THE IMPACT OF IRRIGATION AND NITROGEN MANAGEMENT AND VADOSE ZONE CONDITIONS ON GROUND WATER CONTAMINATION BY NITRATES

by

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Summary

Some type of control on nitrogen fertilizer is very likely within the next few years. This is the result of finding widespread contamination of ground water by what is presumed to be fertilizer nitrogen. To maintain economically viable production under restricted nitrogen amounts, irrigated corn producers will have to pay very close attention to both water and nitrogen amounts and timing of application.

Introduction

There is growing concern on the part of the general public regarding the presence of agricultural chemicals in our country's ground water. Although a wide range of ag chemicals or their breakdown products has been found in ground water samples taken throughout the country, by far the largest single contaminant is nitrate nitrogen (NO_3-N). Much of it comes from crop production. There are many areas that don't yet have a problem. However, in almost all regions with concentrated irrigated corn production, it appears that sooner or later a nitrate contamination problem will develop.

Many members of Congress are gaining the perception that ag chemical contamination of ground water is a problem and that nitrate contamination in particular is very widespread. Accordingly, we are likely to see some new laws enacted within the next two to five years, with the objective of reducing the problem. There have been a number of proposals each with a different approach. Regardless of the final form of the legislation, it is almost certain that the end result will be measures to broadly reduce the amount of nitrogen fertilizer used in crop production. To continue a successful, profitable agriculture, we may have to rethink our total management package for nitrogen and irrigation water. We need to learn more about reducing nitrate leaching, both during and following the growing season, in order to reduce the amount of nitrogen leaving the bottom of the root zone and entering the ground water as a contaminant.

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Many ground water pollution problems can be traced to non-agricultural sources. It is not hard to find examples of poor management of city and village sewage treatment plants and the disposal of sewage effluents and sludge. There is also significant ground water pollution in some urban areas, caused by excessive chemical and water application to lawns. We read frequently of spills of chemical products creating a pollution hazard. Nonetheless, in many rural areas, agriculture must shoulder the responsibility for a high percentage of ground water contamination that has occurred.

It must be emphasized that this is a question of responsibility and not blame. Much of the nitrate contamination of ground water has come about while the farmer has been doing the best that he knows how in terms of management, within the existing economic constraints. Now the game is changing. Management goals must include producing at a profit and keeping ground water pollution to an acceptable level. For nitrate nitrogen, that level is defined by the U.S. Public Health Service as less than 10 parts per million (ppm) in drinking water supplies.

The purpose of this paper is to show where and why ground water contamination problems are occurring in our area and to show that they are likely to occur in many other locations in the next few years. Most importantly, you, as the producer, need to know what this may mean to you and your farm management program during the next few years.

Impact of Soil, Subsoil and Aquifer Conditions on Contaminant Movement and Build-up

Under Great Plains growing conditions it is almost impossible to produce continuous corn under irrigation without some nitrate leaching loss. The actual rate of loss is governed by a number of factors including the soil, water and nitrogen management by the producer, and the weather. Importance of each of these varies from one year to another. In many cases, especially for sprinkler-irrigated land, much of the loss may occur during the spring, before planting time.

Nitrate contamination of ground water usually appears first where there is a shallow water table. A good example of this is the Central Platte Valley near Grand Island, Nebraska. The darkest areas in Figure 1 show the extent of the valley area where nitrate nitrogen concentration in the ground water exceeded 10 ppm in 1974. The contamination problem in the valley resulted from high applications of nitrogen fertilizer and the use of furrow irrigation on coarse-textured soils, which resulted in substantial leaching. The water table is quite shallow (5-30 ft.). Under these conditions travel time from the bottom of the root zone to the water table can be usually small, being on the order of a few days or weeks.

The extent of contamination in 1984 is shown by the cross-hatched area in Figure 1. The area of contamination has expanded considerably and the concentration of nitrate nitrogen in the earlier contaminated area has further increased. NO_3-N concentrations in the ground water increased at the rate of approximately 1 ppm per year during the ten years between the two evaluations and are continuing to increase. The contaminated area has expanded to include heavier soils and areas where the water table is somewhat deeper.

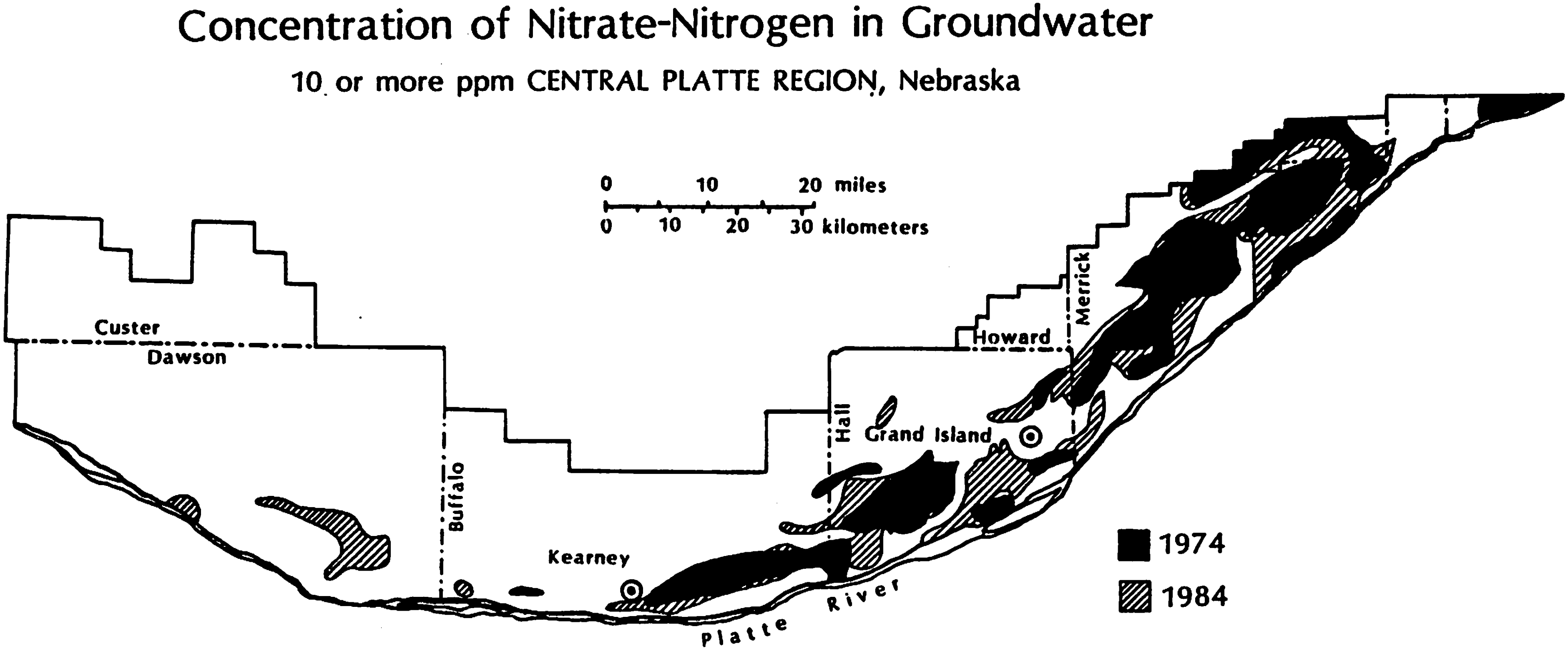

Figure 1. Map showing expansion of area of nitrate concentration in the Central Platte region between 1974 and 1984.

In such cases the travel time for nitrate to reach the water table is greater. Accordingly, it took longer for the problem to develop in those locations. The basic principle is that the deeper and finer textured the subsoil, the longer the delay in the build-up of pollution problems in the aquifer.

Let's consider three examples to clarify the questions of contaminant travel time to reach the aquifer and time required to contaminate an aquifer. All are of irrigated corn production under different conditions. In all cases we'll assume a leaching loss from the crop root zone of 50 lbs/acre of nitrogen per year with a total deep percolation loss of 10 in. per year (combined irrigation loss and excess winter and spring moisture). These are conservative estimates for average management under Nebraska conditions. The three cases are summarized in Table 1 and detailed in the paragraphs which follow.

Table 1. Ground water pollution by nitrate nitrogen.*

Factor Affecting Pollution	Example 1	Example 2	Example 3
Location	River bottom	Sandhills	Upland
Soil	Loamy sand	Fine sand	Silty clay loam
Subsoil	Sand and gravel	Fine sand	Silt, Silt loam
Distance from bottom of root zone to top of aquifer	15 ft.	80 ft.	80 ft.
Thickness of aquifer	30 ft.	75 ft.	150 ft.
Travel time to aquifer (years)	1/4-3/4	8-10	25-30
Time from initial pollution to increase average concentration in aquifer by 10 ppm (years)**	4-6	10-14	20-29
Amount of N to increase concentration in aquifer by 10 ppm (lb/ac--total)**	200-300	500-700	1000-1400

NOTES: *This table assumes an annual percolation loss of 10 inches per year and an annual nitrogen leaching loss of 50 lb. per acre.

**The larger figure assumes a porosity of 35% in the aquifer. The smaller value assumes 25% porosity.

Example 1--River Valley Situation: Travel time to the shallow aquifer is fast because of the short distance and porous subsoil. Since the aquifer is thin, it has relatively little storage capacity. As a result, concentration within the aquifer increases quickly. In the Platte Valley, many of these soils are still furrow irrigated. Deep percolation is closer to 35 inches rather than 10, as some irrigators put on an average of 4 inches every 5 days. Travel time to the water table is a matter of a few weeks at most. Under these conditions, nitrogen loss may greatly exceed the 50 lb/ac that we have assumed.

Example 2--Sandhills Region: For the deep, sandy subsoil, travel time is about 7 1/2-10 ft. per year with 10 in. of percolation. There is an 8-10 year delay from the start of nitrogen loss until the nitrate concentration in the aquifer begins to increase. After that, it takes 10-14 years to increase average aquifer concentration by 10 ppm of NO_3-N.

Example 3--Loess Plateaus: In the fine-textured soils the delay to the start of contamination is 25-30 years. At the loss rates we have assumed, it would take another 20-30 years to thoroughly contaminate the deep aquifer. That means if we could stop all nitrogen loss as soon as the first year's loss arrived at the water table, the aquifer concentration would continue to increase by an additional 10 ppm or more.

If, for any reason, the amounts of deep percolation are increased in any of these examples, the transit times will decrease more or less in proportion. For example, increasing the percolation loss from 10 in. up to 15 in. on the deep silt loam soil would cut the transit time by about one-third (i.e., from 30 years to 20 years, etc.). Also, note that the time required to increase aquifer concentration <u>after</u> arrival of pollutants depends on the thickness of the aquifer and the pollution rate. Thus, if the aquifer under the deep, silty clay loam soil is only 75 ft. thick instead of 150 ft., it would have a shorter time to become totally polluted, as in Example 2, except that the delay to the arrival of contaminants would remain as 20-30 years.

In talking about aquifer contamination, we have assumed that the nitrate is "mixed" in the aquifer like putting something in a blender. In the real world there tends to be a higher concentration in the upper part of the aquifer, more like gasoline floating on water. Mixing usually occurs slowly, over a period of years, especially in relatively deep aquifers. Because domestic wells are often shallower than irrigation wells, household water supplies tend to tap the upper part of the aquifer, finding the higher NO_3-N concentration in the process.

Effect of N Fertilizer Level

Above what nitrogen fertilizer level does nitrogen leaching become a serious problem? It's very difficult to give an ironclad response to this. It depends on the nitrogen mineralization rate in the soil, residual fertilizer nitrogen, uptake of nitrogen by the crop, and the producer's water management. However, long-term research data from the South Central Research and Extension Center near Clay Center, Nebraska provide an indication for one set of conditions.

Continuous corn was produced on furrow-irrigated plots from 1971 through 1985, with the exception of two years when the plots were in soybeans. Annual fertilizer amounts of 0, 100, 200, 300 and 400 lbs./acre were maintained on the same plots, when corn was produced. In 1986 soil cores were taken from the surface to a depth of 60 ft. Results are shown in Figure 2. Under 0 and 100 lbs. of N per acre, the nitrogen distributed through the subsoil is a relatively small amount (120 and 160 lbs./acre for these two rates). At 200 lbs./acre of N application, leaching losses increased significantly, with approximately 280 lbs./acre being in transit to the water table. Above this level subsoil N content becomes very high with about 615 lbs. in transit at the 300 lb. rate and over 1325 lbs. at the 400 lb. rate (not shown in the figure).

In general it would appear that maintaining N rates below 200 lbs. helps hold down the leaching losses on this soil. In fact, other research has shown the optimum rate to be closer to 150 lb/acre on this soil under good irrigation management.

Results from On-Farm Sampling

What happens when water and nitrogen fertilizer management are less certain? On-farm data gathered by Andy Christiansen, Extension Agent in Hamilton County, Nebraska gives a picture for one set of conditions. Figure 3 shows nitrate nitrogen concentration profiles in a silt loam soil at the upper and lower ends of a furrow-irrigated field with a 1/4 mile run. Concentrations in the soil vary between 1 and 7 ppm. (1 ppm is about 3.6 lbs./acre per foot of soil). Total amount of nitrate-N in the profile averages about 700 lbs./acre across the field. This will be enough to add 7-10 ppm of nitrate nitrogen to a typical 100 ft. thick aquifer, when it enters the ground water.

Figure 4 shows data for a furrow-irrigated field with a 1/2 mile run. At the upper end there are over 900 lbs. of N in the profile and at the lower end over 2400 lbs.! Why the difference? At the upper end the 24-hr. set time has provided enough deep percolation to more or less continually flush nitrogen from the root zone to the water table. At the lower end of the field the water application is considerably less so that a substantial amount of the nitrogen leached over the last 20+ years is still in the profile. This figure suggests that in the past, nitrogen application has been well in excess of crop needs. Even where percolation amounts are less, there is a great deal of residual nitrogen that will move out of the crop root zone.

In considering the rate of pollution build-up in the ground water, many operators don't have the "cushion" of build-up time shown in Table 1. Today ground water nitrate levels are usually not beginning at zero. They may already be well on the way to a problem. In the case of the farm in Figure 4, the irrigation water was already at 14 ppm when the sampling was done. By the time the nitrogen in the soil profile is added to that in the aquifer, the concentration will increase by another 17-20 ppm over the next 15-30 years.

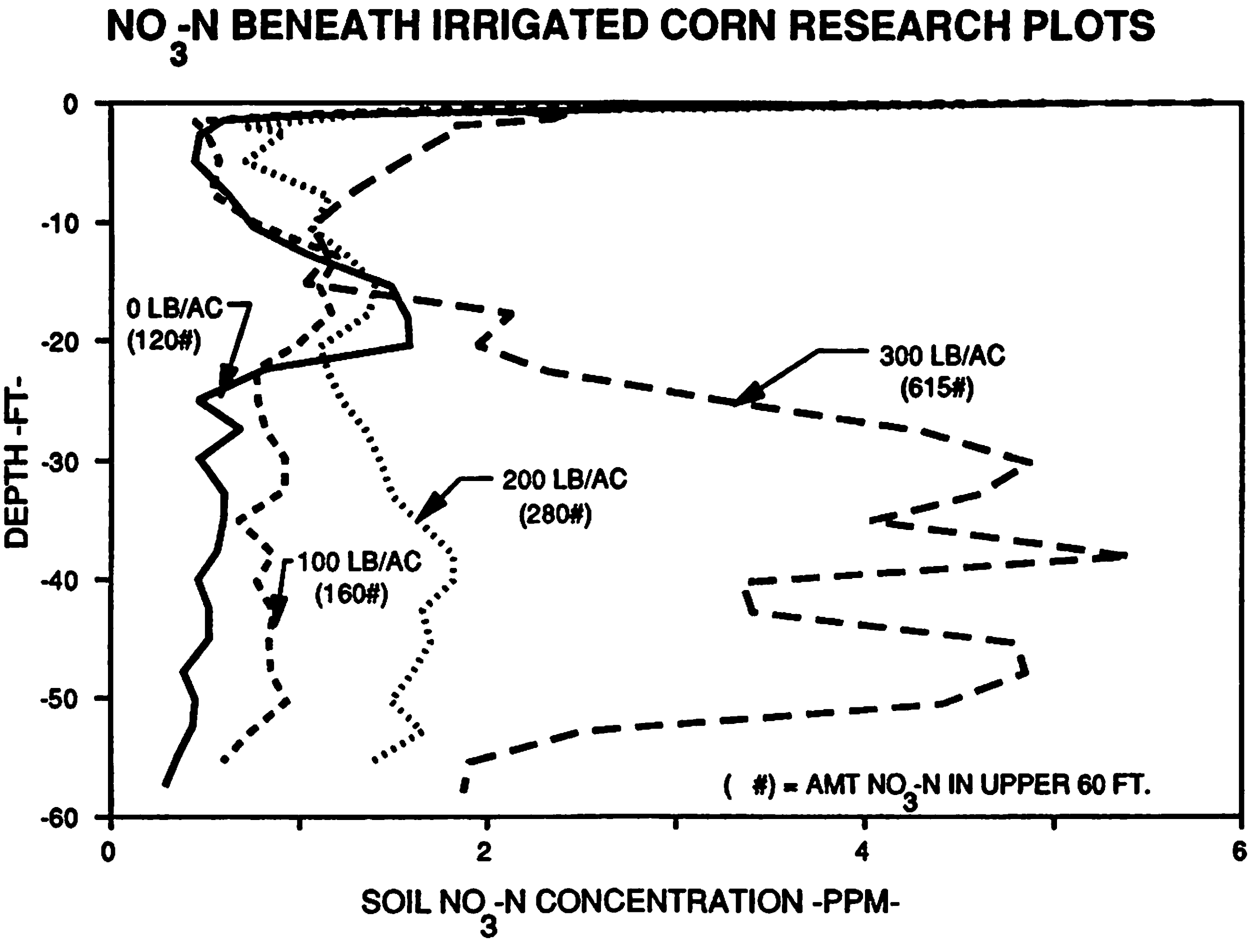

Figure 2. Nitrate nitrogen concentration in the vadose zone beneath long term N rate trials on irrigated corn research plots at the University of Nebraska's South Central Research and Extension Center. (Spalding and Kitchen, 1988)

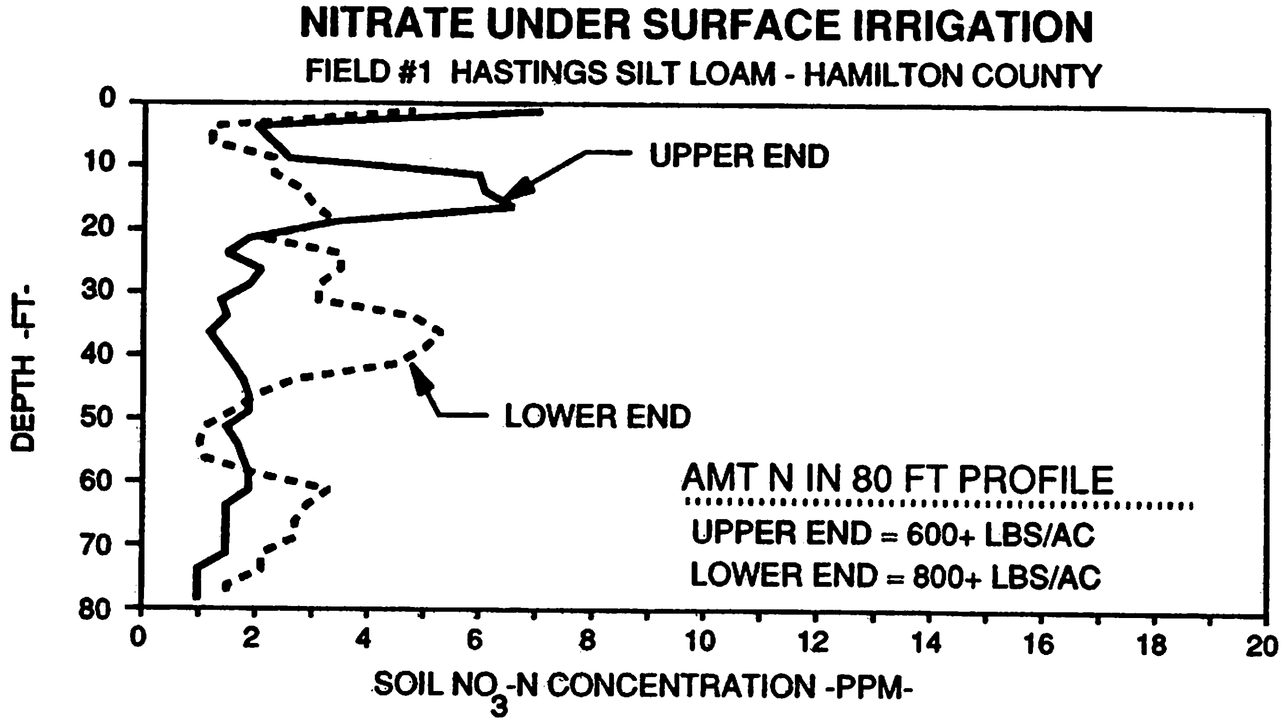

Figure 3. Nitrate nitrogen in the vadose zone beneath furrow irrigated corn with 1/4 mile irrigation run; Hamilton County, Nebraska. (Christiansen, 1988)

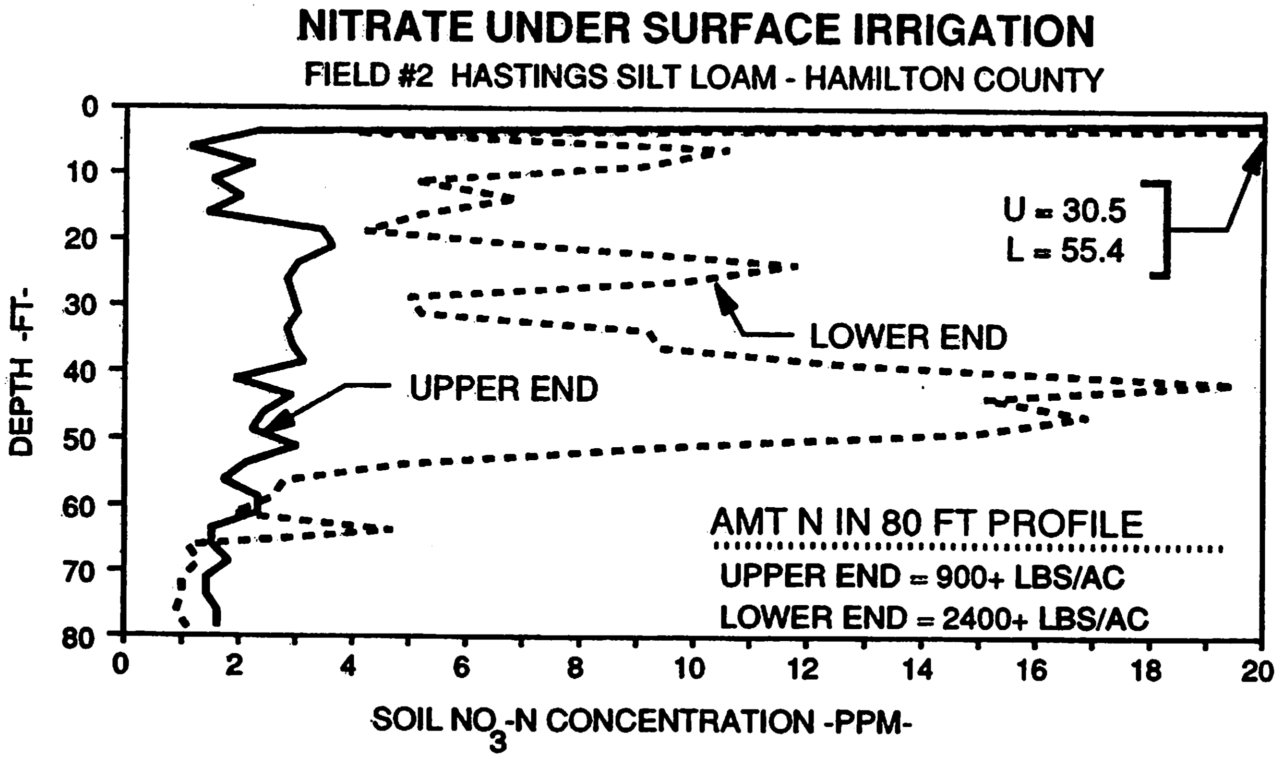

Figure 4. Nitrate nitrogen in the vadose zone beneath furrow irrigated corn with 1/2 mile irrigation run; Hamilton County, Nebraska. (Christiansen, 1988)

In some situations a large part of the annual leaching loss can occur during the non-irrigation season. This occurs especially if the soil profile is left more or less wet at the end of the growing season and/or there is a significant amount of winter or springtime precipitation. This strengthens the case for letting the soil dry down near the end of the growing season. It not only reduces irrigation costs, but N leaching as well.

Management Adjustments

How can the nitrate contamination of our ground water be slowed or stopped? Clearly, steps must be taken to minimize nitrogen loss from the crop root zone. The question that must be answered is how to do so while maintaining profitable production. There are no absolute answers. However, there are some key points that must be considered.

Nitrogen loss is closely linked to the amount and timing of both water and nitrogen applications, with respect to crop needs.

Even with the best water management there is always a potential for nitrogen loss. Where water is tightly controlled, losses will most likely come during the off-season or at the beginning of the following growing season. Percolation following a wet period can leach residual nitrate out of the root zone. The coarser the soil texture, the greater the probability that this will happen.

When fertilizer application exceeds actual crop requirements, the potential loss will be even greater. This situation is illustrated in Figures 5a and 5b which show, for different N fertilizer amounts, the residual nitrate-N following corn harvest on a deep, sandy soil. For good water management, residual nitrate-N increases rapidly beyond an N application of 150 lb/acre, regardless of whether it is applied preplant or in the water. There is more residual with sprinkler-applied N because part of the preplant N was leached early in the growing season by excess rainfall. Where there was excess irrigation, there was substantial N loss regardless of application timing. However, the sprinkler-applied N still shows a larger residual for excess fertilizer amounts. Some of the residual N may remain in the root zone for use the following season. However, the odds are that a good part of it will be leached out over winter.

To reduce potential losses, nitrogen applications must be tailored even more closely to actual crop needs than is being done today. There are promising new techniques to give a quick measure of crop nitrogen status through the growing season. They will allow nitrogen applications to be delayed until absolutely required. This knowledge, together with fertigation or other mid-season nitrogen application techniques, will let the producer reduce fertilizer amounts to the very minimum required.

If excess irrigation is applied, it is likely that nitrogen will be leached from the root zone, even if fertilizer amounts are closely matched to crop needs. Nitrate nitrogen is highly soluble and moves with water.

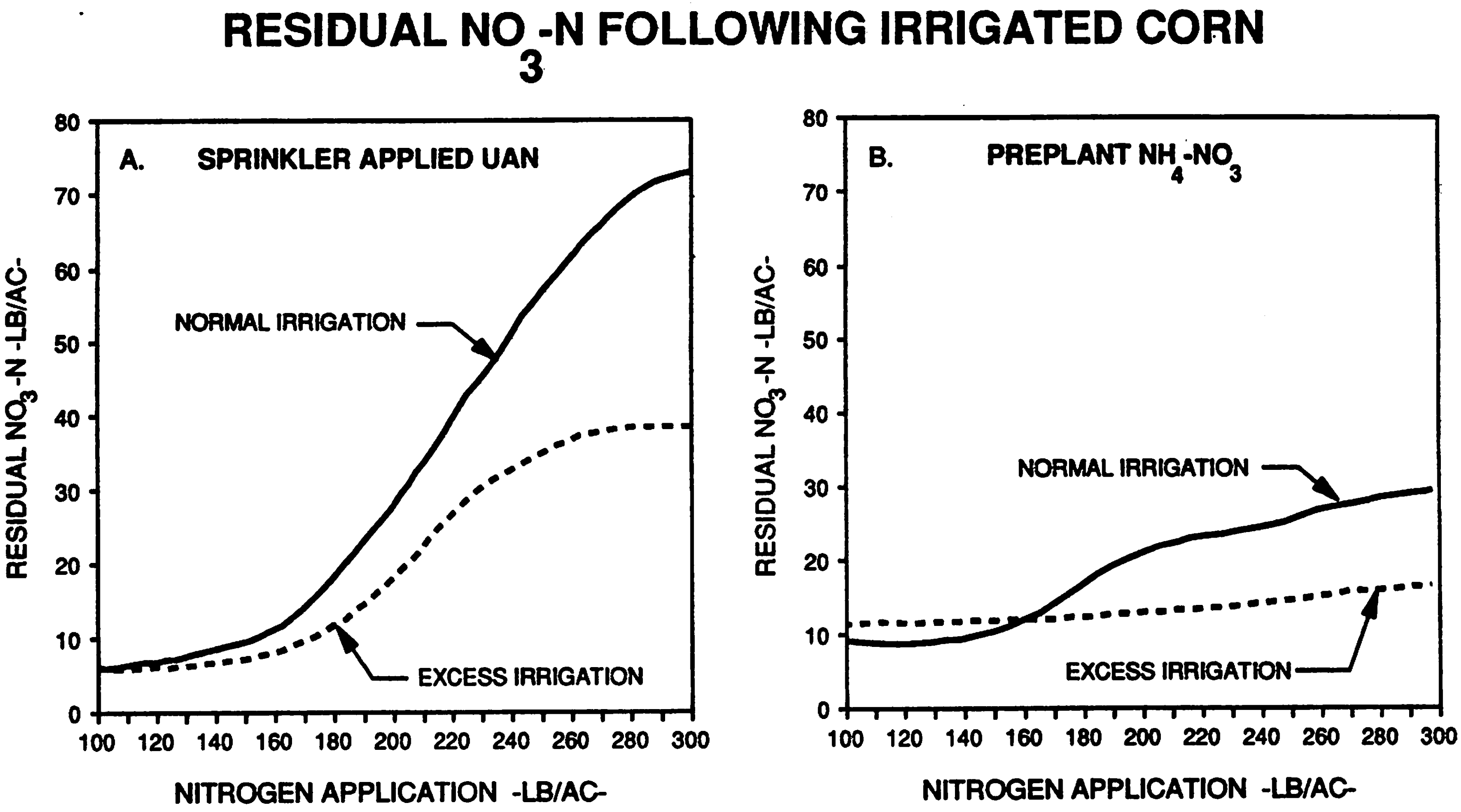

Figure 5. Residual nitrate nitrogen following irrigated corn, for two irrigation management levels; Sandhills Ag. Lab, Tryon, Nebraska. (Smika and Watts, 1978)

Irrigation scheduling and water control are essential keys to reducing nitrogen loss. With furrow irrigation, more attention has to be paid to getting a more uniform spread of water down the length of the field.--Surge irrigation is a tool that offers help here.--We may also be able to incorporate fertigation with surge to get on a delayed nitrogen application.

Any change in cropping pattern that results in lower nitrogen application is usually beneficial.

Use of crops that can recover residual nitrogen is particularly helpful. A good example is a corn-soybean rotation. Soybeans not only make their own nitrogen, they tend to pick up a lot of the residual that may be in the root zone following corn production. The end result is less nitrate leaching when averaged over a multi-year period.

Research is continuing on the use of cover crops, such as rye seeded into corn during the late summer. The cover crop takes up some residual nitrogen and also nitrogen that mineralizes after corn completes its uptake (shortly after blister stage). We have a way to go in terms of perfecting seeding methods. However, some headway has been made with "seedigation" using big gun sprinklers on center pivots. The important point is that the use of a cover crop may temporarily immobilize 20-30 lbs. N per acre that would otherwise be available for off-season leaching.

References

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