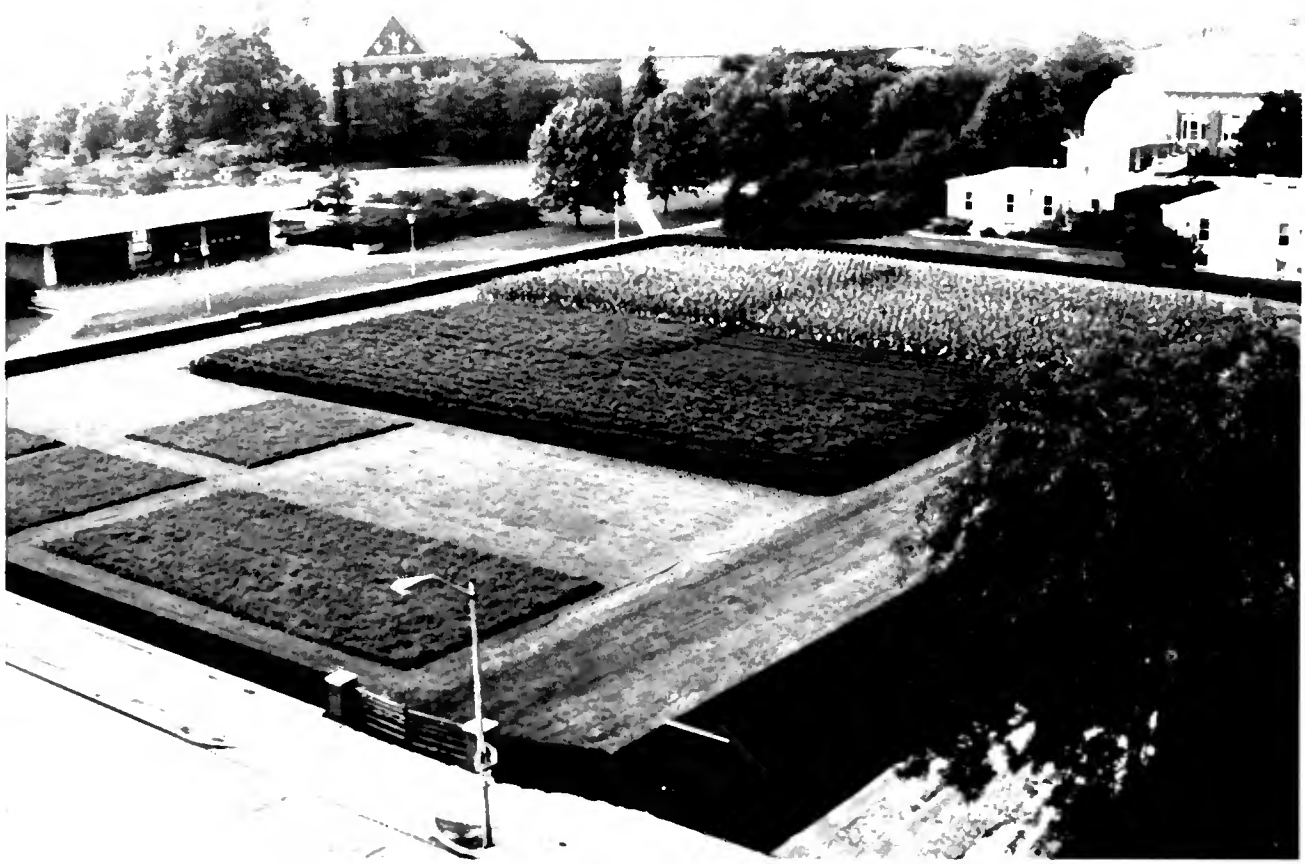
# A Century of Learning



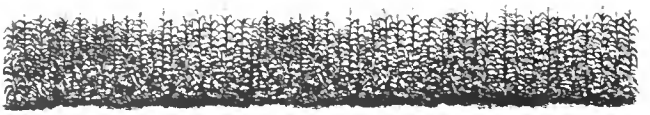
# Preface

The Morrow Plots are the oldest agronomic research plots in the United States and include the oldest continuous corn plot in the world. Their importance was highlighted in 1968 when they were named a National Historic Landmark by the United States Department of the Interior.

For more than 100 years, they have been used to demonstrate the effects of both sound and unsound soil and crop management. During that period agronomists have closely monitored the effects of cropping system and soil treatment upon crop yields and some soil properties.

The average corn yield has ranged from 32 bushels per acre on the continuous-corn plot that received no treatment to approximately 155 bushels on plots that were planted to corn-soybeans or corn-oats-clover and received generous soil treatments. The highest corn yield obtained so far is 215.2 bushels per acre. It was harvested in 1982 on a plot that had been treated with limestone, nitrogen, phosphorus, and potassium since 1954.

Many staff members of the Department of Agronomy have worked with the Morrow Plots. The first was Professor Manley Miles, who laid out the experimental plots in 1876 with assistance from Professor George E. Morrow. We owe much to their foresight and initiative. Since their time these staff members have worked most closely with the Morrow Plots: T.F. Hunt, C.G. Hopkins, J.E. Readhimer, C.C. Chapman, F.C. Bauer, E.E. DeTurk, O.H. Sears, H.J. Snider, A.L. Lang, C.H. Farnham, L.B. Miller, S.W. Melsted, J.W. Pendleton, L.V. Boone, L.F. Welch, M.G. Oldham, and T.R. Peck. We are grateful to these and the many other staff members whose work has made possible this presentation of the major lessons learned from the Morrow Plots since 1876.



# Contents



# Abstract


For more than 100 years, research in soil and crop management has been conducted on the Morrow Plots at the University of Illinois at Urbana-Champaign. This publication describes the effect during that period of cropping system and soil treatment upon crop yield and upon the content of organic matter and nitrogen in the soil.



**Keywords:** Crop rotation, cropping system, crop yield, nitrogen, organic matter, soil fertility, soil treatment



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August, 1982
Slightly revised August, 1984

# Cropping Systems

When the Morrow Plots were established in 1876, they consisted of ten ½-acre plots and were known as Rotation Experiment No. 23. Of those ten plots, only parts of three remain. In 1895 an observatory was built upon the area that had been plots 1 and 2. In 1903 plots 6 through 10 and parts of plots 3, 4, and 5 were taken out of the experiment and seeded to lawn grasses. The remaining three plots (3, 4, and 5) were reduced in size, subdivided, and separated by permanent borders. Since that time no further changes have been made in the overall configuration of the plots, although they have been further subdivided. The present layout of the plots is shown in Figure 1.

Three cropping systems have been followed on the plots that remain. On plot 3 corn (*Zea mays*) has been grown continuously since 1876. Plot 4 grew corn and oats (*Avena sativa*) from 1876 through 1966. From 1904 through 1966, legume catch crops, predominantly sweet clover (*Melilotus alba*) or alfalfa (*Medicago sativa*), were seeded in oats on the southern, fertilized half of plot 4 and plowed down the following spring for corn. In 1967 the crop rotation on plot 4 was changed to corn and soybeans (*Glycine max*) to reflect the current importance of the latter crop in Illinois agriculture. Plot 5 grew corn, oats, and clover in no regular sequence until 1901, when the currently used 3-year rotation of corn, oats, and clover was begun. Red clover (*Trifolium pratense*) was grown from 1901 through 1953, except for a few years when soybeans or cowpeas (*Vigna unguiculata*) was substituted. In 1954 plot 5 was planted to alfalfa, and it has been included in the rotation ever since then. The cropping history of the Morrow Plots is shown in Figure 2.

Until 1955 only crop stubble and root residues were returned to the soil. Beginning in that year, crop residues (including straw and stalks) were returned to the soil on all B subplots except 5SB. In 1967 crop residues were returned to all subplots and have been every year since.

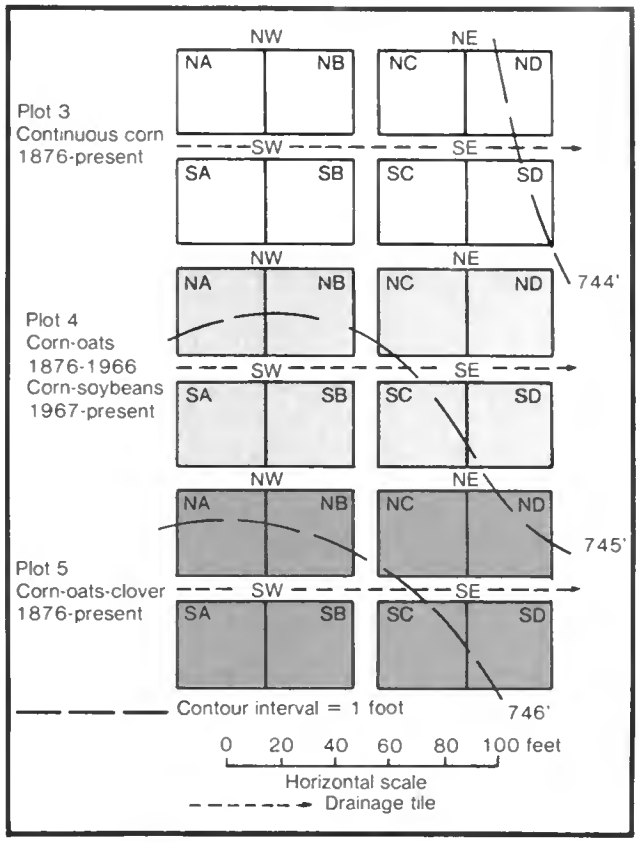
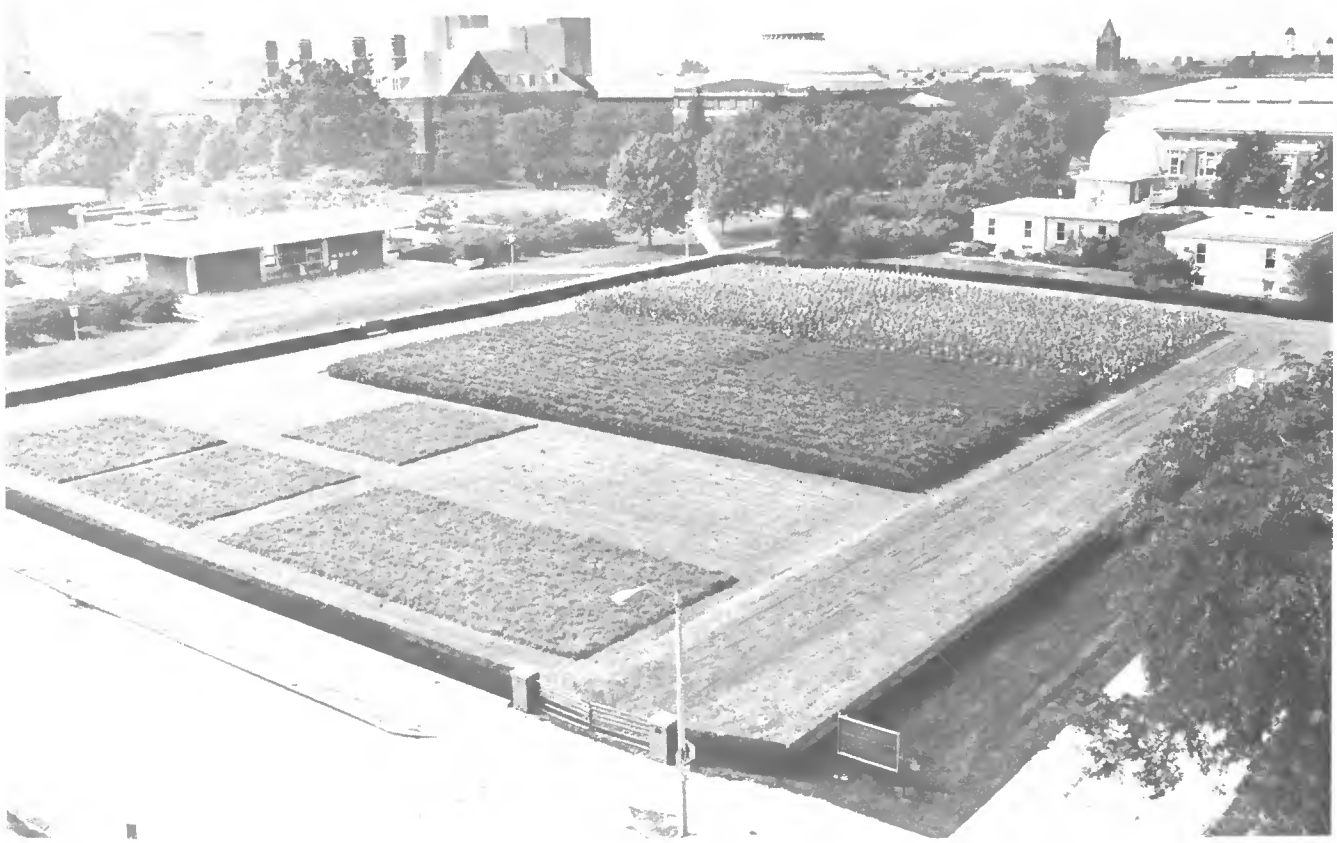


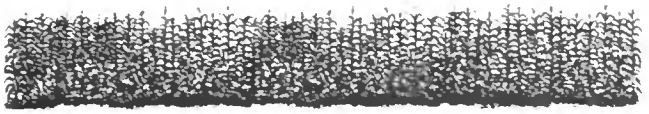

Figure 1. Layout of the Morrow Plots.

| | Plot 3 | Plot 4 | Plot 5 |
|---|---|---|---|
| 1876 | Corn | Corn-oats (no regular sequence) | Corn-oats-clover (no regular sequence) |
| 1879 | | Corn-oats | |
| 1901 | | | Corn-oats-clover |
| 1967 | | Corn-soybeans | |
| Present | | | |

Figure 2. Cropping history of the Morrow Plots.

Crops grown in 1966 (above, with center plot in oats) and in 1978 (below, with center plot in soybeans) on the Morrow Plots.





## Soil Treatments

Until 1904 the cropping pattern was the only variable in the experiment. Before the growing season of that year, plots 3, 4, and 5 were divided, each into four 1/20-acre subplots, and a second variable, fertilizer, was introduced into the experiment.

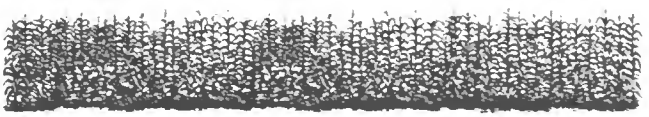
The first soil treatments were applied only to the southern half of each plot. They consisted of limestone (L) at a rate of 0.85 ton per acre, barnyard manure (M) at 2 tons per acre per year (applied prior to the corn crop in each rotation), and two carriers of phosphorus — ground rock phosphate (rP) on the southwest subplot and steamed bonemeal (bP) on the southeast subplot. There is no record of specific amounts of rP or bP being applied after 1919. In 1925 it was decided that additional applications of rP and bP would not be made on these subplots. These first soil treatments and those applied subsequently are described in Figure 3 (page 4). The treatments listed were applied to each of the three plots.

Before the 1955 growing season, nitrogen (N), processed phosphorus (P), and potassium (K) fertilizers were applied for the first time both to the previously untreated areas (NB) and the subplots previously treated with manure, limestone, and unprocessed phosphorus (SB).

Other changes in soil treatment were made before the 1967 season. LNPK was applied regularly and at specific rates on B subplots from 1955 through 1966. Beginning in 1967 the need for additional fertilizer applications was determined by soil tests. Application of a new treatment (high LNPK), begun in 1967 on subplots SA, was also based upon soil tests. This new treatment increases the soil-test levels of phosphorus and potassium and involves larger applications of nitrogen. The table above shows the relationship between soil-test level and the rate of fertilizer application. The results of soil tests for the subplots are discussed on page 16 and listed in Table 6 (page 17).

Beginning in 1957, corn plant populations were adjusted to take full advantage of the fertility levels in the various subplots. Corn plant populations, which range from 8,000 to 24,000 plants per acre for the various soil treatments and cropping systems, are listed with the summary of crop yields in Table 2 (page 7).

| | Soil-test level of $P_1$ | Application of $P_2O_5$ | Soil-test level of K | Application of $K_2O$ |
|---|---|---|---|---|
| | pounds per acre | | | |
| B subplots | less than 40 | 100 | less than 300 | 100 |
| SA subplots | less than 100 | 200 | less than 500 | 200 |



## Soil Properties

The soil on the Morrow Plots is Flanagan silt loam. It is classified as an Aquic Argiudoll in our current soil classification system, which is described in *Soil Taxonomy*. Flanagan silt loam is a nearly level, dark-colored soil that developed in 40 to 60 inches of loess over loam glacial till under prairie vegetation and somewhat poor natural drainage. Before the 1904 season, underground tile lines were installed in the plot borders to provide supplemental drainage (Figure 1). The Morrow Plots slope approximately 0.75 percent to the northeast.

Some physical and chemical properties of two profiles of the Flanagan silt loam on the Morrow Plots are given in Table 1 (page 5). The B horizons contain a maximum of 40 percent clay. The available-moisture-holding capacity is high throughout the profile, and crops rarely suffer serious moisture stress on these soils. Soil depletion is evident in the subplot that is continuously cropped to corn and not fertilized. In that subplot the content of organic carbon and of exchangeable calcium (Ca), magnesium (Mg), and K in the A horizon is significantly lower than that of the subplot fertilized with LNPK since 1955.

The content of organic matter and nitrogen in the surface soils is listed in Table 4 (page 11). The results of soil tests for pH, available P, and available K are listed in Table 6 (page 17). The effects of various treatments on these soil properties over several decades are discussed on pages 10 to 14.

**1876** No soil treatment

**1904**

| NW | NE |
|---|---|
| No soil treatment | No soil treatment |
| **SW** | **SE** |
| MLP<br>M--2 T/A/yr through 1908, an amount equal to the amount of dry matter removed in the crop 1909-1966<br>L--0.85 T/A in 1904, 5 T/A in 1919, 3 T/A in 1943, and 2 T/A in 1949<br>rP--total of 13,200 lb/A applied from 1904 through 1919, none since | bP-- total of 3,300 lb/A applied from 1904 through 1919, none since |

**1955**

| NW | | NE | |
|---|---|---|---|
| **NA** | **NB** | **NC** | **ND** |
| No soil treatment | LNPK<br>L-- 2 ½ T/A in 1955, 3 T/A in 1963<br>N--200 lb/A as urea on corn<br>P (triple superphosphate) 150 lb/A of $P_2O_5$ in 1955, 40 lb/A/yr 1956-1966<br>K (potassium chloride)-- 100 lb/A of $K_2O$ in 1955, 30 lb/A/yr 1956-1966 | No soil treatment | |
| **SW** | | **SE** | |
| **SA** | **SB** | **SC** | **SD** |
| M--continued at an amount equal to the amount of dry matter removed in the crop<br>L--total 1904-1949 10.85 T/A, 2 T/A in 1955<br>rP-- residual 1920-present | L--1 T/A in 1963<br>NPK--same as for NB | bP--residual 1920-present | |

**1967**

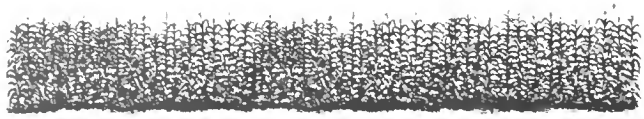
| NW | | NE | |
|---|---|---|---|
| **NA** | **NB** | **NC** | **ND** |
| No soil treatment | N--200 lb/A as urea on corn<br>LPK-- applied to maintain soil-test levels of pH≥6.5, $P_1$≥40, K≥300 | No soil treatment | |
| **SW** | | **SE** | |
| **SA** | **SB** | **SC** | **SD** |
| M--residual 1967-present<br>L--total 1904-1955 12.85 T/A +1 T/A in 1963 on SB<br>rP--residual 1920-present | | M--continued at 2 T/A/yr<br>L--residual 1956-present<br>bP--residual 1920-present | |
| High LNPK<br>N--300 lb/A as urea on corn<br>LPK--applied to maintain soil-test levels of pH≥6.5, $P_1$≥100, K≥500 | LNPK--same as for NB | | |

Figure 3. Soil treatment history of the Morrow Plots.

**Table 1. Physical and Chemical Properties of Two Soil Profiles on the Morrow Plots**

| Horizon | Depth, inches | Sand, percent | Silt, percent | Clay, percent | Bulk density, g/cc | Total porosity, percent | Available-moisture-holding capacity per in. of soil, in. | Organic carbon, percent | pH | Base saturation, percent | Cation exchange capacity, meq/100 g of soil | Exchangeable cations, meq/100 g of soil | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Ca | Mg | K | Na |
| **Subplot 3NC (continuous corn, no treatment)** | | | | | | | | | | | | | | | |
| Ap | 0-9 | 9.0 | 66.8 | 24.2 | 1.45 | 45.3 | 0.25 | 1.32 | 5.1 | 65 | 17.6 | 8.8 | 2.3 | 0.2 | 0.1 |
| A12 | 9-12 | 8.4 | 64.8 | 26.8 | 1.34 | 49.4 | 0.24 | 1.49 | 5.3 | 71 | 18.0 | 9.7 | 2.7 | 0.2 | 0.1 |
| B1 | 12-15 | 5.6 | 58.7 | 35.7 | 1.43 | 46.0 | 0.20 | 1.20 | 6.0 | 83 | 23.1 | 13.4 | 5.5 | 0.1 | 0.1 |
| B21t | 15-22 | 5.2 | 54.8 | 40.0 | 1.50 | 43.4 | 0.25 | 0.62 | 6.2 | 90 | 26.0 | 15.8 | 7.5 | 0.1 | 0.1 |
| B22t | 22-30 | 7.6 | 57.6 | 34.8 | 1.57 | 40.8 | 0.27 | 0.54 | 6.7 | 92 | 22.7 | 13.6 | 7.1 | 0.1 | 0.1 |
| B3 | 30-49 | 12.7 | 60.9 | 26.4 | 1.53 | 42.3 | 0.27 | 0.24 | 7.5 | 100 | 16.8 | 11.2 | 5.8 | 0.1 | 0.1 |
| IIC1 | 49-58 | 26.7 | 57.1 | 16.2 | 1.75 | 34.0 | 0.26 | 0.21 | 8.1 | .. | .. | .. | .. | .. | .. |
| IIC2 | 58-72 | 26.4 | 55.6 | 18.0 | 1.87 | 29.4 | 0.26 | 0.13 | 8.3 | .. | .. | .. | .. | .. | .. |
| **Subplot 5NB (corn-oats-clover, LNPK 1955-present)** | | | | | | | | | | | | | | | |
| Ap | 0-10 | 6.4 | 67.1 | 26.5 | 1.39 | 47.5 | 0.25 | 1.94 | 5.8 | 72 | 21.5 | 10.4 | 4.5 | 0.4 | 0.1 |
| A12 | 10-18 | 3.6 | 65.5 | 30.9 | 1.31 | 50.6 | 0.17 | 1.90 | 5.7 | 74 | 24.1 | 13.1 | 4.3 | 0.3 | 0.2 |
| B1 | 18-23 | 2.8 | 62.9 | 34.3 | 1.40 | 47.2 | 0.18 | 1.24 | 5.7 | 79 | 25.8 | 14.3 | 5.7 | 0.4 | 0.1 |
| B21t | 23-29 | 1.8 | 58.0 | 40.2 | 1.61 | 39.2 | 0.27 | 0.58 | 6.0 | 88 | 28.9 | 16.2 | 8.6 | 0.5 | 0.2 |
| B22t | 29-37 | 2.7 | 63.9 | 33.4 | 1.64 | 38.1 | 0.30 | 0.28 | 6.6 | 93 | 25.7 | 15.2 | 8.3 | 0.5 | 0.1 |
| B3 | 37-45 | 9.4 | 62.9 | 27.7 | 1.69 | 36.2 | 0.30 | 0.22 | 7.2 | 99 | 19.2 | 11.9 | 6.7 | 0.4 | 0.1 |
| IIC1 | 45-69 | 15.3 | 71.1 | 13.6 | 1.57 | 40.8 | 0.31 | .. | 8.1 | .. | .. | .. | .. | .. | .. |
| IIC2 | 69-72 | 48.0 | 43.0 | 9.0 | 1.91 | 27.9 | 0.24 | .. | 8.1 | .. | .. | .. | .. | .. | .. |

Source: C.W. Guernsey et al. 1969. *Jour. Soil and Water Cons.* 24:101.



# Crop Yields

The yields of grain harvested from the Morrow Plots are summarized in Table 2 for the different cropping systems and soil treatments during the period 1888 through 1978. The annual yields of corn, oats, soybeans, and hay are listed in Tables A1 and A2 in the appendix (pages 18 to 21).

There is no record of crop yields from the various plots before 1888, the year in which the Illinois Agricultural Experiment Station was established. The reports do not state why crop yields are not given, but they do state clearly that the cropping systems were maintained as originally planned and that no manure or fertilizers were applied.

For each cropping system and soil treatment, it was determined whether the yields of each grain crop followed a significant straight-line or curvilinear trend during the various periods of uniform management. In the few situations where both the straight-line and curvilinear trend were significant, the most significant trend is reported in Table 2. Where there was no consistent or significant trend, only the mean yields are given because they best document the crop yields obtained. This applies especially to oats and to short experimental periods such as the ones that started in 1967.

Hay yields from plot 5 are not summarized in Table 2 because alfalfa was substituted for red clover beginning in 1954, and the number of hay cuttings per year varied.

As improved varieties of crops were developed, they were used on the Morrow Plots. Cultivation of hybrid corn, for example, was begun in 1937 and has since then contributed to the upward trend in corn yields.

## Corn

From 1904 through 1954, corn yields from the three cropping systems averaged 3.4 bushels per acre more with bP than with rP. However, the southeast (SE) sections of the Morrow Plots, including those on which bP was applied, have always contained more soil organic matter and nitrogen than the southwest (SW) sections on which rP was applied (see Table 4 and the accompanying discussion on page 10). Because the effect of P fertilizer is indistinguishable from that of the soil organic matter and nitrogen, it is impossible to determine the net effects of bP and rP in these experiments. For that reason, crop yields from subplots that received bP were averaged with those that received rP.

Yields of continuous corn were consistently lowest, and corn yields in the corn-oats-clover rotation were consistently highest, whether the soil was fertilized with MLP or not treated (Table 2 and Figure 4).

On untreated plots, corn yields declined between 1888 and the mid-1930s but then increased consistently in all three cropping systems (Figure 4). The decline in corn yields was due primarily to the gradual removal of plant nutrients (see the discussion of soil organic matter and nitrogen on pages 10 to 14) and to unfavorable weather during the 1930s. Severe droughts occurred during 1933, 1934, and 1936.

Since corn was grown only in 1933 on the corn-oats plot and in 1934 on the corn-oats-

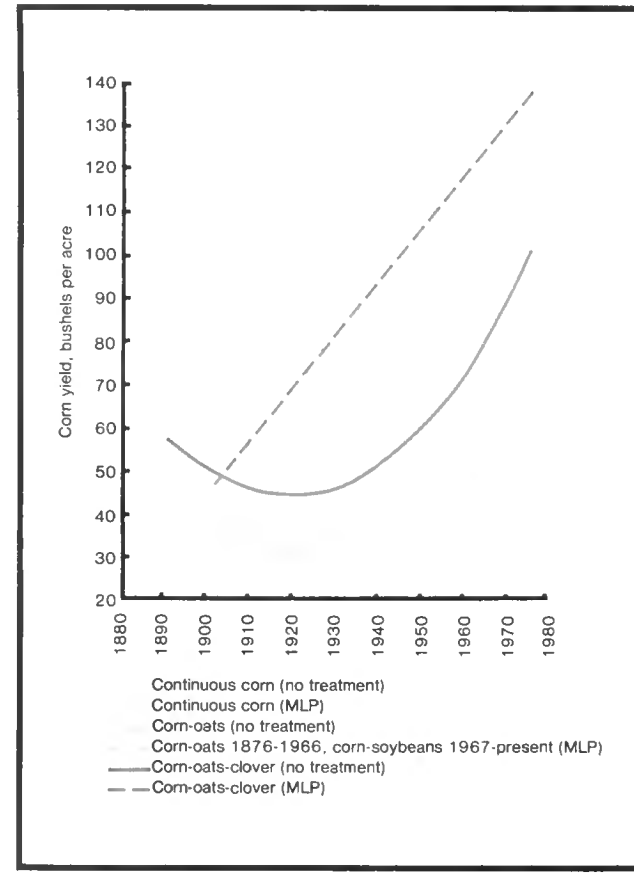



Figure 4. Corn yields on the Morrow Plots with different cropping systems and soil treatments, 1888-1978.

Table 2. Summary of Crop Yields per Acre on the Morrow Plots, 1888-1978

| Cropping system and soil treatment | Corn† | | | | | | | | Oats | | | Soybeans | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Period | No. of observations | Thousand plants per acre | Mean yield, bu/A | $R^2$ | Coefficient of variation, % | Intercept, a | Regression coefficient b | Regression coefficient c | Period | No. of observations | Mean yield, bu/A | Period | No. of observations | Mean yield, bu/A |
| **Plot 3 (continuous corn)** | | | | | | | | | | | | | | | |
| No treatment | 1888-1978 | 91 | 8‡ | 32.3 | 0.474 | 31.3 | 46.4 | −1.186** | 0.014** | | | | | | |
| MLP (avg. of MLbP and MLrP) | 1904-1978 | 75 | 12§ | 60.3 | 0.638 | 24.9 | 26.7 | 0.908** | | | | | | | |
| LNPK 1955-present, previously untreated | 1955-1978 | 24 | 16‖ | 117.8 | 0.252 | 16.4 | 100.0 | 1.547* | | | | | | | |
| MLP 1904-1954 + LNPK 1955-present | 1955-1978 | 24 | 16‖ | 126.6 | | | | | | | | | | | |
| MLP 1904-1966 + high LNPK 1967-present | 1967-1978 | 12 | 24 | 136.0 | | | | | | | | | | | |
| **Plot 4 (corn-oats 1876-1966, corn-soybeans 1967-present)** | | | | | | | | | | | | | | | |
| No treatment | 1888-1966 | 40 | 8‡ | 37.9 | 0.334 | 25.7 | 49.7 | −1.039** | 0.014** | 1888-1966 | 38 | 34.0 | | | |
| MLP (avg. of MLbP and MLrP) | 1904-1978 | 37 | 12§ | 86.6 | 0.652 | 22.5 | 41.7 | 1.214** | | 1904-1966 | 32 | 61.5 | 1967-1978 | 6 | 49.5 |
| LNPK 1955-present, previously untreated | 1955-1978 | 12 | 16‖ | 133.6 | 0.618 | 11.2 | 105.8 | 2.526** | | 1955-1966 | 6 | 59.0 | 1967-1978 | 6 | 47.7 |
| MLP 1904-1954 + LNPK 1955-present | 1955-1978 | 12 | 16‖ | 134.4 | 0.508 | 11.6 | 111.4 | 2.094* | | 1955-1966 | 6 | 70.2 | 1967-1978 | 6 | 48.7 |
| No treatment | 1967-1978 | 6 | 8 | 74.6 | | | | | | | | | 1967-1978 | 6 | 36.6 |
| MLP 1904-1966 + high LNPK 1967-present | 1967-1978 | 6 | 24 | 156.5 | | | | | | | | | 1967-1978 | 6 | 48.7 |
| **Plot 5 (corn-oats-clover)** | | | | | | | | | | | | | | | |
| No treatment | 1888-1978 | 29 | 12 | 59.1 | 0.597 | 23.8 | 62.1 | −1.128* | 0.018** | 1888-1978 | 29 | 44.9 | | | |
| MLP (avg. of MLbP and MLrP) | 1904-1978 | 25 | 12§ | 94.2 | 0.682 | 20.7 | 48.5 | 1.268** | | 1904-1966 | 21 | 69.8 | | | |
| LNPK 1955-present, previously untreated | 1955-1978 | 8 | 16‖ | 139.5 | 0.491 | 11.0 | 119.6 | 1.897* | | 1955-1978 | 8 | 72.3 | | | |
| MLP 1904-1954 + LNPK 1955-present | 1955-1978 | 8 | 16‖ | 139.8 | 0.667 | 8.1 | 118.6 | 2.021* | | 1955-1978 | 8 | 77.2 | | | |
| MLP 1904-1966 + high LNPK 1967-present | 1967-1978 | 4 | 24 | 153.6 | | | | | | | | | | | |

* Significant.
** Highly significant.
† The coefficient of determination ($R^2$), coefficient of variation, intercept (a), and regression coefficients (b and c) are for corn yield on year (see Figures 4 and 5).
‡ The population was 8,000 plants per acre during 1957 and subsequent years, and 12,000 plants per acre during 1956 and the previous years.
§ The population has been 12,000 plants per acre, except on the SC subplots where it was 16,000 plants per acre in 1957 and subsequent years.
‖ Beginning in 1977, the population was increased from 16,000 to 24,000 plants per acre.

clover plot, drought naturally affected the yields of those plots less than it did the yields of the continuous-corn plot (Table A1). Crop yields have increased since the 1930s because of improved technology and especially because of improved corn hybrids.

On plots that were treated with MLP beginning in 1904, corn yields have increased. By 1978 they were approximately three times those of 1904 in each of the three cropping systems (Figure 4).

In response to the new LNPK treatments started in 1955, corn yields have risen in all three cropping systems (Figure 5). Corn yields continued to be highest in the corn-oats-clover rotation and lowest where corn was grown continuously.

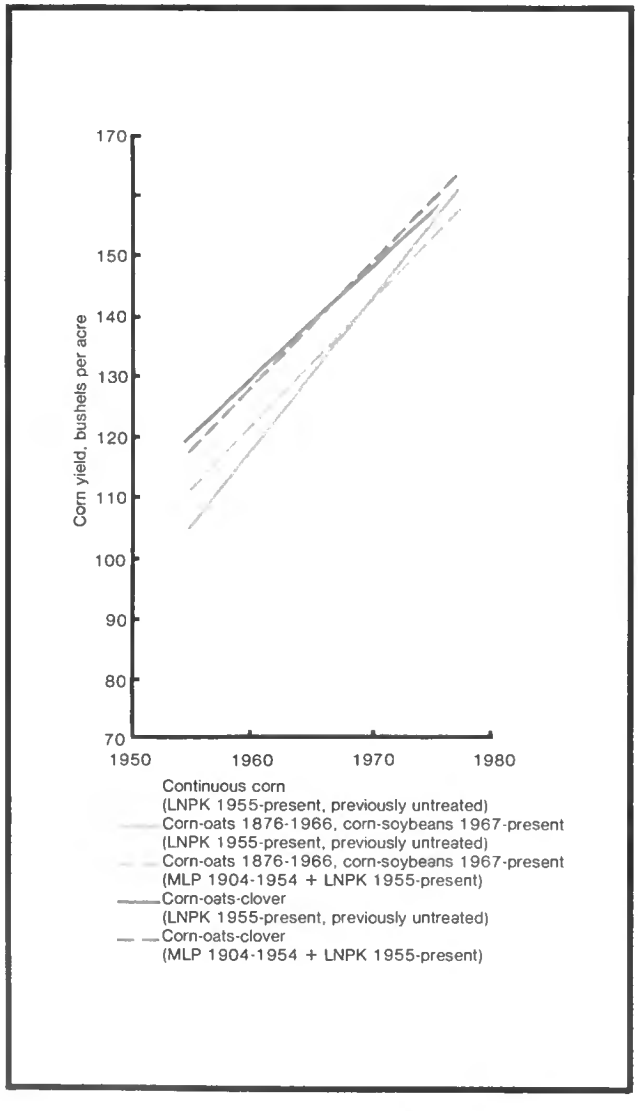


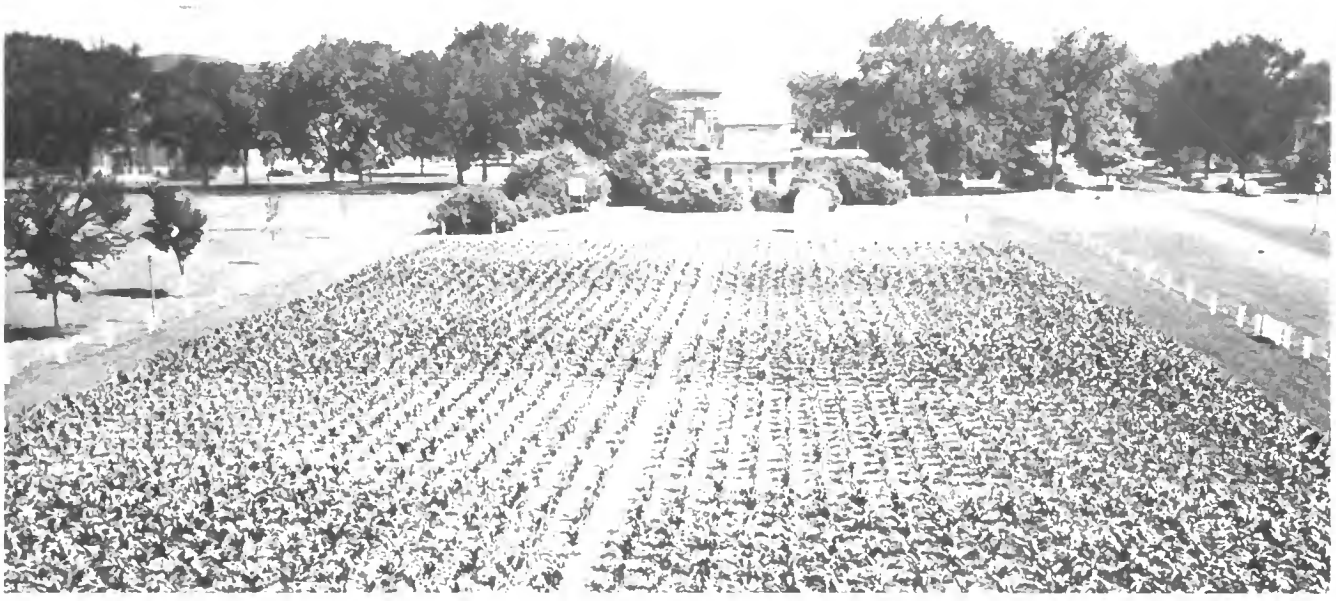

Figure 5. Corn yields on the Morrow Plots with different cropping systems and soil treatments, 1955-1978.

Applications of LNPK on previously untreated soils dramatically increased corn yields, pushing them nearly as high as the yields of subplots that were receiving LNPK treatments but that had previously received MLP. These data demonstrate the recuperative power of the dark-colored Flanagan soils if fertilizers are added to replenish plant nutrients. Corn yields increased significantly after the LNPK soil treatments were begun in 1955 on all B subplots except subplot 3SB (Figures 1 and 3). On that subplot corn was grown continuously, MLP was applied from 1904 to 1954, and LNPK was added after 1954. Subplot 3SB is not included in Figure 5, and only its mean yield per acre is given in Table 2.

Since the LNPK soil treatment was begun in 1955, corn has been grown on all subplots in 1955, 1961, 1967, and 1973. Direct comparison of those years' crops indicates that on the Morrow Plots larger differences in corn yield are caused by the soil treatments than by the cropping systems. The yield of continuous corn without treatment was only 32 percent of that of corn grown in a corn-oats-clover rotation and treated with MLP from 1904 to 1954 and with LNPK beginning in 1955 (Table 3, page 10). Where only the MLP soil treatment was applied, the average corn yields were consistently lower than where LNPK has been applied from 1955 to the present on previously untreated subplots, even though the soil tests for these two groups of subplots produced similar results (Table 6).

The high LNPK treatment, which was started in 1967, increased corn yields over those obtained with previous treatments in all three cropping systems. From 1967 to 1978, corn yields averaged approximately 155 bushels per acre in both the corn-soybeans and corn-oats-clover cropping systems (Table 2). You will notice, however, in Table A2 that the corn yields of the subplots receiving high LNPK were unusually low in 1967, the first year those treatments were applied. Stalk rot in that year was severe, especially on SA subplots that had corn plant populations of 24,000 per acre. Listed below are the percentages of corn plants that were dead on October 11, 1967.

| Soil treatment | Thousand plants per acre | Percentage of plants dead |
|---|---|---|
| No treatment | 8 | 13 |
| MLP | 12 | 72 |
| LNPK 1955-present | 16 | 84 |
| MLP + high LNPK 1967-present | 24 | 98 |



Once every six years corn is grown on all subplots of the Morrow Plots, as shown in the photograph above (1937) and below (1979). In the photograph above the shorter corn is on the untreated subplots, and the taller corn is on subplots treated with MLP beginning in 1904.

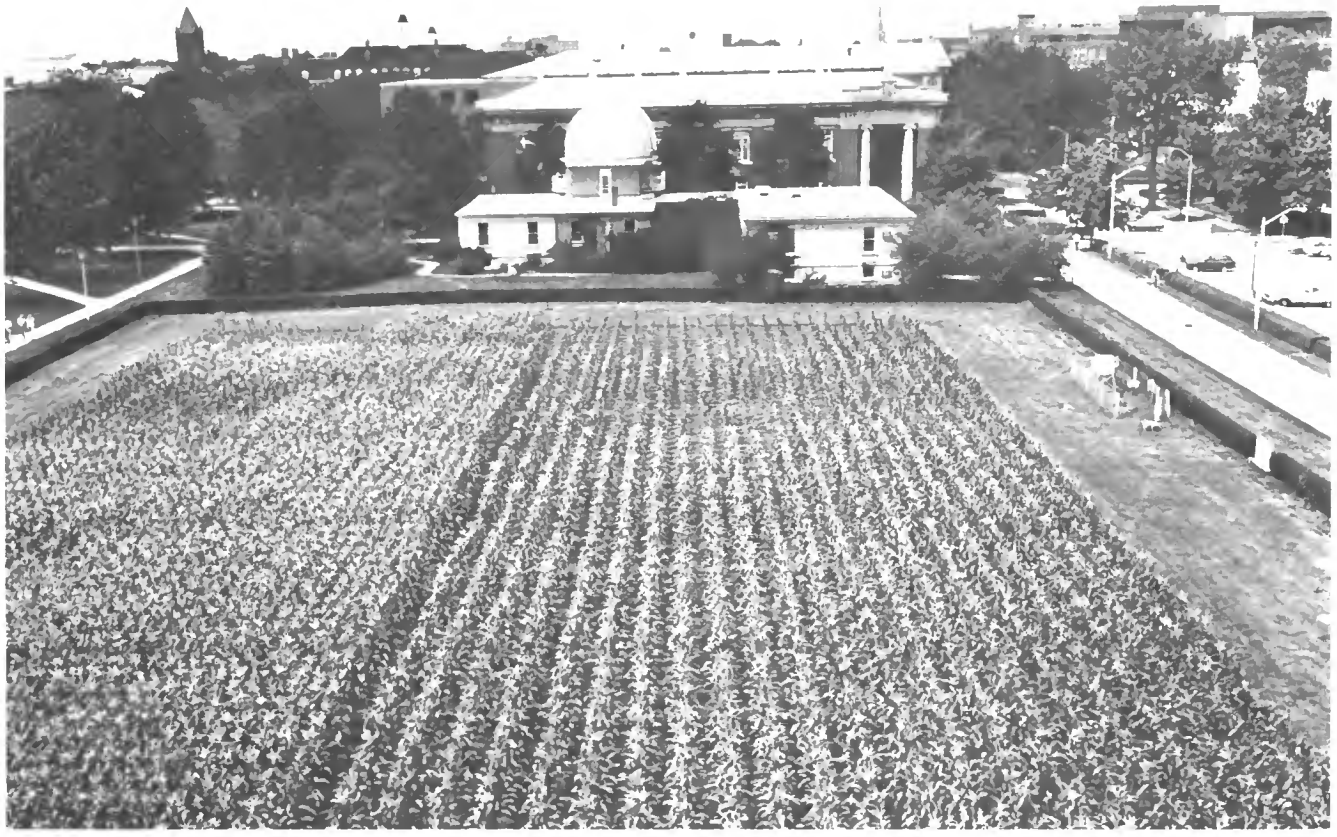


Table 3. **Average Corn Yields per Acre When All Subplots Were Planted to Corn, 1955-1973**

| Soil treatment | Continuous corn | | Corn-oats, 1876-1966 corn-soybeans, 1967-present | | Corn-oals-clover | |
|---|---|---|---|---|---|---|
| | Avg. yield, bu/A | Pct. of 133.6 bu* | Avg. yield, bu/A | Pct. of 133.6 bu* | Avg. yield, bu/A | Pct. of 133.6 bu* |
| No treatment | 42.8 | 32 | 58.2 | 44 | 78.9 | 59 |
| MLP 1904-present | 88.4 | 66 | 118.6 | 89 | 128.2 | 96 |
| LNPK 1955-present, previously untreated | 112.5 | 84 | 126.8 | 95 | 135.4 | 101 |
| MLP 1904-1954 + LNPK 1955-present | 123.7 | 93 | 129.8 | 97 | 133.6 | 100 |

Note: All subplots are planted to corn once every six years.
The yields listed are the averages for 1955, 1961, 1967, and 1973.
* Yield with the best soil treatment in corn-oats-clover rotation.

### Oats

On subplots that did not receive soil treatment, oat yields were 34 bushels per acre in the corn-oats rotation and 45 bushels in the corn-oats-clover cropping system (Table 2). Application of MLP, which was begun in 1904, increased oat yields to 62 bushels in the corn-oats and 70 bushels in corn-oats-clover. Application of LNPK, which was begun in 1955, further increased oat yields on previously untreated plots and on the ones that had received MLP treatments.

### Soybeans

Since the beginning of the corn-soybeans rotation on plot 4 in 1967, soybean yields per acre have averaged 37 bushels on unfertilized areas and 48 to 50 bushels on subplots that have been fertilized (Table 2).

## Changes in the Soil

### Organic Matter

During 1904, 1913, 1923, 1933, 1944, 1953, 1955, 1961, 1967, and 1973, soil samples were collected from the Morrow Plots and analyzed for content of organic carbon and nitrogen. The purpose of the analyses was to follow changes in those constituents under different cropping and soil treatment practices. The results of the organic carbon analyses were multiplied by 1.724 to calculate the organic matter content.

Throughout the period during which organic carbon and nitrogen have been analyzed, the western half (sections A and B, 1955 to the present) of the Morrow Plots has contained less organic matter and nitrogen than the eastern half (sections C and D), even under the same cropping and soil treatment practices. The only exception to that pattern was discovered in 1904 when subplot 3SW (continuous corn, MLrP) was found to contain more organic matter than subplot 3SE (continuous corn, MLbP), as shown in Figure 6 (page 12). The western and eastern halves were probably managed differently before the plots were established in 1876, but no record of their management history before that time is available. This difference between the western and eastern halves should be considered in interpreting the results of experiments on the plots.

In dark-colored soils such as Flanagan silt loam, regular cropping usually reduces organic matter content in the soil unless generous amounts of fertilizer and organic matter are added regularly. Organic matter content declined between 1904 and 1973 on all the subplots that were untreated or received MLrP or MLbP, with the exception of 4SW (4SA, 1955 to the present). The organic matter content of that subplot remained stable during the 70 years for which analyses are available. The organic matter content of the soil was higher in subplots under a corn-oats-clover rotation than in those under the other two cropping systems. It was also higher where MLrP and MLbP were applied to the soil than where no fertilizer was applied.

The results of analyses for organic matter and nitrogen in the surface soils of the Morrow Plots are summarized in Table 4. In cases where those constituents followed a significant straight-line or curvilinear trend during the various study periods, the trends are reported. If there was no

Table 4. Organic Matter and Nitrogen Content of Surface Soils on the Morrow Plots During Selected Years, 1904-1973

| Cropping system and soil treatment | No. of observations | Organic matter | | | | | | Nitrogen | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean,† T/A | $R^2$ | Coefficient of variation, pct. | Intercept, a | Regression coefficient b | Regression coefficient c | Mean,† cwt/A | $R^2$ | Coefficient of variation, pct. | Intercept, a | Regression coefficient b | Regression coefficient c |
| **Plot 3 (continuous corn)** | | | | | | | | | | | | | |
| NW (NA) — no treatment | 10 | 28.0 | 0.947 | 4.4 | 37.3 | −0.390** | 0.003* | 26.7 | 0.963 | 2.8 | 33.3 | −0.254** | 0.002* |
| NE (NC, ND‡) — no treatment | 10 | 31.0 | 0.971 | 3.7 | 41.6 | −0.362** | 0.002 | 28.9 | 0.964 | 3.7 | 38.8 | −0.424** | 0.003** |
| NB — LNPK 1955-present, previously untreated | 4 | 26.3 | 0.919 | 2.1 | 14.6 | 0.195* | | 24.2 | | | | | |
| SE (SC, SD‡) — MLbP | 10 | 38.8 | 0.446 | 7.1 | 42.6 | −0.099* | | 35.4 | 0.854 | 4.3 | 41.0 | −0.146** | |
| SB — MLrP 1904-1954 + LNPK 1955-present | 4 | 32.4 | | | | | | 30.2 | | | | | |
| SW (SA) — MLrP 1904-1966 | 9 | 35.3 | 0.878 | 3.5 | 40.2 | −0.139** | | 32.1 | 0.920 | 2.3 | 35.8 | −0.105** | |
| AVERAGE | | 32.0 | | | | | | 29.6 | | | | | |
| **Plot 4 (corn-oats 1876-1966, corn-soybeans 1967-present)** | | | | | | | | | | | | | |
| NW (NA) — no treatment | 10 | 34.1 | 0.912 | 3.2 | 40.2 | −0.248** | 0.002 | 31.7 | 0.986 | 1.4 | 39.0 | −0.404** | 0.004** |
| NE (NC, ND‡) — no treatment | 10 | 37.8 | 0.893 | 4.1 | 45.1 | −0.248* | 0.001 | 34.5 | 0.964 | 2.8 | 43.5 | −0.391** | 0.003** |
| NB — LNPK 1955-present, previously untreated | 4 | 33.4 | | | | | | 30.2 | | | | | |
| SE (SC, SD‡) — MLbP | 10 | 49.7 | 0.652 | 3.0 | 52.9 | −0.083** | | 44.1 | 0.753 | 1.9 | 46.4 | −0.059** | |
| SB — MLrP 1904-1954 + LNPK 1955-present | 4 | 39.7 | | | | | | 37.2 | | | | | |
| SW (SA) — MLrP 1904-1966 | 9 | 38.9 | | | | | | 36.7 | | | | | |
| AVERAGE | | 38.9 | | | | | | 35.7 | | | | | |
| **Plot 5 (corn-oats-clover)** | | | | | | | | | | | | | |
| NW (NA) — no treatment | 10 | 35.0 | 0.908 | 2.5 | 39.3 | −0.110** | | 33.5 | 0.701 | 3.6 | 36.3 | −0.074** | |
| NE (NC, ND‡) — no treatment | 10 | 48.6 | 0.977 | 1.8 | 58.2 | −0.388** | 0.003** | 43.1 | 0.975 | 1.9 | 52.7 | −0.435** | 0.004** |
| NB — LNPK 1955-present, previously untreated | 4 | 36.6 | 0.999 | 0.1 | 19.3 | 0.288** | | 34.8 | 0.963 | 1.7 | 15.8 | 0.317* | |
| SE (SC, SD‡) — MLbP | 10 | 54.6 | 0.502 | 3.3 | 57.4 | −0.072* | | 49.3 | 0.696 | 2.7 | 52.5 | −0.082** | |
| SB — MLrP 1904-1954 + LNPK 1955-present | 4 | 46.9 | | | | | | 44.0 | | | | | |
| SW (SA) — MLrP 1904-1966 | 9 | 44.6 | | | | | | 41.3 | | | | | |
| AVERAGE | | 44.4 | | | | | | 41.0 | | | | | |

Note: Organic matter and nitrogen were analyzed and studied for 1904, 1913, 1923, 1933, 1944, 1953, 1955, 1961, 1967, and 1973.

* Significant.

** Highly significant.

† The amounts of organic matter and nitrogen per acre were calculated for the top 6⅔ inches of soil. It is assumed that there is 2,000,000 pounds of soil to that depth.

‡ In 1973 data for subplot D were not available.

trend, only the mean is listed. The significant trends are depicted in Figure 7. The figure indicates that the western sections (A) of the Morrow Plots have less organic matter than the eastern (C and D), even under the same cropping system and soil treatment.

Where no soil treatment was applied, the organic matter content first declined rapidly and then continued downward at a slower rate under all three cropping systems, except on subplot 5NW (5NA) where there was a regular decrease (Figure 7). Treatment of the soil with MLbP and MLrP reduced the rate of decline in the organic matter content of the soil. Where LNPK was applied from 1955 to the present on previously untreated subplots (NB), the organic matter content of the soil increased significantly in the continuous corn and corn-oats-clover cropping systems (Figure 7).

We do not know what the organic matter content of the Morrow Plots was when they were established in 1876. In 1944, when the surface soil in the sod border around the Morrow Plots was analyzed, the organic matter content per acre was 65.1 tons in the eastern border and 55.1 tons in the western border. The nitrogen content of the eastern border was 5,587 pounds per acre and that of the western border 4,887 pounds. The western sod border contained approximately 86 percent as much organic matter and nitrogen as

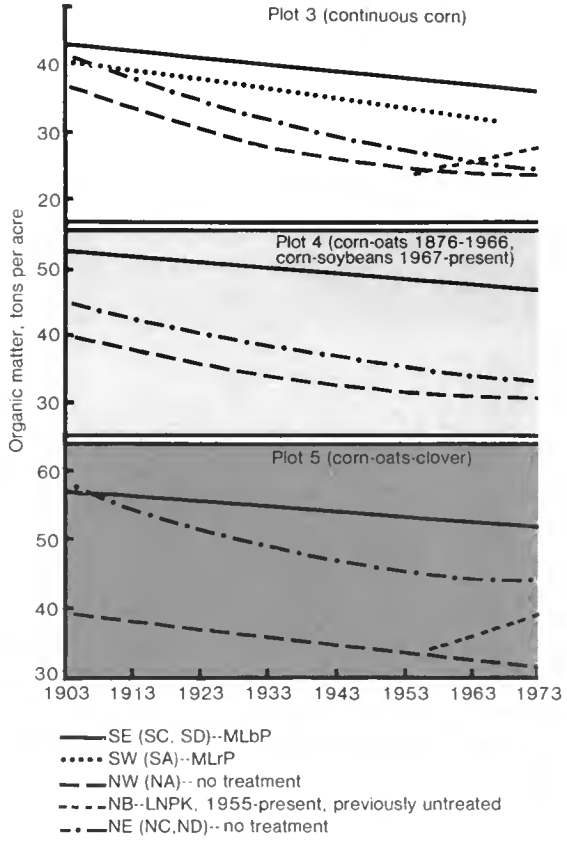



Figure 7. Trends in organic matter content of surface soils on the Morrow Plots, 1904-1973.

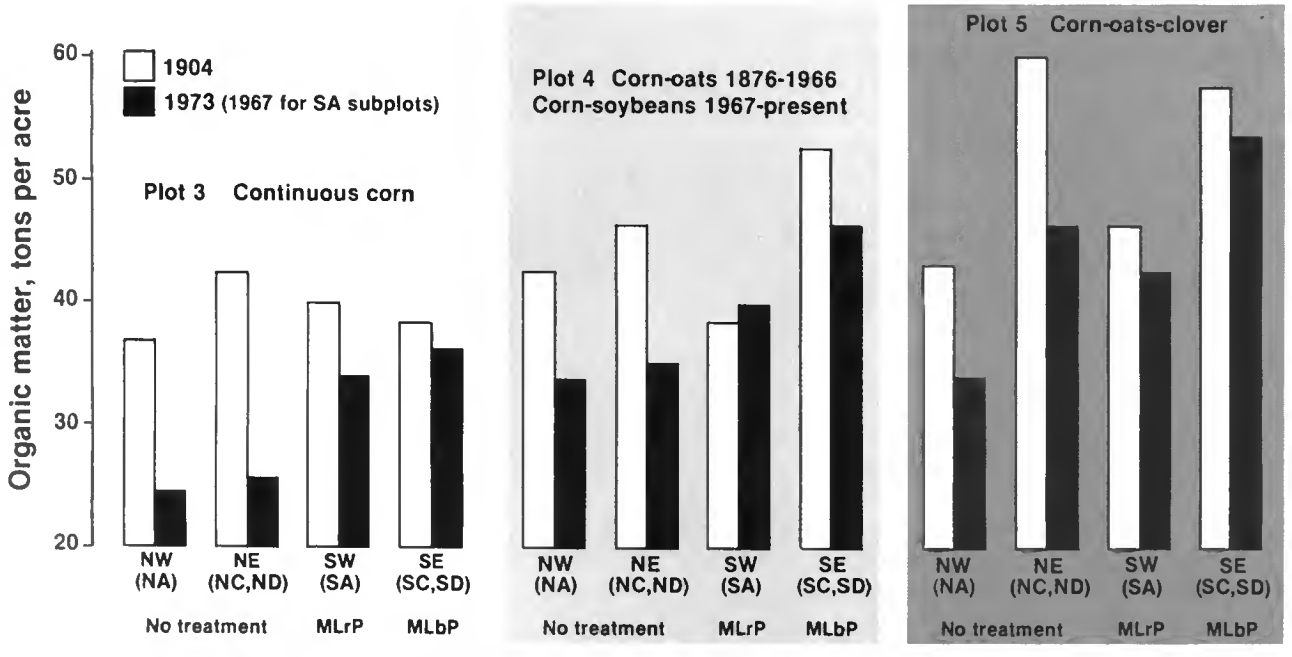



Figure 6. Tons per acre of organic matter in the surface soils of selected subplots of the Morrow Plots in 1904 and 1973. In the SA subplots, data for 1967 instead of 1973 were used because of a change in soil treatment that was made in 1967.

the eastern sod border.

These differences are similar to those found between the western and eastern halves of the plots. The subplots receiving the best soil treatment (5SW and 5SE, corn-oats-clover, MLP) contained slightly more than 80 percent as much organic matter and nitrogen as the eastern sod border. And the subplots receiving no treatment (3NW and NE, continuous corn) contained only about 45 percent as much organic matter and nitrogen in the surface soil, as shown in the list below.

| Crop history and soil treatment | Organic matter | | Nitrogen | |
|---|---|---|---|---|
| | T/A | Percent | lb/A | Percent |
| Eastern sod border no treatment | 65.1 | 100 | 5,587 | 100 |
| Western sod border no treatment | 55.1 | 85 | 4,887 | 87 |
| Corn-oats-clover MLP | 53.7 | 82 | 4,550 | 81 |
| Continuous corn no treatment | 28.7 | 44 | 2,640 | 47 |

If we assume that in 1944 the sod border was comparable to the original prairie sod, it appears that the surface soil contained approximately 55 to 65 tons per acre of organic matter and 4,900 to 5,600 pounds per acre of nitrogen before the Morrow Plots were established in 1876.

## Nitrogen

Since most of the nitrogen in the soil is part of the organic matter, these two constituents are closely associated and follow similar trends. As mentioned previously, the western half (sections A and B, 1955 to the present) of the Morrow Plots has consistently contained less soil nitrogen than the eastern half (sections C and D), even under the same cropping and soil treatment practices (Figure 8). Between 1904 and 1973, soil nitrogen declined on all the subplots that were untreated or received MLrP or MLbP, except subplots 4SW (4SA) and 5SW (5SA). Nitrogen remained stable throughout the 70-year period in subplots 4SW and 5SW. Subplot 4SW was planted in corn-oats and 5SW in corn-oats-clover; both were treated with MLrP.

The nitrogen content was higher under the corn-oats-clover rotation than under the other two cropping systems. Application of MLrP or MLbP helped maintain levels of soil nitrogen because more organic material was returned to the soil in plant residues on the treated plots and because the manure added organic matter and nitrogen.

A summary of the nitrogen content in the surface soils of the Morrow Plots is given in Table 4. Where there were significant trends in soil nitrogen for the various management practices

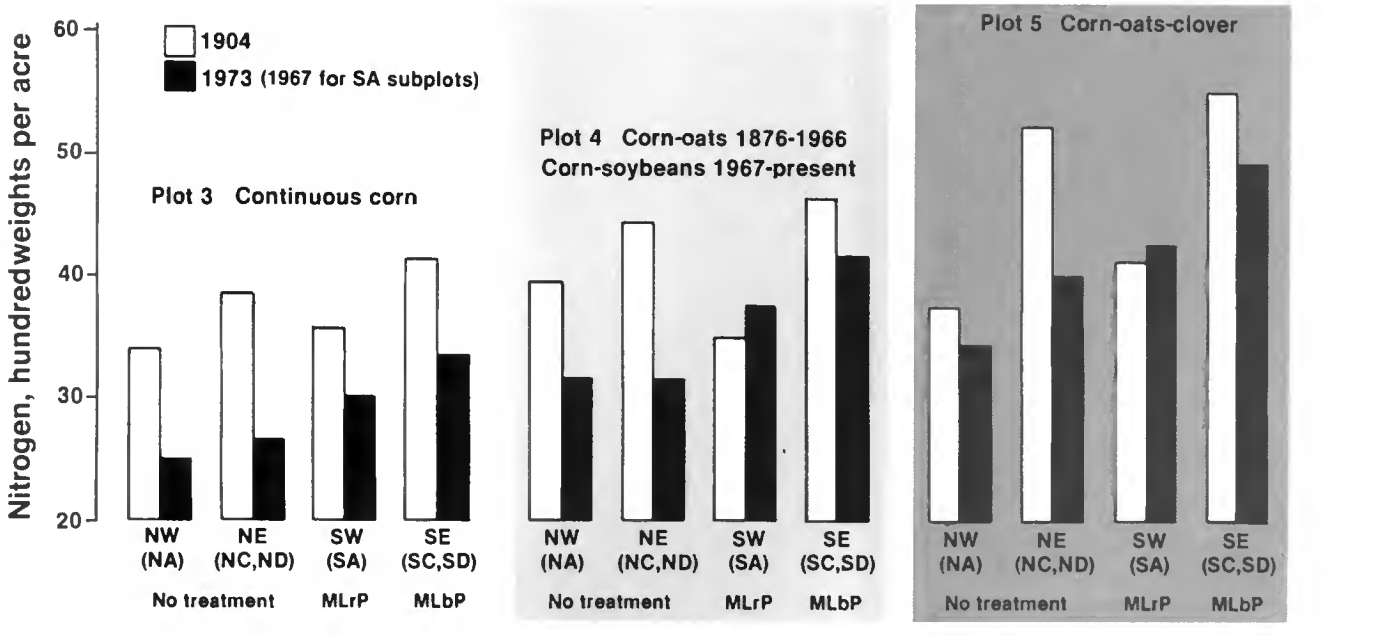



Figure 8. Pounds per acre of nitrogen in the surface soils of selected subplots of the Morrow Plots in 1904 and 1973. In the SA subplots, data for 1967 instead of 1973 were used because of a change in soil treatment that was made in 1967.

and study periods, they are reported; otherwise, only the mean is listed. The significant trends are shown in Figure 9.

Where no soil treatment was applied, soil nitrogen first declined rapidly and then continued downward at a slower rate under all three cropping systems, except on subplot 5NW (5NA) where the decrease was more regular (Figure 9). MLbP and MLrP treatment reduced the rate of decline in soil nitrogen. Where LNPK was applied from 1955 to the present on previously untreated subplots (NB) in corn-oats-clover, the nitrogen content increased significantly (Figure 9).

## Ratios of Carbon to Nitrogen

Carbon:nitrogen ratios remained stable from 1904 to 1973. The average was 12.6 for all subplots. The ratios were also similar for the three cropping systems, although carbon:nitrogen ratios tended to be slightly wider on the eastern half of plot 4 (subplots 4NE and 4SE) and the eastern half of plot 5 (subplots 5NE and 5SE) than on the western halves of the same plots, which contain less organic matter and nitrogen. The average carbon: nitrogen ratio of the surface soil in the sod border around the Morrow Plots was 13.3 in 1944 (Table 5). As is typical in many soils, the average ratio narrows with depth in the Morrow Plots, as shown in the list below.

| Depth, inches | Carbon:nitrogen ratio |
|---|---|
| 0-6 | 12.6 |
| 6-12 | 12.3 |
| 12-18 | 11.7 |
| 18-27 | 9.6 |
| 27-33 | 8.5 |
| 33-40 | 8.3 |

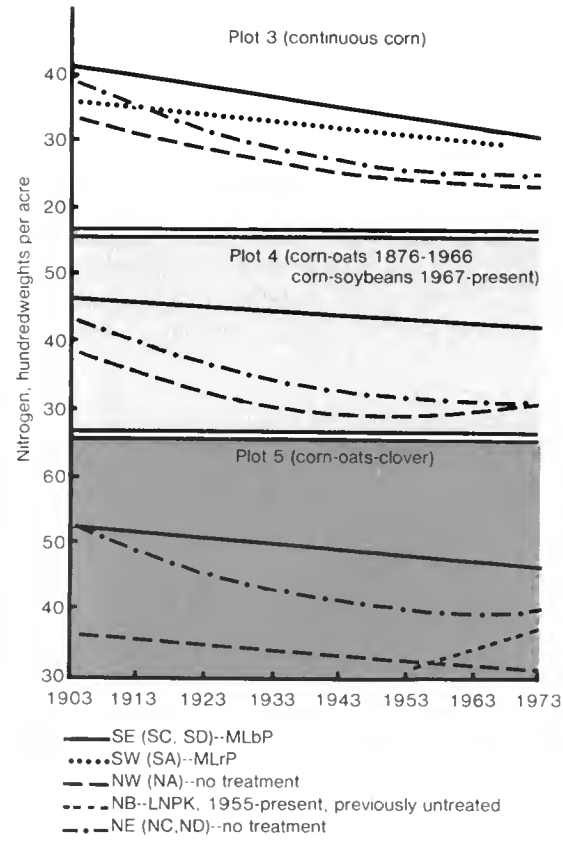



Figure 9. Trends in nitrogen content of surface soils on the Morrow Plots, 1904-1973.

Table 5. Carbon:Nitrogen Ratios in the Surface Soil on the Morrow Plots, 1904-1973

| Cropping system and soil treatment | Carbon:nitrogen ratio | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1904 | 1913 | 1923 | 1933 | 1944 | 1953 | 1955* | 1961 | 1967 | 1973 | Average | Borders in 1944 |
| **Plot 3 (continuous corn)** | | | | | | | | | | | | |
| NW (NA) — no treatment | 12.7 | 12.7 | 13.1 | 12.1 | 12.1 | 11.2 | 11.2 | 12.4 | 12.7 | 11.9 | 12.2 | 13.2 |
| NE (NC, NDt) — no treatment | 12.5 | 12.4 | 12.8 | 13.0 | 13.1 | 12.2 | 12.3 | 11.9 | 12.7 | 11.4 | 12.4 | 13.6 |
| NB — LNPK 1955-present, previously untreated | | | | | | | 11.2 | 13.6 | 13.5 | 12.0 | 12.6 | |
| SE (SC, SDt) — MLbP | 10.4 | 12.7 | 12.8 | 13.3 | 13.9 | 12.9 | 12.5 | 13.3 | 13.4 | 12.2 | 12.7 | 13.7 |
| SB — MLrP 1904-1954 + LNPK 1955-present | | | | | | | 12.4 | 12.6 | 12.8 | 11.9 | 12.4 | |
| SW (SA) — MLrP 1904-1966 | 13.1 | 13.0 | 12.8 | 13.0 | 13.5 | 11.8 | 12.4 | 12.7 | 12.6 | .. | 12.8 | 13.3 |
| **Plot 4 (corn-oats 1876-1966, corn-soybeans 1967-present)** | | | | | | | | | | | | |
| NW (NA) — no treatment | 12.4 | 11.9 | 12.9 | 12.9 | 13.4 | 12.6 | 12.3 | 12.4 | 12.5 | 12.1 | 12.5 | 12.8 |
| NE (NC, NDt) — no treatment | 12.2 | 12.0 | 12.7 | 13.0 | 13.5 | 12.8 | 12.7 | 12.8 | 13.2 | 12.3 | 12.7 | 13.4 |
| NB — LNPK 1955-present, previously untreated | | | | | | | 12.3 | 13.6 | 13.0 | 12.3 | 12.8 | |
| SE (SC, SDt) — MLbP | 13.0 | 12.8 | 13.1 | 13.9 | 14.0 | 12.7 | 12.8 | 12.8 | 12.9 | 12.4 | 13.0 | 13.8 |
| SB — MLrP 1904-1954 + LNPK 1955-present | | | | | | | 12.2 | 12.9 | 12.9 | 11.4 | 12.4 | |
| SW(SA) — MLrP 1904-1966 | 12.4 | 12.0 | 12.4 | 12.7 | 12.8 | 12.4 | 12.2 | 11.9 | 12.1 | .. | 12.3 | 12.9 |
| **Plot 5 (corn-oats-clover)** | | | | | | | | | | | | |
| NW (NA) — no treatment | 12.3 | 12.2 | 12.6 | 12.3 | 12.5 | 12.6 | 12.2 | 12.0 | 11.7 | 11.1 | 12.2 | 12.9 |
| NE (NC, NDt) — no treatment | 13.1 | 12.5 | 12.9 | 13.1 | 13.9 | 13.6 | 13.0 | 12.9 | 13.1 | 13.2 | 13.1 | 13.2 |
| NB — LNPK 1955-present, previously untreated | | | | | | | 12.2 | 12.3 | 12.3 | 11.9 | 12.2 | |
| SE (SC, SDt) — MLbP | 12.5 | 12.7 | 12.1 | 13.8 | 14.0 | 12.5 | 12.9 | 13.3 | 12.9 | 12.4 | 12.9 | 13.5 |
| SB — MLrP 1904-1954 + LNPK 1955-present | | | | | | | 12.7 | 12.5 | 12.5 | 12.2 | 12.5 | |
| SW (SA) — MLrP 1904-1966 | 12.4 | 12.2 | 12.6 | 12.8 | 13.3 | 12.4 | 12.7 | 12.5 | 11.6 | .. | 12.5 | 13.3 |
| AVERAGE FOR ALL PLOTS | 12.4 | 12.4 | 12.7 | 13.0 | 13.3 | 12.5 | 12.3 | 12.7 | 12.7 | 12.0 | 12.6 | 13.3 |

* Soil samples were collected in April of 1955. In the following month, new treatments were applied on subplots 3NB, 4NB, and 5NB and on 3SB, 4SB, and 5SB.
† In 1973 data for subplot D were not available.

## Surface Soil Tests

Samples of surface soil were taken on the Morrow Plots during 1955, 1957, 1961, 1967, 1970, 1974, and 1977, and tests were made for pH, available phosphorus ($P_1$), and available potassium. The results of those tests are currently being used in deciding how much fertilizer to apply on some subplots (Figure 3).

The results of the soil tests are summarized in Table 6. These data were studied for straight-line and curvilinear trends in the same way as crop yields, organic matter, and nitrogen. There were no consistent, significant trends except in pH and available phosphorus on the untreated subplots for all three cropping systems. On these untreated subplots, the pH increased from 5.0 to 5.5 between 1955 and 1977 (Table 6). On those same untreated subplots, the available phosphorus decreased from approximately 17 to 8 pounds per acre. The decline in available phosphorus probably resulted from crop removals. The increases in pH on the untreated subplots may have been due to the addition of basic particles from air or water pollution or from adjacent treated subplots during tillage operations.

The mean soil test values in Table 6 show the fertility of the different subplots. The significance of the different soil test levels is indicated in the list below. The untreated subplots are lowest in fertility. Subplots 3SA, 4SA, and 5SA, where high LNPK was applied from 1967 to the present, have the highest nutrient levels, as planned. The other subplots are intermediate in fertility.

| pH | |
|---|---|
| 5.1-5.5 | Strongly acid |
| 5.6-6.0 | Medium acid |
| 6.1-6.5 | Slightly acid |
| 6.6-7.3 | Neutral |
| 7.4-7.8 | Mildly alkaline |

| $P_1$, pounds per acre | |
|---|---|
| 0-12 | Very low |
| 12-20 | Low |
| 20-30 | Slight |
| 30-45 | Medium |
| 45-65 | High |
| >65 | Very high |

| K, pounds per acre | |
|---|---|
| 0-90 | Very low |
| 90-135 | Low |
| 135-180 | Slight |
| 180-300 | Medium |
| 300-400 | High |
| >400 | Very high |

Table 6. Summary of Surface Soil Tests for the Morrow Plots During Selected Years, 1955-1977

| Cropping system and soil treatment | pH | | | | | | $P_1$ | | | | | | K | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of observations | Mean | $R^2$ | Coefficient of variation, pct. | Intercept, a | Regression coefficient, b | No. of observations | Mean, lb/A | $R^2$ | Coefficient of variation, pct. | Intercept, a | Regression coefficient, b | No. of observations | Mean, lb/A |
| **Plot 3 (continuous corn)** | | | | | | | | | | | | | | |
| NA, NC, ND — no treatment | 7 | 5.2 | 0.947 | 1.3 | 4.8 | 0.030** | 7 | 15 | 0.785 | 12.0 | 19.1 | −0.373** | 7 | 206 |
| NB† — LNPK 1955-present, previously untreated | 6 | 6.0 | | | | | 6 | 40 | | | | | 6 | 246 |
| 5C, 5D — MLbP | 7 | 6.5 | | | | | 7 | 79 | | | | | 7 | 273 |
| 5B† — MLrP 1904-1954 + LNPK 1955-present | 7 | 6.3 | | | | | 6 | 55 | | | | | 6 | 271 |
| 5A‡ — MLrP 1904-1966 | 3 | 6.6 | | | | | 3 | 73 | | | | | 3 | 277 |
| 5A§ — MLrP 1904-1966 + high LNPK 1967-present | 4 | 6.2 | | | | | 4 | 108 | | | | | 4 | 346 |
| **Plot 4 (corn-oats 1876-1966, corn-soybeans 1967-present)** | | | | | | | | | | | | | | |
| NA, NC, ND — no treatment | 7 | 5.3 | 0.788 | 2.7 | 5.0 | 0.030** | 7 | 13 | 0.910 | 9.0 | 17.9 | −0.416** | 7 | 206 |
| NB† — LNPK 1955-present, previously untreated | 6 | 6.1 | | | | | 6 | 50 | | | | | 6 | 251 |
| 5C, 5D — MLbP | 7 | 6.4 | | | | | 7 | 47 | | | | | 7 | 274 |
| 5B† — MLrP 1904-1954 + LNPK 1955-present | 7 | 6.4 | | | | | 6 | 51 | | | | | 6 | 297 |
| 5A‡ — MLrP 1904-1966 | 3 | 6.6 | | | | | 3 | 41 | | | | | 3 | 252 |
| 5A§ — MLrP 1904-1966 + high LNPK 1967-present | 4 | 6.4 | | | | | 4 | 112 | | | | | 4 | 362 |
| **Plot 5 (corn-oats-clover)** | | | | | | | | | | | | | | |
| NA, NC, ND — no treatment | 7 | 5.2 | 0.784 | 2.5 | 4.9 | 0.026** | 7 | 10 | 0.913 | 15.0 | 16.4 | −0.549** | 7 | 214 |
| NB† — LNPK 1955-present, previously untreated | 6 | 6.0 | | | | | 6 | 39 | | | | | 6 | 246 |
| 5C, 5D — MLbP | 7 | 6.5 | | | | | 7 | 45 | | | | | 7 | 234 |
| 5B† — MLrP 1904-1954 + LNPK 1955-present | 7 | 6.6 | | | | | 6 | 90 | | | | | 6 | 280 |
| 5A‡ — MLrP 1904-1966 | 3 | 6.8 | | | | | 3 | 35 | | | | | 3 | 236 |
| 5A§ — MLrP 1904-1966 + high LNPK 1967-present | 4 | 6.7 | | | | | 4 | 96 | | | | | 4 | 321 |

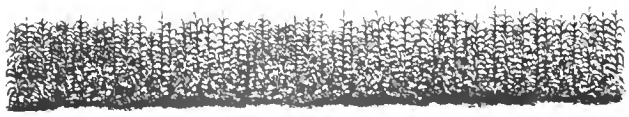
Note: Soil tests were studied for 1955, 1957, 1961, 1967, 1970, 1974, and 1977.

** Highly significant.

† Soil samples were collected in April of 1955. In the following month, new treatments were applied on subplots 3NB, 4NB, and 5NB and 3SB, 4SB, and 5SB. For that reason, the results of 1955 soil tests for subplots 3NB, 4NB, and 5NB and the 1955 $P_1$ and K tests for subplots 3SB, 4SB, and 5SB were not included in the analysis.

‡ The averages are for the soil tests made in 1955, 1957, and 1961.

§ The averages are for the soil tests made in 1967, 1970, 1974, and 1977.



# Appendix

The tables in this appendix show the annual crop yields on the Morrow Plots from 1888 through 1983.

**Table A1. Annual Crop Yields per Acre on the Morrow Plots, 1888-1954**

| | Plot 3 — continuous corn | | | Plot 4 — corn-oats | | | Plot 5 — corn-oats-clover (hay) | | |
|---|---|---|---|---|---|---|---|---|---|
| | No treatment | MLrP | MLbP | No treatment | MLrP | MLbP | No treatment | MLrP | MLbP |
| | *bushels* | | | *bushels* | | | *bushels (c, o) or tons (h)* | | |
| 1888 | 54.3 | | | c 49.5 | | | o 48.6 | | |
| 1889 | 43.2 | | | o 37.4 | | | h 4.04 | | |
| 1890 | 48.7 | | | c 54.3 | | | h 1.51 | | |
| 1891 | 28.6 | | | c 33.2 | | | h 1.46 | | |
| 1892 | 33.1 | | | o 37.2 | | | c 70.2 | | |
| 1893 | 21.7 | | | c 29.6 | | | c 34.1 | | |
| 1894 | 34.8 | | | o 57.2 | | | o 65.1 | | |
| 1895 | 42.2 | | | c 41.6 | | | o 22.2 | | |
| 1896 | 62.3 | | | o 34.5 | | | h .. | | |
| 1897 | 40.1 | | | c 47.0 | | | h .. | | |
| 1898 | 18.1 | | | o .. | | | ? .. | | |
| 1899 | 50.1 | | | c 44.4 | | | c 53.5 | | |
| 1900 | 48.0 | | | o 41.5 | | | o .. | | |
| 1901 | 23.7 | | | c 33.7 | | | c 34.3 | | |
| 1902 | 60.2 | | | o 56.3 | | | o 54.6 | | |
| 1903 | 26.0 | | | c 35.9 | | | h 1.11 | | |
| 1904 | 21.5 | 17.1 | 17.1 | o 17.5 | 22.5 | 28.1 | c 55.3 | 72.7 | 72.7 |
| 1905 | 24.8 | 26.8 | 36.0 | c 50.0 | 40.0 | 49.8 | o 42.3 | 45.0 | 56.2 |
| 1906 | 27.1 | 32.5 | 39.1 | o 34.7 | 44.3 | 60.6 | h 1.42 | 1.88 | 1.60 |
| 1907 | 29.0 | 40.8 | 56.5 | c 47.8 | 81.4 | 93.8 | c 80.5 | 91.4 | 95.8 |
| 1908 | 13.4 | 24.8 | 31.1 | o 32.9 | 46.9 | 43.1 | o 40.0 | 43.8 | 45.0 |
| 1909 | 26.6 | 30.4 | 32.8 | c 33.0 | 60.4 | 69.2 | h 0.65 | 1.72 | 1.75 |
| 1910 | 35.9 | 48.9 | 60.3 | o 33.8 | 51.9 | 66.9 | c 58.6 | 78.3 | 88.3 |
| 1911 | 21.9 | 29.0 | 34.0 | c 28.6 | 44.4 | 48.2 | o 20.6 | 37.8 | 38.2 |
| 1912 | 43.2 | 64.4 | 64.0 | o 55.0 | 81.2 | 80.9 | h 0.86* | 1.20* | 0.97* |
| 1913 | 19.4 | 32.4 | 31.6 | c 29.2 | 22.0 | 28.0 | c 33.8 | 45.2 | 50.4 |
| 1914 | 31.6 | 37.2 | 41.6 | o 33.6 | 56.9 | 59.6 | o 39.6 | 58.9 | 62.0 |
| 1915 | 40.0 | 62.8 | 69.2 | c 49.0 | 80.8 | 81.6 | h 1.12* | 1.18* | 1.12* |
| 1916 | 11.2 | 9.6 | 12.0 | o 37.5 | 62.5 | 66.9 | c 27.8 | 37.6 | 43.6 |
| 1917 | 40.0 | 60.4 | 73.6 | c 48.4 | 77.6 | 85.2 | o 68.4 | 82.5 | 91.2 |
| 1918 | 13.6 | 29.6 | 35.6 | o 27.2 | 53.1 | 65.6 | h 2.58 | 4.05 | 4.04 |
| 1919 | 24.0 | 41.2 | 45.6 | c 30.8 | 65.6 | 66.8 | c 52.2 | 69.2 | 72.4 |
| 1920 | 28.2 | 52.0 | 56.8 | o 37.1 | 48.1 | 55.0 | o 52.2 | 73.8 | 65.6 |
| 1921 | 19.8 | 38.4 | 46.0 | c 30.6 | 68.0 | 68.8 | h 0.26 | 1.47 | 1.18 |
| 1922 | 24.6 | 38.5 | 39.2 | o 39.4 | 56.3 | 55.0 | c 49.1 | 67.3 | 73.2 |
| 1923 | 15.0 | 32.0 | 30.8 | c 17.2 | 50.4 | 42.4 | o 53.4 | 67.5 | 65.6 |
| 1924 | 28.0 | 40.4 | 35.6 | o 36.0 | 68.1 | 68.8 | h 1.82 | 4.29 | 4.54 |
| 1925 | 19.1 | 41.7 | 49.1 | c 26.7 | 39.4 | 39.6 | c 42.0 | 57.4 | 59.9 |
| 1926 | 21.4 | 33.2 | 37.6 | o 22.9 | 76.3 | 76.3 | o 44.3 | 83.1 | 86.9 |
| 1927 | 25.8 | 41.6 | 40.4 | c 29.4 | 74.4 | 77.2 | h 0.81 | 3.63 | 3.70 |
| 1928 | 18.8 | 32.8 | 32.0 | o 34.4 | 73.1 | 70.6 | c 44.2 | 74.4 | 70.4 |
| 1929 | 17.6 | 32.4 | 39.6 | c 23.6 | 67.2 | 63.2 | o 55.6 | 75.8 | 74.8 |

* Soybean hay.

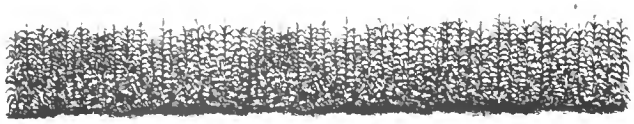
**Table A1. Continued**

| | Plot 3 — continuous corn | | | Plot 4 — corn-oats | | | Plot 5 — corn-oats-clover (hay) | | |
|---|---|---|---|---|---|---|---|---|---|
| | No treatment | MLrP | MLbP | No treatment | MLrP | MLbP | No treatment | MLrP | MLbP |
| | *bushels* | | | *bushels* | | | *bushels (c, o) or tons (h)* | | |
| 1930 | 17.1 | 32.6 | 29.6 | o 34.7 | 59.2 | 68.2 | h 0.82 | 1.83 | 2.35 |
| 1931 | 24.8 | 49.1 | 49.3 | c 33.5 | 59.3 | 56.4 | c 45.4 | 57.8 | 60.5 |
| 1932 | 32.9 | 52.5 | 55.6 | o 46.3 | 75.5 | 76.9 | o 53.3 | 83.8 | 80.3 |
| 1933 | 7.9 | 29.3 | 26.4 | c 8.3 | 30.2 | 24.7 | h 1.61* | 2.41* | 2.18* |
| 1934 | 16.7 | 51.6 | 50.4 | o 5.6 | 27.5 | 14.0 | c 13.0 | 45.0 | 45.5 |
| 1935 | 44.6 | 61.0 | 64.8 | c 52.0 | 54.3 | 53.9 | o 65.9 | 80.6 | 85.9 |
| 1936 | 14.0 | 15.7 | 17.5 | o 39.9 | 63.5 | 64.6 | h 1.43 | 2.60 | 2.29 |
| 1937 | 43.1 | 56.9 | 64.7 | c 44.0 | 71.5 | 81.3 | c 67.4 | 81.0 | 93.2 |
| 1938 | 36.3 | 59.7 | 64.9 | o 45.8 | 67.9 | 69.1 | o 52.3 | 66.4 | 72.6 |
| 1939 | 22.0 | 45.9 | 54.8 | c 31.0 | 82.4 | 87.0 | h 0.88 | 1.98 | 2.20 |
| 1940 | 18.8 | 40.9 | 46.4 | o 47.0 | 83.1 | 85.0 | c 47.0 | 58.3 | 67.5 |
| 1941 | 24.9 | 61.1 | 65.1 | c 32.0 | 71.2 | 69.6 | o 64.8 | 70.8 | 78.8 |
| 1942 | 26.5 | 58.4 | 63.2 | o 33.6 | 56.0 | 52.7 | h 1.13 | 3.51 | 3.20 |
| 1943 | 16.4 | 55.9 | 63.9 | c 26.2 | 83.2 | 84.6 | c 52.9 | 100.9 | 100.0 |
| 1944 | 18.8 | 59.7 | 64.7 | o 29.7 | 50.6 | 57.6 | o 53.2 | 71.9 | 72.8 |
| 1945 | 30.4 | 74.8 | 66.7 | c 45.8 | 108.8 | 106.7 | h 1.24 | 3.47 | 3.73 |
| 1946 | 23.1 | 81.6 | 87.7 | o 32.1 | 77.0 | 83.1 | c 75.8 | 119.3 | 123.3 |
| 1947 | 12.6 | 35.9 | 39.9 | c 22.8 | 75.8 | 75.9 | o 40.8 | 59.4 | 67.4 |
| 1948 | 27.1 | 71.3 | 78.1 | o 36.8 | 85.6 | 88.4 | h 0.71 | 4.91 | 4.18 |
| 1949 | 20.0 | 57.2 | 70.4 | c 32.1 | 104.3 | 110.6 | c 72.7 | 104.2 | 103.6 |
| 1950 | 19.1 | 47.8 | 53.7 | o 26.3 | 44.0 | 48.4 | o 36.8 | 47.7 | 50.6 |
| 1951 | 12.6 | 61.2 | 69.4 | c 31.9 | 120.0 | 119.8 | h 0.40 | 2.86 | 2.56 |
| 1952 | 18.7 | 47.9 | 57.1 | o 19.9 | 49.6 | 51.6 | c 61.5 | 106.7 | 111.2 |
| 1953 | 16.8 | 51.0 | 55.4 | c 39.1 | 92.8 | 94.5 | o 34.1 | 49.6 | 54.1 |
| 1954 | 32.9 | 69.6 | 74.4 | o 15.9 | 43.5 | 42.9 | h 0.42 | 5.83 | 5.69 |

Table A2. Annual Crop Yields per Acre on the Morrow Plots, 1955-Present

| | Plot 3 — continuous corn | | | | | Plot 4 — corn-oats through 1966, corn-soybeans 1967-present | | | | | Plot 5 — corn-oats-clover (hay) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No treatment | LNPK 1955-present, previously untreated | MLP* | MLP + LNPK 1955-present | MLP + high LNPK 1967-present | No treatment | LNPK 1955-present, previously untreated | MLP* | MLP + LNPK 1955-present | MLP + high LNPK 1967-present | No treatment | LNPK 1955-present, previously untreated | MLP* | MLP + LNPK 1955-present | MLP + high LNPK 1967-present |
| | *bushels* | | | | | *bushels* | | | | | *bushels (c, o) or tons (h)* | | | | |
| 1955 | 35.9 | 85.9 | 78.8 | 98.0 | | c 43.5 | 96.5 | 98.4 | 107.2 | | c 63.1 | 102.4 | 99.5 | 101.2 | |
| 1956 | 29.4 | 113.0 | 96.2 | 128.1 | | o 38.7 | 64.3 | 85.8 | 83.8 | | o 55.0 | 82.3 | 74.9 | 70.6 | |
| 1957 | 42.4 | 105.7 | 81.3 | 121.1 | | c 48.7 | 125.0 | 122.2 | 126.2 | | h 0.40 | ...† | 4.30 | 4.33 | |
| 1958 | 32.5 | 129.9 | 74.3 | 138.9 | | o 42.8 | 94.5 | 95.5 | 100.6 | | c 63.1 | 146.4 | 132.6 | 143.6 | |
| 1959 | 25.8 | 55.9 | 77.8 | 95.0 | | c 44.9 | 90.9 | 87.9 | 86.3 | | o 26.4 | 80.0 | 91.7 | 73.1 | |
| 1960 | 49.7 | 96.4 | 79.7 | 119.1 | | o 25.8 | 38.2 | 36.6 | 40.6 | | h 1.08 | ...† | 4.00 | 3.78 | |
| 1961 | 46.2 | 104.0 | 75.1 | 117.2 | | c 49.7 | 114.4 | 113.8 | 124.0 | | c 72.7 | 126.4 | 121.8 | 132.7 | |
| 1962 | 41.4 | 123.8 | 78.4 | 131.5 | | o 23.0 | 58.1 | 64.3 | 76.2 | | o 49.7 | 78.4 | 78.6 | 91.1 | |
| 1963 | 50.2 | 124.3 | 89.4 | 119.2 | | c 52.3 | 137.3 | 123.0 | 134.6 | | h 0‡ | ...† | 5.17 | 5.14 | |
| 1964 | 46.8 | 109.5 | 78.7 | 126.1 | | o 17.0 | 42.5 | 51.1 | 58.5 | | c 71.2 | 143.9 | 129.8 | 140.0 | |
| 1965 | 50.6 | 139.7 | 113.7 | 163.2 | | c 65.7 | 156.9 | 149.4 | 162.4 | | o 38.6 | 78.3 | 98.1 | 99.0 | |
| 1966 | 55.1 | 116.4 | 106.2 | 130.8 | | o 26.9 | 56.2 | 72.0 | 61.7 | | h 0‡ | 4.27 | 4.98 | 5.40 | |
| 1967 | 44.9 | 131.5 | 121.4 | 137.3 | 102.5§ | c 65.7 | 141.1 | 143.7 | 138.0 | 111.8§ | c 80.4 | 148.7 | 150.0 | 144.4 | 119.9§ |
| 1968 | 37.3 | 102.2 | 75.0 | 106.8 | 120.0 | s 37.0 | 49.3 | 50.1 | 51.2 | 49.8 | o 32.3 | 66.4 | 78.9 | 84.0 | 57.9 |
| 1969 | 59.3 | 139.8 | 113.7 | 139.0 | 136.2 | c 70.9 | 140.8 | 130.6 | 147.5 | 145.1 | h 0‡ | 0 | 0 | 0 | 0 |
| 1970 | 37.9 | 132.2 | 75.4 | 129.7 | 127.5 | s 43.0 | 47.4 | 60.9 | 57.2 | 57.1 | c 83.2 | 127.0 | 129.8 | 139.3 | 136.6 |
| 1971 | 52.4 | 131.3 | 100.1 | 127.2 | 146.0 | c 77.9 | 134.0 | 120.2 | 138.2 | 168.9 | o 31.6 | 75.7 | 63.0 | 70.8 | 57.4 |
| 1972 | 57.9 | 135.9 | 101.9 | 144.1 | 159.9 | s 43.2 | 53.9 | 53.3 | 52.7 | 53.1 | h 0‡ | 3.80 | 3.80 | 3.50 | 3.48 |
| 1973 | 44.0 | 128.7 | 78.1 | 142.2 | 148.6 | c 73.8 | 155.0 | 118.4 | 149.9 | 179.5 | c 99.3 | 164.1 | 141.4 | 155.9 | 177.8 |
| 1974 | 39.4 | 100.4 | 72.6 | 98.5 | 105.2 | s 30.9 | 45.2 | 42.8 | 42.3 | 44.5 | o 40.0 | 79.4 | 79.4 | 92.3 | 77.1 |
| 1975 | 48.8 | 135.5 | 76.3 | 146.8 | 161.3 | c 88.6 | 165.1 | 128.6 | 153.3 | 191.4 | h 0‡ | 3.10 | 3.04 | 3.08 | 2.98 |
| 1976 | 49.6 | 105.6 | 82.8 | 102.9 | 135.5 | s 32.0 | 39.7 | 41.7 | 36.8 | 36.2 | c 110.0 | 157.1 | 151.1 | 161.7 | 180.1 |
| 1977 | 51.1 | 117.4 | 87.7 | 108.9 | 113.0 | c 70.4 | 145.8 | 115.6 | 145.7 | 142.3 | o 21.8 | 38.0 | 29.4 | 36.7 | 27.5 |
| 1978 | 58.3 | 162.3 | 98.4 | 167.8 | 176.8 | s 33.7 | 50.6 | 48.0 | 51.8 | 51.3 | h 0‡ | 2.03 | 1.81 | 2.55 | 2.93 |
| 1979 | 35.2 | 112.5 | 63.0 | 124.1 | 115.9 | c 56.9 | 139.3 | 90.2 | 151.8 | 151.4 | c 85.5 | 170.6 | 110.2 | 169.8 | 169.6 |
| 1980‖ | 46.3 | 59.3 | 56.8 | 74.7 | 31.1 | s 31.6 | 47.0 | 44.9 | 49.3 | 45.2 | o 62.2 | 92.2 | 92.9 | 109.9 | 116.6 |
| 1981 | 47.0 | 149.2 | 82.5 | 165.4 | 172.3 | c 49.9 | 166.1 | 112.4 | 169.2 | 184.1 | h .. | .. | .. | .. | .. |
| 1982 | 28.4 | 149.3 | 41.9 | 200.1 | 191.7 | s 37.4 | 49.3 | 47.0 | 57.0 | 52.0 | c 97.9 | 215.2 | 132.9 | 204.6 | 199.8 |
| 1983 | 54.1 | 98.3 | 97.1 | 110.0 | 70.3 | c 79.0 | 122.6 | 107.9 | 128.0 | 99.9 | o 47.8 | 105.8 | 75.5 | 126.6 | 120.3 |

* Average of rock phosphate and bone phosphate.
† None seeded.
‡ Alfalfa seeding was not established because of soil acidity.
§ Stalk rot was severe in 1967, especially on SA subplots that had 24,000 plants per acre and had been treated with MLP + high LNPK since 1967.
‖ Severe drought reduced corn yields in 1980.



# Other Research on the Morrow Plots

This bulletin is concerned primarily with crop yields and the content of organic matter and nitrogen in the soil of the Morrow Plots. Much other research has been done on the Morrow Plots. Selected publications reporting the results of that research are listed below.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**Guernsey, C.W.** 1966. Corn root distribution in soils of the Morrow Plots. M.S. thesis, University of Illinois.

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