CSIRO
Plant Industry

National Carbon Accounting System Project

Final Report

Carbon content of woody roots

by

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September 1999

Summary

The carbon content of dry matter (%C) for woody roots of 4 mm to 300 mm in diameter was determined for diverse forest and woodland tree species from Queensland, NSW and the ACT. The average for 23 species was 44.1%, with a standard deviation of 0.9%. The range of species-averages was from 39.7% to 48.1%. 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 by, and difficult to distinguish from, a strong influence of environment on %C. Fine root for poplar box communities and radiata pine (< 2 mm 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. For root diameters between 10 mm and 300 mm, the value of %C did not vary with diameter.

It is recommended that, where a single generalising figure for the %C content of coarse woody root is required for Australia, a value of 44 ± 1% be adopted pending further evidence. Where a single continental figure is required for %C in forest root, including fine roots < 2 mm, a figure of 43 ± 1 % is suggested. This is a little lower than the 44% found for coarse wood, to allow for the fine root component of below ground, live plant, organic matter.

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 values determined for the NGGI (Gifford & Barrett 1999):

Brigalow scrub root	41± 1%
Pinus radiata root	39± 1%.

However, the root material used in the latter study was washed root recovered from soil cores in the respective ecosystems without regard for root diameter. Fine root, mostly thinner than 1 mm, was dominant in these samples, although there were some pieces of larger woody root in a minority of cores. As fine root may contain significantly more minerals in its dry matter than would large woody root, its fractional C content could be lower. Another factor that would increase the C content of heavy, woody root dry matter is the expected higher lignin content. 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.

If a value of 50% is assumed when it should be 40%, this introduces a significant potential error, of 25%, to the NGGI estimates. Whereas 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, the estimate for %C is relatively easily improved.

The present project extended the measurements on root C in fine roots (Gifford & Barrett 1999) to woody roots greater than 4 mm in diameter for a wide range of tree species.

3 Methods

Four field sampling techniques were used, as described in the relevant sections below. For each root sampled a note was made of either the broad diameter range that it fell within, or the specific diameter was recorded. All root material was oven-dried, ground to a powder, re-dried and cooled in a desiccator before a small subsample was weighed out and analysed for %C and %N in an elemental analyser (Europa ANCA-NT Stable Isotope Analyser). The analyser 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.

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 a few of these samples there were thick woody roots, some probably alive at the time of sampling, others apparently 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 10 mm diameter, or thicker than 10mm. There were no really large roots, the biggest being less than 20 mm.

The root samples were washed, to remove clay, and dried, before being ground in a puck mill. For the same segments of those soilcores from which these larger root pieces were picked, fine root material less than 2 mm in diameter (mostly much finer) 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 $\delta^{13}C$) was also determined. This is because the tree root dry matter would be expected to have a $\delta^{13}C$ of about -25 to -27 parts per thousand, whereas any native tropical grass root present would be distinguishable by its $\delta^{13}C$ of about -6 to -8 parts per thousand.

Table 1. Summary of composition of root dry matter material separated from 1 m 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	$\delta^{13}C$
Root > 10 mm	11	43.4 ± 0.6	0.20 ± 0.01	217 ± 15	-25.9 ± 0.3
Root 4 - 10 mm	19	41.7 ± 0.5	0.34 ± 0.04	123 ± 19	-25.7 ± 0.2
Fine root < 2 mm	30	39.4 ± 0.8	0.51 ± 0.04	77 ± 6	-16.7 ± 0.8

The results indicate that as the root diameter increased up to 10 to 20 mm the %C content increased a little and the %N content decreased (Table 1). Accordingly, the C:N ratio increased substantially. As expected, large roots have a $\delta^{13}C$ signature (-26) characteristic of a "C_3" plant species, which includes trees. Fine roots, as expected, had a $\delta^{13}C$ 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 1 m 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. Unfortunately, none of the cores was found to contain roots greater than 4 mm in diameter. This made a comparison between coarse and fine material from the same cores impossible. 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 5 mm to 120 mm. 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 4 mm bit in a battery powered drill. To collect the drill shavings, the drilling was done through a plastic cup, with an 8 mm hole in the bottom, pressed against the root. 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.

For *Pinus radiata*, fine roots had a lower %C and higher %N than coarse roots (Table 2). However, both 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 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.

Diameter	No. of samples	%C	%N	C:N	$\delta^{13}C$‰
Root > 5 mm	13	45.6 ± 0.3	0.09 ± 0.01	507 ± 78	-26.4 ± 0.2
Root < 2 mm	15	43.7 ± 0.4	0.50 ± 0.02	87 ± 4	-26.2 ± 0.2

4.3 Native temperate forest tree roots

Because it has a wide range of species in a small area, Tallaganda State Forest at Parkers Gap was selected as typical native temperate eucalypt forest. A tractor-mounted soil-coring rig was used to probe around the base of trees until the corer struck a root. However, there were several problems with this approach. Firstly, even when used close up to trees, the corer intercepted a large heavy root infrequently. Secondly, when it did intercept a heavy root the corer either could not penetrate, or if it did enter, the root-plug sample got stuck inside the tube. When the tube struck the edge of a heavy root it bent then tube and it ripped an unrepresentatively large fraction of bark from the root and mixed it with soil. Accordingly, this approach was abandoned. Instead, roots were located by digging with a spade and trowel, and sampled with an axe after scraping and brushing the soil away from the selected segment. The drilling approach adopted later in ACT forests (see above) was the more convenient method. It was 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. Thus, we analysed the bark and stele separately for these samples. The roots sampled were all between 10 mm and 200 mm diameter, but a record of the actual diameters was not kept for all samples. After being washed, the chunks of stele and of bark were sub-sampled in the laboratory, by making hacksaw cuts across them and collecting the sawdust, which was then ground even finer.

The %C contents of the woody roots of the different eucalypt species were similar to each other and to the *P. radiata* roots, but the eucalypt roots had 2- to 3-fold more nitrogen than was present in the pines (Table 3). The stele had a small but significantly higher %C content than the bark. For all species combined, the weighted average for bark plus stele is 44.0%.

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.

Species	n	Bark			Stele		
		%C	%N	C:N	%C	%N	C:N
E. cypellocarpa	1	42.0	0.23	181	45.5	0.21	218
E. dalrympleana	9	43.8	0.22	213	44.8	0.22	314
E. dives	3	42.9	0.18	260	45.3	0.19	286
E. fastigata	4	43.7	0.35	134	44.5	0.30	160
E. fraxinoides	1	42.0	0.31	136	44.7	0.47	95
E. pauciflora	6	43.4	0.19	226	44.4	0.31	210
E. radiata	2	43.6	0.21	246	44.0	0.27	192
E. sieberi	1	44.7	0.11	413	43.7	0.68	64
E. smithii	2	44.1	0.26	173	45.1	0.30	150
E. viminalis	2	41.9	0.40	107	44.2	0.61	85
Weighted Mean	31	43.4	0.24	205	44.6	0.30	220

4.4 Ad hoc root samples from forests of the ACT and NSW

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

Twenty-eight samples of fourteen species were obtained, ranging from 10 mm to 300 mm in diameter. The samples were collected using both the axe and the electric drill methods. The results in Table 4 are for the combined bark and stele, which were not analysed separately.

The range among species for %C content, from 39.4 and 46.4%, was not large. The 39.4% value is for an exotic shrub from a suburban garden. It is therefore not representative of an unfertilised forest environment and is excluded from further summary statistics. Without it the range is from 42.7% to 46.4%.

Table 4. Summary of composition of coarse woody roots taken from diverse tree species in the ACT and NSW.

Species	n	%C	%N	C:N
Acacia decurrens	1	45.3	0.24	189
A. melanoxylon	3	44.0	0.23	206
E. dunnii	2	43.3	0.48	116
E. mannifera	3	44.5	0.23	210
E. bridgesiana	3	43.6	0.26	188
E. fastigata	1	44.3	0.23	194
E. macroryncha	3	46.4	0.17	320
E. polyanthemos	3	45.0	0.21	438
E. sieberi	1	43.7	0.68	64
E. *smithii*	1	44.3	0.30	149
E. tereticornis	1	42.7	1.12	38
E. viminalis ssp. viminalis	2	44.2	0.61	85
Exocarpus cupressiformis	3	43.2	0.20	215
Trachelospermum jasminoides	1	39.4	0.97	41

Weighted average	44.1	0.34	207

5 Discussion

The range of %C found for live woody forest and woodland tree roots of all types ranged from 39.7% to 48.1%. There were 72 samples with a root diameter greater than 10 mm for which we also recorded the actual diameter at the point of sampling. For these 72 samples, C and N concentrations are plotted against root diameter (Figure 1). The full range of %C values is found in small roots with diameters up to 20 mm. As the root diameter increases, the range of %C values appears to decrease. However, this may simply be a statistical reflection of the smaller number of samples from large roots. Overall, for roots above 10 mm diameter, %C varies little.

The species averages range from 42.3% (for *E. populnea* averaging 24 replicates) to 46.4%C (for *E. macrorhynca,* averaging 3 replicates). There are too few samples, and the number of replicates is too variable, to assess whether there are characteristic species differences. However, the average of all 23 forest species-means is 44.1%C with a standard deviation of 0.9% C and a standard error of 0.2% C. Thus, it appears that any characteristic species differences would be small, difficult to demonstrate, and probably confounded with environmental effects.

For fine roots (< 2 mm), we found a value of 39.4%C for *E. populnea* communities. This is lower than the 43.7%C obtained for *P. radiata,* but the material was contaminated by grass roots. These values are slightly higher than those reported in a previous study on *A. harpophylla* (41%C) and *P. radiata* (39%)(Gifford & Barrett 1999).

Considering that the total root mass comprises both coarse-woody and fine root, the data presented here suggest that a figure slightly less than 44% should be adopted in the NGGI. A typical figure for the proportion of forest root that is less than 2 mm may be about 20% (Vogt *et al.* 1996). Thus, where the entire forest root C is being evaluated, a figure of 43% C in dry matter seems appropriate. Where fine root is being accounted for as part of the soil C rather than as part of the root biomass, it is suggested that a figure of 44% C for woody root, dry matter be adopted.

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 44% (standard deviation of 1%). Where a single value to cover all woody roots is required, this study suggests that 44% is more appropriate for Australia than the figure of 50% used in the IPCC/OECD default inventory methodology. For fine roots less than 2 mm diameter, data for the limited number of species examined indicates that about 41%C is a suitable figure. Accordingly, where a single figure to cover all root is required, fine root included, a figure of 43 ± 1% is recommended.

Acknowledgements

I am grateful to: Bruce Robertson for identifying the tree species, helping with sample collection, doing the laboratory preparation of samples and data entry; Helen Adams for the fine root laboratory work; Tricia Wallace for measuring the wood sample composition on the elemental analyser; and Dr Annette Cowie for supplying roots of *E. dunnii* and *E tereticornis*.

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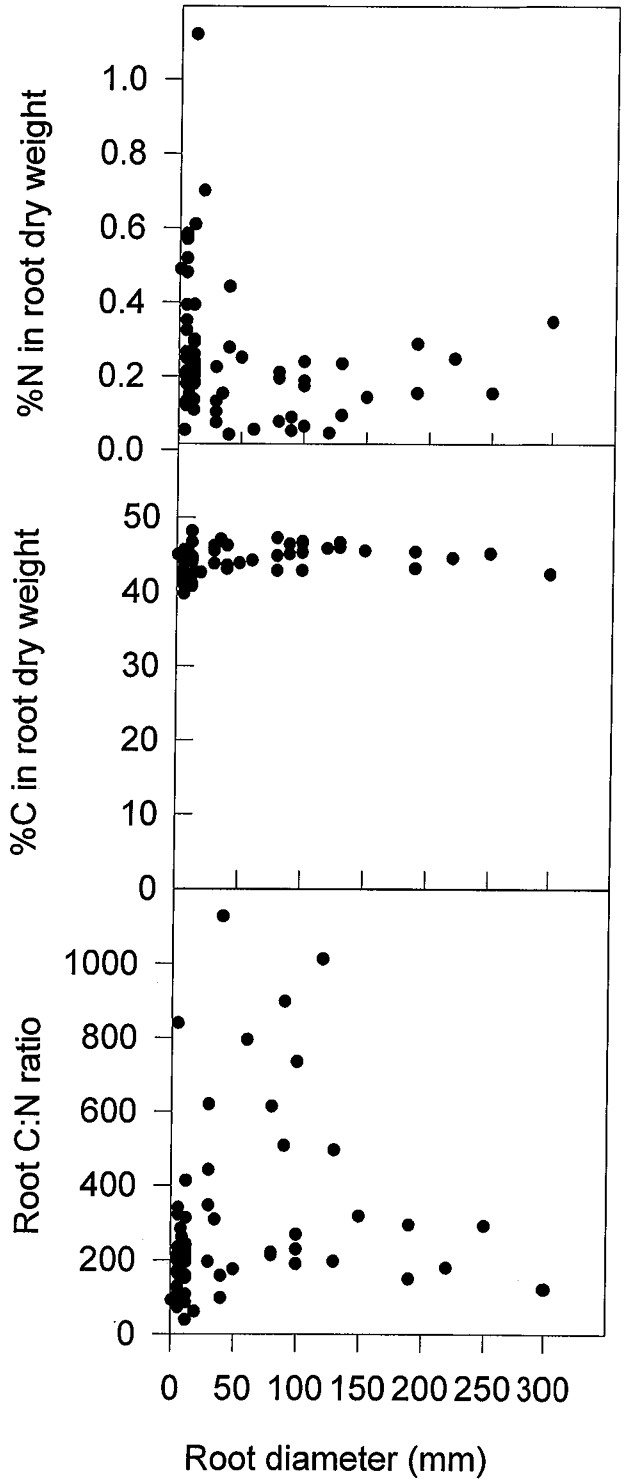

Figure 1. The %N, %C and C:N ratio of coarse woody roots greater than 10 mm diameter, gathered from various sites in ACT, NSW and Queensland.