THE AGRICULTURAL SIGNIFICANCE OF THE TIGHT CLAY SUBSOIL OF SOUTHERN ILLINOIS

PROF. R. S. SMITH AND F. A. FISHER*
ILLINOIS AGRICULTURAL EXPERIMENT STATION

The upland prairie soils of 27 counties in southern Illinois, as well as considerable areas in other states located in the Glacial and Loessial Province, among which are Iowa, northern Missouri, and southern Indiana, have an impervious subsoil known as "tight clay." The exact nature of this impervious stratum, which averages from 8 to 12 inches thick, and lies at a depth of about 17 inches, has not been determined. Its impervious nature is probably due to a high inorganic colloidal content. The comparatively low agricultural value of this section of the state is due to the presence of the tight clay, because of its interference with underdrainage. The economic importance as well as the scientific interest of the problem presented by the presence of this unfavorable substratum is apparent, and the discovery of a method of ameliorating the unfavorable condition would in time add very greatly to the resources of the state as well as to the resources of similar sections in adjoining states.

The causes of this formation, so far as the writer is aware, are not well understood. One theory accounts for it on the assumption that the percolating water carried the fine particles down from the surface soil and deposited them in the subsoil. This theory does not account for the failure of this substratum to form excepting in limited areas in glaciated sections farther north in the state. The formation is apparently associated with a high water table. It is found to occur in the bottom lands and terraces as well as in the prairie uplands in practically every portion of the state, but only locally in the northern two-thirds, while it occurs almost universally in the prairie soils of the southern third, which comprises the area covered by the lower Illinoisan glacial lobe.

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*Mr. Fisher is now Farm Adviser in Wabash County, Illinois.

The recognition of the fact that a soil's response to tillage and fertilizer treatments is never satisfactory when poor drainage conditions exist led the Illinois Experiment Station to lay out four series of four tenth-acre plots each in Cumberland county in 1913 on an area typical of this type. Ground limestone was applied to all plots in the fall of 1913 at the rate of 4 tons to the acre, and finely ground rock phosphate was applied the following spring at the rate of 1 ton to the acre. The application of limestone is to be repeated every 4 years at the rate of 2 tons to the acre, and rock phosphate at the rate of 1 ton to the acre. A rotation of corn, soybeans, wheat, and sweet clover is used, and all residues are returned. The series which is to go in corn is plowed late in the fall, Plot one 5 inches deep, Plot two is subsoiled 12 to 14 inches deep, Plot three is plowed 12 to 14 inches deep with a Spalding deep tillage machine, and Plot four is dynamited and afterwards plowed 5 inches deep. The charges of dynamite are placed in the impervious stratum eight feet three inches apart each way on the dynamited plots of the first two series, and eleven feet apart each way on the dynamited plots of series three and four.

The moisture conditions are such that the soil in this section is supersaturated in the spring due to the impervious nature of the tight clay substratum. It was thought that if the tillage treatments or the dynamiting had remedied this condition, it should be reflected in a lower moisture content of the surface and subsurface strata during this period of supersaturation. Moisture equivalent determinations had previously been made and the plots found to be uniform in this regard.

Early in the spring of 1919, a preliminary series of ten borings per plot were taken from Plots 4, 7, 10, and 13. The samples were taken from systematically distributed points in four depths, as follows: O to 6, 7 to 12, 13 to 18, and 19 to 24 inches. The percentages of moisture found in the individual samples were averaged in groups of ten, five and three, for the purpose of computing the probable error of the averages as a means of determining the number of borings per plot necessary to get a representative average. The following formula was used for computing the probable error of the average.

$$P. E. = (—)0.8453 \frac{\Sigma (—) (V)}{\sqrt{n(n-1)}}$$

In which $\Sigma (—) (V)$ = the sum of the deviations from the mean, their sign being disregarded
n = number of borings entering the average.

It was at once found by inspection that three borings per plot were an insufficient number to give a reliable average, and the possibility of using this small number was at once abandoned. Tables 1 and 2 give the data secured in this preliminary work.

It will be noted that in Plot 4 the highest probable error occurred in the 7 to 12 inch borings, in Plot 7 in the surface borings, and in Plots 10 and 13 in the 19 to 24 inch borings. No explanation is apparent for the high variation found in the above named strata in Plots 4 and 7. In the case of Plots 10 and 13, the wide variations found in the moisture content of the 19 to 24 inch borings seem to be accounted for by the fact that the tight clay stratum does not occur at a uniform depth, and consequently some borings contained more of this material than others. This conclusion led to the abandonment of this plan of taking the borings at these arbitrary depths and the substitution, in all subsequent work, of the following depths: Surface, 0-8 inches, subsurface, 8 inches to the tight clay, subsoil, 6 inches of tight clay. These depths were chosen because they coincided with the very typical strata as they occur in this field.

During the spring of 1919, six sets of samples of 5 borings per plot were taken from Plots 1, 2, 3, and 4 of Series 100 and Plots 13, 14, 15, and 16 of Series 400. Series 100 had been plowed the preceding fall for corn and was undisturbed the following spring due to being too wet, until just prior to taking the last set of samples on June 19.

The plots of this series had received two tillage and dynamite treatments prior to this season's sampling, the first in the fall of 1914 and the second in the fall of 1918. Ap-

Table 1. Average Percent of Moisture, 10 Borings Per Plot. 1919.

Strata	Plot 4	Plot 7	Plot 10	Plot 13
0 - 6	30.8 (—) 0.48	29.6 (—) 0.36	27.4 (—) 0.79	30.9 (—) 0.23
7 - 12	29.4 (—) 0.67	28.3 (—) 0.30	25.2 (—) 0.71	28.7 (—) 0.27
13 - 18	28.5 (—) 0.58	26.3 (—) 0.26	26.0 (—) 0.72	27.7 (—) 0.38
19 - 24	30.4 (—) 0.57	27.2 (—) 0.35	29.6 (—) 0.83	31.6 (—) 0.67
Average 0 - 24	29.8 (—) 0.29	25.4 (—) 0.16	27.0 (—) 0.38	29.7 (—) 0.21

Note.—In this, and in all subsequent tables, the probable error is indicated by a dash in parenthesis, thus (—), instead of the plus and minus signs, as is customary.

Table 2. Average Percent of Moisture, 5 Borings Per Plot. 1919
Odd and Even Borings Averaged

Strata	Plot 4		Plot 7		Plot 10		Plot 13	
	Odd	Even	Odd	Even	Odd	Even	Odd	Even
0 - 6	31.0 (—) 0.76	30.7 (—) 0.63	30.1 (—) 0.62	29.4 (—) 0.35	27.0 (—) 0.55	27.8 (—) 0.23	30.9 (—) 0.20	30.8 (—) 0.43
7 - 12	30.2 (—) 0.84	28.7 (—) 0.98	28.7 (—) 0.33	27.7 (—) 0.55	25.1 (—) 0.98	25.3 (—) 0.52	28.6 (—) 0.32	28.1 (—) 0.57
13 - 18	28.7 (—) 1.00	28.4 (—) 0.74	27.0 (—) 0.41	25.8 (—) 0.38	24.7 (—) 0.84	25.3 (—) 1.00	28.3 (—) 0.66	27.1 (—) 0.37
19 - 24	30.2 (—) 0.76	30.6 (—) 0.95	27.8 (—) 0.36	26.0 (—) 0.43	29.5 (—) 1.37	29.7 (—) 1.16	32.5 (—) 0.96	29.6 (—) 0.62

proximately 5 months elapsed between the tillage and dynamite treatments of 1918 and the taking of the first regular set of samples on April 11, 1919.

The plots of Series 400 had been given the tillage and dynamite treatments in the fall of 1917 and had received but one such treatment. Tables 3, 4, and 5 contain the data obtained in this first season's work.

The probable error of the seasonal average (average of averages) is computed by means of the formula:

$$P.E. = (-)\ \frac{1}{N}\sqrt{n_1^2 e_1^2\ (-)\ n_2^2 e_2^2\ \cdots\ n_n^2 e_n^2}$$

In which N = total number of borings entering the average
n = number of borings in each average
e = probable error of average.

It will be noted that there is no significant difference in the moisture content of the differently treated plots of either series. The moisture content of Plots 2, 3, and 4 is higher in each case than that of the corresponding stratum in Plot 1. It seems apparent, however, that this fact must be attributed to soil heterogeneity rather than to treatment, for corresponding behavior is not found in Plots 14, 15, and 16 compared to Plot 13.

During the spring of 1920 this work was continued by taking four sets of samples from Plots 5, 6, 7, and 8. These plots had received the tillage treatment in the fall of 1915 and again in the fall of 1919. Fourteen systematically distributed borings per plot instead of five were taken during this season's work in order to increase the reliability of the average. The strata sampled were the same as in 1919. Table 6 contains the data obtained during this season's work.

It will be noted again that there are no significant differences in the moisture content of these plots in 1920 which had received a tillage treatment the previous fall and one in the fall of 1915.

It seems apparent that neither the subsoiling, deep tilling, or dynamiting have had any effect which is reflected in the moisture content of this poorly drained prairie soil.

Table 3. Average Percent of Moisture, 5 Borings Per Plot. 1919
Surface 0 - 7 Inches

Plot	1	2	3	4	13	14	15	16
April 11.......	21.5 (—) 1.55	24.9 (—) 1.56	24.3 (—) 0.59	25.5 (—) 0.90	27.4 (—) 0.09	29.3 (—) 0.33	27.1 (—) 0.65	27.5 (—) 0.86
April 25.......	18.8 (—) 1.40	22.0 (—) 1.54	20.8 (—) 0.48	21.2 (—) 0.83	21.2 (—) 0.52	23.6 (—) 0.52	20.5 (—) 1.00	21.6 (—) 0.62
May 19........	23.8 (—) 0.78	25.3 (—) 0.94	25.6 (—) 0.71	26.8 (—) 0.83	26.6 (—) 0.25	27.2 (—) 0.92	25.6 (—) 0.38	27.2 (—) 0.56
May 29........	25.3 (—) 0.39	26.3 (—) 0.68	26.1 (—) 0.41	27.0 (—) 0.66	27.2 (—) 0.22	27.1 (—) 0.20	26.0 (—) 0.46	26.3 (—) 0.37
June 2.........	20.1 (—) 0.38	20.9 (—) 0.58	20.3 (—) 0.99	21.8 (—) 0.96	24.5 (—) 0.22	25.6 (—) 0.29	23.7 (—) 0.80	25.1 (—) 0.61
June 19.......	17.4 (—) 0.56	18.0 (—) 0.58	18.4 (—) 0.44	18.1 (—) 0.65	22.4 (—) 0.26	23.7 (—) 0.16	22.4 (—) 0.85	23.9 (—) 0.35
Seasonal Av...	21.1 (—) 0.38	22.9 (—) 0.42	22.6 (—) 0.26	23.4 (—) 0.33	24.9 (—) 0.11	26.1 (—) 0.19	24.2 (—) 0.31	25.3 (—) 0.24

Table 4. Average Percent of Moisture, 5 Borings Per Plot. 1919
Subsurface—8 Inches to the Tight Clay

Plot	1	2	3	4	13	14	15	16
April 11.......	19.7 (—) 1.01	23.1 (—) 1.46	24.8 (—) 1.49	22.7 (—) 0.90	24.3 (—) 0.19	26.5 (—) 0.29	24.1 (—) 0.70	22.7 (—) 1.08
April 25.......	17.7 (—) 1.04	20.5 (—) 0.77	22.3 (—) 0.48	23.5 (—) 1.01	21.8 (—) 0.20	23.9 (—) 0.52	22.1 (—) 0.66	20.7 (—) 0.36
May 19........	20.8 (—) 1.29	23.2 (—) 1.02	25.7 (—) 0.63	24.0 (—) 0.83	24.8 (—) 0.21	25.9 (—) 0.26	25.6 (—) 0.98	23.5 (—) 0.71
May 29........	21.6 (—) 1.03	24.7 (—) 1.16	26.4 (—) 1.10	25.1 (—) 0.96	26.8 (—) 0.40	27.9 (—) 0.59	25.1 (—) 0.81	25.2 (—) 0.85
June 2.........	17.9 (—) 0.81	19.9 (—) 0.74	22.7 (—) 0.50	20.8 (—) 0.87	22.9 (—) 0.13	24.7 (—) 0.23	22.4 (—) 0.97	21.7 (—) 0.64
June 19.......	17.0 (—) 0.75	18.7 (—) 1.30	19.5 (—) 0.55	18.8 (—) 0.62	20.8 (—) 0.14	22.5 (—) 0.23	21.4 (—) 0.95	23.2 (—) 0.70
Seasonal Av...	19.1 (—) 0.41	21.7 (—) 0.45	23.6 (—) 0.35	22.5 (—) 0.35	23.6 (—) 0.09	25.2 (—) 0.15	23.6 (—) 0.35	22.8 (—) 0.31

Table 5. Average Percent of Moisture, 5 Borings Per Plot. 1919
Subsoil, 6 Inches of Tight Clay

Plot	1	2	3	4	13	14	15	16
April 11........	27.5 (—) 1.01	28.2 (—) 0.89	29.6 (—) 1.34	29.1 (—) 0.36	30.3 (—) 0.55	31.4 (—) 1.06	29.9 (—) 0.73	27.9 (—) 0.38
April 25........	26.4 (—) 1.05	28.5 (—) 0.77	28.3 (—) 1.14	26.2 (—) 1.00	26.8 (—) 1.00	29.4 (—) 1.14	28.7 (—) 0.46	28.3 (—) 0.56
May 19..........	25.2 (—) 0.85	29.1 (—) 0.55	29.9 (—) 1.09	28.6 (—) 0.56	29.8 (—) 1.10	30.7 (—) 0.91	29.7 (—) 0.49	28.2 (—) 0.77
May 29..........	26.0 (—) 0.77	29.1 (—) 0.58	30.1 (—) 0.79	28.4 (—) 0.61	29.9 (—) 0.84	31.3 (—) 0.84	29.4 (—) 0.61	29.5 (—) 0.62
June 2..........	25.9 (—) 1.20	28.9 (—) 1.08	29.4 (—) 0.70	27.8 (—) 0.64	25.8 (—) 0.85	29.2 (—) 0.74	28.6 (—) 0.82	27.8 (—) 0.72
June 19.........	26.7 (—) 0.99	27.5 (—) 1.52	28.6 (—) 0.58	28.4 (—) 0.56	26.9 (—) 1.38	29.8 (—) 0.87	25.1 (—) 1.32	26.8 (—) 1.72
Seasonal Av...	26.3 (—) 0.40	28.5 (—) 0.39	29.3 (—) 0.40	28.1 (—) 0.27	28.2 (—) 0.40	30.3 (—) 0.38	28.6 (—) 0.32	28.1 (—) 0.37

Table 6. Percent of Moisture, 14 Borings Per Plot. 1920

Surface 0 - 8 Inches.

Plot	5	6	7	8
April 30	29.4 (—) 0.33	29.3 (—) 0.24	27.2 (—) 0.16	29.4 (—) 0.27
May 7	27.5 (—) 0.35	27.8 (—) 0.25	25.8 (—) 0.22	29.8 (—) 0.18
May 15	28.2 (—) 0.50	28.2 (—) 0.25	25.1 (—) 0.25	29.2 (—) 0.21
May 21	28.9 (—) 0.28	28.3 (—) 0.27	26.1 (—) 0.20	28.4 (—) 0.28
Seasonal Av	28.5 (—) 0.19	28.4 (—) 0.12	26.1 (—) 0.10	29.3 (—) 0.12

Subsurface 8 Inches to the Tight Clay

Plot	5	6	7	8
April 30	25.0 (—) 0.44	22.9 (—) 0.34	23.8 (—) 0.16	24.2 (—) 0.26
May 7	23.3 (—) 0.40	22.0 (—) 0.32	22.9 (—) 0.20	24.6 (—) 0.23
May 15	24.1 (—) 0.46	24.1 (—) 0.30	23.7 (—) 0.18	25.1 (—) 0.29
May 21	26.3 (—) 0.34	25.7 (—) 0.41	25.5 (—) 0.27	25.9 (—) 0.18
Seasonal Av	24.9 (—) 0.20	23.9 (—) 0.17	24.0 (—) 0.10	24.9 (—) 0.12

Subsoil 6 Inches of Tight Clay.

Plot	5	6	7	8
April 30	28.1 (—) 0.43	25.6 (—) 0.44	25.8 (—) 0.31	26.1 (—) 0.21
May 7	27.5 (—) 0.37	25.4 (—) 0.52	25.3 (—) 0.27	26.9 (—) 0.01
May 15	27.3 (—) 0.51	27.3 (—) 0.35	25.2 (—) 0.28	26.3 (—) 0.22
May 21	28.9 (—) 0.18	26.3 (—) 0.19	26.0 (—) 0.32	26.1 (—) 0.26
Seasonal Av	27.9 (—) 0.20	26.1 (—) 0.21	25.6 (—) 0.14	26.3 (—) 0.10

Crop yield has also been taken as a criterion of effect and here also no consistent or significant difference in the yield of the various plots has occurred.

This information, while entirely negative, is of considerable value as a guide in planning future work which may lead to the discovery of a method of underdraining this extensive area. It also furnishes the Experiment Station with a sound basis upon which to base advice to farmers of this region regarding the advisability of purchasing subsoil or deep tillage plows, or of using dynamite in an effort to shatter and render more pervious the tight clay subsoil. These investigations, together with similar investigations which have been carried on at other stations, seem to point without question to the conclusion that the remedy for this unfavorable subsoil condition is not to be found in deep tillage or in the use of dynamite. Further investigation must determine whether a practicable remedy can be found. The problem is of such far-reaching economic significance that upon its successful solution depends, to a large extent, the material welfare of an extensive area in Illinois.

The possibilities of attack have not been exhausted and valuable information has been secured in the work thus far attempted. Future efforts, it seems, must first be directed toward a study of the exact nature and behavior of this plastic material, and then with this knowledge as a basis we will be in a position to attack the problem in the field more intelligently.

Discussion of Paper on "The Agricultural Significance of the Tight Clay Subsoil."

Mr. Haas asked whether the failure to have any effect through deep plowing, subsoiling or dynamiting might not be due to lack of underdrainage or tiling. In his own experience on a small scale in northern Ohio through dynamiting, from appearances, only, there seem to be a distinct gain in "drawing" power of tile as well as the growth of plants. In reply to the question whether the negative results obtained might not be due to the plowing down of the soil rich in humus and bringing to the surface of large quantities of gumbo, Mr. Smith replied that the color of the surface soil on the plots plowed with the deep tillage machine was distinctly changed, showing a mixing of the subsurface and subsoil with the surface, but that no such inversion has taken place on the subsoiled or dynamited plots, and that no effect on the drainage could be discerned on any of the plots.