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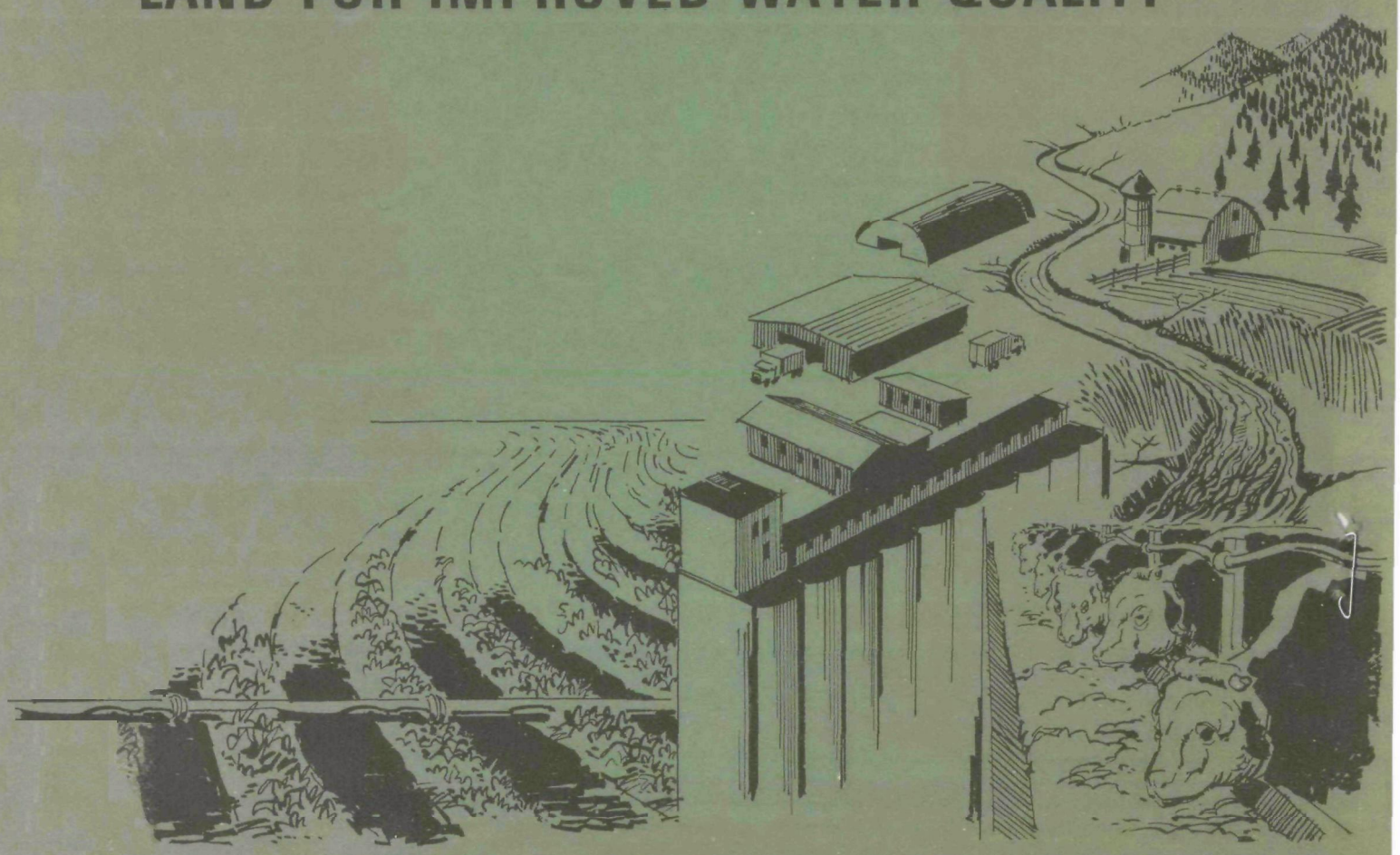
MANAGEMENT OF NUTRIENTS ON AGRICULTURAL LAND FOR IMPROVED WATER QUALITY



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MANAGEMENT OF NUTRIENTS ON AGRICULTURAL LAND FOR IMPROVED WATER QUALITY

by

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for the

OFFICE OF RESEARCH AND MONITORING

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ABSTRACT

A rainfall simulator was utilized to determine the effects of 2, 10, and 20 year storm frequencies on losses of water, soil and nutrients from plots subjected to different crop rotations, fertilizer schemes and manure applications. Crop rotations, rates of fertilizer and manure were compared. Simulations were made on freshly tilled soil.

Comparative erosion losses were as follows: continuous sod < corn - alfalfa rotations < continuous corn. Fertilizer alone tended to increase runoff, but this effect was overcome when fertilizer was used with manure.

Continuous recording of surface and subsurface flow and subsequent losses of nutrients to the environment was conducted on larger plots. Rate and time of fertilization determined the plant nutrients lost. Returning crop residues to the soil improved water infiltration, increasing deep seepage losses. Proper timing of fertilizer applications could control adverse environmental effects.

Phosphorus inputs into cultural media as it related to algal growth was studied. Sustained concentration of phosphorus at or above a critical concentration determined the biomass phosphorus.

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SECTION I

CONCLUSIONS

The overall study was made up of three related studies. This integrated approach has permitted an objective evaluation of the parameters controlling the movement of sediment and nutrients from the land surface to the water.

Rainfall simulation studies on freshly tilled soil showed that continuous corn grown with mineral fertilizer but without manure results in a deterioration of soil physical conditions. This in turn results in greatly increased soil loss and surface runoff.

With manure, fertilizer and crop residues, continuous corn production results in a soil physical condition that is no poorer than that resulting from more conventional corn-small grain-alfalfa crop rotations. The physical conditions of the soil under corn-small grain-alfalfa crop rotations tends to improve in direct proportion to the number of consecutive years alfalfa is in the rotation. Thus, long term hay rotations produce the most stable soil physical conditions, which result in the lowest losses of water, soil and plant nutrients from the land surface.

A large scale field study has shown that the return of crop residues and their incorporation into the soil increases infiltration of water into the soil and reduces surface losses of water and erosional loss of plant nutrients to the environment. The correspondingly higher subsurface loss of water can lead to nitrate nitrogen leaching, which is also undesirable environmentally. By avoiding applications of nitrogen fertilizer in months when crop uptake is low and deep seepage of water is high (October - May), and by restricting the quantity applied to just meet crop requirements, leaching losses of nitrate can be kept to a tolerable level. Phosphate transport in subsurface flow was extremely small.

Transport of phosphorus as a component of surface water is far greater than in subsurface water. In all instances, total removal of phosphorus from the system is extremely small as compared to nitrogen.

Algal nutrient studies have shown that the concentration of phosphate in the growth medium and the total amount of phosphate supplied is important in determining the extent of algal growth. A maintained concentration of 1 μM phosphate produces maximum growth of Chlorella pyrenoidosa and a phosphate concentration maintained at 0.1 μM supports a growth rate which is over 80 percent of the maximum. It is calculated from laboratory studies that to produce a nuisance population of this algae (10^7 μ^3/ml) with an initial phosphate concentration of 0.1 μM, the phosphate must be replenished at least 15 times during the

growing season. Extrapolation of this information to the natural situation, it can be concluded that the concentration of phosphate in a lake may not always be a reliable index of the ability of that lake to produce nuisance blooms of algae. If high concentrations of all nutrients including phosphate are present, algal production will undoubtedly be great. However, the reverse is not necessarily true. While a low concentration of phosphate will slow the algal growth rate, total algal production will depend largely on the degree to which phosphate is replenished from various sources throughout the growing season as well as the rate at which phosphate is lost from the trophic zone of the lake.

SECTION II

RECOMMENDATIONS

The results of this and other research demonstrate that: (1) farmers must apply fertilizer nitrogen directly to the crop. They should limit the amount applied to only that which will be taken up by the crop to which the fertilizer is applied; (2) phosphorus losses from the soil are proportional to surface runoff. They are not directly proportional to the amount of phosphorus fertilizer applied. New York State Extension teaching programs (farmer-educational efforts) are now utilizing these important principles.

Manure has been demonstrated to have a very beneficial effect on reducing surface runoff. This property is particularly important with respect to limiting phosphorus losses. Methods of utilizing manure as a source of crop nutrients and as a soil physical conditioning agent need to be vigorously pursued. Manure may be a good substitute for considerable amounts of fertilizer nitrogen and phosphorus. Particularly important are questions relating to the possible nutrient losses associated with different handling and application schemes. Careful monitoring of subsurface seepage and surface runoff are necessary parts of such an experimental study.

Current trends in the agricultural industry, coupled with growing concern for environmental pollution, make it imperative that data be collected and analysed with regard to proper disposal of animal wastes.

On-going research in the area of animal wastes has dealt extensively with means of altering manures (i.e., dehydration, oxidation, etc.) to render them more manageable. It is apparent that the land is the ultimate disposal site regardless of the type of primary treatment that the animal wastes may have received. In order to achieve a cyclic system of returning nutrients in manures from animals to crops to animals again with minimum losses, it is necessary to further study the soil, crop and manure interactions.

It is recommended that the extensive installation used in the field scale water quality study, described in this report be used to determine the effect of various manure utilization and disposal practices on surface and subsurface water pollution.

Animal wastes both untreated and modified by primary treatment should be evaluated for crop production and land disposal. The environmental consequences of currently evolving disposal practices should be thoroughly studied and recommendations formulated.

SECTION III

GENERAL INTRODUCTION

Since the mid-19th century, sanitary engineers have been successfully operating water treatment plants and waste disposal plants to protect the health of urban and suburban populations. The raw water for many water systems is drawn from streams. For the last 30 to 40 years, sediment from agricultural land has been recognized as a major cause for the deterioration of stream water quality. Until recently there has been little or no consideration of the influence of agricultural chemicals or agricultural nutrients and animal waste upon water quality. Within the past decade, the use of chemical nitrogen fertilizer has more than doubled. A huge feed lot industry has sprung up in the midwestern and great plains states. Dairy and poultry industries of the eastern United States and elsewhere have had their animals concentrated into large centers of operation with a corresponding concentration of animal waste. Thus, it has become increasingly difficult to adequately treat raw water.

The scope of the present project is to evaluate (1) the influence of different rates and times of application of commercial fertilizer upon the quality of water that comes from the land, (2) the influence of animal manures, under various management systems, upon the loss of water sediment, and agricultural nutrients, and on (3) the influence of phosphates in water on the growth of algae.

Before going into the body of the report, a few analogies between soil and water conservation management of nutrients and the management of waste disposal plants are described. One of the basic principles that is constantly used in a well managed waste disposal plant is the principle of the mass balance. That is, the input or loading of a plant must be such that the treatment process will handle the load. If an excessive load or periodic excesses of load go into the plant, and the plant cannot handle such loadings, the effluent will then be irregular in quality. In many respects, the hydrological cycle has the attributes of a waste disposal plant. Seasonal and climatic fluctuations that take place bring about a fluctuation in the loading capacity of the soil to the extent that the output in terms of water quality may be erratic or undesirable. Often these variations in water quality are due to load; the hydrologic and climatic inputs are not uniform. We will equate the soil to the treatment plant in many respects, or we can equate the soil to certain aspects of the treatment plant. We know that for secondary treatment there are usually trickling filter or activated sludge plants. In many respects, the soil profile behaves toward the fertilizer and animal waste that are used in it as the activated sludge and the trickling filter units behave toward the input or loadings that are put into these portions of a plant. To cite some of the more obvious limitations of the soil and water conservation nutrient management system, let us consider the facts of rainfall.

Each climatic zone has its own rainfall characteristics. Parameters used to characterize rainfall are: amount, frequency, intensity and duration. One must consider the total range of rainfall and precipitation events in order to plan a successful water quality operation on the land. Modifying the rainfall or precipitation is very difficult if not impossible. By keeping the facts of rainfall in mind it is often feasible to design the land use and soil receiving system in such a way that it will maximize both water quality and output.

More should be said in the way of background about the influence of land use and land management upon the quality of water. It has been traditional that a well-managed forest in the eastern United States will generally produce high quality water. Many municipalities maintain forested watersheds to supply their municipal needs. This represents an extreme example of control of the watershed or drainage basin to insure high quality water. If is often possible to receive some economic gain from a well-managed forest. Frequently, it is impractical and uneconomical to attempt to establish this type of vegetation over any large area of the land surface. Where large areas of grazing land or idle land are properly managed, the water from such land is frequently of quite satisfactory quality. This is not generally true where over grazing occurs. Cultivated land can be a source of sediment and salts, which can deteriorate water quality, because of poor management practices. The problem is greatly magnified by the fact that there are numerous individual owners who practice various levels of management and who, either through carelessness or lack of knowledge or out of economic necessity, find it impractical or inconvenient to use proper methods of fertilization, animal manure application, and erosion control. It is this complex area of soil, water and nutrient conservation and crop production that we are seeking to develop and clarify so that these same areas of agricultural land will not only serve to enchance the quality of the water emanating from them, but hopefully, they may also be used as sinks for nutrients from waste disposal plants that are currently being developed in many small towns and cities.

High intensity rains of long duration do not cause muddy water to be discharged out of densely covered woodland or grassland areas. The soil surface is protected by vegetation. Land that is cultivated to row crops and less dense growing crops can achieve a measure of the protection inherent in forest and grassland. This is achieved by developing a desirable physical condition. The individual granules or soil aggregates, by proper management become resistant to the destructive action of water. With a porous, open, water stable soil surface, fertilizer salts such as nitrates and phosphates can readily move into the soil.

These salts, and large quantities of water, are thus prevented from running off the soil surface into surface water bodies. However, the fate of these nutrients salts after they enter the soil is highly

variable. Phosphorus is generally held in the soil, and extremely small quantities leave in subsurface water flow. However, nitrates are readily leached and will contaminate subsurface water and ground water to a degree which is dependent on time of application of fertilizer, crops grown, management, etc. This study helps to clarify the effects of these variables.

The body of this report consists of three main areas of work:

(1) The small scale runoff studies

(2) The large scale water quality studies, and

(3) Finally, the effect of nutrients salts on the growth of algae in the surface waters.

SECTION IV

SMALL SCALE RUNOFF STUDY

The preceeding generalizations serve to point out needs and general trends in the water quality field. These generalizations are not quantitative. For many years, agriculturalists, soil and water conservationists, hydrologists, agronomists, and agriculture and sanitary engineers, have tried to develop quantitative expressions or relations that could be utilized to predict the quality of water as it comes from agricultural land. Because so many professional attitudes and concepts have been involved, the resulting predictive expressions are varied.

Historically, the first concern was with erosion as a destroyer of farmland. Early agriculturalists (Hall, 1937) sometimes gave little thought to the down stream influences of erosion in terms of sediment and undesirable nutrients for water quality. The major concern was on site loss to the individual farm. After World War I, a major source of information developed under the leadership of H. H. Bennett. Erosion Experiment Stations were developed by Bennett at some 35 or more locations over the United States. Many soils were studied (Middleton, Slater and Byers, 1932). These "standard stations" made similar measurements on soil and water loss. Thus, cross comparisons became possible between various climatic areas and farming systems. In addition to "standard comparisons," such as forest versus cropland, fallow versus cropland, degree and length of slope, contour versus up and down slope, a very considerable number of watersheds or small drainage basins were also studied. These drainage basins or watersheds ranged in size from a fraction of an acre to several square miles. In many circumstances, improved and prevailing practices were studied on paired drainage basins (Anonymous, 1960).

The runoff plot studies led to the establishment of a Runoff and Soil-Loss Data Center at Purdue University (Wischmeier, 1955). Unfortunately, most of these historic studies covered only soil losses (sediment) and water losses (runoff). Little or no consideration was given to nutrient losses. Cash grain farming served as a model and was neglected. Consequently, management of manure as it might affect the quantity of sediment and the quality of the water was not considered.

Within the last ten years, an approach to agricultural runoff has developed that attempts to combine the small plot and/or drainage basin with the analysis of data collected over larger areas (Amerman and McGuinness, 1967). In effect, the assumption is made that the small plot or drainage basin is a "unit-source watershed." This concept has assumed that the larger basin is made up of representative small units. Therefore, the expense of intermediate or larger basin studies can be spared by simply combining the representative small plot studies (Allis, 1962).

This concept of a "unit-source watershed" was applied to an experimental area that had been developed and utilized by Dr. R. B. Musgrave for a study of rotations that might be adapted to dairy farming and feed production in the period 1954 to 1968. Each rotation carried with it a definite level of mineral fertilization. Some rotations were duplicated with and without manure and it was possible to evaluate the economic return from manure in this type of a system. These data have already been published (McEachron, et. al., 1969).

The more complex question is: Does the cropping program, manuring and fertilization affect the quality of water and sediment that comes off the land? These more complex questions were approached by analyzing components of the general problem of sediment production and nutrient loss. Wischmeier and Smith (1965) summarized information on the so-called "soil loss equation." Without dwelling on the details of this equation, which are available and discussed in the above reference, it will be said here that Stage 1 of the so-called "cropping management" factor (Wischmeier 1960) was studied and this component is usually the major source of sediment and runoff on crop land. By minimizing or almost entirely eliminating such complex factors as length and steepness of slope, and by keeping the study confined to two soil types, it has been possible to arrive at an evaluation of the influence of past management upon the soil itself.

Materials And Methods

A rainfall simulator (Swanson, 1965) was utilized to study runoff and erosion losses from a range of soil management and cropping conditions. The artificial rainfall parameters were treated according to the standards of Wischmeier (1959). The rainfall factor, "R", for one half hour was 25 units. This value is a product of the total artificial rainfall energy expressed in foot tons per acre inch multiplied by the maximum 30 minute rain intensity expressed in inches per hour.

Rainfall simulation plots were selected at random after having eliminated plots containing sand pockets and other abnormalities. These selected plots were then treated as if a conventional seed bed were being prepared for corn. Prior to the normal date of planting, and after a one inch rain, the plots were covered with a four mill sheet of plastic. This plastic was left in place until the rainfall simulation study was carried out. At this time, the plastic was removed. All studies were completed by mid-August.

In the actual operation of the rainfall simulator, three one-half hour rain periods were used consecutively. Each period delivered one and one-quarter inches of water. The rainfall simulation parameters are summarized in Table 1.

Table 1. Rainfall Simulation Parameters.

Storm	R Rainfall Factor	Amount of Rain (Inches)	Duration (hours)	Frequency in years	Probability any one year %
A[1]	25	1.25	0.5	2	50
A + B	50	2.50	1.0	10	10
A + B + C	75	3.75	1.5	20	5

[1] A is equivalent of a 2 year storm, A + B is equivalent of a 10 year storm, and A + B + C is equivalent of a 20 year storm.

The probability values in Table 1 are based on any one storm. If the total rainfall factor R were summed over all rains in central New York, the summed value of R would equal or exceed 75 every other year.

Determinations were made on the original plot soils for organic matter, total nitrogen, total phosphorus, orthophosphate, clay, silt, sand, aggregate stability, and bulk density. These determinations, except

for bulk density and aggregate stability, were again made on the sediment obtained from the plots. Total solids were routinely determined in the runoff obtained from the rainfall simulation. The significance of these observations will be discussed in the next section. All data are summarized in the Appendix. Three main types of management were studied. They were continuous corn, mixed crop rotations, and continuous hay. Aggregate stability tests were also made on all plots in the rotation study. A portion of these results are presented in Figure 9. Not all plots were used for rainfall simulation.

Results And Discussion

Continuous Corn

The seven management treatments studied under rainfall simulation for continuous corn are shown in Table 2. Figure 1 illustrates the rather close relationship between soil loss and runoff. Total soil loss was proportional to runoff regardless of fertilizer and manure variables (Treatments 4, 5, 6, and 7 were combined). However, as will be illustrated in subsequent figures, runoff varied among treatments.

Management Treatment 3 utilized 270 pounds of fertilizer and no manure. Corn residue from grain harvest was returned to the soil. Figures 2 and 5 illustrate that at all levels of rainfall simulation, heavy fertilizer application alone, without manure, resulted in as much as 100% increase in soil loss and water runoff relative to plots which received manure. The condition of no fertilizer and manure applications was not included in the original field study planned by Dr. R. B. Musgrave.

Figure 2 illustrates that runoff was equal or less under manure only than under either of the other two management treatments (fertilizers only and fertilizer plus manure).

Figure 3 shows the total output of nitrogen as nitrates in the runoff during the sequence of three storms. Nitrates are soluble and mobile in the soil profile. It is apparent that nitrate-N was lowest in the fertilizer plus manure treatment during the initial stages of water application. As the soil became more nearly saturated, nitrates from these soil management treatments moved into the runoff water. It suggests that nitrates very likely move through the topsoil layer of ten inches and then "overflow" into the plot runoff.

Figure 4 shows only very minor differences in PO_4-P output. Perhaps the soil management treatment of fertilizer only is the highest while fertilizer plus manure is lower.

Figures 6, 7, and 8 represent the loss of organic matter, nitrogen, and total phosphorus under the three management system of manure only, fertilizer only, and manure plus fertilizer. It is worthy of note that losses of the constituents from the manure treated plots and the manure plus fertilizer plots are very similar. The losses from the fertilizer only plots are fully 20% higher in organic matter, nitrogen and phosphorus than losses from manured plots.

Soil Physical Condition

Interest necessarily centers on those materials which come from the soil and contribute to water pollution. Yet soil physical condition plays a major role in controlling rates of infiltration and water run-

Table 2. Management Treatments for Continuous Corn

Treatment No.	Code	Use	Manure (T/A)	Fertilizer (lbs./A)	Total Fertilizer (lbs./A)
1	(Ay)	Grain	6	0- 0- 0	0
2	(Bw)	Grain	0	30-30-30 (30)[1]	120
3	(Ccy)	Grain	0	30-90-60 (90)	270
4	(Aw)	Grain	6	30-30-30 (30)	120
5	(Ax)	Silage	6	30-30-30 (90)	180
6	(Az)	Grain	6	30-30-30 (90)	180
7	(Ccx)	Grain	6	30-90-60 (90)	270

[1] ( ) = Anhydrous Ammonia Sidedress

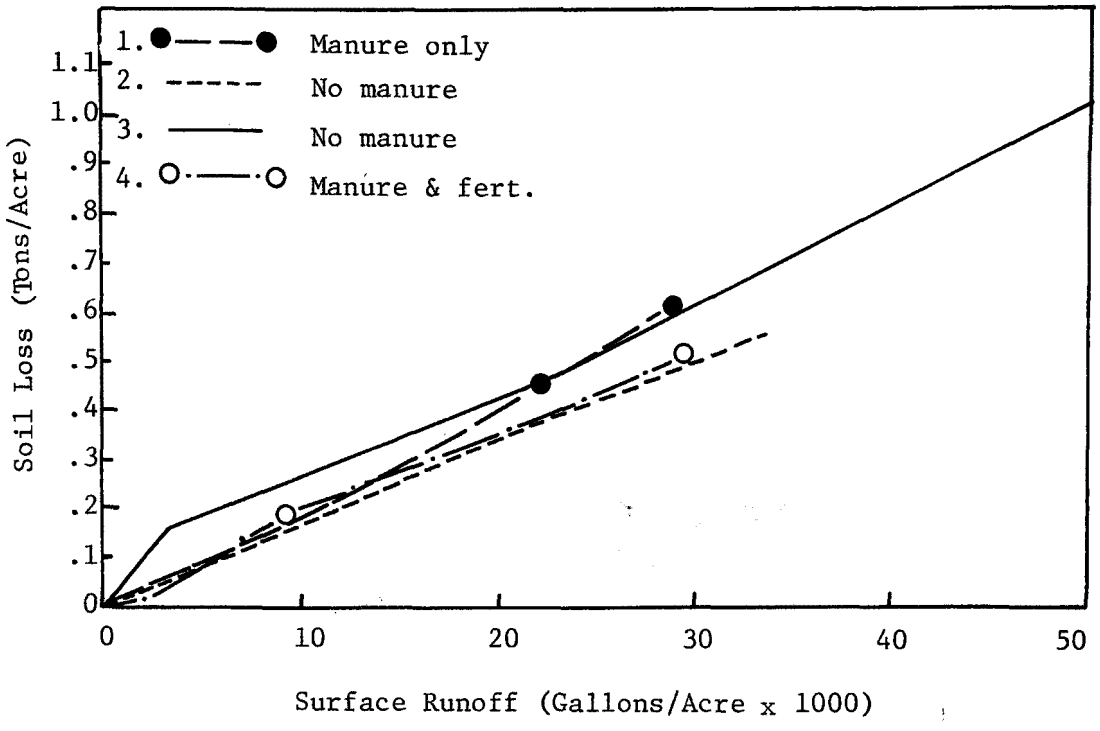


Figure 1. Comparison of Soil Loss and Runoff for Various Treatments for Continuous Corn from Bare Soil

off. Soil aggregate stability against water breakdown has been used as an indication of soil physical condition (Bryant, Bendixen and Slater, 1948).

Figure 9a suggests that for continuous corn production manure and modest amounts of fertilization lead to the largest percent of soil water stable aggregates in the soil.

Under systems of management for continuous corn the importance of return of organic matter to the soil can scarcely be overstressed. This fact is again made plain in Figure 9a, by a soil water stable aggregate content of 39.4% in soil used to produce corn silage. (As noted previously, all plots were studied for aggregate stability but on seven continuous corn treatments were subjected to rainfall simulation.) The equivalent treatments of fertilizer and manure on similar soil used for

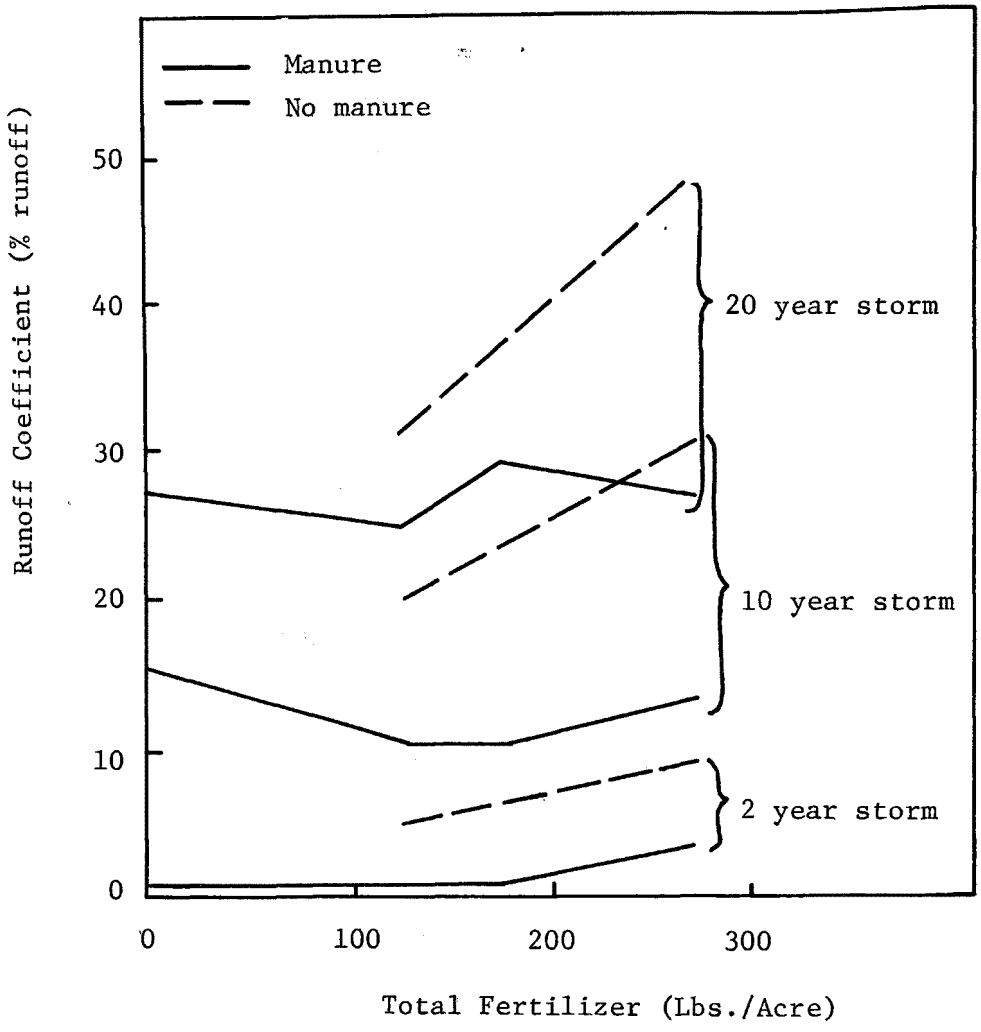


Figure 2. Effect of Fertilizer and Manure on Runoff for Continuous Corn per Storm Frequency from Bare Soil

grain corn production resulted in a soil water stable aggregate content of 56.4%. These differences were significant. One must conclude that the crop residue from corn grain had a beneficial effect upon the physical condition of the soil.

Water stable soil aggregate content illustrated in Figure 9a cannot be used as an exact predictive tool. Yet it is an excellent means for making a qualitative ranking. Treatments ranked number three and seven both received 270 pounds of fertilizer per acre per year. Yet the run-

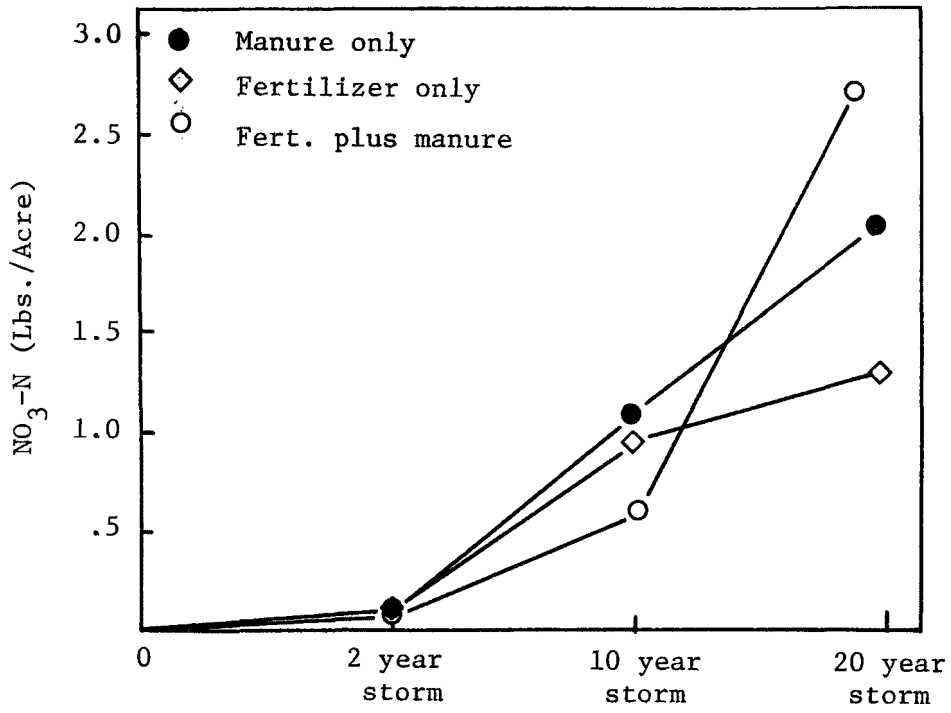


Figure 3. Loss of Nitrate Nitrogen in Surface Runoff for Continuous Corn per Storm Frequency from Bare Soil

off and soil loss from treatment number three was approximately 60% more than number seven which had received six tons of manure (see Figure 1). Figure 9b illustrates the influence of aggregate stability on runoff and soil loss for the two year storm frequency and contains a large amount of variation. All manure treated management systems for continuous corn out rank continuous corn without manure in terms of water stable soil aggregates. Management systems 4 compared to system 7 suggests that manure additions increase water stable soil aggregates by at least 25% at high levels of fertilization. At moderate levels of fertilization there is lesser difference in this aspect of soil physical condition. Contrast management systems 5 and 6 which both receive identical amounts of fertilizer. Reference will be made to soil management as it concerns soil physical condition under economic considerations.

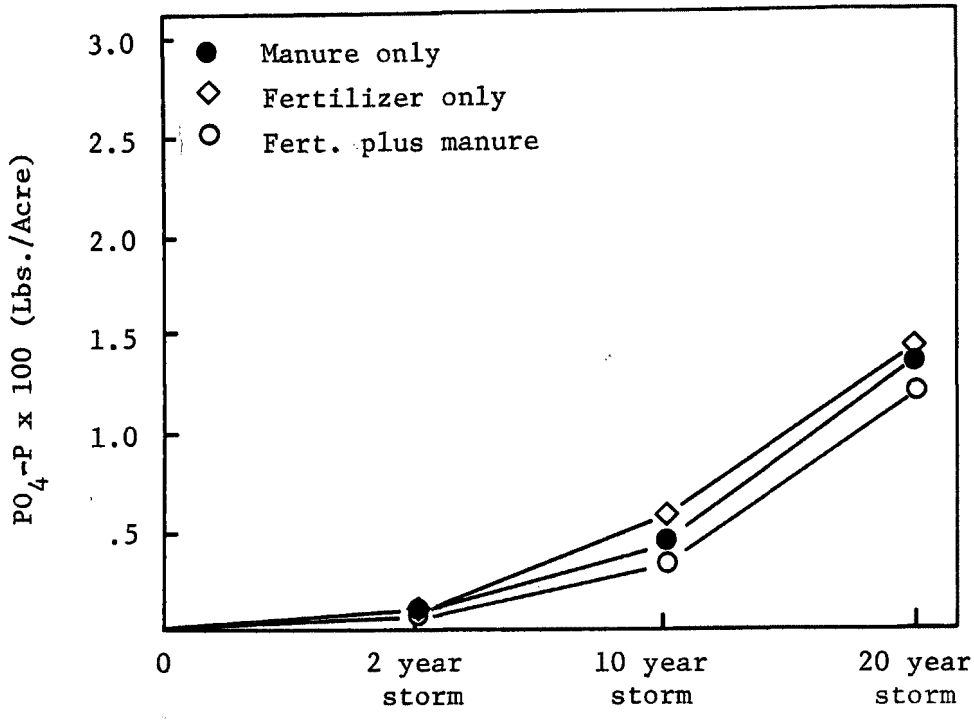


Figure 4. Loss of Soluble Orthophosphate in Runoff Water for Continuous Corn per Storm Frequency from Bare Soil

Mixed Crop Rotations

The management situations and crop sequences available for this study are given in Table 3. Four rotation management systems listed in Figure 10 were selected as being representative of this group.

The percent total suspended solids listed on Figure 10 suggests that these four rotations are all very similar in the amount of suspended material per unit of surface runoff from the small test plots.

Two year storm runoff coefficients for these four management systems average 4%. The number 4 system with no commercial fertilizer and only manure gives the lowest runoff at this initial stage. It is interesting to follow through to the 10 year storm frequency and again compare the four management systems. Here it is clear that number 1 mixed crop rotation containing corn and oats with two years of alfalfa

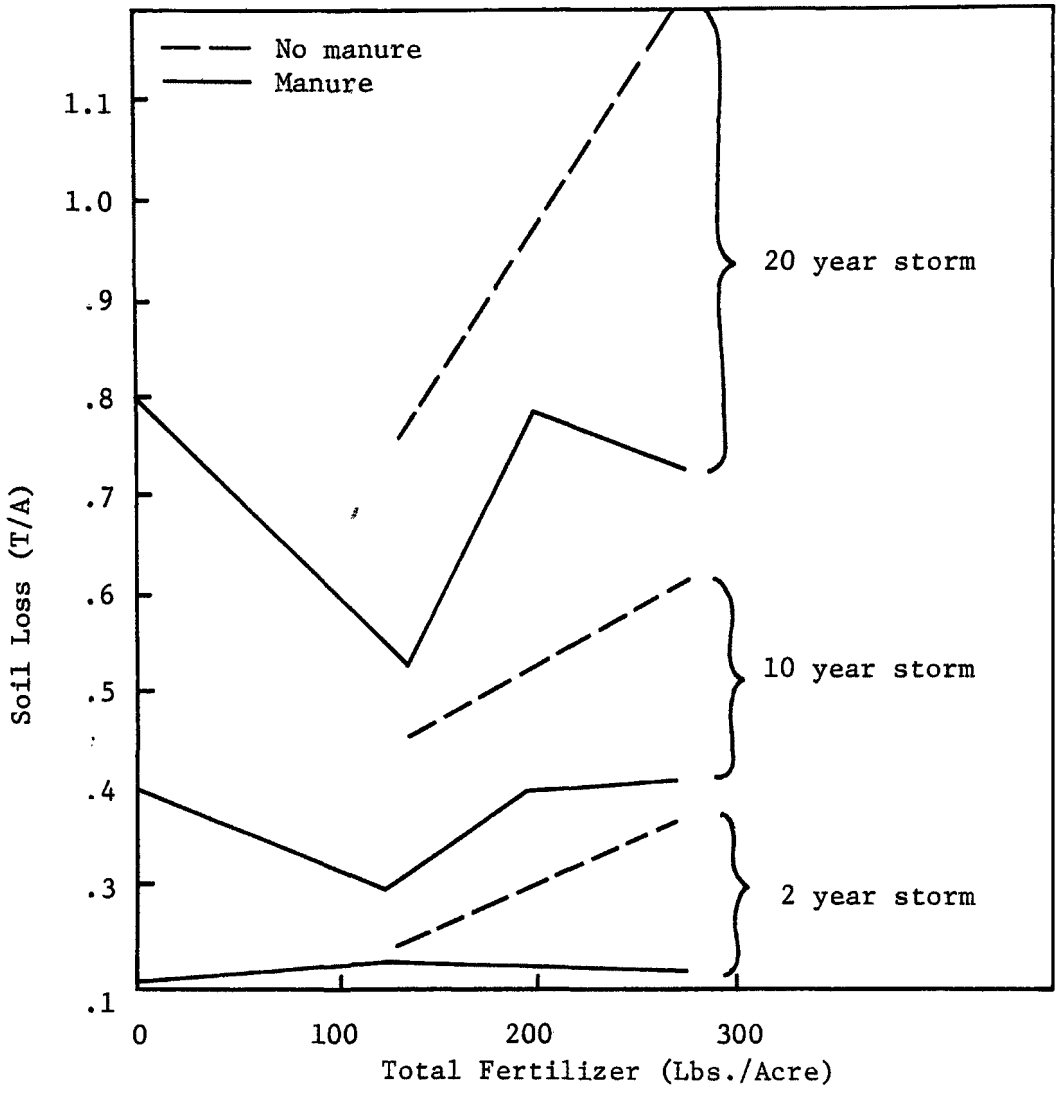


Figure 5. Effect of Fertilizer and Manure on Soil Loss for Continuous Corn per Storm Frequency from Bare Soil

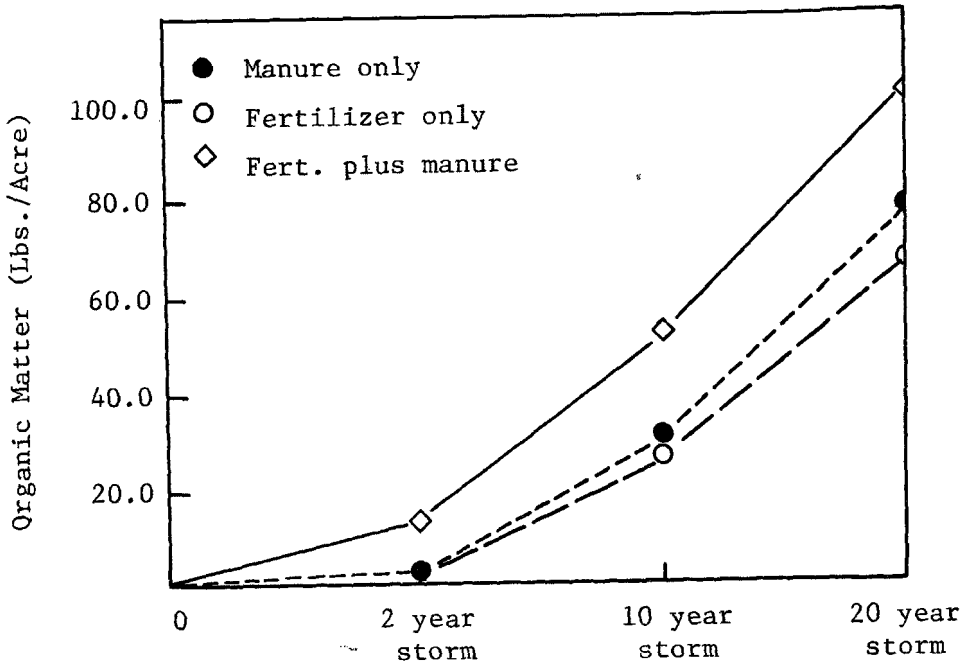


Figure 6. Loss of Organic Matter in Sediment for Continuous Corn per Storm Frequency from Bare Soil

and modest applications of fertilizer is some 4% to 5% lower in runoff than the other three systems. It is suggested that this may be true because system number 2 has no manure and 50% more commercial fertilizer. It has also received 90 pounds of nitrogen as an anhydrous ammonia sidedress. There are indications from the literature that nitrogen fertilization may decrease infiltration rates.

Management systems numbers 3 and 4 each contain two years of alfalfa as do systems numbers 1 and 2. But these two years of alfalfa are separated by a plowing for wheat. Thus in numbers 3 and 4, based on a five year crop rotation, there were three more plowings since 1955 as compared with numbers 1 and 2. Also, they have shorter periods of alfalfa (one year) on the land.

However, the 20 year storm frequency results show a marked contrast. Here again management system number 1 shows superiority over the other systems. Its runoff coefficients is 25% as compared to number 4 at 37% while management systems numbers 2 and 3 show runoff coefficient between these two extremes. An explanation is suggested for the

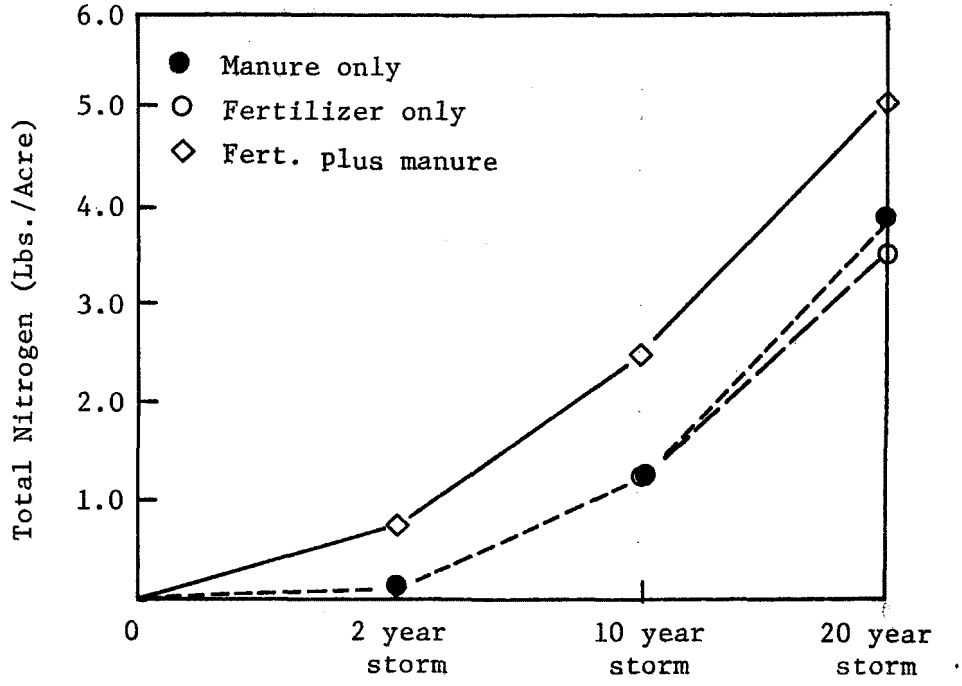


Figure 7. Loss of Total Nitrogen in Sediment for Continuous Corn per Storm Frequency from Bare Soil

increased runoff from management system number 4. As Table 3 indicates this management system receives no commercial fertilizer. Because manure is low in phosphorus this system had produced low yields of alfalfa and hence return of organic matter as root residues was limited relative to the other management systems. This in turn led to a weaker aggregate stability (Wischmeier, 1960b).

The NO_3-N losses under the four various management systems are presented in Figure 11. The two year storm output is remarkably similar for each of the four systems. Apparently very similar factors are operating. Small quantities of water are moving low concentrations of nitrate. During the 10 year storm NO_3-N output is, apparently, inversely related to soil physical conditions. The percent of water stable aggregates in management system number 1 is 74.5. That for number 4 is 78.3 while systems numbers 2 and 3 are 62.9% and 65.2% respectively. It can be postulated that with better aggregation, water and nitrates move downward more freely. Hence there is a lower nitrate loss in surface

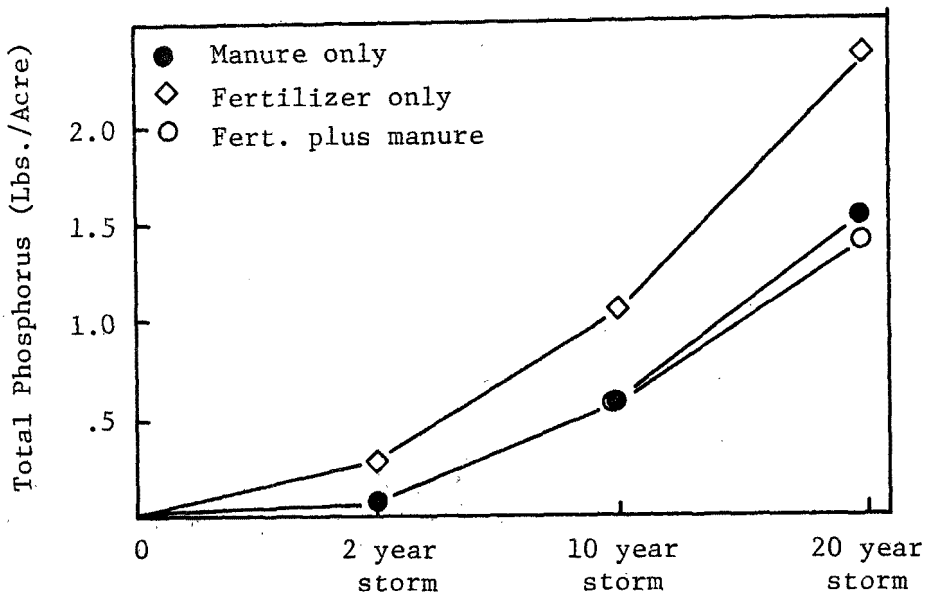


Figure 8. Loss of Total Phosphorus in Sediment for Continuous Corn per Storm Frequency from Bare Soil

runoff. In the case of the 20 year storm, enough water has been applied to cause movement through the topsoil or plow layer. Possibly in management system number 1, two years of alfalfa plus manure reduced runoff and increased infiltration to the point where even the 20 year storm will not cause appreciable quantities of water to move laterally through the topsoil. Management system number 2 without manure has a lower nitrate concentration than systems numbers 3 and 4 with manure. The respective concentrations expressed in parts per million in water coming off are: 5.2 versus 8.2 and 11.4. The differences in concentration together with the runoff differences in addition to the ease of movement of water through the plow layer (great in the case of management systems numbers 3 and 4) account for the differences in NO_3-N output per acre.

The case for PO_4-P (Figure 12) can be explained more simply. Under the 2 year rain there was little or no PO_4-P delivered. In the case of the

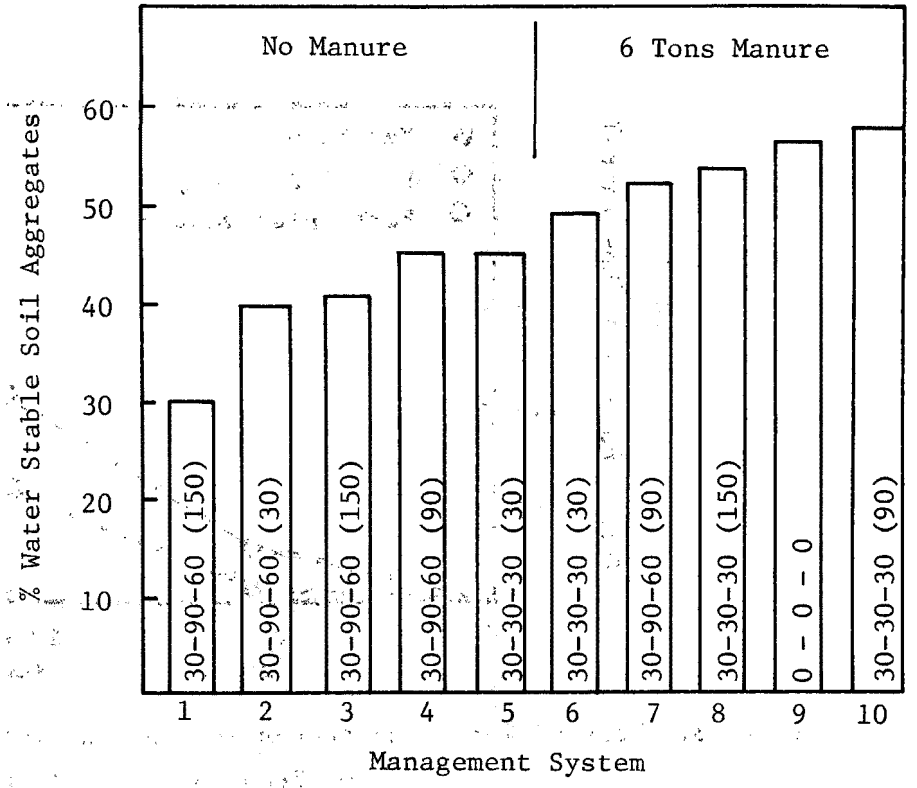


Figure 9a. A Ranking by Soil Aggregate Stability of Ten Continuous Corn Management Systems With and Without Manure.

10 and 20 year storm simulations the PO_4-P delivered under both storm intensities was somewhat proportional to the annual phosphorus and organic matter inputs. These were by systems of management: #1 - 30 pounds plus manure; #2 - 45 pounds, no manure; #3 - 30 pounds plus manure; and #4 - no phosphorus plus manure. If a value of 2.5 pounds of phosphorus, expressed as P_2O_5, is assigned to each ton of the six ton manure application, then each manure application would carry 15 pounds of P_2O_5 with it. Because mineral fertilizer phosphorus is fixed on the soil clay and organic phosphorus from manure is not, it would undoubtedly be safe to assume greater effectiveness of the organic phosphorus in supplying PO_4-P.

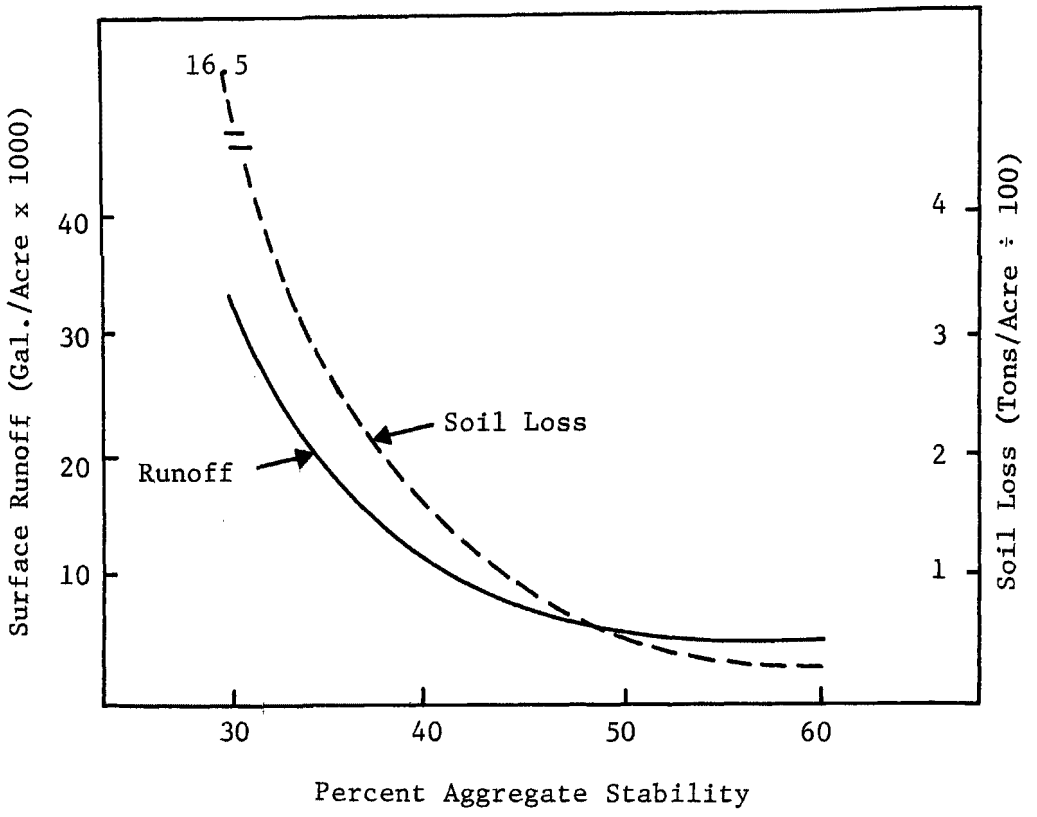


Figure 9b. The Influence of Aggregate Stability on Surface Runoff and Soil Loss from Bare Soil

Soil Loss

Under 2-year simulated rain, soil losses are insignificant (Figure 13). In the case of 10 year and 20 year simulated rain, the soil losses expressed in tons/acre are proportional to the runoff coefficient.

Organic matter losses (Figure 14) are easily understood if the concentration of organic matter in the runoff suspension is considered. Under the two year simulated storm conditions management system number 1 contains 6.6% organic matter in the runoff suspension. Management system number 2 contained only 3.9% organic matter. The manure applied to management system number 1, apparently, greatly increased the concentration of organic matter in the runoff. The fertilizer used in management system number 2 actually decreased the organic matter

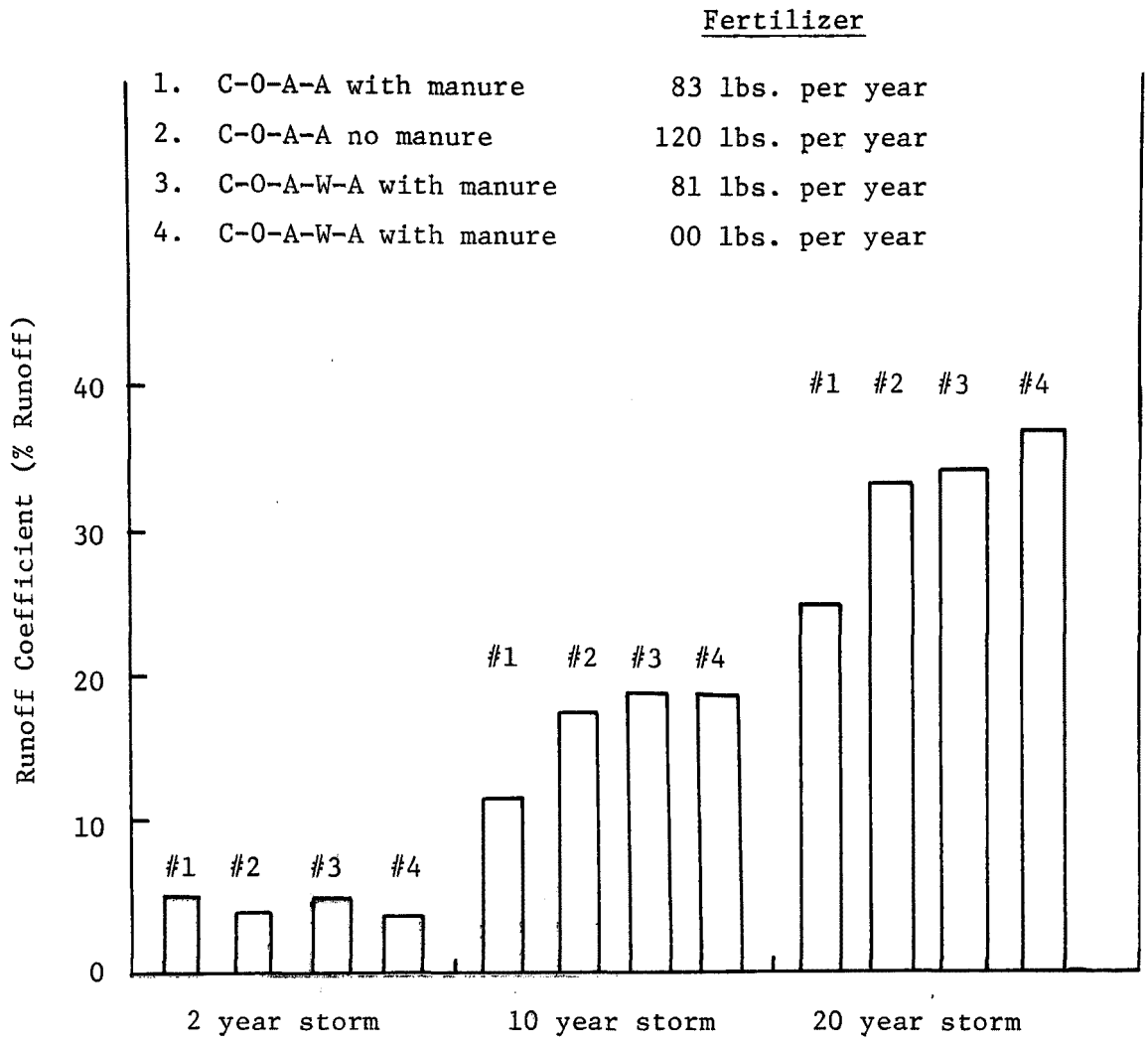


Figure 10. Runoff Coefficients Under Four Selected Rotations per Storm Frequency from Bare Soil

content of the runoff suspension. Management system number 3 also generated less organic matter content in the soil of the eroding suspension than in the original soil (4.3% vs 4.6%). Hence the lower organic matter loss under this system. There was no sample from system number 4 due to inadequate sample size.

The same trends discussed under the two year storm frequency for differences in organic matter between the original soil and the suspended soil in runoff hold true for the 10 and 20 year storms. Management system number 1 organic matter content of soil in runoff exceeds management system number 2 by more than 10% on a comparative basis.

Table 3. Management Treatments for Mixed Rotations

Code	Rotation	Manure (T/A)	Fertilizer (Lbs./A)	Total Fert. (Lbs./A)
C_4W	(1) C-O-A-A			
	Corn	12	30-30-30 (30)[2]	120
	Oats	0	30-30-30	90
	Alfalfa	0	0-30-30	60
	Alfalfa*[1]	12	0-30-30	60
			Mean	83
C_4Y	(2) C-O-A-A			
	Corn	0	30-30-30 (30)	120
	Oats	0	30-30-30	90
	Alfalfa	0	0-30-30	60
	Alfalfa*	0	0-30-30	60
			Mean	83
C_4Z	(3) C-O-A-A			270
	Corn	0	30-90-60 (90)	270
	Oats	0	30-30-30	90
	Alfalfa	0	0-30-30	60
	Alfalfa	0	0-30-30	60
			Mean	120
D_1Y	(2) C-C-O-A-A			
	Corn*	0	30-30-30	90
	Corn	0	30-30-30 (30)	120
	Oats	0	30-30-30	90
	Alfalfa	0	0-30-30	60
	Alfalfa	0	0-30-30	60
			Mean	84
E_5Y	(1) C-O-W-A-A			
	Corn	10	30-30-30 (30)	120
	Oats	0	30-30-30	90
	Wheat	10	15-30-30 (30)	105
	Alfalfa	0	0-30-30	60
	Alfalfa*	10	0-30-30	60
			Mean	87
F_5W	(1) C-O-A-W-A			
	Corn	10	30-30-30 (30)	120
	Oats	0	30-45-45	120
	Alfalfa	0	0- 0- 0	0
	Wheat	10	15-45-45	105
	Alfalfa*	10	0-30-30	60
			Mean	81

Continued on next page

Table 3. (Continued)

Code	Rotation	Manure (T/A)	Fertilizer (Lbs./A)	Total Fert. (Lbs./A)	Code	Rotation	Manure (T/A)	Fertilizer (Lbs./A)	Total Fert. (Lbs./A)
D_1W	(1) C-C-0-A-A				F_5Z	(2) C-0-A-W-A			
	Corn*	10	30-30-30	90		Corn	10	0- 0- 0	0
	Corn	10	30-30-30 (30)	120		Oats	0	0- 0- 0	0
	Oats	0	30-30-30	90		Alfalfa	0	0- 0- 0	0
	Alfalfa	0	0-30-30	60		Wheat	10	0- 0- 0	0
	Alfalfa	10	0-30-30	60		Alfalfa*	10	0- 0- 0.	0
			Mean	84				Mean	0

1. * = Crop plowed under for this experiment.

2. ( ) = Anhydrous Ammonia Sidedress

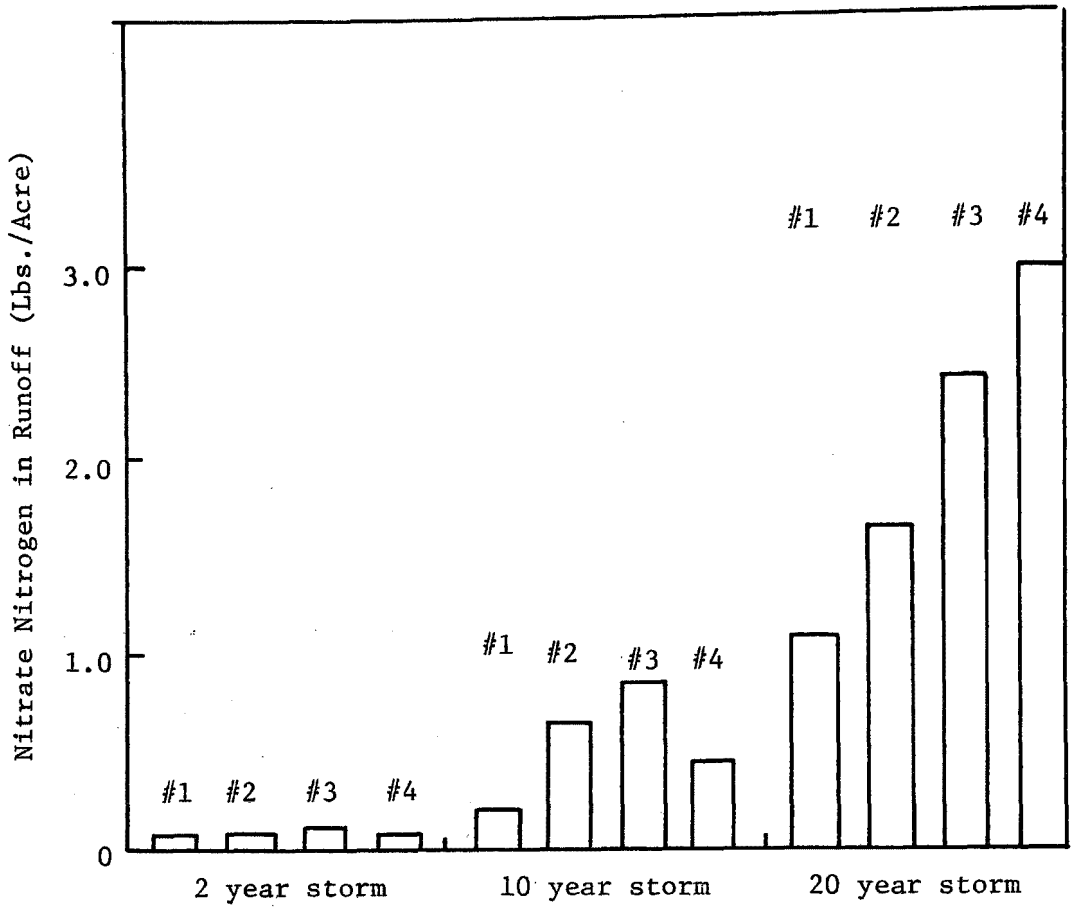


Figure 11. Nitrate-N Loss in Runoff Under Four Selected Rotations per Storm Frequency from Bare Soil

This same comparative basis holds when management systems numbers 3 and 4 are compared.

Total nitrogen loss is presented in Figure 15. These values follow organic matter losses very closely. Total nitrogen contents are approximately 5% of the organic matter content. Nitrogen is lost in the erosion processes primarily as soil organic matter.

Figure 16 presents the total phosphorus losses for these four systems. Again these losses closely parallel the organic matter losses. Total phosphorus losses are approximately 2% of the organic matter losses.

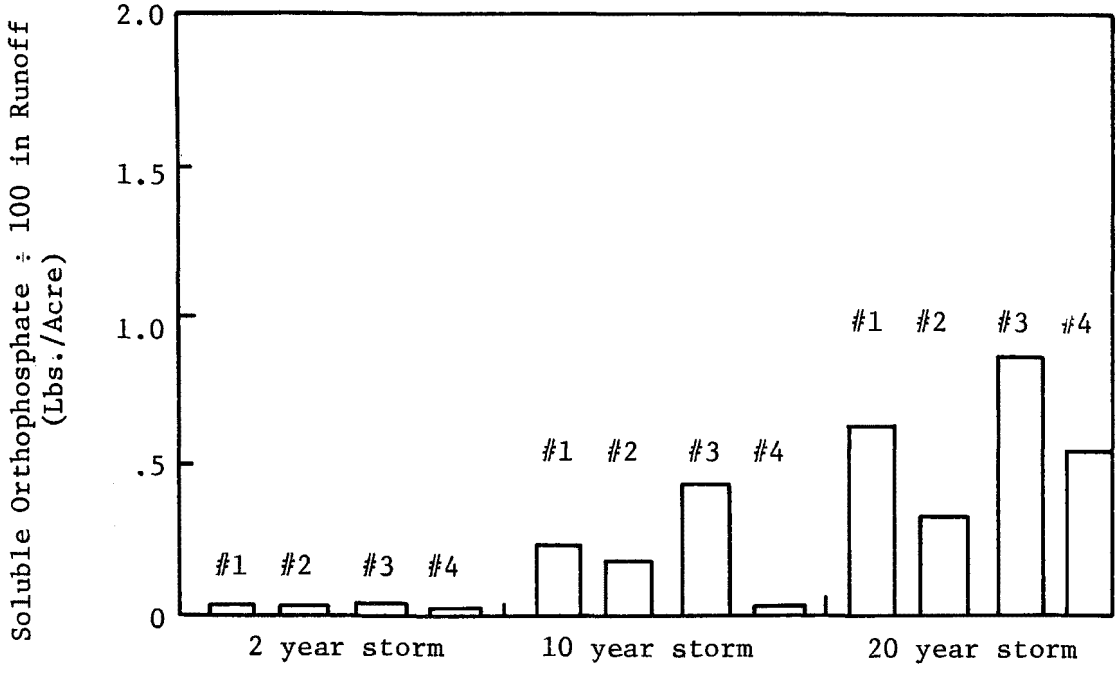


Figure 12. Soluble PO_4-P Loss in Runoff Under Four Selected Rotations Per Storm Frequency from Bare Soil

Soil Physical Condition

Figure 17 shows the percent water stable aggregates for each management system under the corn crop. Except for management system number 4 these values are inverse to the runoff coefficients. Management system number 4 generates increased runoff only under the 20 year storm values. With the 2 year storm the runoff is in good alignment with aggregate stability. It must be concluded that the water stable aggregates generated under system number 4 are less resistant to rain drop impact than under the other three systems.

Continuous Hay Rotations

As a group (Table 4) these management systems are unique. They show low runoff coefficients (Figure 18) and low soil losses (Figure 19). In the group of the three management systems presented here number 3 treatment shows double the runoff over the other two management systems. This difference can be explained by the fact that number 3 is essentially a "neglected meadow" system of management. Although dry

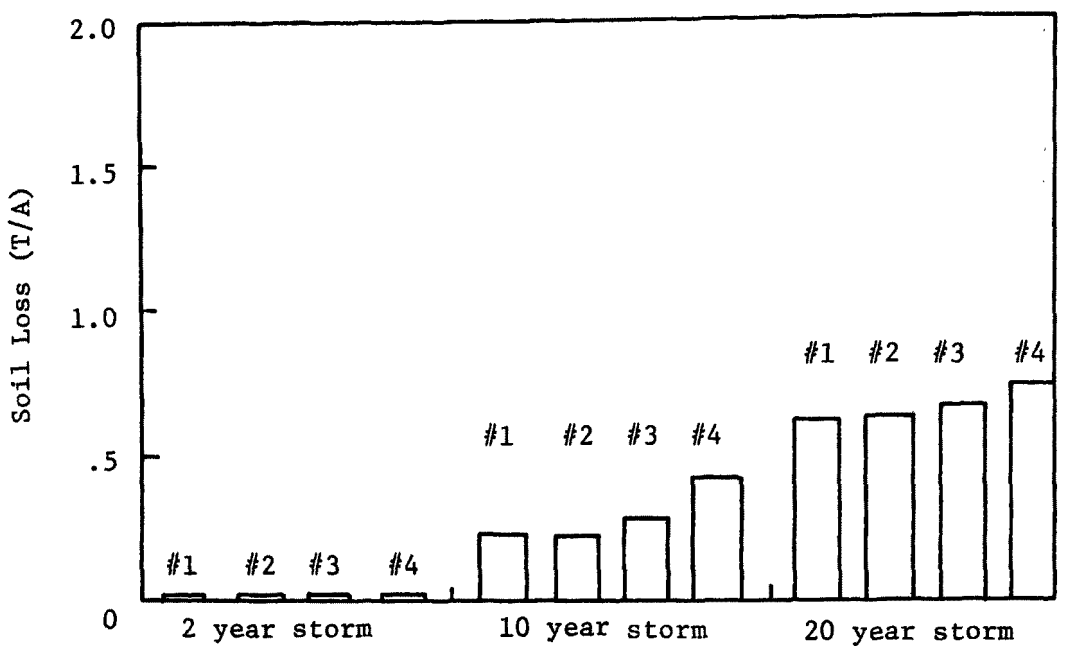


Figure 13. Soil Loss in Runoff Under Four Selected Rotations per Storm Frequency from Bare Soil

matter production under this system is 90% of the numbers 1 and 2 systems, the character of vegetation is far different. It is shallow rooted and more sparse than alfalfa. As a result of this difference in root density the number 3 management systems is subject to continued runoff under continued high rain intensities. This increased runoff carries both NO_3-N (Figure 20) and PO_4-P (Figure 21) with it out of the soil at higher volumes of water (Wischmeier, 1960b)

Soil loss under 10 year storm intensity is much greater with management system number 3 than numbers 1 or 2. It would appear that management system number 3 generates a soil physical condition that resists erosion up to a certain critical value. Even though the system has received manure it then erodes to a considerable degree although less than continuous corn without manure. The above is also true for the 20 year simulated storm.

Organic matter losses (Figure 22) parallel soil losses. Again total nitrogen (Figure 23) makes up approximately 5% of the organic matter. Total phosphorus (Figure 24) is approximately 2%. For the three

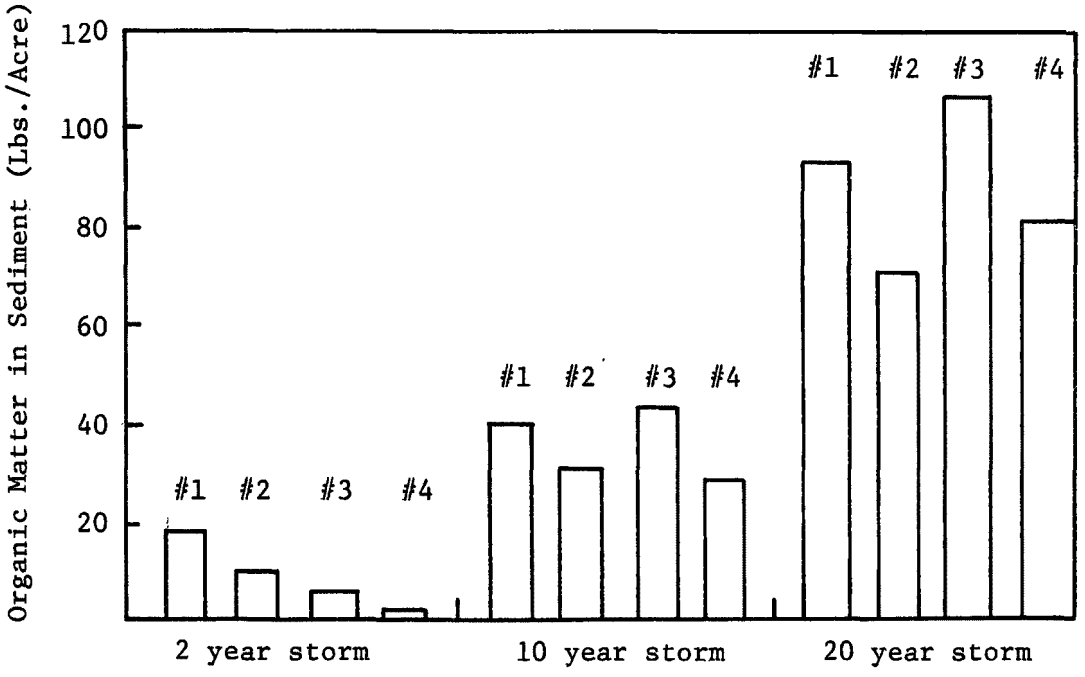


Figure 14. Organic Matter Loss in Sediment Under Four Selected Rotations per Storm Frequency from Bare Soil

management systems the percent of water stable aggregates was very high, having a mean value of 70%. There was no appreciable difference between number 2 management system without manure and the other two systems with manure.

Additional comparisons from the data were made between continuous corn for silage, continuous corn for grain, corn-corn-oats-alfalfa-alfalfa and wheat-alfalfa-alfalfa-alfalfa-alfalfa all receiving six tons of manure per acre per year. The intent was to determine if the effect of manure would tend to mask the differences between continuous corn and rotations consisting of varying amounts of alfalfa. The results showed that additions of manure on continuous corn were beneficial to the point that surface runoff and soil losses were essentially the same as a mixed rotation (C-C-O-A-A), but that nutrient losses were somewhat lower for continuous corn. Long term alfalfa (W-A-A-A-A), as previously demonstrated, was the most resistant to erosion losses.

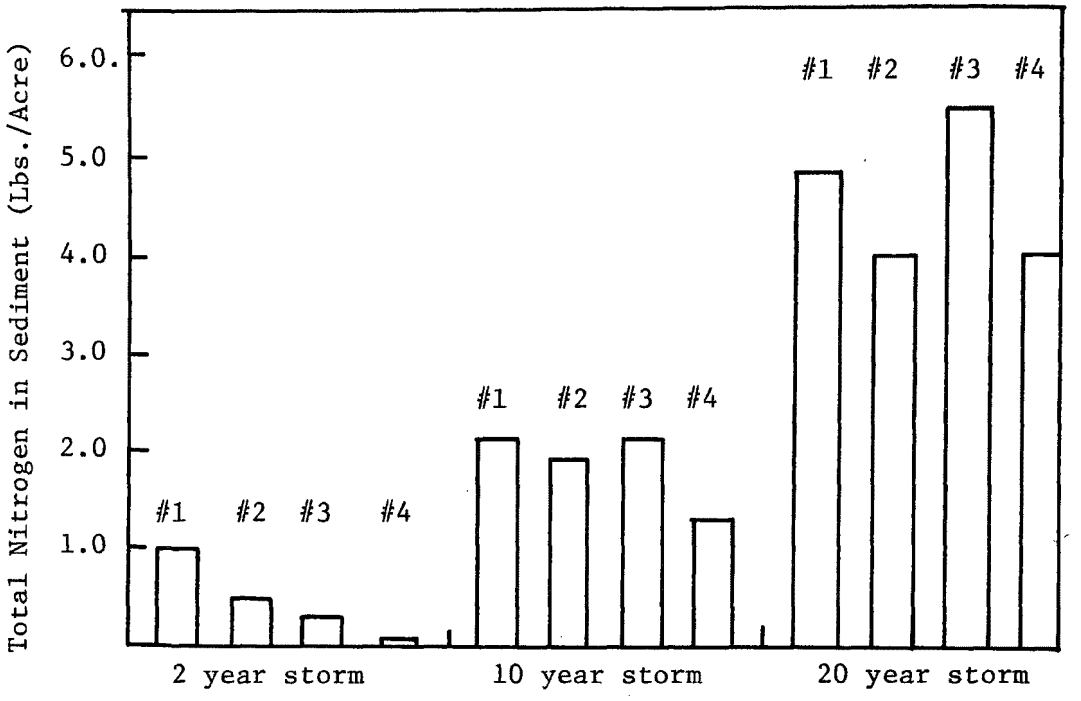


Figure 15. Total Nitrogen in Sediment Under Four Selected Rotations per Storm Frequency from Bare Soil

Continuous corn grown for silage proved to be more erosive than continuous corn grown for grain. Even though both situations received the same amounts of manure, the additional return of plant residues as in the case of corn grown for grain had an additional beneficial effect.

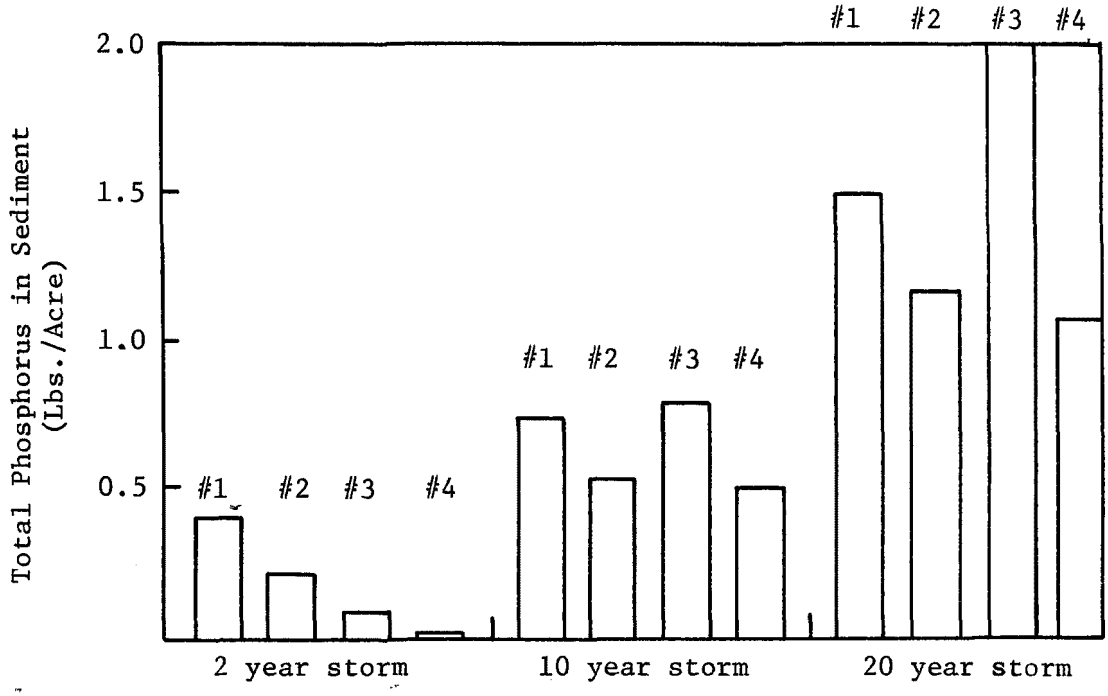


Figure 16. Total Phosphorus in Sediment from Runoff Under Four Selected Rotations per Storm Frequency from Bare Soil

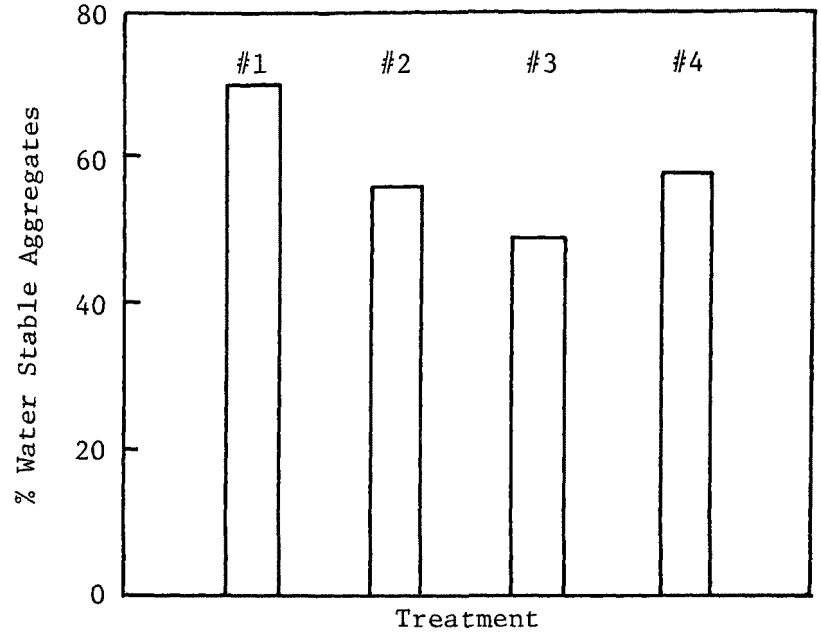


Figure 17. Percent Water Stable Aggregates - Soil from Four Selected Rotations

Table 4. Management Treatments for Continuous Hay

Code	Rotation	Manure (T/A)	Fertilizer (lbs./A)	Total Fertilizer (lbs./A)
1				
H_4W	(1) W-A-A-A-A			
	Wheat	10	15-30-30 (30)[2]	105
	Alfalfa	0	0-30-30	60
	Alfalfa	10	0-30-30	60
	Alfalfa*[1]	0	0-30-30	60
	Alfalfa	10	0-30-30	60
			Mean	69
2				
H_4Z	(2) W-A-A-A-A			
	Wheat	0	15-30-30 (30)	105
	Alfalfa	0	0-30-30	60
	Alfalfa	0	0-30-30	60
	Alfalfa*	0	0-30-30	60
	Alfalfa	0	0-30-30	60
			Mean	69
3				
JW	Continuous Hay	6	0-45-45	90

[1] Crop Plowed under for this experiment.

[2] ( ) = Anhydrous Ammonia Sidedress.

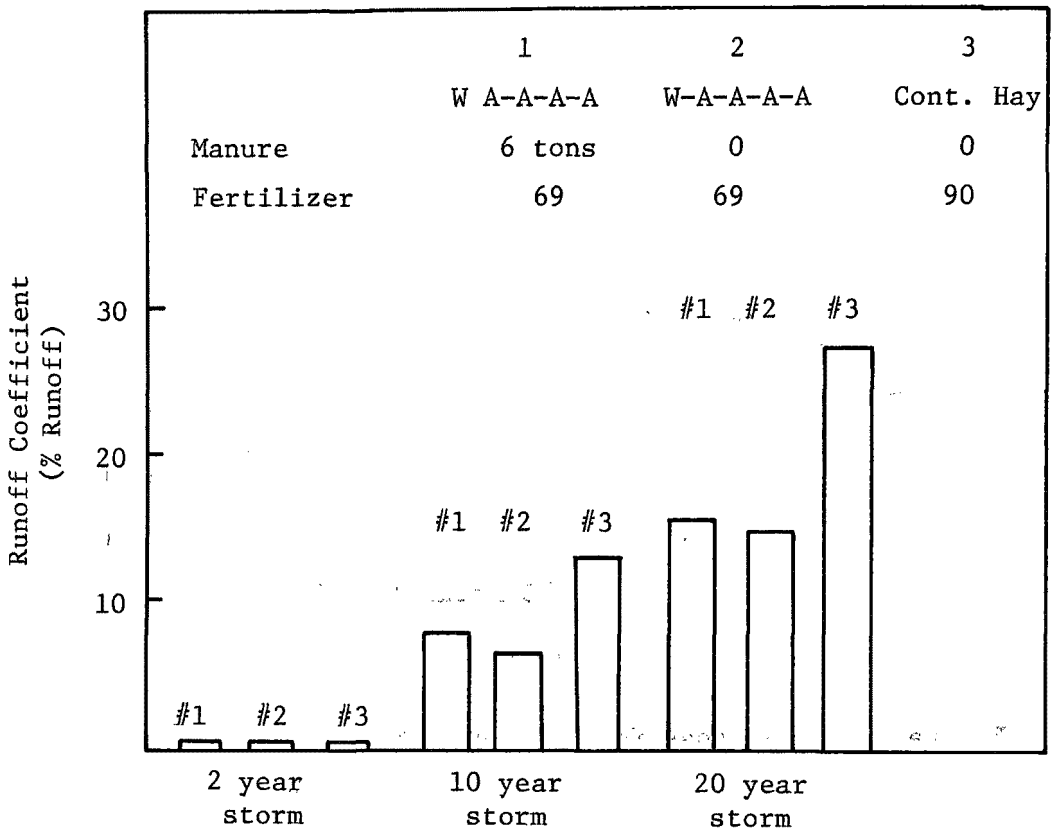


Figure 18. Runoff Coefficients for Hay Rotations per Storm Frequency from Bare Soil

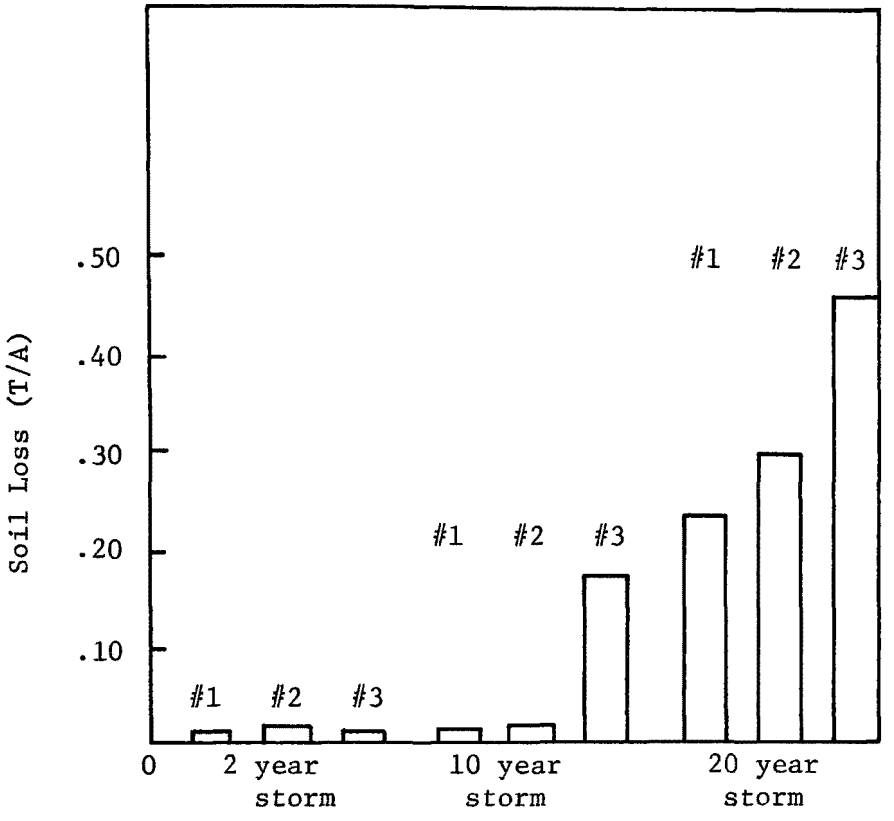


Figure 19. Soil Loss for Hay Rotations per Storm Frequency from Bare Soil

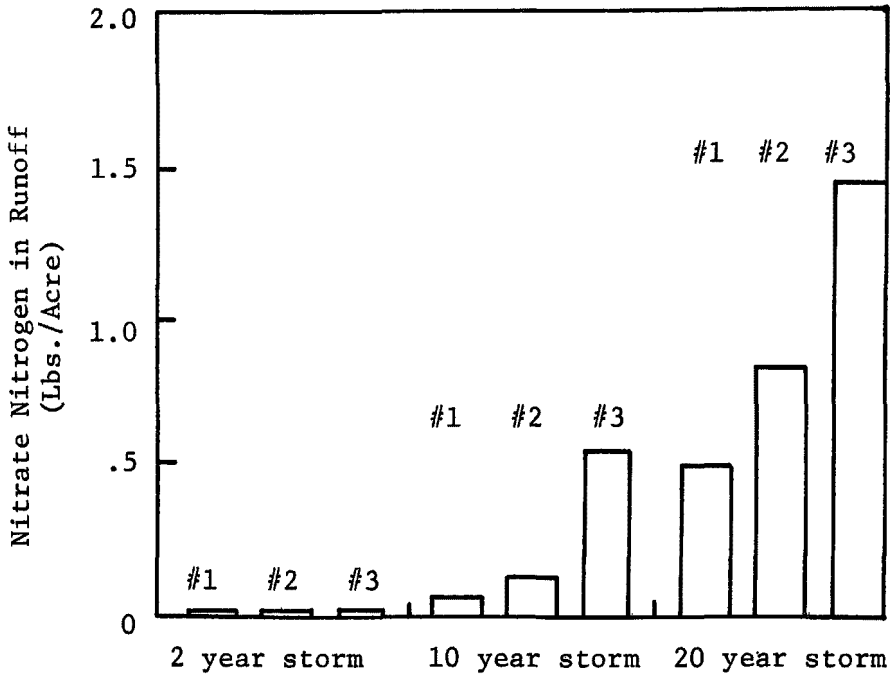


Figure 20. Nitrate-Nitrogen Losses in Runoff for Hay Rotations per Storm Frequency from Bare Soil

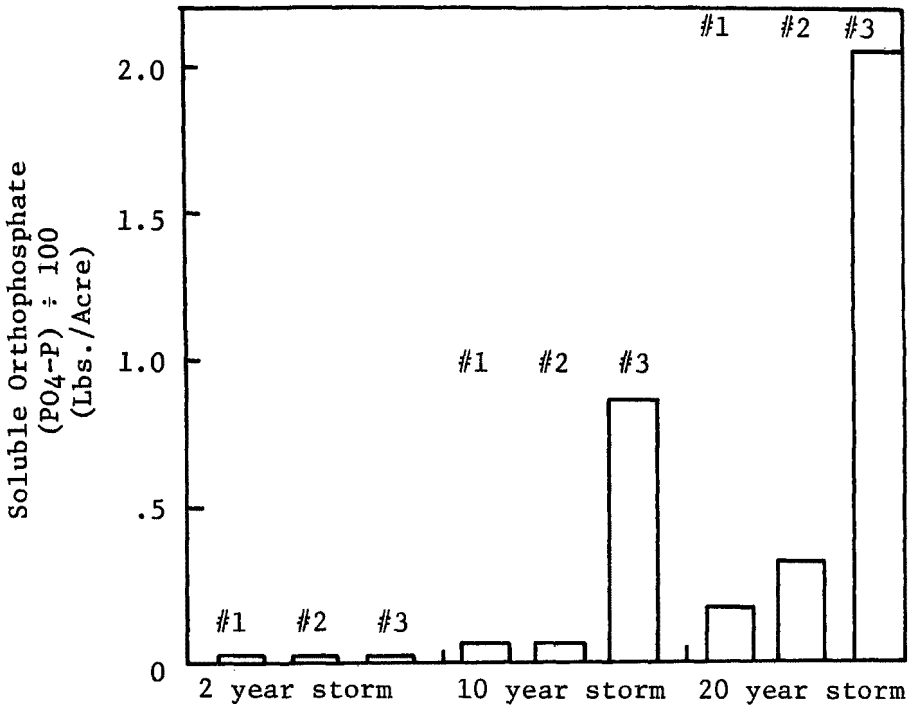


Figure 21. Soluble Orthophosphate Losses in Runoff for Hay Rotations per Storm Frequency from Bare Soil

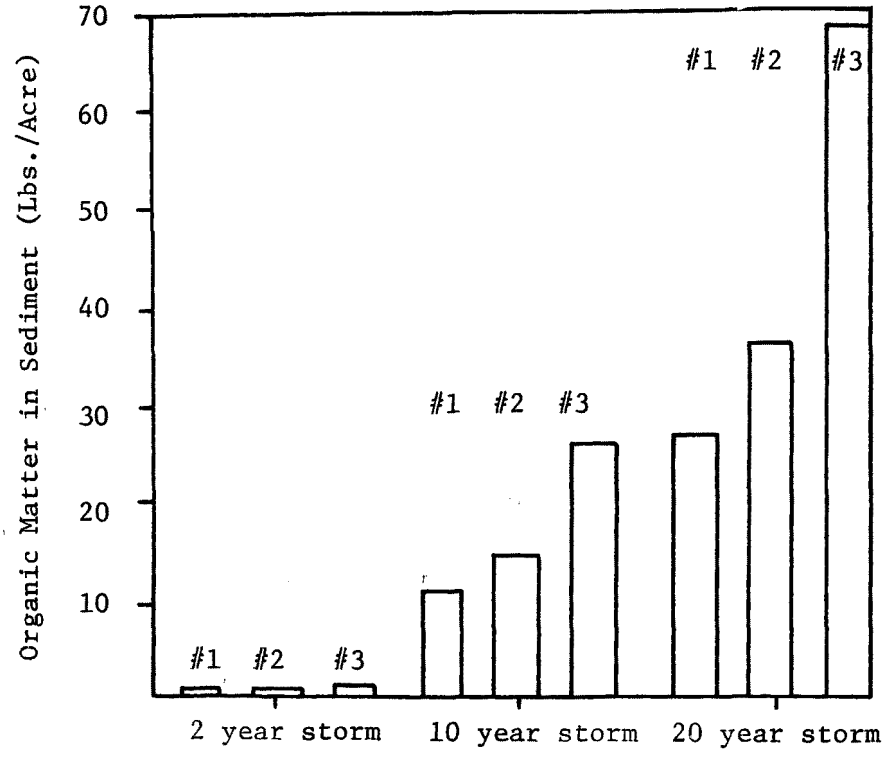


Figure 22. Loss of Organic Matter in Sediment for Hay Rotations per Storm Frequency from Bare Soil

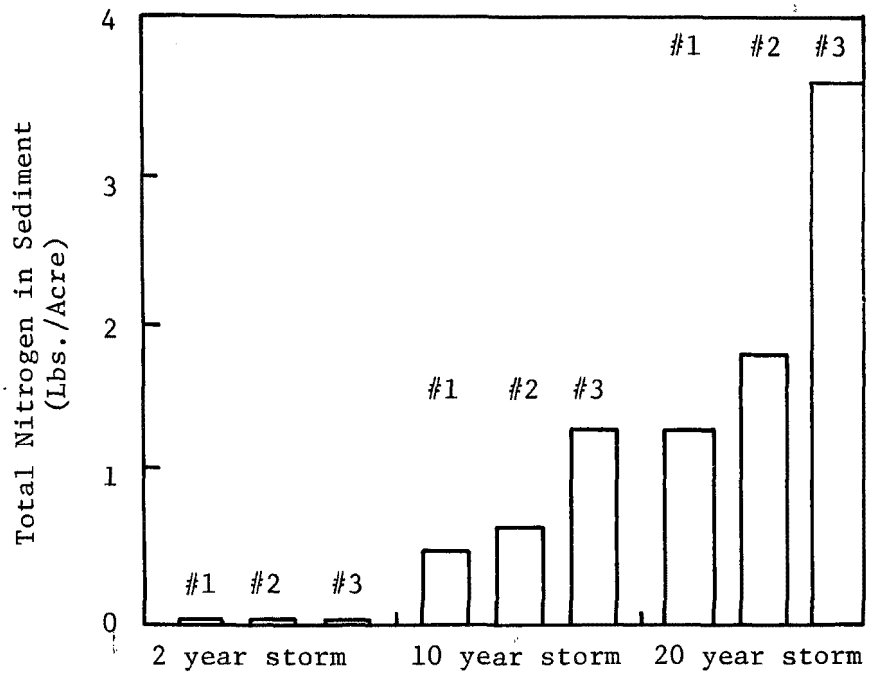


Figure 23. Total Nitrogen Lost in Sediment for Hay Rotations per Storm Frequency from Bare Soil

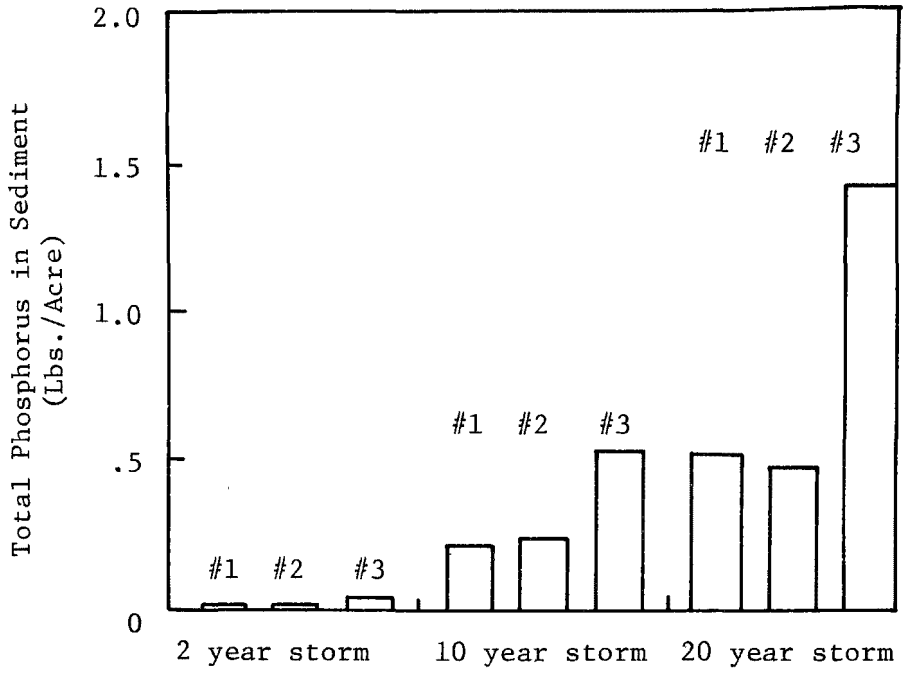


Figure 24. Total Phosphorus Lost in Sediment for Hay Rotations per Storm Frequency from Bare Soil

SECTION V

FIELD SCALE WATER QUALITY STUDY

In the general introduction, we considered the similarity between waste water treatment plants and the natural hydrological cycle as it occurred outdoors in connection with soil and water and nutrient management. Here we attempt to deal with this problem in that we will describe in some detail the general philosophy and the method that has been used to approach the problem so that the findings could be used over relatively large areas.

The outstanding characteristics of the agricultural soil in the eastern and central United States is that they are gently sloping, that for the most part they are silt loams, and that they are subject to moderate degrees of erosion under cultivation. It has been well established that in order to study such phenomena as the rate of movement of water through the soil in the process of underdrainage, a relatively large area is needed to achieve valid results. It is also well-known that the quantities of soil that are removed in studies of natural rainfall and in studies of artificial rainfall applications, are dependent upon the size of the area used for the study. Thus, if we were to have a valid "ecosystem", a unit in which we can measure the inputs and effects of various factors upon the soil and the environment, it would be necessary to have a relatively good sized area so that we could obtain results that would be quite similar to those that we might find in a farmer's field.

It also became apparent that it would be highly desirable, as a first approximation in this study, to emphasize differences between what we will refer to throughout this text as "good" and "poor" practice. We established good and poor practice in a situation that would normally be considered as cash crop farming. While cash crop farming is, at the moment, probably not a major contributing source of pollution in New York State, it has been and may be in the future, a major contributing source of pollution throughout the mid-west. It was for this reason, the two years of preliminary results indicated what harm excessive fertilization might do to water quality; we have used 24 large plots to study primarily the effect of fertilizer, crop, and management. These plots are unique in that they have been treated under good and poor management consistently since 1956. The soil types are representative of fairly large areas. The amount of drainage water that percolates through these plots are intercepted by the drain is a good representation of interception type drainage found throughout the eastern and mid-western part of the United States.

In most other studies of this type, individual random drains have been utilized and nitrates and/or some particular component such as ammonia, have been monitored for irregular periods in connection with the flow

from a particular drain. This study has made it possible to relate nutrient output (NO_3-N, NH_4-N, PO_4-P) to specific cropping practices and specific management practices and specific levels of fertilization. It serves as a guide for recommended levels of fertilization for commercial farmers in New York as well as in the mid-western and eastern states generally.

Methods And Materials

This experimental installation was designed to study the quantity and quality of surface and subsurface water flow. The experimental field is made up of approximately 30 acres of a Lima-Kendaia soil association at the Cornell Agronomy Research Farm near Aurora, New York. A total of 24 plots of 0.8 acres each were installed in 1956. The study was maintained as a drainage study until 1968. Half of the plots appear on the Kendaia silt loam, a somewhat poorly drained soil, the remainder are situated on the Lima silt loam which is moderately well drained soil.

Surface runoff and subsurface drain flow has been studied under crop and management systems that were identical with cash grain farming. All plots are farmed across the slope with a minimum of tillage. The three major treatments considered are crop, fertility, and management.

The crop rotation consists of corn, beans, and wheat each under normal and high fertility levels. Each treatment is further divided into two management schemes. Good management consists of using cover crops wherever possible and returning all plant residue. Poor management is effected by omitting all cover crops and removing all plant residue after harvesting. The cropping and fertilizing system is presented in Figure 25. The treatment schedule appears in Table 1 of Appendix B. The statistical model used is a completely randomized design consisting of a three factor analysis containing two replications. The three by two by two factorial analysis is made up of three crops, each at two levels of fertility, and each at two levels of management, replicated twice for a total of 24 plots ([3x2x2]x2).

Surface water is controlled by a series of small interceptor and broad shallow runoff ditches. Individual plots have surface slopes on an average of two to four percent. Runoff water is diverted into a flume so that total quantity of surface flow may be measured. An integrated sample of the surface runoff is collected for laboratory analysis as follows: all surface water is diverted from the interceptor ditch through an intake grate. The water then flows into a 12 inch H-flume where the height of the water in the flume is recorded automatically against time with an FW-1 stage recorder. A subsample of approximately 1% is collected by a mechanically driven Coshocton wheel. This sample is further divided by a splitter arrangement which collects 20% of the subsample. This integrated water sample, taken over the entire period of flow, is collected in a storage tank. A liquid and solid (soil sediment) sample is collected and analyzed as soon as possible after a storm (see Appendix A). The data points are transferred from the hydrograph to computer cards and a program has been established to calculate flows for given time periods (see Appendix B, Tables 2, 3, and 4).

Subsurface flow of water is studied with the use of a single drain tile approximately three feet below the surface. These tile lines are

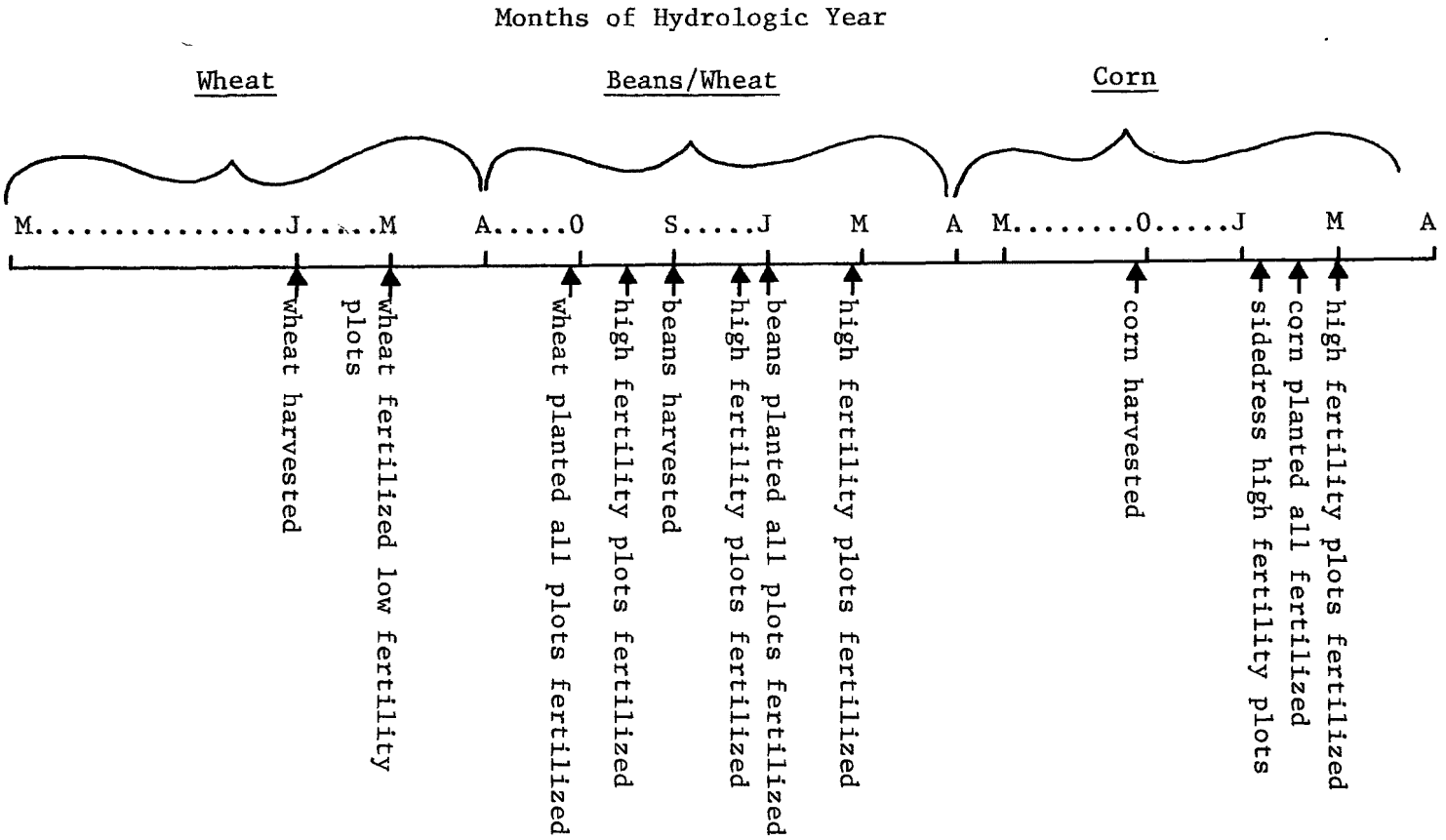


Figure 25. Sequence of Events - 1970-71 - Field Scale Water Quality Study

centered in 12 randomly selected plots. The tile is four inches in diameter and empties into an underground metering tank. The tile flow empties directly into a buffer chamber before flowing through a 90° sharp crested V-notch weir. A Cassela recorder plots the stage height versus time in the form of a hydrograph. Tile flow data is also transferred to computer cards and a program calculates gallonage of tile flow per plot. A representative subsample of tile flow is collected from a uniform drip flow into a container.

Analytical determinations for ammoniaical-nitrogen, nitrate-nitrogen, soluble orthophosphate and, since January 1971, total phosphorus in water, are done at the Cornell University soil testing laboratory. Suspended solids in solution represented as sediment samples, are collected and weighed (see Appendix A).

Results And Discussion

Even though a watershed may have a large capacity to store water in the soil, the infiltration rate may limit the percentage of rainfall that can enter the soil. Whenever rainfall occurs more rapidly than infiltration, water moves downslope across the surface. A portion of the water that does infiltrate may only percolate to a shallow depth and reappear downslope as ground water seepage at the surface, otherwise percolating water, if in excess, will leach through the soil profile to the ground water reservoir, or to a subsurface drain (Figure 26).

Whether water moves across the surface or through the soil profile, it will transport material. Surface runoff, unlike subsurface flow, can transport solids as suspended material. Transport of solids can be of considerable magnitude especially during heavy rains when quantities of soil lost can be very high. Phosphorus, being relatively easily fixed by the soil and rather insoluble, can be lost in large amounts by the physical removal of soil from the land surface. Nitrogen is readily converted to a soluble form and is easily subject to losses by both surface runoff and leaching (Russell 1961).

Any farm management scheme that can promote a reduction in surface runoff and a consequent increase in infiltration is effectively controlling water pollution from surface runoff. This idea had been incorporated into the water quality study as a main treatment, which is designed as good and poor management. In this particular study, good management consists of returning crop residues back to the land and on poorly managed fields, the crop residue is removed. The practicality of this type of treatment can be illustrated by considering a corn field. A poorly managed system can be corn cut for silage in which almost all of the crop is removed, in contrast to corn harvested for grain where almost all of the crop except the grain remains in the field.

The return or addition of organic matter to the soil promotes soil improvement. Organic matter, whether plant residues or manure, has been shown to have an effect on improving soil structure (see previous section). If soil structure is improved, there is better aggregation and a consequent increase in infiltration. This effect is desirable for surface water pollution, but increases the risk of contaminating subsurface water with leached nitrates.

The following figures illustrate the main findings of the study. They confirm many predictions based on the results of the small scale component studies described in the previous section. The hydrologic year used in this study is based on Brakensiek's (1959) demonstration that soil moisture is the most predictable at about April 1. Deep seepage values were calculated from Thornthwaite's (1957) extensive work on soil moisture storage, evapotranspiration and rainfall using actual measured values for rainfall and surface runoff. The tile drain acts

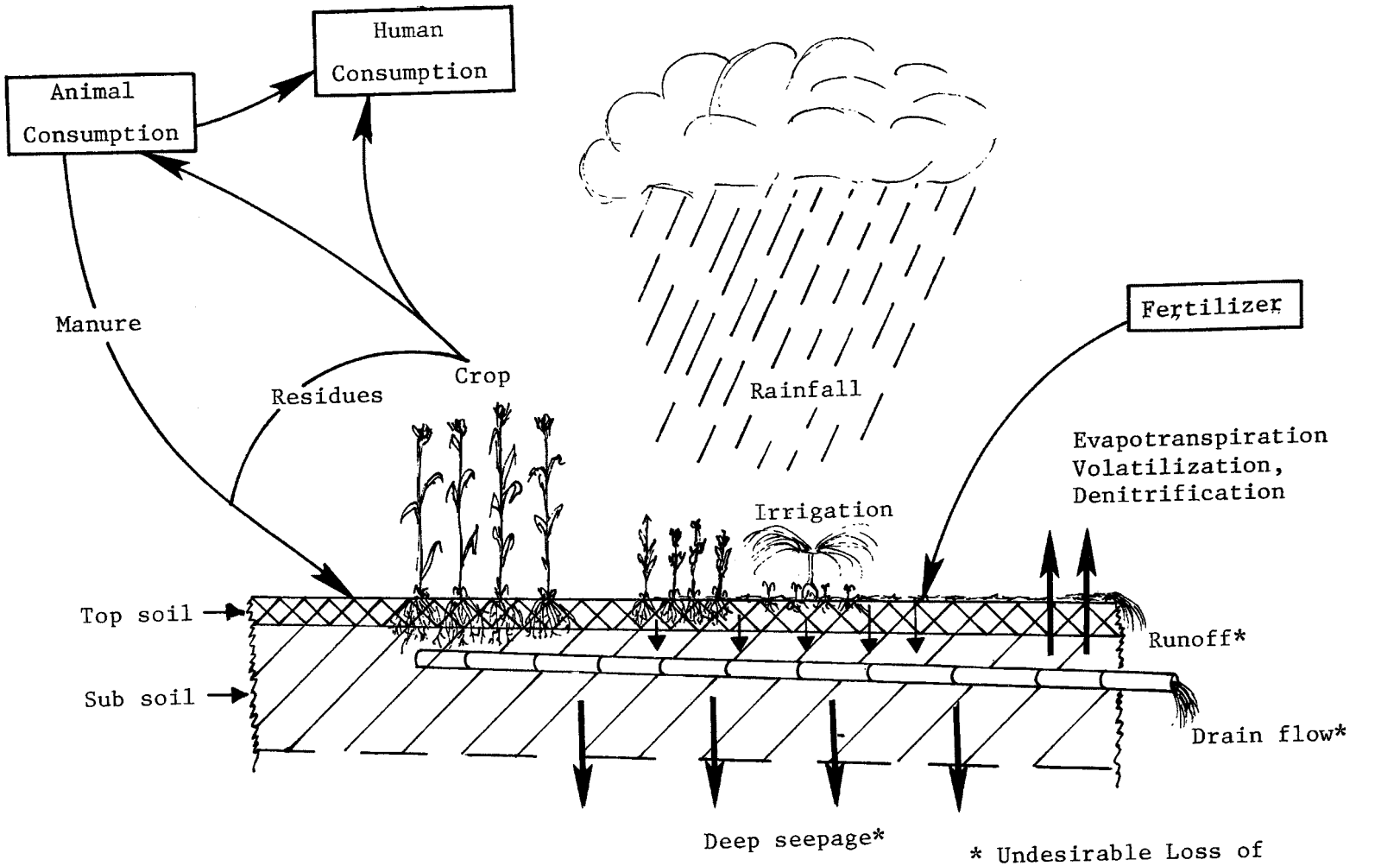


Figure 26. Nutrient and Hydrologic Cycle for Agricultural Land

as an indicator of potential deep seepage conditions, and supplies a sample of percolate for analysis.

Hydrologic Effects

It has been shown that deep seepage occurs mostly between October and December (see Figure 27). The only other time that deep seepage may be of concern is in March when the effect of accumulated snow is most noticeable. This is highly variable from year to year. However, it is almost certain that by June 1, in most years, any appreciable deep seepage will have ceased. During the fall of 1970 frequent heavy rains caused unusually high deep seepage.

The effect of management on deep seepage is the inverse of its effect on surface runoff. Figure 28 shows the decrease in runoff which results from increasing organic matter returns on the well managed plots. Figure 28 also shows the effects of the two management systems on the percentage of rainfall that runs off the land. Data is only presented through December because snow melt is hard to interpret with regard to random snow drifting and runoff. These monthly averages illustrate the effect of good management in reducing overland flow. The effect on deep seepage is clear in Figure 27, but in general, the subsurface flow is greater than surface runoff and the effect is not so dramatic.

Aggregate stability, the resistance of soil particles to destruction by water action, is increased by organic matter returns, confirming effects seen on the small scale study (see Figure 29). It is this aggregate stability, together with soil cover on the well managed plots which decreases runoff on these plots. The effect of the type of crop grown on deep seepage flow appears to be negligible.

Nitrogen

Nitrogen is present in the soil mainly as the organic form incorporated with the soil organic matter, as ammonium, and as nitrate. In the latter form, it is highly mobile and most readily lost from the soil microenvironment as either deep seepage or dissolved in runoff water. Nitrogen usually enters the soil system either in the organic form as crop residue (and manure), as mineral fertilizers, in rainfall, and from the atmosphere via nitrogen fixing bacteria on the roots of legumes. It is removed from the soil system primarily either as ammonium or nitrate ions in runoff, deep seepage or drain effluent, as N_2 gas after denitrification by specialized soil bacteria, or as organic nitrogen contained in crops which are harvested (Russell 1961). The loss to runoff, drain flow and deep seepage can be considered as a loss to the environment external to the plot. It can be considered as undesirable from the standpoint of aquatic nutrient control and groundwater quality. This study has made it possible to determine the relative magnitudes of these losses, and the effect of various parameters on them.

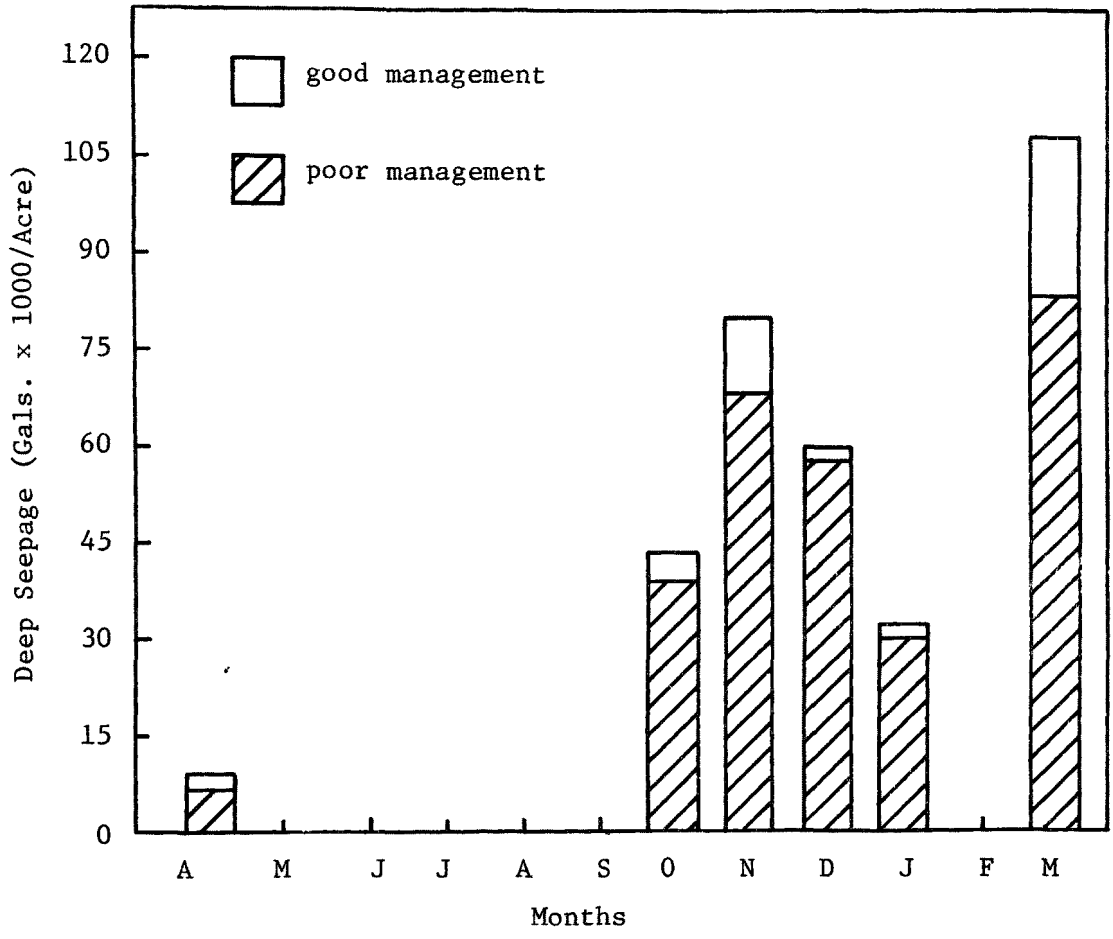


Figure 27. Monthly Water Losses to Deep Seepage - Good and Poor Management - 4/70 - 3/71

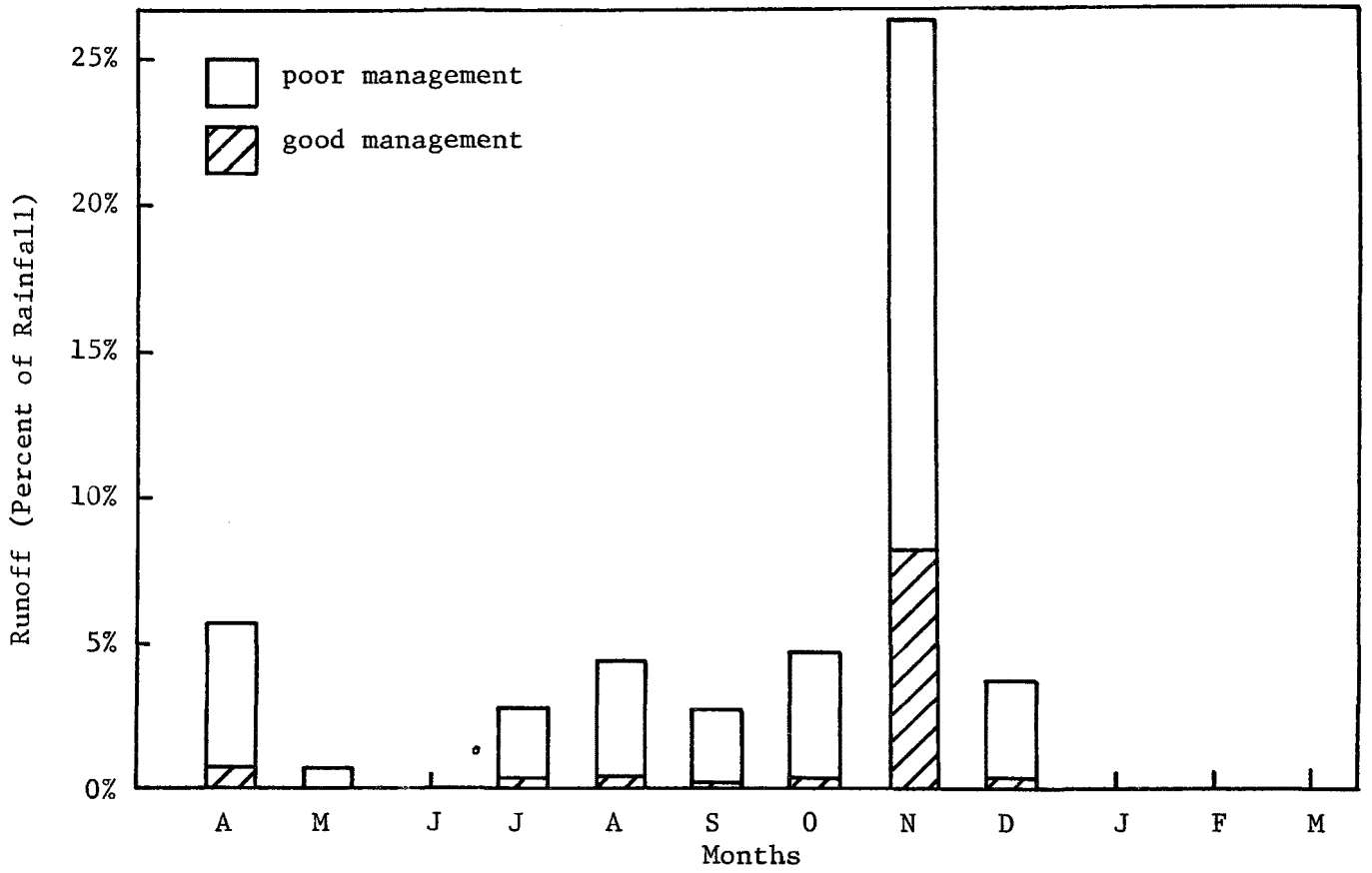


Figure 28. Monthly Averages of the Percentage of Rainfall that Occurred as Surface Runoff Under Two Management Systems, 4/70 - 3/71

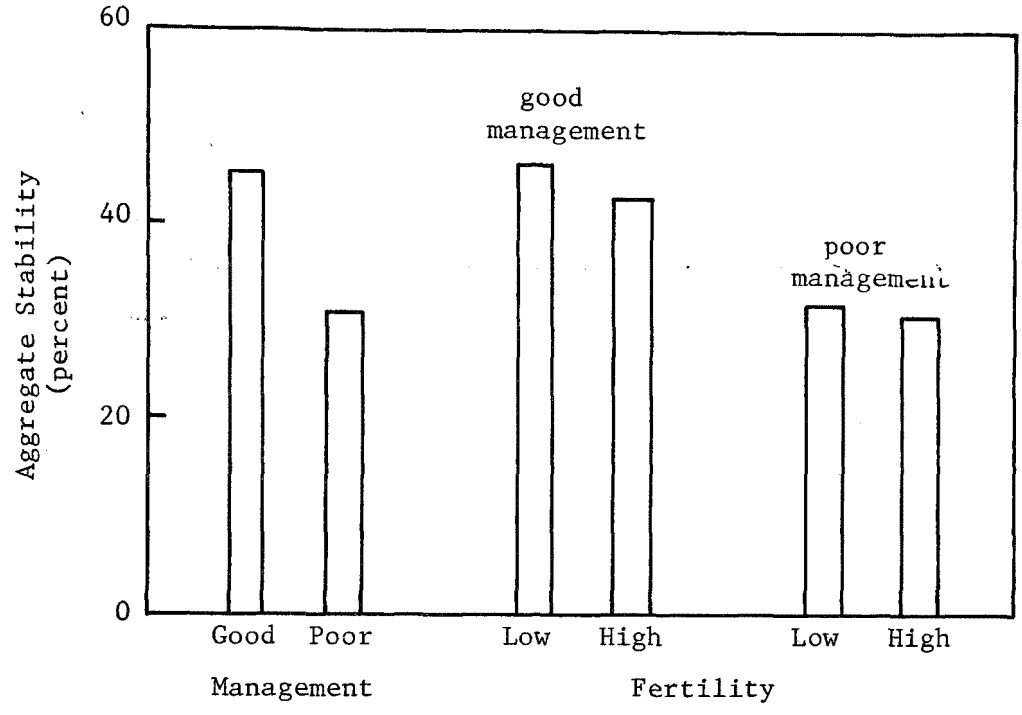


Figure 29. Percent Aggregate Stability of Soil on Plots Under Different Residue Management and Fertility Levels - 4/70-3/71

Deep Seepage and Surface Runoff Losses

Knowledge of subsurface water nitrate and ammonium concentration has enabled calculation of the magnitude of this deep seepage loss of nitrogen to the environment. It has been found that ammoniacal loss in deep seepage is negligible, but that nitrate loss may reach as high as 200 lbs./acre/year (see Appendix B, Table 5). By comparison, surface runoff loss of nitrogen, both dissolved and contained in suspended sediments, was usually small except where heavy rainfall followed recent fertilizer application (see Figure 30) and where management conditions were least effective in controlling runoff, i.e., no plant cover, and low soil aggregate stability. During the period of mid-October to mid-November, the total rainfall was 6.37 inches. The relatively large loss of nitrate-nitrogen under high fertility beans and poor management can be attributed to this one month period.

Figure 31 compares surface runoff for each treatment. Differences between crops were slight and reflected mainly by the amount of ground cover provided by the crop. The slight difference between fertility levels apparently reflects the effect of fertilizer on the soil physical conditions as previously discussed. A highly significant difference in runoff can be attributed to management. Good management practices (return of crop residue and/or cover crop) had the effect of reducing runoff by 50 percent.

The nitrogen and phosphorus losses in runoff (Figure 32) are correlated with the quantity of surface runoff and fertilizer application rate. This implies that time of fertilizer application is important. Indeed, it is critical, for as Figures 33, 34, and 35 show, the deep seepage loss is also affected by time of application. Without exception, the greatest loss to deep seepage was found to occur in November. When no fertilizer was applied this loss was not of much consequence. However, where heavy fertilization occurred in October (as for example the bean plots in preparation for wheat, see Table 1, Appendix B) then the nitrate loss in the deep seepage was clearly excessive.

In general, the deep seepage loss of nitrogen is the major component of losses of nitrogen to the environment. They may be of considerable concern in regions where subsurface drainage is widely used to remove excess water from the soil profile. It can be seen from this study that the type of crop and the type of management do not have much effect on subsurface loss of nitrogen, but that rate of fertilizer applied has a very marked effect. This effect is non-linear in nature, and is undoubtedly greatly increased as fertilizer application rate is increased (see Figure 36). Thus, if less than 100 lb. of nitrogen fertilizer is added in the spring, after deep seepage stops in May, and if runoff is kept to a minimum by good cover and conservation practices, then the loss of nitrogen does not appear to be any greater than that from plots on which no fertilizer was added (see Appendix B, Table 5).

Figure 37 shows the subsurface concentrations of nitrate nitrogen averaged for the hydrologic year. If 10 P.P.M. is the limit of nitrate plus nitrite nitrogen permissible for domestic water supply (FWPCA, 1968), then it can be seen that if available nitrogen (total inputs) exceeds 175 lbs./acre, there is a high probability that subsurface water flow would be unacceptable for domestic supply on the criterion of nitrate alone. Thus, fertilizer application would need to be restricted to approximately 125 lbs./acre where no crop residue is returned, or 100 lbs./acre where residues are returned (depending on type of residue), to meet this water quality standard (Appendix B, Table 5). By contrast, surface water only exceeded permissible nitrate levels for domestic supply on one treatment - high fertilizer application (490 lbs./acre) in the fall with poor soil cover and residue management.

Nitrogen from other sources has been calculated, namely, the inorganic

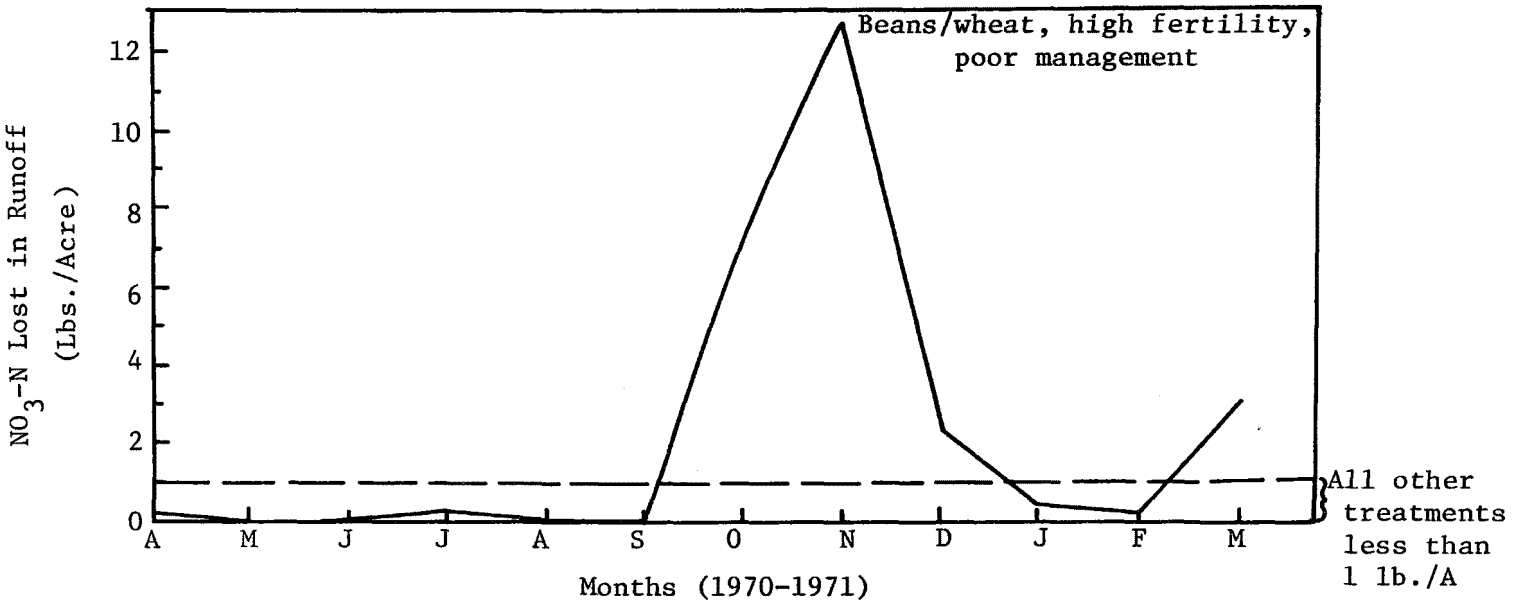


Figure 30. Nitrate-Nitrogen Lost in Runoff Water by Months

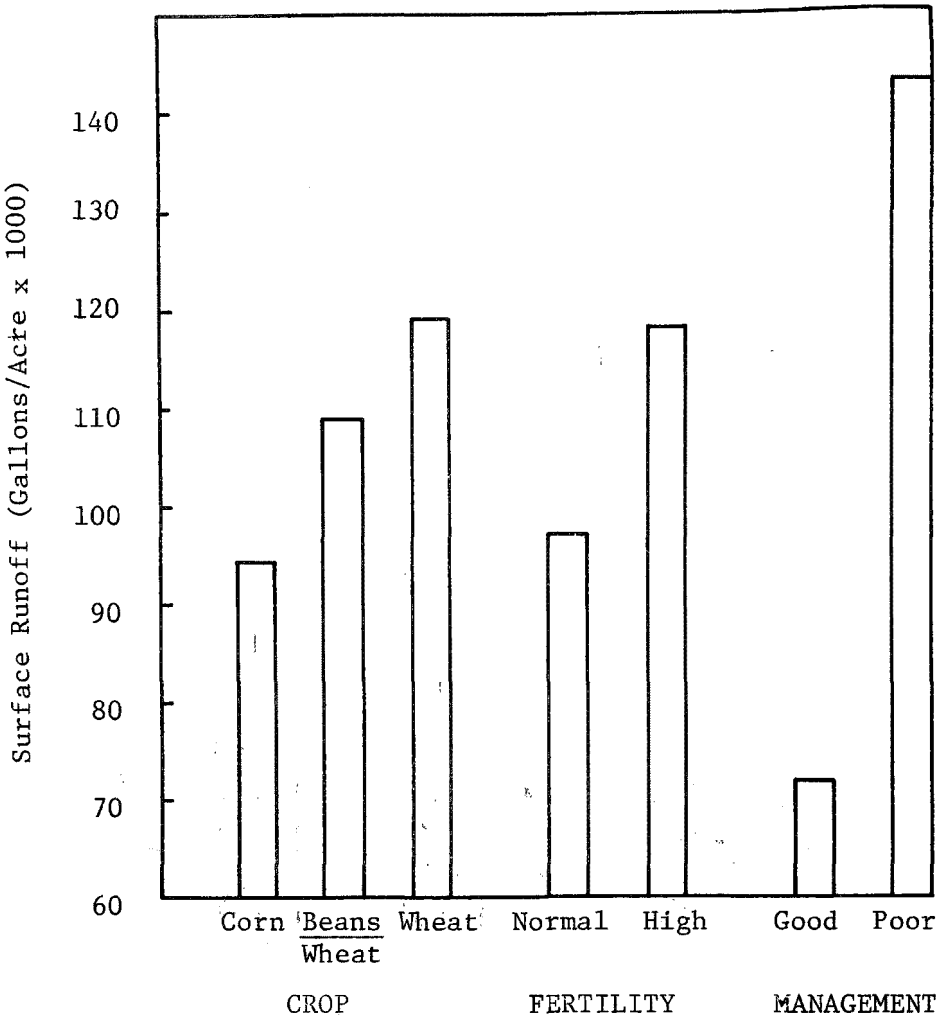


Figure 31. Total Accumulative Annual Surface Runoff Volumes - 4/1/70 - 3/31/71.

nitrogen released by the soil organic matter (mineralization) and that contained in organic matter returned to the soil as crop residues. It does not appear that the source of the nitrogen has any effect on loss, except in that management (amount of crop residue returned and crop cover) affects runoff and soil aggregate stability significantly (see Figure 29).

Application times for non fertilizer nitrogen inputs are more difficult to predict. They are influenced by temperature, moisture, carbon/nitrogen ratio and all other factors which customarily affect the rate of bacterial growth and decay functions. It can be seen that nitrogen applied as mineral fertilizer is readily soluble and thus easily lost

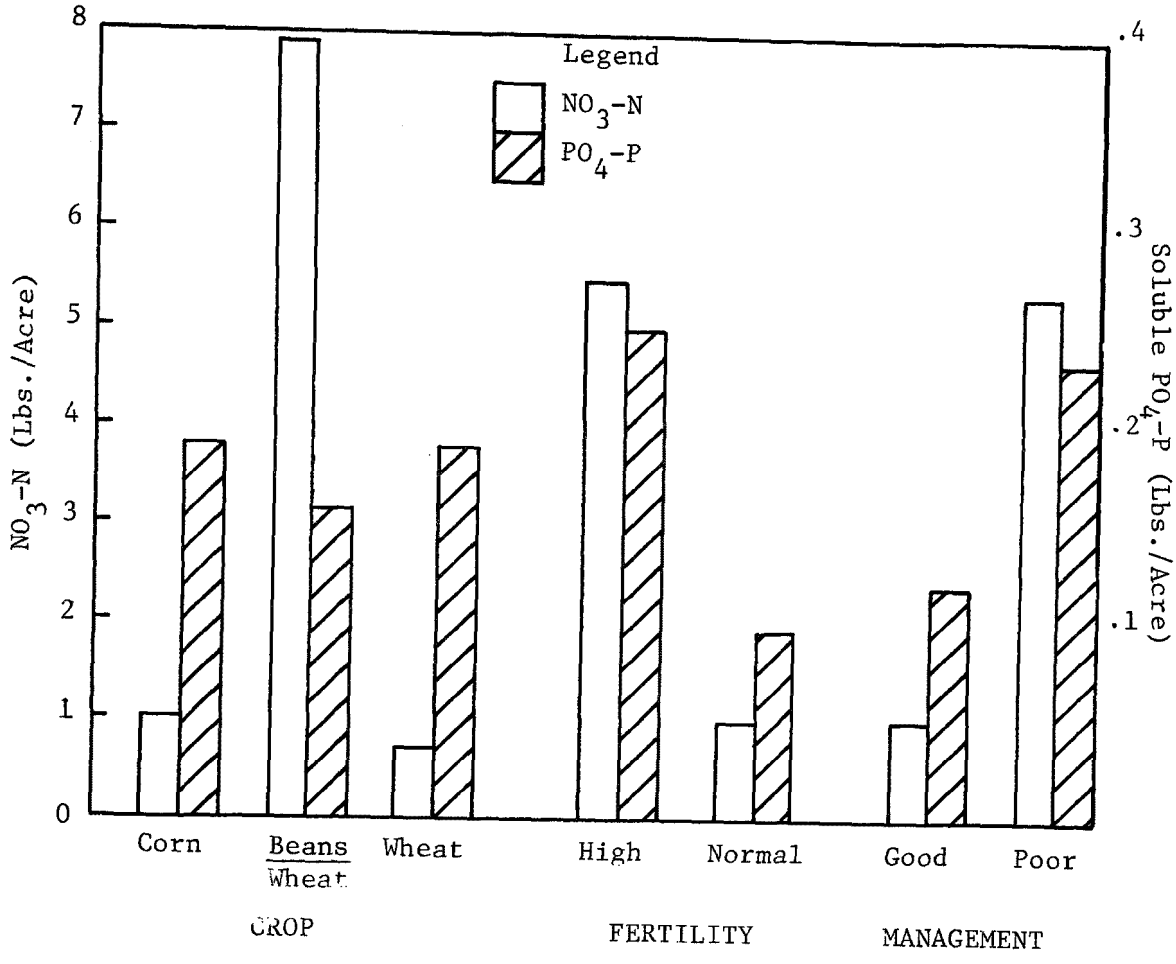


Figure 32. Total Accumulative Annual Nitrate-Nitrogen Phosphorus (Solu. PO_4-P) Losses from Surface Runoff - 4/1/70 - 3/31/71.

in seepage or surface runoff where these occur immediately after application. However, nitrogen in crop residues and other organic forms (e.g., manure) may not be released so rapidly. Rapid release could take place only if conditions for bacterial growth are optimum. Thus, high carbon residues and manure applied with nitrogen fertilizer may tie up some nitrogen in cell material and act as a "buffer" to prevent excessive losses during adverse weather conditions. Further studies on this same area are proposed to help determine to what extent manure nitrogen is retained during high deep seepage periods in comparison to fertilizer nitrogen.

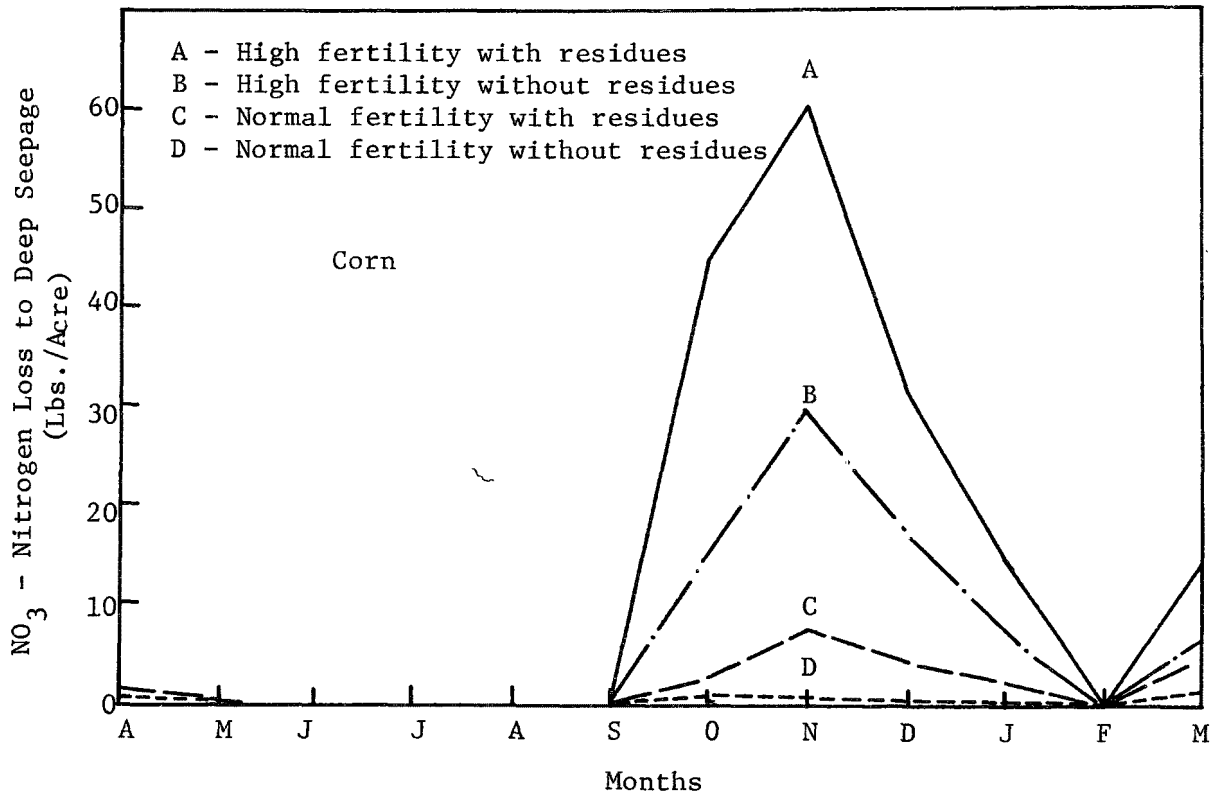


Figure 33. Monthly Nitrate-Nitrogen Loss to Deep Seepage - Corn - 4/1/70 - 3/31/71

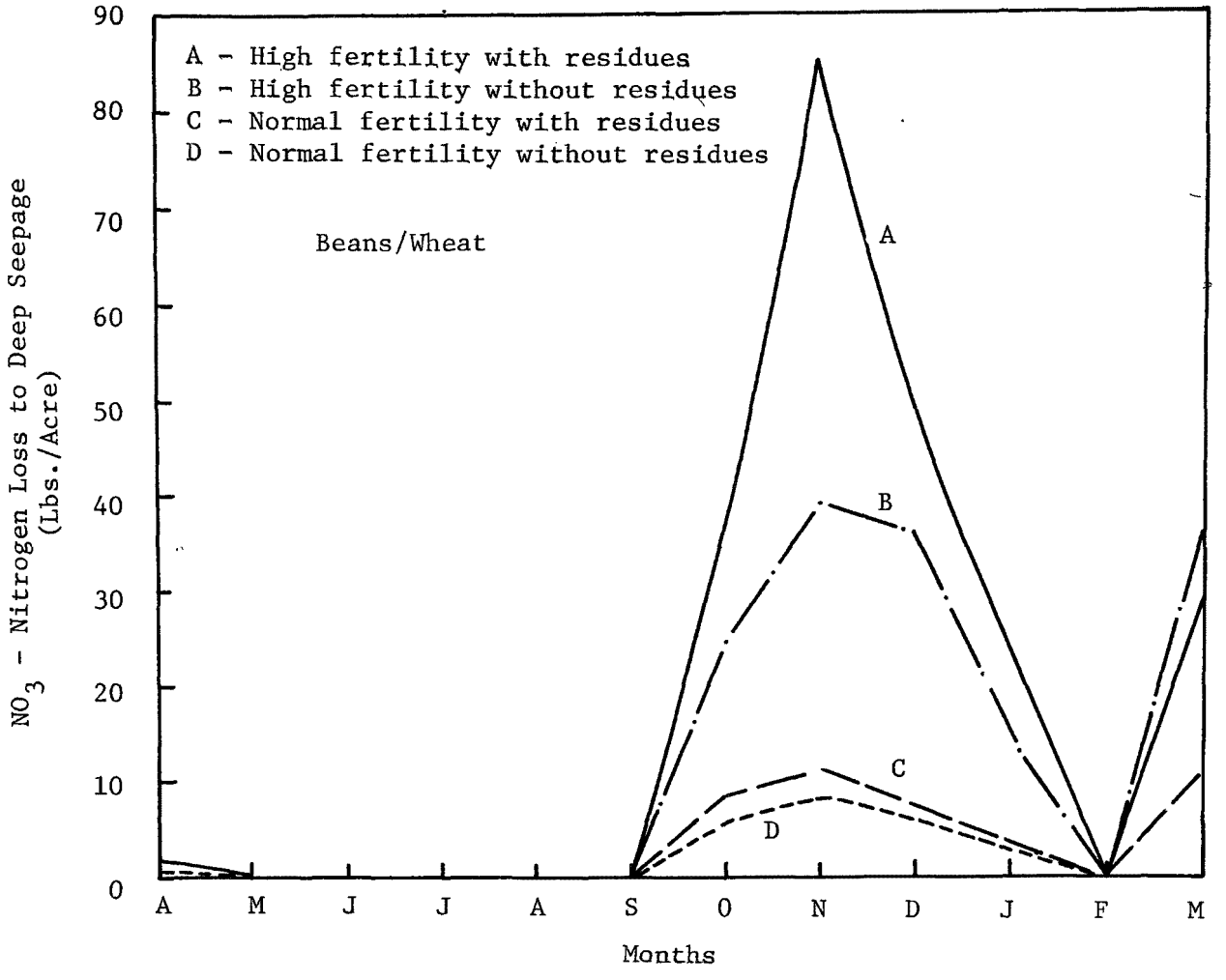


Figure 34. Monthly Nitrate-Nitrogen Loss to Deep Seepage - Beans/Wheat - 4/1/70 - 3/31/71

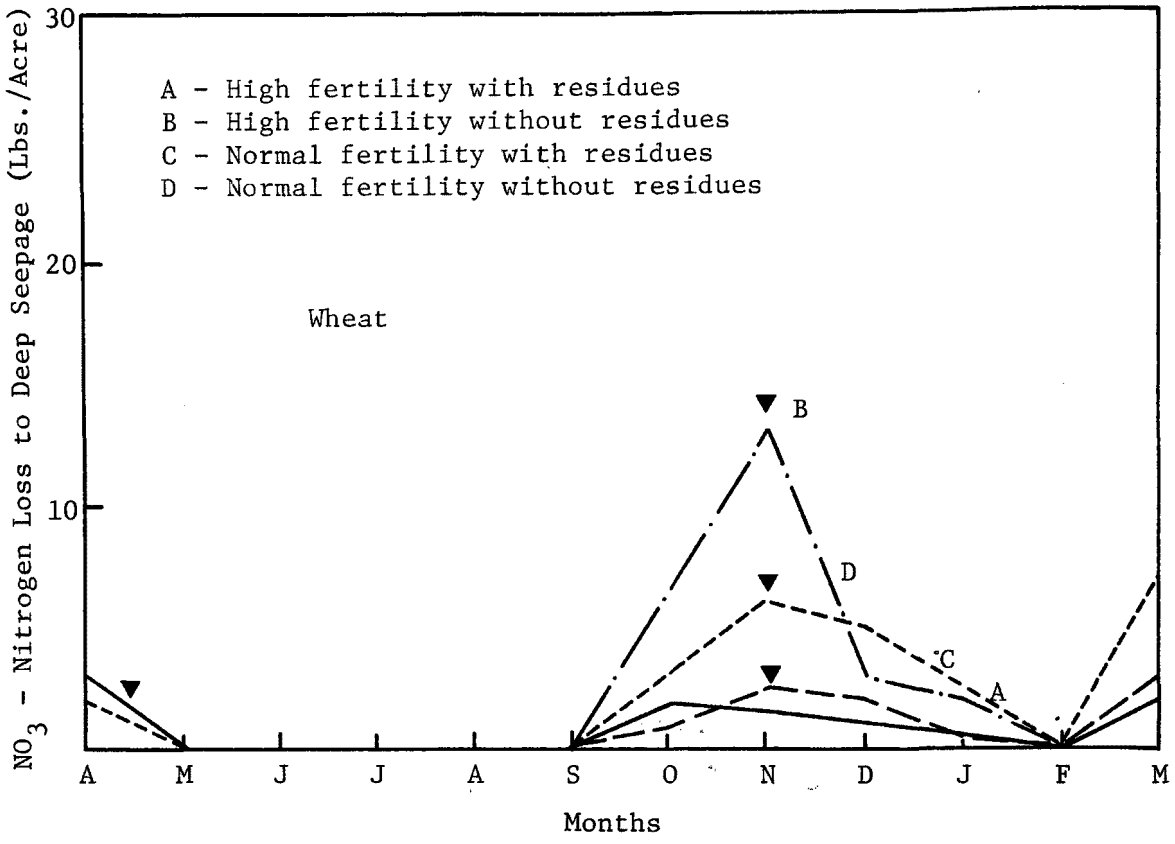


Figure 35. Monthly Nitrate-Nitrogen Loss to deep seepage - Wheat - 4/1/70 - 3/31/71

The actual concentration of nitrates in ground water will depend on the dilution factor of low nitrate water from other parts of the watershed, or ground water contributing area. In an area such as central New York, the proportion of land which is under high fertilizer cash crops is small, and ground water is liable to be low in nitrates because of the dilution effect of low nitrate water. However, in the mid-West, where large areas are almost entirely cultivated to cash crops, and where ground water is shallow, nitrate concentration in ground water may easily exceed permissible levels. Schmidt (1956) found that well water in Minnesota had as high as 120 ppm nitrate-nitrogen on farms where the well was located close to barnyards or cultivated soils. The lowest concentrations (less than 1 ppm) occurred in wells located such that the surrounding soils were in sod. Tile drain effluent tended to be

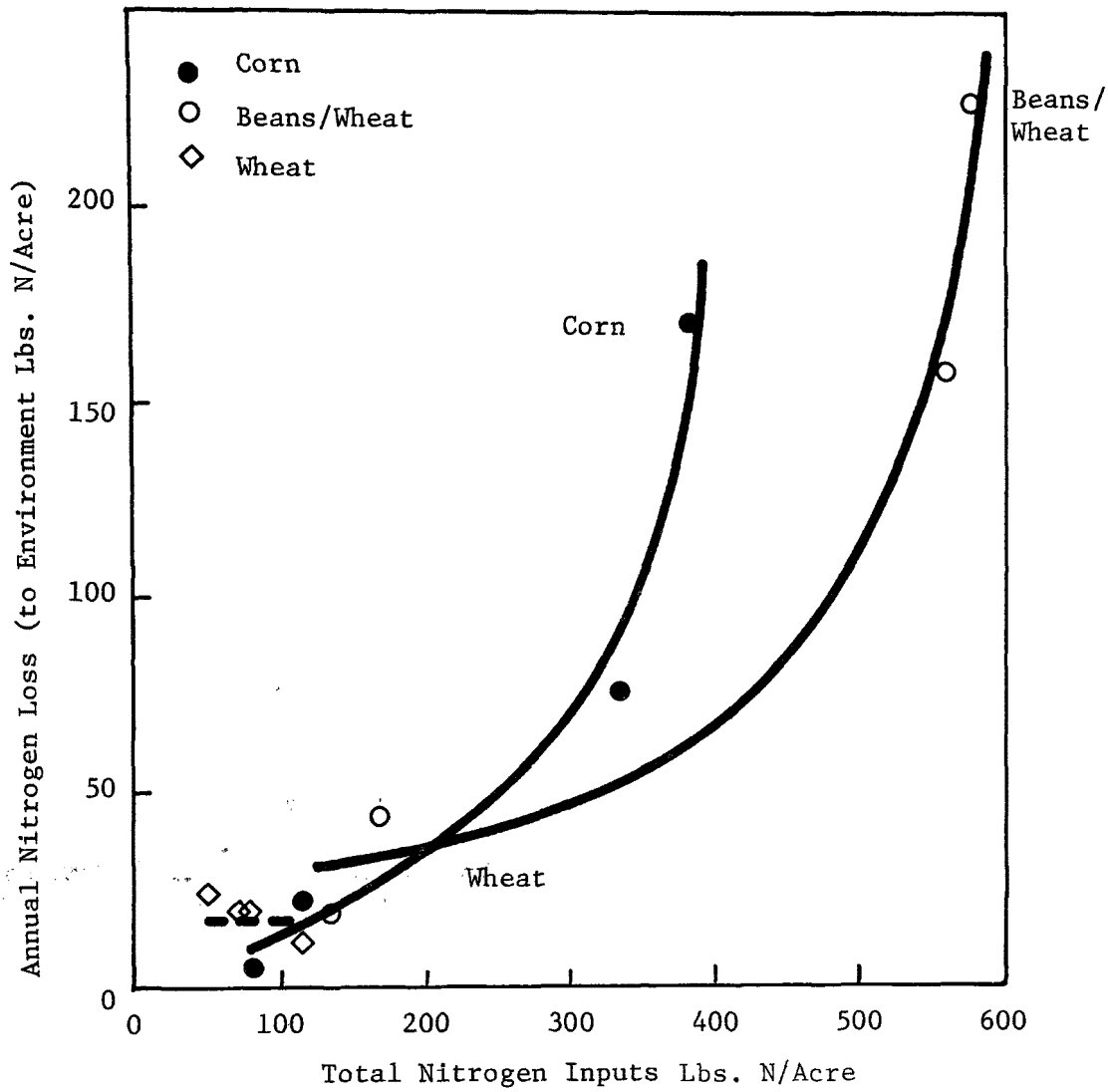


Figure 36. Apparent Relationship Between Annual Nitrogen Inputs and Losses to the Environment (Surface Runoff and Deep Seepage) - 4/1/70 - 3/31/71

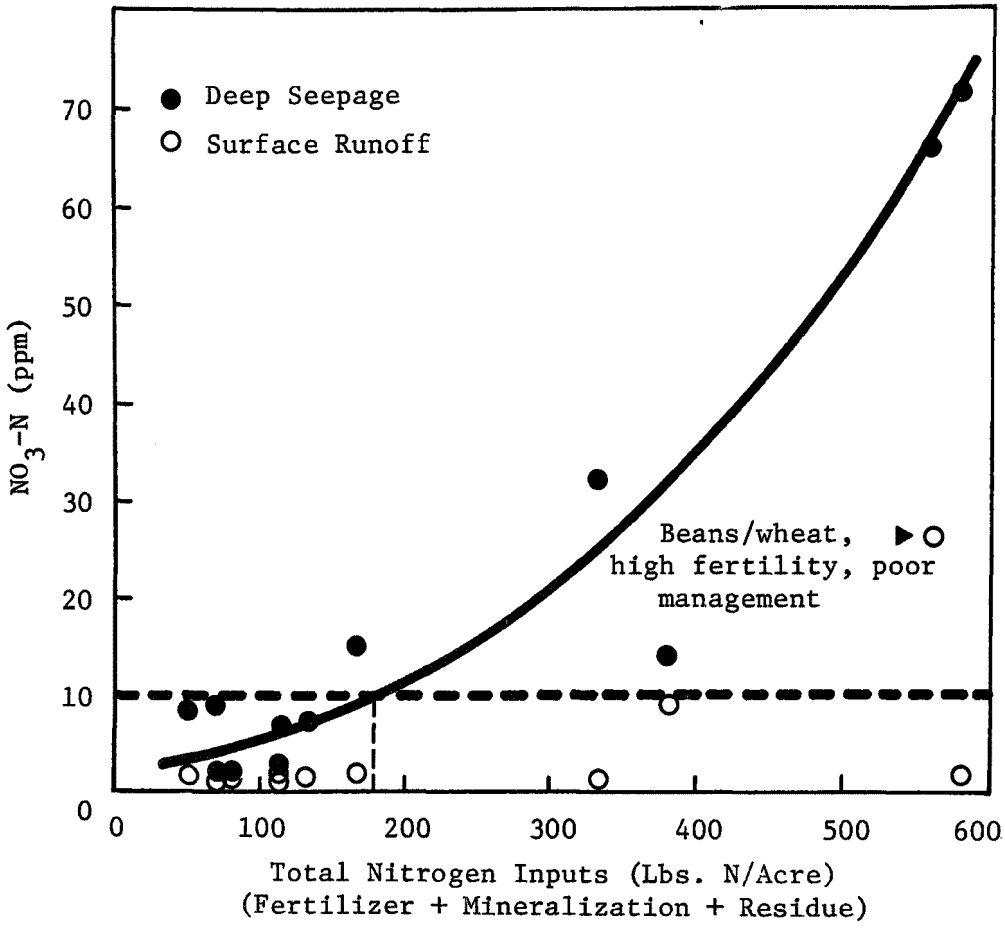


Figure 37. Annual Relationship Between Total Nitrogen Inputs and Nitrate N Concentrations in Subsurface Flow (Deep Seepage) and Surface Runoff - 4/1/70 - 3/31/71

intermediate with average concentrations of 15-20 ppm. Samples were collected in the summer. These high (FWPCA, 1968) levels of nitrate nitrogen are most likely to be a result of high rates of nitrogen fertilizer applications in these areas.

The desirability of high nitrogen applications is also questionable from an economic standpoint. Crop yield and uptake of nitrogen was not higher under high fertility conditions except under poor residue management practices. Thus the suggested overall available nitrogen limits, and fertilizer limits, would appear also to be justified on the basis of yield response and economic return. Unfortunately it is not possible at this time for a dollar value to be placed on a pollution hazard. Thus economists tend to ignore the environmental degradation which should be considered as resulting from high fertilizer applications. At this time, recommendations for high nitrogen applications on the basis of projected yield returns should be carefully reconsidered.

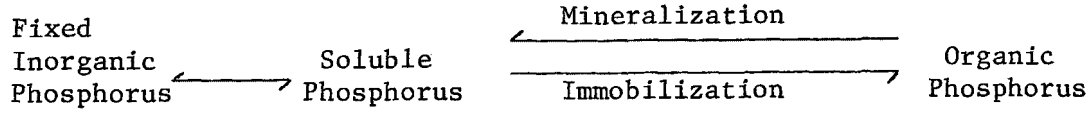
Denitrification

Nitrogen is also lost from the soil as N_2 gas released by certain specialized soil bacteria. This capacity is indicated to be dependent on the amount of nitrogen available to these bacteria (see Appendix B, Table 5). Under conditions of limited nitrogen, this loss is undesirable, but where the soil is being used as a disposal medium then maximum denitrification is desirable. Further studies are proposed to evaluate the degree to which the soil denitrifying ability can be utilized to remove nitrogen from organic wastes.

Phosphorus

Phosphorus, unlike nitrogen, is not mobile within the soil and phosphate ions do not leach readily. Phosphorus is held tightly as a complex anion by clays and the amount of phosphate in solution in the soil water at any one time is extremely small. In most cases, this will be less than a pound per acre.

The relation of soluble phosphate to organic phosphorus and fixed phosphate is shown below:



Soluble phosphate is in chemical equilibrium with fixed phosphorus. When additional phosphorus is added to the soil as in the form of chemical fertilizers, the equilibrium tendency is towards the left. When phosphorus is removed from the soil by plant absorption, the rate of replacement to the soluble or available phosphorus reserve is faster with the addition of phosphorus fertilizers. As organic phosphorus decomposes, the soluble phosphorus reserve is temporarily restored, but

the equilibrium tendency is to drive the reaction to the left.

The soil then, has the potential to adsorb and maintain large amounts of phosphorus. The rate of release of phosphorus is not well correlated with fertilizer additions and the soil can be thought of as a large storage area for incoming phosphorus.

Data present in Appendix B, Table 5 shows that the greater the fertilizer addition, the greater will be the amount of phosphorus that will be fixed. Values ranged from an addition of 17 pounds of phosphorus added and 3 pounds fixed to 139 pounds added and 126 pounds fixed.

Figure 38 (% of fixation) illustrates that the percentage of phosphorus fixed increases as phosphorus inputs increase. This is true because a nearly constant amount of phosphorus is taken up by a crop of equal yield regardless of phosphorus additions as long as the minimum addition satisfies plant requirements.

Most of the phosphorus that is lost from the soil system to the environment is attached to the sediment as a fixed complex (Appendix B, Table 5). Sediment influxes to watercourses is considered by many to be instrumental in inducing algal growth. There is much controversy as to just how much of this phosphorus is made available to aquatic plant growth. Proposed research at Cornell can possibly answer this most important question.

Any means of controlling soil losses is effectively controlling phosphorus losses. Good management systems in which the plant residue is returned to the soil promotes a better soil structure and subsequently a decrease in soil erosion. In addition, a cover crop grown in conjunction with a cash crop is influential in reducing soil losses by increasing infiltration and physically holding the soil intact. In all but one instance (an unexplainably large soil loss from snow melt in March under a system of good managed corn) well managed systems had a lower discharge of sediment in contrast with poorly managed ones. Largest losses of sediment phosphorus (with one exception) occurred under a system of poorly managed wheat plots. These plots were harvested in August and the poorly managed ones were exposed as bare ground. This subjected these soils to a greater amount of soil erosion.

In conclusion, the soil is a natural sink and can fix large quantities of phosphorus. For this reason, very small amounts of phosphorus are present in water discharges from the land surface. Essentially, all of the phosphorus that is removed from a soil system is either by crop uptake or soil erosion. Soil erosion can be diminished by practicing sound conservation practices such as increasing soil aggregation by the addition of organic residues and providing surface covers in the form of a cover crop to reduce the impact of rainfall and the dislodgement of soil.

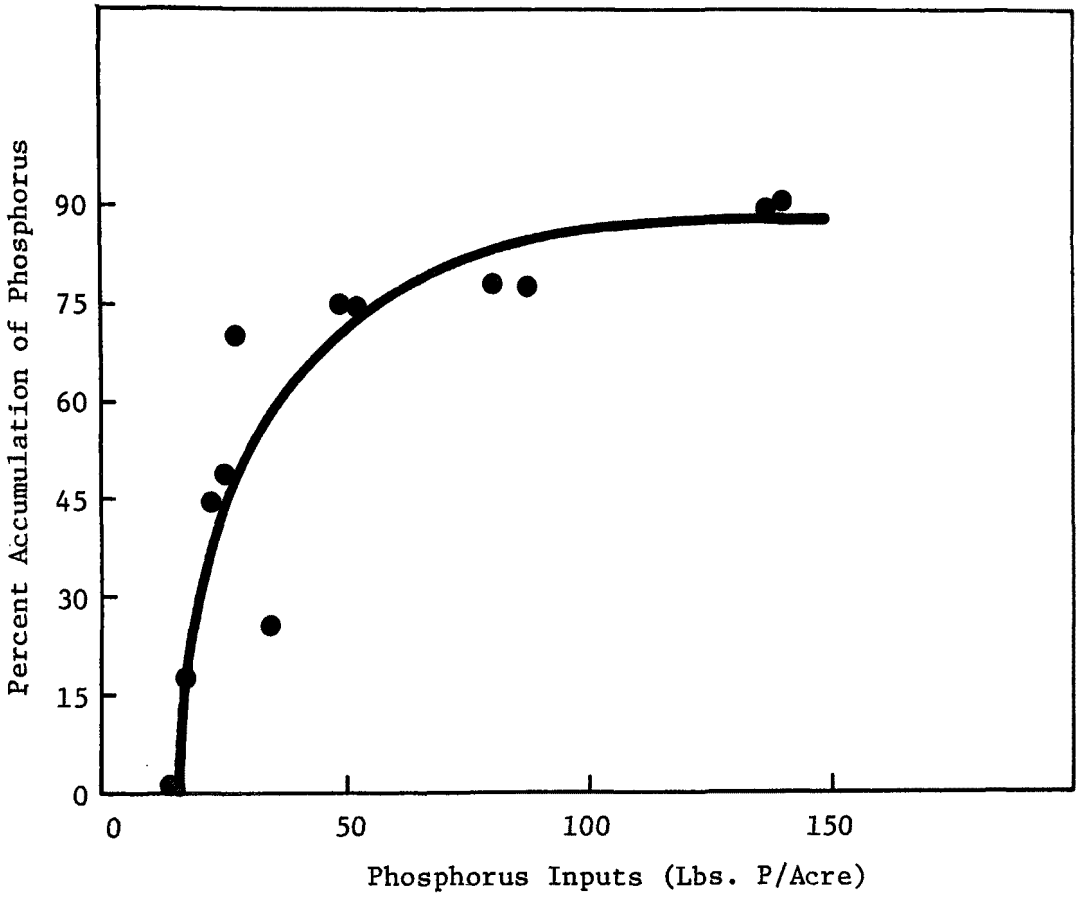


Figure 38. Percentage of Phosphorus Immobilized by the Soil and Phosphorus Losses - 4/1/70 - 3/31/71

SECTION VI

ALGAL NUTRIENT STUDY

The awareness that increased phosphorus input is a major factor in the accelerated eutrophication of lakes has resulted in the need for means to assess the phosphorus status of natural waters particularly as it relates to algal growth. The concept of a critical concentration of phosphorus in the surrounding medium as being a reliable measure of potential algal growth has received much attention. This critical concentration is the concentration of phosphorus in the growth medium above which there is no increase in growth as a result of further additions of phosphorus. Below the critical concentration, the algae are in a state of phosphorus limitation and growth is strictly a function of phosphorus concentration. The experimental value obtained for the critical concentration of phosphorus is highly dependent on the type of culturing system employed and the assumptions and interpretations that are made. Azad and Borchardt (1970) using turbidostatic techniques found this phosphorus concentration to be about 16 μM for Scenedesmus and Chlorella. Thomas and Dodson (1968) using batch cultures of Chaetocerous gracilis obtained a value of 0.22 μM. Rhee (1971) also using batch cultures, obtained a value of about 0.5 μM phosphorus for Scenedesmus. A major disadvantage of the use of turbidostats and chemostats to determine the critical phosphorus concentration is the great difference which often exists between the phosphorus concentration in the input and that which is present in the growth vessel. This disparity is particularly crucial at low concentrations of phosphorus. Growth parameters in these systems are often based on input concentrations. Relating growth characteristics to phosphorus concentrations in batch cultures is also open to question, since the external concentration continually decreases as growth progresses.

In an attempt to circumvent some of these problems, a culturing system was devised which permitted the external phosphorus concentration in the growth vessel to be maintained at any desired level. Using this type of system, the growth of Chlorella pyrenoidosa was measured at different maintained concentrations of phosphorus and the results compared with those obtained by other workers.

Materials and Methods

The organism used for these studies was the green alga, *Chlorella pyrenoidosa*, strained 395 (Culture Collection of Algae, University of Indiana, Bloomington, Indiana). Stock cultures were maintained on agar slants of the basic culture medium in screw cap culture tubes.

The basic culture solution had the following composition: KNO_3, 1.5mM; $Ca(NO_3)_2$, 0.5mM; $MgSO_4$, 0.2mM; $KHCO_3$, 0.6mM; Fe-EDDHA (ferric chelate of ethylenediamine dihydroxyphenylacetic acid), 10 μM; H_3BO_3, 50 μM; $MnSO_4$, 1 μM; $ZnSO_4$, 0.7 μM; $CuSO_4$, 0.1 μM; Na_2MoO_4, 0.1 μM; $Co(NO_3)_2$, 0.1 μM. Phosphate variables were added as aqueous solutions of KH_2PO_4. The solution was sterilized by passage through a membrane filter (0.22 μ pore size, Millipore Crop. Bedford, Massachusetts) into autoclaved culture vessels. The cultures were stirred by bubbling with an air-CO_2 mixture which had been filtered through Dacron wool and a Millipore filter (0.22 μ). The pH of the culture solution was maintained generally between 7.2 and 7.5 with a CO_2 concentration in the mixture of 1% (v/v).

The culture vessels consisted of 9-liter "Pyrex" bottles filled with 7.5 liters of nutrient solution. These were positioned between two fluorescent light banks and received continuous illumination at an intensity at the outer surface of the bottles of 1100 ft-c. The temperature of the cultures was maintained at 26 ± 1 C. Daily aliquots of 100 ml were aseptically withdrawn from each culture. This aliquot was divided into two portions, one of which was used to determine algal growth, and the other was filtered and used to determine phosphate. Checks were made for bacterial contamination by streaking a portion of the culture on a medium consisting of nutrient solution supplemented with glucose and yeast extract and solidified with agar.

Based on the growth rate and phosphate-usage rate, the calculated amount of phosphate to be used in the next 24 hours was added to the cultures daily. This was accomplished by autoclaving the necessary amount of phosphate in a volume of 100 ml and then slowly adding this solution to the culture by pumping with a multi-veined peristaltic pump at a constant rate of 100 ml/24 hours. This procedure maintained both the total volume of the culture and the phosphate concentration in the aqueous phase.

Growth was measured by diluting a suitable aliquot of the culture with KCl to give a final concentration of 0.1M KCl and counting with an electronic particle counter (Coulter, Model B, Coulter Electronics, Inc., Hialeah, Florida). Counts were taken over the particle diameter range of 2 to 8 μ in 1-μ intervals. This range was found to include all of the observed cell sizes of this organism. The interval counts were converted to cell volumes and these volumes summed for all six intervals to obtain the total volume of cells. Growth rates were calculated for the exponential growth phases using the expression $[\log_2 (Vol_2 / Vol_1)] \times (t_2 - t_1)^{-1}$. The reciprocal of the growth rate thus defined is the doubling time.

Phosphate was determined on the filtered (0.22 μ) solutions by the method described by Murphy and Riley (1962). Discarding the first 20 ml of solution to pass through the filter was necessary to avoid phosphate contamination from the filter. Cellular phosphorus was determined by dry-ashing the cells and determining total phosphorus (Greweling, 1966).

Low phosphorus inoculum was used for all experiments. Cells were allowed to grow for several days in low-phosphate liquid media to insure a low-phosphorus status.

All treatments were replicated three times. Occasionally a culture would develop bacterial contamination or other problems would arise and this culture would be discarded. Accordingly, the values presented are the means of three observations generally, but only two observations occasionally.

Results and Discussion

The growth of Chlorella pyrenoidosa at maintained concentrations of phosphate can be separated into three phases. These phases can be easily recognized in Figure 39. The first is characterized by a rapid growth rate which lasts for about one day after inoculation and most likely represents an adjustment to the new physical environment. This is followed by an initial exponential phase of growth which is slower than the final or adapted exponential phase. The duration of the initial exponential phase is dependent on the phosphate concentration of the nutrient medium, being 0 and 6 days at 10 and 0.1 μM phosphate, respectively.

Table 5 shows the growth parameters of the initial and final exponential phases at various phosphate concentrations.

Table 5. The Effect of Various Maintained Phosphate Concentrations on the Initial and Final Exponential Growth Rates of Chlorella pyrenoidosa.

Phosphate Concentration	Initial Exponential Growth Phase		Final Exponential Growth Phase	
	Doubling time	Growth rate	Doubling time	Growth rate
μM	days	day^{-1}	days	day^{-1}
0.1	1.96	0.51	1.03	0.967
1	1.45	0.69	0.85	1.17
10	--	--	0.86	1.16

At 10 μM phosphate, no initial exponential growth phase is evident and the culture passes directly into the final exponential growth phase with the volume of cells doubling every 0.86 day. When the maintained concentration of phosphate is decreased to 1 μM, an initial exponential growth phase lasting about three days is observed but the final exponential growth rate is the same as that observed with 10 μM phosphate. A further decrease in the phosphate concentration to 0.1 μM results in a longer initial exponential growth phase at an even slower growth rate. However, the final growth rate at 0.1 μM phosphate is 0.967 day^{-1} compared to 1.17 and 1.16 day^{-1} and 1 and 10 μM phosphate, respectively.

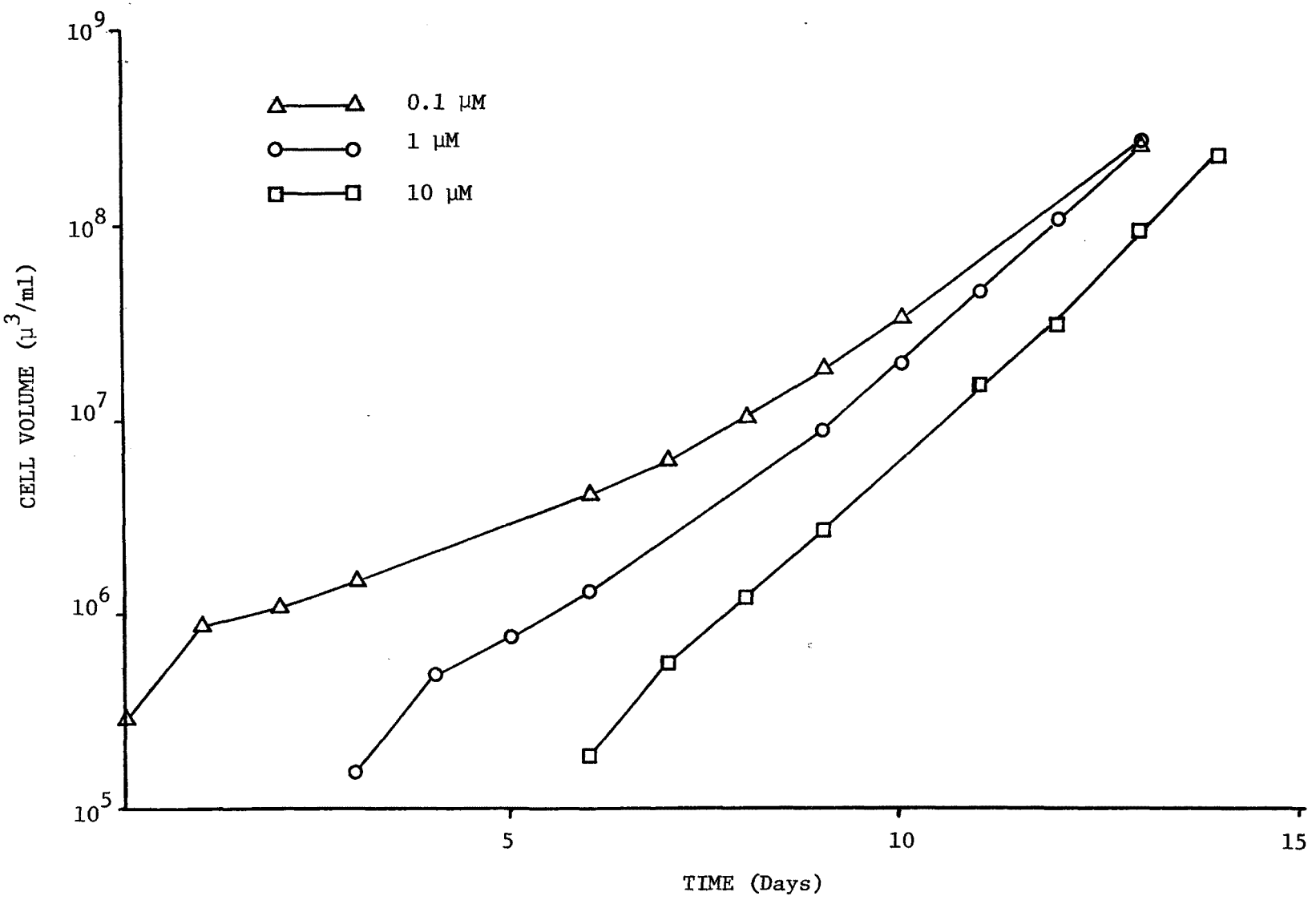


Figure 39. Effect of Various Maintained Phosphate Concentrations on the Growth of *Chlorella pyrenoidosa*. Curves are Displaced 3 Days for Ease of Interpretation.

Several observations may be made from this data. It can be noted that at concentrations below 10 μM phosphate, an initial exponential growth phase is observed which has a growth rate of approximately one-half that of the final growth rate. This phenomenon undoubtedly represents a cellular adaptation to low external concentrations of phosphate. Another important observation is that a maintained phosphate concentration of 1 μM will support maximum growth of this alga. The actual critical concentration of phosphate is between 0.1 and 1 μM. This value is in general agreement with the values obtained for other algal species [Rhee (1971); Thomas and Dodson (1968)] using batch cultures. Experiments currently in progress will measure the growth rate of this alga in batch culture, but the observed agreement of the results of the maintained phosphate experiments with the batch culture experiments of others suggests that batch culture data may give reliable results in determining critical phosphorus concentrations. The final exponential growth rate at the very low phosphate concentration of 0.1 μM is still over 80 percent of the maximum growth rate observed in these experiments. This indicates that the external concentration of phosphate must be extremely low (well below 0.1 μM) before growth of this organism is severely curtailed.

From the discussion thus far, one might conclude that due to the low critical phosphate concentration for this alga, control of such an organism in a natural system would be nearly impossible. There are several important factors which must be considered, however. First of all, it is important to understand that the growth rates obtained in these experiments were with maintained concentrations of phosphate. In order to support a sustained growth rate at very low concentrations of phosphate, the total amount of phosphate that must be added is very great. It thus becomes necessary to consider the total amount of phosphate that must be supplied to support a given standing crop of algae.

A preliminary batch culture experiment has shown that the maximum cell volume attainable with this organism is 6.7×10^6 and 6.2×10^7 μ^3/ml from initial phosphate concentrations of 1 and 10 μM, respectively. In this experiment a two-liter bottle containing nutrient solution with 1 μM or 10 μM phosphate was inoculated with phosphorus-deficient inoculum. Growth was followed until the culture reached a maximum cell density and growth ceased. In both cases, analysis of the cell-free solution showed that there was no phosphate remaining in solution when growth ceased.

It was considered of interest to determine the pattern of algal growth if the cultures were maintained at given concentrations of phosphate and then at some point the addition of phosphate to the cultures be discontinued. Figures 40 and 41 show the results of two such experiments. Following the cessation of phosphate addition, the cell volume doubled at both the 0.1 and 1.5 μM levels. A much more rapid and complete removal of soluble phosphate occurred at the 1.5 μM level than

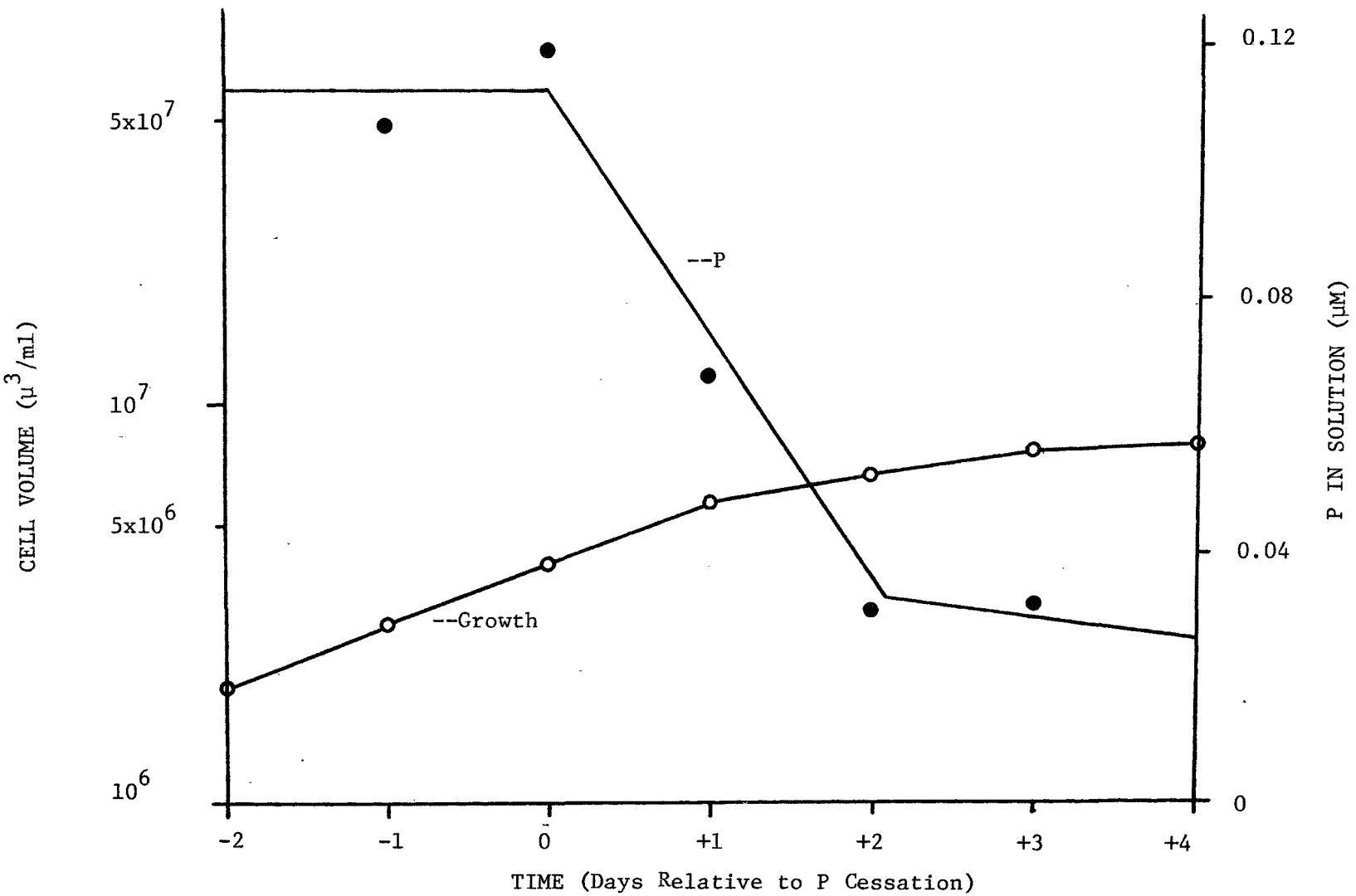


Figure 40. The Effect of Eliminating Phosphorus Supply on the Solution Phosphate Concentration and Growth of Cultures of Chlorella pyrenoidosa Previously Maintained at Approximately 0.1 μM Phosphate.

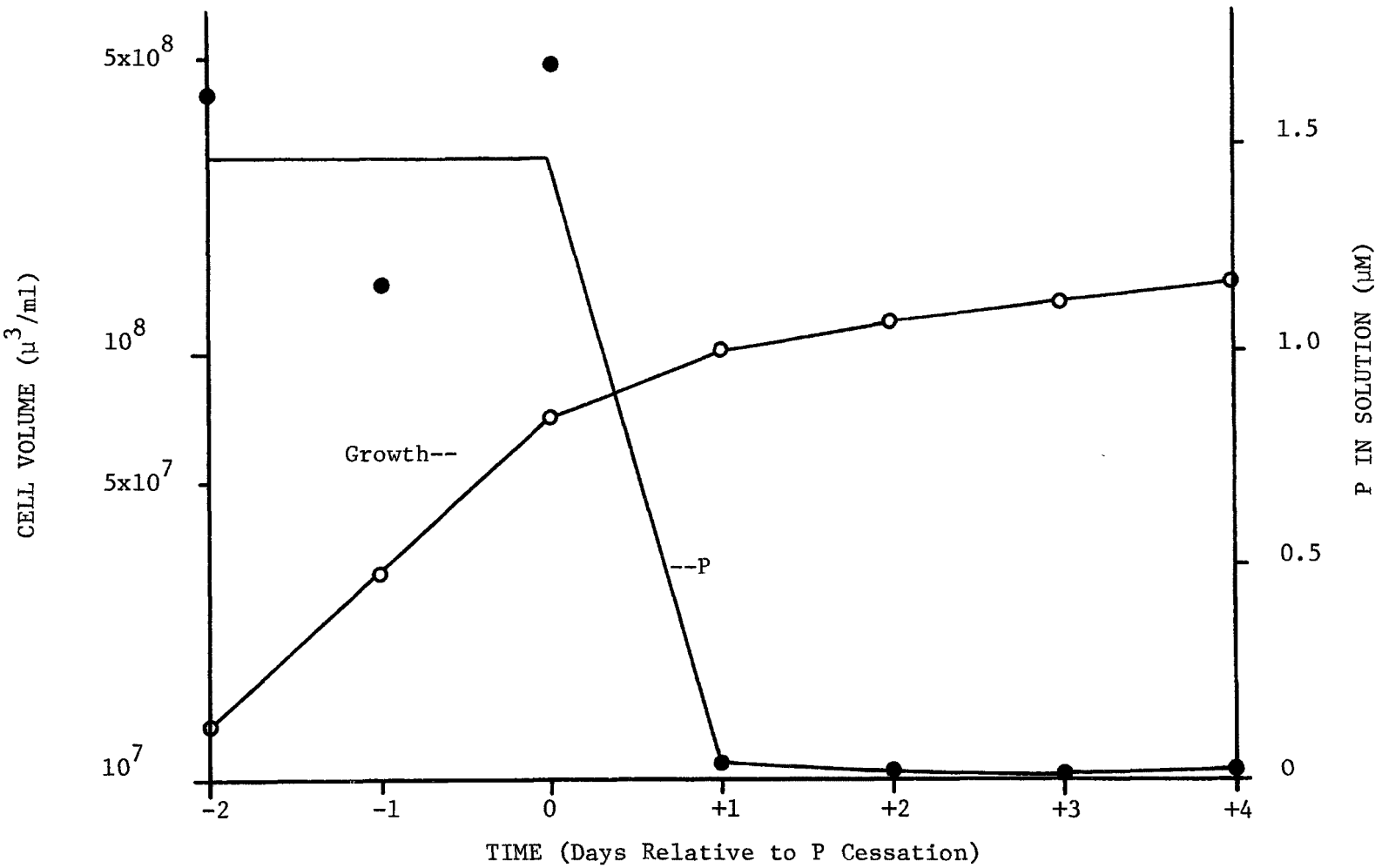


Figure 41. The Effect of Eliminating Phosphorus Supply on the Solution Phosphate Concentration and Growth of Cultures of Chlorella pyrenoidosa Previously Maintained at Approximately 1.5 μM Phosphate.

at the 0.1 μM level. This may have been due in part to differences between the cultures in the density of the algal cells in the culture at the time phosphate additions were discontinued. If the absolute increase in cell volume after the cessation of phosphate addition is measured, it is observed that the cultures which had been maintained at 0.1 μM phosphate increased by 4×10^6 μ^3/ml. The cultures which had been maintained at 1.5 μM phosphate increased by 70×10^6 μ^3/ml. The data from the batch culture experiment would have predicted increases in cell volume about one-sixth of that observed. The most obvious explanation for this observed difference is that even at very low external phosphate concentrations, this alga can store some phosphorus in excess of its growth needs and can utilize this stored phosphate for growth when the external phosphate has been exhausted. This and other possible explanations for the disparity between batch culture and maintained culture experimental results are currently being investigated.

Another approach to predicting maximum algal growth is the use of minimum phosphorus concentrations. For an algal cell to continue to grow and carry out is essential metabolic functions, it requires a certain minimum internal concentration of phosphorus. This minimum internal phosphorus content should provide the basis for calculation of the theoretical maximum algal volume that could be obtained from a given initial concentration of phosphate in the surrounding medium. The calculated value for the batch cultures is 1.6×10^{-10} μmole/μ^3 of cell material. Rhee (1971) found a nearly identical value of 1.56×10^{-10} μmole/μ^3 for batch cultures of the green alga, Scenedesmus. An attempt was made to measure this value directly using cells that had been grown previously at maintained levels of phosphate. One liter of the cultures depicted in Figure 39 was centrifuged when growth had ceased and the cells analyzed for total phosphorus. The cells from this liter contained an average of 217 μg of phosphorus. This converts to a minimum cellular phosphorus concentration of 0.5×10^{-10} μmole/μ^3. This value is about one-third that obtained from calculations using the batch culture data. This procedure is subject to errors both from cell loss during centrifugation and analytical problems due to the small sample size. It is doubtful, however, that these errors could totally account for the observed discrepancy. An explanation for the difference between batch and maintained cultures in this respect is also currently being sought.

Using the value of 1.6×10^{-10} μmole/μ^3 as a minimum phosphorus concentration, one can calculate the maximum algal volume which could be produced by the addition of various amounts of phosphate to a given volume of a phosphorus-deficient algal culture. Figure 42 relates this expected algal volume to the amount of phosphate added per liter of culture. It should be emphasized that these are maximum values since all of the phosphorus is incorporated into cellular material and none of the cellular material is lost due to sedimentation. Considering that it requires an algal cell volume of about 10^7 μ^3/ml to produce a moderately severe water quality problem, it can be seen from Figure 42

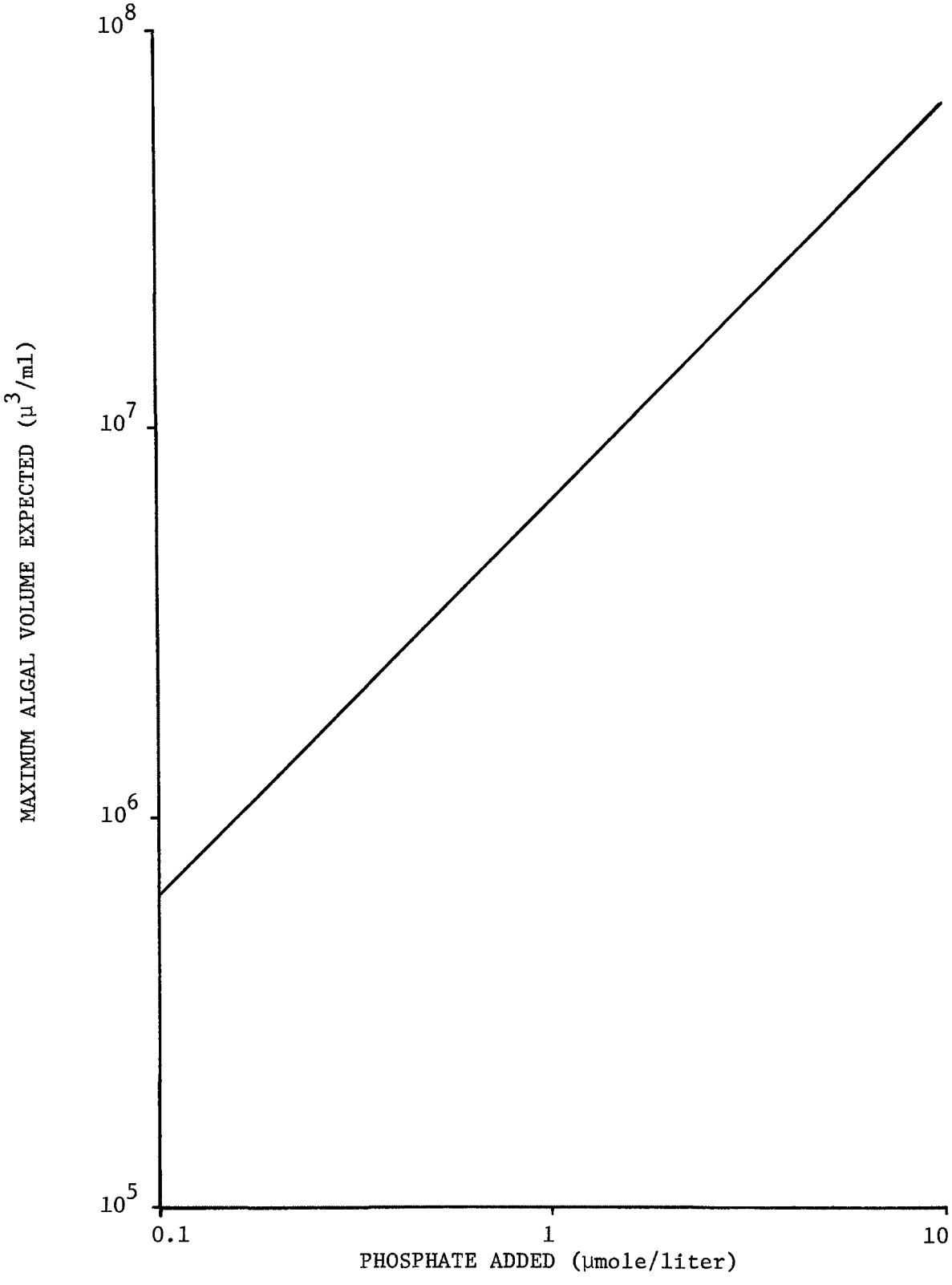


Figure 42. Relation Between Phosphate Addition and Maximum Expected Algal Cell Volume.

that to produce an algal population of this magnitude approximately 1.5 μmole of phosphate per liter is required. Although cell volumes of 2×10^8 μ^3/ml can be produced with a phosphate concentration maintained at 0.1 μM, reference to Figure 40 shows that an unreplenished phosphate concentration of 0.1 μM will produce a maximum growth of only 6.5×10^5 μ^3/ml. This means that to produce a cell volume of 10^7 μ^3/ml with an initial phosphate concentration of 0.1 μM, a replenishment factor of at least 15 is required. It thus becomes evident that to limit algal growth in a lake or pond situation, it is necessary not only to maintain low concentrations of phosphate in the aqueous phase, but also to minimize the total amount of phosphate which enters the body of water.

Another factor which must be considered in a natural situation is the limitation of algal growth due to such processes as competition for nutrients by other organisms and grazing by organisms higher in the food chain. Rhee (1971) has shown that competition by bacteria for phosphate can be significant in influencing the phosphate-dependent growth of Scenedesmus.

Some final factors which also must be considered are: loss of phosphate to and release from bottom sediment during the growing season, and supply of phosphorus from sources other than phosphate such as soluble organic phosphorus compounds and particulate forms of phosphorus. In lakes which develop a thermocline during the summer months, transport of any phosphates released from the sediments may be too slow to be of much significance and indeed Fitzgerald (1970) has found aerobic lake muds to be particularly poor sources of phosphorus for Selenastrum.

Probably one of the biggest uncertainties at present in predicting the crop of algae which a given lake will produce centers around the extent of which incoming soluble organic and particulate forms of phosphorus become available for algal growth during the growing season.

SECTION VII

ECONOMIC CONSIDERATIONS

The soil and water conservation movement started in the United States in the early 1930's. As a result of research and practical observations, many findings are available on economic benefits of soil and water conservation to individual farmers (Anonymous, 1956; Free, 1956; Free, 1970; Sauer, McGurk and Norton, 1950). These benefits have also been passed on to groups of people. This has happened through soil and water conservation districts, watershed groups, and larger valley compacts.

The newer environmental concepts of water quality in relation to animal waste, fertilizer, and land management have not been fully appreciated. Research findings may still be too few to fully apply these concepts to the present land and water situation. However, it would seem in order to point out existing benefits to farms from improved management of manure, fertilizer, and the land resource. Emphasis here is placed upon the findings of this research. The discussion will be concerned with the individual farm.

In a previous study (McEachron, et al., 1969) it was suggested that on farm studies of costs of hauling and spreading manure for dairy were $2.19 per ton. This same study also showed that under field conditions of good management, dairy manure when applied to corn would yield a return of $1.42 per ton. This income return would be obtained from the production increase of continuous corn silage.

Using data presented in this report, Coote (Coote, 1971) calculated a return of 75¢ per acre for reduced erosion losses due to manure application on continuous corn. Manure only and fertilizer plus manure increased nitrate losses at 20 year storm intensities only. Up until 10 year storm frequencies values of nitrates lost from manured and non-manured treatments were the same. Orthophosphate values in runoff were reduced by manure. Manure on continuous corn, either alone or with fertilizer, reduced losses of organic matter, nitrogen and phosphorus by 50%. Nitrogen and phosphorus are priced at approximately 10¢ per pound in fertilizers. If the assumption is made that the organic nitrogen and phosphorus retained on the land is worth the fertilizer price, then it is possible to add 10¢ more to the benefits of manure.

Table 6. Cost and Return per Ton of Manure Spread on Continuous Corn Silage Under Good Management

Costs		Returns	
Labor	.91	Silage yield increase	1.42
Power	.61	Conservation benefits	.75
Equipment	.67	Fertility saved	.10
Total	$ 2.19		$ 2.27
Net			.08

It should be pointed out that the benefits calculated for continuous corn culture in terms of erosion control and fertility kept on the land could not be shown in terms of mixed cropping and continuous hay studies. This is true because the influence of the close growing crop in the rotation (alfalfa) tended to improve the physical condition of the soil to the extent that the beneficial effects of manure were no longer evident. However, (McEachron, et al., 1969) yield increases on alfalfa were 5% for each ton of manure applied. Calculated as haylage, this alfalfa yield increase is valued at $2.88. This is well in excess of the cost of hauling and spreading one ton of manure.

The field scale water study suggests that in exceeding normal rates of fertilization, farmers may not only pollute ground and surface waters, but also spend unnecessarily on fertilizers. The unnecessary expense may range from $20 to $40 per acre per year.

SECTION VIII

ACKNOWLEDGEMENTS

The support of Professor Madison J. Wright, Head of the Department of Agronomy is gratefully acknowledged.

The following Agronomy staff members made major contributions to writing and preparing data for the report: D. R. Bouldin, T. E. Greweling, S. D. Klausner, D. J. Lathwell, D. O. Wilson, and P. J. Zwerman. They were assisted by the following graduate assistants and technicians: D. R. Coote, A. B. Drielsma, D. F. Ellis, G. D. Jones, S. Lee, J. P. Loch, and R. Jones.

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SECTION XI

GLOSSARY

Chemostat	-	A continuous-flow culture system in which the flow rate is kept constant.
Coshocton Wheel	-	A runoff sampler that divides the flow from an experimental area and retains a proportional part of it in a storage tank.
Cubic Micron	-	10^{-12} cm^3; abbreviation μ^3.
Deep Seepage	-	Water leaving the soil downwards permanently.
Divisor	-	Mechanical device for dividing up small flows of water.
Flume	-	A device used to measure the discharge of water. Different types of flumes exist which vary in design.
Intercepter Ditch	-	A ditch used to divert water towards a given point.
Micron	-	10^{-6} meter; abbreviation, μ.
Micromolar	-	10^{-6} mole/liter; abbreviation, μM; 1μ M P = 31 μg/1 P = 31 ppb expressed as P.
Micromole	-	10^{-6} mole/ abbreviation, μmole.
Millimolar	-	10^{-3} mole/liter; abbreviation, mM.
Millimole	-	10^{-3} mole/ abbreviation, mmole.
Runoff Coefficient	-	The percentage of rainfall that occurred as surface runoff.
Stage Height	-	A measure of the head in feet or inches. It is used to calculate the flow through a flume or weir.
Thermocline	-	The boundary between the surface water and deeper water of a lake due to temperature (and hence density) differences.
Turbidostat	-	A continuous-flow culture system in which the density of cells (turbidity) in the growth vessel is kept constant.

Weir	-	Serves the same purpose as a flume but differs in design.

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APPENDIX A

Table 1 can be used throughout Appendix A to distinguish between treatments designated by code. Details of cropping, fertilizing and other management differences are tabulated for easy reference.

Tables 2 through 4 present data for various parameters of runoff from the rainfall simulation. T-test analysis of various comparisons are shown simultaneously, with results noted at 5, 10 and 20 percent (/, x and *, respectively) probability (two tailed test) for readers' information. Data is shown for each of the three storm probabilities, 2, 10 and 20 years.

Tables 5 through 7 present similar data to Tables 2 through 4, but they are shown by half hour storm increments, the 20 year storm being made up of three identical consecutive 1.25 inch storms.

Tables 8 through 10 present data for various parameters of the sediment collected from the rainfall simulation. T-test comparisons are shown for each of the three consecutive half hour storms.

Tables 11 through 13 show the sediment data, by each half hour storm increment, comparing quantities and percentages of each variable in the sediment with that in the original undisturbed soil on the plot. The ratio of each pair of data is presented as the Enrichment Ratio (E.R.).

Tables 14 and 15 present an analysis of variance for a 2 x 4 x 3 factorial and a 2 x 2 x 3 factorial experiment. Table 14 shows little significance between three of the four different crop rotations for the various parameters. In general, hay rotations (H_yW - H_yZ) tended to be lower in total losses of constituents from the land surface during three consecutive half hour storms. Table 15 is a comparison of two continuous corn experiments. The difference exists in the rate of phosphorus fertilizer. Manure showed a definite advantage over no manure.

Table 16 is a presentation of the correlation and regression between surface runoff and soil loss. The strength of the linear relationship between the two is highest in the two year storm frequency for continuous corn (R^2 = 70.6%) and mixed rotations (R^2 = 82.8%). In these two cases, soil stability (aggregate stability) is easily destroyed and more soil is eroded per unit volume of water (see regression coefficients). In the successive 10 and 20 year storm frequencies, much of the erodable soil has already been lost, hence the poor correlation. The low coefficient for the two year storm for continuous hay (R^2 = 16.8%) proves that the high inherent aggregate stability resists the movement of soil by water. The correlation coefficient increases as storm duration increases because soil stability is diminishing.

Table 17 shows the correlation coefficients between constituents in the sediment and the soil from which the sediment is derived along with the enrichment ratio (mean content of constituent in sediment/mean content of constituent in the soil). The correlations for organic matter, total N, and total P are generally fairly good while for sand, silt and clay the correlations were generally poor. The enrichment ratios for organic matter, nitrogen and phosphorus are generally equal to each other for a given storm, and tend to decrease slightly from A to C. These calculations are calculated on the basis of three equal half hour storms with an intensity of 2.5 inches per hour rather than on a storm probability basis.

Table 18 is the correlation between percent solids in the runoff and selected variables as shown in the table. These results confirm the considerable variation among plots and storms in percent solids. The amount of solids in the runoff was not well correlated with other measured variables. These values are for three equal half hour storms with an intensity of 2.5 inches per hour.

Table 19 presents correlations among concentrations of NO_3-N in the soil before the artificial rain was applied and the concentration in the runoff from three equal half hour storms (1.25 in.). None of the variables were well correlated with other variables. Probably this is a reflection of the complicated patterns of water movement within a plot and the influence of properties of the plot on this movement. The high concentrations of NO_3-N found in the runoff from some treatments are a reflection both of high NO_3-N content in the soil plus appreciable downslope movement of water within the plot. If the depth to firm till was shallow, if the air filled pore space above firm till was limited, and if the surface permeability remained high, then the downslope movement of water through the surface soil would be maximum. This would in effect mean that maximum accumulation of NO_3 in the runoff would occur. On the other hand, if the surface sealed or if the depth to firm till and air filled pore space were large, then downslope movement of water through the surface soil would be limited and hence only limited amounts of NO_3-N would accumulate in the runoff. (Note that there was a 12 inch baffle on the downslope side of the plots which effectively forced the water moving downslope in the soil to "surface" and be collected as runoff. At first glance this would appear to bias the experimental results; however, this is not the case since probably downslope movement of water in the surface portion of this profile is the rule and sooner or later this water empties into a natural drainage ditch. Thus the runoff collected is a sample of the water which normally moves in this fashion).

Also shown are correlations among soluble orthophosphate in the water extracts and in runoff. The water extracts were not effective as a means of predicting concentrations of soluble orthophosphate in the runoff from the three storms. However, the correlations among concentrations in the runoff from the three storms were reasonably high;

that is, concentration was not greatly influenced by the duration of the storm. In summary, the procedure used was not particularly helpful in predicting concentrations of nitrate and orthophosphate in the run-off.

Tables 20, 21 and 22 a statistical study of the composition of the sediment from the rainmaker studies in the summer of 1968 was carried out with the objective of finding if one or more of the constituents could be estimated reasonably well from contents of other constituents. For example, the determinations of total N and total P are rather expensive so if these constituents could be estimated from other simpler determinations then a considerable saving in analytical costs could be realized. Shown in Tables 20 and 21 are the means and standard deviations of the means of constituents in the soils and sediments along with the correlation coefficients among constituents. Stepwise regression of selected constituents on other constituents are shown in Table 22. The results show that nitrogen, phosphorus and organic matter are reasonably well correlated with each other, but contents of these constituents are not well correlated with sand, silt, or clay. The regression studies demonstrate that nitrogen can be reasonably well estimated from organic matter content and that phosphorus can be reasonably well estimated from nitrogen content.

Table 1. Description of Treatment Applications per Year.

Continuous Corn

Treatment No.	Code	Use	Manure (Tons/Acre)	Fertilizer (Lbs./Acre)	Total Fertilizer (Lbs./Acre)
1	(Ay)	Grain	6	0- 0- 0	0
2	(Bw)	Grain	0	30-30-30 (30)	120
3	(Ccy)	Grain	0	30-90-60 (90)	270
4	(Aw)	Grain	6	30-30-30 (30)	120
5	(Ax)	Silage	6	30-30-30 (90)	180
6	(Az)	Grain	6	30-30-30 (90)	180
7	(Ccx)	Grain	6	30-90-60 (90)	270

Table 1. (Continued)

Mixed Rotations

Code	Rotation	Manure (Tons/Acre)	Fertilizer (Lbs./Acre)	Total Fert. (Lbs./Acre)
D_1Y	(2) C-C-O-A-A			
	Corn*	0	30-30-30	90
	Corn	0	30-30-30 (30)	120
	Oats	0	30-30-30	90
	Alfalfa	0	0-30-30	60
	Alfalfa	0	0-30-30	60
				Mean 84
E_5Y	(1) C-O-W-A-A			
	Corn	10	30-30-30 (30)	120
	Oats	0	30-30-30	90
	Wheat	10	15-30-30 (30)	105
	Alfalfa	0	0-30-30	60
	Alfalfa*	10	0-30-30	60
				Mean 87
F_5W	(1) C-O-A-W-A			
	Corn	10	30-30-30 (30)	120
	Oats	0	30-45-45	120
	Alfalfa	0	0- 0- 0	0
	Wheat	10	15-45-45	105
	Alfalfa*	10	0-30-30	60
				Mean 81
F_5Z	(2) C-O-A-W-A			
	Corn	10	0- 0- 0	0
	Oats	0	0- 0- 0	0
	Alfalfa	0	0- 0- 0	0
	Wheat	10	0- 0- 0	0
	Alfalfa*	10	0- 0- 0	0
				Mean 0

Table 1. (Continued)

Code	Rotation	Manure (Tons/Acre)	Fertilizer (Lbs./Acre)	Total Fert. (Lbs./Acre)
C_4W	(1) C-O-A-A			
	Corn	12	30-30-30 (30)[2]	120
	Oats	0	30-30-30	90
	Alfalfa	0	0-30-30	60
	Alfalfa*[1]	12	0-30-30	60
				Mean 83
C_4Y	(2) C-O-A-A			
	Corn	0	30-30-30 (30)	120
	Oats	0	30-30-30	90
	Alfalfa	0	0-30-30	60
	Alfalfa*	0	0-30-30	60
				Mean 83
C_4Z	(3) C-O-A-A			
	Corn	0	30-90-60 (90)	270
	Oats	0	30-30-30	90
	Alfalfa	0	0-30-30	60
	Alfalfa	0	0-30-30	60
				Mean 120
D_1W	(1) C-C-O-A-A			
	Corn*	10	30-30-30	90
	Corn	10	30-30-30 (30)	120
	Oats	0	30-30-30	90
	Alfalfa	0	0-30-30	60
	Alfalfa	10	0-30-30	60
				Mean 84

Table 1. (Continued)

Continuous Hay

Code	Rotation	Manure (Tons/Acre)	Fertilizer (Lbs./Acre)	Total Fertilizer (Lbs./Acre)
HYW				
	(1) W-A-A-A-A			
	Wheat	10	15-30-30 (30)	105
	Alfalfa	0	0-30-30	60
	Alfalfa	10	0-30-30	60
	Alfalfa*	0	0-30-30	60
	Alfalfa	10	0-30-30	60
			Mean	69
HYZ				
	(2) W-A-A-A-A			
	Wheat	0	15-30-30 (30)	105
	Alfalfa	0	0-30-30	60
	Alfalfa	0	0-30-30	60
	Alfalfa*	0	0-30-30	60
	Alfalfa	0	0-30-30	60
			Mean	69
JW				
	Continuous Hay	6	0-45-45	90

[1] Crop Plowed under for this experiment

[2] ( ) = Anhydrous Ammonia Sidedress

Table 2. T-Test Comparisons of Treatment Means of Runoff Variables per 3 Storm Frequencies - Continuous Corn[1]

Treatment	Storm Frequency (Years)	Solids (%)		Runoff (Gal./Acre)		Soil Loss (Tons/Acre)		Agg. Stability (%)		O. M. Return (Tons/Acre/Year)	
Ax vs Az	2	.49	.35	1014	298X	.019	.009	33.3	60.1	2.1	4.3*
	10	.47	.51	13865	7686/	.239	.187				
	20	.40	.39	38060	29600	.580	.493				
Bw vs Ay	2	.31	.46	1769	490	.032	.008	32.2	51.9*	2.6	6.0*
	10	.55	.62	14029	963	.257	.206				
	20	.40	.62/	33351	18423	.553	.601				
Ccy vs Ccx	2	.85	.48	3519	1434/	.165	.040/	30.5	38.4/	2.2	4.0*
	10	.49	.80/	22177	8782*	.441	.221/				
	20	.49	.48	50269	27915*	1.023	.535X				
Ccy vs Ay	2	.85	.46	3519	490*	.165	.008*	30.5	51.9*	2.2	4.0*
	10	.49	.62	22177	963X	.461	.206X				
	20	.49	.62	50269	18423*	1.023	.601X				
Ccy vs Aw	2	.85	.23X	3519	150*	.165	.002*	30.5	39.5/	2.2	4.3*
	10	.49	.43	22177	7275*	.441	.109*				
	20	.49	.34/	50269	24717*	1.023	.323*				
Ay vs Az	2	.46	.35	490	298	.008	.009	51.9	40.1X	4.0	4.3X
	10	.62	.51	960	7686	.206	.187				
	20	.62	.39	18423	29601	.601	.493				

Table 2. (Continued)

Treatment	Storm Frequency (Years)	NO_3 -N (Lbs./Acre)		Soluble Orthophosphate (PO_4)-P (Lbs./Acre)	
Ax vs Az	2	.043	.022	.0004	.0001/
	10	1.054	.702	.0053	.0033
	20	2.852	3.146	.0137	.0113
Bw vs Ay	2	.116	.036	.0000	.0001/
	10	.641	1.040	.0016	.0046
	20	1.222	1.996	.0022	.0112/
Ccy vs Ccx	2	.044	.054	.0013	.0005
	10	.494	.691	.0113	.0048
	20	1.364	2.734	.0249	.0162
Ccy vs Ay	2	.044	.036	.0013	.0001*
	10	.494	1.040	.0113	.0046
	20	1.364	1.996	.0249	.0112
Ccy vs Aw	2	.044	.005X	.0013	.0001*
	10	.494	.396	.0113	.0030
	20	1.364	1.745	.0249	.0084
Ay vs Az	2	.036	.022	.0001	.0001
	10	.494	.702	.0046	.0033
	20	1.996	3.146	.0112	.0113

[1] /,X, *Significance of the 20, 10 and 5% level respectively (sign ignored).

Table 3. T-Test Comparisons of Treatment M ans of Runoff Variables per Storm Frequency - 8 Rotations

Treatment	Storm Frequency (years)	Solids (%)		Runoff (Gal./Acre)		Soil Loss (Tons/Acre)		Agg. Stability (%)		O.M. Return (Tons/Acre/Year)	
C_4w vs C_4y	2	.66	.60	1460	130 x	.060	.004 /	74.5	71.0	2.3	1.1 *
	10	.36	.47	9338	8689	.175	.064				
	20	.48	.36	25556	28209	.554	.351				
D_1w vs D_1y	2	.33	.33	1357	510	.041	.009	67.1	51.7 *	2.9	1.4 *
	10	.32	.45	11617	10196	.169	.182				
	20	.38	.36	35727	31491	.570	.466				
C_4z vs D_1w	2	.45	.33	1061	1357	.026	.041	62.9	67.1	1.1	2.9 *
	10	.45	.32	12123	11617	.158	.169				
	20	.42	.38	32673	35727	.473	.570				
C_4y vs F_5z	2	.60	.70	130	990 /	.004	.035	71.0	78.3 1	1.1	2.4 *
	10	.47	.67	8689	12701	.064	.409 /				
	20	.36	.49	28209	37240	.351	.795 /				
E_5x vs F_5w	2	.46	.33	1596	1775	.041	.038	65.2	69.1	2.3	2.4 /
	10	.94	.56 /	14369	12947	.457	.262				
	20	.62	.47	37772	33856	.928	.662				
E_5x vs F_5z	2	.46	.70	1596	990	.041	.035	65.2	78.3 x	2.3	2.4 /
	10	.94	.67	14369	12701	.457	.409				
	20	.62	.49	37772	37240	.928	.795				
F_5w vs F_5z	2	.33	.70 x	1775	990	.038	.035	69.6	78.3 1	2.4	2.4
	10	.56	.67	12947	12701	.262	.409				
	20	.47	.49	33856	37240	.662	.795				

Table 3 (Continued)

Treatment	Storm Frequency (years)	NO_3-N (Lbs./Acre)		Soluble Orthophosphate (PO_4)-P (Lbs./Acre)	
C_4w vs C_4y	2	.031	.002 *	.0004	.0000 x
	10	.202	2.021	.0022	.0002 x
	20	1.101	5.197 /	.0060	.0010 x
D_1w vs D_1y	2	.126	.030	.0008	.0000
	10	1.145	.397	.0075	.0154
	20	4.517	1.763 /	.0212	.0188
C_4z vs D_1w	2	.068	.126	.0001	.0008
	10	.513	1.145	.0011	.0075 x
	20	1.685	4.517	.0032	.0212 *
C_4y vs F_5z	2	.002	.032 /	.0000	.0000
	10	2.021	.390	.0002	.0008 /
	20	5.197	2.909	.0010	.0054 /
E_5x vs F_5w	2	.092	.045	.0003	.0005
	10	.902	.797	.0031	.0042
	20	2.848	2.338	.0079	.0084
E_5x vs F_5z	2	.092	.032	.0003	.0000
	10	.902	.390	.0031	.0008
	20	2.848	2.909	.0079	.0054
F_5w vs F_5z	2	.045	.032	.0005	.0000
	10	.797	.390	.0042	.0008
	20	2.338	2.909	.0084	.0054

Table 4. T-Test Comparisons of Treatment Means of Runoff of Variables for 3 Storm Frequencies - 3 Hay Rotations.

Treatment	Storm Frequency (years)	Solids (%)		Runoff (Gal./Acre)		Soil Loss (Tons/Acre)		Agg. Stability (%)		O.M. Return (Tons/Acre/Year)	
H_4w vs H_4z	2	.22	.37	267	179	.003	.003	62.3	68.2	2.0	0.6 *
	10	.43	.50	4939	4365	.090	.095				
	20	.32	.39	17973	17585	.229	.291				
H_4z vs Jw	2	.37	.35	179	324	.003	.005	68.2	73.6	0.57	1.74 *
	10	.50	.48	4365	8901 /	.095	.165				
	20	.39	.39	17585	27050 /	.291	.447				

Table 4. (Continued)

Treatment	Storm Frequency (years)	NO_3-N (Lbs./Acre)		Soluble Orthophosphate (PO_4)-P (Lbs./Acre)	
H_4w vs H_4z	2	.004	.020	.0000	.0000
	10	.053	.074	.0006	.0005
	20	.495	.829	.0034	.0016
H_4z vs Jw	2	.020	.006	.0000	.0000
	10	.074	.555	.0005	.0091 X
	20	.829	1.471	.0014	.0194 X

Table 5. T-Test Comparisons of Treatment Means of Runoff Variables for Three Equal Consecutive Half Hour (1.25 in.) Storms, Continuous Corn.

Treatment	Storm	Solids (%)		Runoff (Gal./Acre)		Soil Loss (Tons/Acre)		Aggregate Stability (%)		Annual O.M. Return (Tons/Acre)	
A_x vs A_z	A	.49	.35	1014	298^{x}	.019	.009	33.3	40.1	2.1	4.3*
	B	.47	.50	12851	7388$^{/}$	.219	.179				
	C	.37	.36	24195	21914	.341	.306				
B_w vs A_y	A	.31	.46	1769	490	.032	.008	32.2	51.9*	2.6	4.0*
	B	.56	.62	12260	10473	.225	.198				
	C	.33	.61^{x}	19322	17460	.296	.395				
$C_c y$ vs $C_c x$	A	.85	.48	3519	1434$^{/}$	.165	.040$^{/}$	30.5	38.4$^{/}$	2.2	4.0*
	B	.37	.79^{x}	18657	7348*	.276	.181				
	C	.51	.43	28092	19133^{x}	.581	.314^{x}				
$C_c y$ vs A_y	A	.85	.46	3519	490*	.165	.008*	30.5	51.9*	2.2	4.0*
	B	.37	.62$^{/}$	18657	10473^{x}	.276	.198				
	C	.51	.61	28092	17460*	.581	.395^{x}				
$C_c y$ vs A_w	A	.85	.23^{x}	3519	150*	.165	.002*	30.5	39.5$^{/}$	2.2	4.3*
	B	.37	.43	18657	7125*	.276	.107*				
	C	.51	.30$^{/}$	28092	17441*	.581	.214*				
A_y vs A_z	A	.46	.35	490	298	.008	.009	51.9	40.1^{x}	4.0	4.3^{x}
	B	.62	.50	10473	7388	.198	.179				
	C	.61	.36$^{/}$	17460	21914	.395	.306				

Table 5 (continued)

Treatment	Storm	Nitrate-N mg/l		Nitrate-N Lbs./Acre		Soluble Orthophosphate (PO_4)-P mg/l		Soluble Orthophosphate (PO_4)-P Lbs./Acre	
A_x vs A_z	A	4.8	4.6	.043	.022	.043	.030	.0004	.0001/
	B	8.2	7.5	1.010	.680	.043	.043	.0050	.0033
	C	7.7	11.9	1.799	2.444	.039	.045	.0083	.0079
B_w vs A_y	A	3.1	5.3	.116	.036	.006	.028x	.0000	.0001/
	B	3.0	6.2	.525	1.005	.011	.040*	.0016	.0045
	C	2.5	4.1	.481	.956	.008	.043*	.0006	.0066*
C_cy vs C_cx	A	1.4	3.1/	.044	.054	.036	.039	.0013	.0005
	B	3.4	9.1/	.470	.637	.055	.065	.0101	.0043
	C	3.4	12.6x	.870	2.318	.054	.065	.0136	.0114
C_cy vs A_y	A	1.4	5.3	.044	.036	.036	.028	.0013	.0001*
	B	3.4	6.2	.470	1.005	.055	.040	.0101	.0045
	C	3.4	4.1	.870	.956	.093	.043	.0136	.0066
C_cy vs A_w	A	1.4	2.4	.044	.005x	.036	.023	.0013	.0001*
	B	3.4	5.8	.470	.390	.055	.038	.0101	.0029
	C	3.4	9.2x	.870	1.349	.091	.040	.0136	.0055
A_y vs A_z	A	5.3	4.6	.036	.022	.028	.030	.0001	.0001
	B	6.2	7.5	1.005	.680	.040	.043	.0045	.0033
	C	4.1	11.9x	.956	2.444	.043	.045	.0066	.0079

Table 6. T-Test Comparisons of Treatment Means of Runoff Variables for Three Equal Consecutive Half Hour (1.25 in.) Storms, 8 Rotations.

Treatment	Storm	Solids (%)		Runoff (Gal./Acre)		Soil Loss (Tons/Acre)		Aggregate Stability (%)		Annual O. M. Return (Tons/Acre)	
C_4W vs C_4Y	A	.67	.60	1460	130[x]	.060	.004[/]	74.5	71.0	2.3	1.1*
	B	.30	.47	7878	8559	.115	.060				
	C	.54	.38	16218	19520	.379	.287				
D_1W vs D_1Y	A	.33	.33[x]	1357	510	.041	.009	67.1	51.7*	2.9	1.4*
	B	.29	.45	10260	9686	.128	.173				
	C	.39	.32	24110	21295	.401	.284				
C_4Z vs D_1W	A	.45	.33	1061	1357	.026	.041	62.9	67.1	1.1	2.9*
	B	.44	.29	11062	10260	.132	.128				
	C	.41	139	20550	24110	.315	.401				
C_4Y vs F_5Z	A	.60	.70	130	990[/]	.004	.035[/]	71.0	78.3[/]	1.1	2.4*
	B	.47	.67	8559	11711	.060	.374[/]				
	C	.38	.38	19520	24539	.287	.386				
E_5X vs F_5W	A	.46	.33[/]	1596	1775	.041	.038	65.2	69.6	2.3	2.4[/]
	B	.98	.55	12773	11172	.416	.224				
	C	.52	.46	23403	20909	.471	.400				
E_5X vs F_5Z	A	.46	.70	1596	990	.041	.035	65.2	78.3[x]	2.3	2.4[/]
	B	.98	.67	12773	11711	.416	.374				
	C	.52	.38	23403	24539	.471	.386				
F_5W vs F_5Z	A	.33	.70[/]	1775	990	.038	.035	69.6	78.3[/]	2.4	2.4
	B	.55	.67	11172	11711	.224	.374				
	C	.46	.38	20909	24539	.400	.386				

Table 6. (continued)

Treatment	Storm	Nitrate - N mg/l		Nitrate - N Lbs./Acre		Soluble Orthophosphate(PO_4)-P mg/l		Soluble Orthophosphate(PO_4)-P Lbs./Acre	
C_4W vs C_4Y	A	12.4	3.7	.031	.002*	.030	.003*	.0004	.0000x
	B	10.6	12.5	.170	2.019	.021	.006*	.0018	.0002x
	C	4.5	19.2*	.814	3.176x	.024	.007*	.0038	.0008x
D_1W vs D_1Y	A	7.0	8.1	.126	.030	.035	.007	.0008	.0000
	B	12.1	4.2/	1.019	.368	.075	.014*	.0067	.0154
	C	16.2	7.3/	3.371	1.366/	.072	.020*	.0137	.0034*
C_4Z vs D_1W	A	3.8	7.0	.068	.126	.009	.035	.0001	.0008
	B	2.2	12.1x	.445	1.019	.007	.075*	.0010	.0067x
	C	5.2	16.2x	1.172	3.371/	.013	.072*	.0021	.0137*
C_4Y vs F_5Z	A	3.7	5.5	.002	.032/	.003	.014x	.0000	.0000
	B	12.5	4.7	2.019	.358	.006	.015/	.0002	.0008/
	C	19.2	11.4x	3.176	2.520	.007	.025	.0008	.0046
E_5X vs F_5W	A	5.9	2.4	.092	.045	.022	.018	.0003	.0005
	B	5.2	5.0	.810	.752	.023	.025	.0027	.0037
	C	8.5	8.2	1.946	1.541	.025	.024	.0049	.0042
E_5X vs F_5Z	A	5.9	5.5	.092	.032	.022	.014	.0003	.0000
	B	5.2	4.7	.810	.358	.023	.015	.0027	.0008
	C	8.5	11.4	1.946	2.520	.025	.025	.0049	.0046
F_5W vs F_5Z	A	2.4	5.5	.045	.032	.018	.014	.0005	.0000
	B	5.0	4.7	.752	.358	.025	.015	.0037	.0008
	C	8.2	11.4	1.541	2.520	.024	.025	.0042	.0046

Table 7. T-Test Comparisons of Treatment Means of Runoff Variables for Three Equal Consecutive Half Hour (1.25 inch) Storms, 3 Hay Rotations.

Treatment	Storm	Solids (%)		Runoff (Gal./Acre)		Soil Loss (Tons/Acre)		Aggregate Stability (%)		Annual O. M. Return (Tons/Acre)	
H_4W vs H_4Z	A	.22	.37	247	179	.003	.003	67.3	68.2	2.02	0.57*
	B	.43	.50	4692	4186	.087	.092				
	C	.29	.36	13034	13220	.139	.196				
H_4Z vs JW	A	.37	.35	179	324	.003	.005	68.2	73.6	0.57	1.74*
	B	.50	.48	4186	8577	.092	.160				
	C	.36	.36	13220	18149	.196	.282				

Table 7. (continued)

Treatment	Storm	Nitrate - N mg/l		Nitrate - N Lbs./Acre		Soluble Orthophosphate (PO_4)-P mg/l		Soluble Orthophosphate (PO_4)-P Lbs./Acre	
H_4W vs H_4Z	A	1.4	5.4	.004	.020	.011	.010	.0000	.0000
	B	1.1	1.4	.049	.054	.022	.012	.0006	.0005
	C	2.6	5.9	.443	.755	.028	.008*	.0028	.0009
H_4Z vs JW	A	5.4	2.2	.020	.006	.010	.023	.0000	.0000
	B	1.4	4.7	.054	.549	.012	.061*	.0005	.0091
	C	5.9	4.4	.755	.916	.008	.061*	.0009	.0103*

Table 8. T-Test Comparisons of Treatment Means for Variables in Sediment from each of Three Equal Consecutive Half Hour (1.25 inch) Storms, Continuous Corn.

Treatment	Storm	Organic Matter %		Organic Matter Lbs./Acre		Total Phosphorus %		Total Phosphorus Lbs./Acre	
Ax vs Az	A	NS[1]	0.0	NS	0.0	NS	.000	NS	.000
	B	6.9	7.6	30.3	22.7	.144	.145	.642	.432
	C	6.6	8.3	43.3	46.5	.125	.158	.870	.854
Bw vs Ay	A	3.8	NS	6.2	NS	.063	NS	.117	NS
	B	6.0	6.8	37.6	29.3	.115	.142	.714	.552
	C	6.0	6.5	35.7	50.7	.112	.121	1.305	.915
C_cy vs C_cx	A	5.6	5.2	22.7	7.8*	.109	.104	.444	.155
	B	6.5	5.7	36.6	27.0	.136	.139	.770	.609
	C	5.6	4.2	65.7	34.0	.113	.123	1.305	.824
C_cy vs Ay	A	5.6	NS	22.7	NS	.109	NS	.444	NS
	B	6.5	6.8	36.6	29.3	.136	.142	.770	.552
	C	5.6	6.5	65.7	50.7	.113	.121	1.305	.915
C_cy vs Aw	A	5.6	0.0*	22.7	0.0[x]	.109	.000*	.444	.000*
	B	6.5	8.4	36.6	18.7	.136	.146	.770	.325[x]
	C	5.6	8.2*	65.7	34.2[x]	.113	.141	1.305	.584*
Ay vs Az	A	NS	0.0	NS	0.0	NS	.000	NS	.000
	B	6.8	7.6	29.3	22.7	.142	.145	.552	.432
	C	6.5	8.3	50.7	46.5	.121	.158	.915	.854

Table 8. (continued)

Treatment	Storm	Total Nitrogen %		Total Nitrogen Lbs./Acre		Sand %		Silt %		Day %	
Ax vs Az	A	NS	.000	NS	.000	NS	NS	NS	NS	NS	NS
	B	.368	.377	1.636	1.608	6.4	5.1	35.2	34.8	58.4	60.1
	C	.362	.419	2.398	2.365	8.6	4.2	31.7	32.2	59.7	63.5
Bw vs Ay	A	.200	NS	.341	NS	3.4	NS	23.7	NS	40.7	NS
	B	.306	.348	1.484	1.287	5.8	2.9	38.2	31.1[1]	56.0	65.9*
	C	.310	.309	1.855	2.545	1.5	3.2	36.4	31.4	62.1	65.4
C_cy vs C_cx	A	.788	.250	1.181	.208	0.5	3.3	29.3	28.5	70.2	69.7
	B	.344	.360	1.935	1.568	3.3	5.7	31.9	32.6	64.8	61.6
	C	.319	.329	3.677	2.182[1]	6.7	11.0	35.5	36.0	57.8	53.1
C_cy vs Ay	A	.788	NS	1.151	NS	0.5	NS	29.3	NS	70.2	NS
	B	.344	.348	1.935	1.287	3.3	2.9	31.9	31.1	64.8	65.9
	C	.319	.329	3.677	2.545[1]	6.7	3.2[x]	35.5	31.4	57.8	65.4[x]
C_cy vs Aw	A	.788	.000	1.151	.000*	0.5	NS	29.3	NS	70.2	NS
	B	.344	NS	1.935	NS	3.3	13.6[1]	31.9	24.6	64.8	61.8
	C	.319	.405	3.677	2.000[x]	6.7	6.8	35.5	29.8[x]	57.8	54.4
Ay vs Az	A	.200	.000*	NS	.000	NS	NS	NS	NS	NS	NS
	B	.306	.377	1.287	1.608	2.9	5.1	31.1	34.8	65.9	60.1[x]
	C	.310	.419[x]	2.545	2.364	3.2	4.2	31.4	32.2	65.4	63.5

[1] No sample

Table 9. T-Test Comparisons of Treatment Means for Variables in Sediment for each of Three Equal Consecutive Half Hour (1.25 in.) Storms, Eight Rotations

Treatment	Storm	Organic Matter %		Organic Matter Lb/Acre		Total Phosphorus %		Total Phosphorus Lb/Acre	
Cw vs C_y	A	6.6	N.S.[1]	18.8	N.S.	.133	N.S.	0.385	N.S.
	B	7.9	5.6[x]	21.0	6.2	.128	.095	0.329	0.098[x]
	C	8.3	6.8	51.1	42.5	.133	.108	0.783	0.589
D_1w vs D_1y	A	5.1	3.1	10.5	0.7	.105	.086	0.213	0.019
	B	8.4	5.6*	22.7	19.4	.176	.134*	0.460	0.465
	C	8.8	6.0*	73.7	33.5	.166	.145	1.413	0.849
Cz vs D_1w	A	3.9	8.1	8.5	10.5	.088	.105	0.192	0.213
	B	7.0	8.4	22.0	22.7	.105	.176*	0.338	0.465
	C	6.5	8.8	38.8	73.7	.100	.166	0.626	1.413
C_4y vs F_5z	A	N.S.	N.S.	0.0	N.S.	N.S.	N.S.	N.S.	N.S.
	B	5.6	7.4	6.2	27.7*	.095	.133	0.098	0.492*
	C	6.8	6.5	42.5	51.8	.108	.116	0.589	0.909
E_5x vs F_5w	A	2.1	4.3	3.3	5.9	.055	.062	0.089	0.077
	B	5.8	8.0	45.6	37.5	.128	.149	0.817	0.739
	C	7.4	7.5	66.5	61.5	.132	.142	1.140	1.206
E_5x vs F_5z	A	2.1	N.S.	3.3	N.S.	.055	N.S.	0.089	N.S.
	B	5.8	7.4	45.6	27.7	.128	.133	0.817	0.492
	C	7.4	6.5	66.5	51.8	.132	.116	1.140	0.908
F_5w vs F_5z	A	6.5	N.S.	5.9	N.S.	.062	N.S.	0.77	N.S.
	B	4.3	7.4	37.5	27.7	.149	.133	0.739	0.492
	C	8.0	6.5	61.5	51.8	.142	.116	1.206	0.909

Table 9 (continued)

Treatment	Storm	Total Nitrogen %		Total Nitrogen Lb/Acre		Sand %		Silt %		Clay %	
C_4w vs C_4y	A	.352	N.S.	0.99	N.S.	0.00	N.S.	31.8	N.S.	68.2	N.S.
	B	.420	.320[1]	1.11	0.49[1]	3.1	14.4[1]	34.2	32.0	62.7	54.2
	C	.426	.363	2.64	2.03	1.4	6.4[1]	35.9	34.1	63.0	59.4
D_1w vs D_1y	A	.260	N.S.	0.53	N.S.	0.00	N.S.	25.8	N.S.	74.3	N.S.
	B	.457	.312*	1.19	1.08	8.8	10.4	30.8	29.3	60.5	60.2
	C	.453	.334*	3.79	1.90[1]	5.1	8.2	36.7	36.2	58.2	55.6
C_4z vs D_1w	A	.206	.260	0.45	0.53	N.S.	0.00	N.S.	25.8	N.S.	74.3
	B	.444	.457	1.37	1.19	13.8	8.8	26.7	30.8	59.4	60.5
	C	.349	.453[x]	2.06	3.79	5.3	5.1	33.6	36.7	61.1	58.2
C_4y vs F_5z	A	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
	B	.320	.354	0.49	1.32	14.4	5.1	32.0	36.1	54.2	58.8
	C	.363	.317	2.03	2.54	6.4	6.4	34.1	34.5	59.4	59.1
E_5x vs F_5w	A	.331	.197[x]	0.59	0.27	N.S.	6.0	N.S.	23.8	N.S.	70.2
	B	.384	.369	2.59	1.74	9.4	7.1	37.4	29.0*	53.1	63.8[x]
	C	.381	.346	3.37	2.83	4.0	1.4	36.3	38.1	59.7	61.1
E_5x vs F_5z	A	.331	N.S.	0.59	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
	B	.384	.354	2.59	1.32	9.4	5.1	37.6	36.1	53.1	58.8
	C	.381	.317	3.37	2.54	4.0	6.4	36.3	34.5	59.7	59.1
F_5w vs F_5z	A	.197	N.S.	0.27	N.S.	6.0	N.S.	23.8	N.S.	70.7	N.S.
	B	.369	.354	1.74	1.32	7.1	5.1	29.0	36.1*	63.8	58.8
	C	.346	.317	3.37	2.54	1.4	6.4*	38.1	36.5[1]	61.4	59.1

[1] No sample

Table 10. T-Test Comparisons of Treatment Means for Variables in Sediment from each of Three Equal Consecutive Half Hour (1.25 in.) Storms, Three Hay Rotations

		Organic Matter				Total Phosphorus			
Treatment	Storm	%		Lb/Acre		%		Lb/Acre	
(1)									
H_4w vs H_4z	A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	B	6.8	6.4	10.8	13.9	0.113	0.089*	0.186	0.195
	C	5.6	6.2	15.7	21.8	0.112	0.079	0.349	0.294
(2)									
H_4z vs Jw	A	0.0	2.6	0.0	0.826	0.0	0.059	0.0	0.019
	B	6.4	8.5*	13.9	25.0	0.089	0.174*	0.195	0.526
	C	6.2	7.8	21.8	42.4*	0.079	0.156*	0.294	0.879*

Table 10 (continued)

		Total Nitrogen				Sand		Silt		Clay	
Treatment	Storm	%		Lb/A		%		%		%	
(1)											
H_4w vs H_4z	A	0.0	0.0	0.0	0.0	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
	B	0.350	0.339	0.563	0.639	5.7	0.7	34.6	33.1	59.6	66.2
	C	0.286	0.329	0.792	1.169	16.4	8.3	33.6	30.7	50.0	61.0
(2)											
H_4z vs Jw	A	0.0	0.0	0.0	0.0	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
	B	0.339	0.460*	0.639	1.358	0.7	3.9	33.1	34.1	66.2	62.1
	C	0.329	0.453	1.169	2.387*	8.3	2.9	30.7	35.1	61.0	62.0

Table 11. Enrichment Ratios (E.R.) for Variables in Sediment from Each of Three Equal Consecutive Half Hour (1.25 inch) Storms, Continuous Corn.

Treatment	Storm	Organic Matter (%) Soil	Organic Matter (%) Sediment	Organic Matter (%) E.R.	Total Phosphorus (%) Soil	Total Phosphorus (%) Sediment	Total Phosphorus (%) E.R.	Total Nitrogen (%) Soil	Total Nitrogen (%) Sediment	Total Nitrogen (%) E.R.
Ax	A	4.1	NS[1]	---	.081	NS	---	.218	NS	---
	B		6.9	1.7		.144	1.8		.368	1.7
	C		6.6	1.6		.125	1.5		.362	1.7
Bw	A	3.4	3.8	1.1	.070	.063	0.9	.190	.200	1.1
	B		6.0	1.8		.115	1.6		.306	1.6
	C		6.0	1.8		.112	1.6		.310	1.6
$C_c y$	A	3.7	5.6	1.5	.067	.109	1.6	.196	.288	1.5
	B		6.5	1.8		.136	2.0		.344	1.8
	C		5.6	1.5		.113	1.7		.319	1.6
$C_c x$	A	3.9	5.2	1.3	.079	.104	1.3	.189	.250	1.3
	B		5.7	1.5		.139	1.8		.360	1.9
	C		4.2	1.1		. 23	1.6		.329	1.7
Ay	A	4.0	NS	---	.077	NS	---	.196	NS	---
	B		6.8	1.7		.142	1.8		.348	1.8
	C		6.5	1.6		.121	1.6		.329	1.7
Aw	A	4.5	0.0	---	.083	.000	---	.229	.000	---
	B		8.4	1.9		.146	1.8		NS	---
	C		8.2	1.8		.141	1.7		.405	1.8
Az	A	4.8	0.0	---	.093	.000	---	.238	.000	---
	B		7.6	1.6		.145	1.6		.377	1.6
	C		8.3	1.7		.158	1.7		.419	1.8

Table 11. (Continued)

Treatment	Storm	Sand (%) Soil	Sand (%) Sediment	Sand (%) E.R.	Silt (%) Soil	Silt (%) Sediment	Silt (%) E.R.	Clay (%) Soil	Clay (%) Sediment	Clay (%) E.R.
Ax	A	37.7	NS	---	29.0	NS	---	33.3	NS	---
	B		6.4	.17		35.2	1.2		58.4	1.8
	C		8.6	.23		31.7	1.1		59.7	1.8
Bw	A	29.9	3.4	.11	28.5	23.7	.83	41.6	40.7	.98
	B		5.8	.19		38.2	1.3		56.0	1.3
	C		1.5	.05		36.4	1.3		62.1	1.5
$C_c y$	A	35.5	0.5	.00	28.2	29.3	1.0	36.3	70.2	1.9
	B		3.3	.09		31.9	1.1		64.8	1.8
	C		6.7	.19		35.3	1.3		57.8	1.6
$C_c x$	A	40.5	3.3	.08	27.8	28.5	1.0	31.7	69.7	2.2
	B		5.7	.14		32.6	1.2		61.6	1.9
	C		11.0	.27		36.0	1.3		53.1	1.6
Ay	A	29.8	NS	---	28.6	NS	---	41.6	NS	---
	B		2.9	.09		31.1	1.1		65.9	1.6
	C		3.2	.11		31.4	1.1		65.4	1.6
Aw	A	47.8	NS	---	22.4	NS	---	30.0	NS	---
	B			.28		24.6	1.1		61.8	2.1
	C		6.8	.14		29.8	1.3		54.4	1.8
Az	A	29.6	NS	---	29.0	NS	---	43.4	NS	---
	B		5.1	.17		34.8	1.2		60.1	1.4
	C		4.2	.14		32.2	1.1		63.5	1.5

[1] No sample

Table 12. Enrichment Ratios (E. R.) for Variables in Sediment from each of Three Half Hour Storms (1.25 inch) 8 Rotations.

Treatment	Storm	Organic Matter (%) Soil	Organic Matter (%) Sediment	Organic Matter (%) E. R.	Total Phosphorus (%) Soil	Total Phosphorus (%) Sediment	Total Phosphorus (%) E. R.	Total Nitrogen (%) Soil	Total Nitrogen (%) Sediment	Total Nitrogen (%) E. R.
C_4w	A	4.3	6.6	1.5	.108	.133	1.2	.230	.352	1.5
	B		7.9	1.8		.128	1.2		.420	1.8
	C		8.3	1.9		.133	1.2		.426	1.9
C_4y	A	4.8	NS[1]	---	.080	NS	---	.244	NS	---
	B		5.6	1.2		.095	1.2		.320	1.3
	C		6.8	1.4		.108	1.4		.363	1.5
C_4z	A	4.2	3.9	0.9	.063	.088	1.4	.197	.206	1.1
	B		7.0	1.7		.105	1.7		.444	2.3
	C		6.5	1.5		.100	1.6		.349	1.8
D_1w	A	5.2	5.1	1.0	.111	.105	0.9	.264	.260	1.0
	B		8.4	1.6		.176	1.6		.457	1.7
	C		8.8	1.7		.166	1.5		.453	1.7
D_1y	A	3.8	3.1	0.8	.091	.086	0.9	.201	NS	---
	B		5.6	1.5		.134	1.5		.312	1.6
	C		6.0	1.6		.145	1.6		.334	1.7
E_5x	A	4.6	2.1	0.5	.104	.055	0.5	.260	.331	1.3
	B		5.8	1.3		.128	1.2		.384	1.5
	C		7.4	1.6		.132	1.3		.381	1.5
F_5w	A	4.6	4.3	0.9	.084	.062	0.7	.233	.197	0.8
	B		8.0	1.7		.149	1.8		.369	1.6
	C		7.5	1.6		.142	1.7		.346	1.5
F_5z	A	4.9	NS	---	.079	NS	---	.250	NS	---
	B		7.4	1.5		.133	1.7		.354	1.4
	C		6.5	1.3		.116	1.5		.317	1.3

Table 12 (continued)

Treatment	Storm	Sand (%) Soil	Sand (%) Sediment	Sand (%) E. R.	Silt (%) Soil	Silt (%) Sediment	Silt (%) E. R.	Clay (%) Soil	Clay (%) Sediment	Clay (%) E. R.
C_4w	A	30.8	0.0	---	23.4	31.8	1.4	45.8	68.2	1.5
	B		3.1	.10		34.2	1.5		62.7	1.4
	C		1.4	.05		35.9	1.5		63.0	1.4
C_4y	A	26.4	NS	---	27.8	NS	---	45.8	NS	---
	B		14.4	.55		32.0	1.2		54.2	1.2
	C		6.4	.24		34.1	1.2		59.4	1.3
C_4z	A	18.9	NS	---	27.2	NS	---	53.8	NS	---
	B		13.8	.73		26.7	.98		59.4	1.1
	C		5.3	.28		33.6	1.2		61.1	1.1
D_1w	A	20.2	0.0	---	28.5	25.8	.91	51.3	74.3	1.5
	B		8.8	.43		30.8	1.1		60.5	1.2
	C		5.1	.25		36.7	1.3		58.2	1.1
D_1y	A	23.8	NS	---	28.9	NS	---	47.3	NS	---
	B		10.4	.44		29.3	1.0		60.2	1.3
	C		8.2	.34		36.2	1.3		55.6	1.2
E_5x	A	17.5	NS	---	29.7	NS	---	52.8	NS	---
	B		9.4	.38		37.4	1.3		53.1	1.1
	C		4.0	.16		36.3	1.2		59.7	1.3
F_5w	A	24.5	6.0	.24	28.8	23.8	.83	46.7	70.2	1.5
	B		7.1	.29		29.0	1.0		63.8	1.4
	C		1.4	.06		38.1	1.3		61.1	1.3
F_5z	A	27.3	NS	---	29.1	NS	---	43.6	NS	---
	B		5.1	.19		36.1	1.2		58.8	1.3
	C		6.4	.23		34.5	1.2		59.1	1.4

[1] No sample.

Table 13. Enrichment Ratios (E.R.) for Variables in Sediment from each of Three Equal Half Hour Storms (1.25 in.), Three Hay Rotations

Treatment	Storm	Organic Matter (%) Soil	Sed.	E.R.	Total Phosphorus (%) Soil	Sed.	E.R.	Total Nigrogen (%) Soil	Sed.	E.R.
(1)										
H_4w	A	4.5	0.0	---	.045	.000	---	.222	.000	---
	B		6.8	1.5		.113	2.5		.350	1.6
	C		5.6	1.2		.112	2.5		.286	1.3
(2)										
H_4z	A	4.0	0.0	---	.089	.000	---	.207	.000	---
	B		6.4	1.6		.089	1.0		.340	1.6
	C		6.2	1.5		.079	0.9		.329	1.6
(3)										
Jw	A	4.9	2.6	0.5	.100	.059	0.6	.288	.000	---
	B		8.5	1.7		.174	1.7		.460	1.6
	C		7.8	1.6		.156	1.6		.453	1.6

Table 13 (continued)

Treatment	Storm	Sand (%) Soil	Sand (%) Sed.	Sand (%) E.R.	Silt (%) Soil	Silt (%) Sed.	Silt (%) E.R.	Clay (%) Soil	Clay (%) Sed.	Clay (%) E.R.
(1)										
H_4w	A	16.7	N.S.[1]	---	28.4	N.S.	---	54.9	N.S.	---
	B		5.7	.34		34.6	1.2		59.6	1.1
	C		16.4	.98		33.6	1.2		50.0	.91
(2)										
H_4z	A	34.5	N.S.	---	27.0	N.S.	---	40.5	N.S.	---
	B		0.7	.02		33.1	1.2		66.2	1.6
	C		8.3	.24		30.7	1.1		61.0	1.5
(3)										
Jw	A	24.1	N.S.	---	28.9	N.S.	---	47.0	N.S.	---
	B		3.9	.16		34.1	1.2		62.1	1.3
	C		2.9	.12		35.1	1.2		62.0	1.3

[1] No sample

Table 14. Analysis of Variance of Several Crop Rotations . Three Consecutive Half Hour (1.25 in.) Storms

	Runoff			Soil Loss			
	Gal./Acre	NO_3-N (Lbs./Acre)	Solu. Ortho. (PO_4)-P (Lbs./Acre	Tons/Acre	Organic Matter (Lbs./Acre)	Total Nitrogen (Lbs./Acre)	Total Phosphorus (Lbs./Acre)
Rotation							
Aw - Bw	9678a[1]	0.48ab	0.0018a	0.146a	22.09a	1.02ab	0.404ab
C_yw - C_yy	8960a	1.04b	0.0012a	0.151a	19.95a	1.21ab	0.364ab
D_1w - D_1y	11202a	1.05b	0.0067b	0.172a	20.08a	1.42a	0.569a
H_4w - H_4z	5926b	0.22a	0.0008a	0.087a	10.37b	0.53b	0.171b
Treatment							
Manure (6 T/A)	8664a	0.65a	0.0033a	0.140a	18.10a	1.17a	0.418a
No Manure	9219a	0.74a	0.0020a	0.139a	18.14a	0.92a	0.335a
Storm							
A	725a	0.04	0.0002a	0.019a	15.20a	0.23a	0.092a
B	8080b	0.57	0.0037b	0.173ab	18.79a	0.88a	0.347ab
C	18020c	1.47	0.0039b	0.275b	31.03b	2.02b	0.693b

[1] Means followed by the same letter are not significantly different at 5% level.

Table 15. Analysis of Variance of Two Continuous Corn Rotations from Three Consecutive (1.25 inch) Storms.

Factor	Level	Mean						
		Runoff			Soil Loss			
		Gal./Acre	NO_3-N (Lbs./Acre	Soluble Ortho-(PO_4)-P (Lbs./Acre)	Tons/Acre	Organic Matter (Lbs./Acre)	Total Phosphorus (Lbs./Acre)	Total Nitrogen (Lbs./Acre)
Rotation								
Aw - Bw	30# P_2O_5	9678 a[1]	0.48 a	0.0018 a	0.146 a	22.1 a	0.404 a	1.02 a
C_cx - C_cy	90# P_2O_5	13030 b	0.73 a	0.0067 b	0.260 b	32.3 b	0.684 b	1.79 b
Treatment	Manure (6T/A)	8772 a	0.79 a	0.0041 a	0.143 a	20.3 a	0.416 a	1.07 a
	No Manure	13936 a	0.42 a	0.0045 a	0.263 b	34.1 b	0.672 b	1.74 b
Storm	A	1718 a	0.05 a	0.0005 a	0.060 a	9.21 a	0.179 a	0.42 a
	B	11347 b	0.51 a	0.0047 b	0.197 b	29.97 b	0.605 b	1.36 a
	C	20997 c	1.25 b	0.0077 c	0.351 c	42.41 b	0.849 b	2.43 b

[1] Means followed by the same letter are not significantly different at 5% level.

Table 16. Correlation and Regression Coefficients of Surface Runoff (Gal/Acre) and Soil Loss (Tons/Acre) During Three Storm Frequencies (Years).

Storm Frequency / Crop	Correlation Coeff. 2	Correlation Coeff. 10	Correlation Coeff. 20	Regression Coeff. 2	Regression Coeff. 10	Regression Coeff. 20
Continuous Corn	.84	.63	.54	$Y = -.014+4x10^{-5}(X)$	$Y = .087+1x10^{-5}(X)$	$Y = .187+1x10^{-5}(X)$
Mixed Rotations	.91	.51	.50	$Y = -.003+3x10^{-5}(X)$	$Y = .063+1x10^{-5}(X)$	$Y = .144+1x10^{-5}(X)$
Continuous Hay	.41	.88	.86	$Y = .004+1x10^{-5}(X)$	$Y = .004+2x10^{-5}(X)$	$Y = .012+2x10^{-5}(X)$

Table 17. Correlation of Selected Constituents in the Soil and Sediment Derived from the Soil and Enrichment Ratios (E.R.) from Each of Three Consecutive Half Hour (1.25 in) Storms.

	Storm					
	A		B		C	
Constituent	r	E.R.	r	E.R.	r	E.R.
Organic matter	.81	1.8	.70	1.6	.54	1.5
Total P	.60	1.8	.64	1.6	.65	1.5
Total N	.81	1.8	.77	1.7	.78	1.6
Clay	-.32	1.6	.01	1.4	.07	1.4
Silt	-.13	1.0	.40	1.2	-.03	1.2
Sand	-.41	.08	.07	.25	.01	.21

Table 18. Correlations of Percent Solids in Runoff and Selected Variables for Each of Three Consecutive Half Hour (1.25 in) Storms.

			Correlation Coeff.				
Storm	Mean % Solids	Std. Dev. of mean	Runoff	% Slope	% O.M.	Aggregate Stability	% clay
A	.44	.38	.16	.17	.03	.008	-.02
B	.52	.31	-.17	.10	.26	.24	.16
C	.41	.21	-.07	.12	.03	.06	.07

Table 19. Correlations Among Nitrate Nitrogen and Soluble Ortho-Phosphate (PO_4)-P in the Soil and Their Concentrations in Runoff Water for Each of Three Consecutive Half Hour (1.25 in) Storms.

Concentration of NO_3-N in Runoff

	A	B	C
NO_3-N in Soil	.21	.01	.28
Storm A		.28	.21
Storm B			.59

Concentration of Solu. PO_4-P in Runoff

	A	B	C
Solu. PO_4P in Soil	.15	.14	.32
Storm A		.71	.55
Storm B			.83

Table 20. Content and Correlations Among Constituents in the Soil.

Constituent	Mean %	Std. Dev. of mean	Correlation Coeff. P	N	Cl	Si	Sa
Organic Matter (O.M.)	4.30	1.04	.66	.91	.24	.08	-.23
Total P (P)	0.084	0.030		.75	.12	-.03	-.09
Total N (N)	.22	0.06			.22	.11	-.23
Clay (Cl)	44.0	10.0				.17	-.93
Silt (Si)	28.0	4.0					-.49
Sand (Sa)	29.0	12.0					

Table 21. Content and Correlations Among Constituents in the Sediment.

Constituent	Mean %	Std. Dev. of Mean	Correlation Coeff. P	N	Cl	Si	Sa
Organic Matter (O.M.)	6.9	1.9	.69	.81	.20	-.10	-.24
Total P (P)	.13	.038		.75	.12	.03	-.20
Total N (N)	.37	.089			.19	-.06	-.26
Clay (Cl)	61	8.6				-.46	-.67
Silt (Si)	33	5.8					-.23
Sand (Sa)	5.9	6.9					

Table 22. Stepwise Regression of Selected Constitutents on Other Constituents in Sediment.

Stepwise Regression Equation	Multiple Correlation Coeff.
% P = 0.011 + 0.327 (% N)	.75
% P = 0.009 + 0.249 (% N) + 0.0045 (% O.M.)	.77
% N = 0.108 + 0.0378 (% O.M.)	.81
% N = 0.076 + 0.0257 (% O.M.) + 0.876 (% P)	.86
% N = 0.086 + 0.025 (% O.M.) + 0.866 (% P) -0.00084 (% Sa)	.86

Analytical Determination

Surface Runoff

The sample from the Coshocton wheel was transported to the laboratory and weighed on a solution balance. While mixing vigorously to keep the sediment well mixed, three 40 ml (approximately) samples were placed in tared 50 ml centrifuge tubes. The total weight of the sample plus tube was recorded and the samples were centrifuged at 17000 rpm for 30 minutes in a Sorvall superspeed centrifuge. The supernatant solutions were poured off and combined into one solution sample. The residue in the tube was dried and the tube plus dry residue was reweighed. From these data, the sediment content was calculated.

The supernatant solutions were analysed for NH_4-N, NO_3-N, soluble P and total P according to procedures listed under Analytical Procedures.

The above procedures were carried out the day following collection of the sample in most cases. If this was not feasible, they were stored in a refrigerator until analysed.

Bulk samples of solids were prepared as follows. Five ml of a solution of $CaCl_2$ which contained 3 g of $CaCl_2 \cdot 2H_2O$ per 5 ml was added to each gallon of the runoff sample. After 48 hours the supernatant solution was siphoned off and the remaining slurry kept frozen until it was convenient to process it further. After thawing, the slurry was filtered using a Büchner funnel and suction. The samples were oven dried and ground.

Tile Drain Effluents

These samples were usually clear and so no separation of solids was carried out. The solutions were analysed for NH_4-N, NO_3-N, soluble P and total P according to procedures listed under Analytical Procedures.

Analytical Procedures

Solutions

The determinations were made with the Technicon Autoanalyser systems using the following procedures.

Ammonium. This procedure involves the reaction of ammonium, phenol, and hypochlorite in an alkaline medium which yields a blue color. Nitroprusside is added to increase the sensitivity of the determination. The structure of the blue-colored compound is believed to be closely related to that of indophenol. Reference: Russell, J. Biol. Chem. 156, 457, (1944).

Nitrate plus Nitrite. Nitrate is reduced to nitrite by copper and hydrazine sulfate in alkaline solution. The nitrite is determined by diazotization of sulfanilamide in phosphoric acid and coupling with N-(1-Naphthyl) ethylenediamide dihydrochloride. The resulting azo-dye is pink in color, and has an intensity related to nitrite concentration.
Reference: Jacobs and Hochheiser. Anal. Chem. 30, 426, (1958).

Soluble Orthophosphate. Ammonium molybdate in acid solution reacts with orthophosphate to form a heteropoly acid (molybdophosphoric acid). This acid is reduced by stannous chloride and hydrazine sulfate to form the intensely colored molybdenum blue complex.
Reference: Fiske and Subbarow. J. Biol. Chem. 66, 375, (1925).

Total Soluble Phosphate. Polyphosphates are hydrolyzed and organic phosphates oxidized by heating with potassium persulfate solution. The resulting orthophosphate is determined by the procedure described under soluble orthophosphate.
Reference: Menzel and Corwin. Limnology and Oceanography, 10, 280, (1965).

Particulate Matter

Total Phosphorus. The soil is ashed with magnesium nitrate at 55°C. The residue is heated with hydrochloric and nitric acid to hydrolyze polyphosphates to orthophosphate and to precipitate silica. Orthophosphate in the resulting solution is determined by reacting with molybdic and vanadic acids to form the yellow heteropoly molybdovanadophosphoric acid.
Reference: Methods of Analysis for the Association of Official Agricultural Chemists. 6th Ed., A.O.A.C., Washington, 1945. Kitson and Mellon. Anal. Chem. 16, 379, (1944).

Total Nitrogen (Kjeldahl). Soil is digested with sulfuric acid, potassium sulfate and copper sulfate to convert nitrogen to ammonia. The resulting solution is made basic and the ammonia is distilled into boric acid. The ammonia is then titrated with standardized sulfuric acid.
Reference: Methods of Soil Analysis. Am. Soc. Agron., Madison, Wisconsin, (1965).

Organic Matter. Soil is treated with a solution of potassium dichromate and then concentrated sulfuric acid is added. The heat of dilution of the acid is utilized to bring about oxidation of the soil organic matter. After cooling the excess dichromate is measured by titration with ferrous sulfate. The amount of dichromate reduced is related to organic matter concentration of the soil.
Reference: Greweling and Peech. "Chemical Soil Tests." Cornell Univ. Agr. Exp. Sta. Bull. 960 revised. (1965).

Particle Size Analysis. Soil is treated with hydrogen peroxide to destroy organic matter and then washed and centrifuged to remove

dissolved mineral matter. The soil is dispersed with sodium hexametaphosphate and particle size distribution is measured by the Bouyoucos hydrometer method.

Reference: Bouyoucos, Science 64, 362, (1926).

APPENDIX B

Table 1 is a presentation of the treatment schedule on the field scale water quality study. The beans/wheat plots actually receive almost twice as much fertilizer as does the corn because of the fall fertilization of wheat. The wheat already established from the previous fall received little or no fertilizer during the next hydrologic year.

Tables 2, 3, and 4 are computer programs written in Fortran IV and processed on the IBM 360/65 computer. Table 2 is a calculation of surface flow in gallons/acre or acre inches of water. In addition, the centroid time, time of maximum discharge and discharge for any given time interval is calculated. Table 3 is similar except it is used to calculate tile discharges in gallons/plot for any given time interval on a monthly basis. Table 4 is a program to summarize by plots the flow and the quantities of nitrogen and phosphorus lost from the land surface.

Table 5 is a nutrient balance for nitrogen (N) and phosphorus (P) inputs and outputs on the field scale water quality study. Fertilizer inputs were calculated on actual amounts of mineral fertilizer added between 4/1/70 and 3/31/71. The crop residue return was calculated on 49% of the stover weights of corn and wheat to equal grain yield whereas the bean vine weights equal the weight of beans. The alfalfa yield (grown in succession with good managed wheat) was 2,000 pounds/acre. These yields were multiplied by the appropriate percentages of N and P to arrive at a return value for crop residues. It was assumed that 80% of the residue decomposed in the first year and the remainder was tied up in soil organic matter. Mineralization inputs of N were derived by using 58% of the total weight of organic matter as organic carbon. With a C:N ratio of 14:1, 1/14 of this weight is N. The product of this is multiplied by a constant of 1.2%. Mineralization of P is assumed to be 14 pounds/acre/year based on unpublished data of S. Reid (Cornell University).

Total removal of N and P by the crop was developed by using the product of the yield and the percentage of N and P contained in the crop. Runoff, sediment and deep seepage losses of N and P are the product of flow or soil loss and the concentration of the nutrient in question. The total loss to the environment is the total of the losses due to surface runoff, sediment and deep seepage. Denitrification and fixation of phosphorus was determined by subtraction.

Table 6 presents the total accumulative runoff and nutrient losses for the 1970-71 hydrologic year. The values are broken down into the treatment variables studied. The Least Significant Difference (L.S.D.) was calculated to determine real differences between variables.

Table 1. Fertilizer Application Rates on Corn, Beans and Wheat Plots. 4/70-3/71

Element	N		P_2O_5		K_2O	
Fertility Level	High	Normal	High	Normal	High	Normal
			(Pounds Per Acre)			
Corn	275	15	150	30	100	100
Beans	275	15	150	30	100	100
Wheat	215	75	130	50	---	---
Wheat	0	40	0	20	100	100

Table 2. Surface Flow Program.

Variable Name	Description
AINT1	Outer limit of a time interval needed to calculate TARE
AINT2	Inner limit of a time interval needed to calculate TARE
AMON	Accumulation of the product of time and discharge
AREA	Total gallons of runoff for a given storm
ARM	Time accumulation
CENTR	Centroid time of storm
CONCT	Time lag between beginning of runoff and the centroid of the storm
CPDATE	Date of computation
DEPTH	Acre inches of runoff
DISCH	Discharge in gallons for 12 in. H-flume
HMIN	Time point (minutes at start of storm)
HOURS	Time point (hours at start of storm - military time)
ICHECK	Control to reset NCHECK number if different from previous record
ICLASS	Control to reset NCLASS number if different from previous record
ICODER	Control to reset NCODER number if different from previous record
IDAY	Control to reset NDAY number if different from previous record
IMON	Control to reset NMON number if different from previous record
IPLOT	Control to reset NPLOT number if different from previous record
ISTOR	Control to reset NSTOR number if different from previous record
IYEAR	Control to reset NYEAR number if different from previous record
KLASS	Evaluation of KODER
KODER	Name of data transformer
NCHECK	Number code of checker
NCLASS	Number code of KLASS
NCODER	Number code of KODER
NDAY	Day
NMON	Month
NPLOT	Plot number
NSTOR	Storm number
NYEAR	Year
PROG	Person compiling data
QMAX	Maximum discharge that occurred during a storm
STAGE	Stage height (to 0.1 feet)
TARE	Product of the time interval and the discharge

Table 2. (Continued)

Variable Name	Description
TIME	Time point (hours and tenths of hours)
TQMAX	Time of maximum discharge

Table 2. (Continued)

```
C          PROGRAM ROMDEE-AURORA 12 INCH H FLUMES.
      DIMENSION TIME(200),HOURS(200),HMIN(200),DISCH(200),STAGE(200)
      REAL * 8  KODER(9),KLASS(9)
      CHARACTER *8 PROG,CPDATE
      DIMENSION AHOURS(11),AMIN(11),ASTAGE(11)
      DO 105 J=1,200
      HOURS(J)=0.0
      HMIN(J)=0.0
      STAGE(J)=0.0
      DISCH(J)=0.0
  105 TIME(J)=0.0
      L=11
      N=0
      M=1
      READ 80,(KODER(J),J=1,9)
   80 FORMAT(9A8)
      READ 81,(KLASS(J),J=1,9)
   81 FORMAT(9A8)
      READ 400,PROG,CPDATE
  400 FORMAT (2A8)/
   65 READ 60,NPLOT,NMON,NDAY,NYEAR,NCLASS,NCODER,NCHECK,NSTOR,
     1(HOURS(J),HMIN(J),STAGE(J),J=M,L)
   60 FORMAT(4I2,3I1,I3,11(2F2.0,F2.2))
      IF(N)62,62,68
   68 IF(NPLOT-IPLOT)66,61,66
   61 IF(NSTOR-ISTOR)66,62,66
   62 IPLOT=NPLOT
      IMON=NMON
      IDAY=NDAY
      IYEAR=NYEAR
      ICODER=NCODER
      ICHECK=NCHECK
      ISTOR=NSTOR
      ICLASS=NCLASS
      DO 91 J=M,L
      IF(HOURS(J))200,200,202
  200 IF(HMIN(J))201,201,202
  201 IF(STAGE(J))91,91,202
  202 N=N+1
      TIME(J)=HOURS(J)*60.0+HMIN(J)
   91 CONTINUE
      M=L+1
      L=M+10
      GO TO 65
   66 DO 139 J=1,11
      AHOURS(J)=0.0
      AMIN(J)=0.0
  139 ASTAGE(J)=0.0
      DO 140 J=1,11
      K=M-1+J
      AHOURS(J)=HOURS(K)
      AMIN(J)=HMIN(K)
      ASTAGE(J)=STAGE(K)
  140 CONTINUE
      DO 101 J=1,N
      IF(STAGE(J))42,7,8
   42 PRINT 17,HOURS(J),HMIN(J),STAGE(J)
   17 FORMAT(//26H GROSS BULL NEGATIVE STAGE, 3F10.2)
    7 DISCH(J)=0.0
```

Table 2. (Continued)

```
      GO TO 101
    8 IF(STAGE(J)-0.045)9,9,10
    9 DISCH(J)=120.0*(STAGE(J)**1.25)
      GO TO 101
   10 IF(STAGE(J)-0.100)11,11,12
   11 DISCH(J)=262.0*(STAGE(J)**1.50)
      GO TO 101
   12 IF(STAGE(J)-0.222)13,13,14
   13 DISCH(J)=521.0*(STAGE(J)**1.79)
      GO TO 101
   14 IF (STAGE(J)-0.700)15,15,16
   16 PRINT 210,HOURS(J),HMIN(J),STAGE(J)
  210 FORMAT(// 25H STAGE OVER RATING CURVE ,3F10.2//)
   15 DISCH(J)=753.0*(STAGE(J)**2.04)
  101 CONTINUE
      ARM=0.0
      AREA=0.0
      AMOM=0.0
      DEPTH=0.0
      CONCT=0.0
      QMAX=0.0
      TQMAX=0.0
      DO 102 J=1,N
      IF(QMAX-DISCH(J))18,102,102
   18 QMAX=DISCH(J)
      TQMAX=TIME(J)/60.0
  102 CONTINUE
      L=N-1
      DO 103 J=2,L
      AINT1=TIME(J)-TIME(J-1)
      IF(AINT1)30,31,31
   30 AINT1=AINT1+1440.0
   31 AINT2=TIME(J+1)-TIME(J)
      IF(AINT2)32,33,33
   32 AINT2=AINT2+1440.0
   33 TARE=(AINT1+AINT2)*0.5*DISCH(J)
      ARM=ARM+AINT1
      AREA=AREA+TARE
      AMOM=ARM*TARE+AMOM
  103 CONTINUE
      DO 136 J=1,N
  136 TIME(J)=TIME(J)/60.0
      CENTR=AMOM/(AREA*60.0)+TIME(1)
      IF(CENTR-25.00)40,41,41
   41 CENTR=CENTR-24.00
   40 PRINT 70
   70 FORMAT('1',/,49H PLOT    STORM    MONTH DAY YEAR     CODER  CHECKER ,
     166H  DATA RATING    MAX DISCH TIME    CENTROID TIME    TOTAL GALS RUN
     20FF )
C*** SURFACE AREA OF PLOTS INCLUDING DITCH IS 0.9 ACRES.
      DEPTH=AREA/24437.0
      CONCT=CENTR-TIME(1)
      IF(CONCT)403,404,404
  403 CONCT=CONCT+24.0
  404 CONTINUE
      J=ICODER
      IF(J)52,52,53
   52 J=6
   53 K=ICHECK
      IF(K)54,54,55
```

Table 2. (Continued)

```
 54 K=6
 55 L=ICLASS
    IF(L)56,56,57
 56 L=6
 57 PRINT 71,IPLOT,ISTOR,IMON,IDAY,IYEAR,KODER(J),KODER(K),KLASS(L),
   1QMAX,TQMAX,CENTR,AREA
 71 FORMAT     (I4,2I8,I5,I4,2X,A8,1X,A8,5X,A8,F12.2,F8.3,F10.2,10X,
   CF10.2)
    PRINT 401
401 FORMAT(//51H DATA ASSEMBLER   COMPUTATION DATE   INCHES RUNOFF ,
   126H FIRST RUNOFF TO CENTROID )
    PRINT 402,PROG,CPDATE,DEPTH, COMCT
402 FORMAT(4X,A8,10X,A8,10X,F7.3,10X,F10.3//)
    PRINT 74
 74 FORMAT(// 37H        TIME            STAGE   DISCHARGE ,
   15X,37H        TIME            STAGE   DISCHARGE   )
    L=N/2
    M=L+1
    DO 116 J=1,M
    I=J+L
    PRINT 75,HOURS(J),HMIN(J),TIME(J),STAGE(J),DISCH(J),HOURS(I),
   1HMIN(I),TIME(I),STAGE(I),DISCH(I)
 75 FORMAT(2F4.0,3F9.2,5X,2F4.0,3F9.2)
116 CONTINUE
    DO 122 J=1,200
    HOURS(J)=0.0
    HMIN(J)=0.0
    STAGE(J)=0.0
    DISCH(J)=0.0
122 TIME(J)=0.0
    IF(NSTOR-999)121,23,23
121 N=0
    M=1
    L=11
    DO 141 J=1,11
    HOURS(J)=AHOURS(J)
    HMIN(J)=AMIN(J)
    STAGE(J)=ASTAGE(J)
141 CONTINUE
    GO TO 62
 23 STOP
    END
```

Table 3. Tile Flow Program

Variable Name	Description
AVE	Average stage height for each day of the month
CP DATE	Date of computation
DAYTOT	Accumulation of discharge for monthly total
DEPTH	Acre inches
ICHECK	Control to reset NCHECK number if different from previous record
ICLASS	Control to reset NCLASS number if different from previous record
IDAY	Control to reset NDAY number if different from previous record
ILA	Date of the following day
IMON	Control to reset NMON number if different from previous record
IYEAR	Control to reset NYEAR number if different from previous record
IPLOT	Control to reset NPLOT number if different from previous record
JA	Number of days in a month
JOHN	Date + days past initiation of flow (current date)
KLASS	Evaluation of KODER
KODER	Name of data transformer
MARY	One less than the number of days in a month
N	Number of data points
NCHECK	Number code of checker
NCLASS	Number code of KLASS
NCODER	Number code of KODER
ND	Days since start of discharge
NDAY	Day of month
NMON	Month
NPLOT	Plot number
NYEAR	Year
PROG	Person compiling data
Q	Calculation of flow in g.p.m. for the current date and counter for the initial data on a record
S	Entering SS into a T and S matrix
SS	Discharge point (stage height - to 0.01 in.)
T	Entering TT into a T and S matrix
TT	Time point (hours, min. - military time)

Table 3. (Continued)

```
C       PROGRAM TITLE
C       TITLE PROGRAM FOR NEW AURORA FLIGHTS, AFTER SUMMER 1962
        READ*80    KODER(9),KLASS(9),PROG,CDATE
        DIMENSION T(40,40),S(40,40),O(40,40),TT(10),SS(10),ND(10)
        DIMENSION DAY(40),N(40)
        DIMENSION AVE(40)
        READ 556,(KODER(J),J=1,9)
  556   FORMAT(9A8)
        READ 556,(KLASS(J),J=1,9)
        READ 557,PROG,      CDATE
  557   FORMAT(2A8)
        DO 98 J=1,10
   98   ND(J)=0
        NUMBER =0
        DO 99 J=1,10
        TT(J)=0.0
   99   SS(J)=0.0
        DO 100 J=1,40
        DO 100 K=1,40
        T(J,K)=0.0
        S(J,K)=0.0
  100   O(J,K)=0.0
        DO 103 J=1,40
  103   N(J)=0
  200   READ 4,NPLOT,NMON,NYEAR,NCLASS,NCODER,NCHECK,NDAY,TT(1),SS(1),
       1(ND(J),TT(J),SS(J),J=2,10)
    4   FORMAT(3I2,3I1,I2,F3.1,F3.2,9(I1,F 3.1,F3.2))
        IF (NUMBER)802,802,5000
 5000   IF(NPLOT-99)10,120,120
   10   IF(IPLOT-NPLOT)120,801,120
  801   IF(IMON-NMON)120,802,120
  802   IPLOT=NPLOT
        IMON=NMON
        IYEAR=NYEAR
        ICLASS=NCLASS
        ICODER=NCODER
        ICHECK=NCHECK
        IDAY=NDAY
        NUMBER=1
        PLA=N(IDAY)+1
        IF(40-PLA)20,22,22
   20   PRINT 21,IDAY,IMON,IYEAR,IPLOT
   21   FORMAT(//31HMO POINTS TOO LARGE FOR STORAGE,4I6//)
        GO TO 200
   22   T(IDAY,PLA)=TT(1)
        S(IDAY,PLA)=SS(1)
        O(IDAY,PLA)=4.0392*(S(IDAY,PLA)**2.09)
        N(IDAY)=PLA
        IF(T(IDAY,PLA))5,6,6
    5   PRINT 25,T(IDAY,PLA),S(IDAY,PLA),IDAY,IMON,IYEAR
   25   FORMAT(//22H ABSURD TIME OR STAGE ,2F10.2,6H DATE ,3I6//)
    6   IF(S(IDAY,PLA))7,8,8
    7   PRINT 25,T(IDAY,PLA),S(IDAY,PLA),IDAY,IMON,IYEAR
    8   IF(S(IDAY,PLA)-4.25)800,800,9
    9   PRINT 27,T(IDAY,PLA),S(IDAY,PLA),IDAY,IMON,IYEAR
   27   FORMAT(//31HHORRIBLE ERROR STAGE OVER FLUME,2F10.2,4HDATE,3I6//)
  800   CONTINUE
        DO 101  J=2,10
        IF(SS(J))923,923,919
```

Table 3. (Continued)

```
923 IF(TT(J))101,101,919
919 JOHN=IDAY+MD(J)
    IL_A=N(JOHN)+1
    IF(40-IL_A)23,24,24
 23 PRINT 21,IDAY,IMON,IYEAR,IPLOT
    GO TO 200
 24 T(JOHN,IL_A)=TT(J)
    S(JOHN,IL_A)=SS(J)
    Q(JOHN,IL_A)=4.0392*(S(JOHN,IL_A)**2.09)
    N(JOHN)=N(JOHN)+1
    IF(T(JOHN,IL_A))11,12,12
 11 PRINT 25,T(JOHN,IL_A),S(JOHN,IL_A),JOHN,IMON,IYEAR
 12 IF(S(JOHN,IL_A))13,14,14
 13 PRINT 25,T(JOHN,IL_A),S(JOHN,IL_A),JOHN,IMON,IYEAR
 14 IF(S(JOHN,IL_A)-4.25)101,101,16
 16 PRINT 27,T(JOHN,IL_A),S(JOHN,IL_A),JOHN,IMON,IYEAR
101 CONTINUE
    GO TO 200
120 GO TO  (1,2,1,3,1,3,1,1,3,1,3,1),IMON
  1 JA=31
    GO TO 140
  2 IF(IYEAR-64)803,93,803
803 IF(IYEAR- 68) 808,93,808
808 JA=28
    GO TO 140
 93 JA=29
    GO TO 140
  3 JA=30
140 MARY=JA-1
    DO 105 J=1,39
    I=N(J)
    IF(I-1)105,52,52
 52 CONTINUE
    DO 43 K=1,I
    L=I+1-K
    IF(T(J,L)-24.0)105,41,41
 41 T(J,L)=T(J,L)-24.0
    M=N(J+1)
    IF(M-1)46,48,47
 47 CONTINUE
    DO 45 NUMBER=1,M
    LL=M+2-NUMBER
    S(J+1,LL)=S(J+1,LL-1)
    T(J+1,LL)=T(J+1,LL-1)
    Q(J+1,LL)=Q(J+1,LL-1)
 45 CONTINUE
 48 IF(T(J+1,2))49,49,46
 49 T(J+1,2)=T(J+1,1)
    S(J+1,2)=S(J+1,1)
    Q(J+1,2)=Q(J+1,1)
 46 T(J+1,1)=T(J,L)
    S(J+1,1)=S(J,L)
    Q(J+1,1)=Q(J,L)
    T(J,L)=0.0
    S(J,L)=0.0
    Q(J,L)=0.0
    N(J+1)=N(J+1)+1
    N(J)=N(J)-1
 43 CONTINUE
105 CONTINUE
```

Table 3. (Continued)

```
      DO 206 J=1,40
      I=N(J)
      IF(I-1)206,207,207
  207 IF(T(J,1))206,206,208
  208 CONTINUE
      DO 209 K=1,I
      L=I+2-K
      T(J,L)=T(J,L-1)
      S(J,L)=S(J,L-1)
      Q(J,L)=Q(J,L-1)
  209 CONTINUE
      T(J,1)=0.0
      S(J,1)=0.0
      Q(J,1)=0.0
      N(J)=N(J)+1
  206 CONTINUE
      IDA=1
      GO TO 700
  699 IDA=I+1
  700 CONTINUE
      DO 106 J=IDA, MARY
      IF(IDA.GT.MARY)GO TO 70
      LOLO=J+1
      IF(N(J))106,106,701
  701 IF(S(LOLO,1))106,702,106
  702 K=N(J)
      DO 60 L=LOLO,35
      IF(N(L)-1)60,61,643
  643 IF(S(L,1))60,62,61
   60 CONTINUE
   61 MA=1
      GO TO 63
   62 MA=2
   63 TA=T(J,K)+J*24.0
      SA=S(J,K)
      TB=T(L,MA)+L*24.0
      SB=S(L,MA)
      A=TB-TA
      IF(A)67,65,644
  644 IF(SA)106,69,64
   69 IF(SB)106,71,64
   64 SLOPE=(SB-SA)/A
      DO 900 JACK=LOLO,L
      S(JACK,1)=SA+SLOPE*(JACK*24.0-TA)
      IF(N(JACK))900,899,900
  899 N(JACK)=1
  900 Q(JACK,1)=4.0392*(S(JACK,1)**2.09)
   71 I=L-1
      GO TO 699
   65 PRINT 66,J,T(J,K),IMON,IYEAR
   66 FORMAT(//21H TWO TIMES ARE EQUAL ,I5,2F10.3,2I5//)
      GO TO 106
   67 PRINT 68,J,T(J,K),T(L,2),IMON,IYEAR
   68 FORMAT(//23H TIMES OUT OF SEQUENCE ,I5,2F10.3,2I5//)
  106 CONTINUE
   70 CONTINUE
      DO 107 J=1,JA
      DAY(J)=0.0
  107 AVE(J)=0.0
      DAYTOT  =0.0
```

Table 3. (Continued)

```
      DO 109 J=1,JA
      IF(N(J)-1)109,81,80
   80 K=N(J)-1
      DO 108 M=1,K
      MAN=M+1
      IF(T(J,M+1)-T(J,M))2000,2001,2002
 2000 PRINT 68,J,T(J,MAN),T(J,M),IMON,IYEAR
      GO TO 108
 2001 PRINT 66,J,T(J,MAN),T(J,M),IMON,IYEAR
      GO TO 108
 2002 DAY(J)=DAY(J)+(Q(J,M)+Q(J,M+1))*(T(J,M+1)-T(J,M))*30.0
  108 CONTINUE
      K=K+1
      GO TO 82
   81 K=1
   82 DAY(J)=DAY(J)+(Q(J,K)+Q(J+1,1))*(24.0-T(J,K))*30.0
      DAYTOT  =DAYTOT  +DAY(J)
      AVE(J)=((DAY(J)/5760.0)**0.47393)
  109 CONTINUE
      DEPTH=DAYTOT  /26648.0
      L=ICODER
      IF(L)540,540,541
  540 L=9
  541 M=ICHECK
      IF(M)542,542,543
  542 M=9
  543 K=ICLASS
      IF(K)544,544,545
  544 K=9
  545 PRINT 553
  553 FORMAT(1H1,20X,20HTIDE OUTFLOW SUMMARY/76H PLOT   MONTH    YEAR    CO
     1DER    CHECKER    DATA RATING    TOTAL MONTHS DISCHARGE,3X,
     226HDATA ASSEMBLER    COMP DATE)
      PRINT 554,IPLOT,IMON,IYEAR,KODER(L),KODER(M),KLASS(K),DAYTOT,
     1DEPTH,PROG,      CPDATE
  554 FORMAT(I3,I8,I7,2X,A8,1X,A8,5X,A8,7H     GAL,F10.0,6H     IN,F6.3,
     13X,A8,7X,A8//)
      IF(JA-30)647,647,648
  647 INDEX=3
      GO TO 649
  648 INDEX=4
  649 CONTINUE
      DO 650 K=1,INDEX
      M=10*K
      L=M-9
      IF(K-INDEX)652,651,651
  651 M=JA
      IF(JA-30)653,652,658
  653 IF(JA-29)654,656,650
  654 PRINT 655,(J,J=L,M),(DAY(J),J=L,M),(AVE(J),J=L,M),(N(J),J=L,M)
  655 FORMAT(/6H DATE , 8I10/9H TOT FLOW,8F10.0/9H AVE HEAD,
     1 8F10.2/10H NO POINTS,8(I7,3X))
      GO TO 650
  656 PRINT 657,(J,J=L,M),(DAY(J),J=L,M),(AVE(J),J=L,M),(N(J),J=L,M)
  657 FORMAT(/6H DATE , 9I10/9H TOT FLOW,9F10.0/9H AVE HEAD,
     1 9F10.2/10H NO POINTS,9(I7,3X))
      GO TO 650
  658 PRINT 659,M,DAY(M),AVE(M),N(M)
  659 FORMAT(/6H DATE ,I10/9H TOT FLOW,F10.0/9H AVE HEAD,F10.2/
     110H NO POINTS,I7)
```

Table 3. (Continued)

```
      GO TO 650
  652 PRINT 555,(J,J=L,M),(DAY(J),J=L,M),(AVE(J),J=L,M),(N(J),J=L,M)
  555 FORMAT(/6H DATE ,10I10/9H TOT FLOW,10F10.0/9H AVE HEAD,
     110F10.2/10H NO POINTS,10(I7,3X))
  650 CONTINUE
      PRINT 660,(L,L=1,19)
  660 FORMAT(//6H DATE ,19(I4,2X))
      DO 670 J=1,JA
      K=N(J)
      IF(K) 666,666,667
  667 PRINT 661,J,(T(J,L),L=1,K)
  661 FORMAT(I4,2X,(19F6.2))
      PRINT 663,(S(J,L),L=1,K)
  663 FORMAT(6X,(19F6.2)//)
      GO TO 670
  666 PRINT 626,J
  626 FORMAT (I4,/)
  670 CONTINUE
      DO 117 J=1,JA
  117 AVE(J)=0.0
      M=JA+1
      IF(NPLOT-99)122,121,121
  122 M=JA+1
      DO 110 J=1,JA
      DO 110 K=1,40
      T(J,K)=0.0
      S(J,K)=0.0
  110 Q(J,K)=0.0
      DO 998 J=1,JA
  998 N(J)=0
      DO 112 J=M,40
      DO 112 K=1,40
      L=J-JA
      T(L,K)=T(J,K)
      S(L,K)=S(J,K)
      Q(L,K)=Q(J,K)
      N(L)=N(J)
  112 CONTINUE
      DO 113 J=M,40
      DO 113 K=1,40
      T(J,K)=0.0
      S(J,K)=0.0
  113 Q(J,K)=0.0
      DO 999 J=M,40
  999 N(J)=0
      GO TO 802
  121 STOP
      END
```

Table 4. Surface Flow Summary Program.*

Variable Name	Description
CRF	Estimate of the amount of rainfall contributing to runoff
IDATE	Date
IPLOT	Plot number
IROGA	Runoff in gallons per acre
IROGAC	Accumulation of gallons per acre of runoff over time
IROGP	Runoff in gallons per plot
ISTORM	Last storm number identification for sampling period
IYR	Year
RF	Rainfall amount since last sampling period
RFAC	Accumulation of rainfall over time
ROIA	Runoff in inches per acre
ROIP	Runoff in inches per plot
ROIAAC	Accumulation of acre inches of runoff over time
SOPAC	Accumulation of soluble orthophosphate losses in pounds per acre over time
SOPML	Concentration of soluble orthophosphate in mg/l in runoff
SOPPA	Soluble orthophosphate loss in pounds per acre
TOTPPA	Total phosphorus loss in pounds per acre
TOTPAC	Accumulation of total phosphorus losses in pounds per acre over time
TOTPML	Concentration of total phosphorus in mg/l in runoff
XNH4ML	Concentration of ammoniacial nitrogen in mg/l in runoff
XNH4AC	Accumulation of ammoniacial nitrogen losses in pounds per acre over time
XNH4PA	Ammoniacial nitrogen loss in pounds per acre
XNO3AC	Accumulation of nitrate nitrogen losses in pounds per acre over time
XNO3ML	Concentration of nitrate nitrogen in mg/l in runoff
XNO3PA	Nitrogen loss in pounds per acre

* Tile flow summary program is similar except for several conversion factors.

Table 4. (Continued)

```
C***PROGRAM TO CALCULATE LOSSES ON AN ACRE BASIS PLUS ACCUMULATIVE
C***LOSSES BY PLOTS      LARGE DRAINAGE EXPERIMENT- AURORA N.Y.
C***PLOT SIZE=190X205 FEET =38,950SQ FT =0.90 ACRES
      DIMENSION  TRF(24),ROI(24),IROG(24),XNH(24),XNO(24),SOP(24),
     CTOTP(24),INDEX(2,12),C(24),D(24),TREX(12),ROIX(12),IROGX(12),
     CXNHX(12),XNOX(12),SOPX(12),TOTPX(12)
      JCK=0
      N=0
      DO 50 J=1,24
      C(J)=0.0
      ICK=0
      XNH4AC=0.0
      XNO3AC=0.0
      SOPAC=0.0
      TOTPAC=0.0
      ROIAAC=0.0
      IROGAC=0
      RFAC=0.0
      IF(N.EQ.1) GO TO 100
    5 READ(5,10,END=51)IPLOT,IDATE,IYR,ISTORM,RF,CRF,ROIP,IROGP,
     CXNH4ML,XNO3ML,SOPML,TOTPML
   10 FORMAT(I2,1X,I4,I2,1X,I3,1X,F5.2,1X,F5.2,1X,F5.3,1X,I6,
     C1X,F6.3,1X,F6.2,1X,F5.3,1X,F5.3)
      IF(IPLOT.GT.J)GO TO 200
      GO TO 100
  200 N=1
      GO TO 50
  100 ROIA=ROIP*1.111
      IROGA=IROGP*1.111
      XNH4PA=XNH4ML*IROGA*(3.79/454000.0)
      XNO3PA=XNO3ML*IROGA*(3.79/454000.0)
      SOPPA=SOPML*IROGA*(3.79/454000.0)
      TOTPPA=TOTPML*IROGA*(3.79/454000.0)
      ROIAAC=ROIAAC+ROIA
      IROGAC=IROGAC+IROGA
      XNH4AC=XNH4AC+XNH4PA
      XNO3AC=XNO3AC+XNO3PA
      SOPAC=SOPAC+SOPPA
      TOTPAC=TOTPAC+TOTPPA
      RFAC=RFAC+RF
      C(J)=C(J)+1.0
      IF(IDATE.EQ.0000)C(J)=C(J)-1.0
      ROI(J)=ROIAAC
      IROG(J)=IROGAC
      XNH(J)=XNH4AC
      XNO(J)=XNO3AC
      SOP(J)=SOPAC
      TOTP(J)=TOTPAC
      TRF(J)=RFAC
   13 ICK=ICK+1
      IF(ICK.GT.1)GO TO 42
      WRITE(6,12)IPLOT
   12 FORMAT('1',//,6X,'PLOT',1X,I2)
      GO TO (16,14,16,16,16,16,14,16,14,14,14,14,16,14,16,16,16,16,
     C14,14,14,16,14,14),J
   14 WRITE(6,15)
   15 FORMAT(/,6X,'TREATMENTS',5X,'MANAGEMENT= GOOD')
      GO TO 43
   16 WRITE(6,17)
```

Table 4. (Continued)

```
17 FORMAT(/,6X,'TREATMENTS',5X,'MANAGEMENT= POOR')
43 CONTINUE
   GO TO (31,18,31,31,18,31,18,18,31,31,18,18,18,31,18,31,18,18,31,
  C31,31,31,18,18),J
18 WRITE(6,19)
19 FORMAT('+',47X,'FERTILITY= HIGH',10X,'NA= NOT AVAILABLE')
   GO TO 44
31 WRITE(6,32)
32 FORMAT('+',47X,'FERTILITY= NORMAL',10X,'NA= NOT AVAILABLE')
44 CONTINUE
   WRITE(6,20)
20 FORMAT(//,9X,'PLOT  STATISTICS',7X,'|',15X,'ANALYTICAL  DATA',
  C18X,'|',13X,'ACCUMULATIVE  TOTALS',12X,'|')
   WRITE(6,23)
23 FORMAT('+',130(1H_))
   WRITE(6,24)
24 FORMAT(32X,'|',49X,'|',45X,'|',/,32X,'|',49X,'|',45X,'|')
   WRITE(6,21)
21 FORMAT(        1X,'SAMPLE',2X,'TOT.',1X,'CONT',1X,'RUNOFF',
  C1X,'RUNOFF',1X,'NH4-N',2X,'NO3-N',1X,'SOL-P',1X,'TOT-P',
  C2X,'NH4-N',1X,'NO3-N',1X,'SOL-P',1X,'TOT-P',2X,'TOT',2X,
  C'RUNOFF',1X,'RUNOFF',2X,'NH4-N',1X,'NO3-N',2X,'SOL-P',1X,
  C'TOT-P',3X,'C')
   WRITE(6,22)
22 FORMAT(2X,'DATE',3X,'PPT.',1X,'PPT.',1X,'AC.IN.',1X,'GAL/AC',1X,
  C'MG/L',3X,'MG/L',2X,'MG/L',2X,'MG/L',3X,'LB/AC',1X,
  C'LB/AC',1X,'LB/AC',1X,'LB/AC',2X,'PPT.',1X,'AC.IN.',1X,
  C'GAL/AC',2X,'LB/AC',1X,'LB/AC',2X,'LB/AC',1X,'LB/AC')
   WRITE(6,23)
42 CONTINUE
26 WRITE(6,30)       IDATE,IYR,RF,CRF,ROIA,IROGA,XNH4ML,XNO3ML,
  CSOPML,TOTPML,XNH4PA,XNO3PA,SOPPA,TOTPPA,RFAC,ROIAAC,IROGAC,
  CXNH4AC,XNO3AC,SOPAC,TOTPAC,C(J)
30 FORMAT(    1X,I4,I2,1X,F5.2,1X,F4.2,1X,F5.3,1X,I6,2X,F5.3,1X,
  CF6.2,1X,F5.3,1X,F5.3,2X,F5.3,1X,F5.2,1X,F5.3,1X,F5.3,1X,
  CF5.2,1X,F5.2,1X,I7,2X,F5.3,1X,F5.2,2X,F5.3,1X,F5.3,1X,F3.0)
41 CONTINUE
   ICK=ICK+1
   GO TO 5
50 CONTINUE
51 CONTINUE
40 STOP
   END
```

Table 5. Nutrient Balance for Nitrogen (N) and Phosphorus (P) in Pounds/Acre for the 4/70 - 3/71 Hydrologic Year.

Crop	Corn				Beans/Wheat				Wheat			
Fertility	High		Normal		High		Normal		High		Normal	
Management	good	poor	good	poor	good	poor	good	poor	good	poor	good	poor
Plot #	2, 11	15, 18	10, 21	6, 16	12, 23	5, 13	9, 14	3, 4	7, 24	8, 17	19, 20	1, 22
Fertilizer N	275	275	15	15	490	490	90	90	0	0	40	40
Crop Residue N	50	0	50	0	22	0	18	0	15	0	19	0
Mineralization N	50	60	46	59	64	64	58	43	54	48	54	34
Total inputs N	375	335	111	74	576	554	166	133	69	48	113	74
Crop	149	136	134	65	98	98	98	86	73	69	68	59
Runoff N	3	3	1	1	3	28	3	3	1	1	3	1
Sediment N	1	0	3	1	0	3	1	1	0	6	0	3
Deep Seepage N	163	73	23	3	223	130	41	15	19	23	8	18
Total Removal N	316	212	161	70	324	259	143	105	93	99	79	22
Loss to Environ.	167	76	27	5	226	161	45	19	20	30	11	22
Denitrification	59	123	0	4	252	393	23	28	0	0	34	0

Table 5 (Continued)

Crop	Corn				Beans/Wheat				Wheat			
Fertility	High		Normal		High		Normal		High		Normal	
Management	good	poor	good	poor	good	poor	good	poor	good	poor	good	poor
Plot #	2, 11	15, 18	10, 21	6, 16	12, 23	5, 13	9, 16	3, 4	7, 26	8, 17	19, 20	1, 22
Fertilizer P	65.5	65.5	13.1	13.1	122.3	122.3	34.9	34.9	0	0	8.7	8.7
Crop Residue P	7	0	7	0	3	0	3	0	3	0	3	0
Soil Release P	14	14	14	14	14	14	14	14	14	14	14	14
Total inputs P	86.5	79.5	34.1	27.1	139.3	136.3	51.9	48.9	17	14	25.7	22.7
Crop P	18.8	16.9	18.5	9.6	12.6	12.6	12.5	11.0	13.6	13.4	12.7	11.3
Runoff P	.116	.437	.047	.140	.160	.335	.037	.083	.150	.334	.185	.078
Sediment P	.149	.273	1.310	.338	.075	.651	.528	.687	.071	2.931	.076	1.263
Deep Seepage P	.0093	.0083	.0086	.0089	.0610	.0079	.0122	.0117	.0335	.0664	.0632	.0306
Total Removal P	19.07	17.62	19.87	10.09	12.90	13.59	13.08	11.78	13.85	16.73	13.02	12.67
Loss to Environ.	.274	.718	1.366	.487	.296	.994	.577	.78	.255	3.331	.324	1.372
Fixation	67.4	61.9	7.2	24.0	126.4	122.7	38.8	37.1	3.1	0	12.7	10.0
% of Fixation	77.9	77.9	26.6	70.4	90.7	90.0	74.8	75.9	18.2	0	49.4	44.0

Table 6. Total Accumulative Runoff and Nutrient Losses from Water Quality Research Plots for a Period from 4/1/70 - 3/31/71. Means and L.S.D. Values for the Main Factors.

Factor		Runoff (Gal./Acre)	NH_4-N (Lbs./Acre)	NO_3-N (Lbs./Acre)	Soluble Ortho-Phosphate (PO_4-P) (Lbs./Acre)
Crop	Corn	94,517	0.3755	1.04	0.1851
	Beans-Wheat	109,727	0.3834	7.91	0.1537
	Wheat	119,625	0.5019	0.72	0.1870
Fertility	High	118,517	0.4528	5.46	0.2555
	Normal	97,395	0.3878	0.99	0.0950
Management	Good	72,596	0.4167	1.06	0.1159
	Poor	143,316	0.4239	5.38	0.2346
L.S.D. Crop @ 5%		- - -[1]	- - -	4.31	- - -
L.S.D. Fertility @ 5%		- - -	- - -	3.52	0.0801
L.S.D. Management @ 5%		69,260	- - -	3.52	0.0801

[1] L.S.D. Not calculated when non-significant F ratio occurs at given confidence level.

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21 Note

22 Citation

23 Descriptors (Starred First)

*Surface Runoff, *Crop Rotation, *Nutrient Losses, Manure and Fertilizer Application, Rainfall Simulator

25 Identifiers (Starred First)

*Nutrient Losses, *Surface Runoff, *Crop Management

27 Abstract

A rainfall simulator was utilized to determine the effects of 2, 10, and 20 year storm frequencies on losses of water, soil and nutrients from plots subjected to different crop rotations, fertilizer schemes and manure applications. Crop rotations, rates of fertilizer and manure were compared. Simulations were made on freshly tilled soil.

Comparative erosion losses were as follows: continuous sod corn - alfalfa rotations continuous corn. Fertilizer alone tended to increase runoff, but this effect was overcome when fertilizer was used with manure.

Continuous recording of surface and subsurface flow and subsequent losses of nutrients to the environment was conducted on larger plots. Rate and time of fertilization determined the plant nutrients lost. Returning crop residues to the soil improved water infiltration, increasing deep seepage losses. Proper timing of fertilizer applications could control adverse environmental effects. Phosphorous inputs into cultural media as it related to algal growth was studied. Sustained concentration determined the biomass of phosphorous.

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