CARBON-ORGANIC MATTER RELATIONSHIPS IN SOUTHERN NEW ENGLAND FOREST SOILS

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ABSTRACT

Soil organic matter (SOM) data are often used to estimate soil organic carbon (SOC) pools. The ratio of SOC: SOM differs among soil types and can vary with depth, thus the use of any single conversion factor can result in potentially large errors in SOC pools. We examined the relationship between SOC and SOM in the upper 1 m of four soil series varying in drainage class and texture. Ten mapping units (ten pedons per unit) were sampled. To quantify the impact of using C:OM conversion factors to predict SOC pools, actual SOC pools were determined and compared to SOM-based estimates derived from (1) site-specific C:OM regression equations, and (2) the more commonly used 0.58 conversion factor. C:OM ratios differed significantly among horizons in the three mineral soils; no change in the C:OM ratio was observed with depth in the organic soils. Series-specific and general (across series) regression equations were created for each master horizon using data from one mapping unit of each series. Random samples from the other six mapping units were used to test the regression models. The r^2 values of all regression equations ranged from 0.68 to 1.0, with most greater than 0.90. Series-specific C:OM regressions had the lowest residuals ($\pm$ 0.01–2.56 %C), were within 2%, or 3 Mg C ha^{-1}, of the actual SOC pool, and should be used whenever possible to estimate SOC pools in mineral soils. A general regression equation, combining all data from the upper 1 m of peat, estimated SOC within 1%, or 4 Mg C ha^{-1}, of actual SOC pools in the organic soil. Using a 0.58 conversion factor overestimated SOC in the upper 1 m of the three mineral soils by 27-34% (26-62 Mg C ha^{-1}), but was a relatively accurate estimate (within 2% or 12 Mg C ha^{-1}) of SOC pools in the upper 1 m of the organic soil.

Forests in the northeastern U. S. may represent a larger carbon pool than previously thought (Sedjo, 1992; Tans et al., 1990; Fan et al., 1998). The soil accounts for 59% of the carbon stored within these forests (Birdsey, 1992), thus assessing the role of these forests in the global C budget requires accurate estimates of SOC. Accurate estimates of SOC pools are hindered by a number of factors including lack of forest floor and subsoil data for many soil types, variability, and the use of SOM data to estimate SOC pools based on an assumed C:OM ratio (Eswaren et al., 1993; Batjes, 1996; Grossman et al., 1998; Lal et al., 1998). In this study we measured SOM and SOC pools in four forest soils of varying texture and drainage class, calculated C:OM ratios, and assessed the accuracy of using SOM-based approaches to predict SOC pools. The impact of using both soil-specific C:OM regression equations and a 0.58 conversion factor was examined.

SOM data and a C:OM conversion factor (usually 0.58) have often been used to predict SOC pools when actual carbon data has been unavailable. Reviewing the early literature, Alexander and Byers (1932) found that Sprengel, circa 1826, is the earliest mention of humus being composed of 58% carbon, while Wolff and Van Bemmelen, in 1864 and 1890 respectively, are commonly credited for the extensive use and acceptance of the 1.724 OM: C, or 0.58 C:OM, conversion factor. Many studies since then have questioned the validity of assuming a consistent relationship between carbon and organic matter. Read and Ridgell (1922) examined C:OM relationships in thirty-seven soils across eight states and found C:OM ratios for surface soils to range from 0.30-0.56 with a mean of 0.49, while subsoil C:OM ratios ranged from 0.13-0.56 with a mean of 0.39. In addition, C:OM ratios in surface and susbsoils from the same profile were found to differ. Alexander and Byers (1932) concluded that mean values for the carbon content of SOM were actually closer to 0.50. Later Broadbent (1953) suggested using a factor of 0.52 for surface soils and 0.40 for subsoils, however he cautioned that soil or site-specific C:OM factors should be used whenever possible to ensure accuracy. More recent studies (David, 1988; Huntington et al., 1989; Donkin, 1991; Konen et al., 2002) support these earlier findings, which suggest that no single conversion factor or standard relationship between SOM and SOC can be assumed. However, the historic conversion factor of 0.58 is still recommended and used to estimate soil C pools (Birdsey, 1992; Davidson and Lefebvre, 1993; Stevenson, 1994; Homann et al., 1995).

Over 60% of southern New England, approximately 2 million hectares, is forested (USDA, 1998). Other than the early forest floor work done by Lunt (1931) in Connecticut, research focusing on C:OM ratios in these forest soils is lacking. Considering the role of temperate forests in the global carbon cycle (Sedjo 1992; Birdsey et al, 1993; Houghton et al., 1999), the interest in soils as a long-term sink for carbon, and the ongoing debate surrounding the use of SOM-based conversion factors to estimate SOC pools, further investigation of C:OM relationships in this region was needed. The objectives of our study were to develop soil-specific C:OM relationships for four soils commonly found in southern New England, to assess the feasibility of using C:OM regression equation to estimate soil carbon for a range of soil types, and to quantify the potential error associated with using a 0.58 conversion factor to estimate SOC pools.

MATERIALS AND METHODS

In a reconnaissance survey, soil mapping units identified as Windsor, Enfield, Raypol, and Carlisle were examined to identify forested delineations representative of each series. The four soils were chosen because they are commonly found in southern New England and represent a range of textures, parent materials, and drainage classes. Three mapping units of Enfield (coarse-silty over sandy or sandy-skeletal, mixed, active, mesic Typic Dystrudept) and Carlisle (euic, mesic Typic Haplosaprist) and two units of Raypol (coarse-loamy over sandy or sandy-skeletal, mixed, active, mesic Aeric Endoaquept) and Windsor (mied, mesic Typic Udipsamment) series were chosen for detailed studies. All ten of the mapping units supported hardwood forests ranging in age from 70-100 years.

In each mapping unit, soils were sampled at ten locations along two randomly-oriented 100 m long transects (Young et al., 1991). A split-core sampler (4.7 cm diameter) was used to collect mineral soil samples by subhorizon for the entire solum, or to a depth of 1 m, whichever was deeper. In a few instances, sampling was restricted to shallower depths by large coarse fragments below the solum. In the mineral soils Oi, Oe, and Oa horizons were collected from a 15 x 15 cm area. These horizons were removed intact and split into fibric, hemic, and sapric horizons. Thin (0-2 cm) fibric and hemic horizons were not separated. Oi and Oe horizons of the Carlisle soils were collected using the same approach. Sapric horizons beneath the Oi and Oe horizons were collected by horizon to a depth of 1 m using a Macauley peat sampler with a 5 cm diameter half barrel.

Organic matter contents for all soil samples were determined via loss on ignition (Nelson and Sommers, 1965). Samples were heated to 550^{o}C for five hours in a muffle furnace. These soils have low clay contents (<10%) and loss of interstitial water was considered negligible. All samples from four of the mapping units (one unit per series), and selected samples from the remaining six units, were analyzed for carbon using an automated CN analyzer (Carlo-Erba, Milan, Italy). SOM and SOC contents are reported for the < 2mm portion of the soil and based on oven-dry (105^{o}C) weights. Bulk density of the fine earth fraction was determined for each horizon by drying a subsample of soil at 105°C fro 24-36 hours and correcting for mass and volume of fragments > 2mm (Blake and Hartge, 1986).

Statistical Analysis

C:OM ratios were calculated for each master horizon. Due to the degree of morphologic variability in these soils, data for subhorizons were pooled, and weighted averages based on horizon thickness were calculated for the master horizons of each soil. One-way analysis of variance (ANOVA) and Tukey's multiple comparison tests were used to examine differences between mean weighted C:OM ratios.

Regression equations comparing SOM and SOC were developed for each master horizon (O, A, B, C) of the three mineral soils. Regression equations for the Carlisle (organic) soils were determined for the combined Oi and Oe horizons, and the upper (0-50 cm) and lower (50-100 cm) Oa horizons. In addition to these series-specific regression equations, several general regression equations were developed. Data from the three mineral soils were grouped together to construct 'general' equations for the A, B, and C horizons. Data from the organic horizons of the three minerals soils were combined with Oi and Oie horizons from the organic soil to construct a separate regression equation for O horizons. A regression equation was also created for the Carlisle (organic) soil by pooling all Oa horizon data for that series. Regression equations were not forced through the origin as this may falsely indicate a stronger relationship between SOM and SOC than actually exists, and can introduce error into the SOC estimate (Jain et al., 1997).

To test the accuracy the C:OM regression equations to estimate SOC pools in other mapping units of these soils, an average of 4 samples per horizon per series were randomly chosen from the other six mapping units and analyzed for carbon. These SOC data were compared to the predicted values from the corresponding specific and general regression equations using goodness-of-fit and confidence interval analysis. Goodness-of-fit is reported as the mean of the absolute value of the residuals or $(\Sigma|y - \hat{y}|)/n$ where, y= observed value; $\hat{y}$= predicted value based on the regression; and n= the number of samples used to construct the regression. Confidence intervals were calculated at the 95% level from the regression data. All statistical analysis were performed in SPSS v10 software for PC (SPSS, 1999).

The potential impact of using SOM-based methods to predict SOC pools was examined by applying the 0.58 C:OM conversion factor, and both the series-specific and general regression equations, to the SOM data from the four mapping units (one per soil) for which SOC data was available; and comparing these predicted SOC pools to the actual SOC pool.

RESULTS AND DISCUSSION

Mean Weighted C:OM Ratios

Soil organic matter ranged from 5 to over 900 g kg^{-1} in the four soil types (Table 1). Samples from one mapping unit of each soil series were analyzed for both SOM and SOC and C:OM ratios were calculated. Mean weighted C:OM ratios declined with depth in the mineral soils such that the B and C horizons had significantly lower C:OM ratios than A and O horizons (Table 1). These findings support previous literature reporting differences in C:OM ratios between surface and subsurface soils (Read and Rigell, 1922; David, 1988; Huntington et al., 1989; Jain et al., 1997). Mean weighted C:OM ratios for the O horizons ranged from 0.50 to 0.68 and were similar to those reported in the literature for organic horizons in Connecticut, 0.52 – 0.56 (Lunt, 1931) and New Hampshire, 0.54 – 0.56 (Huntington et al., 1989). The B and C horizon ratios ranged from 0.23 to 0.33 and were similar to those found in coniferous forest soils in the Rocky Mountains, 0.15 to 0.36 (Jain et al., 1997); but lower than the C:OM ratios of 0.43 to 0.51 reported for Bhs horizons in New Hampshire (Huntington, et al., 1989).

The differences in C:OM ratios with depth is likely due to a change in carbon chemistry in the soil over time. Soil organic matter is comprised of humic (humic acid, fulvic acid, humin) and non-humic (carbohydrates, proteins, lipids) materials (Tate, 1987). Organic matter decomposition is distinguished by gradual changes in the functional groups of carbon over time as SOM is humified and changes in size and density (McColl and Gressel, 1995). Soil type and depth can affect the composition and quantity of organic matter present in the soil (Fox, 1995). Soil C:OM ratios can change depending upon the composition or organic matter. For instance, humic acids are higher in carbon concentration than lower molecular weight fulvic acids, which have more O and H-rich functional groups (Stevenson, 1986). Therefore, SOM dominated by humic acids should have higher C:OM ratios than SOM dominated by fulvic acids.

Ratios of C:OM in the Carlisle mapping unit increased slightly, but not significantly, with depth and were as high as 0.57 at 1 m below the soil surface (Table 1). Decomposition in organic soils is slowed due to water-logged conditions, acidity, low redox potential and the inhibitory effect of protonated organic acids (Ponnameruma, 1972; Gambrell and Patrick, 1978; Mausbach and Richardson, 1994). As a result of these limiting conditions, decomposition or organic residues is incomplete, intermediate decomposition products accumulate, and SOM is dominated by humic acids (Stevenson, 1986). Even the deepest organic horizons in the Carlisle soils had high C:OM ratios suggesting SOM with high concentrations of humic acids.

While Histosols are dominated by humic acids, mineral horizons of forest soils are higher in fulvic acids (Stevenson, 1986). This should result in lower C:OM ratios within these soils. While the distribution of humic and fulvic acids throughout mineral horizons is not fully understood (Fox, 1995), it is believed that there are higher concentrations of these organic acids in the litter layer with decreasing concentration in mineral horizons. Organic acids have both hydrophobic and hydrophilic fractions. Humic acids (HA) are roughly 75% hydrophobic while fulvic acids (FA) are more hydrophilic, only 34% hydrophobic (Herbert et al., 1993) As the hydrophobic fractions of these acids are preferentially sorbed higher in the soil profile a greater portion of the humic acids (due to their greater hydrophobicity) would be expected to be sorbed, leading to a decreasing ratio of HA:FA with depth in the soil (Herbert and Bertsch, 1995). Since fulvic acids have a lower carbon concentration than humic acids (Stevenson, 1986), C:OM rations of soil should decrease with depth in these mineral soils, mirroring the change in the proportion of HA:FA in the SOM. This was the case for the three mineral soils in this study. Although the C:OM ratios in the Oi, Oe, and Oe horizons of mineral soils were similar to those of the organic series, ratios quickly decreased with depth in the mineral horizons such that the B and C horizon ratios were significantly different than those of the O and A horizons (Table 1.) This suggests that the composition of SOM differs among master horizons of these soils.

Series-specific C:OM Regression Equations

A significant relationship was found between SOM and SOC for 14 of the 15 series-specific regression equations for these soils (Table 2). The C horizon of the Enfield series was the only exception; SOM was not found to be a good predictor of SOC ($r^2 < 0.20$). The r^2 values for the series-specific regressions ranged from 0.76 to 1.0. Only O horizons of the Enfield and Windsor soils, and the deeper Oa horizons in the Carlisle soils, had r^2 values lower than 0.90. The weaker relationships observed in the Enfield and Windsor O horizons are likely due to the irregular mixing of mineral material into the sapric horizons. The lower r^2 values for the deeper peat horizons may be due to differences in the source of the organic materials. Both woody and reed-sedge peat were observed within some of the profiles at these depths. The high r^2 values (11 of the 14 equations had r2 > 0.90) and low residuals (± 2.0 for organics, ± 0.8 for mineral) suggest that loss-on-ignition estimates of SOM, in combination with series-specific regression equations, can be used to predict SOC in these four soil types.

Residuals of samples not used to calculate the regression equation (test samples) are often used to quantify the goodness of fit of an equation to data. Similar or lower residuals for test samples would imply that the regression equations adequately describe C:OM relationships in these soils. Higher test residuals might suggest that more variability exists in the relationship between SOC and SOM than is accounted for by that particular regression equation. The mean absolute residuals of the test samples we used were lower, or within 0.5 units, of the regression residuals for 13 of the 14 equations (Table 2). Most test samples from the Windsor, Enfield and Carlisle soils fell within the 95% confidence intervals of the regressions suggesting that the equations are representative of the relationship between SOM and SOC in these soils.

Five of the eight test samples for the B and C horizons of the Raypol soils were outside the upper 95% confidence limit for the regression equations (Table 2). In addition, test residuals for the A, B, and C horizons for this series were more than twice as high as the regression residuals. The range of parent materials allowed for this series may explain the apparent failure of the regression equation. Raypol soils are comprised of silt deposits underlain by outwash (similar to the Enfield series). However, unlike the Enfield series, these silts have two origins: wind (loess) or water (alluvium). The data used to build the regression equations for the Raypol soils were from a mapping unit whose soils were loessial. The data used to test the regressions were collected from a Raypol unit having both loessial and alluvial parent materials. As a result, there was a great deal of variability in soil morphology within the test unit. Many of the profiles consisted of a series of O, A, Ab, A/C, Ab, C horizons while a few of the profiles had the O, A, B, C horizon sequence. This suggests the presence of both parent materials and could account for the differences in C:OM ratios between the two mapping units.

Periodic flooding at the alluvial site brings an influx of new parent material and organic matter to the soil with each flooding event. Given enough time, these materials may mix or form separate A and AC horizons before the next depositional event. These processes leave a variety of organic matter forms within the profile that vary in age and stage of decomposition. The processes governing carbon distribution in loess soils are more likely related to long-term carbon additions from litter and root inputs, and the subsequent decomposition and transport of the carbon throughout the solum; which are likely to result in more uniform patterns of organic matter composition (C:OM ratios) and distribution throughout the soil profile.

General C:OM Regression Equations

The general C:OM regression equations were constructed for master horizons of the mineral soils, organic horizons for all 4 soils examined, and the sapric horizons of the Carlisle soils (Table 3). Though all of the general regression equations were significant at the 0.01 level, on average r^2 values were lower than those of the series-specific equations (Tables 2 and 3). The r^2 values were strong (0.87 and higher) for the O, A, and B horizons of the mineral soils and the combined Oa horizons of the Carlisle. A weaker relationship existed (r^2=0.68) was observed between SOM and SOC in the C horizons of the mineral soils. Residuals for the general regression equations were similar or higher than series-specific residuals for each horizon (Tables 2 and 3). Test samples for the O, A, and Carlisle Oa horizon regression equations fell within the 95% confidence intervals (Tables 2 and 3). Residuals for the test samples were generally lower (about half) than the residuals associated with the regression equations. Test samples for the subsurface horizons of the Windsor and Enfield soils fell within the 95% confidence intervals of the two general regression equations. Raypol test samples, however, fell outside the confidence intervals (Table 3). This supports the previous conclusion that differences in soil parent material should be considered carefully when applying SOM-based approaches to estimate SOC pools.

Estimating SOC Pools Using SOM Data

We compared SOC pool estimates (Mg ha^{-1}) based on both series-specific and general regression equations with estimates made using the conventional 0.58 conversion factor and examined these results with the actual SOC pools (Table 4). In every case, the series-specific regression equations provided a better estimate of the SOC pool than the 0.58 conversion factor. The series-specific regression equations were within 3 Mg C ha^{-1} of the actual SOC for the three mineral soil series, and within 6 Mg C ha^{-1} for the organic series.

The general regressions for the A and B horizons tended to underestimate SOC in the sandy Windsor soils and overestimate SOC in the silty Raypol and Enfield soils, suggesting that SOM composition in these soils differ (Table 4). There were minor (1 Mg C ha^{-1}) differences in the C horizon estimates. The general C horizon equation most accurately estimated the actual SOC pool. This is probably due to the limited number of samples (n= 3-7) used to construct the series-specific regression equations for this horizon (Table 1).

Specific regressions based on both series and horizon designation provided the most accurate estimate of the SOC within the sola of the mineral soils. The general regression equations for these three series over or under-estimated SOC for the entire solum, up to 16%, and fell outside the standard error range of the actual SOC pool for both the Windsor and Raypol soils (Table 4). For the Carlisle soils, both series-specific and general regression equations were within 1% (4-6 Mg C ha^{-1}) of the actual SOC pool in the upper 1 m of peat.

Using the conventional conversion factor of 0.58 led to large differences in the estimate of the SOC pool, ranging from 25-62 Mg C ha^{-1}, in these four soil types. This is equivalent to a 27-34% overestimate of the SOC pool in three mineral soils (Table 4). The 0.58 conversion factor was a good predictor of C:OM ratios within the sapric horizons of the Carlisle series, estimated SOC pools for the upper 1 m of peat were within 2% of the actual SOC pool (Table 4). Differences in the SOC pool estimates for the combined Oi, Oe, and Oa horizons of the four soils over or under-estimated actual SOC pool 12 to 14 percent. These results confirm that the historically-used 0.58 conversion factor should not be used to calculate SOC pools in mineral soils, and should be verified when used for organic horizons as slight differences in C:OM rations could lead to substantial error in the SOC estimate of these carbon-rich horizons.

SUMMARY AND CONCLUSIONS

In this study we examined the relationship between carbon and organic matter in four soils commonly found in temperate forests of southern New England and evaluated the impact of using SOM-based approaches to estimate SOC pools. In the mineral soils, significantly higher C:OM ratios were found in the O and A horizons compared to the subsurface B and C horizons of the same soils. Declines with depth in mineral soils were most likely related to changes in the chemical composition of the SOM due to changing concentrations of humic and fulvic acids. In contrast, the organic soils showed minimal change in C:OM ratios with depth;

indicative of saturated soils with inhibited organic matter decomposition and high concentrations of humic acids.

Regression analysis revealed a strong relationship (with few exceptions r^2 values were > 0.90) between SOM and SOC in these soils. For the mineral soils, grouping samples for regression analysis by master horizon within a specific soil type (series) yielded the strongest C:OM relationships. General regression equations based on master horizon across series within the study area provided a broader range of C:OM ratios with only a small loss in predictive ability compared to the series-specific regressions.

Considering the interest in soils as a long-term sink for carbon, and the ongoing debate surrounding the use of SOM-based conversion factors to estimate SOC pools, we measured actual SOC pools for four different soil series (one mapping unit per series) and compared these values to results from three SOM-based approaches: developing series-specific regression equations, pooling data across soil types to create general regression equations, and using the 0.58 conversion factor. For the organic soils, all three SOM-based estimates provided reasonably accurate predictions of the SOC pool. In the mineral soils, however, SOC pools were overestimated by as much as 34% when the 0.58 C:OM ratio was used. Series-specific regression equations, split by master horizon, were found to accurately represent SOC pools in mineral soils and should be used whenever possible. For small sample sizes, general (cross-series) regression equations for master horizons can be used to estimate SOC pools with only a minimal loss in accuracy. Differences in soil parent materials and other factors affecting the age and composition of SOM should be considered, however, when making these estimates.

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Figure 1. The relationship between carbon and organic matter in the Ap horizons of the three mineral soil series. The general regression equation for this horizon (shown), tended to underestimate SOC in the Windsor series (loamy sand) and overestimate SOC in the Enfield and Raypol series (silt loam) suggesting that changing soil textures should be considered when grouping data across several soil series.

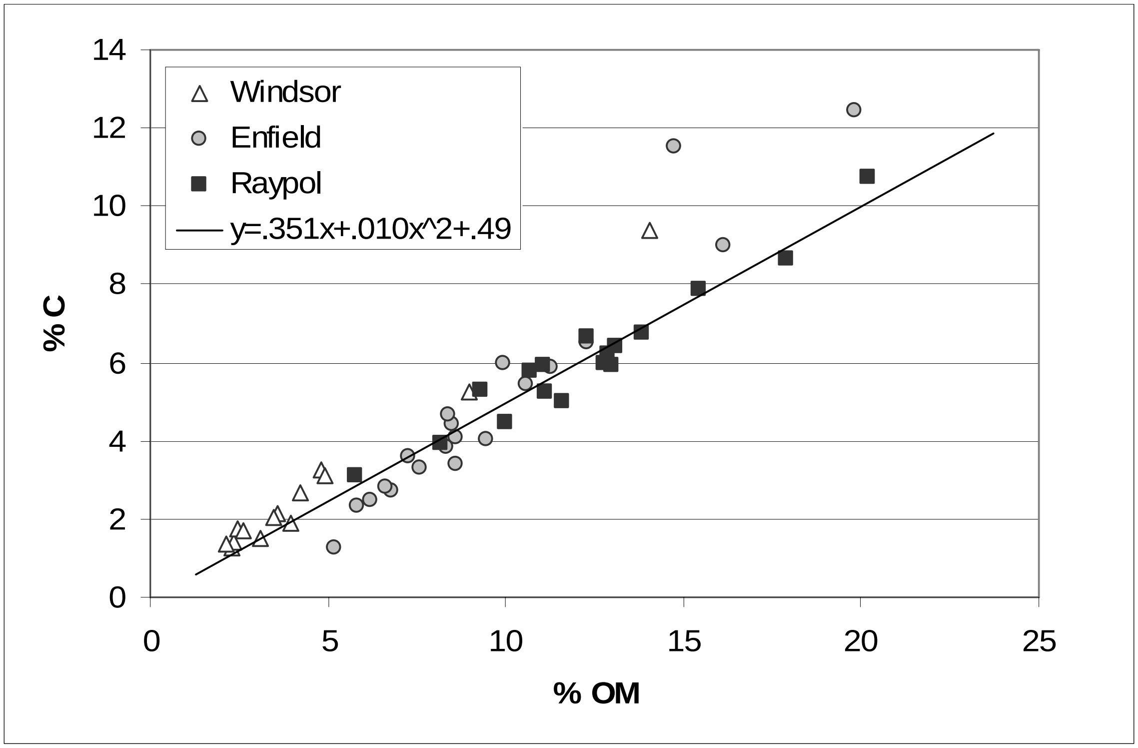

Table 1. Range in soil organic matter (SOM), average carbon:organic matter ratios (C:OM), and estimates of C:OM variability (standard error - SE , and coefficient of variation - CV) within the four mapping units studied.

Master Horizon	SOM range (%)	C:OM mean*	n	C:OM SE	C:OM (% CV)
Windsor (mixed, mesic Typic Udipsamment)					
Oi + Oe	54 - 83	0.60 de	8	0.01	22
A	2 - 9	0.59 cde	10	0.02	11
Bw	1 - 3	0.32 a	10	0.02	20
C	0.5 - 1.2	0.23 a	3	0.02	17
Enfield (coarse-silty over sandy or sandy-skeletal, mixed, active, mesic Typic Dystrudept)					
Oi + Oe		0.57 cd	9	0.01	7
Oa		0.68 e	9	0.02	10
A	6 - 11	0.46 b	9	0.02	15
Bw	2 - 3	0.24 a	9	0.01	18
2C	0.5 - 0.8	0.26 a	7	0.05	50
Raypol (coarse-loamy over sandy or sandy-skeletal, mixed, active, acid, mesic Aeric Endoaquept)					
Oi + Oe		0.53 bcd	9	0.01	6
Oa		0.50 bcd	8	0.02	10
A	9 - 18	0.49 bc	10	0.01	6
Bw	2 - 6	0.33 a	10	0.03	25
2C	0.5 - 1.5	0.28 a	3	0.01	7
Carlisle (euic, mesic Typic Haplosaprist)					
Oi + Oe	77 - 93	0.51 bcd	9	0.00	0
0-50 cm	41 - 90	0.56 bcd	10	0.00	4
50-100cm	67 - 97	0.57 cd	10	0.02	9

* Means followed by different letters are significantly different at the 0.05 level based on Tukey’s multiple mean comparison test.

Table 2. Series-horizon specific C:OM linear regression equations and associated r^2 values for the 4 mapping units studied. Residuals are based on the regression and test sample data, and are calculated as means of the absolute value. Test samples (2 to 6 samples for each horizon of each series) were collected from separate mapping units than used to create the regression equations.

Horizon	**Linear Regression Equation ***	**df**	**R-square**	**Regression Residuals**	**Test Residuals**	**Percentage of Test Samples within 95% CI**
Windsor						
Oi+Oe	y = .391x + 14.355	18	0.81	2.47	1.48	100%
Ap	y = .662x - .214	13	0.98	0.21	0.20	100%
Bw	y = .603x - .397	33	0.94	0.10	0.25	100%
C	y = .135x + .067	3	1.0	0.02	0.05	100%
Enfield						
Oi+ Oe+Oa	y = .430x + 10.985	31	0.88	2.37	3.25	100%
Ap	y = .767x - 2.386	19	0.93	0.80	0.48	100%
Bw	y = .404x - .318	48	0.9	0.13	0.09	100%
2C	not significant	--	-----	-----	-----	----
Raypol						
Oi+Oe+Oa	y = .518x + .116	29	0.97	1.64	1.58	100%
Ap	y = .504x - .007	16	0.94	0.41	0.83	75%
Bw	y = .461x -.413	29	0.97	0.17	0.62	0%
2C	y = .282x - .005	3	0.98	0.02	0.25	25%
Carlisle						
Oi+Oe	y = .477x + 2.946	8	0.99	0.23	0.72	100%
Upper Oa (0-50 cm)	y = .58x - .909	33	0.97	1.67	1.50	100%
Lower Oa (50-100 cm)	y = .40x + 15.98	20	0.76	2.56	0.73	100%

- All of the regression equations were significant at the 0.01 level except where noted.

Table 3. General horizon C:OM linear regression equations and associated r^2 values for the mapping units studied. Soils from the 3 mineral mapping units were grouped together by horizon. The Oi and Oe horizons from the Carlisle soil were grouped with the O horizons of the mineral soils. All the Oa horizons to a depth of 1 m from the Carlisle soils were grouped together. Residuals are based on the regression and test sample data, and are calculated as means of the absolute value. Test samples were collected from separate mapping units than used to create the regression equations.

Horizon	**Linear Regression Equation** *	**df**	**R^2**	**Regression Residuals**	**Test Residuals**	**Percentage of Test Samples within 95% CI**
O	$y = .456x + 7.211$	89	0.87	2.96	1.42	100%
Ap	$y = .351x + .010x^2 + .49$	50	0.9	9.3	4.68	100%
Bw	$y= .364x + .009x^2 - .178$	112	0.91	0.18	0.26	
C	$y = -.251x + .231x^2 + .225$	23	0.68	0.04	0.14	
Carlisle Oa (0-100 cm) *	$y = .541x + 2.494$	52	0.92	2.33	1.11	100%

* All of the regression equations were significant at the 0.01 level.

Table 4. Comparative differences between the actual soil organic carbon (SOC) pools with estimated SOC pools. Estimated SOC pools were calculated using soil series-horizon-specific regression equations, general regression equations, and the conventional 0.58 conversion factor. Standard errors for the actual SOC pool are reported in parentheses. Differences are expressed in Mg/ha and percent (in parentheses).

		Difference		
Horizon	**Actual SOC Pool**	**Specific Regression**	**General Regression**	**0.58 Factor**
	Mg/ha (SE)	Mg/ha (%)	Mg/ha (%)	Mg/ha (%)
Windsor				
Oie	40.6 (3)	-1.7 (-4)	-5.0 (-12)	-4.8 (-12)
A	13.6 (2)	0.0 (0)	-1.6 (-12)	-0.5 (-4)
B	40.2 (4)	1.6 (4)	-8.0 (-20)	30.9 (77)
C	9.8 (1)	-0.7 (-7)	0.1 (1)	12.0 (123)
solum	94.4 (5)	-0.1 (-1)	-14.7 (-16)	25.6 (27)
Enfield				
Oiea	69.5 (8)	0.3 (1)	-4.2 (-6)	-4.5 (-7)
A	55.3 (9)	0.6 (1)	2.7 (5)	11.9 (22)
B	36.2 (6)	2.4 (7)	9.0 (25)	47.8 (132)
C	8.3 (2)	N/D	1.1 (13)	12.6 (152)
solum	161.0 (17)	3.4 (2)	7.5 (5)	55.2 (34)
Raypol				
Oiea	87.6 (18)	2.0 (2)	18.7 (21)	12. 2 (14)
A	61.7 (10)	0.5 (1)	3.3 (5)	10.1 (16)
B	59.7 (11)	0.0 (0)	1.7 (3)	40.0 (67)
C	14.8 (2)	3.6 (24)	-0.2 (-1)	23.5 (159)
solum	209.0 (14)	2.5 (1)	23.7 (11)	62.3 (30)
Carlisle				
Oie	9.2 (1)	-0.5 (-6)	0.5 (5)	1.2 (14)
Upper Oa (0-50 cm)	262.5 (17)	1.3 (1)	4.7 (2)	7.1 (3)
Lower Oa (50-100 cm)	227.0 (32)	5.3 (2)	-1.2 (-1)	3.7 (2)
Upper 1 m	497.8 (45)	6.1 (1)	3.9 (1)	11.9 (2)