TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
MICHIGAN

AGRONOMY #29
SUBJECT: Understanding Soil Organic Matter Changes
DATE: March 4, 1991

TO: All Offices

FROM: James R. Stacey, Assistant State Conservationist-Operations

UNDERSTANDING SOIL ORGANIC MATTER CHANGES

Both commercial and part-time farmers acknowledge the great value of soil organic matter. Unfortunately, few understand the extent of change in soil that can be accomplished even when good management practices are followed. Farmers and the popular press often report changes that are definitely not attainable. For example, an article about organic farming published in Ames, Iowa - the heart of the Corn Belt - reported how a farmer raised his soil humus content from 1.8 percent in 1967 to 6.7 percent in 1977. Few questioned this dramatic change; yet, such a change is nearly impossible.

To evaluate this example, let us assume a topsoil depth of 8 inches. This Iowa farmer had to add at least 12,000 pounds of humus per acre per year. It takes about 5 to 7 pounds of plant or animal residue to produce 1 pound of humus (also called soil organic matter). Thus, the farmer had to apply the equivalent of 70,000 pounds of residue per acre per year. Information supplied by the farmer, however, indicates that the additions of plant residue and crops grown could only offset the losses of humus from decay and soil erosion.

An article on organic farming in the <u>Michigan Farmer</u> (October 1982) asked the question: "How much organic matter will there be in your soil in 20 years?" The implication of the article was that commercial farmers are heading for trouble and cited such practices as the use of ammonia and acid-treated fertilizer. Farmers in Michigan have been hearing this for years from those who are "prophets of doom", but somehow Michigan farmers keep establishing higher crop yields.

The same article also reported how two adjoining fields had marked soil organic matter (O.M.) level differences - one was 2 percent and the other 4 percent. The field with the higher O.M. amount received manure and grew a "little buckwheat". These two fields may differ in O.M. content because of past management. Usually, one cannot expect to find marked improvement in soil humus content even if farm manure at typical farm rates is returned.

Let's illustrate what is involved if we try to change a soil testing 2 percent humus to a content of 4 percent. In our calculations, let's assume an acre plow layer weighs 2,000,000 pounds. Then the humus differences would be:

2 million lbs of soil x 0.04 = 80,000 lbs of humus/acre
2 million lbs of soil x 0.02 = 40,000 lbs of humus/acre
Difference = 40,000 lbs

It requires 5 to 7 pounds of plant material to produce 1 pound of soil humus. Thus, to produce 40,000 pounds of humus requires over 200,000 pounds of plant residue. That's a lot of biomass to go into one acre of soil. This same plant residue would need substantial amounts of nitrogen (N), since humus contains about 5 percent N. The N recovery when plant residue changes to humus is only about 30 to 40 percent. Then the actual nitrogen addition needs to be over 6,000 pounds per acre (40,000 x 0.05 x 3). At present fertilizer prices, this N input would cost over $1,200 per acre!

Now, let's assume we have the two fields (2 percent and 4 percent O.M.) on the same soil type and under similar management programs. What must we do to maintain these levels? If the two soils are a Michigan loam, we can expect an annual decay rate of about 2.0 percent for the 2 percent soil humus and 2.5 percent for the 4 percent soil. (The higher value for the 4 percent O.M. soil is due to more easily decomposable humus.) The annual amounts of decay for the two soils would be:

2 million lbs of soil/A x 0.04 (% O.M.) x 0.025 (decay rate) = 2,000 lbs decay
2 million lbs of soil/A x 0.02 (% O.M.) x 0.020 (decay rate) = 800 lbs decay
Difference = 1,200 lbs decay

To maintain the two levels of soil organic matter, we would need to return at least 10,000 (2,000 x 5) pounds of plant residue equivalent per acre to the 4 percent soil and 4,000 pounds per acre for the 2 percent soil. These calculations assume no soil erosion. If the two soils lose 5 tons of soil per acre per year, then the 4 percent soil would need an additional 3,000 pounds of plant residue and 2 percent O.M. soil 1,500 pounds.

In our comparison, the residue needed totals at least 13,000 pounds for the 4 percent O.M. soil and 5,500 pounds for the 2 percent O.M. soil. A commercial farmer can easily return 5,500 pounds, but can he return 13,000 pounds? If the 2 percent O.M. soil does not cause serious physical problems such as crusting, aeration and infiltration, then why carry out expensive programs that increase production costs? Increasing the O.M. content from 2.0 percent to 2.5 percent might be sufficient to show marked changes in soil condition. Good soil aggregation is the result of active chemical reactions in soils by polysaccharides and humic substances formed during plant residue decay and root activity.

I have pointed out some general guidelines in organic matter changes. Let's compare some actual field trials. The longest soil humus experiment now in progress at Michigan State University (MSU) was started in 1963, and is located on a Metea loamy sand. This season completes 20 years for the trial. Data in Table I show the changes in organic matter when sampled in 1968, 1976 and 1980 for plots that received different amounts of manure and fertilizer. You can assume the soil tested about 2 percent O.M. in 1963. The mineral fertilizer plots showed about the same O.M. content in 1968 and 1976, but showed improvement in 1980. The manure plots reflected O.M. increases based upon amounts applied.

The higher amounts of O.M. in the 1980 data can partly be accounted for by the much greater corn yields, which return more residue. Soil samples were taken in June for 1980. They probably contained some partially decomposed plant residue. The others (1968 and 1976) were sampled in October.

A comparison of the plots used for the annual removal of silage and grain shows an average of about 0.6 percent more O.M. in the soil of the grain plots.

Some organic farming people charge fertilizer as the reason for low soil organic matter. Let's turn to our neighboring state, Ohio, for some information where field trials were started in 1894 on a site that tested only 1.7 percent O.M. Thirty-two years later; for plots growing corn, wheat and clover in rotation; the soil tested 1.5 percent O.M. Plots of this same rotation with 8 tons of manure per rotation showed slightly less than 1.7 percent. These data were collected when essentially no fertilizer was used.

At Purdue University Agronomy Farm near West Lafayette, Indiana, soil changes and corn yields were compared for a silt loam soil where: 1) all top residue was removed, 2) only grain was removed, and 3) grain was removed but additional residue was added equivalent to that in comparison to No. 2. Data in Table II report the results.

Even though the residue treatments showed 0.6 percent more O.M. (Table II) the yields were essentially the same, as ample nitrogen fertilizer was applied to all plots. In the same report, corn yields and soil organic matter contents were compared where three levels of nitrogen were applied - See Table III.

From the data in Table III, we see that nitrogen fertilizer can increase soil organic matter. This is to be expected since the nitrogen fertilizer helps produce more roots and stover. The 0.2 percent difference (2.9-2.7) may not seem much, but for an acre plow layer of soil, this amounts to 4,000 pounds of humus. We know that this change requires over 10,000 pounds of plant residue.

Studies in Iowa found that about 6,000 pounds of residue per acre are needed to maintain the soil organic matter where soil erosion is not a factor. Since soil erosion is often a factor, we must add about an additional 2,000 pounds of residue if the annual soil erosion is about 5 tons per acre.

A corn crop producing 100 bushels of grain per acre will provide about 6,000 pounds of stover residue. In addition, roots and their exudates will provide annually about the equivalent of over 3,500 pounds of residue. These residue sources will maintain our soil organic matter if soils test less than 3 percent O.M. and if soil erosion is not serious.

There are cropping situations where humus additions fall short of matching soil humus losses. Data in Table IV illustrate some of these differences.

Field beans, sugarbeets and most vegetable crops are poor humus producers. When grown, crop sequences should include some that are high plant residue producers. Good soil management includes programs that concentrate the plant residue near the surface to help prevent soil erosion and crusting. Crops that are high soil humus producers, such as grasses, are likely to have high amounts of roots and root exudates. These sources may be as great as the above ground residue. Any fertilizer that promotes plant growth can also be considered as a humus producer.

When we apply plant residues or animal wastes, they show rapid decay rate. We sometimes call these materials "active organic matter". Because of the rapid decay, they do not greatly increase soil organic matter.

We can increase soil organic matter content, but do not expect claims of big changes under realistic commercial field crop practices. However, the impact of long-term no-till farming in Michigan indicates organic matter levels may actually increase at the soil surface. No-till farmers report an improved physical condition results in easier planting with time (see Table V).

If you desire more information on soil organic changes, see MSU Research Report 358, "Soil Organic Matter Dynamics". This publication has a Humus Model and also reports how crops, crop yields and field slope modify soil organic level.

2199E

TABLE I - SOIL ORGANIC MATTER CONTENTS FOR A METEA LOAMY SAND GROWING GRAIN AND SILAGE CORN SINCE 1963, ON PLOTS RECEIVING VARIOUS AMOUNTS OF FERTILIZER AND MANURE

Annual Treatment (Year) 1/ N - P_2O_5 - K_2O (lbs) Manure	Soil Organic Matter Silage Area (%)	Soil Organic Matter Grain Area (%)	Yield 2/ Silage (T/A)	Yield 2/ Grain (Bu/A)
160-40-40 (1968)	2.05	1.98	13	85
160-40-40 (1976)	1.63	2.03	23	141
260-40-40 (1980) 3/	1.93	2.60	25	180
160-190-190 (1968)	2.05	2.07	15	78
160-190-190 (1976)	1.70	1.97	24	147
260-190-190 (1980)	1.83	2.27	29	177
10-40-40 + 10 Tons manure (1968)	2.12	2.10	14	83
10-40-40 + 10 Tons manure (1976)	2.07	2.13	20	120
110-40-40 + 10 Tons manure (1980)	2.60	3.24	28	171
10-40-40 + 30 Tons manure (1968)	2.96	2.63	16	82
10-40-40 + 30 Tons manure (1976)	2.83	2.83	24	147
110-40-40 + 30 Tons manure (1980)	3.37	4.25	30	177

1/ Year indicates when soils were sampled.

2/ Irrigation started in 1974. Yields for the 1968 sampling are averages for the 1963-73 harvest, 1976 for the 1974-76 harvest and 1980 for the 1979-80 harvest.

3/ Nitrogen increased at the rate of 100 lb/A for all plots in 1978.

Note: A combination of manure, crop residues and adequate fertility can build organic matter levels over time. Removing any of these humus builders can result in a slow decline in organic matter levels.

TABLE II - EFFECT OF RESIDUE MANAGEMENT ON CORN GRAIN YIELD AND THE PERCENT OF SOIL ORGANIC MATTER (Data by Barber, Agron. J. 71:625-627)

Treatment	Average Corn Yield 6th to 11th Year (Bu/A)	Percent Organic Matter 6th Year	Percent Organic Matter 11th Year
Residue removed	150	2.8	2.75
Residue returned	154	3.0	3.05
Double residue returned	151	3.4	3.36

Note: Removing all the crop residue for 5 years from this high-yielding field resulted in only a slight decline (0.05 percent) in organic matter. This is probably due to the large contribution provided by corn roots.

TABLE III - EFFECT OF NITROGEN (N) FERTILIZER ON CORN GRAIN YIELDS AND SOIL ORGANIC MATTER
(Raub Silt Loam - Indiana Data)

Annual N Applied (Lb/A)	Corn Grain Yield 12 Year Average (Bu/A)	Soil Organic Matter After 12 Years (%)
0	39	2.70
60	88	2.85
180	141	2.90

Note: The addition of nitrogen fertilizer to achieve a realistic yield goal is beneficial in corn grain fields to building organic matter.

TABLE IV - ESTIMATED ADDITIONS OF HUMUS TO THE SOIL BY SEVERAL CROPS

Crop and Yield	Estimated Humus Addition			Pounds 1/ Plant Residue Equivalent
	Above Ground	Below Ground	Total	
Corn (grain only) - 100 bu/A	1,200	700	1,900	9,500
Soybeans (grain only) - 33 bu/A	600	350	950	4,750
Wheat (grain only) - 45 bu/A	900	500	1,400	7,000
Alfalfa (hay) - 4 Tons/A	350	1,350	1,700	8,500
Field beans - 15 cwt/A	400	150	550	2,750

1/ Assumes 100 pounds of residue to form 20 pounds of soil humus. (Many use a figure of 15 pounds.)

Note: The amount of organic matter returned to the soil varies with the amount of plant residue produced both as roots and tops. To estimate the root biomass of a crop in your cropping sequence, use 50 percent of the above-ground portion.

TABLE V - SOIL ORGANIC MATTER LEVELS OF SEVERAL MICHIGAN SOILS UNDER LONG-TERM NO-TILL 1/ SAMPLED 1988-1989

Soil	Producer	Years No-Till	Soil Sample Depth (In Inches) 0-2	2-4	4-6	6-8	0-8	Soil Mgmt. Group
			Percent Organic Matter					
Ithaca loam	Rawson 2/	14	2.8	2.1	2.1	2.1	2.3	1.5b
Perrinton loam	Rawson	14	2.4	2.8	2.4	1.9	2.0	1.5a
Ziegenfuss loam	Rawson	14	4.7	4.5	4.2	4.2	3.2	1.5c
Kalamazoo loam	Voyce 3/	6	1.8	1.3	1.0	1.1	2.0	3a
Rensselaer silt loam	Strefling 4/	9	2.7	1.7	1.8	1.8	2.1	2.5a
Shoals silt loam	Strefling	9	3.1	2.5	2.0	1.6	1.8	L-2c
Whitaker loam	Strefling	9	2.5	1.9	1.6	1.5	2.0	2.5b

1/ Analysis of organic matter provided by Michigan State University and A&L Labs.
2/ Ray Rawson, Farwell, Michigan, Isabella County, Rotation: C,C,SB,W.
3/ Jerry Voyce, Calhoun County, Rotation: Continuous Corn.
4/ Warren Strefling, Galien, St. Joseph County, Rotation: C,SB,W.

Note: Soil samples taken at 2 inch depths of several long-term no-till fields indicate organic matter levels can increase at the surface over time. Higher organic matter levels are usually credited with improved soil tilth. A collective observation of these farmers of their "clay knob fields" is they get easier to plant the longer they no-till. Higher organic matter levels support their observations.

Prepared By: Jerry Grigar, State Agronomist.

Reference: Robert E. Lucas, Department of Crop and Soil Sciences, Michigan State University, East Lansing, Michigan 48824. Ninth Michigan Seed, Weed and Fertilizer School, December 14-15, 1982 - "Understanding Soil Organic Matter Changes".

2199E