Tillage Techniques on Indiana Prairie Soil[1]

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Abstract

Several variations of tillage methods and of residue management on a fertile prairie soil during six years have resulted in only minor effects on corn yields. Even the no tillage plots produced corn within 2.5 percent of the conventionally treated plots. However, distinct changes in soil properties were observed. These point to eventual major effects on the productivity of the soil.

Introduction

The introduction of increasingly more powerful tractors has made it possible to combine several tillage operations that formerly have been performed by horse-drawn equipment. Recognition of the danger of erosion has pointed to the need of keeping the soil surface receptive for water in order to avoid excessive runoff. Considerably increased fertilization, especially with nitrogen compounds, and use of herbicides have caused many farmers to change from crop rotations that included grass and legume meadows to continuous cropping with corn and soybeans.

Historically one reason for tillage has been to stimulate the decomposition of the mineral and organic components of the soil in order to provide an adequate nutrient supply for the succeeding crop. With the plentiful and relatively inexpensive fertilizers available this reason has ceased to exist.

All these facts have caused the introduction of new systems of tillage and of crop residue management during the last two decades. How do crop yields and soil quality react to this change? In an attempt to find quantitative answers an experiment has been conducted on the Purdue University Agronomy Farm comparing several tillage treatments for corn. It is the purpose of the research reported in this paper to determine what effects continuous cropping with corn has on soil conditions and corn yields under various types of tillage.

Experimental Procedure

An experiment has been designed in which four systems of tillage, and four levels of residues were used. Corn was planted annually on six of the treatments, while two treatments remained without any crop. Every year fertilizer is uniformly broadcast over the entire area at rates designed to result in high yields. Herbicides are used and the plots with corn are cultivated twice during the season.

The treatment are given in Table 1.

The design of this experiment permits the comparison of the effects of corn versus no corn, and of the relative effects of four tillage methods.

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The items that were studied include yield, stalk diameter, and root growth of corn and organic matter content, pore space, and aggregation of the soil.

The soil of the experimental area is a mollisol, a tall grass prairie soil, grading from a Raub silt loam to a Chalmers silt loan. Table 2 presents some of the properties of these soils.

Table 1. Design of the tillage experiment.

Treatment	*Tillage*	*Depth*	*Crop*	*Residue*
No.		*Cm*		
1	Conventional*	20	Corn	Normal
2	Conventional	20	Corn	Stover Removed
3	Conventional	20	Corn	Doubled
4	Field Cultivator	20	Corn	Normal
5	Rototiller	8	Corn	Normal
6	None	0	Corn	Normal
7	Conventional	20	None	None
8	None	0	None	None

* Conventional tillage consists of fall or spring plowing followed by disking.

TABLE 2. Properties of the soils of the experiment area.

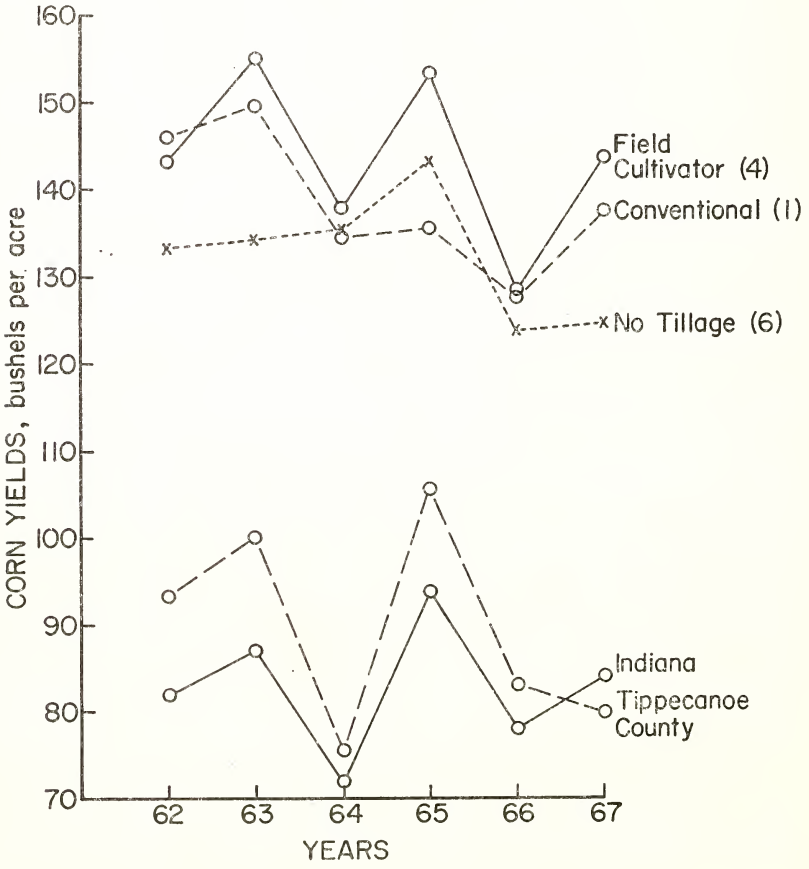
Raub silt loam ("2" profile)						
Depth cm.	Texture	Bulk Density g/cc	Total Porosity percent	Aeration Porosity percent	pH	Organic Matter percent
0-6	Silt loam				6.6	2.7
10-14	Silt loam				6.3	
36-40	Silt loam	1.27	52	9.0	6.4	
54-58	Silty clay loam	1.33	50	6.6	6.4	
75-79	Clay loam	1.54	42	4.8	7.0	
96-100	Loam	1.81	31	5.7	8.2	

Chalmers silt loam ("8" profile)						
Depth cm.	Texture	Bulk Density g/cc	Total Porosity percent	Aeration Porosity percent	pH	Organic Matter percent
0-6	Silt loam				6.0	3.0
10-14	Silt loam				6.0	
32-36	Loam	1.33	50	8.3	5.7	
55-59	Silty clay loam	1.28	52	5.4	5.8	
75-79	Clay loam	1.37	48	4.5	6.5	
96-100	Clay loam	1.54	42	4.1	7.0	

Except for the variables studied all other treatments were identical for the entire experimental area. The same corn hybrid was used. Fertilization consisted of an annual application of 250 lbs N, 100 lbs P_2O_5, and 100 lbs. K_2O per acre. Atrazine at a rate of 4 lbs/acre was used to control grassy weeds. In the fall the stover on all plots was cut with a stalk cutter.

Conventional tillage (treatments 1, 2, 3, 7) consisted of plowing to 20 cm and disking three times. Whenever the soil moisture conditions permitted plowing was done in the fall. All other operations were done immediately preceding corn planting. The field cultivator (Graham-Hoeme type) was used twice to a depth of 20 cm. The rototiller loosened the entire surface soil to about 8 cm depth. Both these treatments included two cultivations. The soil of these treatments (4 and 5) were disked

Figure 1



Comparison of the corn yields of the residue management plots with those in Tippecanoe County and in Indiana

twice. In the case of the "no tillage" treatment the corn planter was used twice in succession in order to get the seed deep enough into the ground. The soil treatments 1, 2, 3, 4, 5, and 7 were cultivated twice. Since treatments 6 and 8 were not cultivated they received an application of 2, 4-D in addition to the atrazine.

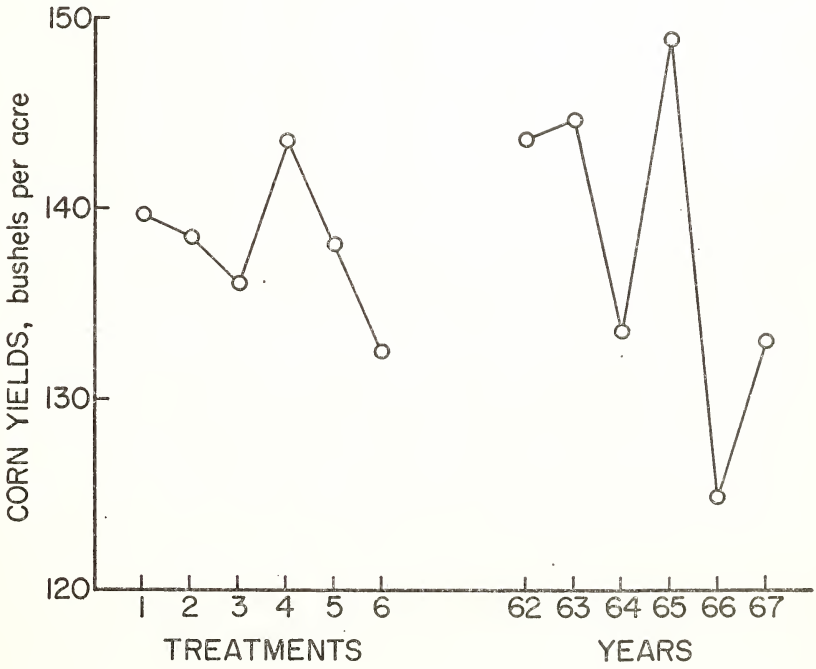
While treatment 7 (no corn) was managed in exactly the same manner as treatments 1, 2, and 3, treatment 8 (no corn) consisted exclusively of application of fertilizers and herbicides.

Results and Discussion

Corn Yields

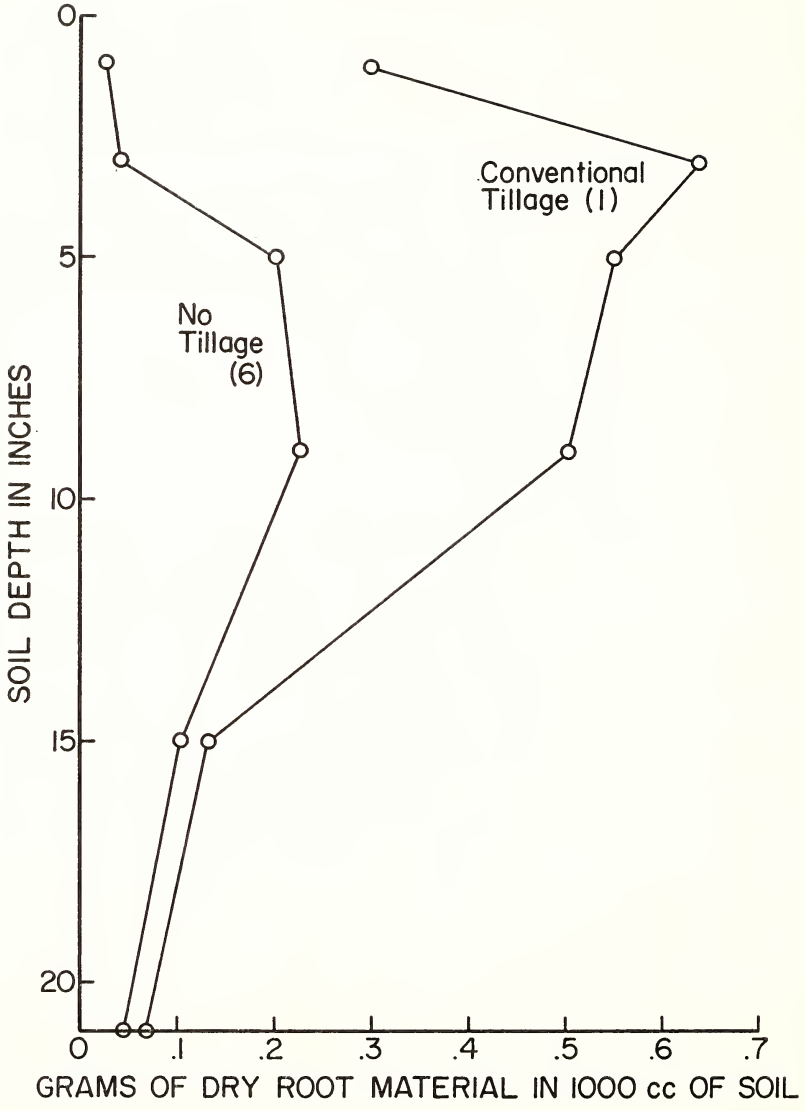
The average corn yields of the four plots of each of the treatments during the first six years of the experiment are given in Table 3. Figure 1 compares the yields of three of the treatments with the average yields for the State of Indiana and Tippecanoe County during the same years. The effect of the changing weather from year to year is quite evident. The yields from the field cultivator plots have been consistently the highest. The yields from the three "Conventional tillage" treatments and from the rototiller treatment did not vary statistically from each other. Prob-

Figure 2



Comparison of the effects of treatments with those of weather on corn yields

Figure 3



Corn root distribution with depth

ably the most astonishing result is that the average yield of the no-tillage treatment was only five percent lower than that of conventional treatment. This difference becomes still smaller when the first two years are excluded from the comparison (2.5 percent difference). In the first two years the no-tillage treatment suffered from inadequate stand because

of the difficulty to get the seed into the ground. This small difference in yield indicates that the soil of the experimental area is very favorable for corn growth even without any tillage treatment.

It is interesting to note (Figure 2) that the differences in yield due to differences in treatment were smaller than due to the variations due to weather from year to year.

Roots

The root distribution of corn in one of the "conventional tillage" plots was compared with that in a "no tillage" plot (Figure 3). At a location 6 inches from the plant "conventional" corn had three times the weight of roots as "no tillage" corn. At a location 20 inches from the plant (midway between the rows) this ratio was two to one. In spite of this great difference in root growth yields were quite similar.

TABLE 3. Corn yields, bushels per acre.

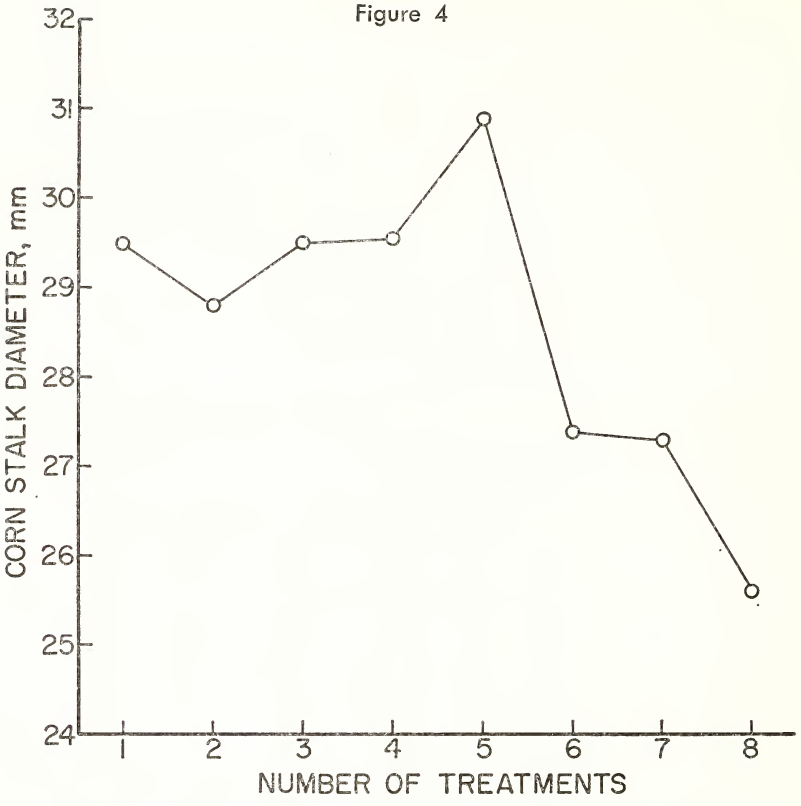
Treatment No.	1962	1963	1964	1965	1966	1967	Six Year Average
1	146.1	149.7	134.6	140.7	127.7	137.6	139.7
2	147.4	146.7	136.2	147.2	125.6	128.2	138.5
3	146.4	144.1	119.1	152.5	123.1	130.5	136.0
4	143.1	155.0	138.0	153.4	138.5	143.9	143.6
5	145.3	138.2	138.2	156.4	125.6	125.6	138.2
6	133.1	134.3	135.5	143.4	123.8	124.7	132.5
Annual Average	143.6	144.7	133.6	148.9	124.9	133.1	

In the seventh year of the experiment (1968) all plots were planted to corn, otherwise the treatments remained the same. A measurement of the diameters of the cornstalks (Figure 4) indicates the cumulative effects of six years of differential treatments. The three conventional plow treatments and the field cultivator treatment gave about the same results. The biggest diameters occurred in the roto-till plots. There was a definite decrease of diameters in the plots that had been fallow for six years as well as in the no-tillage plots. These latter, as has been mentioned before, had a substantially smaller amount of roots than the conventionally treated plots.

Organic matter content of the soil

The organic matter content of the soil of the various treatments was determined anually since 1965. Because the organic matter content of the surface soil has the greatest effect on the moisture regime most of the determinations were made on soil of the 0-4 inch depth. While there have been variations from year to year the relations of organic matter

Figure 4



Diameters of corn stalks as affected by residue treatment and tillage August 1968

TABLE 4. Organic matter content of experimental plots of the 0-4 inch depth of the soils of the treatments of the residue management experiment.

Sampled May 1968

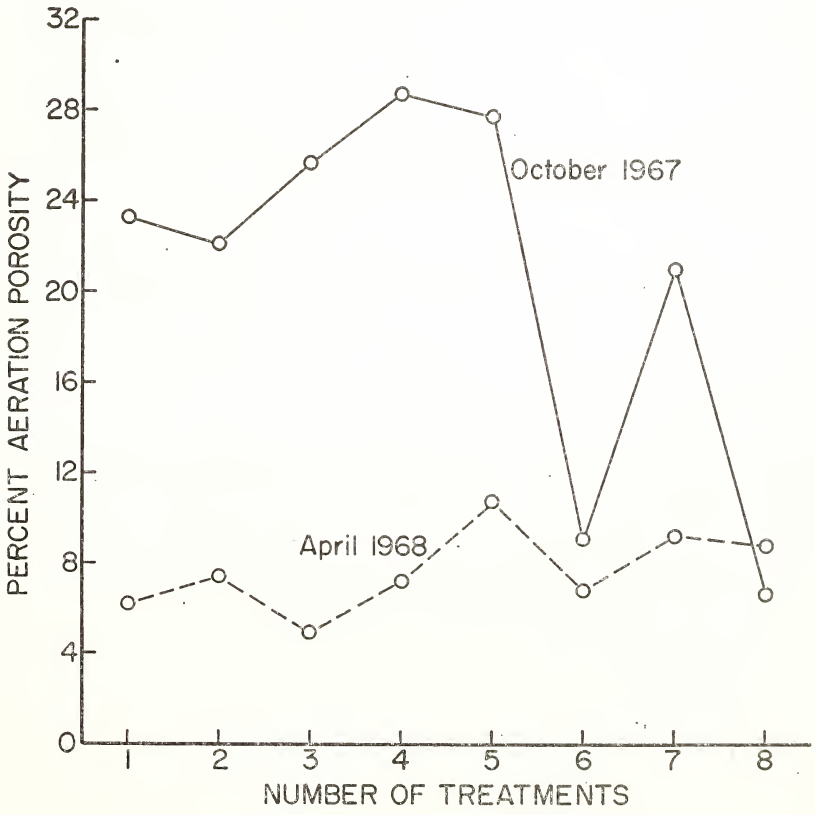
Treatment		Organic Matter Percent
1	Conventional, normal residue	2.6
2	Conventional, residue removed	2.4
3	Conventional, double residue	3.0
4	Field Cultivator	2.8
5	Rototiller	3.2
6	No tillage	3.0
7	No corn—tillage	2.2
8	No corn—no tillage	2.2

content from treatment to treatment have essentially remained the same. Table 4 shows the organic matter situation in the spring of 1968.

It is interesting to note that the highest organic matter content in the surface soil occurs in the roto-tiller plots where the residues are incorporated in the upper four inches only. Leaving the residues on top of the ground as done in the no-tillage plots evidently causes them to decompose more quickly. The addition of extra residues has resulted in a substantial increase in organic matter compared to leaving the normal amount of residues in the field. As was to be expected removing the residues reduced the organic matter content considerably. Leaving the soil bare of any vegetation (treatments 7 and 8) resulted in a decline of the organic matter content even greater than where only the corn roots were left in the ground (treatment 2).

After six years of conventional cropping with corn the soil had 0.4% more organic matter than the soil that remained fallow for the

Figure 5



Effect of treatment and season upon aeration porosity
0–3 inch depth

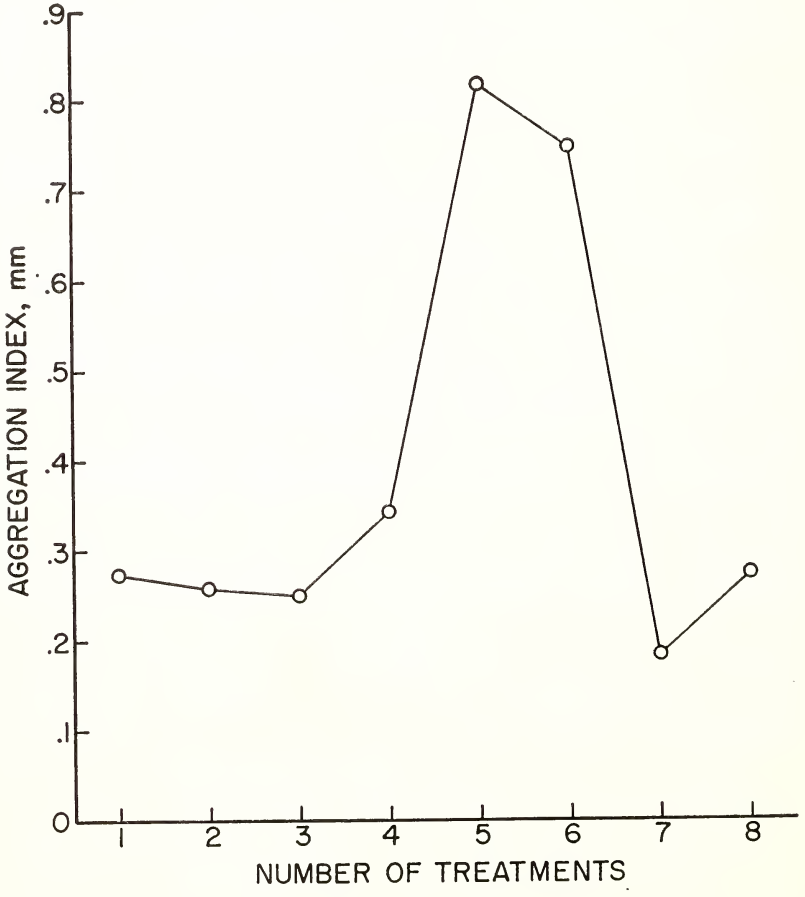
same period. This represents an average annual loss of 1300 lbs per acre of organic matter (dry basis) from the soils that had no vegetation. Surely an outstanding testimony for the value of corn as a soil conserving crop—under conditions of high fertilization and no erosion!

In all the treatments in which the soil was tilled down to 20 cm, the organic matter content was rather uniform to this depth. In the rototill and the no-till plots, however, there was a substantial decrease of organic matter below 10 cm.

Structure

A comparison of the aeration porosities of the soil of all the treatments in the fall of 1967 and in the following spring (Figure 5) shows

Figure 6



Aggregation index of the surface soil (3-5 inch depth) as affected by residue treatment and tillage

very little lasting influence of the treatments. Only the roto-tilled plots (treatment 5) had a substantially higher aeration porosity in the spring than the other treatments. The data for October 1967 are a direct reflection of the mechanical treatments. Most of the soils have maintained their loose structure throughout the growing season. The greatest decrease of porosity of the "conventionally" treated plots occurred in treatment 7 where no vegetation existed that could have protected the soil from the impact of the rain.

Previous experience has shown that 10 percent aeration porosity in the upper root zone is sufficient for satisfactory corn growth. In most of the treatments the actual aeration porosity in the spring before cultivation was somewhat lower than this value. This indicates a need for loosening of the soil and the reason for a decrease in yield of corn on the no-tillage treatment.

The water-stable aggregation of the soil of the various treatments was determined by the wet-sieving method (Figure 6). Most of the soils showed rather satisfactory values between 0.25 and 0.35 mm aggregation index. The two treatments with accumulation of organic residues in the surface (Nos. 5 and 6) had considerably greater aggregation indices. The no-corn, conventional tillage treatment (No. 7) had the lowest value. The fact that no organic matter was added and that the cultivation caused oxidation of the most active part of the humus may be the reason for this.

Temperature fluctuations

A temperature study conducted in the summer of 1966 showed interesting differences in daily temperature fluctuations between the treatments. These data are shown in Table 5.

The fact that temperature fluctuations in the soil increase with increasing thermal conductivity is clearly brought out by these data. The corn in treatments 1 and 2 reduced insolation compared to treatments 7 and 8. The corn residue plowed into the soil of treatment 1 reduced the thermal conductivity compared to treatment 2, from which the residues were removed. The much denser structure of the no-tillage soil (treat-

TABLE 5. Daily temperature fluctuations at 10cm depth in the soil and in the air July 1966.

Treatment		*Average Daily temperature fluctuation degrees F.*
1	Corn, conventional tillage	7.8
2	Corn, conventional tillage, residues removed	10.7
7	Fallow, conventional tillage	12.3
8	Fallow, no tillage	16.9
	Air, 30cm above ground	27.7

ment 8) had a higher thermal conductivity than the soil of treatment 7 which has been plowed every year.

The greater the daily soil temperature fluctuations are, the greater are the vapor pressure fluctuations and consequently losses of soil moisture in the vapor phase. These data indicate clearly that protection from insolation and incorporation of crop residues into the soil assist in moisture conservation.

Conclusion

During the six years this experiment has run the effects of tillage and crop residue management on corn yields have not been great. However, the changes in the physical conditions of the soil have been pronounced. As compared with corn produced with conventional tillage, some treatments caused a decrease in soil physical conditions, whereas other treatments improved them. Where the practices used cause a marked reduction in one or more of the physical conditions this portends a warning that these changes could eventually cause yield decreases. If this is true on the fundamentally very productive mollisols, it would be much more so on soils of lower quality. The farmer must stay forever vigilant to use the best management practices for his soil.