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SOILS.

THE COMPOSITION OF NATIVE AND CULTIVATED SOILS AND THE EFFECTS OF CONTINUOUS CULTIVATION UPON THEIR FERTILITY.

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THE COMPOSITION OF NATIVE AND CULTIVATED SOILS, AND THE EFFECTS OF CONTINUOUS CULTIVATION UPON THEIR FERTILITY.

BY HARRY SNYDER.

Nature and Extent of the Work.—During the past two years, 1892-1893, chemical analyses have been made of many of the cultivated and uncultivated soils of the state. Some of these soils have been under continuous cultivation from one to thirty-five years, while others from adjoining fields have never been under the plow. The conditions for comparison between these cultivated and uncultivated soils are particularly favorable, especially the prairie soils and portions of the Red River Valley region, where there are townships in which the soil is even and uniform, except that some sections and quarter sections have been under cultivation for a longer period than others. The differences in composition between these cultivated and uncultivated soils are marked, as well as the effects of different methods of treatment; both topics are discussed in this bulletin.

The soils that are represented in this bulletin have been sent in mainly by the farmers of the state, some have been received from the students of the Minnesota School of Agriculture, while a few have been taken by members of the station corps. In all cases the soils have been taken according to uniform directions sent out from the station laboratory. The farmers have taken much care in the sampling of many of these soils, and to them credit is due for their share in this work.

Along with the samples of soil have come a number of important questions: "Will this soil wear well?" "Why does small grain lodge so badly on this kind of soil?" "Does this soil contain enough of all of the compounds essential for the growth of our farm crops?" "Is there enough phosphates in this soil for successful wheat growing?" "Why do our old and cultivated soils dry out so much more readily than new soils?" "What is the alkali in this soil and how can it be cured?" "Is the lessened yields of wheat for the past few years due to the giving out of the soil?" These, and many more of the same nature, are the questions that the farmers send in with their samples of soil.

We are well aware of the various views that are held in regard to the value of soil analyses, and it is not the intention in this bulletin to enter into the discussion. The complete chemical and physical analyses of the native and cultivated soils, however, have given valuable information as to the effects of continuous cultivation and different methods of rotation that will be of benefit to the farmers.

In all, about one hundred and fifty samples have been analyzed, and in this bulletin only a few typical cases are selected in order to illustrate the various points under discussion. These points have been verified in a number of similar cases so that the reader in following this work is not considering just one single case as it might appear, but the results of a number of similar cases. Long tables and pages of chemical analyses, necessary as they are, do not make very good general reading matter, and in this report they are embodied as little as possible.

Analyses have been made of both the top and the sub-soil, in all cases; the top soil has been taken down to a depth of about nine inches, or until a change in color between the soil and sub-soil was observed. The sub-soils furnish such a large amount of plant food that their chemical and physical properties are equally important as in the case of the top soil.

At the outset, it can be said that our soils, with some exceptions, are well supplied with all of the necessary mineral food for farm crops, in forms that can be rendered available by good cultivation, provided that the soils are kept in good condition by grass crops and rotation so that the plant food is present in available conditions.

RED RIVER VALLEY SOILS.

The average top soil in the Red River Valley ranges from eighteen to thirty-six inches in depth, is black in color, very sticky when wet, and when dry it crumbles to a very fine powder. The particles which compose this soil are very fine; all are less than 1/40th of an inch in diameter, and in some cases even less than 1/100th of an inch. There are no coarse particles (skeleton) in most of these soils. The native soils are very rich in decaying vegetable and other organic matters, largely due to the accumulation of the crop residues of the native grasses. When these vegetable and other organic matters have reached an intermediate point in their decomposition, they form a class of valuable compounds known as humus, and when the virgin soils are cultivated for a number of years, the humus is gradually consumed by being still farther decomposed. In the uncultivated soils there is usually about five per cent of humus, while in the cultivated soils there is usually less than three per cent. The humus is very rich in nitrogen, the important building material out of which the gluten in wheat and grains is constructed; and when the humus decreases the nitrogen decreases as well and is lost from the soil. The native soils contain from .35 to .40 of a per cent of nitrogen, while the soils that have been under continuous cultivation for twelve or fifteen years, contain from .2 to .3 of a per cent. This is a very unfortunate occurrence because nitrogen is the most expensive material of all of the elements necessary for plant food.

The effects of the humus on the capacity of the soil to retain its water and withstand the evil effects of drought are marked; the native soils will retain about twenty per cent more water than the long cultivated soils, and will not dry out as readily during droughty seasons as the older and long cultivated soils. Another important point: when the humus is taken out of the native soils during the process of analyses, from .06 to .08 of a per cent of phosphoric acid is soluble and associated with it; while only about .02 of a per cent is in this form with the long cultivated soils. Phosphoric acid in this form is very valuable as plant food. There is a good supply of phosphates in all of these soils, but we must keep up the supply of humus in order to keep the phosphates available.

In the analyses reported, the average amount of potash is given as about one-half of one per cent,—this is not the total potash that is in these soils, in fact there is about one and three-quarters of a per cent in all, but one and a quarter per cent, or over two thirds of the total cannot be counted upon for crop purposes because it is combined with the silica (sand) in the form of minute stony particles, that require the strongest chemicals and the highest heat that can be procured in the laboratory to decompose them. The tables only give the amounts of plant food that are soluble in hot muriatic acid, and is just about the amount that plants can reasonably be expected to procure. Each sample has been analyzed twice, and in some cases three times, using solvents that possess different degress of solvent power, in order to determine the forms in which the mineral matters are present in the soil. The results given are based on all the analyses and not simply on just those that are reported.

There is not a great deal of true sand in these soils; in some localities there is more than in others. None of the soils that are reported, except those that are some distance east of the river, contain more than two per cent of true sand; nearly all of the silica is combined with the aluminia to form clay, or with the potash, soda, and lime to form complex silicates. The lime is present mainly in the form of carbonate of lime—limestone particles, a little is in the form of gypsum. All of these soils are well supplied with lime and magnesia, especially the sub-soils that have a greyish color usually contain from 20 to 30 per cent of lime and magnesium carbonates. It is partly due to the abundance of lime in these soils that they owe their remarkable fertility. The dry soils range in weight from 62 to 66 pounds per cubic foot. The native soils contain more of organic matter and weigh less than the well cultivated soils. In the native soils there are from 8 to 15 pounds of organic matter in every 100 pounds of the air-dry soil, while with the long cultivated soils there are from 5 to 8 pounds of organic matter per 100 of soil. The 85 to 90 pounds of mineral matter in the native soils does not always contain quite as much mineral matter as the 95 pounds in the long cultivated soils. The samples are not compared on quite equal bases to show the full extent of the losses during cultivation because in the cultivated soils, the aluminia, iron oxide, etc., appear to increase; this is because the humus is decomposed and decreases so rapidly. If the cultivated and uncultivated soils were all calculated to a uniform basis as to the amount of humus, that would not represent the true conditions of the present state of the soil, and would require a duplication of all of the tables in this work, which is not necessary; but even allowing this factor, the losses of the phosphates, potash, and particularly the nitrogen are quite noticeable. The cultivation of these soils has aided in the decomposition of the silicates, but the drafts of the grain crops have been greater than the amount that is annually liberated.

The potash, soda and aluminia and a part of the lime, are present in the form of double hydrated silicates, called zeolites—forms that are available for plant food, and yet insoluble in water and not easily lost from the soils.

The use of commercial fertilizers by Prof. Hays in 1890, on these soils, did not show any marked increase in the yield of grain, and yet neither the fertilized nor the unfertilized plots gave as heavy yields as when the ground was first broken. The fertilizers used did not supply any humus, and the mineral food that was supplied in the fertilizer did not increase the yield of grain. Both analyses and fertilizer experiments show that these soils are well supplied with mineral food, but the analyses show that the humus is decreasing.

The continual cropping of these soils is not telling so heavily on the mineral matters as it is on the humus that is in the soil, and with the loss of humus follows the decrease in nitrogen, the capacity of the soil to retain its water and withstand drought, and finally in the loss of the phosphoric acid in available forms. The crop residues from grain crops is not active enough in decomposing to serve as humus. The supply of humus can be kept up by occasional grass crops, well prepared farm manures, and occasional green manuring.

These are points that are to receive their due attention from the present agriculturist of the station.

Alkali Soils.—In this region little patches of alkali, an eighth of an acre or so in size, are occasionally observed. These alkali patches are sources of trouble, because in the spring of the year when the land is wet these patches can not be observed, and consequently much labor and seed is spent upon them without any immediate returns. The alkali in one of these soils near Crookston was found to be sodium carbonate. The alkali was all near the surface. These plots should be ploughed very deep and the land well drained. Heavy manuring, especially with horse manure that is well rotted, gives good results. The horse manure when it decomposes furnishes humic and other acids that unite with the alkali. The humus also prevents rapid surface evaporation, and thus aids in preventing the alkali from accumulating near the surface. When horse manure can not be procured, green manuring will be beneficial. This method of treatment has been followed by a number of people in this region, and the results have been "large yields per acre of wheat and oats." When these alkali spots are well cured they are excellent soils, and will withstand drought even better than many other soils. The analyses of an alkali soil is given in the table.

Occasionally the alkali consists of sodium sulphate, commonly known as Glauber's salt, and then again of common salt. These last two substances are not so difficult to contend with as the sodium carbonate (salsoda). When these patches are located so that they can be well drained at comparatively little expense, this should be done, and it will be found to be one of the best and most permanent ways of relief. These alkaline compounds are all soluble in water, and thus in time will be washed out of the soil, provided that the spots are well drained. Where the spots are small, a large amount of the alkali can be removed by scraping off the top in dry times and carting the alkali scrapings away. In very dry times the first inch of the soil will contain from 20 to 30 per cent of the total alkali that is in the soil. The deep ploughing affords relief by removing the alkali from the surface where it destroys the young and tender roots of plants.

These soils will improve with every crop that is removed; and when cured will produce crops that will repay all of the time and labor that has been spent.

Gumbo Soils.—This is the popular term applied to a certain class of very heavy soils, that are "waxy" when wet and through which water percolates with much difficulty. The particles that compose these soils are very fine, less than 1/100th of an inch in size; there is no true sand present. These soils are rich in alkaline compounds, particularly potassium salts. It is the alkali in these soils that gives rise to the soapy and waxy appearance and "feel" when wet. They fail to scour the plow on account of the absence of true sand and the fineness of division of the soil particles. There is too much of the rich alkaline salts present. Lime fertilizers and amendments are not applicable to these soils as they will only make matters worse by rendering the soils more waxy. As yet, no cheap chemicals can be suggested for their improvement. They will improve with cultivation, the deeper the better, and with the loss of the alkali from the soil that is removed in the crops. They are especially adapted for grass and hay crops.

Marshy and Peaty Soils.—The soils from the low marshy places along the water courses are unusually rich in organic matter. They are easily reclaimed on account of the large amount of lime that is present that prevents the formation of "sour mould." One peaty soil contained over fifty per cent of organic matter; it would not require much more combustible matter to make a good fuel peat. There are large tracts of this land being opened up by making large drains through the Beltrami and other marshes.

In the table of analyses reported, the figures given are the number of pounds, or fractions thereof, of potash, lime, etc., that are present in every hundred pounds of the soil, or the amount that is in every one and two-thirds cubic feet of these soils. The figures show that in every hundred pounds of the top soils, there is on the average, a little over half a pound of potash, two and one half pounds of lime, over a third of a pound of phosphates and nitrogen, together with larger amounts of silica, aluminia, etc.,as noted in the table. No exact figures can be set down as to just how much or how little every soil should contain, suffice it to say, however, that all of the necessary mineral elements are present in much larger amounts than the limits usually allowed for any one compound.

Soil samples number 298, 299, 203, and 204 were taken from Marshall county, about five miles west from Warren. Sample 203 has never been under the plow while 298 is from an adjoining plot that has been under cultivation for ten years. Analyses of the corresponding sub-soils are given.

Soil samples 202, 205, 236 and 237 are from Polk county, four miles west from Crookston in the direction of Fisher; 202 is a sample of native soil, while 236, from an adjoining plot, has raised ten crops of small grain. The composition of the corresponding sub-soils is given; sample 201 is a fair example of "alkali soil," taken a short distance east from Crookston, while 272 is a type of "Gumbo," taken north-west from Crookston.

Prof. Hays,who has had much experience in the working of these soils from the Red River Valley says "that they do not puddle and bake like many clay soils, that when puddled and then dried, a little rain, or even the moisture absorbed from the air will cause the lumps to slake like lime."

TABLE I.—SOILS FROM THE RED RIVER VALLEY.

Kind of Soil / Where from	Native. Warren.		Cultivated. Warren.		Native. Crookston.		Cultivated. Crookston.		Native. Crookston.		Native. Barnesville.	
Top Soil or Sub-Soil	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Alkali	Gumbo	Swam-py	Peaty
Number of Soil	203	204	298	299	202	205	236	237	201	272	206	207
Weight per cubic foot	62	65	64	65	58	63	60	63	65	65.	39	35
Fine Earth	100	100	100	100	100	100	100	100	100	100	....	....
Skeleton	....	....	....	....	....	....	....	....	....	....	....	....
Humus	5.34	.89	3.02	.78	5.16	.81	2.87	.74	....	5.16	5.94	5.88
Capacity to retain water	75.	63.	58.	62.	71.	54.	64.	54.	....	59.	139.	130.
Total Nitrogen	.38	.11	.25	.11	.41	.11	.20	.11	....	.38	.52	.49
Phosphates associated with Humus	.07	.02	.03	.01	.06	.06	.03	.01	....	.03	.06	.02
Insoluble Silica and Silicates	47.64	41.21	55.12	40.26	60.20	39.17	58.48	37.25	73.16	60.21	14.33	12.60
Combined Silica	15.43	8.37	16.92	8.98	9.82	15.09	13.05	15.72	10.54	9.00	5.37	5.80
Potash	.54	.25	.50	.20	.60	.60	.54	.61	.65	.90	.44	.40
Soda	.45	.48	.41	.46	.41	.46	.45	.42	1.05	.61	.30	.21
Lime	2.44	7.45	2.40	7.67	2.55	8.10	2.49	7.92	.85	1.07	23.27	12.20
Magnesia	1.85	4.48	1.91	4.62	.67	2.04	.62	2.12	.82	.84	.80	.64
Iron (Oxide)	4.18	3.48	4.20	3.51	4.00	3.98	4.04	4.02	1.98	3.49	.55	.42
Aluminia	7.89	10.72	8.81	11.76	8.10	13.61	8.15	13.50	5.50	9.15	2.70	1.60
Phosphates	.38	.17	.31	.15	.29	.22	.24	.24	.22	.13	.30	.21
Sulphates	.11	.10	.10	.10	.11	.06	.11	.10	.07	.11	.75	.22
Carbonates	2.42	14.26	2.45	14.64	4.51	13.27	4.40	13.24	.63	.13	23.00	12.60
Chlorides	.03	.04	.02	.04	.02	.03	.02	.03	.07	.01	.09	.04
Volatile	15.55	6.22	5.58	6.20	8.10	3.20	5.48	4.22	3.90	14.29	27.72	52.60
Total	98.91	97.23	98.73	98.59	99.38	99.85	98.17	98.39	99.64	99.94	99.62	99.50

In order to complete the series, three additional types of soil are added. One from Twin Valley, Norman county, of a sandy nature, which is particularly noticeable as regards the combined silica This soil has produced seven crops of wheat and oats with one year of fallow. Samples 308 and 309 are from Gossen, Polk Co.; this soil has raised eight crops of grain. It is not as sandy as the sample from Twin Valley; the sub-soil is more of a clayey nature. The sample from Moorhead is a type of the soils near the river, it has raised six crops in all, and in chemical composition is more like the soils from the places given in the following table.

TABLE II.

Where from	Twin Valley.		Gossen.		Moorhead.	
Top Soil and Sub-Soil Number of Soil	Top 306	Sub 307	Top 308	Sub 309	Top 275	Sub 276
Weight per cubic foot	81.	87.7	75.8	85.	65.2	65.2
Fine Earth	100.	100.	98.	98.	100.	100.
Skeleton	....	....	.02	.02	....	....
Humus	2.12	....	3.16	....	4.04	....
Capacity to retain water	48.	39.	57.	43.	70.	56.
Total Nitrogen	.14	.06	.25	.09	.37	.17
Phosphates associated with humus	.03	....	.03	....	.05	....
Insoluble sand and Silicates	87.74	90.36	74.36	66.53	59.19	45.06
Combined Silica	3.41	3.19	5.44	14.11	12.02	16.43
Potash	.18	.17	.30	.30	.73	.81
Soda	.21	.18	.18	.20	.44	.27
Lime	.48	.44	1.20	1.22	1.29	8.84
Magnesia	.25	.24	.80	.74	.39	3.02
Iron Oxide	1.41	1.38	2.30	3.52	4.07	4.22
Aluminia	1.63	1.67	4.77	6.31	9.33	10.20
Phosphates	.13	.20	.19	.20	.20	.27
Sulphates	.13	.10	.11	.06	.09	.09
Carbonates	....	....	.14	.11	.10	7.22
Chlorides	.01	.01	.01	.01	.01	.01
Volatile	4.50	1.72	9.67	5.30	12.05	2.61
Total	100.08	99.66	99.47	98.62	99.91	99.04

WESTERN AND CENTRAL PRAIRIE SOILS.

The prairie soils of the Western and Central portion of the state differ quite materially in the way in which the plant food is stored up, as compared with the soils from the Red River Valley region. The soil particles are a little larger, and there is more silica in the form of sand. Some of the soils are of a more sandy nature than others, and in some localities a number of different types of soil will be found on the same farm. In the soil work, it has been the aim to include samples of all of the types. The most general type that we have to deal with is the black prairie soil ranging from one to three feet in depth resting upon a layer of yellow clay. The top soils are lighter and weigh from 70 to 75 pounds per cubic foot when perfectly dry; when of a sandy nature the weight is greater. The yellow sub-soils range in weight from 75 to 85 pounds per cubic foot, depending upon the proportion of sand and clay that is present.

These soils are quite well supplied with lime, although not to such a liberal extent as the soils already referred to; there is a sufficient amount, however, for all ordinary demands provided that the soils are not too severely taxed in any one line of crop raising. The sub-soils are somewhat better supplied with both potash and lime than the top soils, while the top soils are more liberally supplied with phosphates, humus, and nitrogen. In the management of farm crops this fact should be kept well in mind, and the crops rotated in such a way that the potash and lime in the subsoil, and the phosphates and nitrogen in the top soil are alternately and evenly drawn upon. Clover, provided its growth is made a success, is an excellent crop for this purpose, also field peas.

The continuous cropping of these soils is telling upon the humus in the same way as with the soils already referred to. In some cases the nitrogen is less than .20 of a per cent. As a good illustration of this point, take for an example, the sample of prairie soil (No. 224, Table III.) that has never been under cultivation, compare it with sample No. 312 taken from an adjoining plot that has raised ten successive crops of wheat and note how the humus and total nitrogen have decreased, a smaller amount of phosphates associated with the humus, and finally how the soil has decreased in ability to retain its water.

The loss of the humus and the other organic matters from the cultivated soils will soon be felt in another way. When the humus and other organic matters decompose they furnish liberal amounts of carbon dioxide to the air that is in the pores of the soil. This carbon dioxide, the same gas that is given off in respired air, acts upon the complex mineral matters and aids in rendering them available as plant food. In one sample of native prairie soil containing four per cent of humus, there was produced during the six months' trial, .84 per cent of free carbon dioxide, over twenty times the amount that is in the air that we breath. A sample of long cultivated soil with 1.84 per cent humus, gave .21 per cent carbon dioxide, while a sample of sandy soil with but little organic matter gave only .09 of a per cent of carbon dioxide. The humus in the soil aids in keeping up the supply of carbon dioxide, which is one of the active chemical agents that renders the plant food available.

Since the nitrogen decreases so rapidly in the cultivated soils, we naturally ask—"what becomes of it?" One of the chief causes of the rapid decrease of the humus and nitrogen from the new soil, is the unusual activity of the micro organism in these soils in producing nitrates and nitrites. This is extremely beneficial to the growing crop while it lasts, but the trouble is, it is too active at first, producing too rank a growth of straw, and then is not active enough when the soils become older. These micro organisms which take such an important part in rendering plant food available, perform their work under the most favorable conditions, being well supplied with phosphates, nitrogenous matter, lime, and other alkaline compounds. The soil extracts (leachings) from ten samples of soil produced nitrification in a sterile ammonium chloride solution in from one to five days.

The indirect action of land plaster (gypsum) on these soils in liberating plant food, particularly potash and phosphoric acid, is unusually marked. Experiments conducted in the laboratory have shown that small amounts of gypsum are quite active in rendering potash, phosphoric acid, and even nitrogen soluble in the soil water. It is not the land plaster, itself, that furnishes the food, but it is the power that it possesses in making the mineral matters available, that are already in the soil. Land plaster acts more as a stimulant and not as a direct fertilizer, and if not used to excess it will be a profitable fertilizer to use on these soils especially to bring in grass and clover.

The association of the phosphates and the humus in these soils is marked. In the native soils from .05 to .06 of a per cent of phosphates is associated with the humus, while only .01 to .02 of a per cent is present in that form in the continuously grain cultivated soils.

Soil sample number 224 is a good type of the native prairie soil. It is from Marshall, Lyon county, and has never been under cultivation, while sample 312 has been under continuous, cultivation mainly to wheat, for ten years. Sample number 222 is from Sleepy Eye, Brown county, and has raised five grain crops with one year fallow. The soil from Sacred Heart, number 259, has been cultivated for twenty-two years. Instead of continuous wheat, oats, corn, and other grains have been grown, with an occasional grass crop, and frequent applications of farm manures. Although there is no native soil from the same locality to compare it with, yet the humus and the nitrogen in this soil are as high as in most of the soils that have produced only half as many crops. The good treatment of this soil has shown itself as plainly as the good treatment of a farm animal.

Soil number 249 is a sample that has produced flax for a number of years, "until the flax won't grow any more." The total nitrogen is a little lower than in most of the soils of this nature, but the amount that remains would be called very high for some localities, and is far from indicating an exhausted soil.

Sample number 298 is from Grafton, Sibley county; it has produced seven crops including one crop of flax, and has been fallow one year.

Another type of soils frequently met with, is the reclaimed soils bordering on the edges of the numerous lakes of the central portion of the state, and those soils that are commonly known as old lake bottoms, formed by the filling up and draining of old lakes and water courses. Two types of these soils are given. Number 326 is reclaimed land from the border of the lake at Worthington, Nobles county, and has been under high cultivation for about nine years, and in addition to its stock of native fertility has received very liberal dressings of farm manure. Soils of this class are particularly rich in limestone, the sub soil frequently containing from twenty to thirty per cent of this material.

TABLE III.—WESTERN AND CENTRAL PRAIRIE SOILS.

Kind of Soil	Native Prairie.		Cultivated.		Cultivated.		Cultivated.		Old Flax Soil.		Prairie.	
Top Soil or Sub-Soil	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub
Number of Soil	224	225	312	313	222	223	259	260	249	250	298	299
Weight per cubic foot	72.	78.	74.	81.	70.	76.	72.	78.	85.	94.	71.	75.
Fine Earth	98.	98.	92.5	91.	93.	93.	94.	93.	100.	100.	97.	95.
Skeleton	2.	2.	7.5	9.	7.	7.	6.	7.	....	....	3.	5.
Humus	5.12	....	2.60	....	3.42	....	2.61	....	2.04	....	4.92	....
Total Nitrogen	.38	.22	.22	.09	.28	.10	.20	.11	.17	.08	.41	.25
Capacity to retain water	59.	51.	49.	51.	50.	51.	51.	49.	48.	58.	61.	54.
Phosphates associated with Humus	.05	....	.03	....	.02	....	.02	....	.02	....	.06	....
Insoluble Silicates and Sand	72.30	73.95	70.75	73.77	64.08	65.61	69.85	68.54	74.77	74.82	63.77	67.06
Combined Silica	6.77	6.58	10.14	11.71	13.16	13.36	8.62	11.36	6.50	6.47	12.45	12.39
Potash	.45	.40	.28	.35	.18	.44	.34	.43	.32	.31	.32	.32
Soda	.26	.42	.14	.18	.45	.54	.42	.17	.28	.18	.16	.42
Lime	.69	.70	.65	.73	.61	.67	1.00	1.35	1.53	2.79	.92	.94
Magnesia	.38	.36	.77	.23	.65	.43	.25	.35	.65	.92	.24	.14
Iron (oxide)	2.93	3.05	3.23	2.39	2.99	3.78	2.83	2.90	2.52	2.72	3.05	3.65
Aluminia	3.19	4.63	4.35	5.68	5.52	7.75	5.75	6.15	4.26	3.98	5.75	6.15
Phosphates	.35	.26	.30	.22	.21	.20	.21	.23	.26	.33	.25	.25
Sulphates	.06	.04	.24	.11	.70	.10	.06	.08	.02	.02	.09	.10
Carbonates	.55	.36	.52	.24	.55	1.35	.40	.11	.04	.70	.45	.94
Chlorides	.02	.02	.02	.01	.01	.01	.01	.01	.01	.02	.01	.01
Volatile	10.90	9.12	8.15	4.35	10.33	5.64	9.54	8.09	7.94	6.36	11.50	7.38
Total	98.85	99.89	99.54	99.97	99.44	99.88	99.28	99.83	99.10	99.67	98.96	99.75

Sample number 214 is from Benson, Swift county, it is not one of the typical prairie soils, but belongs more to that class of old "lake basin" soils. Both the top soil and the sub-soil are characteristically rich in limestone. These sub-soils are usually of a greyish color, and do not show the characteristic yellow color of most of the prairie sub-soils. These soils contain limestone to such an extent as to show a marked effervescence when treated with acids, and it can even be observed when strong vinegar is poured on them.

TABLE IV.

Where from	Worthington.		Benson.	
Top Soil and Sub-Soil Number of Soil	Top 326	Sub 327	Top 214	Sub 215
Weight per cubic foot	72.	75.	70.	72.
Fine Earth	100.	100.	100.	100.
Skeleton	....	....	....	....
Humus	4.39	....	2.06	....
Capacity to retain water	71.	45.	56.	51.
Total Nitrogen	.37	.01	.24	.07
Phosphates associated with Humus	.07	....	.05	....
Insoluble Sand and Silicates	62.46	45.84	54.25	57.87
Combined Silica	12.22	15.97	8.13	8.04
Potash	.36	.22	.46	.20
Soda	.28	.44	.37	.32
Lime	1.06	11.33	13.56	12.08
Magnesia	.82	1.72	2.57	.27
Iron (oxide)	1.86	3.28	1.41	2.24
Aluminia	6.07	7.46	3.34	4.90
Phosphates	.65	.25	.27	.26
Sulphates	.21	.08	.04	.06
Carbonates	.37	10.94	10.40	9.82
Chlorides	.01	.01	.02	.02
Volatile	13.19	1.56	4.80	2.18
Total	99.56	99.10	99.62	98.23

SOIL SAMPLES FROM NORTHERN CENTRAL POINTS.

Soil sample number 208 is from Fergus Falls, Otter Tail county. It has produced ten crops of wheat. The top soil is a black loam, about twelve inches in depth, and shows the presence of a little sand. It has no tendency to cake and lump when dry. The top soil is a little weak in potash, but the sub-soil is sufficiently rich to make up for this want. The high phosphoric acid in the top soil, and such a liberal amount of it in available forms, speaks well for the future fertility of these soils. Soil sample number 292 is from Henning, the eastern portion of the same county. It was originally an oak and hard wood clearing, and has raised five crops of wheat. The top soil averages about fourteen inches in depth and then follows a yellow clay sub-soil that is richer in potash and phosphates. A somewhat larger per cent of lime is noted in the top soil; this is a point that appears quite general with the analysis of oak soils. Timothy is reported as thriving well on this soil, but quite frequently difficulty is reported in getting clover started. The surface soil appears to be the weakest in potash of any of the necessary minerals, and young clover requires a good supply of it to get started. Gypsum, will no doubt aid the clover in getting a start, and as soon as the clover roots reach down into the sub-soil then a liberal supply will be found.

Soil number 210 is from Alexandria, Douglas county, and has produced eight successive crops of wheat. This soil sample is selected because it is a good type of the sandy, gravelly sub-soils; it consists of about half fine gravel. Good clay sub-soils are equally as common in this locality. The top soil has a good supply of humus, and shows a correspondingly good capacity for retaining water. This land was originally a lumber tract, and is a black loam, sandy in character as is shown in the analysis.

Soil number 245 is from Wadena, Wadena county; it is a black sandy loam; has produced five successive crops of wheat. The soil particles are a little coarser than those from the south-western portion of the state. All of the soil particles are less than 1/20th of an inch, and about twenty per cent are less than $\frac{1}{40}$th of an inch. Even in these soils of a slight sandy nature there is a good native stock of lime and phosphates; more so than is usually found in sandy loam soils. The top soil contains about three per cent more of organic matter in the form of humus than the sub-soil, and retains one-fifth more water in its pores.

Soil sample number 230 is from Park Rapids, Hubbard county. It is a black sandy soil of about two feet in depth, —the sub-soil is of a yellow sandy nature. The top soil contains about five per cent of combustible matter and humus, while the sub-soil contains only about a half of a per cent. The top soil and sub-soil particles are of about the same size. The top soil, which is about ten times richer in decaying vegetable matters, retains over two-thirds more water than the sub-soil. This soil shows the good effects of the humus and vegetable matters in retaining the water in the soil, as well as any other example that is reported in this work. This soil has produced five consecutive crops of wheat and according to some ideas and books, it would not be put down as a wheat producing soil; but notwithstanding this fact it has produced, and still continues to produce, good crops of wheat. The supply of humus and vegetable matter must be kept up in this soil.

Soil sample 273 is from Fair Haven, Stearns county; it was originally an oak clearing. The soil is six years old and has been treated to a good rotation of corn, oats, millet and wheat. The sub-soil is a yellow clay with some disposition to lump; it is not of a hard-pan nature nor impervious to water. The six years' rotation cultivation has left this soil in good condition, and as far as humus and nitrogen are concerned, compares favorably with the various examples of native soils that are reported.

TABLE V.—SOIL SAMPLES FROM NORTHERN CENTRAL POINTS.

Where from	Fergus Falls.		Alexandria.		Wadena.		Park Rapids.		Henning.		Fair Haven.	
Top Soil and Sub-Soil	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub
Number of Soil	208	209	210	211	245	246	230	231	292	293	273	274
Weight per cubic foot	75.	85.	78.	88.	82.	86.	85.	88.	76.	82.	80.	84.
Fine Earth	90.	90.	87.	48.	100.	60.	95.	95.	97.	98.	96.	95.
Skeleton	10.	10.	13.	52.	....	40.	5.	5.	3.	2.	4.	5.
Humus	2.68	....	3.02	....	3.02	....	2.40	....	3.89	....	4.18	....
Total Nitrogen	.24	.07	.24	.07	.25	.08	.15	.08	.26	.08	.39	.10
Capacity to retain water	49.	39.	50.	29.	50.	40.	41.	25.	48.	42.	43.	38.
Pposphates associated with Humus	.04	....	.02	....	.03	....	.02	....	.04	....	.03	....
Insoluble Sand and Silica	75.42	78.42	76.69	77.22	78.39	84.00	82.79	93.52	76.55	81.35	72.52	73.14
Combined Silica	8.51	7.31	5.64	7.62	5.97	5.10	6.34	3.12	5.88	7.43	10.56	11.63
Potash	.17	.45	.44	.24	.28	47	.26	.10	.19	.42	.20	.21
Soda	.09	.21	.13	.22	.24	.12	.26	.18	.18	.16	.19	.22
Lime	.54	.62	1.26	.72	.60	.25	.61	.31	.63	.31	.77	.40
Magnesia	.33	.42	.35	.64	.60	.37	.18	.07	.13	.11	.25	.34
Iron (oxide)	2.69	2.62	1.57	3.66	2.37	3.46	1.45	.67	2.39	2.82	2.96	3.76
Aluminia	3.60	2.80	3.38	4.39	3.14	2.30	1.61	.09	4.04	4.18	3.99	6.26
Phosphates	.32	.18	.31	.22	.20	.26	.15	.01	.36	.40	.21	.12
Sulphates	.06	.07	.09	.08	.02	.02	.09	.06	.10	.07	.09	.09
Carbonates	.06	.07	.81	.41	.03	.02	.01	.01	.04	.01	.10	.02
Chlorides	.02	.02	.02	.03	....	....	.02	.01	.01	.01	.01	.01
Volatile	7.13	5.48	7.60	4.19	7.09	3.63	5.99	.56	9.10	2.18	8.15	3.80
Total	98.94	98.67	98.29	99.61	98.93	100.	99.76	98.70	99.61	99.45	100.	100.

SOIL SAMPLES FROM NORTH-EASTERN MINNESOTA.

Soil sample number 216 is from Mille Lacs, and is a fair representative of the pine forest soils. This section has been occasionally burned over by forest fires, and hence the analysis does not show the full amount of humus and nitrogen that would otherwise be present in localities that have not been burned over, and where the leaves and dead branches have rotted and formed humus. Frequent and destructive forest fires will seriously decrease the agricultural value of these soils. The soil particles are extremely fine. There is a furrow slice of black top soil overlaying a yellowish sandy sub-soil that contain a very little true clay. This soil is a typical pine producing soil, and in appearance is quite like some of the pine soils from the Southern states. For comparison, an analysis is given, number 236, of an old pine soil from Tennessee. At the time this sample was analyzed it was supposed to be one from this state. When these two soils are placed side by side, they can not be distinguished by the eye or by mechanical analysis. The Tennessee pine soil has been cutivated about sixty years,and will not produce any more crops without fertilizers, while fertilizers have not as yet, come into general use on our cultivated pine soils. The pine soils will require careful farming, and the necessity of a good supply of humus in these soils, is, and will be, the most important want. There is comparatively more plant food in these soils than appears at first glance, because a cubic foot of these soils weighs nearly ninety pounds, as against seventy or seventy-five pounds for many other soils.

Soil sample number 228 is from Hinckley, Pine county. The top soil is a light yellowish red clay from one to two feet in depth. The sub-soil is a bright red clay, that becomes quite hard when dried in the air. The top soil does not lump so badly. These sub-soils contain a high per cent of iron oxide from four to five pounds of it in every hundred pounds of the soil. There is no iron present in the ferrous forms, and hence this large amount is in a perfectly harmless form and will not injure the roots of plants. A very little additional organic matter in these soils improves them to a great extent, especially as regards the ease with which they are worked. The potash reported in the tables for these soils is only the potash that is present in easily soluble forms. There is, all told, from two and a half to three pounds of potash in every hundred pounds of these soils, and as yet we have not sufficient data to determine how much becomes available each year by good cultivation for crop purposes. The evidence appears to be that there is quite a large amount because such large yields of potatoes and root crops are annually raised on these soils without any application of potash fertilizers.

In some small localities, the clay sub-soil gives way to a layer of greyish deposit. This is found particularly in low places. A number of samples of this material have been received at the laboratory. This material is marl and is composed mainly of lime stone with a small amount of clay. On some soils this marl will no doubt do some good when used as a fertilizer, but it will not pay to haul it any great distance. It will probably be found to do the most good on the soils of a sandy character, and will improve the working condition of some of the heavy clay soils. The analysis of the marl reported is from Rush City.

Soil sample number 232 is from New Duluth, St. Louis county. The top soil is well supplied with phosphates, lime and magnesia. The sub-soil is very rich is potash but only about a tenth of it is "unlocked." This soil has been cultivated fifteen years.

Soil number 264 is from Duluth. It is bright red in color with quite a few small gravel stones mixed with it as is indicated in the mechanical analyis. This section joins the city limits on the north side; it has raised one crop of potatoes.

Soil number 212 is from St. Cloud; it is a fine black sandy soil, one of the typical potato soils of that region. It has raised fifteen crops and has been well manured. There is an unsually high content of potash present for these soils.

Sample 288 is from Wyanette, Isanti county. It is a dark sandy soil seven to eight inches in depth overlaying a yellowish sandy sub-soil; it has been cultivated for two years.

TABLE VI.—SOIL SAMPLES FROM NORTH-EASTERN POINTS.

Where from	Mille Lacs.	Pine.	Hinckley.		New Duluth.		Wyanette.		St. Cloud.		Duluth.	Marl.
Top Soil and Sub-Soil	Top	Top	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub
Number of Soil	216	236	228	229	232	233	288	289	212	213	264	244
Weight per cubic foot	86.	88.	86.	90.	89.	95.	80.	88.	74.	84.	80.	....
Fine Earth	100.	100.	95.	92.	96.	98.	100.	99.	98	94.	88.	
Skeleton	....	....	5.	8.	4.	2.	....	1.	2.	6.	12.	....
Humus	.65	.60	1.69	....	1.77	....	1.10	.....	3.24	....	.89	
Capacity to retain water	38.	40.	53.	34.	42.	46.	41.	34.	46.	34.	46.	....
Total Nitrogen	.07	.05	.12	.01	.09	.01	.15	.05	.17	.12	.08	
Phosphates associated with Humus	.01	....	.03	....	.01	....	.02	....	.03	....	.01	....
Insoluble Silicates and Sand	89.80	86.07	76.35	63.35	79.03	64.18	89.50	91.32	83.27	84.72	71.13	12.82
Combined Silica	2.62	2.64	10.76	16.55	9.88	15.07	3.47	2.92	5.44	3.35	7.61	....
Potash	.14	.08	.18	.20	.27	.21	.08	.08	.85	.62	.25	.12
Soda	.34	.04	.20	.40	.16	.18	.08	.18	.35	.35	.36	.06
Lime	.38	.11	.76	.22	.32	.85	.21	.22	.26	.38	.51	38.32
Magnesia	.29	.12	.25	.27	.51	1.04	.13	.20	.10	.38	.12	.72
Iron (oxide)	1.15	1.32	3.55	4.71	1.02	5.90	1.34	1.66	1.66	1 79	5.35	1.25
Aluminia	3.02	3.63	5.73	5.56	3.30	8.55	1.86	1.79	2.22	3.95	5.03	2.01
Phosphates	.22	.04	.12	.36	.33	.08	.10	.13	.19	.15	.45	.35
Sulphates	.10	.07	.06	.13	.02	.02	.10	.07	.09	.06	.03	.34
Carbonates	.05	.25	.01	.03	.38	.45	.02	.03	.07	.04	.04	.01
Chlorides	.01	.01	.01	.02	.01	.01	.01	.01	.03	.04	.02	40.10
Volatile	1.56	3.85	2.00	8.00	3.90	2.94	2.98	1.31	5.12	4.05	8.47	4.09
Total	99.69	98.21	99.98	99.80	99.13	99.48	99.88	99.92	99.65	99.88	99.47	....

Soil from the Experiment Station.—In passing from the Central Eastern points to the soils of the South-Eastern portion of the state, a few words can be said in regard to the composition of the experiment station soil, and particularly as to the effects of heavy applications of well prepared manures during dry seasons. The experiment station is located between the two sections noted above.

The effects of heavy manuring was clearly shown during the season of 1893. A pile of well rotted mixed manure was drawn out in a field that had raised a corn crop the previous year. The well rotted manure was spread very heavy. A prominent knoll was left with one-half heavily manured, and the other half without any. About the last of June an unusually dry time set in. Previous to this, the corn on this knoll appeared to be all about alike, the manure hardly showed itself, but as soon as the dry spell came the manured part kept on growing without showing the effects of the drought to any great extent while the unmanured part made very little progress. The soil on this knoll was sandy and porous, and on the unmanured half it dried out badly, while on the other half a perceptible amount of water remained.

Samples of the soil from each lot were taken to the laboratory on June 30, and the amount of water determined. There was an average of twelve and one half per cent of water in the first six inches of soil in the heavily manured plot, and eight and nine-tenth per cent in the unmanured plot. July 23 there was ten and one half per cent in the manured part and eight and one-tenth in the unmanured part. At one time after two days of hot dry winds the soil water in the unmanured part reached as low as seven per cent, while the manured part never reached below ten per cent. At harvest time the fodder corn on the manured part was on an average two feet taller than the corn on the unmanured part. This was not due so much to the absence of fertility in the soil of the unmanured part as it was to the want of the proper amount of moisture. The greatest value of well prepared farm manures is in furnishing humus and keeping the soil from drying out. In order to be of full benefit the manure must be well rotted before spreading on the land, otherwise in a dry season there is not sufficient moisture in the soil to rot the straw that is in the manure,—it is then plowed under and not infrequently lays in the soil for two or three years before rotting, and causes the soil to dry out more, by being open loose and porous than it otherwise would if this coarse manure were not present. Straw is not manure until it i well rotted. The beneficial effects of well rotted manures in aiding the soil to retain its water, is noted and discussed in connection with some of the soils from South Eastern Minnesota.

A detailed discussion of the composition of the soils from the Experiment Station farm is not given. One analysis is reported, number 241. A number of analyses have been made in connection with plot experiments and the draft of different crops upon the soil, as well as different methods of rotation. The work has not, as yet, been carried on a sufficient length of time to obtain definite results, but sufficiently encouraging results have already been obtained to warrant a continuation of the work.

There are some points as to the general composition of the sample soil (No. 241) that can be noted. The top soil is a black loam, with a sandy nature in some portions of the farm, and clayey in other portions. The sub-soil is a yellow clay; the top soil, when perfectly dry, weighs about seventy-three pounds per cubic foot, and has a fair content of potash, lime and phosphates. The nitrogen is not as high as in the virgin soils, yet nitrogen fertilizers do not appear to be particularly beneficial, nor do potassium preparations show any good results. The top soil will retain more water and for a longer time than the sub-soil. The presence of only a very little sand will cause it to dry out until the first three or four inches is in nearly an air dry condition.

SOILS FROM SOUTH-EASTERN MINNESOTA.

Samples number 277 and 279 are from Farmington, Dakota county. Both were originally native prairie soils and have been under cultivation for thirty-five years. Number 277 has been under high cultivation, received regular and liberal dressings of manure, and raised good crops of corn, oats, wheat and grass.

In another and an adjoining field, that originally raised as heavy crops, sample number 279 was taken. This field has been under cultivation for the same length of time, thirty-five years, has never received any manure, nor been summer fallowed. It has always produced a grain crop, but for the past few years the yield has been unusually low, and during droughty seasons it suffers much more than the adjoining field that has been rotated and well manured.

From the analysis it will be observed that the main differences are in the amounts of humus, sand and nitrogen that are present. The well manured and more productive soil yielded 3.32 per cent humus and .30 per cent nitrogen, against 1.80 per cent humus and .16 per cent nitrogen in the poorer soil. There is the same amount of phosphoric acid in each soil, .20 of a per cent, which would ordinarily be considered a very large amount, but in the poorer soil there is only .01 of a per cent that is associated with humus in available forms, while in the well manured soil there is .04 of a per cent available. The amount of potash as given in the analysis is practically the same for each with a shade of advantage in favor of the better soil, and yet larger quantities of potash have been annually removed in the more productive soil. The total amount in each soil is 1.42 per cent for the manured soil and 1.50 per cent for the poorer soil. There is evidence that the thorough cultivation of the one soil has materially aided in rendering a portion of this insoluble potash available as plant food. The total insoluble matters (sand, silicates, and combined silicates) are about the same in each, when they are compared on an equal footing as to humus. In the case of the better soil, however, there is nearly seven per cent of silica that is combined with the potash, soda, aluminia and lime, while in the poorer soil there is only four per cent in this form. The thorough cultivation of the one soil has without doubt been the chief cause of the decomposition, and breaking up, of this three per cent of stony particles. Plant food can be cultivated into available forms cheaper than it can be purchased.

The history of these two fields, as to their former similarity in every way, their original alike productiveness compared with their present dissimilarity and unlike productiveness, together with the different methods of cultivation that have been the cause of the decline in fertility, and finally their present comparative composition after thirty-five years unlike treatment, are facts that should be carefully considered because they emphatically suggest the necessity of keeping up the organic matter in the soil, coupled with a judicious system of rotating crops.

Sample number 239 is from Rolling Stone, Winona county. It has been under cultivation for forty years and has produced good crops of wheat, corn, barley and oats. For the last twelve years a rotation of corn, barley and oats has been practiced. It is bottom land and has been well kept up by manure; the nitrogen, humus and other points speak well for the land as not suffering from cropping. There is a good content of phosphoric acid present, and a good working supply of potash. The silicates and stony particles appear to be easily decomposed.

Sample number 281 is from Faribault, Rice county. It has been under cultivation for thirty-eight years; the first fourteen years it always produced a grain crop of some kind. It produced hay for two years, was pastured one year, and for the past ten years has produced corn, oats and wheat in rotation. It has occasionally received a dressing of manure, and has never been summer fallowed. The land is in good condition, and the analysis does not indicate any weak points; however, it will not do to allow the humus to reach much below the present point.

Sample number 283 is from Owatonna, Steel county. It was originally a timber tract and has been cultivated for thirty-five years. The land has been well cultivated and occasionally manured, and for the past seven years has produced three crops of corn, three of clover, and one of oats. The soil is in good condition with reasonable working amounts of all of the necessary plant food compounds. The clover appears to have left its mark in a good nitrogen content.

TABLE VII.—SOILS FROM SOUTH-EASTERN MINNESOTA.

Where from	Farmington.		Farmington.		Rolling Stone.		Faribault.		Owatonna.		Ex. Station.	
Top Soil and Sub-Soil	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub
Number of Soil	277	278	279	280	239	240	280	281	283	284	242	243
Weight per cubic foot	70.	74.	72.	74.	74.	79.	76.	77.	86.	87.	76.	78.
Fine Earth	96.	95.	96.	95.	97.	98.	88.	83.	95.	93.	94.	97.
Skeleton	4.	5.	4.	5.	3.	2.	12.	17.	5.	7.	6.	3.
Humus	3.32	....	1.80	....	3.49	....	2.80	....	2.66	....	2.41	....
Total Nitrogen	.30	.21	.16	.17	.25	....	.24	.08	.26	....	.21	.11
Capacity to retain water	48.	46.	39.	46.	49.	46.	41.	34.	47.	39.	53.	51.
Phosphates associated with Humus	.04	....	.01	....	.03	....	.02	....	.30	....	.02	....
Insoluble Silicates and Sand	74.43	74.05	78.32	73.79	71.89	74.81	80.06	79.73	83.25	82.16	73.67	73.51
Combined Silica	6.93	8.46	4.01	9.36	8.85	8.94	6.04	7.07	5.39	7.32	10.41	11.04
Potash	.20	.22	.19	.20	.30	.20	.23	.21	.23	.26	.30	.18
Soda	.19	.16	.16	.13	.23	.32	.18	16	.13	.12	.25	.21
Lime	.46	.51	.48	.35	.41	.40	.54	.50	48	.48	.51	.34
Magnesia	.18	.22	.27	.35	.39	59	.30	.41	.18	.29	.26	.29
Iron (oxide)	2.60	3.27	2.88	3.22	3.01	4.17	2.29	3.06	2.09	1.99	2.56	3.40
Aluminia	4.43	5.44	4.80	4.34	4.63	4.59	3.94	4.58	2.75	2.91	4.24	5.61
Phosphates	.20	.16	.20	.16	.23	.18	.21	.15	.13	12	.23	.21
Sulphates	.15	.12	.12	.15	.04	.03	.08	.05	.09	.08	.06	.08
Carbonates	.09	.09	.09	.08	.12	.11	.09	.09	.13	.09	.29	.02
Chlorides	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
Volatile	9.40	7.29	8.31	6.21	9.81	5.47	5.93	3.85	5.00	4.26	7.04	4.37
Total	99.27	100.	99.84	98.35	99.92	99.82	99.90	99.95	99.86	100.09	99.83	99 27

Sample number 218 is from Austin, Mower county. It is a typical example of a new soil; it is a "Jack oak" clearing and has raised three crops of corn and two of wheat. This soil has a good stock of native fertility and will wear well. It is particularly rich in phosphoric acid, and a fair portion of it is in soluble forms.

The sample from Wells, Faribault county, number 220, is one of the same class of soils, an oak clearing, three years old; corn was grown the first year, and wheat during the two following years. The soil is liberally supplied with plant food; the high per cent of humus—4.17, is noticeable and is a characteristic of the new soils, but unfortunately it does not last very long.

An analysis is given, number 294, of a soil that has been a permanent meadow for about thirty-five years, and produced large crops of native hay; but "during the past ten years bare spots have appeared that have refused to grow any kind of grass; timothy, clover and red top have been tried on these spots but without success and the spots are yearly increasing in size." The soil consists largely (over seventy per cent) of decaying vegetable and other organic matters. It contains a very small amount of mineral matter, less than seven pounds per cubic foot, while many soils contain as high as seventy pounds of mineral matter per cubic foot. There are no other forms of potash present except the .19 of a per cent reported, and the large drafts of the grass crops have told the heaviest on this material. A good application of unleached wood ashes will do the most good for these spots. This tract was originally a marshy place, but by draining it was made to produce good crops of grass, and it is, like many other reclaimed places, the main source of supply of the hay crop. The sub-soil is quite rich in lime and gypsum which prevents the formation of sour mould. The sub-soil is very rich in phosphates, and altogether it is too valuable to be used only as a meadow. There is an unusual amount of fertility in many of these low and marshy places, which, if reclaimed, will prove to be very fertile soils.

TABLE VIII.

Where from / Kind of Soil	Austin. Oak Clearing.		Wells. Oak Clearing.		Mankato. Permanent Meadow.	
Top Soil and Sub-Soil / Number of Soil	Top 218	Sub 219	Top 220	Sub 221	Top 294	Sub 295
Weight per cubic foot	68.	76.	75.	79.	25.	42.
Fine Earth	98.	99.	97.	98.	....	....
Skeleton	2.	1.	3.	2.	....	....
Humus	3.73	....	4.17	....	.24	.14
Capacity to retain water	57.	47.	68.	49.	125.	68.
Total Nitrogen	.30	.15	.37	.20	1.29	.14
Phosphates associated with humus	.04	....	.04	....	.04	....
Insoluble Silicates and Sand	71.19	75.05	66.15	68.79	15.81	31.63
Combined Silica	11.09	9.17	11.49	12.81	2.66	6.58
Potash	.32	.08	.36	.30	.19	.17
Soda	.34	.31	.41	.35	.18	.20
Lime	.48	.21	1.10	.80	.53	4.16
Magnesia	.45	.61	.99	.68	.11	.20
Iron (oxide)	2.81	3.26	2.40	2.68	2.62	5.99
Aluminia	4.77	4.44	3.61	5.92	1.38	4.48
Phosphates	.38	.30	.25	.24	.30	.60
Sulphates	.15	.10	.16	.16	1.66	2.09
Carbonates	1.40	1.43	.56	.75	1.67	3.19
Chlorides	.01	.01	.01	.01	.01	.01
Volatile	6.56	5.00	12.40	6.50	72.80	39.92
Total	99.95	99.97	99.89	99.99	99.92	99.22

SUMMARY.

1. The continued cropping of soils to grain crops only without any system of rotation, or other treatment is telling severely upon the original stock of half decomposed animal and vegetable matters, and nitrogen. Soils which have produced grain crops, exclusively, for ten or fifteen years contain from a third to a half less humus and nitrogen than adjoining soils that have never been plowed.

2. Soils which have been cropped until the organic matters and humus have been materially decreased, retain less water and dry out more readily than when there is a larger amount of organic matter present in the soil.

3. Soils which are rich in humus contain a larger amount of phosphates associated with them in available forms than the soils that are poor in humus.

4. Soils which are rich in humus and organic matters produce a larger amount of carbon dioxide that acts as a solvent upon the soil particles and aids the roots in procuring food.

5. One half of a sandy knoll, heavily manured with well rotted manure, contained nearly a quarter more water during a six week's drought, than the other half that received no manure.

6. The supply of organic matter in the soil must be kept up because it takes such an important part, indirectly, in keeping up the fertility of the soil. A good system of rotation, including sod crops, and well prepared farm manures will do this, and will avoid the introduction and use of commercial fertilizers which are now costing the farmers of the United States over thirty-five million dollars annually. It will not do to wait until this question forces itself upon us.

7. A rotation of crops will soon be necessary on account of the peculiar composition of some of the soils and the corresponding subsoils, especially those in which the surface soils are richer in phosphates and nitrogen while the subsoils are richer in potash and lime. By means of rotation the full benefits of the strong points of both the top soils and the subsoil will be secured.

NOTE IN REGARD TO SOIL ANALYSIS AND SENDING SAMPLES.

The original act that created experiment stations designated soil analysis and soil work as one of the important lines of investigations to be undertaken by the stations. This work has not been pushed by most of the stations as vigorously as many other lines; this has not been on account of any desire not to do a full amount of soil work, but many have questioned whether a soil analysis is justifiable because of its not telling more, and on account of the various difficulties that are connected with soil analysis; but this is no excuse for not attempting to find out more. A knowledge of the chemistry and the related physics of our soils will indicate the ways to better methods of rotations, the production and application of manures, and in an intelligent application of fertilizers when that time comes. Such knowledge, it is hoped, will throw light on many related questions as to methods of cultivation, depth and time for plowing, the use of green manures, etc., so as to retain the present fertility of our soils.

Before sending samples for analysis, you are requested to first write to the Experiment Station for directions for taking the samples of soil. It will not do to go out into a field and take a small sample at random. A blank will be sent with the directions asking the exact location of the plot, section township, range, etc., and the previous history of the cultivation of the soil, crops produced, etc. All this is necessary, not so much for present purposes as for future use,—in case anyone desires to go to these same places again after a number of years farther cultivation, and obtain a sample in order to see just what the changes have been.

All express charges on the soil sample must be prepaid; this is to insure protection against generous sized unpaid packages of soil. The analysis will be made free of charge. Only a limited number of analyses can be made and it is the aim, that these should represent as many soils, sections, and conditions as possible. Some idea of the labor involved will be gained from the fact that the first operation in soil analysis requires five days in order to get the different materials dissolved, while as many more days are required for their separate determination. The analyses are made in sets of six or eight. When the sample is received at the laboratory it will be acknowledged. Do not expect a report in too short a time, because there are always soil samples waiting to be analyzed, as well as other work waiting to be done, but as soon as the analysis is completed a report will be sent to you.