SOIL FACTORS AND YIELD VARIABILITY IN FURROW-IRRIGATED CORN[1]

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Variability of Soil Factors

Variability of soil productivity and yield within a field is a factor that many producers recognize. After farming a field for awhile, most producers are aware of areas which are more or less productive in the field, due to erosion, drainage, organic matter, slope, cropping history or any number of additional factors. Some producers may make some effort to farm such areas of the field accordingly, such as making an extra fertilizer pass in areas which are eroded or low in fertility. If producers are familiar with the soil survey, they may associate differences in productivity with different soil types. Research over the past ten years or so has expanded our knowledge of how fields vary in productivity. Various researchers have investigated the variability of factors such as soil test values for organic matter, phosphorus, and nitrate, the activity of soil enzymes such as phosphatase, urease, and protease, and hydraulic properties. In Nebraska, research conducted from 1987 to 1991 investigated the spatial variability of soil residual nitrate on 43 fields across the state. On these fields, the average soil nitrate level in 4 ft was 94.5 lb N/acre, with a median of 77 lb N/acre, and a C.V. of 59%. Nitrate-N levels in 4 ft ranged from a low of 3 lb/acre to a high of 1386 lb/acre.

Recent advances in technology have allowed the summary of information about field variability into a quantified format which can be used to control various field operations automatically. The adjustments which some producers have made "by the seat of their pants" can now be controlled by computers. Considerable attention has been given to this technology (sometimes called farming by soils or farming by the foot) in popular farm magazines over the last couple of years. Much of the interest and technology to date has been oriented towards application of non-mobile nutrients,

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such as phosphorus and potassium.

Infiltration Variability with Furrow-Irrigation

The inherent non-uniformity of water application associated with furrow-irrigation is a problem of considerable interest among researchers and producers alike. The decreasing amount of water infiltrating at the downstream end of the furrow (because of reduced opportunity time), as illustrated in Figure 1, results in an introduced variability which influences the accumulation and movement of mobile nutrients, such as nitrate. In many cases, the upstream end of the field is over-watered in order to adequately water the downstream end. Nitrate and other mobile nutrients are carried in the excess water below the root zone. Such over-application of water with the resultant nitrate loss is one factor contributing to nitrate contamination of ground water, particularly in areas with intensive development of furrow-irrigation.

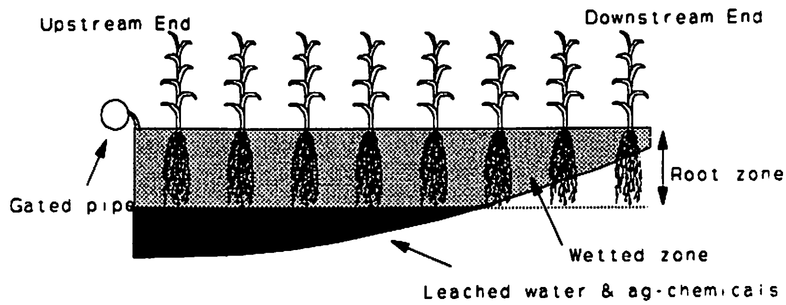

Figure 1. A typical infiltration profile with furrow-irrigation.

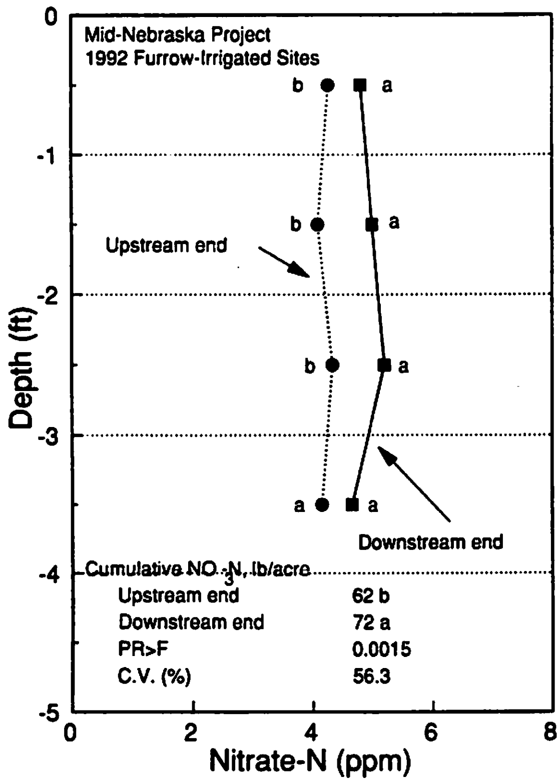

Figure 2. Nitrate-N in the root zone Mid-Nebraska Project, 1992. Depths with different letters have sig. different NO_3-N at P of .95.

Irrigation Influence on Root Zone and Vadose Zone Nitrate

One result of the infiltration profile illustrated in Figure 1 may be differences in the amount of nitrate-N in the root zone which are predictable. Of 28 fields sampled for nitrate-N in the root zone as part of the Mid-Nebraska Water Quality Demonstration Project in 1992, 12 had significantly lower nitrate-N accumulations in the root zone at the upstream end of the field compared to the downstream end. Averaged across all fields, significant differences in nitrate-N were observed in the upper 3 ft of the root zone (Figure 2). The total amount of nitrate in the root zone, on average, at the upstream end of the field was 62 lb N/acre, compared to 72 lb N/acre at the downstream end.

Depending on the amount of water infiltrating and the concentrations of nitrate carried with it, the vadose zone (the layer of soil or parent material between the bottom of the root zone and the top of the aquifer - also called the unsaturated zone) nitrate levels will also be influenced by differences in the irrigation water infiltration profile. With excessive water application, nitrate may be carried through the vadose zone and into the aquifer. Figure 3 illustrates the nitrate-N accumulation in the shallow vadose zone of one Mid-Nebraska demonstration site. At this site, excessive irrigation water at the upstream end of the field has leached nitrate below the root zone and below the shallow vadose zone as well. Consequently, the cumulative nitrate in the shallow vadose zone is much less at the upstream end compared to the downstream end of the field. Curves for nitrate-N distribution are means of two cores at each end of the field. Due to the large variability of nitrate in soil, there is not a statistically significant difference between the upstream and downstream ends of the field. However, it is likely that these differences are real, and would be statistically so with a larger number of samples.

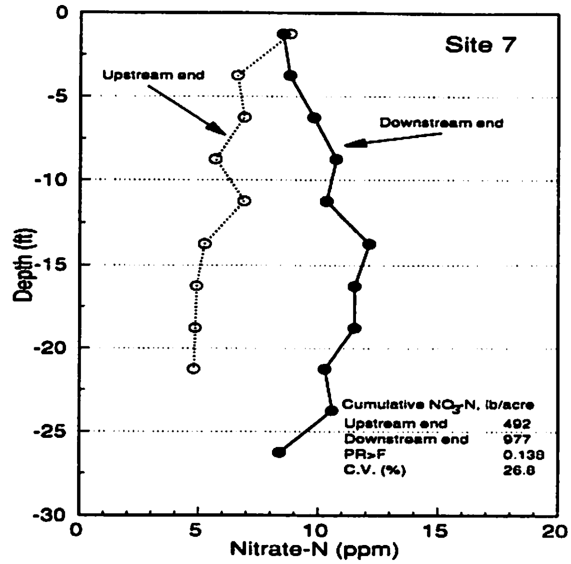

Figure 3. Nitrate-N in the vadose zone, Mid-Nebraska Project Site 7, 1992.

Research to Address Soil and Irrigation Variablity

The knowledge that an irrigation-imposed trend in nitrate-N in the root zone exists presents the opportunity to adjust fertilizer rates accordingly. However, other factors besides irrigation water infiltration will also influence nitrate accumulation and leaching. Research was initiated in Nebraska in 1992 to evaluate the potential to adjust fertilizer rates according to spatial variables in the field. One potential factor for rate adjustment is the yield potential of specific points within a field. Other soil factors which may influence N use efficiency are residual soil nitrate and organic matter level.

Two sites on farmers fields were sampled in the spring of 1992 on a grid basis for residual nitrate. Both sites were demonstration sites for the Mid-Nebraska Water Quality Demonstration Project. Soil samples were collected to a depth of four feet on a 200 ft grid. Maps of nitrate levels in these fields are shown in Figures 4 and 5. Figure 4 illustrates the distribution of residual nitrate in a field in Seward county on the Dean Rocker farm. This figure illustrates the effect of the irrigation water infiltration profile on residual nitrate. Residual nitrate generally increases with distance from the irrigation pipe. The increase in concentration at a distance of 700 - 900 ft, followed by a decrease, is likely related to other variables which were not mapped, such as elevation, clay content, compaction, differences in drainage, etc. The highest residual N levels, in the range of 120 - 160 lb N/acre in 4 ft, were found at the farthest downstream points.

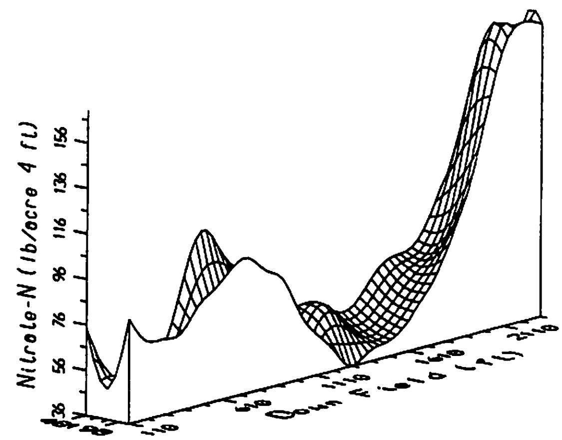

Figure 4. Soil residual nitrate-N to 4 ft, Dean Rocker farm, spring 1992.

Figure 5 illustrates the distribution of residual nitrate-N at the Milton Ruhter farm in Adams county. Nitrate-N levels in 4 ft ranged from approximately 15 lb/acre to over 230 lb/acre in this field. The site is relatively complex regarding how it is managed for irrigation, which explains some of the trends in residual nitrate. The field has a draw running across it approximately 2/3 of the distance from the "upper" end. Gated irrigation pipe is laid at both ends of the field, and water runs towards the draw. Residual nitrate levels are lowest at both ends of the field, and highest in the vicinity of the draw. Besides being the low point of the field, part of the draw area is also mapped as a Butler soil, which is less well-drained than the majority of the field, which is mapped as a Hord soil. A area of elevated nitrate is noted at one corner of the "upper" end of the field. This area was significantly cut and filled when the field was leveled for irrigation. The area is poorly drained, and generally observed by the cooperator to be less productive than the rest of the field. Both the corner of the field and the draw area apparently have a lower yield potential than the rest of the field, and consequently use less of the applied fertilizer nitrogen. It is likely that the high areas of residual nitrate are due to differences in irrigation water infiltration as well as yield potential of the soil.

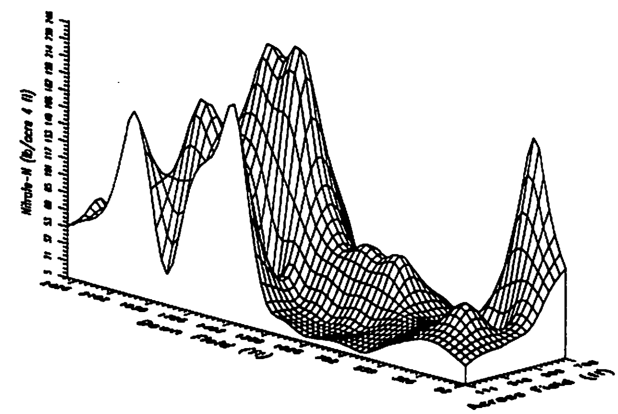

Figure 5. Soil residual nitrate-N to 4 ft, Milton Ruhter farm, spring 1992.

A variable rate anhydrous ammonia applicator was used at the Ruhter farm to variably apply nitrogen according to the soil nitrate level. The cooperator applied 30 lb N/acre as starter. The balance of the N required for an expected yield of 180 bu/acre was applied as sidedressed ammonia, with rates ranging from 0 to 185 lb N/acre, for total amounts of N in the field ranging from 30 to 215 lb N/acre. Four treatments were applied in a randomized complete block design with six replications. The four treatments were: variable N rate; uniform UNL recommended N rate (180 lb N/acre); -55 lb/acre rate (125 lb N/acre); and a +35 lb/acre rate (215 lb N/acre). Each treatment was applied to field length strips which were eight rows wide.

A research combine capable of measuring yield on-the-go from Kansas State University was used to harvest the strips. Spatial yield data from these measurements is not yet available. However, yield from each strip was measured with a weigh wagon. Average yields from the four treatments are shown in Table 1.

Treatment	Total N Rate (lb/acre)	Yield (bu/acre)
-55	125	152
REC	180	158
Variable	VAR	157
+35	215	155

Grain yields were reduced at the -55 lb N/acre rate, but were the same statistically with the other three treatments. Figure 6 illustrates the trend of grain yield across the field, with vertical bars indicating yield for individual strips. Grain yield was evidently influenced somewhat by the position of the strip in the field, with yield in the fourth through tenth strips somewhat lower than other strips no matter what the N rate. The total N applied is shown at the top of Figure 6. These total indicate the amount of N applied to the strip, not the rate per acre. Each strip was approximately 1.4 acres in area. The total strip application illustrates that the variable N rate approach did not apply less N than the uniform, recommended N rate of 180 lb N/acre, on average. The distribution of N was substantially different, however. Averaged across 6 reps of the variable rate treatment, the total amount applied to the strip was 252 lb of N. The total amount applied to the recommended N rate strips was 248 lb N, on average. At this site, the variable rate approach did not reduce the amount of N applied or affect yield, compared to the uniform recommended N rate. However, variable rate

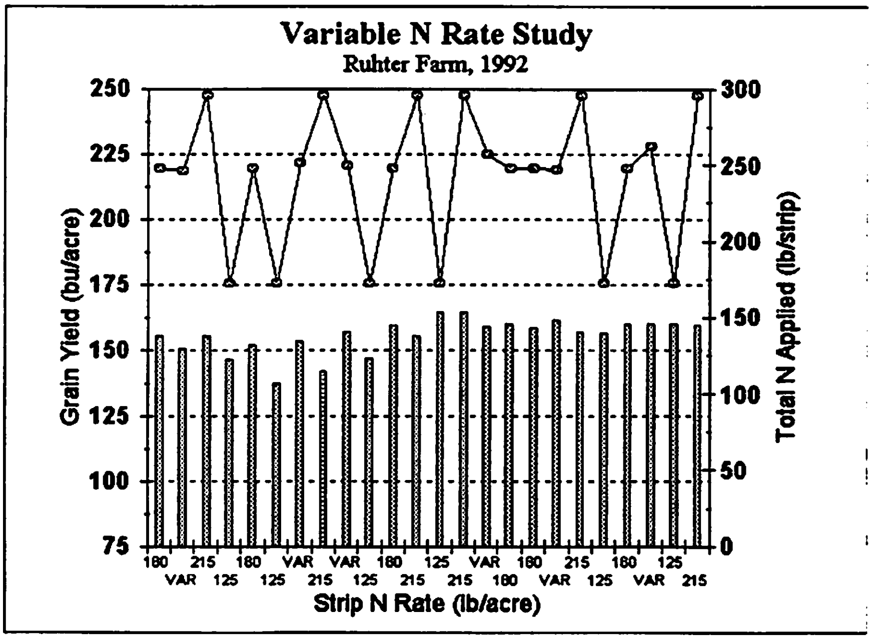

Figure 6. Grain yield and total N applied, Ruhter variable rate site, 1992.

application did allow fertilizer N to be distributed much differently, which may increase fertilizer use efficiency and reduce the amount of nitrate-N left in the soil subject to leaching. Soil samples will be collected from these strips in the winter of 1993 to evaluate the effect of variable N application on residual N levels.

Summary

In summary, variability introduced with furrow-irrigation and spatial variability within fields of soil properties can substantially influence grain yield, fertilizer nitrogen use efficiency and the potential for nitrate leaching. Knowledge of how these factors interact within fields may allow more detailed management of nitrogen fertilizer and irrigation systems for increased efficiency.

Recent advances in electronic technology has provided producers the ability to map fields for a wide variety of soil factors. This spatial database, coupled with computer-controlled equipment for fertilizer or pesticide application, for tillage, or planting operations, will allow producers to ability to fine tune field operations for increased efficiency. Research is on-going at the University of Nebraska and Kansas State University, as well as other locations, to learn how to utilize this technology for increased efficiency and protection of water quality.