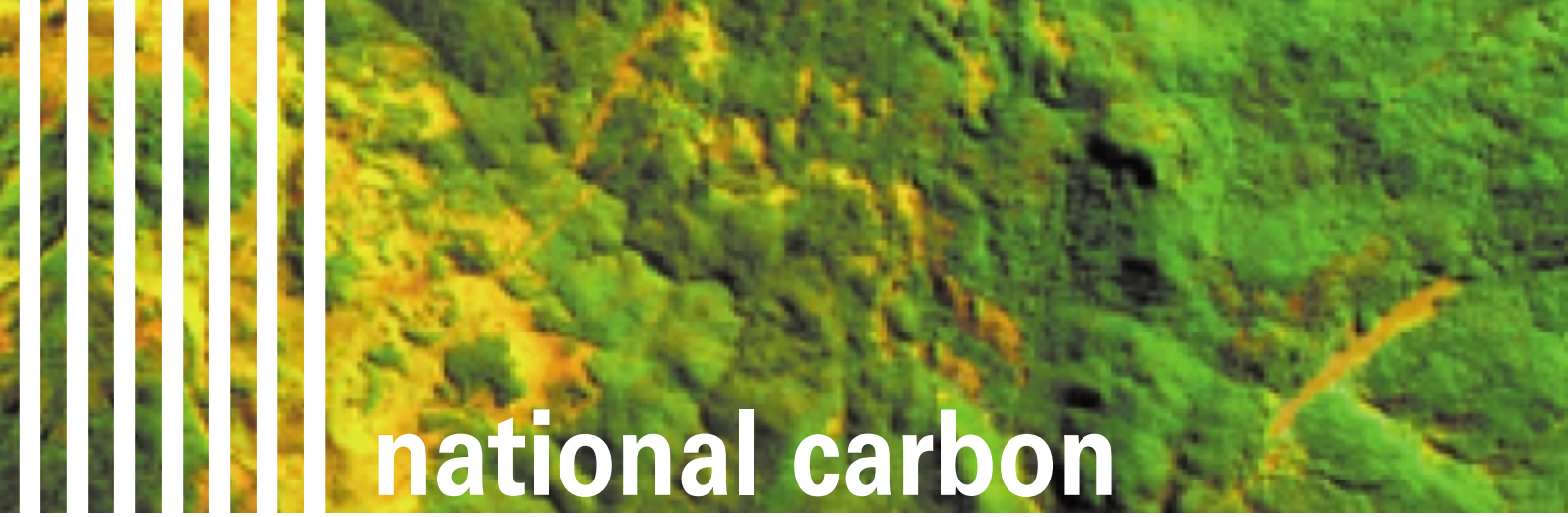

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technical report no. 7

Carbon Content of Woody Roots

(Revision 1)

Roger M. Gifford

AUSTRALIAN Greenhouse Office

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CARBON CONTENT OF WOODY ROOTS

Revised Analysis and a Comparison with Woody Shoot Components

Roger M. Gifford

CSIRO Plant Industry

National Carbon Accounting System
Technical Report No. 7 (Revision 1)

October 2000

AUSTRALIAN
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October 2000

Environment Australia Cataloguing-in-Publication
Gifford, Roger, M.

Carbon Content of Woody Roots: Revised Analysis and a Comparison with Woody Shoot Components / Roger M. Gifford.

p. cm.

(National Carbon Accounting System technical report; no. 7 (revision 1))

Bibliography:

ISSN: 14426838

1. Roots (Botany)-Carbon content. I. Australian Greenhouse Office. II.Title. III. Series

581.498-dc21

SUMMARY

This document replaces and extends Gifford (1999) - *National Carbon Accounting System Technical Report No. 7, Carbon Content of Woody Roots.* The replacement is necessitated by a subsequent update of the % carbon (C) and % nitrogen (N) values adopted for the material used as a routine calibration standard in the elemental analyser used in this investigation. The %C contents of dry matter for woody roots having diameters between 4mm and 300mm were determined for diverse forest and woodland tree species from Queensland, NSW and the ACT. The average %C content of woody root for 23 species examined was 49% with a standard deviation of 1%. The range of species-averages was from 46.7% to 51.2% but this study was not designed to assess whether statistically significant differences exist between species. However, it seems likely that any apparent species differences would be heavily confounded with, and difficult to distinguish from, a strong influence of environment on %C within the range that it varies. There was no trend in the value of %C with root diameter between 10mm and 300mm. Fine root for poplar box communities and radiata pine (<2mm diameter) had a %C content about 3 percentage points lower than that of coarse woody root, although for the poplar box community about half the fine root was of grass species.

From this work it is recommended that, where a single generalised figure for the %C content of coarse woody root is required for Australia, a value of 49±1% be adopted until further evidence suggests modifying that assumption. Where a single continental figure is required for %C in forest root including fine roots < 2mm, a figure of 48±2% is suggested by the data set, this being a little lower than the 49% found for coarse wood, to allow for the fine root component of below ground live plant organic matter. Where a single figure to cover all woody components of trees above and below ground is required a figure of 49±2%C is suggested.

1. PROJECT OBJECTIVE

The objective was to measure the carbon content of diverse woody tree roots for use in National Greenhouse Gas Inventory algorithms such as Equation 19 of the NGGI Workbook 4.2 Revision 2 (Environment Australia 1997).

2. BACKGROUND

The NGGI Workbook 4.2 Revision 2 assumed a fractional C content of root dry matter to be 42% for crops and grasses and adopted the IPCC default assumption of 50% for woody roots. These figures compare with the following measurements determined for the NGGI (Gifford and Barrett 1999): viz. Brigalow scrub root, 41±1%; *Pinus radiata* root, 39±1%.

However the root material used in the latter study was the washed root recovered from soil cores in the respective ecosystems without regard for root diameter. Fine root, mostly thinner than 1mm, was dominant in these samples although there were some pieces of larger woody root involved in a minority of cores. As fine root may contain a lot more minerals in its dry matter than would be present in the large woody roots, their fractional C content could be lower than for heavy root. Another factor that would increase the C content of heavy woody root dry matter is the expected higher lignin contents. A combination of lower mineral content and higher lignin content might lead to fractional C contents as high as 50% compared with about 40% for fine root.

While other aspects of the national inventory of CO_2 fluxes in Land Use Change and Forestry Sector contribute more substantially to uncertainty of the fluxes than does the fractional C content of wood, this matter is relatively easily improved. The potential error (of 25%) is not insignificant if a value of 50% were assumed when it should be 40%.

The present project extended the measurements on root C to woody roots greater than 4mm in diameter for a wide range of tree species.

3. METHODS

Four field sampling approaches were adopted as listed below. For each root sampled a note was made of either a broad diameter range that a root fell within, or a specific diameter was recorded. All root material was oven dried, ground to a powder, re-dried and cooled in a desiccator before weighing out a small subsample that was analysed for %C and %N in an elemental analyser (Europa ANCA-NT Stable Isotope Analyser, Crewe, UK) that was re-calibrated after every eight samples using a standard wheat flour as the routine secondary standard. Each root sample was determined in duplicate. When duplicate readings differed by more than 5% further subsamples were measured to decide upon the more accurate value.

The wheat flour used as a common standard to routinely adjust the instrument for any drift after each 8 samples was one (with a local designation of WWFlour) that was used for measurements of the root samples of this study using the elemental analyser with mass spectrometer as the detector. The analytical services laboratory involved undertook a review of procedures and recalibration of laboratory standards using contemporary secondary standards obtained from Leco Corporation (St Joseph, Michigan, USA). The new standard adopted was EDTA (ethylene diamine tetra-acetic acid) that had been standardised against the primary standards NIST-SRM-19d for C and against NIST-SRM-148 for N of the National Institute of Standards and Technology, Standard Reference Material collection. Both the samples and the standards were dried at 70˚C for at least 16 hours, cooled in a dessicator and weighed out when cool.

This revision of standards has led to a revision of calculations for measurements made originally and these revisions are reported herein. The revised data are directly comparable with the data for above-ground biomass in the report "Carbon contents of above-ground tissues of forest and woodland trees" (Gifford 2000).

4. RESULTS

4.1 TROPICAL POPLAR BOX IN QUEENSLAND

Hand-separated samples of roots were available from soil cores collected in non-cleared poplar box (*Eucalyptus populnea*) communities at Wandobah near Dingo, central Queensland. In some, but not many, of these samples there were thick woody roots, some probably alive at the time of sampling others appearing dead and partially decayed. We selected samples of woody roots that looked as though they were probably alive at the time of soil coring. These were classified as being between 4 mm and 10mm diameter or thicker than 10mm. There were no really large ones, the biggest being less than 20mm. They were washed to remove clay and dried before being ground in a puck mill. For the same segments of the soil cores from which these larger root pieces were picked, the fine root material less than 2mm in diameter (mostly much finer than that) was also washed and the %C and %N of dry matter determined. The proportion of the C present as the stable isotope ^{13}C (and expressed as δ^{13} C) was also determined. This is because the tree root dry matter would be expected to have a δ^{13} C of about –25 to 27 ‰ while the native tropical grass root would have a δ^{13} C of about –6-8 ‰.

Table 1. Summary of composition of root dry matter material separated from 1m long soil cores taken from poplar box (*E. populnea*) woodland sites on the Wandobah property, Dingo, Queensland. Mean ± standard error of the mean.

Diameter	No. of samples	%C	%N	C:N	δ^{13} C ‰*
Root > 10mm	11	47.9±0.6	0.23±0.01	206±15	-25.9±0.3
Root 4 to 10mm	19	46.1±0.5	0.37±0.04	126±19	-25.7±0.2
Fine root < 2mm	30	43.5±0.8	0.55±0.04	79±6	-16.7±0.8

* ‰ is parts per thousand

The results (Table 1) indicate that as the root diameter increased up to 10 to 20 mm the %C content increased a little and the %N content decreased. Accordingly the C:N ratio increased substantially. As expected the large roots have a δ^{13} C signature (-26 ‰) characteristic of a "C_3" plant species which includes trees. The fine roots, as expected, had a δ^{13} C value intermediate between –27 and –7 ‰ suggesting that about half of them are of tropical grasses having the "C_4" characteristics.

4.2 RADIATA PINE IN THE ACT

Soil cores up to 1m depth were collected from *P. radiata* plantations in ACT Forests in the course of another study. From these cores roots were picked out by hand. It turned out that none of the cores contained roots having a diameter greater than 4mm. So a comparison of coarse and fine material from the same cores was not possible. Instead course woody roots were collected on separate trips from radiata pine forests at Stromlo, Narrabundah Hill, Pierces Creek and Ingeldene. The root diameters sampled ranged from 5mm to 120mm. The roots were located by digging around trees and scraping the soil from along a suitable root with a trowel. After brushing loose soil off the root with a hand brush, it was sampled *in situ* with a clean 4mm bit in battery powered drill. To collect the drill shavings, a plastic cup with a 8mm hole in the bottom was pressed against the root and the drilling done through that. By drilling to the centre of the root, this approach sampled bark and different ages of the stele (i.e. the core of the root) in approximately representative proportions.

As for the poplar box communities, the fine roots had a lower %C and higher %N than the coarse roots (Table 2). However, %C content of both sizes were 2 to 3 percentage points higher than for the poplar box. The C^{13} signature of both the fine and coarse roots is characteristic of C_3 plant types; this is as expected given the lack of both ground vegetation and tropical grasses in ACT pine forests.

Table 2. Summary of root composition of material gathered in ACT pine (*P. radiata*) forests. Coarse roots were sampled individually and fine roots were separated from soil cores.

	No. of samples	%C	%N	C:N	δ^{13}C ‰
Root > 5mm	13	50.4±0.3	0.10±0.01	519±78	-26.4±0.2
Root < 2mm	15	48.3±0.4	0.54±0.02	89±4	-26.2±0.2

4.3 NATIVE TEMPERATE FOREST TREE ROOTS

An area of native forest in Tallaganda State Forest at Parkers Gap was selected to represent native temperate eucalypt forest as it has a wide range of species in a small area. As proposed, using a tractor-mounted soil coring rig we probed around the base of trees until the corer struck a root. There were several problems with this approach. First, even close up to trees it is surprising how infrequently the corer intercepted a large heavy root. Second when it did intercept a heavy root the corer either could not penetrate or, if it did, the root-plug so formed got stuck inside the tube. When the tube made a glancing blow on a heavy root it did two things: the tube bent and it ripped an unrepresentatively large fraction of bark from the root mixing it with soil as it went. Accordingly this approach was abandoned. Instead the roots were located by digging with a spade and trowel and sampled with an axe after scraping and brushing the soil away from the segment to be cut. The drilling approach, adopted later in ACT forests, is the more convenient method. It is also less damaging to the root.

An advantage of cutting a wedge of root with an axe is that the bark readily peels from the stele (i.e. the vascular core) of the root. We used the opportunity to analyse the bark and stele separately for these samples. The roots sampled were all between 10mm and 200mm diameter but a record of the actual diameters was not kept for all of them. After being washed, the chunks of stele and bark were subsampled in the laboratory by making hacksaw cuts across them and collecting the sawdust for grinding even finer.

The %C content of the woody roots of the different eucalypt species were similar to each other and to the *P. radiata* roots but they had 2 to 3-fold more N in the root dry matter than the pines (Table 3). The stele had a small but significantly higher %C content than the bark. The average of all species of the simple average of bark and stele is 48.5%.

Table 3. Summary of root composition of coarse woody roots sampled in Tallaganda Forest at Parkers Gap, NSW. "n" is the number of trees analysed for each species. The values shown are the means of the replicates examined. The standard deviation refers to variation among species means.

Species	n	Bark			Stele		
		%C	%N	C:N	%C	%N	C:N
E. cypellocarpa	1	46.4	0.25	187	50.3	0.23	221
E. dalrympleana	9	48.4	0.24	204	49.5	0.24	208
E. dives	3	47.4	0.19	244	50.0	0.21	244
E. fastigata	4	48.3	0.38	128	49.2	0.32	152
E. fraxinoides	1	46.4	0.33	138	49.4	0.51	97
E. pauciflora	6	47.9	0.21	233	49.0	0.33	146
E. radiata	2	48.2	0.23	212	48.6	0.29	167
E. sieberi	1	49.4	0.12	415	48.3	0.73	66
E. smithii	2	48.7	0.28	173	49.8	0.32	154
E. viminalis	2	46.3	0.43	107	48.8	0.66	74
Un-weighted mean		**47.7**	**0.27**	**204**	**49.3**	**0.38**	**153**
Standard deviation		**1.1**	**0.1**	**87**	**0.6**	**0.2**	**61**

4.4 *AD HOC* ROOT SAMPLES FROM FORESTS OF THE ACT AND NSW

To broaden the base of information several sampling forays to were conducted at Black Mountain, ACT; in a suburban Kaleen garden, ACT; in the vicinity of Forbes Creek Rd in Tallaganda State Forest; in the vicinity of Main Range Forest Rd, Tallaganda State Forest; and in the vicinity of Granite Bluff Rd, Monga State Forest. In addition samples of *E. dunni* from Toloom Station near Urbenville, NSW and *E. tereticornis* from University of NSW were supplied by Dr. A. Cowie.

Twenty eight samples of fourteen species were obtained ranging from 10mm to 300mm diameter. The sampling method was both by use of the axe and the electric drill. The results in Table 4 are for the combined bark and stele; they were not analyzed separately.

Again the range among species for %C content was not large being from 43.5 to 51.2%. The 43.5% value is in fact for an exotic shrub (*Trachelospermum jasminoides*) from a suburban garden and is therefore not representative of an unfertilised forest environment. It is excluded from further summary statistics. Without it the range is from 47.2% to 51.2%.

Table 4. Summary of composition of coarse woody roots taken from miscellaneous trees in the ACT and NSW. "n" is the number of trees analysed for each species. The values shown are the means of the replicates examined. The standard deviation refers to variation among species means.

Species	n	%C	%N	C:N
Acacia decurrens	1	50.0	0.26	193
A. melanoxylon	3	48.6	0.25	196
E. dunnii	2	47.8	0.52	92
E. mannifera	3	49.2	0.25	198
E. bridgesiana	3	48.2	0.28	171
E. fastigata	1	48.9	0.25	197
E. macroryncha	3	51.2	0.18	279
E. polyanthemos	3	49.7	0.23	219
E. sieberi	1	48.3	0.73	66
E. smithii	1	48.9	0.32	151
E. tereticornis	1	47.2	1.21	39
E. viminalis ssp. viminalis	2	48.8	0.66	74
Exocarpus cupressiformis	3	47.7	0.22	221
Un-weighted mean		**48.8**	**0.41**	**118**
Standard deviation		**1.0**	**0.3**	**71**
Trachelospermum jasminoides	1	43.5	1.05	42

5. DISCUSSION

There were 72 samples having root diameter greater than 10mm for which we also recorded the actual diameter of the root at the point of sampling. The range of %C found for individual live woody forest and woodland tree roots of all types was from 43.8% to 53.1%. For these 72 samples the C and N concentrations are plotted against root diameter in Figure 1. It shows that for %C the full range of values is found in the diameter up to 20mm. The diminishing spread of %C values as the root diameter increases may simply be a statistical reflection of the reducing number of samples as the size increases. Overall there is no trend in %C as size increases above 10mm. The species averages range from 46.7% (for *E. populnea* average of 24 reps) to 51.2%C (for *E. macrorhynca* average of 3 reps) but there are too few and variable numbers of replicates to assess whether there are characteristic species differences. It appears that any characteristic species differences would be small, difficult to demonstrate, and probably confounded with environmental effects. The average of all 23 forest species-means is 49%C with a standard deviation of 1%C.

For the fine roots examined (<2mm) we found lower values of 43.5%C for *E. populnea* communities, but this fine root material was about half grass root, and 48.3%C *for P. radiata*. These values are higher than found in a previous study for *A. harpophylla* (39%C) and *P. radiata* (41%). However, the latter values are also subject to the revised calibration of the composition of WWflour tertiary standard used for calibrating analyses of material having carbon content in the vicinity of 50%. The revised values for those prior measurements are 43%C for *A. harpophylla* and 45% for *P. radiata*.

A typical figure for the proportion of forest root that is less than 2mm may be about 20% (Vogt *et al*. 1996). Thus where the entire forest root C is being evaluated a figure of 48% C in dry matter seems appropriate on the basis of this study this being slightly less than the figure of 49% C in woody root dry matter alone.

Table 5 combines the results of this root study with those of the shoot study for species common to both studies (Gifford 2000). It shows that on average the C content of woody roots is very similar to that of sapwood of the same set of species – 49±3%. In fact, for all four woody tissues (branchwood, stem sapwood, stem deepwood and coarse root) the means average 49%C, falling within the range of 47-51%.

Table 5. Comparison of the %C in dry weight of above- and below-ground tree components. Data for above ground components are from Gifford (2000). Different trees were sampled for the above-ground and the below-ground data. "Deepwood" refers to the centre of tree stems. The values shown are the means of the replicates examined. The standard deviation refers to variation among species means.

Species	Branchwood	Sapwood	Deepwood	Coarse root
A. decurrens	48.1	47.5	48.4	50
A. melanoxylon	48.6	46.4	49.5	48.6
Callitris sp.	na	51.8	52.9	47.8
E. bridgesiana	47.2	50.9	50.2	48.2
E. cypellocarpa	46.2	49.2	49.8	50.3
E. dalrympleana	42.7	49.8	54.1	49.5
E. dives	47.7	50.7	51.4	50
E. fastigata	48.3	48.4	50.7	48.9
E. macrorhyncha	48.2	51.1	51.1	51.2
E. mannifera	48.2	50.1	50.4	49.2
E. pauciflora	47	49.9	51.6	49
E. polyanthemos	47.7	50.2	50.8	49.7
E. populnea	na	39.6	51.8	47.9
E. radiata	46.8	49.3	50.1	48.6
E. viminalis	46.7	49.4	50.2	48.8
Exocarpus cupressiformis	46.8	48.4	50.5	47.7
P. radiata	51.4	49	54.1	50.4
Mean	**47.4**	**48.9**	**51.0**	**49.2**
Standard deviation	**1.7**	**2.7**	**1.5**	**1.0**

6. CONCLUSION

For a range of 23 tree species growing in tropical and temperate Australian forests or plantations, the fractional C content of the dry biomass of woody roots was 49±1% . Where a single value to cover all woody root is required, that is the figure this study suggests as being appropriate for Australia. That is close to the 50% suggested by the IPCC/OECD default inventory methodology. For fine roots less than 2mm diameter, limited data indicates that about 46%C seems to be a suitable figure. Accordingly where a single figure to cover all root is required, fine root included, a figure of 48±2% is recommended. Where a single figure is required to cover all woody parts of a tree including branches and coarse roots, 49±2% is recommended.

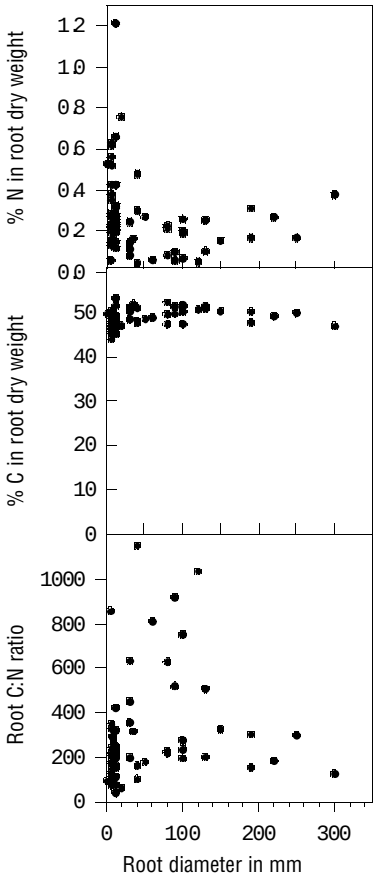

Figure 1. The %N, %C and C:N ratio of coarse woody roots greater than 10mm diameter gathered from various sites in ACT and NSW and Queensland.

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ACKNOWLEDGEMENTS

I am grateful to: Bruce Robertson for identifying the tree species, helping with sample collection, doing the lab preparation of samples and data entry; to Helen Adams for the fine root lab work; to Lorraine Tonnet and the Analytical Services Laboratory of CSIRO Plant Industry for measuring the wood sample composition on the elemental analyser; and to Dr Annette Cowie for supplying roots of *E. dunnii* and *E. tereticornis.*

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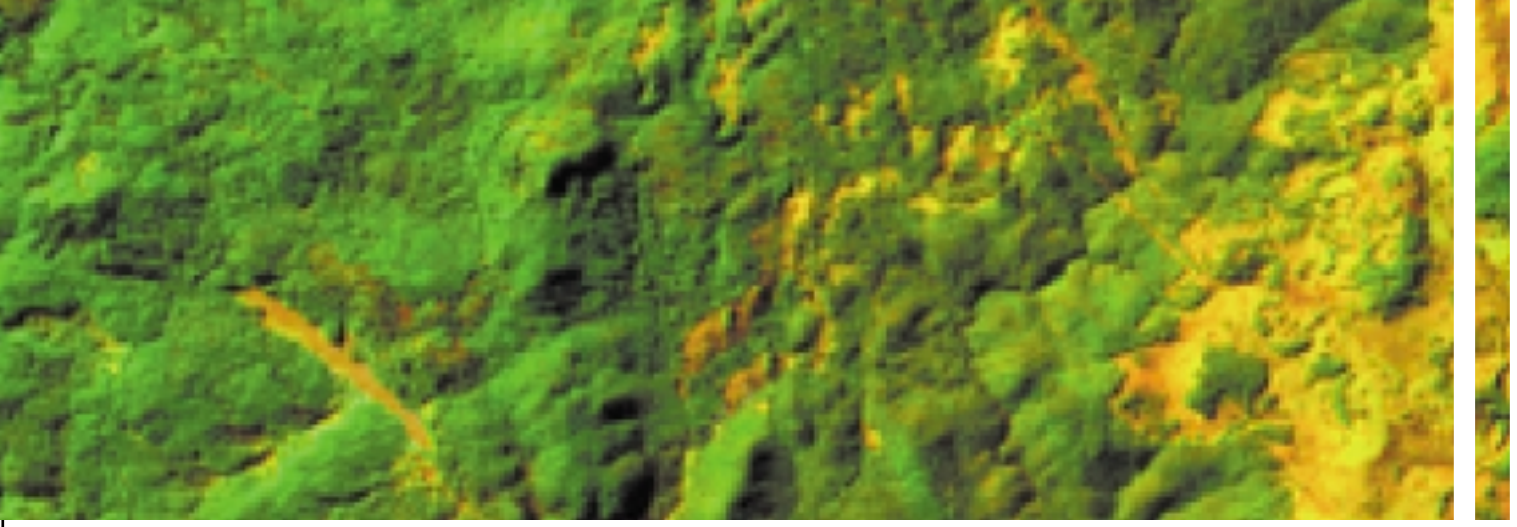

The National Carbon Accounting System provides a complete accounting and forecasting capability for human-induced sources and sinks of greenhouse gas emissions from Australian land based systems. It will provide a basis for assessing Australia's progress towards meeting its international emissions commitments.

technical report no. 7 (Revision 1) Carbon Content of Woody Roots

Roger M. Gifford