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RESEARCH REPORT NO. 52

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1972

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ABSTRACT

Soils from several areas in Kentucky were placed in columns and leached with $Ca(NO_3)_2$. Subsoils high in iron oxide were found to retard the leaching of nitrate very significantly. In other soils, the nitrate moved through as fast as or slightly faster than the water.

Field application of nitrogen to corn was most efficient when done in the spring or summer near the time that the corn takes it up. The one exception to this was a red soil, where fall application of nitrogen resulted in little loss due to the retarding effect mentioned in the first paragraph.

Soils on which a sod or cover crop is killed and in which corn is planted have little loss of water by evaporation. Because of this, much more water movement occurs and nitrate moves out of the soil during the summer. In contrast, the soil without a killed sod mulch suffers no loss of nitrate during the growing season.

Stream samples taken in 1971 and 1972 during the months of January through May showed a poor relation between nitrate in the water and land use. The highest nitrate was found in a stream draining a grassland watershed where little fertilizer is used.

The tile drain effluent and total water reaching a drainage ditch were determined. The nitrate in the tile effluent was much higher than that in the non-tile drainage. This leads to the conclusion that the nitrate concentrations of tile effluents are not reliable indicators of nitrate leaving a tiled field.

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CHAPTER I

INTRODUCTION

The objective of this research was to relate the movement of nitrate in Kentucky soils to (1) movement of soil water, and (2) to soil chemical properties, in order to predict where contamination of ground water will occur.

The interest in nitrate movement through soils was, for a long time, restricted to an agricultural concern about loss of available nitrate from the root zone of soils. This loss resulted in lowered yields of crops and was considered to be unfortunate but largely unavoidable. Later work has shown that application of fertilizer nitrogen as near as possible to the period when the plant is actively growing minimizes losses from the root zone of the soil. However, there still is no control over movement from the soil of nitrate formed by microbial nitrification.

Microbial nitrification, particularly in fertile soils, may account for more nitrate than is added in fertilizers. There may be a considerable amount of nitrate formed after the crop has died both from soil organic matter and from decomposition of the plant residue. In this case, the nitrate in the soil will be susceptible to loss by water leaching even though it is of natural origin and not related to fertilizer application. Lysimeter studies (Karraker & Bortner, 1937) done at Lexington showed heavy losses of nitrate-nitrogen by leaching whenever crops planted in them died or when a soil was kept free of vegetation. No fertilizer was used in any of the treatments.

The present interest in nitrate movement through soils stems from the possibility that ground and surface waters may be contaminated by the nitrate. There are two concerns about nitrate in water that have prompted this interest. First, the possibility of infant poisoning under certain conditions including a high level of nitrate in water; and second, the possible accelerating effect of nitrate-nitrogen on the growth of algae and other weeds in surface waters. Neither of these effects are wholly proven, but there is enough evidence in this direction to elicit some concern for the "quality" of ground and surface waters with regard to nitrate-nitrogen.

It is characteristic of all soils to exchange cations since they all contain some mineral and organic cation-exchangers which possess a net negative charge. Essentially all soils have the power to immobilize phosphorus as a phosphate salt of calcium, aluminum or iron. In the case of nitrate-nitrogen, however, there is a very general impression that, since it is an anion and since it forms soluble salts, there is essentially no reaction between it and the soil. There probably are a few soils with which the nitrate ion has no significant interaction. An example might be a very sandy soil, low in organic matter.

For most other types of soils, however, there is a positive or negative interaction with nitrate. For example, soils with a very dense negative charge on their surfaces do not only fail to attract nitrate, they actively repel it. Although this behavior, known variously as negative adsorption, repulsion or anion exclusion, has been recognized for a long time (Mattson, 1927), the practical effect on nitrate leaching has been shown only rather recently (Dyer, 1965, Thomas and Swoboda, 1970). This effect is to exclude nitrate from some of the soil water, making the net pathway of nitrate through the soil shorter than it would be if all the soil water had to be used. As a result, the removal of nitrate from a soil profile which is highly negatively charged (i.e., has a high cation-exchange capacity) is accomplished with substantially less water than is held in the soil.

In soils in which iron oxide thickly coats the clay particles, there are both positively- and negatively-charged sites present. The positively-charged sites will react with nitrate and retard its progress through the soil as water moves (Thomas, 1960). Again, this effect has been known for a long time (Mattson, 1927) but only limited practical application has been made of it. In most soils that possess bright red subsoil colors the movement of nitrate is substantially slowed (Thomas, 1970).

The downward movement of water through soils in Kentucky and in most of the humid and subhumid regions of the United States follows a definite seasonal pattern. Movement begins in December and continues through May. Movement diminishes during April, May and June and almost no downward movement occurs during the months of July through October (Anonymous, 1970). Since the largest amount of water flows through soils from December through March, there is a tendency for any residual nitrate from the summer growing season to be lost from the soil in the winter unless there is a crop actively growing during that time. Examples of crops that retard nitrate loss are permanent grass and small grain. Where some crop is not present, nitrate is mobile and losses will occur. Losses will be small if the soil is high in iron oxides and nearly complete if the soil is permeable and possesses a high cation-exchange capacity.

One more aspect of water movement needs to be mentioned briefly. Soil pores range very greatly in diameter and the potential flow rate through them increases as the fourth power of the radius. If a soil is rather wet to start with and a high-intensity rain occurs, nearly all the water flow will occur in the larger pores. Only the nitrate located in or on the walls of these pores is subject to leaching, but on the other hand, that portion which is leached is typically moved much deeper than it would be if uniform water flow occurred throughout all soil pores.

In this connection, the agricultural practice of chemically killing a sod or small grain and planting corn or soybeans in the residue is important. The killed sod or grain greatly reduces evaporation from the soil surface (hence upward movement of salts). This lack of evaporation also causes the soil to be wetter near the surface, which allows deeper water and nitrate penetration into the soil when rains occur. Other solutes of interest in ground water pollution act in precisely the same way. Since the water can move deeply in the large pores and not nearly so far in the smaller pores, the tendency is for the leading edge of water and nitrate to reach ground water well before it is expected and for the trailing edge to be very slow in arriving. Since the nitrate does not move as a "slug" of salt but as a very diffuse salt solution, there is a much lower concentration of nitrate contained in a much larger volume of water than would be expected from theory.

In addition to leaching, the loss of nitrate by microbial reduction to nitrogen gas (denitrification) is an important pathway of loss when the oxygen supply in the soil is low. This occurs because certain bacteria have the ability to use the oxygen from nitrate if oxygen gas is scarce. Obviously, loss of nitrate by this mechanism does not have any effect on ground or surface water.

All the points mentioned above will be discussed in light of the data obtained. All of them had a substantial impact on the results.

CHAPTER II

RESEARCH PROCEDURES

A. Column Experiments

Soils from the major physiographic regions of Kentucky were ground to pass a 1 mm screen and 100 g was placed in glass columns approximately 1 inch in diameter. A solution 0.02 N in $Ca(NO_3)_2$ was allowed to flow through the columns and the breakthrough curve plotted from nitrate analyses on the column effluent. Nitrate was estimated using an Orion nitrate electrode fitted to a Beckman research pH meter.

B. Field Experiments

1. Time of nitrogen application. Nitrogen (as ammonium nitrate) was applied to three plot areas in November 1969 or May, 1970 at rates varying from 0 to 200 lbs. per acre. Corn was planted in May 1970 and nitrate-nitrogen analyses were made on soil samples taken to 36 inches at several different dates. Nitrate was determined on a slurry of soil and distilled water using the nitrate electrode as before. Corn was harvested in September, 1970 and yields determined. Soils used were Pembroke, in Simpson Co., Ky.; Melvin and Stendal in Ohio Co., Ky.

2. Conventional vs. no-tillage corn. An experiment was set up in 1970 at Lexington, Ky. on Maury soil, in which half the plots were plowed and disked prior to corn planting and in which the other half were sprayed with the chemicals atrazine and paraquat to kill the existing bluegrass sod. Corn was planted in May 1970 and nitrogen was applied at rates of 0, 75, 150

and 300 lbs. per acre. Nitrate-nitrogen was determined with the nitrate electrode and soil water content was determined gravimetrically on samples taken to 36 inch depth several times during the season.

In 1971, the experiment was repeated and, in addition, end plots, not planted to corn, were fertilized at the rate of 300 lbs. per acre of nitrogen as ammonium nitrate and 750 lbs. per acre of chloride as potassium chloride. Two of the end plots were tilled and left bare and two were sprayed with atrazine-paraquat and left in killed sod mulch. The end plots were sampled to 36 inches as before, but nitrate was determined using the reduction procedure of Lowe and Hamilton (1967) since chloride interferes with the nitrate electrode. Chloride was determined using an automatic chloride titrimeter which can be calibrated through a standard curve. A similar experiment to the end plot portion of the above experiment was established on Lowell soil in Owen Co., Ky. and samples were taken and analyzed as above.

C. Stream Samples for Nitrate

Between January and May 1971, 10 streams draining small agricultural watersheds were sampled monthly. Approximately one liter of water was taken in a plastic bottle which was refrigerated immediately upon returning to Lexington. Nitrate-nitrogen was determined using the nitrate electrode. In 1972 (January through May) the same procedure was followed except that two streams were eliminated (leaving eight) and nitrate was determined using the method of Lowe and Hamilton (1967) to avoid possible effects of chloride and bicarbonate on the nitrate value found using the nitrate electrode.

All streams were sampled at the U.S. Geological Survey Gaging Stations. These same streams had been studied by Haan and Read (1970) and found to be substantially free of human pollution. The watersheds also represent most of the soil and geological groups found in Kentucky.

D. Tile Effluent Experiment

As a result of some preliminary samples taken in 1970, measurement of tile, intertile and streamflow and the nitrate concentrations of each was carried out on March 10 and May 1 of 1972. The area used was 41.65 acres and was completely tiled. All of it had been planted to corn except for one-half acre of tobacco. A natural stream had been dredged to form a drainage ditch. Into this stream ran five tile outlets. Three of them were measured for flow using a stopwatch and a five-gallon bucket. Two were in bad repair so that flow was measured by positioning a V-notch weir below the outlets and flow was measured using the height above the notch and standard tables. The drainage ditch flow above and below the tiled fields was determined using large sheet-metal weirs with a 5 : 1 V-notch. The height above the notch was related to flow using standard tables. Nitrate-nitrogen concentrations in the water from each flow measuring point were determined from one-liter samples using the method of Lowe and Hamilton (1967). None-tile flow was estimated by the difference between the increase in ditch flow and the tile outlet flow. Nitrate-nitrogen in the non-tile flow was estimated by mass difference.

CHAPTER III

DATA AND RESULTS

A. Column Experiments

The results of the column experiments are shown in Table 1. The distribution coefficient is a convenient method of expressing the affinity of a solute for a solid surface and was employed as follows (Ketelle and Boyd, 1947).

$$K_d = \frac{(V_{NO_3} - V_{H_2O})}{\text{Soil Mass}}$$

Where: K_d is the distribution coefficient of nitrate between soil and water in meq/g/meq/ml.

V_{NO_3} is the ml of H_2O required to elute the nitrate

V_{H_2O} is the ml of H_2O held in the column

Soil Mass is the grams of soil in the column.

Any value of K_d above zero indicates that nitrate is held by the soil. A value of zero indicates no adsorption by the soil and a negative value (while the numbers have no physical meaning) indicates that nitrate is excluded by the negative charge on the soil.

The soils with large K_d values are confined to the red limestone soil area of the Pennyroyal in South Central Kentucky. These soils would be expected to resist leaching of nitrate even though considerable water flowed through them. The soils with negative K_d values would be expected to lose nitrate fastest. Soils with small positive K_d values would be expected to be intermediate.

From the results of this initial laboratory investigation, soils with each of these characteristics were chosen for field work. Initially (1969-1970), the work was done on Maury, Pembroke, Stendal (similar to Calloway) and Melvin (similar to Alligator) soils. In 1971 Lowell (similar to Eden) and Maury soils were used. Thus, the column results were used to guide our selection of field locations.

B. Field Experiments

1. Time of nitrogen application. The effect of adding ammonium nitrate to soils in November 1969 vs. adding it in May 1970 on nitrate concentrations in the soil profiles is shown in Table 2. It is evident that loss of nitrate by late May, 1970 was greater from the Melvin and the Stendal soils than from the Pembroke soil. As the season progressed, this same order of loss prevailed until the period (late July) when corn uptake of nitrogen lowered the nitrate content of all soils to a low value.

The effect of November, 1969 application of nitrogen is compared to the effect of May 1970 application on the yield of 1970 corn in Table 3. It is evident that, again, the largest difference in yield between fall and spring application agreed with the soil nitrate data, i.e. large for Melvin and Stendal and virtually no difference for Pembroke.

These data fit in perfectly with the soil chemical characteristics. From the K_d values for similar soils (Table 1) it would be expected that Melvin and Stendal soils would lose much nitrate and that Pembroke would lose very little nitrate. This, however may be partly fortuitous. As a result of these experiments, denitrification was investigated as a possible nitrate loss mechanism. Studies carried out under parts C and D of this study discuss this probability.

It should be noted that the loss of fall-applied nitrate-nitrogen is a serious problem in many Kentucky soils. This occurs because of the excess of rainfall over evapotranspiration during the months of November through April. The water balance for all of Kentucky can be represented by the stream runoff and rainfall diagram shown in Fig. 1. These data are for a single year of stream runoff and rainfall near the Lexington airport, but they apply very closely to other areas of Kentucky and represent the gross pattern for every year. Regardless of the rainfall during July, August, and September there is very little net water movement through the soil. In October, rainfall usually is very light. Beginning in November, rainfall picks up and evapotranspiration is very insignificant. The result is a large amount of flow through the soil which expresses itself as stream runoff. During the winter and early spring a very high percentage of the precipitation travels through the soil carrying with it solutes such as nitrate. The typical evapotranspiration from Kentucky soils is 27 inches per year and the average rainfall is 45 inches per year. Therefore, on the average there are 18 inches of water which can move through the soil. Nearly all of the water moves through the soil during the months of November through April so that nitrate present in the soil during that period is subject to leaching. Absence of appreciable nitrate during that period is the best guarantee that water will not be contaminated with nitrate. Therefore, fertilization just before summer cropping begins (in May) at a rate which assures adequate plant growth but leaves little nitrate residue is the most efficient way of protecting ground water (and of growing crops as well). The results of these field experiments confirm that idea.

2. Conventional vs. no-tillage corn. Beginning in 1960, a method was developed to grow corn and other crops in a killed sod or other killed residue without disturbing the soil. This method depended on herbicides for control of unwanted vegetation. Since the killed residue prevented erosion, the use of rolling and hilly land for corn was expanded, giving Kentucky and other states with similar topography more usable cropland. In addition, it was found that the added water in the soil (under the killed residue) gave corn some protection against summer drouth. What was not anticipated was that the added water could contribute to leaching of nitrate from the soil. A preliminary observation, made in 1969, showed that there was far less nitrate in the soil under the no-till corn than in the soil under conventional corn where evaporation occurs from the soil surface. Beginning in 1970 an experiment was set up at Lexington to quantitatively measure this effect.

The effect of the mulch is particularly evident from mid-May to July 1, when corn is not removing much water. Results from June 1 and June 6, 1970 for 36 inch profiles are shown in Fig. 2. The rainfall between the two dates was 2.6 inches. About half of the nitrate was lost from the mulched soil whereas none was lost from the bare soil to a depth of 36 inches. The experiment was repeated in 1971 and data for June 1 and June 25 are shown in Fig. 3. The rainfall between these two dates was 3.7 inches. Again the results are similar. Corn yields reflected the loss of nitrate-nitrogen both years, but particularly in 1971 (Table 4). Given the strong dependence of corn yield on water and nitrate-nitrogen, the results are exactly as predicted.

Since there was some question about the importance of denitrification in accounting for part of the nitrate loss, experiments were set up in 1971 on some end plots near the corn experiment on Maury soil and in Owen Co., Ky. on a Lowell soil. To these plots both KCl and NH_4NO_3 were added so that chloride could be used as a tracer of nitrate.

The results for both soils, showing the proportion of added chloride and nitrate remaining at different dates, are given in Table 5. They show that in the Maury soil nitrate was acting as an isotope of chloride. Leaching accounted for all the loss of nitrate in both conventionally-tilled and the killed sod plots. As in the case where corn was present, leaching was much more severe on the killed sod plots than where the surface was left bare. In the Lowell soil, however, leaching of chloride was faster from the bare plots than with the Maury and a killed sod accelerated this. Nitrate leached as well, but a very substantial portion apparently was denitrified to gaseous nitrogen since it disappeared from the profile faster than the chloride did.

The Lowell soil is much less aerated than the Maury and the denitrification results are in accord with that, since denitrification depends on an oxygen shortage. The faster leaching of chloride and nitrate with a killed sod mulch indicates that leaching is enhanced when evaporation is curtailed. There appear to be two reasons for this. First, the upward movement of salts and water to the soil surface is stopped and second, the water flowing through wet soils moves through the large pores rather deeply into the profile without being sucked into the soil aggregates. In a dry soil, in contrast, the rain water will tend to be taken up by the dry aggregates so that the depth of movement through large pores is very much less.

These experiments show conclusively that anything which keeps a soil wet will enhance leaching. In it was a killed sod mulch, but it could have been just as easily a gravel mulch or a soil crust. Probably the most original contribution in the entire study was this finding.

C. Stream Samples

To obtain an idea of the actual nitrate-nitrogen concentrations in Kentucky streams draining agricultural watersheds, monthly samples were taken during the high streamflow months of January to May in both 1971 and 1972. The characteristics of the watersheds are given in Table 6. Two of the streams (Little Plum Creek and Cane Branch) were not sampled in 1972. Nitrate-nitrogen was highest both years in Cave Creek, the watershed of which is mostly in grass. As pasture, it receives very little fertilizer. Rose Creek, which was second highest is nearly all in corn and soybeans and does receive a great deal of fertilizer. The nitrate in the other streams bears little relation to land use. A study done in 1921 in Kentucky (McHargue and Peter, 1921) showed values of nitrate to be quite high in the Inner Bluegrass. At that time no fertilizer was used. Values for other parts of the state were lower but comparable with the 1971-2 figures we obtained (Table 7). The results cast doubt on the role of fertilizer nitrogen in causing nitrate buildup in streams. The results do suggest that various geological formations and the soils formed from them are related to the nitrate-nitrogen found in streams. For example, soils in the Inner Bluegrass are very fertile and this is reflected in the high stream concentrations of nitrate (Cave Creek). Soils in the mountains are very infertile and this also is reflected in the low level of nitrate (Helton Branch). McHargue and Peter (1921) concluded the same thing.

Their paper should be required reading for self-styled ecologists.

D. Tile Effluent Experiment

As a result of the stream sample results and some preliminary measurements of nitrate concentrations in drainage tile effluent, an experiment was set up to account for the rather low concentrations of nitrate in streams compared to the high concentrations of nitrate in tile effluent. A map of the tiled area is shown in Fig. 4. The results from the first sampling are given in Table 8. The flow was very high at this sampling. The tile effluent accounted for only about one-third of the flow reaching the drainage ditch. The bulk of the flow arose from non-tile seepage. Although the nitrate-nitrogen in the drainage tile effluent was more than 15 ppm the increase in the drainage ditch water was only from 0.25 to 1.91 ppm. This can only be accounted for if the concentration in the non-tile drainage is about 3 ppm of nitrate-nitrogen.

At the second sampling date, May 1, 1972 (Table 9), the tile effluent accounted for only a little over 10 per cent of the total flow reaching the drainage ditch. The tile effluent nitrate-nitrogen concentration was lower (8.7 ppm) than before. The drainage ditch had no measurable nitrate before it reached the tiled area and only 0.25 ppm NO_3-N as it left. Thus, it can be calculated that the non-tile drainage, which accounts for most of the seepage, had no nitrate in it at all, (actually the calculation showed it to be slightly negative, which is impossible).

These results conclusively show two things at least for typical western Kentucky fields that have been tiled. First, the tile flow gives no indication of the total flow reaching a stream. Second, the nitrate concentration of tile effluent is much higher than the nitrate in the non-tile flow. This accounts for the low values of nitrate usually found in streams. It occurs because of denitrification, the reduction of nitrate by bacteria to nitrogen gas (Meek et al., 1969). Around the tile drains, which are installed at about a three foot depth, there is an oxidized zone which allows nitrate to leach through unchanged. In the bulk of the soil, oxygen is in short supply and the nitrate is reduced. The lack of stream contamination from this soil (Stendal-like) strongly suggests that the bulk of the nitrate lost from the Stendal and Melvin soils (Bl) is denitrified before it reaches ground water or a stream, even though it may have been leached through the soil. This reaction is not observed in the Maury soil, a well oxidized soil where stream concentration of nitrate were highest but probably occurs in many other soils throughout Kentucky, particularly in the wetter ones.

CHAPTER IV

CONCLUSIONS

1. Nitrate-nitrogen leaching is retarded by red limestone-derived soils in Kentucky. The nitrate is held in the root zone of crops for some time (a year or more) so that there is more likelihood of crop removal than of loss to ground water. Soils that possess high cation-exchange capacities tend to lose nitrate extremely fast.

2. Nitrogen fertilizer should be applied as closely as possible to the time when the plant will take it up from the soil. This greatly lessens the opportunity for nitrate to enter ground and surface waters and gives better crop yields as well. For this reason, fall or winter nitrogen fertilization of crops grown the following summer is not practical under the climatic conditions found in Kentucky.

3. Soils on which a sod or cover crop is killed with herbicide, followed by the planting of corn or other crop lose little water by evaporation. For this reason, until the crop is large, the soil stays much wetter in the surface than does the same soil which is tilled mechanically. The wetter soil allows the entering rainwater to flow in the large pores past the wet aggregates. Thus, for each rainfall event, the water moves deeply into the soil, carrying nitrate with it. In a conventionally-tilled soil, the upper portion is dry and much of the rainwater is pulled into the soil aggregates near the soil surface. In addition, after the rain, the nitrate is moved back towards the soil surface by water evaporation in the conventionally-tilled soil. In the soil with a killed sod mulch,

evaporation is unimportant and nitrate is not reconcentrated at the soil surface. After several rains, the nitrate is much deeper in the mulched soil than in the conventionally-tilled soil.

4. Although more water moves through the mulched soil than through the conventionally-tilled soil, the increased leaching in the former should not result in a significantly higher nitrate concentration in the ground water since the nitrate does not reach the ground water in a large concentration at one time. However, more total nitrate will reach ground water with a killed sod mulch than with a conventionally-tilled soil.

5. Stream samples for nitrate from agricultural watersheds across Kentucky did not show a good relation between nitrate concentration and the land use. The highest concentration was found in a grassland watershed where nitrogen fertilizer use is low. Some streams with little cropland in their watersheds were higher than streams from intensively-cropped watersheds.

6. There is no evidence that Kentucky agricultural streams are higher in nitrate than they were 50 years ago.

7. The concentration of nitrate-nitrogen in tile effluent is a most unreliable estimate of the actual delivery of nitrate to ground or surface waters. The reason for this is that the oxidized zone around tiles protects the nitrate ion from biological reduction to nitrogen gas. Water that does not flow through tiles is lower in nitrate and much higher in total flow rate than is the tile flow. (This is true at least in a typical western Kentucky tile field).

PUBLICATIONS

1. Thomas, G. W. 1970. Soil and Climatic Factors Which Affect Nutrient Mobility. In *Nutrient Mobility in Soils: Accumulations and Losses*. Soil Sci. Soc. Am. Special Publ. No. 4, 1-20.

2. Thomas, G. W. and B. J. Barfield. The Unreliability of Tile Effluent For Monitoring Nitrate-Nitrogen Losses From Soils. (Submitted to Water Resources Research)

LITERATURE CITED

Anonymous. 1970. Water resources data for Kentucky. Part 1. Surface water records. U.S. Geological Survey 186 pp.

Dyer, K. L. 1965. Unsaturated flow phenomena in Panoche sandy clay loam as indicated by leaching of chloride and nitrate ions. Soil Sci. Soc. Amer. Proc. 29:121-126.

Haan, C. T. and H. R. Read. 1970. Prediction of monthly, seasonal and annual runoff volumes for small agricultural watersheds in Kentucky. Kentucky Agr. Exp. Sta. Bull. 711.

Karraker, P. E. and C. E. Bortner. 1937. Nitrogen leaching in soil on the experiment station farm at Lexington. Soil Sci. Soc. Amer. Proc. 2: 393-398.

Ketelle, B. H. and G. E. Boyd. 1947. The exchange adsorption of ions from aqueous solution by organic zeolites: IV The separation of the yttrium group of rare earths. J. Amer. Chem. Soc. 69:2800-2812.

Lowe, R. H. and J. Hamilton. 1967. Rapid method for the determination of nitrate in plant and soil extracts. J. Ag. and Food Chem. 15:359-361.

Mattson, S. 1927. Anionic and cationic adsorption by soil colloidal materials of varying $SiO_2/Al_2O_3 + Fe_2O_3$ ratio. Trans. Intern. Congr. Soil Sci. 1st Congr. Washington 2:199-211.

McHargue, J. S. and A. M. Peter. 1921. The removal of mineral plant food by natural drainage waters. Kentucky Agr. Exp. Sta. Res. Bull. 237.

Meek, B. D., L. B. Grass and A. J. MacKenzie. 1969. Applied nitrogen losses in relation to oxygen status of soils. Soil Sci. Soc. Amer. Proc. 33:575-578.

Thomas, G. W. 1970. Soil and climatic factors which affect nutrient mobility. In *Nutrient Mobility in Soils: Accumulation and Losses*. Soil Sci. Soc. Amer. Special Publ. 4:1-20.

Thomas, G. W. and A. R. Swoboda. 1970. Anion exclusion effects on chloride movement in soils. Soil Sci. 110:163-166.

LIST OF TABLES

Table 1. Distribution coefficients (Kd's) of NO_3 for several Kentucky soils.

Soil and Horizon	Location (Physiographic Region)	Kd
Maury B 21	Inner Bluegrass	0.065
Maury B 22	" "	0.056
Eden B 2	Hills of Bluegrass	-0.015
Crider B 22	Pennyroyal	0.256
Decatur B 22	"	0.308
Pembroke B 3	"	0.307
Alligator A 2	Mississippi River Floodplain	-0.006
Sharkey A 2	" " "	-0.035
Calloway B 2	Jackson Purchase	0.048
Henry B 3	" "	0.006

Table 2. The effect of nitrogen rate and time of application on the pounds of nitrogen remaining in the 36-inch soil profile

Treatment lbs. N/A	Soil and Location	Date of Sampling May 26	June 9	June 22	July 3	July 20
		lbs. of Nitrate-N in 36 Inches of Soil				
0	Melvin, Ohio Co.	80	58	46	18	22
100 Fall		122	48	22	24	18
100 Spring		242	124	34	32	22
200 Fall		122	74	36	40	24
200 Spring		316	234	144	116	26
0	Stendal, Ohio Co.	28	34	18	36	22
160 Fall		118	128	90	26	28
160 Spring		226	286	104	136	52
0	Pembroke, Simpson Co.	70	36	36	16	22
80 Fall		132	132	192	46	62
80 Spring		202	158	164	32	54
160 Fall		166	146	258	140	58
160 Spring		184	198	200	60	76

Table 3. Yield of corn as affected by nitrogen rate and time of application on three Kentucky soils.

Treatment lbs. N/A	Soil and Location	Yield (bu/A)
0	Melvin, Ohio Co.	17
100 Fall		34
100 Spring		96
200 Fall		61
200 Spring		137
0	Stendal, Ohio Co.	13
160 Fall		48
160 Spring		78
0	Pembroke, Simpson Co.	76
80 Fall		84
80 Spring		96
160 Fall		90
160 Spring		88

Table 4. Yields of corn grown on killed sod and under conventional tillage on Maury silt loam, Lexington.

Nitrogen Rate (lbs/A)	Soil Preparation	Yield (bu/A)	
		1970	1971
0	Conventionally-tilled	91	151
75		90	180
150		90	159
300		90	162
0	Killed sod	90	99
75		99	166
150		99	169
300		104	172

Table 5. Percentage of added nitrate-nitrogen or chloride found in profiles. (1972)

	Date	Chloride		Nitrate-Nitrogen	
		Bare Soil	Killed Sod Mulch	Bare Soil	Killed Sod Mulch
Lowell Soil (30 inches)	June 28	108	80	71	40
	July 8	62	69	44	42
	August 16	89	52	68	10
Maury Soil (36 inches)	June 1	107	94	99	78
	June 25	106	94	83	115
	July 23	111	82	90	110
	September 28	100	47	--	--
	December 22	125	57	195	47
	April 18 (73)	50	3	25	1

Table 6. The size, location, and use, geology, population and annual runoff of ten agricultural watersheds in Kentucky

Watershed Name	Size (sq. miles)	County Where Located	Land Use	Geology	Human Population	Annual Runoff (inches)
Cave Creek	2.53	Fayette	Pasture, 2% tobacco	Ordovician Limestone	125	14.62
Flat Creek	5.63	Franklin	Pasture, 54% wooded	Ordovician shales and limestone	200	15.48
Little Plum Creek	5.15	Spencer	Pasture, corn and tobacco	Ordovician limestone	---	18.37
Plum Creek	31.8	Spencer	Pasture, corn and tobacco	" "	---	15.93
McGills Creek	2.14	Lincoln	75% wooded, remainder in pasture and corn	Mississippian shales and siltstones	40	17.01
West Bays Fork	7.47	Allen	20% wooded, remainder in pasture, corn and tobacco	Osage and Meramec limestones and shales	180	18.95
Rose Creek	2.10	Hopkins	Corn, soybeans, hay, 5% wooded	Pennsylvanian siltstones and shales, Alluvium	70	13.94
Cane Branch	0.67	McCreary	Daniel Boone National Forest, 25% strip mined	Pennsylvanian Sandstones and shales	0	17.25
Helton Branch	0.85	McCreary	Daniel Boone National Forest, 94% wooded	Pennsylvanian Sandstones and shales	200	17.48
Perry Creek	1.72	Graves	Corn, soybeans, hay	Loess, Tertiary gravels, sands and clays	45	13.16

Table 7. Average nitrate-nitrogen in streams, January-May.

Stream	1971	1972
West Bays Fork	1.90	0.64
Cave Creek	6.48	4.48
Flat Creek	2.57	0.49
Helton Branch	0.58	0.09
McGills Creek	1.54	0.48
Perry Creek	1.76	0.93
Plum Creek	2.78	1.08
Rose Creek	5.79	2.74
Little Plum Creek	2.18	--
Cane Branch	0.44	--

Table 8. Water flow and nitrate-nitrogen data under high flow conditions. March 10, 1972.

	Rep I	Rep II
Upstream Flow (cfs)	0.805	0.820
Downstream Flow (cfs)	1.035	1.050
Difference (cfs)	0.230	0.230
Tile Flow (cfs)	0.085	0.083
Seepage Flow (cfs)	0.145	0.147
% of Flow from Tile	36.96	36.09
ppm NO_3-N in Upstream	0.25	--
ppm NO_3-N in Downstream	1.91	--
ppm NO_3-N in Tile Flow	15.65	15.77
ppm NO_3-N in Seepage Flow	3.10	3.34

Table 9. Water flow and nitrate-nitrogen data under low flow conditions. May 1, 1972.

	Rep I	Rep II
Upstream Flow (cfs)	.155	0.160
Downstream Flow (cfs)	0.225	0.225
Difference (cfs)	0.070	0.065
Tile Flow (cfs)	0.00788	0.00789
Seepage Flow (cfs)	0.06212	0.05711
% of Flow from Tile	11.26	12.14
ppm NO_3-N in Upstream	0	--
ppm NO_3-N in Downstream	0.275	--
ppm NO_3-N in Tile Flow	8.67	8.70
ppm NO_3-N in Seepage Flow	(-.105)	(-0.118)

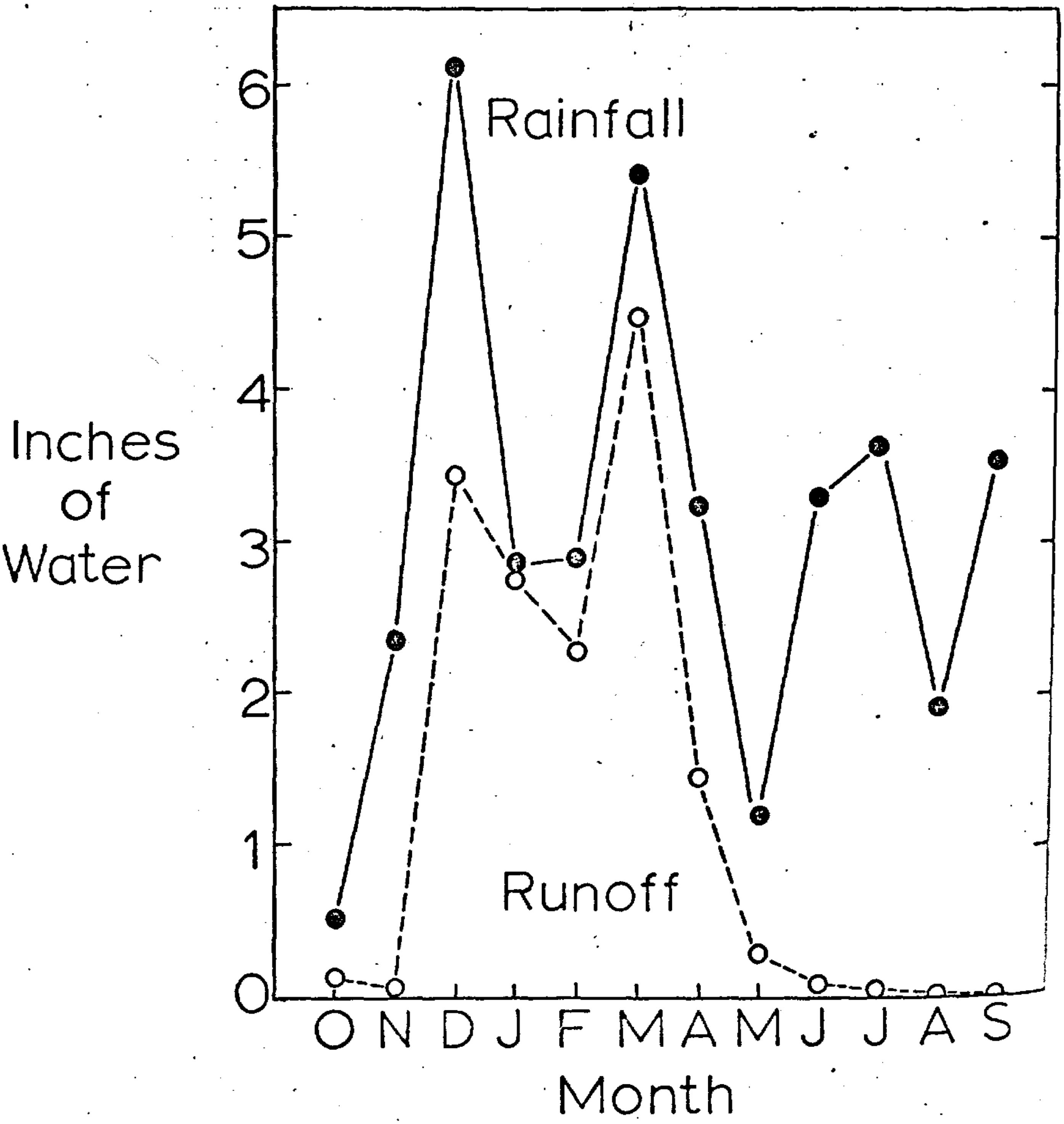
Figure Legends:

Fig. 1. Rainfall and stream runoff for Cave Creek near Lexington, Ky.

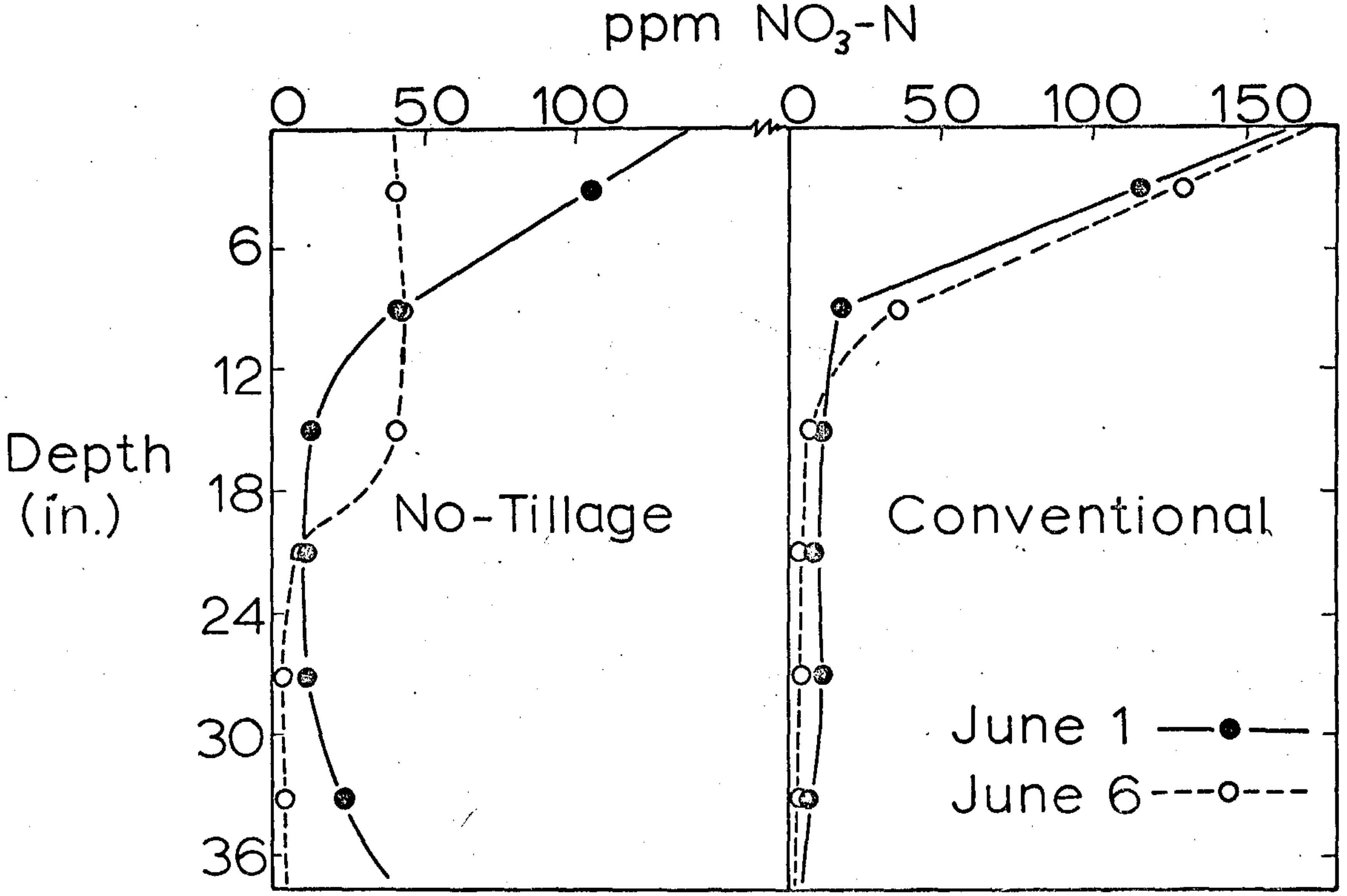
Fig. 2. Nitrate-nitrogen distribution before and after 2.6 inches of rain on no-till and conventionally prepared land. Maury soil, 1970.

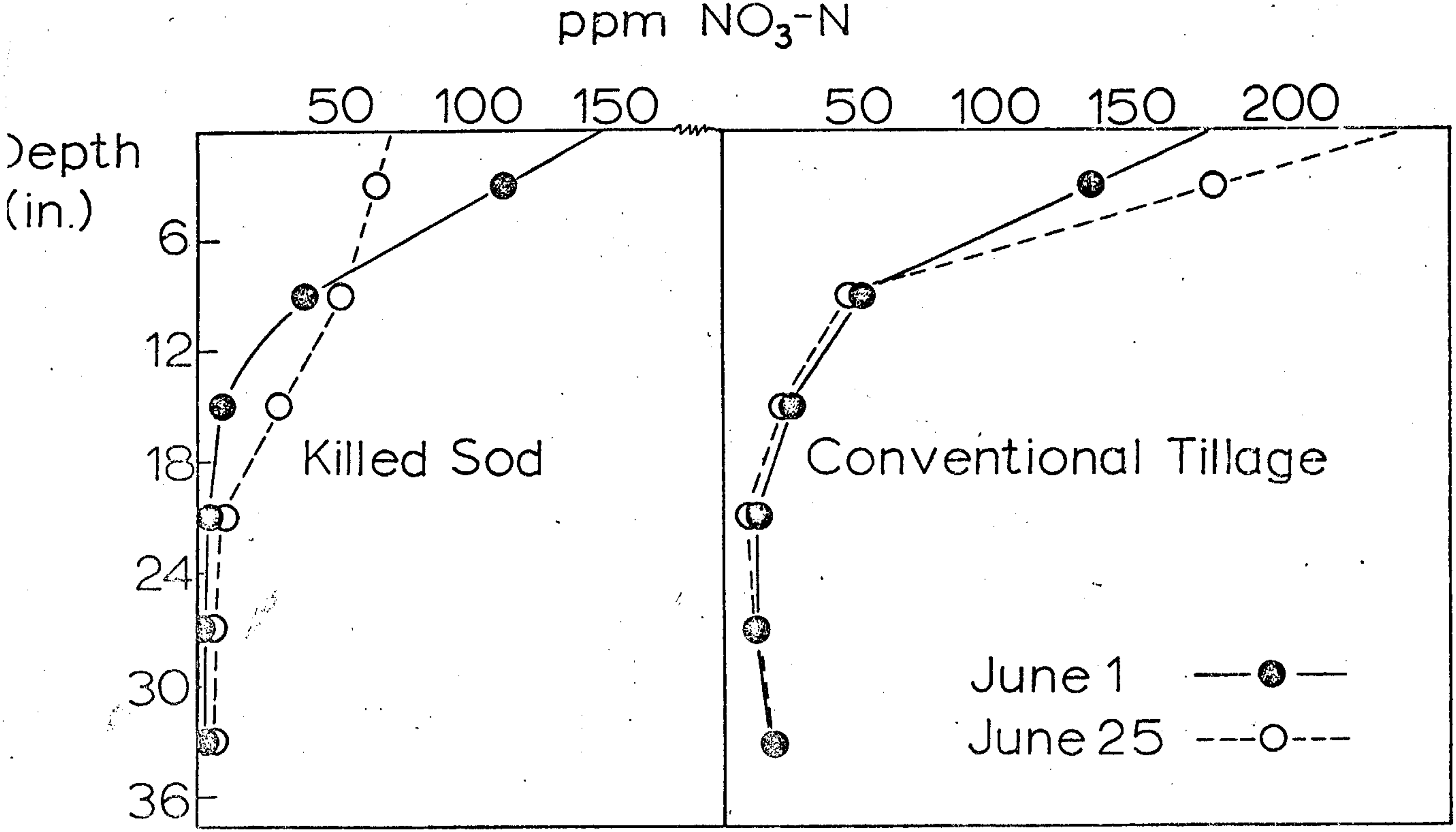
Fig. 3. Nitrate-nitrogen distribution before and after 3.7 inches of rain on killed sod and conventionally prepared land. Maury soil, 1971.

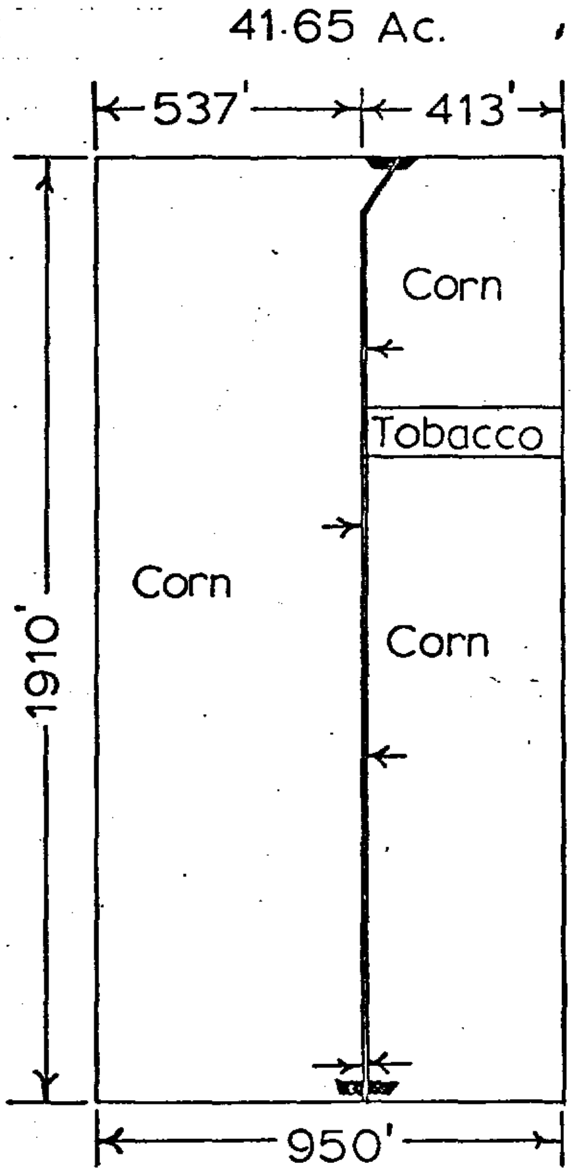
Fig. 4. Diagram of area used for tile effluent study.



Rainfall
Runoff
Inches of Water
0
1
2
3
4
5
6
O
N
D
J
F
M
A
M
J
J
A
S
Month


ppm NO₃-N
0
50
100
0
50
100
150
Depth
(in.)
6
12
18
24
30
36
No-Tillage
Conventional
June 1
June 6


ppm NO_3-N
50
100
150
50
100
150
200
Depth (in.)
6
12
18
24
30
36
Killed Sod
Conventional Tillage
June 1
June 25



ppm NO_3-N