OKLAHOMA
AGRICULTURAL AND MECHANICAL COLLEGE
AGRICULTURAL EXPERIMENT STATION

C. P. BLACKWELL, Director
Stillwater, Oklahoma

The Economy of Soil Nitrogen Under Semiarid Conditions

H. H. FINNELL
Associate Agronomist
OKLAHOMA AGRICULTURAL EXPERIMENT STATION

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H. H. FINNELL

Introduction

The continued prosperity of a new agricultural community depends to a great extent on the maintenance of soil fertility at a highly productive level. If conditions permit the successful control of soil depletion coupled with a profitable production, the earliest possible recognition of the problems involved is important to the public welfare. It was with this in mind that the following study was undertaken at the Panhandle Agricultural Experiment Station at Goodwell, Oklahoma.

Facts Concerning the Use of Soil Nitrogen

The total soil nitrogen in the six-foot soil section is shown by analyses to average between 8,000 and 11,000 pounds per acre. From 1,200 to 2,500 pounds of this amount may be found in the surface six inches of soil. Observations of depletion,[3] as reckoned from the comparative analyses of cropped and virgin soils taken from seven representative types analyzed in 1929, showed 15 percent less total nitrogen in the topsoil of cultivated fields than was found in adjacent areas of native sod.

The draft on soil nitrogen by the usual cropping system has averaged about 20 pounds per acre annually; and by effective crop rotation systems it has averaged 25 pounds or more per acre annually. Since crop yields in this area are caused to vary widely by the amount and distribution of moisture supply, the removals of nitrogen may fluctuate from zero in case of crop failures to as high as 85 pounds per acre in case of a bumper yield.

Farm practices affecting the utilization of moisture also have a fertility significance. On heavy silt loam soil, where the penetration of surface water is relatively slow, approximately two-thirds of the total rainfall is lost by immediate surface evaporation.[1 2] Losses estimated at 13.5 percent of the total rainfall occur as the result of surface runoff. Altogether, only about 20 percent of the annual rainfall reaches the subsurface and subsoil, where it is available for crop production. Adjusting the cropping plan to allow longer intervals between crops not only permits the more or less efficient storage of moisture but also the accumulation[4] of soluble nitrogen which may be used by the succeeding crop or lost by leaching to subsoil levels below the root zone. This relation of the problems of moisture utilization and nitrogen utilization, coupled with the prevailing soil and climatic conditions of the area, results in cropping practice assuming a vital importance in the economy of utilization of soil resources under semiarid conditions.

A survey of the forces which are more or less active in building up or wearing out the soil with reference to nitrogen indicates the following:

1. While surface erosion is a highly destructive factor on the lighter and more sloping types of High Plains soils, it does not appear to be a predominating agency of fertility depletion on the heavy, nearly level soils. The amount of runoff from the latter types of soil has been small enough to allow complete prevention by means of properly constructed level terraces[2] which have proved highly profitable as a moisture saving practice.

2. Analyses of rainwater,[5] determined for three years at Goodwell, Oklahoma, show an income of nitrate nitrogen amounting to less than three-fourths pound per acre annually. This is of very small importance in the nitrogen economy of the soil.

3. Wind erosion, transporting dust of the surface soils relatively high in organic matter, may be a serious factor in individual cases; but the net loss or gain over the area as a whole is probably of no consequence.

Therefore it would appear that a change in the nitrogen balance must depend mostly on the fixation of atmospheric nitrogen by soil organisms as a natural source of income and on the crop removals, with possible losses by leaching into the lower subsoil, as the principal forces of depletion.

Gainey, Sewell and Latshaw,[6] observing the effects of a twelve-year cropping period in western Kansas, found widely varying changes in the topsoil nitrogen content. There the nitrogen losses appeared to relate, first, to the original amount present and, second, (a particular level of total nitrogen given) to the kind of cropping system employed.

Continuous small grain culture and alternate small grain and fallow culture were most conservative or original nitrogen stores. Extended fallowing, and sorghum culture either continuous or alternating with fallow, caused relatively large losses. Rotation systems occupied an intermediate position. Explanations of these observations suggested by Gainey and associates were the leaching of nitrates during periods when the soil was unoccupied by a growing crop and interference with the natural replenishing of the supply by nitrogen fixing organisms as a result of limited organic residues accumulating during row-crop culture and fallowing.

The purpose of the study which follows was to learn the relative importance of major factors affecting the nitrogen balance in heavy plains soils and their significance in working out a system of conservative crop production.

The Nitrogen Content of Cultivated Soils Under Various Systems of Cropping

The nitrogen content of the topsoils on 15 plots on the Panhandle Agricultural Experiment Station farm has been determined annually for eight years. An unbroken record for seven years is available for seven additional plots of the same series. This constitutes a block of land lying nearly level, with a grade of less than one-half of one percent sloping to the north and west. The plots are numbered from north to south, being 28 feet in width and 267 feet long. As will be noted by reference to Table 1, the natural fertility decreases in this series from approximately 1,800 pounds to about 1,400 pounds of nitrogen per acre-six-inches, running north to south. Seven general cropping systems have been practiced within this series, repeated at intervals with some variation in cultural methods, the schedule having been adopted primarily for the purpose of studying the behavior of soil moisture.

These soils were sampled each year in January by taking approximately 15 tube cores distributed over the plot. These were mixed together and pulverized to pass a 20-mesh sieve. The samples obtained in this way were used for the determination of total nitrogen and nitrate nitrogen according to the official methods. All analyses for total nitrogen were checked to within a variation of seven parts per million from the mean.

The removals of nitrogen during the 7-year period, 1924-30, are shown in Table 2. The crop failures noted on this table were due to adverse weather conditions in all cases except plots 3 and 11 in 1930 which were due to insect depredations.

The variations in trend of topsoil nitrogen under different cropping conditions were so great that adequate explanations must be sought not only for losses but for gains.

TABLE 1.—Total Nitrogen Content of Topsoil, 1924-31, in P. P. M. of Dry Weight.

Plot No.	Jan.* 1924	Jan. 1925	Jan. 1926	Jan. 1927	Jan. 1928	Jan. 1929	Jan. 1930	Jan. 1931	Plot Mean
1303		934	919	956	916	920	986	941	938.8
1304		930	930	942	906	894	882	848	904.5
1305		919	924	868	880	880	870	840	883.0
1306	913	848	916	882	824	876	742	763	845.5
1307	930	865	868	882	835	850	817	778	853.1
1308	919	840	875	875	814	846	749	740	832.2
1309	803	824	782	772	761	747	733	711	766.6
1310	866	795	740	758	695	673	711	639	734.6
1311		791	709	740	742	740	758	754	747.7
1312		769	704	710	676	711	722	684	710.8
1313	760	730	700	691	702	691	699	631	700.5
1314	739	713	679	677	625	671	645	617	670.7
1315		698	664	658	658	658	659	631	660.8
1316	731	731	671	647	676	703	664	632	681.8
1317	724	705	712	638	645	615	615	602	657.0
1318	705	705	667	680	639	649	613	600	657.2
1319	626	671	638	642	649	693	635	626	647.5
1320	668	671	679	700	642	723	613	607	662.8
1321		641	686	672	711	744	694	666	687.8
1322	668	675	709	675	656	700	701	659	680.3
1323	709	638	693	679	638	719	686	691	681.6
1324	700	683	649	686	686	705	694	685	686.0
Annual Mean	764.0**	762.5	750.6	746.8	726.1	743.9	722.6	697.5	

*1924 sampling 0 to 9 inches. All remaining samplings 0 to 6 inches.

**1924 average is of 15 plots only. Averages for all remaining years are of 22 plots.

Trends of Topsoil Nitrogen as Affected by Cropping

It is apparent from studying the annual nitrogen content of these plots that it has been materially affected by the manner of cropping, both as to the trend of rise or decline and as to the variations noted from year to year. In Table 3 are shown together the crop removals of nitrogen, the average topsoil nitrogen content, the standard deviation and coefficient of variability, and the progress of nitrogen change during the period. The latter, shown as annual decline or gain in nitrogen expressed as parts per million of topsoil in the last column of Table 3, was calculated by use of the formula

$$r\frac{\text{standard deviation N}}{\text{standard deviation T}}.$$

The nitrogen content (N) of each plot was correlated with time (T) as a factor and the regression line determined for each plot, the data for which are shown in Table 1.

In grouping the plots according to manner of cropping, some very significant facts are evidenced. (See Table 4). In all cases where continuous cropping with closely spaced plants was followed, the topsoil nitrogen was maintained with slight gains. In each group of plots where extended fallowing was practiced, losses of from 160 to 266 pounds of nitrogen per acre-six-inches of topsoil were indicated for the seven-year period. The amounts depended on the total amount present on one hand and the relative amount of time given to fallowing on the other. These observations are in agreement with those of Gainey, Sewell and Latshaw in western Kansas.

TABLE 2.—Estimated Nitrogen Removed by Crops During Period 1924-30, in Pounds per Acre and Parts per Million of Topsoil.

Plot No.		1924	1925	1926		1928	1929	1930	Total	Total P.P.M.
1303	Straw	15.61		12.63		16.12	3.87			
	Grain	6.54	F	28.19	F	41.34	18.27	F	142.57	71.28
1304	Straw	18.22	----	12.87	----	16.76	----	1.57		
	Grain	17.31	----	30.43	----	42.58	----	3.66	143.40	71.70
1305	Straw	----		----		----	12.18	----		
	Grain	----	F	----	F	----	45.80	----	57.98	28.99
1306	Straw	----		----	----	23.13	----	----		
	Grain	----	F	----	----	63.43	----	----	86.56	43.28
1307	Straw	----	----	21.44	----	----	12.80	----		
	Grain	----	----	46.00	----	----	46.86	----	127.10	63.55
1308	Straw	16.90	----	----		----	----	8.10		
	Grain	8.08	----	----	F	----	----	25.68	58.85	29.42
1309	Straw	----	----	----	----	----	----	----		
	Grain	----	----	----	----	----	----	----	----	----
1310	Straw	----	----	----	----	----	----	----		
	Grain	----	----	----	----	----	----	----	----	----
1311	Straw	11.89		11.17		14.87	2.56			
	Grain	5.24	F	33.23	F	35.84	14.25	F	129.05	64.52
1312	Straw	11.36	----	13.53	----	14.49	----	4.61		
	Grain	3.73	----	37.00	----	28.42	----	18.21	131.35	65.67
1313	Straw	----		----		----	13.85	----		
	Grain	----	F	----	F	----	46.27	----	60.12	30.06
1314	Straw	----		----	----	12.86	----	----		
	Grain	----	F	----	----	59.03	----	----	71.89	35.94
1315	Straw	----	----	20.74	----	----	12.45	----		
	Grain	----	----	56.54	----	----	48.30	----	138.03	69.01
1316	Straw	10.44	----	----		----	----	8.39		
	Grain	2.86	----	----	F	----	----	30.30	51.99	25.99
1317	Straw	----	----	----	----	----	----	----		
	Grain	----	----	----	----	----	----	----	----	----
1318	Straw	----	----	----	----	----	----	----		
	Grain	----	----	----	----	----	----	----	----	----
1319	Stover		8.40		19.53					
	Grain	26.84	1.00	18.52	26.25	27.32	17.90	48.90	194.66	97.33
1320	Stover		4.60		11.78					
	Grain	17.87	8.44	13.13	23.00	23.82	23.05	30.26	155.95	77.97
1321	Stover		15.50		11.54					
	Grain	16.67	2.39	15.59	25.22	12.86	20.55	31.46	151.78	75.89
1322	Stover		5.51		8.99					
	Grain	13.59	12.86	12.51	19.66	14.21	21.08	30.09	138.50	69.25
1323	Hay	8.90	21.24	22.50	38.16	21.74	8.23	16.22	137.99	68.99

"F" indicates crop failure.

TABLE 3.—Trends of Topsoil Nitrogen Content Under Various Systems of Culture, 1924-31.

Plot No.	Culture	Nitrogen Removed in Crops During Seven Years (P.P.M.)	TOTAL NITROGEN IN TOPSOIL 0"-6" (P.P.M.)		Co-efficient of Vari-ability	Annual Decline or Gain in Nitrogen (P.P.M. of Topsoil)
			Period Mean	Standard Deviation (Annual)		
1303	Continuous wheat	71.28	938.8	24.5	2.6	+ 4.18
1304	Alternate wheat and fallow	71.70	904.5	32.6	3.6	−13.95
1305	Alternate wheat and fallow	28.99	883.0	27.4	3.1	−11.92
1306	Wheat, fallow, fallow	43.28	845.5	60.9	7.2	−21.05
1307	Wheat, fallow, fallow	63.55	853.1	42.5	4.9	−16.82
1308	Wheat, fallow, fallow	29.42	832.1	58.5	7.0	−22.22
1309	Continuous fallow	0.00	766.6	34.7	4.5	−14.53
1310	Continuous fallow	0.00	734.6	67.6	9.2	−27.21
1311	Continuous wheat	64.52	747.7	23.1	3.0	− .46
1312	Alternate wheat and fallow	65.67	710.8	28.7	4.0	− 7.80
1313	Alternate wheat and fallow	30.06	700.5	34.3	4.9	−12.86
1314	Wheat, fallow, fallow	35.94	670.7	39.4	5.8	−15.20
1315	Wheat, fallow, fallow	69.01	660.8	19.2	2.9	− 7.55
1316	Wheat, fallow, fallow	25.99	681.8	35.0	5.1	−10.81
1317	Continuous fallow	0.00	657.0	45.9	6.9	−19.01
1318	Continuous fallow	0.00	657.2	37.1	5.6	−15.44
1319	Continuous milo, 3½' rows	97.33	647.5	21.8	3.3	− .09
1320	Continuous milo, 7' rows	77.97	662.8	38.2	5.7	− 7.69
1321	Continuous milo, 3½' rows	75.89	687.8	31.0	4.5	+ 5.83
1322	Continuous milo, 7' rows	69.25	680.3	20.3	3.0	+ .26
1323	Continuous sudan	68.99	681.6	28.1	4.1	+ 1.82
1324	Continuous sudan	81.61	686.0	15.8	2.3	+ 1.41

Loss of Nitrates by Leaching

The danger of serious losses of soil nitrogen into the substratum beyond reach of the root systems of crops has been established by a thorough study of the movements of soil water and nitrates in the same plots. In that study[4] it was shown that the amounts of nitrate found in the lower levels of the subsoil were largely determined by two factors: (1) the time of the crop growing season, relative to moisture distribution; and (2) the frequency of cropping in any system of culture employing summer fallowing. Another factor of possibly considerable importance was the amount of raw organic matter returned to the soil as crop residues, bacterial oxidation of which tended to tie up some of the nitrates present.

TABLE 4.—Summary of Nitrogen Change in Topsoil According to Cultural Groups.

Cropping	Number of Plots	Average Soil Nitrogen P.P.M.	Average Annual Loss or Gain P.P.M.	Percent of Annual Loss or Gain
Continuous wheat	2	843.2	+ 1.86	+ .22
Alternate wheat and fallow	4	799.7	−11.63	− 1.45
Fallow, fallow, wheat	6	757.3	−15.60	− 2.05
Continuous fallow	4	703.8	−19.04	− 2.70
Continuous milo, 3½' rows	2	667.6	+ 2.87	+ .43
Continuous milo, 7' rows	2	671.5	− 3.71	− .55
Continuous sudan, close drilled	2	683.8	+ 1.61	+ .23

Since the data on soil nitrogen indicate that the larger losses have occured on plots subjected to extensive fallowing, and since these plots usually showed less nitrogen taken off in crops, the losses appear chargeable primarily to leaching.

It is not assumed, however, that all the nitrogen removed in the harvest of crops came directly from the surface soil. In fact, topsoils where crops were introduced only once in two or three years have shown marked increases of nitrogen, due presumably to the recovery of nitrates which were leached during the period of fallow and have accumulated in the subsoil to the depth of moisture penetration but still within the root zone of the crop grown. A portion of the nitrogen carried down in soluble form during previous years was thus returned to the surface soil in the form of plant residue.

A notable example of this result occurred in the year 1927 in which wheat completely failed. Abnormal opportunities for leaching nitrogen from the surface soil were afforded on all plots. Significant increases in the topsoil generally were shown after heavy crop yields the following year.

The path of annual fluctuation in topsoil nitrogen rather definitely follows the cropping program in those systems having one and two years of summer fallow intervening. In so far as this problem has been investigated, it appears that the prevention of nitrogen losses by leaching is a far more important step in maintaining native fertility than the exercise of moderation in the removal of this element in the crops grown.

The Possibility of Bacterial Fixation of Atmospheric Nitrogen

As soon as the trends of nitrogen change became apparent in this series of plots, indicating a nitrogen income from some unknown source to supply what was being removed in crops, an attempt was made to determine whether considerable nitrogen fixation was possible in the particular soil type under observation and whether it was affected by the presence of a carbonaceous residue such as wheat straw.

Experimental Method

This experiment consisted of the incubation of four jars of soil in the laboratory for two years. Sufficient soil was taken from plot 1314 in tube cores 2" by 6" to provide in excess of 20 kilograms of prepared soil. This soil was prepared by drying nearly air dry, sufficient to allow pulverizing it to pass a 20-mesh sieve. It was sieved and thoroughly mixed, a sample being taken for moisture determination and chemical analyses. On the basis of dry soil, 4886.1 grams were placed in each of four six-inch glass bell jar inverted with a perforated porcelain cone over the neck. An amount of finely chopped wheat straw equivalent to the estimated residues from the average wheat crop was added to two of the jars. The others were left untreated. Available nitrogen was removed as formed by thorough leaching of all jars every six months instead of growing plants in the soil. Extreme care was exercised to protect the jars from contamination of any kind and accurate measures taken of the nitrogen added in straw subsequent to each leaching and also of the nitrogen removed in the leach water. Altogether five leachings were made as shown in Table 6. Care was taken to remove only clear solutions as leach water. When cloudiness appeared due to the breaking through of soil particles, the mouth of a jar was thoroughly washed down and the material returned to the jar. Throughout the course of incubation at room temperatures, distilled water was applied in equal amounts to the four jars, sufficient to maintain an average but fluctuating moisture content similar to that experienced in field soils; but at no time was sufficient water added to cause percolation through the body of soil except at the regular leaching times. After the last leaching, August 4, 1931, no additional treatment of straw was given and the soils were allowed to become dry. They were pulverized, air dried, weighed, sampled and analyzed as at the beginning of the incubation.

The nitrogen content, expressed in parts per million of dry soil, is shown in Table 5. The amount of nitrogen per jar at the end of the experiment was calculated on the basis of the weight present at the time of sampling, which was less than that present at the beginning of the test due to total solids other than nitrogen removed in leaching and oxidation. The differences here represent the changes undergone by the soil during the incubation of two years. No account has been taken of the nitrogen added in straw or removed in leach water.

Table 7 shows the balance of nitrogen income and outgo in the four jars, with all solid nitrogen accounted for.

When samples were extracted and water dilutions made for bacterial counts, the soil residues were carefully preserved and returned to the jars. So far as is known no mechanical losses of soil were sustained during the period of incubation. Therefore the nitrogen balance sheet as shown by the figures in Table 7 represents as strict an accounting of the nitrogen as the laboratory facilities would permit. Satisfactory checks were obtained with duplicate jars in regard to the changes noted in organic nitrogen. Treated soils practically maintained their organic nitrogen content by the straw which was added. The untreated soils lost organic nitrogen at the rate of 44.5 P.P.M. in two years.

Although the changes observed in organic nitrogen were consistent with the treatments in incubated soils, the delivery of nitrate nitrogen removed by periodic leaching did not check out as well. Net gains of nitrogen were indicated in all jars. For the untreated checks the gains were made at the rate of 18.15 and 12.34 P.P.M., respectively, an average of 15.24 P. P. M. The straw treated soils gained 30.70 and 23.59 P.P.M., respectively, averaging 78 percent more than the checks. These gains are presumably attributable to the fixation of atmospheric nitrogen by free living soil organisms and are consistent with the theory that nitrogen fixation of this character is stimulated by the presence of an excess of carbonaceous organic matter. The nitrogen fixation in the untreated soils appears to have been limited by the supply of residues present in the soil at the time it was taken from the field during the summer of 1929, following a crop of wheat which was produced in 1928.

Azotobacter was identified by cultures obtained from all four of the jars at various times during the experiment. Total bacterial counts were made on all jars, under varying conditions of soil moisture which existed during the experiment, by the direct microscopic method as described by H. J. Conn[7] in his modification of the original Winogradsky suggestion.

Earlier in the experiment the counts averaged nearly the same for all treatments; but out of a total of 84 direct microscopic counts made after the last leaching, the untreated soils showed 2,632,000 and 2,680,000 bacteria per gram while the straw treated soils contained 5,020,000 and 5,962,000, respectively.

Although there may be some doubt as to the actual demonstration of nitrogen fixation by azotobacter in this experiment it will undoubtedly admit of such a possibility. Nitrogen fixation by one or more kinds of organism was evident. While the soil composition and moisture conditions were the only factors of similarity between field soils and the incubated soils, temperature conditions varying and the manner of removing solubles varying, there is still a correspondence of results observed.

Soils high in raw organic matter both in the laboratory and in the field maintained a more constant level of nitrogen and suffered smaller losses from leaching. In the case of the incubated soils, 16.09 percent less nitrate nitrogen was leached from the straw treated jars than from the untreated checks. (See Table 6.)

The possibility of nitrogen fixation and that of the return of subsoil nitrogen to the surface are the only ways so far suggested of explaining the observed maintenance of topsoil nitrogen under conditions of heavy continuous cropping.

TABLE 5.—Dispostion of Incubated Soils by Weight.

Jar No.	Treat-ment	Total dry soil at start	Total dry straw added	Nitrate nitrogen leached	Other solids removed	Total final dry soil
1	0	4886.10	0	.34	33.94	4851.82
2	Straw	4886.10	21.82	.30	54.72	4853.50
3	0	4886.10	0	.30	28.77	4857.63
4	Straw	4886.10	21.82	.26	45.14	4863.04

TABLE 6.—Nitrate Nitrogen Leached from Incubated Soils at Intervals During the Experiment, Expressed in Parts per Million of Dry Soil.

Date	Jar 1	Jar 2	Jar 3	Jar 4
August 2, 1929	15.20	14.67	16.41	12.41
March 20, 1930	38.06	29.77	27.68	18.39
August 6, 1930	2.79	3.07	4.69	7.53
March 4, 1931	5.90	5.16	5.51	6.18
August 4, 1931	7.77	9.07	8.62	9.00
Total nitrate nitrogen leached	69.72	61.74	62.91	53.51

TABLE 7.—Balance of Nitrogen in Incubated Soils, 1929-31, on a Basis of 4886.1 Grams Dry Soil.
(All Values in Grams of Nitrogen)

Jar No.	Treat-ment	Organic nitrogen in soil at start	Nitrate nitrogen in soil at start	Total nitrogen in soil at start	Organic nitrogen added in straw	Total known nitrogen income	Final organic nitrogen in soil	Final nitrate nitrogen in soil	Final total nitrogen in soil	Nitrate nitrogen leached	Total of all nitrogen accounted for	Net loss or gain of organic nitrogen	Net gain of all nitrogen
1	0	3.00739	.05814	3.06553	.0	3.06553	2.78591	.02762	2.81353	.34068	3.15421	−.22148	.08868
2	Straw	3.00739	.05814	3.06553	.12000	3.18553	3.00189	.03192	3.03381	.30175	3.33556	−.00550	.15003
3	0	3.00739	.05814	3.06553	.0	3.06553	2.79410	.02436	2.81846	.30740	3.12586	−.21329	.06033
4	Straw	3.00739	.05814	3.06553	.12000	3.18553	3.01557	.02371	3.03928	.26153	3.30081	+.00818	.11528

Distribution of Soil Nitrogen Under Diverse Cultural Conditions

The foregoing trends in topsoil nitrogen contents seem to indicate that significant changes in the subsoil may also be related to cropping and moisture movements. The topsoil changes could not be satisfactorily explained without some knowledge of what was going on below.

In order to determine the comparative effects of fallowing and intensive cropping upon the entire available nitrogen store, composite one-foot samples to a depth of six feet were taken from 70 plots on the rotation and moisture study series in January, 1932. This group included the 22 plots on which annual topsoil nitrogen determinations have been made and all together represented a fairly wide range of extremes in intensity of cropping.

Total nitrogen was determined and the plots divided into three groups according to depth of subsoil. Since initial analyses were lacking for comparison, two methods of interpretation have been attempted: (1) comparison of **nitrogen contents** to that of native sod where available adjoining the various subsoil types; and (2) the comparison of **nitrogen distributions** within the six-foot soil section. The data of total nitrogen are presented in Tables 8, 9, and 10, in which the plots are grouped according to soil depths.

Group A (Table 8) consists of 20 plots in which the subsoil extended to depths of six feet or more without encountering unweathered tertiary materials in sufficient quantity to produce a white to pinkish white color in the composite sample.

Group B (Table 9) consists of 32 plots in which the subsoil extended to a depth of approximately five feet. The sixth foot composite samples, in all cases, although being free of caliche granules, were white or nearly so in color.

Group C (Table 10) includes 18 plots in which the subsoil extended to a depth of approximately four feet, the fifth and sixth feet consisting of whitish unweathered material as described above.

Each of these soil groups have been subdivided according to the intensity of cropping practiced on each particular plot. An authentic record of crop-

TABLE 8.—Total Nitrogen as P.P.M. of Dry Soil, Group A, January 1932.

Plot No.	0'-1'	1'-2'	2'-3'	3'-4'	4'-5'	5'-6'	Av., 6'
1220	796.8	617.7	449.4	386.4	350.2	348.8	491.55
1221	796.7	569.2	449.4	386.4	357.1	328.3	481.18
1222	762.1	548.3	470.1	427.8	343.3	307.8	476.56
1223	713.6	541.4	435.5	413.9	350.2	348.8	467.23
1224	734.4	596.9	387.7	386.4	384.6	328.3	469.71
1310	794.5	627.7	511.7	413.2	363.8	363.8	512.45
1311	836.2	627.8	539.2	454.6	388.2	314.2	526.70
1312	771.2	736.0	695.0	414.0	371.6	328.3	552.68
1313	715.4	547.0	470.0	409.6	385.7	363.9	481.93
1314	732.9	563.7	491.7	411.5	379.9	336.6	486.05
1315	732.0	482.9	483.4	444.7	391.5	427.5	493.66
1316	753.7	474.5	454.1	479.9	408.0	408.5	496.45
1317	791.2	505.3	480.8	455.4	429.5	425.1	514.55
1318	716.2	544.5	400.0	480.3	451.8	425.1	502.98
1319	694.6	588.6	558.3	509.3	462.5	392.8	539.35
1320	719.5	547.0	566.7	405.8	410.5	394.4	507.31
1321	757.9	521.3	383.3	397.5	396.4	394.4	475.13
1322	747.0	627.7	466.7	461.2	396.4	396.9	515.98
1323	766.2	590.3	439.2	463.7	441.0	392.0	515.40
1324	765.4	538.6	533.4	446.3	429.5	386.1	516.55

TABLE 9.—Total Nitrogen as P.P.M. of Dry Soil, Group B, January 1932.

Plot No.	0'-1'	1'-2'	2'-3'	3'-4'	4'-5'	5'-6'
1101	858.0	574.7	481.8	364.9	218.0	128.9
1102	851.1	592.7	426.7	316.7	218.0	135.7
1103	885.7	588.5	406.0	337.4	204.4	146.0
1119	737.0	519.3	426.7	351.1	261.6	183.5
1120	742.1	540.1	433.6	358.0	268.5	204.4
1121	737.0	505.5	426.7	351.1	282.3	122.6
1122	747.3	533.2	399.2	337.4	268.5	128.9
1123	742.2	533.2	426.7	364.9	275.4	204.4
1124	742.1	553.9	419.8	344.2	282.3	210.7
1201	846.6	605.6	394.9	360.8	297.1	407.2
1202	863.3	647.4	469.9	410.7	326.0	172.2
1203	838.3	580.5	411.6	302.6	239.2	68.4
1204	888.4	555.4	436.6	377.5	288.8	191.5
1205	775.7	538.7	428.2	360.8	292.9	176.4
1206	844.6	593.0	344.9	344.2	235.0	151.6
1207	721.4	549.7	478.2	248.4	235.0	135.2
1208	817.4	555.0	436.6	365.0	283.8	197.0
1209	813.2	580.5	407.3	319.3	276.4	176.4
1210	792.4	622.3	394.9	319.3	284.7	250.5
1211	767.3	513.6	378.2	331.2	322.3	291.8
1212	679.6	551.2	387.2	319.3	301.2	110.4
1213	754.8	505.2	403.2	310.9	307.2	176.4
1214	792.6	455.3	366.4	344.9	281.5	205.2
1215	762.1	520.6	400.9	351.9	274.7	174.2
1216	796.7	555.3	442.5	345.2	302.1	177.8
1217	748.3	534.4	421.7	386.4	315.9	205.2
1218	789.8	541.4	442.5	420.9	377.7	259.9
1219	775.9	610.8	449.4	400.2	343.3	232.5
1306	806.9	590.3	440.8	342.7	239.5	181.9
1307	824.5	641.4	529.2	496.9	256.0	173.6
1308	724.5	566.2	466.7	376.0	338.6	272.9
1309	832.7	607.8	458.3	386.1	330.3	256.3

TABLE 10.—Total Nitrogen as P.P.M. of Dry Soil, Group C, January 1932.

Plot No.	0'-1'	1'-2'	2'-3'	3'-4'	4'-5'	5'-6'
1104	858.0	643.9	461.1	364.9	177.1	108.5
1105	899.6	602.4	426.7	330.5	177.1	176.4
1106	906.5	609.3	440.4	296.0	163.5	122.1
1107	892.6	630.1	429.6	337.4	211.2	88.2
1108	871.9	630.1	468.0	351.1	149.9	108.5
1109	837.3	609.3	392.3	306.6	190.7	74.6
1110	858.0	630.1	447.3	337.4	211.2	74.6
1111	816.5	547.0	378.5	275.4	95.4	67.8
1112	788.8	595.5	419.8	344.2	218.0	135.7
1113	775.0	602.4	433.6	330.5	238.4	135.7
1114	726.6	560.8	419.8	309.8	190.7	122.1
1115	733.5	519.3	344.1	309.8	238.4	115.3
1116	733.5	491.6	385.4	344.2	197.5	108.5
1117	742.1	470.8	371.6	289.2	136.2	122.6
1118	726.6	540.1	378.5	337.4	204.4	166.6
1303	936.9	953.5	437.5	380.9	152.8	152.9
1304	838.6	602.7	408.3	322.9	162.9	96.7
1305	824.5	573.6	415.8	334.5	292.3	176.9

ping covers the period of 11 years from 1921 to 1931, which was approximately one-half the total period this land has been in cultivation. As well as can be determined from the memory of men familiar with the locality, the first half of the cropping period of this land, after it was broken from the native sod, was uniform; therefore it is believed that any soil changes which may be ascribed to diverse cropping may fairly be attributed to the conditions prevailing after plot experiments were introduced in the year 1923. Intensity of cropping has been represented by the percentage of time a plot was covered by a growing crop during the last 11 years.

As the variation in intensity of cropping has not been uniform in each of the three soil divisions, the same interval between mean values of the subgroups could not be adopted, but each soil division has been divided into three parts representing low, medium, and high degrees of crop coverage of as nearly equal interval between means as possible. The diagram (Figure I) shows a plat of the land with boundaries of the soil subdivisions indicated and the intensity of cropping represented by shading. The figures entered in each plot are the percentages of time covered by growing crops.

Summaries of the amount and distribution of nitrogen in each of the three soils according to intensity of cropping are shown in Tables 11, 12 and 13. The analyses of native sod shown in Table 11 with the plots of Group A represent undisturbed portions of the athletic field directly adjacent to plots 1224 and 1324. Those shown in Table 12 along with the plots of Group B were taken from a similar area adjacent to plot 1124. As indicated by color variations which are quite marked in the subsoils, the sod samples were representative of their respective groups. No undisturbed native sod was available directly adjacent to either of the two areas of four-foot soils.

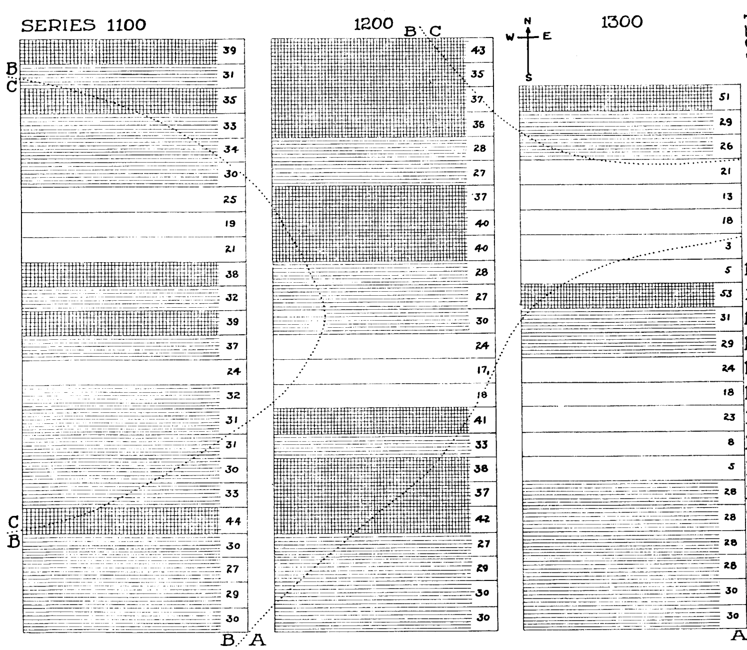

Figure I.—Location of plots relative to soil subtypes A, B and C. Intensity of cropping indicated by shading.

TABLE 11.—Amount and Distribution of Nitrogen in Soils Variously Cropped; Group A, 6' Soils.

Depth in feet	Native sod	CULTIVATED LAND COVERED WITH CROPS, PERCENT OF TIME								
		13.77[1]	29.23[2]	47.28[3]	13.77	29.23	47.28	13.77	29.23	47.28
		(Total Nitrogen P.P.M.)			(Apparent Loss or Gain)			(Percent Distribution)		
1	921.3	753.4	745.2	816.5	−167.9	−176.1	−104.8	25.06	24.93	26.73
2	643.5	533.1	579.4	622.7	−110.4	− 64.1	− 20.8	17.73	19.31	20.38
3	508.6	470.3	487.9	494.3	− 38.3	− 20.7	− 14.3	15.65	16.20	16.14
4	436.7	447.5	426.8	420.5	+ 10.8	− 9.9	− 16.2	14.89	14.24	13.74
5	430.7	404.1	394.0	369.2	− 26.6	− 36.7	− 61.5	13.44	13.06	12.07
6	370.0	397.7	363.5	331.5	+ 27.7	− 6.5	− 38.5	13.23	12.13	10.88
Av.	551.8	501.0	499.4	509.1	− 50.8	− 52.4	− 42.7			

[1]Average of 6 plots.
[2]Average of 12 plots.
[3]Average of 2 plots.

TABLE 12.—Amount and Distribution of Nitrogen in Soils Variously Cropped; Group B, 5' Soils.

Depth in feet	Native sod	CULTIVATED LAND COVERED WITH CROPS, PERCENT OF TIME								
		16.48[1]	29.56[2]	38.80[3]	16.48	29.56	38.80	16.48	29.56	38.80
		(Total Nitrogen P.P.M.)			(Apparent Loss or Gain P.P.M.)			(Percent Distribution)		
1	1005.7	785.5	763.7	818.2	−220.2	−242.0	−187.5	29.67	30.37	30.76
2	663.9	555.2	540.9	575.7	−108.7	−123.0	− 88.2	20.97	21.51	21.64
3	497.9	437.9	406.7	437.7	− 60.0	− 91.2	− 60.2	16.54	16.17	16.45
4	373.4	372.9	343.9	354.7	− 0.5	− 29.5	− 18.7	14.08	13.67	13.33
5	283.5	289.7	278.3	281.5	+ 6.2	− 5.2	− 2.0	10.94	11.06	10.58
6	137.4	205.8	181.0	192.1	+ 68.4	+ 43.6	+ 54.7	7.77	7.19	7.22
Av.	493.7	441.1	419.0	443.3	− 52.6	− 74.7	− 50.4			

[1]Average of 7 plots.
[2]Average of 12 plots.
[3]Average of 13 plots.

TABLE 13.—Amount and Distribution of Nitrogen in Soils Variously Cropped; Group C, 4' Soils.

Depth in feet	CULTIVATED LAND COVERED WITH CROPS, PERCENT OF TIME					
	21.50[1]	30.49[2]	41.38[3]	21.50	30.49	41.38
	(Total Nitrogen P.P.M.)			(Percent Distribution)		
1	811.9	815.6	839.6	33.27	33.74	31.71
2	600.1	566.4	695.3	24.59	23.43	26.26
3	426.7	403.6	434.5	17.48	16.69	16.41
4	322.5	322.0	348.2	13.21	13.32	13.15
5	177.1	186.9	205.1	7.25	7.73	7.74
6	101.7	122.7	124.7	4.16	5.07	4.71
Av.	407.3	402.8	441.2			

[1]Average of 3 plots.
[2]Average of 11 plots.
[3]Average of 4 plots.

Trends of Changing Distribution

Not much difference is shown in the total nitrogen content of the six-foot soil section in either of the groups, although the more heavily cropped soils in each instance were slightly higher. As an indication of retarded depletion these differences are probably not significant, but coupled with the fact of the increased nitrogen in crops removed they may be of importance. Eleven years would, under most soil conditions, be a relatively short time in which changes in total nitrogen could be expected to become apparent to a depth of six feet.

What is perhaps of greatest significance is the tendency exhibited in each of these groups toward maintaining the naturally high nitrogen levels in the upper root zone under heavy cropping in contrast to the apparent increase of lower subsoil nitrogen at the expense of surface soil supplies under fallow systems. In Table 14 are summarized the group data, showing the proportionate distribution for all plots of Groups A and B by intensities of cropping for the normal root zone, which for those crops best adapted to the locality includes approximately the upper four feet of soil. It is noticeable that the distribution of nitrogen in all the cultivated soils has been considerably modified as compared to that in the virgin soils which are also shown in this table, but the distribution which was found under systems of heaviest cropping more nearly approaches that of the native sod than does any other.

TABLE 14.—Summary —Proportionate Distribution of Nitrogen Within Root Zone of Soils A and B With Native Sod Comparison.
(Expressed as Percent of Total Amount in the Six-Foot Soil Section.)

Soil depths	INTENSITY OF CROPPING			Native sod
	Light	Medium	Heavy	
0'-1'	27.36	27.65	28.74	30.72
0'-2'	46.71	48.06	49.75	51.56
0'-3'	62.81	64.24	66.05	67.60
0'-4'	77.29	78.20	79.58	80.51

This trend of relaxation in the topsoil nitrogen concentration under tillage does not appear to have progressed far enough to limit yields during the short period of time diverse systems of cropping have been in effect, but it

TABLE 15.—Total Nitrogen, Adjacent Plots Paired for Light and Heavy Cropping, January 1932.
(Expressed as P.P.M. of Dry Soil)

Plot No.	HEAVY CROPPING Depth by Feet						Plot No.	LIGHT CROPPING Depth by Feet					
	1st	2nd	3rd	4th	5th	6th		1st	2nd	3rd	4th	5th	6th
(Group A)													
1311	836	628	539	454	388	314	1310	794	628	512	413	364	364
1311	836	628	539	454	388	314	1312	771	736	695	414	371	328
1316	754	474	454	480	408	408	1317	791	505	481	455	429	425
1319	694	588	558	509	462	393	1318	716	544	400	480	452	425
1220	797	618	449	386	350	349	1221	797	569	449	386	357	328
Av.	783	586	518	456	399	355		774	596	507	429	394	377
Group Mean						514.9							512.6
(Group B)													
1120	742	540	433	358	268	204	1119	737	519	427	351	261	183
1216	797	555	442	345	302	178	1215	762	520	401	352	275	174
1207	721	550	478	248	235	135	1206	844	593	345	344	235	151
1204	888	555	436	377	289	191	1205	776	539	428	361	293	176
1120	742	540	433	358	268	204	1121	737	505	427	351	282	122
Av.	778	548	444	337	262	182		771	535	405	352	269	161
Group Mean						427.0							415.7
(Group C)													
1110	858	630	447	337	211	74	1109	837	609	392	306	191	74
1113	775	602	433	330	238	136	1114	726	561	420	310	191	122
1115	733	519	344	310	238	115	1114	726	561	420	310	191	122
1107	892	630	429	337	211	88	1108	872	630	468	351	150	108
Av.	814	595	413	328	224	103		790	590	425	319	181	106
Group Mean						413.2							402.0

points toward ultimate depletion of these soils if the effects already noted continue under conditions of summer fallowing.

Examples of Variation in Nitrogen Economy

In order to make direct comparison of the nitrogen economy in plots subject to varying intensity of culture without involving too much error in natural soil variation, certain pairs of plots were selected where extremes of cultural intensity occurred side by side. The nitrogen contents of all such available pairs are tabulated in Table 15. Intensity of culture and nitrogen removals since diverse cultures were instituted on these plots are shown in Table 16. A summary of the nitrogen economy of the three groups will be found in Table 17.

The averages calculated in Table 15 show plots heavily cropped to be consistently higher in the upper soil section than adjoining plots which have been lightly cropped, but in every case a point was reached in the subsoil where the nitrogen content for the corresponding foot was higher under conditions of light cropping. This occurred in the sixth foot in deep soils, in the fourth and fifth feet of five-foot soils, and in the third foot of four-foot soils.

TABLE 16.—Crop Removals of Nitrogen 1924-31, and Intensity of Culture, of Paired Plots in Table 15.

	HEAVY CROPPING		LIGHT CROPPING		
Plot No.	Nitrogen removed in crops (Lbs. per acre)	Percent time covered	Plot No.	Nitrogen removed in crops (Lbs. per acre)	Percent time covered
(Group A)					
1311	193.22	52.79	1310	0	5.06
1311	193.22	52.79	1312	131.35	30.94
1316	51.99	23.07	1317	0	7.69
1319	212.42	28.14	1318	0	5.06
1220	100.72	41.78	1221	174.06	27.27
Av.	150.31	39.71		61.08	15.20
(Group B)					
1120	109.45	43.88	1119	30.67	32.86
1216	110.94	41.43	1215	99.88	18.35
1207	284.44	36.88	1206	169.76	26.74
1204	111.20	36.53	1205	36.73	27.79
1120	109.45	43.88	1121	180.38	30.41
Av.	145.09	40.52		103.48	27.23
(Group C)					
1110	192.42	38.46	1109	165.30	21.15
1113	146.73	36.88	1114	143.45	23.77
1115	153.77	31.64	1114	143.45	23.77
1107	396.92	25.34	1108	155.51	19.58
Av.	222.46	33.08		151.92	22.06

TABLE 17.—Nitrogen Economy Under Heavy and Light Cropping.
(All Nitrogen in Pounds per Acre)

Group	Depth of soil	No. plot pairs	Percent time covered by crops	Total N, 6' soil section	Difference favoring heavy cropping	Nitrogen removed in crops	Total difference favoring heavy cropping
A	6'	5	39.71	11328		150	
	6'	5	15.20	11271	57	61	146
B	5'	5	40.52	9394		145	
	5'	5	27.23	9145	249	103	291
C	4'	4	33.08	9090		222	
	4'	4	22.06	8844	246	152	315
				Total N 4' soil section			
A	6'	5	39.71	8497		150	
	6'	5	15.20	8363	134	61	223
B	5'	5	40.52	7640		145	
	5'	5	27.23	7481	169	103	211
C	4'	4	33.08	7798		222	
	4'	4	22.06	7701	97	152	167

If nothing more than a better maintenance of native fertility were accomplished by heavy cropping, attention to this factor of soil management would be desirable; but there appears also the consideration of utilization. By reference to Table 16 it will be noted that in only two instances among the 14 pairs of plots has the system involving summer fallowing produced more nitrogen removed in crops than has the more intensive method. An analysis of the nitrogen economy of the paired plots by soil groups was based, as shown in Table 17, on the present differences in soil nitrogen and crop removals. A virgin soil nitrogen content might be assumed for Groups A and B though none was available for Group C; but the difficulty of correctly ascribing a proper portion of the total assumed loss shown to the latter half of the period of cultivation in which divisions of method occurred would be great and any value assigned would be wholly arbitrary. Charging one-half the total loss to the period 1921-31 (which is probably too large as indicated by the observation of newly broken sod during the early years of cultivation) would indicate a waste under continuous cropping of from one to four times as much nitrogen as was removed in crops, and where fallow systems were used from five to eight times as much nitrogen lost as was utilized.

A more practical application of these figures considers the existing differences accruing from the contrasting systems plus the differences in nitrogen utilized as crops removed. It may be a question whether soil resources to a depth of six feet should be considered available to wheat and sorghum crops, but the important result of the calculation is approximately the same as when figured at shallower depths. The total advantage in conservation and utilization by continuous cropping over summer fallowing amounts to from 100 to 300 pounds of nitrogen per acre in the eight-year period.

The paired plots, last referred to, may be assumed to have been at the start as nearly equal in both amount and distribution of nitrogen as would be possible to obtain, because complication by soil boundaries was avoided in selection. The small balance in residual nitrogen remaining in favor of intensive cropping in spite of the greater withdrawals in crop yields, when either topsoil alone or the six-foot soil section was considered, indicates possible relations to the control of leach losses and to the encouragement of nitrogen fixation by free living organisms.

DISCUSSION

An attempt has been made to evaluate the various factors affecting the soil nitrogen economy on heavy types of High Plains soil. It was evident that the surface soil nitrogen supply had been augmented in some manner to prevent reduction of the total in the presence of normal crop removals. The return of subsoil nitrogen to the surface by plants, the fixation of atmospheric nitrogen by free living organisms and the deposit of nitrogen contained in rainwater are three means whereby the results observed could be temporarily or permanently maintained.

The nitrogen income from rainwater, though dependable, was found to be too small to affect the general scheme of soil nitrogen economy.

The return of subsoil nitrogen to the surface layers was observed in two ways. The annual fluctuation of topsoil nitrogen was consistent with the expectations from variations in cropping schedule and seasonal condition. The nitrogen distributions within the six-foot soil section brought about by diverse cropping methods also confirmed this deduction. Soil nitrogen was found to be concentrated nearer the surface after the closest possible cropping continuity had been maintained over a period of years.

If the maintenance of topsoil nitrogen, coincident with maximum crop removals, were brought about by drafts upon the subsoil supply, measurable declines would be expected in the total root zone supply. Such were not found to have occurred but a marked change in distribution was apparent. It is possible that the topsoil nitrogen maintenance observed may be a temporary condition which will terminate when the limit of redistribution, resulting from changed cropping systems, shall have been reached; but it seems more likely that the observations, being made during the period of natural readjustment between the virgin state and the final low cultivated level of fertility, indicate an arrest of the depletion process rather than a direct reversal of the depletion movements.

The differences in net nitrogen economy shown by various cropping practices are of sufficient importance to command attention whether they may be wholly the result of reducing the waste of soil fertility or partly the result of encouraging a nitrogen income. Laboratory experiments with this type of soil, covering a period of two years, indicate a possibility of nitrogen fixation increasing with the conditions which correspond to the best nitrogen economy observed in the field.

The average total nitrogen decline in the six-foot soil section, during the period of 22 years since this land was broken from the native sod, was approximately fifty pounds per year. The normal experience of new lands would make this rate considerably higher for the first few years of cultivation and tend to run less and less as cultivation goes on until the new balance at low level has been reached. Aproximately 20 pounds of this annual loss could be accounted for in crops removed, leaving 30 pounds of nitrogen annually to be wasted. It would appear that at least 20 pounds of this waste could be avoided while at the same time the nitrogen yielded in the form of crops removed would be increased by continuous cropping. These approximations indicate that the rate of nitrogen decline may not be greater at the end of 22 years cultivation than can be compensated by carefully conservative methods. In other words, it may be barely possible to maintain the level of fertility now existing under these conditions by the use of appropriate methods, but it is certain that abusive practices will result in further losses of nitrogen.

Under the conditions of topography of soils involved in this investigation, surface erosion was a negligible factor of waste due to the low rainfall and minimum slope. However, the prevention of nitrogen losses under the most severe conditions of erosion existing in the High Plains is a simple engineering problem to be solved by the control of surface waters with terraces.

The release of soil nitrogen in gaseous form has not been directly investigated, but considering the generally prevalent conditions of high aeration and lime excess in plains soil it does not seem that losses through denitrification can be of any practical importanace excepting in very localized areas. In the experiments cited here, denitrification losses appeared much more probable in the incubated soils during the periods of from one to two weeks while leaching was in progress than at any time under field conditions. If nitrogen were lost as ammonia, the replacement by fixation was sufficient to more than offset this and other removals except by leaching.

The leaching of nitrates to unavailable levels appeared to be the most serious menace to nitrogen supplies. Two factors aided in preventing leaching losses, both of which were brought into play by heavy continuous cropping. The maintenance of surplus quantities of raw organic matter in the surface soil by the regular return of crop residues reduced the accumulation of nitrates so that the amount of nitrates present in the soil at any one time was so much less than the possible limit of accumulation that little opportunity for loss was experienced even when abnormal rainfall penetrated to dangerous levels. Continuous cropping, especially of wheat which made demands upon soil moisture for approximately three-fourths of the year, in most cases was capable of utilizing the rainfall as it came, not allowing penetrations of surface water beyond the potential root zone of the crop.

The greatest difficulty of carrying soil conservation by these means to the fullest extent lies in the relative productiveness of continuous cropping and rotation. Rotations which provide a somewhat greater time spacing between succeeding crops, allowing moderate accumulations of moisture and available fertility, have proved more productive. A practical program will probably result in a compromise between production and conservation which does not seriously violate either consideration. At the same time it appears that with the tendencies here shown carried out over a long period of time, continuous cropping would sustain yields longer and possibly overcome the present advantage of a more rapid use of the soil.

SUMMARY

1. Annual analyses of topsoil nitrogen on 22 plots for periods of seven or eight years show that trends of topsoil nitrogen varied according to crop practice between the extremes of average annual losses of 38.08 pounds of nitrogen per acre and gains of 5.74 pounds per acre.
2. In cropping systems using various combinations of wheat and fallow the nitrogen losses from topsoil were roughly in proportion to the extent of fallowing employed.
3. Topsoil nitrogen losses averaged more where wide spacing of the crop was used than where close spacing was used.
4. Under continuous wheat, sudan hay and closely spaced milo, the topsoil nitrogen was maintained with slight gains.
5. A laboratory study of the soil in question indicated a nitrogen fixing flora, the activity of which was slightly increased by the addition of straw during an incubation period of two years.
6. After eight years of diverse field management the balance of residual nitrogen was approximately the same in the six-foot soil section of plots intensively cropped as in comparable plots lightly cropped.
7. Continuous cropping resulted in the concentration of total nitrogen nearer the surface than did systems employing summer fallowing.
8. All trends observed indicated permanent losses of nitrogen from the root zone by leaching were increased by fallowing.
9. The balances of total nitrogen in the soil, added to increased yields of nitrogen in crops removed, gave intensive cropping an annual advantage in net nitrogen economy of from 15 to 30 pounds of nitrogen per acre over fallow cropping.

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