# EFFECTS OF LONG-TIME FERTILITY TREATMENTS ON SELECTED CHEMICAL PROPERTIES OF A MOLLISOL

by

ELMER DEAN GRAUERHOLZ

B. S., Kansas State University, 1968



---

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1970

Approved by:

Major Professor

TABLE OF CONTENTS

# INTRODUCTION

The farm land in Kansas has been cultivated for a shorter period of time than land in states to the east, and Kansas soils are, on the whole, comparatively productive. The productivity of these soils, however, has been reduced greatly because of improper cropping systems and inadequate management which have permitted nutrient loss, structural deterioration, and erosion.

High productivity of a soil implies that high yields can be obtained in relation to the labor required or to the cost of production. Some soils differ in their productivity from one crop to another, and may require different management practices for different crops. The management practices may include tillage operations, application of fertilizers and/or lime, provision of satisfactory erosion-control techniques, drainage and irrigation. Thus, management can influence soil productivity. In most cases good soil management can counteract low soil productivity.

Soil fertility is included in the concept of soil productivity, but refers only to the content, balance, and availability of the chemical compounds in the soil that are necessary for plant growth.

Climate, soil depth, soil acidity, nutrient content, slope, texture and susceptibility to erosion are some of the characteristics that influence soil fertility. Since soil is the result of the action of the environment on soil material, each soil property, including soil fertility, is changed slowly under natural conditions until it is in equilibrium with the forces that destroy or deplete and those that build or renew. Under natural conditions the equilibrium state is usually satisfactory for the growth of some types of plants. Under the artificial conditions imposed by cultivation, however, it often happens that soil conditions are not satisfactory for the production of optimum, or at least economical, crop yields. Often soil management practices are developed and used in these instances to increase the possibility of high-level crop production.

The Soil Fertility Project, started in 1909 by L. E. Call on the Agronomy Farm, Kansas State University, Manhattan, Kansas, has been a site for conducting investigations on the effect of crop rotations and fertilizer practices upon crop yields and upon the nitrogen and organic-carbon content of the soil. The material presented in this thesis is but one of a series on these investigations. It will present information on the effect of management upon the available phosphorus, nitrogen, and organic carbon content of the soil.

This project was located on the SE 4.8 acres of the NW 1/4 of the SE 1/4 and the SW 6 acres of the NE 1/4 of the SE 1/4 of S 1 T 10S R 7E. The area on which this experiment was located has been under cultivation since 1864. During the time from 1864 until this experiment was started in 1909, the land was planted to corn and occasionally to oats or wheat. Alfalfa had been grown on the eastern half of the experimental area, but probably not on the western part.

The soil in this area has been called Geary silty clay loam. The Geary series includes the well drained, moderately dark colored, moderately fine textured, Reddish Prairie soils which have developed on reddish-brown loess or loess-like materials believed to be of post-Illinoian age, which overlie old alluvium. Slopes are predominantly in the range of 2 to 6%. In the new classification scheme the Geary soil is classed as a fine-silty, mixed, mesic, Udic Argiustoll.

Carbon and nitrogen may be lost from the soil in several different ways: leaching, erosion, crop removal, oxidation and volatilization. Phosphorus is lost mainly by crop removal and by erosion. Cultivation tends to reduce soil permeability, which in turn would reduce the amount of leaching, but would increase the amount of runoff and erosion. The amount of erosion that may be expected depends upon the cropping system, aspect of the field, slope of field, and amount and kind of tillage. Cultivation tends to lower the nitrogen and carbon content of the soil by reducing the amounts of residues returned to the soil and by increasing the rates of organic-matter oxidation. With continued cultivation annual carbon and nitrogen losses brought about by tillage usually become smaller.

During the experimental period, 1909 to 1968, the amount of leaching was probably negligible on this site. The erosion losses probably varied from time to time because of the crops produced, changes in the yearly climate, and because of variable slope over the experimental site. Net organic-matter losses resulting from oxidation from 1958 to 1968 likely were low because the land has been cultivated for about 100 years.

## REVIEW OF LITERATURE

Many investigators have shown the effects of management upon the fertility of the land. Brage *et al.* (3) report that with a 20-ton application of manure the organic-carbon and nitrogen contents of the soil can be increased by a considerable amount. Ten- and 5-ton applications brought about corresponding smaller increases. Adsorbed phosphorus of the soil was markedly increased by manure while the acid-soluble phosphorus content was raised by a smaller amount.

Haas *et al.* (6) reported that the total inorganic phosphorus content of soil was not reduced by cropping without manure, but that organic phosphorus was reduced an average of 35%, as compared to virgin sod. Manure applied in the rotation increased inorganic phosphorus considerably, but did not reduce the loss of organic phosphorus.

Pratt *et al.* data (22) showed that after 28 years of cropping with citrus trees there were significant decreases in soluble phosphorus in the soil to a depth of 36 inches, when the plots received no phosphates. Where the plots received phosphates or manure, increases in soluble phosphorus were noted even in the 24- to 36-inch soil layer. More than 60% of the accumulated phosphorus from the application of phosphate or organic materials was in the soil in the 0 to 6-inch depth and more than 80% was in the soil in the 0 to 12-inch depth. Very little phosphorus penetrated beyond 24 inches.

Owensby et al. (10) reported the organic matter content of bromegrass sodland was not affected by 20 years of nitrogen and phosphorus applications. However, phosphorus applications did increase the amounts of available phosphorus through the 36-inch soil layer.

After 24 years of growing wheat (Triticum aestivum L.) under various tillage and cropping practices in the Southwestern Great Plains, Unger (12) found that differences in tillage practices caused significant differences in soil organic matter under a wheat-fallow. Values were highest under a delayed stubble-mulch tillage system. Differences in soil organic matter content due to tillage practices were not significant under continuous wheat, but contents of continuous wheat plots were higher than those of wheat-fallow plots with comparable tillage. Total soil-nitrogen content was affected significantly by the tillage practice used for the wheat-fallow also, but not for the continuous wheat system. Nitrogen contents were also higher on continuous wheat plots than on wheat-fallow plots with comparable tillage treatments. Soil organic matter was closely related to total soil nitrogen.

Haas et al. (5) stated that nitrogen losses varied from 24 to 60% of the original level after 30 to 43 years of cropping. Organic carbon losses were similar to nitrogen losses, but were slightly greater. They found that land which had been continuously cropped to small grains, or which had been cropped alternately to small grains and fallow, lost much less nitrogen than land which had been planted to row crops. Alternate small grain and fallow land lost more nitrogen than that continuously cropped to small grains at every location except one. With row crops, however, the organic matter loss was greater under alternate row crops and fallow than under continuous row crops, at only 7 out of 13 locations.

Young et al. (14) studied the effectiveness of various long-time management practices in maintaining the fertility of Fargo clay and found soil organic-carbon and nitrogen contents declined 27% in the check plots and 20% in residue or manure plots. Phosphorus-treated plots suffered slightly greater loss than similar plots without phosphorus. Carbon to nitrogen ratio did not change.

Myers et al. (9) analyzed soil samples from the Hays, Colby and Garden City branch agricultural experiment stations. They reported a continuous decrease in soil nitrogen at these stations, but found indications that the nitrogen content of the soil tended to approach a state of equilibrium more or less characteristic of a given cropping system and soil. They also stated that there was a definite relationship between the cropping system and losses of nitrogen and organic carbon. Small grains produced the smallest losses while continuous row crops, and alternate row crop and fallow produced the greatest losses. Rotations including row crops and small grain produced intermediate losses. The losses of both nitrogen and carbon were also related to the original nitrogen and carbon contents of the soil.

Van Bavel and Schaller (13) working on Marshall soil found that changes in soil organic matter content were dependent upon cropping treatment as well as upon soil erosion. A corn, oats, meadow rotation did not entirely maintain the soil organic matter. The decrease was very small, however, and probably was not significant. They also found that 11 years of continuous alfalfa raised the soil organic matter content, whereas 11 years of bluegrass did not.

Mazurak and Conrad (8) stated that it was necessary to use nitrogen fertilizer if the nitrogen content of Chestnut and Chernozem soils, used for grain production, was to be maintained. The effect of nitrogen fertilizer on the total nitrogen content of soil was evident in the 0- to 6-inch depth but not in the 6- to 12-inch depth. Total oxidizable organic matter content showed the same trends as the total nitrogen content in the soil. Carbon to nitrogen ratio increased slightly during the seven years of cropping to cool-season grasses. Warm-season grasses decreased carbon to nitrogen ratio in a Brunizem soil.

Hobbs and Brown (7), reporting on the nitrogen and organic-carbon content of soils in western Kansas, found that losses of these constituents were related to the original soil content and to the cropping system. Losses were most rapid immediately after breaking the virgin sod and gradually became less with continued cultivation. These authors found that the greatest losses occurred under row-crop production, and the smallest losses accompanied small-grain production.

# EXPERIMENTAL PROCEDURE

## Design

The Soil Fertility Project was laid out systematically, with no previous investigations on the uniformity of the nitrogen and organic-carbon content of the soil. This experiment consisted originally of ten series. Of these ten, one series was discontinued in 1932, one in 1940, and four were dropped in 1956. The present study deals with the remaining four series. These series were arranged in two north and south columns with a road between. They were numbered beginning on the south with the odd-numbered series on the east side of the road and the even numbers on the west side of the road. These series originally were occupied by a 16-year rotation consisting of alfalfa for four years and a corn, corn, wheat sequence for the remaining twelve years. This was changed in 1922 to four years of alfalfa and a corn, wheat, wheat sequence for twelve years.

In 1968, within each of the series there remained seven 0.1-acre plots parallel to the center road. The plots were numbered beginning at the center road and proceeding both east and west. Plots 2 and 5 received no special treatments and were designated as check plots. The other plots received additions of mineral fertilizers, manure, etc.

Plot one received a treatment of fertilizer phosphorus. Plot four was given a fertilizer treatment of phosphorus and potassium. Phosphorus, potassium and nitrogen were added to plot six. Plot three received rock phosphate plus a green-manure crop preceding corn; while plot seven received phosphorus each year plus 5 tons of manure on the aftermath of second-year alfalfa and prior to plowing for corn. The various treatments applied to the different plots are shown in Table 1.

There were four replications of each fertilizer treatment and eight replications of the check plot in the 16-year rotation.

## Sampling

As listed in the annual Soil Fertility Project reports, the first adequate soil sampling of these plots was accomplished in 1915. Later samplings were made in 1923, and in 1934, 1946, and 1956. In 1968 a composite sample consisting of six cores from the surface to a depth of 6 2/3 inches was taken from each plot with a sampling tube. Composite samples consisting of six cores from 6 2/3 to 10, 10 to 13 1/3, 13 1/3 to 16 2/3, 16 2/3 to 20, and 20 to 36 inches were also taken from each plot. Care was taken not to include the surface residue in the samples. These samples were oven dried and ground.

## Chemical Analysis and Laboratory Procedures

In the laboratory, the 1968 composite samples were analyzed for available phosphorus, total nitrogen and organic carbon.

Table 1.--Fertilizer treatments for the plots in the 16-year rotation, Manhattan, Kansas

| Plot no. | Fertilizer treatment | Rate of Application | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fertilizer, lbs/A | | | Av. available nutrients applied per year, lbs/A | | |
| | | Alfalfa | Corn | Wheat | N | $P_2O_5$ | $K_2O$ |
| 1 | Superphosphate* | 190 | 75 | 80 | | 17.4 | |
| 2 | Check | No fertilizer | | | No nutrients | | |
| 3 | Rock phosphate,† green manure | 1500 lbs before corn | | | | 11.2 | |
| 4 | Superphosphate,* | 190 | 75 | 80 | | 17.4 | |
| | muriate of potash ‡ | 90 | 50 | 40 | | | 33.0 |
| 5 | Check | No fertilizer | | | No nutrients | | |
| 6 | Superphosphate * | 190 | 75 | 80 | | 17.4 | |
| | Mur. of potash ‡ | 90 | 50 | 40 | | | 33.0 |
| | Sodium nitrate § | 240 | 110 | 80 | 19.1 | | |
| 7 | Superphosphate,* | 190 | 75 | 80 | | 17.4 | |
| | manure μ | 5 tons | 5 tons | | 15.6 | 7.8 | 15.6 |

* Superphosphate (0-16-0) changed to triple superphosphate (0-45-0) in 1951.

† Ground rock phosphate had a composition of approximately 30% total $P_2O_5$ with about 3% available $P_2O_5$.

‡ Muriate of potash (0-0-60).

§ Sodium nitrate (15-0-0) changed to ammonium nitrate (33.5-0-0) in 1946.

μ Manure contained approximately 10 pounds of N, 5 pounds of $P_2O_5$ and 10 pounds of $K_2O$ per ton.

The available phosphorus was determined by the Bray weak-acid extraction method (4). The total nitrogen determination followed the Gunning - Hibbard procedure (2, p. 32), modified to reduce nitrates to ammonia. The organic carbon was determined by Allison's modification of the Schollenberger method (1) using chromic acid. The factor of 1.15 was used to relate values obtained by this method to those obtained by the dry combustion method.

## Check Plots

As explained earlier two check plots were present in each series of this experiment. The results of the analysis of these two check plots were averaged and reported for the check treatment in each series. Since the fertilizer treatments had only one plot for each series, using the average figure for the check plots seemed reasonable. By this means the check plots were considered as one treatment in the statistical analysis.

## Statistical Analysis

Where possible, statistical analyses of experimental results were conducted. There is some doubt that the results of this study are suited to statistical analyses: (a) the plots were laid out in a geometric design rather than at random, (b) no analysis for soil phosphorus was made prior to 1968, (c) carbon and nitrogen analyses of soil samples from these plots were not made prior to 1915. In spite of these discrepancies it seemed desirable to provide some indication of the significance of the differences between treatments and so use was made of statistical manipulation.

# EXPERIMENTAL RESULTS

## Phosphorus

Average available phosphorus of the soils on the different treatments by depths are presented in Table 2. These average values are in parts per million (ppm). The available phosphorus of each individual depth sample for each plot are presented in the Appendix, Table 1.

Table 2.--Effect of treatment and soil depth on available phosphorus content of a Geary silty clay loam

| Soil depth (inches) | Available P (ppm) | | | | | |
|---|---|---|---|---|---|---|
| | Check | P | P+K | N+P+K | Rock P | Man + P |
| 0-6 2/3 | 13.2 | 45.4 | 62.3 | 39.9 | 51.8 | 59.0 |
| 6 2/3-10 | 8.2 | 17.5 | 27.5 | 14.4 | 18.2 | 22.0 |
| 10-13 1/3 | 3.8 | 6.5 | 11.1 | 7.8 | 10.1 | 11.0 |
| 13 1/3-16 2/3 | 2.5 | 2.8 | 3.8 | 4.3 | 4.6 | 4.3 |
| 16 2/3-20 | 3.0 | 2.9 | 3.2 | 2.6 | 3.3 | 2.6 |
| 20-36 | 2.8 | 3.3 | 3.4 | 2.6 | 3.8 | 3.0 |
| L.S.D. ($p = 0.05$) | | | 8.0 | | | |

Table 2 shows conclusively that the available phosphorus was highest in the plow layer (0 to 6 2/3 inches) and became progressively lower with increasing depth to 20 inches. The phosphorus content was nearly the same in the 20 to 36-inch layer as it was in the 16 2/3 to 20-inch layer. This reduction in available phosphorus with depth was the same regardless of soil treatment.

All additions of phosphorus significantly increased the supply of available phosphorus. This was true not only in the plow layer, where the phosphorus fertilizers were added, but also in the 6 2/3- to 10-inch layer. Increases in the 10- to 13 2/3-inch layers are indicated also, but these were not large enough to be statistically significant.

These data show that the rock phosphate and the manure and phosphate-treated plots, which received the largest additions of phosphorus over the years, had very high levels of available phosphorus. The nitrogen, phosphorus and potassium treated plots had the lowest values of the fertilized plots. The only obvious explanation for this fact is that the complete fertilizer plots always produced larger yields than did the other plots. These higher yielding crops probably removed larger supplies of nutrients, including phosphorus, leaving smaller amounts in the soil. No explanation can be offered for the very high content of available phosphorus in the phosphorus and potassium treated plots.

The results presented in Table 2 do not give the actual amounts of available phosphorus in the soils of the various plots because of variation in thickness of the depth samples. The data in Table 3 which were calculated from those in Table 2, give a better picture of the phosphorus contents to a depth of

36 inches. The actual amounts of phosphorus in the various layers and in the whole profiles were calculated assuming that the bulk density of the soil was a uniform 2,000,000 pounds per acre-6 2/3 inches.

Table 3.--Effect of soil treatment and soil depth on the supply of available phosphorus in a Geary silty clay loam

| Soil depth (inches) | Available phosphorus (lbs/A) | | | | | |
|---|---|---|---|---|---|---|
| | Check | P | P+K | N+P+K | Rock P | Man + P |
| 0 to 6 2/3 | 26.5 | 90.8 | 124.6 | 79.8 | 103.6 | 118.0 |
| 6 2/3 to 10 | 8.2 | 17.5 | 27.5 | 14.4 | 18.2 | 22.0 |
| 10 to 13 1/3 | 3.8 | 6.5 | 11.1 | 7.8 | 10.1 | 11.0 |
| 13 1/3 to 16 2/3 | 2.5 | 2.8 | 3.8 | 4.3 | 4.6 | 4.3 |
| 16 2/3 to 20 | 3.0 | 2.9 | 3.2 | 2.6 | 3.3 | 2.6 |
| 20 to 36 | 13.4 | 15.8 | 16.3 | 12.5 | 18.2 | 14.4 |
| 0 to 36 | 57.4 | 136.3 | 186.5 | 121.4 | 158.0 | 172.3 |
| L.S.D. (p = 0.05) | | | 44.6 | | | |

These data show clearly the difference in available phosphorus in the different plots. Major increases due to fertilizer and manure applications are in the top 10 inches of the profile, but slight differences are seen also in the 10 to 13 1/3-inch layer.

## Nitrogen

Average 1968 soil-nitrogen contents in percent in the various layers in the different treatments are presented in

Table 4. Actual nitrogen contents of each replicate for each treatment and depth are given in the Appendix, Table 1.

Table 4.--Effect of treatment and depth on total soil nitrogen in a Geary silty clay loam

| Soil depth (inches) | Total N (percent) | | | | | |
|---|---|---|---|---|---|---|
| | Check | P | P+K | N+P+K | Rock P | Man + P |
| 0-6 2/3 | .138 | .138 | .139 | .140 | .139 | .146 |
| 6 2/3-10 | .126 | .123 | .130 | .128 | .133 | .126 |
| 10-13 1/3 | .108 | .102 | .107 | .106 | .110 | .107 |
| 13 1/3-16 2/3 | .088 | .080 | .091 | .090 | .091 | .086 |
| 16 2/3-20 | .076 | .072 | .079 | .074 | .076 | .078 |
| 20-36 | .062 | .062 | .066 | .060 | .065 | .065 |
| L.S.D. (p = 0.05) | | | 0.006 | | | |

Table 4 shows convincingly that the nitrogen content was highest in the plow layer (0 to 6 2/3 inches) and became progressively lower with increasing depth. This change in nitrogen content with depth was the same regardless of the soil treatment.

Differences in soil nitrogen content between treatments were not significant. This was true not only in the surface 6 2/3 inches but also in the entire profile sampled. These data show that the two plots which received nitrogen in fertilizer or manure had the highest percent nitrogen in the surface 6 2/3 inches. The differences in content between these two treatments and the rest were not significant and differences did not carry beyond the surface 6 2/3-inch soil layer. The only explanation for this fact is that the nitrogen additions were of such small magnitude that the crops removed all of the nitrogen added.

The results presented in Table 4 do not give the actual amounts of total nitrogen in the soils of the various plots because of the variation in depth of the different samplings. The data in Table 5, which were calculated from those in Table 4, present a better picture of the nitrogen contents to a depth of 36 inches. The actual amounts of nitrogen in the various layers and in the entire profiles were calculated assuming the bulk density of the soil was a uniform 2,000,000 pounds per acre-6 2/3 inches.

Table 5.--Effect of soil treatment and soil depth on the supply of available nitrogen in a Geary silty clay loam

| Soil depth (inches) | Total nitrogen (lbs/A) | | | | | |
|---|---|---|---|---|---|---|
| | Check | P | P+K | N+P+K | Rock P | Man + P |
| 0 to 6 2/3 | 2,750 | 2,760 | 2,780 | 2,800 | 2,780 | 2,920 |
| 6 2/3 to 10 | 1,260 | 1,230 | 1,300 | 1,280 | 1,330 | 1,260 |
| 10 to 13 1/3 | 1,085 | 1,020 | 1,070 | 1,060 | 1,100 | 1,070 |
| 13 1/3 to 15 2/3 | 880 | 800 | 910 | 900 | 910 | 860 |
| 16 2/3 to 20 | 755 | 720 | 790 | 740 | 760 | 780 |
| 20 to 36 | 2,976 | 2,976 | 3,168 | 2,880 | 3,120 | 3,120 |
| 0 to 36 | 9,696 | 9,506 | 10,018 | 9,660 | 10,000 | 10,010 |
| L.S.D. (p = 0.05) | | | | 370 | | |

The data in Table 5 show that there is little difference between total nitrogen per acre-36 inches in the check plot and in the fertilized plots, even those receiving additions of nitrogen. Maximum difference between the check plot and any treated plot is only 322 pounds of nitrogen per acre-36 inches, or 322 pounds per 108,000,000 pounds, or 0.003%. This is in the order of the permissible analytical error in nitrogen determination in the laboratory.

Table 6 contains data for the nitrogen content of the surface 6 2/3 inches in each treatment in 1915, 1934, 1946, 1956, and 1968. The actual nitrogen loss between 1915 and 1968 is also presented, as is the loss calculated as a percent of the 1915 content. Values for 1915 and 1934 were obtained from project annual reports. Data for 1946 and 1956 were obtained from M.S. theses by Dodge[1] and Fritschen[2] respectively.

No statistical analysis of these data was possible because in 1956 individual values for each replicate of each treatment were not recorded. However, the data do show the trend of nitrogen-content change over the years. Nitrogen decreased rapidly through 1946, but between 1946 and 1968 the content appeared to have become stabilized. There were no large

---

[1]Dodge, Darold A. The effect of longtime fertility treatments on the nitrogen and carbon content of a Prairie soil. Master's Thesis. Kansas State College. 1946.

[2]Fritschen, Leo J. Effect of crop rotation and fertilizer treatment on the nitrogen and carbon content of a Prairie soil. Master's Thesis. Kansas State College. 1957.

Table 6.--Effect of time and fertilizer treatment on the nitrogen content of a Geary silty clay loam

| | Nitrogen content (percent) | | | | | |
|---|---|---|---|---|---|---|
| Year | Check | P | P+K | N+P+K | Rock P | Man + P |
| 1915 | .167 | .174 | .167 | .164 | | |
| 1934 | .143 | .147 | .142 | .145 | | |
| 1946 | .133 | .136 | .140 | .137 | | |
| 1956 | .131 | .134 | .133 | .140 | .135 | .140 |
| 1968 | .138 | .138 | .139 | .139 | .138 | .146 |
| Loss 1915-1968 | .029 | .036 | .028 | .025 | | |
| Loss, % of 1915 content | 17.4 | 20.7 | 16.8 | 15.2 | | |

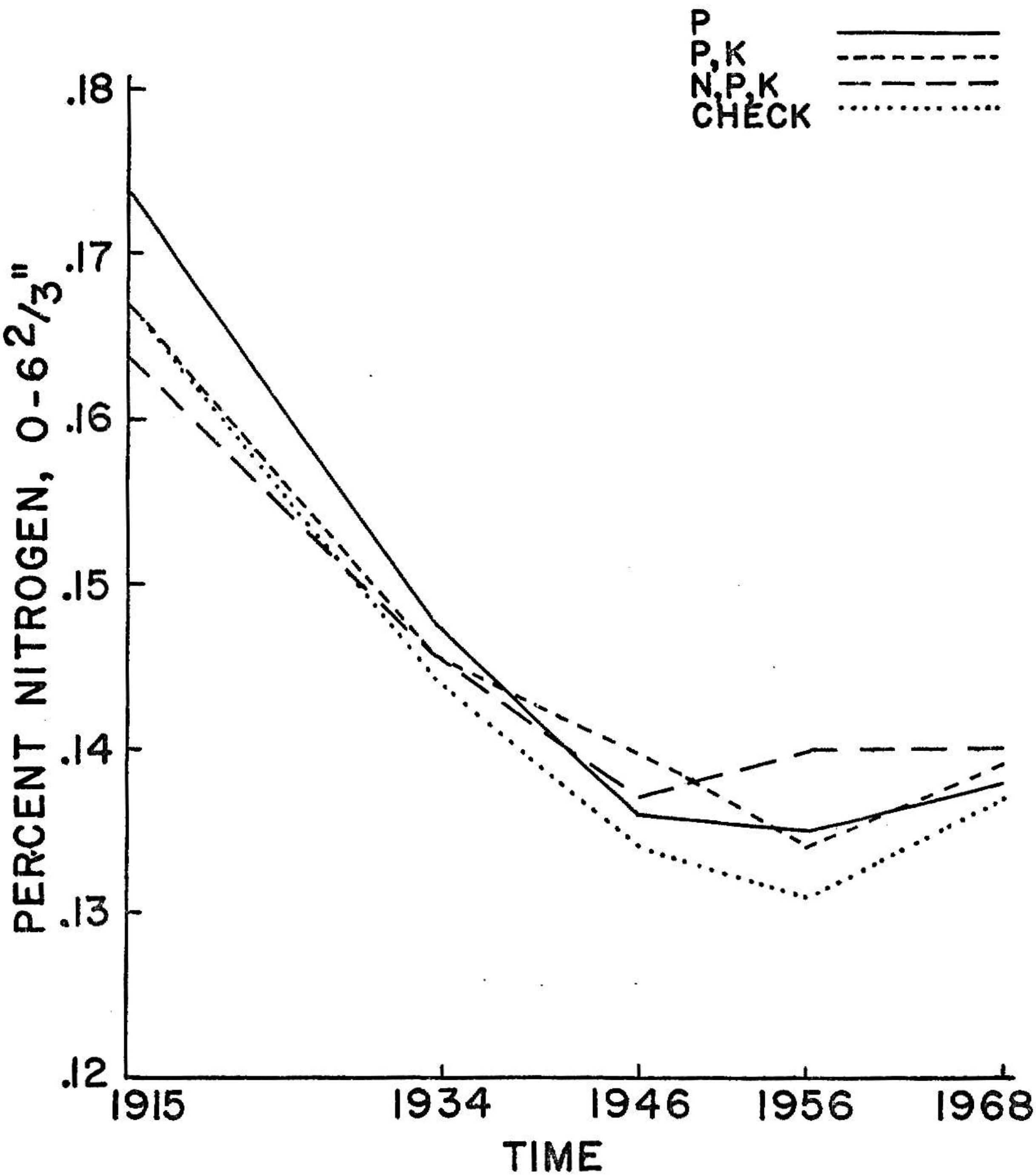
Differences in the rates of decline in the plots treated with different fertilizers, although the manured plots apparently lost nitrogen, at least its 1956 and 1968 values are highest.

These same data are presented in graphical form in figure 1 on page 23.

## EXPLANATION OF PLATE 1

Fig. 1. Average total nitrogen contents of the soil as influenced by treatment and length of cultivation.

PLATE 1


P
P,K
N,P,K
CHECK
.18
.17
.16
.15
.14
.13
.12
PERCENT NITROGEN, 0-6 2/3"
1915
1934
1946
1956
1968
TIME

## Organic Carbon

Average 1968 organic-carbon contents, expressed in percent, of the various soil depths in the different treatments are presented in Table 7. The actual values for each replicate of each treatment and depth are given in the Appendix, Table 1.

Table 7.--Effect of treatment and soil depth on percent organic-carbon in a Geary silty clay loam

| Soil depth (inches) | Organic-carbon content (percent) | | | | | |
|---|---|---|---|---|---|---|
| | Check | P | P+K | N+P+K | Rock P | Man + P |
| 0 to 6 2/3 | 1.58 | 1.55 | 1.55 | 1.59 | 1.61 | 1.68 |
| 6 2/3 to 10 | 1.37 | 1.30 | 1.42 | 1.35 | 1.37 | 1.35 |
| 10 to 13 1/3 | 1.04 | 0.76 | 1.03 | 1.03 | 1.16 | 1.03 |
| 13 1/3 to 16 2/3 | .74 | .75 | .79 | .81 | .80 | .75 |
| 16 2/3 to 20 | .60 | .60 | .62 | .65 | .56 | .67 |
| 20 to 36 | .48 | .51 | .44 | .54 | .49 | .56 |
| L.S.D. (p = 0.05) | | | | 0.10 | | |

These data show that the organic-carbon content of the soil was the highest in the surface 6 2/3 inches and became progressively lower with increasing depth through the 36-inch layer. This change in organic-carbon with depth was essentially the same regardless of soil treatment. Decreases in organic-carbon content with depth were uniformly significant through 20 inches in all treatments and to 36 inches in all but the phosphorus and the rock phosphate treatment.

The results presented in Table 7 do not give the actual amounts of organic-carbon in the soils of the various plots because of the variation in depth of the different samplings. The data in Table 8, which were calculated from those in Table 7, present a better picture of the organic-carbon contents to a depth of 36 inches. The actual amounts of organic-carbon in the various layers and in the entire profiles were calculated assuming the bulk density of the soil was a uniform 2,000,000 pounds per acre 6 2/3 inches.

Table 8.--Effect of soil treatment and soil depth on the supply of organic-carbon in a Geary silty clay loam

| Soil depth (inches) | Organic Carbon (lbs/A) | | | | | |
|---|---|---|---|---|---|---|
| | Check | P | P+K | N+P+K | Rock P | Man + P |
| 0 to 6 2/3 | 31,500 | 31,000 | 31,000 | 31,800 | 32,200 | 33,600 |
| 6 2/3 to 10 | 13,700 | 13,000 | 14,200 | 13,500 | 13,700 | 13,500 |
| 10 to 13 1/3 | 10,350 | 7,600 | 10,300 | 10,300 | 11,600 | 10,300 |
| 13 1/3 to 16 2/3 | 7,450 | 7,500 | 7,900 | 8,100 | 8,000 | 7,500 |
| 16 2/3 to 20 | 6,050 | 6,000 | 6,200 | 6,500 | 5,600 | 6,700 |
| 20 to 36 | 23,040 | 24,480 | 21,120 | 25,920 | 23,520 | 26,880 |
| 0 to 36 | 92,090 | 89,580 | 90,720 | 96,120 | 94,620 | 98,480 |
| L.S.D. ($p = 0.05$) | | | | 5,620 | | |

These data appear to indicate that the plots which received nitrogen either as fertilizer or manure had more organic-carbon per acre-36 inches than did the other treatments. However, the major differences in organic-carbon contents were found in the lower layers, and it is unlikely that these resulted from the fertilizer treatments.

The percent carbon in the surface 6 2/3 inches in 1915, 1934, 1946, 1956, and 1968 is shown in Table 9. The carbon loss between 1915 and 1958 is also shown in this table. These data show that there has been a continual decrease in percent organic carbon since 1915 in all treatments. Losses between 1956 and 1968 seemed to be as great as in earlier periods. The complete fertilizer treatment was the only treatment that gave less percent loss than the check plots. These results follow those of nitrogen presented in Table 6, except that the carbon losses were slightly greater percentagewise.

Table 9.--Effect of treatment and time on the organic-carbon content of a Geary silty clay loam

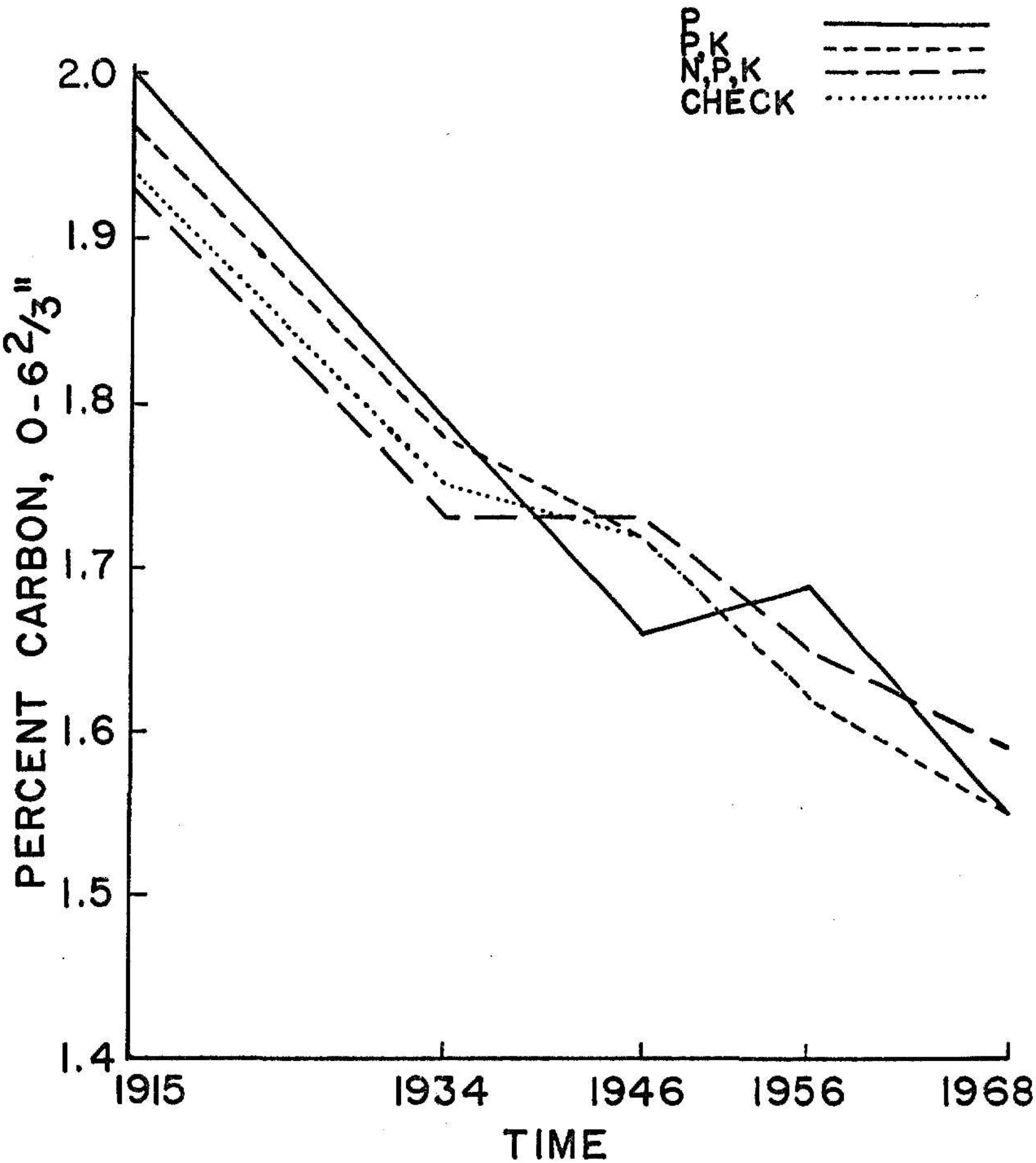
| Year | Organic-carbon content (percent) | | | | | |
|---|---|---|---|---|---|---|
| | Check | P | P+K | N+P+K | Rock P | Man + P |
| 1915 | 1.94 | 1.99 | 1.96 | 1.93 | | |
| 1934 | 1.75 | 1.79 | 1.78 | 1.73 | | |
| 1946 | 1.72 | 1.65 | 1.72 | 1.73 | | |
| 1956 | 1.62 | 1.69 | 1.69 | 1.65 | 1.65 | 1.67 |
| 1968 | 1.55 | 1.55 | 1.55 | 1.59 | 1.61 | 1.67 |
| Loss 1915-1968 | 0.39 | 0.44 | 0.41 | 0.34 | | |
| Loss, % of 1915 content | 20.1 | 22.1 | 20.9 | 12.4 | | |

These same date are presented in graphical form in figure 2. This figure shows the continued decline in organic carbon content through 1968 in all treatments.

EXPLANATION OF PLATE 2

Fig. 1. The average organic-carbon contents of soil as influenced by treatment and length of cultivation.

PLATE 2


P
P,K
N,P,K
CHECK
2.0
1.9
1.8
1.7
1.6
1.5
1.4
PERCENT CARBON, 0-6 2/3"
1915
1934
1946
1956
1968
TIME

## DISCUSSION OF RESULTS

This study showed that all phosphorus treatments produced significant increases in the available-phosphorus content of a Geary silty clay loam after over 50 years of fertilizer additions. The phosphorus content of the soil was significantly increased in the 0 to 10-inch layer. Increases in the 10 to 16 2/3-inch layer though consistant were not statistically significant. The phosphorus plus potassium treatment gave the greatest available phosphorus increase, manure plus phosphorus gave the second highest increase, followed by rock phosphate and greenmanure, and by phosphorus alone. The complete fertilizer treatment (N+P+K) gave the smallest increase.

Similar results were reported by Brage _et al_. (3) and Pratt _et al_. (11). The latter reported that 60% of accumulated phosphorus was in the 0 to 6-inch soil layer and 80% was in the 0 to 12-inch soil layer after 28 years of applications of inorganic phosphates or organic materials. They also showed evidence of movement of phosphorus into the 24 to 36-inch soil layer but not beyond. Owensby _et al_. (10) reported increases of phosphorus from fertilizer application through the 36-inch soil layer. Haas _et al_. (6) showed little effect upon reducing losses of organic phosphorus by cropping with manure in the fertilizer applications.

Although Brage et al. (3), and Unger (12) reported increases of nitrogen and organic-carbon after heavy applications of manure, in the present study there were losses of nitrogen and organic-carbon for all the treatments studied. The phosphate treatment had the greatest percent loss of both nitrogen and organic carbon. The complete fertilizer (N+P+K) had the least percent loss of both nitrogen and organic-carbon followed by the potassium and phosphorus treatment; however, only the complete fertilizer treatment showed less loss of nitrogen and organic-carbon than did the check plot. It may be that the additions of the complete fertilizer tended to retard the loss of nitrogen by replacing some of the nitrogen that was utilized by crops, and to retard the loss of organic-carbon by producing more residues which were later incorporated in the soil.

Haas et al. (5) also reported nitrogen losses from 24 to 60% of the original level and similar losses in organic carbon after long periods of cropping. Similar results were reported by Young et al. (14), Myers et al. (9), and Hobbs and Brown (7).

# CONCLUSION

The results of this study on the Soil Fertility Project at Manhattan, Kansas, showed an increase in the content of available soil phosphorus with fertilizer additions, but a decrease in nitrogen and organic carbon contents, over the period of the study, 1915-1968.

All phosphorus fertilizer treatments used in this experiment gave an increase in available phosphorus in the surface ten inches with the phosphorus plus potassium treatment giving the greatest increase. There were also increases through the 16 2/3 inch soil layer but these were not statistically significant.

Although all four treatments used in this experiment permitted decreases in nitrogen and organic-carbon during the period studied, the losses of nitrogen were more rapid for the first years of the experiment, then tended to approach a new equilibrium for each treatment. The magnitude of the losses of both nitrogen and carbon tended to be associated with the size of the original contents.

Treatments of phosphate, and phosphate and potassium tended to permit the greatest losses of both nitrogen and organic-carbon, while the complete fertilizer treatment tended to retain the highest level of productivity.

## ACKNOWLEDGMENT

The author wishes to express his sincere appreciation to his major instructor, Dr. J. A. Hobbs, for his excellent guidance in doing the research work and preparation of this thesis.

## LITERATURE CITED


1. Allison, L. E., 1935. Organic soil carbon by reduction of chromic acid. Soil Sci. 40:311-320.

2. Association of Official Agricultural Chemists. 1950. Official and tentative methods of analysis. Assoc. Offic. Agrl. Chemists., Washington D.C. Seventh edition, p. 32.

3. Brage, B. L., M. J. Thompson, and A. C. Caldwell, 1952. Long-time effect of applying barnyard manure at varied rates on crop yield and some chemical constituents of the soil. Agron. J. 44:17-20.

4. Bray, R. H., and L. T. Kurtz, 1945. Determination of total, organic, and available forms of phosphorus in soils. Soil Sci. 59:1-39.

5. Haas, H. J., C. E. Evans, and E. F. Miles, 1957. Nitrogen and carbon changes in Great Plains soils as influenced by cropping and soil treatments. U. S. Dept. Agr. Tech. Bul. 1164.

6. Haas, H. J., D. L. Grunes, and G. A. Reichman, 1961. Phosphorus changes in Great Plains soils as influenced by cropping and manure applications. Soil Sci. Soc. Amer. Proc. 25:214-218.

7. Hobbs, J. A. and P. L. Brown, 1957. Nitrogen and organic carbon changes in cultivated western Kansas soils. Kansas Agr. Exp. Sta. Tech. Bul. 89.

8. Mazurak, A. P. and E. C. Conrad, 1966. Changes in content of total nitrogen and organic matter in three Nebraska soils after seven years of cropping treatments. Agron. J. 58:85-88.

9. Myers, H. E., A. L. Hallsted, J. B. Kuska, and H. J. Haas, 1943. Nitrogen and carbon changes in soils under low rainfall as influenced by cropping systems and soil treatment. Kansas Agr. Expt. Sta. Tech. Bul. 56.

10. Owensby, Clenton E., Kling L. Anderson, and David A. Whitney, 1968. Some chemical properties of a silt loam soil after 20 years of nitrogen and phosphorus fertilization of smooth bromegrass. Soil Science. 108:24-29.

11. Pratt, P. F., W. W. Jones, and H. D. Chapman, 1956. Changes in phosphorus in an irrigated soil during 28 years differential fertilization. Soil Sci. 82:295-306.

12. Unger, P. W., 1968. Soil organic matter and nitrogen changes during 24 years of dryland wheat tillage and cropping practices. Soil Sci. Soc. Am. Proc. 32:427-429.

13. van Bavel, C. H. M. and F. W. Schaller, 1951. Soil aggregation, organic matter, and yields in a long-time experiment as affected by crop management. Soil Sci. Soc. Am. Proc. 15:399-404.

14. Young, R. A., J. C. Zubriski, and E. B. Norum, 1960. Influence of long-time fertility management practices on chemical and physical properties of a Fargo clay. Soil Sci. Soc. Am. Proc. 24:124-128.

# APPENDIX

Table 1 Available phosphorus (ppm), total nitrogen (%), and organic carbon (%) contents of individual plots in the 16-year rotation on the Soil Fertility Project, Manhattan, Kansas. 1968.

| Series | Plot, treatment and depth | Available P | Total N | Organic C |
|---|---|---|---|---|
| I | 1, P, 0-6 2/3 | 52.5 | .129 | 1.47 |
| | 1, P, 6 2/3-10 | 22.0 | .109 | 1.17 |
| | 1, P, 10-13 1/3 | 6.5 | .087 | 0.79 |
| | 1, P, 13 1/3-16 2/3 | 4.2 | .068 | 0.54 |
| | 1, P, 16 2/3-20 | 2.9 | .066 | 0.50 |
| | 1, P, 20-36 | 2.8 | .062 | 0.49 |
| | 2, Ck, 0-6 2/3 | 19.5 | .128 | 1.44 |
| | 2, Ck, 6 2/3-10 | 11.0 | .124 | 1.46 |
| | 2, Ck, 10-13 1/3 | 10.0 | .110 | 1.09 |
| | 2, Ck, 13 1/3-16 2/3 | 3.3 | .091 | 0.80 |
| | 2, Ck, 16 2/3-20 | 2.8 | .080 | 0.72 |
| | 2, Ck, 20-36 | 3.2 | .068 | 0.59 |
| | 3, RP, 0-6 2/3 | 62.6 | .134 | 1.57 |
| | 3, RP, 6 2/3-10 | 13.5 | .124 | 1.23 |
| | 3, RP, 10-13 1/3 | 8.0 | .108 | 1.05 |
| | 3, RP, 13 1/3-16 2/3 | 5.3 | .082 | 0.80 |
| | 3, RP, 16 2/3-20 | 3.8 | .070 | 0.59 |
| | 3, RP, 20-36 | 4.0 | .065 | 0.59 |
| | 4, PK, 0-6 2/3 | 55.2 | .123 | 1.48 |
| | 4, PK, 6 2/3-10 | 13.5 | .124 | 1.41 |
| | 4, PK, 10-13 1/3 | 7.5 | .110 | 0.96 |
| | 4, PK, 13 1/3-16 2/3 | 3.4 | .094 | 0.73 |
| | 4, PK, 16 2/3-20 | 3.0 | .082 | 0.68 |
| | 4, PK, 20-36 | 2.7 | .062 | 0.51 |
| | 5, Ck, 0-6 2/3 | 12.5 | .122 | 1.39 |
| | 5, Ck, 6 2/3-10 | 10.0 | .122 | 1.31 |
| | 5, Ck, 10-13 1/3 | 2.2 | .105 | 0.92 |
| | 5, Ck, 13 1/3-16 2/3 | 2.0 | .088 | 0.76 |
| | 5, Ck, 16 2/3-20 | 4.7 | .075 | 0.70 |
| | 5, Ck, 20-36 | 3.4 | .062 | 0.59 |
| | 6, NPK, 0-6 2/3 | 32.5 | .124 | 1.52 |
| | 6, NPK, 6 2/3-10 | 5.5 | .114 | 1.24 |
| | 6, NPK, 10-13 1/3 | 4.0 | .095 | 0.88 |
| | 6, NPK, 13 1/3-16 2/3 | 5.0 | .084 | 0.81 |
| | 6, NPK, 16 2/3-20 | 2.2 | .070 | 0.63 |
| | 6, NPK, 20-36 | 1.4 | .060 | 0.49 |

Table 1, Continued

| Series | Plot, treatment and depth | Available P | Total N | Organic C |
|---|---|---|---|---|
| | 7, M+P, 0-6 2/3 | 34.5 | .125 | 1.54 |
| | 7, M+P, 6 2/3-10 | 13.5 | .118 | 1.26 |
| | 7, M+P, 10-13 1/3 | 11.0 | .094 | 0.92 |
| | 7, M+P, 13 1/3-16 2/3 | 3.2 | .083 | 0.73 |
| | 7, M+P, 16 2/3-20 | 2.5 | .075 | 0.62 |
| | 7, M+P, 20-36 | 2.0 | .063 | 0.54 |
| II | 1, P, 0-6 2/3 | 40.0 | .133 | 1.56 |
| | 1, P, 6 2/3-10 | 8.0 | .124 | 1.21 |
| | 1, P, 10-13 1/3 | 2.5 | .110 | 0.99 |
| | 1, P, 13 1/3-16 2/3 | 2.4 | .096 | 0.80 |
| | 1, P, 16 2/3-20 | 2.4 | .078 | 0.67 |
| | 1, P, 20-36 | 2.3 | .064 | 0.65 |
| | 2, Ck, 0-6 2/3 | 10.0 | .133 | 1.50 |
| | 2, Ck, 6 2/3-10 | 5.0 | .130 | 1.32 |
| | 2, Ck, 10-13 1/3 | 3.0 | .114 | 1.04 |
| | 2, Ck, 13 1/3-16 2/3 | 2.3 | .092 | 0.75 |
| | 2, Ck, 16 2/3-20 | 2.2 | .078 | 0.62 |
| | 2, Ck, 20-36 | 2.3 | .063 | 0.42 |
| | 3, RP, 0-6 2/3 | 55.5 | .134 | 1.66 |
| | 3, RP, 6 2/3-10 | 13.0 | .134 | 1.32 |
| | 3, RP, 10-13 1/3 | 14.5 | .116 | 1.12 |
| | 3, RP, 13 1/3-16 2/3 | 5.8 | .100 | 0.79 |
| | 3, RP, 16 2/3-20 | 4.4 | .082 | 0.50 |
| | 3, RP, 20-36 | 3.4 | .068 | 0.26 |
| | 4, PK, 0-6 2/3 | 48.0 | .139 | 1.55 |
| | 4, PK, 6 2/3-10 | 26.5 | .138 | 1.46 |
| | 4, PK, 10-13 1/3 | 7.5 | .113 | 1.10 |
| | 4, PK, 13 1/3-16 2/3 | 2.7 | .098 | 0.86 |
| | 4, PK, 16 2/3-20 | 3.0 | .083 | 0.63 |
| | 4, PK, 20-36 | 2.2 | .066 | 0.39 |
| | 5, Ck, 0-6 2/3 | 15.0 | .134 | 1.54 |
| | 5, Ck, 6 2/3-10 | 5.0 | .118 | 1.24 |
| | 5, Ck, 10-13 1/3 | 3.0 | .099 | 0.98 |
| | 5, Ck, 13 1/3-16 2/3 | 2.6 | .084 | 0.66 |
| | 5, Ck, 16 2/3-20 | 3.0 | .074 | 0.47 |
| | 5, Ck, 20-36 | 2.2 | .057 | 0.26 |

Table 1, Continued

| Series | Plot, treatment and depth | Available P | Total N | Organic C |
|---|---|---|---|---|
| | 6, NPK, 0-6 2/3 | 41.0 | .141 | 1.66 |
| | 6, NPK, 6 2/3-10 | 14.0 | .134 | 1.45 |
| | 6, NPK, 10-13 1/3 | 9.5 | .116 | 1.12 |
| | 6, NPK, 13 1/3-16 2/3 | 4.8 | .094 | 0.92 |
| | 6, NPK, 16 2/3-20 | 2.6 | .076 | 0.76 |
| | 6, NPK, 20-36 | 1.3 | .059 | 0.68 |
| | 7, M+P, 0-6 2/3 | 100.0 | .162 | 1.81 |
| | 7, M+P, 6 2/3-10 | 36.5 | .134 | 1.41 |
| | 7, M+P, 10-13 1/3 | 10.5 | .126 | 1.19 |
| | 7, M+P, 13 1/3-16 2/3 | 4.2 | .090 | 0.77 |
| | 7, M+P, 16 2/3-20 | 0.5 | .092 | 0.73 |
| | 7, M+P, 20-36 | 0.5 | .074 | 0.76 |
| III | 1, P, 0-6 2/3 | 39.0 | .145 | 1.64 |
| | 1, P, 6 2/3-10 | 27.0 | .132 | 1.47 |
| | 1, P, 10-13 1/3 | 7.5 | .115 | 1.07 |
| | 1, P, 13 1/3-16 2/3 | 2.4 | .074 | 0.85 |
| | 1, P, 16 2/3-20 | 3.6 | .067 | 0.62 |
| | 1, P, 20-36 | 4.3 | .060 | 0.46 |
| | 2, Ck, 0-6 2/3 | 11.5 | .140 | 1.62 |
| | 2, Ck, 6 2/3-10 | 8.5 | .133 | 1.54 |
| | 2, Ck, 10-13 1/3 | 6.0 | .116 | 1.13 |
| | 2, Ck, 13 1/3-16 2/3 | 1.3 | .092 | 0.81 |
| | 2, Ck, 16 2/3-20 | 0.5 | .073 | 0.63 |
| | 2, Ck, 20-36 | 2.2 | .064 | 0.51 |
| | 3, RP, 0-6 2/3 | 39.0 | .146 | 1.59 |
| | 3, RP, 6 2/3-10 | 32.0 | .149 | 1.57 |
| | 3, RP, 10-13 1/3 | 12.0 | .123 | 1.27 |
| | 3, RP, 13 1/3-16 2/3 | 5.3 | .102 | 0.86 |
| | 3, RP, 16 2/3-20 | 2.5 | .083 | 0.63 |
| | 3, RP, 20-36 | 3.6 | .062 | 0.49 |
| | 4, PK, 0-6 2/3 | 75.0 | .144 | 1.63 |
| | 4, PK, 6 2/3-10 | 64.0 | .146 | 1.58 |
| | 4, PK, 10-13 1/3 | 25.4 | .117 | 1.27 |
| | 4, PK, 13 1/3-16 2/3 | 6.0 | .098 | 0.99 |
| | 4, PK, 16 2/3-20 | 4.3 | .078 | 0.65 |
| | 4, PK, 20-36 | 3.2 | .073 | 0.41 |

Table 1, Continued

| Series | Plot, treatment and depth | Available P | Total N | Organic C |
|---|---|---|---|---|
| | 5, Ck, 0-6 2/3 | 10.0 | .142 | 1.54 |
| | 5, Ck, 6 2/3-10 | 11.0 | .142 | 1.59 |
| | 5, Ck, 10-13 1/3 | 2.5 | .114 | 1.24 |
| | 5, Ck, 13 1/3-16 2/3 | 3.2 | .092 | 0.88 |
| | 5, Ck, 16 2/3-20 | 3.2 | .080 | 0.69 |
| | 5, Ck, 20-36 | 2.5 | .061 | 0.48 |
| | 6, NPK, 0-6 2/3 | 30.7 | .148 | 1.66 |
| | 6, NPK, 6 2/3-10 | 24.2 | .135 | 1.52 |
| | 6, NPK, 10-13 1/3 | 11.2 | .112 | 1.02 |
| | 6, NPK, 13 1/3-16 2/3 | 5.0 | .095 | 0.81 |
| | 6, NPK, 16 2/3-20 | 3.2 | .074 | 0.58 |
| | 6, NPK, 20-36 | 3.2 | .063 | 0.52 |
| | 7, M+P, 0-6 2/3 | 56.0 | .150 | 1.70 |
| | 7, M+P, 6 2/3-10 | 33.5 | .150 | 1.66 |
| | 7, M+P, 10-13 1/3 | 10.0 | .114 | 1.14 |
| | 7, M+P, 13 1/3-16 2/3 | 5.1 | .093 | 0.84 |
| | 7, M+P, 16 2/3-20 | 4.7 | .076 | 0.66 |
| | 7, M+P, 20-36 | 4.3 | .064 | 0.55 |
| IV | 1, P, 0-6 2/3 | 50.0 | .146 | 1.53 |
| | 1, P, 6 2/3-10 | 13.0 | .128 | 1.37 |
| | 1, P, 10-13 1/3 | 9.5 | .098 | 1.00 |
| | 1, P, 13 1/3-16 2/3 | 2.4 | .083 | 0.81 |
| | 1, P, 16 2/3-20 | 2.6 | .076 | 0.60 |
| | 1, P, 20-36 | 3.8 | .062 | 0.46 |
| | 2, Ck, 0-6 2/3 | 13.5 | .157 | 1.81 |
| | 2, Ck, 6 2/3-10 | 5.0 | .127 | 1.44 |
| | 2, Ck, 10-13 1/3 | 1.0 | .106 | 1.01 |
| | 2, Ck, 13 1/3-16 2/3 | 2.0 | .086 | 0.75 |
| | 2, Ck, 16 2/3-20 | 3.8 | .068 | 0.52 |
| | 2, Ck, 20-36 | 3.4 | .060 | 0.43 |
| | 3, RP, 0-6 2/3 | 50.0 | .141 | 1.62 |
| | 3, RP, 6 2/3-10 | 14.0 | .124 | 1.29 |
| | 3, RP, 10-13 1/3 | 6.0 | .094 | 1.18 |
| | 3, RP, 13 1/3-16 2/3 | 1.9 | .080 | 0.75 |
| | 3, RP, 16 2/3-20 | 2.6 | .068 | 0.51 |
| | 3, RP, 20-36 | 4.0 | .066 | 0.42 |

Table 1, Continued

| Series | Plot, treatment and depth | Available P | Total N | Organic C |
|---|---|---|---|---|
| | 4, PK, 0-6 2/3 | 71.0 | .150 | 1.54 |
| | 4, PK, 6 2/3-10 | 6.0 | .113 | 1.23 |
| | 4, PK, 10-13 1/3 | 4.0 | .088 | 0.78 |
| | 4, PK, 13 1/3-16 2/3 | 3.2 | .074 | 0.59 |
| | 4, PK, 16 2/3-20 | 2.4 | .074 | 0.50 |
| | 4, PK, 20-36 | 5.8 | .062 | 0.44 |
| | 5, Ck, 0-6 2/3 | 14.0 | .142 | 1.59 |
| | 5, Ck, 6 2/3-10 | 10.0 | .116 | 1.05 |
| | 5, Ck, 10-13 1/3 | 2.5 | .094 | 0.86 |
| | 5, Ck, 13 1/3-16 2/3 | 3.4 | .078 | 0.52 |
| | 5, Ck, 16 2/3-20 | 3.6 | .076 | 0.50 |
| | 5, Ck, 20-36 | 3.4 | .062 | 0.52 |
| | 6, NPK, 0-6 2/3 | 55.5 | .146 | 1.53 |
| | 6, NPK, 6 2/3-10 | 15.5 | .128 | 1.20 |
| | 6, NPK, 10-13 1/3 | 6.5 | .100 | 1.10 |
| | 6, NPK, 13 1/3-16 2/3 | 2.4 | .085 | 0.70 |
| | 6, NPK, 16 2/3-20 | 2.6 | .075 | 0.62 |
| | 6, NPK, 20-36 | 4.3 | .058 | 0.48 |
| | 7, M+P, 0-6 2/3 | 45.5 | .148 | 1.66 |
| | 7, M+P, 6 2/3-10 | 4.5 | .104 | 1.08 |
| | 7, M+P, 10-13 1/3 | 12.5 | .094 | 0.86 |
| | 7, M+P, 13 1/3-16 2/3 | 4.8 | .078 | 0.66 |
| | 7, M+P, 16 2/3-20 | 2.6 | .071 | 0.68 |
| | 7, M+P, 20-36 | 5.3 | .060 | 0.45 |

Table 2 Analysis of variance summary. Available phosphorus, ppm

| Item | SS | DF | MS | F | Sgn | 5%F | 1%F |
|---|---|---|---|---|---|---|---|
| Treat | 2,542.81 | 5 | 508.56 | 15.86 | *** | 2.34 | 3.27 |
| Depth | 32,893.41 | 5 | 6,578.68 | 205.19 | *** | 2.34 | 3.27 |
| Tr x Dpth | 4,790.92 | 25 | 191.64 | 5.98 | *** | 1.66 | 2.05 |
| Repl. | 359.95 | 3 | 119.98 | 3.74 | * | 2.73 | 4.06 |
| Repl. x Tr. | 1,678.93 | 15 | 111.93 | 3.49 | ** | 1.82 | 2.30 |
| Repl. x Dpth | 1,692.73 | 15 | 112.85 | 3.52 | ** | 1.82 | 2.30 |
| Error | 2,404.84 | 75 | 32.06 | | | | |
| | 46,363.59 | 143 | | | | | |

Table 3 Analysis of variance summary. Total nitrogen, percent.

| Item | SS | DF | MS | F | Sng | 5%F | 1%F |
|---|---|---|---|---|---|---|---|
| Treat | .000,360 | 5 | .000,072 | 3.27 | ** | 2.34 | 3.27 |
| Depth | .108,436 | 5 | .021,687 | 985.57 | *** | 2.34 | 3.27 |
| Tr x Dpth | .000,800 | 25 | .000,032 | 1.45 | ns | 1.66 | 2.05 |
| Repl. | .003,834 | 3 | .001,278 | 58.09 | *** | 2.73 | 4.06 |
| Repl. x Tr. | .001,846 | 15 | .000,123 | 5.59 | *** | 1.82 | 2.30 |
| Repl. x Dpth | .003,125 | 15 | .000,208 | 9.45 | *** | 1.82 | 2.30 |
| Error | .001,621 | 75 | .000,022 | | | | |
| | .120,022 | 143 | | | | | |

Table 4 Analysis of variance summary. Organic carbon, percent.

| Item | SS | DF | MS | F | Sgn | 5%F | 1%F |
|---|---|---|---|---|---|---|---|
| Treat | 0.0608 | 5 | 0.0122 | 2.39 | * | 2.34 | 3.27 |
| Depth | 22.2135 | 5 | 4.4427 | 871.21 | *** | 2.34 | 3.27 |
| Tr x Dpth | .2091 | 25 | .0084 | 1.65 | * | 1.66 | 2.05 |
| Repl. | .4347 | 3 | .1449 | 28.41 | *** | 2.73 | 4.06 |
| Repl. x Tr. | .3408 | 15 | .0227 | 4.45 | *** | 1.82 | 2.30 |
| Repl. x Dpth | .3393 | 15 | .0226 | 4.43 | *** | 1.82 | 2.30 |
| Error | .3822 | 75 | .0051 | | | | |
| | 23.9804 | 143 | | | | | |

# EFFECTS OF LONG-TIME FERTILITY TREATMENTS ON SELECTED CHEMICAL PROPERTIES OF A PRAIRIE SOIL

by

ELMER DEAN GRAUERHOLZ

B. S., Kansas State University, 1968

---

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1970

The effects of cropping systems and fertilizer treatments on the nitrogen and organic-carbon contents of a Geary silty clay loam have been studied on the Soil Fertility Project of the Agronomy Farm, Kansas State University, Manhattan, Kansas, since 1915. Previous reports of changes which had occurred in the soils were made by Metzger in 1939, Dodge and Jones in 1946, and Fritschen and Hobbs in 1956.

The cropping systems originally included a sixteen-year rotation consisting of four years of alfalfa, and a corn, corn, wheat sequence for twelve years; a three-year rotation consisting of corn, cowpeas (for hay), and wheat; continuous wheat; continuous corn; and continuous alfalfa. The four latter cropping systems were discontinued in 1956 or earlier, so this paper deals only with plots the sixteen-year rotation.

The treatments in this study included the addition of phosphate fertilizers; phosphate and potassium fertilizer; phosphate, potassium and nitrogen fertilizer; manure plus phosphate fertilizer; and no treatment of check.

Samples were taken in 1915, 1934, 1946, 1956 and 1968 from the surface to a depth of six and two-thirds inches, and in 1968 from 6 2/3 to 10, 10 to 13 1/3, 13 1/3 to 16 2/3, 16 2/3 to 20, and from 20 to 36 inches.

The samples taken in 1968 were oven-dried, ground and analyzed for available phosphorus, total nitrogen, and organic-carbon content. The nitrogen and organic-carbon results were then compared with the results obtained from earlier samplings. There were no previous analyses on phosphorus.

The results of this study show that all phosphorus fertilizer additions gave a significant increase in the available phosphorus content in the surface 0 to 10 inch soil layer. There were also increases through the 16 2/3-inch layer, but these were not statistically significant.

Losses of nitrogen and organic carbon were the most rapid in the earlier years of the study. There were losses of nitrogen and organic-carbon from all fertilizer applications, but the greatest loss was observed in the plots receiving phosphate alone. The complete fertilizer treatment gave the smallest decrease in nitrogen and organic-carbon contents. The losses of nitrogen appear to be approaching an equilibrium for each treatment, but organic carbon losses continued through 1968.