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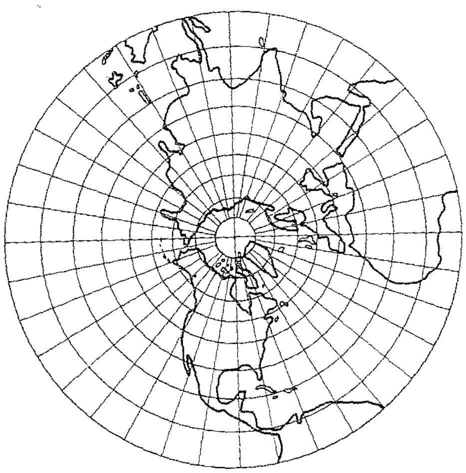

ABSTRACT

Determination of the source of sediment in rivers and streams is important in order to effectively implement a program to reduce its concentration. This project uses agricultural chemicals as indicators of current sources of sediment from farm fields in the Cedar River, Iowa watershed. We hypothesized that the relations of sediment, nitrogen, and phosphorous yields to precipitation would indicate whether sediment originated from erosion of fields or from channel bank erosion of floodplains. The changes in sediment, nitrate, and phosphorus in the channel in response to rainfall events were determined. In simple regressions, all three variables have similar slopes when regressed on seven-day precipitation sums. On the basis of the results of the regressions, it appears that, for the months used for this project, the major source of channel sediment is agricultural land.

KEW WORDS: nitrate, non-point source pollution, phosphorous, sediment, water quality.

INTRODUCTION

Agricultural non-point source pollution has a major impact on the stream ecosystems in agricultural areas worldwide, and sediment remains the major component (Clark *et al.* 1985). The determination of the inputs of sediment to rivers is important for the assessment of off-farm impacts of soil erosion and for the selection of the best means to reduce both on-farm and off-farm impacts. In the midwestern United States a widespread belief is that agricultural land is the major source of sediment input to streams and rivers due to the large area committed to growing crops. Today farmers are playing a major role in protecting their lands from erosion, and our waterways from non-point pollution. However, high concentrations of sediment persist and a possibility exists that another source of sediment, i.e. floodplains, possibly more important than agricultural land, may be to blame for current sediment levels.

Two major schools of thought debate the source of sediment in midwestern streams. The traditional view is that sediment from sheet erosion transported by runoff has been, and remains, the major source. The alternate theory is that the sediment comes in large part from stream bank erosion and mass wasting process.

Oulman and Lohnes (1985) reported that for three rivers in central Iowa bank erosion is of almost no importance and sheet and gully erosion are the major contributors to sediment yield. Distinguishing among agricultural sources, Wilkin and Hebel (1982) reported that cropped floodplain surfaces are important sources for sediment yield from the basin. Trimble and Knox (1984) objected to this study, and noted that in all of their observations in Iowa, Illinois, Minnesota and Wisconsin they found deposition, not erosion, on the floodplains because streams would not normally gain the tractive force necessary to entrain sediment in these areas because of their low gradients.

Odgaard (1987) estimated that bank erosion accounts for at least 45 percent of the sediment leaving Iowa through river transport. In Wisconsin, Trimble (1983) noted that sediment budgets vared by location within the basin, and he letermined that up to 50 percent of hisorically eroded sediment had gone into 'oodplain storage while less than 7 perent had left the basin. Because of dif›rences among basins and perhaps at ifferent places within basins the pro›sses and details of Trimble's (1983) odel are disputed (e.g., Knox 1987, 89; Trimble 1989), but the implicans are not. This floodplain storage of diment means that efforts by farmers reduce soil loss may not have a sigcant effect on water quality if stream ıveyance capacity is met by channel l bank erosion.

Ve hypothesize that the loading of ogen and phosphorous in runoff can) to distinguish between these two ment sources. The two fertilizers are different in the way that they react soil and water. The phosphorus is ily adsorbed by the soil particles, while nitrate is soluble in water, and nitrate undergoes denitrification, so the pathways for phosphorus and nitrogen are quite different. The most notable difference occurs in the riverine riparian zone. Extensive research has been conducted in how riparian areas may act as both surface and subsurface filters for agricultural chemicals and sediment (Malanson, 1993; e.g., Peterjohn and Correll, 1984). While most studies have emphasized the role of the riparian filter in terms of its location between upland sources and the river, retention of overbank flood waters also leads to filtering (e.g. Lowrance *et al.*, 1986; Hill and Shacklet, 1989; Phillips, 1989; Sanchez-Perez *et al.*, 1991). In general, phosphorus can be stored in riparian soils for long periods (Cooper and Gilliam 1987). Licht (1991) found high levels of phosphorus many feet deep in the riparian area, indicating that phosphorus has indeed been stored there for many years. Conversely, nitrogen undergoes denitrification in this area and is lost from the hydrological system.

The aim of this project is to determine the source of sediment based on the sediment and chemical levels found in the river channel. We assume that sediment and nutrients entering streams by either pathway will depend greatly on precipitation as a surrogate for the force moving them to the river. If the sediment is coming from the agricultural land, nitrogen, phosphorus, and sediment should be entering the stream together, so we would expect to find parallel relations between each of the three variables and precipitation (Fig. 1). If the source of sediment is from bank erosion, however, the relations of nitrogen to precipitation will not be parallel to those of phosphorous and sediment. Since phosphorus is being stored in the riparian area, and bonds with soil particles, it is reasonable to assume that sediment coming from either the riparian area or from fields will contain phosphorous. Nitrogen will accompany sediment originating in fields, but not sediment originating in floodplains.

We propose that regressions of these three dependent variables on precipita-

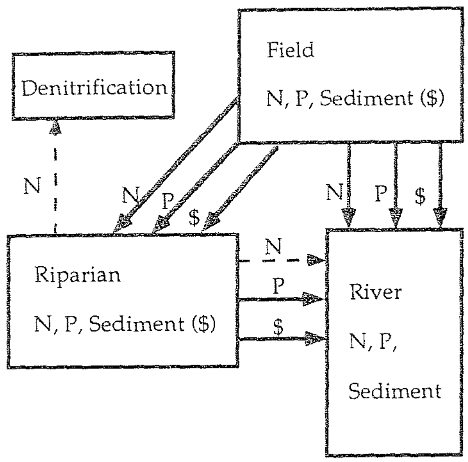

FIGURE 1. Hypothetical pathways of nitrogen (N), phosphorous (P), and sediment ($) from farm fields and riparian areas into Midwestern rivers.

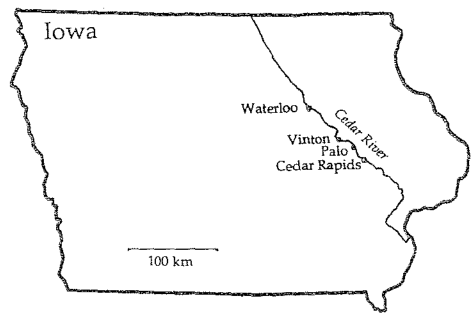

FIGURE 2. Location of the Cedar River, the water quality sampling site at Palo, the USGS gauge at Cedar Rapids, and the weather stations at Vinton and Waterloo.

tion will have the same slope if all are originating from field erosion, but, if the source is bank erosion, nitrogen regressed on precipitation will have a lower slope than the phosphorous or sediment regressions. Given that the slope of a regression depends on the units chosen, we propose these relations for the case where all measures are in the same units.

METHODS

The data used for this research project were comprised of sediment, nitrate, and phosphorus readings from the Cedar River near Palo, Iowa (Fig. 2), and daily rainfall data published by the U.S. Environmental Data Service. The sediment and chemical data were obtained from yearly reports published for the Iowa Electric Light and Power Company as part of the operation of Duane Arnold Nuclear Power Plant near Palo (e.g., McDonald 1991). Sampling and chemical analysis have been done twice per month since 1972. Data for the years 1979–1990 were available. The Cedar River drains predominantly agricultural land on calcareous glacial till and loess, and the alluvial sediment includes silt and clay in suspension and sand as bed load.

Since the major portion of yearly rainfall, farm chemical application, and sediment load occurs during the spring and early summer, data from April, May, and June for each year were used. Some data points were not available due to lack of data from one of the sources or to sampling problems or laboratory mishaps. These problems were infrequent, and most of the data were usable. Discharge is not measured at Palo, and values were taken from the USGS gauge at Cedar Rapids, 20 km downstream.

The amounts of sediment and chemicals present in the Cedar River in response to rainfall events were compared using simple regressions. The three variables of concentration, nitrate (mg/L-N), phosphorous (mg/L-P) and sediment (mg/L) were transformed into an absolute, value by multiplying them by the discharge for that day. These data were used to develop three relations by regressing these variables on precipitation.

The precipitation data were obtained from rainfall records (e.g., U.S. Environmental Data Service, 1990) from the Vinton and Waterloo recording stations (Fig. 2); by averaging these two stations we were able to represent the basin as well as possible given the lack of a denser network. We tried different periods of record to account for the time lag between the occurrence of precipitation and when surface runoff reaches a gauge; the

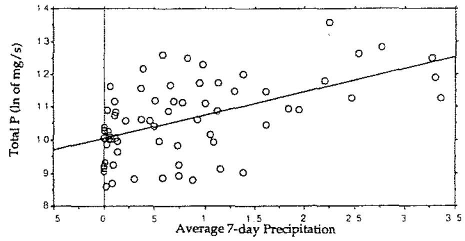

FIGURE 3. Phosphorous values regressed on precipitation (April 1–June 30, 1979–1990).

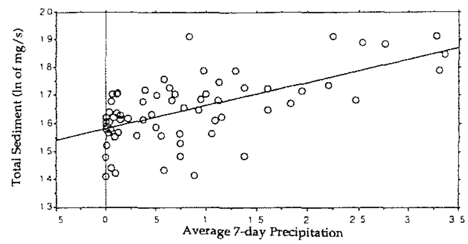

FIGURE 5. Sediment values regressed on precipitation (April 1–June 30, 1979–1990).

best statistical relations were obtained using the precipitation at the two stations for the seven days prior to the dates on which the river was sampled at Palo.

RESULTS

The data from the dependent variables were not normally distributed. Therefore the information was converted using the natural log, which resulted in a near normal distribution. The data for phosphorus yielded a slope of 0.708 (Fig. 3). The F ratio test for these data resulted in a value of 8.141 with a probability of $p = 0.0001$. These data reveal that the line fits the data well, and the amount of explained error is reasonable, with the adjusted $R^2 = 0.287$. Figure 4 shows that the slope of the line resulting from the nitrate data is 0.807. The F value was again significant at 5.236 with $p = 0.0017$. The adjusted R^2 value was a lower 0.128. Figure 5 reveals that the regression slope for the sediment data is 0.832. The value resulting from

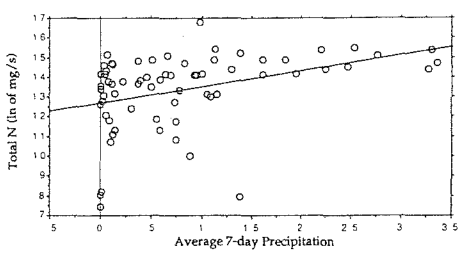

FIGURE 4. Nitrate values regressed on precipitation (April 1–June 30, 1979–1990).

the F test is very good, at 22.672 with $p = 0.0001$. Once again, the line fits the data well, and in this case the amount of explained error is much better, with the R^2 at 0.371. Although the results may appear to be influenced by four low outliers for nitrogen and by three influential points for high precipitation, the general conclusions are not changed by removal of either or both of these data.

The R^2 value is low for nitrate, but reasonably high for both phosphorous and sediment for this type of analysis. The remaining variance might be explained by the variability in the rainfall data due to the large area drained by the Cedar River, or by the introduction of the chemicals in question from point sources upstream from the sample point. Although much of the variance is unexplained, the results can be considered significant, and the regression equations can, therefore, be used to draw some inferences concerning processes. Because the slopes are almost identical, we did not have to interpret the degree of dissimilarity in the equations of nitrogen and phosphorous on one hand and sediment on the other.

DISCUSSION AND CONCLUSIONS

The three figures and the slope values show that the phosphorus, nitrate, and sediment concentrations rise in similar manners as the magnitude of rainfall increases. From these observations it is reasonable to conclude that the three variables are originating from the same source. As discussed above, if the source of sediment was stream bank erosion, the relation between the nitrate and precipitation should have differed from those of sediment and phosphorus due to denitrification in the riparian area. These results tend to support the premise that in this instance, runoff from the agricultural land is the main source of sediment in the channel.

The results are specific to the April to June time period. It is quite possible that the major source of sediment varies temporally between agricultural lands, during those periods when the ground is most vulnerable to erosion by rainfall, and from bank erosion during other parts of the year. This is another area of research that could be explored in more detail.

The significant regression equations indicate the feasibility of using farm chemicals as indicators of sediment origin in agricultural watersheds. This method perhaps will not become standard procedure in studying river sediment, but could be used in conjunction with other, more firmly established, procedures to accomplish the goals of the research. This procedure may be particularly useful when applied to lower order streams that receive runoff from agricultural lands more directly. In such a situation the variability of rainfall data could be more accurately accounted for, and any other possible upstream sources of chemicals could be eliminated.

The implications of these results are important. Whether further efforts should be spent on improving on-farm management practices or shifted to reducing channel erosion is an critical question for conservation efforts. The question of whether additional on-farm efforts would have any effect at all, supposing that any sediment conserved there would be replaced by sediment from earlier field erosion now in riparian storage, hinges on the supposition that current sediment yield originates in and along the channel. This study indicates that at least in the late spring, when a major portion of sediment yield occurs, fields may still be the most important source or sediment. Because further reductions in this source may still be compensated for by additional bank erosion, as indicated by Trimble's (1983) model, attention to both sources is still necessary.

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