SOME ENVIRONMENTAL IMPLICATIONS WHEN RESTORING CROP PRODUCTIVITY OF ERODED LAND WITH MANURE

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Introduction

Soil erosion has been a problem in agriculture since ancient times. The main impact of erosion on the soil is a loss of soil productivity because of decreased capacities in soil biological, chemical, and physical properties. Various researchers have reported reduced crop yields in eroded soils (Frye et al., 1982; Olson and Carmer, 1990; Chengere and Lal, 1995; Shaffer et al., 1995). This loss in crop productivity is caused by the removal of the surface soil, or topsoil, where most of the soil organic matter is present. It has been shown that reduced crop production in eroded soils comes from reduced water holding capacity in the soil (Andraski and Lowery, 1992). In general, reduced yields are noted with erosion, but similar and greater yields have been reported in eroded areas when compared to uneroded soils. This largely reflects weather differences between years, especially rainfall (Swan et al., 1987). Therefore, the productivity of an eroded soil could be restored if its plant-available water holding capacity is increased.

Application of manure has been reported to over time improve soil aggregation, reduce bulk density, increase soil water retention and hydraulic conductivity (Chaney and Swift, 1986; Mbagwu, 1989; Droogers and Bouma, 1996), and increase crop yields (Dormaar et al., 1988; Larney and Janzen, 1996). This is mainly caused by an increase in organic matter content. Therefore, application of animal manure should lessen the negative effects of erosion on soil physical properties and crop production, and in general increase soil quality. For this reason, the use of animal manure has been proposed as an ameliorating amendment for eroded soils.

Nitrate and atrazine leaching under corn production has been studied extensively (Angle et al., 1989; Starr and Glotfelty, 1990; Edwards et al., 1993; Toth and Fox, 1998; Kladivko et al., 1999). However, chemical movement studies in eroded land receiving animal waste are infrequent. In addition, studies on chemical leaching in corn fields receiving animal wastes have focused only in NO_3 (Jemison and Fox, 1994; Jemison et al., 1994; Eigenberg and Nienaber, 1998). Therefore, little is known about the effects of past erosion and manure application on chemical leaching. Since the use of manure applications on eroded land has been proposed to restore crop production in eroded land, it seems pertinent to assess what environmental impact such a practice might have on water quality. Consequently, the objective of this study is to evaluate NO_3 and atrazine leaching in an eroded silt loam treated with animal manure.

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Materials and Methods

The research site is located in the driftless region of southwestern Wisconsin, at the Lancaster Agricultural Research Station of the University of Wisconsin-Madison. Soil at the study area is a Dubuque silt loam (fine-silty, mixed, mesic, Typic Hapludalf). These soils are formed in loess underlain by a red clay residuum. The site is 295 by 148 feet and is located on a 10 to 14% southwest-facing slope. Three levels of past erosion (slight, moderate and severe) have identified using the depth to the red clay residuum (2Bt horizon) as a baseline (Table 1) (Andraski and Lowery, 1992). Depth to the red clay residuum ranges from 12 to 47 inches.

Table 1. Horizon depth and textural classification for three erosion levels of a Dubuque silt loam soil in 1985 (adapted from Andraski and Lowery, 1992).

Erosion level	Soil horizon	Average depth	Textural class	Sand content	Clay content
		inch		------------- %	------------
Slight	Ap	0 to 14	Silt loam	5	13
	Bt	14 to 37	Silty clay loam	2	32
	2Bt	37 to >44	Silty clay	5	54
Moderate	Ap	0 to 10	Silt loam	6	16
	Bt	10 to 29	Silty clay loam	2	29
	2Bt	29 to >39	Silty clay	3	45
Severe	Ap	0 to 7	Silt loam	5	17
	Bt	7 to 18	Silty clay loam	3	33
	2Bt	18 to 31	Silty clay	4	40

Three plots were established for each erosion level at the beginning of the study. In Fall 1988, cattle manure slurry was applied to evaluate its effect on corn production on eroded land. For this, the plots were split in half across the slope. The manure slurry was injected in the bottom half of the plots (downslope). Use of cattle manure slurry applications were changed to solid cattle manure in Fall 1992 to assure a more uniform distribution of the manure. Solid cattle manure was incorporated into the soil with the fall chiseling. Tillage operations included chisel plowing in the Fall and disking in Spring. Anhydrous ammonia was used as preplant N fertilizer, and N, P and K fertilizer were applied at planting (Table 2). Anhydrous ammonia applications were reduced in those subplots receiving manure to compensate for the N applied with the manure. In 1997 and 1998, weeds were controlled by applying 2 lb/acre of Aatrex 4L (atrazine) and Dual II (metolachlor). Herbicides were applied as a preemergence on May 20, 1997 and May 22, 1998. Prior to this study, the research site had not received any atrazine herbicide for the past 12 years.

Environmental impact assessment started during Spring 1997 with the installation of soil water sampling devices or porous-cup samplers (PCS) installed to monitor solute movement in the root zone. These samplers consist of a polyvinyl chloride (PVC) body with a threaded porous ceramic cup at one end. Two high-density polyethylene tubes were attached to the other end of the PVC body. One of these tubes served as a sampling line and the other to apply a vacuum to the device. Two PCS were installed on each subplot, one at 1.6 feet and the other at 3.3 feet, for a total of 36 samplers.

After installation, a suction of 10 psi was applied to the PCS to begin sampling. The first sample collected 5 days after installation was discarded. Sampling was performed once a week. Soil water samples were stored in glass bottles with Teflon®-lined caps and packed in a cooler with ice for transportation from the field. They were stored at 36°F until subsamples were collected and analyses done. However, towards the end of the growing season, it was not possible to collect water samples from all samplers every week because of lack of rainfall and increased water use by plants.

Soil water samples were analyzed for NO_3, atrazine, deethylatrazine (DEA), and deisopropylatrazine (DIA). Nitrate analysis was performed with an ion chromatography instrument. Pesticide analysis was performed with a gas chromatography technique. Extraction of atrazine, DEA and DIA was done using solid-phase extraction columns. The extraction technique used is similar to that described by Fermanich et al. (1996). After extraction, samples were stored under refrigeration until they were ready for analysis. A gas chromatograph with a nitrogen phosphorus detector (NPD) was utilized to determine pesticide concentrations.

Results and Discussion

Manure applications increased corn grain yield for all erosion phases (Figure 1). However, the increase is statistically significant for the slight erosion phase only. We suspect that manure applications have to be done for longer periods of time in order to restore soils that have been more heavily eroded.

No distinct pattern in nitrate leaching due to erosion level has been observed from nitrate concentration data. In 1997, greater NO_3-N concentrations were detected in slightly eroded subplots receiving no manure for most of the sampling season at the 1.6- and 3.3-foot depth (Figures 2 and 3). In general, soil water collected from the unmanured moderate erosion level subplots at both depths had greater NO_3-N concentrations than the unmanured severely eroded subplots. For the 1998 sampling season, similar trends were observed (data not shown), but concentrations were less pronounced than in 1997. Increasing clay content with increasing level of erosion could be a contributing factor for lower detected NO_3 concentrations in the unmanured severe erosion subplots. A high cation exchange capacity (CEC) is usually associated with clay particles; however, they also have a small anion exchange capacity (AEC). Even though AEC is generally weak for most soils, it can retard the leaching of anions like NO_3^-. In addition, water usually moves at a slower rate through clay layers in the soil, allowing more time for plant uptake of NO_3^-.

Figure 3. Nitrate concentrations detected in soil water collected from porous-cup samplers installed at 3.3 feet for the 1997 season. The top graph shows the data collected for the subplots receiving no manure.

After almost 10 years of Fall manure applications, slightly greater NO_3-N concentrations were detected in collected soil water at both depths during 1997 and 1998 in those subplots receiving manure. The exception to this trend is the slight erosion level at 1.6 feet during 1997 and at 3.3 feet during 1998. Inexplicably, greater NO_3-N concentrations were recorded in the slightly eroded subplots receiving no manure when compared to any other erosion-manure treatment combination. Detected NO_3-N concentrations at both depths and for most of 1997 and 1998 were greater than 10 ppm. However, these samples were not taken in groundwater, but it should be noted that the water table in this area has been reported at around 5 feet.

Unfortunately atrazine application was close in time to when a vacuum was first applied to the PCS for sampling. For this reason and also because of fast peak arrival times, a complete breakthrough curve was not recorded in 1997 at 1.6 m of depth (data not shown). However, it can be observed that greater atrazine concentrations were detected for slight and moderate erosion levels in the manured subplots when compared to the unmanured subplots. Peak arrival times for atrazine in 1997 at 3.3 feet appear to be around 50 days.

Soil water samples collected in 1998 revealed greater atrazine concentrations for the manured subplots at 1.6 ft (Figure 4). No peak was detected for the moderate erosion level with no manure. Peak arrival times at 1.6 feet for the manured subplots appear to be shorter than in the unmanured subplots by about 5 days.

Figure 4. Atrazine concentrations detected in soil water collected from porous-cup samplers installed at 1.6 feet for the 1998 season. The top graph shows the data collected for the subplots receiving no manure. Arrow displays the atrazine application day (May 22, 1998).

Atrazine concentrations at 3.3 feet for 1998 in subplots receiving manure decreased drastically when compared to water samples collected at 1.6 feet (Figure 5). In the subplots receiving no manure, atrazine concentrations were greater than in the manured subplots at 3.3 feet. This suggests greater atrazine decomposition or adsorption rates. In addition, atrazine concentrations at 3.3 feet in the unmanured subplots were greater than at 1.6 feet. Again, the greatest atrazine concentrations at 3.3 feet were detected in the severe erosion level in both manured and unmanured subplots. Peak arrival times at 3.3 feet in the subplots receiving no manure were approximately 10, 18, and 38 days for the slight, moderate and severe erosion levels, respectively. In the subplots receiving manure, the peak arrival time for the severe erosion level was about 38 days, similar to the unmanured severe erosion. No peaks were detected at 3.3 feet for the slight and moderate erosion levels in the manured subplots in 1998.

Figure 5. Atrazine concentrations detected in soil water collected from porous-cup samplers installed at 3.3 feet for the 1998 season. The top graph shows the data collected for the subplots receiving no manure. Arrow displays the atrazine application day (May 22, 1998).

Conclusions

Long-term manure applications are necessary to restore the crop productivity of an eroded soil. However, long-term cattle manure applications can impact the environment. In general, we have found in this study that greater NO_3-N concentrations were recorded in the soil solution in areas where manure was applied. In addition, it appears that atrazine can leach at a faster rate in manured soils. Nevertheless, it seems as if atrazine is degraded faster in manured areas, which can be a critical factor. It is important to notice that the observations described here are not universal, and that under different conditions, we can encounter different results.

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Table 2. Planting day, seeding, fertilizer, and manure rates since 1985 at the Lancaster Agricultural Research Station.

Agronomic practice	1988	1989	1990	1991	1992	1993 1994 1995 1996 1997 1998
Planting date	May 4	May 3	May 8	May 2	May 5	May 14 May 3 May 16 May 1 May 15 M

(seed/acre)							,78730,80031,98930,98932,000
Starter fertilizer †	250	200	200	200	200	200	

							1 4 5 1 4 5
(lb/acre)							
Anhydrous NH_4,	250	NA‡	200	200	200	160	
							1 6 0 1 6 0 1 8 0 1 6 0 1 6 0
no manure plots (lb/acre)							
Anhydrous NH_4,	NR §	NA	120	100	120	80	
							8 0

manure plots (lb/acre)							80
Manure loading rate (ton/acre)	3.3	4.8	7.4	12.2	22.5	NR	8.8 NA NR 5.3 5.8
Available N in	103	160	225	479	295	NR	114 N

manure (lb/acre)

† The N-P-K fertilizer used in 1988 through 1993 was 6-24-24; in 1994 through 1998, it was 8-31-17.

‡ NA = not available.

§ NR = not reported.