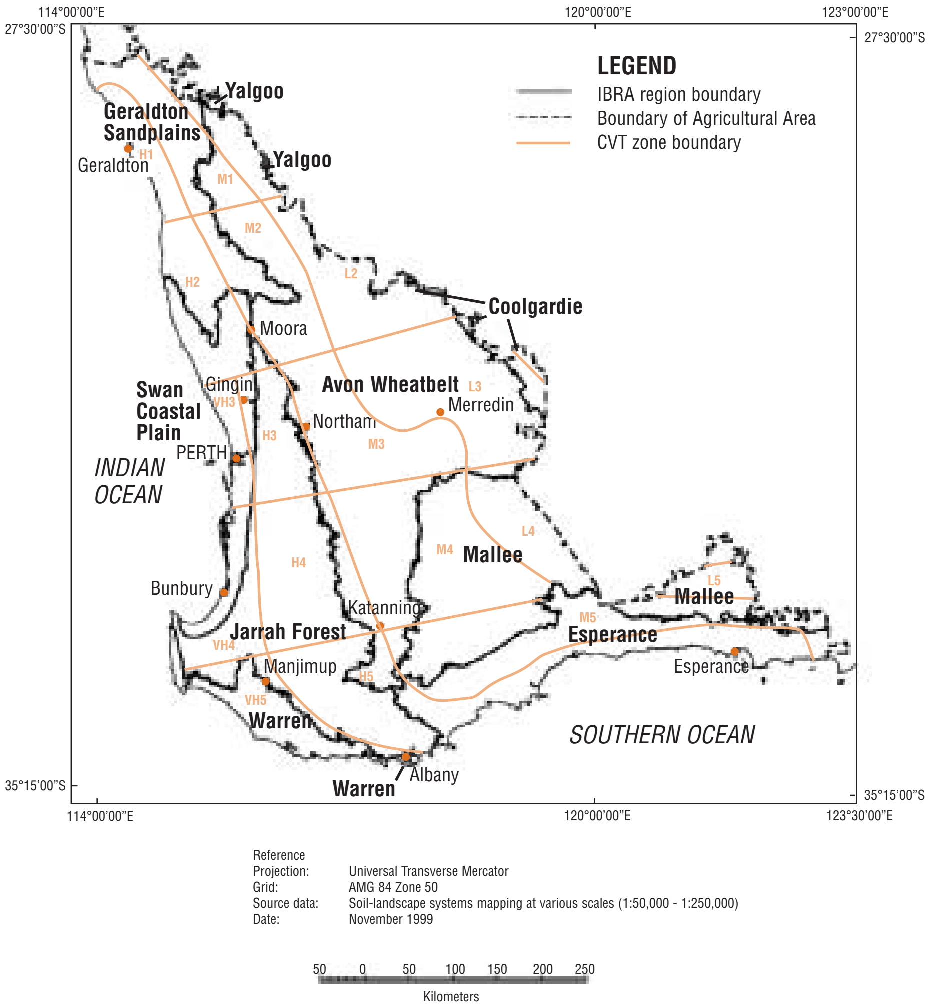

Figure 2. IBRA regions and CVT zones in South-Western Australia.

The zone level of the AGWEST's soil-landscape mapping (Figure 3), shows a significant parallel with the rainfall isohyets reflecting in part soil development's dependence on climate.

There is also significant parallel between the zones and the IBRA regions. This is to be expected through the inter-relationship between vegetation and soil. There are some minor inconsistencies but many of the zones effectively subdivide the IBRA regions, and a combination of IBRA regions subdivided by zones, groups of zones, or in the case of the Swan Coastal Plain –rainfall isohyets, are selected as the spatial unit for this study.

2 Western Region

21 Swan Province
- 211 Coastal Dune Zone
- 212 Bassendean Zone
- 213 Pinjarra Zone

22 Greenough Province
- 221 Coastal Dune Zone
- 222 Coastal Dune Zone
- 223 Coastal Dune Zone
- 224 Coastal Dune Zone
- 225 Coastal Dune Zone
- 226 Coastal Dune Zone

23 Carnevon Province
- 231 Coastal Dune Zone
- 232 Coastal Dune Zone
- 233 Coastal Dune Zone
- 224 Coastal Dune Zone

24 Stirling Province
- 241 Coastal Dune Zone
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- 245 Coastal Dune Zone
- 246 Coastal Dune Zone
- 247 Coastal Dune Zone

25 Avon Province
- 251 Coastal Dune Zone
- 252 Coastal Dune Zone
- 253 Coastal Dune Zone
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- 255 Coastal Dune Zone
- 256 Coastal Dune Zone
- 257 Coastal Dune Zone
- 258 Coastal Dune Zone
- 257 Coastal Dune Zone

26 Murchison Province
- 261 Coastal Dune Zone

27 Murchison Province
- 271 Coastal Dune Zone
- 272 Coastal Dune Zone

Zone Boundary

Boundary of Agricultural Area

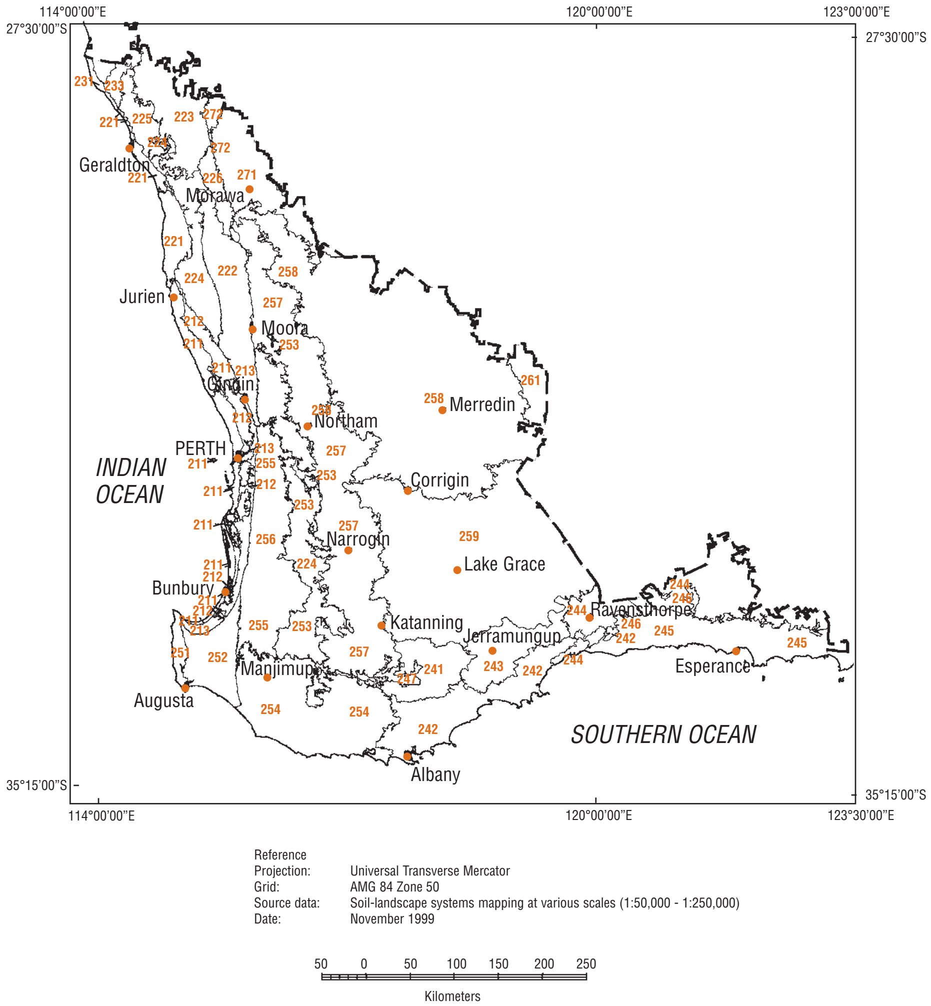


Figure 3. Soil-landscape zones in south-western Australia.

2.1.3 IBRA-Zone/Climate Cells as the Spatial Unit

Figure 4 is the product of the subdivisions used in this project. This recognises the major two or three zones within each IBRA regions and in some regions these are an aggregation of several zones.

The one exception to the use of soil-landscape zones for subdivision is the Swan Coastal Plain region which is divided into three– one on the basis of a soil-landscape zone and the other two roughly on rainfall isohyets.

The subdivided IBRA cells are more internally homogeneous in soil unit composition (refer to Table 2), land uses and clearing history compared to the IBRA regions alone. For example, the eastern portion of the Avon wheatbelt IBRA region was settled much later and had more clearing since 1970 than other parts of the region.

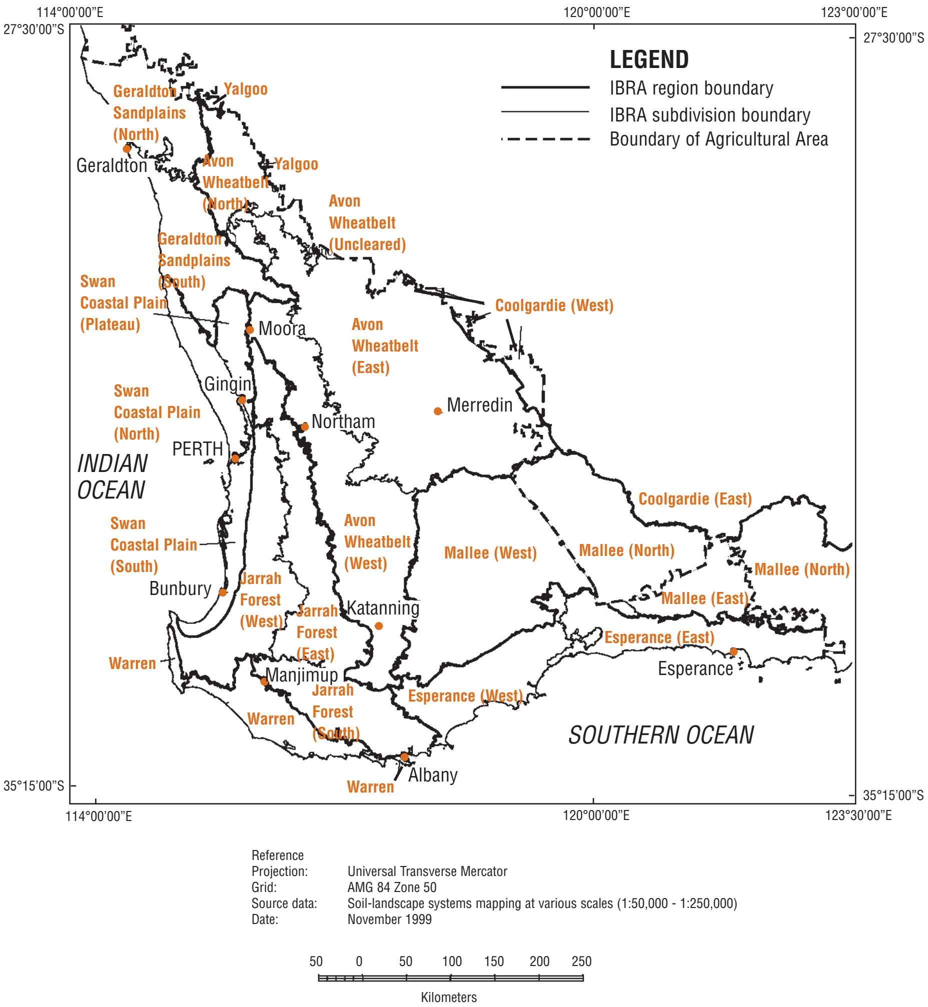


Figure 4. IBRA regions in south-western Australia subdivided by soil-landscape zones and climate.

2.2 SOIL UNITS

2.2.1 Definition

Soil Groups (Schoknecht 1999) are aggregated into soil units as the basis for attributing soil related qualities to the map units. The descriptions of the soil units is given in Table 1, and the aggregations of the Soil Groups into soil units is given in Table 2. The Soil Groups are a local classification system of about 60 units based on a combination of readily recognised surface and sub-surface properties. While this soil classification is much less detailed than the Australian Soil Classification (Isbell 1997), it is too detailed for the current project. The WA Soil Groups are well suited to an aggregation for the current purpose because of the importance of surface properties and the consistency of the control sections used.

With the object of having just a few main soil units for each IBRA subdivision, several different models for aggregation were considered. The final objective was to minimise trivial heterogeneity of the surface (upper 30 cm) properties of the soil units. This generated soil units that were easily recognised by those from whom land use and crop production data were to be obtained. Table 1 contains the soil units used.

Table 1. Soil units used - based on aggregation of WA soil groups (Schoknecht 1999).

Code	Name	Description
co_s	coloured sands	coloured sands - shallow and deep coloured sands, coloured sandy earths & coloured deep (> 30 cm) sandy duplexes
gr	gravels	lateritic gravels and/or duricrust within 15 cm of surface
l_c	loams and clays	shallow loams, loamy earths, loamy duplexes and clays
ns_w	non-saline wet	non-saline wet and semi wet soils (saturated within 80 cm of surface for several months, various textures)
oth	other	rocky soils, disturbed areas and water bodies
pa_s	pale sands	pale and grey sands - shallow and deep pale sands, gravelly pale deep sand, pale sandy earths & grey deep (> 30 cm) sandy duplexes
s_d	sandy duplexes	shallow sandy duplexes (< 30 cm sand)
sa	saline	primary and secondary saline soils

Table 2. Aggregation of WA soil groups into soil units for this project.

Soil Unit	Soil Group
Coloured sands	Red deep sandy duplex
	Yellow/brown deep sandy duplex
	Red shallow sand
	Yellow/brown shallow sand
	Deep sands supergroup
	Brown deep sand
	Red deep sand
	Yellow deep sand
	Sandy earths supergroup
	Acid yellow sandy earth
	Brown sandy earth
	Red sandy earth
	Yellow sandy earth
Gravels	Ironstone gravelly soils supergroup
	Deep sandy gravel
	Duplex sandy gravel
	Loamy gravel
	Shallow gravel
Loams and clays	Loamy duplexes supergroup
	Acid shallow duplex
	Alkaline grey shallow loamy duplex
	Alkaline red shallow loamy duplex
	Grey shallow loamy duplex
	Brown deep loamy duplex
	Red deep loamy duplex
	Red shallow loamy duplex
	Yellow/brown shallow loamy duplex
	Shallow loams supergroup
	Calcareous shallow loam
	Red shallow loam
	Red-brown hardpan shallow loam
	Loamy earths supergroup
	Brown loamy earth
	Calcareous loamy earth
	Friable red/brown loamy earth
	Red loamy earth
	Yellow loamy earth

Soil Unit	Soil Group
Loams and clays cont.	Cracking clays supergroup
	Hard cracking clay
	Self-mulching cracking clay
	Non-cracking clays supergroup
	Grey non-cracking clay
	Red/brown non-cracking clay
non-saline wet	Wet or waterlogged soils supergroup
	Semi-wet soil
	Wet soil
Other	Rocky or stony soils supergroup
	Bare rock
	Calcareous stony soil
	Stony soil
	Miscellaneous soils supergroup
	Disturbed land
	Water
	No suitable group
	Undifferentiated soils
Pale sands	Alkaline grey deep sandy duplex
	Grey deep sandy duplex
	Reticulite deep sandy duplex
	Shallow sands supergroup
	Calcareous shallow sand
	Pale shallow sand
	Calcareous deep sand
	Gravelly pale deep sand
	Pale deep sand
	Pale sandy earth
Sandy duplexes	Sandy duplexes supergroup
	Alkaline grey shallow sandy duplex
	Grey shallow sandy duplex
	Red shallow sandy duplex
	Yellow/brown shallow sandy duplex
Saline	Saline wet soil
	Salt lake soil
	Tidal soil

2.2.2 Soil Units – Distribution in the IBRA Subdivisions

Soil-landscape mapping at the systems level (nominal scale 1:250,000) has been completed for the agricultural areas of south-western Australia. Attributed to this mapping is the proportional allocation of WA Soil Groups (Schoknecht 1999).

The allocation of these soil units to the IBRA subdivisions was based on area weighted proportions of soil-landscape systems within each IBRA subdivision and the proportional allocation of WA Soil Groups to the systems. The results are shown in Table 3.

Many of the IBRA subdivisions have all eight soil units. Most, however, have just two or three soil units that could be considered dominant.

The dominant soil unit in each of the soil-landscape systems was assigned to the system to give an indication of the spatial distribution of the soil unit within the IBRA subdivision. This allocation was provided in a database, with the shape file to which this data should be associated is provided separately. This assignment proved a gross simplification and should be used as an indication of what the most likely soil type would be.

2.2.3 Soil Units – Clearing in the IBRA Subdivisions

The estimated clearing rates between 1970 and 2000 of each soil type in each IBRA subdivision is provided in Table 4. These data were generated by Griffin *et.al.* (2000). This shows considerable differences, mainly across regions but also across soil types. Those highlighted are the soils that are > 10% of the IBRA subdivision (Table 3) and are estimated to have had > 10% of their area cleared since 1970.

Table 3. Soil units in each IBRA subdivision (% and area).

Spatial Unit		% of Soil Unit Area ('000 ha) of Soil Unit								
IBRA	Subdivision	gr	co_s	pa_s	s_d	l_c	oth	ns_w	sa	Σ
Avon Wheatbelt	eastern	8	20	10	8	36	8	1	9	
		394	986	493	394	1776	394	49	444	4934
	northern	6	33	3	4	44	7		3	
		63	350	31	42	467	74		31	1063
	western	12	11	29	11	20	10	1	6	
		358	328	867	328	598	299	29	179	2990
Coolgardie	western	4	17	5	4	59	7		4	
		11	49	14	11	171	20		11	290
Esperance Plains	eastern	3	1	52	23	10	8	1	2	
		37	12	651	287	125	100	12	25	1252
	western	9	1	29	21	20	11	5	4	
		115	12	371	268	256	140	64	51	1280
Geraldton Sandplains	northern	5	32	26	7	27	2		1	
		54	351	285	76	296	21		10	1098
	southern	15	28	42	2	4	4	2	3	
		206	384	576	27	54	54	27	41	1373
Jarrah Forest	eastern	37	6	22	7	13	9	3	3	
		639	103	380	120	224	155	51	51	1727
	southern	42	5	20	3	10	6	12	2	
		483	57	230	34	115	69	138	23	1151
	western	42	6	9	1	22	7	12	1	
		681	97	146	16	357	113	194	16	1623
Mallee	eastern	1		20	55	16	1		7	
		8		176	484	140	8		61	880
	western	12	9	16	21	23	6	1	12	
		390	292	520	683	748	195	32	390	3252
Swan Coastal Plain	northern		35	49		1	3	11	1	
			201	282		5	17	63	5	575
	plateau	17	38	31		2	3	5	4	
		68	153	125		8	12	20	16	403
	southern	3	16	40	1	10	4	24	2	
		15	83	207	5	51	20	124	10	518
Warren	all	29	9	21		16	5	19	1	
		241	74	174		133	41	158	8	833

Table 4. Estimated percent of soil units cleared between 1970 and 2000 in each IBRA subdivision (% and area).

Spatial Unit		% of Soil Unit Area ('000 ha) of Soil Unit								
IBRA	**Subdivision**	**gr**	**co_s**	**pa_s**	**s_d**	**l_c**	**oth**	**ns_w**	**sa**	**Σ**
Avon Wheatbelt	eastern	30	**35**	40	30	10	10	30	16	
		118	**345**	197	118	177	39	14	71	1079
	northern	35	**60**	60	5	**30**	25		10	
		22	**210**	19	2	**140**	18		3	414
	western	10	**12**	**31**	6	2	4	4	3	
		35	**39**	**268**	19	11	11	1	5	389
Coolgardie	western	2	**17**	21	28	5	20		15	
		0	**8**	3	3	8	4		1	27
Esperance Plains	eastern	32	31	**36**	**32**	7	10	5	11	
		12	3	**234**	**92**	8	10	0	2	361
	western	13	30	**15**	**18**	**19**	7	21	23	
		14	3	**55**	**48**	**48**	9	13	11	201
Geraldton Sandplains	northern	32	**43**	**36**	23	**22**	18		40	
		17	**151**	**102**	17	**65**	3		4	359
	southern	**32**	**13**	**38**	13	10	19	10	11	
		65	**50**	**219**	3	5	10	2	4	358
Jarrah Forest	eastern	6	7	4	5	1	7	8	10	
		38	7	15	6	2	10	4	5	87
	southern	2	0	4	10	1	0	2	10	
		9	0	9	3	1	0	2	2	26
	western	1	0	2	1	1	3	1	3	
		6	0	2	0	3	3	1	0	15
Mallee	eastern	51		**60**	**45**	**23**	41		52	
		4		**105**	**217**	**32**	3		32	393
	western	**37**	42	**40**	**31**	**18**	20	14	7	
		144	122	**208**	**211**	**134**	39	4	27	889
Swan Coastal Plain	northern		**14**	**19**		4	8	**13**	12	
			28	**53**		0	1	**8**	0	90
	plateau	**23**	**26**	**37**		7	9	11	11	
		15	**39**	**46**		0	1	2	1	104
	southern	15	**21**	**39**	26	10	10	**16**	26	
		2	**17**	**80**	1	5	2	**19**	2	128
Warren	all	1	1	1		0	0	2	0	
		2	0	1		0	0	3	0	6

Figures bolded are those which are >10% of IBRA subdivision and apparently had >10% cleared between 1970 and 2000 (derived from Tables 3 and 4).

2.3 SITES AVAILABLE FOR ANALYSIS

A small proportion of the morphological and laboratory data in Agriculture Western Australia's soil profile database is from sites in apparently natural areas. Figure 5 is the distribution of those "natural" sites which had organic carbon data. This is shown in relation to the IBRA subdivisions. Table 5 lists the frequency of these sites by soil unit and IBRA subdivision. While these sites were from 14 different projects, three-quarters were from just three: CSIRO 'P sites'; Reference Sites (McArthur, 1991); and SAP sites (Western Australian Department of Conservation and Land Management, Mr Norm McKenzie, pers. comm.). The laboratory data for the SAP project was acquired during this study.

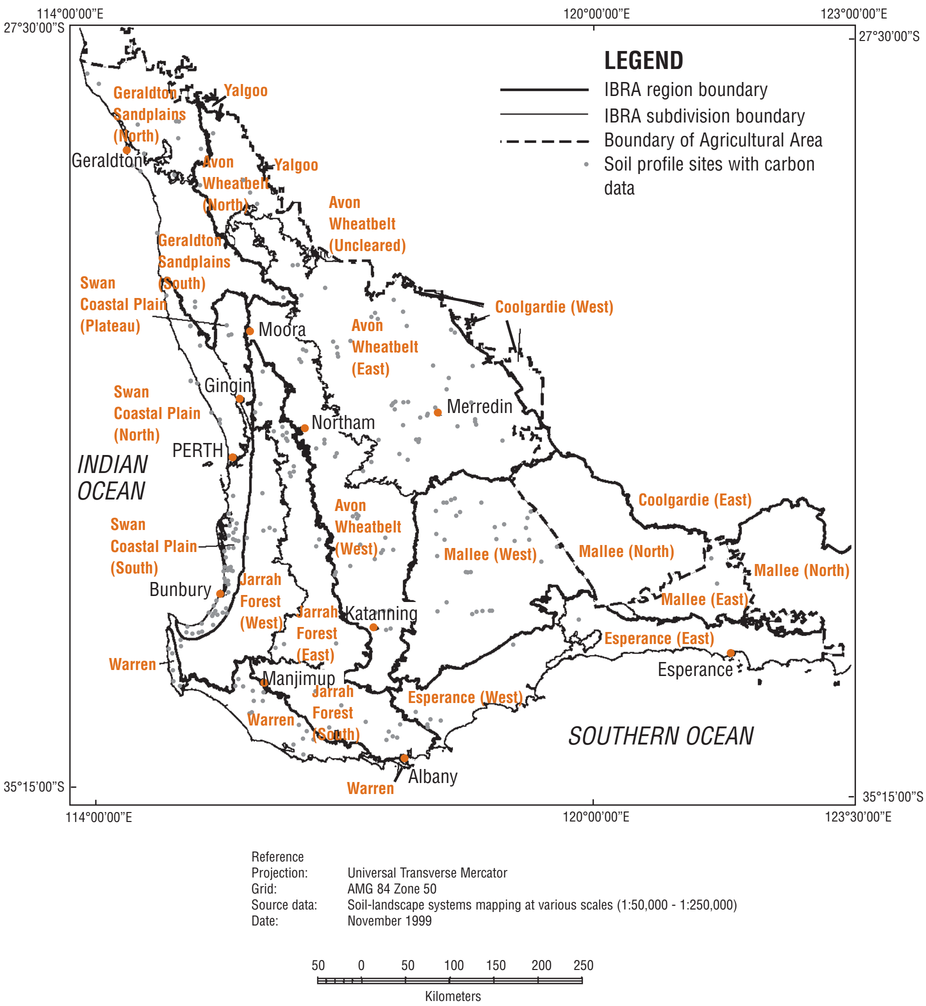


Figure 5. IBRA subdivisions showing scatter plot of sites with soil carbon analyses.

Table 5. Numbers of sites per IBRA subdivision - soil unit combinations.

Spatial Unit		% of Soil Unit Area ('000 ha) of Soil Unit								
IBRA	**Subdivision**	**gr**	**co_s**	**pa_s**	**s_d**	**l_c**	**oth**	**ns_w**	**sa**	**Σ**
Avon Wheatbelt	eastern	17	5	23			4	10	3	62
Avon Wheatbelt	non_ag	1	1							2
Avon Wheatbelt	northern	2		5				2		9
Avon Wheatbelt	western	11	4	18		1	6	3	2	45
Coolgardie	non_ag	1		1						2
Esperance Plains	eastern	3		1			2			6
Esperance Plains	western	1		1			2	3		7
Geraldton Sandplains	northern	8	1	2	1		2	1		15
Geraldton Sandplains	southern	15		1			16	1		33
Jarrah Forest	eastern	2	7	10	2		7	3		31
Jarrah Forest	southern	3	2	10		6	10	11		42
Jarrah Forest	western	6	14	8			2	1		31
Mallee	eastern			1				2		3
Mallee	non_ag		1	1						2
Mallee	western	6	1	15			5	5	3	35
Swan Coastal Plain	northern						7			7
Swan Coastal Plain	plateau	6	1							7
Swan Coastal Plain	southern	17	2	8	4	1	25	1	1	59
Warren	all	4	14	15	1	1	12	1		48
TOTALS		**103**	**53**	**120**	**8**	**9**	**100**	**44**	**9**	**446**

Note: non_ag = areas outside of the agricultural area

Typically, the laboratory data available do not completely satisfy the requirements of the present project. Virtually all the organic carbon data is weight % of the fine earth fraction. The sample preparation typically rejects coarse organic matter. The organic carbon data are mostly by the Walkley and Black method. There was also some loss on ignition data where there was no organic carbon data. Some of this data was used to supplement the organic carbon data.

Many sites had the percent clay in the fine earth fraction. Some had the coarse fragments percentage of the whole soil. However, there was virtually no data on bulk density, especially from sites in natural areas.

2.4 FINE ORGANIC CARBON

Because of the typical exclusion of coarse organic matter, the analysis provided below is the fine organic carbon fraction.

The product required from these analyses is the weight of organic carbon in the top 30 cm expressed per unit of area. This involves a number of variables that are not immediately available in the laboratory data. Laboratory data is typically the weight % in the fine earth fraction of various sample intervals. To make the conversions, it is necessary to:

- account for the % coarse fragments (assumed to be devoid of organic carbon);
- convert the sample to a weight by volume using bulk density; and
- sum the values over the top 30 cm.

This should be done on an individual sample basis. However, the % coarse fragments data is not recorded in many of the samples and the bulk density data was absent in all but a couple of samples. Also the samples containing organic carbon data often do not completely cover the top 30 cm for many sites. It was, therefore, impossible to get the integrated data on a site basis.

The best solution is to use the available laboratory data to generate curves describing the average concentrations of organic carbon in the fine earth fraction (weight %). These are generated for each combination of IBRA subdivision and soil unit. In so doing, it was assumed that the coarse fragment proportions and the bulk density was consistent for all samples in each combination. This is likely to be a different degree of presumption for different soils.

The required data is then generated by functions involving these estimates of organic carbon, estimates of coarse fragments and estimates of bulk density. The organic carbon data are mostly by the Walkley and Black method. Some data from unknown methods were also included. It was assumed that the variation between samples was greater that the variation between laboratory methods. Also since the amount of data available was limited, it was decided to investigate the use of converted loss on ignition data. The results of this conversion seemed reasonable enough to use (see below for examination of this aspect).

2.4.1 Estimating Coarse Fragments and Fine Earth Fraction

The average coarse fragments percentages are estimated for soil unit by determining values for each of the Soil Groups and then aggregating and averaging these values by soil unit (Table 6). Fine earth fraction (%) can be determined by subtracting the coarse fragment % from 100.

Table 6. Estimation of average coarse fragments percentages for soil units.

Soil Unit	Coarse Fragments % 0 – 5 cm	Coarse Fragments % 5 – 15 cm	Coarse Fragments % 15 – 30 cm
coloured sands	1	2	5
gravels	10	30	40
loams and clays	2	2	3
non-saline wet	0	0	0
other	60	70	70
pale sands	1	3	10
sandy duplexes	0	2	5
saline	0	0	0

2.4.2 Estimating Bulk Density

Bulk density data is very limited in Western Australia. For this project, data from a number of sources is used to generate estimates of bulk density for each of the soil units used in this analysis. Two techniques were used to estimate bulk density:

1) using the properties of the WA Soil Groups; and

2) using a relationship between organic carbon and bulk density. Bulk density estimates are made for each depth intervals 0-5 cm, 5-15 cm and 15-30 cm.

2.4.2.1 Using WA Soil Groups

The average bulk densities (g/cm^3) are estimated for soil unit by determining values for each of the Soil Groups and then aggregating and averaging these values by soil unit (Table 7).

2.4.2.2 Using Organic Carbon

There is no simple relationship between particle size distribution and bulk density (Dr Neil McKenzie, pers. comm.) This is understandable as it does not take into account structure and other important factors. A moderately good relationship was described between bulk density (BD) and organic carbon (OC) and clay (Dr Jan Skjemstad,

BD = 1.58 -0.121(OC%) - 0.0053(clay%)
for surface < 30 cm R^2=0.64

BD = 1.61 -0.165(OC%) - 0.0005(clay%)
for sub-soils > 30 cm R^2=0.21.).

Unfortunately, these were not able to be used for the present study because of the limited clay data available. A separate relationship between bulk density and organic carbon % in the fine earth fraction is described in Graph 1. This was from a limited data set, virtually all from modified soils. It is clearly a composite of family of relationships that could be described for different soil types.

Table 7. Estimation of bulk density for soil units using soil groups data.

Soil Unit	Bulk Density g/cm^3 0 – 5 cm	Bulk Density g/cm^3 5 – 15 cm	Bulk Density g/cm^3 15 – 30 cm
coloured sands	1.4	1.5	1.5
gravels	1.5	1.6	1.6
loams and clays	1.2	1.3	1.4
non-saline wet	1.2	1.4	1.4
other	1.3	1.3	1.3
pale sands	1.4	1.5	1.5
sandy duplexes	1.3	1.3	1.6
saline	1.3	1.3	1.4

2.4.2.3 Method Used

Because of limited data, it was decided to use a combination of the above methods. Where the organic carbon values were very low, the values used were those in Table 7. Others were discounted roughly in proportion to the concentration in organic carbon in the fine earth. The values used are reported in Table 9.

2.4.3 Organic Carbon Estimation from Loss on Ignition Data

The purpose of this investigation was to provide additional data for samples that had no organic carbon data (Graph 2). Loss on ignition (LOI) is not just a function of organic matter content. It could also be a function of bond water in sesquioxides and also carbonates. It is not easy to define a relationship between LOI and organic carbon even if the other data is known and taken into account.

An investigation of the relationship between LOI and organic carbon suggested a good fit in the surface layers and poorer at depth. This is probably a function of increasing carbonates and bound water with depth. This examination was difficult since the difference between upper and lower depths of samples varied greatly.

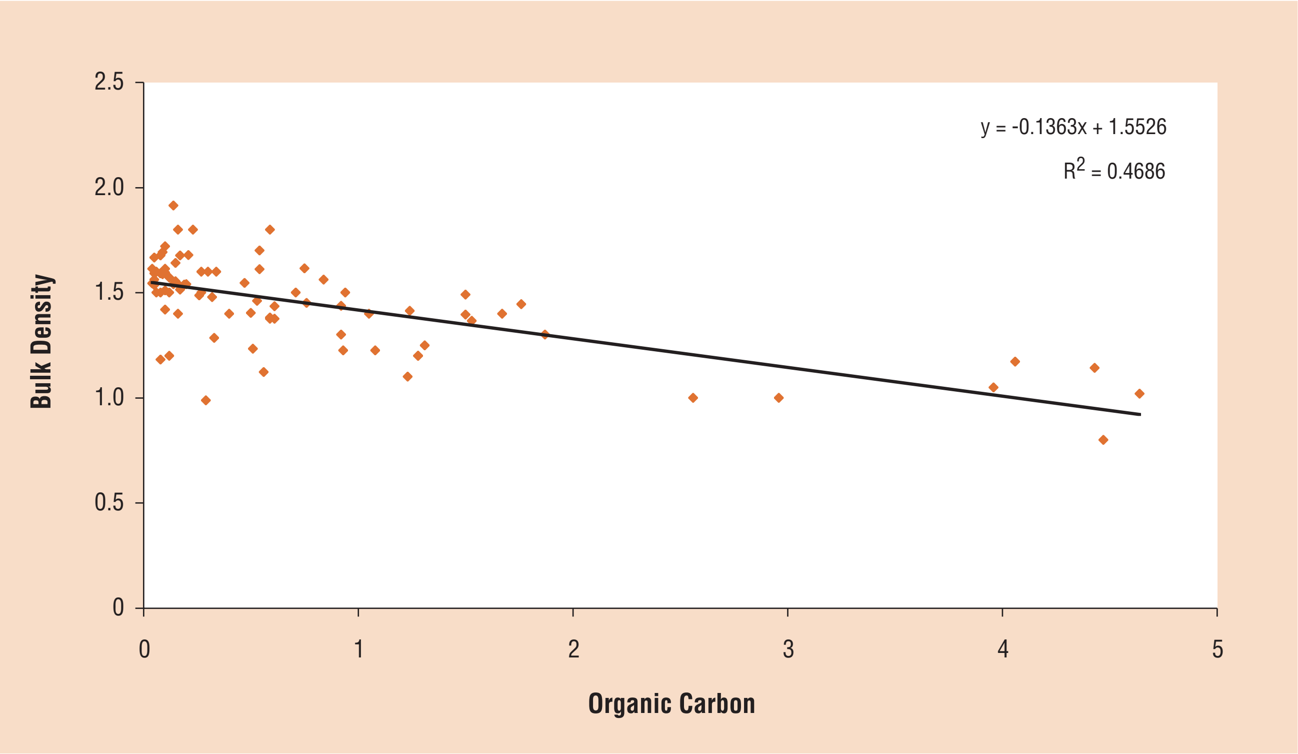
A series of expressions were derived - one for each depth class:

average depth of the sample < 10 cm, OC_calc = 0.4*LOI;

average depth of the sample 10 - < 20 cm, OC_calc = 0.3*LOI;

average depth of the sample 20 - < 30 cm, OC_calc = 0.25*LOI; and

average depth of the sample > 30 cm, OC_calc = 0.18*LOI.



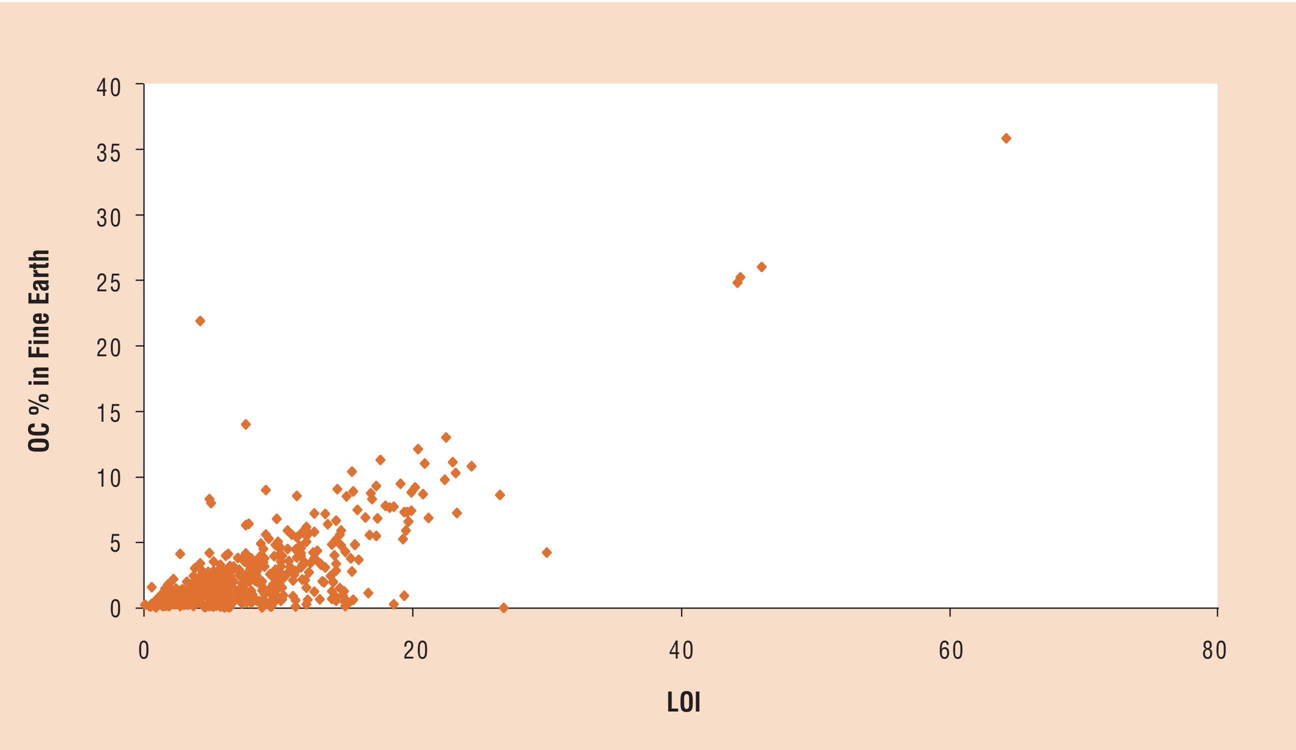
Graph 1. Bulk density versus organic carbon % in fine earth fraction.

Graphs 3, 4, 5 and 6 provide the expression of the predicted values verses the measured values. It was considered, however, that the relationships for only depths < 20 cm were reliable enough to use to predict organic carbon levels. These data amounted to about one sixth of the samples used in the present analysis.

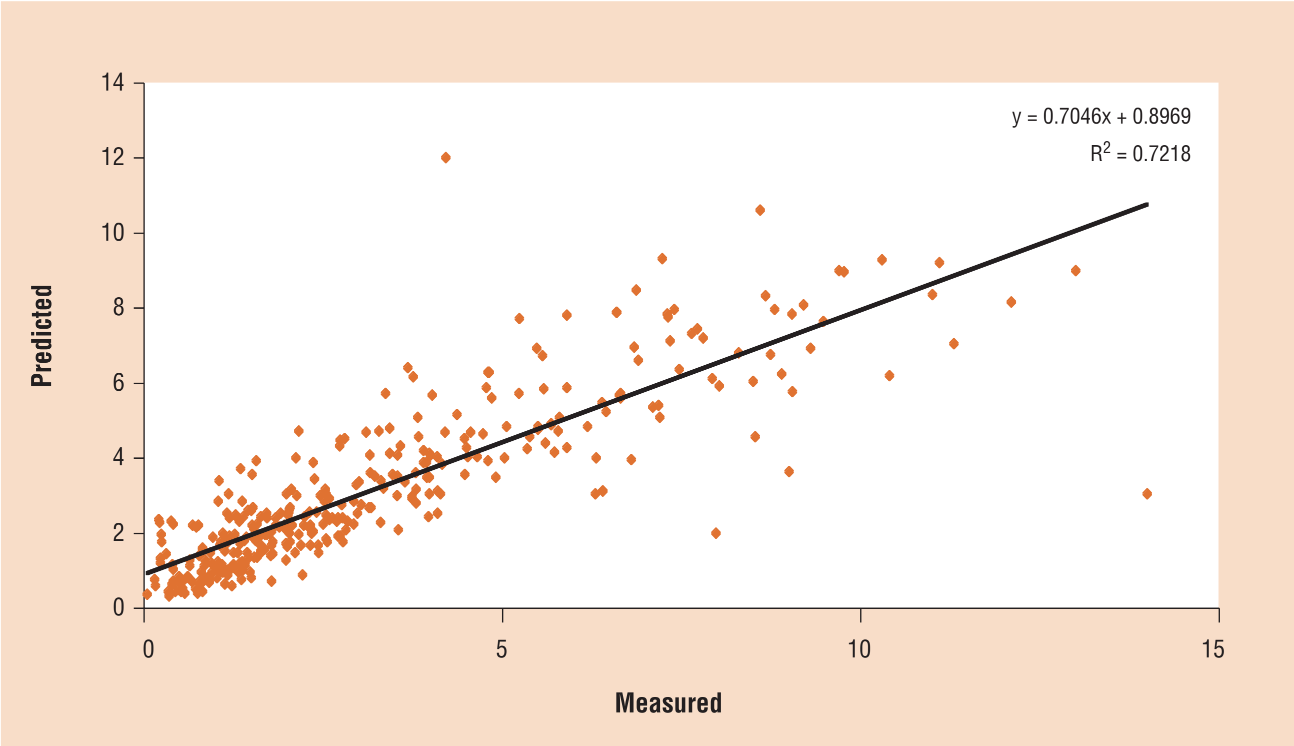
2.4.4 Estimating Values of Fine Organic Carbon in Fine Earth for Soil Units

The samples used were those in apparently undisturbed sites from those with measured organic carbon and mid-point of the sample interval < 100 cm, and those with predicted organic carbon from LOI and mid-point of the sample interval < 20 cm. These values were plotted against the mid–point of the sample interval.

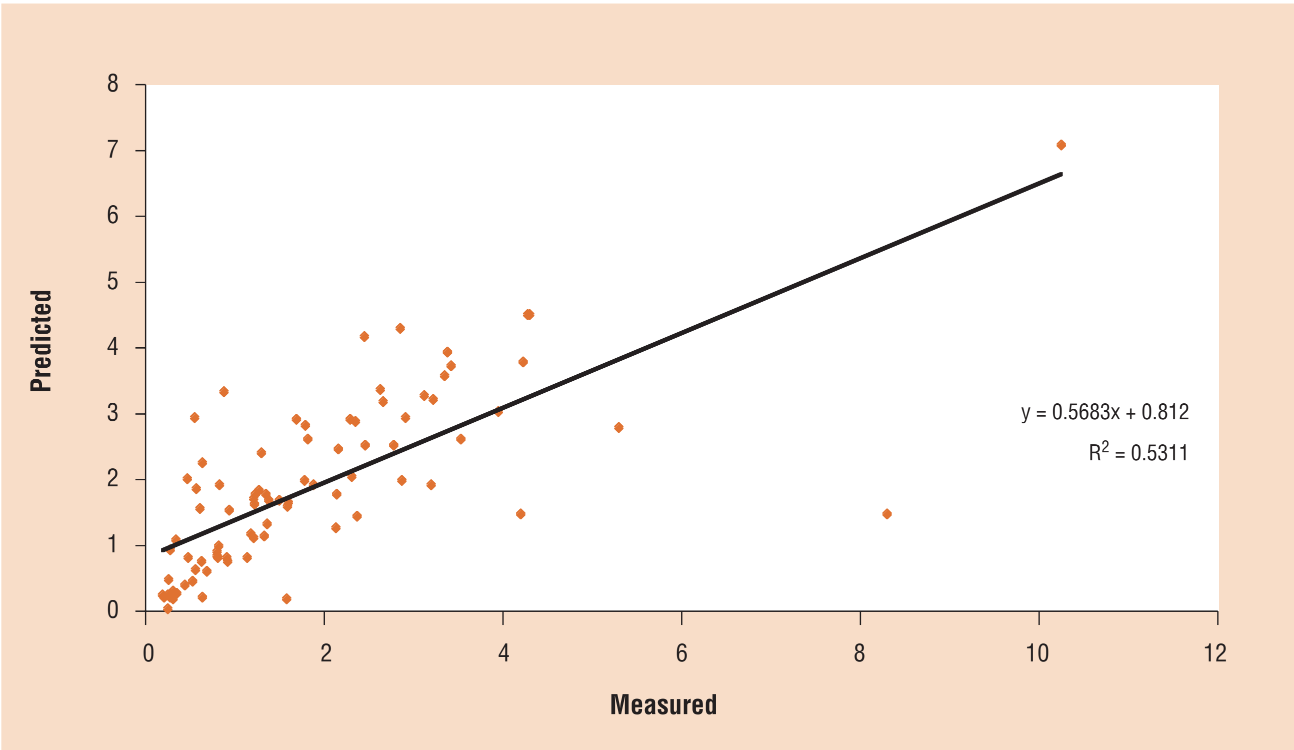
This was done separately for each IBRA subdivision and soil unit combination using the MS Access form "ibra_soil_OC_depth" which was based on "Query6". This Access form also fits a curve based on a power function (OC = a*Depth^b) to the points. (This type of curve was used after the investigation of a number of standard functions. When 'b' is negative it follows the conceptual model of the highest concentration being at the surface and declining with depth at a decreasing rate.) An example of this is provided in Graph 7.



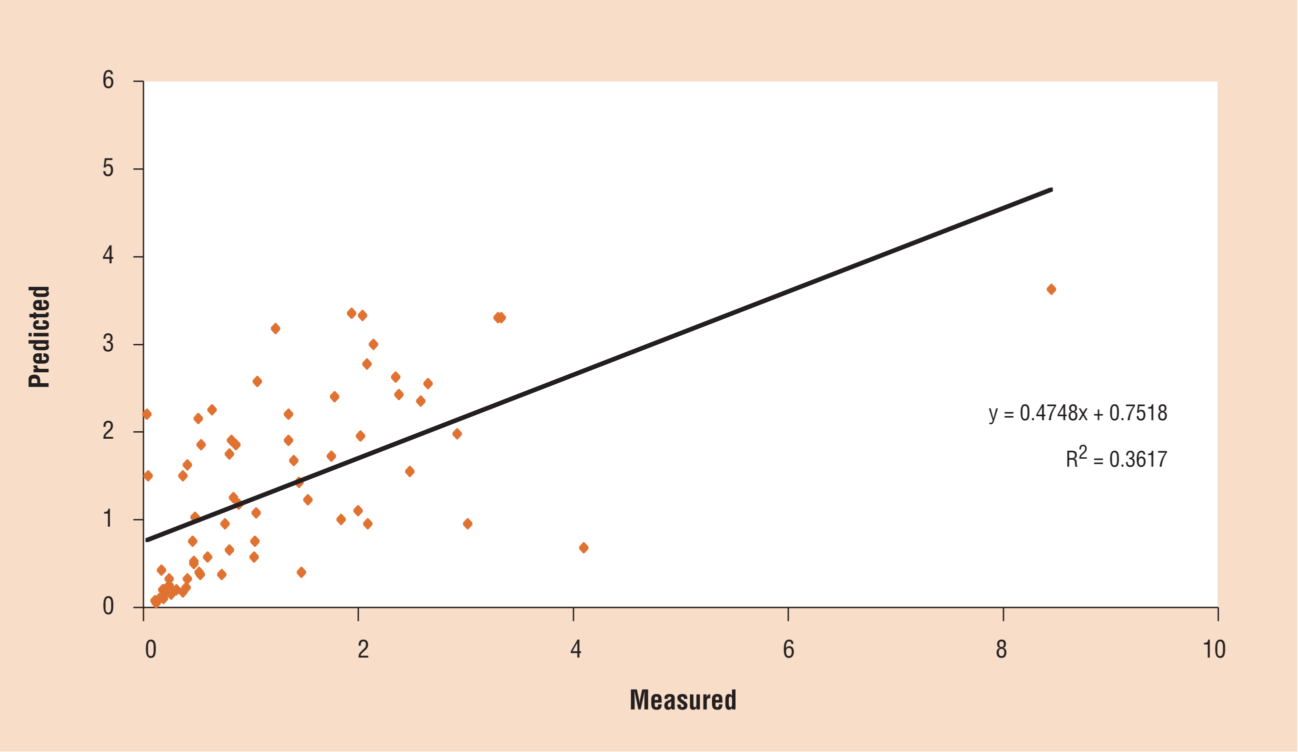
Graph 2. Organic carbon % in fine earth fraction vs loss on ignition (LOI).



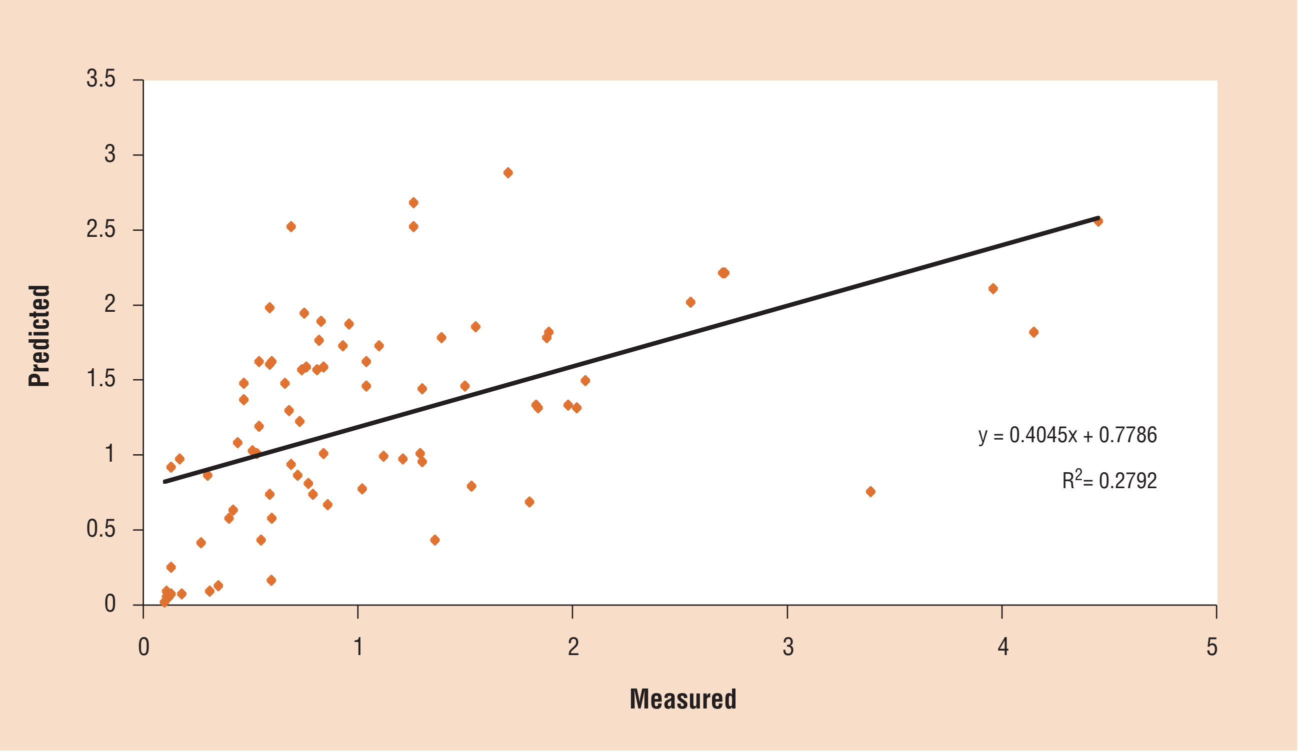
Graph 3. Organic carbon in fine earth, depth < 10 cm, predicted from LOI*0.4 vs measured.



Graph 4. Organic carbon in fine earth, depth > 9.99 cm and < 20 cm, predicted from LOI*0.3 vs measured.

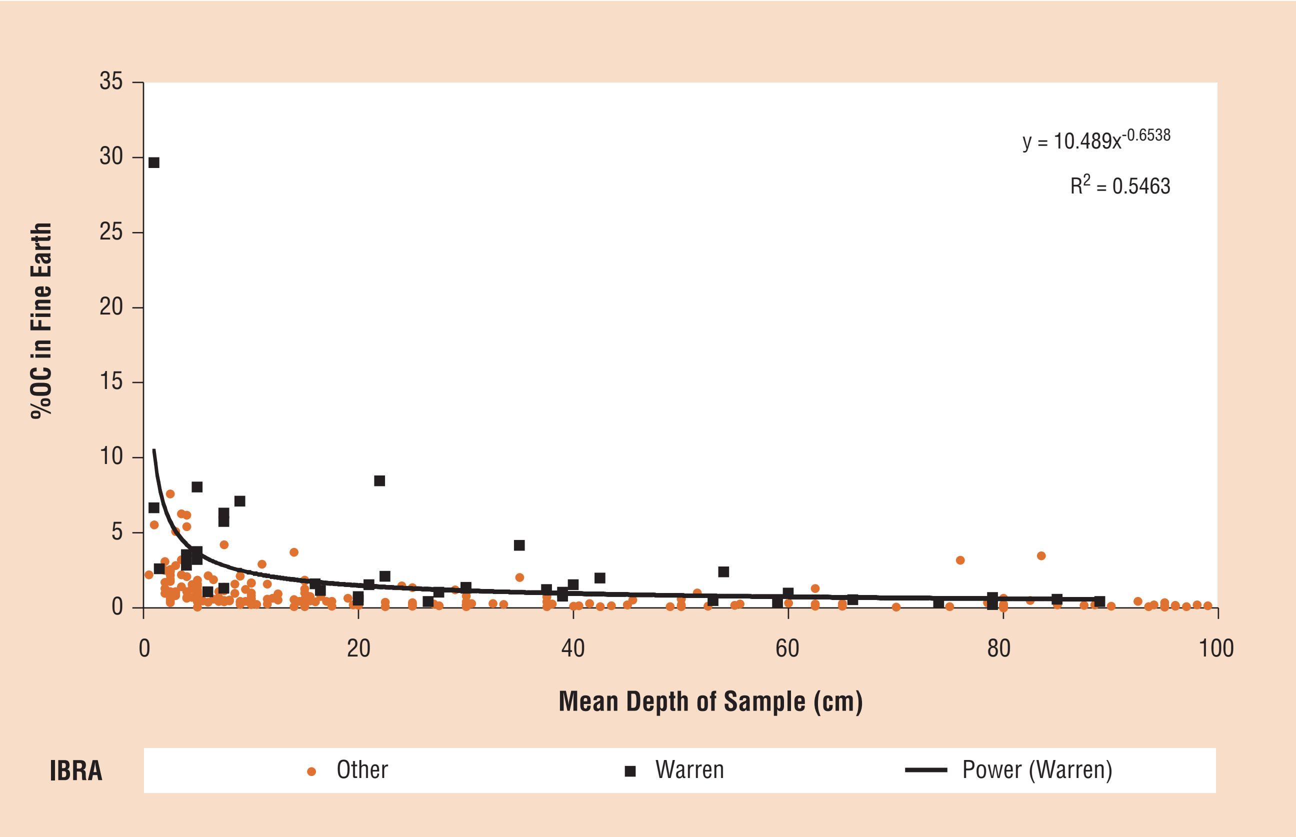


Graph 5. Organic carbon in fine earth, depth > 19.99 cm and < 30 cm, predicted from LOI*0.25 vs measured.



Graph 6. Organic carbon in fine earth, depth > 29.99 cm and < 50 cm, predicted from LOI*0.18 vs measured.

The values of a, b and R^2 for each IBRA subdivision and soil unit combination were recorded. The probability that the values were statistically significant was determined with n-2 degrees of freedom. Some IBRA subdivision and soil unit combinations had no data. Some of the curves were poor 'fits' because of the low probability of significance. However, most of those with more than 15 samples used in the curve generation had significant probability. This suggested that the low number of samples was the main reason for the poor fits.



Graph 7. Organic carbon % in the fine earth fraction plotted against average depth of sample (e.g. Pale deep sand, all other areas and Warren IBRA region).

Table 8. Organic carbon (%) in the fine earth fraction calculated using fitted curves.

IBRA	Subdiv	Soil Unit	no	const (a)	power (b)	R^2	sign	OC% Fine Earth		
								0-5cm	5-15cm	15-30cm
Avon Wheatbelt	eastern	coloured sands	35	1.0001	-0.3909	0.5144	**	0.70	0.41	0.30
Avon Wheatbelt	eastern	gravels	10	1.0348	-0.1519	0.0449	NS	0.90	0.73	0.64
Avon Wheatbelt	eastern	loams and clays	63	1.7307	-0.3597	0.3087	*	1.24	0.76	0.56
Avon Wheatbelt	eastern	non-saline wet								
Avon Wheatbelt	eastern	other								
Avon Wheatbelt	eastern	pale sands	7	0.8927	-0.216	0.0441	NS	0.73	0.54	0.46
Avon Wheatbelt	eastern	saline	6	0.4613	-0.15	0.0316	NS	0.40	0.33	0.29
Avon Wheatbelt	eastern	sandy duplexes	20	0.9366	-0.154	0.0347	NS	0.81	0.66	0.58
Avon Wheatbelt	non_ag	coloured sands	1							
Avon Wheatbelt	non_ag	gravels	1							
Avon Wheatbelt	northern	coloured sands	3	0.5223	-0.0932	0.6969	NS	0.48	0.42	0.39
Avon Wheatbelt	northern	gravels		1.0348	-0.1519			0.90	0.73	0.64
Avon Wheatbelt	northern	loams and clays	17	1.2882	-0.3979	0.8204	**	0.89	0.52	0.37
Avon Wheatbelt	northern	other								
Avon Wheatbelt	northern	pale sands		0.8927	-0.216			0.73	0.54	0.46
Avon Wheatbelt	northern	saline								
Avon Wheatbelt	northern	sandy duplexes	8	1.1972	-0.5063	0.6882	NS	0.75	0.37	0.25
Avon Wheatbelt	western	coloured sands	39	2.5961	-0.6313	0.5563	**	1.46	0.61	0.36
Avon Wheatbelt	western	gravels	6	2.0773	-0.569	0.3425	NS	1.23	0.56	0.35
Avon Wheatbelt	western	loams and clays	60	4.9983	-0.6155	0.554	**	2.84	1.21	0.74
Avon Wheatbelt	western	non-saline wet								
Avon Wheatbelt	western	other	7	4.0756	-0.9886	0.5899	NS	1.65	0.42	0.19
Avon Wheatbelt	western	pale sands	12	2.1867	-0.6195	0.4528	NS	1.24	0.53	0.32
Avon Wheatbelt	western	saline	4	6.2623	-0.8956	0.4952	NS	2.76	0.80	0.39
Avon Wheatbelt	western	sandy duplexes	10	2.0162	-0.8164	0.9132	**	0.95	0.31	0.16
Coolgardie	non_ag	coloured sands	2	0.939	-0.2382	1	NS	0.75	0.54	0.45
Coolgardie	non_ag	loams and clays	2	0.9178	-0.1011	1	NS	0.84	0.73	0.67
Coolgardie	western	coloured sands		1.0001	-0.3909			0.70	0.41	0.30
Coolgardie	western	gravels		1.0348	-0.1519			0.90	0.73	0.64
Coolgardie	western	loams and clays		1.7307	-0.3597			1.24	0.76	0.56
Coolgardie	western	other								
Coolgardie	western	pale sands		0.8927	-0.216			0.73	0.54	0.46
Coolgardie	western	saline		0.4613	-0.15			0.40	0.33	0.29
Coolgardie	western	sandy duplexes		0.9366	-0.154			0.81	0.66	0.58

IBRA	Subdiv	Soil Unit	no	const (a)	power (b)	R^2	sign	OC% Fine Earth		
								0-5cm	5-15cm	15-30cm
Esperance Plains	eastern	coloured sands	14	1.5516	-0.441	0.3868	NS	1.04	0.56	0.39
Esperance Plains	eastern	gravels								
Esperance Plains	eastern	loams and clays	5	3.9351	-0.6893	0.9411	*	2.09	0.80	0.46
Esperance Plains	eastern	non-saline wet								
Esperance Plains	eastern	other								
Esperance Plains	eastern	pale sands	11	1.9454	-0.529	0.789	**	1.20	0.58	0.37
Esperance Plains	eastern	saline								
Esperance Plains	eastern	sandy duplexes		2	-0.7			1.05	0.40	0.23
Esperance Plains	western	coloured sands	2	1.7	-0.7699	1	NS	0.84	0.29	0.15
Esperance Plains	western	gravels								
Esperance Plains	western	loams and clays	4	5.3587	-0.5598	0.9411	NS	3.21	1.48	0.94
Esperance Plains	western	non-saline wet								
Esperance Plains	western	other								
Esperance Plains	western	pale sands	7	4.095	-0.8758	0.8685	*	1.84	0.55	0.27
Esperance Plains	western	saline								
Esperance Plains	western	sandy duplexes	7	1.6813	-0.4274	0.817	*	1.14	0.63	0.44
Geraldton Splains	northern	coloured sands	34	1.0777	-0.5817	0.688	**	0.63	0.28	0.18
Geraldton Splains	northern	gravels	2	1.6197	-0.2996	1	NS	1.23	0.81	0.64
Geraldton Splains	northern	loams and clays	8	2.1323	-0.6583	0.9285	**	1.17	0.47	0.27
Geraldton Splains	northern	non-saline wet	2	3.6785	-1.0465	1	NS	1.41	0.33	0.14
Geraldton Splains	northern	other								
Geraldton Splains	northern	pale sands	2	1.3	-0.2861	1	NS	1.00	0.67	0.53
Geraldton Splains	northern	saline								
Geraldton Splains	northern	sandy duplexes	2	0.8454	-0.314	1	NS	0.63	0.41	0.32
Geraldton Splains	southern	coloured sands	39	1.1238	-0.4914	0.5852	**	0.72	0.36	0.24
Geraldton Splains	southern	gravels		1.2525	-0.1341			1.11	0.92	0.82
Geraldton Splains	southern	loams and clays	6	3.5417	-0.6305	0.9435	**	1.99	0.83	0.50
Geraldton Splains	southern	non-saline wet								
Geraldton Splains	southern	other								
Geraldton Splains	southern	pale sands	42	2.0187	-0.5324	0.5096	**	1.24	0.59	0.38
Geraldton Splains	southern	saline								
Geraldton Splains	southern	sandy duplexes	5	3.1161	-0.7021	0.7365	NS	1.64	0.62	0.35
Jarrah Forest	eastern	coloured sands	5	3.3329	-0.554	0.8525	NS	2.01	0.93	0.59
Jarrah Forest	eastern	gravels	19	11.425	-0.7732	0.7128	**	5.63	1.93	1.03
Jarrah Forest	eastern	loams and clays	37	6.9997	-0.7907	0.7336	**	3.39	1.13	0.60
Jarrah Forest	eastern	non-saline wet	3	42.171	-1.0819	0.9975	*	15.65	3.49	1.45
Jarrah Forest	eastern	other								
Jarrah Forest	eastern	pale sands	16	4.9152	-0.8656	0.8828	**	2.22	0.67	0.33

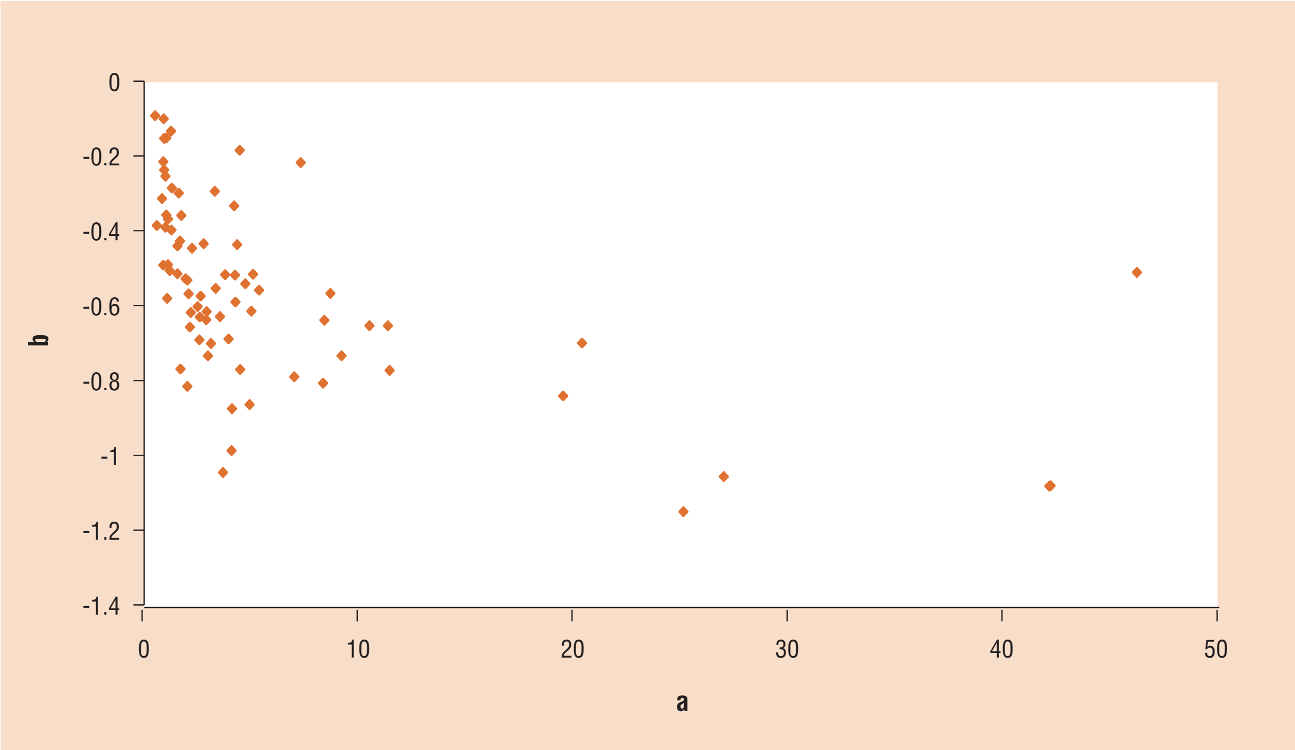
Table 8. Organic carbon (%) in the fine earth fraction calculated using fitted curves. continued

IBRA	Subdiv	Soil Unit	no	const (a)	power (b)	R^2	sign	OC% Fine Earth		
								0-5cm	5-15cm	15-30cm
Jarrah Forest	eastern	saline								
Jarrah Forest	eastern	sandy duplexes	6	2.572	-0.6915	0.5991	NS	1.36	0.52	0.30
Jarrah Forest	southern	coloured sands	3	4.4529	-0.1847	0.153	NS	3.76	2.91	2.51
Jarrah Forest	southern	gravels	2	4.48	-0.7712	1	NS	2.21	0.76	0.41
Jarrah Forest	southern	loams and clays	20	5.0803	-0.5169	0.6041	**	3.16	1.55	1.02
Jarrah Forest	southern	non-saline wet		50	-1			20.00	5.00	2.22
Jarrah Forest	southern	other	17	7.2818	-0.2181	0.0364	NS	5.96	4.41	3.69
Jarrah Forest	southern	pale sands	16	3.2915	-0.2949	0.1144	NS	2.51	1.67	1.31
Jarrah Forest	southern	saline								
Jarrah Forest	southern	sandy duplexes	24	2.7823	-0.435	0.3811	NS	1.87	1.02	0.72
Jarrah Forest	western	coloured sands	22	4.2351	-0.5194	0.5657	**	2.63	1.28	0.84
Jarrah Forest	western	gravels	57	8.6761	-0.5673	0.6183	**	5.16	2.35	1.48
Jarrah Forest	western	loams and clays	17	9.1962	-0.7351	0.7815	**	4.69	1.69	0.93
Jarrah Forest	western	non-saline wet		50	-1			20.00	5.00	2.22
Jarrah Forest	western	other								
Jarrah Forest	western	pale sands	9	4.3391	-0.4379	0.402	NS	2.90	1.58	1.11
Jarrah Forest	western	saline								
Jarrah Forest	western	sandy duplexes	2	3.7738	-0.5178	1	NS	2.35	1.15	0.75
Mallee	eastern	gravels								
Mallee	eastern	loams and clays	6	2.9053	-0.6388	0.9238	**	1.62	0.67	0.40
Mallee	eastern	other								
Mallee	eastern	pale sands		1.5	-0.45			0.99	0.53	0.37
Mallee	eastern	saline								
Mallee	eastern	sandy duplexes	9	2.6286	-0.5751	0.7783	*	1.55	0.70	0.44
Mallee	non_ag	gravels	5	26.973	-1.0576	0.9826	**	10.23	2.36	1.00
Mallee	non_ag	loams and clays	5	25.082	-1.1517	0.9752	**	8.73	1.77	0.70
Mallee	western	coloured sands	17	1.0373	-0.3582	0.4336	NS	0.75	0.45	0.34
Mallee	western	gravels	2	1.1221	-0.3692	1	NS	0.80	0.48	0.36
Mallee	western	loams and clays	53	2.2362	-0.4473	0.5304	*	1.48	0.80	0.56
Mallee	western	non-saline wet								
Mallee	western	other								
Mallee	western	pale sands	11	0.6054	-0.3858	0.4526	NS	0.43	0.25	0.18
Mallee	western	saline	5	0.6202	-0.2822	0.4875	NS	0.48	0.32	0.26
Mallee	western	sandy duplexes	13	1.5602	-0.5152	0.5891	*	0.97	0.48	0.31
Swan Coastal Plain	northern	coloured sands		1.1238	-0.4914			0.72	0.36	0.24
Swan Coastal Plain	northern	loams and clays		3.5417	-0.6305			1.99	0.83	0.50
Swan Coastal Plain	northern	non-saline wet								

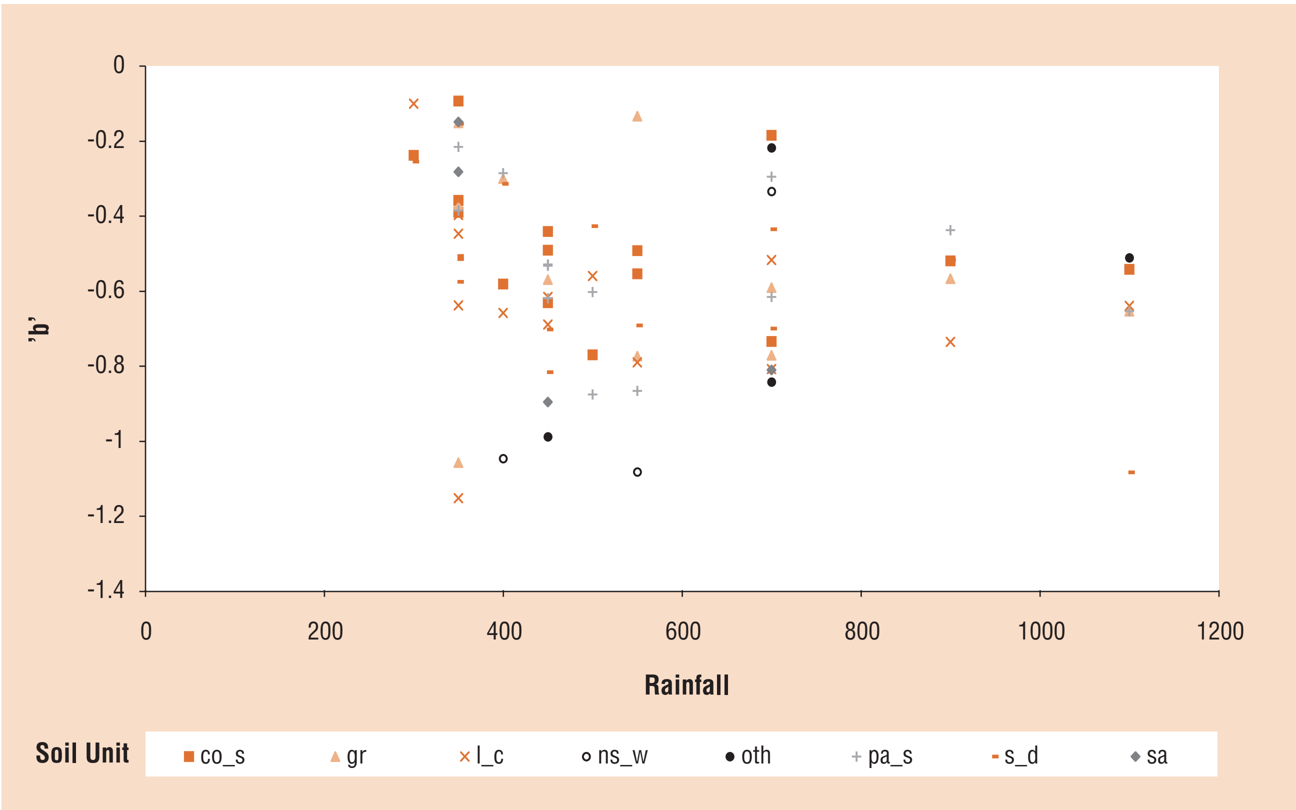
IBRA	Subdiv	Soil Unit	no	const (a)	power (b)	R^2	sign	OC% Fine Earth		
								0-5cm	5-15cm	15-30cm
Swan Coastal Plain	northern	other								
Swan Coastal Plain	northern	pale sands	29	2.4876	-0.6031	0.4268	*	1.43	0.62	0.38
Swan Coastal Plain	northern	saline								
Swan Coastal Plain	plateau	coloured sands	24	0.9082	-0.4922	0.6038	**	0.58	0.29	0.20
Swan Coastal Plain	plateau	gravels	2	1.2525	-0.1341	1	NS	1.11	0.92	0.82
Swan Coastal Plain	plateau	loams and clays		3.5417	-0.6305			1.99	0.83	0.50
Swan Coastal Plain	plateau	non-saline wet								
Swan Coastal Plain	plateau	other								
Swan Coastal Plain	plateau	pale sands		2.0187	-0.5324			1.24	0.59	0.38
Swan Coastal Plain	plateau	saline								
Swan Coastal Plain	southern	coloured sands	69	2.9774	-0.735	0.6819	**	1.52	0.55	0.30
Swan Coastal Plain	southern	gravels	4	4.2561	-0.5905	0.7906	NS	2.48	1.09	0.68
Swan Coastal Plain	southern	loams and clays	22	8.3208	-0.8082	0.6809	**	3.97	1.29	0.67
Swan Coastal Plain	southern	non-saline wet	8	4.1966	-0.334	0.0477	NS	3.09	1.94	1.48
Swan Coastal Plain	southern	other	2	19.49	-0.8418	0.7602	NS	9.01	2.81	1.42
Swan Coastal Plain	southern	pale sands	50	2.92	-0.6161	0.3556	*	1.66	0.71	0.43
Swan Coastal Plain	southern	saline	2	2.72	-0.8105	1	NS	1.29	0.42	0.22
Swan Coastal Plain	southern	sandy duplexes	1	20.367	-0.7003	0.7625	NS	10.72	4.06	2.30
Warren	all	coloured sands	11	4.7094	-0.5423	0.9027	**	2.87	1.35	0.87
Warren	all	gravels	45	11.352	-0.6538	0.6792	**	6.24	2.52	1.48
Warren	all	loams and clays	43	8.3932	-0.6396	0.7975	**	4.67	1.92	1.15
Warren	all	non-saline wet	4	384.26	-1.4152	0.9398	NS	105.07	14.77	4.69
Warren	all	other	6	46.177	-0.5116	0.8778	*	28.90	14.22	9.39
Warren	all	pale sands	40	10.489	-0.6538	0.5463	**	5.76	2.33	1.37
Warren	all	saline								
Warren	all	sandy duplexes	5	42.112	-1.0827	0.9045	*	15.62	3.48	1.45

Every row of data represents combinations that are represented in each IBRA subdivision (see Table 4);
'no', is the number of samples used to generate the curve. Where this is blank and there is data, interpolations have been made from similar climates;
'a' and 'b', are from the individual fitted values for the function $OC\% = a*depth^b$;
'sign', probability of fitted curve being significant, ** < 0.01, * < 0.05 and NS > 0.01; and
Calculated depth intervals are 0-5 cm, 5-15 cm and 15-30 cm.

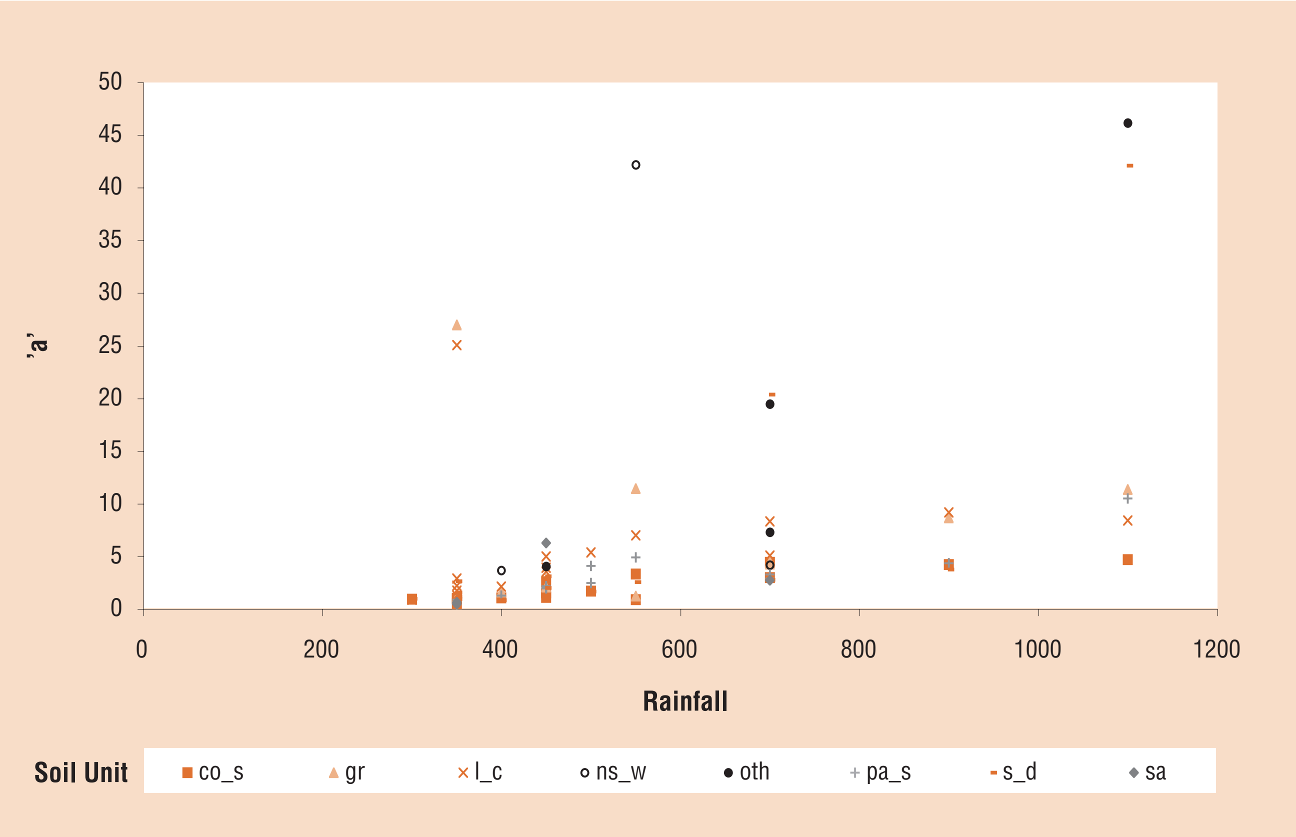
Importantly, an analysis of the values of 'a' and 'b' suggested that they follow the same trend irrespective of the number of samples in each data set. The values for 'a' and 'b' are moderately related to each other (MS Access form "constants") (Graph 8). More detailed analysis shows that both appear related to rainfall (of the IBRA subdivision) and soil unit (Graph 9 and 10). This suggests that the fitted curves are roughly of the same family for each soil unit. The data also shows the potential for surfaces to be fitted between these factors. This would potentially be more reliable than generating many individual curves as was done here.



Graph 8. Relationship between constants ‘a’ and ‘b’ for the fitted curves. Organic carbon in fine earth % = a*depth^{b}. Depth in cm. Point at ‘a’ = 384 and ‘b’ = -1.4 omitted.



Graph 9. Relationship between constant ‘b’ and rainfall for soil units.



Graph 10. Relationship between 'a' and rainfall for soil units.

More importantly for this report, the analysis suggests that while many of the fitted curves might not be statistically significant, the values could still be used with some confidence to predict organic carbon values. These analyses also provide support to attribute IBRA subdivision and soil unit combinations with no data by matching them to soil units from areas with similar rainfall. However, it is considered that this is not possible for some combinations, especially the more variable soil units (e.g. non-saline wet).

The values derived from these curves are used to predict the organic carbon concentrations for three intervals which reflect the major portions of the soil carbon distribution in the upper 30 cm (0-5, 5-15, 15-30 cm) (Table 8).

These values were used together with the percentage of coarse fragments in the whole soil (Table 6) to calculate the organic carbon values weight % of the whole soil (Table 9). Also shown are the values for bulk density estimated for each soil unit at each of the three depths.

Table 9. Calculated whole soil organic carbon content (%) and bulk densities (g/cm^3) for depth.

IBRA	Subdiv	Soil Unit	OC 0-5	BD 0-5	OC 5-15	BD 5-15	OC 15-30	BD 15-30
Avon Wheatbelt	eastern	coloured sands	0.69	1.4	0.40	1.5	0.28	1.5
Avon Wheatbelt	eastern	gravels	0.81	1.5	0.51	1.6	0.39	1.6
Avon Wheatbelt	eastern	loams and clays	1.22	1.15	0.74	1.3	0.55	1.4
Avon Wheatbelt	eastern	non-saline wet		1.2		1.4		1.4
Avon Wheatbelt	eastern	other		1.3		1.3		1.3
Avon Wheatbelt	eastern	pale sands	0.73	1.4	0.53	1.5	0.41	1.5
Avon Wheatbelt	eastern	saline	0.40	1.3	0.33	1.3	0.29	1.4
Avon Wheatbelt	eastern	sandy duplexes	0.81	1.3	0.64	1.3	0.55	1.6
Avon Wheatbelt	non_ag	coloured sands		1.4		1.5		1.5
Avon Wheatbelt	non_ag	gravels		1.5		1.6		1.6
Avon Wheatbelt	northern	coloured sands	0.47	1.4	0.41	1.5	0.37	1.5
Avon Wheatbelt	northern	gravels	0.81	1.5	0.51	1.6	0.39	1.6
Avon Wheatbelt	northern	loams and clays	0.88	1.2	0.51	1.3	0.36	1.4
Avon Wheatbelt	northern	other		1.3		1.3		1.3
Avon Wheatbelt	northern	pale sands	0.73	1.4	0.53	1.5	0.41	1.5
Avon Wheatbelt	northern	saline		1.3		1.3		1.4
Avon Wheatbelt	northern	sandy duplexes	0.75	1.3	0.37	1.3	0.24	1.6
Avon Wheatbelt	western	coloured sands	1.44	1.35	0.59	1.5	0.35	1.5
Avon Wheatbelt	western	gravels	1.11	1.45	0.39	1.6	0.21	1.6
Avon Wheatbelt	western	loams and clays	2.79	1.1	1.19	1.25	0.71	1.4
Avon Wheatbelt	western	non-saline wet		1.2		1.4		1.4
Avon Wheatbelt	western	other	0.66	1.3	0.13	1.3	0.06	1.3
Avon Wheatbelt	western	pale sands	1.23	1.35	0.51	1.5	0.29	1.5
Avon Wheatbelt	western	saline	2.76	1.2	0.80	1.3	0.39	1.4
Avon Wheatbelt	western	sandy duplexes	0.95	1.3	0.30	1.3	0.15	1.6

IBRA	Subdiv	Soil Unit	OC 0-5	BD 0-5	OC 5-15	BD 5-15	OC 15-30	BD 15-30
Coolgardie	non_ag	coloured sands	0.75	1.4	0.53	1.5	0.42	1.5
Coolgardie	non_ag	loams and clays	0.82	1.2	0.71	1.3	0.65	1.4
Coolgardie	western	coloured sands	0.69	1.4	0.40	1.5	0.28	1.5
Coolgardie	western	gravels	0.81	1.5	0.51	1.6	0.39	1.6
Coolgardie	western	loams and clays	1.22	1.15	0.74	1.3	0.55	1.4
Coolgardie	western	other		1.3		1.3		1.3
Coolgardie	western	pale sands	0.73	1.4	0.53	1.5	0.41	1.5
Coolgardie	western	saline	0.40	1.3	0.33	1.3	0.29	1.4
Coolgardie	western	sandy duplexes	0.81	1.3	0.64	1.3	0.55	1.6
Esperance Plains	eastern	coloured sands	1.03	1.35	0.55	1.5	0.37	1.5
Esperance Plains	eastern	gravels		1.5		1.6		1.6
Esperance Plains	eastern	loams and clays	2.05	1.1	0.79	1.3	0.45	1.4
Esperance Plains	eastern	non-saline wet		1.2		1.4		1.4
Esperance Plains	eastern	other		1.3		1.3		1.3
Esperance Plains	eastern	pale sands	1.19	1.35	0.56	1.5	0.34	1.5
Esperance Plains	eastern	saline		1.3		1.3		1.4
Esperance Plains	eastern	sandy duplexes	1.05	1.25	0.39	1.3	0.21	1.6
Esperance Plains	western	coloured sands	0.83	1.4	0.28	1.5	0.15	1.5
Esperance Plains	western	gravels		1.5		1.6		1.6
Esperance Plains	western	loams and clays	3.14	1.05	1.45	1.25	0.91	1.4
Esperance Plains	western	non-saline wet		1.2		1.4		1.4
Esperance Plains	western	other		1.3		1.3		1.3
Esperance Plains	western	pale sands	1.82	1.35	0.53	1.5	0.24	1.5
Esperance Plains	western	saline		1.3		1.3		1.4
Esperance Plains	western	sandy duplexes	1.14	1.25	0.62	1.3	0.42	1.6
Geraldton Sandplains	northern	coloured sands	0.63	1.4	0.28	1.5	0.17	1.5
Geraldton Sandplains	northern	gravels	1.11	1.45	0.57	1.6	0.38	1.6
Geraldton Sandplains	northern	loams and clays	1.14	1.15	0.46	1.3	0.27	1.4
Geraldton Sandplains	northern	non-saline wet	1.41	1.15	0.33	1.4	0.14	1.4
Geraldton Sandplains	northern	other		1.3		1.3		1.3
Geraldton Sandplains	northern	pale sands	0.99	1.4	0.65	1.5	0.48	1.5
Geraldton Sandplains	northern	saline		1.3		1.3		1.4
Geraldton Sandplains	northern	sandy duplexes	0.63	1.3	0.40	1.3	0.30	1.6
Geraldton Sandplains	southern	coloured sands	0.71	1.4	0.36	1.5	0.23	1.5
Geraldton Sandplains	southern	gravels	1.00	1.5	0.64	1.6	0.49	1.6
Geraldton Sandplains	southern	loams and clays	1.95	1.15	0.81	1.3	0.48	1.4
Geraldton Sandplains	southern	non-saline wet		1.2		1.4		1.4
Geraldton Sandplains	southern	other		1.3		1.3		1.3
Geraldton Sandplains	southern	pale sands	1.23	1.35	0.57	1.5	0.35	1.5

Table 9. **Calculated whole soil organic carbon content (%) and bulk densities (g/cm^3) for depth.** continued

IBRA	Subdiv	Soil Unit	OC 0-5	BD 0-5	OC 5-15	BD 5-15	OC 15-30	BD 15-30
Geraldton Sandplains	southern	saline		1.3		1.3		1.4
Geraldton Sandplains	southern	sandy duplexes	1.64	1.25	0.61	1.3	0.33	1.6
Jarrah Forest	eastern	coloured sands	1.99	1.35	0.91	1.5	0.56	1.5
Jarrah Forest	eastern	gravels	5.06	1.3	1.35	1.55	0.62	1.6
Jarrah Forest	eastern	loams and clays	3.32	1.05	1.11	1.25	0.58	1.4
Jarrah Forest	eastern	non-saline wet	15.65	1	3.49	1.25	1.45	1.35
Jarrah Forest	eastern	other		1.3		1.3		1.3
Jarrah Forest	eastern	pale sands	2.20	1.3	0.65	1.5	0.30	1.5
Jarrah Forest	eastern	saline		1.3		1.3		1.4
Jarrah Forest	eastern	sandy duplexes	1.36	1.25	0.51	1.3	0.28	1.6
Jarrah Forest	southern	coloured sands	3.72	1.25	2.85	1.4	2.38	1.4
Jarrah Forest	southern	gravels	1.99	1.45	0.53	1.6	0.24	1.6
Jarrah Forest	southern	loams and clays	3.10	1.05	1.51	1.25	0.99	1.4
Jarrah Forest	southern	non-saline wet	20.00	1	5.00	1.2	2.22	1.3
Jarrah Forest	southern	other	2.39	1.2	1.32	1.25	1.11	1.25
Jarrah Forest	southern	pale sands	2.49	1.3	1.62	1.45	1.18	1.45
Jarrah Forest	southern	saline		1.3		1.3		1.4
Jarrah Forest	southern	sandy duplexes	1.87	1.25	1.00	1.25	0.68	1.6
Jarrah Forest	western	coloured sands	2.61	1.3	1.26	1.45	0.80	1.5
Jarrah Forest	western	gravels	4.64	1.3	1.64	1.55	0.89	1.6
Jarrah Forest	western	loams and clays	4.60	1	1.66	1.25	0.90	1.4
Jarrah Forest	western	non-saline wet	20.00	1	5.00	1.2	2.22	1.3
Jarrah Forest	western	other		1.3		1.3		1.3
Jarrah Forest	western	pale sands	2.88	1.3	1.54	1.45	1.00	1.5
Jarrah Forest	western	saline		1.3		1.3		1.4
Jarrah Forest	western	sandy duplexes	2.35	1.2	1.12	1.25	0.72	1.6
Mallee	eastern	gravels		1.5		1.6		1.6
Mallee	eastern	loams and clays	1.59	1.15	0.65	1.3	0.39	1.4
Mallee	eastern	other		1.3		1.3		1.3
Mallee	eastern	pale sands	0.98	1.4	0.52	1.5	0.33	1.5
Mallee	eastern	saline		1.3		1.3		1.4
Mallee	eastern	sandy duplexes	1.55	1.25	0.69	1.3	0.42	1.6
Mallee	non_ag	gravels	9.21	1.3	1.65	1.55	0.60	1.6
Mallee	non_ag	loams and clays	8.56	1	1.73	1.25	0.67	1.4
Mallee	western	coloured sands	0.74	1.4	0.45	1.5	0.32	1.5
Mallee	western	gravels	0.72	1.5	0.34	1.6	0.21	1.6
Mallee	western	loams and clays	1.45	1.15	0.78	1.3	0.54	1.4

IBRA	Subdiv	Soil Unit	OC 0-5	BD 0-5	OC 5-15	BD 5-15	OC 15-30	BD 15-30
Mallee	western	non-saline wet		1.2		1.4		1.4
Mallee	western	other		1.3		1.3		1.3
Mallee	western	pale sands	0.42	1.4	0.24	1.5	0.16	1.5
Mallee	western	saline	0.48	1.3	0.32	1.3	0.26	1.4
Mallee	western	sandy duplexes	0.97	1.3	0.47	1.3	0.30	1.6
Swan Coastal Plain	northern	coloured sands	0.71	1.4	0.36	1.5	0.23	1.5
Swan Coastal Plain	northern	loams and clays	1.95	1.15	0.81	1.3	0.48	1.4
Swan Coastal Plain	northern	non-saline wet		1.2		1.4		1.4
Swan Coastal Plain	northern	other		1.3		1.3		1.3
Swan Coastal Plain	northern	pale sands	1.42	1.35	0.60	1.5	0.34	1.5
Swan Coastal Plain	northern	saline		1.3		1.3		1.4
Swan Coastal Plain	plateau	coloured sands	0.57	1.4	0.29	1.5	0.19	1.5
Swan Coastal Plain	plateau	gravels	1.00	1.5	0.64	1.6	0.49	1.6
Swan Coastal Plain	plateau	loams and clays	1.95	1.15	0.81	1.3	0.48	1.4
Swan Coastal Plain	plateau	non-saline wet		1.2		1.4		1.4
Swan Coastal Plain	plateau	other		1.3		1.3		1.3
Swan Coastal Plain	plateau	pale sands	1.23	1.35	0.57	1.5	0.35	1.5
Swan Coastal Plain	plateau	saline		1.3		1.3		1.4
Swan Coastal Plain	southern	coloured sands	1.50	1.35	0.54	1.5	0.29	1.5
Swan Coastal Plain	southern	gravels	2.23	1.4	0.76	1.6	0.41	1.6
Swan Coastal Plain	southern	loams and clays	3.89	1.05	1.27	1.25	0.65	1.4
Swan Coastal Plain	southern	non-saline wet	3.09	1.05	1.94	1.35	1.48	1.35
Swan Coastal Plain	southern	other	3.60	1.15	0.84	1.3	0.43	1.3
Swan Coastal Plain	southern	pale sands	1.64	1.35	0.69	1.5	0.39	1.5
Swan Coastal Plain	southern	saline	1.29	1.25	0.42	1.3	0.22	1.4
Swan Coastal Plain	southern	sandy duplexes	10.72	1.1	3.98	1.15	2.19	1.5
Warren	all	coloured sands	2.84	1.3	1.32	1.45	0.83	1.5
Warren	all	gravels	5.61	1.3	1.76	1.55	0.89	1.6
Warren	all	loams and clays	4.58	1	1.89	1.25	1.11	1.35
Warren	all	non-saline wet	105.07	1	14.77	1.2	4.69	1.2
Warren	all	other	11.56	1.1	4.27	1.1	2.82	1.2
Warren	all	pale sands	5.70	1.2	2.26	1.4	1.23	1.45
Warren	all	saline		1.3		1.3		1.4
Warren	all	sandy duplexes	15.62	1.1	3.41	1.15	1.37	1.55

Depth intervals are 0-5 cm, 5-15 cm and 15-30 cm.

2.4.5 Estimated Values of Fine Organic Carbon per Unit Area

The fine organic carbon (weight % of whole soil) was used with the bulk density to calculate a value per unit area in each depth interval and these were summed over the top 30 cm soil layer (Table 10). The formula used was:

OC(t/ha)=100*BD*D*OC%

Where:

BD is bulk density in g/cm^3;
D is depth of interval in metres; and
OC is % organic carbon in whole soil.

Table 10. Calculation of organic carbon (t/ha) per layer and total over 30 cm.

IBRA_name	CLIM_code	SO_name	OC 0-5	OC 5-15	OC 15-30	OC 0-30
Avon Wheatbelt	eastern	coloured sands	5	6	6	17
Avon Wheatbelt	eastern	gravels	6	8	9	23
Avon Wheatbelt	eastern	loams and clays	7	10	12	29
Avon Wheatbelt	eastern	non-saline wet				
Avon Wheatbelt	eastern	other				
Avon Wheatbelt	eastern	pale sands	5	8	9	22
Avon Wheatbelt	eastern	saline	3	4	6	13
Avon Wheatbelt	eastern	sandy duplexes	5	8	13	26
Avon Wheatbelt	non_ag	coloured sands				
Avon Wheatbelt	non_ag	gravels				
Avon Wheatbelt	northern	coloured sands	3	6	8	17
Avon Wheatbelt	northern	gravels	6	8	9	23
Avon Wheatbelt	northern	loams and clays	5	7	8	20
Avon Wheatbelt	northern	other				
Avon Wheatbelt	northern	pale sands	5	8	9	22
Avon Wheatbelt	northern	saline				
Avon Wheatbelt	northern	sandy duplexes	5	5	6	16
Avon Wheatbelt	western	coloured sands	10	9	8	27
Avon Wheatbelt	western	gravels	8	6	5	19
Avon Wheatbelt	western	loams and clays	15	15	15	45
Avon Wheatbelt	western	non-saline wet				
Avon Wheatbelt	western	other	4	2	1	7
Avon Wheatbelt	western	pale sands	8	8	6	22
Avon Wheatbelt	western	saline	17	10	8	35
Avon Wheatbelt	western	sandy duplexes	6	4	4	14

IBRA_name	CLIM_code	SO_name	OC 0-5	OC 5-15	OC 15-30	OC 0-30
Coolgardie	non_ag	coloured sands	5	8	10	23
Coolgardie	non_ag	loams and clays	5	9	14	28
Coolgardie	western	coloured sands	5	6	6	17
Coolgardie	western	gravels	6	8	9	23
Coolgardie	western	loams and clays	7	10	12	29
Coolgardie	western	other				
Coolgardie	western	pale sands	5	8	9	22
Coolgardie	western	saline	3	4	6	13
Coolgardie	western	sandy duplexes	5	8	13	26
Esperance Plains	eastern	coloured sands	7	8	8	23
Esperance Plains	eastern	gravels				
Esperance Plains	eastern	loams and clays	11	10	9	30
Esperance Plains	eastern	non-saline wet				
Esperance Plains	eastern	other				
Esperance Plains	eastern	pale sands	8	8	8	24
Esperance Plains	eastern	saline				
Esperance Plains	eastern	sandy duplexes	7	5	5	17
Esperance Plains	western	coloured sands	6	4	3	13
Esperance Plains	western	gravels				
Esperance Plains	western	loams and clays	17	18	19	54
Esperance Plains	western	non-saline wet				
Esperance Plains	western	other				
Esperance Plains	western	pale sands	12	8	5	25
Esperance Plains	western	saline				
Esperance Plains	western	sandy duplexes	7	8	10	25
Geraldton Sandplains	northern	coloured sands	4	4	4	12
Geraldton Sandplains	northern	gravels	8	9	9	26
Geraldton Sandplains	northern	loams and clays	7	6	6	19
Geraldton Sandplains	northern	non-saline wet	8	5	3	16
Geraldton Sandplains	northern	other				
Geraldton Sandplains	northern	pale sands	7	10	11	28
Geraldton Sandplains	northern	saline				
Geraldton Sandplains	northern	sandy duplexes	4	5	7	16
Geraldton Sandplains	southern	coloured sands	5	5	5	15
Geraldton Sandplains	southern	gravels	7	10	12	29
Geraldton Sandplains	southern	loams and clays	11	11	10	32
Geraldton Sandplains	southern	non-saline wet				
Geraldton Sandplains	southern	other				
Geraldton Sandplains	southern	pale sands	8	9	8	25

Table 10. Calculation of organic carbon (t/ha) per layer and total over 30 cm. continued

IBRA_name	CLIM_code	SO_name	OC 0-5	OC 5-15	OC 15-30	OC 0-30
Geraldton Sandplains	southern	saline				
Geraldton Sandplains	southern	sandy duplexes	10	8	8	26
Jarrah Forest	eastern	coloured sands	13	14	13	40
Jarrah Forest	eastern	gravels	33	21	15	69
Jarrah Forest	eastern	loams and clays	17	14	12	43
Jarrah Forest	eastern	non-saline wet	78	44	29	151
Jarrah Forest	eastern	other				
Jarrah Forest	eastern	pale sands	14	10	7	31
Jarrah Forest	eastern	saline				
Jarrah Forest	eastern	sandy duplexes	9	7	7	23
Jarrah Forest	southern	coloured sands	23	40	50	113
Jarrah Forest	southern	gravels	14	8	6	28
Jarrah Forest	southern	loams and clays	16	19	21	56
Jarrah Forest	southern	non-saline wet	100	60	43	203
Jarrah Forest	southern	other	14	17	21	52
Jarrah Forest	southern	pale sands	16	23	26	65
Jarrah Forest	southern	saline				
Jarrah Forest	southern	sandy duplexes	12	13	16	41
Jarrah Forest	western	coloured sands	17	18	18	53
Jarrah Forest	western	gravels	30	25	21	76
Jarrah Forest	western	loams and clays	23	21	19	63
Jarrah Forest	western	non-saline wet	100	60	43	203
Jarrah Forest	western	other				
Jarrah Forest	western	pale sands	19	22	22	63
Jarrah Forest	western	saline				
Jarrah Forest	western	sandy duplexes	14	14	17	45
Mallee	eastern	gravels				
Mallee	eastern	loams and clays	9	9	8	26
Mallee	eastern	other				
Mallee	eastern	pale sands	7	8	7	22
Mallee	eastern	saline				
Mallee	eastern	sandy duplexes	10	9	10	29
Mallee	non_ag	gravels	60	26	14	100
Mallee	non_ag	loams and clays	43	22	14	79
Mallee	western	coloured sands	5	7	7	19
Mallee	western	gravels	5	5	5	15
Mallee	western	loams and clays	8	10	11	29

IBRA_name	CLIM_code	SO_name	OC 0-5	OC 5-15	OC 15-30	OC 0-30
Mallee	western	non-saline wet				
Mallee	western	other				
Mallee	western	pale sands	3	4	4	11
Mallee	western	saline	3	4	5	12
Mallee	western	sandy duplexes	6	6	7	19
Swan Coastal Plain	northern	coloured sands	5	5	5	15
Swan Coastal Plain	northern	loams and clays	11	11	10	32
Swan Coastal Plain	northern	non-saline wet				
Swan Coastal Plain	northern	other				
Swan Coastal Plain	northern	pale sands	10	9	8	27
Swan Coastal Plain	northern	saline				
Swan Coastal Plain	plateau	coloured sands	4	4	4	12
Swan Coastal Plain	plateau	gravels	7	10	12	29
Swan Coastal Plain	plateau	loams and clays	11	11	10	32
Swan Coastal Plain	plateau	non-saline wet				
Swan Coastal Plain	plateau	other				
Swan Coastal Plain	plateau	pale sands	8	9	8	25
Swan Coastal Plain	plateau	saline				
Swan Coastal Plain	southern	coloured sands	10	8	6	24
Swan Coastal Plain	southern	gravels	16	12	10	38
Swan Coastal Plain	southern	loams and clays	20	16	14	50
Swan Coastal Plain	southern	non-saline wet	16	26	30	72
Swan Coastal Plain	southern	other	21	11	8	40
Swan Coastal Plain	southern	pale sands	11	10	9	30
Swan Coastal Plain	southern	saline	8	5	5	18
Swan Coastal Plain	southern	sandy duplexes	59	46	49	154
Warren	all	coloured sands	18	19	19	56
Warren	all	gravels	36	27	21	84
Warren	all	loams and clays	23	24	23	70
Warren	all	non-saline wet	525	177	84	786
Warren	all	other	64	47	51	162
Warren	all	pale sands	34	32	27	93
Warren	all	saline				
Warren	all	sandy duplexes	86	39	32	157

Depth intervals are 0-5 cm, 5-15 cm, 15-30 cm and 0-30 cm.

2.4.6 Estimated Clay Content for Each Depth Interval

The clay content was estimated from plotting the % clay in the fine earth fraction against the mid point of the sample interval. The samples used were those in apparently undisturbed sites from those with measured organic carbon and mid-point of the sample interval < 100 cm, and those with predicted organic carbon from LOI and mid-point of the sample interval < 20 cm.

This was done separately for each IBRA subdivision and soil unit combination, using the MS Access form "ibra_soil_clay_depth" which was based on "Query6_clay". Curve fitting was not considered appropriate for there was no conceptual model by which the clay content could be related to depth. It was obvious how heterogeneous some soil units were from these data. Nevertheless, for the depth intervals 0-5, 5-15 and 15-30 cm the values for clay were estimated from the scatter of the points. These interpretations are shown in Table 11. A weighted average over the top 30 cm is calculated. These data shows significant variation in the clay content of the different:

- soil units;
- depth intervals; and
- IBRA subdivisions.

There are also significant interactions between these.

It must be noted that many of these interpretations are based on very limited number of samples. They generally show the trends and they relate to, but are not necessary the same as, the data set from which the organic carbon was estimated.

Table 11. Estimated clay content from samples per depth layer and mean over 30 cm.

IBRA	Subdiv	Soil Unit	% Clay 0-5	% Clay 5-15	% Clay 15-30	% Clay 0-30
Avon Wheatbelt	eastern	coloured sands	7	11	15	12
Avon Wheatbelt	eastern	gravels	5	7	8	7
Avon Wheatbelt	eastern	loams and clays	15	20	28	23
Avon Wheatbelt	eastern	non-saline wet				
Avon Wheatbelt	eastern	other				
Avon Wheatbelt	eastern	pale sands	4	4	4	4
Avon Wheatbelt	eastern	saline	5	15	30	21
Avon Wheatbelt	eastern	sandy duplexes	10	15	35	24
Avon Wheatbelt	non_ag	coloured sands				
Avon Wheatbelt	non_ag	gravels	6	8	9	8
Avon Wheatbelt	northern	coloured sands	6	11	14	12
Avon Wheatbelt	northern	gravels	5	7	9	8
Avon Wheatbelt	northern	loams and clays	12	18	23	20
Avon Wheatbelt	northern	other				
Avon Wheatbelt	northern	pale sands	4	4	4	4
Avon Wheatbelt	northern	saline				
Avon Wheatbelt	northern	sandy duplexes	5	8	30	19
Avon Wheatbelt	western	coloured sands	6	7	8	7
Avon Wheatbelt	western	gravels	5	7	9	8
Avon Wheatbelt	western	loams and clays	10	12	15	13

IBRA	Subdiv	Soil Unit	% Clay 0-5	% Clay 5-15	% Clay 15-30	% Clay 0-30
Avon Wheatbelt	western	non-saline wet				
Avon Wheatbelt	western	other	7	7	7	7
Avon Wheatbelt	western	pale sands	4	5	6	5
Avon Wheatbelt	western	saline				
Avon Wheatbelt	western	sandy duplexes	5	5		
Coolgardie	non_ag	coloured sands	7	12	15	13
Coolgardie	non_ag	loams and clays	5	12	20	15
Coolgardie	western	coloured sands	7	11	15	12
Coolgardie	western	gravels	5	7	8	7
Coolgardie	western	loams and clays	15	20	28	23
Coolgardie	western	other				
Coolgardie	western	pale sands	4	4	4	4
Coolgardie	western	saline	5	15	30	21
Coolgardie	western	sandy duplexes	10	15	35	24
Esperance Plains	eastern	coloured sands	4	5	5	5
Esperance Plains	eastern	gravels				
Esperance Plains	eastern	loams and clays	30	50	60	52
Esperance Plains	eastern	non-saline wet				
Esperance Plains	eastern	other				
Esperance Plains	eastern	pale sands	3	3	3	3
Esperance Plains	eastern	saline				
Esperance Plains	eastern	sandy duplexes				
Esperance Plains	western	coloured sands	4			
Esperance Plains	western	gravels				
Esperance Plains	western	loams and clays	35	45	55	48
Esperance Plains	western	non-saline wet				
Esperance Plains	western	other				
Esperance Plains	western	pale sands	2	2	2	2
Esperance Plains	western	saline				
Esperance Plains	western	sandy duplexes	5	15	30	21
Geraldton Sandplains	northern	coloured sands	4	6	8	7
Geraldton Sandplains	northern	gravels	3	4	5	4
Geraldton Sandplains	northern	loams and clays	7	10	15	12
Geraldton Sandplains	northern	non-saline wet	2	2	2	2
Geraldton Sandplains	northern	other				
Geraldton Sandplains	northern	pale sands	3	3		
Geraldton Sandplains	northern	saline				
Geraldton Sandplains	northern	sandy duplexes	8	10	20	15
Geraldton Sandplains	southern	coloured sands	3	4	6	5

Table 11. Estimated clay content from samples per layer and mean over 30 cm. continued

IBRA	Subdiv	Soil Unit	% Clay 0-5	% Clay 5-15	% Clay 15-30	% Clay 0-30
Geraldton Sandplains	southern	gravels	3	4	5	4
Geraldton Sandplains	southern	loams and clays	12	12	12	12
Geraldton Sandplains	southern	non-saline wet				
Geraldton Sandplains	southern	other				
Geraldton Sandplains	southern	pale sands	3	4	4	4
Geraldton Sandplains	southern	saline				
Geraldton Sandplains	southern	sandy duplexes	5	10		
Jarrah Forest	eastern	coloured sands	5	7	13	10
Jarrah Forest	eastern	gravels	5	7	8	7
Jarrah Forest	eastern	loams and clays	12	25	40	30
Jarrah Forest	eastern	non-saline wet	5	5	5	5
Jarrah Forest	eastern	other				
Jarrah Forest	eastern	pale sands				
Jarrah Forest	eastern	saline				
Jarrah Forest	eastern	sandy duplexes	5	10	25	17
Jarrah Forest	southern	coloured sands	3			
Jarrah Forest	southern	gravels	5			
Jarrah Forest	southern	loams and clays	12	25	40	30
Jarrah Forest	southern	non-saline wet				
Jarrah Forest	southern	other				
Jarrah Forest	southern	pale sands	3	3	3	3
Jarrah Forest	southern	saline				
Jarrah Forest	southern	sandy duplexes	8	10	40	25
Jarrah Forest	western	coloured sands	4	4	5	5
Jarrah Forest	western	gravels	6	7	8	7
Jarrah Forest	western	loams and clays	12	19	25	21
Jarrah Forest	western	non-saline wet				
Jarrah Forest	western	other				
Jarrah Forest	western	pale sands	7	10	10	10
Jarrah Forest	western	saline				
Jarrah Forest	western	sandy duplexes	8	10	40	25
Mallee	eastern	gravels				
Mallee	eastern	loams and clays	20	25	30	27
Mallee	eastern	other				
Mallee	eastern	pale sands				
Mallee	eastern	saline				
Mallee	eastern	sandy duplexes	5	10	30	19

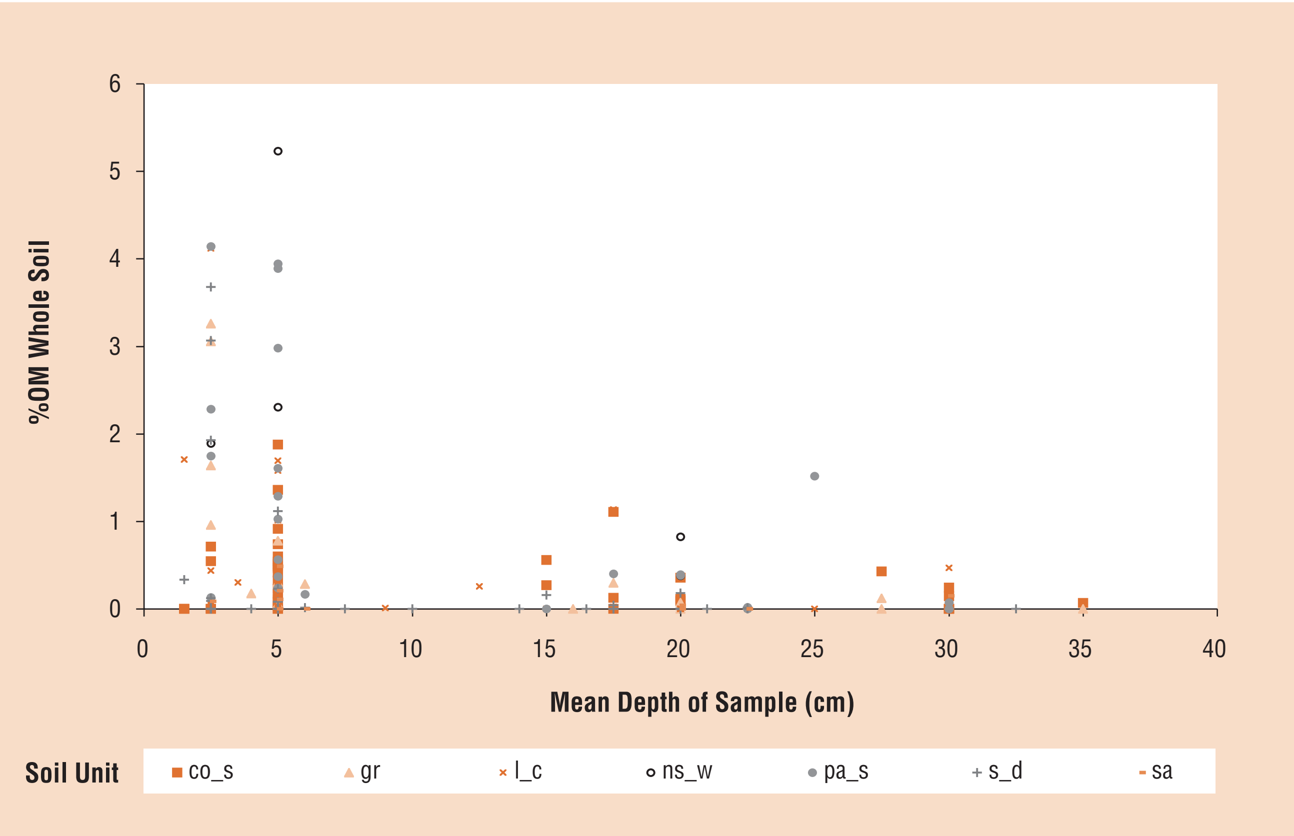
IBRA	Subdiv	Soil Unit	% Clay 0-5	% Clay 5-15	% Clay 15-30	% Clay 0-30
Mallee	non_ag	gravels	8	14	18	15
Mallee	non_ag	loams and clays	20	25	30	27
Mallee	western	coloured sands	6	9	13	11
Mallee	western	gravels	6	7	9	8
Mallee	western	loams and clays	15	25	30	26
Mallee	western	non-saline wet				
Mallee	western	other				
Mallee	western	pale sands	3	3	3	3
Mallee	western	saline	5	10	25	17
Mallee	western	sandy duplexes	8	12	30	20
Swan Coastal Plain	northern	coloured sands	3	4	6	5
Swan Coastal Plain	northern	loams and clays	12	12	12	12
Swan Coastal Plain	northern	non-saline wet				
Swan Coastal Plain	northern	other				
Swan Coastal Plain	northern	pale sands	2	5	5	5
Swan Coastal Plain	northern	saline				
Swan Coastal Plain	plateau	coloured sands	2	3	4	3
Swan Coastal Plain	plateau	gravels	5	6	7	6
Swan Coastal Plain	plateau	loams and clays	12	12	12	12
Swan Coastal Plain	plateau	non-saline wet				
Swan Coastal Plain	plateau	other				
Swan Coastal Plain	plateau	pale sands	3	4	4	4
Swan Coastal Plain	plateau	saline				
Swan Coastal Plain	southern	coloured sands	2	3	3	3
Swan Coastal Plain	southern	gravels	5	6	7	6
Swan Coastal Plain	southern	loams and clays	12	20	25	21
Swan Coastal Plain	southern	non-saline wet				
Swan Coastal Plain	southern	other	2	2	2	2
Swan Coastal Plain	southern	pale sands	5	4	4	4
Swan Coastal Plain	southern	saline	12	12	12	12
Swan Coastal Plain	southern	sandy duplexes	5	10	20	14
Warren	all	coloured sands	2	3	4	3
Warren	all	gravels	6	7	8	7
Warren	all	loams and clays	10	15	20	17
Warren	all	non-saline wet	20	25	30	27
Warren	all	other	2	3	4	3
Warren	all	pale sands	5	5	5	5
Warren	all	Saline				
Warren	all	Sandy duplexes	5	10		

Depth intervals are 0-5 cm, 5-15 cm, 15-30 cm and 0-30 cm.

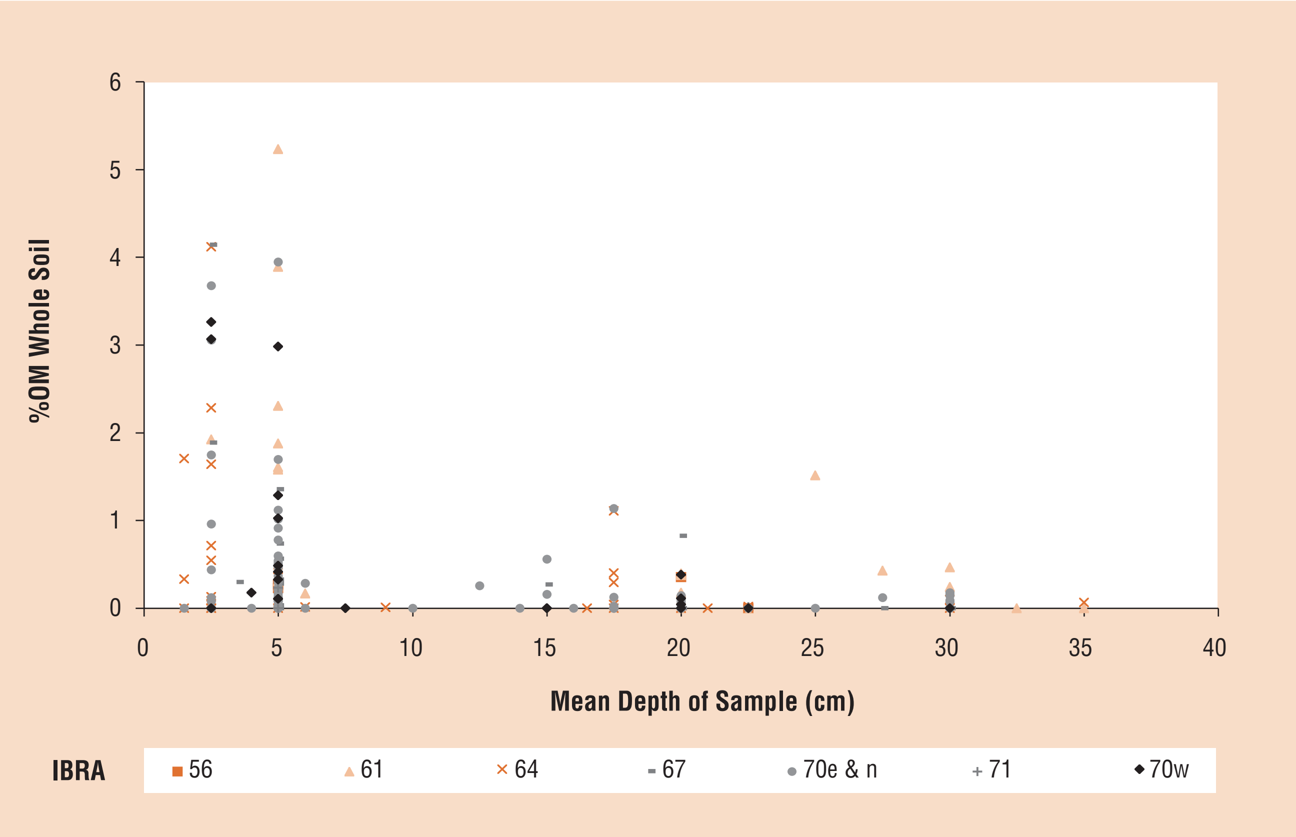
2.5 COARSE ORGANIC MATTER

While sample preparation can be expected to reduce aggregates to < 2 mm, thereby allowing coarse fragments (> 2 mm) to be determined, the way coarse organic matter has been dealt with is likely to be inconsistent. Woody roots and charcoal are likely to be included in the coarse fragments. The greater the need to break up aggregates, the higher the likely-hood that this material has been broken up. To ascertain the nature of this issue, the composition of a batch of samples analysed during this project were assessed.

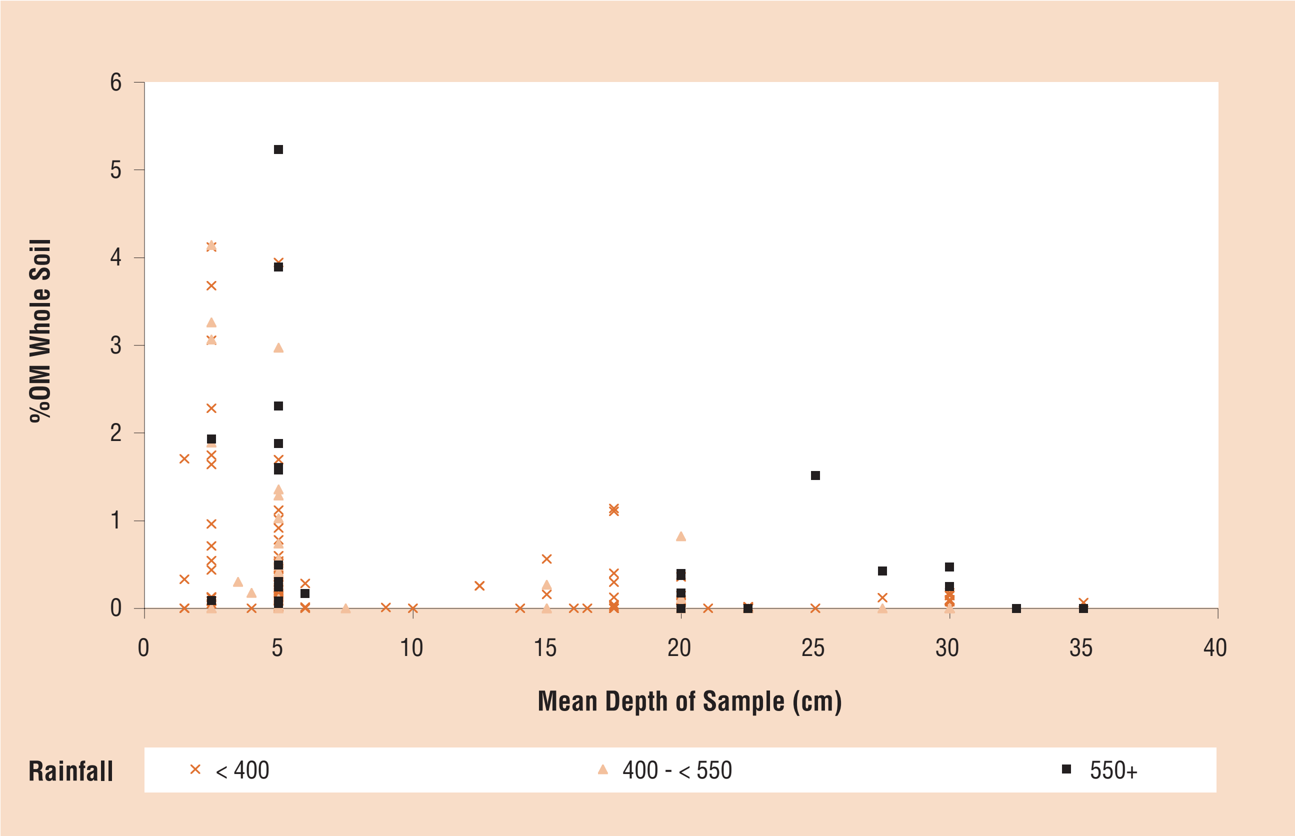
The organic matter, mainly roots, included in the coarse fragments varied from 0 to over 5% of the whole soil in the 177 samples. As could be expected, more was found in the surface samples than depth (Graph 11). The amount of organic matter in the samples showed poor relationships with a number of variables that are influential in biomass accumulation. These data suggest that soil unit (Graph 11), geographic region (Graph 12) and rainfall (Graph 13) have only a slight influence on the organic matter content.



Graph 11. Organic matter vs depth of sample. Samples grouped by soil unit.

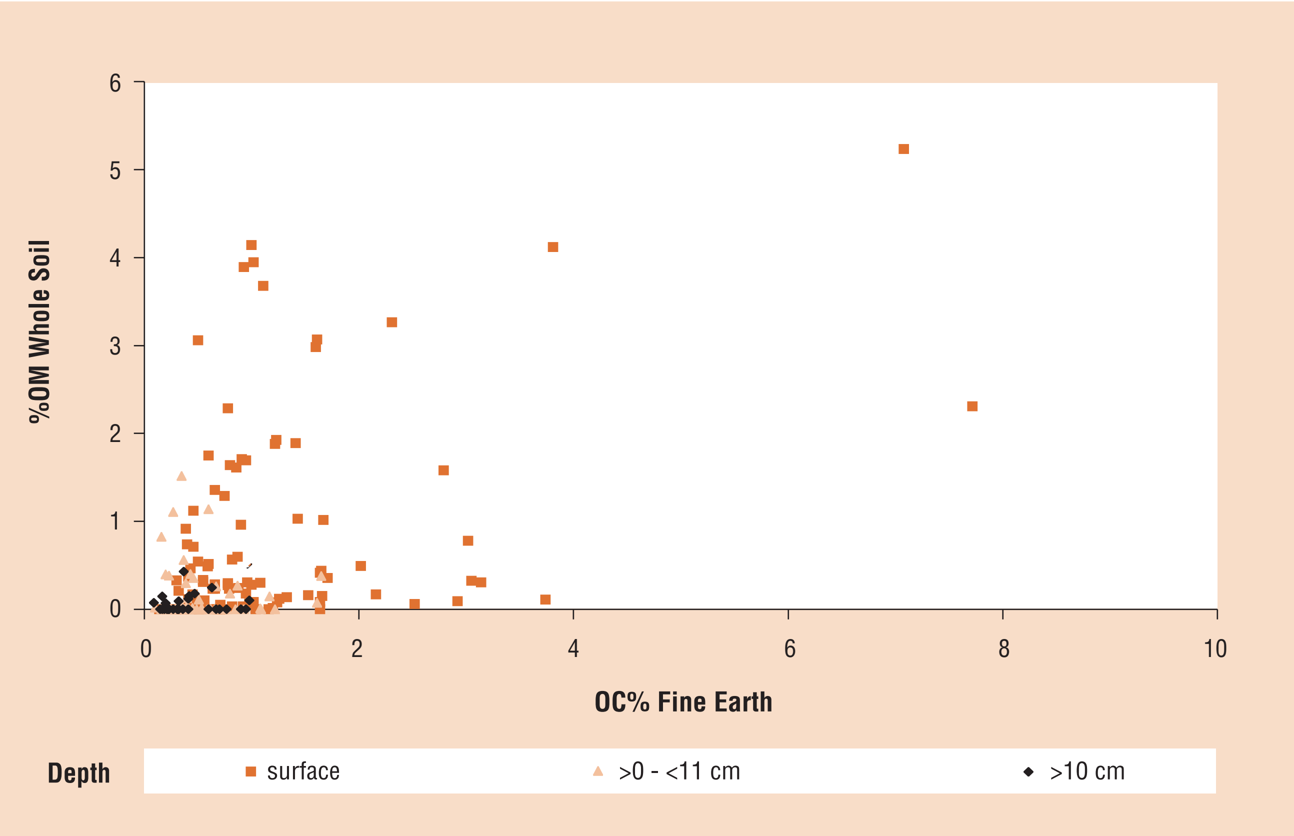


Graph 12. Organic matter vs depth of sample. Samples grouped by IBRA region or subdivision.



Graph 13. Organic matter vs depth of sample. Samples grouped by indicative rainfall (mm) of IBRA region or subdivision.

Whatever the factors influencing organic matter accumulation, the important issue for the moment is - can this fraction be accounted for? To be useful, a significant relationship should exist between the coarse organic matter and the organic carbon in the fine earth fraction. For the samples analysed, there was no such relationship (Graph 4). Therefore, the fine earth data cannot be scaled to account for the coarse organic matter that may have been rejected in sample preparation.



Graph 14. Organic matter in whole soil vs organic carbon in fine earth. Samples grouped by upper depth.

There is clearly more coarse organic matter in the surface layers declining with depth in a way similar to the way fine organic carbon declines. This suggests that a relationship should exist. That none was found suggests a number of things. Firstly, the samples taken were not representative of the different fractions. This is highly likely for roots that have a strongly uneven distribution. Secondly, there could be a different accumulation/decomposition relationship for the different fractions.

How then can values be determined for this coarse fraction? A rough value would be 50% of the fine earth fraction.

3. DISCUSSION

3.1 UNCERTAINTY

The method of estimating the values reported here have many uncertainties associated with them. These include:

- heterogeneity of soil unit;
- moderately large climate range in some IBRA regions;
- limited fine earth organic carbon for some soil units in some regions;
- limited coarse fragments percentage;
- almost no bulk density values;
- limited clay content for some soil units in some regions; and
- missing or uncertain coarse organic matter percentages.

Together these make it very difficult to estimate the uncertainty associated with the values predicted. The fine organic carbon values reported (Table 10) could easily be plus or minus 50% at any one point. To this a value for the coarse organic carbon needs to be added. A rough estimate is that total soil carbon could be in the order of 150% of fine organic carbon.

Despite the uncertainties, the relative values provided for soil units by IBRA subdivision should be accepted with a moderate degree of confidence.

3.2 MISSING DATA

This report provides data for over 100 combinations of IBRA subdivisions by soil unit. These covered all but one of the 33 combinations that are important in areas cleared since 1970 (see highlighted cells in Table 4). Some of the 32 are missing reliable values.

4. ACKNOWLEDGEMENTS

Assistance provided by the following people in preparing this report is gratefully acknowledged:

- Mr Dennis van Gool;
- Mr Phil Goulding; and
- Mr Kus Kuswardiyanto.

The data obtained from soil samples collected by the Western Australian Department of Conservation and Land Management (CALM) during their biodiversity project under the Salinity Action Plan were extremely useful.

The samples provided by CALM were analysed by the Chemistry Centre of WA.

The project was planned by an inter-agency group consisting of Dr Bob Nulsen (Chair), Mr Ted Griffin, Mr Greg Beeston (Agriculture WA), Dr Richard Harper (CALM), Dr Dave Allen and Dr Surender Mann (Chemistry Centre).

We are also grateful to CSIRO Land & Water for the opportunity to be involved in this project.

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APPENDIX 2

PRE-CLEARING SOIL CARBON LEVELS IN THE NORTHERN TERRITORY

Brian Lynch
(Department of Land Planning and Environment)

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1. BACKGROUND

The flux in soil carbon associated with land use change is a key component of Australia's greenhouse gas balance. The Australian Greenhouse Office (AGO) is developing methods to estimate the extent of the flux using soil carbon change modelling supported by observations from key sites nationally. Information for the project is stratified within the boundaries of the Interim Bio-geographic Regionalisation of Australia (IBRA Version 4, Thackway & Cresswell 1995). A key background measurement underlying this analysis is the level of soil carbon prior to significant land use change, that is soil carbon in pre-cleared conditions. An initial estimate of this level is being obtained from State and Territory agencies based on existing data.

There is some urgency in developing an initial table/map of soil carbon contents for major soils in the IBRA regions to support the estimation of the 1990 baseline of carbon fluxes in Australia. Data on the pre-cleared soil carbon is required for significant soil units in each IBRA cell to allow modelling of changes due to changed land use.

The AGO and its consultants are working closely with key contacts in each State and Territory Government and CSIRO to derive a table for each IBRA cell, with supporting documentation showing the basis of decisions on aspects such as area of major soils, amalgamation of soil groups, soil carbon estimation/allocation. The resultant table will be updated as new improved data become available.

2. OBJECTIVES

1. Identify the major soils in each IBRA cell and provide a spatial estimate using the most appropriate data available. The project concentrated on the ten IBRA cells in the northern half of the Northern Territory (Figure 1);
2. Allocate soil carbon content (t/ha 0-30 cm) for major soil/spatial units; and
3. Provide supporting documentation on decisions.

3. METHOD

The method for this project essentially involved linking limited point source information to an extensive spatial coverage. This involved two phases. One was to develop a spatial distribution of Soil Orders within each of the ten IBRA regions covering the northern part of the Northern Territory. The second was to derive soil carbon contents for each of the Soil Orders within each region.

The majority of the northern part of the Northern Territory is covered by land system mapping at scales ranging from 1:100,000 to 1:1,000,000 (Figure 2). The Atlas of Australian Soils still provides the only regional soils information for the southern part of the Sturt Plateau and a large portion of the Tiwi Islands. Each of the land system coverages was attributed with the major Soil Order. This was considered the most appropriate option as it was easier to allocate Soil Orders to the soil profiles from which the soil carbon contents were derived.

There are some inconsistencies where coverages join due to scale differences and interpretive variations. The allocation of Soil Orders to replace the Great Soil Groups was relatively straight forward. The assumption that all 'skeletal soils' and Lithosols translate to Rudosols may be somewhat tenuous.

This would not appear to effect the overall outcome of this assessment. The properties of shallow depth and high gravel contents still come into consideration. The distribution of the major Soil Orders is shown in Figure 3.

The allocation of soil carbon contents involved two stages. Initially, a comprehensive 'data search' was conducted to determine the extent of existing soil and chemical information required for calculating soil carbon contents. This information was contained in various technical reports, box files, laboratory files and computer print outs. Some information was in digital format but was not readily retrievable.

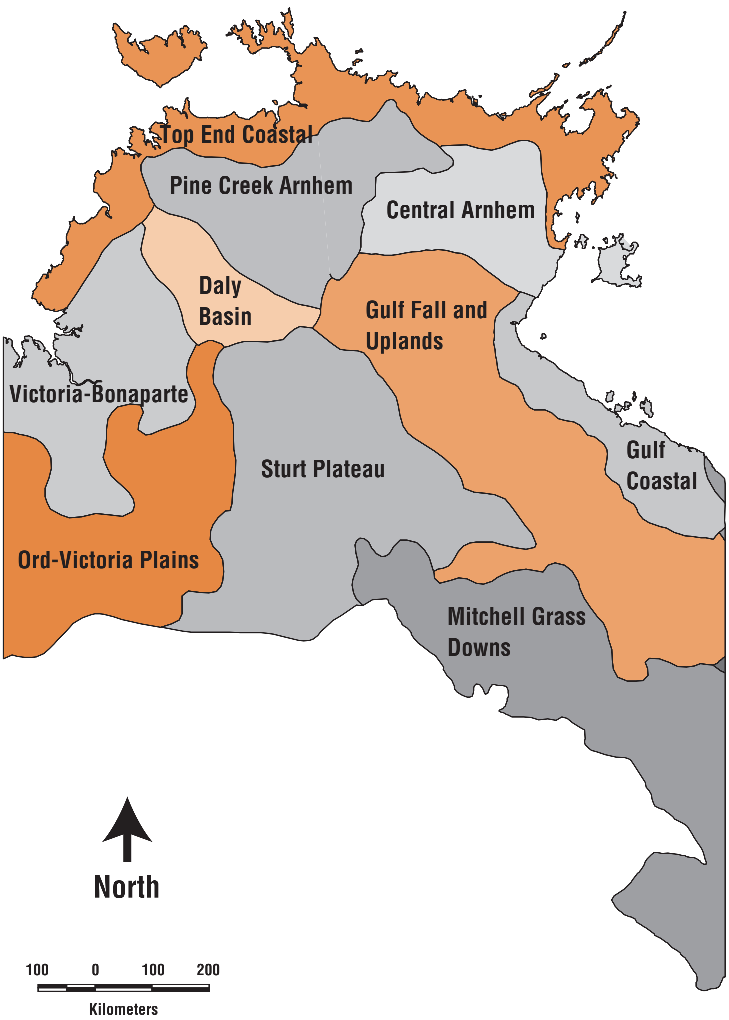


Figure 1. Interim Biogeographic regions of the northern part of the Northern Territory.

Although not exhaustive, the search uncovered a considerable number of soil profiles with organic carbon % analyses. These were entered into a spreadsheet. There are outstanding profiles for the Daly Basin (Kandosols) and Alligator Rivers Area (mostly Top End Coastal Vertosols and Hydrosols), which are yet to be added. The biggest problem in using this information is the lack of bulk density measurements. Additionally, there are inconsistencies in sampling depths and the depths on which analyses were conducted. For some of the surveys, the profiles sampled and analysed were biased towards those soils with favourable agricultural potential. These were the deep, gravel free profiles, which were not necessarily the most extensive soils. A summary of this information is shown in Attachment A.

The soils analysed along the Stuart Highway by the Carbon Budget Project in 1997 (from survey sites shown in Attachment C, following Skjemstad *et.al.*, unpublished data) provided a comprehensive set of data for the calculation of carbon contents. This information was used and supplemented where possible with information collected from the above data search. Only a small number of profiles (from the data search) were used due to time constraints, lack of geo referencing and the inconsistencies mentioned previously. It may be possible to incorporate more of this information at a later stage. In particular, there were 76 profiles analysed in the Gulf Fall and Uplands (GFU) and Gulf Coastal (GUC) regions, which have not been used (largely due to time constraints).

Organic carbon contents (t/ha) were determined for soil profiles then averaged for each of the Soil Orders within each IBRA region. Where there was no information for a Soil Order the value of another Soil Order was used and adjusted accordingly. This was often the case with Rudosols. The carbon contents of the Rudosols were generally determined from the Tenosols or Kandosols, with a reduction factor, to account for higher gravel contents. Where there was no information for an IBRA region then the values of the most appropriate adjacent region were used.

3.1 TOP END COASTAL BIOGEOGRAPHIC REGION (TEC)

The Top End Coastal Region (TEC) covers an area of some 70,860 sq kms. There are five major Soil Orders: Kandosols (45%); Tenosols (20%); Vertosols (15%); Hydrosols (12%); and Rudosols (8%). The Hydrosols include both tidal and freshwater Suborders. These were combined as there were no available organic carbon data for the tidal Suborder. If such data is available, the Hydrosols could be split into tidal (8%) and freshwater (4%).

3.1.1 Kandosols

Carbon contents (t/ha) were calculated for 23 profiles (Table 1), using bulk densities calculated by averaging 19 profiles from the Carbon Budget Project (Table 2).

The majority of these profiles were gravel free. The following assumptions were made to account for gravel contents:

- 20% of the area covered by Kandosols has 0% gravel in the 0-30 cm horizon;
- 20% of the area covered by Kandosols has 10% gravel in the 0-30 cm horizon;
- 50% of the area covered by Kandosols has 30% gravel in the 0-30 cm horizon; and
- 10% of the area covered by Kandosols has 50% gravel in the 0-30 cm horizon.

These assumptions were based on land unit mapping in the Darwin Region.

This was used to convert the organic carbon (OC) fine earth in the 0–30 cm to OC whole earth (from 59.6 t/ha to 46.5 t/ha).

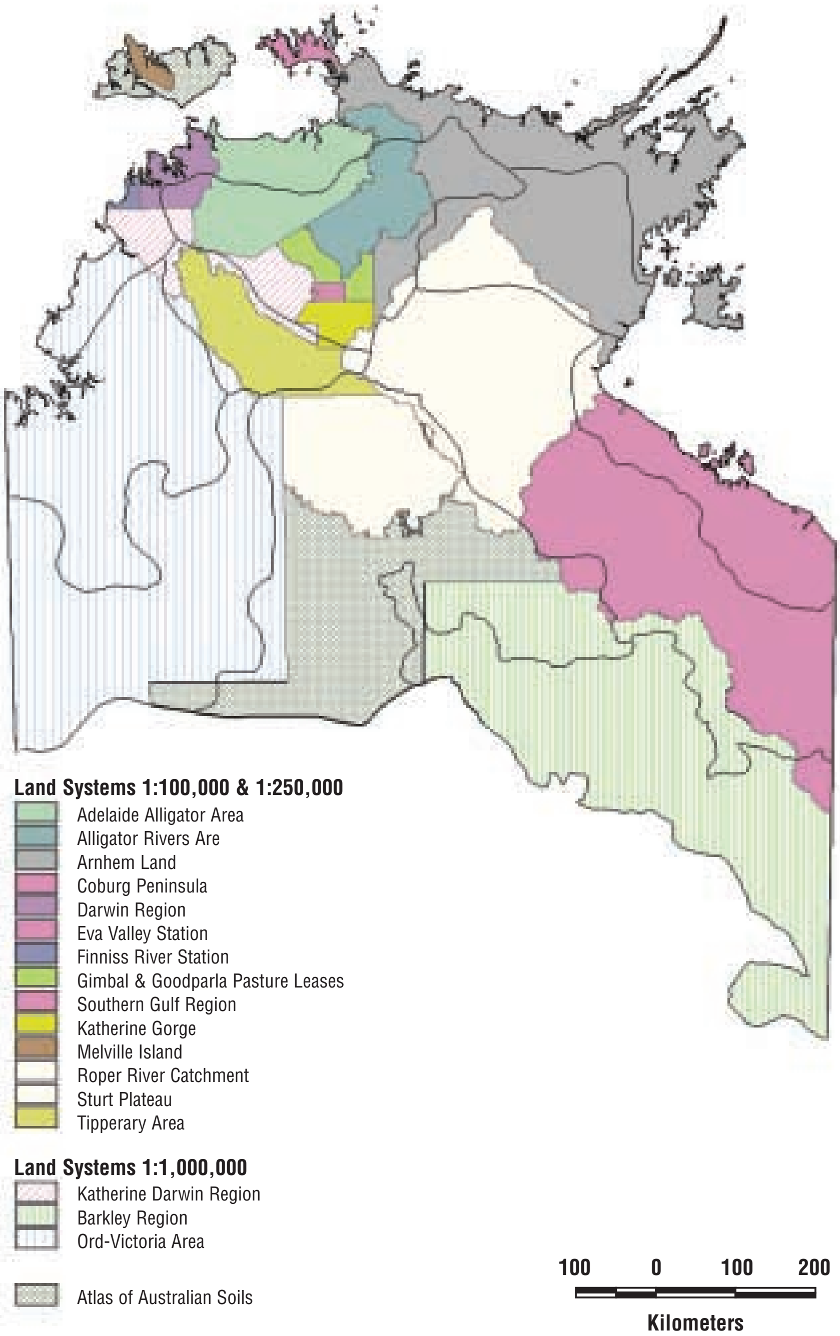


Figure 2. Land system mapping - northern part of the Northern Territory.

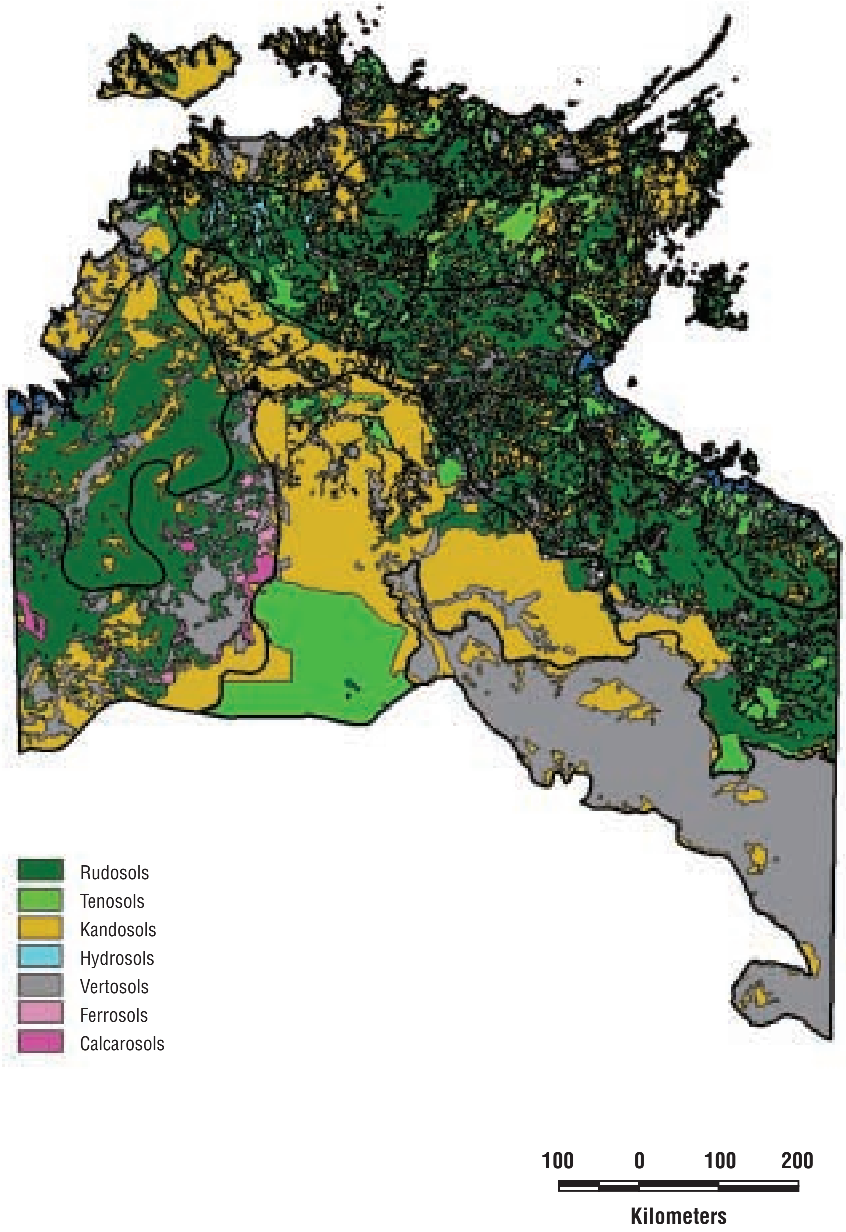


Figure 3. Major soil orders - northern part of the Northern Territory.

Table 1. Carbon contents of Kandosol profiles – Top End Coastal.

Survey	Site Number	OC Fine Earth (0-30 cm) (t/ha)
ANNABURROO	108	13.3
DWN-BLCK-ELIZ	ER 118 PIT 2	15.6
ANNABURROO	107	20.9
ANNABURROO	109	26.4
DWN-BLCK-ELIZ	SITE 50 PIT 7 DBE	28.6
DWN-BLCK-ELIZ	ER 187 PIT 3	30.3
HARRISONDAM	Red Lateritic Earth	32.3
DWN-BLCK-ELIZ	ER 97 PIT 1	34.5
DWN-BLCK-ELIZ	SITE 160	36.9
WILDMAN	WR 74	38.1
HARRISONDAM	Duplex Red Earth (5 sites)	40.4
DWN-BLCK-ELIZ	PIT 9	42.2
ANNABURROO	61	46.3
WILDMAN	WR 44	63.2
WILDMAN	WR 37	75.9
DWN-BLCK-ELIZ	SITE 52 PIT 8	79.6
WILDMAN	WR 42	94.6
DWN-BLCK-ELIZ	ER148 PIT4	97.7
WILDMAN	WR 34	97.8
WILDMAN	WR 50	98.4
DWN-BLCK-ELIZ	SITE 33	99.3
WILDMAN	WR 38	106.2
WILDMAN	WR 33	152.9
	Average	**59.6**

3.1.2 Tenosols

As there was no data available for Tenosols the Kandosol figures were used and modified to account for gravel content. The assumption was made that there are two general groupings of Tenosols: one group being the deep, gravel free sands; and the other shallow to moderately deep and gravelly. Land system mapping was used to derive the following estimates:

- 60% of the area covered by Tenosols has 0% gravel in the 0-30 cm horizon; and
- 40% of the area covered by Tenosols has 50% gravel in the 0-30 cm horizon.

These assumptions were used to derive a figure of 47.7 t/ha for OC whole earth (0-30 cm).

Table 2. Bulk densities (gm/cm^3) for Kandosols – Carbon Budget Project.

Site Number	Depth		
	0-10 cm	10-20 cm	20-30 cm
4	1.23	1.44	1.51
5	1.34	1.43	1.46
6	1.13	1.45	1.49
7	1.26	1.56	1.62
9	1.44	1.54	1.57
10	1.41	1.54	-
11	1.05	1.30	1.40
12	1.12	1.33	1.49
13	1.14	1.38	1.44
14	0.92	1.43	1.42
15	1.09	1.37	1.41
17	1.31	1.48	1.56
18	1.35	1.65	1.63
19	1.15	1.45	1.57
20	1.43	1.57	1.62
21	1.23	1.42	1.54
22	1.52	1.47	1.52
23	1.34	1.53	1.61
24	1.43	1.51	1.54
Average	**1.26**	**1.47**	**1.52**

3.1.3 Rudosols

As with the Tenosols there was no data available for Rudosols so Kandosol figures were used also, with gravel content taken into account. The gravel content estimated from profiles sampled during land system mapping averaged in the order of 70%. The figure of 19.9 t/ha was used as the best estimate OC whole earth for 0-30 cm for the Rudosols.

3.1.4 Hydrosols

Carbon content (t/ha) calculated from 6 profiles (Table 3), using bulk densities averaged from 3 profiles from the Carbon Budget Project (Table 4). The assumption was made that the Hydrosols are generally gravel free. Consequently, the OC (fine earth) has not been altered for the OC (whole earth) estimate.

Table 3. Carbon Contents of Hydrosol profiles – Top End Coastal.

Survey	Site Number	OC Fine Earth (0-30 cm)
		t/ha
DWN-BLCK-ELIZ	ER 96 PIT 5	16.3
DWN-BLCK-ELIZ	SITE 54 PIT 6	24.6
DWN-BLCK-ELIZ	SITE 138 PIT 4	35.5
DWN-BLCK-ELIZ	SITE 132	44.6
DWN-BLCK-ELIZ	SITE 49	61.5
KOONGARA	KOO79 40	104.3
	Average	**47.8**

Table 4. Bulk densities (gm/cm^3) for Hydrosols – Carbon Budget Project.

Site Number		Depth	
	0-10 cm	10-20 cm	20-30 cm
8	1.09	1.45	1.43
25	1.36	1.51	1.58
16	1.67	1.73	1.70
Average	**1.37**	**1.56**	**1.57**

3.1.5 Vertosols

Carbon content (t/ha) calculated from 24 profiles (Table 5), using bulk densities averaged from 5 profiles from the Carbon Budget Project (Table 6).

The profiles used for the bulk density figures were Vertosols located in the Sturt Plateau and Barkly regions.

A summary of the results for the Top End Coastal Region is provided in Table 7.

Table 5. Carbon contents Vertosol profiles – Top End Coastal.

Survey	Site Number	OC Fine Earth (0-30 cm)
		(t/ha)
COOPER CREEK	CO079 9	27.7
COOPER CREEK	CO079 11	34.5
COOPER CREEK	CO079 12	43.4
COOPER CREEK	CO079 16	50.2
COOPER CREEK	CO079 3	50.8
COOPER CREEK	CO079 7	51.2
COOPER CREEK	CO079 6	54.7
COOPER CREEK	CO079 5	59.9
COOPER CREEK	CO079 4	63.4
COOPER CREEK	CO079 8	63.5
COOPER CREEK	CO079 15	64.8
COOPER CREEK	CO079 2	68.7
COOPER CREEK	CO079 10	76.3
COOPER CREEK	CO079 1	76.7
COOPER CREEK	CO079 13	81.6
COOPER CREEK	CO079 17	86.1
KOONGARA	KO079 34	93.4
COOPER CREEK	CO079 14	108.3
WILDMAN	WR 23	123.5
COOPER CREEK	CO079 18	128.0
WILDMAN	WR 7	177.0
KOONGARA	KO079 35	183.0
WILDMAN	WR 2	201.3
WILDMAN	WR 3	208.1
	Average	**90.7**

Table 6. Bulk densities (gm/cm^3) for Vertosols – Carbon Budget Project.

Site Number		Depth	
	0-10 cm	10-20 cm	20-30 cm
233	1.46	1.39	1.39
236	1.44	1.42	1.43
271	1.35	1.32	1.30
267	1.34	1.39	1.38
263	1.38	1.55	1.43
Average	**1.39**	**1.41**	**1.39**

Table 7. Carbon contents and areas for major soil orders in the Top End Coastal Region.

Soil Orders	OC Whole Earth (0-30 cm)	Area	Total OC
	t/ha	ha	t
Kandosols	46.5	319,160,000	14,840,940,000
Tenosols	47.7	141,410,000	6,745,257,000
Rudosols	19.9	59,460,000	1,183,254,000
Hydrosols	47.8	85,350,000	4,079,730,000
Vertosols	90.7	103,220,000	9,362,054,000
Total		**708,600,000**	**36,211,235,000**

As a comparison the following were determined from the Carbon Budget Project (1997). These were not incorporated in the determinations above.

Kandosols (17 profiles)

OC fine earth (0-30 cm) – 46.8 t/ha; and
OC whole earth (0-30 cm) – 33.6 t/ha.

Hydrosols (4 profiles)

OC fine earth (0-30 cm) – 28.2 t/ha; and
OC whole earth (0-30 cm) – 24.6 t/ha.

Vertosols (1 profile)

OC fine earth (0-30 cm) – 63.4 t/ha; and
OC whole earth (0-30 cm) – 63.4 t/ha.

3.2 PINE CREEK - ARNHEM BIOGEOGRAPHIC REGION (PCA)

The Pine Creek-Arnhem Biogeographic Region (PCA) covers an area of 51,591 sq kms. The region has six major Soil Orders: Rudosols (53%); Tenosols (23%); Kandosols (12%); Hydrosols (8%); Ferrosols (3%); and Vertosols (1%).

Organic carbon was determined from profiles 25 to 136 from the Carbon Budget Project. As the field site data (in particular volumetric gravel estimates) were readily available, the 'whole earth' carbon contents were determined on a site-by-site basis, then averaged. This was a slightly different approach to that used in the Top End Coastal, as the soils sampled on Carbon Budget Project covered a fairly representative transect of the Pine Creek-Arnhem Region.

3.2.1 Rudosols & Tenosols

None of profiles were classified as Rudosols, however, the 20 profiles classified as Tenosols provided an appropriate estimate (Table 8).

3.2.2 Kandosols

59 profiles were used to determine the carbon content of Kandosols (Table 9).

3.2.3 Hydrosols

18 profiles were used to determine the carbon content of Hydrosols (Table 10).

Table 8. Carbon contents of Tenosol profiles – Pine Creek-Arnhem.

Site Number	OC Whole Earth (0-30 cm)	OC Fine Earth (0-30 cm)
	t/ha	t/ha
25	22.57	22.57
32	11.21	25.81
33	17.23	31.18
46	19.50	27.86
84	12.26	15.33
85	10.88	15.31
87	18.94	24.43
88	16.89	26.53
89	13.11	34.70
101	19.87	29.23
103	18.21	26.02
106	16.76	27.57
123	8.31	12.29
124	13.65	17.87
125	12.25	20.38
127	7.10	7.94
128	10.77	14.35
130	13.40	19.32
135	16.17	21.47
136	20.45	39.73
Average	**15**	**23**

Table 9. Carbon contents of Kandosol profiles – Pine Creek-Arnhem.

Site Number	OC Whole Earth (0-30 cm)	Site Number	OC Whole Earth (0-30 cm)
	t/ha		t/ha
27	31.07	83	21.59
28	42.34	91	49.61
29	28.06	92	30.03
30	19.28	93	38.1
36	54.33	95	12.69
37	35.09	98	7.95
38	15.42	99	16
39	39.46	100	12.51
40	36.03	104	13.53
41	59.45	105	14.09
43	14.46	107	15.31
45	23.65	108	14.37
47	21.66	109	17.9
50	23.2	110	12.72
62	15.1	112	9.2
65	14.48	113	23.16
66	32.05	114	16.56
67	21.81	115	12.99
69	25.67	116	14.39
71	23.02	117	17.63
72	19.77	118	15.78
73	15.18	119	7.29
74	29.38	120	10.91
75	21.31	126	60.87
76	22.35	129	13.2
77	18.23	131	8.99
78	21.96	132	12.07
79	21.7	133	11.99
80	10.13	134	11.13
81	14.94	**Average**	**21.9**

Table 10. Carbon contents of Hydrosol profiles – Pine Creek-Arnhem.

Site Number	OC Whole Earth (0-30 cm)
	t/ha
31	8.24
35	13.92
42	39.81
44	17.62
48	25.54
51	26.09
54	15.26
55	39.3
56	27.96
57	28.97
58	10.88
59	21.87
60	27.85
63	24.09
64	27.44
86	15.46
90	19.78
96	14.72
Average	**22.5**

3.2.4 Ferrosols

As there was no data available for Ferrosols, the value for Kandosols was used.

3.2.5 Vertosols

As there was no data available for Vertosols, the value for Vertosols in Top End Coastal was used.

A summary of the results for the Pine Creek-Arnhem Region is provided in Table 11.

Table 11. Carbon contents and areas for major soil orders in the Pine Creek-Arnhem Region.

Soil Orders	OC Whole Earth (0-30 cm)	Area	Total
	t/ha	ha	t
Rudosols	15.0	275,040,000	4,125,600,000
Tenosols	15.0	116,690,000	1,750,350,000
Kandosols	21.9	63,660,000	1,394,154,000
Hydrosols	22.5	43,330,000	974,925,000
Ferrosols	21.9	12,700,000	278,130,000
Vertosols	90.7	4,500,000	408,150,000
Total		**515,920,000**	**8,931,309,000**

3.3 DALY BASIN BIOGEOGRAPHIC REGION (DAB)

The Daly Basin Biogeographic Region (DAB) covers an area of 20,899 sq kms. The region has four major Soil Orders: Kandosols (69%); Rudosols (16%); Tenosols (8%); and Vertosols (7%).

Soil carbon contents were determined from profiles 139 to 192 from the Carbon Budget Project. These profiles provided a transect through the south-east corner of the Daly Basin. There is a considerable amount of information throughout the remainder, except for bulk densities. This may be worth incorporating at a later stage.

3.3.1 Kandosols

38 profiles were used to determine the carbon content of Kandosols (Table 12).

Table 12. Carbon contents of Kandosol profiles – Daly Basin.

Site Number	OC Fine Earth (0-30 cm) t/ha	OC Whole Earth (0-30 cm) t/ha
140	12.03	11.92
141	15.62	5.27
166	11.35	11.24
139	15.49	6.52
145	25.01	23.68
146	44.00	36.93
147	12.72	12.46
149	51.88	50.31
150	55.47	55.47
151	21.54	21.54
152	116.57	113.83
153	37.31	37.31
155	30.75	29.61
156	37.01	37.01
157	33.88	33.88
158	44.94	44.87
159	71.00	35.50
160	37.49	37.49
161	24.22	23.73
162	37.31	37.31
163	22.16	22.16
164	12.47	12.47
168	8.88	8.88
169	37.68	33.14
170	35.86	34.78
171	13.48	13.48
172	25.48	25.48
173	11.54	11.54
174	15.29	15.29
175	20.23	20.02
176	24.89	24.89
178	13.31	5.80
179	61.63	43.91
181	15.64	9.23
182	18.80	14.04
183	19.27	13.98
188	18.27	16.93
189	22.29	21.45
Average	**29.8**	**26.7**

3.3.2 Tenosols

14 profiles were used to determine the carbon content of Tenosols (Table 13).

3.3.3 Rudosols

No profiles were classified as Rudosols, so the Tenosol average was used.

3.3.4 Vertosols

No profiles were classified as Vertosols. The fine earth average for Kandosols was used, as Vertosols typically have very little or no gravel.

A summary of the results for the Daly Basin Region is provided in Table 14.

Table 13. Carbon contents of Tenosol profiles – Daly Basin.

Site Number	OC Fine Earth (0-30 cm)	OC Whole Earth (0-30 cm)
	t/ha	t/ha
142	12.60	8.29
143	18.09	7.29
144	9.95	5.83
154	13.22	13.22
165	12.99	12.86
167	17.58	17.22
180	28.71	17.88
184	6.78	6.44
185	9.59	6.19
186	20.95	13.62
187	19.27	11.56
190	8.85	6.96
191	8.42	5.64
192	17.88	17.88
Average	**14.6**	**10.8**

Table 14. Carbon contents and areas for major soil orders in the Daly Basin Region.

Soil Orders	OC Whole Earth (0-30 cm)	Area	Total
	t/ha	ha	t
Kandosols	26.7	143,950,000	3,843,465,000
Rudosols	10.8	33,550,000	362,340,000
Tenosols	10.8	16,090,000	173,772,000
Vertosols	29.8	15,410,000	459,218,000
Total		**209,000,000**	**4,838,795,000**

3.4 STURT PLATEAU BIOGEOGRAPHIC REGION (STU)

The Sturt Plateau Biogeographic Region covers an area of some 105,200 sq kms. The region has four major Soil Orders: Kandosols (60%); Tenosols (25%); Vertosols (10%); and Rudosols (5%). Soil carbon contents were determined on profiles 201 to 259 from the Carbon Budget Project.

3.4.1 Kandosols

44 profiles were used to determine the carbon content of Kandosols (Table 15).

Table 15. Carbon contents of Kandosol profiles – Sturt Plateau.

Site Number	OC Fine Earth (0-30 cm) t/ha	OC Whole Earth (0-30 cm) t/ha
201	29.45	29.45
202	24.30	24.30
203	21.99	21.99
204	19.35	19.35
205	16.72	16.72
207	16.48	16.48
208	12.22	12.22
209	21.07	21.07
211	23.96	23.96
215	15.37	13.27
216	23.37	22.06
217	13.84	9.07
219	18.77	18.77
221	44.98	44.98
222	36.89	36.89
224	52.80	52.80
225	28.38	27.28
226	43.12	43.12
227	25.50	25.50
228	31.76	31.12
229	22.73	22.73
231	56.87	55.02
233	17.86	17.86
234	31.18	25.46
236	15.67	15.67
237	29.42	13.69
238	42.47	41.13
239	24.74	24.50
240	42.43	42.01
241	17.15	17.15
242	21.46	21.46
244	32.12	20.79
246	22.23	20.44
248	18.88	18.88
249	32.26	32.26
250	18.79	12.08
251	11.54	8.31
252	19.14	15.76
253	21.71	21.29
254	19.82	19.42
255	58.81	48.47
257	27.44	27.44
258	31.39	31.39
259	41.39	31.01
Average	**27.2**	**25.3**

3.4.2 Tenosols

7 profiles were used to determine the carbon content of Tenosols (Table 16).

3.4.3 Vertosols

2 profiles were used to determine the carbon content of Vertosols (Table 17).

3.4.4 Rudosols

There were no profiles for Rudosols, so the Tenosol average was used.

A summary of the results for the Sturt Plateau Region is provided in Table 18.

Table 16. Carbon contents of Tenosol profiles – Sturt Plateau.

Site Number	OC Fine Earth (0-30 cm)	OC Whole Earth (0-30 cm)
	t/ha	t/ha
206	12.98	12.98
210	15.68	15.68
213	30.60	20.63
214	14.74	14.74
218	20.77	15.49
220	12.76	9.01
256	25.96	16.87
Average	**19.1**	**15.1**

Table 17. Carbon contents of Vertosol profiles – Sturt Plateau.

Site Number	OC Fine Earth (0-30 cm)	OC Whole Earth (0-30 cm)
	t/ha	t/ha
232	41.76	41.76
235	32.93	31.08
Average	**37.4**	**36.4**

Table 18. Carbon contents and areas for major soil orders in the Sturt Plateau Region.

Soil Orders	OC Whole Earth (0-30 cm)	Area	Total
	t/ha	ha	t
Kandosols	25.3	631,200,000	15,969,360,000
Tenosols	15.1	263,000,000	3,971,300,000
Vertosols	37.4	105,200,000	3,934,480,000
Rudosols	15.1	52,600,000	794,260,000
Total		**1,052,000,000**	**24,669,400,000**

3.5 MITCHELL GRASS DOWNS BIOGEOGRAPHIC REGION (MGD)

The Mitchell Grass Downs Biogeographic Region covers 84,869 sq kms. There are two major Soil Orders: Vertosols (85%); and Kandosols (15%).

Table 19. Carbon contents for Vertosol profiles – Mitchell Grass Downs.

Site Number	OC Fine Earth 0-30 cm t/ha	OC Whole Earth 0-30 cm t/ha
263	9.41	9.41
267	15.03	15.03
271	16.31	16.31
Average	**13.58**	**13.58**

Organic carbon was determined on profiles 260 to 283 from the Carbon Budget Project.

3.5.1 Vertosols

3 profiles were used to determine the carbon content of Vertosols (Table 19).

3.5.2 Kandosols

7 profiles were classified as Kandosols. Another 8 profiles were classified as Tenosols. These two groups were combined to give an average value for the Kandosols (Table 20).

Table 20. Carbon contents for Kandosol profiles – Mitchell Grass Downs.

Site Number	OC Fine Earth (0-30 cm) t/ha	OC Whole Earth (0-30 cm) t/ha	Soil Order
260	41.43	24.65	KA
261	24.53	24.53	KA
262	15.40	12.40	KA
268	17.97	17.97	KA
270	10.27	10.24	KA
273	12.06	12.06	KA
279	12.94	12.94	KA
264	15.46	4.64	TE
269	10.44	10.44	TE
272	11.81	11.81	TE
274	12.95	12.53	TE
276	11.33	10.42	TE
277	25.45	24.44	TE
280	15.47	15.47	TE
283	14.67	13.26	TE
Average	**16.8**	**14.5**	

Table 21. Carbon contents and areas for major soil orders in the Mitchell Grass Downs region.

Soil Orders	OC Whole Earth (0-30 cm)	Area	Total
	t/ha	ha	t
Vertosols	13.6	721,390,000	9,810,904,000
Kandosols	14.5	127,300,000	1,845,850,000
Total		**848,690,000**	**11,656,754,000**

Table 22. Carbon contents and areas for major soil order in the Central Arnhem region.

Soil Orders	OC Whole Earth (0-30 cm)	Area	Total
	t/ha	ha	t
Tenosols	47.7	133,880,000	6,386,076,000
Rudosols	19.9	100,020,000	1,990,398,000
Kandosols	46.5	77,100,000	3,585,150,000
Hydrosols	47.8	23,720,000	1,133,816,000
Vertosols	90.7	11,290,000	1,024,003,000
Total		**346,010,000**	**14,119,443,000**

3.6 CENTRAL ARNHEM BIOGEOGRAPHIC REGION (CA)

The Central Arnhem Biogeographic Region covers an area of 34,601 sq kms. The region has five major Soil Orders: Tenosols; Rudosols; Kandosols; Hydrosols; and Vertosols. There is no data available for this region, so the values for the Top End Coastal Region have been used as defaults (Table 22).

3.7 ORD-VICTORIA PLAINS BIOGEOGRAPHIC REGION (OVP)

The Ord-Victoria Plains Biogeographic Region covers an area of 70,904 sq kms. The region has five major Soil Orders: Rudosols (45%); Vertosols (25%); Kandosols (20%); Calcarosols (5%); and Ferrosols (5%).

There appears to be very little available information for this region. There are surface horizon analyses for four Kandosol and two Vertosol profiles. These were not used in the following determinations. Default values were taken from adjacent regions to derive the following estimates (Table 23).

Rudosols – taken from Sturt Plateau (and Pine Creek-Arnhem) regions;

Vertosols – taken from Mitchell Grass Plains region;

Kandosols – taken from Sturt Plateau region;

Calcarosols – as for Kandosols; and

Ferrosols – as for Vertosols.

Table 23. Carbon Contents and Areas for major soil order in the Ord-Victoria Plains region.

Soil Orders	OC Whole Earth (0-30 cm)	Area	Total
	t/ha	ha	t
Rudosols	15	319,070,000	10,798,607,000
Vertosols		177,260,000	2,410,736,000
Kandosols	25.3	141,810,000	3,587,793,000
Calcarosols	25.3	35,450,000	896,885,000
Ferrosols	13.6	35,450,000	482,120,000
Total		**709,040,000**	**12,163,584,000**

3.8 VICTORIA-BONAPARTE BIOGEOGRAPHIC REGION (VB)

The Victoria-Bonaparte Biogeographic Region covers an area of 53,878 sq kms. The region consists of four major Soil Orders: Rudosols (67%); Kandosols (20%); Vertosols (9%); and Hydrosols (4%).

There is very little available information for this region. There are OC% data for the surface horizons in thirty-one Vertosols, five Kandosols and three Hydrosols in the Lower Weaber and Keep Plains. This information was not used in the following determinations. Default values were taken from adjacent regions to derive the following estimates (Table 24).

Rudosols – taken from Sturt Plateau (and Pine Creek-Arnhem) regions;

Kandosols – taken from Sturt Plateau region;

Vertosols – taken from Top End Coastal region; and

Hydrosols – taken from Top End Coastal region.

The value for Vertosols was considered more appropriate as the Hydrosols in this region are associated with the coastal floodplains.

Table 24. Carbon contents and areas for major soil order in the Victoria-Bonaparte region.

Soil Orders	OC Whole Earth (0-30 cm)	Area	Total
	t/ha	ha	t
Rudosols	15	359,130,000	5,386,950,000
Kandosols	25.3	111,760,000	2,827,528,000
Vertosols	90.7	46,460,000	4,213,922,000
Hydrosols	90.7	21,430,000	1,943,701,000
Total		**538,780,000**	**14,372,101,000**

3.9 GULF FALL AND UPLANDS BIOGEOGRAPHIC REGION (GFU)

The Gulf Fall and Uplands Biogeographic Region covers an area of 106,015 sq kms. The region consists of four major Soil Orders: Rudosols (55%); Kandosols (20%); Vertosols (15%); and Tenosols (10%).

There are 76 profiles for the Gulf Fall and Uplands (GFU) and Gulf Coastal (GUC) Biogeographic Regions. All appear to have OC% for the 0-10 cm, 10-20 cm and 20-30 cm depth layers. No bulk densities are available and the volumetric gravels need retrieving from field sheets. These were not used in the following determinations (due to time constraints), however, they may be useful at a later stage. Default values were taken from adjacent regions to derive the following estimates (Table 25).

Rudosols and Tenosols – taken from Sturt Plateau (and Pine Creek-Arnhem) regions;

Kandosols – taken from Sturt Plateau region; and

Vertosols – taken from Mitchell Grass Downs region.

3.10 GULF COASTAL BIOGEOGRAPHIC REGION (GUC)

The Gulf Coastal Biogeographic Region covers an area of 28,463 sq kms. The region consists of four major Soil Orders: Rudosols (31%); Tenosols (31%); Hydrosols (14%); Kandosols (12%); and Vertosols (12%).

As previously mentioned, there are 76 profiles for the Gulf Fall and Uplands (GFU) and Gulf Coastal (GUC) Biogeographic Regions. All appear to have OC% for the 0-10 cm, 10-20 cm and 20-30 cm depth layers. No bulk densities are available and the volumetric gravels need retrieving from field sheets. These were not used in the following determinations (due to time constraints), however, they may be useful at a later stage.

Default values were taken from adjacent regions to derive the following estimates (Table 26).

Rudosols and Tenosols – taken from Sturt Plateau (and Pine Creek-Arnhem) regions;

Kandosols – taken from Sturt Plateau region; and

Vertosols – taken from Mitchell Grass Downs region.

Table 25. Carbon contents and areas for major soil order in the Gulf Fall and Uplands region.

Soil Orders	OC Whole Earth (0-30 cm)	Area	Total
	t/ha	ha	t
Rudosols	15	583,080,000	8,746,200,000
Kandosols	25.3	212,030,000	5,364,359,000
Vertosols	13.6	159,020,000	2,162,672,000
Tenosols	15	136,050,000	2,040,750,000
Total		**1,090,180,000**	**18,313,981,000**

Table 26. Carbon contents and areas for major soil order in the Gulf Coastal region.

Soil Orders	OC Whole Earth (0-30 cm)	Area	Total
	t/ha	ha	t
Rudosols	15	87,340,000	1,310,100,000
Tenosols	15	87,620,000	1,314,300,000
Hydrosols	90.7	39,200,000	3,571,120,000
Kandosols	25.3	34,700,000	877,910,000
Vertosols	13.6	35,770,000	486,472,000
Total		**284,630,000**	**7,559,902,000**

4. COMMENTS

This project essentially involved extrapolating site data collected along a north-south transect (provided by the Stuart Highway) across to the Queensland and Western Australia borders, under the Carbon Budget Project (see Skjemstad *et.al.*, unpublished data). Although there is a considerable amount of other data from various land resource surveys, this information was generally not used. This was due to a lack of bulk density data, as well as the analyses not always being conducted on each of the soil horizons in the surface 30 cm. Much of this information could be useful in conjunction with the appropriate statistical procedures.

Apart from the Stuart Highway transect, which was undertaken as part of the Carbon Budget Project in 1997 (see Skjemstad *et.al.*, unpublished data), there is limited geo-referenced site data. For the coastal regions, it may be more appropriate to distinguish between the saline and freshwater Hydrosols.

The extrapolation of Soil Order OC contents from adjacent regions is very subjective and the estimates should be considered accordingly.

5. REFERENCES

Skjemstad, J.O, Janik, L.J., Spouncer L.R. & Merry, R. M. (unpublished data). *Improving the Understanding of Australia's Soil Carbon Sink: Final Report for the Bureau of Rural Sciences*, October 1999. CSIRO, Land & Water, Adelaide.

Thackway, R. & Cresswell, I.D. (eds) 1995, *An Interim Biogeographic Regionalisation for Australia: A Framework for Setting Priorities in the National Reserves System Cooperative Program*. Australian Nature Conservation Agency, Canberra, ACT. Version 4, 31 March 1995.

ATTACHMENT A

NUMBERS OF SOIL PROFILES WITH ORGANIC CARBON % FROM LAND RESOURCE SURVEYS

Survey	Number of Profiles	IBRA Region
Darwin-Blackmore-Elizabeth	14	Top End Coastal
Katherine-Douglas	13 (O.M.%)	Daly Basin
Sturt Plateau	15	Sturt Plateau
Wyworri	3	Sturt Plateau
Humbert	6	Ord-Victoria
Gulf	45	Gulf Falls & Gulf Coastal
Fish River	24	Daly Basin
Wildman	13	Top End Coastal
Harrison Dam	2 + average of 5 sites	Top End Coastal
Roper	30	Gulf Falls
Upper Katherine (levee)	7	Daly Basin
Lower Weaber and Keep Plains	39	Victoria-Bonapart
Annaburroo	11	Top End Coastal & Pine Creek-Arnhem
Daly River Agricultural Area	6	Top End Coastal
Dry River	9 (includes averages)	Sturt Plateau
Dorisvale	2	Daly Basin
Moroak	3 (includes averages)	Gulf Falls
Fertility Studies (Adelaide & Daly)	6 (averages of 6 profiles)	Daly Basin & Pine Creek-Arnhem
Fertility Studies (Daly)	3	Daly Basin
Manbulloo Experimental	6	Daly Basin
ADMA Project Farms	12	Daly Basin
Upper Adelaide River	7	Pine Creek-Arnhem
Marrakai	14	Pine Creek-Arnhem
Cooper Creek Floodplain, 1979	18	Top End Coastal

ATTACHMENT B

CLAY CONTENTS AND COARSE FRAGMENT CONTENTS FOR MAJOR SOIL ORDERS WITHIN IBRA REGIONS IN THE NORTHERN PART OF NORTHERN TERRITORY

Table 27. Summary of clay contents and coarse fragment contents for major soil orders within IBRA regions in the northern part of Northern Territory.

IBRA Region	Soil Order	Volumetric Gravel %	Clay %	Reference
Top End Coastal (TEC)	Kandosols	22	13	Table 28
	Tenosols	20	8	Gravel based on assumptions on page 64, clay based on assumption that these are generally lighter textured than Kandosols.
	Rudosols	70	8	70% used as default gravel content for Rudosols, clay based on assumption that these are generally lighter textured than Kandosols.
	Hydrosols	5	18	Table 29
	Vertosols	0	61	Table 30
	Ferrosols	22	13	As for TEC Kandosols
Pine Creek–Arnhem (PCA)	Tenosols	33	11	Table 31
	Kandosols	26	15	Table 32
	Hydrosols	4	16	Table 33
	Rudosols	70	11	70% used as default gravel content for Rudosols, clay content assumed as for PCA Tenosols.
	Vertosols	0	61	As for TEC Vertosols
	Ferrosols	26	15	As for PCA Kandosols
Daly Basin (DAB)	Kandosols	10	15	Table 34
	Tenosols	26	4	Table 35
	Ferrosols	10	15	As for DAB Kandosols
	Hydrosols	4	16	As for PCA Hydrosols
	Rudosols	70	4	70% used as default gravel content for Rudosols, clay content assumed as for DAB Tenosols.
	Vertosols	0	58	As for STU Vertosols
Sturt Plateau (STU)	Kandosols	8	18	Table 36
	Tenosols	19	8	Table 37
	Vertosols	0	58	Table 38
	Hydrosols	1	14	Table 39
	Chromosols	24	4	Table 40 (site data used from DAB Region)
	Calcarosols	8	18	As for STU Kandosols
	Dermosols	8	18	As for STU Kandosols
	Ferrosols	8	18	As for STU Kandosols
	Rudosols	70	8	70% used as default gravel content for Rudosols, clay content assumed as for STU Tenosols.

IBRA Region	Soil Order	Volumetric Gravel %	Clay %	Reference
Mitchell Grass Downs	Vertosols	0	66	Table 41
(MGD)	Kandosols	9	16	Table 42
	Tenosols	12	11	Table 43
	Dermosols	0	66	As for MGD Vertosols
	Rudosols	70	11	70% used as default gravel content for Rudosols, clay content assumed as for MGD Tenosols.
Central Arnhem (CA)	Ferrosols	22	13	As for TEC Kandosols
	Hydrosols	5	18	As for TEC Hydrosols
	Kandosols	22	13	As for TEC Kandosols
	Rudosols	70	8	As for TEC Rudosols
	Tenosols	20	8	As for TEC Tenosols
	Vertosols	0	61	As for TEC Vertosols
Ord-Victoria Plains (OVP)	Calcarosols	8	18	As for STU Kandosols
	Ferrosols	8	18	As for STU Kandosols
	Hydrosols	1	14	As for STU Hydrosols
	Kandosols	8	18	As for STU Kandosols
	Rudosols	8	18	As for STU Kandosols
	Tenosols	19	8	As for STU Tenosols
	Vertosols	0	66	As for MGD Vertosols
Victoria-Bonaparte (VB)	Ferrosols	8	18	As for STU Kandosols
	Hydrosols	1	14	As for STU Hydrosols
	Kandosols	8	18	As for STU Kandosols
	Rudosols	70	8	As for STU Rudosols
	Tenosols	19	8	As for STU Tenosols
	Vertosols	0	58	As for STU Vertosols
Gulf Fall & Uplands (GFU)	Hydrosols	1	14	As for STU Hydrosols
	Kandosols	8	18	As for STU Kandosols
	Rudosols	8	18	As for STU Kandosols
	Tenosols	19	8	As for STU Tenosols
	Vertosols	0	66	As for MGD Vertosols
Gulf Coastal (GUC)	Hydrosols	1	14	As for STU Hydrosols
	Kandosols	8	18	As for STU Kandosols
	Rudosols	70	8	As for STU Rudosols
	Tenosols	19	8	As for STU Tenosols
	Vertosols	0	66	As for MGD Vertosols

Table 28. Clay % and coarse fragment % for Kandosols in Top End Coastal biogeographic region.

Site Number	Depth	Volumetric Gravel %	Clay %
4	0-10 cm	20	19
	10-20 cm	15	23
	20-30 cm	20	24
5	0-10 cm	20	19
	10-20 cm	15	22
	20-30 cm	12	22
6	0-10 cm	65	10
	10-20 cm	63	13
	20-30 cm	63	18
7	0-10 cm	75	14
	10-20 cm	68	17
	20-30 cm	65	9
9	0-10 cm	45	8
	10-20 cm	45	8
	20-30 cm	40	13
11	0-10 cm	25	16
	10-20 cm	30	13
	20-30 cm	40	19
12	0-10 cm	40	18
	10-20 cm	50	18
	20-30 cm	30	18
13	0-10 cm	35	13
	10-20 cm	35	10
	20-30 cm	35	12
14	0-10 cm	50	15
	10-20 cm	50	16
	20-30 cm	30	17
17	0-10 cm	50	10
	10-20 cm	50	4
	20-30 cm	45	9
18	0-10 cm	40	6
	10-20 cm	20	10
	20-30 cm	20	14

Site Number	Depth	Volumetric Gravel %	Clay %
19	0-10 cm	25	11
	10-20 cm	15	6
	20-30 cm	20	11
20	0-10 cm	25	9
	10-20 cm	15	14
	20-30 cm	15	11
21	0-10 cm	10	19
	10-20 cm	7	11
	20-30 cm	7	15
22	0-10 cm	25	14
	10-20 cm	15	12
	20-30 cm	15	13
23	0-10 cm	20	11
	10-20 cm	15	5
	20-30 cm	15	8
24	0-10 cm	20	9
	10-20 cm	20	10
	20-30 cm	40	12
	Average (0-30 cm)	**32***	**13**

* The average coarse fragment content from the Carbon Budget Project was 32%. However, the value of 22% was used for coarse fragments. This was based on the estimates on page 61– (20% of the area having 0% gravel, 20% having 10% gravel, 50% having 30% gravel and 10% having 50% gravel in the top 0-30 cm horizon).

Table 29. Clay % and coarse fragment % for Hydrosols in Top End Coastal biogeographic region.

Survey	Site Number	Depth	Volumetric Gravel %	Clay %
Carbon Budget Project	8	0-10 cm	0	20
		10-20 cm	0	26
		20-30 cm	0	38
	15	0-10 cm	45	15
		10-20 cm	30	14
		20-30 cm	25	16
	16	0-10 cm	0	2
		10-20 cm	0	1
		20-30 cm	0	0
	25	0-10 cm	0	13
		10-20 cm	0	14
		20-30 cm	0	12
DWN-BLCK-ELIZ	ER96PIT5	0-10 cm	0	1
		10-20 cm	0	1
		20-30 cm	0	1
	SITE49	0-10 cm	0	9
		10-20 cm	0	25
		20-30 cm	0	25
	SITE54PIT6	0-10 cm	0	25
		10-20 cm	0	59
		20-30 cm	0	59
		Average (0-30 cm)	**5**	**18**

Survey locations shown in Attachment C.

Table 30. Clay % and coarse fragment % for Vertosols in Top End Coastal biogeographic region.

Survey	Site Number	Depth	Volumetric Gravel %	Clay %
Carbon Budget Project	3	0-10 cm	0	40
		10-20 cm	0	38
		20-30 cm	0	36
Cooper Creek	CO079 18	0-10 cm	0	68
		10-20 cm	0	71
		20-30 cm	0	72
	CO079 14	0-10 cm	0	67
		10-20 cm	0	67
		20-30 cm	0	73
	CO079 11	0-10 cm	0	41
		10-20 cm	0	63
		20-30 cm	0	59
	CO079 9	0-10 cm	0	68
		10-20 cm	0	66
		20-30 cm	0	68
	CO079 7	0-10 cm	0	68
		10-20 cm	0	70
		20-30 cm	0	70
		Average (0-30 cm)	**0**	**61**

Survey locations shown in Attachment C.

Table 31. Clay % and coarse fragment % for Tenosols in Pine Creek - Arnhem biogeographic region.

Site Number	Depth	Volumetric Gravel %	Clay %
25	0-10 cm	0	13
	10-20 cm	0	14
	20-30 cm	0	12
32	0-10 cm	50	7
	10-20 cm	60	7
	20-30 cm	65	8
33	0-10 cm	35	5
	10-20 cm	50	7
	20-30 cm	60	6
46	0-10 cm	30	14
	10-20 cm	30	16
	20-30 cm	30	14
84	0-10 cm	20	13
	10-20 cm	20	12
	20-30 cm	20	11
85	0-10 cm	25	12
	10-20 cm	30	0
	20-30 cm	35	0
87	0-10 cm	20	14
	10-20 cm	25	15
	20-30 cm	25	16
88	0-10 cm	30	0
	10-20 cm	40	10
	20-30 cm	40	4
89	0-10 cm	60	8
	10-20 cm	65	10
	20-30 cm	65	10
101	0-10 cm	22	8
	10-20 cm	40	10
	20-30 cm	45	10
103	0-10 cm	30	14
	10-20 cm	30	17
	20-30 cm	30	16

Site Number	Depth	Volumetric Gravel %	Clay %
106	0-10 cm	30	8
	10-20 cm	40	8
	20-30 cm	55	10
123	0-10 cm	2	12
	10-20 cm	70	11
	20-30 cm	50	12
124	0-10 cm	20	16
	10-20 cm	25	16
	20-30 cm	30	19
125	0-10 cm	45	7
	10-20 cm	35	9
	20-30 cm	35	12
127	0-10 cm	2	9
	10-20 cm	2	11
	20-30 cm	30	10
128	0-10 cm	25	10
	10-20 cm	25	11
	20-30 cm	25	8
130	0-10 cm	25	17
	10-20 cm	35	16
	20-30 cm	35	22
135	0-10 cm	20	12
	10-20 cm	30	12
	20-30 cm	30	11
136	0-10 cm	30	17
	10-20 cm	60	18
	20-30 cm	60	17
	Average (0-30 cm)	**33**	**11**

Table 32. Clay % and coarse fragment % for Kandosols in Pine Creek - Arnhem biogeographic region.

Site Number	Depth	Volumetric Gravel %	Clay %
27	0-10 cm	3	11
	10-20 cm	2	14
	20-30 cm	12	9
28	0-10 cm	9	11
	10-20 cm	6	14
	20-30 cm	6	15
29	0-10 cm	10	13
	10-20 cm	6	17
	20-30 cm	2	20
30	0-10 cm	40	9
	10-20 cm	60	7
	20-30 cm	60	3
36	0-10 cm	0	16
	10-20 cm	0	18
	20-30 cm	0	20
37	0-10 cm	40	9
	10-20 cm	40	10
	20-30 cm	35	13
38	0-10 cm	0	10
	10-20 cm	0	12
	20-30 cm	0	22
39	0-10 cm	0	19
	10-20 cm	0	21
	20-30 cm	0	20
40	0-10 cm	20	21
	10-20 cm	25	21
	20-30 cm	25	21
41	0-10 cm	35	18
	10-20 cm	40	17
	20-30 cm	40	17
43	0-10 cm	30	10
	10-20 cm	50	9
	20-30 cm	50	12

Site Number	Depth	Volumetric Gravel %	Clay %
45	0-10 cm	0	14
	10-20 cm	0	17
	20-30 cm	5	21
47	0-10 cm	25	17
	10-20 cm	30	18
	20-30 cm	35	18
50	0-10 cm	0	18
	10-20 cm	0	19
	20-30 cm	0	18
62	0-10 cm	55	11
	10-20 cm	60	10
	20-30 cm	60	12
65	0-10 cm	40	14
	10-20 cm	50	14
	20-30 cm	50	10
66	0-10 cm	0	10
	10-20 cm	30	21
	20-30 cm	30	18
67	0-10 cm	0	14
	10-20 cm	15	18
	20-30 cm	30	20
69	0-10 cm	0	16
	10-20 cm	0	14
	20-30 cm	0	18
71	0-10 cm	45	15
	10-20 cm	30	14
	20-30 cm	30	17
72	0-10 cm	0	17
	10-20 cm	0	19
	20-30 cm	0	20
73	0-10 cm	0	12
	10-20 cm	0	14
	20-30 cm	0	16

Table 32. Continued

Site Number	Depth	Volumetric Gravel %	Clay %
74	0-10 cm	0	18
	10-20 cm	0	18
	20-30 cm	0	19
75	0-10 cm	0	16
	10-20 cm	0	18
	20-30 cm	0	18
76	0-10 cm	0	14
	10-20 cm	0	18
	20-30 cm	0	20
77	0-10 cm	60	13
	10-20 cm	60	14
	20-30 cm	60	16
78	0-10 cm	60	14
	10-20 cm	60	12
	20-30 cm	60	13
79	0-10 cm	50	12
	10-20 cm	60	11
	20-30 cm	60	11
80	0-10 cm	30	14
	10-20 cm	40	16
	20-30 cm	40	19
81	0-10 cm	50	14
	10-20 cm	60	15
	20-30 cm	60	14
83	0-10 cm	0	12
	10-20 cm	0	16
	20-30 cm	0	17
91	0-10 cm	40	13
	10-20 cm	30	17
	20-30 cm	30	16
92	0-10 cm	20	15
	10-20 cm	20	17
	20-30 cm	30	18

Site Number	Depth	Volumetric Gravel %	Clay %
93	0-10 cm	40	17
	10-20 cm	35	15
	20-30 cm	30	16
95	0-10 cm	45	12
	10-20 cm	40	14
	20-30 cm	40	15
98	0-10 cm	40	11
	10-20 cm	50	8
	20-30 cm	45	11
99	0-10 cm	25	15
	10-20 cm	30	15
	20-30 cm	30	13
100	0-10 cm	40	10
	10-20 cm	35	12
	20-30 cm	35	13
104	0-10 cm	25	17
	10-20 cm	25	17
	20-30 cm	25	19
105	0-10 cm	20	12
	10-20 cm	25	13
	20-30 cm	25	14
107	0-10 cm	55	12
	10-20 cm	50	15
	20-30 cm	50	18
108	0-10 cm	20	13
	10-20 cm	25	16
	20-30 cm	25	19
109	0-10 cm	7	12
	10-20 cm	50	15
	20-30 cm	50	14
110	0-10 cm	75	11
	10-20 cm	65	13
	20-30 cm	45	17

Table 32. Continued

Site Number	Depth	Volumetric Gravel %	Clay %
112	0-10 cm	60	11
	10-20 cm	60	19
	20-30 cm	50	22
113	0-10 cm	30	20
	10-20 cm	20	27
	20-30 cm	20	31
114	0-10 cm	4	14
	10-20 cm	35	17
	20-30 cm	25	21
115	0-10 cm	40	12
	10-20 cm	40	13
	20-30 cm	0	21
116	0-10 cm	0	15
	10-20 cm	0	15
	20-30 cm	0	16
117	0-10 cm	0	7
	10-20 cm	0	16
	20-30 cm	5	10
118	0-10 cm	35	13
	10-20 cm	40	11
	20-30 cm	40	12
119	0-10 cm	50	9
	10-20 cm	50	12
	20-30 cm	60	18
120	0-10 cm	30	10
	10-20 cm	35	9
	20-30 cm	35	11
126	0-10 cm	0	17
	10-20 cm	20	11
	20-30 cm	20	13
129	0-10 cm	30	17
	10-20 cm	40	20
	20-30 cm	40	19

Site Number	Depth	Volumetric Gravel %	Clay %
131	0-10 cm	35	10
	10-20 cm	35	8
	20-30 cm	45	11
132	0-10 cm	10	15
	10-20 cm	15	14
	20-30 cm	15	13
133	0-10 cm	40	14
	10-20 cm	50	12
	20-30 cm	50	15
134	0-10 cm	0	13
	10-20 cm	0	13
	20-30 cm	0	14
	Average (0-30 cm)	**26**	**15**

Table 33. Clay % and coarse fragment % for Hydrosols in Pine Creek – Arnhem biogeographic region.

Site Number	Depth	Volumetric Gravel %	Clay %
31	0-10 cm	0	6
	10-20 cm	0	7
	20-30 cm	0	6
35	0-10 cm	10	7
	10-20 cm	50	6
	20-30 cm	50	5
42	0-10 cm	0	24
	10-20 cm	0	22
	20-30 cm	0	23
44	0-10 cm	0	18
	10-20 cm	0	14
	20-30 cm	0	16
48	0-10 cm	0	14
	10-20 cm	0	19
	20-30 cm	0	19
51	0-10 cm	0	9
	10-20 cm	0	18
	20-30 cm	0	19
54	0-10 cm	0	15
	10-20 cm	0	16
	20-30 cm	0	17
55	0-10 cm	0	24
	10-20 cm	0	25
	20-30 cm	0	26
56	0-10 cm	0	14
	10-20 cm	0	23
	20-30 cm	0	21
57	0-10 cm	0	16
	10-20 cm	0	18
	20-30 cm	0	22
58	0-10 cm	0	12
	10-20 cm	0	13
	20-30 cm	0	16

Site Number	Depth	Volumetric Gravel %	Clay %
59	0-10 cm	0	19
	10-20 cm	0	21
	20-30 cm	0	24
60	0-10 cm	0	21
	10-20 cm	0	21
	20-30 cm	0	19
63	0-10 cm	0	6
	10-20 cm	0	15
	20-30 cm	0	17
64	0-10 cm	0	20
	10-20 cm	0	21
	20-30 cm	0	24
86	0-10 cm	7	4
	10-20 cm	7	2
	20-30 cm	0	7
90	0-10 cm	0	11
	10-20 cm	0	12
	20-30 cm	0	16
96	0-10 cm	5	10
	10-20 cm	10	8
	20-30 cm	10	9
111	0-10 cm	20	17
	10-20 cm	20	24
	20-30 cm	40	21
	Average (0-30 cm)	**4**	**16**

Table 34. Clay % and coarse fragment % for Kandosols in Daly Basin biogeographic region.

Site Number	Depth	Volumetric Gravel %	Clay %
139	0-10 cm	40	6
	10-20 cm	60	0
	20-30 cm	80	0
145	0-10 cm	7	12
	10-20 cm	7	15
	20-30 cm	1	20
146	0-10 cm	20	10
	10-20 cm	12	17
	20-30 cm	12	22
147	0-10 cm	2	6
	10-20 cm	2	8
	20-30 cm	2	10
149	0-10 cm	5	15
	10-20 cm	1	18
	20-30 cm	2	23
150	0-10 cm	0	15
	10-20 cm	0	18
	20-30 cm	0	21
151	0-10 cm	0	8
	10-20 cm	0	11
	20-30 cm	0	14
152	0-10 cm	5	30
	10-20 cm	0	33
	20-30 cm	0	34
153	0-10 cm	0	15
	10-20 cm	0	19
	20-30 cm	0	19
155	0-10 cm	5	20
	10-20 cm	2	19
	20-30 cm	2	24
156	0-10 cm	0	9
	10-20 cm	0	18
	20-30 cm	0	20

Site Number	Depth	Volumetric Gravel %	Clay %
157	0-10 cm	0	18
	10-20 cm	0	18
	20-30 cm	0	22
158	0-10 cm	0	20
	10-20 cm	0	22
	20-30 cm	1	24
159	0-10 cm	50	20
	10-20 cm	50	22
	20-30 cm	50	21
160	0-10 cm	0	27
	10-20 cm	0	23
	20-30 cm	0	22
161	0-10 cm	2	11
	10-20 cm	2	15
	20-30 cm	2	15
162	0-10 cm	0	15
	10-20 cm	0	20
	20-30 cm	0	18
163	0-10 cm	0	8
	10-20 cm	0	10
	20-30 cm	0	15
164	0-10 cm	0	5
	10-20 cm	0	5
	20-30 cm	0	8
168	0-10 cm	0	6
	10-20 cm	0	6
	20-30 cm	0	10
169	0-10 cm	10	17
	10-20 cm	15	22
	20-30 cm	15	22
170	0-10 cm	3	18
	10-20 cm	3	21
	20-30 cm	3	20

Table 34. Continued

Site Number	Depth	Volumetric Gravel %	Clay %
171	0-10 cm	0	6
	10-20 cm	0	6
	20-30 cm	0	7
172	0-10 cm	0	5
	10-20 cm	0	8
	20-30 cm	0	10
173	0-10 cm	0	7
	10-20 cm	0	11
	20-30 cm	0	11
174	0-10 cm	0	6
	10-20 cm	0	6
	20-30 cm	0	8
175	0-10 cm	1	8
	10-20 cm	1	11
	20-30 cm	1	13
176	0-10 cm	0	13
	10-20 cm	0	15
	20-30 cm	0	18
178	0-10 cm	55	8
	10-20 cm	60	8
	20-30 cm	55	9
179	0-10 cm	30	16
	10-20 cm	30	17
	20-30 cm	25	18
181	0-10 cm	35	8
	10-20 cm	45	11
	20-30 cm	45	17
182	0-10 cm	20	11
	10-20 cm	30	9
	20-30 cm	30	10
183	0-10 cm	10	7
	10-20 cm	35	12
	20-30 cm	40	17

Site Number	Depth	Volumetric Gravel %	Clay %
188	0-10 cm	3	12
	10-20 cm	4	13
	20-30 cm	20	20
189	0-10 cm	3	16
	10-20 cm	1	21
	20-30 cm	10	24
	Average (0-30 cm)	**10**	15

Table 35. Clay % and coarse fragment % for Tenosols in Daly Basin biogeographic region.

Site Number	Depth	Volumetric Gravel %	Clay %
142	0-10 cm	15	5
	10-20 cm	50	0
	20-30 cm	50	0
143	0-10 cm	60	1
	10-20 cm	60	6
	20-30 cm	60	6
144	0-10 cm	25	0
	10-20 cm	55	0
	20-30 cm	55	1
154	0-10 cm	0	11
	10-20 cm	0	12
	20-30 cm	0	11
165	0-10 cm	1	0
	10-20 cm	1	3
	20-30 cm	1	5
167	0-10 cm	2	6
	10-20 cm	2	8
	20-30 cm	2	10
180	0-10 cm	35	8
	10-20 cm	40	7
	20-30 cm	40	7

Table 35. Continued

Site Number	Depth	Volumetric Gravel %	Clay %
184	0-10 cm	5	5
	10-20 cm	5	5
	20-30 cm	5	5
185	0-10 cm	20	2
	10-20 cm	20	2
	20-30 cm	70	3
186	0-10 cm	35	4
	10-20 cm	35	0
	20-30 cm	35	3
187	0-10 cm	40	3
	10-20 cm	40	7
	20-30 cm	40	4
190	0-10 cm	15	4
	10-20 cm	15	0
	20-30 cm	40	0
191	0-10 cm	15	4
	10-20 cm	50	0
	20-30 cm	50	1
192	0-10 cm	0	6
	10-20 cm	0	8
	20-30 cm	0	14
	Average (0-30 cm)	**26**	**4**

Table 36. Clay % and coarse fragment % for Kandosols in Sturt Plateau biogeographic region.

Site Number	Depth	Volumetric Gravel %	Clay %
201	0-10 cm	0	6
	10-20 cm	0	6
	20-30 cm	0	6
202	0-10 cm	0	12
	10-20 cm	0	17
	20-30 cm	0	16
203	0-10 cm	0	7
	10-20 cm	0	10
	20-30 cm	0	16
204	0-10 cm	0	4
	10-20 cm	0	5
	20-30 cm	0	5
205	0-10 cm	0	5
	10-20 cm	0	6
	20-30 cm	0	6
207	0-10 cm	0	3
	10-20 cm	0	4
	20-30 cm	0	5
208	0-10 cm	0	3
	10-20 cm	0	3
	20-30 cm	0	6
209	0-10 cm	0	8
	10-20 cm	0	10
	20-30 cm	0	13
211	0-10 cm	0	9
	10-20 cm	0	10
	20-30 cm	0	15
215	0-10 cm	10	9
	10-20 cm	15	10
	20-30 cm	20	10
216	0-10 cm	5	14
	10-20 cm	6	18
	20-30 cm	6	19

Table 36. Continued

Site Number	Depth	Volumetric Gravel %	Clay %
217	0-10 cm	25	9
	10-20 cm	40	8
	20-30 cm	45	11
219	0-10 cm	0	11
	10-20 cm	0	15
	20-30 cm	0	15
221	0-10 cm	0	17
	10-20 cm	0	19
	20-30 cm	0	18
222	0-10 cm	0	25
	10-20 cm	0	20
	20-30 cm	0	20
224	0-10 cm	0	21
	10-20 cm	0	21
	20-30 cm	0	23
225	0-10 cm	2	19
	10-20 cm	5	27
	20-30 cm	5	21
226	0-10 cm	0	21
	10-20 cm	0	21
	20-30 cm	0	22
227	0-10 cm	0	16
	10-20 cm	0	19
	20-30 cm	0	19
228	0-10 cm	2	21
	10-20 cm	2	22
	20-30 cm	2	25
229	0-10 cm	0	23
	10-20 cm	0	26
	20-30 cm	0	30
231	0-10 cm	4	25
	10-20 cm	3	24
	20-30 cm	2	28

Site Number	Depth	Volumetric Gravel %	Clay %
232	0-10 cm	0	20
	10-20 cm	0	23
	20-30 cm	0	25
234	0-10 cm	20	28
	10-20 cm	15	29
	20-30 cm	20	31
235	0-10 cm	4	24
	10-20 cm	4	25
	20-30 cm	10	27
237	0-10 cm	55	14
	10-20 cm	55	17
	20-30 cm	50	18
238	0-10 cm	5	27
	10-20 cm	2	24
	20-30 cm	1	25
239	0-10 cm	1	26
	10-20 cm	1	25
	20-30 cm	1	27
240	0-10 cm	1	17
	10-20 cm	1	22
	20-30 cm	1	23
241	0-10 cm	0	26
	10-20 cm	0	25
	20-30 cm	0	26
242	0-10 cm	0	22
	10-20 cm	0	23
	20-30 cm	0	24
244	0-10 cm	30	15
	10-20 cm	35	17
	20-30 cm	45	18
246	0-10 cm	5	21
	10-20 cm	6	22
	20-30 cm	15	24

Table 36. Continued

Site Number	Depth	Volumetric Gravel %	Clay %
248	0-10 cm	0	19
	10-20 cm	0	15
	20-30 cm	0	19
249	0-10 cm	0	16
	10-20 cm	0	17
	20-30 cm	0	15
250	0-10 cm	30	15
	10-20 cm	30	18
	20-30 cm	50	17
251	0-10 cm	25	15
	10-20 cm	30	20
	20-30 cm	30	19
252	0-10 cm	15	31
	10-20 cm	20	36
	20-30 cm	20	33
253	0-10 cm	25	11
	10-20 cm	50	12
	20-30 cm	60	14
254	0-10 cm	2	20
	10-20 cm	2	21
	20-30 cm	2	21
255	0-10 cm	15	16
	10-20 cm	20	17
	20-30 cm	20	14
257	0-10 cm	0	18
	10-20 cm	0	19
	20-30 cm	0	20
258	0-10 cm	0	21
	10-20 cm	0	21
	20-30 cm	0	18
259	0-10 cm	20	21
	10-20 cm	30	18
	20-30 cm	30	24
	Average (0-30 cm)	**8**	**18**

Table 37. Clay % and coarse fragment % for Tenosols in Sturt Plateau biogeographic region.

Site Number	Depth	Volumetric Gravel %	Clay %
206	0-10 cm	0	2
	10-20 cm	0	4
	20-30 cm	0	4
210	0-10 cm	0	4
	10-20 cm	0	5
	20-30 cm	0	6
213	0-10 cm	10	10
	10-20 cm	50	10
	20-30 cm	50	13
214	0-10 cm	0	5
	10-20 cm	0	6
	20-30 cm	0	9
218	0-10 cm	15	5
	10-20 cm	35	7
	20-30 cm	35	7
220	0-10 cm	25	8
	10-20 cm	30	8
	20-30 cm	35	12
256	0-10 cm	35	10
	10-20 cm	35	13
	20-30 cm	35	12
	Average (0-30 cm)	**19**	**8**

Table 38. Clay % and coarse fragment % for Vertosols in Sturt Plateau biogeographic region.

Site Number	Depth	Volumetric Gravel %	Clay %
233	0-10 cm	0	58
	10-20 cm	0	62
	20-30 cm	0	60
236	0-10 cm	0	55
	10-20 cm	0	60
	20-30 cm	0	54
	Average (0-30 cm)	**0**	**58**

Table 39. Clay % and coarse fragment % for Hydrosols in Sturt Plateau biogeographic region.

Site Number	Depth	Volumetric Gravel %	Clay %
243	0-10 cm	0	11
	10-20 cm	1	16
	20-30 cm	10	22
245	0-10 cm	0	11
	10-20 cm	0	14
	20-30 cm	0	17
247	0-10 cm	0	10
	10-20 cm	0	12
	20-30 cm	0	13
	Average (0-30 cm)	**1**	**14**

Table 40. Clay % and coarse fragment % for Chromosols in Sturt Plateau biogeographic region.

Site Number	Depth	Volumetric Gravel %	Clay %
140	0-10 cm	0	6
	10-20 cm	0	1
	20-30 cm	5	4
141	0-10 cm	35	4
	10-20 cm	85	4
	20-30 cm	85	4
166	0-10 cm	1	5
	10-20 cm	1	3
	20-30 cm	1	5
	Average (0-30 cm)	**24**	**4**

Table 41. Clay % and coarse fragment % for Vertosols in Mitchell Grass Downs biogeographic region.

Site Number	Depth	Volumetric Gravel %	Clay %
263	0-10 cm	0	65
	10-20 cm	0	69
	20-30 cm	0	66
267	0-10 cm	0	65
	10-20 cm	0	63
	20-30 cm	0	66
271	0-10 cm	0	64
	10-20 cm	0	67
	20-30 cm	0	67
	Average (0-30 cm)	**0**	**66**

Table 42. Clay % and coarse fragment % for Kandosols in Mitchell Grass Downs biogeographic region.

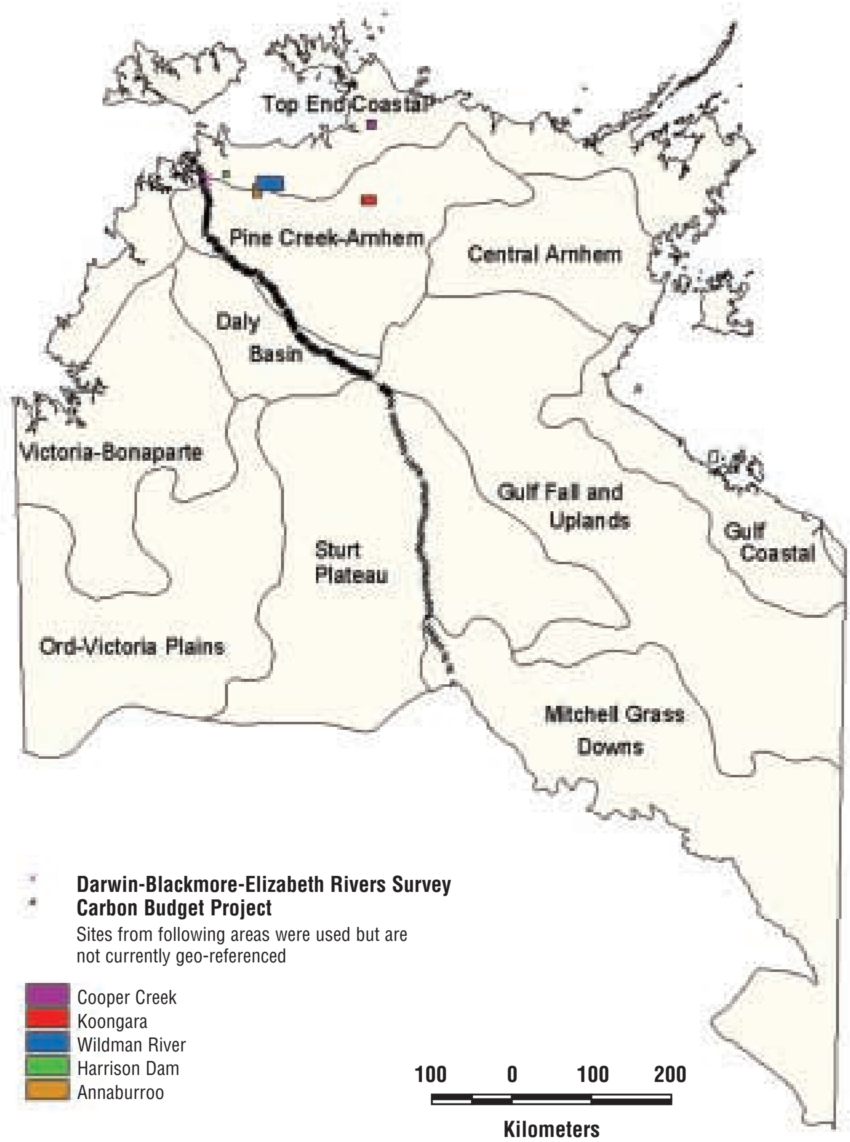
Site Number	Depth	Volumetric Gravel %	Clay %
260	0-10 cm	25	17
	10-20 cm	50	19
	20-30 cm	50	19
261	0-10 cm	0	22
	10-20 cm	0	22
	20-30 cm	0	23
262	0-10 cm	5	16
	10-20 cm	27	28
	20-30 cm	27	29
268	0-10 cm	0	11
	10-20 cm	0	14
	20-30 cm	0	14
270	0-10 cm	0	10
	10-20 cm	0	14
	20-30 cm	1	16
273	0-10 cm	0	7
	10-20 cm	0	8
	20-30 cm	0	10
279	0-10 cm	0	12
	10-20 cm	0	13
	20-30 cm	0	15
	Average (0-30 cm)	**9**	**16**

Table 43. Clay % and coarse fragment % for Tenosols in Mitchell Grass Downs biogeographic region.

Site Number	Depth	Volumetric Gravel %	Clay %
260	0-10 cm	25	17
	10-20 cm	50	19
	20-30 cm	50	19
261	0-10 cm	0	22
	10-20 cm	0	22
	20-30 cm	0	23
262	0-10 cm	5	16
	10-20 cm	27	28
	20-30 cm	27	29
268	0-10 cm	0	11
	10-20 cm	0	14
	20-30 cm	0	14
270	0-10 cm	0	10
	10-20 cm	0	14
	20-30 cm	1	16
273	0-10 cm	0	7
	10-20 cm	0	8
	20-30 cm	0	10
279	0-10 cm	0	12
	10-20 cm	0	13
	20-30 cm	0	15
	Average (0-30 cm)	**9**	**16**

ATTACHMENT C

ADDITIONAL SURVEY SITES USED FOR ESTIMATION OF PRECLEARING SOIL CARBON LEVELS IN THE NORTHERN TERRITORY



APPENDIX 3

PRE-CLEARING SOIL CARBON LEVELS IN VICTORIA

Mike Grundy
(for Webbnet Land Resource Services Pty Ltd)

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1. INTRODUCTION

This report accompanies a GIS shapefile (***Vic-oc-estimate-geo.shp***) which shows the distribution of pre-clearing soil carbon (t/ha) in the top 30 cm of soil in Victoria. The data are an estimate which involved a number of significant assumptions about data correlation based on a small number of independent sites. They are thus intended to provide an indication of potential variability in soil carbon distribution and should be considered to be highly uncertain.

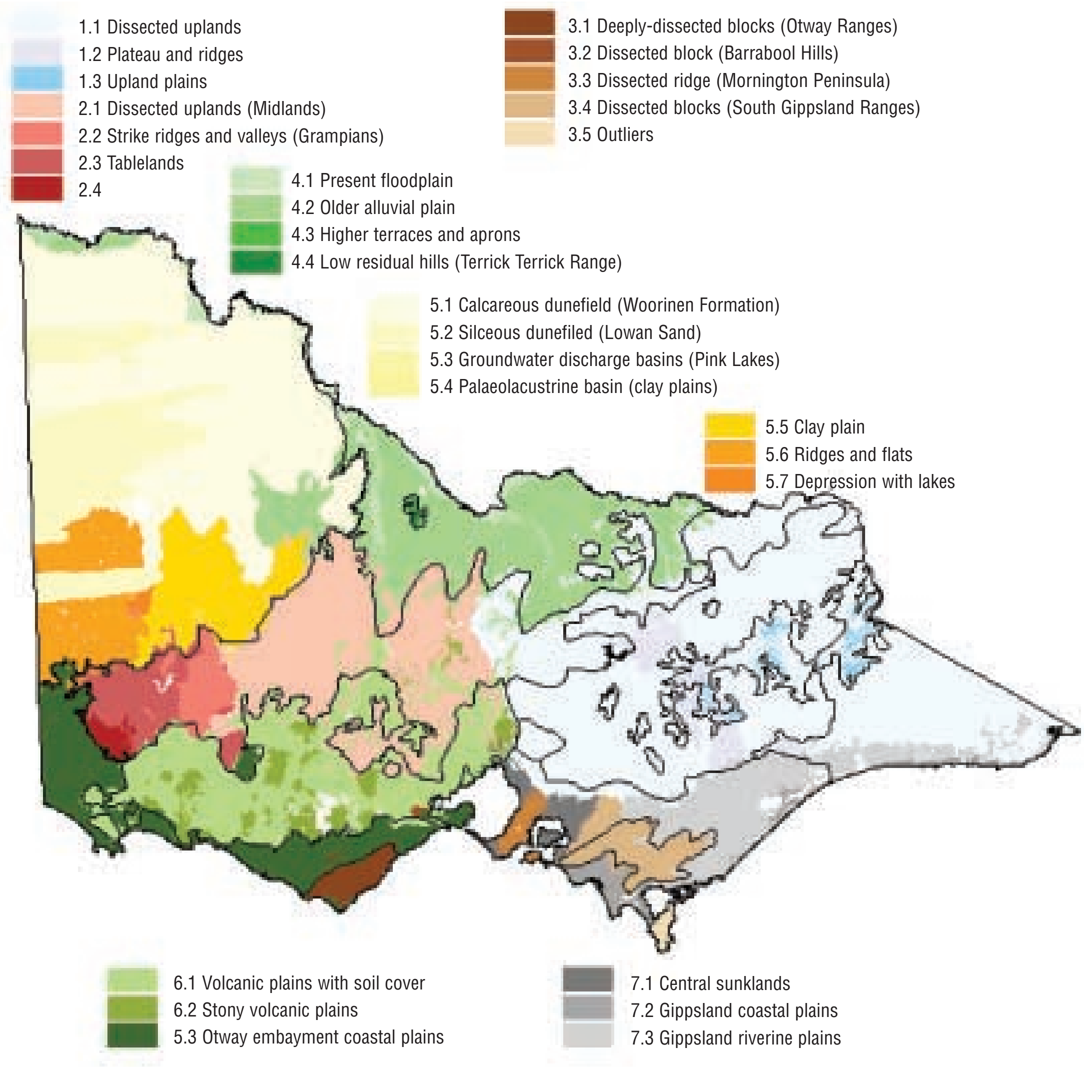

Figure 1. Distribution of Geomorphic Management Units (GMU) in Victoria.

The analysis was based on a small set of sites where soil carbon was measured in undisturbed areas or areas with limited disturbance. These data had to be manipulated in a number of ways to obtain an estimate of the weight of soil carbon to 30 cm depth. The assumptions involved and the manipulations performed are detailed below. Since there were very small site numbers and these sites did not cover the range of soil types or land systems mapped in Victoria, the data were spatially distributed by assigning the data to geomorphic management units (GMU), which are broad composite units covering Victoria (Figure 1). Use of finer scale mapping units would have created an impression of precision which was not matched by the available data. Even at this scale, a number of GMUs did not contain sites. These were assigned data based on apparent similarity to other GMUs or mapped areas in adjacent States (usually South Australia). These assumptions are also detailed below.

The end result is a distribution (Figure 2) which only broadly corresponds to South Australian and New South Wales soil carbon mapping. One reason for the discrepancies is the averaging effect produced by assigning the site data to broad mapping units. A better coverage is unlikely to be obtained without a significantly increased site data set.

The final data are provided in an attached CD-ROM. They include the GIS shapefile, an MS Excel file with the manipulated site data and graphics file of the carbon distribution in Victoria. It should be stressed that given the limitations of this analysis, the resulting spatial distribution has limited utility for analyses other than broad assessments. Any site point modelling carried out using these estimates will have a high degree of uncertainty.

The remainder of this report outlines the methods employed to produce the spatial coverage.

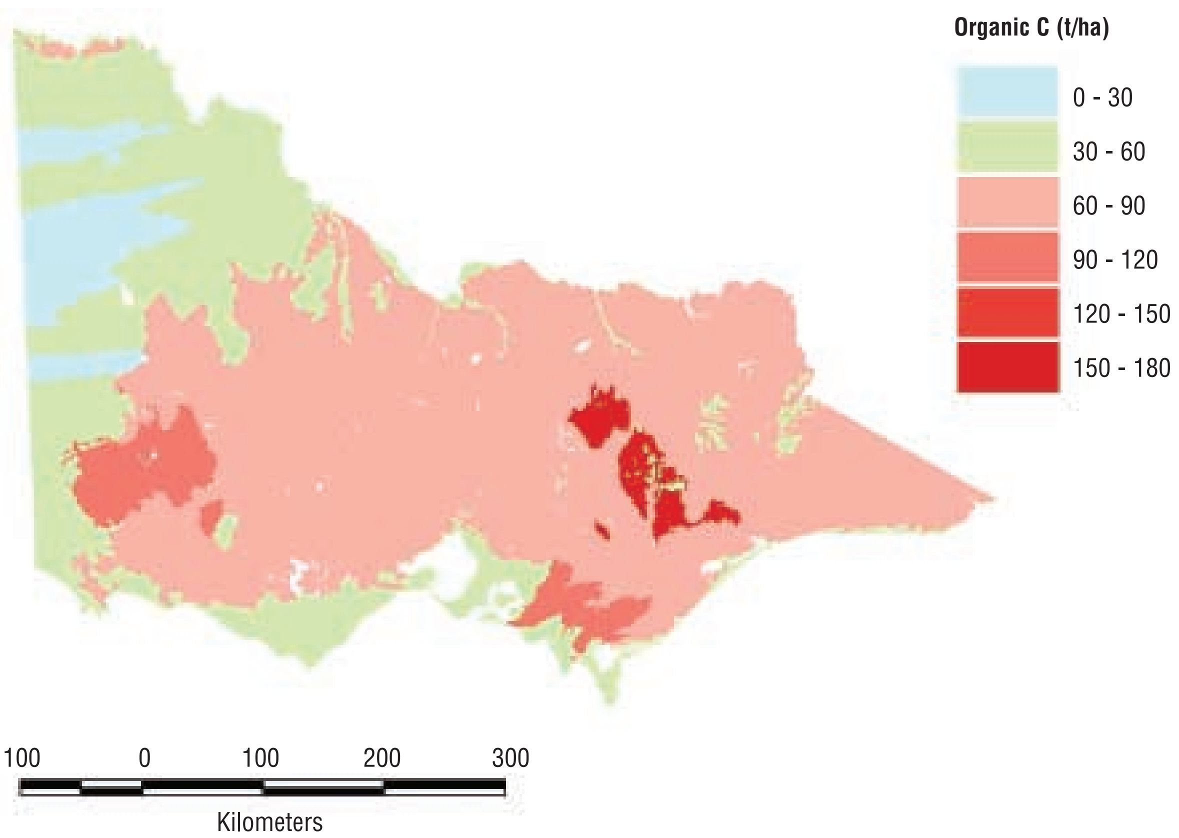

Figure 2. Distribution of pre-clearing soil carbon (t/ha) estimated for Victoria.

2. ANALYSIS OF VICTORIAN SITE DATA

Site data were provided from two sources; a set of paired site data in an MS Excel file and a set of non-paired data in an MS Access file. These data had different characteristics and required different handling. The aim was to produce a site distribution of pre-clearing soil carbon in t/ha over the top 30 cm of soil from the provided sites. None of the data were in this form and all required a number of assumptions and estimates as well as considerable data manipulation to produce the required data set.

2.1 FROM PAIRED SITES

The supplied paired site data consisted of 108 sites with locations, texture, age and organic carbon (OC). Soil depths were in increments to 20 cm. The data were derived from two MS Excel files which have been combined in the supplied MS Excel file "all vic point data.xls". From these a shape file "paired sites.shp" was created with easting, northing, depth (0.05 m) and undisturbed OC. There is no indication of units, method, or bulk density supplied with the data.

Initial analysis consisted of assuming a purely arbitrary bulk density for each depth increment (1, 1.2, 1.3, 1.3 for each of 0-5, 5-10, 10-15 and 15–20 cm increments) and calculating an initial t/ha figure. These data were then investigated to attempt to derive a measurement for the 20-30 cm layer which wasn't measured. The data were quite variable (Table 1). As an initial estimation, the assumption was made that the rate of change from 15-20 cm continues to apply to 30 cm and a multiplier of 0.83 of the 15-20 cm value was used to derive the 20-25 cm value and a similar value was used for the last 5 cm.

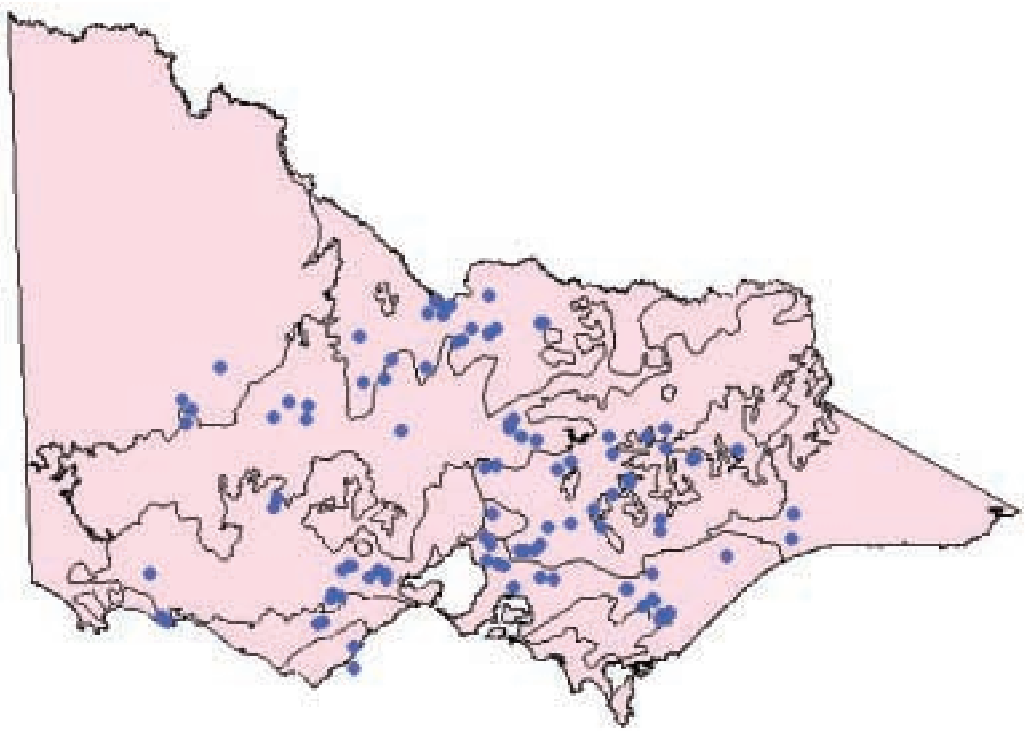

Figure 3. Location of paired sites in Victoria.

Table 1. Rate of change data measured from the paired sites. Gross outliers and missing values were removed. SD, standard deviation.

	Ratio of Lowest Layer to Top Layer		Ratio of Lowest Layer to Next Layer	
	Mean	SD	Mean	SD
Dr	32.13	8.66	77.79	16.92
Dy	37.23	25.83	80.75	18.73
Gn	41.15	18.48	96.45	75.63
Uc	40.19	18.93	72.76	17.67
Overall	38.44	22.23	83.27	41.54

The data were then summed over the 0-30 cm depth. Some sites had missing values and failed to return a summed figure; others had clear outliers which produced questionable results.

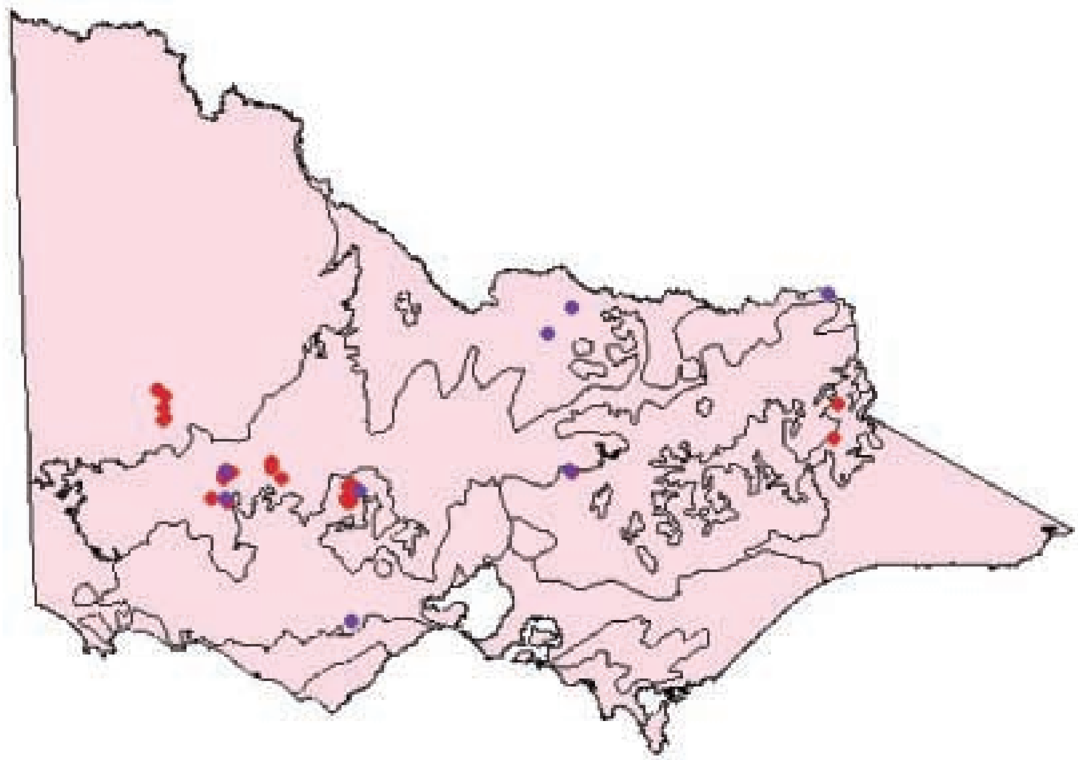

Figure 4. Location of other sites with soil carbon in Victoria (blue - undisturbed; red - limited clearing).

2.2 FROM SITES DATABASE

The sites extracted from the supplied sites MS Access database fell into two groups: undisturbed; and limited clearing. Given the paucity of observations, both were used in the analysis. The sites did not have standard depths, did not contain bulk density data or coarse fragment data and did not necessarily cover all depths. In order to derive a volumetric measurement, bulk densities were assumed as above. However, given the variation in sampling depths, the bulk density estimates could not be applied effectively to the nominated depths. The first layer sampled, regardless of depth, was assumed to have a bulk density of 1, the second 1.2 and subsequent depths, where present, 1.3. Few sites stopped measurement at the 30 cm depth. Where measurements crossed the 30 cm depth point, it was assumed that the organic carbon percentage measured for the whole sample applied to the sample for the depth up to 30 cm. Most sites had measurements to 30 cm and beyond. Three sites had incomplete (or incorrectly entered) data and had to be deleted.

When all sources of data were complete, 114 sites were available with estimated soil carbon to 30 cm depth. The distribution of these sites coloured for carbon content is illustrated in Figure 5.

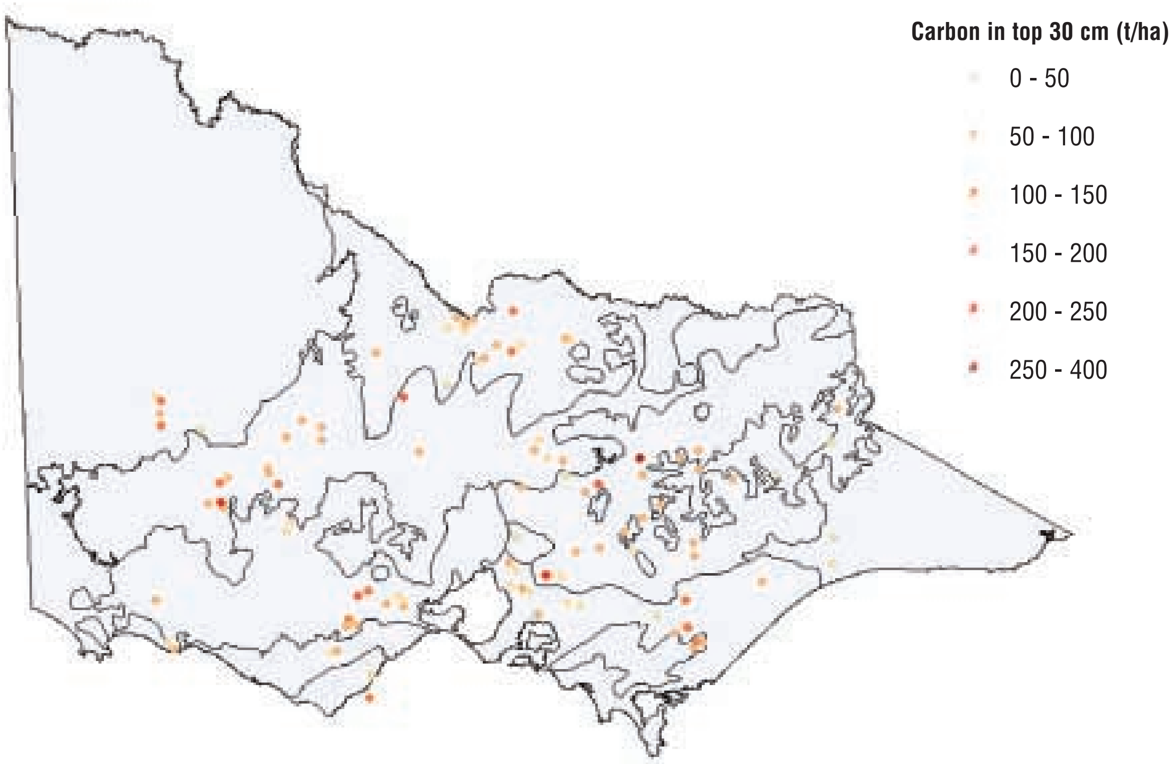

Figure 5. Distribution of pre-clearing soil carbon sites in t/ha in Victoria.

3. APPLICATION TO SPATIAL UNITS

These sites were intersected with the spatial coverage for GMUs. Not all GMUs had sites present. The distribution of sites within GMUs, site numbers, mean and standard deviation (SD) are listed in Table 2. These values were attached to the GMU coverage available for Victoria. Missing values were assigned by:

- Comparison with neighbouring State data. In particular, the distribution of carbon levels in South Australia matched reasonably closely the GMU distribution in Victoria; and
- Assuming that values within the same group of GMUs was similar.

Table 2. Carbon contents of sites found in GMUs.

GMU	Av t/ha	No Sites	SD
1.1	63	32	3583
1.2	175	3	19221
1.3	38	1	N/A
2.1	74	11	3347
2.2	105	5	7765
3.1	40	1	N/A
3.4	98	2	5706
4.1	53	4	1768
4.2	63	12	3331
5.5	65	7	2980
6.1	71	11	3448
6.2	76	6	5028
6.3	48	2	1424
7.1	51	7	2879
7.3	79	8	4258

The final distribution of carbon for each GMU in Victoria is illustrated in Table 3. South Australian values from adjacent areas were assigned to GMU 5.2 and GMU 5.1 (siliceous and calcareous dunefields, 28 t/ha and 45 t/ha, respectively) - these appeared to provide a clear geographic match. GMU 5.6 (ridges and flats) was assigned 45 t/ha which provided a match with some areas in South Australia. Other assigned data (GMUs with no samples) can be seen in Table 3. In each case, the value was derived from similar GMUs. There are major discrepancies between the estimated Victorian data and those submitted for New South Wales. Notable differences included:

- The dissected uplands of north-east Victoria which had 32 sites had clearly lower values than similar areas in New South Wales. This difference is the main cause for the visible discrepancy between New South Wales and Victoria;
- The present Murray River floodplain which had 4 sites had an average value of 53 t/ha; much lower than the 125 assigned to similar and adjacent units in New South Wales; and
- The older alluvial plain (12 sites; mean 63 t/ha) was significantly lower than the similar unit in New South Wales.

No adjustment was made to these areas since site data were available in these cases. It is probable, however, that the values presented are underestimated.

There were no data to support the data assumptions. The resulting spatial distribution of pre-clearing soil carbon, therefore, should only be seen as an indicative illustration of carbon variation. Any analytical use would require significantly more data points.

Table 3. Pre-clearing carbon content for each Victorian GMU. GMUs with no sites had values assigned as described on page 120.

GMU	Av t/ha	No Sites	SD
1.1	62.81	32	35.8
1.2	174.75	3	192.2
1.3	37.47	1	
2.1	74.39	11	33.5
2.2	104.76	5	77.6
2.3	100	0	
2.4	100	0	
3.1	40.12	1	
3.2	40	0	
3.3	40	0	
3.4	97.77	2	57.1
3.5	40	0	
4.1	53.13	4	17.7
4.2	62.61	12	33.3
4.4	60	0	
5.1	45	0	
5.2	28	0	
5.5	65.48	7	29.8
5.6	45	0	
5.7	65	0	
6.1	70.5	11	34.5
6.2	75.7	6	50.3
6.3	48.3	2	14.2
7.1	51.05	7	28.8
7.2	50	0	
7.3	78.5	8	42.6

APPENDIX 4

PRE-CLEARING SOIL CARBON LEVELS IN QUEENSLAND

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SUMMARY

The flux in soil carbon associated with land use change is a key component of Australia's greenhouse gas balance. The AGO is developing methods to estimate the extent of the flux using soil carbon change modelling supported by paired site observations. This appendix reports on work commissioned by the AGO of the Queensland Department of Natural Resources (QDNR) which estimates the level of soil carbon which existed prior to land clearing as part of a national inventory of existing data. The project consists of the supply of spatial data in a form appropriate for use by the AGO and of an analysis of that data which estimates the spatial extent of carbon levels across the State prior to clearing.

QDNR did not collect new data although a considerable quantity of non-digital data was captured for the analysis. The spatial estimation was based on a stratification of the State based on major soil types within IBRA polygons. Consequently, the project produced a polygon coverage of soil types (based on the Australian Soil Classification) which used the best soils mapping available for any area in the State and a spatial site database which includes soil carbon levels to 30 cm where the soil was sampled from uncleared areas. The polygon coverage includes approximately 430,000 individual polygons and the site database includes 3,369 sites. The available soil data contained significant data gaps and deficiencies and a series of assumptions were made to produce a set of sites that contained volumetric soil carbon to 30 cm. These assumptions and calculations are detailed in the report.

The spatial estimation was derived by overlay of the site coverage over the polygons. Where one or more sites fell within a polygon, the mean value was ascribed to the polygon. For other polygons, the mean values of soil carbon observed in polygons of similar dominant soil type within the same IBRA region was used. This approach produces an approximate result at best but was supported by data showing the variation in soil carbon between soil types and IBRA regions.

The main output of the project was a set of ARCVIEW GIS files which were submitted to the AGO on CD. The scripts and original polygon data are not included (they are many gigabytes in size) but are available to the AGO if required. A series of tables summarising some of the results of the analysis is included in the appendix.

1. INTRODUCTION AND BACKGROUND

The flux in soil carbon associated with land use change is a key component of Australia's greenhouse gas balance. The AGO is developing methods to estimate the extent of the flux using soil carbon change modelling supported by paired site observations. The information collection for this work is stratified within the boundaries of the Interim Bio-geographic Regionalisation of Australia (IBRA Version 4, Thackway & Cresswell 1995). A key background measurement underlying this analysis is the level of soil carbon prior to significant land use change. An initial estimate of this level is being obtained from State agencies based on existing data. To this end, the Queensland Department of Natural Resources (QDNR) was commissioned to supply an analysis of pre-clearing carbon levels as part of a national inventory of existing data. While this analysis could be conducted with a number of approaches, for national consistency there were a number of guidelines for the task. In addition, the task required estimation of the weight of soil carbon to a depth of 30 cm and documentation of all decisions required. The project was required to produce the following deliverables:

1. A report on the project including:
   - tables and maps of pre-clearing soil carbon estimates for each IBRA polygon in Queensland; and
   - documentation of process, assumptions, calculations and limitations;
2. A compact disk with:
   - a GIS dataset with the spatial estimate of pre-clearing soil carbon; and
   - the point data underlying the derivation of soil carbon estimates.

1.1 METHODOLOGY

1.1.1 Overall

The approach used the available site data as the most reliable estimate of pre-clearing soil carbon at the site and as one of a population of observations which could be used to characterise polygons dominated by similar soils within IBRA regions. Since most soil mapping has been conducted to determine the spatial variation of soil types and a limited number of easily observable soil features, they are likely to have limitations as predictors of soil carbon variation. That limitation is likely to increase as scale broadens – so the analysis used the finest scale polygon data available for any part of the State.

The spatial estimation was derived by overlay of the site coverage over the polygons. Where one or more sites fell within a polygon, the mean value was ascribed to the polygon. For other polygons, the mean values of soil carbon observed in polygons of similar dominant soil type within the same IBRA region was used

1.1.2 Spatial Base

A spatial coverage of the major soils within each IBRA polygon was compiled from the Queensland land resource survey database (SALI-UMA). There is no single soil survey coverage of Queensland so all existing projects were extracted and evaluated as to the most accurate coverage at each point in the State. In some cases, this included high intensity surveys; at the other extreme, the only soil coverage is the Atlas of Australian Soils. The polygons were interpreted for major soils expressed in the Australian Soil Classification (ASC) at Order level and then overlaid on the IBRA polygons. The end result was a patchwork of surveys of various scales within each IBRA region. Figure 1 shows the spatial extent and project scale of the datasets used. The full coverage contains some 430,000 polygons and is very large. This was the data used for the analysis. For subsequent use of the data, the polygon layer was dissolved where similar ASC soil types occur. This coverage is included in a CD submitted to the AGO and includes some 56,000 polygons.

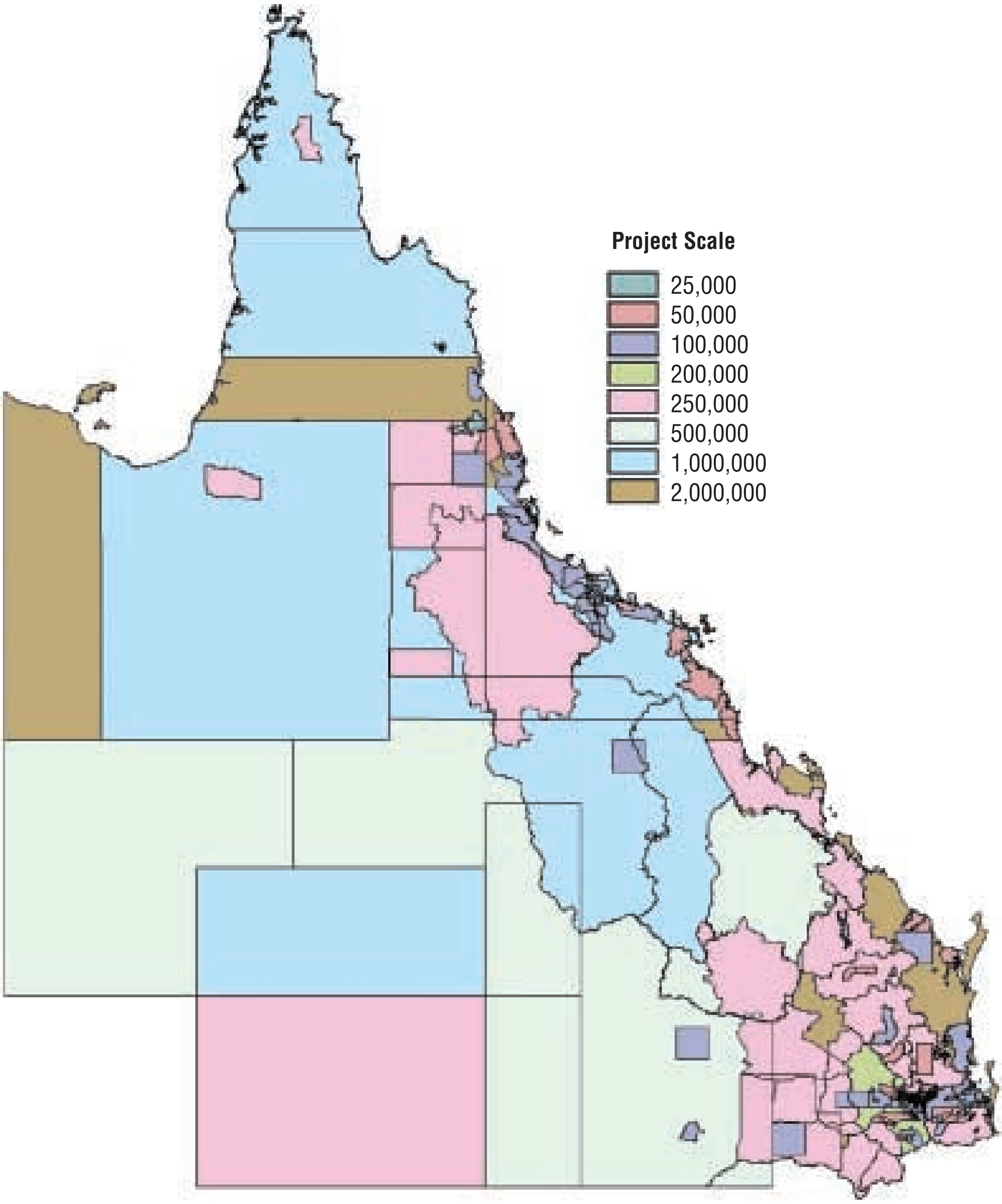

Figure 1. The extent and project scale of land resource surveys and other soil surveys over Queensland.

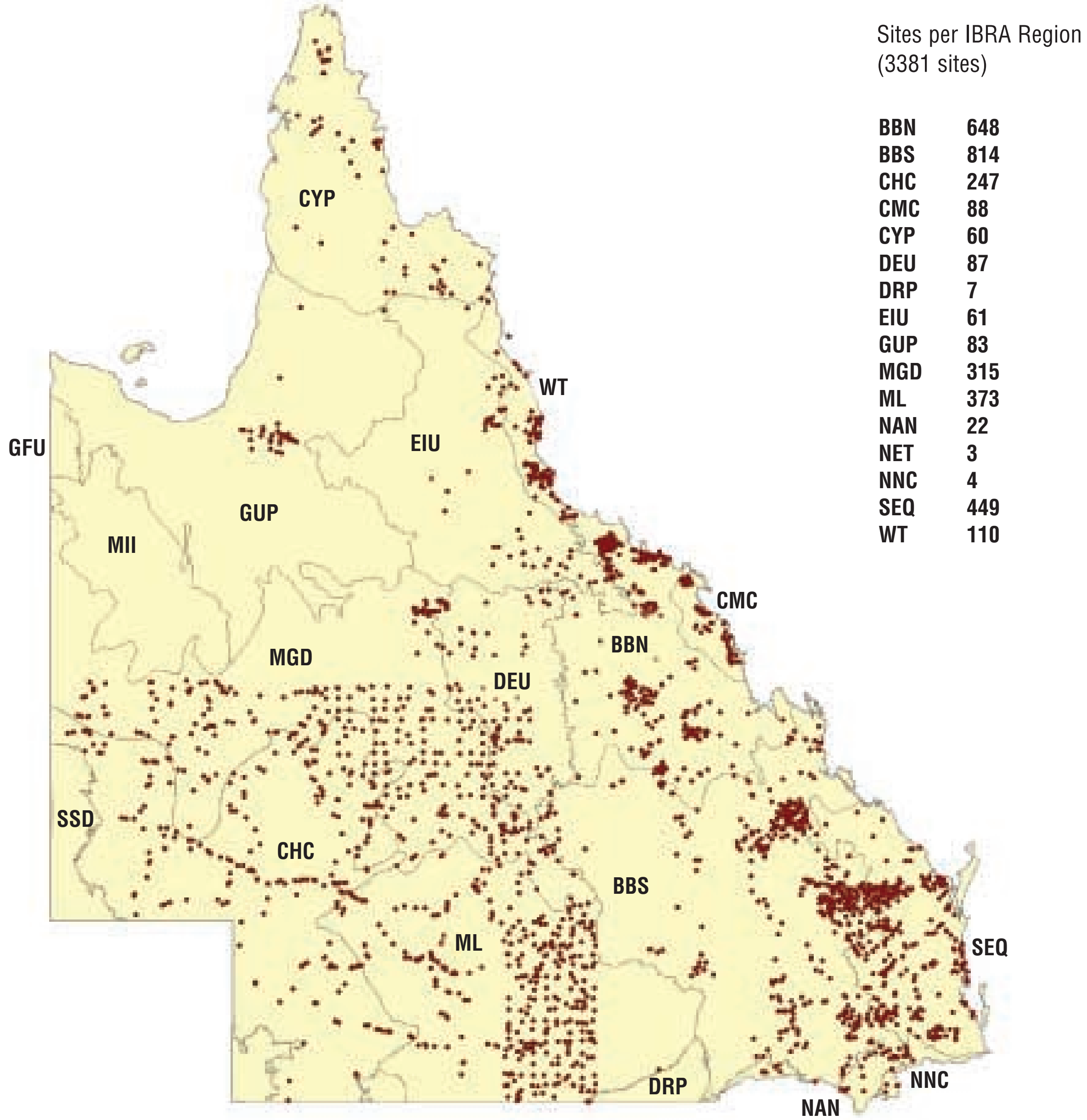

Figure 2. The distribution of sites across Queensland IBRA regions.

1.1.3 Development of the Site Data

The analysis used site data from the DNR land resource survey database (SALI SITE and SALI CHEM), data collected by CSIRO in Queensland as well as data collected during other research and inventory activities. Many of the latter sites were not digital and significant time was spent in capturing these data. Sites with zero or limited disturbance were included in the analysis. Where no disturbance data were available, it was assumed that the recording of tree vegetation for the site was evidence that it met the criteria. In addition, a search of published literature was undertaken to provide a small number of additional sites and data on carbon to depth and bulk density. Figure 2 represents the distribution of the sites within Queensland IBRA regions.

There were a number of significant limitations in the data for the purpose. These included:

- almost complete lack of bulk density measurement;
- paucity of measurements below 10 cm; and
- poor coverage of site data from undisturbed sites especially in the north west and to a lesser extent in the central highlands.

While the extent of coverage could not be improved without more field work, a number of analytical approaches were adopted to deal with the lack of bulk density and organic carbon to depth and thus produce a set of sites with imputed values of carbon quantities per unit area. These are detailed in Attachment A. With these methods, each site included the volume of soil carbon to 30 cm.

1.1.4 Measurement Corrections

Soil carbon flux modelling is based on organic carbon measurements derived from combustion in a LECO furnace. The method used to derive soil carbon values in the analysed sites was the Walkley and Black method (1934) which has evolved over time in various laboratories and thus produced results which have varied over time. These differences have been measured in a series of analytical trials in the CSIRO Adelaide Laboratories (Skjemstad *et.al.* 2000) and in the Brisbane QDNR Laboratories (Lyons, pers. comm.). The site data includes analyses from the QDNR Biloela Laboratory which was not included in the Skjemstad *et.al.* (2000) study. Discussions with local staff suggest that the Brisbane adjustment factors would apply (B. Cowie pers.comm.). Based on these studies, the site organic carbon values were adjusted based on the date of analysis (Table 1).

Table 1. Correction factors used to convert Walkley-Black measurements to equate to LECO combustion measurements.

Laboratory	Year	Adjustment factor
Queensland DNR Brisbane and Biloela Laboratories	Prior to and including 1988	1.35
	After 1988	1.05
Townsville CSIRO Laboratories	Prior to and including 1968	1
	1968 - 1984	1.24
	After 1984	1
Canberra CSIRO Laboratories	All years	1
Brisbane CSIRO Laboratories	Prior to and including 1968	1.32
	After 1968	1

1.1.5 Attribution of Polygons with Carbon Values

The final spatial product includes approximately 56,000 polygons covering Queensland (Figure 3). Each polygon has a value for pre-clearing soil carbon in t/ha to 30 cm allocated. This was done in three stages.

Initially, an average value for each soil order within each IBRA polygon was derived from the soil site data. Where this combination existed in the spatial coverage (i.e. IBRA region and soil order), the value was assigned to each polygon in the coverage. This was the default coverage.

In some IBRA regions where the soil site data were sparse, no site data exist for a large number of polygons and in many IBRA polygons, some ASC orders have not been sampled. In these cases, values are assigned from the nearest IBRA polygon with the ASC present or from similar soil orders within the IBRA polygon.

Finally, in polygons dissolved for common ASC orders, where one or more sites exist, the average value of the sites within the polygon was allocated to the polygon. These are likely to be the most precise spatial points in the total coverage and while the overall result is likely to be a good average estimate across soil types within IBRA regions, the spatial variation inherent in the site data is also captured to some extent.

The overall result was then checked against published detailed studies for anomalies and general trends.

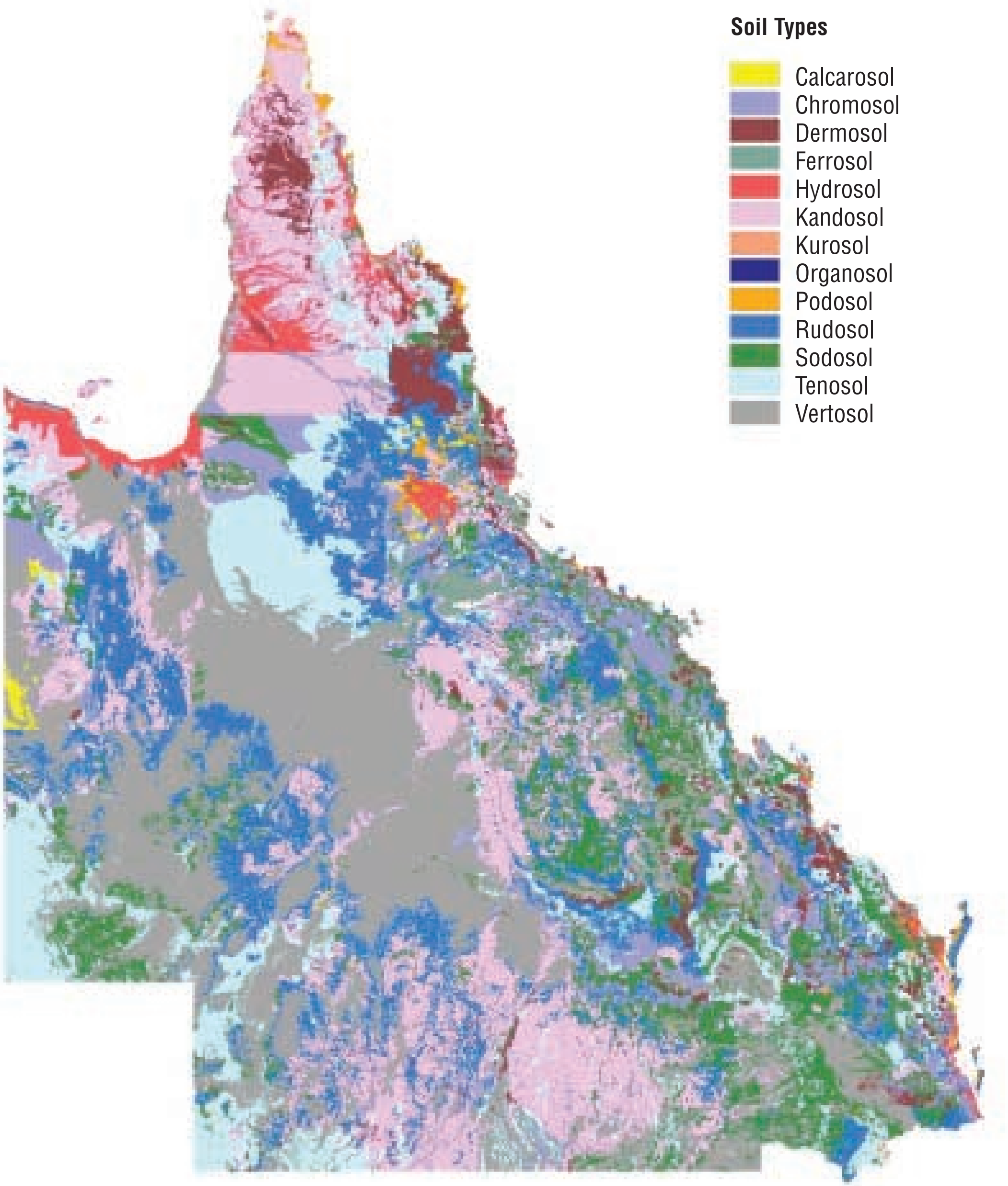

Figure 3. The distribution of soil types across Queensland (Australian Soil Classification).

2. RESULTS

The main output of the project was a set of ARCVIEW GIS files which accompany this appendix on CD. They include shape files (*.shp) of the soil carbon polygons and soil sites with values of soil carbon to 30 cm and legend files (*.avl) to facilitate viewing the data in ARCVIEW. The scripts and original polygon data are not included (they are many gigabytes in size) but are available to the AGO if required. Similarly, the original site data with the uncorrected values and significant data gaps is not included but can be supplied if required.

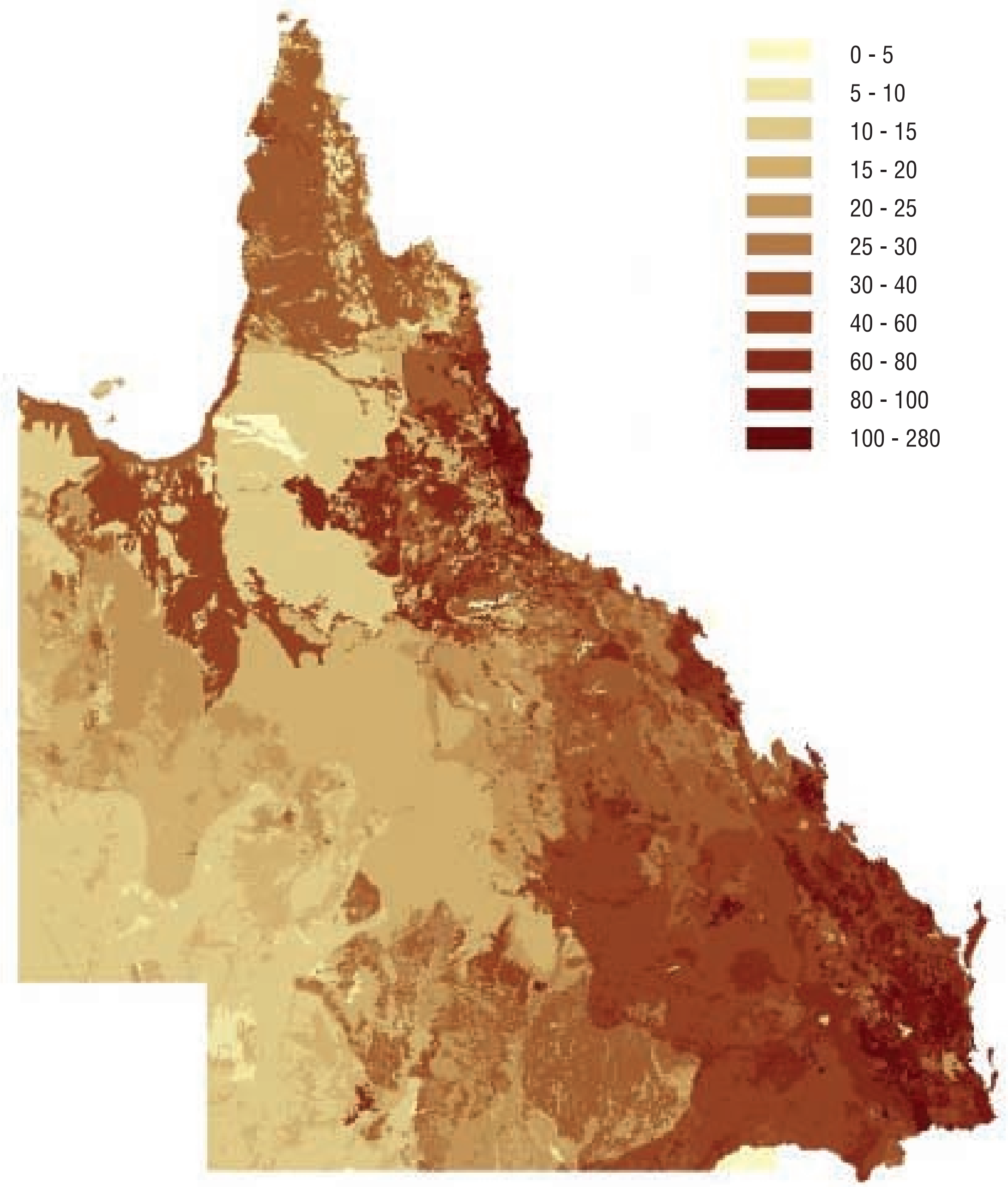

Figure 4. Soil carbon (t/ha) derived from site observations from uncleared areas.

2.1 SPATIAL DISTRIBUTION OF SOIL CARBON

The distribution of soil carbon which results from the analysis reflects the IBRA stratification (Figure 4). Highest values are in the wetter areas of the State both in terms of received rainfall and evaporative potential. While values in the west are uniformly low, there is variation between soil types.

The distribution also reflects the distribution of site data and the availability of finer scale mapping. Large areas of the State have a very low density of observations and the resultant spatial distribution needs to be treated with caution. This deficiency is exacerbated in areas where the only polygon mapping is the Atlas of Australian Soils or one of the broader land system studies. In situations where there is a reasonable distribution of sites but the polygonal mapping is broad, the analysis has produced results which are on average accurate but which do not reflect local variation.

Other limitations to the analysis arise from the nature of the input data. The site data came from a wide range of sources. Very few of them were collected with the modelling of spatial soil carbon as an aim. In many cases, the sampling was biased towards agriculturally significant soils, low sloping areas and areas with established agricultural land uses. Similarly, the polygonal mapping was not intended to produce a surface of soil carbon when the various studies were compiled. The extent to which the polygons delineate soil carbon variation depends on the correlation between the mapped entity (e.g. soil type or land system) and soil carbon. Review of the sites available for this analysis indicates that correlation does exist but that the relationship is imprecise. There are a number of other drivers for soil carbon. Given the time and resource limitations, the analysis was not able to use the environmental drivers for soil carbon in an explicit modelling framework. That would produce better surfaces but would require some purposive sampling and refinement of environmental layers.

2.1.1 Site Carbon Values

The average soil carbon (in t/ha) for each region illustrates the effect of rainfall, temperature and soil substrate variation in initial soil carbon (Table 2).

A selection of IBRA regions illustrating the distinctions between regions is shown in Figure 5. It is clear that there are substantial differences between regions corresponding to the change in climate. There are also substantial differences between soil types in those regions where organic carbon levels are relatively high. In the far western drier areas typified by the channel country region, soil carbon levels are uniformly low. In most eastern regions, soil carbon levels in Ferrosols tend to be much higher than for other soil orders. In the uncleared State, these soils often support vine forest or similarly high vegetative biomass where organic matter levels are high and there is active nutrient cycling. Clearing substantially reduces these levels. Other soil orders which tend to have higher soil carbon levels are the Dermosols and Hydrosols.

Table 2. Average organic carbon (OC) level (t/ha) in the top 30 cm of soil for Australian Soil Classification (ASC) orders within IBRA regions (where site values were available).

IBRA Code	ASC code	OC	IBRA Code	ASC Code	OC
					t/ha
BBN	CA	40.13	**BBS**	CH	43.86
	CH	34.61		DE	76.97
	DE	40.13		FE	116.49
	FE	46.67		KA	62.27
	HY	47.10		KU	26.61
	KA	36.96		RU	57.10
	PO	23.31		SO	56.31
	RU	55.93		TE	43.07
	SO	35.74		VE	58.73
	TE	23.53	**CMC**	CH	50.70
	VE	38.56		DE	68.76
CHC	CH	17.55		HY	57.02
	DE	15.86		KA	35.69
	KA	19.53		7PO	18.52
	RU	18.16		RU	106.44
	SO	12.26		SO	55.28
	TE	12.83		TE	96.94
	VE	15.22		VE	80.67
CYP	CH	24.45	**DEU**	CA	20.31
	DE	34.08		CH	16.66
	FE	136.34		HY	5.24
	HY	31.26		KA	22.44
	KA	33.27		RU	40.62
	SO	23.57		SO	27.93
	TE	10.95		TE	20.31
	VE	43.68		VE	22.97
DRP	SO	32.92	**GUP**	CH	14.77
EIU	CH	32.05		DE	18.32
	DE	39.61		FE	9.31
	FE	73.35		KA	10.10
	HY	84.16		CH	11.30
	KA	19.58	**MGD**	KA	22.13
	RU	63.06		RU	21.27
	SO	74.49		SO	17.78
	TE	15.76		TE	35.69
	VE	38.41		VE	19.93

Table 2. Average organic carbon (OC) level (t/ha) in the top 30 cm of soil for Australian Soil Classification (ASC) orders within IBRA regions (where site values were available). continued

IBRA Code	ASC code	OC
ML	CH	24.69
	DE	25.95
	KA	30.17
	RU	29.04
	SO	27.16
	TE	17.52
	VE	21.46
NNC	VE	197.37
SEQ	CH	86.66
	DE	108.47
	FE	132.66
	HY	88.67
	KA	68.28
	KU	43.70
	PO	60.66
	RU	70.18
	SO	50.01
	TE	94.40
	VE	96.58

IBRA Code	ASC Code	OC
		t/ha
NAN	CH	83.99
	RU	66.61
	SO	58.65
	TE	70.27
	VE	52.85
NET	KU	41.82
	SO	29.67
	TE	38.02
WT	CH	75.44
	DE	75.28
	FE	101.10
	HY	116.33
	KA	52.50
	PO	64.30
	RU	23.22
	SO	46.92
	TE	66.56
	VE	95.59

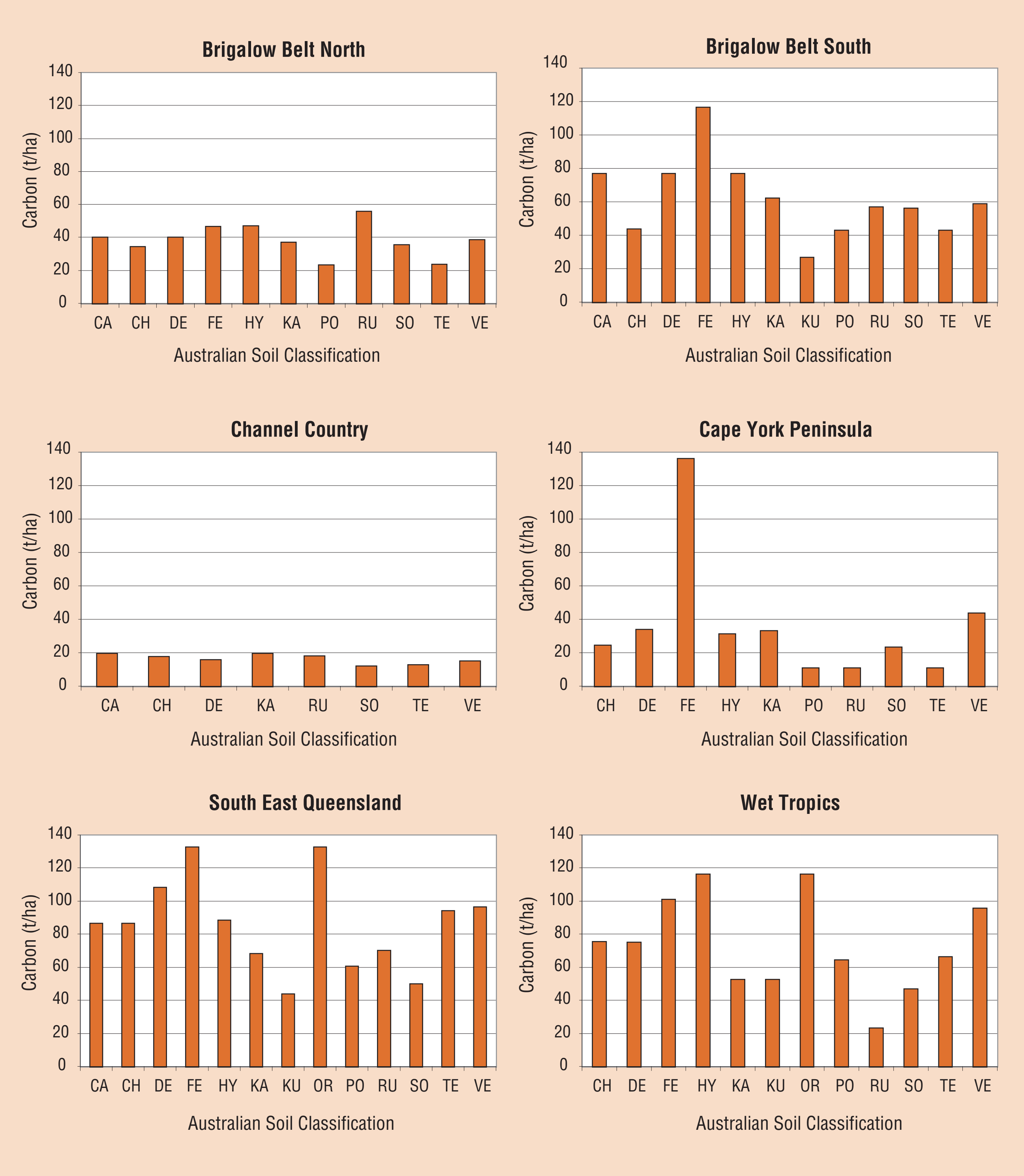

Figure 5. Average soil carbon in the top 30 cm of soil (t/ha) for ASC orders in selected IBRA regions.

3. SOIL CARBON QUANTITIES

The analysis identified approximately 5.6 billion tonnes of soil carbon across Queensland. The distribution of this carbon across IBRA regions is illustrated in Figure 6. The data included on the attached CD will allow more extensive analysis of the Queensland situation.

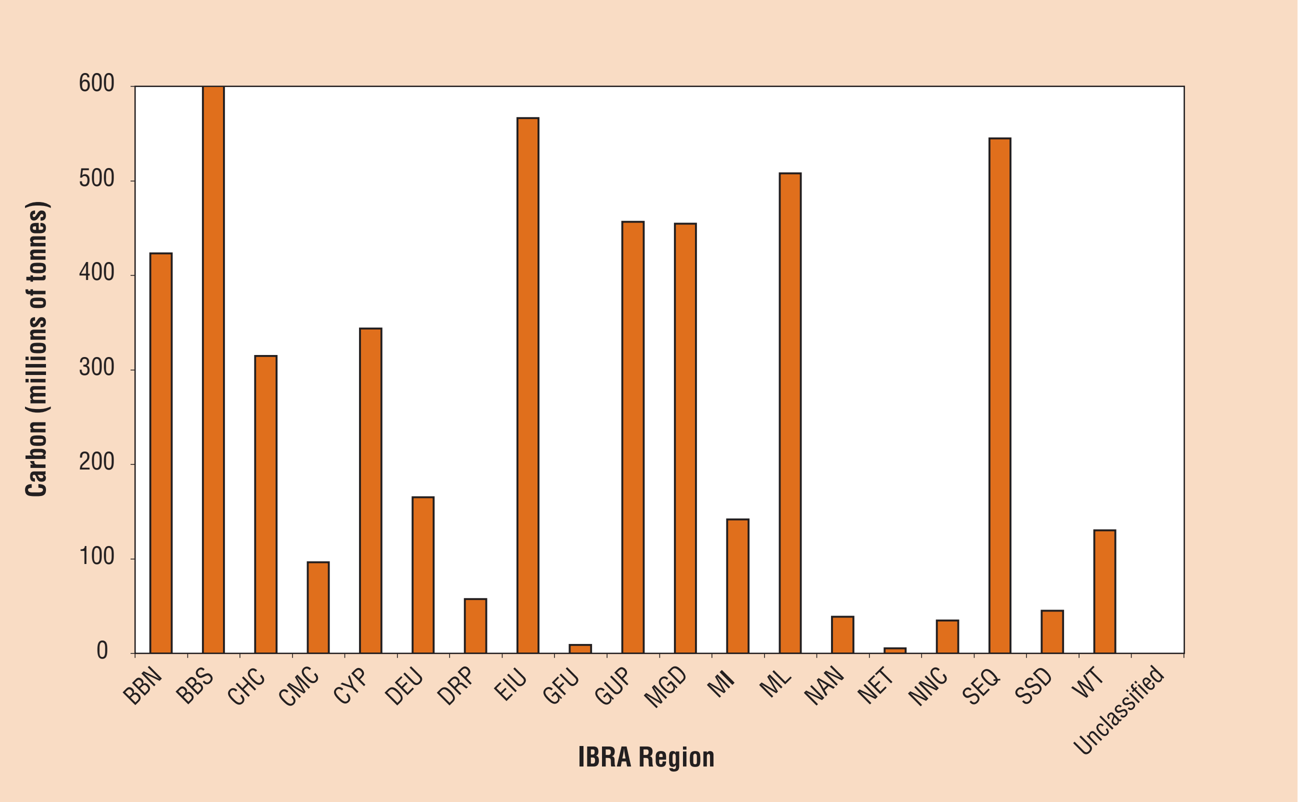

Figure 6. Total weight of soil carbon in IBRA regions in Queensland (from uncleared areas).

4. DATA AND INFORMATION SOURCES

Land Resource Survey reports and data covering over 100 surveys (see Attachment B).

Various incomplete or unreported studies – data was captured from field sheets or supplied by scientist.

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Skjemstad, J.O., Spouncer, L.R. & Beech, T.A. (2000). *Carbon Conversion Factors for Historical Soil Carbon Data.* National Carbon Accounting System Technical Report No. 15, September 2000.

Standley, J., Hunter, H.M., Thomas, G.A., Blight, G.W. & Webb, A.A. (1990). *Tillage and crop residue management affect vertisol properties and grain sorghum growth over seven years in the semi-arid sub-tropics: 2. Changes in soil properties.* Soil and Tillage Research 18, 367-388.

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Walkley, A. & Black, L.A. (1934). *An examination of the Dgtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method.* Soil Science 37:29-38.

Walker, B., Kerridge, P.C. & Webb, A.A. (1979). *Soil fertility studies for pastures in the Mackay wet tropical coast of Queensland.* Tropical Grasslands 13, 110-122.

Warrell, L.A., Thompson, W.P. & Cannon, M.G. (1984). *Soils of the Kairi Research Station, Atherton Tableland.* Queensland Department of Primary Industries Bulletin QB84006. ISSN 1055-221X.

Webb, A.A. (1977). *Studies on the gilgaied clay soils (Ug 5.2) of the Highworth Land System in central Queensland: 2. Glasshouse assessment of plant nutrient status.* Queensland Journal of Agricultural and Animal Sciences 34(1), 67-74.

Webb, A.A. & Dowling, A.J. (1984). *Characterisation of the basaltic clays of central Queensland: 1. Clays of the Oxford and Waterford Land Systems - Profile descriptions and analytical results.* Section 3: Ghindi-Rollerston area. Agricultural Chemistry Branch, Queensland Department of Primary Industries.

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ATTACHMENT A

IMPUTED SITE DATA

1. IMPUTING CARBON VALUES TO DEPTH

There were two assumptions underlying the analysis of site data.

For a small number of QDNR sites and in many CSIRO sites, the OC value was for a smaller proportion of the surface than 10 cm (e.g. 3, 5 or 8 cm). Where there were no other measurements in deeper layers, we have assumed that the proportional value applies across the top 10 cm. In sites where deeper data were available, a proportional change was assumed between the surface and the deeper value so that, in general, a smaller value of carbon was assigned to the lower part of the top 10 cm.

Of more significant concern was the absence of any measurements below 10 cm in most sites. The approach was based on an analysis of the trends in the sites where deeper measurements were available. Table 3 illustrates the relationship between values of soil carbon in the top 10 cm to those in the 10-20 cm layer based on soil type as classified in the Great Soil Group classification and Table 4 as classified at a high level in the Northcote system. No similar analysis was attempted for the Australian Soil Classification (ASC) although each site was classified to order level in the classification. It was considered that a classification made at the time of survey was more reliable for this purpose.

Table 3. Average and standard deviation of ratios of soil carbon in the top 10 cm to carbon in the 10-20 cm layer for each Great Soil Group classification in the QDNR soil site data base.

GSG	Average Ratio 10 to 20	SD	Number of Sites
GP	0.56054	0.236043	6
RBE	0.56226	0.131894	10
SH	0.580434	0.19587	19
BP	0.581381	0.034902	2
HG	0.59058	0.095809	3
P	0.596464	0.116871	7
K	0.598929	0.187008	11
SDS	0.615557	0.14643	70
SS	0.640268	0.188565	8
RP	0.643755	0.191076	12
E	0.651605	0.180243	5
NKB	0.663725	0.250559	4
A	0.672016	0.217579	7
YP	0.672844	0.392587	23
GC	0.675822	0.219276	49
NSG	0.678308	0.229413	36
PS	0.682844	0.180151	7
BE	0.689468	0.16088	41
BC	0.699437	0.190459	21
YE	0.708027	0.155402	11
RE	0.808284	0.266408	9
ES	0.857143	0.202031	2
Overall	**0.663533**	**0.315259**	**417**

Table 4. Average and standard deviation of ratios of soil carbon in the top 10 cm to carbon in the 10-20 cm layer for each high level subdivision in the Northcote classification in the QDNR soil site data base.

Profile Type	Average Ratio 10 to 20	SD	Number of Sites
Dy	0.616433	0.23137	159
Uf	0.645264	0.228068	20
Uc	0.653806	0.174715	16
Ug	0.685714	0.195298	114
Gn	0.693351	0.214425	49
Um	0.736279	0.171252	13

Table 5. Average and standard deviation of ratios of soil carbon in the top 10 cm to carbon in the 10-20 cm layer for each IBRA region.

IBRA	Decode	Average	SD	Count
CMC	Central Mackay Coast	0.525864	0.176183	26
BBN	Brigalow Belt North	0.653245	0.190754	152
BBS	Brigalow Belt South	0.674869	0.267647	90
SEQ	South East Queensland	0.677924	0.2425	66
WT	Wet Tropics	0.687126	0.653834	59
DEU	Desert Uplands	0.75		1
ML	Mulga Lands	0.761302	0.202055	7
MGD	Mitchell Grass Downs	0.790844	0.126957	16

A similar analysis of the site data was undertaken using IBRA polygons (Table 5). While there were some trends in changes within soil types, the ratios were remarkably similar and the trends which were evident did not change in a predictable fashion based on texture. The IBRA analysis, however, indicated a significant difference between eastern and western regions in the decline in soil carbon with depth. Consequently, it was resolved to use a value of 0.66 for eastern IBRA regions and 0.75 for the west. A lookup table reflecting this was created to produce values for the 20-30 cm layer (Table 6).

Table 6. Look up table for 10-20 cm soil carbon values as a proportion of 0-10 cm values.

IBRA Region	Ratio of Imputed 10-20 cm Layer to Measured Surface Layer
Brigalow Belt North	0.66
Cape York Peninsula	0.66
Central Mackay Coast	0.66
Channel Country	0.75
Darling Riverine Plains	0.75
Desert Uplands	0.75
Einasleigh Uplands	0.66
Mitchell Grass Downs	0.75
Mulga Lands	0.75
Nandewar	0.66
New England Tableland	0.66
NSW North Coast	0.66
South Brigalow	0.66
South Eastern Queensland	0.66
Wet Tropics	0.66

Table 7. Average and standard deviation of ratios of soil carbon in the top 10 cm to carbon in the 20-30 cm layer for each IBRA region.

IBRA	Decode	Average	SD	Number
WT	Wet Tropics	0.459272	0.550588	19
SEQ	South East Qld	0.627903	0.30343	29
Overall		0.565995	0.396176	56

Of the QDNR spatial sites, only some 56 had values in the 20-30 cm range (Table 7). These did not provide enough examples to subdivide the sample, so a global ratio of 0.5 of measured surface values was used for all sites.

The end result was a set of sites with organic carbon values to 30 cm.

2. IMPUTING BULK DENSITY VALUES

Virtually no bulk density values which are required to convert measured organic carbon values to quantity per unit area are available for the spatial sites. A survey of published bulk density data augmented by measured values available through personal communication was used to assemble data for uncleared sites to base estimates for the sites. Pedo-transfer functions often based on measured organic carbon is routinely used to estimate bulk density in Queensland. However, this was considered to introduce a significant amount of circularity; the measured amount of organic carbon varies as bulk density varies. Consequently, a value was estimated from the measured sites for all orders in the ASC. Data for more than a small number of sites were only available for Vertosols, Dermosols, Ferrosols, Sodosols and Chromosols. Even among these sites, any overall imputed value is a gross simplification. Nonetheless, the imputed values allowed a calculation of carbon contents which can be modified where measured values are available. The full list of imputed values is detailed in Table 8.

Table 8. Look up table of bulk density values used in calculating carbon quantities per unit area.

Australian Soil Classification	0-10 cm	10-20 cm	20-30 cm
DE	1.10	1.20	1.30
OR	1.25	1.35	1.35
TE	1.25	1.35	1.35
OR	1.25	1.35	1.35
VE	1.00	1.20	1.40
VE	1.00	1.20	1.40
CH	1.40	1.50	1.50
DE	1.10	1.20	1.30
DE	1.10	1.20	1.30
DE	1.10	1.20	1.30
SO	1.35	1.50	1.60
FE	1.10	1.20	1.30
TE	1.25	1.35	1.35
CA	1.25	1.35	1.35
CH	1.40	1.50	1.50
VE	1.00	1.20	1.40
KA	1.25	1.35	1.35
HY	1.25	1.35	1.35
HY	1.25	1.35	1.35
PO	1.25	1.35	1.35
FE	1.10	1.20	1.30
CA	1.25	1.35	1.35
RU	1.25	1.35	1.35
RU	1.25	1.35	1.35
CH	1.40	1.50	1.50

Australian Soil Classification	0-10 cm	10-20 cm	20-30 cm
CH	1.40	1.50	1.50
OR	1.25	1.35	1.35
NSG	1.25	1.35	1.35
PO	1.25	1.35	1.35
PO	1.25	1.35	1.35
DE	1.10	1.20	1.30
CA	1.25	1.35	1.35
CH	1.40	1.50	1.50
CA	1.25	1.35	1.35
VE	1.00	1.20	1.40
KA	1.25	1.35	1.35
CA	1.25	1.35	1.35
CH	1.40	1.50	1.50
CA	1.25	1.35	1.35
SO	1.35	1.50	1.60
SO	1.35	1.50	1.60
SO	1.35	1.50	1.60
HY	1.25	1.35	1.35
TE	1.25	1.35	1.35
SO	1.35	1.50	1.60
CA	1.25	1.35	1.35
VE	1.00	1.20	1.40
DE	1.10	1.20	1.30
KA	1.25	1.35	1.35
CH	1.40	1.50	1.50
no entry	1.25	1.35	1.35

ATTACHMENT B

LAND RESOURCE SURVEYS AND OTHER SOIL SURVEYS USED IN THIS ANALYSIS

Code	Project Title	Scale
3MC	Resource Survey of Three Moon Creek North Burnett QLD	25000
ABC	Land Resources of the Central Burnett Region	250000
ABN	North Burnett Land Resource Survey	250000
ABS	Land Resources of the South Burnett Region	250000
ACR	Land Resources of the Cooyar Rangelands	50000
AGW	Soil Survey of the Sandstone Walloons	100000
AGWF	Soil Survey of the Sandstone Walloons - Freestone	25000
AGWJ	Soil Survey of the Sandstone Walloons - Junabee	25000
ARD	Auburn River Dam Agricultural Suitability Assessment	50000
ASA	Land Resources Survey of Basaltic Soils Pittsworth QLD	25000
ATG	Land Management Field Manual - Crows Nest QLD	300000
ATLAS	The Atlas of Australian Soils	2000000
AWA	Land Resources Survey and Assessment of WARLUS Part 1	250000
BAB	Developing Sustainable Natural Resource Management Systems for Bundaberg	50000
BAT	Resource Assessment of Batavia Downs QLD	250000
BBC	Wet Tropical Coast Study - North Queensland - Babinda/Cairns Area	50000
BER	Soil Survey - Elliot River to Bowen Molongle Creek to Elliot River	100000
BRB	Land Resources Survey of the Burdekin Right Bank QLD	100000
BRCL	Burnett River Coalstoun Lakes Land Resource Area	50000
BRL	Soils of the Lower Burdekin River Barratta Creek - Haughton River Area	100000
BSA	Survey of the Soils of the Lower Burdekin ValleyNorth QLD	100000
BVL	Brisbane Valley Land Resources Assessment	50000
BWA	Land Resources Survey and Assessment of WARLUS Part 2	1000000
CBW	Soils and Agricultural Suitability Assessment of the Coastal Burnett-Wide Bay Region	100000
CCL	Land Resources and Evaluation of the Capricornia Coastal Lands Broadsound Shire QLD	250000
CIS	Evaluation and Planning of Ceratodus Upper Burnett Irrigation Potential	50000
CTI	Wet Tropical Coast Study - North Queensland - Cardwell/Tully/Innisfail Area	100000
CWA	Land Resources Survey and Assessment of WARLUS Part 4	500000
CYP	Soil Survey and Agricultural Suitability of Cape York Peninsula	900000
DLR	Preliminary Assessment and Survey of Land Degradation in the Dalrymple Shire QLD	250000
DWA	Land Resources Survey and Assessment of WARLUS Part 3	500000
EDD	Land Inventory of the Eastern Downs Area Darling Downs South QLD	200000
EDS	Soil survey of the Eastern Darling Downs	50000
EDSCL	Soil and suitability of Clifton shire	50000
EDSWK	Soil and suitability of Warwick township area	50000
EIL	Soil Survey of the Emerald Irrigation Left Bank	25000
EIR	Land Resources of the Emerald Irrigation Area Right Bank QLD	25000
ETD	Elphinstone-Talgai Study Area Darling Downs	30000
FLN	Land Resources Survey and Assessment of the Upper Flinders River Irrigation Area	250000

Code	Project Title	Scale
FWA	Land Resources Survey and Assessment of WARLUS Part 5	500000
GDR	Resource Assessment and Evaluation of the Goodar 100 000 sheet Waggamba Shire QLD	100000
GRT	Land Inventory of the Granite and Traprock Areas South East QLD	250000
HLS	Horticultural Land Suitability Study - Sunshine Coast Southeast Queensland	100000
HTC	Survey of the Burdekin River Irrigation Area - Haughtons Central	25000
HTN	Survey of the Burdekin River Irrigation Area - Haughtons North	25000
HTS	Survey of the Burdekin River Irrigation Area - Haughtons South	25000
HWA	Land Resources Survey and Assessment of WARLUS Part 6	500000
IMC	Land Resources Survey of the Burdekin River Irrigation Area - Inkerman Central Section	25000
IMW	Land Resources Survey of the Burdekin River Irrigation Area - Inkerman West Section	25000
ITTG	Soil Survey of the Inglewood Talwood Tara and Glenmorgan Regions QLD	253440
JFD	Soil Survey of the Burdekin Irrigation Area (BRIA) - Jarvisfield Section	25000
KAL	Land Resources Survey of Kalbar ACL-126 Sheet South East QLD	25000
KCM	Land Resources Survey and Evaluation of the Kilcummin Area QLD	100000
LAK	Soils and Soil Landscapes of the Lakeland Downs Area QLD	100000
LDL	Land Resources Assessment of Land Degradation in the Lockyer Catchment	100000
LDR	Soil Survey of the Burdekin River Irrigation Area - Leichhardt Downs Relift QLD	25000
LOC	Soil Survey of the Lockyer Valley	50000
MAJCK	Land Resources of the Major Creek Area North Queensland	100000
MCD	Central Downs Land Management Field Manual	250000
MCL	Mackay Sugar Cane Land Suitability Study	50000
MDIA	Soils and Land Suitability of the Mareeba-Dimbulah Irrigation Area North Queensland	25000
MFM	Moreton Land Management Manual	250000
MGR	Soil Survey of Riparian Lands Between Gayndah and Munduberra	50000
MHB	Developing Sustainable Natural Resource Management Systems for Maryborough	50000
MIL	Land Resources Inventory and Assessment of the Miles Area.	253440
MJA	Wet Tropical Coast Study - North Queensland - Mossman-Julatten Area	100000
MLG	Burdekin River Irrigation Area - Mulgrave Section	25000
MMT	Land Resources Survey of the Moonie Millmerran and Tara Regions	250000
MRE	Survey of the Millaroo Extension Area	25000
MSA	Evaluation of Agricultural Land Suitability in the Moreton Shire	100000
MVL	Land Resources Survey of the Mayvale Land System Gulf of Carpentaria	250000
NHC	Land Resources Survey of the Burdekin River Irrigation Area - Northcote Section	25000
NLH	Soil Survey of the Burdekin River Irrigation Area - Leichhardt Downs	25000
PCS	Plane Creek Sugar-Cane Land Suitability Study	50000
PSS	Proserpine Integrated Land Use Study	50000
RAV	Land Assessment and Land Management - Dry Tropics - Ravenshoe-Mt Garnet Area	100000
RBO	Burdekin Right Bank Overview	50000
ROM	Land Resources Roma Resource Mapping	100000

Code	Project Title	Scale
SAT	Land Resources of the Einasleigh/Atherton Dry Tropics	250000
SEQ	LOGAN - Land Resource Assessment South East Queensland 2001	25000
SEQ	ALBERT - Land Resource Assessment South East Queensland 2001	25000
SEQ	BEECH - Land Resource Assessment South East Queensland 2001	25000
SEQ	KILCOY- Land Resource Assessment South East Queensland 2001	25000
SEQ	MARY - Land Resource Assessment South East Queensland 2001	25000
SGI	St George Irrigation Project	100000
SLK	Land Resources Survey of the Burdekin - Selkirk Area	25000
SRM	Stanthorpe-Rosenthal Land Management Manual	250000
TAB	Soils and Land Suitability of the Atherton Tablelands North Queensland	50000
TAR	Land Resources Assessment and Evaluation of Agricultural Land in the Taroom Shire	250000
TVB	Investigation into the Irrigation Suitability of Teviot Brook Area Boonah QLD	100000
WTC	Wet Tropical Coast - North Queensland - Ingham and Herbert River Section	100000
ZAA	Soil Landscapes of Brisbane and South East Environs	100000
ZAT	Soils and Land Use of the Brisbane and Beenleigh Areas	1000000
ZAV	Soil Survey of the Boonah-Beaudesert Area	63360
ZAZ	Soils and Land Use in the Kurrawa Area	100000
ZBA	Land Resources of the Balonne/Maranoa Area QLD	500000
ZBX	Soil Survey of the Northern Portion of the Parish of East Prairie Darling Downs QLD	31680
ZCQ	Soils Survey of the Nogoa-Belyando Area QLD	1013760
ZDD	Lands of the Dawson-Fitzroy Area Queensland	500000
ZDK	Survey of the Isaac-Comet Area QLD	1013760
ZEB	Survey of the Burdekin-Townsville Region Soils	1000000
ZED	Soil Survey of the Northern Section of the Townsville Coastal Plains QLD	100000
ZEG	Soil Survey of the Leichhardt-Gilbert Area QLD	1000000
ZMN	Survey of the Mitchell-Normanby Area Cape York Peninsula	2000000
ZTB	Land Resources Assessment of the Soils and Land Use in the Toowoomba Area QLD	95040

APPENDIX 5

PRE-CLEARING SOIL CARBON LEVELS IN SOUTH AUSTRALIA

Leonie Spouncer, Jan Skjemstad and Richard Merry
(CSIRO Land and Water)

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1. BACKGROUND

The flux in soil carbon associated with land use change is a key component of Australia's greenhouse gas balance. The AGO is developing methods to estimate the extent of the flux using soil carbon change modelling supported by observations from key sites nationally. The information collection for this work is stratified within the Interim Bio–geographic Regionalisation of Australia (IBRA Version 4, Thackway & Cresswell 1995). A key background measurement underlying this analysis is the level of soil carbon prior to significant land use change ie. soil carbon in pre-cleared conditions.

There is some urgency in developing an initial table/map of soil carbon contents for major soils in the IBRA regions to support the estimation of the 1990 baseline of carbon fluxes in Australia. Data on the pre-cleared soil carbon is required for each IBRA cell to allow modelling of changes due to changed land use.

A table for each IBRA cell on soil carbon estimation is to be produced with supporting documentation and will be updated as new, improved data becomes available.

2. OBJECTIVES

- Identify the major soils in each IBRA cell in South Australia and provide a spatial estimate using the most appropriate data available;
- Allocate soil carbon content (kg/ha 0-30 cm) for major soil groups/spatial units; and
- Provide supporting documentation on decisions.

3. IBRA REGIONS OF SOUTH AUSTRALIA

Figure 1 shows the IBRA regions in South Australia and an estimate of area cleared from 1980-1990. It is possible that the amount of clearing shown on this map has been over-estimated since South Australia suffered some of its worst bushfires during that period. Despite the uncertainty in the given clearing data, this map along with anecdotal evidence suggests that the majority of the clearing has taken place in IBRA regions 1, 2, 35 and 36. Consequently, the other IBRA regions in South Australia have not been included in this study. IBRA region 37, where clearing is indicated in Figure 1, is national park and rangeland where clearing is not known to have occurred. The amount of clearing per IBRA region is shown in Table 1. Although the total clearing between 1980 and 1990 appears to exceed 200,000 ha, this represents < 5% of the total clearing over this period across Australia.

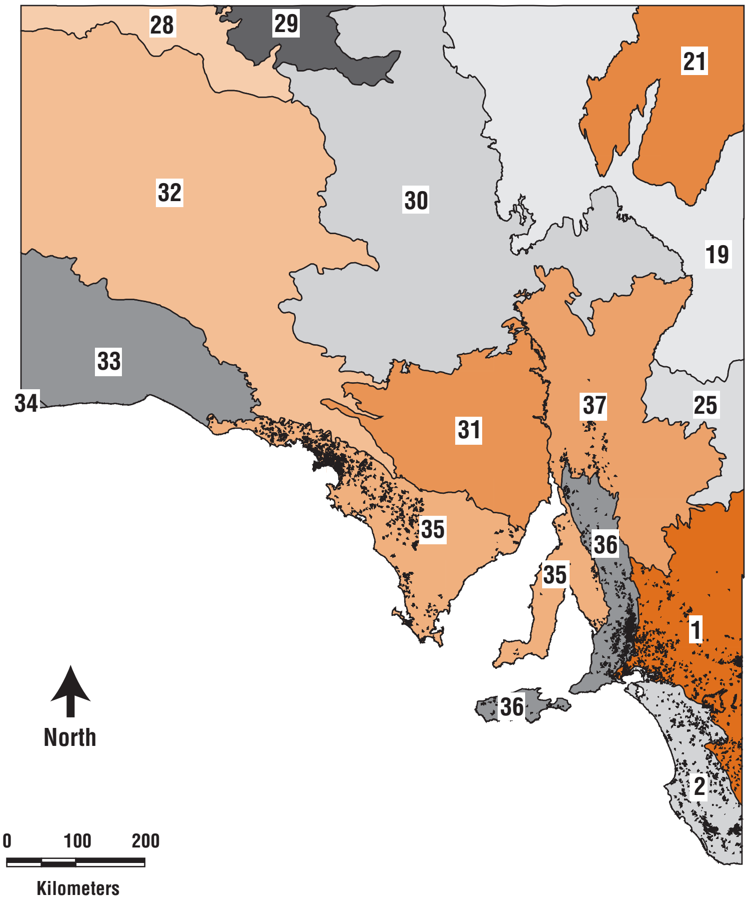

Figure 1. IBRA Regions of South Australia showing estimated clearing.

Table 1. Amount of clearing in South Australia by IBRA region.

IBRA Region	Clearing	Percentage of Total Clearing in Australia
	ha	%
1	65,410	1.5
2	41,497	1.0
35	83,686	1.9
36	23,848	0.5

4. MAJOR SOILS BY IBRA REGIONS

Because of the relatively small proportion of clearing that has occurred post 1970 in South Australia, the Atlas of Australian Soils (1:2,000,000) was considered adequate for the purposes of this study.

To estimate major soils in each IBRA region, the digital Atlas of Australian Soils was spatially over-layed with the IBRA regions (Figure 2).

From this, the areas of dominant soils at subdivision level of the Principal Profile Form (PPF) of the Factual Key (Northcote, 1979) within each IBRA region were estimated and these are presented in Table 2. The major soil types found in IBRA regions 1 and 35 are calcareous earths (Gc) and in IBRA regions 2 and 36 are duplex soils (Dr, Dy).

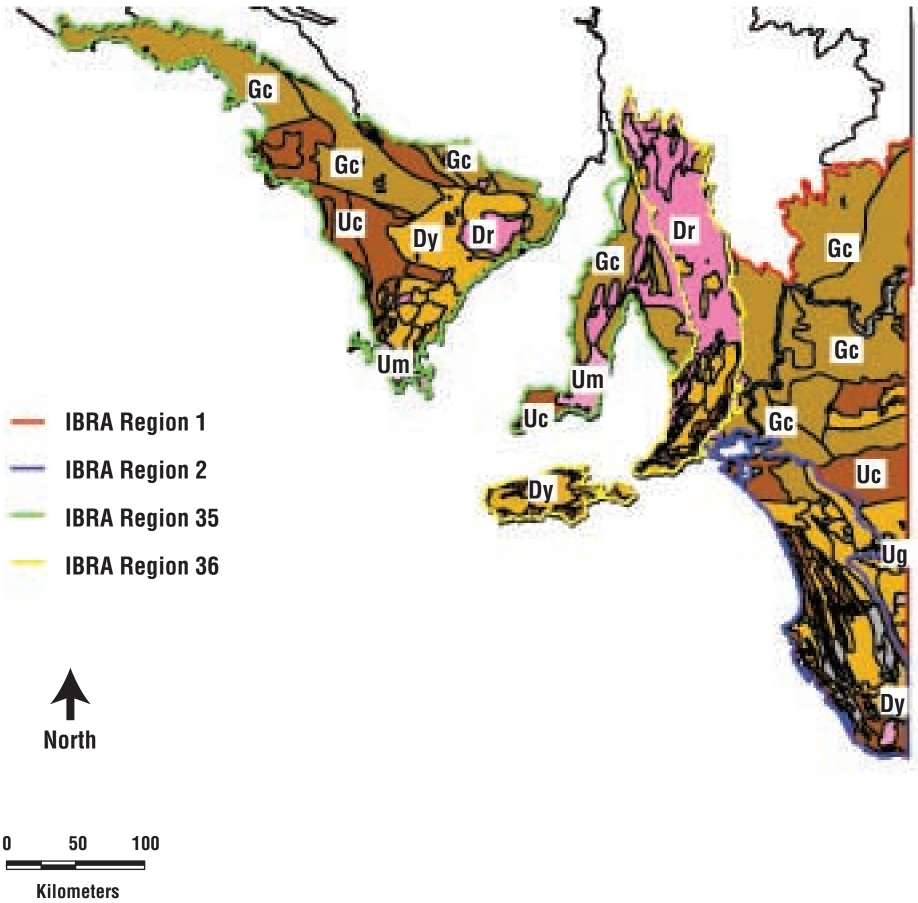

Figure 2. Dominant soils by factual key subdivision in each IBRA region.

Table 2. Area and percentage area of soils by IBRA region.

IBRA	PPF	Description	Area	Area
			%	km^2
1	Gc	Calcareous Earths	71	34,194
1	Uc	Sand Soils	11	5,252
1	Ug	Cracking Clay Soils	5	2,012
1	Dy	Yellow Duplex Soils	11	4,856
2	Gc	Calcareous Earths	6	1,355
2	Uc	Sand Soils	27	6,112
2	Ug	Cracking Clay Soils	13	2,742
2	Um	Loamy Soils	4	751
2	Dy	Yellow Duplex Soils	48	10,777
35	Gc	Calcareous Earths	43	26,126
35	Uc	Sand Soils	24	14,428
35	Um	Loamy Soils	5	2,801
35	Dr	Red Duplex Soils	10	5,677
35	Dy	Yellow Duplex Soils	16	10,014
36	Gc	Calcareous Earths	4	1,010
36	Uc	Sand Soils	8	1,972
36	Um	Loamy Soils	4	900
36	Dr	Red Duplex Soils	49	11,669
36	Dy	Yellow Duplex Soils	31	7,221

5. SOIL PROFILE DATA

Geo-referenced soil profiles with carbon analysis to 30 cm and profile descriptions were retrieved from the CSIRO national database (34 pasture, 38 undisturbed sites) and PIRSA database (159 cropping, 95 pasture sites). The locations of these sites and other CSIRO sites (31 undisturbed sites) are shown in Figure 3. The latter 31 sites had carbon data for the top 10 cm only. Some PIRSA sites were not included due to lack of profile description. These were located on Kangaroo Island and the Yorke Peninsula. Due to the lack of undisturbed sites with carbon data, it was decided to investigate the possibility of utilising all sites including those under cropping. In particular the western part of IBRA 35 had been sparsely sampled but it was clear that this region had been relatively heavily cleared and that some carbon data would be required.

There were two serious limitations with the undisturbed sites: low numbers (69) and poor geographical distribution. Figure 3 shows that there were no undisturbed sites for western IBRA 1, northern IBRA 2, central IBRA 36 and western IBRA 35. Because of these limitations and the knowledge that pasture has much less impact on soil carbon than cropping, it was decided early to combine the data from pasture and undisturbed sites. The appropriateness of this approach could not be adequately tested with the limited data available and it is hoped that as more data from undisturbed sites becomes available this bulking will not be necessary.

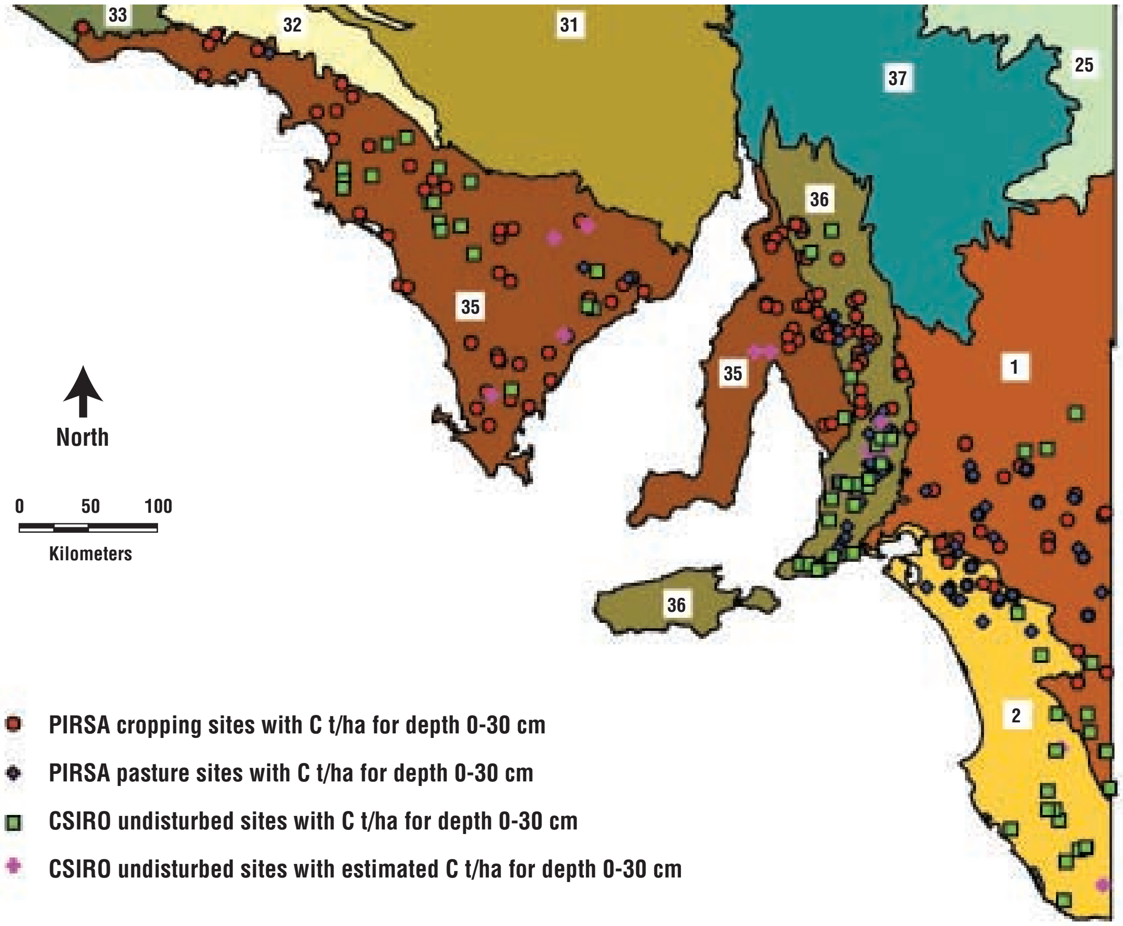

Figure 3. Soil sampling sites.

6. METHODS OF ESTIMATING BULK DENSITY

Georeferenced measured bulk density data for soils are very sparse in South Australia. To facilitate the estimation of bulk density, a pedo-transfer function was derived from the relationship of soil carbon with bulk density (Figure 4) on 35 South Australian pasture sites (Merry, 2000, pers. comm.).

The equation derived was:
$BD = 1.608 - 0.0872\%C$ (r^2=0.46, n=105)

The pedo-transfer function was very similar to that derived by Skjemstad (1999, pers. comm.) for Queensland and NT soils. The 95% prediction interval for this regression was approximately ± 0.25 g/cc.

To test this method against other approaches, bulk densities for the PIRSA sites were also estimated using a default set (McKenzie *et.al.*, 2000) which estimates bulk density for A and B horizons by soil type. Carbon in t C/ha calculated by both methods was very similar (Figure 5), particularly at the lower end. Only three sites at the extremity of the high end showed significant deviation with the McKenzie *et.al.* (2000) approach giving higher bulk densities. These three sites were under native vegetation and it would be expected that the bulk densities would tend to be low. Although it is not possible to test which of these two approaches is correct, we would have greater confidence in the lower values. It was decided to use the derived pedo-transfer function throughout this study.

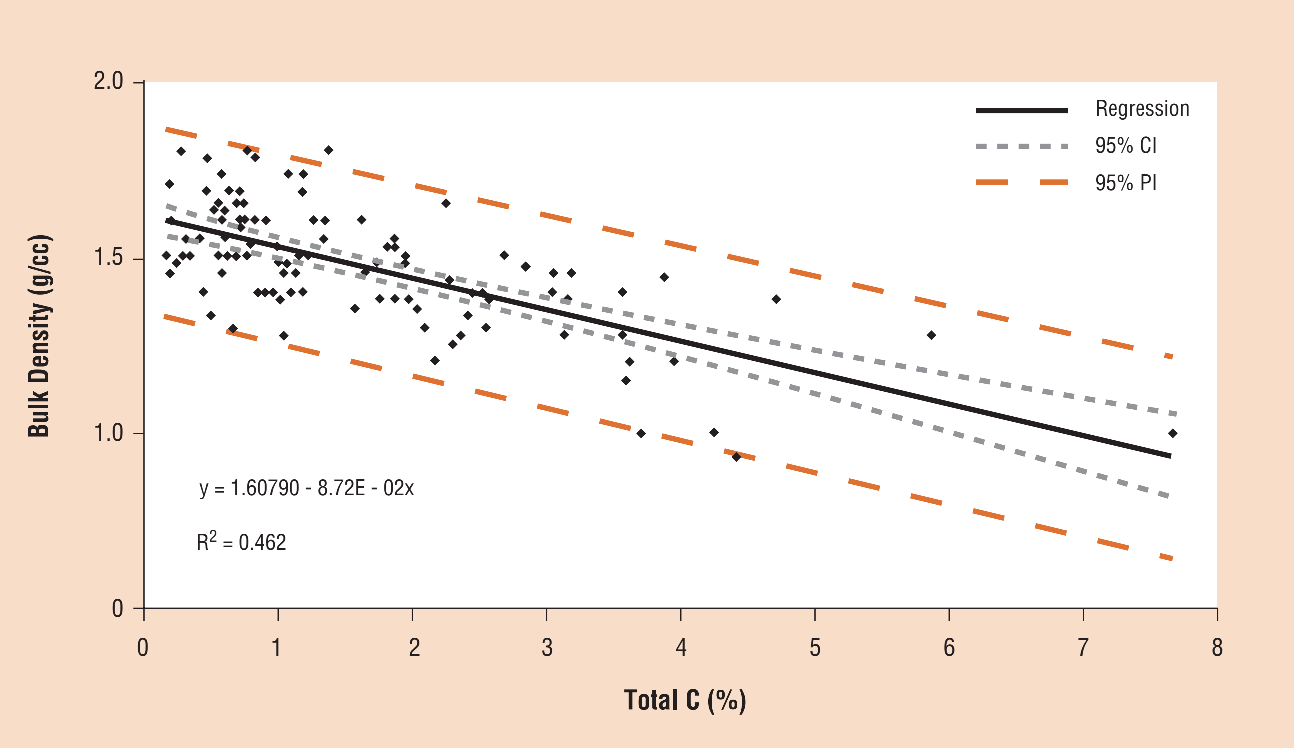

Figure 4. Prediction of bulk density from % carbon in South Australian pasture soils (0-30 cm).

7. COMPARISON OF SOIL CARBON IN CROPPING AND PASTURE SITES

Average carbon content of each soil type from the PIRSA cropping and pasture sites were calculated and compared (Figure 6). The average carbon is similar for pasture and cropped sites except when there are few samples (Gc and Gn). It was expected that, on average, the pasture sites would be higher in carbon than the cropped sites but this was not always the case (Dr, Uc). There appears to be no clear relationship between the carbon in pasture and cropped soils. For this reason, we decided to use the cropped sites for areas where no alternative data was available.

8. ESTIMATING CARBON IN 10-30 CM PORTION FROM THE 0-10 CM PORTION

The CSIRO database contained profiles from undisturbed sites with carbon measured only for the 0-10 cm portion. From previous work on Queensland and Northern Territory soils, Skjemstad (1999, pers. comm.) found that on average, the amount of carbon in the 0-10 cm portion of a soil profile is similar to that found in the 10-30 cm portion when converted to t C/ha. This relationship was tested on the CSIRO and PIRSA data (Figure 7) and was found to be valid. The ratios were 1.1 (SA), 0.9 (Qld) and 0.9 (NT). The ratio for the South Australian soils was used to convert these 0-10 cm horizons to 0-30 cm. This allowed the addition of 31 profiles from undisturbed sites to the database (see Figure 3 for locations).

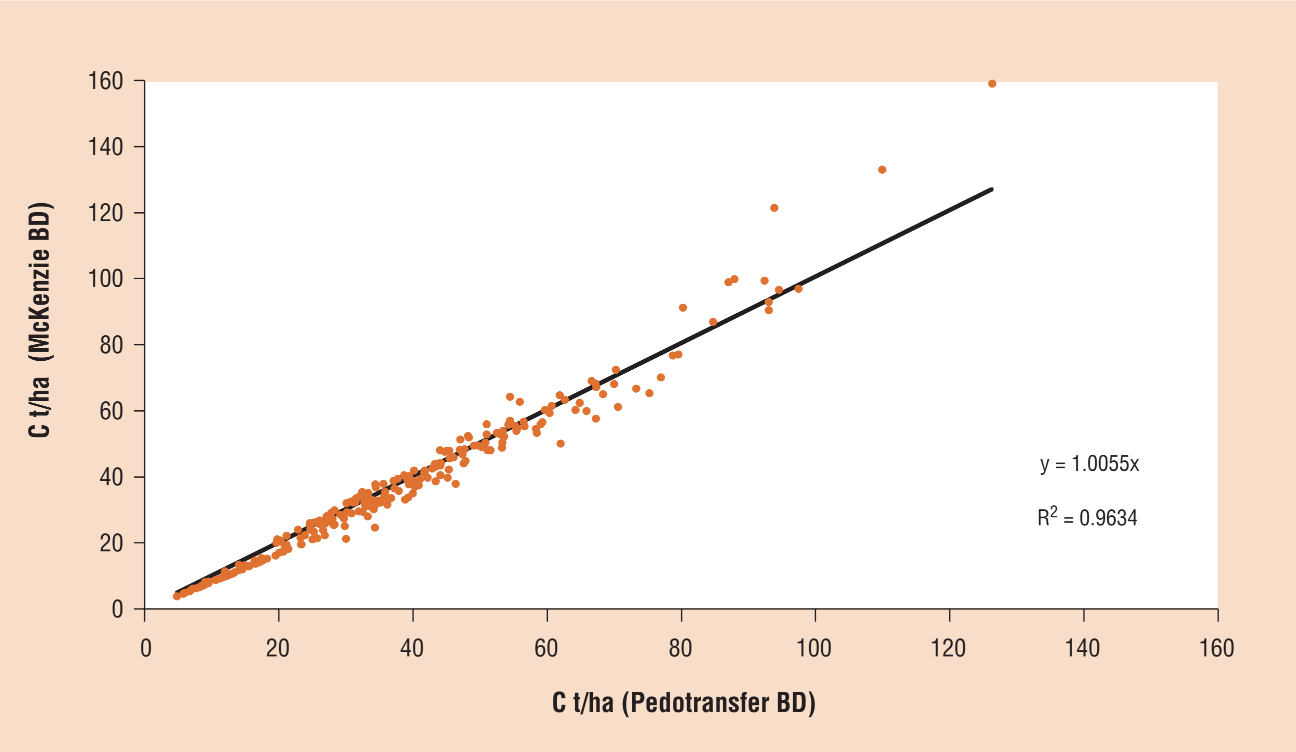

Figure 5. Comparison of carbon (t/ha) on pasture and cropping soils (PIRSA sites) calculated using two methods of estimating bulk density.

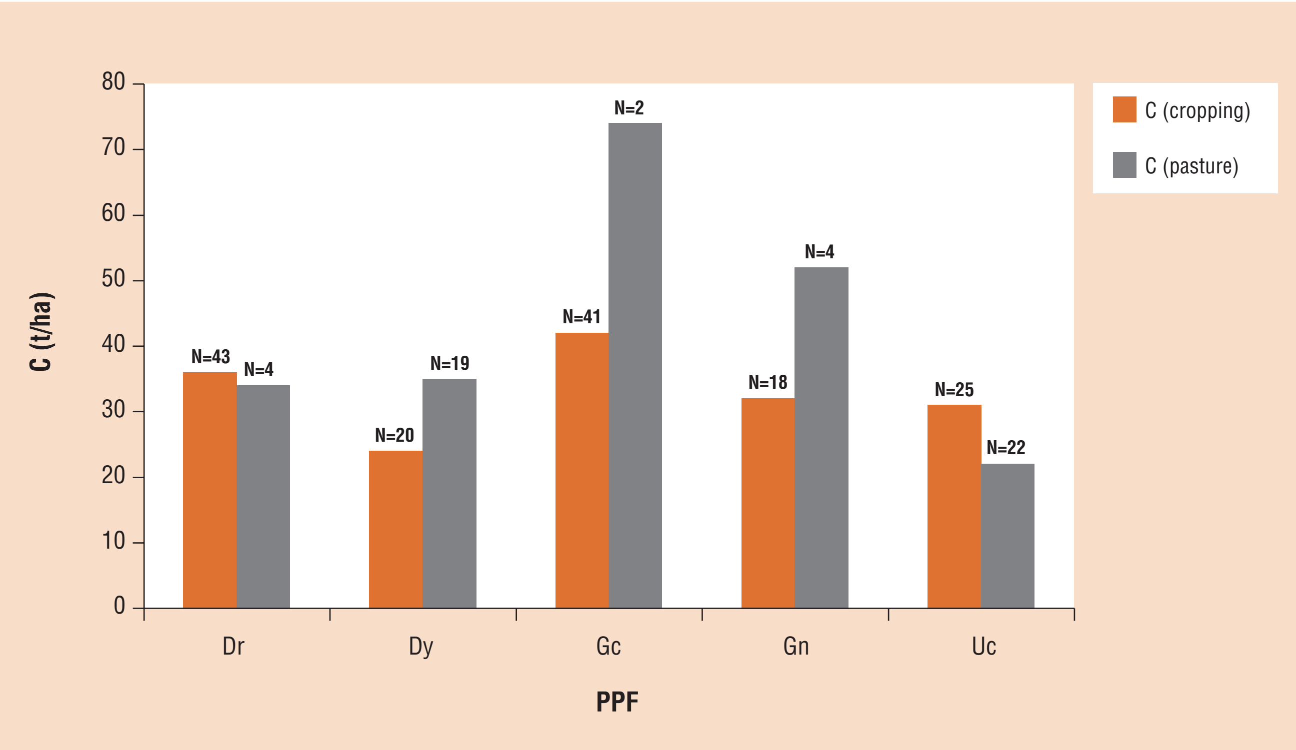

Figure 6. Soil carbon: cropping vs pasture sites.

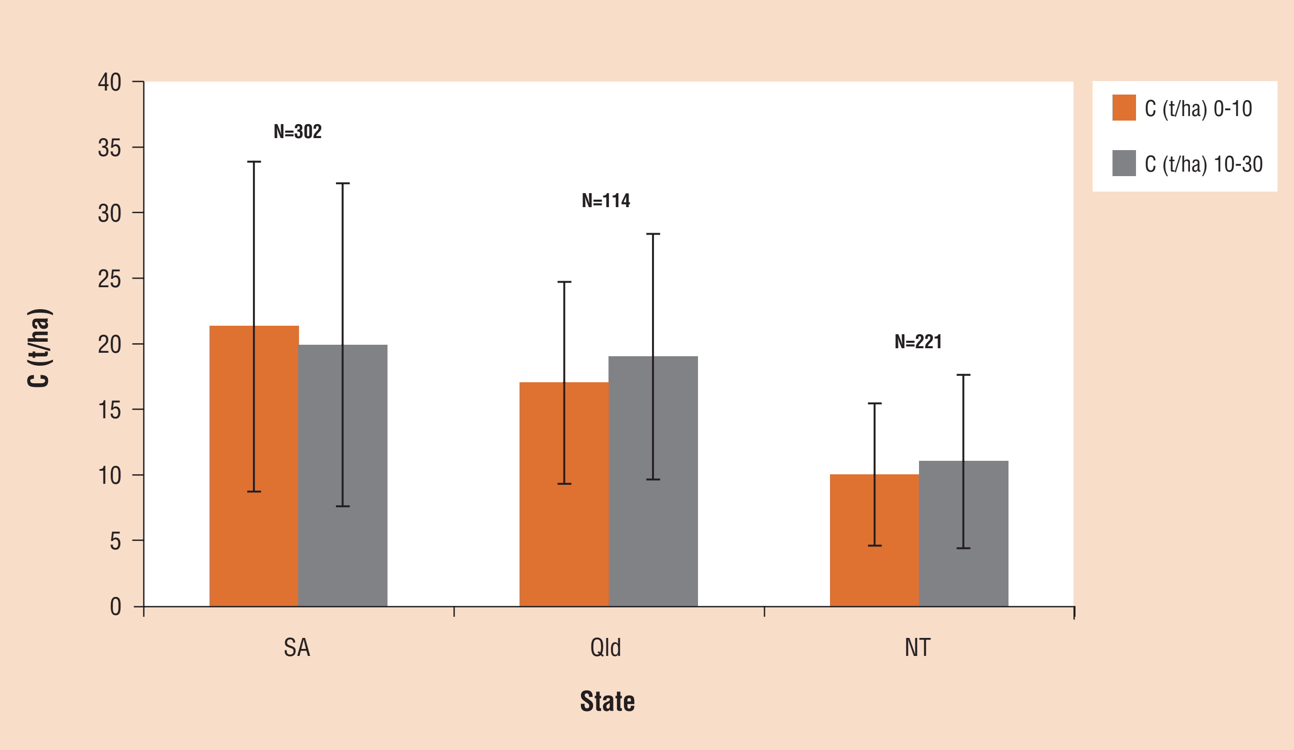

Figure 7. Carbon (t/ha) for 0-10 cm and 10-30 cm horizons by State.

9. SOIL CARBON DATABASE

Attachment A lists carbon (0-30 cm), average bulk density, % clay (0-10 cm), PPF and land use for all the soils used in this compilation. Sites with A and SW prefixes are CSIRO samples from undisturbed sites, AS are CSIRO pasture sites and the remainder are PIRSA sites.

10. SOIL CARBON ESTIMATES

Table 3 lists the average soil carbon by IBRA region and soil type for all sites and separately for pasture and undisturbed sites. Removal of the cropping sites from the data set did not change significantly the average carbon content of the profiles from data for all sites where numbers are adequate and would cause some soil types, mainly Ug, to be omitted. We would, therefore, recommend that where there are more than three pasture and undisturbed sites within a soil type that these values should be used. Where there are three or less, values should be derived from all sites. This ensures that all soil types are represented. Table 4 gives the data by IBRA, PPF soil C, % clay and soils recommended to be used by the National Carbon Accounting System for South Australia. An indicative map of soil carbon using data from all sites is presented in Figure 8.

Table 3. Comparisons of all sites and the pasture and undisturbed sites soil carbon estimates by IBRA region and soil type. Mean and SE data are for the soils marked with an asterisk only. These sites have at least three representatives in each group.

IBRA	PPF	All Sites			Pasture and Undisturbed		
		C	Clay	No	C	Clay	No
		t/ha	%		t/ha	%	
1	Db	61	9	1	61	9	1
1	Dr	30*	15*	8	34*	15*	3
1	Dy	26*	10*	17	28*	8*	9
1	Gc	45	12	4	55	20	1
1	Gn	16	10	9	19	12	2
1	Uc	23*	8*	19	21*	7*	12
1	Ug	43	45	1			
2	Dr	56	16	2	57	13	1
2	Dy	35*	10*	21	38*	8*	16
2	Gc	36	12	3			
2	Gn	44	30	1			
2	Uc	27*	7*	14	23*	5*	11
2	Uf	53	5	1			
2	Ug	73	40	2			
2	Um	85	18	2	85	18	2
35	Dr	34*	18*	24	39*	18*	7
35	Dy	23*	8*	10	23*	6*	4
35	Gc	45*	19*	40	54*	26*	8
35	Gn	27	17	7	21	7	1
35	Uc	34*	10*	20	40*	7*	6
35	Ug	43	35	2			
35	Um	91	28	3	91	28	3
36	Db	59	14	14	59	14	14
36	Dr	52*	20*	42	61*	20*	22
36	Dy	59	12	36	60	13	35
36	Gc	48	27	3			
36	Gn	72	23	12			
36	Uc	57*	10*	6	60*	8*	5
36	Ug	54	42	8	69	48	2
36	Um	79	16	3	79	16	3
*****	**mean**	**35.1**	**12.3**		**38.3**	**11.6**	
*****	**SE mean**	**3.48**	**1.45**		**4.40**	**1.20**	

Table 4. Recommended soil carbon estimates by IBRA.

IBRA	PPF	C t/ha	Clay %	No of Sites
1	Db	61	9	1
1	Dr	30	15	8
1	Dy	28	8	9
1	Gc	45	12	4
1	Gn	16	10	9
1	Uc	21	7	12
1	Ug	43	45	1
2	Dr	57	13	1
2	Dy	38	8	16
2	Gc	36	12	3
2	Gn	44	30	1
2	Uc	23	5	11
2	Uf	53	5	1
2	Ug	73	40	2
2	Um	85	18	2
35	Dr	39	18	7
35	Dy	23	6	4
35	Gc	54	26	8
35	Gn	27	17	7
35	Uc	40	7	6
35	Ug	43	35	2
35	Um	91	28	3
36	Db	59	14	14
36	Dr	61	20	22
36	Dy	60	13	35
36	Gc	48	27	3
36	Gn	72	23	12
36	Uc	60	8	5
36	Ug	54	42	8
36	Um	79	16	3

11. RECOMMENDATIONS

It is recommended that more soil cores be taken for carbon and bulk density analyses in the areas where clearing has been more intensive. Of highest importance are the Gc soils in IBRA 35 and 1, the Uc soils in IBRA 35 and the Ug soils in IBRA 1 and 2.

In the interim, we recommend that the data for South Australia given in Table 4 form the basis of initial soil data for national carbon accounting purposes.

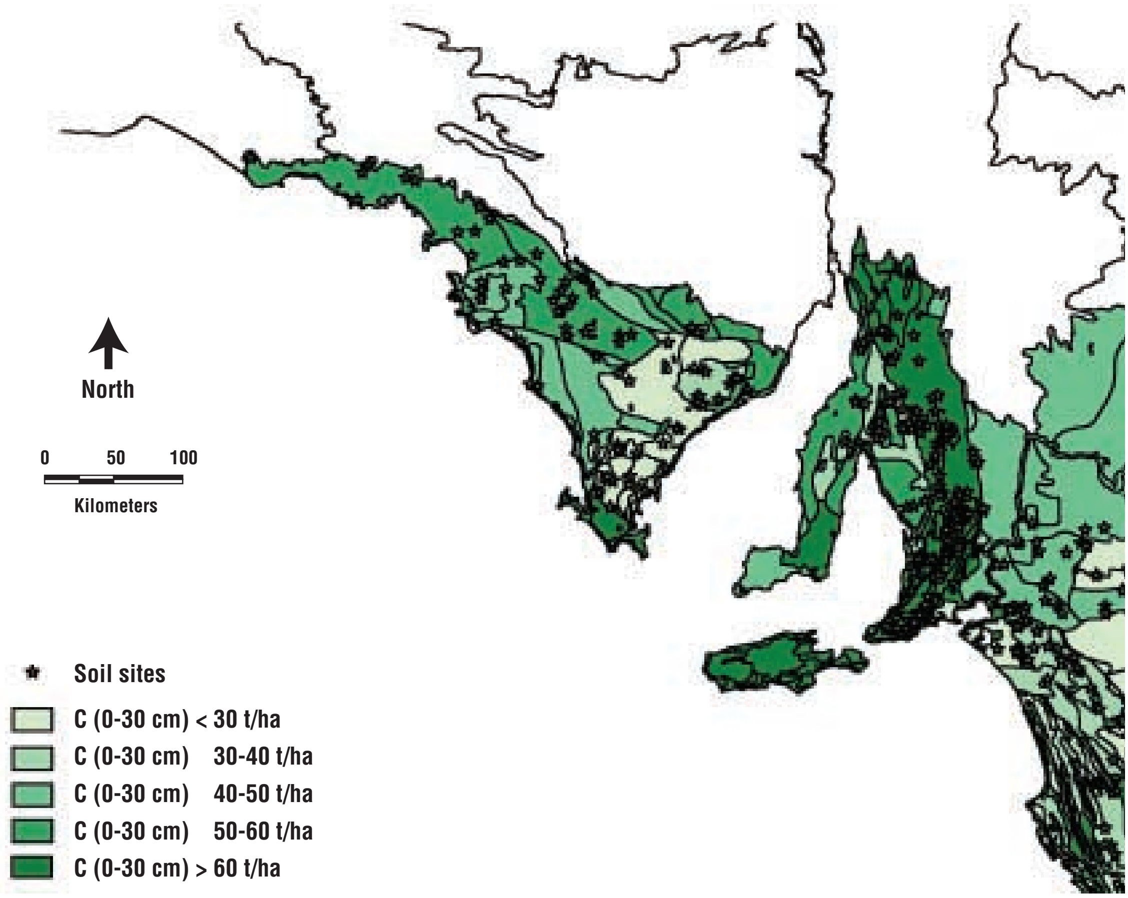

Figure 8. Map of average carbon (0-30 cm) for IBRA regions 1, 2, 35 and 36 in t/ha.

12. REFERENCES

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ATTACHMENT A

Soil carbon (t/ha) and bulk density for 0-30 cm and clay (%) for 0-10 cm by IBRA region and PPF.

Site	IBRA	C (t/ha)	BD	% Clay	PPF	Land Use
AS35	1	60.7	1.64	9	Db	Pasture
A971	1	40.2	1.52	11	Dr	Undisturbed
MM001	1	27.8	1.56	10	Dr	Cropping
MM003	1	20.2	1.57	10	Dr	Cropping
MM031	1	30.7	1.55	30	Dr	Cropping
MM058	1	34.4	1.54	20	Dr	Pasture
MM062	1	27.7	1.56	10	Dr	Cropping
SE001	1	30.1	1.50	15	Dr	Cropping
SW5	1	28.3	1.45	15	Dr	Undisturbed
A541	1	40.3	1.49	7	Dy	Undisturbed
AS33	1	43.2	1.47	7	Dy	Pasture
AS8	1	37.4	1.38	7	Dy	Pasture
AS9	1	39.6	1.36	7	Dy	Pasture
MM029	1	14.6	1.58	5	Dy	Cropping
MM033	1	26.1	1.56	30	Dy	Cropping
MM040	1	38.8	1.53	10	Dy	Cropping
MM041	1	17.6	1.57	10	Dy	Cropping
MM042	1	6.0	1.59	5	Dy	Cropping
MM049	1	20.8	1.57	10	Dy	Pasture
MM055	1	16.8	1.57	10	Dy	Cropping
MM057	1	8.6	1.59	5	Dy	Pasture
MM059	1	19.5	1.57	10	Dy	Pasture
MM060	1	28.0	1.54	10	Dy	Pasture
MM063	1	12.5	1.58	5	Dy	Pasture
SE004	1	39.1	1.52	25	Dy	Cropping
SE005	1	29.7	1.55	10	Dy	Cropping
MM027	1	55.4	1.49	20	Gc	Undisturbed
MM036	1	50.3	1.51	10	Gc	Cropping
MM052	1	28.2	1.55	10	Gc	Cropping
MM053	1	47.5	1.53	10	Gc	Cropping
MM002	1	14.0	1.59	5	Gn	Cropping
MM015	1	34.8	1.52	20	Gn	Cropping
MM017	1	8.6	1.59	10	Gn	Cropping
MM024	1	9.0	1.59	10	Gn	Cropping
MM032	1	23.3	1.56	10	Gn	Cropping
MM038	1	6.8	1.56	5	Gn	Cropping
MM048	1	15.6	1.57	10	Gn	Pasture
MM108	1	12.0	1.58	10	Gn	Cropping

Site	IBRA	C (t/ha)	BD	% Clay	PPF	Land Use
SW13	1	22.2	1.57	13	Gn	Undisturbed
MM004	1	12.2	1.59	5	Uc	Pasture
MM005	1	9.5	1.59	10	Uc	Cropping
MM014	1	11.8	1.58	5	Uc	Pasture
MM020	1	40.3	1.53	10	Uc	Cropping
MM025	1	7.2	1.59	5	Uc	Pasture
MM026	1	97.4	1.41	20	Uc	Undisturbed
MM028	1	8.6	1.59	5	Uc	Pasture
MM030	1	6.7	1.59	5	Uc	Pasture
MM045	1	11.8	1.58	5	Uc	Cropping
MM051	1	8.2	1.59	10	Uc	Cropping
MM054	1	10.6	1.59	5	Uc	Pasture
MM061	1	9.5	1.59	5	Uc	Pasture
MM064	1	32.5	1.55	10	Uc	Undisturbed
MM065	1	13.4	1.58	5	Uc	Cropping
MM069	1	58.5	1.49	20	Uc	Cropping
MM071	1	31.9	1.53	10	Uc	Cropping
MM073	1	16.5	1.58	5	Uc	Pasture
MM117	1	23.3	1.56	5	Uc	Pasture
SW15	1	21.4	1.55	8	Uc	Undisturbed
MM056a	1	42.9	1.52	45	Ug	Cropping
AS37	2	57.1	1.41	13	Dr	Pasture
MM083	2	54.5	1.50	20	Dr	Cropping
A544	2	34.7	1.54	4	Dy	Undisturbed
AS10	2	38.2	1.50	15	Dy	Pasture
AS38	2	60.4	1.46	8	Dy	Pasture
AS39	2	59.4	1.46	7	Dy	Pasture
AS41	2	66.3	1.49	8	Dy	Pasture
AS45	2	38.0	1.44	6	Dy	Pasture
AS46	2	47.0	1.41	5	Dy	Pasture
AS47	2	47.9	1.33	5	Dy	Pasture
AS49	2	40.5	1.42	7	Dy	Pasture
AS5	2	23.1	1.44	7	Dy	Pasture
MM010	2	20.6	1.56	5	Dy	Pasture
MM078	2	16.4	1.58	10	Dy	Cropping
MM080	2	32.7	1.55	30	Dy	Cropping
MM084	2	15.5	1.57	10	Dy	Cropping
MM085	2	48.2	1.50	20	Dy	Cropping
MM087	2	33.2	1.56	10	Dy	Pasture

Soil carbon (t/ha) and bulk density for 0-30 cm and clay (%) for 0-10 cm by IBRA region and PPF.

Site	IBRA	C (t/ha)	BD	% Clay	PPF	Land Use
MM089	2	25.0	1.56	10	Dy	Pasture
MM092	2	20.1	1.57	5	Dy	Pasture
MM093	2	34.7	1.54	10	Dy	Pasture
MM098	2	17.4	1.57	10	Dy	Pasture
MM100	2	12.9	1.58	10	Dy	Cropping
MM079	2	32.9	1.53	20	Gc	Cropping
MM102	2	41.7	1.49	5	Gc	Cropping
MM109	2	34.1	1.53	10	Gc	Cropping
MM076	2	43.7	1.49	30	Gn	Cropping
AS36	2	47.7	1.54	1	Uc	Pasture
AS44	2	50.8	1.41	4	Uc	Pasture
MM075	2	12.5	1.58	5	Uc	Pasture
MM081	2	51.1	1.51	20	Uc	Cropping
MM082	2	11.4	1.59	5	Uc	Pasture
MM086	2	14.5	1.58	5	Uc	Pasture
MM088	2	21.4	1.56	10	Uc	Pasture
MM090	2	26.6	1.55	10	Uc	Pasture
MM096	2	8.6	1.59	5	Uc	Pasture
MM097	2	36.4	1.54	10	Uc	Cropping
MM099	2	13.3	1.59	5	Uc	Pasture
MM101	2	34.3	1.53	10	Uc	Cropping
MM103	2	18.2	1.57	5	Uc	Pasture
SE007	2	26.8	1.57	5	Uc	Pasture
MM115	2	53.5	1.49	5	Uf	Cropping
MM110	2	70.5	1.46	40	Ug	Cropping
MM114	2	76.9	1.45	40	Ug	Cropping
A970	2	35.0	1.51	15	Um	Undisturbed
A972	2	135.2	1.06	21	Um	Undisturbed
A1210	35	32.3	1.53	20	Dr	Undisturbed
A1213	35	76.3	1.46	24	Dr	Undisturbed
A570	35	36.6	1.52	11	Dr	Undisturbed
CL014	35	70.2	1.50	30	Dr	Cropping
CM007	35	31.1	1.55	30	Dr	Cropping
CM024	35	32.1	1.55	25	Dr	Cropping
CM031	35	48.3	1.50	30	Dr	Cropping
CU001	35	25.6	1.56	10	Dr	Cropping
CU019	35	19.6	1.57	20	Dr	Cropping
CU023	35	26.1	1.54	40	Dr	Cropping

Site	IBRA	C (t/ha)	BD	% Clay	PPF	Land Use
EC099	35	27.1	1.55	20	Dr	Cropping
EE052	35	25.3	1.57	5	Dr	Cropping
EE063	35	28.3	1.55	20	Dr	Cropping
EE065	35	27.6	1.55	10	Dr	Cropping
EE066	35	26.9	1.55	5	Dr	Cropping
EE067	35	22.8	1.56	5	Dr	Pasture
EE100	35	20.1	1.56	5	Dr	Cropping
EL001	35	44.0	1.51	10	Dr	Cropping
EL009	35	21.2	1.57	5	Dr	Cropping
EL037	35	31.4	1.52	30	Dr	Cropping
EL043	35	31.4	1.55	10	Dr	Cropping
SW18	35	30.9	1.54	14	Dr	Undisturbed
SW22	35	22.9	1.58	17	Dr	Undisturbed
SW6	35	54.4	1.45	38	Dr	Undisturbed
A1219	35	45.8	1.52	6	Dy	Undisturbed
EE050	35	14.9	1.58	10	Dy	Cropping
EL002	35	35.8	1.53	10	Dy	Cropping
EL004	35	43.4	1.52	10	Dy	Cropping
EL008	35	25.7	1.56	10	Dy	Cropping
EL032	35	14.0	1.58	10	Dy	Cropping
EL042	35	9.5	1.59	10	Dy	Cropping
SW1	35	13.2	1.54	3	Dy	Undisturbed
SW21	35	24.1	1.54	13	Dy	Undisturbed
SW24	35	8.9	1.50	2	Dy	Undisturbed
A1201	35	89.0	1.42	39	Gc	Undisturbed
A1205	35	49.2	1.51	30	Gc	Undisturbed
A1215	35	38.3	1.53	25	Gc	Undisturbed
A622	35	42.2	1.53	8	Gc	Undisturbed
CM001	35	37.9	1.54	30	Gc	Cropping
CM002	35	59.3	1.53	20	Gc	Cropping
CM005	35	35.7	1.51	10	Gc	Cropping
CM009	35	37.2	1.53	30	Gc	Cropping
CM011	35	64.2	1.51	10	Gc	Cropping
CM020	35	39.6	1.54	30	Gc	Cropping
CM023	35	49.8	1.51	30	Gc	Cropping
CM025	35	41.7	1.53	30	Gc	Cropping
CM026	35	41.6	1.54	30	Gc	Cropping
CM029	35	60.7	1.48	10	Gc	Cropping
CM032	35	66.6	1.47	30	Gc	Cropping
CU021	35	30.1	1.56	20	Gc	Cropping

ATTACHMENT A continued

Soil carbon (t/ha) and bulk density for 0-30 cm and clay (%) for 0-10 cm by IBRA region and PPF.

Site	IBRA	C (t/ha)	BD	% Clay	PPF	Land Use
EC056	35	31.6	1.55	20	Gc	Cropping
EC059	35	62.6	1.48	25	Gc	Cropping
EC078	35	73.3	1.47	10	Gc	Cropping
EC079	35	30.9	1.54	20	Gc	Cropping
EC080	35	23.3	1.56	10	Gc	Cropping
EC083	35	53.6	1.50	10	Gc	Cropping
EC097	35	65.8	1.48	10	Gc	Cropping
EE064	35	26.4	1.56	5	Gc	Cropping
EF013	35	14.2	1.58	5	Gc	Cropping
EF027	35	35.7	1.53	10	Gc	Cropping
EF029	35	45.1	1.51	10	Gc	Cropping
EL010	35	46.0	1.45	30	Gc	Cropping
EL041	35	55.5	1.50	30	Gc	Cropping
EW072	35	27.9	1.55	10	Gc	Cropping
EW073	35	93.0	1.48	20	Gc	Pasture
EW075	35	40.0	1.55	20	Gc	Cropping
EW091	35	36.2	1.54	10	Gc	Cropping
EW092	35	43.4	1.51	10	Gc	Cropping
EW093	35	41.0	1.53	20	Gc	Cropping
EW094	35	25.2	1.56	10	Gc	Cropping
EW095	35	23.9	1.56	10	Gc	Cropping
SW19	35	34.5	1.55	20	Gc	Undisturbed
SW20	35	31.8	1.56	32	Gc	Undisturbed
SW7	35	51.3	1.46	32	Gc	Undisturbed
A1214	35	21.1	1.57	7	Gn	Undisturbed
CL015	35	33.4	1.54	10	Gn	Cropping
CM008	35	42.2	1.53	20	Gn	Cropping
CM034	35	29.8	1.56	5	Gn	Cropping
EE068	35	12.8	1.59	10	Gn	Cropping
EL033	35	19.8	1.53	40	Gn	Cropping
EW076	35	33.3	1.53	30	Gn	Cropping
A1207	35	15.2	1.58	4	Uc	Undisturbed
A1209	35	16.9	1.58	4	Uc	Undisturbed
A1212	35	100.5	1.40	14	Uc	Undisturbed
A1216	35	24.1	1.56	12	Uc	Undisturbed
A1222	35	74.7	1.46	5	Uc	Undisturbed
CM003	35	17.1	1.58	10	Uc	Cropping
CM004	35	8.8	1.58	10	Uc	Cropping

Site	IBRA	C (t/ha)	BD	% Clay	PPF	Land Use
CM006	35	5.7	1.60	10	Uc	Cropping
CM010	35	16.4	1.57	10	Uc	Cropping
CM035	35	79.6	1.44	10	Uc	Cropping
CU020	35	7.7	1.59	10	Uc	Cropping
EC082	35	44.0	1.52	10	Uc	Cropping
EC096	35	94.5	1.38	30	Uc	Cropping
EC098	35	8.9	1.59	10	Uc	Cropping
EE046	35	10.7	1.58	5	Uc	Pasture
EE069	35	4.8	1.56	5	Uc	Cropping
EE071	35	58.3	1.49	20	Uc	Cropping
EF024	35	34.3	1.54	10	Uc	Cropping
EL034	35	20.7	1.56	5	Uc	Cropping
EW074	35	30.0	1.55	10	Uc	Cropping
CM012	35	45.3	1.51	30	Ug	Cropping
CU022	35	40.8	1.52	40	Ug	Cropping
A1202	35	92.1	1.42	35	Um	Undisturbed
A1203	35	65.6	1.46	40	Um	Undisturbed
A1221	35	114.8	1.39	9	Um	Undisturbed
A1124	36	47.0	1.47	7	Db	Undisturbed
AS57	36	51.6	1.55	11	Db	Pasture
CH013	36	67.3	1.47	10	Db	Pasture
CH016	36	87.9	1.40	10	Db	Pasture
CH017	36	67.2	1.45	5	Db	Pasture
CH022	36	126.3	1.37	30	Db	Pasture
CH028	36	39.4	1.50	10	Db	Pasture
CH029	36	47.8	1.50	10	Db	Pasture
CH035	36	53.3	1.52	10	Db	Pasture
CH036	36	35.1	1.53	10	Db	Pasture
CH039	36	70.0	1.50	20	Db	Pasture
CH040	36	34.5	1.54	10	Db	Pasture
CH041	36	53.4	1.52	30	Db	Pasture
CH043	36	45.4	1.52	25	Db	Pasture
A1104	36	87.4	1.32	17	Dr	Undisturbed
A1113	36	145.4	0.94	10	Dr	Undisturbed
A1126	36	126.0	1.13	18	Dr	Undisturbed
A1140	36	76.7	1.45	22	Dr	Undisturbed
A538	36	23.0	1.56	43	Dr	Undisturbed
A539	36	42.3	1.49	27	Dr	Undisturbed
A738	36	67.3	1.40	9	Dr	Undisturbed
AS23	36	56.6	1.31	39	Dr	Pasture

ATTACHMENT A continued

Soil carbon (t/ha) and bulk density for 0-30 cm and clay (%) for 0-10 cm by IBRA region and PPF.

Site	IBRA	C (t/ha)	BD	% Clay	PPF	Land Use
AS24	36	85.4	1.32	11	Dr	Pasture
AS50	36	57.4	1.51	14	Dr	Pasture
AS51	36	48.4	1.49	4	Dr	Pasture
AS55	36	95.1	1.50	14	Dr	Pasture
AS58	36	78.6	1.50	10	Dr	Pasture
AS65	36	53.9	1.34	22	Dr	Pasture
CH032	36	33.2	1.54	10	Dr	Pasture
CL001	36	32.7	1.56	25	Dr	Cropping
CL002	36	52.9	1.51	25	Dr	Cropping
CL003	36	37.7	1.54	10	Dr	Cropping
CL005	36	27.2	1.55	25	Dr	Cropping
CL006	36	37.1	1.55	10	Dr	Cropping
CL013	36	38.7	1.54	10	Dr	Vineyard
CL019	36	47.0	1.52	25	Dr	Cropping
CL020	36	55.9	1.50	30	Dr	Cropping
CL021	36	32.4	1.54	10	Dr	Cropping
CL023	36	45.4	1.52	25	Dr	Cropping
CM013	36	24.6	1.56	10	Dr	Cropping
CM014	36	44.7	1.52	30	Dr	Pasture
CM017	36	61.9	1.45	25	Dr	Cropping
CM022	36	24.6	1.56	10	Dr	Cropping
CM028	36	44.0	1.52	20	Dr	Cropping
CM036	36	47.0	1.51	30	Dr	Cropping
CM038	36	51.0	1.51	30	Dr	Cropping
CM039	36	55.2	1.50	25	Dr	Cropping
CM044	36	49.1	1.51	5	Dr	Vineyard
CM045	36	36.7	1.54	10	Dr	Vineyard
CU018	36	50.9	1.51	30	Dr	Cropping
CU032	36	45.0	1.51	10	Dr	Cropping
MP005	36	40.1	1.53	25	Dr	Cropping
MP006	36	35.6	1.54	10	Dr	Cropping
SW12	36	25.8	1.57	25	Dr	Undisturbed
SW27	36	37.8	1.55	39	Dr	Undisturbed
SW28	36	29.6	1.56	51	Dr	Undisturbed
A1107	36	89.4	1.31	29	Dy	Undisturbed
A1110	36	29.4	1.55	7	Dy	Undisturbed
A1121	36	44.4	1.48	9	Dy	Undisturbed
A1123	36	56.3	1.50	9	Dy	Undisturbed

Site	IBRA	C (t/ha)	BD	% Clay	PPF	Land Use
A1125	36	44.0	1.52	7	Dy	Undisturbed
A1131	36	30.4	1.52	9	Dy	Undisturbed
A1134	36	101.1	1.26	15	Dy	Undisturbed
A1135	36	43.4	1.52	5	Dy	Undisturbed
A1138	36	106.4	1.24	27	Dy	Undisturbed
A1139	36	93.4	1.30	21	Dy	Undisturbed
A1141	36	35.5	1.54	9	Dy	Undisturbed
A543	36	74.6	1.45	7	Dy	Undisturbed
A686	36	29.0	1.53	6	Dy	Undisturbed
A689	36	59.9	1.43	17	Dy	Undisturbed
A724	36	34.4	1.51	10	Dy	Undisturbed
A727	36	52.3	1.45	7	Dy	Undisturbed
A733	36	41.1	1.49	12	Dy	Undisturbed
A760	36	39.2	1.53	6	Dy	Undisturbed
AS53	36	94.3	1.47	20	Dy	Pasture
AS54	36	82.3	1.41	18	Dy	Pasture
AS59	36	87.5	1.35	7	Dy	Pasture
AS60	36	99.1	1.37	19	Dy	Pasture
AS61	36	65.0	1.40	18	Dy	Pasture
AS62	36	75.9	1.36	9	Dy	Pasture
AS63	36	59.5	1.65	4	Dy	Pasture
AS64	36	56.7	1.45	4	Dy	Pasture
CH001	36	87.0	1.42	10	Dy	Pasture
CH015	36	64.8	1.44	5	Dy	Pasture
CH018	36	39.3	1.55	10	Dy	Pasture
CH019	36	80.2	1.43	30	Dy	Pasture
CH031	36	43.2	1.52	10	Dy	Pasture
CH037	36	32.8	1.55	10	Dy	Pasture
CH042	36	39.4	1.53	5	Dy	Pasture
CH044	36	47.7	1.53	25	Dy	Pasture
CL009	36	47.3	1.52	25	Dy	Vineyard
CU016	36	29.2	1.54	10	Dy	Cropping
CL018	36	44.1	1.54	30	Gc	Cropping
CU012	36	40.0	1.49	20	Gc	Cropping
CU014	36	60.3	1.47	30	Gc	Cropping
A1130	36	129.7	1.10	14	Gn	Undisturbed
A1132	36	41.6	1.49	5	Gn	Undisturbed
A1137	36	69.6	1.39	16	Gn	Undisturbed
CH020	36	109.9	1.33	25	Gn	Forest
CH030	36	52.5	1.50	10	Gn	Pasture

Soil carbon (t/ha) and bulk density for 0-30 cm and clay (%) for 0-10 cm by IBRA region and PPF.

Site	IBRA	C (t/ha)	BD	% Clay	PPF	Land Use
CH033	36	59.6	1.48	10	Gn	Pasture
CH045	36	78.7	1.41	25	Gn	Pasture
CL022	36	84.7	1.41	30	Gn	Cropping
CM018	36	56.5	1.48	25	Gn	Cropping
CM021	36	56.6	1.50	30	Gn	Cropping
CM037	36	54.2	1.44	45	Gn	Cropping
CM046	36	68.3	1.47	40	Gn	Vineyard
A1120	36	38.9	1.50	5	Uc	Undisturbed
AS56	36	49.0	1.55	4	Uc	Pasture
CH021	36	93.0	1.42	10	Uc	Pasture
CH023	36	93.8	1.38	10	Uc	Pasture
CH034	36	24.7	1.55	10	Uc	Pasture
CU002	36	40.3	1.53	20	Uc	Cropping
CL004	36	51.6	1.53	35	Ug	Cropping
CL007	36	35.1	1.55	30	Ug	Cropping
CL011	36	62.0	1.49	50	Ug	Vineyard
CM016	36	46.3	1.53	45	Ug	Cropping
CM040	36	59.0	1.50	45	Ug	Cropping
CM043	36	75.2	1.46	45	Ug	Vineyard
CU015	36	36.7	1.51	35	Ug	Cropping
CU017	36	67.2	1.46	50	Ug	Cropping
A1127	36	91.4	1.41	22	Um	Undisturbed
A1128	36	87.4	1.32	22	Um	Undisturbed

APPENDIX 6

PRE-CLEARING SOIL CARBON LEVELS IN TASMANIA

Darren Kidd
(Department of Primary Industries, Water & Environment, Tasmania)

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1. METHODS

- Soils were allocated to each IBRA using existing soil coverages, where possible. These soil maps cover a relatively small percentage of the State. Department of Primary Industries, Water and Environment (DPIWE) site data is mainly on agricultural land, with limited chemical and physical analysis. Forestry Tasmania soils data was used extensively for this exercise, with all sites on uncleared land.

- Landsystem units were used to extrapolate existing soil information to unmapped areas, as these units take into account many biophysical and geophysical attributes. These include elevation, topography, soil parent material, vegetation type, annual rainfall and brief soil descriptions with percentage estimates of each soil type. Dominant soils were assigned from soil map information included within each landsystem unit. Where no dominant soil could be determined, co-dominant soils were allocated. A dominant soil was considered as those covering greater than 70% of each unit. The local soil name was assigned to assist in validation by Tasmanian soils professionals. Australian Soil Classification to soil order was also determined for each soil type, following Isbell (1996).

- In determining pre-cleared carbon levels, soil vegetation was considered one of the main influences on carbon levels, usually wetter forests displaying more organic litter accumulation and decomposition than drier forests. Dry forests are also more subjected to fire events, which may also result in carbon losses. Three Forestry Tasmania 1:100,000 soil maps were used, with these soil types extrapolated to surrounding land, where possible, within identical landsystem units, ie. same altitude, rainfall, geology, vegetation communities, topography and basic soil type.

- Where no soil data was available, each landsystem was interrogated, with soils assigned from the Forestry Tasmania - National Landcare - F&FIC publication "Forest Soils of Tasmania – A Handbook for Identification & Management" by Grant *et.al.* (1995). This publication provides descriptions of the most typical Tasmanian forest soils, with morphological and chemical data. Each soil was assigned by choosing soils from this book with the same parent material, vegetation type, altitude, topography and rainfall, and which matched the brief landsystems soil descriptions.

- DPIWE site chemical data was used, where possible, to estimate organic carbon levels. The majority of these sites are on cleared (disturbed) land. These sites were not used. Sites with land surface description ranging from "limited clearing" to "undisturbed" were used. Where no site data exists, organic carbon and bulk density was allocated from the most typical Forestry Tasmania soil sites. This was thought to be a more accurate estimate of base-line soil carbon levels than using post-clearing data. No DPIWE bulk density data was available, with all estimates assigned from Forestry Tasmania data. Where no bulk density data was available, values were estimated from similar soils, with comparable parent material, textures and vegetation cover. (These calculations were all recorded for future verification).

- OC and bulk density values were not available at standard depths, but per horizon. Values were therefore assigned to 30 cm using weighted averages for each horizon. OC kg ha^{-1} was calculated for each landsystem unit. These were then dissolved where bordering units were considered to contain similar dominant soils, with the smallest polygons and slivers eliminated. The southwest world heritage areas contain no or very little data, and along with national parks, were excluded from the exercise. Land-use in these areas has not and will not be changed.

2. SOURCES USED

- DPIWE soils database sites;
- 1:63,000 CSIRO Reconnaissance Soil Map Series;
- 1:100,000 DPIWE Revised and Correlated CSIRO Reconnaissance Soil Map Series;
- Forestry Tasmania 1:100,000 soil surveys, Pipers (Laffan *et.al.* 1995), Forth (Hill *et.al.* 1995), Forester (Grant *et.al.* 1995);
- Forest Soils Handbook, (Grant *et.al.* 1995);
- DPIWE Landsystems of Tasmania Series 1:100,000; and
- Expert advice.

3. VALIDATION

- As many of the dominant soil types and carbon/ bulk density values have been extrapolated over relatively broad areas, there would be a lack of reliability in much of the data provided.
- The final allocation was checked by Mike Laffan from Forestry Tasmania and presented at a soils workshop in July in front of 30-odd of Tasmania's soil professionals for evaluation of the final outputs and the methodologies used.

4. SUMMARY OF SOILS FOR EACH IBRA REGION

The following tables show soil summaries for each IBRA region.

Table 1. Soil summary for Ben Lomond IBRA region.

SOIL	ASC	Pre-cleared OC	Total Area
		kg ha^{-1} (0-30 cm)	m^2
albion	TE	46 200	485240896.0
albion-canola	TE-VE	97 500	2236514640.0
arthur	DE-FE	42 900	12166207.3
bacala	KU	72 600	174710939.4
baker	HY	214 200	594498678.1
blumont	DE	112 800	703682451.3
cuckoo	DE	174 300	143736501.5
diddleum	DE	174 300	399090592.0
duncraggen	PO	87 000	402794745.9
eastfield	CH	82 500	211381065.2
excalibur-arthur	DE-FE	187 200	107361792.0
holloway	FE	46 800	2133556608.9
hurst	HY	214 200	311633975.4
interlaken	FE	24 000	114074016.3
jensen	KU	54 600	784789385.2
kapai-knockup	FE	181 800	189643254.9
knight	KU	125 400	93798592.0
lauderdale	KA	87 000	15919416.0
lefroy	DE	42 000	393625314.3
maweena	DE	125 400	1475872072.9
mckay	CH	62 400	227402364.0
memory-hogarth	KA	118 800	24754590.0
nabowla	DE	125 400	178578481.0
oldina	KU	158 400	79625460.3
retreat	KU	36 300	48732780.5
sands	RU	2 400	159720317.8
sideling	DE	133 200	172301696.0
springfield	DE	128 700	318720056.0
tonganah	KU	90 000	38625983.0

Table 2. Soil summary for Central Highlands IBRA region.

SOIL	ASC	Pre-cleared OC kg ha^{-1} (0-30 cm)	Total Area m^2
albion	TE	46 200	89870743.5
buckland	KU	72 600	774789818.9
cam	KU	158 400	452863520
castra	DE	133 200	1980710326
eastfield	CH-SO	82 500	1500134374
forcett	KU	82 500	369574830.5
forcett	KU	158 400	515634555.8
fulton	TE	65 100	2305502647
gregory	KU	65 100	11064530
holloway	FE	46 800	4762479687
interlaken	FE	24 000	5986887411
minnow	FE	77 400	459448988
murdunna	FE	72 000	1658462462
national park	national park	Na	36799136906
oldina	KU	158 400	761953174.1
oldina-interlake	KU	24 000	286514760
oonah	FE	46 500	2997039919
roland	PO	65 100	2066787427
sandspit	KU	52 800	484366420.4
sheffield	DE	92 400	293375250.3
sorell	DE	82 500	271226615
stonleigh	DE	68 400	23453808.75
stonleigh-sorell	DE	68 400	88704920.19
tiger	TE	108 900	913423968
water	water	0	702243064

Table 3. Soil summary for D'Entrecasteaux IBRA region.

SOIL	ASC	Pre-cleared OC	Total Area
		kg ha^{-1} (0-30 cm)	m^2
eastfield	CH	82 500	494471253.7
forcett	KU	82 500	547196414.6
forcett-alluvium	KU-HY	121 800	45432804
holloway	FE	46 800	84730884.5
interlaken	FE	24 000	1966854040
kermandie	FE	156 000	1377587889
murdunna	FE	72 000	5054739086
national park	national park	Na	10972121388
sands	RU	900	140838970.5
sandspit	KU	52 800	550579476

Table 4. Soil summary for Freycinet IBRA region.

SOIL	ASC	Pre-cleared OC	Total Area
		kg ha^{-1} (0-30 cm)	m^2
albion	TE	46 200	1098871479
albion-canola	TE-VE	97 500	283793893.3
albion-eastfield	TE-CH	58 500	10680508
bender	DE	74 100	4434608.625
bu-albion-ea	TE-CH-FE	64 800	52144992
buckland	KU	72 600	824280841.6
ea-ho-belmont	CH-FE-DE	117 000	77388744.38
eastfield	CH	82 500	710719842.8
eastfield-hollow	CH-FE	68 400	489846973.3
forcett	KU	158 400	55670843.5
holloway	FE	46 800	3697303344
holloway-eastfie	CH-FE	68 400	557030087.9
holloway-eastfie	FE-CH	62 400	2421917058
interlaken	FE	24 000	570541658
jensen	KU	54 600	483375678.3
lefroy	DE	42 000	97750412
mckay	CH	62 400	119648266
national park	national park	Na	101684281.5
oldina	KU	158 400	110818200
sands	RU	900	171054476.8
sands-dolerite	RU-TE	6 000	24638140
sandspit	KU	52 800	178794795.4
sorell	DE	218 400	74836763.94
stonleigh	FE	100 800	68699898.31

Table 5. Soil summary for Furneaux IBRA region.

SOIL	ASC	Pre-cleared OC kg ha^{-1} (0-30 cm)	Total Area m^2
altmoor	PO	70 200	108004266.9
carena	PO	87 000	12362273
duncraggen	PO	87 000	229609156.8
lenna	KA	48 600	79752496.88
nala	PO	94 500	274186932.1
petibela-memana	KU-CA	72 000	263379111
quoin	KU	62 100	417518486.2
ranga	RU	69 300	213129256.6
retreat	KU	36 300	61721485.5
sands	RU	6 000	156304326.9

Table 6. Soil summary for Tasmanian Midlands IBRA region.

SOIL	ASC	Pre-cleared OC kg ha^{-1} (0-30 cm)	Total Area m^2
albion	TE	46 200	92076430
alluvium	DE	82 500	74168060.31
alluvium	DE	97 500	1933244427
alluvium	TE	56 700	21970912
alluvium	VE	97 500	130328360.9
breadalbane	FE	46 500	43094372.88
brickendon	CH	12 000	216968617.9
brumby	SO	89 100	832850801.3
buckland	KU	72 600	4143031343
cam	KU	158 400	44158460
canola	VE	218 400	109305851.4
eastfield	SO-CH	82 500	14520537919
forcett	KU	158 400	734615773.5
gregory	KU	65 100	22129060
high moor peat	OR	396 000	13861898
holloway	FE	46 800	3877730694
interlaken	FE	24 000	10649589842
kermandie	FE	156 000	325115712
laterite	FE	18 000	44383816.38
M4 (minnow)	FE	720 000	61831530.63
murdunna	FE	72 000	245765784
oldina-interlake	KU	24 000	40930680
oonah	FE	46 500	28790260

Table 6. Soil summary for Tasmanian Midlands IBRA region. continued

SOIL	ASC	Pre-cleared OC kg ha^{-1} (0-30 cm)	Total Area m^2
panshanger	TE	9 000	372703396
quamby	DE	108 900	245337832
roland	PO	65 100	8848291
sands	RU	900	53601150.47
sandspit	KU	52 800	59144996
sorell	DE	218 400	522659748.8
stonleigh	DE	68 400	115584935
water	water	0	9684932
woodstock	CH	45 000	82880592

Table 7. Soil summary for Southwest Tasmania IBRA region.

SOIL	ASC	Pre-cleared OC kg ha^{-1} (0-30 cm)	Total Area m^2
alluvium	TE	159 900	68210894
balfour	HY	612 300	185172528.8
cam	KU	158 400	127675441
castra	DE	133 200	1633021968
chisolm	OR	645 600	119484855
dolcoath	CH	67 200	381109891.8
eastfield	CH	82 500	1319682784
forcett	KU	158 400	257009024
frankland	OR	799 500	358705417
hellyer	KU	158 400	137457472
hellyer-oldina	KU	158 400	1128173502
holloway	FE	46 800	45066156
lupari	PO	102 000	197543000
minnow	FE	72 000	1299046701
national park	national park	Na	52925165244
oonah	FE	46 500	4831185166
roland	PO	65 100	152002869.4
sands	RU	900	270393407
sandspit	KU	52 800	1377267549
stony heath	TE	148 500	504205146
temma	DE	526 500	3925988016
un-named peats	OR	106 800	15240649.25
yolla	FE	46 500	70021499.63

Table 8. Soil summary for Woolnorth IBRA region.

SOIL	ASC	Pre-cleared OC	Total Area
		kg ha^{-1} (0-30 cm)	m^2
alluvial soils	TE	56 700	234806409.5
asbestos	DE	151 200	190304805.5
buckland	KU	72 600	15149937
burnie-lapoinya	FE	46 500	1076997874
calder	FE	117 000	29781395
cam	KU	158 400	273648093.2
cam-healy	KU-PO	158 400	36244628
cam-sisters hill	KU-RU	113 400	131850430.8
castra	DE	122 100	1154629150
chisolm	OR	645 600	109593640
dalrymple	PO	37 800	308644080.6
deloraine	FE	46 500	64898033.06
dolcoath	CH	67 200	463397790
eastfield	CH	82 500	702644653.7
hellyer	KU	158 400	308584058
hellyer-oldina	DE-KA	158 400	381655069.4
henty	TE	9 000	86137450.63
holloway	FE	46 800	204113131.4
interlaken	FE	24 000	1630538016
lappa sands	PO	56 700	355010645.1
lupari	PO	102 000	96377019.84
mersey-cam	DE-KU	31 500	18833767
minnow	FE	72 000	35713968
montagu-brittons	HY-PO	56 700	151840894
national park	national park	Na	193547796.7
natone	DE	67 200	162532745
nugara	HY	56 700	63479220.88
oonah	FE	46 500	11457804697
pegarah	KU	113 400	369781742.1
roebuck	DE	50 400	350904629.1
roland	PO	65 100	1452819680
sands	RU	900	235991184
sheffield	DE	92 400	317588865.4
sisters hills sands	RU	12 600	85476179.94
south esk	TE	56 700	2408586949
stony heath	TE	148 500	565512902.6
swamp soils	HY	56 700	17199656.25
taroona sands	PO	56 700	73368867

Table 8. Soil summary for Woolnorth IBRA region. continued

SOIL	ASC	Pre-cleared OC kg ha^{-1} (0-30 cm)	Total Area m^2
tatana	PO	49 500	336024624.4
temma	DE	526 500	1961189975
tiger	TE	108 900	785644352
un-named	TE-CH	46 200	90567128.25
un-named peats	OR	106 800	65622974.25
warrina	KU	79 200	117527479.8
west ridgely	FE	46 500	208586966.8
woolnorth sands	PO	56 700	740614282.7
yambacoona	PO	56 700	23795579.75
yolla	FE	136 800	300245458.3

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APPENDIX 7

PRE-CLEARING SOIL CARBON LEVELS IN NEW SOUTH WALES

Robert Banks and Dermot McKane
(Soil Survey Unit, New South Wales Department of Land and Water Conservation)

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1. INTRODUCTION

The flux in soil carbon associated with land use change is a key component of Australia's greenhouse gas balance. The AGO is implementing a program to estimate the extent of the flux using soil carbon change modelling supported by paired site observations. This work is being stratified within the boundaries of the Interim Bio-geographic Regionalisation of Australia (IBRA Version 4, Thackway & Cresswell 1995). A key background measurement underlying this analysis is the level of soil carbon prior to significant land use change. An initial estimate of this level has been made by the New South Wales (NSW) Department of Land and Water Conservation (DLWC) based on existing data.

The objectives of the project were:

1. Identify the major soils in each IBRA cell and provide a spatial estimate using the most appropriate data available;
2. Allocate soil carbon content (kg/ha, 0-30 cm) for major soil groups/ spatial units; and
3. Provide supporting documentation on decisions.

The resultant tables and maps of soil carbon data for major soil/spatial units in each IBRA region are provided in this report.

2. APPROACH

Soil Carbon Storage Units (CSUs) for Interim Bioregions in NSW were created by grouping the DLWC Soil Landscapes (1:100 000 and 1:250 000 scale) where available, soil units from the Soil Resources Map of NSW (Atkinson, 1988) and from DLWC's Land Systems maps of the Western Division of NSW (Walker 1991). Soil carbon data for relatively undisturbed sites associated with soil profiles in each created CSU were sub-setted and averaged to give an average figure for soil carbon in each CSU, expressed as kg/ha/top 30 cm. Where available, average textures were derived for topsoils in each CSU.

3. SPATIAL COVERAGE

The Atlas of Australian Soils (Northcote *et.al.* 1960-68) was investigated for use in CSU construction, especially in the New England Tablelands, however, the data attached was found to be very time consuming for construction of CSUs. In many cases, descriptions of areas of important soils for carbon storage such as Red Ferrosols or Kraznosems were not well represented by explanation codes and soil codes associated with the polygon data.

Robert Banks and Dermot McKane compiled the CSU data from existing mapping. Where possible the authors of 1:100,000 Soil Landscape reports were given the opportunity to review the relative CSU allocation. Alterations were made if suggested.

The IBRA regions were compiled as follows:

Soil Surveyor	IBRA Regions
Robert Banks	Brigalow Belt South (Bbs)
	Channel Country (Chc)
	Darling Riverine Plains (Drp)
	Mulga Lands (Ml)
	Nandewar (Nan)
	New England Tableland (Net)
	NSW North Coast (Nnc)
	Simpson-Strzelecki (Ssd)
Dermot McKane	Australian Alps (Aa)
and Robert Banks	Broken Hill Complex (Bhc)
	Cobar Peneplain (Cp)
	Murray Darling Depression (Mdd)
	NSW South Western Slopes (Nss)
	Riverina (Riv)
	Sydney Basin (Sb)
	South East Corner (Sec)
	South East Highlands (Seh)

The spatial details of this report accompany this memo in ARCVIEW format.

4. SOIL CARBON ESTIMATIONS

The spatial carbon values for the top 30 cm of each soil profile, in t/ha were over-layed on available soils mapping polygon information for each IBRA region. The most detailed or precise available soil mapping in each IBRA region was used to develop a model for CSUs in each IBRA region, basically an average for carbon in kg/ha was ascribed to each CSU, using the point profile carbon values. If there were no data available in a CSU, data were used from the same CSU or a similar environment in adjacent IBRA regions to give an estimate that may represent the order of magnitude of carbon storage for that CSU.

Soil carbon data were derived from site organic carbon data determined by the Walkley Black method as described by Rayment and Higginson (1992). There are over 6,000 data points in the NSW Soil and Land Information System (SALIS) with soil organic carbon data throughout the profile in NSW. These data are mostly concentrated in the eastern half of the State and within areas covered by NSW Soil Landscape Mapping. The western division of NSW has some organic data points (over 600) most of which are associated with a survey of the NSW natural Gas pipeline survey.

As bulk density has seldom been measured in NSW soil surveys, it had to be estimated for each soil data point so that a value for carbon in kg/ha could be derived. For the eastern half of NSW there are good Plant Available Water (PAW) carbon measurements. These were used to estimate bulk density using PAWCERcalc provided by Neil McKenzie (CSIRO). Bulk densities for the Western Division were estimated using texture only in a look up table in Excel. Bulk density estimates using PAWCERcalc have been thoroughly checked and are generally thought to be reasonable estimates. The western division estimates really only qualify as 'best guess' estimates, but in the absence of any other data, these had to be used to generate carbon data. Both sets of figures were then adjusted to reflect carbon in the top 30 cm of each profile.

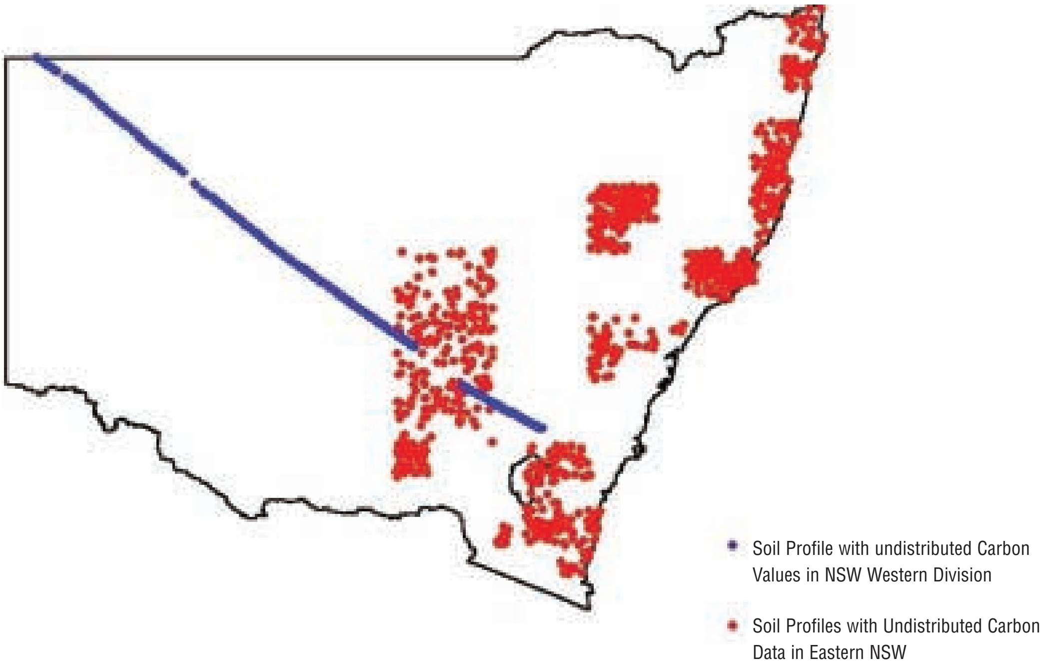

Figure 1. New South Wales undisturbed soil carbon sites.

4.1 IBRA REGIONS WITH CARBON RESULTS

Details of the derivation of the soil CSUs and the carbon values allocated to them are given in the following section. Figure 2 shows the distribution of soil carbon levels for the CSUs.

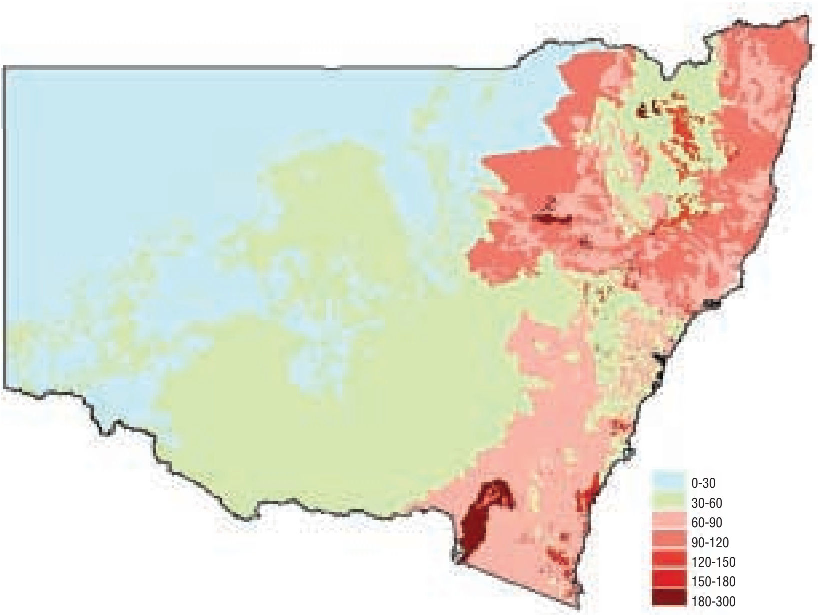

Figure 2. Soil carbon levels for New South Wales (t/ha, 0-30 cm).

4.1.1 Aa - Australian Alps

The NSW soil resources map covers this IBRA region. As this IBRA region is a data poor area for soil data, carbon storage areas have been estimated from adjacent regions.

Description of soil carbon units

CSU	Unit Name	Kg/ha/ top 30 cm	Clay Content %	Source
1	Alpine country, peat soils	200,000	5	Bbs
3	Near Alpine, soils generally not peats	120,000	20	Bbs

NSW soil resource map units used to create CSUs

CSU	NSW Soil Resource Map Units
1	shallow loams
3	deep structured red clay loams, yellow & red texture contrast soil, massive red & yellow earths, deep structured red clay loams

4.1.2 Bbs - Brigalow Belt South

Carbon store values were estimated using the soil carbon figures for the areas covered by Soil Landscape Mapping and extrapolated to the broader CSUs derived from the soil resources map.

Description of soil carbon units

CSU	Unit Name	Texture	Clay Content%	kg/ha/ top 30 cm
1	Steep, low C	Loam	20	111,500
2	Steep, high C	Silty Clay Loam	37	100,000
3	Undulating-rolling lighter soils and western vertosols	Sandy Clay Loam	28	97,100
4	Undulating-rolling Black Vertosols	Sandy Clay	43	81,600
8	Upland swamps (peat bogs)	Silty Clay Loam	40	240,000
9	Floodplains mixed lighter soils and vertosols	Sandy Clay	47	101,500
10	Floodplains Dominated by Black Vertosols	Silty Clay	53	69,200
11	Undulating-rolling uplands, high C	Clay Loam, Sandy	35	191,800

Soil landscapes and NSW soil resource map units used to create CSUs

CSU	Soil Landscapes and NSW Soil Resource Map Units
1	H8934nr, H8935el, Si_55_4SLbd, Si_55_4SLlp, Si_56_1Ebh, Si_56_1SLlp, Si_56_1Slol, SHALLOW LOAMS, STONY SANDY LOAMS
2	H8934cb, H8934gg, H8934ln, H8934mt, H8935bh, H8935mm, H8935mt, H8935mw, H8935ph, Si_55_4Ebh SHALLOW BLACK SELF MULCHING CLAY
3	
4	H8934ah, H8934bj, H8934bw, H8934ce, H8934ch, H8934cha, H8934er, H8934gk, H8934ki, H8934lg, H8934lga, H8934lo, H8934mn, H8935bj, H8935cr, H8935lg, H8935lo, H8935ma, H8935nj, H8935pn, H8935ta, Si_55_4BEah, Si_55_4CSme, Si_55_4Ewg, Si_56_1Amw, Si_56_1BEah, Si_56_1BEbw, Si_56_1BErg, Si_56_1RCbr, DEEP FRIABLE RED & BROWN CLAYS
8	H8934no
9	H8935bo, H8935ca, H8935dh, H8935gi, Si_55_4Alr, Si_55_4Ami, Si_55_4BCtv, COARSELY CRACKING GREY & BROWN CLAYS
10	H8934cd, H8934cda, H8934cs, H8934mo, H8934pc, H8934pca, H8934wc, H8934wca, H8934wcb, H8934ya, H8934ym, H8935cd, H8935cu, H8935gl, H8935lr, H8935mo, H8935qc, H8935ya, Si_55_4Amd, Si_55_4Atb, Si_56_1Atb, DEEP ALLUVIAL LOAMS, DEEP BLACK CRACKING CLAYS
11	H8934pb, H8934wg DEEP STRUCTURED RED CLAY LOAMS

4.1.3 Bhc - Broken Hill Complex

The land systems of western NSW mostly cover this region, with the northern remainder covered by the NSW soil resources map.

Description of soil carbon units

CSU	Unit Name	Clay Content %	Kg/ha/ top 30 cm	Source
2	River Channel	29	23 000	Drp
3	Backplains & floodouts, seasonal lakes	29	53 000	Drp
4	Undulating to rolling	29	53 900	Drp
5	Rolling to steep & stony	23	16 000	Drp
6	Steep, low carbon	23	30 000	Drp
7	Sand dunes & plains, saline lake beds	15	6 800	Drp

Land systems of western NSW and NSW soil resource map units used to create CSUs

CSU	Land Systems and NSW Soil Resource Map Units
2	Dl
3	De, Nl, Tb, Tv
4	Cb, Cp, Du, Mk, Nu, Yp, COARSELY CRACKING GREY & BROWN CLAYS
5	Cl, Cn, Fl, Gb, Hy, Kz, Nm, Ok, Te, MASSIVE RED & YELLOW EARTHS
6	Be, Bw, Cm, Em, Fc, Ft, Kh, Ko, Kt, Li, Ne, Nn, Ou, Ov, Pl, Vi, Wk, CALCAREOUS EARTHS, SCALDED RED TEXTURE CONTRAST SOILS, SHALLOW LOAMS
7	Br, By, Fw, Rg, Ss, Tm, Wm, SALINE SCALDED LAKE BED CLAYS, SILICEOUS DUNE SANDS

4.1.4 Chc - Channel Country

The Channel Country has no land systems data set available digitally. As this IBRA region is a data poor area for soil data, some carbon storage values had to be estimated from adjacent regions.

Description of soil carbon units

CSU	Unit Name	Clay Content %	kg/ha/ top 30 cm	Source
3	Undulating-rolling, low C	28	16 000	MI
9	Floodplains low C	29	23 000	DRP
12	Western Aeolian Sands	17	15 000	Ssd
13	Undulating to rolling very low C	32	16 000	
14	Saline Lake beds			No data

NSW Soil Resource map units used to create CSUs

CSU	NSW Soil Resource Map Units
3	calcareous earths
9	coarsely cracking grey & brown clays
12	siliceous dune sands
13	calcareous earths, massive red & yellow earths, scalded red texture contrast soils, shallow loams
14	saline scalded lake bed clays

4.1.5 Cp - Cobar Peneplain

The land systems of western NSW mostly cover this region, with the remainder covered by the NSW soil resources map.

Description of soil carbon units

CSU	Unit Name	Clay Content %	Kg/ha/ top 30 cm	Source
3	Plains adjacent floodplains	28	15 700	Ml
4	Extensive plains	23	23 900	
5	Very low to low sloping ridge lines	24	25 300	
6	Undulating mallee to low sandstone ridges	24	27 100	
7	Dunefield and stony ranges	23	26 200	

Land systems of western NSW and NSW soil resource map units used to create CSUs

CSU	Land Systems and NSW Soil Resource Map Units
3	Do, Lc, Lm, My, Nl, Tb, Ud
4	Bt, Gg, Kc, Ni, Nw, Tg, COARSELY CRACKING GREY & BROWN CLAYS
5	Cx, Et, Ki, Kl, Kw, Me, Ml, Pa, Pd, Wr, Yk, CALCAREOUS EARTHS, MASSIVE RED & YELLOW EARTHS, RED BROWN EARTHS
6	Bf, Bi, Bk, Bl, Bv, Cg, Ch, Ct, Em, Fu, Gu, Hd, Ir, Kr, Ld, Ly, Ma, Pi, Pv, Ro, Td, Tl, Tr, Wp, Wt, Wy, Ya, SCALDED RED TEXTURE CONTRAST SOILS, SHALLOW LOAMS, SILICEOUS DUNE SANDS
7	Bp, Bq, Bx, Bz, Ca, Cz, Er, Go, Gz, Hw, Jk, Ke, Kg, Kn, Kp, Ls, Lv, Mi, Mj, Mz, Nb, Ph, Rx, Sh, Wa, Ww, Yb, Yr

4.1.6 Drp - Darling Riverine Plains

This area is extensively covered by land systems mapping for the part of the Darling River Plains, which falls into the western division. For the remainder of the Darling River Plains the NSW soil resources map has been used. There is a small area of steep low carbon land in the far east of the map for which carbon content was estimated from adjacent mapping.

Description of soil carbon units

CSU	Unit Name	Clay Content %	kg/ha/ top 30 cm	Source
1	Steep, low C	23	77 600	Nan
3	Undulating-rolling, low C	29	53 900	
9	Floodplains low C	29	23 300	
12	Western Aeolian Sands	30	6 800	
13	Undulating to rolling very low C	15	16 000	

Soil landscapes and NSW soil resource map units used to create CSUs

CSU	Land System Code, NSW Soil Resource Map Units
1	SHALLOW LOAMS
3	Ar, Cg, Cz, Do, Gi, Gr, Kw, Lr, Mv, Pg, Pi, Pp, Pt, Pv, Ru, Td, Ty, Vi, Ya, CALCAREOUS EARTHS, MASSIVE RED AND YELLOW EARTHS, RED BROWN EARTHS, YELLOW AND RED TEXTURE CONTRAST SOILS
9	Ab, An, Bb, Cs, Cy, Db, Gd, Hd, Jo, Km, Lm, My, Ni, Nl, Nr, Ok, Pd, Po, Rs, Tb, Tv, Tw, Tz, Ud, Wd, Wg, Wq, Wx, COARSELY CRACKING GREY AND BROWN CLAYS
10	Cb, DEEP ALLUVIAL LOAMS, DEEP BLACK CRACKING CLAYS
12	Bd, Bx, Bz, Ez, Hy, Kd, Ta, Ta, Wp, SILICEOUS DUNE SANDS
13	As, Be, Bm, Bv, Bw, Ca, Cl, Cp, Cu, Cv, De, Dl, El, Em, Et, Fl, Fr, Kz, La, Ll, Mk, Mm, Ms, Mt, Mz, Ne, Ng, Nj, Ou, Ov, Pa, Rp, SCALDED RED TEXTURE CONTRAST SOILS

4.1.7 Ml - Mulga Lands

This region is mostly covered by land systems of western NSW, with a small section on the western flank covered by the NSW soil resources map.

Description of soil carbon units

CSU	Unit Name	Clay Content %	kg/ha/ top 30 cm	Source
3	Undulating-rolling, low C	28	15 700	
9	Floodplains low C	29	23 300	Drp
10	Floodplains high C	53	69 000	Bbs
12	Western Aeolian Sands	5	4 400	

Soil landscapes and NSW soil resource map units used to create CSUs

CSU	Land System Code, NSW Soil Resource Map Units
3	Av, Ce, Cp, De, Do, Du, El, Em, Et, Fi, Fl, Gb, Gl, Gm, Ja, Kt, La, Le, Lr, Mq, Ms, Nn, Ou, Pe, Pi, Pl, Pn, Qp, Qv, Re, Rg, Sb, Ty, Vi, Wl, Wv, Yp, CALCAREOUS EARTHS, MASSIVE RED & YELLOW EARTHS, SCALDED RED TEXTURE CONTRAST SOILS, SHALLOW LOAMS
9	Ab, Cs, Ft, Gy, Km, Lm, Mv, My, Ni, Nl, Ok, Po, Pr, Tb, Tz, Ud, Ur, Wd, Wg, COARSELY CRACKING GREY & BROWN CLAYS
10	Cb
12	Bd, By, Bz, Gp, Gx, Kd, Ma, Nd, Ny, Ta, Tl, Tn, Wn, Wp, SILICEOUS DUNE SANDS

4.1.8 Mdd - Murray Darling Depression

The land systems of western NSW mostly cover this region, with only a small area in the south-east corner requiring the NSW soil resources Map.

Description of soil carbon units

CSU	Unit Name	Clay Content %	Kg/ha/ top 30 cm	Source
2	River channel country		23 000	Drp
3	Ana branch of the Darling river	20	26 200	
4	Ephemeral lakes and transitions Riverine Plains	24	24 500	
5	Relict flood plains and plains	30	45 000	Nss
6	Undulating mallee to low sandstone ridges	23	29 000	
7	Sandplain and dune fields	16	40 300	

Land systems of western NSW and NSW soil resource map units used to create CSUs

CSU	Land Systems and NSW Soil Resource Map Units
2	Dl, Mc, Rl, Wh
3	Ab, An, Cy, De, Do, Lc, Nl, Tb, Tv, Tw
4	Cb, Gs, Kc, Lh, Nw, Pk, Pt, Sy, Tg, Vc, Vi
5	Fr, Hy, Kl, Ml, Ox, Pa, Rr, Yk, COARSELY CRACKING GREY & BROWN CLAYS, MASSIVE RED & YELLOW EARTHS, SHALLOW LOAMS
6	As, Be, Bf, Bi, Bk, Bl, Bm, Bv, Bw, Cl, Ct, Cu, Dm, Em, Ez, Fu, Gu, Hf, Kf, Ko, Kr, Kz, Ld, Ly, Ma, Mh, Mr, Mt, Ne, Ng, Nj, Ov, Pp, Ro, Rt, Te, Tl, Tr, Wk, Wt, Wy, Yh, CALCAREOUS EARTHS, CALCAREOUS SANDS, SCALDED RED TEXTURE CONTRAST SOILS
7	Ap, Bp, Bx, Bz, Ca, Cd, Cv, Gn, Gt, Gz, Hu, Kb, Ke, Kn, Kp, Ls, Lv, Mi, Mm, Mo, Mu, Mx, Mz, Nb, Ph, Qb, Rx, Sc, Sh, Ww, Yb, Yg, SALINE SCALDED LAKE BED CLAYS, SILICEOUS DUNE SANDS

4.1.9 Nan - Nandewar

Although there are currently no soil landscapes maps published for this region, the southern part of the region has a lot of soil data gathered for the Tamworth Soil Landscapes map (Banks, in press).

Description of soil carbon units

CSU	Unit Name	Texture	Clay Content %	kg/ha/ top 30 cm	Source
1	Steep, low C	Clay Loam	23	77 600	
2	Steep, high C	Silty Clay Loam	37	100 100	Bbs
3	Undulating-rolling lighter soils and western vertosols	Clay Loam, Sandy	42	43 700	
4	Undulating-rolling black vertosols	Silty Clay Loam	36	45 200	
10	Floodplains high C	Sandy Clay	40	71 000	
11	Undulating-rolling uplands, high C	Clay Loam, Sandy	35	191 000	Bbs

NSW soil resource map units used to create CSUs

CSU	NSW Soil Resource Map Units
1	shallow loams
2	shallow black self mulching clay
3	massive red & yellow earths red brown earths, stony sandy loams
4	deep black cracking clays, yellow & red texture contrast soils
10	coarsely cracking grey & brown clays, deep alluvial loams
11	deep structured red clay loams

4.1.10 Net - New England Tableland

Surprisingly, the New England tableland IBRA region has the poorest selection of soil data. There are no soil profile data for this region. Even though the Northcote soils of Australia was available for this area map (more detailed than the NSW soil resources map), the high rainfall, and high carbon soils (predominantly the Red Ferrosols or Kraznosems) are poorly represented by this map. Soil carbon values are all estimates from adjacent IBRA regions with relevant soil data.

Description of soil carbon units

CSU	Unit Name	Texture	Clay Content %	kg/ha/ top 30 cm	Source
1	Steep, low C	Lighter than Clay Loam	23	111 500	Nan
2	Steep, high C	Silty Clay Loam		100 000	Bbs
3	Undulating-rolling, lighter textured soils	Lighter than Clay Loam, Sandy	42	43 700	Nan
4	Undulating-rolling, Black Vertosols and well structured soils	Silty Clay Loam	36	45 200	Nan
9	Floodplains low C	Sandy Clay	47	101 500	Bbs
11	Undulating-rolling uplands, Red Ferrosols (Kraznozems)	Clay Loam, Sandy	35	146 000	Bbs

NSW soil resource map units used to create CSUs

CSU	NSW Soil Resource Map Units
1	shallow loams
2	shallow black self mulching clay
3	stony sandy loams, yellow & red texture contrast soils
4	deep black cracking clays, well structured red & brown earths
9	deep alluvial loams
11	deep structured red clay loams

4.1.11 Nnc - NSW North Coast

This IBRA region has by far the greatest soil landscape coverage and the highest soil profile density in northern NSW.

Description of soil carbon units

CSU	Unit Name	Texture	Clay Content %	kg/ha/ top 30 cm
1	Steep, low C	Silty Loam	25	92 300
2	Steep, high C	Clay Loam	31	114 000
3	Undulating-rolling, low C	Silty Loam	27	84 400
4	Undulating-rolling, high C	Clay Loam, Sandy	33	108 100
5	Coastal fluvial-deltaic floodplains	Clay Loam	31	106 100
6	Coastal swamps	Silty Clay	19	208 900
7	Coastal sands	Sandy loam	5	69 000

Soil landscapes and NSW soil resource map units used to create CSUs

CSU	Soil Landscapes and NSW Soil Resource Map Units
1	H9232bi,H9232ch, H9232cm, H9232eca, H9232gg, H9232gi,H9232gr, H9232hb, H9232hh, H9232im, H9232mj, H9232tr, H9232wea, H9332am, H9332cm, H9332ec, H9332gg, H9332jh, H9332mg, H9332mh,H9332rra, H9332tr, H9435by, H9435chs, H9435co,H9435cos, H9435ko, H9435mos, H9435ti, H9436bs, H9436mu, H9436rk, H9437ag, H9437bm, H9437bo, H9437bw, H9437di, H9437kc, H9437mg, H9437mga, H9437mk, H9437ny, H9437sn, H9437sna, H9537ag, H9537bm, H9537bo, H9537bw, H9537bwa, H9537wca, H9537wcb, H9540nrb, H9540pi, H9541bid, H9541cac, 9541nub, H9541pi, H9541pia, H9541pib, Si_56_1SLmb, Si_56_1SLol, Si_56_1Ypgb “SHALLOW LOAMS"
2	H9332bp, H9435fw, H9435gm, H9435ths, H9436di, H9436gm, H9436sn, H9436sna, H9437df, H9437dfa, H9437dfb, H9437nn, H9437su, H9537nn, H9537su, H9540bu, H9540co, H9540fh, H9540gp, H9540ma, H9540mb, H9540ni, H9540nr, H9540nra, H9540nrc, H9540ro, H9541bm, H9541bu, H9541bua, H9541cab, H9541fh, H9541fha, H9541gea, H9541gp, H9541ko, H9541ma, H9541maa, H9541m, H9541nu, H9541nua, Si_56_1Ecn, Si_56_1Kwm, Si_56_1Ypch “SHALLOW BLACK SELF MULCHING CLAY"
3	H9232bc, H9232be, H9232bh, H9232bia, H9232br, H9232bra, H9232cha, H9232cl, H9232ec, H9232gga, H9232gl, H9232gt, H9232gw, H9232gwa, H9232hi, H9232ima, H9232md, H9232me, H9232mi, H9232nc, H9232ng, H9232pa, H9232rr, H9232sc, H9232se, H9232sea, H9232seb, H9232tb, H9232tm, H9232tma, H9232va, H9232we, H9232wg, H9232wga, H9332eca, H9332gc, H9332gga, H9332gh, H9332mp, H9332nc, H9332nca, H9332ng, H9332no, H9332pr, H9332rr, H9332sw, H9332tb, H9435al, H9435be, H9435bf, H9435ch, H9435chl, H9435cp, H9435eu, H9435hy, H9435kg, H9435mo, H9435rf, H9435sr, H9435ye, H9436al, H9436bf, H9436br, H9436cp, H9436eu, H9436fw, H9436kg, H9436kk, H9436mk, H9436ne, H9436pn, H9436tb, H9436tc, H9436tg, H9436vl, H9436we, H9436ww, H9436ye, H9437av, H9437bk, H9437bp, H9437bpa, H9437cg, H9437de, H9437du, H9437gl, H9437gn, H9437gp, H9437ko, H9437kr, H9437me, H9437pl, H9437pn, H9437sh, H9437to, H9437tw, H9437ul, H9437va, H9437wc, H9537av, H9537bc, H9537bn, H9537cc, H9537de, H9537gl, H9537gn, H9537gp, H9537ko, H9537kr, H9537lo, H9537me, H9537mo, H9537ne, H9537pl, H9537pn, H9537re, H9537sc, H9537sh, H9537tw, H9537ul, H9537wc, H9540ba, H9540baa, H9540bab, H9540cc, H9540ck, H9540cl, H9540cla, H9540clb, H9540dpa, H9540na, H9540sc, H9540yo, H9540yoa, H9540yob, Si_56_1Ahu, Si_56_1BPst, Si_56_1BREml, Si_56_1NKBlv, Si_56_1RBElh, Si_56_1Rpro, Si_56_1RPrv, Si_56_1SCbj, Si_56_1SCbz, Si_56_1SCck, Si_56_1Scse, Si_56_1Shig, Si_56_1SHlb, Si_56_1SHld, Si_56_1SHrh, Si_56_1SHsf, Si_56_1SSww, Si_56_1YEca, Si_56_1YPad, Si_56_1YPbx, Si_56_1YPgl, Si_56_1YPls, Si_56_1YPrx, Si_56_1Ypsc "MASSIVE RED & YELLOW EARTHS”, “RED BROWN EARTHS", "YELLOW & RED TEXTURE CONTRAST SOILS"
4	H9232bib, H9232hba, H9232ne, H9435bw, H9435ca, H9435hn, H9435lf, H9435mm, H9435rb, H9435rh, H9435th, H9435yes, H9436ba, H9436ca, H9436hn, H9436lf, H9436mm, H9436nr, H9436rw, H9436wa, H9436ya, H9437be, H9437bi, H9437ch, H9437da, H9437daa, H9437do, H9437doa, H9437mgb, H9437nr, H9437or, H9437pp, H9437ppa, H9437rc, H9437tt, H9537be, H9537bu, H9537ch, H9537ci, H9537da, H9537np, H9537or, H9537sha, H9540bg, H9540bi, H9540bia, H9540dp, H9540el, H9540ela, H9540elb, H9540ew, H9540fr, H9540ge, H9540gea, H9540geb, H9540gec, H9540ku, H9540le, H9540mba, H9540mc, H9540mca, H9540mi, H9540mib, H9540my, H9540nc, H9540nca, H9540roa, H9540ta, H9540te, H9540wo, H9540woa, H9540wob, H9541bc, H9541bi, H9541bia, H9541bib, H9541bic, H9541by, H9541ca, H9541caa, H9541cc, H9541cd, H9541cl, H9541cr, H9541cu, H9541cua, H9541cub, H9541dp, H9541ge, H9541geb, H9541ged, H9541gpa, H9541ku, H9541kua, H9541kub, H9541le, H9541li, H9541lia, H9541lib, H9541mb, H9541me, H9541mi, H9541mt, H9541mta, H9541no, H9541noa, H9541og, H9541oga, H9541ox, H9541oxa, H9541pu, H9541ru, H9541te, H9541wl, Si_56_1Acm, Si_56_1BCdb, Si_56_1CSbt, Si_56_1Csmi, Si_56_1Egu, Si_56_1Esg, Si_56_1Krt, Si_56_1SLbg “DEEP ALLUVIAL LOAMS", “DEEP BLACK CRACKING CLAYS", “DEEP FRIABLE RED & BROWN CLAYS", “DEEP STRUCTURED RED CLAY LOAMS", "WELL STRUCTURED RED & BROWN_EARTHS"
5	H9232cc, H9232hs, H9232hu, H9232hua, H9232hub, H9232mf, H9232nw, H9232ri, H9232tba, H9232wr, H9232wra, H9332bf, H9332mr, H9332nw, H9332nwa, H9332sbc, H9435ae, H9435bpm, H9435gd, H9435mr, H9435pc, H9436ae, H9436gd, H9436mr, H9436pc, H9436ra, H9437ra, H9537ra, H9540du, H9540ep, H9540mu, H9541mu, H9541tw, H9541twb “MASSIVE BLACK & GREY COASTAL CLAYS"
6	H9232ba, H9232fc, H9232sbc, H9232ss, H9232tbb, H9232ts, H9332es, H9332fc, H9332ss, H9332ssa, H9332tba, H9332ty, H9332tya, H9435bl, H9435blt, H9435cc, H9435ck, H9435de, H9435gdt, H9435gdw, H9435hh, H9435hhw, H9435mc, H9435mcw, H9435mrw, H9436ch, H9436ck, H9436cy, H9436hh, H9436ma, H9436mc, H9436se, H9436tm, H9436tmb, H9537cca, H9537cf, H9537tm, H9540bp, H9540tu, H9540tya, H9541cb, H9541cba, H9541cbb, H9541cbc, H9541tu, H9541twa, H9541uk
7	H9232ba, H9232fc, H9232sbc, H9232ss, H9232tbb, H9232ts, H9332es, H9332ss, H9332ssa, H9332tba, H9332ty, H9332tya, H9435bl, H9435blt, H9435cc, H9435ck, H9435de, H9435gdt, H9435hh, H9435hhw, H9435mc, H9435mcw, H9435mrw, H9436ch, H9436ck, H9436cy, H9436hh, H9436ma, H9436mc, H9436se, H9436tm, H9436tmb, H9537cca, H9537cf, H9537tm, H9540bp, H9540tu, H9540tya, H9541cb, H9541cba, H9541cbb, H9541cbc, H9541tu, H9541twa, H9541uk.

4.1.12 Nss - NSW South Western Slopes

Carbon storage units were estimated using the soil carbon figures for the areas covered by Soil Landscape Mapping and extrapolated to the broader CSUs derived from the NSW soil resources map.

Description of soil carbon units

CSU	Unit Name	Texture	Clay Content %	Kg/ha/top 30 cm
2	River Channels	Clay loam	30	23 000
3	Occasional swamps and near river plains	Clay loam to light clay	36	45 000
4	Gently undulating rises	Sandy loam	32	46 200
5	Rises to low hills, often cleared for cropping and grazing	Sandy loam	30	43 200
6	Vegetated hills to low hills	Sandy loam	24	
7	Dunes and stony sandy hills	Coarse sandy loam	24	
8	Steep, stony low hills to hills	Sandy loam	20	

Soil landscapes and NSW soil resource map units used to create CSUs

CSU	Land System and NSW Soil Resource Map Units
0	H8327water, Si_55_12water, Si_55_7xx, Si_55_8water, WATER
2	Si_55_8Alh
3	H8327be, H8327bu, H8327bua, H8327eb, H8327fa, H8327fh, H8327kp, H8327pe, H8327rp, Si_55_7bc, Si_55_7gb, Si_55_7gr, Si_55_7gu, Si_55_7lh, Si_55_7sb, DEEP ALLUVIAL LOAMS
4	H8327bk, H8327bka, H8327bl, H8327bla, H8327bs, H8327gb, H8327gl, H8327kd, H8327kpa, H8327ma, H8327wo, H8327ya, Si_55_12bi, Si_55_12CSmc, Si_55_12CSta, Si_55_12Ecl, Si_55_12NKBkb, Si_55_12YEbi, Si_55_4Abe, Si_55_4Acd, Si_55_4Alr, Si_55_4Alw, Si_55_4Amd, Si_55_4Ami, Si_55_4Atb, Si_55_4CSme, Si_55_4Ebh, Si_55_4Ecl, Si_55_4Emo, Si_55_4Enb, Si_55_4Etk, Si_55_4Ewg, Si_55_4NKBbs, Si_55_4NKBcm, Si_55_4NKBmm, Si_55_4NKByv, Si_55_4TRwc, Si_55_7ba, Si_55_7bo, Si_55_7dn, Si_55_7hu, Si_55_7lc, Si_55_7ml, Si_55_7mp, Si_55_7oo, Si_55_7ru, Si_55_7se, Si_55_7ty, Si_55_7wh, Si_55_7ww, Si_55_8Amq, Si_55_8CSgi, Si_55_8Ecl, Si_55_8Emo, Si_55_8Kct, Si_55_8Kpa, Si_55_8Kpr, Si_55_8Ksb, Si_55_8Kto, Si_55_8NKBkb, Si_55_8Ypcr, COARSELY CRACKING GREY & BROWN CLAYS, DEEP BLACK CRACKING CLAYS, DEEP FRIABLE RED & BROWN CLAYS, SHALLOW BLACK SELF MULCHING CLAY
5	H8327br, H8327gr, H8327gra, H8327ld, H8327lda, H8327mfa, H8327ob, H8327oba, H8327obb, H8327re, H8327ri, H8327vi, Si_55_12Ago, Si_55_12na, Si_55_12NKBcd, Si_55_12NKBke, Si_55_12NKBmu, Si_55_12NKBna, Si_55_12oc, Si_55_12RPrl, Si_55_12SHbc, Si_55_12SHbl, Si_55_12SLoc, Si_55_12YEmi, Si_55_12YEvu, Si_55_12YPbu, Si_55_12YPbw, Si_55_12YPcr, Si_55_12YPcy, Si_55_12YPga, Si_55_12YPla, Si_55_12YPtr, Si_55_12YSil, Si_55_4BEah, Si_55_4CSmg, Si_55_4Ebz, Si_55_4Ena, Si_55_4ESgn, Si_55_4ESti, Si_55_4NKBav, Si_55_4NKBbk, Si_55_4NKBbt, Si_55_4NKBgu, Si_55_4NKBll, Si_55_4NKBmn, Si_55_4NKBng, Si_55_4NKBrh, Si_55_4NKBsu, Si_55_4RBEar, Si_55_4RBEtl, Si_55_4REno, Si_55_4REtu, Si_55_4RPbi, Si_55_4RPbl, Si_55_4RPbr, Si_55_4RPcg, Si_55_4RPcu, Si_55_4RPsh, Si_55_4RPso, Si_55_4RSdu, Si_55_4RSgd, Si_55_4RStt, Si_55_4RSws, Si_55_4SHdh, Si_55_4SHmk, Si_55_4SHmu, Si_55_4YPbc, Si_55_4YPcp, Si_55_4YPer, Si_55_4YPul, Si_55_4YSlc, Si_55_7bk, Si_55_7bn, Si_55_7bp, Si_55_7bv, Si_55_7by, Si_55_7bz, Si_55_7ca, Si_55_7ck, Si_55_7cm, Si_55_7co, Si_55_7cr, Si_55_7da, Si_55_7de, Si_55_7ec, Si_55_7kb, Si_55_7ma, Si_55_7mu, Si_55_7na, Si_55_7sa, Si_55_7sy, Si_55_7wc, Si_55_7we, Si_55_7ya, Si_55_8Ewo, Si_55_8NKBcd, Si_55_8NKBkf, Si_55_8NKBmn, Si_55_8NKBna, Si_55_8REno, Si_55_8REtu, Si_55_8REvb, Si_55_8RPbl, Si_55_8RPbr, Si_55_8RPcu, Si_55_8RPcw, Si_55_8RPoe, Si_55_8RPpu, Si_55_8RPrl, Si_55_8RPso, Si_55_8RPwf, Si_55_8RSdu, Si_55_8RSgd, Si_55_8SHmk, Si_55_8SHmu, Si_55_8SLla, Si_55_8SLpe, Si_55_8TRbp, Si_55_8TRgc, Si_55_8YPbu, Si_55_8YPcp, Si_55_8YPga, Si_55_8Yptr, CALCAREOUS EARTHS, DEEP STRUCTURED RED CLAY LOAMS, MASSIVE RED & YELLOW EARTHS, RED BROWN EARTHS, SCALDED RED TEXTURE CONTRAST SOILS, YELLOW & RED TEXTURE CONTRAST SOILS

Soil landscapes and NSW soil resource map units used to create CSUs continued

CSU	Land System and NSW Soil Resource Map Units
6	H8327li, H8327mf, H8327pu, H8327pua, H8327rb, H8327wa, Si_55_12ch, Si_55_12co, Si_55_12SLab, Si_55_12SLbj, Si_55_12SLco, Si_55_12SLli, Si_55_12SLpm, Si_55_12SSpc, Si_55_12SSwy, Si_55_12YEcb, Si_55_12YEct, Si_55_4ESap, Si_55_4ESbn, Si_55_4RBEbm, Si_55_4SLbd, Si_55_4SLcs, Si_55_4SLdx, Si_55_4SLlp, Si_55_4SLsr, Si_55_4SShr, Si_55_4SSmp, Si_55_4SSox, Si_55_4SSrs, Si_55_4SSry, Si_55_4SSwl, Si_55_7am, Si_55_7be, Si_55_7bh, Si_55_7bu, Si_55_7bx, Si_55_7cd, Si_55_7cp, Si_55_7du, Si_55_7eg, Si_55_7fw, Si_55_7hs, Si_55_7lm, Si_55_7mi, Si_55_7mn, Si_55_7mt, Si_55_7pa, Si_55_7rv, Si_55_7wa, Si_55_7wl, Si_55_7wy, Si_55_8ESgo, Si_55_8NKBll, Si_55_8SLab, Si_55_8SLbd, Si_55_8SLce, Si_55_8SLco, Si_55_8SLcs, Si_55_8SLlm, Si_55_8SLpm, Si_55_8SLyp, Si_55_8SSgu, Si_55_8SSqu, Si_55_8Sswy, SHALLOW LOAMS, SILICEOUS DUNE SANDS, STONY SANDY LOAMS
7	H8327cw, H8327cwa, H8327ro, Si_55_12Lbk, Si_55_12SLmy, Si_55_12SLrb, Si_55_4SLba, Si_55_4SLdw, Si_55_4SLgl, Si_55_4SLrb, Si_55_4SLts, Si_55_4SLyp, Si_55_4SSgg, Si_55_4SSgo, Si_55_4SSki, Si_55_7bi, Si_55_7bl, Si_55_7cb, Si_55_7dr, Si_55_7eu, Si_55_7ga, Si_55_7gf, Si_55_7go, Si_55_7ir, Si_55_7mg, Si_55_7my, Si_55_7ot, Si_55_7pp, Si_55_7pr, Si_55_7re, Si_55_7sp, Si_55_7tu, Si_55_7yp, Si_55_8SLmy, Si_55_8SLrb, Si_55_8SSki, Si_55_8SSro
8	Si_55_7bd, Si_55_7jr, Si_55_7mm, Si_55_7sh, Si_55_7wb, Si_55_7wm

4.1.13 Riv - Riverina

The land systems of western NSW mostly cover this region, with the remainder covered by the NSW soil resources map.

Description of soil carbon units

CSU	Unit Name	Clay Content %	Kg/ha/ top 30 cm	Source
2	River Channels	30	23 000	Drp
3	Floodplains & backplains	36	45 000	Nss
4	Plains, High C	32	45 000	Nss
5	Plains, low C	30	40 000	Nss
6	Sand plains and dunes with low C	24	46 000	Nss
7	Steep Stony low C	23	40 000	Drp

Land systems of western NSW and NSW soil resource map units used to create CSUs

CSU	Land System and NSW Soil Resource Map Units
2	Mc, Rl
3	Lb, Lc
4	Gs, Kc, Pk, Vc, We, COARSELY CRACKING GREY & BROWN CLAYS
5	Ox, Pa, Rt, Yk, CALCAREOUS EARTHS, MASSIVE RED & YELLOW EARTHS, RED BROWN EARTHS, SHALLOW LOAMS, YELLOW & RED TEXTURE CONTRAST SOILS
6	Ap, Bm, Dm, Hf, Kf, Lv, Mh, Mr, Ov, Tr, Wk, Yh, CALCAREOUS SANDS, SALINE SCALDED LAKE BED CLAYS, SCALDED RED TEXTURE CONTRAST SOILS, SILICEOUS DUNE SANDS
7	Cd, Gn, Gt, Gz, Kn, Ls, Mu, Rx, Yg

4.1.14 Sb - Sydney Basin

Carbon storage units were estimated using the soil carbon figures for the areas covered by Soil Landscape Mapping and extrapolated to the broader CSUs derived from the NSW soil resources map.

This IBRA region has by far the greatest soil landscape coverage and the highest soil profile density in northern NSW.

Description of soil carbon units

CSU	Unit Name	Texture	Clay Content %	Kg/ha/top 30 cm	Source
1	Coastal Swamps	Silty Loam	25	208 900	Nnc
2	Coastal fluvial-deltic floodplains	Silty Loam	33	122 000	
3	Undulating-rolling high C	Coarse sandy Loam	29	161 400	
4	Steep, high C	Coarse sandy Loam	30	81 300	
5	Undulating-rolling low C	Coarse sandy Loam	23	82 300	
6	Steep, low C, Sydney Sandstone	Coarse sandy Loam	25	56 000	
7	Coastal sands	Sand	24	66 300	
8	Beaches & Stony headlands	Sand	0	0	

Soil landscapes and NSW soil resource map units used to create CSUs

CSU	Land System and NSW Soil Resource Map Units
0	H8930water, H8930xx, H9028water, H9028xx, H9029water, H9029xx, H9030water, H9030xx, H9031water, H9031xx, H9130water, H9130xx, H9131water, H9131xx, H9232water, H9232xx, H9332WATER, H9332xx,, Si_56_1water, W
1	H9028mc, H9029mc, H9130et, H9130mc, H9131bs, H9131mc, H9131ts, H9232ba, H9232fc, H9232Hma, H9232ss, H9232ts, H9332es, H9332fc, H9332ss, H9332ssa
2	H9028ro, H9028wi, H9030ba, H9031wfb, H9131Hr, H9232bf, H9232bfa, H9232cc, H9232Hs, H9232Hu, H9232Hua, H9232Hub, H9232mf, H9232nw, H9232ri, H9232wy, H9332bf, H9332lp, H9332sbc
3	H8930dc, H8930dca, H8930ir, H8930ls, H8930to, H8931dc, H8931dca, H8931ir, H8931to, H8931xx, H9028ba, H9028bg, H9028ja, H9028ka, H9028ki, H9030bs, H9031to,, Si_56_1Amw,, Si_56_1Atb, Si_56_1Awd, Si_56_1BCdb, Si_56_1BEah, Si_56_1BEbw, Si_56_1BErg, Si_56_1CMby, Si_56_1CSmv, Si_56_1CSsx, Si_56_1Ecn, Si_56_1Esg, Si_56_1Kco, Si_56_1RCbr, DEEP ALLUVIAL LOAMS, MASSIVE BLACK & GREY COASTAL CLAY
4	H8930cx, H8930kg, H8931ho, H8931kg, H9028fa, H9028md, H9028sf, H9029fa, H9029md, H9030kg, H9031ch, H9031cha, H9031gc, H9031ho, H9031hr, H9031kg, H9031wf, H9130ho, H9130lc, H9131bl, Si_55_4Atb, Si_55_4Ebh, Si_55_4Kct, Si_56_1Ahu, Si_56_1Awo, Si_56_1Aya, Si_56_1Knm, Si_56_1SSww, DEEP BLACK CRACKING CLAYS, DEEP FRIABLE RED & BROWN CLAYS, SHALLOW BLACK SELF MULCHING CLAY, WELL STRUCTURED RED & BROWN EARTH
5	H8930bg, H8930ke, H8930li, H8930pf, H8931ga, H8931mr, H8931ro, H8931um, H8931wr, H9028bo, H9028ca, H9028el, H9028sh, H9028wm, H9028wt, H9029bk, H9029bt, H9029lu, H9029mk, H9029wn, H9030bg, H9030bt, H9030fr, H9030gn, H9030lu, H9030ri, H9030up, H9030wf, H9030wl, H9031lg, H9031lga, H9031lgb, H9031pc, H9031wl, H9031woa, H9031wob, H9130bg, H9130bt, H9130cb, H9130dc, H9130er, H9130gn, H9130wa, H9130wn, H9130wp, H9131aw, H9131cb, H9131er, H9131gn, H9131lg, H9131wl, H9131wn, H9131wy, H9131ya, H9232aw, H9232be, H9232bea, H9232bh, H9232bha, H9232ce, H9232do, H9232ga, H9232hg, H9232ki, H9232kia, H9232me, H9232mi, H9232nr, H9232sh, H9232sna, H9232sua, H9232wa, H9232wc, H9332mp, H9332nc, Si_55_4BEah, Si_55_4ESgn, Si_55_4ESti, Si_55_4NKBbt, Si_55_4RPcg, Si_55_4YEcr, Si_55_4YPbc, Si_55_4YPcp, Si_55_4YPul, Si_56_1Erc, Si_56_1ESbn, Si_56_1ESgn, Si_56_1ESti, Si_56_1NKBlv, Si_56_1PSqb, Si_56_1REmo, Si_56_1RPcg, Si_56_1RPro, Si_56_1RPrv, Si_56_1SCbe, Si_56_1SCbj, Si_56_1SCbz, Si_56_1SCck, Si_56_1SCdv, Si_56_1SCge, Si_56_1SCnh, Si_56_1SCsy, Si_56_1SCwp, Si_56_1Shbu, Si_56_1Shjp, Si_56_1Shld, Si_56_1Shsf, Si_56_1SLha, Si_56_1SLol, Si_56_1SSmp, Si_56_1SSry, Si_56_1YEcr, Si_56_1YEiw, Si_56_1YPad, Si_56_1YPbc, Si_56_1YPbx, Si_56_1YPcp, Si_56_1YPlg, Si_56_1YPpk, Si_56_1YPrx, Si_56_1Ypsc, DEEP STRUCTURED RED CLAY LOAMS, MASSIVE RED & YELLOW EARTHS, RED BROWN EARTHS, SHALLOW LOAMS

Soil landscapes and NSW soil resource map units used to create CSUs continued

CSU	Land System and NSW Soil Resource Map Units
6	H8930cb, H8930cv, H8930fb, H8930gy, H8930hw, H8930ka, H8930mb, H8930ms, H8930msa, H8930rm, H8930wb, H8930wo, H8931cb, H8931cg, H8931co, H8931fb, H8931gy, H8931hw, H8931mb, H8931ms, H8931np, H8931wb, H8931wo, H9028ap, H9028co, H9028fb, H9028fo, H9028gp, H9028gw, H9028ie, H9028lh, H9028no, H9028pn, H9028pr, H9028sm, H9028wb, H9029bp, H9029bu, H9029fb, H9029gw, H9029gy, H9029ie, H9029la, H9029lh, H9029pn, H9029sc, H9029tp, H9029vo, H9029wb, H9029ya, H9030bp, H9030fb, H9030gy, H9030hw, H9030lh, H9030pn, H9030sc, H9030vo, H9030wb, H9031gy, H9031la, H9031lh, H9031ma, H9031mb, H9031np, H9031of, H9031ofa, H9031ofb, H9031so, H9031st, H9031wb, H9031wfa, H9031wo, H9130fb, H9130gy, H9130gy/la, H9130la, H9130lh, H9130of, H9130so, H9131awa, H9131do, H9131er/wo, H9131gk, H9131gy, H9131la, H9131lh, H9131ma, H9131ml, H9131of, H9131so, H9131st, H9131wa, H9131wo, H9232awa, H9232sn, H9232su, H9332gg, Si_55_4ESbn, Si_55_4SLdx, Si_55_4SLlp, Si_55_4, S, Shr, Si_55_4SSmp, Si_55_4SSrs, Si_55_4SSry, Si_56_1BPaw, Si_56_1BPtw, Si_56_1Ebh, Si_56_1SLlp, Si_56_1SLts, Si_56_1SLwn, SILICEOUS DUNE SANDS, STONY SANDY LOAMS, YELLOW & RED TEXTURE CONTRAST SOIL
7	H8930ha, H8931ha, H9028ha, H9028kn, H9029ha, H9029kn, H9029ri, H9030ab, H9030ha, H9031ha, H9031haa, H9031wn, H9130ha, H9130nh, H9130nh/tg, H9130np, H9130tg, H9130ww, H9131ha, H9131nr, H9131tg, H9131ww, H9232bt, H9232hm, H9232hn, H9232lp, H9232sb, H9232sba, H9232sbb, H9232sk, H9232tg, H9232tn, H9232tna, H9232tnb, H9332bt, H9332fh, H9332hn, H9332sb, H9332sba, H9332sk, H9332tn, Si_55_4REmb, Si_55_4SLba, Si_55_4SLts
8	H9028wg, H9029wg, H9130na, H9131na

4.1.15 SEC - SOUTH EAST CORNER

Carbon storage units were estimated using the soil carbon figures for the areas covered by Soil Landscape Mapping and extrapolated to the broader CSUs derived from the NSW soil resources map.

Much of the data has come from the draft 1:100,000 Soil Landscape Mapping for the Cobargo (Tulau draft), Eden (Tulau and McKane draft) and Narooma (Tulau draft) map sheets.

Description of soil carbon units

CSU	Unit Name	Texture	Clay Content %	Kg/ha/ top 30 cm	Source
2	Moist gully, with vegetation	Loam	38	122 000	
3	Rolling country	Sandy Loam	28	161 400	
4	Rolling to steep	Sandy Loam	26	81 300	
5	Steep, often granites	Coarse Sandy Loam	25	82 300	
6	Steep, mainly metasedimentary country	Sandy Loam	33	56 000	
7	Very steep and stony, low C	Coarse Sand	5	66 300	
8	Beaches & Stony headlands	Coarse Sand	0	0	No data

Soil landscapes and NSW soil resource map units used to create CSUs

CSU	Land System and NSW Soil Resource Map Units
0	H8823water, H8823xx, H8824water, H8824xx, H8825WATER, H8925water
2	H8823bla, H8823bod, H8824ba, H8827Hw
3	H8823bh, H8823bo, H8823bob, H8823fc, H8823gca, H8823nb, H8823ps, H8823psb, H8823sc, H8823ss, H8823ssa, H8823wta, H8823wy, H8824bb, H8824be, H8824bh, H8824bo, H8824boc, H8824gh, H8824jj, H8824md, H8824mda, H8824nb, H8824nl, H8824ns, H8824ps, H8824tr, H8825bb, H8825bba, H8825ck, H8825gh, H8825mb, H8825nb, H8825ns, H8825tt, H8827hwa, H8925bm, H8925bn, H8925ck, H8925ls, H8925lsb, H8925ps, H8925sl, H8925tt, H8925wg, H8925wga, DEEP BLACK CRACKING CLAYS, DEEP STRUCTURED RED CLAY LOAMS
4	H8823boa, H8823boe, H8823br, H8823cu, H8823cua, H8823ebb, H8823ebc, H8823gc, H8823gcc, H8823ji, H8823mec, H8823mob, H8823moe, H8823mp, H8823nga, H8823pab, H8823pee, H8823ti, H8823tj, H8823to, H8823tr, H8823trb, H8823wt, H8823wtc, H8823ypd, H8824bi, H8824bp, H8824bpa, H8824gc, H8824ji, H8824lb, H8824mp, H8824mu, H8824psa, H8824psb, H8824tj, H8824wc, H8824wl, H8825bp, H8825bpb, H8825br, H8825dr, H8825kr, H8825ky, H8825mba, H8825mbb, H8825mp, H8825mu, H8825psa, H8825psb, H8825tf, H8825tj, H8825ts, H8825ut, H8825uw, H8825uwa, H8825ypd, H8827cu, H8827mb, H8827mba, H8827mo, H8925bd, H8925bl, H8925br, H8925co, H8925dr, H8925mu, H8925mub, H8925muc, H8925na, H8925tf, H8925tj, H8925ts, H8925wgb, H8925wl, MASSIVE RED & YELLOW EARTHS, WELL STRUCTURED RED & BROWN EARTH, YELLOW & RED TEXTURE CONTRAST SOIL
5	H8823bub, H8823eb, H8823eba, H8823jia, H8823jib, H8823ka, H8823me, H8823med, H8823mee, H8823mef, H8823mg, H8823mgb, H8823mib, H8823mo, H8823moc, H8823ng, H8823nm, H8823nma, H8823nmb, H8823nmc, H8823pa, H8823paa, H8823pe, H8823qu, H8823te, H8823tib, H8823wtb, H8823wtd, H8823yp, H8823ypb, H8823ype, H8823ypf, H8823yw, H8824br, H8824jia, H8824ka, H8824mg, H8824mgb, H8824mm, H8824mma, H8824ng, H8824pa, H8824pab, H8824pad, H8824pb, H8824qu, H8824te, H8824trb, H8824wo, H8824yp, H8824ypa, H8824ypb, H8824ypc, H8825cb, H8825cba, H8825cm, H8825cma, H8825da, H8825daa, H8825dab, H8825du, H8825gu, H8825ji, H8825mg, H8825mm, H8825mpb, H8825mub, H8825muc, H8825pb, H8825rh, H8825tr, H8825wo, H8825ws, H8825yp, H8825ypa, H8827ea, H8925gu, H8925ka, H8925pa, H8925qu, H8925wla, SHALLOW LOAMS, STONY SANDY LOAMS
6	H8823bu, H8823bua, H8823meb, H8823mi, H8823mia, H8823mn, H8823moa, H8823pea, H8823peb, H8823pec, H8823ped, H8823tu, H8823wya, H8823ywa, H8824bra, H8824brb, H8824mga, H8824pba, H8824psc, H8824tu, H8824wa, H8825jia, H8825jib, H8825jic, H8825pba, H8825pbb, H8825psc, H8825wa
7	H8823bra, H8823brb, H8823cj, H8823cja, H8823gcb, H8823jr, H8823jra, H8823kp, H8823toa, H8823wh, H8823wha, H8823whc, H8823whd, H8823whe, H8823whf, H8824jr, H8824jra, H8824kp, H8825waa, H8925kp
8	H8823ab, H8823qp, H8823ta, H8823taa, H8823tac, H8823wf, H8824qp, H8824ta, H8824tac, H8824wf, H8925qp, H8925ta, H8925wf

4.1.16 She - South East Highlands

Carbon storage units were estimated using the soil carbon figures for the areas covered by Soil Landscape Mapping and extrapolated to the broader CSUs derived from the NSW soil resources map.

Description of soil carbon units

CSU	Unit Name	Texture	Clay Content %	Kg/ha/top 30 cm
2	River Channels and Volcanic Plains	Clay Loam	28	115 000
3	Rolling vegetated country	Clay Loam	28	87 100
4	Rolling stony country	Sandy Clay Loam	26	71 000
5	Steep, often granites	Coarse Sandy Loam	23	67 000
6	Rolling to steep stony low C country	Sandy Loam	19	60 500
7	Steep, stony, low C	Sandy Loam	25	57 900
8	Very steep & stony, low C	Sandy Loam	5	39 000

Soil landscapes and NSW soil resource map units used to create CSUs

CSU	Land System and NSW Soil Resource Map Units
0	H8726xx, H8727Lake, H8727Lake George, H8727RESERVOIR, H8727xx, H8827lake, H8827xx, H8930water, H8930xx, H8931dam, H8931xx, Si_55_12water, , Si_55_8waterWATER
2	H8725br, H8725brc, H8725sv, H8726brc, H8726sv, H8727la, H8727mg, H8727mga, H8727mgb, H8727mx, H8827bra, H8827hw, H8827la, H8827laa, H8827lac, H8827lb, H8827mn, H8827to, H8827tu, Si_55_8AHmc, Si_55_8Alh
3	H8725bb, H8725brb, H8725cda, H8725ky, H8725maa, H8725mab, H8725rf, H8725uc, H8726bb, H8726bn, H8726bna, H8726cf, H8726maa, H8726rf, H8726wi, H8727cf, H8727fr, H8727hf, H8727hfa, H8727jp, H8727wi, H8727wia, H8824bb, H8824ns, H8825bb, H8825bba, H8825nb, H8825ns, H8827cf, H8827dhb, H8827lab, H8930dca, H8930mo, H8931dc, H8931dca, H8931ls, H8931to, COARSELY CRACKING GREY & BROWN CLAY
4	H8725an, H8725bc, H8725bra, H8725cd, H8725cl, H8725da, H8725daa, H8725du, H8725mb, H8725mba, H8725mbb, H8725mf, H8725mu, H8725nl, H8725oa, H8725ph, H8725rm, H8725ut, H8725wt, H8726an, H8726ba, H8726baa, H8726bo, H8726mb, H8726mbc, H8726rm, H8726wt, H8727an, H8727ba, H8727baa, H8727bo, H8727bz, H8727gd, H8727gu, H8727hs, H8727hsa, H8727ka, H8727lu, H8727lub, H8727mbc, H8727mk, H8727mp, H8727wn, H8825an, H8825du, H8825kr, H8825ky, H8825tr, H8825tw, H8825twa, H8825ut, H8827bw, H8827cu, H8827fa, H8827ip, H8827ka, H8827kaa, H8827mi, H8827mk, H8827mo, H8827toa, H8930bc, H8930cx, H8930gb, H8931ho, Si_55_12CSmc, Si_55_12CSta, Si_55_12GClg, Si_55_12Kpr, Si_55_12REob, Si_55_12YEbi, Si_55_12YPgu, Si_55_12YScc, Si_55_4Ecl, Si_55_4Kct, Si_55_8Amq, Si_55_8CSgi, Si_55_8Ecl, Si_55_8Emo, Si_55_8Kct, Si_55_8Kpa, Si_55_8Kpr, Si_55_8Ksb, Si_55_8Kto, Si_55_8REob, Si_55_8SLcn, Si_55_8Ypye, DEEP ALLUVIAL LOAMS, DEEP BLACK CRACKING CLAYS, SHALLOW BLACK SELF MULCHING CLAY, WELL STRUCTURED RED & BROWN EARTHS
5	H8725bd, H8725bdd, H8725bj, H8725bn, H8725bs, H8725bw, H8725cc, H8725df, H8725dr, H8725ma, H8725mc, H8725mi, H8725mm, H8725pha, H8725rh, H8725rv, H8725sa, H8725saa, H8725sc, H8725sk, H8725tia, H8725wa, H8726bd, H8726bdb, H8726bdc, H8726bdd, H8726be, H8726ca, H8726caa, H8726cc, H8726dr, H8726gu, H8726li, H8726mc, H8726mm, H8726mma, H8726nu, H8726nua, H8726on, H8726rh, H8726rma, H8726sc, H8726sl, H8727al, H8727be, H8727bg, H8727bt, H8727by, H8727ca, H8727caa, H8727gc, H8727hh, H8727hha, H8727mm, H8727ms, H8727pi, H8727pid, H8727rh, H8727tc, H8824te, H8825cc, H8825da, H8825dab, H8825ji, H8825pb, H8825rh, H8827al, H8827bha, H8827br, H8827brb, H8827bt, H8827bwa, H8827cc, H8827ea, H8827eaa, H8827hh, H8827hha, H8827ipa, H8827kab, H8827km, H8827ms, H8827si, H8827tc, H8827tca, H8827tw, H8827twa, H8827twb, H8827twc, H8827wi, H8930bb, H8930bp, H8930br, H8930gv, H8930ke, H8930li, H8930mr, H8930mw, H8930pf, H8930ry, H8931bb, H8931ga, H8931li, H8931mr, H8931mw, H8931pf, H8931pm, H8931ro, H8931ry, H8931um, Si_55_12Ago, Si_55_12CSmh, Si_55_12Ecg, Si_55_12PSda, Si_55_12PSso, Si_55_12RPbo, Si_55_12RPrl, Si_55_12SHbc, Si_55_12SHbl, Si_55_12SLma, Si_55_12SLoc, Si_55_12YEje, Si_55_12YEmi, Si_55_12YEst, Si_55_12YEvu, Si_55_12YPbr, Si_55_12YPbw, Si_55_12YPcy, Si_55_12YPga, Si_55_12YPla, Si_55_12YPmn, Si_55_12YPtr, Si_55_4NKBbk, Si_55_4RPcg, Si_55_4SHmk, Si_55_4SHmu, Si_55_4YPbo, Si_55_4YPcp, Si_55_8Aep, Si_55_8BCbg, Si_55_8NKBba, Si_55_8NKBwi, Si_55_8REbs, Si_55_8REno, Si_55_8REsc, Si_55_8REtu, Si_55_8REvb, Si_55_8RPbl, Si_55_8RPbr, Si_55_8RPby, Si_55_8RPoe, Si_55_8RPpu, Si_55_8RPrl, Si_55_8RPso, Si_55_8RPwf, Si_55_8RSra, Si_55_8SHmk, Si_55_8SHmu, Si_55_8SLla, Si_55_8SLma, Si_55_8SLpe, Si_55_8TRbp, Si_55_8TRli, Si_55_8YEvu, Si_55_8YPbo, Si_55_8YPbu, Si_55_8YPcp, Si_55_8YPga, Si_55_8YPlo, Si_55_8YPmf, Si_55_8YPtr, Si_56_1SCbe, Si_56_1SCdv, DEEP STRUCTURED RED CLAY LOAMS, MASSIVE RED & YELLOW EARTHS, RED BROWN EARTHS, SHALLOW LOAMS, STONY SANDY LOAMS
6	H8725am, H8725bda, H8725bde, H8725bg, H8725cr, H8725mg, H8725sr, H8725ti, H8726bg, H8726co, H8726cr, H8726gn, H8726mn, H8726sr, H8726ta, H8726th, H8726ti, H8727cab, H8727cac, H8727cc, H8727cr, H8727dhb, H8727le, H8727lea, H8727nu, H8727pdc, H8727pia, H8727pib, H8727pic, H8727qn, H8727sr, H8727th, H8825jic, H8825pba, H8825pbb, H8825wa, H8827bh, H8827dd, H8827dh, H8827dha, H8827pa, H8827sia, H8827ta, H8930cb, H8930hw, H8930jc, H8930ka, H8930kt, H8930mb, H8930ms, H8930msa, H8930rm, H8930tt, H8930wb, H8930wo, H8931cb, H8931cg, H8931co, H8931hw, H8931mb, H8931ms, H8931np, H8931wb, H8931wo, Si_55_12SLab, Si_55_12SLbj, Si_55_12SLck, Si_55_12SLco, Si_55_12SLgf, Si_55_12SLgg, Si_55_12SLli, Si_55_12SLpm, Si_55_12SSdm, Si_55_12SSwi, Si_55_12, S, Swy, Si_55_12YEct, Si_55_12YPtl, Si_55_4E, Sap, Si_55_4SLbd, Si_55_8ESgo, Si_55_8Ewo, Si_55_8Ksh, Si_55_8RPcb, Si_55_8SLab, Si_55_8SLbd, Si_55_8SLbm, Si_55_8SLce, Si_55_8SLco, Si_55_8SLcs, Si_55_8SLlm, Si_55_8SLpm, Si_55_8SSdm, Si_55_8SSqu, Si_55_8, S, Swy, Si_56_1SLts, YELLOW & RED TEXTURE CONTRAST SOIL
7	H8725fo, H8725go, H8725my, H8726fo, H8726lc, H8726md, H8727cpa, H8727fo, H8727foa, H8727pd, H8727pda, H8727pdb, H8825waa, H8827oa, H8827oaa, H8827oo, H8827sg, H8827sh, Si_55_12Lbk, Si_55_12SLrb, Si_55_4SLba, Si_55_4SLts, Si_55_8SLla/rb, Si_55_8SLrb, Si_55_8SLts, Si_55_8SSgy, Si_55_8, S, Ski, Si_55_8SSro
8	H8726go, H8727cp, H8827cp, H8827cpa

4.1.17 Ssd - Simpson-Strzelecki Desert

Description of soil carbon units

CSU	Unit Name	Clay Content %	kg/ha/top 30 cm	Source
9	Floodplains low C	29	23 300	Drp
12	Western Aeolian Sands	16.9	17 000	
13	Undulating to rolling very low C	19	15 000	
14	Saline Lake beds		0.0	No Data

NSW soil resource map units used to create CSUs

CSU	NSW Soil Resource Map Units
9	COARSELY CRACKING GREY & BROWN CLAYS
12	SHALLOW LOAMS, SILICEOUS DUNE SANDS
13	CALCAREOUS EARTHS, MASSIVE RED & YELLOW EARTHS, SCALDED RED TEXTURE CONTRAST SOILS
14	SALINE SCALDED LAKE BED CLAYS

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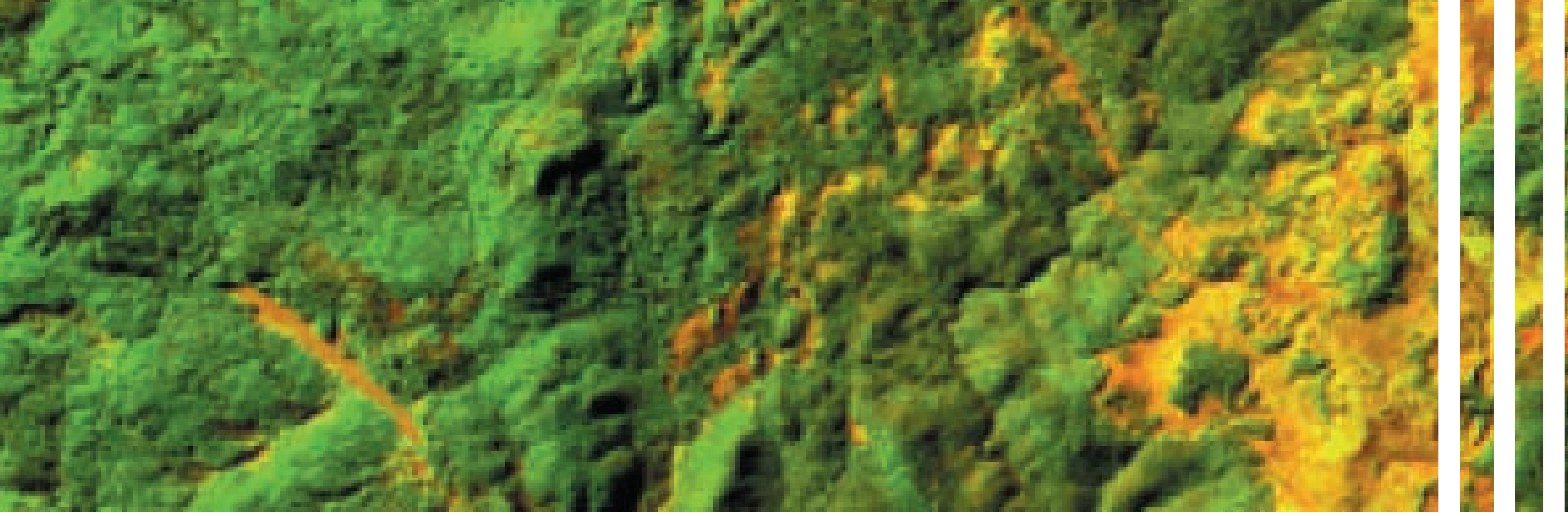

The National Carbon Accounting System provides a complete accounting and forecasting capability for human-induced sources and sinks of greenhouse gas emissions from Australian land based systems. It will provide a basis for assessing Australia's progress towards meeting its international emissions commitments.

technical report no. 12

Pre-Clearing Soil Carbon Levels in Australia