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Organic Carbon in Soils of Missouri

A Summary of Accumulated Research Data

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Columbia, Missouri

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A Summary of Accumulated Research Data

C. L. Scrivner and D. T. Cooper

Soil organic matter's influence on soil properties and management has long been recognized. Fertility level, structure, water holding capacity, erodibility, cation exchange capacity, and carbon dioxide release are some characteristics of a soil related to its level of organic matter. The purpose of this research bulletin is to summarize existing data on soil organic carbon obtained from classified soil profiles in Missouri. This summary provides a broad perspective on soil organic carbon levels within major regions of the state and between key groupings of individual soils.

The amount of organic matter within a particular soil is a complex interrelationship of many factors including climate, vegetation, topography, and the physical and chemical properties of the soil material itself. Any long term equilibrium in the level of organic matter achieved in a soil by these natural forces may be subject to abrupt change by man's land use practices. Conversion of timberland to grassland or grassland to cropland, application of fertilizers and lime, soil erosion, and land drainage can drastically alter levels of soil organic matter. Given this variability due to man's activities, individuals needing information on organic matter levels for a specific tract of land should have the soils tested, and not rely on average values reported in this bulletin.

Methods

The data for this summary was compiled from soil investigations conducted in support of the Missouri Cooperative Soil Survey. In Table 1, a list of those soil investigations is provided. The code letter assigned to each soil investigation in Table 1 is used in Figure 1 to show the location of the data in the state by county. Soil investigations conducted in a specific county are identified by code letter within the borders of the county. In addition, the number following each code letter represents the number of soil profiles providing soil organic matter data from that investigation.

Most of the soils were tested following the procedure described by Brown and Rodriquez (1983) and expressed as percent organic matter. The data were converted to organic carbon expressed on a weight per volume per depth increment basis according to Equation 1.

Equation 1. $Db\ (g/cm^3) \times STV\ (\%) \times 5.8\times10^{-2} = OC\ (kg/m^2/cm)$

where: Db = Bulk Density

STV = Soil Test Value

OC = Organic Carbon

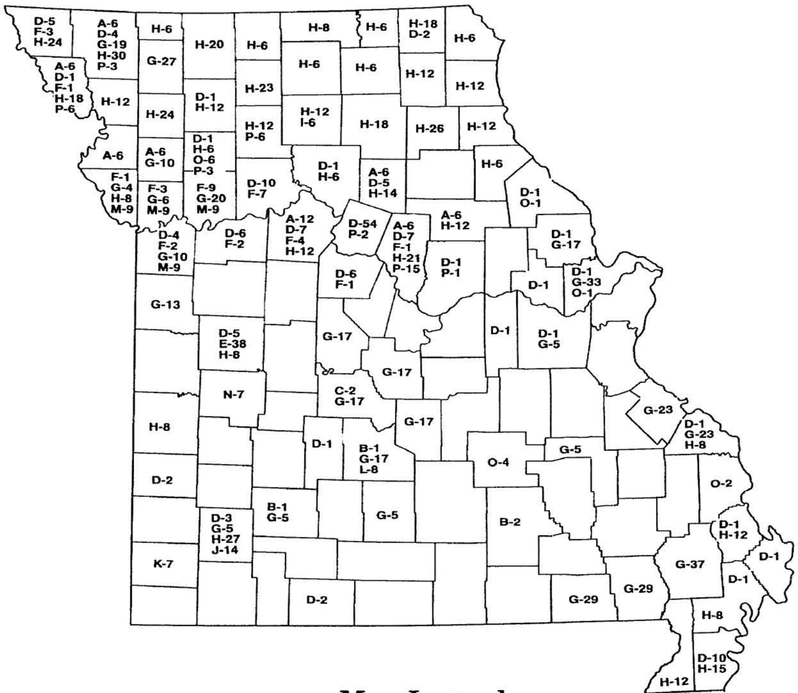
TABLE 1.

Soil Investigations Providing Organic Matter Data.

Code Letter	Soil Investigation
A	Brower, D. L. 1966. A correlation of soil type and soil profile chemical characteristics. M.S. thesis. University of Missouri-Columbia.
B	Miller, B. J. 1965. A characterization of four limestone derived soils from the Missouri Ozarks. M.S. thesis. University of Missouri-Columbia.
C	Ruppert, D. A. 1970. Available moisture storage capacities of some limestone derived soils. M.S. thesis. University of Missouri-Columbia.
D	Scrivner, C. L. 1950-80. Characterization studies of Missouri soils. Unpublished data. Soil Survey Investigations Laboratory, University of Missouri-Columbia.
E	Scrivner, C. L. 1959-62. Henry County soil survey correlation samples. Unpublished data. Soil Survey Investigations Laboratory, University of Missouri-Columbia.
F	Scrivner, C. L. 1967. Missouri River alluvial valley survey correlation samples. U.S. Dept. of Interior, OWRR Project B-005-MO. Unpublished data. Soil Survey Investigations Laboratory, University of Missouri-Columbia.
G	Scrivner, C. L. 1977-81. Pedology-fertility study of Missouri soil survey correlation samples. Missouri Dept. of Natural Resources, Accelerated Soil Survey Project. Unpublished data. University of Missouri-Columbia.
H	Scrivner, C. L. 1978-79. Productivity index study. Missouri Dept. of Natural Resources, Accelerated Soil Survey Project. Unpublished data. University of Missouri-Columbia.
I	Scrivner, C. L. 1975. Soils of Cornett Farm. Unpublished data. Soil Survey Investigations Laboratory, University of Missouri-Columbia.
J	Scrivner, C. L. 1969. Soils of the Southwest Missouri Research Center. Unpublished data. Soil Survey Investigations Laboratory, University of Missouri-Columbia.
K	Soil Conservation Service. 1980. Fragipan characterization study, Newton County. Unpublished data. USDA, Columbia, MO.
L	Soil Conservation Service. 1981. Geomorphic study, Laclede County. Unpublished data. USDA, Columbia, MO.
M	Soil Conservation Service. 1979-80. Northwest Missouri Mollisols characterization study; Clay, Ray, Platte and Jackson counties. Unpublished data. USDA, Columbia, MO.
N	Soil Conservation Service. 1982. Soil characterization study, St. Clair County. Unpublished data. USDA, Columbia, MO.
O	Soil Conservation Service. 1966. Soil Survey laboratory data and description for some soils of Arkansas, Louisiana,- and Missouri. Soil Survey Investigations Report No. 6, USDA. U.S. Government Printing Office, Washington, D.C.
P	Vogt, K. D. 1963. Phosphorus profile comparisons of some north Missouri soils. M.S. thesis. University of Missouri-Columbia.

FIGURE 1.

Location of Soil Organic Matter Data in Missouri by County.



Map Legend

Letters represent soil investigations identified in Table 1.

Numbers represent the number of soil profiles examined per investigation.

The following assumptions were used for this conversion to organic carbon.

1. Assumed all organic matter is 58 percent organic carbon.
2. Assumed a bulk density of $1.3 g/cm^3$ for all horizons or depth increments lacking measured values.
3. Made no adjustments for the presence of particle diameter sizes in soils greater than 2.00mm.

The weight of organic carbon in kg/m^2 was summed from the soil surface to depths of 20cm and 100cm respectively. Table 2 shows the conversion of organic carbon in units of $Kg/m^2/20cm$ to percent organic matter in 20cm (8 inches) of soil.

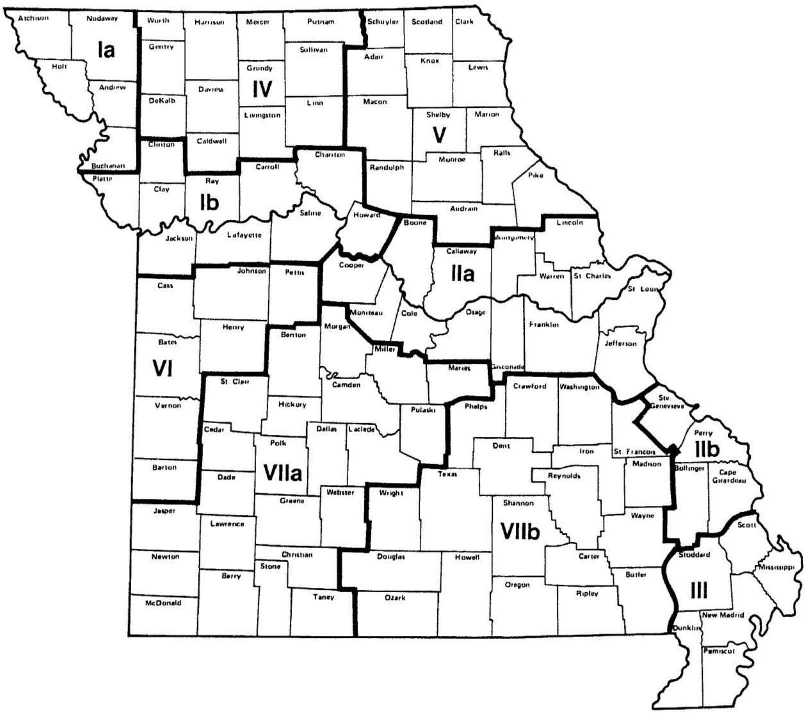
TABLE 2.
Comparison of Organic Carbon Expressed as Weight per Volume to Organic Matter Percentage.*

Organic Carbon in 20cm of Soil (kg/m^2)	Organic Matter (%)
0.8	0.5
1.5	1.0
2.3	1.5
3.0	2.0
3.8	2.5
4.5	3.0
6.0	4.0
7.5	5.0
9.0	6.0

*Assume-organic matter is 58% organic carbon
-bulk density equals $1.3 g/cm^3$
-no particle diameter sizes greater than 2.00mm

To compare soil organic carbon values obtained for landscapes in different parts of the state, Missouri was divided into ten major land systems as shown in Figure 2. These major land systems are similar in concept to the land resource regions and areas used by the Soil Conservation Service - USDA (1981), but were simplified to follow county boundaries exclusively. In Table 3 the total number of soil profiles used for determining the 20cm and 100cm organic carbon values for each major land system are given. The number of soil profiles listed for each system simply reflects the availability of data, and no attempt was made to exclude or screen values prior to inclusion in the data set. All soil profiles were grouped and analyzed by landscape position and taxonomic classification for each major land system.

FIGURE 2.
Major Land Systems in Missouri



I. Western Missouri Deep Loess
- Ia Northwest
- Ib West-central

II. Eastern Missouri River Hills
- IIa East-central
- IIb Southeast

III. Southeastern Missouri Delta

IV. North-central Missouri Loess-Till

V. Northeastern Missouri

VI. Southwestern Missouri Prairies

VII. Ozarks
- VIIa Western Ozarks
- VIIb Eastern Ozarks

TABLE 3.
Number of Soil Profiles Examined in Each Major Land System.

Major Land System		# of soil profiles-20cm/100cm
I.	Western Missouri Deep Loess	
	A. Northwest	142/137
	B. West-Central	209/202
II.	Eastern Missouri River Hills	
	A. East-Central	120/110
	B. Southeast	25/22
III.	Southeastern Missouri Lowlands	90/88
IV.	North-Central Missouri Loess-Till	165/156
V.	Northeastern Missouri	168/149
VI.	Southwestern Missouri Prairies	76/62
VII.	Ozarks	
	A. Western	92/89
	B. Eastern	40/35
	TOTAL	1,127/1,050

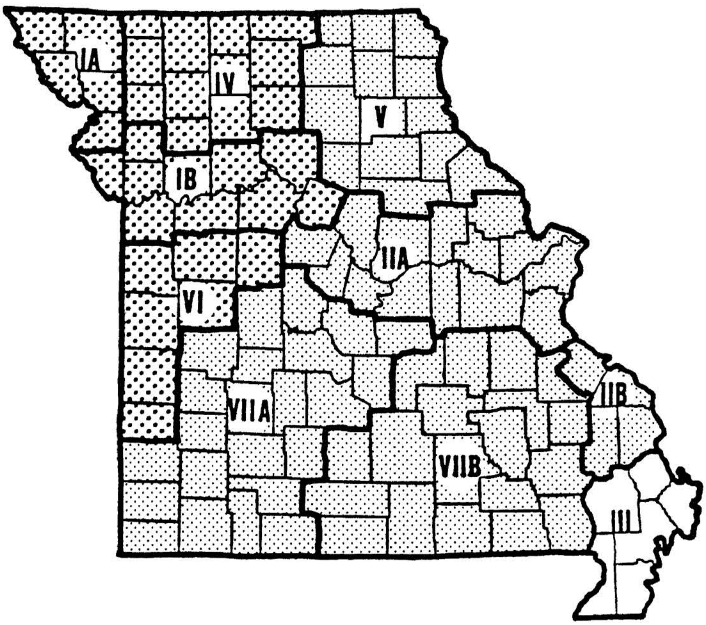
To further examine the soil organic carbon values calculated for the major land systems, the available data was subsampled by key soil series identified by taxonomic classification. Four major comparisons of soil organic carbon profile distributions and total amounts by depth were conducted. Comparisons were made for the following: soils occurring on broad summit divides across northern Missouri, soils formed under forest and prairie/forest transition canopies in southern Missouri, soils comprising the two main claypan areas in Missouri, and soils formed in clayey and in silty/loamy alluvium in the southeast lowlands of Missouri.

Results & Discussion

A concise summary of the organic carbon in soil profiles within each of the ten major land systems is presented in Table 4. Each soil profile was grouped on the basis of landscape position, either upland or bottomland, and then three further divisions were made according to the soil taxonomy criteria published by the Soil Conservation Service-USDA (1975). Soils classified as upland were separated into Mollisols, Mollic subgroups of all orders, and non-Mollic subgroups of all orders. Bottomland soils were divided into Mollisols, Alfisols, and Entisols/Inceptisols.

FIGURE 3.

Average Amount of Organic Carbon Within the Upper 20 cm of All Upland Soils for Each Major Land System in Missouri.



Average Amount of Organic Carbon (kg/m^2)

- 2.5
- 3.5
- 4.5

TABLE 4.
Average Amount of Organic Carbon by Landscape Position and Soil Taxonomic Groupings for Each Major Land System.

Landscape Position & Soil Taxonomic Groupings	Major Land System (See Figure 2)	Average Amount of Organic Carbon in 20 cm of soil		100 cm of soil	
		kg/m^2	n*	kg/m^2	n*
Uplands					
Mollisols	IA	4.6	65	13.7	63
	IB	5.0	89	14.4	87
	IIA	5.3	6	12.2	4
	IIB	No Data	-	No Data	-
	III	2.0	1	8.4	1
	IV	4.9	81	12.6	78
	V	3.2	24	10.6	23
	VI	4.5	41	13.2	33
	VIIA	5.6	2	12.6	1
	VIIB	7.7	1	No Data	-
Mollic Subgroups	IA	4.1	16	11.7	15
	IB	4.1	22	10.2	20
	IIA	3.6	35	10.5	28
	IIB	2.4	3	6.1	3
	III	2.4	3	8.7	3
	IV	3.8	29	9.9	27
	V	3.4	85	10.0	69
	VI	4.2	6	12.6	6
	VIIA	4.1	10	12.3	10
	VIIB	No Data	-	No Data	-
Non-mollic Subgroups	IA	3.4	12	8.8	11
	IB	2.9	25	8.3	24
	IIA	2.9	48	7.6	47
	IIB	3.1	16	7.0	13
	III	2.4	16	7.2	15
	IV	3.3	8	8.4	8
	V	3.0	43	8.8	42
	VI	4.0	10	7.9	4
	VIIA	3.5	42	8.4	42
	VIIB	3.3	21	8.4	18

(Continued page 8)

Table 4 (Continued)

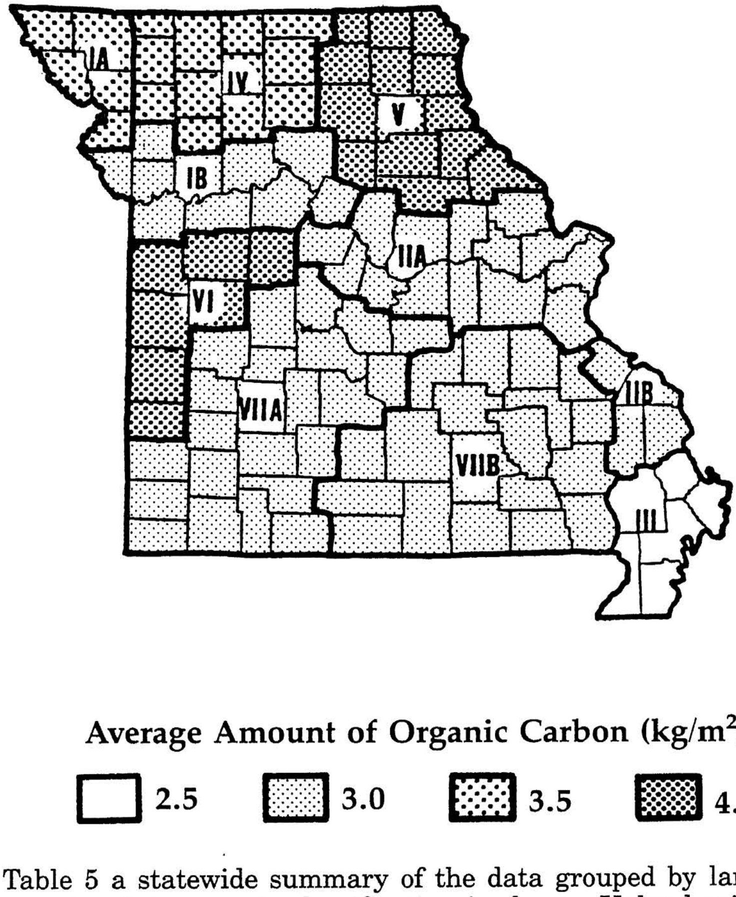
Bottomlands					
Mollisols	IA	4.2	21	14.8	21
	IB	4.0	43	12.5	41
	IIA	4.1	10	12.7	10
	IIB	3.9	3	9.6	3
	III	3.0	10	11.0	10
	IV	4.2	36	14.9	34
	V	4.6	12	16.6	12
	VI	4.4	14	15.5	14
	VIIA	3.5	29	12.6	27
	VIIB	3.6	2	17.8	2
Alfisols	IA	No Data	-	No Data	-
	IB	3.0	3	8.2	3
	IIA	2.8	6	10.9	6
	IIB	No Data	-	No Data	-
	III	2.4	37	7.6	37
	IV	2.3	7	9.8	6
	V	3.6	3	11.7	3
	VI	3.2	5	8.3	5
	VIIA	3.2	7	10.4	7
	VIIB	2.0	11	5.6	11
Entisols & Inceptisols	IA	3.3	28	11.3	27
	IB	2.1	27	8.1	27
	IIA	2.5	15	9.2	15
	IIB	4.4	3	9.7	3
	III	2.9	23	9.2	22
	IV	3.4	4	16.6	3
	V	1.9	1	No Data	-
	VI	No Data	-	No Data	-
	VIIA	4.2	2	14.3	2
	VIIB	2.1	5	8.6	4

*Number of soil profiles sampled.

Major Land Systems

IA	Western Missouri Deep Loess - Northwest
IB	Western Missouri Deep Loess - West Central
IIA	Eastern Missouri River Hills - East Central
IIB	Eastern Missouri River Hills - Southeast
III	Southeastern Missouri Lowlands
IV	North Central Missouri Loess-Till
V	Northeastern Missouri
VI	Southwestern Missouri Prairies
VIIA	Ozarks - Western
VIIB	Ozarks - Eastern

FIGURE 4.
Average Amount of Organic Carbon Within the Upper 20 cm of All Bottomland Soils for Each Major Land System in Missouri.



In Table 5 a statewide summary of the data grouped by landscape position and soil taxonomic classification is shown. Upland soils were separated into summit and shoulder/backslope landscape positions according to criteria described by Ruhe and Walker (1968).

Approximately one-third of the total values in the table were generated from a sample population of 20 or more profiles. These figures can be considered the most reliable, however those values dependent on small sample populations of less than 20 profiles should be used with caution. Only a few or no soil profiles were available for some landscape and taxonomic divisions within a major land system.

For upland soil groups (Table 5), Mollisols contained the greatest amount of organic carbon, followed by mollic subgroups, and then non-mollic subgroups. Mollisols in bottomlands had less organic carbon in the upper 20cm, but more organic carbon contained within a 100cm depth than did upland Mollisols. Alfisols and Entisols/inceptisols in bottomland positions had less organic carbon than any grouping of mollisols. These soils also had lower levels of organic carbon in the upper 20cm depth than did upland soils not classified as Mollisols, but this difference was not apparent in the values for 100cm depths. Soils on summit positions contained slightly less organic carbon in the upper 20cm than soils found on shoulders/backslopes, but had slightly more within the upper 100cm of the profile.

To show trends in the amounts of organic carbon (organic matter) in soils across the state, the data in Table 4 were combined into upland and bottomland landscape positions for each major land system. This information is presented in Table 6, and in Figures 3-6. Upland soils tend to increase in organic carbon content as one moves from southeast to

TABLE 5.

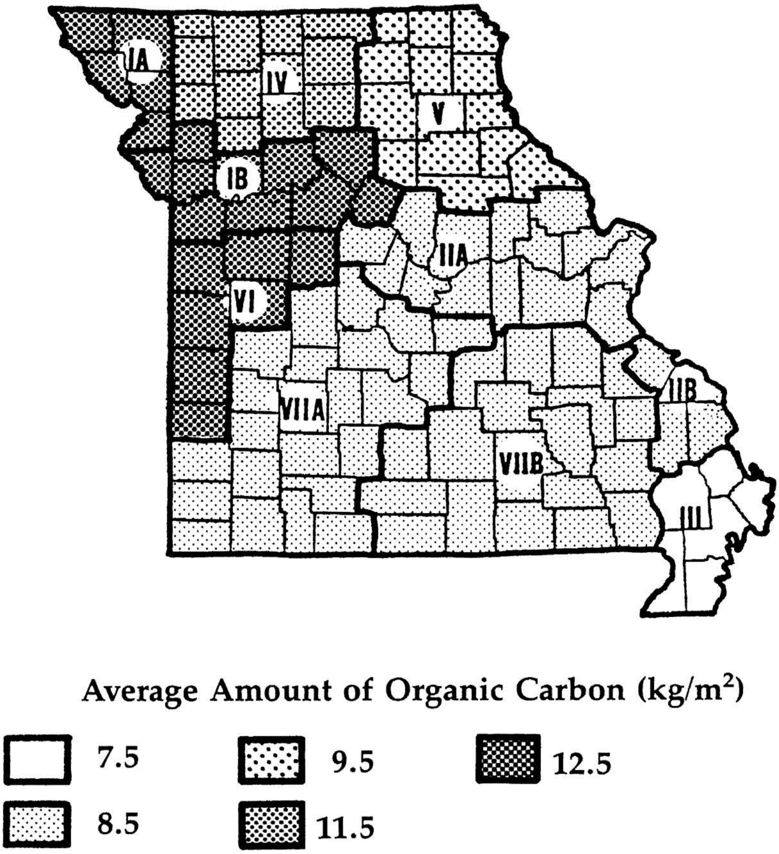
Average Amount of Organic Carbon by Landscape Position and Soil Taxonomic Groupings for Missouri.

Landscape Position & Soil Taxonomic Groupings	Average Amount of Organic Carbon in 20cm of soil		100cm of soil	
	kg/m^2	n*	kg/m^2	n*
Uplands - Summits Only				
Mollisols	4.4	86	13.1	82
Mollic Subgroups of all Soil Orders	3.4	95	10.3	73
Non-mollic Subgroups of all Soil Orders	3.0	22	8.8	20
Uplands - Shoulders & Backslopes Only				
Mollisols	4.8	114	13.0	105
Mollic Subgroups of all Soil Orders	3.6	76	10.0	71
Non-mollic Subgroups of all Soil Orders	3.1	104	8.2	98
Uplands - All Slope-profile Components				
Mollisols	4.7	310	13.3	290
Mollic Subgroups of all Soil Orders	3.6	209	10.3	181
Non-mollic Subgroups of all Soil Orders	3.1	241	8.1	224
Bottomlands				
Mollisols	4.0	180	13.7	174
Alfisols	2.5	79	8.2	78
Entisols & Inceptisols	2.8	108	9.8	103

*Number of soil profiles sampled.

FIGURE 5.

Average Amount of Organic Carbon Within the Upper 100 cm of All Upland Soils for Each Major Land System in Missouri.



northwest Missouri. While the same general trend is true for bottomland soils, maximum organic carbon values were centered more on the two major land systems, V and VI, dominated by claypan soils.

In addition to providing information on the general levels of soil organic carbon within the state, the accumulated data enabled summaries to be made on the profiles of organic carbon in several major groups of soils. These major soil groups fell into four categories for comparison: broad summit divides across northern Missouri, forest and prairie/forest transition canopies in southern Missouri, claypan areas, and clayey and silty/loam alluvium in the southeastern Missouri lowlands.

TABLE 6.
Summary of Organic Carbon Amounts by Landscape Position for Each Major Land System in Missouri.

Major Land System	Average Amount of Organic Carbon* in Uplands		Bottomlands	
	20cm of soil kg/m^2	100cm of soil kg/m^2	20cm of soil kg/m^2	100cm of soil kg/m^2
IA	4.5	12.5	3.5	13.0
IB	4.5	12.5	3.0	10.5
IIA	3.5	8.5	3.0	10.5
IIB	3.5	8.5	3.0	10.5
III	2.5	7.5	2.5	8.5
IV	4.5	11.5	3.5	14.5
V	3.5	9.5	4.0	15.5
VI	4.5	12.5	4.0	13.5
VIIA	3.5	8.5	3.0	10.5
VIIB	3.5	8.5	3.0	10.5

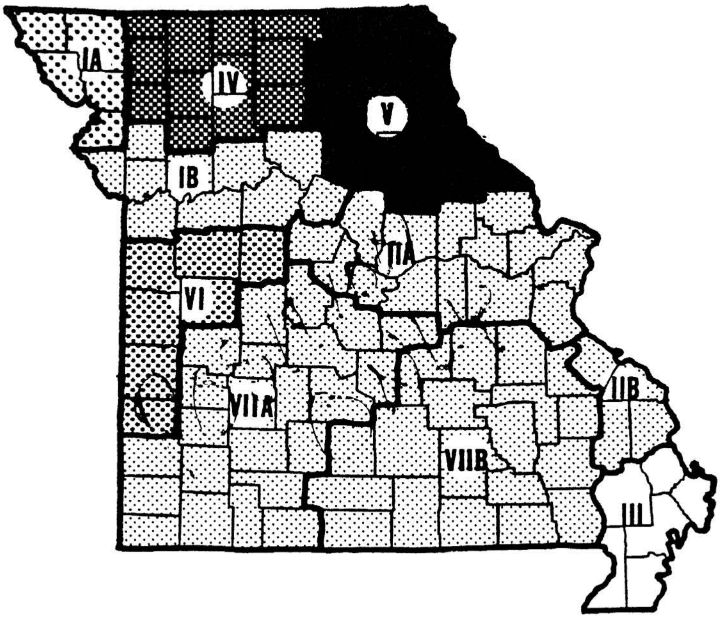
*Rounded to nearest 0.5 kg/m^2.

In Table 7 soils typical of broad summit divides across northern Missouri are listed with amounts of organic carbon shown for 20cm and 100cm depths. In Figure 7 the quantity of organic carbon as a function of depth is plotted as an average of all data available on a particular soil or group of soils. Kucera (1961) shows that the vegetation on these soils was primarily tall grass prairie. The soil series occurring on these prairie summit divides are Marshall, Sharpsburg, Grundy, and Putnam-Mexico moving from west to east across northern Missouri (Scrivner, Baker, and Miller, 1975).

In Table 8 and Figure 9, soils typical of the forest and prairie/forest transition regions of southern Missouri (see Figure 8) are compared for organic carbon content. No adjustments were made to account for the percentage of chert or other coarse separates greater than 2mm in size, and a bulk density of $1.3 g/cm^3$ was assumed for all soils, even fragipans, lacking density measurements. The distribution of organic carbon within the southwest Missouri prairie/forest mollic subgroups of alfisols is very similar to the pattern for Sharpsburg shown in Figure 7. Figure 9 also shows that the Menfro, a forested Alfisol formed in thick loess, and Ozark forest Alfisols and Ultisols have identical organic carbon contents except

FIGURE 6.

Average Amount of Organic Carbon Within the Upper 100 cm of All Bottomland Soils for Each Major Land System in Missouri.



Average Amount of Organic Carbon (kg/m^2)

8.5
10.5
13.0
13.5
14.5
15.5

TABLE 7.
A Comparison of Organic Carbon Amounts by Depth for Soils on Broad Summit Divides Across Northern Missouri.

Soils	Average Amount of Organic Carbon in 20cm of soil kg/m^2	n*	100cm of soil kg/m^2	n*
Marshall (M)	4.5	18	14.1	18
Sharpsburg (S)	4.5	18	12.8	18
Grundy (G)	5.7	18	14.8	18
Putnam - Mexico (PM)	3.6	36	10.4	18

*number of soil profiles sampled

References and number of profiles used.
M - A-18
S - F-5, G-2, H-4, L-4, S-3
G - A-18
PM - A-18, G-8, H-10 (only G & H for 100cm value)

FIGURE 7.
Profile Distributions of Organic Carbon Within Soils on Broad Summit Divides Across Northern Missouri.

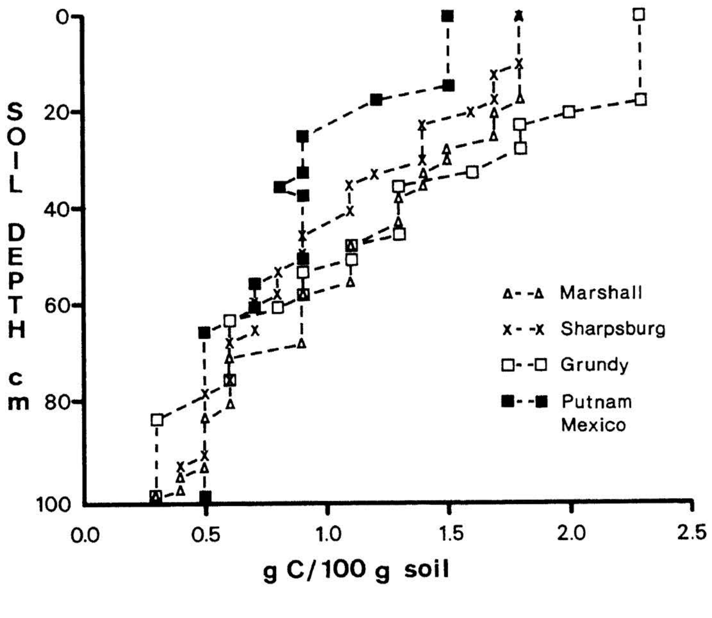


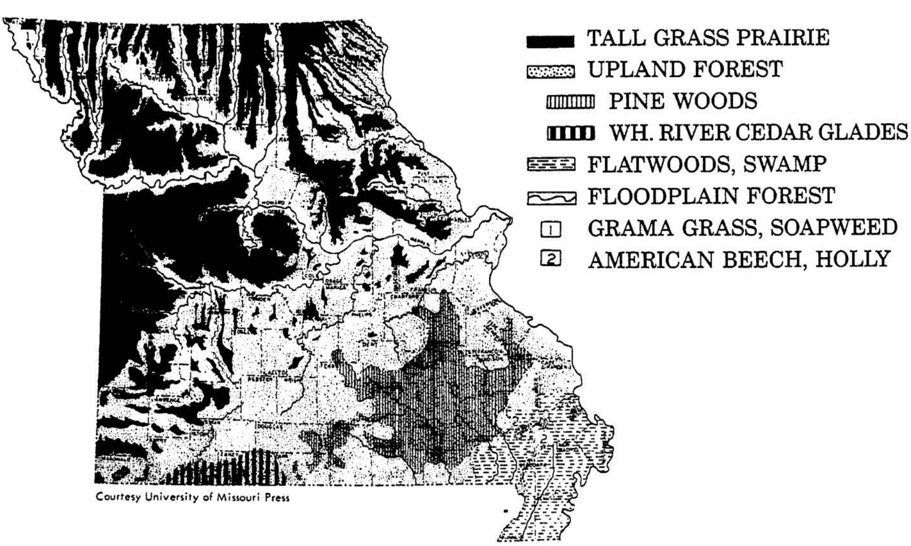
TABLE 8.
A Comparison of Organic Carbon Amounts by Depth for Soils Formed Under Forest and Prairie/Forest Transition Canopies in Southern Missouri.

Soils	Average Amount of Organic Carbon in 20cm of soil kg/m^2	n*	100cm of soil kg/m^2	n*
Menfro (M)	2.6	18	6.6	18
Ozark Forest (OF) - Alfisols and Ultisols (Captina, Clarksville, Doniphan, Lebanon, Plato)	3.3	17	7.3	17
SW Missouri Prairie/Forest (PF) - mollic subgroups of Alfisols (Craig, Creldon, Eldon, Gerald, Hoberg, Keeno)	4.3	18	12.3	17

*number of soil profiles sampled

References and number of profiles used.
M - F-4, I-10, L-1, S-3
OF - B-1, F-8, J-1, O-4, Q-1, R-2
PF - D-3, F-4, M-6, N-4, Q-1 (only D-2 available for 100cm value)

FIGURE 8.
Vegetation Map of Missouri. (From Kucera, 1961)



for the upper 13cm (5″) of the profile. Low amounts of organic matter in the surface 13cm of Menfro may be the result of cultivation. Most soils of the Ozarks were sampled in non-cultivated forest sites.

In Table 9 and Figure 10, amounts and distribution of organic carbon in soils from the two claypan regions of the state are shown to be quite similar. These soils have the lowest amounts of organic carbon when compared to the other major soils of the state in tall grass prairie areas, but still have considerably more organic carbon than forested soils in the Ozarks.

In Table 10 and Figure 11, the poorly drained Sharkey soils formed from clayey alluvium are shown to contain more organic carbon throughout the profile than Alfisols formed in better drained silty and loamy textured alluvium. The silty and loamy Alfisols are similar to the Menfro soil in organic carbon content and distribution. The amount of organic carbon found in 100cm of Sharkey soil is at the midpoint in the range of values determined for claypan soils.

FIGURE 9.

Profile Distributions of Organic Carbon Within Soils Formed Under Forest and Prairie/Forest Transition Canopies in Southern Missouri.

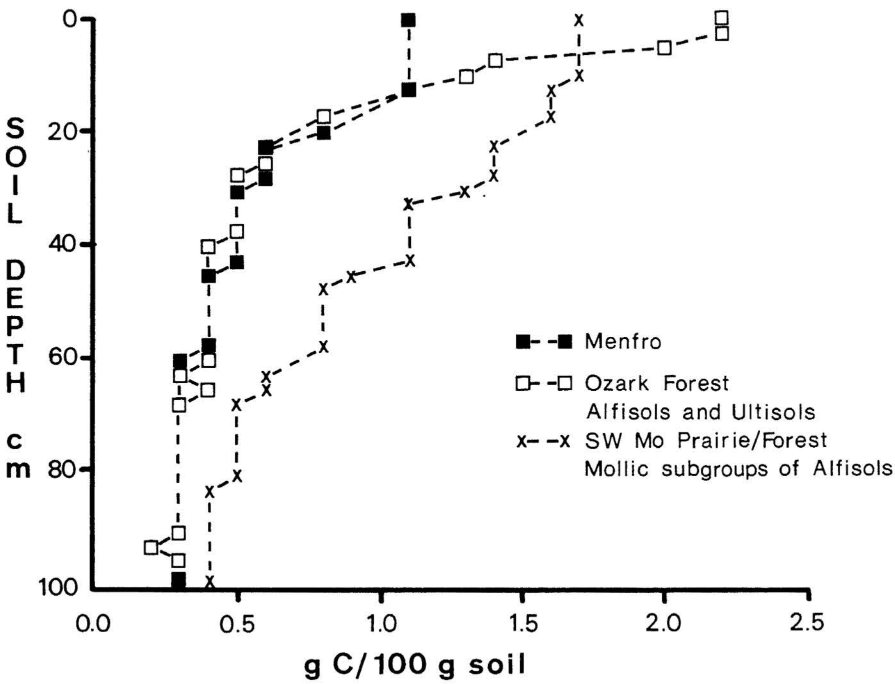


TABLE 9.

A Comparison of Organic Carbon Amounts by Depth for the Claypan Soils of Missouri.

Soils	Average Amount of Organic Carbon in 20cm of soil kg/m²	n*	100cm of soil kg/m²	n*
Putnam - Mexico (PM)	3.6	36	10.4	18
Parsons - Hartwell (PH)	3.5	15	11.0	15

*number of soil profiles sampled

References and number of profiles used.
PM - A-18, G-8, H-10 (only G & H for 100cm value)
PH - D-3, G-9, J-1, L-1, Q-1

FIGURE 10.

Profile Distributions of Organic Carbon Within Claypan Soils of Missouri.

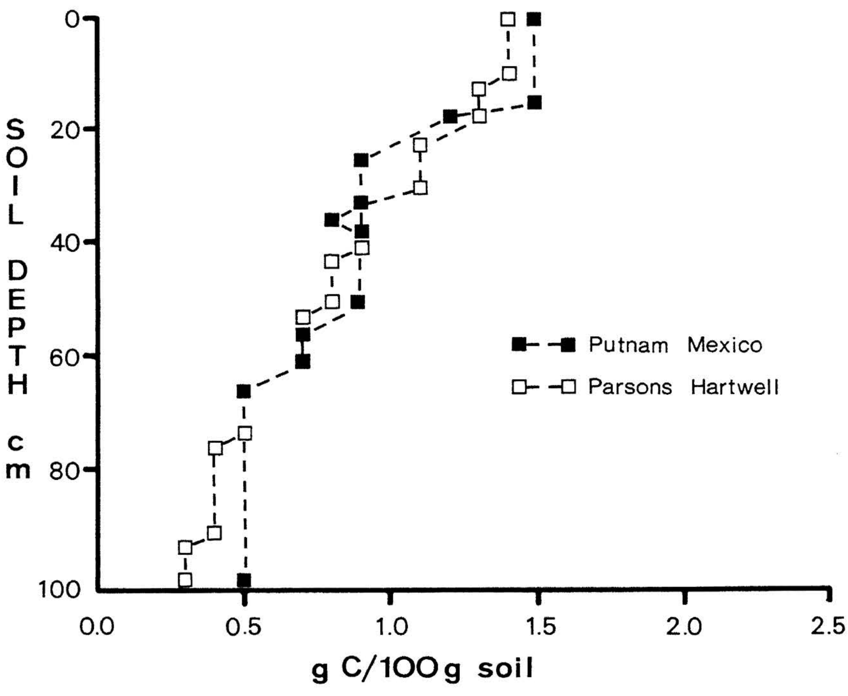


TABLE 10.

A Comparison of Organic Carbon Amounts by Depth for the Soils Formed in Clayey and Silty or Loamy Alluvium in the Southeastern Missouri Lowlands.

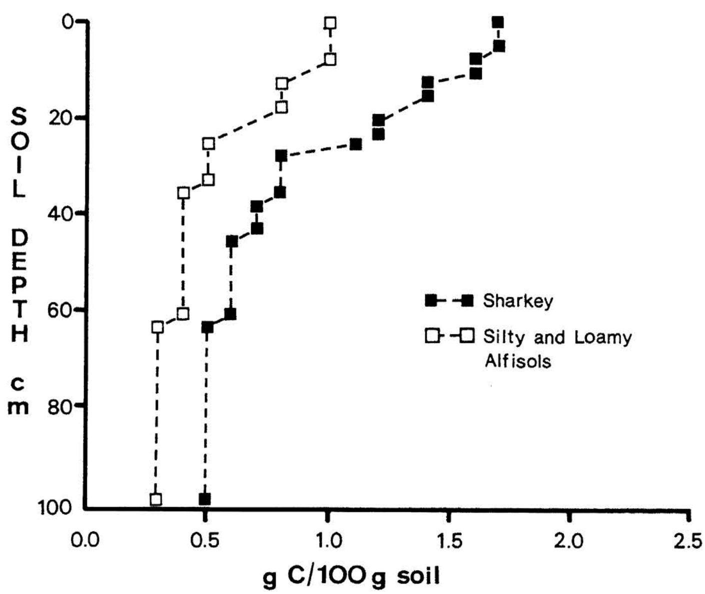
Soils	Average Amount of Organic Carbon in 20cm of soil kg/m^2	n*	100cm of soil kg/m^2	n*
Sharkey (S)	3.3	5	10.7	5
Silty & Loamy Alfisols (A) (Amagon, Bosket, Broseley, Calhoun, Dubbs, Dundee, Foley, Tuckerman)	2.3	18	6.4	18

*number of soil profiles sampled

References and number of profiles used.
S - F-3, J-1, L-1
A - F-14, G-4

FIGURE 11.

Profile Distributions of Organic Carbon Within Soils Formed in Clayey and in Silty and Loamy Alluvium in the Southeastern Missouri Lowlands.



Conclusions

This summary of soil organic carbon data provides the reader with a broad inventory of that important constituent of soils. We have provided inventories of regional variations as well as profile patterns that can serve as standards for current amounts of organic carbon. Organic carbon contents prior to cultivation of Missouri's soils were not a part of our study. However, future research of carefully selected samples might use our summary to quantify the effects of man's activities on major soils.

The profile summaries show that Alfisols and Mollisols are quite different. This should be expected partially because of the very definitions of those two soil orders. The intent of their definition was to distinguish soils formed under prairie vegetation from those formed under forest. The magnitudes of the differences are documented for Missouri. Mollic subgroups of Alfisols represent soils with a vegetative history thought to represent a transition from prairie to forest. Organic carbon profiles were shown to reflect that presumed history.

The profile summaries also show that within Mollisols, amounts of organic carbon vary (see Figure 7). The Marshall, Sharpsburg and Grundy soil series are classified as Mollisols.

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