

# Root Biomass Calculation Using a Modified Counting Technique

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## Abstract

Data on root weight, length, and surface area are useful in soil characterization, ecosystem description, and studies of plant-soil interaction. Characterization of root systems is often thought to be so laborious and inaccurate that little data are collected. Root counts are used in soil surveys to evaluate root abundance; but these counts are not useful in most applications where data on roots are needed. An improved counting method provided root count data which correlated with measured root weight ( $AW = 0.97 PW, r^2 = .85$ ) where  $AW$  = actual weight and  $PW$  = predicted weight. Counts were made in a  $dm^2$  plexiglass frame parallel to the soil surface under short- and mid-grass prairie vegetation. As many as 30 samples were necessary to estimate root biomass within 25% ( $P < .10$ ) with either root weighing or counting methods. Total root biomass calculated from root counts in the upper 100 cm of 15 southeastern Montana soils and in mine spoils ranged from 310 to 1,610 g/m<sup>2</sup> which is similar to published data on root biomass in other grassland communities.

In a study of 76 Hawaiian and Indian soils, Pandey (1969) found that estimates of root abundance were highly correlated with precipitation, bulk density, organic carbon content, and other soil properties, and are therefore important in the prediction of many key soil properties. Hillel et al. (1976) and others used root length

in models to predict water use from field soils (Newman 1966). Other workers have suggested root surface area should correlate with water and nutrient uptake. Changes in root biomass are sometimes measured as a component of ecosystem productivity (Bartos and Sims 1974). If root counting techniques (Soil Survey Staff 1975) could be correlated with other measures of root abundance, extensive data on root weight, length, and area could be obtained quickly through soil survey programs.

Characterization of the root systems of plants has long been a problem of agronomists, plant ecologists, and range scientists. Methods commonly used to investigate roots are laborious and often inaccurate. In a study of Montana soils, Decker (1972) found that root observations were often omitted from pedon descriptions. Lack of data on roots may indicate that estimation of root abundance is regarded as unimportant or difficult. In this paper we present a simple field method for rapidly collecting data on roots. A geometric model to calculate root weight from root counts is proposed.

## Materials and Methods

Fifteen soils were selected for study in the Colstrip, Montana, area. Five pedons consisted of old strip-mined spoil, from 30- to 50-years old, five pedons were newer spoils less than 10 years old, and five were undisturbed native range. Native soils were classified as Borollic Camborthids or Aridic Haploborolls and were sandy

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Fig. 1. A  $1\text{ m}^2$  plexiglass frame was used for counting roots at 10, 50, and 100 cm in 15 soil profiles near Colstrip, Mt.

loam in texture (Schafer et al. 1977). Dominant vegetative types included mixed mid- and short-grass prairie, half-shrub communities, and mixed shrub-grasslands.

Backhoe pits were excavated and roots were counted in  $1\text{ m}^2$  plexiglass frames at five randomly selected locations at the 10-, 50-, and 100-cm depths (Fig. 1). Roots in five different size classes were counted separately. Root diameter was visually estimated (Soil Survey Staff 1975).

Symbol	Class	Diameter (mm)
MF	microfine	visible-0.5
VF	very fine	0.5-1.0
F	fine	1-2
M	medium	2-5
C	coarse	>5

Roots were counted in a horizontal plane which was perpendicular to the primary orientation of roots. After a count, a cube of soil 1 dm on each side was collected from the counting location for separation and weighing of roots. Roots were washed free of soil on a 1-mm sieve and were weighed after oven-drying at  $60^\circ\text{C}$  for 48 hours and again after ignition at  $600^\circ\text{C}$  overnight. Root weights are reported on an ash-free basis (Table 1).

A geometric model was used to calculate root weight from root counts. Melhuish and Lang (1969) derived an equation to calculate root length density within the volume of a soil cube based on the number of roots intersecting a single face.

$$L = 2N \quad (1)$$

where  $N$  is the number of roots crossing the cube face and  $L$  is the root length density in the cube in centimeters. Assuming that roots resemble cylinders in shape, then root volume in a cubic decimeter of soil can be calculated:

$$V = 2N (\pi r^2 H) = 20N(\pi r^2). \quad (2)$$

where  $V$  is root volume in  $\text{cm}^3$ ,  $r$  is the mean diameter in cm, and  $H$  is the root height, which in the case of a cubic decimeter of soil would be 10 cm. Root biomass for a single root size class can be calculated by multiplying root volume by root density. Finally root biomass from all size classes (microfine to coarse) can be summed to obtain total root biomass:

$$W = 20D \sum_{y=1}^5 N_y \pi r_y^2 \quad (3)$$

Where  $W$  is the root weight in a cubic decimeter of soil and  $D$  is the root density in  $\text{g}/\text{cm}^3$ ,  $N_y$  is the number of roots counted on the  $y^{\text{th}}$  size class, and  $r_y$  is the mean diameter of roots in the  $y^{\text{th}}$  size class (i.e. .03, .08, .15, .3, .5 cm).

## Results and Discussion

### Predicted and Measured Root Weight

Measured root weights were divided by root volumes calculated by equation (2) to find a value for  $D$ , root density ( $.12\text{ g}/\text{cm}^3$ ). When a density of  $0.12\text{ g}/\text{cm}^3$  was substituted in equation (3), the following relationship was found using a least squares linear regression for the data in Table 1.

$$AW = 0.97 PW \quad r^2 = 0.85 \quad (4)$$

where  $AW$  was actual root weight and  $PW$  was predicted weight using equation (3). It is apparent that root weights predicted from root counts are highly correlated with weights obtained by the more time-consuming root separation technique. This suggests that root counting would be of value as a quick field test of root biomass.

### Number of Counts Needed to Estimate Root Abundance

The number of counts ( $n$ ) needed to predict a mean within given confidence limits (Snedecor and Cochran 1974) was used as a measure of the variability of the root weighing and root counting techniques (Table 2):

$$(n = 4\sigma^2/L^2) \quad (5)$$

Where  $n$  is the number of samples needed to estimate mean root biomass within specified confidence limits,  $L$ , at  $P = .90$ , and  $\sigma$  is the population standard deviation. Both root weighing and counting methods require extensive replication to give accurate root biomass estimates. The extreme variability of data on root abundance has also been reported by Schuurman and Goedewaagen (1965). The root weighing method is the most accurate near the soil surface while the counting method is more accurate below 10 cm. For characterizing roots in a soil profile, an equal number of samples are needed with root counts as with the more laborious root weighing method.

Counts of the same soil area obtained by two different observers generally varied less than 10%. Good lighting and careful observation were necessary for consistent recognition of the finest roots. Root counts obtained with the plexiglass frame and

**Table 1. Measured and predicted root weights (g/dm<sup>3</sup>) are shown by depth (10, 50, and 100 cm) in natural soils, 30-50-year-old minesoils, and 1- to 10-year-old minesoils. Total root biomass is expressed in g/m<sup>2</sup>.**

Depth (cm)	Site <sup>1</sup> No.	Natural soils		Site No.	Old minesoils		Site No.	New minesoils	
		Measured root wt.	Predicted root wt.		Measured root wt.	Predicted root wt.		Measured root wt.	Predicted root wt.
10	Chinook 1	3.59 <sup>2</sup>	2.04	1928-3	3.30	1.31	1975-11	1.23	1.12
50		.56	.51		.27	.11		.01	.07
100		.04	.16		.13	.08		.00	.00
Total		1,198	845		1,025	423		313	315
10	Boxwell 2	1.57	1.94	1928-5	3.36	2.66	1973-12	1.45	1.89
50		—	.16		.74	1.01		.06	.10
100		.00	.06		.63	.77		.04	.02
Total		393	595		1,525	1,555		413	533
10	Ethridge 4	2.01	1.12	1928-7	2.18	3.89	1972-13	2.23	3.56
50		.29	.11		.09	.29		.10	.79
100		.17	.04		.04	.04		.02	.00
Total		733	355		610	1,120		564	1,285
10	Reidel 6	4.29	3.41	1928-9	1.68	1.73	1969-14	1.66	1.16
50		.06	.11		.12	.19		.38	.20
100		.00	.00		.05	.23		.10	.22
Total		1,103	908		505	613		655	500
10	Chinook 8	3.35	3.04	1929-10	2.94	3.58	1970-15	1.74	1.28
50		.48	.32		.61	.85		.11	.10
100		.19	.20		.17	.58		.13	.14
Total		1,173	1,020		1,125	1,610		555	440

<sup>1</sup>Site names represent either the soil series name for the natural soils or date of last disturbance of the minesoils.

<sup>2</sup>Data presented represent the mean of five root weights (g/dm<sup>3</sup>) at 10, 50, and 100 cm. Total profile root weight, expressed in Kg/ha are a weighted average of root biomass at the above depths.

## Literature Cited

**Table 2. Number of counts needed to estimate mean root weight within 25% with 95% probability.**

Depth (cm)	Root weight method	Root count method
10	7	15
50	30	30
100	44	28

modified counting technique proposed were compared to root estimates made by experienced soil scientists using the standard SCS method (Soil Survey Staff 1975). The standard method underestimated root abundance by a full class (few, common, or many) in 22% of the observations.

## Field Application

Roots were counted as previously described at 10-, 50-, and 100-cm in 15 soils near Colstrip, Montana. Only 15 minutes were required to characterize the roots in each pedon.

Root biomass was calculated using equation (3) based on root numbers in horizontal plane (root/dm<sup>2</sup>). Total profile root biomass (upper 100 cm) obtained by this method (Table 1) ranged from 310–1,610 g/m<sup>2</sup>. Most root weights were (1,000–1,500 g/m<sup>2</sup>) similar to published data for the Colorado short-grass prairie: 1,600–1,800 g/m<sup>2</sup> (Bartos and Sims 1974; Singh and Coleman 1974), Missouri tall-grass prairie: 1,400–1,900 g/m<sup>2</sup> (Dahlman and Kucera 1965), and Utah cool desert communities: 1,600–1,800 g/m<sup>2</sup>, (Caldwell and Camp 1974). Average root biomass in the upper 10 cm (340 g/m<sup>2</sup>) found in this study was similar to that found during late summer by Lauenroth et al. (1976) in the Colstrip area.

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