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THE INFLUENCE OF TRUCK FARMING ON SOIL FERTILITY

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by

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Knowing the different elements which constitute the principal and essential parts of the soil on the one hand, and the requirements of the different plants on the other, it appears evident that various methods of farming influence soil fertility differently. A number of methods of farming have been studied at this station as to their influence on soil fertility. As a continuation of this kind of work, this thesis may be classified. Its object is to ascertain, if possible, the influence of truck farming on soil fertility.

For this purpose there were selected six cropped soils and their corresponding virgin soils taken from adjacent lots where crops have never been grown and where the topography, drainage and physical character were, as nearly as possible, the same as those of the cropped soils. These soils have been analyzed for carbon dioxide, organic matter, total nitrogen, total phosphoric anhydride and phosphoric anhydride soluble in N/5 nitric acid. The determination of carbon dioxide was made to show the variation in carbonate content of the soils. Phosphoric anhydride soluble in N/5 nitric acid is supposed to show the amount of phosphoric anhydride combined as calcium phosphate, since other phosphates, such as iron and aluminum phosphates, are not soluble in N/5 nitric acid to any extent. These soils have been cropped from 15 to 61 years

mostly to truck crops, and their histories are fairly well known. The histories are as follows:

No. 1054. Milwaukee. Cropped 51 years entirely to asparagus with good yields, except for last five years. Manuring, 30 loads of horse manure per acre every year. Black sand.

No. 1060. Milwaukee. Cropped 15 years the entire time to rhubarb. Average yield 22 tons per acre. Manured for the first twelve years at the rate of 45 loads per acre every year with horse manure containing a great deal of shavings. Rhubarb leaves after cutting always left on field. Black loam soil.

No. 1064. Milwaukee. Cropped 32 years. Potatoes 4 years, hay 4 years, corn 3 years, barley 2 years, cucumbers 7 years, cabbage 7 years and onions 5 years. Black loam soil.

No. 1073. Racine. Cropped 61 years. Cleared and broken, then seeded and pastured 10 years, then sowed to grain, at the same time seeded and used for hay and pastured 11 years. History for last 40 years is as follows; potatoes 12 years, strawberries 2 years, onions 6 years, cabbage 13 years, asparagus 7 years. Since 1867 manured about every other year at a rate of about 20 tons per acre. Heavy black loam.

No. 1089. Racine. Cropped 49 years. Cropped to onions the last 21 years without rotation. Cropping history during entire period is as follows; potatoes 9 years, 175 bushels per acre; wheat 7 years, 25 bushels per acre; oats 6 years; corn 1 year; strawberries 2 years; hay 3 years, 2.5 tons per acre;

onions 21 years, 600 bushels per acre; During last 21 years the field was manured every year at the rate of about 10 tons per acre. Before this it was manured about every three years with about 15 tons per acre. Black sand soil.

No. 1095. Racine. Cropped 29 years. The following crops were grown: onions 10 crops, average yield 600 bushels per acre; cabbage 1 crop, 10 tons per acre; corn, 2 crops fair yield; potatoes 2 crops, 200 bushels per acre; oats, 2 crops; red top hay 12 years, about 1.5 tons per acre. Manured every year for last 10 years at about 1.5 cars per acre. A car contains about 20 tons. The field also received 400 lbs. per acre of an onion commercial fertilizer on each of 3 years. Previous to the growing of onions, the field received 3 dressings of 18-20 tons of manure per acre. Black sandy loam soil.

As the records show, the above soils are practically all sandy soils. The two loam soils contain considerable sand. No. 1073 is the least sandy, and is well classified as heavy loam.

METHODS OF ANALYSIS

The methods employed for the determination of the various components of the soil, are described briefly as follows:

CARBON DIOXIDE.- 25 grams of 20 mesh soil were placed in a 500 cc. round bottom flask fitted with a rubber stopper through which were inserted a dropping funnel, a tube connected with two guard bottles containing potassium hydroxide solution, sp. gr. 1.27, and a third tube which led to a train of apparatus

consisting of a condenser, a U tube containing silver sulphate to absorb any chlorine evolved from the flask; a second U tube containing concentrated sulphuric acid to absorb water, and a third U tube containing calcium chloride for the same purpose as the preceding. Next came a Geissler bulb containing potassium hydroxide solution, sp. gr. 1.27, to absorb the carbon dioxide evolved, then a guard tube containing sticks of potassium hydroxide, and lastly an aspirator. By means of the aspirator about two liters of air were run through the whole apparatus, then the Geissler bulb was weighed and connected in its place. 75 cc. of eight per cent phosphoric acid were run through the dropping funnel into the flask which was heated to boiling until no more carbon dioxide was evolved. Then two liters of air were run again through the train of apparatus, the Geissler bulb cooled in a desiccator and weighed. The increase in weight was carbon dioxide.

ORGANIC MATTER.- The chromic acid method was followed and the same apparatus described above was used. Two grams of 20 mesh soil were placed in the flask, mixed with two grams of ignited quartz sand to dilute the mass and two grams of potassium dichromate; two liters of air run through and the bulb weighed as before. 50 cc. of concentrated sulphuric acid were introduced into the flask through the dropping funnel, heated until white fumes appeared, and then kept heated for eight or ten minutes more. Again two liters of air were run through, the bulb cooled in a desiccator and weighed. The increase

in weight multiplied by the factor 0.471 is organic matter. Where the soil was so sandy and contained so much organic matter that it separated from the rest, thus making it impossible to get fair, duplicate samples, 100 mesh soil sample was taken. This was done with soils Nos. 1054 and 1090.

PHOSPHORIC ANHYDRIDE.- The gravimetric fusion method was used. Two grams of 100 mesh soil were mixed thoroughly with fusion mixture in a platinum crucible, heated to fusion first in an ordinary Bunsen burner and then in a blast. After cooling, the melt was dissolved in dilute nitric acid, evaporated to dryness and silica dehydrated at 120 degrees C. dissolved again in dilute nitric acid and filtered. The filtrate was made alkaline with ammonium hydroxide, then acidified slightly with nitric acid, 10 grams of ammonium nitrate being added, and heated to 65 degrees C. 50cc. of molybdic solution were added to precipitate the phosphorus in the form of yellow ammonium-phosphomolybdate and the solution kept over night. Then the yelow precipitate was filtered, washed with a solution containing one per cent of nitric acid and 10 per cent of ammonium nitrate, and dissolved with ammonium hydroxide and hot water. The solution was acidified with hydrochloric acid, then made slightly alkaline with ammonia and cooled. 5cc. of magnesia mixture were added to precipitate the phosphorus in the form of magnesium-ammonium-phosphate and the precipitate allowed to settle over night. The precipitate was filtered through an ashless filter paper, washed until free from chlorides with 10 per cent ammonium hydroxide and finally dried and ignited

in a weighed porcelain crucible and weighed as magnesium pyrophosphate. In order to find the equivalent phosphoric anhydride, the factor 0.6376 was used.

PHOSPHORIC ACID SOLUBLE IN N/5 NITRIC ACID.- 25 grams of 100 mesh soil were treated with 250 cc. N/5 nitric acid in a flask fitted with a rubber stopper through which a tube over two feet long was inserted to serve as a condenser. The flask was placed in a water bath and heated to 40 degrees C. and maintained at this temperature for five hours, the flask being shaken every hour. The contents were filtered and from the filtrate two portions, 100 cc. each, were taken, made alkaline with sodium hydroxide and oxidized with bromine for several hours in a water bath, acidified with nitric acid, evaporated to dryness, silica dehydrated, etc. as in total phosphoric anhydride determination.

TOTAL NITROGEN.- 10 grams of 20 mesh soil were placed in a Kjeldahl flask with 10 grams of potassium sulphate, 0.7gr. of mercuric oxide and 30 cc. concentrated sulphuric acid and digested until the liquid appeared white, indicating that all organic matter was oxidized. After cooling 100 cc. of water were added and the flask allowed to stand for some time to settle. The supernatant liquid was decanted into another flask, 50 cc. of water added and let settle and decanted into the second flask. The same was repeated until the volume in the second flask was about 300 cc. About 40 cc. of potassium sulphide were added to the last flask, a few pieces of gran-

ulated zinc, 200 cc. of concentrated potassium hydroxide, and placed in a distilling apparatus and about 150 cc. distilled over. The distillate was received in a convenient amount of standard N/10 sulphuric acid and the excess titrated with standard N/10 ammonium hydroxide.

EXPLANATION OF TABLES

The result of the analyses of the virgin and cropped soils described above are given in Tables II, III, and IV. Table II needs no explanation as it shows the results in percentage as they were found in the laboratory. Likewise the first three columns of Tables III and IV.

The columns under the head of "Pounds per Acre, Estimated" are results taken from several calculations, the data of which are given below. The figures in the column headed "Excess of P_2O_5" were found by obtaining the difference between the per cent of phosphoric anhydride in virgin and cropped soils, and estimating the number of pounds of phosphoric anhydride in an acre eight inches deep. By a similar process the figures under the head "Excess of Nitrogen" in Table III have been derived. It has been assumed that an acre of sand, eight inches deep, weighs 2,500,000 pounds and of loam 2,000,000 pounds. In estimating the figures under the columns "Taken by Crops" the following data were used:

TABLE I

COMPOSITION OF CROPS RAISED IN ABOVE SOILS AND THE AVERAGE YIELD ASSUMED

Names of crops	Phosphoric anhydride in pounds	Nitrogen in pounds	Average yield Estimated
Asparagus(1)	0.80 per 1000	2.90 per 1000	1.5 T. to A.
Rhubarb(1)	0.20 " "	1.30 " "	
Potatoes(1)	0.70 " "	2.10 " "	5.0 " " "
Hay(Tim.)(1)	5.30 " "	12.60 " "	2.0 " " "
Cucumbers(1)	1.20 " "	1.60 " "	11.0 " " "
Cabbage(1)	1.10 " "	3.80 " "	25.0 " " "
Onions(1)	0.40 " "	1.40 " "	12.5 " " "
Strawberries(1)	1.10 " "	1.50 " "	3.0 " " "
Red top hay(1)	3.60 " "	11.50 " "	2.0 " " "
Corn(2)	0.50 " bu.	1.30 " bu.	30.0 bu. " "
Barley(2)	0.50 " "	1.00 " "	26.0 " " "
Wheat(2)	1.00 " "	1.75 " "	14.0 " " "
Oats(2)	0.36 " "	1.00 " "	33,0 " " "

(1) Year Book, U. S. Dept. of Agric. 1894.
(2) Bull. 47 Minn. Exp. Sta.

The figures for average yields given in Table I, were used when the exact or aproximate yields were not recorded in the history of the soil.

In estimating the amount of phosphoric anhydride and nitrogen taken by crops from soil No. 1073, the 21 years during which it was pastured, were not taken into consideration, as it was assumed that what was taken by the cattle was returned through their manure.

In estimating the number of pounds of phosphoric anhydride and nitrogen added to the soil through manure and onion fertilizer, it was assumed that one load, or one ton, of manure contained 7 lbs. of phosphoric anhydride and 10 lbs. of nitrogen and that the onion commercial fetilizer contained 10 per

cent of phosphoric anhydride and 7 per cent of nitrogen.

The figures in the columns of the Tables III and IV have been derived by subtracting the sum of "Excess of P_2O_5 (or N) in cropped soil" and the number of pounds "Taken by crops" from the number of pounds "Added in manure and fertilizer." Where the figures under "Excess of P_2O_5 (or N)" are negative, it means that the virgin soil is richer than the cropped, and to derive the last column, the number of pounds "Taken by crops" is subtracted from the sum of "Excess of P_2O_5 (or N) in virgin soil" and the number of pounds of P_2O_5 (or N) "Added in manure and fertilizer."

In obtaining the history of soil No. 1064, the amount of fertilizer or manure added must have been overlooked. Truck farmers almost without exception apply large quantities of manure, and the excess of phosphoric anhydride in the cropped soil over the virgin soil brings out this fact. For this reason soil No. 1064 was not considered in taking the average of the results in the last two columns of Tables III and IV.

The "Averages" are the arithmetical averages of the various columns of the results.

TABLE II

CARBON DIOXIDE, ORGANIC MATTER AND SOLUBLE PHOSPHORIC ANHYDRIDE IN TRUCK SOILS

Lab. No.		Per cent of CO_2 in		Per cent of org. matter		Per cent of P_2O_5 by N/5 HNO_3	
Virgin-Cropped		Virgin	Cropped	Virgin	Cropped	Virgin	Cropped
1055	1054	0.79	0.46	7.87	9.72	0.068	0.179
1061	1060	.35	.22	8.82	7.36	.036	.069
1065	1064	.08	.63	8.57	7.05	.019	.037
1074	1073	.07	.17	9.34	6.53	.011	.045
1090	1089	.06	.05	6.48	3.69	.016	.028
1096	1095	.25	2.07	6.45	7.51	.009	.058
Average		.27	.60	7.92	6.98	.027	.069

DISCUSSION OF RESULTS

In Table II it is to be noted that the carbon dioxide in cropped soils tends to increase. The increase is more noticeable in all but one loam soil, No. 1060, while in soils Nos. 1054 and 1089, which are sandy, there is a loss of carbon dioxide. This appears clear knowing that sands have little absorptive power and consequently such soluble salts as calcium and magnesium carbonates are leached out easily. The abnormal per cent of carbon dioxide for soil No. 1095 is striking. It is not reasonable to suppose that such increase has come from the addition of manure, but it seems more probable that in collecting the sample from the field a piece of limestone might have been struck by the sampler. But even without this particular result, the average of the five

cropped soils, is 0.31 per cent over 0.27 per cent for the virgin soils.

The percentage of organic matter, on the other hand, has decreased in the cropped soils and this fact is to be expected when their carbon dioxide content has increased. In the decomposition of organic matter, the calcium salts which originally were found in the plant, are returned to the soil in the form of carbonate(1). Of course, this is not the only cause of increase in carbon dioxide content of these soils, for the excessive manure which they have received is responsible for most of it. The percentage of organic matter in cropped soils shows a decided decrease in all but two cases. In one of these exceptions the increase over the virgin soil is rather small, 0.06 per cent, while the other is considerable, 0.85 per cent over the virgin. In the latter an exceptionally large amount of manure has been added every year. The average, however, of the six cropped soils shows a decrease of 0.94 per cent of organic matter which is considerably less than in soils where crops have been grown for many years and not much attention has been paid to the conservation of the organic matter.

In the last column of Table II, it is seen that the amount of calcium phosphate has considerably increased in the cropped soils. The gains are proportional to the total per-

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(1) Hall & Miller, Proc. Roy. Soc. B. Vol. 77 (1907).

centage of phosphoric anhydride in the same soils. An interesting fact to be noted is that the average gain of phophoric anhydride soluble in N/5 nitric acid of cropped soils over the virgin soils is 0.044; the average gain of total phophoric anhydride of cropped soils over the virgin soils (as it is seen in Table III) is 0.06. This means that a greater part of the phophoric anhydride added in the manure was soluble in N/5 nitric acid, in other words is largely calcium phophate.

TABLE III

INFLUENCE OF TRUCK FARMING ON PHOPHATE CONTENT OF SOILS, SURFACE EIGHT INCHES

Lab. No.		Per cent of P_2O_5 in		POUNDS PER ACRE, ESTIMATED			
Virgin	Cropped	Virgin soil	Cropped soil	Excess of P_2O_5 in virgin =- cropped =+	Taken by crops	Added in manure and fertilizer	Loss above crop
1055	1054	0.27	0.36	+2250	122	10710	8338
1061	1060	.21	.23	+ 400	132	4095	3563
1065	1064	.17	.26	+1800	804	0	-2604
1074	1073	.21	.26	+1000	246	2800	1554
1090	1089	.04	.09	+1250	672	2415	493
1096	1095	.10	.20	+2000	382	2619	237
Average		.17	.23	1450	393	4528	2837

In looking over Table III, it is seen that there is a marked increase of total phosphoric anhydride in cropped soils. The gain is shown not only in the average but in every case. In estimating to pounds per acre, it gives the considerable average of 1450 pounds of phosphoric anhydride. The next col-

umn shows that truck crops do not remove much phosphoric anhydride. As can be seen in this table and in the history, these soils have been manured quite heavily, and, as a result of this practice, almost 3000 pounds of phosphoric anhydride have been lost. The average loss of phosphoric anhydride in the manure added to the field, is about 63 per cent. It is to be noted that soils Nos. 1054 and 1060 which have received the largest amount of manure, suffered the greatest loss. It can be considered that soils Nos. 1089 and 1095 suffered practically no loss in their phosphoric anhydride content, for the figures 493 and 237 pounds fall within the limit of error in analytical work, which limit is 0.02 per cent in case of phosphoric anhydride. This means 500 pounds per acre for sands and 400 pounds for loams. Although the average loss of phosphoric anhydride per acre is considerable, the fields, unlike those where tobacco was grown (1) with heavy application of manure, have retained rather large quantities of this important element.

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(1) Wis. Agr. Exp. Sta. Research Bull. No.2, page 49.

TABLE IV

INFLUENCE OF TRUCK FARMING ON NITROGEN CONTENT OF SOILS, SURFACE EIGHT INCHES

Lab. No. Virgin	Lab. No. Cropped	Per cent of N in Virgin soil	Per cent of N in Cropped soil	POUNDS PER ACRE, ESTIMATED Excess of N in virgin =- cropped =+	Taken by crops	Added in manure and fertilizer	Loss above crop
1055	1054	0.425	0.475	+1250	444	15300	13606
1061	1060	.420	.365	-1100	858	5850	6092
1065	1064	.453	.394	-1180	2206	0	1026
1074	1073	.535	.346	-3780	3011	4000	4769
1090	1089	.211	.184	- 675	1761	3450	2364
1096	1095	.316	.444	+2560	1244	3654	- 150
Average		.394	.368	- 488	1587	6451	5336

Table IV shows a large loss of nitrogen and is almost twice as much as that of phosphoric anhydride. Moreover, the average per cent of nitrogen in cropped soils is less than the original in virgin soils. This means that the soils were not able to retain the nitrogen in the large amount of manure applied to them. The next thing to be noted in this table is that truck crops remove about four times as much nitogen as phophoric anhydride from the field, but still they are not able to take all of the nitrogen added in manure and fertilizer nor to aid the soil in retaining this nitrogen. 82 per cent of the amount added in the manure was lost.

It is observed in Table III that soil No. 1095 suffered practically no loss of phophoric anhydride; in the case of its nitrogen content, a negative figure has resulted. This

means that there was more nitrogen in cropped soil than there was added. This is absurd, but the negative figure can be overlooked as it falls within the limit of error in analytical work. It is to be noted that soils Nos. 1054,1060 and 1073, where truck crops only were grown with large applications of manure, have suffered the greatest loss of both nitrogen and phophoric anhydride; and that soils Nos. 1089 and 1095, where besides truck crops, grain and hay crops have been grown, the least loss has occured.

CONCLUSION

From the above work there may be drawn the following conclusions;

1. Truck farming results in an actual loss of organic matter but an increase in carbonates and available phosphoric anhydride.

2. Heavy manuring in truck farming adds to the store of phosphoric anhydride in the soil but its excessive application results in a great net loss.

3. Truck farming tends to maintain the nitrogen in the soil, but does not prevent a very large net loss.

4. A ratio cannot be determined, but it appears clear that the larger the quantities of manure added, the greater the loss of both phosphoric anhydride and nitrogen.

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