Organic Carbons in Soils from Black Rock Forest, Cornwall, N.Y.

By Woonji Lisa Paek

Barnard College
Department of Environmental Science

May 11, 1998

Table of Contents

Charts

Figures

Tables

Appendix

Abstract

Soil from sample pits from Black Rock Forest was analyzed for organic carbon content. Pits were dug at various locations throughout the forest. Horizons in each pit were identified and soil was taken from each layer. Analysis was performed by weight loss on ignition method. The store of carbon in soils is a delicate reservoir that can be modified by land management practices. Through careful study, we can determine where and how much carbon is stored in the soil. As unwise and exploitative land use practices can reduce the intake and storage of carbon by soils, educated, informed use can enhance and perhaps increase the process.

Introduction

Soil is defined in Soil and the Environment, an Introduction by Alan Wild as "the loose material composed of weathered rock and other minerals, and also partly decayed organic matter, that covers large parts of the land surface of the Earth" (Wild, 1993).

How does soil work as part of an ecosystem? The soil is an essential part of the carbon cycle. In the course of natural cycling, CO_2 is taken from the atmosphere by autotrophic organisms through photosynthesis. Some of the carbon is incorporated into the soil by the plants as organic substances. The soil is also a source of carbon when decomposers release CO_2 into the atmosphere through oxidation of organic compounds.

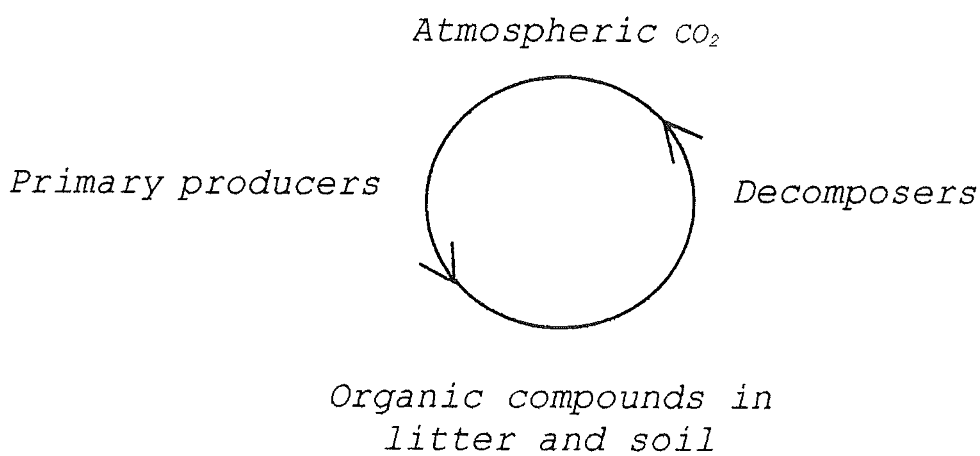

Figure 1. The carbon cycle in the atmosphere-plant-soil ecosystem (Wild, 1993).

The natural sequence of the carbon cycle is altered when carbon from anthropogenic sources is released into the environment. Deforestation turns primary producers into a source, not sink, of carbon. Increase in land use also increases the flux of carbon from the soil to the atmosphere.

The soil serves as a reservoir that is not yet fully understood in the carbon cycle. According to measurements from the Mauna Loa Observatory in Hawaii, concentrations of CO_2 have increased significantly over the years (Wild, 1993). With the ever-increasing use of fossil fuels and increased emissions, how will it affect global warming? How much of the carbon can and is taken into the soils?

The focus of the soil analysis will be the amount of organic matter in soil, the percentage of organic carbon in the soil's organic matter and comparison of carbon content between the different layers, or horizons

Methods

Field Work

Soil samples were collected during the summer of 1997 by Sarah Helm, a student working in the Pew Science Program. Pits were dug in the Cascade Brook watershed area of Black Rock Forest. The depths of soil horizons in each pit were recorded. Samples were taken from the following layers: 1) litter, 2) 3-8 cm depth, including the roots, 3) 8-13 cm depth, 4) 18-23 cm depth, 5) 38-43 cm depth, and 6) 79-84 cm depth. Soil was placed in zip loc plastic bags and labeled with appropriate date, location and horizon (Table 1). Samples were placed into refrigeration at approximately 8°C for storage.

Table 1. Soil sample list.

Pit numbers are given with location, date and volume of sampling, where available. Sample numbers are listed with their depth from surface.

Soil Sample List		
Pit BRF 17-001, near Glycerine Hollow Lookout on Carpenter. 08/01/97		
Sample# BRF 17-001-1	L	131 ml
BRF 17-001-2	5 cm, A	131 ml
BRF 17-001-3	13 cm, B1	131 ml
BRF 17-001-4	23 cm, B2	131 ml
BRF 17-001-5	46 cm, C top	131 ml
BRF 17-001-6	76 cm, C bottom	131 ml
Pit BRF 19-001 08/15/97		
Sample# BRF 19-001-1	L	
BRF 19-001-2	5 cm, A	
BRF 19-001-3	25 cm, B	
BRF 19-001-4	48 cm, C	
Pit BRF 20-002		
Sample# BRF 20-002-1	L	
BRF 20-002-2	3 cm, A	
BRF 20-002-3	8 cm, B1	
BRF 20-002-4	20 cm, B2	
BRF 20-002-5	43 cm, C	
Pit BRF 20-003, Bottom of Glycerine Hollow. 08/01/97		
Sample# BRF 20-003-1	L	131 ml
BRF 20-003-2	8 cm, A	131 ml
BRF 20-003-4	25 cm, B top	131 ml
BRF 20-003-5	33 cm, B bottom	131 ml
BRF 20-003-6	61 cm, C top	131 ml
BRF 20-003-7	76 cm, C bottom	131 ml
Pit BRF 20-004, Bottom of Glycerine Hollow. 08/01/97		
Sample# BRF 20-004-1	L	131 ml
BRF 20-004-2	10 cm, A	131 ml
BRF 20-004-3	25 cm, B	131 ml
BRF 20-004-4	51 cm, C top	131 ml
BRF 20-004-5	91 cm, C bottom	131 ml
Pit BRF 20-005 08/15/97		
Sample# BRF 20-005-1	L	
BRF 20-005-2	8 cm, A	

BRF 20-005-3	30 cm, B	
BRF 20-005-4	53 cm, C	
Pit BRF 20-006		
Sample# BRF 20-006-1	L	
BRF 20-006-2	8 cm, A	
BRF 20-006-3	25 cm, B top	
BRF 20-006-4	33 cm, B bottom	
Pit BRF 20-007 08/12/97		
Sample# BRF 20-007-1	L	
BRF 20-007-2	3 cm, A	
BRF 20-007-3	10 cm, B1	
BRF 20-007-4	23 cm, B2	
BRF 20-007-5	51 cm, C	
Pit BRF 20-008		
Sample# BRF 20-008-1	L	
BRF 20-008-2	3 cm, A	
BRF 20-008-3	13 cm, B1	
BRF 20-008-4	25 cm, B2	
BRF 20-008-5	51 cm, C	210 ml
Pit BRF 21-001, Go-Down Rd. 07/23/97		
Sample# BRF 21-001-1	L	160 ml
BRF 21-001-2	5 cm, A	192 ml
BRF 21-001-3	10 cm, B?	152 ml
BRF 21-001-4	20 cm, B	160 ml
BRF 21-001-5	41 cm, C top	210 ml
BRF 21-001-6	81 cm, C middle	166 ml
BRF 21-001-7	122 cm, C bottom	75 ml

Soil Organic Analysis

Materials:

- aluminum foil
- crucibles
- tongs
- low temperature oven
- desiccator
- balance
- sieve (#10, 2mm)
- plastic zip-lock bags
- mortar and pestle
- weighing paper
- analytical balance
- furnace
- glass vials

The methods used to analyze soil organic carbon content are based on those used in a senior thesis by Dan Farrell (The Diversity and Species in a Managed Forest, May 1997). Farrell based his methods on two texts, Soils and the Environment: an Introduction, Wild and Soil sampling, preparation, and analysis, Tan.

Plastic bags of samples were opened, covered with aluminum foil and left out to air dry for 24 hours. Samples were weighed in the bag after complete drying (Appendix A). The soil was then sieved to remove all twigs, stones and other debris larger than 2mm. The debris caught in the sieve was put into a separate bag and weighed (Appendix A). The sieved soil was then pulverized into a homogenous mixture with a mortar and pestle. The weight of a piece of weighing paper taken and recorded as P_I. An aliquot of approximately 1-2 g of the sieved soil was weighed and its weight was recorded as "S". Crucibles were washed, labeled, and dried in the oven. They were then cooled and weighed. Individual weights for each crucible were recorded as "Cr". Each sample "S" was placed into a crucible and the paper used to weigh the soil sample was reweighed. Weight was recorded as P_F. If P_F did not equal P_I, then a correction was applied to "S" (Appendix D). The actual weight of soil put into the crucible was noted as S_i. Crucibles with their samples were then placed into an oven at 100°C for one hour, then were cooled in a dessicator, after which the sample and crucible were weighed again. The final weight of the sample (S_f) was determined by subtracting the weight of its crucible (Cr). Moisture loss was calculated using the formula:

$$\% \text{ moisture loss} = 100(S_i - S_f)/S_i$$

Crucibles were then placed into a furnace and combusted at 375°C for six hours. They were cooled in a dessicator, weighed and after correcting for crucible weight, the weight of the remaining soil sample was recorded as S_c. Loss on ignition (LOI) and fraction of loss on ignition (%LOI) of the organic matter in the soil was calculated using the formulae:

$$LOI = S_f - S_c$$

$$\%LOI = 100[(S_f - S_c)/S_f]$$

Because organic carbon content is approximately 50% of the organic matter content (Tan, 1996, 223), percent of organic carbon content ($\%C_{ORG}$) in the soil can be calculated with the formula:

$$\%C_{ORG} = \%LOI/2$$

After analysis, all samples were stored in labeled glass vials. Each sample from a horizon was analyzed in duplicate.

Results

Table 2. Percent organic carbon for soil samples. Raw data located in Table A2 and A3.

Sample #	DEPTH	RUN #1	RUN #2	AVERAGE	SD	SE
17-001-2	5	1.304	1.509	2.058	0.145	0.103
17-001-3	13	1.107	1.413	1.813	0.216	0.153
17-001-4	23	4.086	4.004	6.088	0.058	0.041
17-001-5	46	0.352	0.402	0.553	0.036	0.025
17-001-6	76	0.101	0.201	0.201	0.071	0.050
19-001-2	5	10.399	10.775	15.786	0.266	0.188
19-001-3	25	4.721	5.288	7.365	0.401	0.284
19-001-4	48	3.184	3.283	4.825	0.070	0.049
20-002-2	3	3.770	6.515	7.028	1.941	1.372
20-002-3	8	2.534	2.521	3.794	0.009	0.006
20-002-4	20	1.235	1.562	2.016	0.232	0.164
20-002-5	43	1.060	1.326	1.723	0.187	0.133
20-003-2	8	4.806	6.746	8.179	1.372	0.970
20-003-3	25	1.907	2.622	3.218	0.506	0.358
20-003-4	33	1.552	1.835	2.469	0.200	0.142
20-003-5	61	0.785	1.148	1.359	0.257	0.181
20-003-6	76	0.371	0.651	0.697	0.198	0.140
20-004-2	10	8.066	8.865	12.499	0.565	0.399
20-004-3	25	3.381	3.885	5.324	0.357	0.252
20-004-4	51	0.403	0.504	0.655	0.071	0.050
20-004-5	91	0.251	0.300	0.401	0.035	0.025
20-005-2	8	4.551	4.015	6.559	0.379	0.268
20-005-3	30	2.716	2.439	3.936	0.196	0.139
20-005-4	53	0.267	0.432	0.483	0.116	0.082
20-006-2	10	3.864	4.556	6.142	0.489	0.346
20-006-3	30	2.220	1.960	3.200	0.184	0.130
20-006-4	46	1.735	1.418	2.444	0.224	0.158
20-007-2	3	5.736	5.330	8.401	0.287	0.203
20-007-3	10	1.972	1.613	2.778	0.254	0.179
20-007-4	23	1.919	1.414	2.626	0.357	0.253
20-007-5	51	0.961	0.914	1.417	0.033	0.023
20-008-2	3	9.117	8.391	13.312	0.513	0.363
20-008-3	13	2.391	1.984	3.383	0.288	0.203
20-008-4	25	1.931	1.623	2.743	0.218	0.154
20-008-5	51	0.608	0.405	0.810	0.144	0.102
21-001-2	5	12.758	10.271	17.893	1.758	1.243
21-001-3	10	6.998	5.582	9.789	1.001	0.708
21-001-4	20	2.848	2.588	4.142	0.184	0.130
21-001-5	41	1.545	1.553	2.321	0.006	0.004
21-001-6	81	0.456	0.404	0.659	0.037	0.026
21-001-7	122	0.251	0.251	0.377	0.000	0.000

In soil analyses, as with any scientific experiment, a standard or a known is tested along with each sample. SLOSH, Standard Lamont Observatory Sediments from the Hudson, was used as the standard. Percent organic carbon for standard samples. are shown, along with average and standard deviation.

Table 3. Organic carbon content of standards. Raw data located in Table A3.

SLOSH	%Corg	SLOSH	%Corg	Average
RUN #1	2.905	RUN #26	3.067	2.916
RUN #2	3.001	RUN #27	3.061	
RUN #3	3.052	RUN #28	2.959	**SD**
RUN #4	3.103	RUN #29	2.902	0.277
RUN #5	3.204	RUN #30	2.964	
RUN #6	3.157	RUN #31	2.599	**SE**
RUN #7	3.201	RUN #32	2.497	0.039
RUN #8	3.265	RUN #33	2.701	
RUN #9	3.208	RUN #34	2.444	
RUN #10	2.554	RUN #35	2.352	
RUN #11	2.965	RUN #36	2.696	
RUN #12	2.965	RUN #37	2.701	
RUN #13	2.902	RUN #38	2.795	
RUN #14	2.908	RUN #39	3.004	
RUN #15	2.911	RUN #40	3.007	
RUN #16	2.905	RUN #41	3.103	
RUN #17	2.809	RUN #42	3.150	
RUN #18	2.500	RUN #43	3.154	
RUN #19	2.605	RUN #44	3.201	
RUN #20	2.500	RUN #45	3.249	
RUN #21	2.294	RUN #46	3.154	
RUN #22	2.198	RUN #47	3.204	
RUN #23	3.119	RUN #48	3.106	
RUN #24	3.112	RUN #49	3.160	
RUN #25	3.071	RUN #50	3.163	

Discussion

Visually, there was a difference in soils from different horizons. Generally, the greater the depth from the surface, the lighter and more clay-like the soil appeared. In these horizons, I expected less % moisture loss, LOI, %LOI and $\%C_{ORG}$. Decomposition of litter on the forest floor enriches the uppermost layers of the soil with organic carbon and this enriching becomes more and more limited as the soil layers go deeper.

I expected differences between the same horizons of different pits only if the locations differed greatly in type of vegetation. The more vegetation there is at the site, the more litter. The more litter there is, the greater the amount of carbon in the soil's upper horizons.

Analysis of soil samples show that there is a strong correlation between horizon and soil organic carbon content (Chart 1). Generally the deeper the horizon is, the less the organic carbon content of that soil. A horizons had, in most samples, organic carbon content higher than that of B or C horizons. Organic carbon also decreased with increasing depth from the surface.

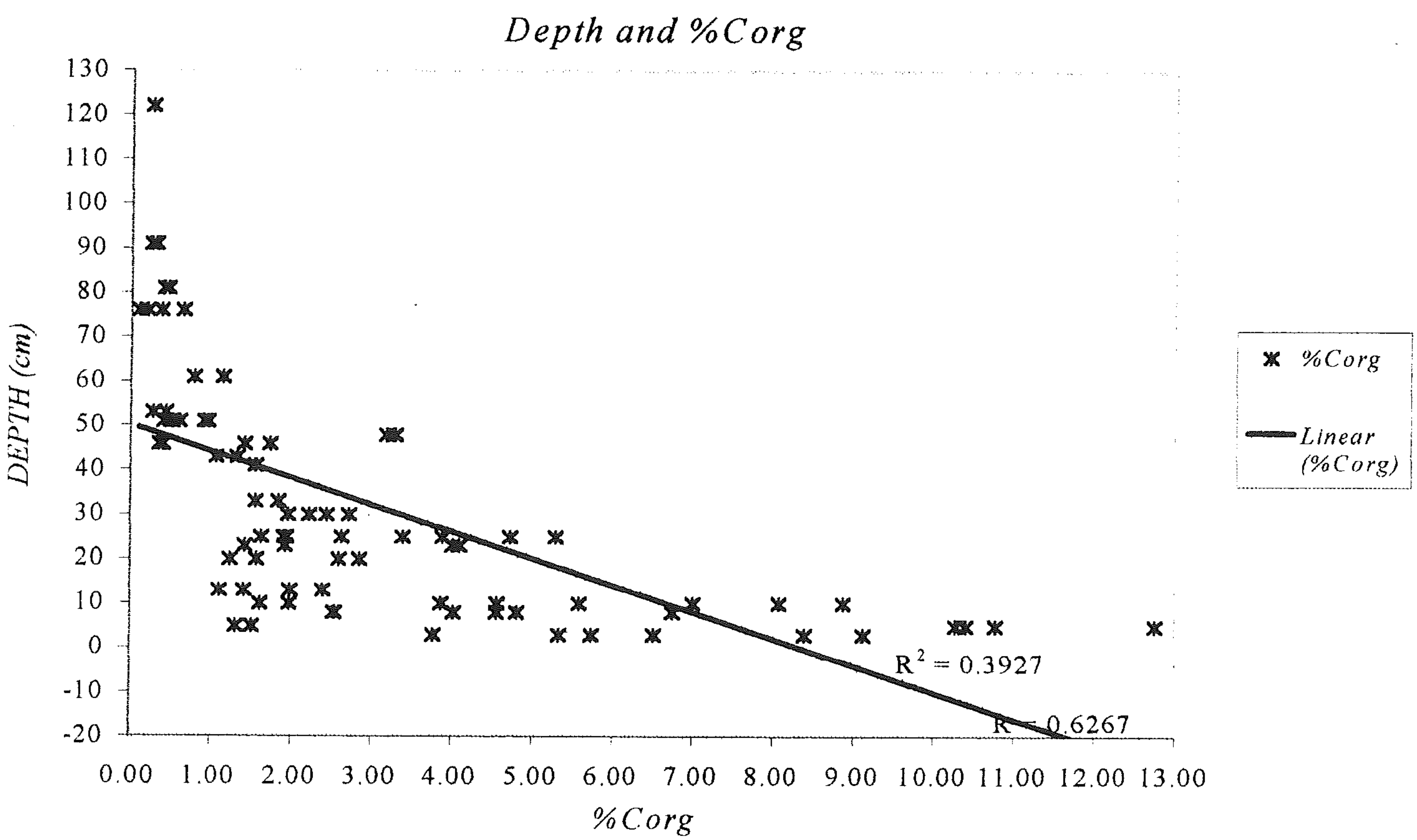

Chart 1. Depth and %Corg of soil samples with regression line.

Using one way analysis of variance (ANOVA), the obtained value of F of all sample tests was found to be less than the critical value of 1.686 (Table 1).

Table 4. ANOVA Single Factor: All sample test for significant difference in organic carbon content.

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
17-001-2	2.0000	2.8130	1.4065	0.0210		
17-001-3	2.0000	2.5194	1.2597	0.0468		
17-001-4	2.0000	8.0899	4.0450	0.0033		
17-001-5	2.0000	0.7538	0.3769	0.0013		
17-001-6	2.0000	0.3020	0.1510	0.0051		
19-001-2	2.0000	21.1737	10.5868	0.0708		
19-001-3	2.0000	10.0095	5.0047	0.1610		
19-001-4	2.0000	6.4665	3.2332	0.0049		
20-002-2	2.0000	10.2850	5.1425	3.7657		
20-002-3	2.0000	5.0548	2.5274	0.0001		
20-002-4	2.0000	2.7971	1.3985	0.0538		
20-002-5	2.0000	2.3860	1.1930	0.0351		
20-003-2	2.0000	11.5524	5.7762	1.8811		
20-003-3	2.0000	4.5294	2.2647	0.2559		
20-003-4	2.0000	3.3866	1.6933	0.0401		
20-003-5	2.0000	1.9336	0.9668	0.0658		
20-003-6	2.0000	1.0225	0.5113	0.0393		
20-004-2	2.0000	16.9317	8.4658	0.3191		
20-004-3	2.0000	7.2666	3.6333	0.1272		
20-004-4	2.0000	0.9063	0.4532	0.0051		
20-004-5	2.0000	0.5511	0.2755	0.0012		
20-005-2	2.0000	8.5662	4.2831	0.1437		
20-005-3	2.0000	5.1552	2.5776	0.0384		
20-005-4	2.0000	0.6993	0.3497	0.0135		
20-006-2	2.0000	8.4194	4.2097	0.2396		
20-006-3	2.0000	4.1796	2.0898	0.0338		
20-006-4	2.0000	3.1531	1.5765	0.0502		
20-007-2	2.0000	11.0660	5.5330	0.0825		
20-007-3	2.0000	3.5846	1.7923	0.0644		
20-007-4	2.0000	3.3333	1.6667	0.1275		
20-007-5	2.0000	1.8743	0.9371	0.0011		
20-008-2	2.0000	17.5078	8.7539	0.2637		
20-008-3	2.0000	4.3744	2.1872	0.0828		
20-008-4	2.0000	3.5541	1.7771	0.0475		

20-008-5	2.0000	1.0128	0.5064	0.0206		
21-001-2	2.0000	23.0290	11.5145	3.0911		
21-001-3	2.0000	12.5796	6.2898	1.0020		
21-001-4	2.0000	5.4359	2.7179	0.0337		
21-001-5	2.0000	3.0976	1.5488	0.0000		
21-001-6	2.0000	0.8608	0.4304	0.0013		
21-001-7	2.0000	0.5020	0.2510	0.0000		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	653.1179	40.0000	16.3279	54.6883	0.0000	1.6856
Within Groups	12.2411	41.0000	0.2986			
Total	665.3590	81.0000				

The null hypothesis is therefore rejected and therefore it can be concluded that there are significant differences in organic carbon content among the different horizons. ANOVAs were also performed on each group of samples from the same horizons. For A horizon samples, the obtained F value was less than the critical value and therefore the conclusion is that there are no sufficient reasons for differences among the samples (Table 5).

Table 5. ANOVA Single Factor: A horizon test for significant difference in organic carbon content.

Anova: Single Factor, A horizon, 3-10 cm						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
17-001-2	2.0000	2.8130	1.4065	0.0210		
19-001-2	2.0000	21.1737	10.5868	0.0708		
20-002-2	2.0000	10.2850	5.1425	3.7657		
20-003-2	2.0000	11.5524	5.7762	1.8811		
20-004-2	2.0000	16.9317	8.4658	0.3191		
20-005-2	2.0000	8.5662	4.2831	0.1437		
20-006-2	2.0000	8.4194	4.2097	0.2396		
20-007-2	2.0000	11.0660	5.5330	0.0825		
20-008-2	2.0000	17.5078	8.7539	0.2637		
21-001-2	2.0000	23.0290	11.5145	3.0911		

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	180.3056	9.0000	20.0340	20.2810	0.0000	3.0204
Within Groups	9.8782	10.0000	0.9878			
Total	190.1837	19.0000				

The same holds true for B horizon samples (Table 6). If the null hypothesis is retained for the B horizon sample results, we conclude that there are no significant differences. Therefore, among the various sampling locations, the amount of organic carbon did not vary greatly at the same horizon. This may be a result of all sites having very similar groundcover and litter. It may also indicate that the different groundcover and litter found within these sites do not greatly impact the organic carbon content of the topsoil and upper horizons.

Table 6. ANOVA Single Factor: B horizon test for significant difference in organic carbon content.

Anova: Single Factor, B horizons, 13-33 cm						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
17-001-3	2.0000	53.6975	26.8487	851.1068		
17-001-4	2.0000	8.0899	4.0450	0.0033		
19-001-3	2.0000	10.0095	5.0047	0.1610		
20-002-3	2.0000	5.0548	2.5274	0.0001		
20-002-4	2.0000	2.7971	1.3985	0.0538		
20-003-3	2.0000	4.5294	2.2647	0.2559		
20-003-4	2.0000	3.3866	1.6933	0.0401		
20-004-3	2.0000	7.2666	3.6333	0.1272		
20-005-3	2.0000	5.1552	2.5776	0.0384		
20-006-3	2.0000	4.1796	2.0898	0.0338		
20-006-4	2.0000	3.1531	1.5765	0.0502		
20-007-3	2.0000	3.5846	1.7923	0.0644		
20-007-4	2.0000	3.3333	1.6667	0.1275		
20-008-3	2.0000	4.3744	2.1872	0.0828		
20-008-4	2.0000	3.5541	1.7771	0.0475		
21-001-3	2.0000	12.5796	6.2898	1.0020		
21-001-4	2.0000	5.4359	2.7179	0.0337		

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1154.4000	16.0000	72.1500	1.4375	0.2327	2.2888
Within Groups	853.2284	17.0000	50.1899			
Total	2007.6284	33.0000				

Generally, the organic carbon content of the A sample was 2-5 times greater than the B sample. For C horizon samples, the obtained F value was greater than the critical value and therefore the conclusion is that there are differences among the samples (Table 7). C horizon contains soils that are classified as "parent material" and A and B horizons as "eluvial" and "illuvial" (White, 1989). With these definitions in mind, organic carbon content can be similar in the A and B horizons if we consider the movement from nutrient sources into the A horizon ("eluvial") which then washes down and collects in the B horizon ("illuvial"). By these processes, soils in different parts of the forest can have the same source of influx in the A and B horizons. Parent material lies deep beneath the reach of the nutrients washing downwards into the profile. The soil here is largely the product of weathering of the rock underneath (White, 1989) and will retain most of the characteristics of that rock. If different types of bedrock underlie the C horizons, then the organic carbon contents will differ as well.

Table 7. ANOVA Single Factor: C horizon test for significant difference in organic carbon content.

Anova: Single Factor, C horizon,41-122 cm						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
17-001-5	2.0000	0.7538	0.3769	0.0013		
17-001-6	2.0000	0.3020	0.1510	0.0051		

19-001-4	2.0000	6.4665	3.2332	0.0049		
20-002-5	2.0000	2.3860	1.1930	0.0351		
20-003-5	2.0000	1.9336	0.9668	0.0658		
20-003-6	2.0000	1.0225	0.5113	0.0393		
20-004-4	2.0000	0.9063	0.4532	0.0051		
20-004-5	2.0000	0.5511	0.2755	0.0012		
20-005-4	2.0000	0.6993	0.3497	0.0135		
20-007-5	2.0000	1.8743	0.9371	0.0011		
20-008-5	2.0000	1.0128	0.5064	0.0206		
21-001-5	2.0000	3.0976	1.5488	0.0000		
21-001-6	2.0000	0.8608	0.4304	0.0013		
21-001-7	2.0000	0.5020	0.2510	0.0000		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16.9768	13.0000	1.3059	94.0294	0.0000	2.5073
Within Groups	0.1944	14.0000	0.0139			
Total	17.1712	27.0000				

In terms of methods, there have been questions as to when soil should be sieved. Sieving was a faster way of sorting debris. The other alternative was sorting by hand using tweezers. This was both time consuming and subjective. In both processes, a stone larger than 2 mm was more easily picked out than a root hair larger than 2 mm. The sorting of debris was not error free either way. Soil aggregates were somewhat eliminated when soil was pulverized before sieving. But moisture within the particles caused them to clump into aggregates, even after pulverization with mortar and pestle. These aggregates can and should be part of the sieved soil that is used in analysis. Instead, the aggregates were sorted out in the sieve and become part of the debris. Some root hairs were not trapped in the sieve and fell into the portion of the sample to be tested. Crucibles could have lost more weight after heating in the furnace and oven with the soils in them. Some soil could have been lost during the transfer from the balance to the crucible, or from the furnace or oven to the desiccator. These are all sources of systematic and random errors.

Conclusion

Results show that most of the organic carbon was located in the A and B horizons. These layers receive the products of decomposition of litter and runoff from precipitation. They are also the most directly affected by land management use. Any actions taken above ground will directly affect the carbon storage underground. Logging, agriculture, land development all upset the layers within the profile. Soils in general are stores of approximately twice the amount of carbon present in the atmosphere as carbon dioxide (Wild, 1993). Soils are a key in the carbon cycle for the uptake of carbon. Cultivated lands, pastures for livestock, deforestation and other changes in land use can all lead to the release of carbon to the atmosphere. More of the organic matter is exposed to oxygen, soil moisture and temperature can increase and this can accelerate the respiratory release of carbon (Lal, 1995). Any addition of carbon into the atmosphere can tip the delicate balance of carbon cycling in the ecosystem.

There are many factors that affect the rate of carbon storage of carbon in soils. While it is important to know how much is stored where, that knowledge is secondary to other information. What are the consequences of land use practices, not just in forests, but everywhere? Will it decrease the uptake of carbon by the soil? Will it release carbon and cause a potential sink to become a source? How can we maintain and enhance the natural role of the soil? The key here is an informed and educated modification in the approaches to handling our resources to benefit both our needs and the needs of the environment.

Acknowledgements

Stephanie Pfirman, Jim Simpson, and Martin Stute provided advice and encouragement. Peter Bower introduced me to his Pew Scholar project, which extended into this thesis. Sarah Helm provided the soil samples and performed the fieldwork. Barnard College Security allowed me access to the Environmental Science laboratories at all hours of the night. Special thanks to the many others, too many to list, who supported me in my struggle to finish my thesis.

References

Butcher, Samuel S., et. al. (1992) *Global Biogeochemical Cycles*, London, San Diego, New York, Boston, Sydney, Tokyo, Toronto; Academic Press.

Farrell, Dan (1997) *The Diversity and Species Composition of Woody Plant Species in a Managed Forest,* Undergraduate Senior Thesis, Columbia University

Harrison, A.F., et. al. (1990) *Nutrient Cycling in Terrestrial Ecosystems*, London, New York; Elsevier Applied Science.

Hesse, P.R. (1971) *A Textbook of Soil Chemical Analysis*, New York; Chemical Publishing Co., Inc.

Helm, Sarah L. (1997) Field notes, Undergraduate research, Pew Science Program, Barnard College

Lal, R., et. al., (1998) *Management of Carbon Sequestration in Soil*, Boca Raton, New York; CRC Press.

Lal, R., et. al. (1995) *Soils and Global Change*, Boca Raton, New York; CRC Press.

Remezov, N.P. and P.S. Pogrebnyak, (1965) *Forest Soil Science*, Jerusalem; Israel Program for Scientific Translations.

Tan, Kim H. (1996) *Soil sampling, preparation, and analysis*, New York; Marcel Dekker, Inc.

Tate, Robert L. III, (1987) *Soil Organic Matter, Biological and Ecological Effects*, New York, Chichester, Brisbane, Toronto, Singapore; John Wiley & Sons

White, R.E. (1987) *Introduction to the Principles and Practice of Soil Science*, 2nd. Editon, Oxford, London, Edinburgh, Boston, Palo Alto, Melbourne; Blackwell Scientific Publications.

Wild, Alan (1993) *Soils and the Environment*, Cambridge, New York, Melbourne; Cambridge University Press

Welkowitz, Joan., et. al., (1988) *Introductory Statistics for the Behavioral Sciences*, San Diego, New York, Chicago, Austin, Washington,D.C., London, Sydney, Tokyo, Toronto; Harcourt Brace Jovanovich, Publishers.

Winegardner, Duane L. (1995) *An Introduction to Soils for Environmental Professionals*, Boca Raton, New York, London, Tokyo; Lewis Publishers

TABLE A1. SAMPLE WEIGHTS

Whole soil samples weighed in the bag, after complete drying at room temperature. Debris collected with #10 (2mm) sieve and then weighed.

SAMPLE#	WHOLE WEIGHT (g)	DEBRIS WEIGHT (g)
17-001-2	189.129	108.557
17-001-3	109.137	45.366
17-001-4	87.603	20.596
17-001-5	119.508	24.386
17-001-6	152.842	39.534
19-001-2	49.376	7.108
19-001-3	64.605	11.027
19-001-4	81.664	17.810
20-001-3	187.277	85.752
20-002-2	34.911	5.751
20-002-3	75.781	16.318
20-002-4	68.910	33.010
20-002-5	84.213	28.231
20-003-2	73.877	36.452
20-003-3	133.228	43.937
20-003-4	148.028	24.133
20-003-5	162.967	54.335
20-003-6	179.388	78.985
20-004-2	58.608	5.032
20-004-3	88.17	19.733
20-004-4	132.054	54.359
20-004-5	129.786	50.44
20-005-2	94.324	20.766
20-005-3	150.308	108.410
20-005-4	135.129	36.265
20-006-2	86.360	8.952
20-006-3	87.000	8.952
20-006-4	85.147	13.944
20-007-2	115.699	61.522
20-007-3	74.205	24.833
20-007-4	122.448	60.159
20-007-5	80.050	22.046
20-008-2	51.628	9.846
20-008-3	70.062	10.365
20-008-4	84.498	14.641
20-008-5	66.942	22.886
21-001-2	94.046	21.611
21-001-3	95.877	16.011
21-001-4	141.564	26.406
21-001-5	212.028	59.070
21-001-6	193.785	57.991
21-001-7	107.006	36.534

Table A2. Raw data from first run of samples.

Sample	Pi (g)	Weight (g)	Pf (g)	Si	Cr (g)	Sf + Cr (g)	Sf (g)	Sc + Cr (g)	Sc (g)	%moist. loss	LOI	%LOI	%Corg
17-001-2	0.447	1.004	0.448	1.003	12.940	13.937	0.997	13.911	0.971	0.598	0.026	2.608	1.304
17-001-3	0.457	1.000	0.459	0.998	12.790	13.784	0.994	13.762	0.972	0.401	0.022	2.213	1.107
17-001-4	0.373	1.000	0.374	0.999	11.334	12.313	0.979	12.233	0.899	2.002	0.080	8.172	4.086
17-001-5	0.464	0.999	0.466	0.997	13.549	14.544	0.995	14.537	0.988	0.201	0.007	0.704	0.352
17-001-6	0.386	1.002	0.387	1.001	13.001	13.995	0.994	13.993	0.992	0.699	0.002	0.201	0.101
19-001-2	0.394	1.002	0.396	1.000	12.196	13.124	0.928	12.931	0.735	7.200	0.193	20.797	10.399
19-001-3	0.385	1.003	0.392	0.996	12.357	13.289	0.932	13.201	0.844	6.426	0.088	9.442	4.721
19-001-4	0.451	1.002	0.458	0.995	13.138	13.986	0.848	13.932	0.794	14.774	0.054	6.368	3.184
20-001-3	0.366	1.001	0.371	0.996	12.940	13.866	0.926	13.845	0.905	7.028	0.021	2.268	1.134
20-002-2	0.386	1.003	0.391	0.998	12.790	13.652	0.862	13.587	0.797	13.627	0.065	7.541	3.770
20-002-3	0.463	1.001	0.470	0.994	11.336	12.224	0.888	12.179	0.843	10.664	0.045	5.068	2.534
20-002-4	0.375	1.003	0.380	0.998	13.550	14.522	0.972	14.498	0.948	2.605	0.024	2.469	1.235
20-002-5	0.451	1.001	0.455	0.997	14.929	15.872	0.943	15.852	0.923	5.416	0.020	2.121	1.060
20-003-2	0.447	1.002	0.455	0.994	12.978	13.727	0.749	13.655	0.677	24.648	0.072	9.613	4.806
20-003-3	0.407	1.002	0.415	0.994	12.820	13.659	0.839	13.627	0.807	15.594	0.032	3.814	1.907
20-003-4	0.414	1.002	0.419	0.997	13.054	13.924	0.870	13.897	0.843	12.738	0.027	3.103	1.552
20-003-5	0.449	1.004	0.452	1.001	12.195	13.15	0.955	13.135	0.940	4.595	0.015	1.571	0.785
20-003-6	0.364	1.003	0.367	1.000	12.195	13.273	1.078	13.265	1.070	-7.800	0.008	0.742	0.371
20-004-2	0.368	1.002	0.373	0.997	13.138	13.981	0.843	13.845	0.707	15.446	0.136	16.133	8.066
20-004-3	0.385	1.001	0.388	0.998	14.929	15.905	0.976	15.839	0.910	2.204	0.066	6.762	3.381
20-004-4	0.463	1.003	0.466	1.000	12.979	13.972	0.993	13.964	0.985	0.700	0.008	0.806	0.403
20-004-5	0.363	1.002	0.365	1.000	12.821	13.818	0.997	13.813	0.992	0.300	0.005	0.502	0.251
20-005-2	0.441	1.002	0.448	0.995	12.791	13.593	0.802	13.520	0.729	19.397	0.073	9.102	4.551
20-005-3	0.381	1.002	0.384	0.999	11.335	12.237	0.902	12.188	0.853	9.710	0.049	5.432	2.716
20-005-4	0.460	1.003	0.477	0.986	14.714	15.649	0.935	15.644	0.930	5.172	0.005	0.535	0.267
20-006-2	0.397	1.002	0.411	0.988	14.303	15.183	0.880	15.115	0.812	10.931	0.068	7.727	3.864
20-006-3	0.385	1.002	0.390	0.997	14.078	15.024	0.946	14.982	0.904	5.115	0.042	4.440	2.220
20-006-4	0.369	1.002	0.372	0.999	13.251	14.202	0.951	14.169	0.918	4.805	0.033	3.470	1.735
20-007-2	0.374	1.004	0.380	0.998	14.577	15.562	0.985	15.449	0.872	1.303	0.113	11.472	5.736
20-007-3	0.448	1.001	0.454	0.995	14.037	15.026	0.989	14.987	0.950	0.603	0.039	3.943	1.972
20-007-4	0.393	1.000	0.396	0.997	12.435	13.425	0.990	13.387	0.952	0.702	0.038	3.838	1.919
20-007-5	0.415	1.001	0.421	0.995	14.994	15.983	0.989	15.964	0.970	0.603	0.019	1.921	0.961
20-008-2	0.453	1.003	0.457	0.999	12.792	13.664	0.872	13.505	0.713	12.713	0.159	18.234	9.117

20-008-3	0.462	1.002	0.465	0.999	11.336	12.319	0.983	12.272	0.936	1.602	0.047	4.781	2.391
20-008-4	0.388	1.002	0.391	0.999	13.550	14.508	0.958	14.471	0.921	4.104	0.037	3.862	1.931
20-008-5	0.462	1.002	0.465	0.999	13.002	13.989	0.987	13.977	0.975	1.201	0.012	1.216	0.608
21-001-2	0.385	1.002	0.388	0.999	12.196	12.972	0.776	12.774	0.578	22.322	0.198	25.515	12.758
21-001-3	0.385	1.000	0.390	0.995	12.358	13.194	0.836	13.077	0.719	15.980	0.117	13.995	6.998
21-001-4	0.375	1.003	0.379	0.999	13.139	14.052	0.913	14.000	0.861	8.609	0.052	5.696	2.848
21-001-5	0.440	1.002	0.444	0.998	12.979	13.95	0.971	13.920	0.941	2.705	0.030	3.090	1.545
21-001-6	0.382	1.000	0.383	0.999	14.037	15.023	0.986	15.014	0.977	1.301	0.009	0.913	0.456
21-001-7	0.407	1.002	0.410	0.999	13.053	14.048	0.995	14.043	0.990	0.400	0.005	0.503	0.251

Table A3. Raw data from second run of samples.

Sample	Pi (g)	Weight (g)	Pf (g)	Si	Cr (g)	Sf + Cr (g)	Sf (g)	Sc + Cr (g)	Sc (g)	%moist. loss	LOI	%LOI	%Corg
17-001-2	0.447	1.002	0.452	0.997	12.979	13.973	0.994	13.943	0.964	0.301	0.030	3.018	1.509
17-001-3	0.396	1.001	0.400	0.997	13.731	14.722	0.991	14.694	0.963	0.602	0.028	2.825	1.413
17-001-4	0.399	1.002	0.402	0.999	14.916	15.890	0.974	15.812	0.896	2.503	0.078	8.008	4.004
17-001-5	0.442	1.002	0.445	0.999	14.714	15.709	0.995	15.701	0.987	0.400	0.008	0.804	0.402
17-001-6	0.454	1.000	0.454	1.000	14.303	15.296	0.993	15.292	0.989	0.700	0.004	0.403	0.201
19-001-2	0.375	1.002	0.378	0.999	14.076	15.018	0.942	14.815	0.739	5.706	0.203	21.550	10.775
19-001-3	0.465	1.020	0.465	1.020	13.252	14.188	0.936	14.089	0.837	8.235	0.099	10.577	5.288
19-001-4	0.389	1.000	0.394	0.995	14.577	15.430	0.853	15.374	0.797	14.271	0.056	6.565	3.283
20-002-2	0.469	1.001	0.474	0.996	13.754	14.675	0.921	14.555	0.801	7.530	0.120	13.029	6.515
20-002-3	0.378	1.002	0.383	0.997	13.819	14.771	0.952	14.723	0.904	4.514	0.048	5.042	2.521
20-002-4	0.466	1.002	0.469	0.999	12.929	13.921	0.992	13.890	0.961	0.701	0.031	3.125	1.562
20-002-5	0.383	1.003	0.389	0.997	12.791	13.734	0.943	13.709	0.918	5.416	0.025	2.651	1.326
20-003-2	0.382	1.002	0.389	0.995	12.939	13.695	0.756	13.593	0.654	24.020	0.102	13.492	6.746
20-003-3	0.382	1.004	0.387	0.999	13.549	14.407	0.858	14.362	0.813	14.114	0.045	5.245	2.622
20-003-4	0.440	1.003	0.447	0.996	13.000	13.872	0.872	13.840	0.840	12.450	0.032	3.670	1.835
20-003-5	0.380	1.002	0.386	0.996	13.550	14.508	0.958	14.486	0.936	3.815	0.022	2.296	1.148
20-003-6	0.380	1.002	0.391	0.991	13.001	13.922	0.921	13.910	0.909	7.064	0.012	1.303	0.651
20-004-2	0.447	1.002	0.460	0.989	12.197	13.043	0.846	12.893	0.696	14.459	0.150	17.730	8.865
20-004-3	0.396	1.003	0.404	0.995	12.359	13.337	0.978	13.261	0.902	1.709	0.076	7.771	3.885
20-004-4	0.400	1.002	0.407	0.995	13.139	14.132	0.993	14.122	0.983	0.201	0.010	1.007	0.504
20-004-5	0.451	1.003	0.452	1.002	12.979	13.978	0.999	13.972	0.993	0.299	0.006	0.601	0.300

20-005-2	0.464	1.002	0.485	0.981	13.732	14.529	0.797	14.465	0.733	18.756	0.064	8.030	4.015
20-005-3	0.378	1.003	0.393	0.988	14.916	15.818	0.902	15.774	0.858	8.704	0.044	4.878	2.439
20-005-4	0.389	1.002	0.394	0.997	13.754	14.680	0.926	14.672	0.918	7.121	0.008	0.864	0.432
20-006-2	0.452	1.003	0.458	0.997	14.930	15.808	0.878	15.728	0.798	11.936	0.080	9.112	4.556
20-006-3	0.397	1.002	0.403	0.996	12.979	13.923	0.944	13.886	0.907	5.221	0.037	3.919	1.960
20-006-4	0.409	1.000	0.414	0.995	12.821	13.773	0.952	13.746	0.925	4.322	0.027	2.836	1.418
20-007-2	0.444	1.001	0.448	0.997	13.818	14.803	0.985	14.698	0.880	1.204	0.105	10.660	5.330
20-007-3	0.447	1.004	0.453	0.998	14.029	15.021	0.992	14.989	0.960	0.601	0.032	3.226	1.613
20-007-4	0.382	1.003	0.388	0.997	14.682	15.672	0.990	15.644	0.962	0.702	0.028	2.828	1.414
20-007-5	0.462	1.003	0.467	0.998	12.941	13.926	0.985	13.908	0.967	1.303	0.018	1.827	0.914
20-008-2	0.383	1.000	0.387	0.996	13.732	14.602	0.870	14.456	0.724	12.651	0.146	16.782	8.391
20-008-3	0.386	1.001	0.390	0.997	14.915	15.898	0.983	15.859	0.944	1.404	0.039	3.967	1.984
20-008-4	0.385	1.002	0.387	1.000	14.715	15.670	0.955	15.639	0.924	4.500	0.031	3.246	1.623
20-008-5	0.446	1.002	0.449	0.999	14.304	15.292	0.988	15.284	0.980	1.101	0.008	0.810	0.405
21-001-2	0.410	1.001	0.414	0.997	14.078	14.852	0.774	14.693	0.615	22.367	0.159	20.543	10.271
21-001-3	0.405	1.001	0.410	0.996	13.252	14.094	0.842	14.000	0.748	15.462	0.094	11.164	5.582
21-001-4	0.446	1.002	0.450	0.998	14.579	15.487	0.908	15.440	0.861	9.018	0.047	5.176	2.588
21-001-5	0.456	1.001	0.461	0.996	14.037	15.003	0.966	14.973	0.936	3.012	0.030	3.106	1.553
21-001-6	0.383	1.003	0.388	0.998	14.993	15.982	0.989	15.974	0.981	0.902	0.008	0.809	0.404
21-001-7	0.452	1.003	0.455	1.000	13.754	14.751	0.997	14.746	0.992	0.300	0.005	0.502	0.251

Table A4. Raw data for SLOSH standard.

Sample	Pi (g)	Weight (g)	Pf (g)	Si	Cr (g)	Sf + Cr (g)	Sf (g)	Sc + Cr (g)	Sc (g)	%moist. loss	LOI	%LOI	%Corg
SLOSH 1	0.460	1.005	0.464	1.001	12.435	13.416	0.981	13.359	0.924	1.998	0.057	5.810	2.905
SLOSH 2	0.388	1.005	0.391	1.002	14.994	15.977	0.983	15.918	0.924	1.896	0.059	6.002	3.001
SLOSH 3	0.381	1.005	0.384	1.002	13.754	14.737	0.983	14.677	0.923	1.896	0.060	6.104	3.052
SLOSH 4	0.386	1.005	0.389	1.002	14.930	15.913	0.983	15.852	0.922	1.896	0.061	6.205	3.103
SLOSH 5	0.440	1.005	0.444	1.001	12.979	13.962	0.983	13.899	0.920	1.798	0.063	6.409	3.204
SLOSH 6	0.411	1.003	0.414	1.000	12.820	13.802	0.982	13.740	0.920	1.800	0.062	6.314	3.157
SLOSH 7	0.406	1.006	0.409	1.003	13.818	14.802	0.984	14.739	0.921	1.894	0.063	6.402	3.201
SLOSH 8	0.455	1.003	0.458	1.000	14.029	15.009	0.980	14.945	0.916	2.000	0.064	6.531	3.265
SLOSH 9	0.461	1.006	0.464	1.003	14.681	15.663	0.982	15.600	0.919	2.094	0.063	6.415	3.208
SLOSH 10	0.462	1.002	0.463	1.001	12.939	13.918	0.979	13.868	0.929	2.198	0.050	5.107	2.554
SLOSH 11	0.469	1.004	0.473	1.000	12.792	13.770	0.978	13.712	0.920	2.200	0.058	5.930	2.965
SLOSH 12	0.375	1.003	0.378	1.000	11.336	12.314	0.978	12.256	0.920	2.200	0.058	5.930	2.965
SLOSH 13	0.382	1.006	0.385	1.003	13.550	14.532	0.982	14.475	0.925	2.094	0.057	5.804	2.902
SLOSH 14	0.378	1.005	0.382	1.001	13.002	13.982	0.980	13.925	0.923	2.098	0.057	5.816	2.908
SLOSH 15	0.446	1.003	0.450	0.999	12.196	13.175	0.979	13.118	0.922	2.002	0.057	5.822	2.911
SLOSH 16	0.395	1.005	0.399	1.001	12.359	13.340	0.981	13.283	0.924	1.998	0.057	5.810	2.905
SLOSH 17	0.399	1.004	0.402	1.001	13.139	14.118	0.979	14.063	0.924	2.198	0.055	5.618	2.809
SLOSH 18	0.463	1.002	0.466	0.999	12.979	13.959	0.980	13.910	0.931	1.902	0.049	5.000	2.500
SLOSH 19	0.455	1.005	0.458	1.002	13.733	14.712	0.979	14.661	0.928	2.295	0.051	5.209	2.605
SLOSH 20	0.389	1.005	0.393	1.001	14.916	15.896	0.980	15.847	0.931	2.098	0.049	5.000	2.500
SLOSH 21	0.466	1.006	0.469	1.003	14.715	15.696	0.981	15.651	0.936	2.193	0.045	4.587	2.294
SLOSH 22	0.381	1.003	0.384	1.000	14.304	15.282	0.978	15.239	0.935	2.200	0.043	4.397	2.198
SLOSH 23	0.380	1.004	0.385	0.999	14.078	15.056	0.978	14.995	0.917	2.102	0.061	6.237	3.119
SLOSH 24	0.382	1.005	0.386	1.001	13.251	14.231	0.980	14.170	0.919	2.098	0.061	6.224	3.112
SLOSH 25	0.446	1.004	0.450	1.000	14.578	15.555	0.977	15.495	0.917	2.300	0.060	6.141	3.071
SLOSH 26	0.390	1.004	0.393	1.001	14.037	15.015	0.978	14.955	0.918	2.298	0.060	6.135	3.067
SLOSH 27	0.407	1.004	0.411	1.000	12.434	13.414	0.980	13.354	0.920	2.000	0.060	6.122	3.061
SLOSH 28	0.448	1.005	0.451	1.002	14.994	15.974	0.980	15.916	0.922	2.196	0.058	5.918	2.959
SLOSH 29	0.449	1.006	0.453	1.002	13.753	14.735	0.982	14.678	0.925	1.996	0.057	5.804	2.902
SLOSH 30	0.382	1.004	0.385	1.001	14.929	15.909	0.980	15.851	0.922	2.088	0.058	5.928	2.964
SLOSH 31	0.458	1.005	0.461	1.002	12.978	13.959	0.981	13.908	0.930	2.096	0.051	5.199	2.599
SLOSH 32	0.386	1.002	0.388	1.000	12.434	13.415	0.981	13.366	0.932	1.900	0.049	4.995	2.497
SLOSH 33	0.385	1.005	0.389	1.001	13.818	14.799	0.981	14.746	0.928	1.998	0.053	5.403	2.701

SLOSH 34	0.381	1.005	0.385	1.001	14.028	15.010	0.982	14.962	0.934	1.898	0.048	4.888	2.444
SLOSH 35	0.443	1.005	0.448	1.000	14.680	15.658	0.978	15.612	0.932	2.200	0.046	4.703	2.352
SLOSH 36	0.408	1.006	0.415	0.999	12.791	13.774	0.983	13.721	0.930	1.602	0.053	5.392	2.696
SLOSH 37	0.408	1.004	0.413	0.999	11.335	12.316	0.981	12.263	0.928	1.802	0.053	5.403	2.701
SLOSH 38	0.449	1.006	0.454	1.001	13.550	14.534	0.984	14.479	0.929	1.698	0.055	5.589	2.795
SLOSH 39	0.455	1.006	0.461	1.000	13.002	13.984	0.982	13.925	0.923	1.800	0.059	6.008	3.004
SLOSH 40	0.384	1.005	0.390	0.999	12.197	13.178	0.981	13.119	0.922	1.802	0.059	6.014	3.007
SLOSH 41	0.457	1.005	0.463	0.999	12.358	13.341	0.983	13.280	0.922	1.602	0.061	6.205	3.103
SLOSH 42	0.392	1.005	0.397	1.000	13.138	14.122	0.984	14.060	0.922	1.600	0.062	6.301	3.150
SLOSH 43	0.379	1.005	0.384	1.000	13.732	14.715	0.983	14.653	0.921	1.700	0.062	6.307	3.154
SLOSH 44	0.388	1.004	0.392	1.000	14.916	15.900	0.984	15.837	0.921	1.600	0.063	6.402	3.201
SLOSH 45	0.439	1.006	0.443	1.002	14.715	15.700	0.985	15.636	0.921	1.697	0.064	6.497	3.249
SLOSH 46	0.415	1.004	0.420	0.999	14.303	15.286	0.983	15.224	0.921	1.602	0.062	6.307	3.154
SLOSH 47	0.408	1.005	0.413	1.000	14.078	15.061	0.983	14.998	0.920	1.700	0.063	6.409	3.204
SLOSH 48	0.453	1.005	0.459	0.999	13.251	14.233	0.982	14.172	0.921	1.702	0.061	6.212	3.106
SLOSH 49	0.443	1.003	0.448	0.998	14.578	15.559	0.981	15.497	0.919	1.703	0.062	6.320	3.160
SLOSH 50	0.387	1.003	0.393	0.997	14.037	15.017	0.980	14.955	0.918	1.705	0.062	6.327	3.163