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STUDIES IN SOIL NITROGEN AND ORGANIC MATTER MAINTENANCE

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COLUMBIA, MISSOURI

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Studies in Soil Nitrogen and Organic Matter Maintenance

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Liberal supplies of nitrogen and of readily decomposable organic matter in the soil provide the foundation for economic crop production. It has generally been thought that these supplies can readily be maintained and if they are low, they can be increased through good soil management practices. Experiments indicate, however, that considerable difficulty may be encountered in doing this. Nevertheless, the fundamental importance to maximum crop production of providing liberal supplies of nitrogen and of readily decomposable organic matter within the soil is so great as to warrant thorough-going studies of the problems involved.

The object of the studies here reported was to determine to what extent the nitrogen and the organic matter content of an upland soil of medium fertility, under central Missouri climatic conditions, may be maintained or increased through the use of widely different crops, cropping systems, and green manures. Methods of supplying the proper kind and amount of organic substance through farm manures, green manures, and crop residues, present important practical problems. Moreover, as shown by Jenny[2], the level to which the supply of nitrogen and organic matter may be increased, or at least maintained, in the soils of the United States depends largely on the climatic zone in which the soil is located. In general, but more particularly in the humid regions of the country, the organic matter and nitrogen contents of soils will run higher in the cooler regions and lower in the warmer ones. Central Missouri is far enough south that decay processes are active during much of the year and the retention of large quantities of organic matter and nitrogen becomes difficult.

Analyses show that since put into cultivation the soils of Mis-

[1]The methods and procedures in the early development of this project were largely the work of F. L. Duley who was a member of the staff of the Department of Soils from 1915 to 1925. During the latter half of the experimental period the details were handled by H. H. Krusekopf and Geo. Smith. For most of the period L. B. Stuckey was responsible for detailed field work. All analyses were made by the Department of Agricultural Chemistry.

[2]Jenny, H. A Study of the Influence of Climate upon the Nitrogen and Organic Matter Content of the Soil. Missouri Exp. Sta. Research Bul. 152, 1930.

souri have lost, on the average, about 35 per cent of the virgin supply of nitrogen. In other words, losses of this element during the last 75 to 100 years have outrun replacements to this extent. This indicates that, without special treatment, the natural productivity has doubtless declined in somewhat similar proportions. The matter of determining the possibilities of increasing, or at least maintaining, this important constituent in the soil, along with the accompanying organic substance, is exceedingly important.

Considerable work has been done by investigators in various states and Canada, in attempting to determine the gain or loss of soil nitrogen under different systems of cropping and manuring. No attempt is made to review these investigations in this publication. In general, these various investigations indicate that to increase greatly the supply of nitrogen or organic matter in soils of moderate fertility under the usual systems of farming is a difficult matter.

The results here reported apply to an upland soil of medium fertility in a definite climatic zone. The investigation covers a period of twenty-four years. The results will doubtless have application to most upland soils in Missouri and probably to other states, or parts of states, having similar climatic conditions.

Plan of the Investigation

The Soil.—The soil on which this investigation was carried out is a rolling phase of the Putnam silt loam at Columbia. The surface soil (A_1 horizon), gray-brown in color, is about 8 inches deep in this location, and is underlaid by a 6-inch subsurface layer (A_2 horizon of lighter colored, silty material. There is a plastic clay subsoil layer (B_1 horizon) beginning at about 18 inches. The soil is one of about medium fertility for Missouri. It had been cropped under the usual system of agriculture for about 60 years. However, two phases of this soil, lying close together, were used in the investigation, one with a 2.1 per cent slope and another with a slope of 2.7 per cent, running lengthwise of the plots. The latter had suffered somewhat more from erosion than the former, the surface soil was slightly shallower and the nitrogen content appreciably lower. In the more level area this nitrogen content, at the beginning of the experiment, averaged 2719 pounds in the surface 2,000,000 pounds of an acre (0-7 inches), while in the more sloping area the corresponding surface soil averaged 2197 pounds. The reason for using these two areas was to ascertain, in some measure, the influence which cropping systems would have on the nitrogen content of the soil under these two initial nitrogen levels, with somewhat different possibilities for erosion.

Plot Arrangements.—Duplicate series of eight plots each, Series 1 and 2, were laid out on the better soil phase. The plots were each 10 feet 8 inches wide by 30 feet long, one series following the other, from north to south. A two foot interval was left between individual plots. This layout is shown, along with the cropping system on each plot, in Figure 1.

It will be observed that the cropping systems in these two duplicate series provided for a wide variation in the amount of organic matter going back to the soil. The plan included one standard cropping system, continuous bluegrass sod, continuous alfalfa, and several systems designed to give the maximum additions of organic matter from crops grown on the land. The harvested produce from all crops, excepting that of the three year rotation, the alfalfa, and one red clover plot, was returned to the individual plot from which it came. It was, of course, realized that some of these systems with continuous crops were impractical from a farmer's standpoint, but they were used in such cases in order to give maximum additions of nitrogen and organic matter.

The harvested produce of all crops, excepting the bluegrass sod, was weighed, the dry matter determined, and the amount is reported on an acre basis. That to be left on the plots was returned after harvest. With the exception of the bluegrass these crops returned were usually chopped up and ultimately spaded into the surface seven inches, using a guard-protected spading fork to insure the proper depth of working the soil.

Two additional duplicate series of plots, Series 3 and 4, were laid out on the poorer phase of this soil, each consisting of four plots 20 feet 4 inches wide by 30 feet long. These series, along with the cropping systems on each, are shown in Figure 1. The cropping systems represent certain duplications of those in Series 1 and 2, with the addition of a plot of continuous sweet clover, turned under every other year.

Soil Treatments.—An application of ten mesh, high-calcium ground limestone was spread evenly over the four series in 1916, just before the beginning of the study. The rates of application were approximately 1000 pounds per acre in excess of that determined by the Veitch test. On Series 1 and 2 this application was at the rate of 2700 pounds per acre and on Series 3 and 4 at the rate of 4200 pounds.

The same kind of limestone was again applied in the winter of 1930 at the rate of three tons per acre on all four series and again in September 1932 at the rate of two tons per acre. These additions were made with the idea that the legume growth would be further stimulated.

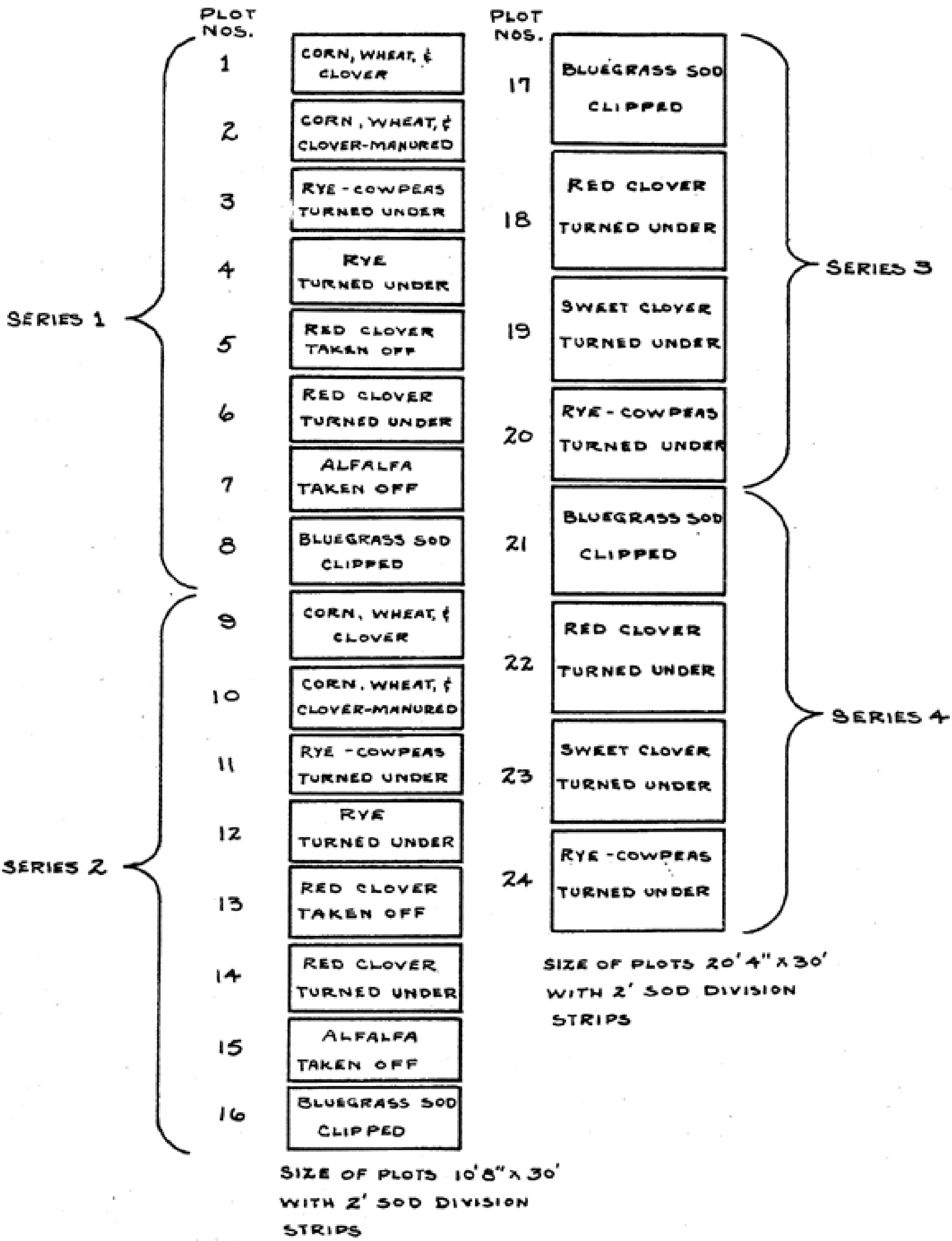

Figure 1.—Plot Arrangement and Cropping Systems

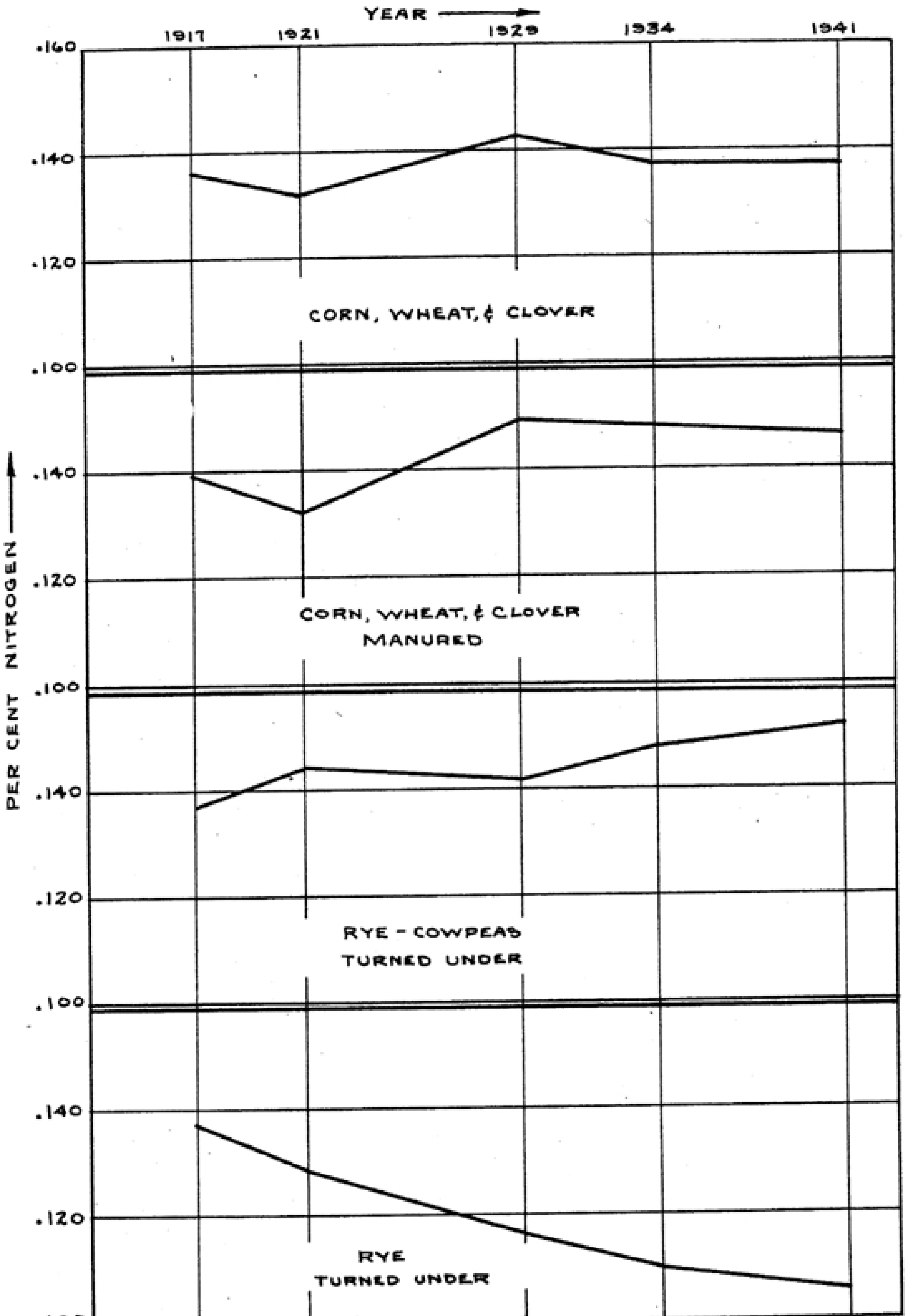

Figure 2.—Average Nitrogen Content of Soil (top 7 inches) in Series 1 and 2.

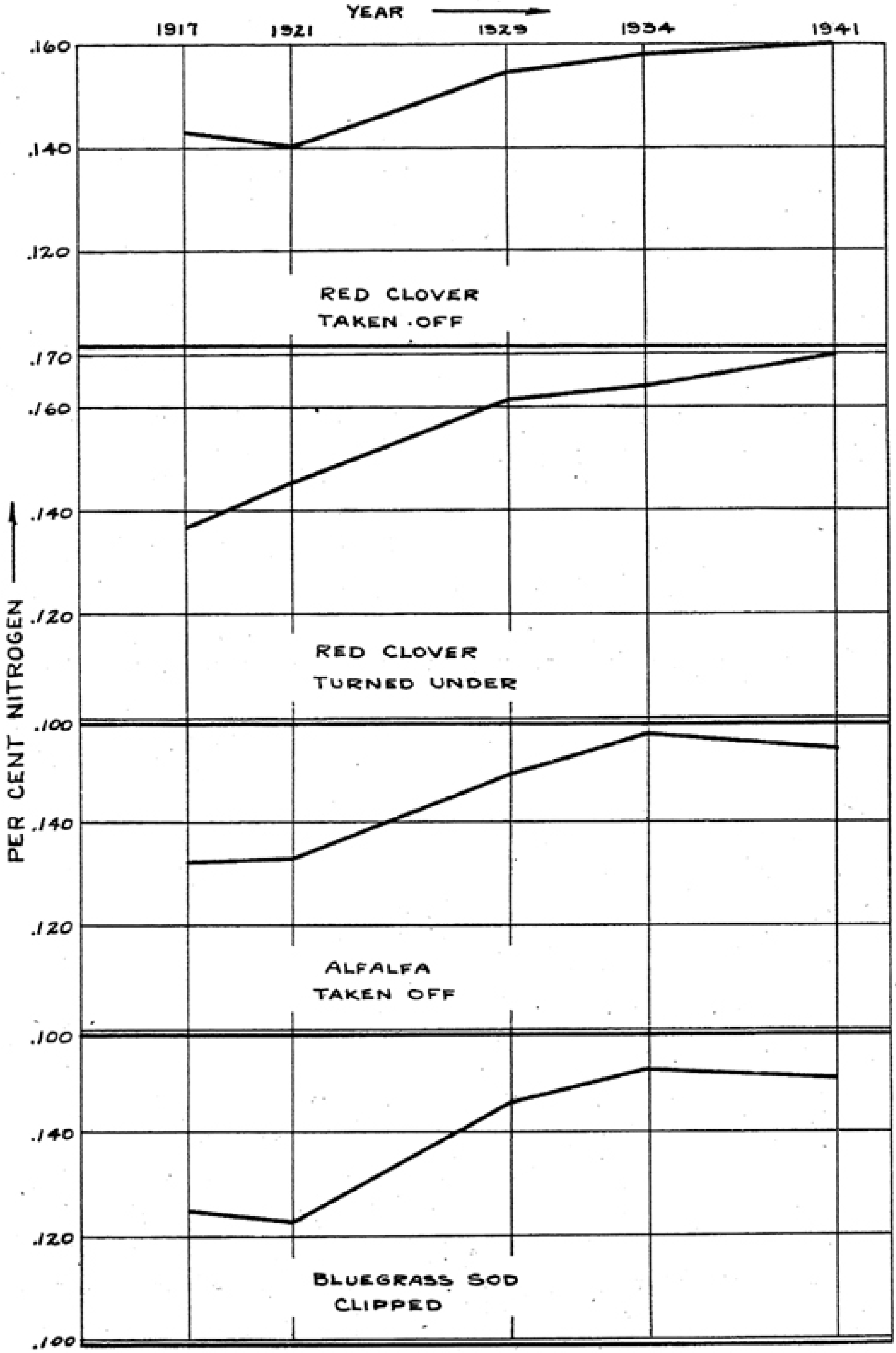

Fig. 2 (Continued).—Average Nitrogen Content of Soil (0-7 inches) in Series 1 and 2.

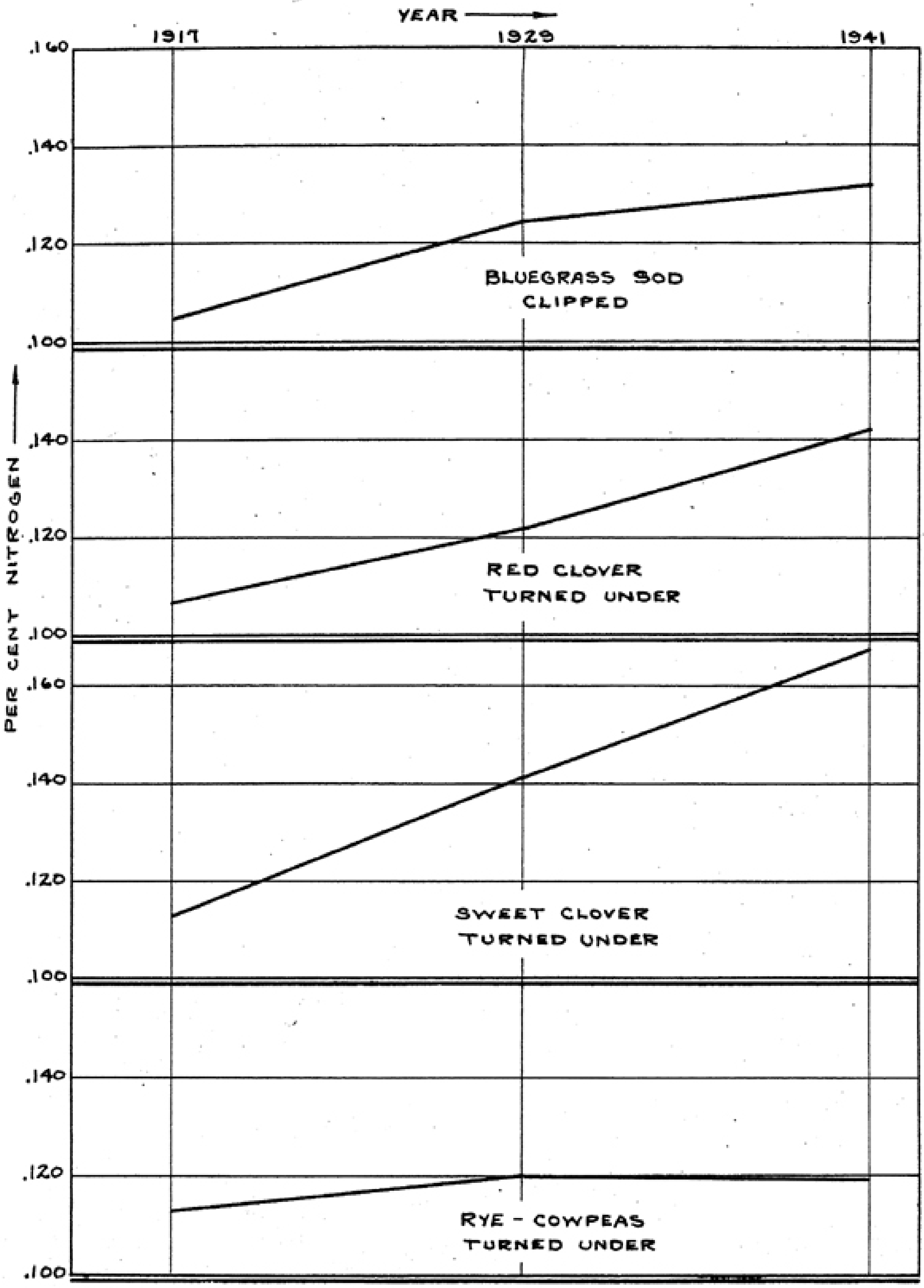

Figure 3.—Average Nitrogen Content of Soil (0-7 inches) in Series 3 and 4.

Manure was applied, at the rate of 4 tons per acre, before corn, on Plots 2 and 10 in Series 1 and 2, a total of 28 tons during the twenty-four years. This rate represented approximately the amount which could be produced if all the crops, excepting the wheat grain, were fed or used as bedding.

Fertilizers.—The original plan did not include the use of fertilizers. The idea was to determine the influence of the various cropping systems on the nitrogen and organic matter content of the soil, using lime only to take care of the legume demands. Yields of the various crops in the early years were low and crop failures frequent. As a consequence, an application of 300 pounds of 20 per cent superphosphate was applied to all plots in 1930, and similar applications were made again in 1932 and in 1935. The phosphate applications were usually worked into the soil after spading unless crops were on the ground when they were worked into the unspaded surface. These treatments were quite effective as shown by the yield records.

Soil Sampling for Analysis.—Approximately 30 soil samples were taken from each plot on the four series on each sampling date, using permanent steel corner posts as a basis for establishing the locations for the sampling points. Special wooden frames were placed at the ends of each plot at the time of sampling. Wires from each of these were evenly spaced and stretched lengthwise of the plots, with knots at regular intervals along them for designating the sampling points. By adjusting these wires so as to move the sam-

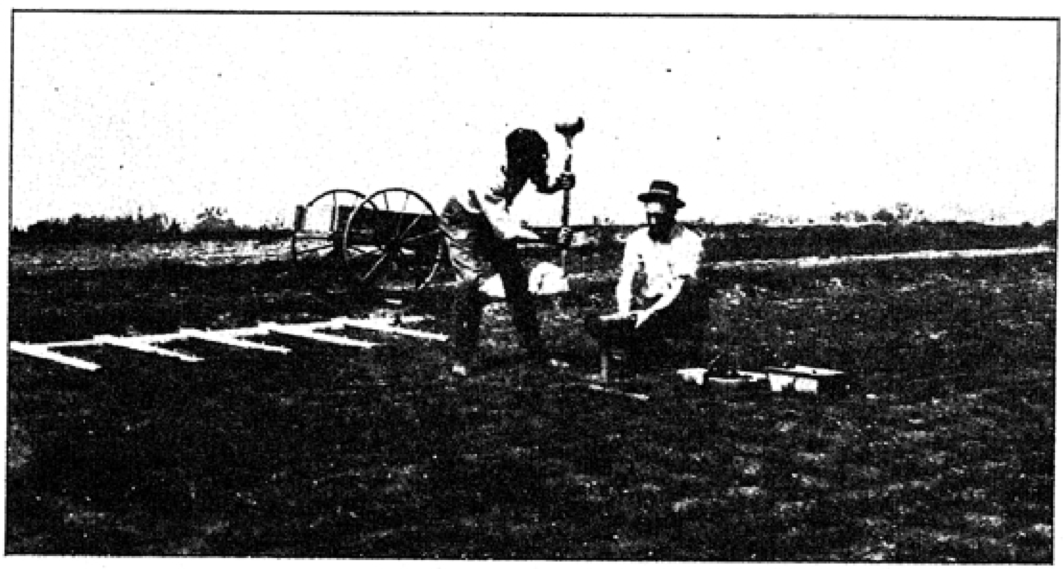

Figure 4.—Sampling the soil for analysis. Note the frame at end of the plot from which knotted wires were strung in order to maintain the proper distribution of sampling points.

pling points ten inches from those of the previous sampling a regular and uniform distribution of the samples was made possible. However, the last samples (1941) were taken within six inches of the initial sampling points in 1917. The reason for this change was that recent investigations have indicated more accurate comparisons where subsequent samples are taken a short distance from the original sampling points. It is likely, therefore, that the 1941 samples provided the most reliable comparisons with those taken in the beginning.

Samples were taken of the surface seven inch soil layer, or the plow soil, and of the subsurface 7-12 inch layer of each plot thus providing samples to one foot in depth. The plan followed was to drive into the soil, to a depth of seven inches, a two-inch steel sampling tube with a sharpened and slightly constricted cutting edge. A closely fitting auger was used to remove the soil from within the tube. An auger with a diameter of an inch and a half was then used to remove the subsurface 7-12 inch sample thus preventing any mixing of the samples from the two depths.

The soil and subsurface soil samples from each plot were dried, ground, thoroughly mixed for a composite sample, and an aliquot was passed through a 100 mesh sieve for analysis. The nitrogen determinations were run on these composite samples. All analytical runs were made in triplicate, with repeats in case the triplicates did not check closely. Samples of Series 1 and 2 were taken, and analyses were made in 1917, 1921, 1929, 1934, and 1941, and of Series 3 and 4 in 1917, 1929, and 1941.

Crop Yields

A summation of the yields of crops from the various plots is given in Table 1. There are omissions in the case of the continuously clipped bluegrass since no weights were taken, the clippings from the mower falling back on the surface. Some yields are missing due to crop failure, but these are considered as zero in securing the average annual yields.

It will be observed that the average yields of most crops were rather low. This is particularly true of red clover since in most years, only the first crop was harvested, and this on alternate years. The alfalfa yields were not high, as this crop, even with lime and phosphate, is not particularly suited to the soil. Continuous rye and rye followed by cowpeas gave quite satisfactory yields. The failure of most of the crops to average well was due to occasional crop failures and to the generally low level of production of this Missouri soil of medium, or slightly below medium fertility, particularly during the first half of the period when no fertilizer was used.

Table 1. Pounds of Dry Matter Produced Per Acre Annually on the Various Plots
(All weights on oven dry basis excepting corn grain and stover, wheat and straw which were field cured.)

Plots	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929
Series 1													
1. Corn, wheat, clover	2139	3756	5649	2990		2355	10222	1434	1191	4394	1862	1915	2248
2. Corn, wheat, clover, manured	2004	3901	6839	3538		2755	10017	2066	1445	8100	1354	1767	3577
3. Rye - cowpeas (Rye	1914	1749	2876	3907	3430	3421	3451	3366	1415	4067	1498	1662	2675
turned under (Cowpeas	2121	2432	3032	2124	2655	1183	3238	2238	2026		2554	3716	223
4. Rye, turned under	2566	1753	3272	3425	3199	2920	2905	3165	1028	1080	756	1136	1787
5. Red clover, taken off	952	209	3259		583		2910	1115		930	832	1790	1172
6. Red clover, turned under	886	472	2954		642		3564	1742		847	1051	1846	916
7. Alfalfa, taken off	3147		5238	4014	2576	2517	1789	3306	2149	3813	1665	3817	2371
8. Bluegrass sod, clipped	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod
Series 2													
9. Corn, wheat, clover	1564	2316	5816	1699		1959	8711	1187	741	3848	2275	1921	2656
10. Corn, wheat, clover, manured	1805	2120	6867	3130		2411	9532	1865	794	8174	2230	1843	3676
11. Rye - cowpeas (Rye	1252	883	1817	2675	2630	1816	2152	2699	612	4054	1444	1795	2491
turned under (Cowpeas	2247	2493	3296	2079	3186	979	3080	1594	2020		2213	4060	446
12. Rye, turned under	2209	1196	2719	2556	2924	3074	2428	2439	1001	834	852	1437	1787
13. Red clover, taken off	1476	314	2887		756		2436	1100		2053	826	1149	633
14. Red clover, turned under	1525	317	2335		889		3052	1593		437	788	1095	517
15. Alfalfa, taken off	2831	1760	4833	1940	1537	1619	1413	2526	1467	2210	831	2875	1298
16. Bluegrass sod, clipped	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod
Series 3													
17. Bluegrass sod, clipped	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod
18. Red clover, turned under	1106	752		1198		1540		2554				1875	1190
19. Sweet clover, turned under	1642	2512		1296		1613		4265		717	576		3378
20. Rye - cowpeas (Rye	1156	730	1590	1327	1690	1331	1901	1736	961	2457	733	696	920
turned under (Cowpeas	4047	2210	3150	1051	1687	1090	1942	993	2421		2112	1997	444
Series 4													
21. Bluegrass sod, clipped	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod
22. Red clover, turned under	724	165		694		1188		1748				1277	953
23. Sweet clover, turned under	2050	2090		1243		1572		2554		641	580		2125
24. Rye - cowpeas (Rye	886	728	1593	1731	2298	1904	1622	1467	871	699	1081	851	1341
turned under (Cowpeas	3472	2501	2794	2276	2249	1100	2403	1242	4054	1883	2282	1489	698

Note: The lack of yield data on certain years is largely from the red clover plots where in some cases the first year's growth was too small to harvest. In some cases also the clover failed. No attempt was made to secure weights of grass clippings on the bluegrass plots.

Table 1. (con't.)

Plots	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	Total	Yearly Average
Series 1													
1. Corn, wheat, clover	2859	1226	1498	3610	1634	3774	2316		6120		2393	65,585	2732.7
2. Corn, wheat, clover, manured	3265	1362	2248	4427	1839	5040	2316		5916		2815	76,591	3191.2
3. Rye - cowpeas (Rye	2229	3062	4604	5109	4264	2615	2575	3518	3987	4036	3814	75,244	3135.1
turned under (Cowpeas	674	2806	3324	1662		1291		2675	1897	2239	3194	47,304	1971.0
4. Rye, turned under	1547	2218	3324	3107	2343	3269	2288	1510	2698	2521	2779	56,596	2358.1
5. Red clover, taken off			1022	4087		3541	1498	2720	2053	312	1876	30,861	1285.8
6. Red clover, turned under			1498	4427		4495	1907	3264	2584	571	2611	36,277	1511.5
7. Alfalfa, taken off	2403	3610	7287	7628	6347	7660	3405	1496	1305	1564	3345	82,452	3435.5
8. Bluegrass sod, clipped	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod
Series 2													
9. Corn, wheat, clover	2655	817	1580	3678	1498	4496	2452		6052		2080	60,001	2500.0
10. Corn, wheat, clover, manured	3539	1226	2452	4632	1498	6267	3024		6596		2529	76,210	3175.4
11. Rye - cowpeas (Rye	2145	2683	2411	4591	3092	5326	2629	3575	1170	3308	3835	61,085	2545.2
turned under (Cowpeas	991	2493	2832	1893		1595		2800	2454	1898	3579	48,228	2009.5
12. Rye, turned under	1401	2248	2479	2874	2288	2070	1771	1117	3752	2188	2652	50,296	2095.6
13. Red clover, taken off			681	4427		3950	1771	2488	1795	353	1618	30,713	1279.7
14. Red clover, turned under			953	4155		4700	2112	2720	2366	516	1618	31,688	1320.3
15. Alfalfa, taken off	1743	2452	5121	5108	4386	5686	2384	1020	1088	1142	2448	59,718	2488.2
16. Bluegrass sod, clipped	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod
Series 3													
17. Bluegrass sod, clipped	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod
18. Red clover, turned under			2043	7288		6607	3406	3763	951	1008	2016	37,297	1554.0
19. Sweet clover, turned under			3000			4441			2344		2344	28,128	1172.0
20. Rye - cowpeas (Rye	2064	3406	2179	5476	4836	2275	2602	1685	2573	2879	2191	49,394	2058.0
turned under (Cowpeas	626	4359	4441	2901	1547	791		2536	1572	1974	745	44,636	1859.8
Series 4													
21. Bluegrass sod, clipped	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod	Sod
22. Red clover, turned under			1703	9128		6198	3882	2769	816	816	2066	34,127	1421.9
23. Sweet clover, turned under			3000			4304			2015		2015	24,189	1007.8
24. Rye - cowpeas (Rye	1456	3774	4332	8242	4904	3760	3678	2900	3045	2448	3534	59,145	2464.3
turned under (Cowpeas	611	5694	4358	3188	2180	1877		2459	1770	2252	2716	55,548	2316.0

The sweet clover yields were not taken during the last three years, and in these cases average yields from the plots for the year's preceding were used. The totals in these cases are therefore close approximations rather than actual yields.

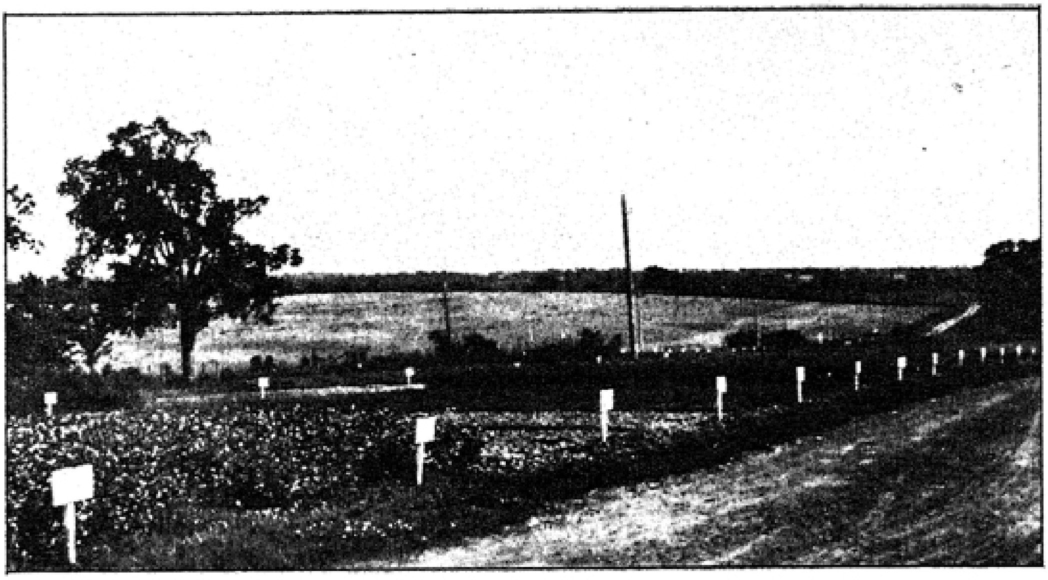

Figure 5.—General view of most of Series 1 and 2 in foreground and of a part of Series 3 and 4 in background.

Nitrogen Content of the Soils under the Different Crops and Cropping Systems

Surface Soil.—An examination of the nitrogen content of the surface soil (0-7 inches) of the various plots sampled at the different periods (Tables 2 and 4 and Figures 2 and 3) shows rather widely varying trends. Some irregularities exist, particularly in the plots with the three year rotation where the nitrogen content of the second sampling appears rather low and that of the third sampling rather high. These were doubtless due to slight variations in the samples from these plots taken under different crops. However, when one observes the general trend in the nitrogen content of the various plots during the twenty-four year period, these variations are not particularly disturbing.

Subsurface Soil.—The nitrogen content of the subsurface soil (7-12 inches) shows much less change resulting from the various crops and cropping systems than does that of the surface soil (Tables 3 and 5). As a matter of fact, there are more cropping systems showing losses than those showing gains and in most cases, the differences are negligible. It is, of course, understandable that the surface soil, in

Table 2. Nitrogen Content of the Surface Soils (0-7 inches) at the Different Sampling Dates (Percentage of Water Free Soil as Averages of the Duplicate Series) (1)

Series 1 and 2

Plots	Crops	1917	1921	1929	1934	1941
1 & 9	Corn, wheat, clover	.136	.132	.143	.137	.137
2 & 10	Corn, wheat, clover & manure	.139	.132	.149	.148	.146
3 & 11	Rye & cowpeas, turned under	.137	.144	.141	.147	.151
4 & 12	Rye, turned under	.137	.128	.116	.109	.105
5 & 13	Red clover, taken off	.143	.140	.155	.158	.160
6 & 14	Red clover, turned under	.137	.146	.161	.164	.170
7 & 15	Alfalfa, taken off	.132	.133	.149	.157	.154
8 & 16	Bluegrass sod, clipped	.125	.123	.146	.152	.150

Series 3 and 4

		1917	1929	1941
17 & 21	Bluegrass sod, clipped	.105	.125	.132
18 & 22	Red clover, turned under	.107	.122	.142
19 & 23	Sweet clover, turned under	.113	.141	.167
20 & 24	Rye & cowpeas, turned under	.113	.120	.119

(1) See Appendix for complete tabular data.

Table 3. Nitrogen Content of the Subsurface Soils (7-12 Inches) at the Different Sampling Dates (Percentage of Water Free Soil as Averages of the Duplicate Series)

Series 1 and 2

Plots	Crops	1917	1921	1929	1934	1941
1 & 9	Corn, wheat, clover	.092	.084	.095	.091	.087
2 & 10	Corn, wheat, clover, & manure	.092 (1)	.084	.109	.099	.086
3 & 11	Rye & cowpeas, turned under	.091	.085	.095	.106	.088
4 & 12	Rye, turned under	.093	.087	.092	.094	.081
5 & 13	Red clover, taken off	.096	.093	.103	.109	.094
6 & 14	Red clover, turned under	.093	.089	.105	.112	.097
7 & 15	Alfalfa, taken off	.089	.085	.094	.105	.091
8 & 16	Bluegrass sod, clipped	.081	.081	.091	.103	.084

Series 3 and 4

		1917	1929	1941
17 & 21	Bluegrass sod, clipped	.065	.066	.064
18 & 22	Red clover, turned under	.066	.064	.062
19 & 23	Sweet clover, turned under	.074	.073	.078
20 & 24	Rye & cowpeas, turned under	.074	.072	.066

(1) All these samples from the duplicate plots making up the averages were run twice in triplicate. In one triplicate run on plot 2, the results were far too high and were omitted from this average for the four runs for plots 2 and 10, giving an average of .092 used in the calculations.

which most of the crop roots are found and into which the crops and crop residues were spaded, would be that in which the important nitrogen changes would take place. However, it is rather surprising that the subsurface nitrogen changed so very little, particularly under the deep rooted legumes.

An experiment by Albrecht[3] on a similar soil, to which 2½ tons of chopped red clover hay were applied annually, likewise showed that the major nitrogen accumulations took place in the surface soil. As an average of two series of plots, the gain in nitrogen in the surface seven inches during a period of 14 years was 346 pounds per acre and in the subsurface soil (7-12 inches) it was only 76 pounds.

In both of these experiments the changes in subsurface nitrogen are so minor that in discussing total nitrogen trends it makes little difference whether that of the surface seven inches is considered or that of the surface foot. As a consequence, in the discussion which follows, major attention is given to the nitrogen changes in the surface seven inches.

Nitrogen Gains or Losses in the Surface Soil

In a discussion of the nitrogen gains or losses taking place in an investigation of this character major trends are of prime importance. Since the plot series were in duplicate only, it has been impossible to apply the usual statistical methods to the data. The method followed has been to take the averages of the nitrogen content of the duplicate plots and show these data in tabular as well as graphic form, from the beginning to the end of the experiment. Certainly differences of 100 pounds of nitrogen in an acre seven inches of soil between the beginning and the end of the twenty-four-year period are insignificant, except in showing that such cropping systems resulted in no material nitrogen change at all. However, most differences are several times this figure, and when viewed as trends they have real significance and are certainly far beyond experimental error.

Significant increases in the nitrogen in the surface soil during the twenty-four year period took place under the continuous sod and the continuous legume systems (Table 4). The 3-year rotation of corn, wheat, and clover resulted in a nitrogen change which was negligible. This same system with the addition of manure registered only a slight gain and of negligible quantity.

Continuous red clover, with the first crop and sometimes the second crop removed, in Series 1 and 2 gave an average gain of 340 pounds per acre and where the crops were turned under, the average

[3]Albrecht, W. A. Methods of Incorporating Organic Matter with the Soil in Relation to Nitrogen Accumulations. Missouri Agr. Exp. Sta. Research Bul. 249. 1936.

gain for all four series was 680 pounds. Continuous sweet clover turned under, on Series 3 and 4, gave an average increase of 1080 pounds per acre. Continuous sod on all four series averaged 520 pounds gain. Continuous alfalfa when crops were removed gave a gain of 440 pounds.

The most significant change in nitrogen content, outside the gain under continuous sweet clover, was the large loss where rye alone was grown and turned under each year. This loss was 640 pounds per acre during the 24-year period, a loss which was consistent from the beginning to the end of the experiment. Undoubtedly a considerable amount of this loss can be attributed to erosion. Erosion measurements on similar land, with a slope of approximately 4 per cent, when in continuous wheat showed a nitrogen loss in the eroded material of around 30 pounds per acre annually. Erosion loss curves based on different slopes indicate that the loss from a 2 per cent slope, which was approximately that of the continuous rye plots,

Table 4. Changes in the Nitrogen Content of the Surface Soil (0-7 Inches) under the Different Cropping Systems, 1917 to 1941.
(Weight of Acre 7 inches of Surface Soil Calculated at 2,000,000 pounds.)

Cropping Systems Averages of Series 1 and 2	Pounds Nitrogen Gain or Loss Per Acre	Cropping Systems Averages of Series 3 and 4	Pounds Nitrogen Gain Per Acre
Corn, wheat, clover	+ 20	Bluegrass sod, clipped	+ 540
Corn, wheat, clover, manured	+140	Red clover, turned under	+ 700
Rye-cowpeas, under	+280	Sweet clover, turned under	+1080
Rye, under	-640	Rye-cowpeas, turned under	+ 120
Red clover, taken off	+340		
Red clover, turned under	+660		
Alfalfa, taken off	+440		
Bluegrass sod, clipped	+500		

Table 5. Changes in the Nitrogen Content of the Subsurface Soil (7-12 inches) under the Different Cropping Systems, 1917 to 1941.
Weight of Acre 5 inches of Subsurface Calculated at 1,700,000 pounds.)

Cropping Systems Averages of Series 1 and 2	Pounds Nitrogen Gain or Loss Per Acre	Cropping Systems Averages of Series 3 and 4	Pounds Nitrogen Gain or Loss Per Acre
Corn, wheat, clover	- 85	Bluegrass sod, clipped	- 17
Corn, wheat, clover, manured	-102	Red clover, turned under	- 68
Rye-cowpeas, turned under	- 51	Sweet clover, turned under	+ 68
Rye, turned under	-204	Rye-cowpeas, turned under	-136
Red clover, taken off	- 34		
Red clover, turned under	+ 68		
Alfalfa, taken off	+ 34		
Bluegrass sod, clipped	+ 51		

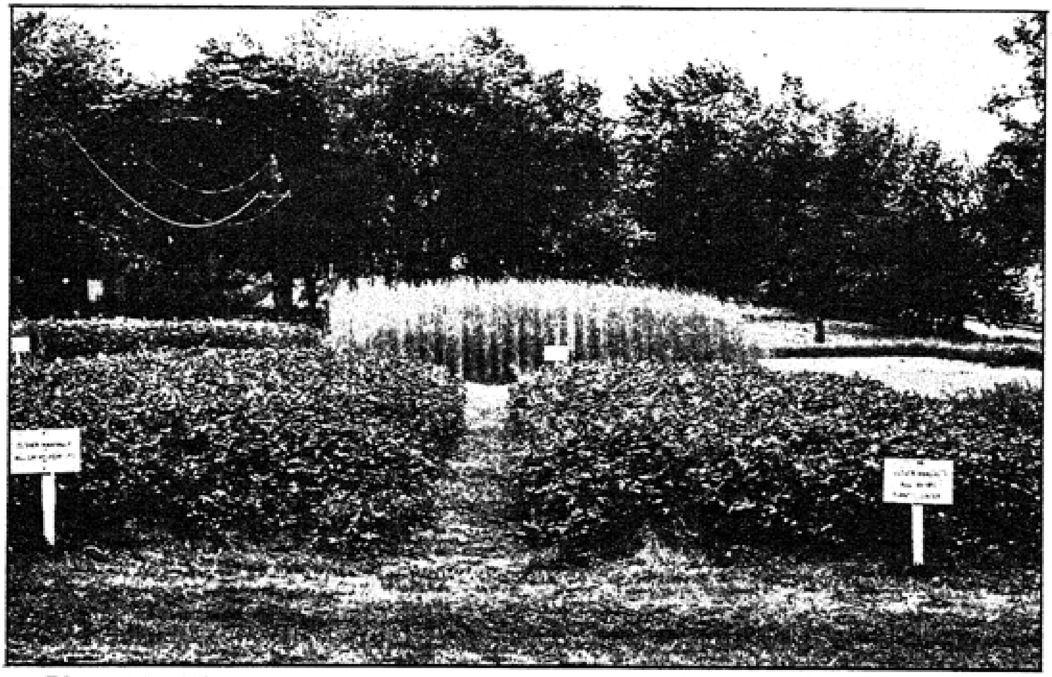

Figure 6.—View of plots of red clover and of rye taken in May before harvesting for weights.

would be near one-half of that from the 4 per cent slope or about 15 pounds per acre annually. For the 24-year period this would total 360 pounds. It must be remembered that this continuous rye plot was exposed to erosion from the time of spading in the rye in May until the next crop covered the ground in September.

Much of the loss from the rye plots can undoubtedly be attributed to the rapid decay of the rye which was cut just before heading in May, chopped into fine pieces, and incorporated with the surface seven inches of the soil, when it was green and succulent, so that it decomposed rapidly. The ground was left bare from the time the rye was spaded in until the next crop had started growth in September. Four months allowed for almost complete decomposition of the green rye unless the soil moisture was deficient. During this period a considerable part of the nitrogen of the crop was made soluble and was subject to leaching downward, particularly during the late summer and early fall rains, and to ultimate removal, probably through a lateral water movement just below the subsurface soil.

It would seem that the benefit often attributed to rye as a green manure must result largely from the available nitrogen set free and its immediate utilization by the following crop such as corn. It seems evident that little increase in nitrogen content of the soil can be expected where rye is used as a green manure.

It is of interest to note that in the case of the plots where cowpeas followed rye each year and where both crops were spaded into the soil, the cowpeas more than offset the loss resulting from continuous rye. During the 24-year period these rye-cowpea plots averaged a consistent gain in nitrogen as compared with the loss under rye alone. The nitrogen gathering ability of the cowpeas and the cover on the land during the summer resulted in a nitrogen gain of 280 pounds on Series 1 and 2 as compared with the 640 pound loss from the rye alone. The total conserving action of the cowpeas in changing a large loss to a significant gain represented 900 pounds of nitrogen.

The 520-pound increase in nitrogen under four plots in continuous bluegrass is both substantial and interesting. It can be attributed to the presence of some white clover in the sod, and to such fixation as may have taken place through the activities of azotobacter and similar nitrogen-fixing micro-organisms. Of course, the plot was not pastured, so that no nitrogen was removed through animals and there was little erosion or leaching. The annual gain of about 20 pounds bears out the general belief that, under continuous bluegrass, land gradually improves.

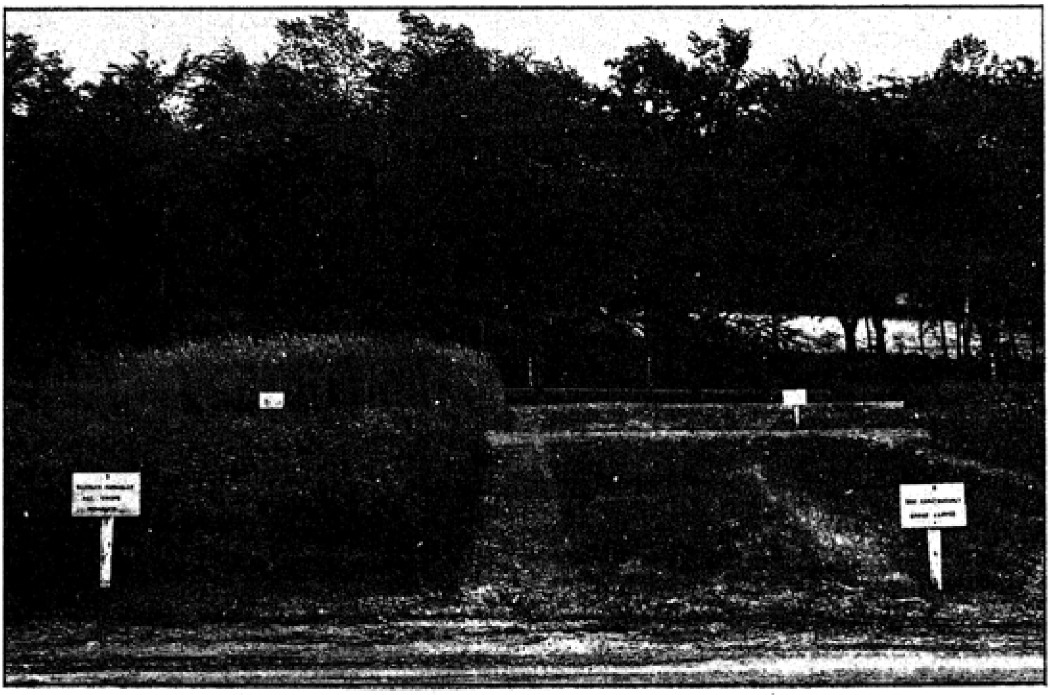

Figure 7.—View of plots of alfalfa and bluegrass sod in Series 1 and 2 in foreground and of rye and bluegrass sod in Series 3 and 4 in background. Taken in May.

Carbon-Nitrogen Ratios and the Total Amounts of Organic Matter in the Soil of the Different Plots

One phase of this study dealt with the relative amounts of carbon and nitrogen (C-N ratio) and of the total amount of organic matter in the soil of the different plots, as influenced by the cropping systems (Table 6). In the beginning the organic matter of the soil from the different plots had the usual C-N ratio of around 10. However, at the close of the study in 1941 this ratio had widened in all plots, ranging, as the final figures for the different plots show, from 12.2 to 14.9 with an average of 13.4. The maximum ratio of 14.9 was in the soil which had continuous rye turned under. Since this plot lost a large amount of nitrogen during the period and since a highly carbonaceous material was turned under, these had opposite effects. As a result a wide C-N ratio would be anticipated. However, the ratio in the soil of the other plots is also rather wide since the accumulation of carbon from 1917 to 1941 is in some instances quite large.

The increases in both nitrogen and carbon and also the increase in the amount of organic matter, as determined by multiplying the increase in organic carbon by 1.724, are shown in Table 7.

Using this type of calculation, it is of interest to observe that the organic matter of the soil in continuous sweet clover, turned under on alternate years, increased at the rate of 1400 pounds annually and that of the soil with red clover turned under, as well as that in bluegrass sod, showed about 1000 pounds annual increase. The other

Table 6. The Average Carbon-Nitrogen Ratios for the Surface Soils of Series 1 and 2 and Series 3 and 4 at the Beginning and the End of the Experiment.

Series 1 and 2		1917			1941		
Plots	Cropping Systems	C	N	N&C Ratio	C	N	N&C Ratio
1 & 9	Corn, wheat, clover	1.42	.136	10.4	1.96	.137	14.3
2 & 10	Corn, wheat, clover and manure	1.44	.139	10.3	2.06	.146	14.1
3 & 11	Rye and cowpeas, turned under	1.47	.137	10.7	2.04	.151	13.5
4 & 12	Rye, turned under	1.39	.137	10.1	1.57	.105	14.9
5 & 13	Red clover, taken off	1.52	.143	10.6	2.08	.160	13.0
6 & 14	Red clover, turned under	1.39	.137	10.1	2.09	.170	12.2
7 & 15	Alfalfa, taken off	1.40	.132	10.6	2.01	.154	13.0
8 & 16	Bluegrass sod, clipped	1.32	.125	10.5	2.07	.150	13.8
Series 3 and 4							
17 & 21	Bluegrass sod, clipped	1.10	.105	10.4	1.85	.132	14.0
18 & 22	Red clover, turned under	1.06	.107	9.9	1.75	.142	12.3
19 & 23	Sweet clover, turned under	1.09	.113	9.6	2.07	.167	12.3
20 & 24	Rye and cowpeas, turned under	1.14	.113	10.0	1.61	.119	13.5

Table 7. Increases in Nitrogen, Carbon, and Organic Matter of the Surface Soil (0-7 inches) of the Different Plots, 1917 to 1941.

Series 1 and 2 (Averages) Cropping Systems	% N	Lbs. N per acre	% Org. C	Lbs. Org. C per acre	Lbs.1/ Org. Mat. per acre	Tons Org. Mat. per acre	Lbs. N Increase per acre annually	Lbs. Org. Matter Increase per acre annually
Corn, wheat, clover	.001	30	.54	10,800	18,819	9.4	.8	775
Corn, wheat, clover-manure	.007	140	.62	12,400	21,377	10.6	5.8	890
Rye and cowpeas-under	.014	280	.57	11,400	19,653	9.8	11.6	818
Rye-under	-.032	- 640	.18	3,600	6,206	3.1	-26.6	258
Red clover-off	.017	340	.56	11,200	19,308	9.6	14.1	804
Red clover-under	.033	660	.70	14,000	24,136	12.0	27.5	1,005
Alfalfa-off	.022	440	.61	12,200	21,032	10.5	18.3	878
Bluegrass sod	.025	500	.75	15,000	25,860	12.9	21.6	1,077
Series 3 and 4 (Averages)								
Bluegrass sod	.027	540	.75	15,000	25,860	12.9	22.5	1,077
Red clover-under	.035	700	.69	13,800	23,791	11.8	29.1	991
Sweet clover-under	.054	1080	.98	19,600	33,790	16.8	45.0	1,407
Rye and cowpeas-under	.006	120	.47	9,400	16,205	8.1	5.0	676

1/ Organic matter = Organic Carbon multiplied by 1.724.

systems, with the exception of continuous rye, showed annual increases ranging from 675 and 990 pounds. The soil from the rye plot, in spite of its wide C-N ratio in 1941, gave an annual increase of only 258 pounds of organic matter.

All of these increases, with the exception of that from the rye, are substantial ones. They indicate that the turning under of organic matter regularly, may have a pronounced influence in building up this material in the soil, even where the nitrogen increase is only a moderate one. Such a substantial accumulation of organic material should be of benefit to soil productivity even when the nitrogen accumulation does not keep pace with it. However, the larger increases in organic matter in the soil are in those plots in which there has also been a material increase in nitrogen and this should naturally have a pronounced effect on crop production. This fits into the general picture of an abundant nitrogen and organic matter supply as a most important consideration in the management of Missouri soils.

Nitrogen Returned in Crops

It is of interest to compare the amounts of nitrogen turned back into the soil by crops with the gain or loss of soil nitrogen per acre (Table 8). The figures showing the nitrogen returned were secured from the weights of crops and the average nitrogen content of the crops harvested. These, however, do not show the total amounts of nitrogen returned, in most cases, since no weights could well be taken of the residues of the crops or of certain small growths not large enough to be harvested readily. The influence of these residues and this unharvested growth is quite significant in the case of red clover in which the first year's growth carries considerable nitrogen. It is much more significant in the case of sweet clover where the first year's growth and the unharvested residues are usually large. This undoubtedly accounts for the very significant gains in both nitrogen and organic matter under the sweet clover crop where the matured stalks alone, which were cut and weighed as second year growth, gave rather small weights.

In the case of the three year rotation of corn, wheat, clover, without manure, the total nitrogen found and removed in crops, as an average of the two plots, was 850 pounds. The total nitrogen gain in the surface soil was a negligible amount entirely within the field of experimental error. It is seen, however, that in this rotation, without manure, but with second crops of clover often remaining on the ground, no significant loss of nitrogen occurred during the twenty-four year period.

In the case of the rotation of corn, wheat, clover, receiving manure, the crops contained and removed 900 pounds of nitrogen. Twenty-eight tons of manure were applied during the course of the experiment, carrying back to the soil, during this time, a total of approximately 280 pounds of nitrogen. The soil gained 140 pounds. Other investigations on a somewhat similar soil, show that the acre loss of nitrogen through erosion in this type of rotation would have been only 2 or 3 pounds per year, so that erosion was not an important factor. However, this actual soil increase is so small, during a period of twenty-four years, that it may be considered as of little importance. It does indicate, however, that under a good rotation where most of the crops are fed, the nitrogen of this soil may be fairly well maintained approximately at the existing level, unless erosion causes significant losses.

One of the most interesting comparisons is that of continuous rye turned under and continuous rye followed by cowpeas, both turned back to the land. The continuous rye returned to the soil a total of 760 pounds of nitrogen during the 24 years, while in the same time the soil lost 640 pounds. This nitrogen was taken up by the crop but disappeared almost entirely when it was returned to the soil.

In the case of the rye-cowpeas plots, the total nitrogen turned back in the two crops as an average of four plots was 2150 pounds while the soil gained an average of only 200 pounds. Naturally the rye following the cowpeas took up some of the nitrogen gathered by this legume crop so that the total in the rye was 910 pounds as

Table 8. Some Striking Data from the Plots, 1917-1941 (Average Figures)

Cropping Systems	Nitrogen in Crops 1917 - 1941 (Lbs. per A.)	Nitrogen Turned Under 1917 - 1941 (Lbs. per A.)	Gain or Loss of Nitrogen 1917 - 1941 (Lbs. per A.)	C and N Ratio 1917	C and N Ratio 1941	Org. Mat. in Crops 1917 - 1941 (Lbs. per A.)	Org. Mat. Turned Under 1917 - 1941 (Lbs. per A.)	Gain of Org. Mat. 1917 - 1941 (Lbs. per A.)
Corn, wheat, clover (Avg. two series)	850	0	+ 20	10.4	14.3	62700	0	18800
Corn, wheat, clover - manured (Avg. two series)	900	280 (in manure)	+ 140	10.4	14.1	76400	56000 (Fresh Manure or 14000 Dry Manure, Est.)	21300
Rye - turned under (Avg. two series)	760	760	- 640	10.1	14.9	53400	53400	6200
Rye-Cowpeas - turned under (Avg. four series)	2150 (Rye 910) (Cowpeas 1240)	2150	+ 200	10.3	13.5	100100	110100 (Rye 61200 Cowpeas 48900)	17900
Red clover - taken off (Avg. two series)	670	0	+ 340	10.6	13.0	30700	0	19300
Red clover - turned under (Avg. four series)	760	760	± 680	10.0	12.2	34800	34800	23900
Alfalfa - taken off (Avg. two series)	1790	0	+ 440	10.6	13.0	71000	0	21000
Sweet clover - turned under (Avg. two series)	560	560	+1080	9.6	12.3	26100	26100	33700
Bluegrass sod - clipped (Avg. four series)	---	---	+ 520	10.5	13.9	-----	------	25800

Note: The organic matter figures are given in hundred units and the nitrogen in ten units.

an average of four plots as compared with a total of 760 pounds in the rye of the two plots carrying no cowpeas. The cowpeas carried an average from four plots of 1240 pounds. Undoubtedly much of the nitrogen appeared in both crops but the total, when the amounts in both crops were added together, was 2150 pounds as indicated above. Most of this disappeared, evidently through erosion and leaching. It is quite evident that unless these crops, or at least the cowpeas, are harvested and utilized there is no point in growing the two the same year and turning them under. Even if a crop of wheat or other valuable crop were fall seeded there would most certainly be an unwarranted nitrogen loss. Evidently this fall seeded crop would not utilize all the nitrogen made available. A year given to the growing and turning under of these two crops, either for nitrogen accumulation or for the benefit of the crop following, would not be worthwhile.

It is of interest to observe that red clover hay, taken off, contained, as an average of the two plots, a total of 670 pounds of nitrogen. At the same time the soil gained 340 pounds, a substantial increase evidently from nitrogen fixation. In the case of the clover turned under, the crops contained, as an average of all four plots, 760 pounds, while the average gain to the soil, in this case, was 680 pounds or a little less than that found in the hay. If the clover roots and stubble in these plots contributed the same amounts of nitrogen as in those plots where the clover was removed, there must have been a material loss of the nitrogen turned under. It is possible that the better showing made by the clover in conserving nitrogen, than that made by the rye-cowpeas, was due in part to the larger amounts of minerals in the clover residues which aided the micro-organisms in building up this element.

The average amount of nitrogen removed in the alfalfa was 1790 pounds per acre, but at the same time the soil gained 440 pounds. This indicates that in spite of the large amount removed in the crop, alfalfa contributes materially to soil nitrogen accumulation. Where the land is well adapted to this crop, the nitrogen secured from the air must be large.

It was unfortunate that no crop weights were secured from the bluegrass since the nitrogen gains in the soil were quite significant. Evidently bluegrass sod, as already indicated, can be depended upon to provide a material nitrogen increase in this soil.

General Evaluation of Results

The results of this twenty-four year study of nitrogen gains and losses under different cropping systems offer some interesting considerations. It is evident that in the climatic zone of Central Missouri it is difficult to increase greatly the nitrogen content of an average upland soil above its existing level through ordinary soil management practices. It was largely through the rather extraordinary and generally impractical cropping methods of supplying organic matter and nitrogen to the soil that marked gains were secured.

The three-year rotation of corn, wheat, and clover, even when approximately the manure equivalent of crops fed was returned to the land, gave but a small nitrogen increase through this long period. Under continuous alfalfa, however, a practical system on soils which will grow it, it seems possible to register material nitrogen gains for the years this crop is on the land. It is usually grown on a limited part of the farm, however, so that such gains do not have much influence in raising the nitrogen level of the soil on the farm as a whole.

Continuous bluegrass, with nothing removed, gave results somewhat similar to those from alfalfa where the hay was taken off. This is, of course, a practical system of nitrogen building for certain parts of a farm kept in permanent pasture, assuming that only moderate amounts of the nitrogen are removed in the animal bodies.

In all cases of continuous legume production, particularly when the crop is returned to the soil, the possibilities of some nitrogen increase are good. Unfortunately there are few farms where systems of this character can be continued for more than a year or two on a given piece of land, except in the case of a legume like alfalfa or lespedeza. On fields where the legumes can be pastured, the influence of these crops may be extended over a number of years. Unfortunately it was impossible, with the small areas under study, to provide for pasture trials, so that the increase under pasturing can only be estimated. If it is assumed that under bluegrass or legume pasturage two-thirds of the nitrogen in the crops is left on the land, this plan has definite possibilities for those years when such crops are grown

Farmers usually know that pasturing legumes increases the yields of crops following and they often assume that the soil has been materially built up. It is probable, however, that the immediate increase in crop yields is due largely to the rapid decomposition of the legume and other crop residues through which available fertility elements, particularly nitrogen, are released. Such a plan may result in no important accumulation of nitrogen in the soil.

It is probable that if a larger use of lime and fertilizers had been employed throughout the period of this study, including liberal applications of nitrogen, much more significant gains in soil nitrogen would have resulted, particularly in the case of the corn, wheat, clover rotation plots. It is possible that on young soils, containing rather large amounts of readily available mineral nutrients, including abundant lime, the nitrogen level can be more readily increased. It is quite evident, however, that with a heavily cropped soil of around average fertility, under Missouri climatic conditions, handled under the usual cropping systems, with only moderate fertilization, little gain in nitrogen can be anticipated.

Nitrogen Turnover

As a result of the data secured from this and other experiments, along with general observations, the Missouri Station has adopted the term *nitrogen turnover* as an appropriate one to use in relation to the supply of soil nitrogen from year to year or rotation to rotation. In general, the conclusion has been reached that it is uneconomical under the climatic conditions existing in Missouri and under the usual systems of cropping and fertilization, to increase very greatly the nitrogen content of the average soil above what it is today. This, however, need not be a matter of great concern so long as reasonably large amounts of organic matter, particularly that from legume crops, are regularly returned to the soil. The important thing, from the standpoint of continued crop production, is to provide, from rotation to rotation, or year to year, a regular and abundant supply of readily decomposable organic matter that is reasonably high in nitrogen. The decay of this within the soil will set free sufficient available nitrogen for satisfactory crop yields. In other words, it is the decomposition of these regular and abundant additions of organic matter, largely from legumes, that is important, although the accumulation of a large nitrogen reserve within the soil would be advantageous.

The means of providing ample supplies of nitrogen and organic matter from rotation to rotation are not difficult. As a matter of fact, there is opportunity for supplying large amounts of this material through proper soil and crop management. Such supplies may be provided through farm manures, through crop residues, such as roots and stubble, and through the use of certain legume crops, grown solely for green manure or pasture. Naturally, such additions should be sufficient to prevent any appreciable decline in the nitrogen level of the soil. Where good systems of green manuring and pasturing are practiced a moderate increase in this level may be anticipated. The important thing, however, is to provide ample amounts of organic matter and nitrogen for this turnover.

The opportunities for providing a large turnover of nitrogen and organic matter are greatly increased in the regions of longer growing seasons such as prevail in the central and southern parts of the country. In these regions the land may often be double cropped so that a legume green manure or pasture crop may be grown almost every year in addition to a regular harvested crop. The possibilities of such systems are apparent.

These statements do not mean that no nitrogen need be supplied from commercial sources. While a proper management of this turnover from crops may, in many cases, make this unnecessary, it is probable that with increasing supplies of synthetic nitrogen, available at low cost, such as ammonium nitrate, liquid ammonia, or other nitrogen fertilizer, these may be applied with profit along with the organic matter. They may even supply the key to nitrogen and organic matter accumulation through the greater amounts of organic residues and green manures that may be made available by their use. The return of organic manures, in conjunction with the use of nitrogen fertilizers, should be of even greater importance in that the nitrogen turnover should be increased and any decline in productivity due to poor structural conditions could be avoided. While it is evident from the results of this long experiment that under the usual systems of soil management the accumulation of soil nitrogen will not be large, the advent of cheap nitrogen may greatly alter the situation.

SUMMARY

1. The results of a 24-year field study of the influence of different crops, cropping systems, and green manures on the gain or loss of nitrogen and organic matter in an upland Missouri soil of medium fertility are reported and evaluated.

2. It was found that the nitrogen and organic matter changes during the 24-year period were confined almost entirely to the surface seven inches which represented approximately the surface soil. The changes in the subsurface layer (7-12 inches) were insignificant and these figures are omitted from the discussion.

3. Significant increases in the nitrogen content in the surface 7 inches of an acre during the 24-year period, in order of increasing amounts were as follows:

Continuous red clover, with the hay crops removed, a gain of 340 pounds.

Continuous alfalfa, all crops removed, a gain of 440 pounds.

Continuous bluegrass sod, nothing removed, a gain of 520 pounds.

Continuous red clover, all crops turned under, a gain of 660 pounds.

Continuous sweet clover, all crops turned under, a gain of 1080 pounds.

4. A 3-year rotation of corn, wheat, clover, maintained the nitrogen of the soil at near the original level. The same rotation with the manure equivalent of the crops grown, applied to the land, resulted in the small gain of 140 pounds per acre which was not a significant increase.

5. Continuous rye, turned under in May, while still green, and the land left bare until reseeding in September, resulted in a continuous and consistent nitrogen loss totaling 640 pounds per acre during the 24-year period. This loss evidently resulted in part through erosion from the fallow land during the summer months and in part through the rapid release of the nitrogen in the decomposition of the green rye and in its removal through leaching.

6. Continuous rye, turned under green and immediately followed by cowpeas, turned under in the fall, resulted in a gain of 200 pounds during the 24 years. While this is not a very significant gain over the nitrogen level at the outset, the cowpeas at least offset the loss which occurred under rye alone. However, the nitrogen turned into the soil in these two crops totaled 2150 pounds. While a part of this nitrogen was undoubtedly present in both crops, nevertheless the total loss was large.

7. In general, significant gains in the nitrogen content of the soil during this long period occurred only under those systems where legumes or bluegrass were grown continuously. These systems would be impractical so far as an entire farm is concerned. The practical system of a crop rotation, with and without manure, gave no significant gain in nitrogen although it did maintain it at near the level existing when the investigation was inaugurated.

8. The results show rather definitely that for the soil under study in the climatic zone of Central Missouri, it is difficult and largely impractical under the usual systems of farming to build up the nitrogen content significantly. It would seem, therefore, that the thing for the farmer to strive for is a good "nitrogen turnover" from year to year or rotation to rotation. However, with much more liberal fertilizer applications than were used in this experiment, including much nitrogen, important gains in soil nitrogen may be possible.

9. In spite of the fact that no great increase in the nitrogen content of the soil resulted from most of the systems used, nevertheless, in most cases, the total organic matter, as determined from the amount of organic carbon present, increased considerably. These gains varied from the small amount of 6200 pounds under continuous rye to the large amount of 33700 pounds under continuous sweet clover. In general, the larger increases were under those crops where the nitrogen content also showed a material gain, although the gain

in organic matter was proportionately larger than that of nitrogen.

10. The results reported and the conclusions reached from this study refer to a Missouri soil of medium or average fertility receiving moderate applications of phosphate fertilizer and lime. It is probable that heavy applications of fertilizer, carrying liberal amounts of nitrogen, phosphate, and potash with large applications of lime, would have resulted in considerably larger nitrogen gains.

APPENDIX

Table 9. Nitrogen Content of Surface Soil (0-7 inches) for Series 1, 2, 3 & 4 at Different Dates of Sampling.

Plots	Crops	1917	1921	1929	1934	1941
Series 1 and 2						
1.	Corn, wheat, clover	.140	.135	.150	.140	.142
2.	Corn, wheat, clover and manure	.141	.135	.151	.153	.146
3.	Rye and cowpeas, turned under	.145	.149	.142	.153	.153
4.	Rye, turned under	.146	.136	.119	.114	.106
5.	Red clover, taken off	.154	.147	.163	.167	.168
6.	Red clover, turned under	.150	.156	.179	.177	.185
7.	Alfalfa, taken off	.145	.146	.165	.174	.168
8.	Bluegrass sod, clipped	.136	.134	.155	.165	.163
9.	Corn, wheat, clover	.132	.130	.137	.135	.133
10.	Corn, wheat, clover and manure	.137	.129	.147	.143	.146
11.	Rye and cowpeas, turned under	.130	.140	.141	.142	.149
12.	Rye, turned under	.129	.120	.114	.104	.105
13.	Red clover, taken off	.133	.134	.147	.149	.153
14.	Red clover turned under	.124	.136	.144	.151	.155
15.	Alfalfa, taken off	.119	.121	.134	.140	.140
16.	Bluegrass sod, clipped	.113	.112	.137	.139	.137
Series 3 and 4						
17.	Bluegrass sod, clipped	.109		.129		.131
18.	Red clover, turned under	.114		.133		.149
19.	Sweet clover, turned under	.116		.137		.168
20.	Rye and cowpeas, turned under	.112		.124		.113
21.	Bluegrass sod, clipped	.102		.122		.133
22.	Red clover, turned under	.101		.111		.136
23.	Sweet clover, turned under	.111		.145		.167
24.	Rye and cowpeas, turned under	.114		.116		.125

Table 10. Nitrogen Content of Subsurface Soil (7-12 inches) for Series 1, 2, 3 and 4 at Different Dates of Sampling.

Plots	Crops	1917	1921	1929	1934	1941
Series 1 and 2						
1.	Corn, wheat, clover	.090	.085	.093	.083	.088
2.	Corn, wheat, clover and manure	.105	.084	.118	.095	.084
3.	Rye and cowpeas, turned under	.085	.082	.092	.106	.086
4.	Rye, turned under	.091	.086	.097	.096	.080
5.	Red clover, taken off	.099	.095	.111	.114	.095
6.	Red clover, turned under	.100	.096	.114	.125	.106
7.	Alfalfa, taken off	.099	.096	.105	.117	.104
8.	Bluegrass sod, clipped	.092	.090	.103	.112	.098
9.	Corn, wheat, clover	.094	.083	.098	.100	.086
10.	Corn, wheat, clover and manure	.092	.084	.101	.103	.089
11.	Rye and cowpeas, turned under	.097	.088	.099	.107	.091
12.	Rye, turned under	.095	.088	.088	.092	.083
13.	Red clover, taken off	.094	.092	.096	.105	.093
14.	Red clover, turned under	.087	.083	.096	.099	.088
15.	Alfalfa, taken off	.079	.075	.084	.094	.078
16.	Bluegrass sod, clipped	.070	.072	.080	.095	.071
Series 3 and 4						
17.	Bluegrass sod, clipped	.068		.067		.063
18.	Red clover, turned under	.070		.069		.063
19.	Sweet clover, turned under	.074		.071		.074
20.	Rye and cowpeas, turned under	.069		.064		.060
21.	Bluegrass sod, clipped	.063		.066		.065
22.	Red clover, turned under	.062		.060		.062
23.	Sweet clover, turned under	.075		.075		.082
24.	Rye and cowpeas, turned under	.079		.080		.072

TABLE 11. Nitrogen and Carbon Determinations, 1917; Surface 7 inches

Plot Nos.	Crop	Total N	Org. C	C & N Ratio
Series 1				
1	Corn, wheat, clover	.140	1.51	10.7
2	Corn, wheat, clover, manure	.141	1.54	10.9
3	Rye & cowpeas, turned under	.145	1.60	11.0
4	Rye, turned under	.146	1.54	10.5
5	Red clover, taken off	.154	1.66	10.7
6	Red clover, turned under	.150	1.47	9.8
7	Alfalfa, taken off	.145	1.54	10.6
8	Bluegrass sod, clipped	.136	1.45	10.6
Series 2				
9	Corn, wheat, clover	.132	1.34	10.1
10	Corn, wheat, clover, manure	.137	1.34	9.7
11	Rye & cowpeas, turned under	.130	1.35	10.3
12	Rye, turned under	.129	1.25	9.6
13	Red clover, taken off	.133	1.39	10.4
14	Red clover, turned under	.124	1.31	10.5
15	Alfalfa, taken off	.119	1.26	10.5
16	Bluegrass sod, clipped	.113	1.20	10.6
Series 3				
17	Bluegrass sod, clipped	.109	1.11	10.1
18	Red clover, turned under	.114	1.08	9.4
19	Sweet clover, turned under	.116	1.12	9.6
20	Rye & cowpeas, turned under	.112	1.13	10.0
Series 4				
21	Bluegrass sod, clipped	.102	1.09	10.6
22	Red clover, turned under	.101	1.04	10.2
23	Sweet clover, turned under	.111	1.07	9.6
24	Rye & cowpeas, turned under	.114	1.15	10.0

Averages Series 1 and 2

Plot Nos.	Crop	Total N	Org. C	C & N Ratio
1 & 9	--Corn, wheat, clover	.136	1.42	10.4
2 & 10	--Corn, wheat, clover, manure	.139	1.44	10.3
3 & 11	--Rye & cowpeas, turned under	.137	1.47	10.7
4 & 12	--Rye, turned under	.137	1.39	10.1
5 & 13	--Red clover, taken off	.143	1.52	10.6
6 & 14	--Red clover, turned under	.137	1.39	10.1
7 & 15	--Alfalfa, taken off	.132	1.40	10.6
8 & 16	--Bluegrass sod, clipped	.125	1.32	10.5

Averages Series 3 & 4

Plot Nos.	Crop	Total N	Org. C	C & N Ratio
17 & 21	-Bluegrass sod, clipped	.105	1.10	10.4
18 & 22	-Red clover, turned under	.107	1.06	9.9
19 & 23	-Sweet clover, turned under	.113	1.09	9.6
20 & 24	-Rye & cowpeas, turned under	.113	1.14	10.0

TABLE 12. Nitrogen and Carbon Determinations, 1941; Surface 7 inches

Plot Nos.	Crop	Total N	Org. C	C & N Ratio
Series 1				
1	Corn, wheat, clover	.142	2.04	14.3
2	Corn, wheat, clover, manure	.146	2.05	14.0
3	Rye & cowpeas, turned under	.153	2.08	13.5
4	Rye, turned under	.106	1.69	15.9
5	Red clover, taken off	.168	2.26	13.4
6	Red clover, turned under	.185	2.31	12.4
7	Alfalfa, taken off	.168	2.34	13.9
8	Bluegrass sod, clipped	.163	2.38	14.6
Series 2				
9	Corn, wheat, clover	.133	1.89	14.2
10	Corn, wheat, clover, manure	.146	2.07	14.1
11	Rye & cowpeas, turned under	.149	2.01	13.4
12	Rye, turned under	.105	1.46	13.9
13	Red clover, taken off	.153	1.91	12.4
14	Red clover, turned under	.155	1.88	12.1
15	Alfalfa, taken off	.140	1.68	12.0
16	Bluegrass sod, clipped	.137	1.77	12.9
Series 3				
17	Bluegrass sod, clipped	.131	1.98	15.1
18	Red clover, turned under	.149	1.88	12.6
19	Sweet clover, turned under	.168	2.25	13.3
20	Rye & cowpeas, turned under	.113	1.60	14.1
Series 4				
21	Bluegrass sod, clipped	.133	1.72	12.9
22	Red clover, turned under	.136	1.63	11.9
23	Sweet clover, turned under	.167	1.89	11.3
24	Rye & cowpeas, turned under	.125	1.62	12.9

Averages Series 1 and 2

Plot Nos.	Crop	Total N	Org. C	C & N Ratio
1 & 9	--Corn, wheat, clover	.137	1.96	14.3
2 & 10	--Corn, wheat, clover, manure	.146	2.06	14.1
3 & 11	--Rye & cowpeas, turned under	.151	2.04	13.5
4 & 12	--Rye, turned under	.105	1.57	14.9
5 & 13	--Red clover, taken off	.160	2.08	13.0
6 & 14	--Red clover, turned under	.170	2.09	12.2
7 & 15	-- Alfalfa, taken off	.154	2.01	13.0
8 & 16	--Bluegrass sod, clipped	.150	2.07	13.8

Averages Series 3 and 4

Plot Nos.	Crop	Total N	Org. C	C & N Ratio
17 & 21	-Bluegrass sod, clipped	.132	1.85	14.0
18 & 22	-Red clover, turned under	.142	1.75	12.3
19 & 23	-Sweet clover, turned under	.167	2.07	12.3
20 & 24	-Rye & cowpeas, turned under	.119	1.61	13.5