Nitrate Losses Through Subsurface Tile Drainage in CRP, Alfalfa, and Row Crop Systems

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Introduction

Drainage of excess water from the soil profile through subsurface tiles commonly is used to improve crop production on poorly-drained soils, particularly in the Upper Midwest. This drainage water can carry dissolved nutrients, suspended sediment, and pesticides from the field, and subsequently impact surface and ground water. Although nitrate-N (NO_3-N) losses have been monitored under fertilized crops in many areas, there is little information about the impact of perennial species, such as alfalfa and mixtures planted for the Conservation Reserve Program (CRP). Because perennial crops typically use more water than annual crops, and because neither CRP nor alfalfa receive fertilizer N inputs, we hypothesized that NO_3-N losses would be lower than when more typical annual row crop rotations were grown.

Methods

The experiment was conducted on a moderately well drained Normania clay loam (Aquic Haplustoll) at the University of Minnesota Southwest Experiment Farm at Lamberton, MN, from 1988-1993. Subsurface tiles had been installed in 1972 to allow monitoring of drainage in 15 individual 14- by 15-m plots, which were isolated to a depth of 1.8 m by 12-mil plastic sheeting. Five cropping treatments [continuous corn (C-C), corn after soybean (Sb-C), soybean after corn (C-Sb), alfalfa (Alf), and CRP] were established in the spring of 1988 in three replicates as a randomized, complete block design. Recommended hybrids, rates of seeding, fertilizer, and pesticides, tillage practices, and harvest schedules were used for grain (C-C, C-Sb, Sb-C) and hay (Alf) production.

No supplemental irrigation was provided. Tile flow rates and NO_3-N concentrations were measured and flow-weighted NO_3-N concentration was calculated. Total above ground dry matter and total N were measured, with estimates from 1-m^2 subplots in the otherwise undisturbed CRP plots. Standard analysis of variance was used to compare treatments.

Results

Growing season rainfall during the first two years was only 64 and 73% of the normal 530 mm, which limited crop yields, prevented tile drainage, and reduced stored soil water reserves. Tile flow did not resume until late May 1990. Above normal precipitation (by 13 to 66%) in the last three years resulted in higher yields (except in the cool 1993 season) and plentiful tile flow.

Above ground dry matter yields ranged up to nearly 15 Mg/ha in the corn plots (Fig. 1), of which about 58% was grain. Soybean yields ranged up to 10 Mg/ha, with an average of one third as bean dry matter. Alfalfa herbage yields peaked at 11.9 Mg/ha, whereas CRP standing above ground biomass attained only 5.3 Mg/ha. There was a close relationship between dry matter and N in the above ground crop (Fig. 1), but the slope for corn was only one third as steep as for alfalfa and soybean. These results support earlier conclusions that greatest potential N removal can be achieved with high yielding perennial forage species, like alfalfa. Both legumes likely fixed some atmospheric N_2, while absorbing some of the available soil N, but we cannot determine how much fixation or uptake occurred in this experiment. Alfalfa and CRP had about 65% less residual soil NO_3-N to a depth of 1.5 m in autumn than C-C, and corn/soybean rotations had about 17% less than C-C. In both cases, lower fertilizer N inputs may have contributed to lower residual soil N concentrations. Less water also was present in the soil profile in autumn under perennial crops than annual crops in all years but the wettest

(1993). Soil water reserves were reduced to depths of 3 m under alfalfa and 2.4 m under CRP.

As a result of increased water use and lower soil NO_3-N concentrations, NO_3-N loss in tile drainage was insignificant under both alfalfa and CRP, regardless of drainage flow (Fig. 2). In contrast, there was a close relationship between NO_3-N loss and water drained in the annual crops up to about 250 mm annual drainage. Total NO_3-N losses through tile drainage over the 6 yr period were 218 kg N/ha in C-C, 203 kg N/ha for corn/soybean rotations, 7 kg N/ha for alfalfa, and 4 kg N/ha for CRP. These losses represent about 25% of the fertilizer N rate applied to the annual row crop systems.

Flow-weighted NO_3-N concentration in tile drainage water during this study averaged 32 mg NO_3-N/L in C-C, 24 mg NO_3-N/L in the corn/soybean rotation, 3 mg NO_3-N/L in alfalfa, and 2 mg NO_3-N/L in CRP. In nearly all monthly time periods measured, the perennial crops maintained drainage water quality to concentrations below the public health limit of 10 mg NO_3-N/L.

Conclusions

In this experiment, we used the best practices available to optimize crop production and profitability, but NO_3-N concentrations in tile drainage water exceeded the public health limit in most instances under annual row cropping. Therefore, a production system of annual row crops on highly productive soils where biological influences can be significant will have difficulty attaining drainage water quality goals, even when prudent N fertilization is followed. Adding perennial species to the crop rotation will help reduce NO_3-N losses in tile drainage. In addition, perennial crop species will reduce the volume of water delivered to surface water through these drainage systems, thereby helping reduce flood potential in these areas.

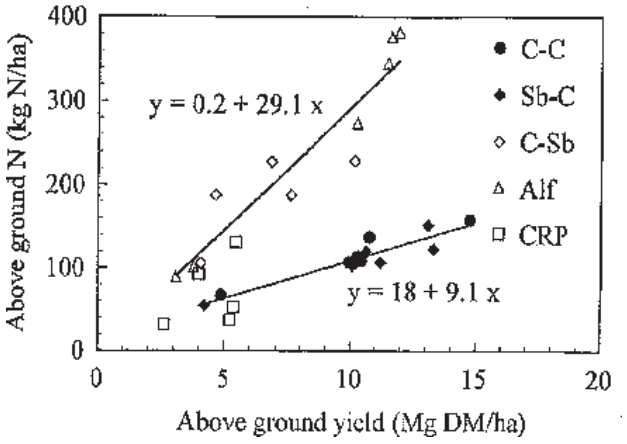

Figure 1. Relationships between above ground biomass yields and N content in five cropping treatments at Lamberton, MN, 1988-1993. In the corn/soybean rotation, data were obtained from the soybean phase in C-Sb, and from the corn phase in Sb-C. Regression lines were fit to alfalfa and soybean data or to corn data; CRP was omitted from both equations. Each regression had an $R^2 > 0.87$.

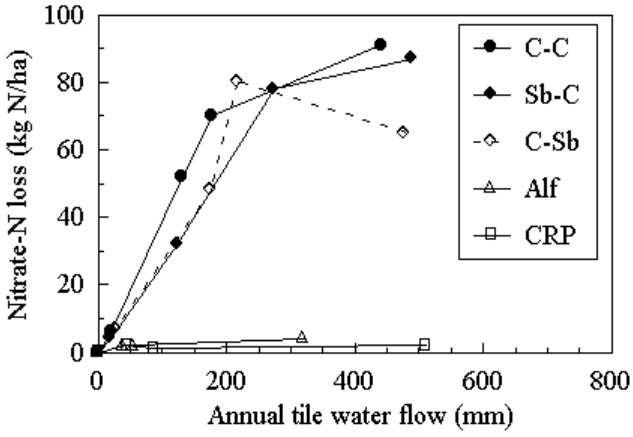

Figure 2. Relationship between annual flux of water and NO_3-N through subsurface drainage tiles in five cropping treatments at Lamberton, MN, 1988-1993. In the corn/soybean rotation, data were obtained from the soybean phase in C-Sb, and from the corn phase in Sb-C.