Proceedings of the Indiana Academy of Science
(1988) Volume 98 p. 463-471.

RELATION OF ORGANIC MATTER CONTENT TO TEXTURE AND COLOR OF INDIANA SOILS

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INTRODUCTION

Organic matter is an important constituent of soils, because it has a high capacity for absorbing water, nutrients, and some agricultural chemicals such as herbicides. It also binds mineral particles together to form stable aggregates that give the soil favorable physical properties.

There is a general relationship between the organic matter content of the surface horizon of a soil and its color and texture. The term *organic matter* refers to the remains of plant and animal tissue in the soil. *Organic carbon (C)* refers to the carbon component of organic matter, which is about one-half the mass of organic matter. In the field, soil texture can be estimated by feel, and color can be determined by comparing the soil with standard Munsell color charts. Then, if the relationship between these properties and organic C were defined, one could use it with field estimates of color and texture to estimate the organic matter content of the soil. Some guidelines are available to help make this estimate. Alexander (1971) published a color chart for estimating the organic matter content of soil plow layers in Illinois with medium texture, and Steinhardt and Franzmeier (1979) summarized the relationship of organic matter content and soil color for silt loam soils in Indiana. Also, Fernandez, *et al.* (1988) showed that there is a very close relationship between Munsell color value (darkness) and organic matter content in a toposequence of soils, most of which had silt loam textures.

During the Cooperative Soil Survey of Indiana, the Purdue Soil Characterization Laboratory analyzed many soil pedon (profiles) that soil scientists had selected to represent a particular soil series in a county. These data can be summarized to establish the pertinent relationships for all soils of the State. Thus, the main objectives of this study were to (1) characterize the relationship of soil texture and color to soil organic C content and to (2) learn if this relationship was the same across the State and for various natural drainage classes.

METHODS AND MATERIALS

The Purdue Soil Characterization Laboratory analyzed about 1660 pedons between 1968 and 1988. In this laboratory, soil organic carbon (C) was determined by oxidation with sulfuric acid and potassium dichromate, using external heat according to the Mebius method, and particle-size distribution (texture) was determined by the pipet method and sieving. These methods were described by Franzmeier, *et al.* (1977). These data have been published in a series of Experiment Station Bulletins. The latest one is listed under Indiana Soil Survey Staff (1988), and it contains a listing of 10 previous bulletins.

TABLE 1. Organic C content of Ap horizons by soil texture and color.

Texture	Statistic[2]	Color (value/chroma for 10YR hue)						
		2/1	2/2	3/1	3/2	3/3	4/2	4/3
		%C						
Fine sand	x̄	—	—	—	0.75	0.41	0.64	0.37
and sand	N	—	—	—	1	9	1	9
	SD	—	—	—	—	0.11	—	0.11
Loamy fine sand	x̄	2.46	0.86	1.47	0.82	0.81	0.72	0.54
and loamy sand	N	6	1	6	16	9	10	16
	SD	1.25	—	0.53	0.29	0.28	0.25	0.14
Fine sandy loam	x̄	2.24	1.54	1.47	1.31	0.94	0.92	0.87
and sandy loam	N	21	12	22	28	19	38	42
	SD	1.05	0.77	0.61	0.38	0.28	0.32	0.31
Loam	x̄	3.40	1.72	2.24	1.67	1.74	1.28	1.17
	N	21	6	21	23	13	40	28
	SD	1.95	0.24	0.99	0.56	0.97	0.29	0.43
Silt loam[1]	x̄	3.19	2.12	2.47	1.77	1.82	1.31	1.17
	N	21	11	36	62	26	155	246
	SD	1.17	0.58	0.79	0.41	0.65	0.42	0.35
Clay loam	x̄	3.70	—	2.05	1.83	—	1.20	1.17
	N	10	—	7	7	—	6	7
	SD	2.86	—	0.44	0.31	—	0.27	0.24
Silty clay loam	x̄	3.49	2.43	2.67	2.22	2.05	1.33	1.23
	N	32	3	32	28	6	16	10
	SD	1.28	0.25	0.75	0.57	0.65	0.45	0.24
Silty clay	x̄	3.73	2.37	3.06	2.78	—	2.22	1.65
and clay	N	4	2	9	7	—	6	3
	SD	0.78	0.30	0.71	0.79	—	1.19	0.57

[1] Other values for silt loam.

	10YR5/2	10YR5/3	10YR5/4
x̄	0.99	1.07	1.09
N	38	42	18
SD	0.27	0.38	0.52

[2] x̄ = mean; N = number of samples; and SD = standard deviation.

The laboratory data and field morphological descriptions were placed in a data base management system (Knowledgeman, version 2.01), which was used to sort data by various parameters and to determine mean and standard deviation. Analysis of variance and multiple linear regression were done using SAS (1985). In addition, a Student-Newman-Keuls means separation test was performed on the data in Table 3. The test was adopted for computer use from standard texts by statisticians in the Agronomy Department.

RESULTS AND DISCUSSION

The data for Ap horizons with 10YR hue from all regions of the State were first stratified by USDA texture class and color (Table 1). This grouping included 1268 samples; it excluded Ap horizons with hue other than 10YR and those from soils that had never been plowed. The average standard deviation (SD) in Table 1 was 1.48 %C for soils with 10YR 2/1 color, the darkest color on the commonly

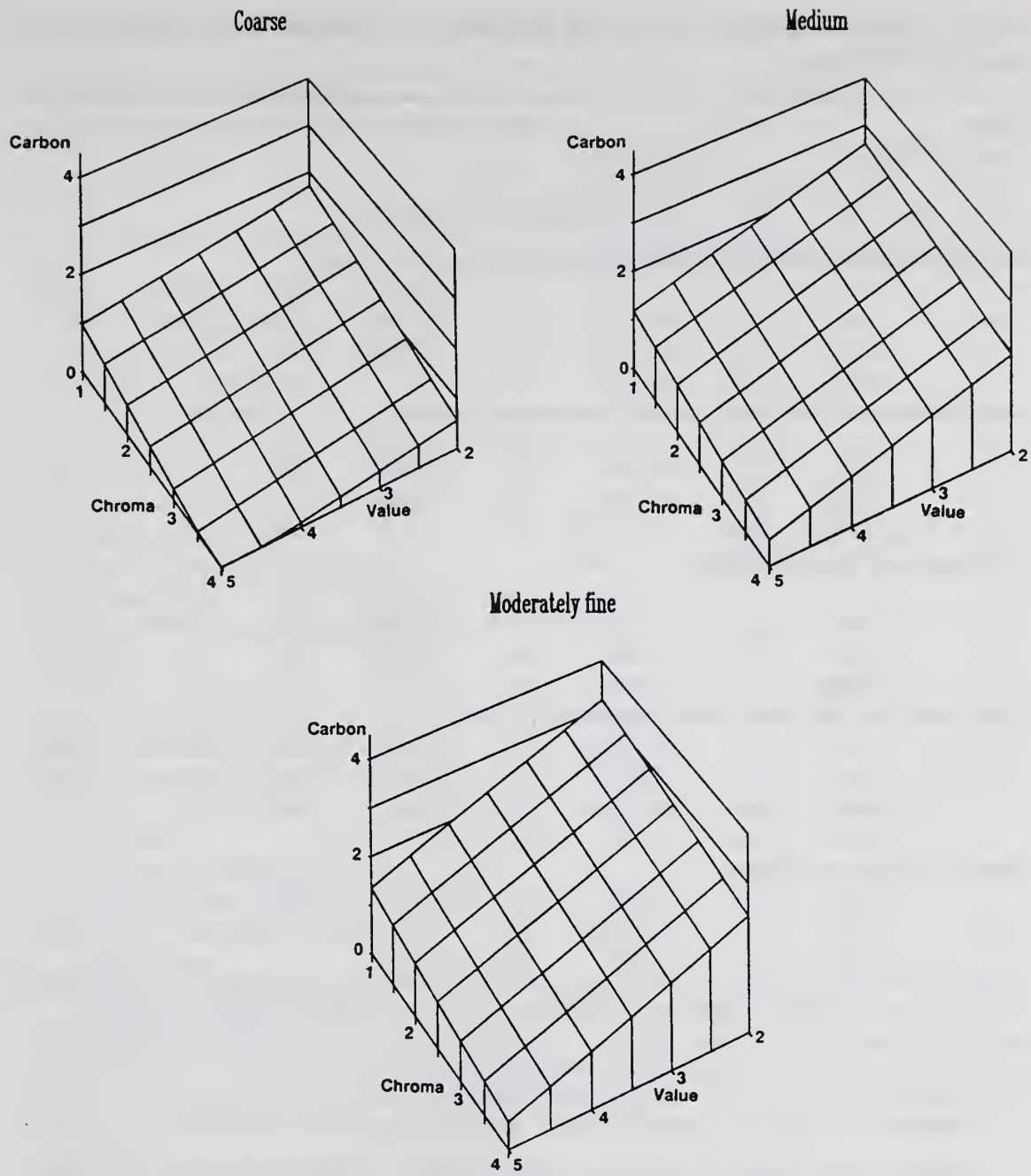

FIGURE 1. Graphs showing the effects of color value and chroma on organic C content (%) as derived from regression equations for soils in three texture classes.

used chart, and 0.46 %C for all other colors. Soils with a few percent of organic C are as dark as 10YR 2/1, and more organic C does not result in darker colors. Soils recognized as organic soils in the field were not included in the study. Many of them, however, have 10YR 2/1 colors.

Next, the USDA texture classes were combined into five larger classes (Table 2) used in soil judging (Yahner, *et al.*, 1980). This table is arranged like the Munsell color charts, with low color values and chromas (dark colors) in the lower left corner. The data were then smoothed by calculating a multiple linear regression with organic C as the dependent variable and value and chroma as independent variables for each texture group. The resulting equations are listed below by texture group:

TABLE 2. Mean organic C content of Ap horizons by soil texture group and soil color (10YR hue).

Color value	Color chroma 1		2		3		4	
	%C (number of samples)							
Sand, fine sand, loamy fine sand, and loamy sand (Coarse)								
5	—		—		0.6(2)	0.2*	0.3(3)	−0.2
4	—		0.7(11)	0.8	0.5(25)	0.5	0.5(3)	0.1
3	1.5(6)	1.5	0.8(17)	1.1	0.6(18)	0.7	—	
2	2.5(6)	1.7	0.9(1)	1.3	—		—	
Sandy loam and fine sandy loam (Moderately coarse)								
5	—		0.4(1)	0.7	0.7(3)	0.4	—	
4	1.8(2)	1.3	0.9(38)	1.0	0.9(42)	0.8	0.7(2)	0.5
3	1.5(22)	1.6	1.3(28)	1.4	0.9(19)	1.1	—	
2	2.2(21)	2.0	1.5(12)	1.7	—		—	
Silt loam and loam (Medium)								
5	—		1.0(39)	1.0	1.1(42)	0.7	1.1(19)	0.5
4	1.2(3)	1.7	1.3(195)	1.4	1.2(274)	1.2	1.1(19)	1.0
3	2.4(57)	2.1	1.7(85)	1.9	1.8(39)	1.7	—	
2	3.3(42)	2.6	2.0(17)	2.4	—		—	
Clay loam and silty clay loam (Moderately fine)								
5	—		1.5(1)	1.1	1.4(5)	0.8	1.0(1)	0.5
4	1.6(5)	2.0	1.3(22)	1.7	1.2(17)	1.4	1.0(2)	−1.1
3	2.6(39)	2.6	2.1(35)	2.3	2.1(6)	2.0	—	
2	3.5(42)	3.2	2.4(3)	2.9	—		—	
Clay and silty clay (Fine)								
4	2.5(2)	2.5	2.2(6)	2.0	1.7(3)	1.5	—	
3	3.1(9)	3.1	2.8(7)	2.5	—		—	
2	3.7(4)	3.6	2.4(2)	3.1	—		—	

* Actual mean, (number of samples), and values calculated from regression equations.

Coarse: $C = 2.56 - 0.241$ Value $- 0.377$ Chroma, $R^2 = 0.47$.

Moderately coarse: $C = 2.90 - 0.337$ Value $- 0.267$ Chroma, $R^2 = 0.38$.

Medium: $C = 3.77 - 0.473$ Value $- 0.222$ Chroma, $R^2 = 0.45$.

Moderately fine: $C = 4.66 - 0.606$ Value $- 0.274$ Chroma, $R^2 = 0.31$.

Fine: $C = 5.18 - 0.532$ Value $- 0.523$ Chroma, $R^2 = 0.47$.

These equations were used to calculate organic C contents to give a smooth relationship with value and chroma (Table 2). They show three trends: 1) for a given color, soil organic C content increases with finer texture; 2) for a given texture and chroma, organic C increases with decreasing color value; and 3) for a given texture and color value, organic C increases with decreasing chroma. Some of the these relationships are shown graphically in Figure 1.

The question of whether the relationship of organic C content with soil texture and color is the same across the entire State was then explored. The only texture that is common to all soil regions (Franzmeier, *et al.,* 1989) of the State is silt loam, and the most common colors of silt loam Ap horizons are 10 YR 4/2 and

TABLE 3. Organic C content of silt loam Ap horizons by soil color and soil region.

Soil region, parent material, and representative soil series	Soil color					
	10YR4/2			10YR4/3		
	x̄	N	SD	x̄	N	SD
	%C			%C		
2, Illinoian lacustrine deposits, Bartle	1.02	13	0.18	1.03	24	0.27
2, Wisconsin lacustrine deposits, Markland	1.37	3	0.45	1.56	1	—
3, Alluvial deposits Genesee	1.24	22	0.37	1.14	41	0.31
3, Terrace deposits, Fox	1.11	33	0.29	1.10	57	0.26
5, Deep loess, Sylvan	1.37	8	0.67	1.03	16	0.28
6, Loamy Wisconsin till (Cary), Crosier	1.08	4	0.42	0.82	2	0.16
7, Clayey Wisconsin till (Cary), Blount	1.46	19	0.42	1.41	12	0.16
8, Loamy Wisconsin till (Tazewell), Crosby	1.38	24	0.34	1.23	30	0.45
9, Loess and loamy Wisconsin till (Tazewell), Fincatle	1.38	14	0.46	1.07	9	0.38
10, Loess and Illinoian till, Cincinnati	1.34	10	0.53	1.22	34	0.34
11, Loess and weathered siltstone and shale, Wellston	1.26	1	—	1.24	9	0.18
12, Loess and weathered limestone, Crider	1.39	1	—	1.24	14	0.25
13, Loess and weathered shale and limestone, Eden	1.83	2	0.01	1.88 *	5	0.39

* Mean organic C content of Eden soils with 10YR4/3 color is different at the 1% level from all other means except for the Markland and Blount groups. No other means are significantly different at that level.

10YR 4/3. Therefore, this texture and these colors were used to examine the relationship. The number of samples in each class stratified by soil region, texture, and color ranged from 1 to 57 (Table 3). To test for differences among these classes, an analysis of variance test adjusted for unequal numbers of observations and a mean separation test were used. These tests showed very few differences. Only the Eden group (soil region 13) with color of 10YR 4/3, which contained only five samples, was different from several other groups as noted at the bottom of Table 3. Thus, in general, there were no great differences due to soil region for the silt loam soils. This might be expected, because most of the silt loam Ap horizons were derived from loess, which was quite similar across the State. More detailed investigations, however, might show some differences.

The data for a set of soils with a certain color and texture was also examined to learn if the naturally wet soils have the same organic C content as the naturally

TABLE 4. Organic C content of Ap horizons by soil texture and color for somewhat poorly, poorly, and very poorly drained soils.

Texture	Statistic[2]	Color (value/chroma for 10YR hue)						
		2/1	2/2	3/1	3/2	3/3	4/2	4/3
		%C						
Loamy fine sand	x̄	—	—	—	0.79	—	—	—
and loamy sand	N	—	—	—	3	—	—	—
	SD	—	—	—	0.05	—	—	—
Fine sandy loam	x̄	2.48	1.58	1.64	1.35	0.97	0.78	0.83
and sandy loam	N	17	2	13	16	3	16	3
	SD	1.02	0.57	0.72	0.42	0.18	0.21	0.27
Loam	x̄	3.35	2.13	2.44	1.97	—	1.29	1.26
	N	19	1	18	13	—	21	3
	SD	2.04	—	0.92	0.52	—	0.30	0.36
Silt loam[1]	x̄	3.21	2.16	2.50	1.84	1.54	1.25	1.01
	N	20	5	30	32	6	105	32
	SD	1.19	0.87	0.70	0.48	0.37	0.40	0.26
Silty clay loam	x̄	3.52	—	2.67	2.26	—	1.38	—
	N	29	—	32	22	—	11	—
	SD	1.34	—	0.75	0.64	—	0.35	—
[1] Other values for silt loam		10YR5/2		10YR5/3		10YR5/4		
	x̄	0.98		1.04		0.91		
	N	37		27		7		
	SD	0.26		0.26		0.15		

[2] x̄ = mean; N = number of samples; and SD = standard deviation.

dry ones. The detailed results are in Table 4 for the wetter soils and in Table 5 for the dryer ones. The number of samples in the various classes again was highly variable. The standard deviations in these tables are mostly < 0.75 %C, except for the "wet" soils with 10YR 2/1 color for which all the standard deviations are > 1.0 %C. Thus, the variability for 10YR 2/1 soils noted in Table 1 is mainly due to the wetter soils, not the better drained ones.

In Table 6, the results are compared for classes, where both the wet and the dry members had five or more samples. There is little difference due to natural drainage, but for the darker soil colors (10YR 2/2, 3/1, 3/2), the wet soils consistently contain more organic C.

To apply this information in soil management, one must know the organic *matter* content of the soil. For example, the label on some herbicides lists application rates according to soil organic matter content. The organic *matter* values in Table 7 were calculated by multiplying the calculated (smoothed) values for organic *carbon* in Table 2 by two. The texture groupings in that table are familiar to many people, who have learned about soil properties in the high school soil judging program. This table can be used to estimate organic matter contents. A laboratory determination should be done, if more accurate informaiton is required, especially for dark-color Ap horizons of poorly drained soils.

TABLE 5. Organic C content of Ap horizons by soil texture and color for moderately well, well, and excessively drained soils.

Texture	Statistic[2]	Color (value/chroma for 10YR hue)						
		2/1	2/2	3/1	3/2	3/3	4/2	4/3
		%C						
Loamy fine sand and loamy sand	x̄	—	—	—	0.83	—	—	0.54
	N	—	—	—	13	—	—	16
	SD	—	—	—	0.32	—	—	0.14
Fine sandy loam and sandy loam	x̄	1.19	1.53	1.23	1.25	0.93	1.02	0.88
	N	4	10	9	12	16	22	39
	SD	0.07	0.83	0.28	0.33	0.30	0.35	0.32
Loam	x̄	3.82	1.63	1.08	1.29	1.74	1.26	1.16
	N	2	5	3	10	13	19	25
	SD	0.68	0.14	0.40	0.36	0.97	0.28	0.44
Silt loam[1]	x̄	2.90	2.09	2.36	1.71	1.90	1.45	1.19
	N	1	6	6	30	20	49	214
	SD	—	0.28	1.22	0.30	0.70	0.45	0.36
Silty clay loam	x̄	3.18	—	—	2.07	—	1.22	—
	N	3	—	—	6	—	5	—
	SD	0.42	—	—	0.17	—	0.64	—
[1] Other values for silt loam		10YR5/2		10YR5/3		10YR5/4		
	x̄	1.40		1.12		1.21		
	N	1		15		11		
	SD	—		0.55		0.64		

[2] x̄ = mean; N = number of samples; and SD = standard deviation.

TABLE 6. Organic C content by natural drainage group, soil texture, and soil color.[1]

Texture	Drainage group[2]	Color (value/chroma for 10YR hue)					
		2/2	3/1	3/2	3/3	4/2	4/3
		%C					
Fine sandy loam and sandy loam	Wet	—	1.64	1.35	—	0.78	
	Dry	—	1.23	1.25	—	1.02	—
Loam	Wet	—	—	1.97	—	1.29	—
	Dry	—	—	1.29	—	1.26	—
Silt loam	Wet	2.16	2.50	1.84	1.54	1.25	1.01
	Dry	2.09	2.36	1.71	1.90	1.45	1.19
Silty clay loam	Wet	—	—	2.26	—	1.38	—
	Dry	—	—	2.07	—	1.22	—

[1] Classes with more than four wet and four dry samples are listed.

[2] "Wet" soils are somewhat poorly, poorly, or very poorly drained; "Dry" soils are excessively, well, or moderately well drained.

TABLE 7. Mean organic matter content of Ap horizons by soil texture group and soil color (10YR hue) derived from calculated values in Table 2.

Color value	Color chroma			
	1	2	3	4
	%C (number of samples)			
Sand, fine sand, loamy fine sand, and loamy sand (Coarse)				
5	—	—	0.4	0.1
4	—	1.6	1.0	0.2
3	3.0	2.2	1.4	—
2	3.4	2.6	—	—
Sandy loam and fine sandy loam (Moderately coarse)				
5	—	1.4	0.8	—
4	2.6	2.0	1.6	1.0
3	3.2	2.8	2.2	—
2	4.0	3.4	—	—
Silt loam and loam (Medium)				
5	—	2.0	1.4	1.0
4	3.4	2.8	2.4	2.0
3	4.2	3.8	3.4	—
2	5.2	4.8	—	—
Clay loam and silty clay loam (Moderately fine)				
5	—	2.2	1.6	1.0
4	4.0	3.4	2.8	2.2
3	5.2	4.6	4.0	—
2	6.4	5.4	—	—
Clay and silty clay (Fine)				
4	5.0	4.0	3.0	—
3	6.2	5.0	—	—
2	7.2	6.2	—	—

CONCLUSIONS

Soil organic matter content of Ap horizons (plow layers) increases with increasing clay content, decreasing color value, and decreasing color chroma. For dark grayish brown to brownish (10YR 4/2 and 4/3) silt loam soils, which are very common in Indiana, the effects of location in the State and of natural drainage on the content of organic C were small. The deviation from the mean was relatively large for poorly drained soils with dark color and relatively small for lighter colored poorly drained soils and all better drained soils. The relationships can be used to estimate the organic matter content of many soils, but laboratory determinations may also be required.

ACKNOWLEDGMENTS

Many soil scientists of the cooperative soil survey collected the soil samples. Most of the laboratory work was sponsored by the Division of Soil Conservation, Indiana Department of Natural Resources. Dan Koller assisted with computer data processing, and Judy Santini conducted the statistical analysis. Journal article no. 11,840 of the Purdue University Agricultural Experiment Station.

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