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Losses of Fertilizers and Pesticides from Claypan Soils

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LOSSES OF FERTILIZERS AND PESTICIDES FROM CLAYPAN SOILS

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ABSTRACT

Nitrates, ammonia, phosphates and pesticides have been determined in the runoff and sediment under field conditions from a claypan, cornbelt soil. The North Central Watershed Research Unit, U.S.D.A. Agricultural Research Service operates an extensive facility on the Midwest Claypan Experiment Station near Kingdom City, Missouri, where runoff and erosion are measured from instrumented field plots. The study was modified in 1970 to include wider variation in fertilizer rates, cropping systems, tillage methods and ground cover as variables. Samples for laboratory analyses were provided from 33 plots, by individual storms during the 1971, 1972 and 1973 seasons. The soil is a claypan and is representative of more than 4 million hectares [10 million acres] in the mid-continent area. In addition there are more than 16 million hectares [40 million acres] of glacial soils with low subsoil permeability, where the results would be applicable. Corn and soybeans are the principal row crops.

Chemical fertilizer additions were varied from amounts that were inadequate for satisfactory crop yields, to quantities in excess of crop requirements. In the three growing seasons precipitation varied, with heavy runoff and soil loss, to conditions of moisture shortages and where limited supplemental irrigation was applied to summer crops to reduce drouth damage. The results provide information under different seasonal conditions on losses of fertilizers and pesticides that may occur under different practical methods of production of crops. The data obtained show the methods that can be employed to obtain optimum crop yields, with the use of nitrogen and phosphorus fertilizers. The results point to methods that can minimize erosion and losses of nutrients in runoff.

This report was submitted in fulfillment of project number R-801-666. The study was a cooperative effort between the U.S. Department of Agriculture, Agricultural Research Service, North Central Watershed Research Unit, and the University of Missouri. Partial financial support of the Environmental Protection Agency was provided to the Agricultural Experiment Station, Missouri College of Agriculture. The work supported by the Environmental Protection Agency was initiated June 1, 1971 and completed as of December 31, 1973.

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ACKNOWLEDGEMENTS

This project was a joint effort of the Agronomy Department, Missouri College of Agriculture, the U.S.D.A., Agricultural Research Service, North Central Regional Research Unit and the U.S. Environmental Protection Agency. Many individuals were interested in this practical study and made contributions.

Special acknowledgment is due Dr. Robert W. Blanchar, who served as consultant and supervised technicians, (Mary Monzyk, Tom Morton and Ronald Hess) who made determinations for ammonia, nitrate and phosphate compounds. Field work and collection of sediment and runoff samples were the responsibilities of H. A. Krueger and J. L. McCowan. Their long experience provided accurate data, that when combined with laboratory measurements made possible the calculations reported.

Dr. James O. Pierce of the Missouri Trace Substance Laboratory served as consultant for pesticide analyses. Special thanks are given to Dr. Corazon R. Hastings, Dr. Walter Aue and Mr. Tom Cleavenger, who provided the laboratory data on pesticides in runoff.

The cooperation of Mr. Arthur Burks, project officer, and Dr. George Bailey both of the Southeast Environmental Research Laboratory, Athens, Georgia in conducting this project is greatly appreciated.

SECTION I

CONCLUSIONS

The rate of nitrogen applications to corn in this study varied from less, to more than has been regularly used in mid-continent crop production. The smallest addition was insufficient to produce satisfactory yields of corn. In three seasons 163 kilograms of N per hectare [145 lb/a] produced optimum yields of corn. Where minimum tillage was practiced yields were slightly increased by higher rates of nitrogen application. There was a slight reduction in yield from high rates of nitrogen with conventional tillage. Losses of nitrogen in runoff were only slightly higher where the application rates were sufficient for satisfactory crop production, than where yields were limited by a nitrogen deficiency.

Total rainfall, storm intensity, and crop development were important factors in losses of N and P in runoff and in sediment. In the low rainfall seasons of 1971, 1972 and 1973 losses from experimental field areas were small. Precipitation in the growing seasons of these three years was below average. In the "start-up" year of 1970, when rainfall was near the 100 year frequency, and in experiments conducted in the past under higher rainfall conditions, erosion and runoff were considerably higher. It is probable that average losses during most 10 year periods would be greater than during the three years (1971-1973) this study was conducted. The application of ammonium nitrate at rates which produced the highest corn yields, with conventional tillage, produced nitrogen losses in runoff water of 7-8 percent of the applied nitrogen.

Where the amount of chemical nitrogen applied to corn was approximately that removed in the crop, losses in runoff were little higher than where most of the nitrogen was derived from decomposition of crop residues or from the mineralization of soil organic matter. Addition of chemical nitrogen in excess of plant need or absorption resulted in an increase of nutrients in runoff.

Soil treatments that promoted early and vigorous crop growth, and provided soil cover, resulted in less loss of nitrogen and phosphorus from some storms than where little treatment was applied.

The colloidal fraction of claypan soils has a high "fixing capacity" for phosphates. Where phosphate was incorporated in the soil the total loss of phosphorus was associated with the amount of erosion. Where the phosphate was surface applied on no-till type of planting, phosphorus losses were higher, although soil loss was negligible.

A cover crop (rye) was effective in reducing both runoff and sediment loss. Where rye in the heading stage was killed by a herbicide and left standing there was an increase in phosphorus in the runoff water from some rains. This could be the result of leaching from the dead tissue. Where soil moisture is near field capacity the phosphorus is apparently carried from the field rather than being adsorbed on the soil complex.

Losses of nitrate and ammonia in runoff water was much greater from surface applications to a wet soil than where treatments had been plowed down earlier. The methods and time of fertilizer application can effect absorption by crops and the amount of nutrients that may be lost in runoff.

Concentration of a number of pesticides, applied at recommended rates, in runoff water was low. There was little natural runoff in any of the three seasons, in the 2-4 weeks following application. A major portion of the pesticide compounds in runoff water can be attributed to the addition of supplemental irrigation.

Application of sound soil and crop management practices can reduce losses of farm chemicals in runoff. Good soil cover (both residues and the growing canopy) can reduce erosion. Only where soil was bare was there substantial erosion. These results indicate farm chemicals can be applied to claypan soils without significant increase in nutrient losses to surface waters.

The results from this three-year field study indicate that losses of N and P and a number of pesticides when applied at recommended rates, the loss to surface water supplies was not great. Losses were lower than has been found where chemical fertilizers have been added to small areas and where simulated rainfall has been added to rapidly saturate a soil and produce runoff in a short period(1).

SECTION II

RECOMMENDATIONS

Measurements of nutrient losses were made in three seasons when the rainfall in the period following planting, and during the summer growing season was low and below the long-time average. Studies of this type should be conducted over a longer period to include seasons when rainfall is above average. From past experience, on this same facility where runoff and erosion were measured, it can be expected that the results obtained and reported in this study are below those that would be found over a longer period.

This study was conducted on a claypan soil. Effort should be made by qualified scientists to extrapolate this data to other soils of the mid-continent area where similar runoff and ersoion data are available. Similar type studies are needed on other major soil groups where liberal fertilizer applications are made to row crops.

Prices of foods are increasing. Agricultural exports are wanted to assist with U.S. balance of payments. Currently there is demand for increased grain production. Fertilizer addition is an essential crop production practice. The supply is inadequate to satisfy demand. Substantial quantities of natural gas are required for the synthesis of nitrogen fertilizers. Efficient use of fertilizer is required to produce the needed crops and conserve petroleum supplies.

Research and education programs are needed that will:

(a) Cause the amount of fertilizer applied to crops to be the kind and amounts that will produce optimum yields.

(b) Insure that methods of fertilizer application be followed that will result in efficient utilization by crops, with a minimum amount lost in runoff and in sediment.

(c) Adopt soil and crop management practices that will provide soil cover to minimize erosion and prevent the runoff of limited precipitation.

(d) Reduce or prohibit the use of chemical fertilizers on non-food producing lands.

SECTION III

INTRODUCTION

CHEMICAL FERTILIZERS IN CROP PRODUCTION

The use of chemical fertilizers for grain and forage production has increased during the same period there has been awareness of degradation of quality of the nation's water supplies. There has been speculation that high nitrate content in many rural water supplies is caused by the addition of nitrgoen fertilizers to agricultural land. Losses of both phosphates and nitrogen compounds from farm fields are frequently considered the major source of nutrients responsible for eutrophication in many lakes and slow-moving, clear streams. Some popular writers have made little distinction between plant nutrients and pesticides when discussing runoff and water pollution from agriculture.

Chemical fertilizers are considered now to increase yields of crops in the United States more than one third (2). The World Food and Agriculture Organization has reported that one ton of fertilizer will make available up to 8 tons of food production (3). It is not possible to secure absolute figures and it is difficult to generalize, however, the United States figure is accepted by agronomists for the grain and meat producing region of the midwest. An estimated increase in yields of 30% from chemical fertilizers is probably too low on the more highly leached soils in the humid sections of the county and possibly too high in the drier areas where there is little runoff and nitrogen is usually the only added element that will give consistent increased crop growth. This added agricultural production is a major factor in providing an ample food supply for the United States. Export of agricultural products is an important contributor to maintenance of balance of payments.

Anhydrous ammonia, or some derivative, is the principal chemical nitrogen material applied to farm crops in the United States. During the past 25 years nitrogen fertilizer used in the United States has increased from about a million tons annually to more than 8 million tons in 1972 (4). Currently about 80% of the anhydrous ammonia produced in this country is utilized for direct application to farm crops or conversion to other chemical fertilizers.

Natural gas has supplied the hydrogen required in the synthesis of anhydrous ammonia. About 11,300 hl^3 [40,000 ft^3] of gas is required to produce one ton of NH_3 (about one kg of gas per kg of ammonia). Most ammonia plants have been owned or controlled by natural gas producers. The ammonia plants have provided an outlet for gas in the summer months. Petroleum producers were interested in nitrogen production when a greater economic return could be obtained from the conversion of natural gas to ammonia than could be realized from other uses. During the past decade the application of these nitrogen materials has become standard practice on most U.S. farms in humid areas, and coupled with favorable seasons has greatly stimulated crop production. Plant capacity for production of fertilizers in the decade preceding the 1973 season was in excess of demand. Retail prices were depressed. For some years chemical fertilizers were the lowest cost input in crop production. Many good farm managers have made liberal applications. Although on a national basis crop removal of nutrients has been in excess of additions, there are areas where the rate of treatment has been in excess of crop needs--which could lead to excesses reaching surface or ground water.

Fertilizer use changed with the 1973 crop season. Foreign purchases of grain in 1972 removed surpluses. Prices of all grains greatly increased. Domestic price ceilings and devaluation of the U.S. dollar stimulated export demand for nitrogen and phosphate fertilizer from U.S. producers. A combination of these factors made the demand for fertilizers greater than production capacity. All government acreage controls were removed in 1973 and full production was encouraged to meet food demands. Price ceilings on fertilizer were removed. Costs of fertilizers to farmers have advanced, but demand is greater than supply. During the period July through December 1973 fertilizer tonnage reports from Missouri (5) indicated the amount shipped was more than one-third higher than during the same period in 1972.

Currently the low carry-over of grains and the energy shortage have diverted emphasis from losses of nitrogen and phosphorus from crop land, to need for all-out production of food. Since the nitrogen industry is geared to the use of natural gas as the supply of hydrogen, major effort (6) is being made to secure allocations of gas for ammonia synthesis. Crop forecasts predict lowered food production unless adequate chemical fertilizers are produced.

Public attitudes toward the role of farm fertilizers has changed since this study was initiated in 1971. Environmental concern for nutrients lost from land has been largely replaced by concern for soil fertility methods that will provide adequate food for domestic use and for export.

The source and amount of nutrients in water originating from farmland has received much attention since environmental quality has been of major public concern. A recent review by the Smithsonian Information Exchange (7) lists more than 140 current research studies relating to "Nitrates in Soils." Opinions and conclusions on the importance and extent of this problem vary, because of lack of specific information. Some ecologists (8) have expressed opinions that chemical fertilizers are a threat to the environment. A committee on nitrate accumulation of the National Academy of Sciences has recently reviewed the role of nitrate and related nitrogen compounds in the environment (9). Recent hearings (10) in Illinois concluded that there was some evidence that the nitrate content of drainage water from heavily fertilized cornfields had increased, but there was no cause for regulation of fertilizer use at this time. The following references provide a review of research concerning the reactions of nitrogen compounds and phosphates applied to land as soil amendments (11, 12, 13, 14).

HERBICIDES AND INSECTICIDES

Organic pesticides, largely herbicides and insecticides, are widely used in the production of field crops. Herbicides are extensively used in crop production on claypan soils. These compounds have been particularly useful on poorly drained soils in controlling unwanted vegetation when mechanical weed control is not possible. These materials have made possible the use of minimum or no-till row crop production. This type of soil management gives greater protection from beating rains and a reduction of sediment loss through erosion. The use of insecticides has made possible the use of monocultures (continuous corn and soybeans in the mid-continent area) which has increased food production.

Pesticides in common use vary in rate of degradation. The fate of these materials in different soils has received much research attention. The following references discuss the possible environmental contamination of pesticides and provide reviews of current information (15, 16, 17).

OBJECTIVES

1. Determine under practical field conditions the amount of nitrogen and phosphorus transported in runoff water and sediment from claypan agricultural land where optimum to excessive rates of inorganic fertilizers are applied. Treatment with inadequate fertilizer application are included.

2. Determine the quantity of herbicides and other pesticides carried in runoff from land producing corn and soybeans, and where recommended amounts of chemicals are applied.

3. Determine the effect of reduced tillage, no-till planting, and chemical weed control on runoff and erosion and the comparative losses of nitrogen, phosphorus and chemicals from a claypan agricultural soil.

LOCATION

This study was conducted on a claypan (Mexico silt loam) soil near Kingdom City (McCredie) in Central Missouri. The soil is derived from loess, but the high colloidal content of the claypan retards water movement and the subsoil is poorly drained. The slope will average about three percent, and may have lengths of more than 450 meters [1500 ft]. The soil was originally covered with tall grass prairie vegetation. Erosion losses have removed much of the topsoil (18). The Mexico silt loam is generally considered more productive than other claypans with less slope, and not as well drained. The Mexico silt loam is usually darker in color and not as highly leached as the more level types. This soil is closely related to more than 4 million hectares [10 million acres] in Missouri, Eastern Kansas, and Oklahoma, Southern Iowa, Illinois and Indiana and Ohio (Figure 1). The results from this investigation can also be applied to an additional 16 million hectares [40 million acres] of glacial soils of the midwest, with slowly permeable subsoils.

There is probably no group of soils in the United States that has changed as much in crop output and value as have these claypans since chemical fertilizers and herbicides have become a standard management practice in the mid-continent area. Formerly the major crops on these soils were small grains and hay. Slow internal drainage and warming in the spring limited mineralization of organic nitrogen. When the soil was wet in the spring added phosphorus was rapidly fixed by soluble iron, manganese and aluminum. Legume growth,

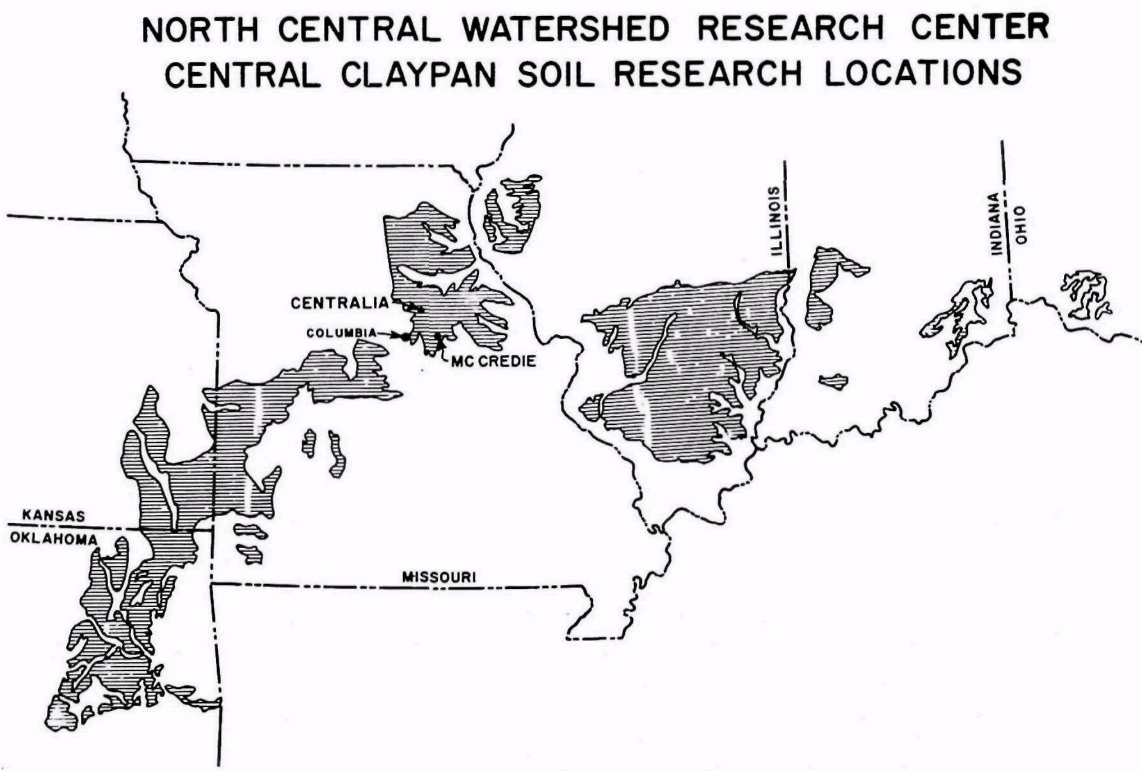

Figure 1. Extent of claypan soils in the mid-continent area and location of the McCredie Experimental Field. There are more than 4 million hectares (10 million acres) of this type of soil.

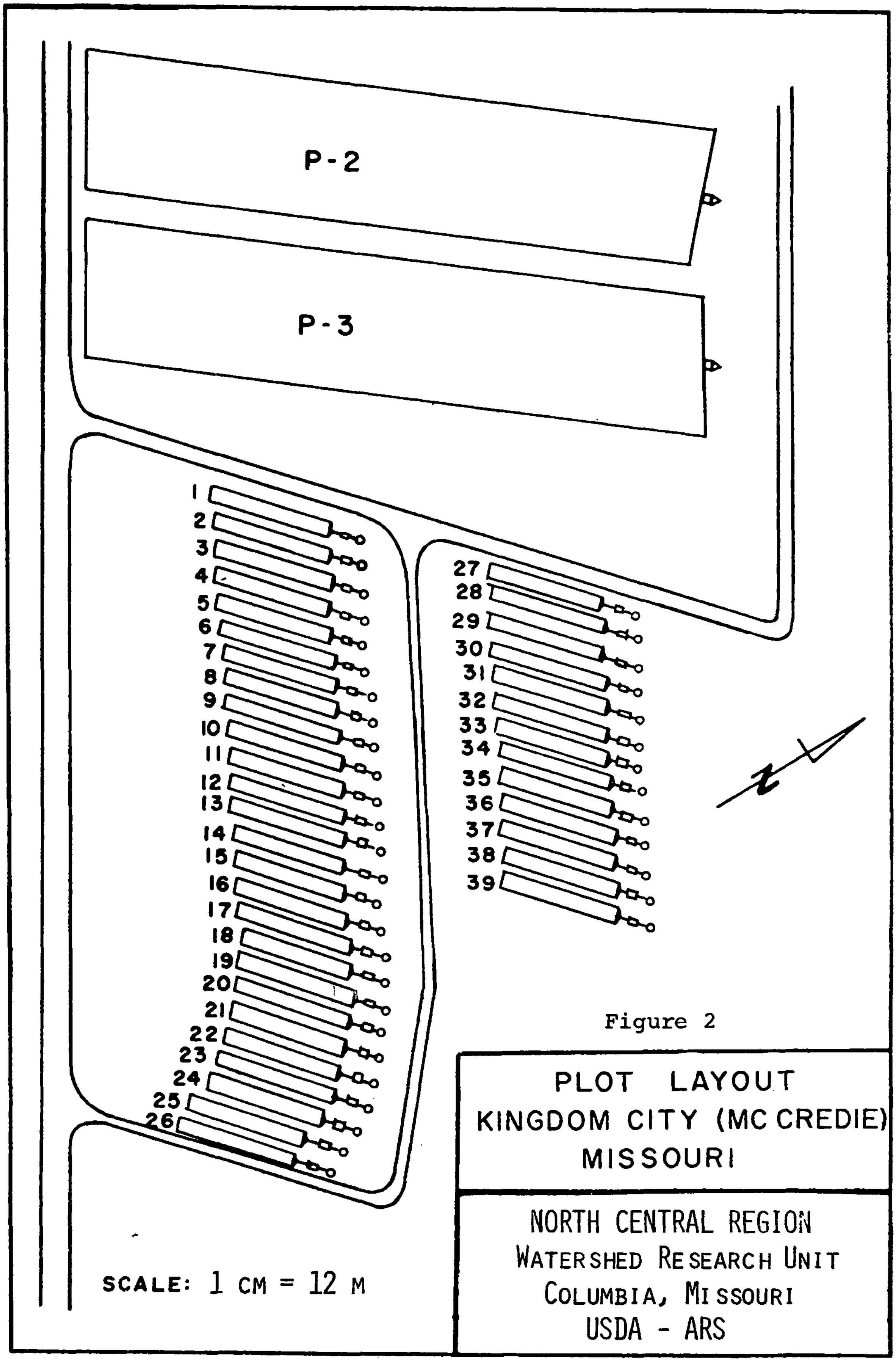
P-2
P-3
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
27 28 29 30 31 32 33 34 35 36 37 38 39
SCALE: 1 CM = 12 M
PLOT LAYOUT
KINGDOM CITY (MC CREDIE)
MISSOURI
NORTH CENTRAL REGION
WATERSHED RESEARCH UNIT
COLUMBIA, MISSOURI
USDA - ARS

Figure 2

including soybeans, was limited by need for lime and phosphorus. Availability of chemical nitrogen fertilizers has stimulated crop growth in cool wet seasons. Herbicides have reduced the hazards of weed competition when early cultivation is not possible. Adoption of complete soil fertility and crop management practices have made this soil group a major food production area, with corn and soybeans major crops. Livestock production has been stimulated as a result of abundant feed supplies. Claypan soils have a lower moisture holding capacity than many of the dark glacial prairie soils or the open loessal soils of the cornbelt. Adequate nutrient levels have made limited supplies of moisture more effective (19) and in seasons with good rainfall distribution the soils are now well above average for productivity in the United States. Because of shortages of precipitation in summer months, supplemental irrigation is developing on the better managed farms with this type of soil.

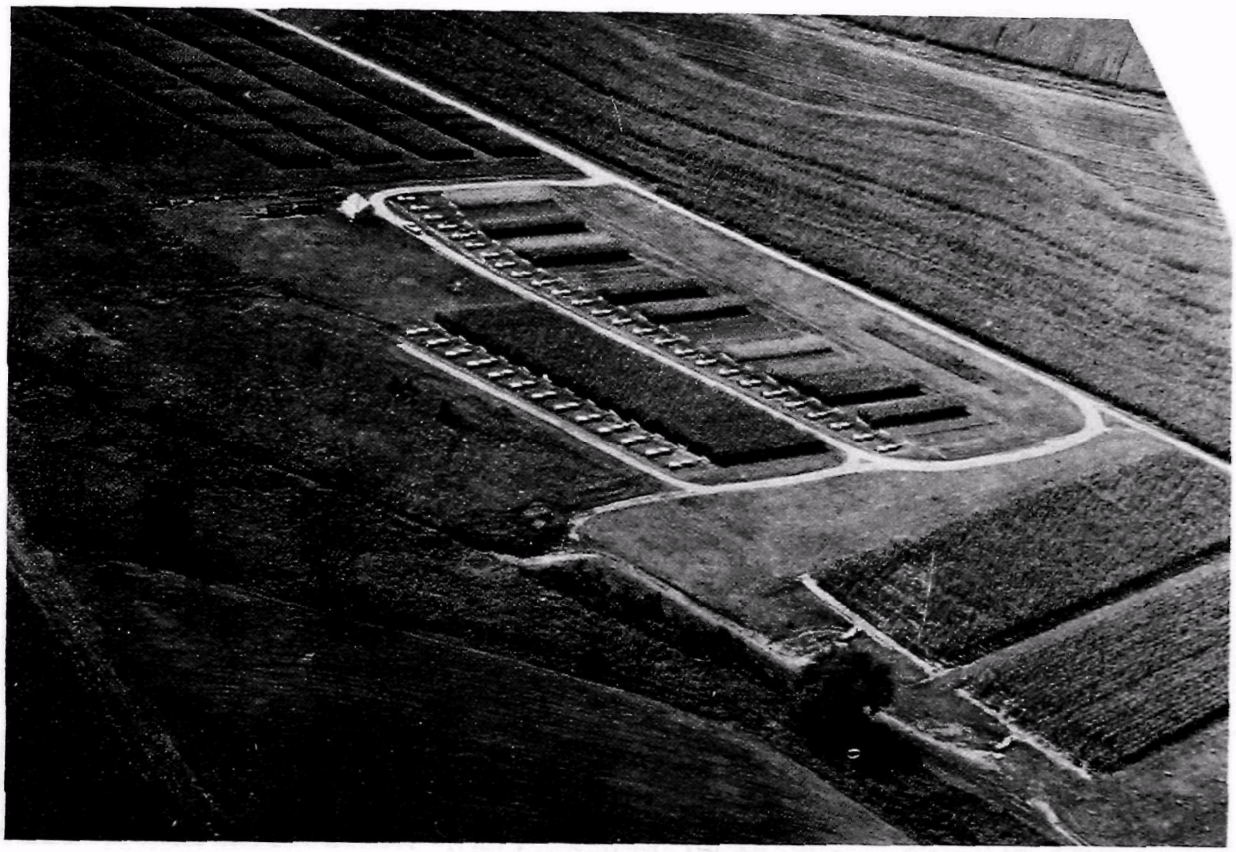

Figure 3. Aerial view of runoff and erosion plots, McCredie Field. Thirty-three of the small plots (center of photo) were utilized in this study. The two areas in the lower right .405 hectares each (one acre) are instrumented and utilized to obtain runoff and erosion data from a larger area.

SECTION IV

RESEARCH PROCEDURE

Field Plot Layout: A 41 plot facility (33 included in this study) has been in operation on the Midwest Claypan Experiment Station for more than 30 years. It is probably the most extensive facility in the country for measuring runoff and sediment losses under practical field conditions. The layout and experimental techniques are refinements of the original method developed by Duley and Miller (20) and widely adopted as a means of measuring runoff and erosion. Evidence obtained with this type of experiment in past years has been used in securing basic data for soil conservation programs. The data obtained with this type of facility is more realistic and applicable than where small, bare, or mulch covered plots are utilized under non crop conditions, with artificial rain equipment. Results from small watersheds may only apply to the area where measurements were made. Various cooperative studies involving crop and soil management practices have been conducted on these plots in past years by the U.S.D.A., Agricultural Research Service, North Central Regional Watershed Research Unit and the Missouri Agricultural Experiment Station. Of particular value is the skill of the U.S.D.A. supervisor F. D. Whitaker and technicians who have worked with this facility for many years and have developed the techniques essential to minimize experimental errors in studies of this kind.

A description of the soil and results of some past experiments have been summarized in U.S.D.A. Technical Bulletin 1379 (21). This publication also provides an extensive review of research in applicable soil and water loss studies. The experimental field plots (Figure II) are located on a three percent slope. Individual plots are 3.2 x 27.4 meters [10.5 x 90 ft], surrounded by metal dividers placed sufficiently deep in the soil to prevent lateral loss or interflow of runoff water. The runoff measuring equipment for each plot consists principally of two volumetrically calibrated tanks connected by a nine-slot divisor unit. All of the runoff and sediment from a plot flows into the first catchment tank that holds about 1 cm [1/3 inch] of runoff from the plot. A container with a capacity of about 0.57 hl [2 cu ft] is located in the first tank under the conduit that delivers the runoff and sediment from the plot to the tanks. This container retains runoff from very small flows. When the first tank is full, one-ninth of the water and suspended sediment is directed into a second tank and the remainder is wasted into drains. About 15.24 cm [6 inches]

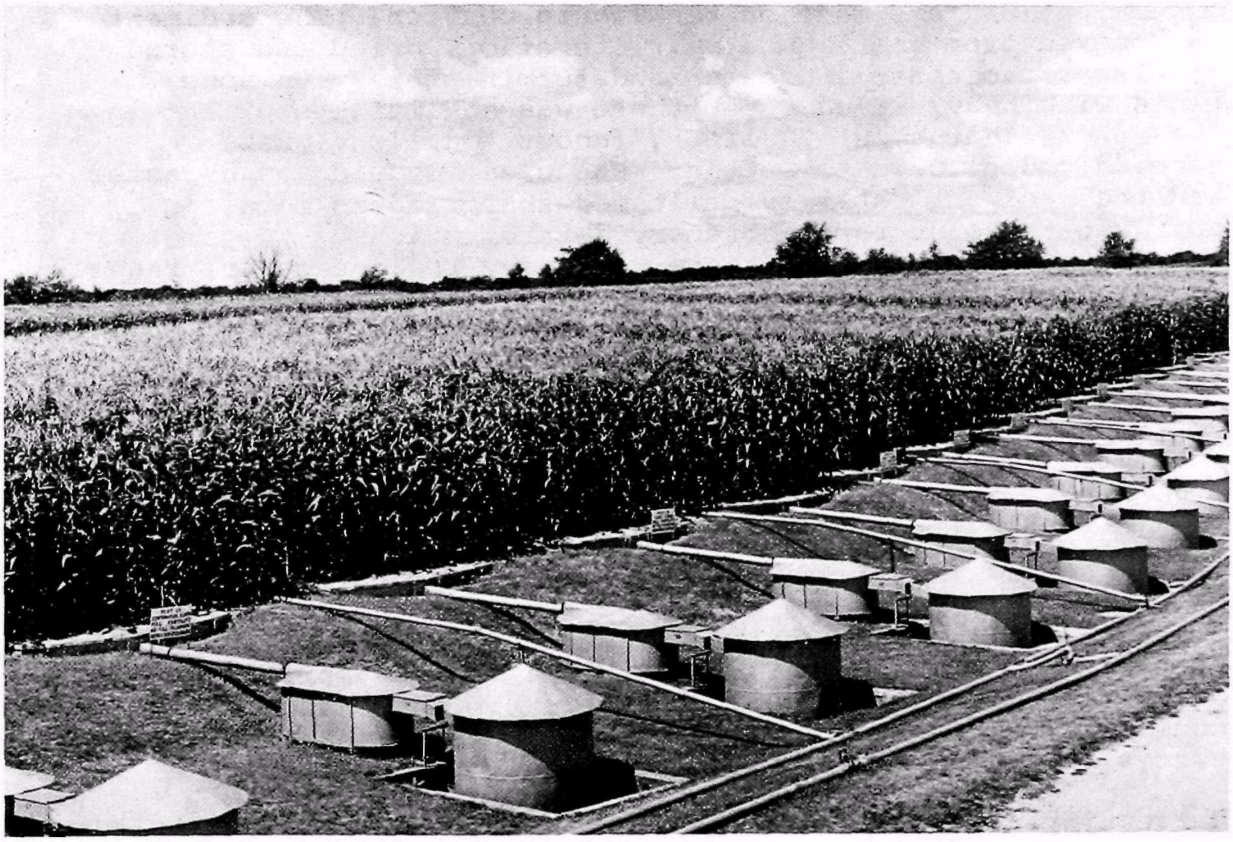

Figure 4. Tanks and equipment utilized for collecting runoff and sediment from experimental plots. This facility can provide accurate data on storms where the total runoff can be more than 15 cm (6 inches). Note the irrigation pipe in place. The addition of water can reduce drouth damage and can raise soil moisture to produce runoff in seasons when precipitation would be absorbed.

of runoff from a single rain can be measured before the final tank overflows.

Collecting Samples: After each rain the catchment tanks are emptied and cleaned. The volume is measured. Sediments and water collecting from the experimental areas are thoroughly mixed and triplicate samples collected to determine sediment content. Additional samples are taken in glass bottles, immediately cooled and stored at 0°C [32°F] until laboratory determinations are made on the liquid portion. The sediment is removed from the liquid by filteration, dried and stored for later phosphate and ammonia determinations. On some plots with heavy mulch cover there was so little sediment in the runoff that about 20 liters [about 5 gallons] were removed and allowed to settle. The clear liquid was decanted and the sediment retained, filtered and dried to obtain a sufficient amount for laboratory determinations. In some runoff events, and where there was heavy residue cover, the runoff contained insufficient sediment for measurements.

There is a 2.13 meter [7 ft.] border area between plots. This permits the planting of two outside border rows of a crop such as corn or soybeans, or 1.07 meter [3.5 ft.] of small grains or grasses. This planting outside of dividers minimizes border effect variations that are inherent with small plots. Tillage operations are conducted with an appropriate equipped farm tractor. Methods of soil preparation, seeding, fertilizer application cultivation and pesticide applications are similar to those on large farm acreages. The farm technicians have had long experience in operating this equipment. Their skill insures uniformity across all plots. Damage to dividers, to crops and measuring equipment, and elimination of rodent tunnels, that can cause errors in the data collected is minimal.

Harvesting: Small grains and soybeans are harvested with a self propelled combine. Yields of corn and meadow crops are obtained by a combination of machine and hand methods. In past experiments on this facility soil amendments have been applied mostly by hand. However, in the course of this study, machinery has been modified to apply both fertilizers and pesticides by methods regularly employed in large scale cropping. The plot operation permits the securing of accurate field data of runoff, sediment loss and yields from a number of variable (and partly replicated) treatments.

Large Plots: In addition to the 3.2 x 27.4 meter plots [10.5 x 90 ft.], two fields, 31.6 meters wide and a length of 128 meters [103.7 x 420 ft.] are cropped on the contour to a rotation of corn and soybeans. These larger areas are shown

Figure 5. Preparing runoff for sampling. The container being emptied collects the runoff when the amount is small. When the quantity exceeds this volume the contents are mixed with the overflow.

Figure 6. Triplicate samples of runoff being collected for the determination of sediment content. Separate samples are collected and refrigerated for laboratory determinations of nutrients and pesticides.

as P-2 and P-3 in Figure 2. These two different sized plots permit comparisons of results under a minimum tillage system. Water level recorders and flumes are used to measure the volume of runoff on these larger plots. Coshocton runoff sampling wheels are used to secure representative samples for measurement of sediment losses and of both water and sediment for laboratory analyses. These two plots provide data to aid in the extrapolation of data on the small plots to fields or small watersheds.

Adding Water: Supplemental water is provided by sprinkler irrigation equipment that is set up after corn and soybeans are planted. Nozzles are on a 9.14 x 10.7 meter [30 x 35 ft.] spacing and are left in position throughout the growing season. This equipment is designed to provide uniform distribution of water at a rate of about 1.9 cm [.75 inch] per hour. This equipment is not designed to apply artificial rainfall. However, sprinkling can be used to raise soil moisture content, so runoff will occur in some seasons when precipitation is below average, but rains do fall on moist soil. This permits securing data in some seasons when there would be little natural runoff. Also, there may be short periods when drouth may damage summer crops early in the season. This added water can permit normal crop development so meaningful soil and water loss experimental data can be obtained in the latter part of the growing season.

Treatment Variables: The plots utilized in this study have in the past provided information on erosion and runoff under different cropping practices and soil management systems that are applicable in the region (21). Experience has shown that past soil differences that may have developed are small and will be overcome in one or two seasons with new systems. Residual differences are minor. Organic matter and physical property variations are usually small and difficult to detect by laboratory procedures. Soil tests have been performed on all plots and any differences in calcium or other mineral nutrients that could effect crop growth were applied in 1970 to balance nutrient differences and provide uniformity. The study was changed in 1970 and a new set of variables established. Soil and crop management practices as outlined in this section were initiated.

In this "change-over" season all treatments were applied according to plan and operations were only slightly modified in the following seasons that are reported. In 1970 rainfall approached the 100 year frequency. Only a portion of the laboratory data was obtained, but agreement on losses on replicated plots was generally good and indicated little

Figure 7. Planting corn in "chopped stalks" with a "no-till" planter on a runoff plot. A complete fertilizer is applied in bands separate from the seed.

Figure 8. Applying a pesticide where corn has been seeded with a "no-till" planter. Note the metal dividers that separate the plot areas from borders. Borders minimize climatic effects on small plots.

effect of past history. In 1970 experience was modified and improved. Hand applications of fertilizer, for example, was replaced by machine placement, which is similar to methods used on commercial farms. The results obtained in 1971, 1972 and 1973 indicated only minor effects of previous cropping practices.

The investigation can be divided into two major portions, (a) where different rates of nitrogen and phosphorus are applied to continuous corn, grown with conventional tillage operations, or where residues remain on the surface and corn is grown with a no-till system. Meadow plots receiving two rates of nitrogen are also included in this portion of the study; and (b) where adequate uniform applications of fertilizer is applied to corn and soybeans grown under different crop and soil management systems.

Soil Treatments and Crop Management.

1. Fertilizer Applications

   a. Basic application; according to soil tests (23) provided the following levels in plow layer --(all other essential nutrients present in adequate amounts for optimum crop growth).
      P-98 kg per ha [200 lbs P_2O_5per/a]
      K-2.4 percent base saturation
      Ca-80 percent base saturation
   b. Variable fertilizer treatments - see tables 1, 2 and 3.
   c. Nitrogen and starter fertilizer treatments (in addition to basic treatment) where fertilizer application rate is not an experimental variable.

   Corn
   1. Ammonium nitrate at 336 kg per ha [300 lbs/a] applied on surface before plowing, or banded in soil with no-till or field cultivator tillage systems.
   2. Starter fertilizer; 224 kg per ha of 6-10.5-19.9 (N-P-K) [200 lbs./a 6-24-24] banded near row at planting.
   3. Ammonium nitrate at 224 kg per ha [200 lbs per a] side dressed when corn was about 30 cm tall (12 inches).

   Soybeans
   Starter fertilizer; 224 kg per ha [200 lbs./a] of 6-10.5-19.9 (N-P-K) [200 lbs./a 6-24-24] banded near row at planting.

   Grass
   See Table 3.

TABLE 1 Rates of nitrogen fertilizer applied to continuous corn, grown (A) with conventional plowing, planting and cultivation, and (B) where crop residues remain on the surface and no-till practices are followed.*

Conventional (A)	No-Till (B)	Total** kg/ha	Nitrogen Applied Annually*** kg/ha	
Plot	Plot		Before planting	Sidedressed
12	14	15	0	0
17	10	89	37	37
4	21	163	74	74
8	16	237	148	74
15	5	348	222	111

* Phosphorus, potassium and calcium maintained at optimum levels according to Missouri Soil Tests (22).

** Starter fertilizer applied annually at planting, equivalent to 245 kg/ha of 6-10.5-19.9 (NPK).

*** Solid ammonium nitrate (33-34% N).

Figure 9. Special equipment and care is required to cultivate corn on small runoff and erosion plots. Damage to stand or dividers can influence results. Note the upright sprinkler in place that can add water in the event of a dry season.

Small Grain (for winter cover)

1. Ammonium nitrate at 112 kg per ha [100 lbs./a] after corn is removed for silage and tilled into surface soil before seeding small grain.
2. Row fertilizer of 168 kg per ha of 6-10.5-19.9 (N-P-K) [150 lbs./a 6-24-24] at seeding.
3. Ammonium nitrate at 112 kg per ha [100 lbs./a] after soybean harvest.

2. Crop Variables

a. Continuous Corn
b. Continuous Soybeans
c. Corn-Soybean Rotation
d. Continuous Grass

3. Tillage Variable

a. Seed bed prepared by conventional plowing, discing and harrowing with cultivation for weed control.
b. "No-till" planting in chopped residues of previous season or in cover crops; weed control with herbicides.
c. Field Tiller; residues chopped and seed bed prepared by cultivator that did not incorporate organic material.

4. Mulch Variable

a. None; all residues shredded and plowed under in fall or spring.
b. Crop residues in or near surface; residues shredded; soil worked with field tiller.
c. Crop residue on surface; shredded in fall and crops planted with no-till planter.
d. None; corn removed for silage.
e. Soybean residue and winter cover crop (rye) on soil surface at soybean planting; herbicide used to kill cover crop.
f. Cover crop (rye) seeded after removal of corn for silage; corn planted directly in cover crop, using herbicide to kill the growing cover crop.

5. Planting Rates

Corn - planted about 20 cm (8" spacing) in 76 cm [30"] rows, - approximately 64,000 plants per ha [26,000 plants/a].
Soybeans - seeded 56 kg per ha (50 lbs per acre)

Figure 10. Corn growing in small grain that has been killed by a herbicide. This mulch is most effective in reducing erosion. The paper bags contain weighed amounts of ammonium nitrate to be applied to runoff plots, by hand, as a side dressing.

TABLE 2 Phosphate applications to continuous corn grown with (A) conventional plowing, planting and cultivation and (B) where crop residues remain on the surface and no-till practices are followed.*

Conventional (A)	No-Till (B)	Phosphorus Treatment P - kg/ha	
Plot	Plot	Starter**	Broadcast
12	14	25.7	0
15	5	25.7	To Soil Test***
13	7	25.7	To Soil Test*** + 98 kg P/ha

* Plots 5, 7, 13 and 15 received adequate potassium and lime, and 348 kg/ha of nitrogen. Plots 12 and 14 received only starter fertilizer.

** 245 kg/ha of 6-10.5-19.9 (NPK).

*** Reference (22).

TABLE 3 Nitrogen applied annually to continuous meadow* (kg/ha).

Plot	Total N	DATE OF APPLICATION		
		March 1	May 1	June 1
2	112	37	37	38
23	224	74	75	75

* Solid ammonium nitrate - lime, phosphorus and potassium available in adequate quantities, according to soil tests (22).

TABLE 4 Cropping Systems for Tillage and Mulch Cover Study.*

Plots	Crop	Tillage	Crop Use
6-19	Corn	No-Till - no cultivation	Grain Residues Returned
30-37	"	Field Cultivator	" "
22-28	"	Spring Plow-Cultivated	" "
27	"	Fall Plow-Cultivated	" "
31-33	"	No-Till - no cultivation	Silage
32-34	"	" " "	Silage Rye Cover Crop**
36-39	Soybeans	" " "	Grain Residues Returned
3-35	"	" " "	Grain Rye Cover Crop**
29-38	"	Field Cultivator	Grain Residues Returned
P-2-P3	Rotation Corn-Soybeans	No-Till - no cultivation	Grain Residues Returned

*All areas received lime, phosphorus and potassium fertilizers to provide adequate levels as shown by soil tests (22). All corn received 185 kg/ha (165 lbs/a) N as solid ammonium nitrate with 60% plowed down or applied before planting and 40% side dressed. A 6-10.5-19.9 (N-P-K) starter fertilizer at 245 kg/ha was applied to both corn and soybeans at planting.

**Cover crops received 37 kg/ha N. Cover crop on plots 32 and 34 received 168 kg/ha, 6-10.5-19.9, at seeding.

in 76 cm (30") rows, approximately 2.5 cm [1" spacing].

Small grain for winter cover

a. One hundred kg per ha, (six pecks per acre) broadcast before harvest of soybeans.

b. One hundred kg/ha (six pecks per acre) drilled after corn is removed for silage.

6. Pesticides

Herbicdes and insecticides were applied at rates recommended for this particular soil, by the manufacturers. Aldrin, Atrazine, Lasso, Furadan, and Paraquat were applied to specific plots. (See Tables 14, 15 and 16).

Laboratory Methods:

Nitrate and ammonia in water (and ammonia in sediment) determined by the magnesium oxide-Devarda alloy steam distillation method of Bremner (23). The work of Bremner and evaluations in the laboratory of the principal investigator have shown this method to be reliable.

Ammonia: Magnesium oxide is added to a measured sample and distilled with ammonia free steam into a boric acid solution using a mixed indicator. The ammonia evolved is measured by titration of the boric acid.

Nitrate: After removing ammonia, Devarda's Alloy prepared by ball-milling a good quality alloy until it will pass a screen with 100 openings per cm is added to the residue in the flask from the ammonia determination. The ammonia produced from the reduction of the nitrate ions in the samples are distilled into boric acid and the nitrates calculated from the titration.

Total Nitrogen: Total nitrogen in sediment is determined on acidified samples (taken to dryness) by the standard Kjeldahl method, excluding nitrates.

Water Soluble Phosphorus: Soluble phosphates were determined by the molydenum blue methods as outlined by Olson and Dean (24). Where the phosphorus content in water was below 25 ppb modification of the method by absorption on exchange resins, for concentration and extraction was used.

Active Phosphorus: The dried sediments were extracted with 0.01N-HCl and 0.025 NH_4F (22). Determination of phosphorus was made with ammonium molybdate-stannous chloride reagents measuring the color photometrically using 660 mu incident light.

Organic Pesticides: Samples of water were collected in glass bottles after storms, placed in ice chests, and held at 0°C [32°F] until determinations were made. Determination of pesticide compounds were made by gas chromatographic analysis by the University of Missouri Environmental Trace Substance Center Laboratories. Personnel from both the Trace Substance Center and the Agricultural Experiment Station Laboratories served as consultants on this phase of the study.

In 1971 and 1972 all determinations were made on filtered samples. In 1973 analysis for Aldrin and Dieldrin were made on filtered water, but the remainder of the determinations (Lasso, Atrazine and Furadan were made on unfiltered water.

SECTION V

RESULTS AND DISCUSSION

Temperature variations and rainfall distribution during summer months are critical factors in crop production in the mid-continent region. The period from seed bed preparation until a crop canopy is grown is the critical time for maximum sediment and water loss. On claypan soils a mild shortage of rainfall in the period immediately after planting usually is favorable to crop growth. Plant needs for moisture during the early stages of growth are not high. When rainfall is heavy before the crop provides ground cover, erosion and runoff can be high. In July and August the effect of storms is not as conductive to erosion. A good growth breaks the force of the rain drops, and where crops have depleted soil moisture there is storage capacity and less runoff.

Temperatures in the three seasons this study was conducted (1971, 1972 and 1973) were near normal and had no major influence on the production of corn, soybeans or meadow grasses. The temperatures given in Table 5 show an average of 12.5°C (54.5°F) for the 12 month period. The average temperatures for the three years that this study was conducted showed departures from this mean of 0.4°C (.7°F). April and May of 1973 were slightly cooler than the long time average, but other months during the growing seasons in all three years were near normal.

Rainfall for the last 80 years in this locality was 96.16 cm [37.86 in]. In both 1971 and 1972 the total precipitation was considerably below this amount (Table 5). In 1973 March rainfall was nearly four times the average, which delayed planting of row crops. However, in May and June available moisture was actually below the amount for optimum crop growth. There were no severe storms during the period that corn and soybeans were making early growth. Erosion and runoff from all plots were less than has been obtained from these same plots in previous years and with somewhat similar cropping systems. In 1973, with the above normal precipitation, much of this extra rainfall came in March, July and the fall months when the soil was protected by residues or a growing crop.

The absence of above normal rainfall in April through June in all of these three seasons would suggest that the reported erosion, nutrient and pesticide losses would be lower than in seasons with above average precipitation. Experiments (21) conducted on this same field in previous years have shown that storms of above average amount and intensity caused more runoff and soil loss than was measured from individual events during this three year period. Damage is most severe in the spring months from time of seed bed preparation until the crop provides ground cover. There have been occasions on this claypan soil when storms in two or three months of a single year have caused greater erosion and runoff than may have occurred over a period of years. Weather is seasonal at this mid-continent location. It is suggested that losses from most of the management systems used in this study would be greater in seasons when spring and early summer rainfall is above average.

Crop Yields

The corn yields obtained from the different treatments in the three years of these measurements ranged from below the state average (low nitrogen application) to amounts that were almost double the yields for the state according to crop reporting services. The amount of fertilizer applied in this study varied from considerably less to an excess of the quantity regularly used by commercial farms.

Table 6 and Figures 11 and 12 give the yield of corn grain (15 percent moisture) on selected plots receiving different rates of nitrogen and phosphorus fertilizer. Yields are included for both no-till and conventional cultivation practices. The average yield for the state for the three year period was 5,582 kg/ha [88.9 bu/a]. In 1971, where only 15 kg N/ha [13 lbs/a] were added, yields were slightly higher than the state average. In both 1972 and 1973 the application of only nitrogen in starter fertilizer produced yields considerably lower than the average yield reported for the state.

The highest yields of corn produced with both conventional and no-till systems were nearly two times the state averages for the three years. More nitrogen was required where no tillage was practiced. The highest average yield, 10,476 kg/ha [167 bu/a] was produced on no-tillage corn that had received ammonium nitrate to supply 348 kg N/ha [310 lbs/a]. In all seasons the yield of corn increased on the no-till plots as additional nitrogen was applied.

Where land was cultivated (conventional) the highest yields were obtained with 163 kg of N/ha [145 lbs/a]. The yields from the 163 kg/ha rate was substantially greater than where only 89 kg/ha [79 lbs/a] were applied. Additional nitrogen above the 163 kg/ha rate reduced yields. This relationship

TABLE 5 Monthly Precipitation and Temperature During 1971, 1972 and 1973 at the Midwest Claypan Experiment Farm, Kingdom City (McCredie) Missouri.

	Mean Temperature C°				Rainfall - cm			
Month	30 year average	1971	1972	1973	80 year average	1971	1972	1973
January	-1.2	-3.4	-1.7	-0.5	4.78	3.30	1.75	6.55
February	1.1	-.5	.1	0.7	4.32	5.03	1.02	3.76
March	6.0	5.6	7.5	9.5	7.19	1.73	7.93	26.47
April	12.9	14.1	13.3	11.6	9.63	3.30	10.29	6.93
May	18.0	16.8	17.9	17.0	11.76	11.43	7.42	10.90
June	22.5	24.7	22.6	23.2	11.91	4.98	1.98	5.33
July	24.9	23.1	24.4	24.4	9.07	8.56	5.77	19.53
August	24.1	23.1	24.9	24.4	8.38	3.89	3.35	2.74
September	20.1	21.9	21.9	20.7	10.52	6.58	13.56	14.58
October	14.4	17.5	13.3	16.8	8.03	4.04	6.35	9.73
November	6.7	7.8	4.6	8.4	5.79	5.36	12.22	6.55
December	.8	3.4	-1.7	-.7	4.80	11.25	6.10	8.15
Average	12.5	12.7	12.3	12.9	96.16	69.44	77.72	121.22

Table 6. Corn Yields as Affected by Rates of Nitrogen and Phosphorus Applications

N Applied Annually kg/ha	No-Till Plot	No-Till Yield - kg/ha 1971	1972	1973	3 yr. Average	Conventional plot	Conventional Yield - kg/ha 1971	1972	1973	3 yr. Average
18	14	5,802	3,443	1,857	3,701	12	5,958	3,826	2,841	4,208
89	10	9,132	6,259	6,203	7,198	17	9,690	6,793	7,087	7,857
163	21	10,782	7,539	9,427	9,249	4	11,741	9,301	10,242	10,428
237	16	11,064	8,078	10,430	9,857	8	11,515	8,913	9,571	10,000
348	5	11,697	9,226	10,506	10,476	15	11,095	8,292	8,906	9,431
P Applied Annually kg/ha*										
25.7**	14	4,802	3,443	1,857	3,701	12	5,958	3,826	2,841	4,208
25.7+ to Soil Test	5	11,697	9,226	10,506	10,476	15	11,095	8,292	8,906	9,431
25.7+ to Soil Test +98 kg/P/ha	7	10,349	8,235	9,320	9,301	13	11,641	9,163	9,671	10,158
STATE AVERAGE							5,519	5,709	5,519	5,582

*All plots received a starter fertilizer of 245 kg/ha of 6-10.5-19.9 (N-P-K) at planting.

**Plots 14 and 12 received only 15 kg/ha of nitrogen in starter fertilizer; plots 5, 7, 13 and 15 received 348 kg/ha of N as ammonium nitrate.

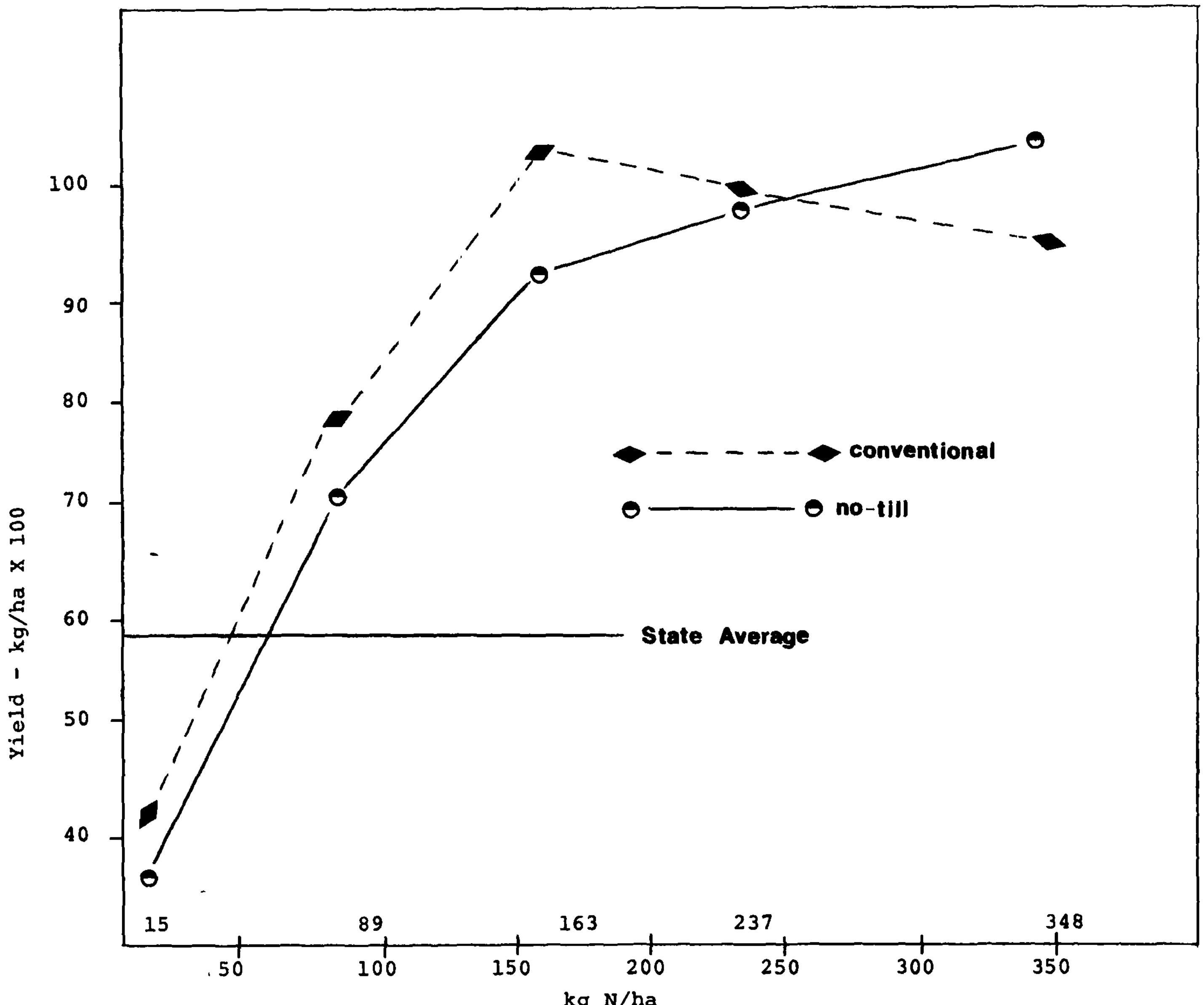

Figure 11. Average corn yields for three years where different rates of nitrogen fertilizer were applied to crop produced with conventional seed bed preparation and cultivation, and with no tillage.

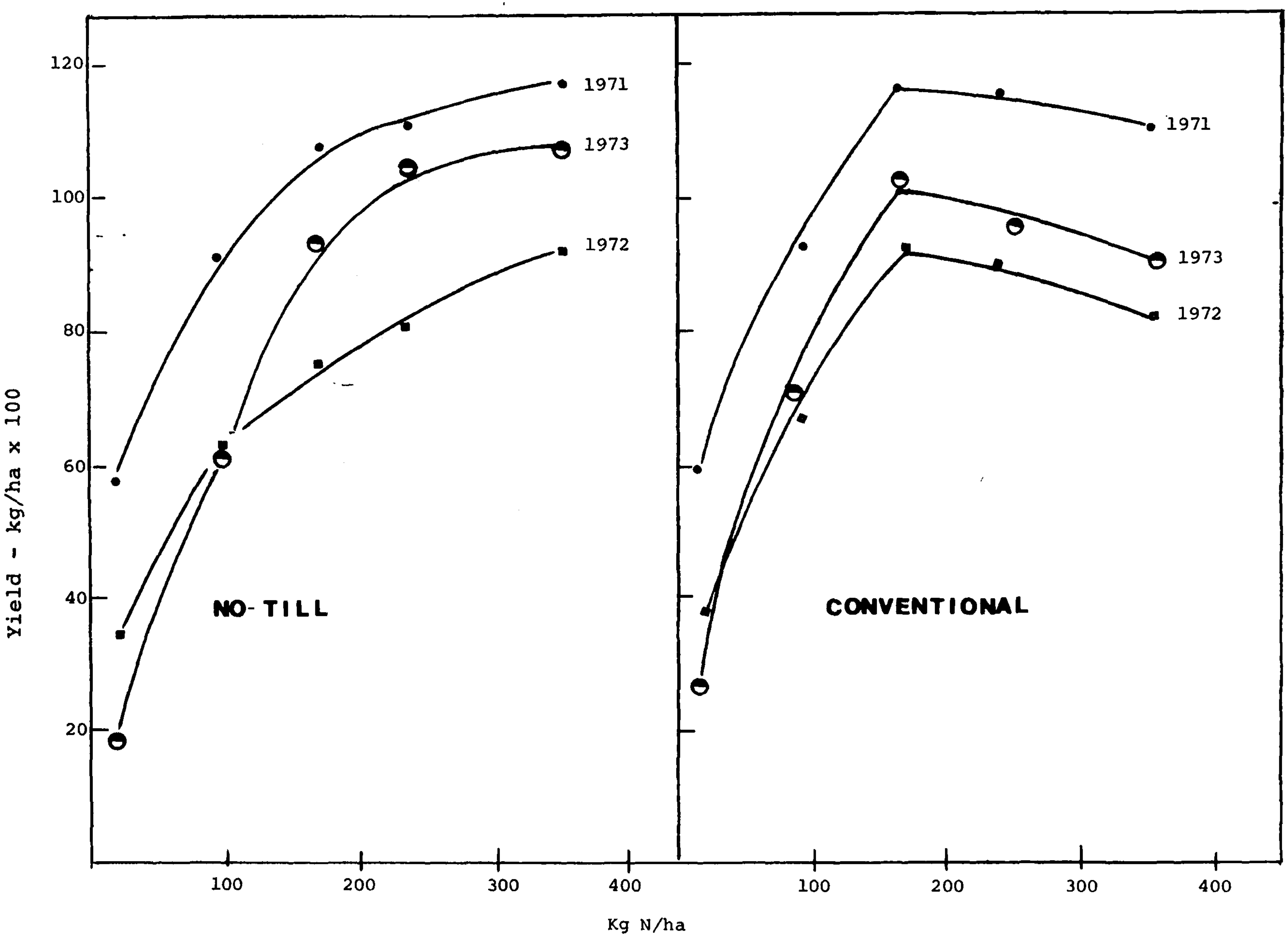

Figure 12. Corn yields by years, receiving different rates of nitrogen fertilizer where no-till or conventional planting and cultivation was followed.

was evident in each of the three years. The drop in yields with successive years is evident where the only nitrogen applied was in the starter fertilizer, 15 kg/ha, [13 lbs/a]. In 1971 the yields with starter fertilizer alone were above the state average. In 1972 yields of grain on both the no-till and the conventional tillage methods were about 2000 kg/ha [more than 30 bu/a] below this average.

In 1973 the state average was 5,519 kg/ha [87.9 bu/a]. The no-till plot receiving only 15 kg N/ha [13 lbs/a] produced only 1857 kg/ha [29.6 bu/a] and the conventional treatment 2841 kg/ha [45.3 bu/a]. This is typical of yield loss when nutrient removal is in excess of soil additions. The greater reduction in yield on the no-till plots can be explained by failure of the crop residues to release nitrogen and other nutrients to the following crop when they are not incorporated in the soil, but remain on the surface.

Currently there is interest in the use of reduced tillage to conserve energy in crop production. These yield data show that where cultivation is reduced on a claypan soil, that additional nitrogen will be required to prevent a reduction in grain yields. These results illustrate the role of chemical soil amendments in recent years in improvement of production on these claypan soils.

Response of the corn to additions of phosphates varied with the tillage practices, Table 6. Plots 5 and 15 received phosphate additions that are considered adequate for corn production as shown by soil tests (22) generally used in the mid-continent area. Where an extra 98 kg of P/ha [200 lbs, P_2O_5/a] was applied annually the average yield on the no-till plots was reduced 1175 kg/ha [18.7 bu/a]; but where the conventional practices were followed grain production increased 727 kg/ha [11.6 bu/a]. This difference was evident in each of the three years. No explanation is available for these difference in effect of high phosphorus level on yields. It is possible that on the no-till areas some essential element may have combined with the phosphate to create a deficiency when high yields are produced.

Soybean production was not exceptional, but varied because of some problems in obtaining stands. No yield tables are included, but appearance of plots and yields of 2016-2352 kg/ha [32-37 bu/a] were similar to those obtained from farm fields in the area of the McCredie station.

The yields of crops produced in the three years of this study indicate the results should be representative of a variety of field conditions. The lowest rate of nitrogen application was inadequate to sustain corn yields and production was below average for both claypan soils and for all corn land in the state. The highest rates of both nitrogen and phosphorus applied were considerably larger than are currently used in farm practice. Where the land was plowed and cultivated the highest rates of nitrogen applied failed to increase yields. The losses of nitrogen and phosphorus found in runoff water should be indicative of the amount that would be lost from farm fields under a variety of management practices.

Losses of Soil, Water and Nutrients

Table 7 gives the summary of runoff, erosion, and nitrogen and phosphorus (in water) lost from seven representative plots. Tables in the appendix include data for individual storms from these treatments that represent a variety of crop and soil management practices.

Runoff

The quantity of runoff from the experimental plots, with different amounts of cover, is in agreement with data obtained on claypan soils in the past (21). The average loss of water, for the three year period, from a thick, well fertilized meadow cover was 8.69 cm [3.4 in], which was the lowest found in this group of seven plots. The highest loss of 29.17 cm [11.5 in] occurred where corn was removed for silage and the land was left bare over winter. Where a cover crop was planted soon after the silage was removed, runoff was reduced more than 50 percent to 13.88 cm [5.5 in]. This runoff was near the same quantity as is reported in Table 7 for other crop management systems where the values ranged from 12.69 to 18.88 cm [5 - 7.4 in]. Runoff from no-till corn was 17.04 cm [6.7 in] for the three year period which was more than the 12.69 cm [5 in] from the comparison, conventional plot. Where residues remained on the surface they provided a mulch that reduced evaporation. Frequently when rain did occur, there was a higher moisture content in the no-till areas and greater runoff occurred than where soils were more deficient in moisture.

Rainfall in both 1971 and 1972 was below long time averages. In 1973, when total precipitation was greater, the heavier rains occurred when the soil was either protected by a growing crop canopy or shredded crop residues. The average runoff from these seven plots, for the three year period, was 16.6 cm [6.5 in] which is only slightly more than one sixth of the average annual rainfall. From past studies on this field it would be expected that over a longer period the percentage of runoff from most plots would be greater.

Table 7. Runoff, Soil and Nutrients (in water) Lost from Seven Representative Plots.*

Crop Management**	Runoff (cm)				Soil Loss t/ha				$NO_3^-+NH_4^+$-N kg/ha in Runoff				Phosphorus kg/ha in Runoff			
	1971	1972	1973	Avg.	1971	1972	1973	Avg.	1971	1972	1973	Avg.	1971	1972	1973	Avg.
Meadow 112 kg N/ha	2.54	3.56	19.96	8.69	0	0	0	0	.44	1.70	2.61	1.58	.01	.46	.96	.48
Continuous Corn No-Till, 163 kg N/ha	5.18	11.61	34.32	17.04	.09	.11	.47	.22	5.90	16.66	11.82	11.46	.44	1.55	2.87	1.62
Continuous Corn Conventional 163 kg N/ha	5.44	5.79	26.85	12.69	2.00	.13	2.24	1.46	3.22	13.37	12.33	9.64	.01	.28	.40	.23
Continuous Corn Silage, 202 kg N/ha	11.38	28.63	47.50	29.17	5.45	25.60	39.66	13.57	5.01	8.29	12.00	8.43	.07	.90	.65	.54
Continuous Corn Silage-Cover Crop@ No-Till 202 kg N/ha	4.67	4.09	32.87	13.88	.13	.09	1.14	.45	2.08	9.80	16.32	9.40	.16	.40	1.24	.60
Continuous Soybeans Field Cultivator	7.11	90.85	29.69	15.88	.43	.74	2.58	1.25	4.52	8.67	13.12	8.77	.13	.50	.84	.49
Continuous Soybeans No-Till, Cover Crop@	9.83	10.29	36.53	18.88	0	0	.11	.04	3.13	4.61	8.54	5.43	.94	1.87	3.39	2.07
Average 7 plots	6.59	10.69	32.53	16.60	1.16	3.81	6.60	3.86	3.47	9.02	10.96	7.82	.25	.85	1.48	.86

*Detailed losses by storms listed in Appendix.

**Includes starter fertilizer applied to corn annually at planting, equivalent to 245 kg/ha of 6-10.5-20.5 (N-P-K) and 168 kg/ha at planting with soybeans.

@ Cover crops received 37 kg/ha (33 lbs/a) N. Cover crops following corn received 168 kg/ha 6-10.5-19.9,(N-P-K) at seeding. No starter applied with soybean cover crop.

Soil Loss

The amount of soil lost from the different management systems shows the effectiveness and need for soil cover to prevent sediment from leaving cropped fields and entering reservoirs and streams. Where corn was removed for silage and no cover crop planted the total soil loss in 1971 was 5.45 t/ha [2.4 t/a]. The amount was 39.66 t/ha [17.7 t/a] in 1973, with an average of 23.57 t/ha [10.5 t/a] for three years. In contrast, the well fertilized meadow lost insufficient soil for measurement in any of the three years. Where a cover crop was seeded in soybeans no measurable soil loss was found in 1971 or 1972 and only .11 t/ha [.05 t/a] in 1973. Where a cover crop was planted after removal of corn for silage the average soil loss for the three years was reduced to only .45 t/ha [.2 t/a].

The effectiveness of the surface cover in reducing sediment loss is shown by comparing the two plots producing corn with no-till and conventional practices. In each of the three years erosion with no tillage was lower. For the three years the no-till area lost an average of only .22 kg/ha [.1 t/a] of soil while management that included plowing and cultivation resulted in an average loss of 1.46 t/ha [.65 t/a].

With the exception of the corn harvested for silage, and the soil left unprotected the sediment losses measured are less than is normally considered acceptable (26) for this type of soil. Annual parent material weathering and soil renewal would be greater than the amount lost under these better management systems.

Nitrate and Ammonia Nitrogen in Runoff Water

Table 7 contains figures for the total of nitrate-N plus ammonia-N lost during 1971, 1972 and 1973. The rates of nitrogen fertilization are typical of the quantities used by good farm managers. The amount of nitrogen applied varies from only 6 percent N in starter fertilizers for soybeans, a total of 168 kg/ha [150 lbs/a] to corn or corn plus cover crop where as much as 202 kg/ha [180 lbs/a] of N were applied. The smallest amount lost was from the continuous meadow receiving 112 kg/ha [100 lbs/a] of nitrogen annually. The average loss over the three year period was only 1.58 kg/ha [1.4 lbs. N/a]. Where soybeans were produced using a field cultivator and a nitrogen addition of about 10 kg, N/ha [8.9 lbs. N/a] the NO_3+ NH_4-N loss was 8.77 kg/ha [7.8 lbs/a]. The loss from soybeans was reduced to 5.43 kg/ha [4.8 lbs/a] when a cover crop was seeded before harvest.

Production of corn with nitrogen additions of 168-202 kg N/ha [150-180 lbs N/a] showed average combined losses of these nitrogen containing ions of from 8.43 to 11.46 kg N/ha [7.5-10.2 lbs/a]. Under climatic conditions that prevailed in these three seasons losses of soluble nitrogen in runoff water from liberally fertilized corn was little higher than from soybeans that received only nitrogen in starter fertilizer. The total nitrate and ammonia nitrogen contained in the runoff water from corn land varied from about four to seven percent of the amount applied as chemical fertilizer.

Phosphorus in Runoff

The quantity of soluble phosphates found in the runoff water from these representative plots was a very small percentage of the amount available for plant growth. This is to be expected since there is rapid adsorption of soluble phosphates on the colloidal fraction of claypan soils. As shown in Table 7 the average loss of phosphorus for the seven plots was .86 kg/ha [.77 lbs/a]. The lowest average amount was .23 kg/ha [.2 lbs/a] for corn produced by conventional methods. The highest was 2.07 kg/ha [1.84 lbs/a] for soybean land where a cover crop was seeded. The second highest was 1.62 kg/ha [1.44 lbs/a] where corn was planted in the previous year's residues with no-till practices. The remaining plots showed losses between these two extremes. The higher losses of phosphorus, where crop residues or a killed cover crop remained on the surface, can probably be explained by the leaching of the phosphate from the organic materials. It has previously been shown these covers probably reduced evaporation resulting in higher runoff. It is believed the phosphates contained in the plant tissues were leached and lost in the runoff before there was opportunity for absorption by the soil. This theory is supported by the small loss in the runoff from the cultivated corn, where the organic matter was incorporated in the plow layer.

Losses of phosphates were larger in the higher rainfall year of 1973 than were measured in the drier seasons of 1971 or 1972. All quantities are small and the losses in water during the 1973 season represent less than one percent of the phosphates that were available to a growing crop. It is probable that in seasons with greater precipitation and runoff the losses of phosphates would increase.

Table 8. Runoff and Soil Loss from Continuous Corn Receiving Different Rates of Nitrogen Fertilization.*

	RUNOFF - cm								EROSION - t/ha							
N Applied Annually	No-Till				Conventional				No-Till				Conventional			
kg/ha	1971	1972	1973	Avg.	1971	1972	1973	Avg.	1971	1972	1973	Avg.	1971	1972	1973	Avg.
15	12.93	17.04	43.46	24.48	8.10	9.86	36.45	18.14	.40	.78	.87	.68	2.22	.27	4.80	2.43
89	10.39	15.14	32.64	19.36	4.80	10.85	34.82	16.82	.31	.31	.47	.36	1.21	.25	2.91	1.46
163	5.18	11.61	34.32	17.04	5.44	5.79	26.85	12.69	.09	.11	.47	.22	2.00	.13	2.24	1.46
237	9.68	13.44	34.52	19.21	7.24	10.19	37.62	18.35	.18	.20	.56	.31	2.11	.25	2.80	1.72
348	5.51	12.90	35.41	17.94	4.90	12.34	46.84	21.36	.22	.11	.45	.26	.85	.20	4.06	1.70
Average	8.74	14.01	36.07	19.61	6.10	9.81	36.52	17.47	.24	.30	.56	.37	1.68	.22	3.36	1.75

*All plots received adequate levels of phosphorus, potassium and calcium.

Table 9. Nitrate and Ammonia Nitrogen in Runoff Water From Continuous Corn Receiving Different Rates of Nitrogen Fertilizer (kg/ha).

N Applied Annually kg/ha	No-Till 1971	No-Till 1972	No-Till 1973	No-Till Avg.	Conventional 1971	Conventional 1972	Conventional 1973	Conventional Avg.
15	5.08	9.74	6.04	6.95	2.24	7.11	7.88	5.74
89	8.38	15.95	10.51	11.61	2.68	21.19	20.42	14.76
163	5.90	16.67	11.82	11.46	3.21	13.37	12.33	9.64
237	18.86	18.65	19.01	19.01	9.70	36.62	34.76	27.03
348	15.62	27.41	31.54	24.86	8.55	49.67	52.94	37.05
Average	10.77	17.68	15.89	14.78	5.28	25.59	25.66	18.84

Nitrogen Fertilizer Effects on Runoff and Erosion

Nitrogen was applied in increasing amounts to corn grown under both no-till and conventional practices. Table 8 gives the runoff and erosion that occurred from 5 rates of nitrogen application over three growing seasons. Where only nitrogen in starter fertilizer was added, 15 kg/ha, [13.4 lbs/a] runoff from the no-till treatments was 24.48 cm (9.6 in.]. This amount was higher in all three seasons than where additional nitrogen was added. It was evident the adequate nitrogen additions produced more residue and the soil was provided with a better cover than where the inadequate starter fertilizer did not promote vigorous plant growth.

Where conventional planting and cultivation was practiced in 1971 the greatest runoff also occurred from the lowest level of fertilization. However, in 1972 and 1973 there were no consistent differences in runoff that can be related to the fertilizer treatment. This condition was also found with other treatments (Table 7) where runoff was slightly higher with no-till than with the residues plowed under.

Erosion losses from both tillage methods, for the three years, were highest when inadequate fertilizer was added. Although the amount of sediment lost from the no-till plots was small, .37 t/ha average [.16 t/a] the added nitrogen reduced the movement of soil. Where the soil was cultivated erosion was greater, with an average loss of 3.36 t/ha [1.5 t/a] in 1973 and an average loss of 1.75 t/ha [.78 t/a] for the three years. In 1973 the corn grown by conventional methods with 15 kg of N/ha [13 lbs/a] produced erosion in the amount of 4.80 t/ha [2.14 t/a] but yielded only 2841 kg/ha [45 bu/a]. Where 163 kg N/ha [145 lbs/a] was applied the yield was 10,428 kg/ha [166 bu/a]. Although the erosion losses are not great the results from these 10 plots demonstrate that adequate nutrient levels that produce optimum crop yields can reduce the loss of sediments from farm fields.

Nitrogen Fertilizer Effects on Nitrogen Loss in Runoff Water

Nitrates are normally considered the principal form of nitrogen lost from agricultural land. Although ammonia is adsorbed on the soil complex, heavy and banded applications of ammonium salts may be present in concentrations in excess of the soils exchange capacity in limited areas. When soil temperatures are too low for rapid conversion to nitrate, ammonia in a substantial concentration may be lost in runoff. In the transition year of 1970 (data not given) some ammonium nitrate was broadcast on wet soil. Some early storm events produced runoff that contained considerable ammonia. In the years reported in this study much of the nitrogen was placed below the surface and little runoff occurred immediately after application. Since both ammonia and nitrate can be utilized by many plants, and biological reactions can convert ammonia to nitrate, the data tabulated in Table 9 is a total of the individual laboratory measurements for nitrate and ammonia.

Table 9 contains data on nitrate + ammonia-N for the same rate of nitrogen treatments included in Table 8 where runoff and erosion data were tabulated. The lowest rate of nitrogen application was 15 kg/ha [13 lbs N/a]. As discussed under corn yields, the first season produced yields near the amount reported as average for the state. However, after three years the return would not meet production costs. With this treatment the combined average loss of nitrate and ammonia-N was 6.95 kg/ha [6.2 lbs/a] for the no-till land and 5.74 kg/ha [5.1 lbs/a] with conventional management. Since the runoff from these two plots was 24.48 cm [9.64 in.] and 18.14 cm [7.14 in.] respectively this would represent average concentrations in the runoff water of 2.84 and 2.34 parts per million N. This concentration is comparable to the amounts found in water from large springs where there is little habitation or the equilibrium concentration in reservoirs at some seasons of the year (27).

Combined losses of nitrate and ammonia in runoff water were similar for 1972 and 1973, but considerably higher than in the lower rainfall year of 1971. Lack of correlation between total runoff and nitrogen loss in the latter two years can be explained by a substantial amount of the precipitation falling before the fertilizer was applied or after the crops had adsorbed a major portion of the nutrients required for growth.

The amount of nitrate and ammonia lost was greater as the rate of application was increased. There are variations in individual seasons, but with both the no-till and conventional methods of tillage the average losses are similar when the rate of application was 163 kg/ha [145 lbs/a]. The average loss for the three years was 11.4 and 9.6 kg/ha [10.2 and 8.6 lbs/a] respectively. This loss was 7-8 percent of the nitrogen applied in fertilizer. This was only approximately twice the amount found where only starter fertilizer was added. A portion of this nitrogen loss was from non-fertilizer sources (soil humus or leachate from crop residue). It is not possible to make an accurate determination of the amount of non-fertilizer nitrogen included in the losses.

Table 10. Soluble Phosphorus in Runoff Water from Continuous Corn Receiving Different Rates of Nitrogen (kg/ha).

Nitrogen Applied Annually kg/ha	No-Till				Conventional			
	1971	1972	1973	ave.	1971	1972	1973	ave.
15*	.35	1.60	3.88	1.94	.08	.56	.86	.50
97	.53	1.39	3.14	1.69	.01	.36	.34	.24
172	.44	1.55	2.87	1.62	.01	.28	.40	.23
249	.41	.87	1.02	.77	<.01	.38	.43	.27
363	.15	.63	1.66	.81	.01	.36	.33	.23
Average	.38	1.21	2.51	1.37	.02	.39	.47	.29

* Starter fertilizer only applied annually at planting, equivalent to 245 kg/ha of 6-10.5-19.9 (N-P-K). Remainder of plots received additional nitrogen as ammonium nitrate.

Losses of soluble nitrogen increased where the 237 or the 348 kg/ha [212 or 310 lbs/a] rates of nitrogen were added. The data in Table 6 showed the yield of corn was increased some by these higher rates of nitrogen addition where minimum tillage was used, but slightly depressed grain production with conventional cultivation. As an average for the three years the total nitrogen loss for the no-tillage plots receiving 237 and 348 kg/ha was 1.7 and 2.2 times respectively the amount where the 163 kg/ha rate of N fertilizer was applied. For the conventional cultivation the increases in loss were 2.8 and 3.8 times the losses where the highest corn yield were obtained. For the no-till plots the ammonia and nitrate lost at these highest rates of application (3 year average) were about 8 and 7 percent respectively of the nitrogen fertilizer added. For the conventional cultivation the percentage loss figures were 11.4 and 10.6 respectively. Combining the losses for all five of the no-till and conventional plots for the three years the average nitrogen losses were about .94, 2.5 and 2.4 percent respectively of the annual nitrogen applications. This should compare with losses from commercial fields where the rate of nitrogen application would range from insufficient, to more than is required for optimum growth. Although the increases in nitrogen loss during the last two years may be associated with time of rainfall and intensity of individual storms, it is also probable there was accumulation of soluble nitrogen in the soil or a higher concentration in crop residues from previous years applications of the ammonium nitrate.

On the basis of three years data on this claypan soil losses of soluble nitrogen in runoff from continuous corn was about 7-8 percent of the nitrogen applications that gave optimum yield.

Soluble Phosphorus in Runoff from Continuous Corn

In the studies where rates of nitrogen application to corn was the variable, the levels of phosphorus available to the crop was uniform on all plots. Table 10 gives data on the amount of phosphorus in runoff water from no-till and conventional cultivation plots where five rates of nitrogen were applied. This data shows uniformity in two factors:

a. In all three years except for the no-till system in 1971 the losses of phosphorus were lower where nitrogen, in addition to the 15 kg/ha [13 lbs/a] was applied.

b. There was less phosphorus in the runoff from conventional cultivation than where the residues remained on the surface.

The soil testing methods used in this study (22) showed average levels of phosphorus of 224 kg/ha [200 lbs/a] of phosphorus in the plow layer (17.8 cm. or 7 inches). In 1973 the no-till plot receiving only starter nitrogen showed a phosphorus loss of 3.88 kg/ha [3.47 lbs/a] which was the highest value obtained. The three year average was 1.94 kg/ha (1.73 lbs./a) or less than two percent of the phosphorus available to the growing crop, and more than double the amount lost where the highest rates of nitrogen produced the largest yields.

Where conventional cultivation was practiced and starter treatment was the only fertilizer added the phosphorus loss in runoff water for the three years was only .5 kg/ha [.44 lbs/a]. This is approximately twice the amount found where ammonium nitrate was side dressed at increasing rates.

The average value for all of these losses range from a low of about .10 to less than two percent of the available soil phosphate. These values should be representative of the range that could be expected under practical farming conditions where good soil management is practiced.

Although none of these values can be considered high it is of interest that losses were greater in all cases where crop residues were chopped and remained on the soil surface. It is only possible to speculate on the reason for this finding. The concentration of soluble phosphorus in plant tissue is much higher than in soil. It is probable rain falling with sufficient intensity to cause rapid runoff that the nutrients were leached from the crop residues and were lost. Where the crop vegetation had been turned under the runoff water was in contact mostly with soil and very little plant material. The quantity of phosphorus lost from the no-tilled systems was very small. This increase is only of academic interest when the effectiveness of a surface mulch is considered in the reduction of soil loss.

Total Nitrogen in Sediment

Table 11 gives data on the quantity of total nitrogen (Kjeldahl) found in the sediment from plots receiving different rates of ammonium nitrate applied to corn. These figures are based on calculations for erosion losses (Table 8) and a nitrogen content in the sediment of .3 percent. Most of this nitrogen would be soil humus materials. Nitrates were not included in the laboratory method used. Larger pieces of undecomposed organic material were screened out in the sample preparation. Some adsorbed ammonia could

Table 11. Total Nitrogen* (Kheldahl) in Sediment Lost From Continuous Corn Receiving Different Rates of Nitrogen Fertilizers**. (kg/ha)

N Applied Annually	No-Till				Conventional			
kg/ha	1971	1972	1973	Avg.	1971	1972	1973	Avg.
15	1.2	2.2	2.6	2.03	6.7	.8	14.4	7.03
89	.9	.9	1.4	1.07	3.6	.7	8.7	4.33
163	.3	.3	1.4	.67	6.0	.4	6.7	4.37
237	.5	.6	1.7	.93	6.3	.7	8.4	5.13
348	.7	.3	1.4	.80	2.6	.6	12.2	5.13

* Calculated on basis of 0.3% total N for all plots.

** All plots received adequate levels of phosphorus, potassium and calcium.

be present when storm events occurred soon after the nitrogen fertilizer was applied.

Since erosion was higher where the conventional management was practiced the total nitrogen loss was greater than where the no-till system was followed. There were few severe storms in any of these three seasons when the land surface was not protected by crop residues or a vigorous crop. The nitrogen losses are below those that would be expected in seasons with higher rainfall, and particularly when the storms occurred immediately after seedbed preparation.

The results do show that all losses of total nitrogen in sediment was greater where there was insufficient nitrogen applied to promote vigorous growth. In all cases nitrogen losses were greater where only 15 kg/ha of N [13 lbs/a] in starter fertilizer was the only treatment. The average for the three years for starter fertilizer treatment only was 2.03 kg/ha [1.8 lbs/a]. Where additional nitrogen was applied all values were lower. The comparable figure for conventional tillage was about 2.5 times higher, 7.03 kg N/ha (6.28 lbs/a]. Also on the conventional treatments the added nitrogen fertilizers reduced erosion and losses of organic nitrogen. The average figure for all no-till plots for the three seasons was 1.09 kg N/ha [.97 lbs/a]. The amount for all conventional tillage plots was 5.20 kg N/ha [4.64 lbs/a].

The plow layer of this soil weighs about 2,242 t/ha [1,000 t/a]. With a nitrogen content of 0.3 percent this would be 6720 kg N/ha [6,000 lbs/a]. The total amount lost in the sediment is small. Little of this nitrogen would be from the fertilizer application. Under conditions when erosion is high the loss of organic nitrogen would be much larger. Any treatment or management practice that will reduce sediment loss would be useful in reducing the amount of low solubility nutrients moving from land, as part of the soil mass.

Phosphorus in Runoff from Continuous Corn

Table 12 gives the amount of soluble phosphorus lost from plots that supplied three rates of phosphorus. The first plot received only starter fertilizer. The second plot received additional phosphate in an amount required for optimum growth. The third treatment consisted of an additional 98 kg P/ha [87 lbs/a] annually. As shown in Table 6, this additional phosphorus had only limited effect on yield. There was an indication of a depression in yield on the no-till plots and a slight increase where the soil was cultivated.

Table 12. Phosphorus in Runoff from Continuous Corn Receiving Different Rates of Phosphorus Application (kg/ha).

P Applied*	No-Till				Conventional			
	1971	1972	1973	Avg	1971	1972	1973	Avg.
21*	.35	1.60	3.73	1.89	.08	.56	.86	.50
Soil Test *@	.16	.63	1.66	.82	.01	.36	.33	.23
Soil Test *@ + 98 kg P/ha	1.29	3.02	7.86	4.06	.01	.56	.61	.39

* All corn received 245 kg/ha of 6-10.5-19.9 (N-P-K) as starter fertilizer in bands near row at planting. The first treatment received only 15 kg N/ha (13 lbs/a). The last two plots received additional nitrogen in the amount of 348 kg/ha (310 lbs/a).

@ According to soil tests will eliminate phosphorus as a factor in production.

Adequate fertility, both phosphorus and nitrogen, reduced runoff and the total amount of phosphorus lost. When an excess of phosphorus was applied losses were about 5 times greater on the no-till. Where the adequate treatment was added to the no-tilled plots the average phosphorus lost in runoff was .82 kg/ha [.73 lbs/a]. Where the starter fertilizer was the only treatment the phosphorus loss was 1.89 kg/ha [1.69 lbs/a]. Where conventional cultivation was practiced the losses were .23 kg/ha [.21 lbs/a] and .50 kg/ha [.44 lbs/a] respectively. Where the additional phosphate was applied the losses from the no-till land was nearly five times the amount, 4.06 as compared to .82 kg/ha [3.62 - .73 lbs/a]. Where the optimum treatment was applied on the cultivated land this extra fertilizer treatment showed average loss of .39 kg P/ha [.35 lbs/a]. Where treatment was according to soil test the average loss was .23 kg/ha [.21 lbs/a].

These measurements show that where the phosphorus in the soil is at a level to give optimum grain production of corn the amount of this element in the runoff was relatively small. The experiment also shows that phosphorus losses will be increased if application of the fertilizer is greater than plant requirements. Soil tests are a useful method to determine the amount of phosphorus needed to produce good yields without adding extra that may be lost from the land.

Available Phosphorus in Sediment

The phosphate ion in most agricultural soils is considered immobile since most is held by the colloidal complex with only a relatively small portion that can be extracted with water. Most laboratory methods of determining the quantity available to plants utilize extracting solutions, that through field correlations will show soil levels and probable response to added phosphorus. In the mid-continent area, with high exchange capacity soils, the weak Bray extracting solution (0.01 N NH_4F and .025 N-HCl) is commonly used (22) for determination of orthophosphate--the phosphate ion utilized by higher plants.

In this study the sediment in runoff water was removed by filteration and dried at room temperature. Laboratory analyses were made for available phosphorus on this sediment utilizing the weak Bray method and following the same procedure used on soil in determining need for fertilizer phosphorus. Table 13 gives the amount of phosphorus removed in three years from plots fertilized with three levels of phosphorus and where corn was grown with no-till or conventional management. The three levels of phosphorus are (a) starter fertilizer only (nitrogen levels were inadequate to sustain yields) (b) phosphorus and nitrogen applied at rates utilized by good farm managers. and (c) where an additional 98 kg/ha of P [200 lbs P_2O_5/a] was added.

As previously discussed, erosion losses were low in all of these three years when the land was protected by crop residues. The figures in Table 13 give a high value for phosphorus losses in sediment of .027 kg P/ha [.06 lbs./a P_2O_5/a] with a number of the samples containing only a trace.

All amounts are low, but with the exception of the corn receiving starter fertilizer only in 1971 with the no-till management, losses of phosphorus were higher at the lower rates of fertilization. This can be explained by the greater erosion losses with nutrient levels that do not permit vigorous growth. The excess phosphate fertilizer application did show an increase in phosphorus loss. However, the amount lost in these three seasons with below average rainfall is only a fraction of a percent of the extra phosphate applied. Although phosphorus is fixed on the soil the amount of loss in sediment is considerably less in this study than was lost in runoff, as previously discussed, with data presented in Table 12. These results are opposite to most textbook statements where most loss of phosphorus is in sediments. Much of the results reported in the literature is from bare soil. These results further demonstrate the effectiveness of

Table 13. Available Phosphorus* in Sediment Lost From Continuous Corn, Receiving Different Rates of Phosphate Fertilizer (kg/ha).

P Applied** (kg/ha)	No-Till			Conventional		
	1971	1972	1973	1971	1972	1973
21**	.012	.034	.003	.027	.011	.025
Soil Test **@	.009	Trace	Trace	.009	.011	.015
Soil Test **@ + 98	.016	.011	.008	.015	Trace	.016

* Soil material (sediment) with Bray's (weak) reagent. (0.01 NNH_4F and .025 N-HCl).

** All corn received 224 kg/ha of 6-10.5-19.9 (N-P-K) as starter fertilizer in bands near row at planting.

@ According to soil tests will eliminate phosphorus as a factor in production.

erosion control and vigorous plant growth to aid in preventing the loss of phosphorus from farm land. Although this excess of phosphorus did not have much effect on total loss in sediment from this land, it is still advisable that quantities of phosphorus amendments added should be no greater than the amount needed for good crop yields.

Pesticides in Runoff

The data given in Tables 14, 15 and 16 show the concentration and total amount of some pesticides in runoff water from specific events. Since rainfall was low in the period following application of these materials, many of the analyses were made on supplemental water applied with the sprinkler system. Had natural rainfall been the only source of moisture, runoff and pesticide loss would have been less. All materials were applied to corn and soybeans at rates recommended by manufactures. Applications to corn or soybeans were uniform over all plots for a single season. Dates of application (shown in footnotes of individual tables) varied with dates of planting, but in all years were in late April, May or early June. Most materials were applied as sprays. Plastic drag sheets were used to prevent drift. Effort was made to make applications during calm periods. Contamination is always a problem with small plots. It is possible that some of the high concentrations in low volumes of runoff soon after application could have been drift that settled on collection equipment. It is also possible that drift could account for the small quantities found in runoff from plots that did not receive treatments. Samples of runoff were collected from representative plots, and from runoff events when concentration of pesticides would be expected to be present in highest concentrations. The results given for 1971 and 1972 are of filtered water samples. In 1973 Aldrin and Dieldrin figures are for filtered water, while Lasso, Atrazine and Furadan were made on runoff that contained particles too small to settle after refrigerated storage.

Rainfall during the 6-8 week period following planting and application of herbicides was insufficient to cause much runoff. Sufficient water was added to all plots to prevent drouth damage. Because the possibility existed that there would be no storm events in this period after planting that would provide runoff from all treatments, supplemental water was added with the sprinkler system to provide runoff. The data for June 14 and July 19, 1971, June 21, 1972 and July 13, 1973 were from analysis of runoff water of this source--not rainfall. All determinations for pesticides in the water

Table 14. Pesticides in Runoff from a Claypan Soil, 1971 (Filtered Water).

Plot	Date	Crop Tillage Method	Runoff	ALDRIN		DIELDRIN		LASSO		ATRAZINE		FURADAN	
			cm	ppb	g/ha	ppb	g/ha	ppb	g/ha	ppb	g/ha	ppb	g/ha
4	6-14	Corn Conventional	.61	.05	.003	.56	.034	<15	< .90	51	3.11	373	22.76
4	7-19	" "	.69	<.02	<.001	1.07	.074	< 6	< .40	55	3.80	177	12.21
4	12-15	"	.10	<.02	<.001	.22	.002	< 6	< .06	50	.50	---	-----
5	6-14	Corn No-Till	.94	.03	.003	.49	.046			610	57.30	320	30.08
5	7-19	" "	.71	<.02	<.001	.35	.025			78	5.54	36	2.56
5	12-15	"	.46	<.02	<.001	.49	.023			50	2.30	---	-----
6	6-14		.99	.01	<.001	.50	.050			1290	127.71	248	24.55
6	7-19	"	3.10	<.02	<.006	1.20	.372			90	27.90	27	8.37
6	12-15	" "	1.04	<.02	<.002	.66	.069			50	.52	---	-----
15	6-14	Corn Conventional	.38	.06	.002	.68	.026			33	1.25	< 15	< .57
15	7-19	" "	.43	<.02	<.001	.62	.027			38	1.63	< 6	< .26
21	6-14	Corn No-Till	.89	.02	.002	.74	.066			< 15	< 1.33	328	29.19
21	7-19	" "	.56	<.02	<.001	.57	.032			32	1.79	47	2.63
28	6-14	Corn Conventional	.36	.02	.001	.29	.010			65	2.34	298	10.73
28	7-19	" "	1.17	.06	.007	1.55	.181			30	3.51	47	3.50
30	6-14	Corn Field Cultivator	.43	.13	.006	2.07	.089			45	1.94	498	21.41
30	7-19	" " "	1.17	.02	.002	1.25	.146			38	4.44	61	7.14
3	6-14	Soybeans Cover Crop	1.17	.02	.002	.28	.033	< 15	<1.75	< 15	< 1.75	< 15	<1.75
3	7-19	" " "	2.82	<.02	<.006	.48	.135	< 6	<1.69	48	13.54	< 6	<1.69
29	6-14	Soybeans Field Cultivator	.81	.02	.002	.61	.049	< 15	<1.21	< 15	< 1.21	< 15	<1.21
29	7-19	" " "	1.40	.03	.004	1.94	.272	< 6	< .84	6	< .84	< 6	< .84
36	6-14	Corn No-Till	1.47	.01	.001	.47	.069			12	1.76	< 15	<2.20
36	6-29	" "	.51	---	----	---	----			15	< .76	< 15	< .76
36	7-12	" "	.08	<.02	<.001	.53	.004			22	.17	< 15	< .12
36	7-15	"	.13	<.02	<.001	.79	.010			22	.29	< 15	< .19
36	7-19	" "	2.29	<.02	<.005	.47	.108			38	8.70	< 6	<1.37
31	7-12	Corn Silage	.28	<.02	<.001	.53	.015			22	.62	< 15	< .42

Corn: Aldrin @ 11.2 kg/ha (10 lbs/a of 20% material) 4-20; Atrazine @ 3.25 kg/ha (2.9 lbs/a 80% material) 5-5; and Furadan 11.2 kg/ha (10 lbs/a of 10% material), 6-2. No Lasso applied to corn in 1971.

Soybeans: Paraquat @ 2.9 l/ha (1.25 q/a) and Lasso 5.07 l/ha (2.17 qts/a), 5-18. Paraquat applied only to plot with rye cover. No Aldrin, Atrazine or Furadan applied to soybeans.

Table 15. Pesticides in Runoff from a Claypan Soil, 1972 (filtered water).

Plot	Date	Crop Tillage Method	Runoff cm	ALDRIN ppb	ALDRIN g/ha	DIELDRIN ppb	DIELDRIN g/ha	LASSO ppb	LASSO g/ha	ATRAZINE ppb	ATRAZINE g/ha	FURADAN ppb	FURADAN g/ha
6	5-15	Corn No-Till	.10	12.0	.12	0.1	---	1100	11.0	3100	31.0	ND	---
6	6-21	" "	3.30	1.4	.46	3.2	1.06	25	8.2	230	75.9	310	102.3
5	6-21	" "	3.25	1.5	.49	2.9	.94	20	6.5	230	74.7	290	94.2
21	6-21	" "	3.35	.8	.27	3.9	1.31	10	3.3	180	60.3	290	97.1
30	6-21	Corn Field Cultivator	.84	.7	.59	5.0	.42	10	.8	230	19.3	230	19.3
28	6-21	Corn Conventional	1.12	.9	.10	5.2	.58	40	4.5	250	28.0	290	32.5
4	6-21	" "	.71	1.0	.07	1.8	.13	35	2.5	500	35.5	310	22.0
15	6-21	" "	2.46	.8	.20	2.4	.59	40	9.8	350	86.1	230	56.6
3	6-21	Soybeans Winter Cover-Rye	2.08	2.6	.54	2.0	.42	ND	---	ND	---	ND	---
29	6-21	Soybeans Field Cultivator	1.80	1.2	.22	1.8	.32	30	5.4	ND	---	ND	---
36	6-21	Soybeans No-Till	.79	1.6	.13	2.8	.22	40	3.2	ND	---	ND	---
		Irrigation Water		ND	---	0.1	---	ND	---	ND	---	ND	---
		Minimum Detectable		0.1		0.1		5.0		25		100	

Corn: Aldrin @ 11.2 kg/ha (10 lbs/a of 20% material), 5-5; Atrazine @ 3.25 kg/ha (2.9 lbs/a of 80% of material) 5-10; and Lasso 5.07 l/ha (2.17 qts/a) 5-10 and Furadan 11.2 kg/ha (10 lbs/a of 10% material), 5-31.

Soybeans: Paraquat @ 2.9 l/ha (1.25 q/a) and Lasso 5.07 l/ha (2.17 qts/a) 5-18. Paraquat applied only to plot with rye cover. No Aldrin, Atrazine, or Furadan applied to soybeans.

Table 16. Pesticides in Runoff Water from a Claypan Soil, 1973.

Plot	Date	Crop Tillage Method	Runoff	ALDRIN*		DIELDRIN*		LASSO**		ATRAZINE**		FURADAN**	
			cm	ppb	g/ha	ppb	g/ha	ppb	g/ha	ppb	g/ha	ppb	g/ha
4	5-29	Corn Conventional	.33	ND	---	0.5	.016	250	8.25	875	28.9	ND	---
5	5-29	Corn No-Till	.64	ND	---	0.4	.025	360	23.04	1700	108.8	10	0.6
6	5-29	Corn No-Till	.64	ND	---	0.4	.025	230	14.49	1200	76.8	ND	---
15	5-29	Corn Conventional	.23	ND	---	0.5	.011	200	4.60	750	17.3	ND	---
21	5-29	Corn No-Till	.25	ND	---	0.5	.012	225	5.62	1300	32.5	10	0.2
28	5-29	Corn Conventional Field	.13	ND	---	0.5	.006	200	2.40	900	10.8	ND	---
30	5-29	Corn Cultivator	.03	ND	---	1.0	.003	180	0.54	700	2.1	ND	---
5	6-6	Corn No-Till	.05	ND	---	0.4	.002	80	0.48	850	4.3	10	0.5
6	6-6	Corn No-Till	.20	ND	---	0.6	.012	40	0.80	1100	22.0	ND	---
4	7-13	Corn Conventional	.79	ND	---	1.0	.079	5	0.40	250	19.7	600	47.4
5	7-13	Corn No-Till	4.85	ND	---	2.0	.970	10	4.85	140	67.9	300	145.5
6	7-13	Corn No-Till	2.18	ND	---	0.8	.174	20	4.36	240	52.3	340	74.1
15	7-13	Corn Conventional	4.75	ND	---	2.0	.950	20	9.50	170	80.6	340	161.5
21	7-13	Corn No-Till	3.53	ND	---	0.8	.282	ND	---	90	31.8	290	102.4
28	7-13	Corn Conventional Field	1.98	ND	---	2.0	.396	10	1.98	210	41.6	280	55.4
30	7-13	Corn Cultivator	3.91	ND	---	2.0	.782	10	3.90	190	74.3	600	234.6
36	5-29	Soybeans No-Till	.05	ND	---	ND	---	750	3.75	70	0.4	ND	---
3	7-13	Soybeans Winter Cover-Rye Field	3.53	ND	---	0.5	.176	8	2.82	210	74.1	ND	---
29	7-13	Soybeans Cultivator	2.74	ND	---	0.9	.247	40	10.96	190	52.1	ND	---
36	7-13	Soybeans No-Till	4.39	ND	---	0.7	.307	ND	---	20	8.8	ND	---
Minimum Detectable				0.2		0.4		5		5		10	

Determination on *Filtered Water, on **Unfiltered Water

Corn: Aldrin @ 11.2 kg/ha (10 lbs/a of 20% material) 5-14. Atrazine @ 3.25 kg/ha (2.9 lbs/a of 80% material) 5-17 and Lasso 5.07 l/ha (2.17 qts/a) 5.17 and Furadan 11.2 kg/ha (10 lbs/a of 10% material) 6-6.

Soybeans: Paraquat @ 2.9 l/ha (1.25 q/a) and Lasso 5.07 l/ha (2.17 qts/a) 5-23. Paraquat applied only to plot with rye cover. No Aldrin, Atrazine or Furadan applied to soybeans.

used for supplemental irrigation showed amounts below the limits of detectibility.

Aldrin

In 1971 the amount of Aldrin found in runoff occurring in June and July from corn plots was only slightly higher than from soil growing soybeans that had not received this compound. In all measurements the combined loss for two events was less than .01 g/ha. In 1972, .10 cm of runoff from plot 6 on May 15 (10 days after application) contained 10 ppb of Aldrin but this amounted to only .12 g/ha. The amount of Aldrin, in the runoff that occurred on June 21, 1972 was higher than in 1971. However, some of the corn plots showed lower total loss than did companion plots producing soybeans. Plot 3, growing soybeans in rye with the no-till system gave an Aldrin analysis in the runoff from June 21 of .54 g/ha, while all of the corn plots except 30 (field cultivator with a .59 g/ha loss) were lower. The only explanation for these small quantities showing Aldrin in runoff, where the compound was not applied, could be drift that settled on aprons of sampling devices.

In 1973 the amount of Aldrin in runoff samples collected in May, June and July were all below the level of detectibility.

Dieldrin

Dieldrin in low concentration, was present in all samples in all three years. The concentration ranged from .22 to 2.07 ppb in 1971. Total loss from a single runoff event for the corn plots sampled varied from .002 to .372 g/ha. This was the largest amount found. Plots 3 and 29, growing soybeans and receiving no Aldrin, showed detectable quantities of Dieldrin on both June 14 and July 19.

In 1972 the water collected on May 15 from plot 6 showed no Dieldin. The runoff on June 21, 1972 from the seven samples from the corn plots removed from .13 to 1.31 g/ha of Dieldin. Determinations for Dieldin in the 1973 season showed a range of .003 to .025 g/ha of Dieldin from the low volume runoff of May 29--15 days after application. On July 13 when runoff was greater, Dieldin lost in the runoff water from seven corn plots varied from a low of .079 to .970 g/ha.

Lasso

Lasso was applied only to soybeans in 1971, but to both corn and soybeans in 1972 and 1973. The determinations showed concentrations in runoff losses below the limits of determination by the laboratory. In 1972 the .10 cm of runoff from plot 6 on May 15 (Lasso applied May 10) contained 1100 ppb. which amounted to 11.0 g/ha. This high concentration in this small amount of runoff suggests contamination in addition to loss from soil. Determinations for Lasso were made from the runoff of 10 plots on June 21. Plots 6 and 15 lost the most, 8.2 and 9.8 g/ha respectively. The remaining plots lost smaller amounts, ranging down to .8 g/ha from plot 30 (corn-field cultivator) and none from plot 36 (soybeans-no-till). No Lasso was detected in the irrigation water. In 1973 samples collected on May 29 (six days after application) contained from 180 to 750 ppb of Lasso. Using the volume of runoff in the calculations the total loss ranged from .54 to 23.04 g/ha. Since the volume of runoff on this date was small this concentration could have resulted in a high level in a small stream or reservoir where the ratio of the watershed area to the receiving water was wide. Runoff was considerably higher from the July 13 water application in 1973. The concentration of Lasso in the runoff from this event was much lower, ranging from none (plots 21 and 36) to 40 ppb (plot 29). The largest loss on this date was 10.96 and 9.50 g/ha on plots 29 and 15 respectively.

Atrazine

Atrazine was found in the runoff water from most of the corn plots where this chemical was applied. Small quantities were detected in the runoff from soybeans (plots 3 and 29) receiving the application on July 19, but none on June 14 in 1971. None was detected in these same plots in 1972 but significant amounts were reported by the laboratory in 1973. No explanation is offered. In 1971 the runoff on June 14 from plot 6, growing corn with the no-till system, contained 1290 ppb (127.71 g/ha) in .99 cm of runoff. On the same date plot 5 with similar crop, and soil management had a value of 610 ppb (57.3 g/ha) from .94 cm of runoff. On all other samples collected in 1973 on June 14 or July 19 the concentrations ranged down from 90 ppb. The laboratory determinations of runoff occurring on December 15, 1971 on plots 4, 5 and 6 showed concentrations of Atrazine of 50 ppb. Since runoff from the no-till land (plots 5 and 6) was 4.6 and 10.4 times respectively that with conventional tillage (plot 4), there was greater loss from the land with minimum tillage. In 1972 the .10 cm of runoff that occurred, from plot 6 on May 15 (5 days after application) had a concentration of 3100 ppb, and amounted to 31.0 g/ha. On June 21 the 3.30 cm of runoff from plot 6 had a concentration of this chemical in the amount of 230 ppb, which was a loss of 75.9 g/ha. Some of the concentrations found from other plots on this date were higher, but with a lower volume of water loss, the total amount of chemical leaving the plots was less. Only plot 15 with a concentration of 350 ppb lost more than plot 6, 86.1 g/ha. The total loss of Atrazine from plot 6 on May 15 and June 21 was 106.9 g/ha. This would have been approximately 4.5 percent of the active ingredients applied. Plots 4, 28 and 30 showed smaller losses than did 5, 6, 15 and 21. However, this data would suggest when heavy runoff occurs soon after surface application of Atrazine that significant amounts could be lost to surface waters. The results obtained in 1973 are in general agreement with the findings in 1971 and 1972. It is evident that in runoff samples taken on May 29, 1973, six days after application, the concentration of Atrazine was high in the low volume of runoff. The greater amount of water loss on July 13 produced lower concentrations, but the total loss from the corn plots on this date ranged from 19.7 to 80.6 g/ha. Atrazine apparently is not as strongly adsorbed on these soil colloids as are some other pesticides. The residual effects of this chemical on fall seeded small grain following corn is well known.

Furadan

Furadan was applied on June 2 in 1971 at the rate of 11.2 kg/ha [10 lbs/a] of 10 percent active material. Analyses were made of runoff on June 14, July 19, and December 15. There are variations in losses between different plots. Concentration and total amount of this chemical lost was substantially higher when the runoff occurred on June 14 than when measurements were made in July. None of this material was detected in the December runoff. In 1972 none was detected in the irrigation water or in a sample collected from plot 6 on May 15, (Furadan applied May 31). Analyses made on runoff that occurred on June 21 contained from 230 to 310 ppb, with total loss from this event ranging from 19.3 to 102.3 g/ha. This would have been from 1.8 to 9.1 percent of the active ingredients applied. (According to the laboratory making the analyses the limit of accuracy would be about 0.9 percent of the applied material.) Analyses of runoff water in 1973 made before Furadan was applied showed only trace quantities present. The determinations made on runoff occurring July 13, following application on June 6 showed concentrations of 280 to 600 ppb. The total lost in runoff from individual areas during this one event ranged from 47.4 to 234.6 g/ha.

Pesticide Loss -- Summary

The amounts of these chemicals that were lost from corn and soybeans produced under practical farm management conditions in these three seasons are probably less than would occur in many seasons with above average amounts of precipitation. The rainfall and runoff in the 4-8 weeks after application of these chemicals was lower than occurs in many seasons. If supplemental water had not been applied the losses measured from both corn and soybeans in June and July would have been much smaller. It can be theorized that when rainfall is adequate in June and July the losses could be substantially greater than was found.

The amount of loss was associated with the volume of runoff. Management systems that will reduce water movement and loss would also lower the amount of these chemicals that are lost from fields. Where materials are adsorbed on the surface of soils colloids, the reduction of erosion would also be effective in limiting losses. It can be expected that the incorporation of these materials in the soil, rather than application to the surface, particularly if soil moisture is near field capacity, would reduce losses.

Atrazine was the only material used where the runoff in the fall months, after crop harvest, contained substantial amounts of the chemical.

These results are in general agreement with other studies (16, 28). These investigators worked with some different compounds, and on different soil types. There is evidence that soil properties including organic matter, pH and cation exchange capacity were regulating factors in the reactions between pesticides and soils. On the Ida silt loam (28) data was obtained where runoff was much heavier than was found in this study, and losses were much larger. The variation that have been obtained in these different conditions show that care should be exercised in forecasting losses under widely different soil conditons.

Although measurements are needed where summer rainfall is above normal these results do indicate that significant losses can occur when there is runoff soon after application. Both reduction in surface water pollution and economics in production can be effected by applying no more of these chemicals than is necessary for pest control.

SECTION VI

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SECTION VII

GLOSSARY

Banding of Fertilizers - Placing fertilizer separate from, and below, seed in bands at time of planting.

Bray's Strong Reagent - A soil extracting solution of 0.1N-HCl containing 0.03N-NH_4F. Removes phosphorus reserves from soil, not necessarily available to immediate crop.

Bray's Weak Reagent - A soil extracting solution of 0.025N HCl containing 0.03N-NH_4F. Removes phosphorus from soil that is considered active or available to crops.

Conventional Tillage - Land prepared by turning with a moldboard plow, discing, harrowing and cultivation of row crops (the long time method of corn and soybeans production in the mid-continent area).

Coshocton Wheel - A runoff sampler that divides the flow from an experimental area and retains a proportional part of it in a storage tank.

Fertilizer Formula - (as 6-24-24) Containing 6% nitrogen, 24% P_2O_5 and 24% K_2O. Also expressed on elemental basis as N-P-K (6-10.5-19.9). P_2O_5 is 43.7% P and K_2O is 83% K.

Field Tilled - Land prepared by tilling with a cultivator that does not invert the soil. Seed usually planted without further preparation. Weed control may be cultivaton or Herbicides.

Meadow - A mixture of adapted perennial grasses and legumes that provides thick ground cover. Harvested for hay in this investigation.

Minimum Tillage - System of row crop production where the least amount of seed bed preparation and cultivation is practiced.

Mixed Fertilizer - A fertilizer containing two or more essential elements.

Monoculture - Where a single crop is grown continuously on the same land without rotating or changing with other crops.

No-Till - System of row crop production where crop residues from previous years are chopped and remain on surface. Seed is planted through these residues with no additional land preparation. Weeds controlled by use of herbicides.

Starter Fertilizer - Usually a mixed fertilizer containing more than one element, that is placed near (but separate from) seed of row crops, that promotes early growth, but is usually insufficient for all of a crop's need.

SECTION VIII

APPENDICES

Runoff, Erosion, Nitrogen and Phosphorus Losses by Storms; Mexico Silt Loam, McCredie, Mo., 1971, 1972 and 1973.

Plot: 2 Crop: Meadow Tillage: None Starter: Fert. None kg/ha, N: 112 kg/ha

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Clean Date	Rain		Runoff Losses												Soil Losses		
				Nitrate-N			Ammonia N			Total N		Phosphate			acc	N	P
1971	Date	cm	cm	ppm	kg/ha	acc kg/ha	ppm	kg/ha	acc kg/ha	kg/ha	acc.N kg/ha	ppm	kg/ha	acc.P kg/ha	t/ha	kg/ha	kg/ha
1-4	1/2-3	3.30	1.12	.9	.10	.10	.54	.06	.06	.16	.16	.02	.003	.003			
2-4	2/3-4	2.90	.89	1.3	.12	.22	.54	.05	.11	.17	.33	.02	.003	.006			
2-26	2/21-22	1.93	.48	.7	.03	.25	.54	.03	.14	.06	.39	.02	.003	.009		(CLEAR)	
12-15	12/13-14	4.32	.02	T	T	.25	11.80	.03	.17	.03	.42	.10	T	.009			
12-30	12/29-30	2.05	.02	T	T	.25	10.80	.03	.20	.03	.45	.04	T	.009			
1972																	
2-14	2/8-10	snow	.36	3.7	.13	.13	1.34	.05	.05	.18	.18	2.25	.08	.08			
3-13	3/12-13	4.98	.69	13.4	.92	1.05	.97	.07	.12	.99	1.17	2.25	.15	.23			
3-16	3/14-15	1.90	.33	6.1	.20	1.25	.29	.01	.13	.21	1.38	2.18	.07	.30			
4-20	4/19	6.58	.61	.6	.04	1.29	.11	.01	.14	.05	1.43	.49	.03	.33			
4-24	4/20-21	1.29	.02	1.5	T	1.30	.17	T	.14	T	1.45	.07	T	.33			
5-1	4/30-5/1	2.56	.02	4.5	.01	1.31	24.50	.06	.20	.07	1.52	.07	T	.33		(CLEAR)	
11-14	11/12-13	snow	.23	.6	.01	1.32	.56	.01	.21	.02	1.54	.91	.02	.35			
12-12		snow	.08	1.3	.01	1.33	.04	T	.21	.02	1.56	.70	.01	.35			
12-22		snow	1.04	.8	.08	1.41	.10	.01	.22	.09	1.65	.77	.08	.43			
12-27		snow	.18	.2	T	1.42	.02	T	.22	T	1.67	.71	.01	.44			
1973																	
1-3	1/3	2.29	.69	.54	.04	.04	.06	T	.00	.05	.05	.54	.04	.04			
1-19	1/18	1.85	.43	.62	.03	.07	.11	T	.00	.04	.09	.60	.03	.07			
1-22	1/21-22	1.85	.89	.35	.03	.10	.28	.02	.02	.05	.14	.62	.06	.13			
2-2	2/1-2	1.40	.13	.38	.01	.11	.08	T	.02	T	.16	.58	.01	.14			
2-13	2/12	1.98	.33	.22	.01	.12	.24	.01	.03	.02	.18	.80	.03	.17			
3-7	3/4-7	6.78	4.93	2.20	1.88	1.19	.50	.25	.28	2.16	2.30	.44	.22	.39			
3-12	3/10-11	4.17	2.95	.48	.14	1.33	.13	.04	.32	.18	2.62	.30	.09	.48			
3-15	3/13-14	2.41	1.17	.52	.06	1.39	.14	.02	.34	.08	2.76	.15	.02	.50			
3-26	3/24-25	4.06	1.17	.40	.05	1.44	.15	.02	.36	.07	3.17	.21	.02	.52			
3-30	3/28-29	1.19	.03	.13	T	1.44	.05	T	.36	.02	3.17	.14	T	.53		(CLEAR)	
4-2	3/30-31	3.30	1.40	.17	.02	1.46	.10	.01	.37	.03	3.22	.06	.01	.54			
4-12	4/8-9	2.39	.46	.49	.02	1.48	.38	.02	.39	.04	3.28	.17	.01	.55			
4-17	4/14-16	3.18	.69	.24	.02	1.50	.04	T	.39	.03	2.33	.14	.01	.56			
7-23	7/20-21,22	8.86	.69	[illegible]	.13	1.63	.20	.01	.40	.14	2.60	.90	.06	.62			
7-24	7/23	3.07	1.09	1.85	.20	1.83	.20	.02	.42	.22	4.02	.68	.07	.69			
7-26	7/24	1.22	.10	1.85	.02	1.85	.20	T	.42	.03	4.06	.84	.01	.70			
10-15	10/12-13	3.73	.66	.63	.04	1.89	.31	.02	.44	.06	4.16	1.47	.10	.80			
11-27	11/24-26	3.76	.28	.37	.01	1.90	.12	T	.44	.02	4.18	1.13	.03	.82			
12-5	12/3-5	4.60	1.50	1.58	.24	2.14	.10	.02	.46	.26	4.68	.86	.13	.95			

Runoff, Erosion, Nitrogen and Phosphorus Losses by Storms; Mexico Silt Loam, McCredie, Mo., 1971, 1972 and 1973.

Plot: 4 Crop : corn Tillage : conventional Starter Fert: 6-10.5-19.9 @ 245 kg/ha, N: 148 kg/ha

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Clean Date	Rain		Runoff Losses												Soil Losses		
				Nitrate-N			Ammonia N			Total N		Phosphate				N	P
1971	Date	cm	cm	ppm	kg/ha	acc kg/ha	ppm	kg/ha	acc kg/ha	kg/ha	acc.N kg/ha	ppm	kg/ha	acc.P kg/ha	t/ha	kg/ha	kg/ha
1/4	1/2-3	3.30	1.32	1.20	.16	.16	.54	.07	.07	.22	.22	.003	T	T	---	---	---
2/4	2/3-4	2.90	1.19	1.70	.20	.36	.54	.07	.13	.27	.49	.003	T	T	---	---	---
2/26	2/21-22	1.93	.23	6.20	.15	.50	.54	.01	.15	.16	.65	.003	T	T	---	---	---
5/10	5/7-10	1.57	.30	1.40	.04	.54	.81	.02	.17	.07	.72	.018	.000	.000	.60	1.20	.005
5/12	5/11	2.67	.64	.90	.06	.60	.81	.04	.22	.11	.83	.010	.001	.001	.13	.50	.001
5/24	5/23-24	2.62	.36	1.7	.06	.66	1.09	.03	.26	.10	.93	.096	.003	.004	.22	.52	.002
6/15	6/14	2.54	.91	8.6	.53	1.19	3.26	.20	.46	.72	1.65	.061	.003	.007	1.00	2.07	.014
7/19	7/19	5.49	.69	19.0	1.30	2.48	1.19	.08	.53	1.39	3.01	.010	T	.010	.04	.09	.001
12/15	12/13-15	4.32	.10	2.5	.03	2.52	15.40	.16	.69	.18	3.21	.007	.000	.007	---	----	----
1972																	
3/13	3/12-13	4.98	.38	9.8	.37	.37	.74	.02	.02	.39	.39	1.02	.039	.039	---	---	---
3/16	3/14-15	1.90	.58	12.0	.71	1.08	.37	.02	.04	.73	1.12	.96	.056	.095	.02	.09	---
4/20	4/19	6.58	.51	51.0	2.59	3.66	36.13	1.84	1.88	4.42	5.54	.72	.036	.131	.02	.09	---
4/24	4/20-21	1.30	.20	40.0	.82	4.48	6.85	.13	2.03	.95	6.50	.42	.009	.14	.02	.06	---
5/1	4/30-5/1	2.57	T	21.9	---	---	4.83	---	2.03	---	---	.10	---	---	.02	.05	---
6/21	6/20	I	.71	80.0	5.69	10.17	2.7	.19	2.21	5.88	12.38	1.20	.085	.225	---	---	---
11/2	10/31	5.31	.56	6.7	.37	10.54	.16	.01	2.23	.38	12.76	.03	.001	.227	.02	.06	---
11/14	11/12-13	5.36	.99	1.6	.16	10.71	.13	.01	2.24	.17	12.92	.11	.011	.237	.02	.06	---
12/12	12/11	4.19	.18	1.55	.02	10.72	.22	.00	2.24	.02	12.95	.12	.002	.240	---	---	----
12/22	S	S	1.45	1.68	.25	10.96	.15	.02	2.26	.27	13.22	.23	.033	.273	---	---	---
12/30	S	S	.23	5.70	.13	11.09	.20	.00	2.27	.13	13.35	.41	.009	.282	---	---	---
																---	---
1973																	
1/3	1/3	2.29	.13	2.6	.03	.03	.07	T	T	.04	.04	.09	.00	.00	---	---	---
1/19	1/18	1.85	.66	6.0	.39	.42	.11	.01	.02	.40	.44	.14	.01	.01	.02	.05	---
1/22	1/21-22	1.85	.71	5.5	.39	.81	.13	.01	.03	.40	.84	.09	.01	.02	.02	.05	---
2/2	2/1-2	1.40	.41	5.5	.22	1.03	.07	T	.03	.22	1.06	.08	.00	.02	---	---	---
2/13	2/12-13	1.98	.15	6.4	.10	1.13	.42	.01	.04	.11	1.17	.16	.00	.02	---	---	---
2/14	2/12-13	1.98	.23	7.2	.16	1.29	.08	.00	.04	.16	1.33	.01	.00	.02	---	---	---
3/2	3/1-2	I	.10	12.2	.12	1.41	.16	.00	.04	.12	1.45	.10	.00	.02	---	---	---
3/7	3/4-7	6.78	2.24	2.4	.53	1.94	.11	.03	.07	.56	2.01	.27	.06	.08	.25	.73	---
3/12	3/10-11	4.17	3.05	.8	.25	2.19	.06	.02	.09	.27	2.28	.05	.02	.10	.36	1.05	---
3/15	3/13-14	2.41	1.42	.4	.06	2.25	.05	.01	.10	.07	2.35	.04	.01	.11	.16	.48	---
3/26	3/24-25	4.06	.94	1.5	.14	2.39	.13	.01	.11	.15	2.50	.04	.00	.11	.04	.12	---
3/30	3/28-29	1.14	.28	.4	.01	2.40	.05	.00	.11	.01	2.51	.03	.00	.11	.02	.05	---
4/2	3/30-31	3.30	1.35	.4	.05	2.45	.05	.01	.11	.05	2.56	.05	.01	.12	.07	.23	---
4/12	4/6-9	2.39	.89	1.3	.11	2.56	.18	.02	.13	.13	2.69	.04	.00	.12	.02	.05	---
4/17	4/14-16	3.18	1.02	.7	.07	2.63	.08	.01	.14	.08	2.77	.08	.01	.13	T	T	---
4/24	4/21-22	1.07	.15	2.7	.04	2.67	.15	T	.14	.04	2.81	.16	.00	.13	.02	.06	---
5/9	5/5-8	4.11	.33	40.0	1.32	3.99	2.10	.07	.21	1.39	4.20	.07	.00	.13	.04	.16	---
5/29	5/26-28	3.12	.33	46.0	1.52	5.51	2.40	.08	.29	1.60	5.80	.36	.01	.14	.04	.12	---
7/13	7/12	I	.79	1.8	.14	5.65	6.6	.52	.81	.66	6.46	.11	.01	.15	T	T	---
7/23	7/20-23	8.86	4.01	6.2	2.49	8.14	.6	.26	1.07	2.75	9.21	.10	.04	.19	.65	1.97	---
7/24	7/23	3.07	1.63	6.2	1.01	9.15	.6	.10	1.17	1.11	10.32	1.03	.17	.36	.18	.55	---
7/26	7/24	1.22	.66	6.2	.41	9.56	.6	.04	1.21	.45	10.77	.12	.01	.37	.07	.23	---
7/31	7/30	1.47	.25	1.1	.03	9.59	.2	.01	1.22	.04	10.81	.09	.00	.37	.04	.14	---
10/15	10/12-13	3.73	1.52	1.0	.15	9.74	.1	.01	1.23	.16	10.97	.08	.01	.38	.07	.19	---
10/31	10/30-31	1.42	.10	21.5	.22	9.96	.1	.00	1.23	.22	11.19	.09	T	.39	T	---	---
11/21	11/20-21	1.70	.23	.9	.02	9.98	.1	T	1.23	.02	11.21	.19	T		T	---	---
11/27	11/24-26	3.76	1.78	2.4	.42	10.40	.2	.01	1.23	.43	11.64	.04	.01		.07	---	---
12/5	12/3-5	4.60	1.45	4.7	.68	11.09	.1	.01	1.25	.69	12.34	.06	.01	.40	.09	.26	
12/24	12/18-19,23,24	2.46	.05	1.2	.01	11.10	.1	T	1.25	.01	12.35	.01	T	.40	----	---	

Runoff, Erosion, Nitrogen and Phosphorus Losses by Storms; Mexico Silt Loam, McCredie, Mo., 1971, 1972 and 1973.

Plot: 21 Crop: Corn Tillage: No-Till Starter Fert.: 6-10.5-19.9 @245kg/ha, N: 148 kg/ha

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Clean Date	Rain		Runoff Losses												Soil Losses		
				Nitrate-N			Ammonia N			Total N		Phosphate				N	P
1971	Date	cm	cm	ppm	kg/ha	acc kg/ha	ppm	kg/ha	acc kg/ha	kg/ha	acc.N kg/ha	ppm	kg/ha	acc.P kg/ha	t/ha	kg/ha	kg/ha
1/4	1/2-3	3.30	.86	.70	.06	.06	.54	.05	.05	.11	.11	.87	.08	.08			
2/5	2/3-4	2.90	1.30	3.10	.40	.46	.54	.07	.12	.47	.58	.87	.11	.19			
2/26	2/21-22	1.93	.48	7.9	.38	.84	.54	.03	.15	.41	.99	.87	.04	.23			
5/12	5/11	2.67	.74	30.5	2.25	3.09	3.80	.28	.43	2.53	3.52	.20	.02	.25	.02	.10	.001
6/15	6/14	2.54	.89	15.9	1.41	4.50	3.53	.31	.74	1.72	5.24	1.43	.13	.38	.07	.41	.004
7/20	7/19	5.49	.56	2.6	.15	4.65	1.78	.10	.84	.25	5.49	1.14	.06	.44			
12/15	12/13-15	4.32	.36	2.8	.10	4.75	8.8	.31	1.15	.41	5.90	.15	.01	.45			
1972																	
3/13	3/12-13	4.98	.76	9.2	.70	.70	.72	.06	.06	.76	.76	1.89	.14	.14			
3/16	3/14-15	1.91	.58	7.3	.43	1.13	.41	.02	.08	.45	1.21	1.75	.10	.24			
4/20	4/19	6.58	2.57	6.8	1.75	2.88	.06	.02	.10	1.77	2.98	.32	.08	.32	.09	.25	.001
4/24	4/20-21	1.30	.03	5.6	.01	2.89	13.12	.03	.13	.04	3.02	2.78	.01	.33			
5/1	4/30-5/1	2.57	.41	6.2	.25	3.14	6.41	.05	.18	.30	3.32	1.30	.05	.38	.02	.08	T
6/21	6/20	I	3.35	32.8	11.00	14.14	2.7	.91	1.09	11.91	15.23	2.35	.79	1.17			T
11/2	10/30	5.31	1.25	5.6	.70	14.84			1.09	.70	15.93	.63	.08	1.25			
11/4	11/12-13	5.36	1.80	3.1	.56	15.40	.18	.03	1.12	.59	16.52	1.28	.23	1.48			
12/12	12/11-12	4.19	.03	1.3	.00	15.40	.28	.00	1.12	.00	16.52	.51	.00	1.48			
12/22		SN	.69	.8	.06	15.46	.12	.01	1.13	.06	16.58	.69	.05	1.53			
12/30		SN	.15	5.3	.08	15.54	.38	.01	1.14	.08	16.66	.77	.01	1.54			
1973																	
1/3	1/3	2.29	.36	4.1	.15	.15	.21	.01	.01	.16	.16	1.30	.046	.046	—		
1/19	1/18	1.85	.66	5.0	.33	.48	.15	.01	.02	.34	.50	1.06	.070	.116			
1/22	1/21-22	1.85	.94	4.4	.41	.89	.09	.01	.03	.42	.92	1.00	.094	.210			
2/2	2/1-2	1.40	.15	5.2	.08	.97	.06	T	.03	.08	1.00	.99	.015	.225			
2/13	2/12-13	1.98	T	T	T	.97	T	T	.03	T	1.00	T	T	.225			
2/14	2/12-13	1.98	.02	T	T	.97	T	T	.03	T	1.00	T	T	.225			
3/7	3/4-7	6.78	6.43	1.1	.73	1.70	.07	.04	.07	.77	1.77	.76	.489	.714			
3/12	3/10-11	4.17	3.61	.5	.18	1.88	.08	.03	.10	.21	1.97	.65	.235	.948	.13	.389	.001
3/15	3/13-14	2.41	1.50	.8	.12	2.00	.09	.01	.11	.13	2.11	.48	.072	1.020			
3/26	3/24-25	4.06	1.80	.9	.16	2.16	.08	.01	.13	.18	2.28	.78	.141	1.161			
3/30	3/28-29	1.19	.03	1.4	T	2.16	.05	T	.12	T	2.28	.44	.001	1.162			
4/2	3/30-31	3.30	1.75	1.4	.25	2.41	.05	.01	.13	.26	2.54	.76	.133	1.295			
4/12	4/8-9	2.39	.56	2.7	.15	2.56	.06	T	.13	.16	2.70	.63	.035	1.331			
4/17	4/14-16	3.18	.86	1.4	.12	2.68	.06	.01	.14	.13	2.82	.34	.029	1.360			
5/9	5/5-8	4.11	.76	3.1	.23	2.91	.90	.07	.21	.30	3.12	.86	.066	1.425	.04	.11	.0004
5/29	5/26-28	3.12	.25	38.0	.97	3.88	14.00	.36	.57	1.33	4.45	3.71	.094	1.520	.02	.06	.0003
7/13	7/12	I	3.53	7.4	2.61	6.49	.72	.25	.57	2.86	7.31	1.23	.435	1.955			
7/24	7/20-23	11.94	5.03	2.5	1.26	7.75	.12	.06	.82	1.31	8.64	.75	.378	2.332	.27	.84	.0037
7/26	7/24	1.22	.46	2.5	.11	7.86	.12	.01	.88	.12	8.75	.57	.026	2.358			
10/15	10/12-13	3.73	1.65	7.4	1.22	9.08	.13	.02	.89	1.24	9.99	.80	.133	2.491			
11/21	11/20-21	1.70	.03	4.1	.01	9.09	.03	T	.91	.01	10.00	.82	.002	2.494			
11/27	11/24-26	3.76	1.83	3.9	.71	9.80	.02	T	.91	.72	10.72	.71	.130	2.624			
12/5	12/3-5	4.60	1.91	4.6	.88	10.68	.06	.20	1.11	1.08	11.79	1.22	.232	2.856			
12/24	12/18 19 23 24	2.46	.20	.4	.01	10.69	.20	T	1.11	.01	11.80	.71	.015	2.871			

Runoff, Erosion, Nitrogen and Phosphorus Losses by Storms; Mexico Silt Loam, McCredie, Mo., 1971, 1972 and 1973.

Plot: 29 , Crop: Soybeans , Tillage: Field Cult. , Starter Fert. 6-10.5-19.9 @ 245 kg/ha , N: None kg/ha

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Clean Date	Rain		Runoff Losses												Soil Losses		
				Nitrate-N			Ammonia N			Total N		Phosphate				N	P
	Date	cm	cm	ppm	kg/ha	acc kg/ha	ppm	kg/ha	acc kg/ha	kg/ha	acc N kg/ha	ppm	kg/ha	acc P kg/ha	t/ha	kg/ha	kg/ha
1971																	
1/4	1/2-3	3.30	1.45	.47	.07	.07	1.09	.16	.16	.22	.22	.02	.002	.002			
2/5	2/3-4	2.90	1.40	3.40	.47	.54	1.09	.16	.32	.63	.85	.02	.002	.006			
2/26	2/21-22	1.93	.51	8.70	.44	.98	1.09	.06	.38	.49	1.34	.02	.001	.006			
5/13	5/11	2.68	.53	1.70	.09	1.07	.81	.04	.42	.13	1.47	.45	.025	.030			
6/15	6/14	2.54	.81	10.80	.87	1.94	6.25	.50	.92	1.39	2.86	.18	.014	.044	.25	.76	.007
7/20	7/20	6.73	1.40	6.90	.96	2.90	1.19	.17	1.09	1.13	3.99	.66	.093	.138			
12/15	12/13-15	4.32	.36	2.20	.08	2.98	12.60	.45	1.54	.53	4.52	.01	T	.139	.02	.09	.001
12/30	12/29-30	2.06	.05	3.40	.01	2.99	3.70	.02	1.56	.03	4.55	.00	T	.139			
1972																	
3/13	3/12-13	4.98	.46	10.30	.47	.47	3.86	.18	.18	.65	.65	.77	.035	.035	.07	.19	.003
3/16	3/14-15	1.91	.74	8.30	.62	1.09	1.82	.13	.31	.75	1.40	.77	.057	.092	.13	.40	.006
4/21	4/19-21	7.34	1.25	4.60	.57	1.66	4.49	.56	.87	1.13	2.53	.30	.037	.129	.20	.64	.010
4/24	4/21	.53	.24	3.80	.10	1.76	1.47	.03	.90	.13	2.66	.07	.002	.131	.02	.06	.001
5/1	4/30-5/1	2.57	.43	2.40	.10	1.86	3.09	.13	1.03	.24	2.90	.40	.017	.148	.02	.09	.002
6/22	6/21	I	1.80	26.90	4.85	6.71	4.00	.72	1.75	5.57	8.47	.52	.094	.242	.09	.25	.003
11/2	10/31	5.31	.94	2.32	.21	6.92		---	1.76	.21	8.68	.27	.026	.268	.07	.23	.004
11/14	11/12-13	5.36	1.80	.27	.04	6.96	.08	.01	1.76	.06	8.74	.32	.057	.325	.16	.46	.007
12/12	12/11-12	4.19	.38	1.50	.06	7.02	.13	.00	1.76	.06	8.80	.27	.010	.336			
12/22		SN	1.50	.92	.13	7.15	.22	.03	1.79	.17	8.97	.46	.068	.404			
12/26		SN	.43	.48	.02	7.17	.05	.00	1.79	.02	8.99	.53	.022	.428			
12/27		SN	.46	.18	.01	7.18	.35	.01	1.80	.02	9.01	.48	.022	.449			
12/29		SN	.28	.53	.01	7.19	1.60	.04	1.84	.06	9.07	.14	.003	.452			
1973																	
1/3	1/3	2.29	.25	.68	.02	.02	.08	.00	.00	.02	.02	.22	.01	.01	---	---	
1/19	1/18	1.85	.28	2.72	.08	.10	.26	.01	.01	.09	.11	.25	.01	.02	.02	.08	
1/22	1/21-22	1.85	.91	1.90	.17	.27	.14	.01	.02	.18	.29	.18	.02	.04	.16	.46	
2/2	2/1-2	1.40	.71	---	---	.27	---	---	.02	---	.29	---	---	.04	.02	.08	
2/13	2/12-13	1.98	.02	8.20	.02	.29	.66	T	.02	.02	.31	.25	T	.04	---	---	
2/14	2/12-13	1.98	.10	---	---	.29	---	---	.02	---	.31	---	---	.04	---	---	
3/7	3/4-7	6.78	3.00	1.29	.39	.68	.18	.05	.07	.44	.75	.08	.02	.06	.45	1.36	.006
3/12	3/10-11	4.17	3.86	.37	.14	.82	.11	.04	.11	.18	.93	.12	.05	.11	.67	2.01	.004
3/15	3/13-14	2.41	1.88	.41	.08	.90	.32	.06	.17	.14	1.07	.16	.03	.14	.52	1.53	.003
3/26	3/24-25	4.06	1.40	.64	.09	.99	.16	.02	.19	.11	1.18	.11	.02	.16	.09	.26	
3/30	3/28-29	1.19	.36	.01	.00	.99	.04	T	.19	T	1.18	.12	T	.16	T	.03	
4/2	3/30-31	3.30	1.91	.01	.00	.99	.04	.01	.20	.01	1.19	.24	.05	.21	.22	.65	
4/12	4/8-9	2.39	1.02	1.38	.14	1.13	.09	.01	.21	.15	1.34	.09	.01	.22	.02	.05	
4/17	4/14-16	3.18	.79	.32	.03	1.16	.11	.01	.22	.04	1.38	.04	T	.22	.02	.09	
4/24	4/21-22	1.07	.13	.66	.01	1.17	.03	T	.22	.01	1.39	.26	T	.22	T	.03	
5/9	5/5-8	4.11	.71	1.20	.09	1.26	.05	T	.22	.09	1.48	.22	.02	.24	---	---	
7/16	7/13	I	2.74	20.00	5.49	6.75	.19	.05	.27	5.54	7.02	.42	.12	.36	.11	.36	
7/26	7/20-23, 24	13.16	4.17	10.00	4.17	10.92	.18	.08	.35	4.25	11.27	.31	.13	.49	.49	1.50	.005
7/31	7/30	1.47	.13	1.42	.02	10.94	.15	T	.35	.02	11.29	.27	T	.49	T	.03	
10/15	10/12-13	3.73	1.17	7.10	.83	11.77	.32	.04	.39	.87	12.16	.65	.08	.57	---	---	
11/21	11/20-21	1.70	.10	1.25	.01	11.78	.36	.04	.43	.05	12.21	1.56	.02	.59	T	.02	
11/27	11/24-26	3.76	1.25	1.08	.13	11.91	.08	.01	.44	.14	12.35	.55	.07	.66	.04	.14	
12/5	12/3-5	4.60	2.77	1.52	.42	12.33	.13	.31	.75	.73	13.08	.55	.15	.81	.09	.28	
12/24	12/18, 19, 23, 24	2.46	.28	1.46	.04	12.37	.56	.02	.77	.06	13.14	.89	.09	.90	---	---	

Runoff, Erosion, Nitrogen and Phosphorus Losses by Storms; Mexico Silt Loam, McCredie, Mo., 1971, and 1972

Plot: 31   Crop: Corn   Tillage: No till silage   Starter Fert: 6-10.5-19.9 @ 245 kg/ha.   N: 168 kg/ha

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Clean Date	Rain		Runoff Losses												Soil Losses		
				Nitrate-N			Ammonia N			Total N		Phosphate				N	P
1971	Date	cm	cm	ppm	kg/ha	acc kg/ha	ppm	kg/ha	acc kg/ha	kg/ha	acc.N kg/ha	ppm	kg/ha	acc.P kg/ha	t/ha	kg/ha	kg/ha
1/4	1/2-3	3.30	.81	.22	.02	.02	.54	.04	.04	.06	.06	.003	.000	.000	.12	.33	.002
2/5	2/3-4	2.90	1.42	1.40	.20	.21	.54	.08	.12	.28	.34	.003	.000	.001	.38	1.24	.008
2/26	2/21-22	1.93	1.01	6.80	.69	.91	.54	.06	.18	.75	1.09	.003	.000	.001	.09	.27	.002
5/11	5/7-10	1.65	.41	1.80	.07	.99	3.80	.16	.32	.22	1.31	.031	.001	.002	1.57	4.71	.032
5/13	5/11	2.67	.79	2.20	.17	1.15	1.48	.11	.45	.29	1.60	.050	.003	.006	.22	.66	.00
5/24	5/23-24	2.62	.64	2.14	.13	1.29	1.63	.10	.55	.24	1.84	.189	.012	.018	.78	2.35	.016
6/10	6/10	1.04	.10	7.8	.08	1.37	8.15	.08	.63	.16	2.00	.175	.002	.020	.07	.21	.002
6/14	6/12	1.02	.05	7.8	.03	1.41	6.25	.03	.66	.07	2.07	.005	T	.020	.04	.15	.002
6/14	6/14 B	1.09	.74	1.8	.13	1.55	6.25	.46	1.12	.59	2.67	.005	.000	.020	.09	.27	.003
6/15	6/14	2.54	1.47	4.7	.69	2.24	2.72	.40	1.52	1.10	3.76	.005	.001	.021	2.29	6.84	.038
7/12	7/9	1.35	.28	1.6	.04	2.27	1.63	.04	1.57	.09	3.85	.096	.002	.024	.04	.12	.001
7/15	7/14-15	1.83	.25	1.4	.03	2.32	1.09	.02	1.60	.07	3.90	.035	.001	.025	.04	.12	.001
7/20	7/20	6.73	.89	.79	.07	2.39	1.19	.10	1.70	.18	4.08	.096	.009	.034	---	---	---
8/11	8/10	1.68	.08	2.1	.01	2.40	1.20	.01	1.71	.02	4.11	.067	.000	.034	T	.0	T
9/16	9/15-16	1.40	.13	1.4	.01	2.42	1.20	.01	1.72	.03	4.14	.067	.001	.035	.12	.34	.003
10/4	12/2-3	1.63	.05	1.9	.01	2.43	56.20	.28	2.01	.29	4.45	.054	.000	.035	T	.03	T
10/20	12/19-20	2.11	.13	3.2	.04	2.46	.00	---	---	.04	4.48	.096	.001	.036	.02	.07	
11/2	11/1	.97	.28	3.5	.13	2.56	.00	---	---	.10	4.58	.101	.002	.039	.34	1.0	.009
12/6	S.M.	1.78	.13	1.8	.02	2.59	44.80	.57	2.59	.59	5.17	.000	---	---	T	.03	
12/10	12/9-10	3.30	.76	.31	.02	2.61	2.00	.16	2.73	.18	5.35	.025	.002	.040	.13	.40	.003
12/15	12/13-15	4.32	2.13	.30	.07	2.68	.54	.11	2.85	.18	5.53	.000	---	---	.99	2.99	.026
12/30	12/29-30	2.06	1.14	.10	.01	2.69	3.40	.39	3.24	.40	5.92	.031	.003	.045	1.18	3.57	.030
1972																	
2/14	2/8-12	S.N.	.58	4.80	.28	.28	1.0	.06	.06	.34	.34	1.80	.069	.069	.04	.14	.002
3/13	3/12-13	4.98	1.79	.58			.14	.02	.08	.12	.46	1.80	.209	.279	4.73	14.20	.171
3/16	3/14-15	1.91	.89	.98	.09	.47	.45	.03	.12	.12	.58	.99	.088	.367	2.58	7.71	.093
4/21	4/19-21	7.34	3.81	1.30			.05	.02	.15	.52	1.10	.31	.105	.474	14.8	44.39	.536
4/24	4/21	.53	.43	.94	.04	1.0	1.22	.06	.19	.10	1.31	.56	.025	.497	2.44	7.33	.088
5/1	4/30-5/1	2.57	1.35	2.70	.36	1.37	.52	.07	.27	.43	1.73	.31	.041	.539	1.86	5.61	.068
5/15	5/12-13	2.36	.13	20.00	.26	1.62	4.00	.04	.31	.30	2.04	.01	.000	.539	.16	.48	.006
5/30	5/28-29	2.01	.08	12.30	.09	1.71	3.50	.02	.33	.11	2.03	.08	.000	.539	.07	.19	.002
6/22	6/21	I	2.39	5.60	.75	2.48	3.00	.40	.75	1.15	3.19	.08	.019	.559	.16	.50	.006
7/19	7/18	3.02	.74	.64	.04	2.52	3.00	.22	.96	.27	3.57	.20	.015	.575	.27	.82	.014
7/25	7/24	I	.64	2.80	.18	2.70	2.70	.17	1.14	.35	3.92	.02	.001	.576	---	-----	-----
9/1	9/1	2.29	1.27	2.70	.35	3.03	4.50	.57	1.71	.92	4.72	.45	.057	.633	.02	.05	.001
9/8	9/7	4.83	2.44	2.50	.60	3.65	3.00	.73	2.44	1.33	6.06	.24	.058	.691	.40	.09	.002
9/14	9/13	2.62	1.02	2.20	.22	3.87	1.60	.16	2.61	.38	6.44	.30	.030	.721	.02	.05	.001
9/21	9/20	2.51	.81	3.75	.30	4.17	1.80	.15	2.76	.45	6.89	.26	.021	.743	2.44	7.32	.072
10/24	10/21	4.37	1.40	1.18	.52	4.69	.86	.37	3.12	.52	7.41	.21	.029	.772	1.70	5.11	.059
11/2	10/31	5.31	4.34	.76	.32	5.01	.03	.01	3.14	.34	7.75	.09	.038	.811	1.30	3.89	.045
11/10	11/9	1.14	.36	12.00	.43	5.44	.03	T	3.14	.43	8.18	.37	.013	.824	.07	.23	.003
11/14	11/12-13	5.36	2.69	.10	.02	5.48	.16	.04	3.18	.07	8.25	.10	.026	.851	.94	2.82	.032
12/12	12/11	4.19	.64	.91	.06	5.53	.17	.01	3.19	.07	8.32	.03	.002	.852	-----	-----	-----
12/22	12/15	.43	.76	1.11	.08	5.62	.16	.01	3.20	.09	8.41	.07	.004	.858	-----	-----	-----
12/23	"	S.N.	.43	.52	.02	5.64	.50	.02	3.22	.04	8.45	.02	.001	.859	-----	-----	-----
12/27	"	S.N.	.76	1.12	.09	5.72	.85	.07	3.29	.16	8.60	.12	.009	.868	.13	.39	.005
12/29	"	S.N.	.15	2.29	.03	5.75	.50	.01	3.30	.04	8.64	.06	.001	.869	-----	-----	-----
12/30	"	S.N.	.13	2.92	.03	5.80	.25	T	3.30	.03	8.68	.14	.002	.871	-----	-----	-----

Runoff, Erosion, Nitrogen and Phosphorus Losses by Storms; Mexico Silt Loam, McCredie, Mo., 1973

Plot 31 Crop Corn Tillage No till silage Starter Fert. 6-10.5-19.9 @ 245 kg/ha N: 168 kg/ha

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Clean Date	Rain		Runoff Losses												Soil Losses		
				Nitrate-N			Ammonia N			Total N		Phosphate			acc	N	P
	Date	cm	cm	ppm	kg/ha	acc kg/ha	ppm	kg/ha	acc kg/ha	kg/ha	acc N kg/ha	ppm	kg/ha	acc P kg/ha	t/ha	kg/ha	kg/ha
1973																	
1/3	1/3	2.29	2.39	1.35	.32	.32	.170	.04	.04	.36	.36	.01	.002	.002	.16	.48	-----
1/17	I	I	.05	10.4	.05	.37	.475	T	.04	.05	.41	.01	---	.002	T	.01	-----
1/19	1/18	1.85	.48	.30	.01	.38	.068	T	.04	.01	.42	.14	.007	.009	.07	.23	-----
1/22	1/21-22	1.85	.91	.98	.09	.47	.127	.01	.05	.10	.52	.07	.006	.015	.29	.88	-----
2/2	2/1-2	1.35	1.12	3.25	.36	.83	.70	.08	.13	.44	.96	.09	.010	.025	.72	2.17	-----
2/13	2/12-13	1.98	1.70	6.4	1.09	1.92	.26	.04	.17	1.13	2.09	.06	.010	.035	1.16	3.48	-----
2/21	2/18-19	.20	.15	22.0	.34	2.26	.32	T	.17	.34	2.43	.01	.000	.035	---	-----	-----
3/2	3/1-2	I	.10	9.4	.10	2.36	.28	T	.17	.10	2.53	---	---	.035	.02	.07	-----
3/7	3/4-7	6.78	5.69	4.2	2.39	4.75	.023	.01	.18	2.40	4.93	.14	.08	.115	11.07	33.22	.060
3/12	3/10-11	4.17	8.05	2.39	1.93	6.68	.097	.08	.26	2.01	6.94	.10	.081	.196	6.97	20.88	.030
3/15	3/13-14	2.41	1.17	1.50	.18	6.86	.37	.04	.30	.22	7.16	.05	.006	.202	6.91	20.72	.055
3/26	3/24-25	4.06	1.85	1.34	.25	7.11	.16	.03	.33	.28	7.44	.06	.011	.213	1.34	4.04	-----
3/30	2/28-29	1.19	.56	.16	.01	7.12	.08	T	.33	.01	7.45	.06	.003	.216	.13	.37	-----
4/2	3/30-31	3.30	1.42	.16	.02	7.14	.08	.01	.34	.03	7.48	.07	.010	.226	2.67	8.01	-----
4/12	4/8-9	2.39	1.12	2.85	.32	7.46	.175	.02	.36	.34	7.82	.03	.003	.229	.34	1.02	-----
4/17	4/14-16	3.18	1.42	3.00	.43	7.89	.145	.02	.38	.45	8.27	.05	.007	.236	.58	1.73	.003
4/20	4/19	.30	.13	11.00	.14	8.03	.24	T	.38	.14	8.41	.06	.001	.237	.02	.05	-----
4/24	4/21-22	1.07	.69	3.95	.27	8.30	.24	.02	.40	.29	8.70	.09	.006	.243	.58	1.73	-----
5/2	5/1	1.30	.36	5.20	.19	8.49	.024	T	.40	.19	8.89	.06	.002	.245	.46	1.38	.002
5/9	5/5-8	4.11	1.40	1.10	.15	8.64	.15	.02	.42	.17	9.06	.08	.011	.256	1.01	3.05	.005
5/10	5/10	.46	.20	6.00	.12	8.76	.42	.01	.43	.13	9.19	.07	.002	.258	.22	.68	-----
5/30	5/26-28	3.12	.61	10.30	.63	9.39	4.5	.27	.70	.90	10.09	.17	.010	.268	.40	1.22	.004
6/6	6/4-5	1.78	.10	7.61	.08	9.47	2.46	.02	.72	.10	10.19	.13	.001	.269	.04	.13	-----
7/16	7/13	I	1.14	4.6	.53	10.00	.175	.02	.74	.55	10.74	.10	.011	.280	.07	.21	-----
7/26	7/20-21-23-24	13.16	6.60	1.0	.66	10.66	.25	.17	.91	.83	11.57	.04	.023	.303	3.43	10.30	.020
7/30	7/29	1.68	.41	1.2	.05	10.71	.073	T	.91	.05	11.62	.26	.011	.314	.09	.25	T
7/31	7/30	1.47	.66	1.06	.07	10.78	.172	.01	.92	.08	11.70	.42	.028	.342	.20	.62	T
9/10	9/8-9	2.89	.61	1.02	.06	10.84	.148	.01	.93	.07	11.77	.09	.006	.348	.11	.31	T
9/24	9/23	2.26	.97	2.48	.24	11.08	.47	.05	.98	.29	12.06	.11	.011	.359	.36	1.10	-----
10/1	9/28-30	2.13	.71	1.02	.07	11.15	1.03	.07	1.05	.14	12.20	.40	.029	.388	.36	1.12	.035
10/4	10/3-4	1.93	.74	1.4	.10	11.25	.31	.02	1.07	.12	12.32	.29	.021	.409	.16	.48	.019
10/15	10/12-13	3.73	2.01	8.8	1.77	13.02	.08	.02	1.09	1.79	14.11	.07	.14	.413	.36	1.10	-----
10/31	10/30-31	1.42	.05	1.1	.01	13.03	.10	T	1.09	.01	14.12	.13	.001	.424	-----	-----	-----
11/21	11/20-21	1.70	.28	.40	.01	13.04	.25	.01	1.10	.02	14.14	.11	.003	.427	.07	.21	-----
11/27	11/24-26	3.76	1.04	.49	.05	13.09	.17	.02	1.12	.07	14.21	1.00	.104	.531	.13	.37	-----
12/5	12/3-5	4.60	1.93	2.52	.48	13.57	.008	.34	1.46	.82	15.03	.01	.003	.534	.27	.84	-----
12/24	12-18	2.44	.33	2.18	.07	13.64	.470	.02	1.48	.09	15.12	.37	.109	.643	-----	-----	-----
12/25	M.S.	M.S.	.15	----	-----	13.64	-----	----	1.48	----	15.12	----	-----	.643	-----	-----	-----

Runoff, Erosion, Nitrogen and Phosphorus Losses by Storms; Mexico Silt Loam, McCredie, Mo., 1971, 1972 and 1973.

Plot: 32 Crop. Corn Tillage: No till silage Starter Fert: 6-10.5-19.9 @ 245 kg/ha. N: 201 kg/ha

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Clean Date	Rain		Runoff Losses												Soil Losses		
				Nitrate-N			Ammonia N			Total N		Phosphate				N	P
	Date	cm	cm	ppm	kg/ha	acc kg/ha	ppm	kg/ha	acc kg/ha	kg/ha	acc.N kg/ha	ppm	kg/ha	acc.P kg/ha	t/ha	kg/ha	kg/ha
1971																	
1/4	1/2-3	3.30	.81	2.5	.20	.20	.54	.04	.04	.25	.25	.003	.000	.000	---	---	---
2/5	2/3-4	2.90	1.14	2.8	.18	.38	.54	.06	.10	.25	.50	.003	.000	.000	---	---	---
2/26	2/21-22	1.93	.79	2.1	.17	.55	.54	.04	.14	.20	.70	.003	.000	.001	---	---	---
6/15	6/14	2.54	.51	4.6	.24	.78	2.99	.15	.29	.38	1.08	.944	.048	.048	.13	.37	.004
7/20	7/20	6.73	1.17	4.1	.48	1.27	1.78	.20	.49	.68	1.76	.929	.109	.157	---	---	---
12/15	12/13-15	4.32	.03	4.1	.01	1.28	16.10	.04	.53	.04	1.80	.149	.000	.158	---	---	---
1972																	
2/14	2/8-12	S.M.	.05	5.7	.03	.03	3.00	.01	.01	.04	.04	1.05	.006	.006	---	---	---
3/13	3/12-13	4.98	.03	3.8	.01	.03	2.69	.01	.02	.02	.06	1.05	.002	.008	---	---	---
3/16	3/14-15	1.91	.18	1.3	.02	.06	.41	.01	.03	.03	.09	2.06	.036	.044	.05	.12	.002
4/21	4/19-21	7.34	.15	1.1	.01	.08	.09	T	.03	.01	.10	.75	.011	.056	T	.03	T
4/24	4/21	.53	.08	1.0	.01	.09	.24	.00	.03	.01	.11	.86	.007	.062	---	---	---
5/1	4/20-5/1	2.57	.13	2.3	.03	.11	1.44	.02	.05	.06	.17	.98	.012	.075	.02	.06	.001
6/22	6/21	I	1.52	53.5	8.15	8.26	4.80	.73	.78	8.88	9.05	.64	.097	.172	---	---	---
9/8	9/7	4.83	.08	5.8	.04	8.31	4.00	.03	.81	.08	9.13	2.50	.019	.191	T	T	---
9/14	9/13	2.62	.05	3.5	.01	8.33	1.70	.01	.82	.02	9.15	1.12	.006	.197	T	T	---
9/21	9/20	2.51	.05	5.3	.02	8.36	2.70	.01	.83	.03	9.18	1.00	.004	.202	.02	.08	.001
11/14	11/12-13	5.36	.36	.84	.03	8.39	.30	.01	.85	.03	9.21	.87	.031	.233	---	---	---
12/12	12/11-12	4.19	.10	1.17	.01	8.42	.17	T	.85	.01	9.22	.56	.006	.239			
12/22		SN	.76	1.17	.09	8.49	.50	.03	.88	.12	9.34	.36	.026	.267			
12/27		SN	.15	.35	.00	8.50	1.05	.01	.89	.01	9.35	.29	.004	.271			
12/30		SN	.08	1.55	.01	8.51	1.12	.01	.90	.02	9.37	.68	.006	.276			
1973																	
1/3	1/3	2.29	.30	1.50	.043	.049	.59	.018	.018	.061	.061	.49	.015	.015			
1/19	1/18	1.85	.41	1.30	.053	.102	.44	.018	.036	.071	.132	.97	.039	.054			
1/22	1/21-22	1.85	.99	1.18	.117	.219	.26	.026	.062	.143	.275	.60	.060	.114			
2/2	2/1-2	1.40	.51	1.98	.101	.319	1.60	.081	.143	.182	.457	.70	.036	.150			
2/13	2/12-13	1.98	.51	7.80	.396	.716	.75	.038	.181	.434	.891	.51	.026	.176			
2/14	2/12-13	1.98	.13	---	---	.716	---	---	.181	.897	---	---	---	.176			
3/7	3/4-7	6.78	2.84	.60	.171	.887	.30	.085	.266	.256	1.147	.59	.168	.344	.16	.48	.002
3/12	3/10-11	4.17	3.20	.365	.117	1.003	.12	.038	.304	.155	1.302	.34	.109	.453	.16	.45	.001
3/15	3/13-14	2.41	1.65	.42	.069	1.073	.27	.045	.349	.114	1.416	.31	.051	.504	.11	.31	.001
3/26	3/24-25	4.06	1.42	.22	.031	1.104	.14	.020	.369	.051	1.467	.27	.038	.542			
3/30	3/28-29	1.19	.10	1.65	.017	1.121	.10	.001	.370	.018	1.485	.22	.002	.544			
4/2	3/30-31	3.30	1.75	1.65	.289	1.410	.10	.018	.388	.302	1.792	.31	.054	.598			
4/12	4/8-9	2.34	.28	1.45	.041	1.451	.18	.005	.393	.046	1.838	.31	.009	.607			
4/17	4/14-16	3.18	.46	.365	.017	1.467	.042	.002	.395	.019	1.857	.30	.014	.621			
5/9	5/5-8	4.11	.58	.13	.008	1.475	.062	.004	.399	.012	1.869	.74	.043	.664	.02	.06	T
5/30	5/26-28	3.12	.15	48.00	.732	2.207	22.50	.343	.742	1.074	2.943	3.72	.057	.721		.02	---
1/16	1/13	I	2.24	19.50	4.360	6.567	.56	.125	.867	4.485	7.428	.49	.409	.830			
7/26	7/20-21-24	13.16	3.76	9.00	3.385	9.952	.38	.143	1.010	3.528	10.956	.26	.098	.928	.13	.40	.002
7/31	7/30	1.47	.08	2.68	2.043	11.994	.36	.003	1.013	2.046	13.002	.54	.004	.932			
10/15	10/12-13	3.78	.38	6.80	.059	12.254	.295	.011	1.024	.270	13.272	.48	.056	.988	.02	.08	---
12/5	12/3-5	4.60	1.25	.77	.095	12.349	.044	.346	1.370	.442	13.714	.56	.069	1.057			
12/24	12/18-20, 23, 24	2.46	/.05	.44	.002	12.353	.535	.003	1.373	.005	13.719	.86	.114	1.171			

Runoff, Erosion, Nitrogen and Phosphorus Losses by Storms; Mexico Silt Loam, McCredie, Mo., 1971, 1972 and 1973.

Plot: 35 Crop: Soybeans Tillage: No-Till winter-cover Starter Fert: 6-10.5-19.9 @ 245 kg/ha N: 37 kg/ha

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Clean Date	Rain		Runoff Losses												Soil Losses		
	Date	cm	cm	Nitrate-N ppm	Nitrate-N kg/ha	Nitrate-N acc kg/ha	Ammonia N ppm	Ammonia N kg/ha	Ammonia N acc kg/ha	Total N kg/ha	Total N acc.N kg/ha	Phosphate ppm	Phosphate kg/ha	Phosphate acc.P kg/ha	t/ha	N kg/ha	P kg/ha
1971																	
1/4	1/2-3	3.30	1.88	.62	.11	.11	.27	.04	.04	.17	.17	.72	.13	.13			
2/5	2/3-4		1.65	2.90	.48	.59	.27	.04	.08	.53	.70	.72	.12	.25			
2/26	3/21-22	1.93	1.76	.75	.06	.65	.27	.02	.10	.08	.78	.72	.06	.31			
6/14	6/14	2.69	.25	14.70	.37	1.02	2.17	.06	.16	.43	1.21	1.94	.04	.35			
6/15	6/14	2.54	1.47	5.30	.78	1.80	1.36	.20	.36	.99	2.20	1.64	.24	.59			
7/20	7/20	6.73	3.56	1.10	.39	2.19	1.48	.53	.89	.92	3.12	1.14	.40	.99			
12/15	12/13-15	4.32	.23	1.30	.03	2.22	4.00	.09	.98	.12	3.24	.27	.01	1.00			
12/30	12/29-30	2.06	.18	1.70	.03	2.25	3.90	.07	1.05	.10	3.34	.24	T	1.00			
1972																	
2/14	2/8-12	sm	.20	5.10	.10	.10	1.25	.02	.02	.12	.12	2.20	.04	.04			
3/13	3/12-13	5.03	.76	2.20	.17	.27	.49	.03	.05	.20	.32	2.20	.17	.21			
3/16	3/14-15	1.91	.76	1.10	.08	.35	.10	.01	.06	.09	.41	1.71	.13	.34			
4/21	4/19-21	7.34	2.16	.90	.19	.54	.22	.04	.10	.24	.65	.81	.18	.52			
4/24	4/21	.53	.25	1.10	.02	.56	.57	.01	.11	.03	.68	.53	.01	.53			
5/1	4/30-5/1	2.57	.58	1.40	.08	.64	2.70	.16	.27	.24	.92	1.13	.07	.60			
6/22	6/21	I	1.83	12.20	2.24	2.88	1.50	.27	.54	2.51	3.43	.80	.15	.75			
11/2	10/31	5.31	.71	8.80	.63	3.51	3.30	.24	.78	.86	4.29	1.28	.09	.84			
11/14	11/12-13		2.82	2.10	.59	4.10	.21	.06	.84	.65	4.94	1.38	.39	1.23			
12/12			.15	2.80	.05	4.15	1.30	.02	.86	.07	5.02	1.50	.02	1.25			
12/22			2.11	1.50	.33	4.48	1.42	.30	1.10	.63	5.64	1.93	.40	1.65			
12/27			.33	.30	.01	4.49	2.25	.08	1.18	.09	5.72	1.71	.06	1.71			
12/29			.25	1.05	.02	4.51	.10	.00	1.18	.02	5.74	2.23	.06	1.77			
12/30			.15	4.40	.07	4.58	.10	.00	1.18	.07	5.81	.91	.01	1.78			
1973																	
1/3	1/3	2.29	.74	1.20	.09	.09	.52	.04	.04	.13	.13	.70	.05	.05			
1/19	1/18	1.85	.76	2.39	.18	.27	.03	T	.04	.18	.31	1.10	.08	.13			
1/22	1/21-22	1.85	.91	1.65	.15	.42	.22	.02	.06	.17	.48	.78	.07	.20			
2/2	2/1-2	1.40	.58	1.50	.09	.51	.86	.05	.11	.14	.62	.99	.06	.26			
2/13	2/12-13	1.98	.51	2.45	.12	.63	.90	.05	.16	.17	.79	.85	.04	.30			
2/14	2/12-13	1.98	.10			.63								.30			
3/2	3/1-2	I	.05	3.05	.02	.65	.56	T	.16	.02	.81			.30			
3/7	3/4-7	6.78	6.99	.52	.36	1.01	.34	.24	.40	.60	1.41	.43	.30	.60			
3/12	3/10-11	4.17	3.18	.59	.19	1.20	.34	.11	.51	.30	1.71	.58	.18	.78			
3/15	3/13-14	2.41	1.40	.46	.06	1.26	.50	.07	.58	.13	1.84	.63	.09	.87			
3/26	3/24-25	4.06	10.16	.16	.16	1.42	.11	.11	.69	.27	2.11	.45	.46	1.33			
3/30	3/28-29	1.19	.18	.38	.01	1.43	.10	T	.69	.01	2.12	.36	.01	1.34			
4/2	3/30-31	3.30	2.01	.38	.08	1.51	.10	.02	.71	.10	2.22	.22	.04	1.38			
4/12	4/8-9	2.39	.76	1.00	.08	1.59	.13	.01	.72	.09	2.31	.27	.02	1.40			
4/17	4/14-16	3.18	1.32	.30	.03	1.62	.06	.01	.73	.04	2.35	.12	.02	1.42			
4/24	4/21-22	1.07	.05	.29	.00	1.62	.45	T	.73	T	2.35	.38	T	1.42			
5/9	5/5-8	4.11	1.24			1.62	.18	.02	.75	.02	2.37	.35	.04	1.46			
7/16	7/13	I	3.40	8.40	2.86	4.48	.35	.12	.87	2.98	5.35	1.39	.47	1.93			
7/26	7/20-21,23,24	13.16	7.21	4.40	3.18	7.66	.03	.02	.89	3.20	8.55	1.40	1.01	2.94	.22	.70	T
7/31	7/30	1.47	.79	4.20	.33	7.99	.38	.03	.92	.36	8.91	1.64	.13	3.07			
10/15	10/12-13	3.73	1.24	2.60	.32	8.31	.29	.04	.96	.36	9.27	1.40	.17	3.24			
11/21	11/20-21	1.70	.03	27.70	.07	8.38	.21	.00	.96	.06	9.33	2.99	.01	3.25			
11/27	11/24-26	3.76	1.27	10.17	1.29	9.67	.80	.10	1.06	1.39	10.6	2.26	.29	3.54			
12/5	12/3-5	4.60	1.83	.69	.13	9.80	.12	.41	1.47	.54	11.27	1.53	.28	3.82			
12/24	12/18-19,23	2.44	.76	.30	.02	9.82	.02	T	1.47	.02	11.29	2.26	.17	3.99			

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16. Abstract

Analyses of runoff and sediment were made from 33 instrumented plots at the Midwest Claypan Experiment Station. Nitrogen compounds, phosphates and some specific pesticides were determined where fertilizer treatments, cropping and cultural practices varied. The results show the losses of nitrogen and phosphate compounds that may be expected under practical field conditions on soils that have a minimum slope and where percolation rates are slow.

Results from three seasons are reported. In all three years rainfall during the critical period, where there was minimum ground cover, was below long time averages. Optimum fertilization treatments that produced a vigorous canopy, or a good residue cover reduced both erosion and nutrient losses. In none of the three years did the optimum use of fertilizer or pesticides produce large losses of chemicals.

The results point to systems of soil management that will produce optimum yields of grain crops with a minimum contamination of receiving water by chemicals.

17a. Descriptors

Water pollution, agricultural pollution, fertilizers, nitrates, phosphates, pesticides, sediments, erosion, runoff, eutrophication

17b. Identifiers

17c. COWRR Field & Group

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