Comparison of Soil Structure Resulting From Permanent Pasture and Continuous Row Crop

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Physical properties of soils are an important factor in soil management to improve yield and promote continued soil productivity. Because the parameters that measure physical properties have been difficult to equate with yield response they have often been relegated to a secondary role as compared to the clearer relationship between soil fertility levels and yield.

Recent examples of yield reduction from subsoil compaction and increased erosion noted on soils with poor soil structure has increased interest in maintaining soil structure and determining important components of it. In Fulton County, Indiana on a loamy sand soil a corn yield reduction from about 6.4 metric ton/ha (100 bu/acre) to 1.9 metric ton/ha (30 bu/acre) was due to compaction. And recent studies in Illinois show that sloping lands under intense cultivation are losing poorly structured surface soil at a rate that is too high to retain productivity.

Currently in Indiana many soils have poor structure in the surface horizon. Two reasons have been suggested for this situation. First continuous row crops especially soybeans, do not add enough crop residue to promote soil structure. And second, less organic matter is being added to soils from animal agriculture because animal manure has been considered to be too low in nutrients for the effort needed to apply it, because of environmental concerns, and many farms have eliminated this part of their operation.

Poor soil structure has also been evidenced by subsoil compaction problems that have occurred over a wide range of soil textures. Part of this is due to tilling wet soils, tilling at the same depth, and excessive use of a disk.

Methods and Materials

On a farm near Roachdale Indiana, a four acre pasture which had not been plowed in 75 years was available for a study to compare the soil physical properties under these conditions contrasted to those under continuous row cropping in the adjacent field. Two soils differing in drainage were present in the pasture, the somewhat poorly drained Fincastle and the poorly drained Ragsdale. These soils were also present in the adjacent plowed field. Field descriptions were made at each of the four sites representing each of four soil conditions, somewhat poorly drained Fincastle and poorly drained Ragsdale, both plowed and unplowed. Descriptions were made following the Soil Survey Manual guidelines (Soil Survey Staff, 1951) and the procedures of the Purdue University Soil Characterization Laboratory (Franzmeier et al., 1977).

Ten pound bulk samples of the surface horizon were taken for characterization and aggregate analysis. Procedures for particle-size analysis, organic carbon, and chemical analysis followed those of the Purdue University

Soil Characterization Laboratory (Franzmeier et al., 1977) except that the particle-size analysis was completed both with and without destroying organic matter with hydrogen peroxide prior to analysis.

Aggregate analysis followed a procedure developed by McFree (personal communication) which was based on a method by Kemper and Chepil (1965). The steps in the analysis are:

1. Sieve air dry natural aggreates through a sieve with square 8 mm openings. Discard material larger than 8 mm.
2. Place the material that passed the 8 mm sieve on a sieve with a square 2 mm opening. Keep the material for analysis that is retained on the 2 mm sieve.
3. Place the 10g samples in moisture dishes to determine air dry moisture content.
4. Fill the container that is used for the wet sieving with water to within one inch of the top. Use a nest of 4 sieves with the following openings: 4.76mm, 2.00mm, 1.00mm, and 0.21mm. Place each nest on a rack that attaches to the apparatus that oscillates the sample up and down 35 times per minute through a stroke of 38 mm. Adjust the nest of sieves so that at the top of the stroke the mesh of the top sieve is at the water surface. Be sure that any entrapped air is released.
5. Place two 25g samples of air dry soil for each soil on the top sieve at the top of the stroke and sieve the sample for ten min.
6. After ten minutes of sieving remove the nest of sieves from the water container and drain. Place a dish under each sieve and over dry at 105° C for thirty minutes.
7. Weigh the oven dry aggregates. Place the aggregates in a dish, add a small amount of water and dispersing solution, and crush with a rubber policeman. Wash through the sieve that retained the aggregate until only sand particles remain. Place in the oven and dry at 105° C.
8. Weigh sand fraction and subtract from original aggregate weight. The total oven dry weight is calculated from the sample weight and air dry moisture content.
9. Determine the corrected aggregate amount retained on each sieve and determine the amount of fines by difference.
10. Calculate fraction of total sample in each size fraction. Multiply this fraction by the mean size of each fraction. The sum of these numbers is the mean weight diameter (MWD).

Results

The field description of the two soils are shown in Tables 1 and 2. The differences between the plowed and unplowed soils are basically surface color and the strength of the granular structure in the surface horizon. The soils are classified as the Ragsdale silt loam in the poorly drained condition and Fincastle silt loam in the somewhat poorly drained condition. However, the color of the surface horizon in the unplowed Fincastle is darker than the modal concept.

Table 3 contains the characterization data to compare the soil differences. Particle-size analysis shows that the field determination of silt loam texture class

TABLE 1—*Field Description of the Unplowed and Plowed Fincastle Silt Loam*

Location—Jones Farm, Roachdale IN, Vegetation—Pasture
Soil—Fincastle Silt Loam Unplowed, Date—April 19, 1977

Horizon	Depth, cm	Boundary	Color	Texture	Structure	Consistance
A1	0-12	Clear	10YR3/3*	Silt Loam	Moderate medium and coarse granular	Friable
A2	12-17	Clear	10 YR5/3 with 10YR6/2 & 7.5YR4/6	Silt Loam	Weak thin platy	Friable
B1	17-28	Clear	10YR5/6 with 10YR6/2	Silt Loam	Moderate medium subangular blocky	Friable
B21t	28-43		10YR4/3 with 10YR6/2 & 10YR5/6	Silty Clay Loam	Moderate medium subangular blocky	Friable
B22t	43-82		10YR5/4 with 10YR6/2 & 10YR5/1	Silty Clay Loam		
IIB23t	82+		10YR5/4 with 10YR6/2 & 10YR5/1	Silty Clay Loam		
Soil—Fincastle Silt Loam Plowed				Vegetation—Corn stubble		
Ap	0-20	Abrupt	10YR4/3	Silt Loam	Weak medium and fine granular	Friable

Remainder same as above for similar depth

*This is darker than the normal Fincastle.

TABLE 2—*Field Description of the Unplowed and Plowed Ragsdale Silt Loam*

Location—Jones Farm, Roachdale IN, Vegetation—Pasture
Soil—Ragsdale Silt Loam Unplowed, Date—April 19, 1977

Horizon	Depth, Cm	Boundary	Color	Texture	Structure	Consistance
Al	0-28	Clear	10YR3/2	Silt Loam	Moderate medium granular	Friable
B21t	28-40	Clear	10YR4/1 with 10YR5/6 & 10YR5/4	Silty Clay Loam	Moderate medium subangular blocky	Firm
B22t	40-90		10YR5/2 with 10YR5/6	Silty Clay Loam	Moderate medium subangular blocky	Firm
IIB23t	90+		10YR5/2 with 10YR5/6	Silty Clay Loam		
Soil—Ragsdale Silt Loam Plowed				Vegetation—Corn Stubble		
Ap	0-20	Abrupt	10YR3/3	Silt Loam	Weak fine granular	Friable
A12	20-30	Clear	10YR3/3	Silt Loam	Weak medium granular	Friable

Remainder same as above for similar depth.

TABLE 3. *Results of Analysis on Fincastle Silt Loam Unplowed and Plowed and Ragsdale Silt Loam Unplowed and Plowed.*

	% Sand		% Silt		% Clay		H_2O Content	Mean Weight Diameter	Organic Carbon	Organic Matter	Color	Predicted Organic Matter
	OM Free	With OM	OM Free	With OM	OM Free	With OM	Air Dry %	mm	%	%	10YR	%
Fincastle Unplowed	18.2	23.4	64.4	71.4	17.4	5.2	2.1	4.29	2.80	5.6	3/3	3-5
Fincastle Plowed	16.0	18.7	67.8	67.6	13.7	13.7	1.8	1.18	1.35	2.7	4/3	3
Ragsdale Unplowed	16.9	23.1	59.6	66.1	23.5	10.8	2.0	3.39	2.76	5.6	3/2	3-5
Ragsdale Plowed	19.5	22.3	59.6	59.4	20.9	18.3	3.0	1.07	1.66	3.3	3/3	3-5

was correct. The Ragsdale soils were slightly higher in clay than the Fincastle soils. In swell and swale topography the lower lying, very poorly drained soils in the swale are often slightly higher in clay content than the somewhat poorly drained soils on the swells.

When organic matter was destroyed by hydrogen peroxide the clay content is consistently higher for both the plowed and unplowed condition. This would show the ability of organic matter to aggregate clay and silt size particles into silt and sand size particles. These aggregates were very durable because they withstood overnight shaking with the dispersing solution of sodium metaphosphate and sodium carbonate. In both the unplowed Fincastle and Ragsdale the difference between organic matter free and organic matter included clay content was approximately 12.5%. This compared with a difference of about 2.5% for both the Fincastle and Ragsdale. This showed that the additional organic matter found in these unplowed soils was effective in enhancing soil structure.

There has been some speculation that some of the silt size aggregates of clay size particles may act more like silt than clay in the soil. Comparing the air dry moisture content shown in Table 3 with clay content measured with and without organic matter destruction shows that this moisture content is more closely related to clay content determined after organic matter destruction. However, there might be another aspect to this relationship because silt size particles are related more to available moisture (Franzmeier et al., 1960 and Steinhardt, 1968) than air dry moisture content and it may be in this property where these silt size aggregates have a measurable effect on soil moisture.

Calculated mean weight diameter (MWD) is shown on Table 3. As expected both unplowed soils had coarser MWD than the plowed soils. The data also indicates that the Fincastle in both the plowed and unplowed condition had slightly stronger structure than the Ragsdale in a similar condition. This is contrary to what has been thought about these soils. There has been more concern about compaction and structure problems on the somewhat poorly drained than on the poorly drained soil. This data shows that current thinking about potential problems of soil structure may need examination.

Another interesting feature of the aggregate analysis was the appearance of the aggregate before and after analysis. Before wet sieving aggregates from both plowed and unplowed soils, except for color, appeared quite similar. But after wet sieving there was a considerable difference, the aggregates in both unplowed soils had distinct faces on the individual granules compared to both plowed soils where the faces on individual aggregates were not as smooth or regular. It appeared as if the aggregates from the plowed soils were still being eroded away by the wet sieving while the unplowed soils had been worked down to an aggregate that would resist further breakdown. The unplowed aggregates were much larger and more durable which would improve the infiltration and permeability of the surface horizon for both dry and excessively wet conditions.

Organic carbon content was also measured and it is shown in Table 3. As expected both unplowed soils were higher in organic carbon content than the unplowed soils. In the unplowed condition Fincastle and Ragsdale were quite similar in organic carbon content. On the cropped two different equilibrium contents were found with the poorly drained soils having a higher organic carbon content probably because of higher moisture content more time through the year.

In other work (Steinhardt et al., 1977) there has been a relationship established for silt loam soil texture between the soil color as determined on the Munsell Soil Color Chart and organic matter content in the plow layer of Indiana soils. Samples from the plow layer horizon of 114 soils that had a silt loam texture and had a color of the 10YR hue were examined. These separations could be consistently made: >5% organic matter 10YR2/2 and N2/0; 3-5% organic matter 10YR2/2, 3/1, 3/2, and 3/3; less than 3% organic matter all other 10YR colors found for surface soils. This relationship changes for coarser textured soils to a lower organic matter content for the same color and to higher organic matter contents for the same color in finer textured soils. At this point, not enough samples have been completed to establish precise numbers. Of course, this relationship is not applicable in a different climate or moisture regime.

The estimate of organic matter content with that actually measured was correct for the plowed soils and low for both unplowed soils. This indicates that a different equilibrium has been set up in the unplowed vs plowed soils and as a result the relationship between soil color and organic matter content must be limited to cropped soils.

Summary and Conclusions

Unplowed soils have a much higher content of clay particles aggregated into larger particles than plowed soils. However, the relationship of air dry moisture content is more closely related to clay content measured after organic matter is destroyed.

The somewhat poorly drained Fincastle has slightly stronger structure than Ragsdale. This points out that poorly drained soils may have some potential structure problems that should be carefully examined.

The unplowed soils have organic matter content which is higher than the plowed soils. These unplowed soils have a different relationship between soil color and organic carbon content which limits the application of the relationship between soil color and organic carbon content established for plowed soils. With higher organic carbon content, soil structure was much coarser and more durable. Both of these properties promote infiltration and improved moisture holding properties. This would support the value of soil management systems that promote addition of organic matter to soils for the improvement of soil physical properties.

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