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# Nitrogen and phosphorus in eroded sediment from corn and soybean tillage systems

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ABSTRACT Runoff, soil loss and sediment bound total Kjeldahl nitrogen (TKN) and Bray P-1 phosphorus losses from simulated rainfall were measured from five alternative corn and soybean tillage systems. Runoff and soil loss were influenced by contouring and tillage treatment. TKN concentration in the sediment was not greatly affected by tillage treatment and the average TKN enrichment ratio was 1.15. Bray P-1 concentration in the soil and eroded sediment was significantly reduced by inversion plowing, and concentrations in the eroded sediment tended to decrease as soil loss increased. Bray P-1 Enrichment ratios ranged from 1.7 to 4.5, and variations were not well correlated with soil loss.

## INTRODUCTION

Midwestern US cropland soils have been eroding at rates believed to be damaging to the productivity of the soils (National Research Council, 1986). Declining in water quality in the lower Mississippi, Ohio and Missouri Rivers has been linked to erosion from row crop agriculture (Smith et al., 1987). The Food Security Act and the Federal Water Pollution Control Act contain provisions which encourage farmers to reduce erosion to tolerable levels and reduce non-point discharges of pollutants from cropland, respectively.

In addition to erosion and water quality legislative measures, the changing economics and technology of agriculture has lead to the development and widespread adoption of reduced or "conservation" tillage systems (Gebhardt et al., 1985). Reduced tillage systems eliminate or reduce the use of the traditional moldboard plow which inverts the soil and exposes it to the forces of wind and water erosion. Research literature is nearly unanimous in the conclusion that reduced tillage systems reduce soil erosion by leaving crop residues on the soil surface, and/or by leaving the soil surface in a rough condition (Laflen et al., 1980, Cogo et al., 1984). However, water quality consequences of reduced tillage systems are not always favorable (Baker & Laflen, 1983).

Many studies have concluded that reduced tillage increases infiltration and thus increases the potential of leaching soluble chemicals to the groundwater (Baker, 1987). Also, when inversion tillage is eliminated, certain chemicals become concentrated at the soil surface which may lead to increased concentrations of chemicals in runoff and eroded sediment (Laflen & Tabatabai, 1984).

Additionally, as soil erosion is reduced, many researchers have observed that the eroded sediment is enriched with clay and adsorbed chemicals. McDowell & McGregor (1984) reported less soil loss and greater enrichment ratios (ratios of chemical concentration in the eroded sediment to that in the original soil) for conservation tillage systems, as compared with conventional tillage systems. Menzel (1980) reviewed the literature and presented the following equation for enrichment ratio as a function of soil loss:

$$\ln(ER)=2-0.2*\ln(sed) \quad (1)$$

where ER is the enrichment ratio and sed is the soil loss in kg/ha. According to this equation, as soil loss decreases, enrichment ratio and chemical concentrations in the sediment increase which may have important water quality and ecological consequences. Sharpley (1980) demonstrated that equation (1) was approximately applicable to small plots with erosion rates less than 2.3 t/ha. However, this equation is based upon a wide variety of land use practices and experimental methods, and Menzel cautioned that measured enrichment ratios for a single event may differ from that predicted by equation (1) by a factor of five.

The objective of this study was to compare the runoff, soil loss and total Kjeldahl nitrogen (TKN) and Bray P-1 phosphorus concentrations and losses in the eroded sediment from several alternative tillage systems for corn and soybeans in a moderately well drained soil in east central Illinois.

## MATERIALS AND METHODS

### The Soil

Field studies were conducted just south of Champaign, Illinois on a Catlin silt loam soil (fine silty, mesic typic Arguidolls) at slopes ranging from 3 to 5 percent. The Catlin is a dark colored prairie soil with 3 to 4 percent organic matter, 18 to 27 percent clay and moderate permeability (15-50 mm/hr).

### Tillage Systems

Four basic tillage systems were studied: 1) The Conventional system consisted of no tillage in the fall following soybean harvest, chisel plowing and two disk passes in the spring before planting corn, row cultivation one month after planting and moldboard plowing in the fall following corn harvest. Spring tillage prior to planting soybeans was two disk passes; soybeans were row cultivated one month after planting. 2) The Ridge-till system consisted of planting corn or soybeans into ridges formed the previous year, then row cultivating and reforming the ridges one month after planting. 3) The Strip-till system employed the Bushog Ro-till unit which uses fluted coulters, an 18 cm deep chisel and a rolling basket ahead of the planter, which places the seed into the chisel mark. This tillage system was tested with and without row cultivation and ridges. 4) The No-till system consisted of planting and the only other soil disturbance was that caused by injecting anhydrous ammonia.

The Conventional, Ridge and Strip-till treatments were evaluated during two years of a corn-soybean rotation. Measurements were taken from at least four plots of each treatment with rows oriented along the contour and four plots with rows oriented up-and-down the slope. The No-till system was evaluated only when corn was planted on the contour after soybeans.

Prior to our runoff studies, soybeans were grown over the entire study area and primary tillage was disking and field cultivation for two years. In 1985, replicate blocks for each tillage system were identified and ridges were formed at cultivation time for the ridge-till and strip-till with ridge systems. In the fall of 1985, 33 kg/ha of phosphorus was applied as granular fertilizer. In the spring of 1986, 220 kg/ha nitrogen was applied as anhydrous ammonia, tillage treatments were performed and corn was planted.

In the fall of 1986, 33 kg/ha of phosphorus was applied as granular fertilizer and the conventional tillage treatment was moldboard plowed. In the spring of 1987, appropriate tillage operations were performed and soybeans were planted.

## Rainfall Simulation

Rainfall simulations were conducted twice during the 1986 and 1987 growing seasons: Immediately after planting and one month later (after row cultivation and ridge formation of the specified treatments). Using a rotating boom rainfall simulator of the type described by Swanson (1965), simulated rain was applied to two plots simultaneously (each 3 m wide by 11 m long) at approximately 64 mm/hr for at least sixty minutes or until a constant rate of runoff was observed for ten minutes. Some tillage treatments required more than 60 minutes to produce a constant runoff rate. We present the runoff results only from the first 60 minutes in order to compare the tillage treatments under equal rainfall.

Before and after rainfall simulation, photographic slides were taken to determine the percent residue and canopy cover (McIsaac et al., 1987). Three soil samples from the top 5 cm of each plot were taken before and after rainfall simulation, stored at 10 deg. C and later analyzed for total Kjeldahl nitrogen and Bray P-1 phosphorus (Page et al., 1982). Water for the rainfall simulations was taken from the public water supply. Nitrogen and phosphorus concentrations in the applied water were measured and were insignificant.

During rainfall simulation events, runoff rates were measured volumetrically every three minutes. Runoff samples taken between rate measurements were later gravimetrically analyzed for sediment concentration. To determine the nitrogen and phosphorus concentrations in the sediment, at least two additional samples were taken: One approximately seven minutes after the initiation of runoff, and another after a constant rate of runoff was observed. These samples were stored at 10 deg C for several weeks until the chemical analyses could be conducted. The aqueous phase was decanted and the sediment was dried and analyzed for total Kjeldahl nitrogen and Bray P-1 phosphorus.

Soil erosion and nutrient loss were calculated by multiplying the runoff increment by the corresponding sediment and nutrient concentrations, respectively. Weighted average concentrations of nutrients were calculated by dividing the nutrient loss by soil loss for the 60 minute interval. Enrichment ratios were calculated for each plot by dividing the average nutrient concentration in the sediment by the average soil nutrient concentration.

Differences in runoff, soil and nutrient loss from the tillage treatments were determined by Duncan's Multiple Range Test at the 5 percent level of significance. Linear and non-linear regression procedures were used to identify relationships among measured variables (SAS Institute, 1985).

## RESULTS AND DISCUSSION

Runoff, soil loss, and N and P loss were significantly affected by crop, row orientation and, and tillage treatment (Table 1). Due to limitations of space, only the major effects and general trends significant to the transport of sediment bound N and P will be discussed in detail.

**Table 1** Runoff, soil, and nutrient loss from simulated rainfall

| Treatment | n | residue cover (%) | runoff (mm) | soil loss (t/ha) | TKN loss (kg N/ha) | Bray P-1 loss (kg P/ha) |
|---|---|---|---|---|---|---|
| ---corn planted up-and-down the slope, 1986--- | | | | | | |
| Conv. | 16 | 1.9 | 44.3 a | 5.77 a | 11.15 a | 1.19 ab |
| Ridge | 8 | 3.2 | 35.7 b | 5.54 a | 10.62 a | 1.06 abc |
| Strip | 8 | 3.3 | 42.2 ab | 5.89 a | 9.99 a | 1.35 a |
| Strip/r | 8 | 1.6 | 34.2 b | 4.89 a | 9.49 a | 0.97 bc |
| ---corn planted along the contour, 1986--- | | | | | | |
| Conv. | 8 | 2.8 | 15.2 cd | 1.53 bc | 2.54 bc | 0.31 d |
| Ridge | 8 | 4.8 | 10.5 de | 1.06 bc | 1.94 bc | 0.24 d |
| Strip | 8 | 5.2 | 18.1 c | 1.17 bc | 1.98 bc | 0.27 d |
| Strip/r | 8 | 2.3 | 6.4 e | 0.49 c | 0.92 c | 0.09 d |
| No-till | 12 | 10.1 | 40.2 ab | 2.52 b | 4.39 b | 0.66 c |
| ---soybeans planted up-and-down the slope, 1987--- | | | | | | |
| Conv. | 8 | 5.7 | 32.9 a | 5.35 a | 10.32 a | 0.41 bc |
| Ridge | 8 | 24.4 | 26.3 ab | 4.13 ab | 7.88 ab | 0.72 ab |
| Strip | 8 | 41.1 | 22.8 ab | 1.89 bc | 3.37 bc | 0.30 c |
| Strip/r | 8 | 18.3 | 21.8 ab | 5.43 a | 11.02 a | 0.81 a |
| ---soybeans planted along the contour, 1987--- | | | | | | |
| Conv. | 8 | 4.7 | 21.4 ab | 1.93 bc | 3.67 bc | 0.16 c |
| Ridge | 8 | 22.3 | 6.5 c | 0.87 c | 1.62 c | 0.12 c |
| Strip | 8 | 27.7 | 28.6 a | 1.57 c | 2.95 c | 0.32 c |
| Strip/r | 8 | 9.9 | 14.6 bc | 1.44 c | 2.79 c | 0.20 c |

Mean values within a column, within a year are not significantly different at the 0.05 level of significance if they are followed by any identical letters.

The greatest runoff was generally from the up-and-down slope tillage treatments. Likewise, soil and nutrient losses were greater from the up-and-down slope treatments. Contouring reduced runoff by retaining water behind ridges, tillage marks and depressions in the soil surface. However, runoff from the contoured No-till was as great as runoff from the up-and-down hill treatments because the No-till created these soil depressions only to a minor degree. The soil loss and TKN and Bray P losses from the no-till were significantly greater than those from the other contoured tillage treatments following soybeans in 1986. No-till following corn has yet to be tested.

Considering all treatments and crop stages, 98 percent of the variation in TKN loss (kg N/ha) could be explained by a linear equation with soil loss (t/ha) with a regression coefficient of 1.8 kg N/t and an intercept of zero. Thus, tillage practices which reduced soil loss proportionally reduced TKN loss. The constant slope and large coefficient of determination indicate that sediment TKN concentration was not greatly affected by the quantity of soil loss or tillage system used. The regression coefficient represents the average sediment TKN concentration. The average TKN concentration of the soil was 1.56 kg N/t which gives an average TKN enrichment ratio of 1.15. This value is slightly less than TKN enrichment ratios reported by McDowell & McGregor (1984) and Young et al. (1986).

Ninety two percent of the variation in Bray P-1 losses for all treatments that were not moldboard plowed could be described by a quadratic regression equation with soil loss (Figure 1). The linear regression coefficient represents the Bray P-1 concentration in the

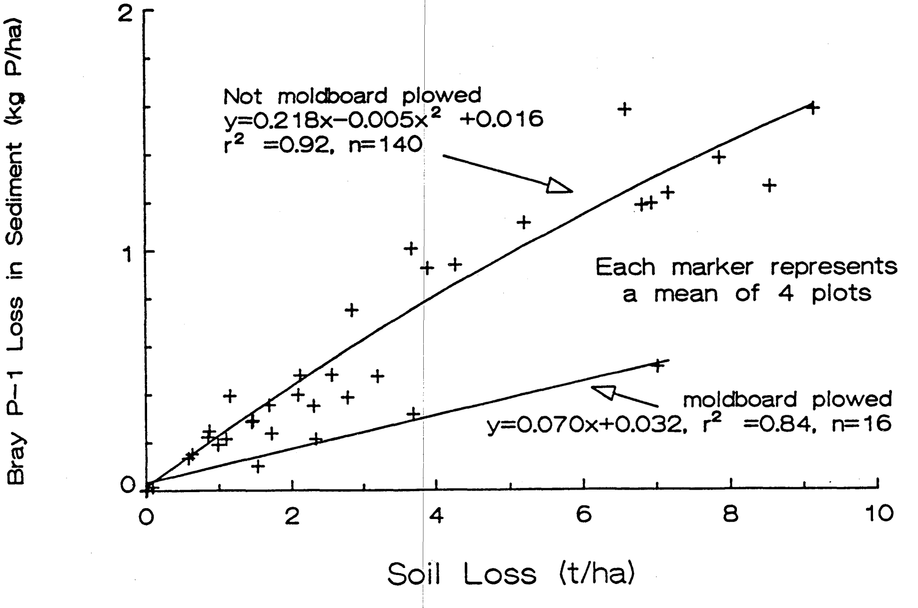


**Figure 1** Regression equations of Bray P-1 loss vs. soil loss.

sediment (0.218 kg P/t) at low soil losses. The negative quadratic regression coefficient indicates that the sediment P concentration decreased to 0.170 as soil loss increased to 10 t/ha. The average Bray P-1 measured in the soil was 0.072 kg P/t.

The concentration of Bray P-1 in the top 5 cm of soil of the moldboard plowed plots was 0.025 kg P/t, one third the concentration measured for all other treatments. Moldboard plowing apparently moved the fertilizer P deeper into the soil giving approximately one third the P concentration of the other treatments. Correspondingly, the linear regression coefficient of regression of Bray P-1 loss against soil loss for the moldboard plowed plots was 0.070 kg P/t, approximately one third of the linear regression coefficient for all other treatments (0.218 kg P/t). Thus, moldboard plowing reduced the concentrations of Bray P-1 in the eroded sediment.

Consequently, even though the soil loss from the up-and-down hill Conventional system was equal to soil loss from the Strip-till with ridge system in 1987, there was significantly less Bray P-1 loss from the Conventional tillage system than from the Strip-till with ridge system (Table 1).

In spite of significantly lower soil and sediment Bray P-1 concentration, the enrichment ratios for the conventional tillage treatment in 1987 were not markedly different than the other tillage treatments (Table 2). Greater enrichment ratios from the contour tillage treatments may be partially explained by lesser soil loss,

**Table 2** Bray P-1 enrichment ratios

| Treatment | ----Corn, 1986 ---- | | --Soybeans, 1987 -- | |
|---|---|---|---|---|
| | At Plant | At Cult. | At Plant | At Cult. |
| | ---tillage up-and-down the slope--- | | | |
| Conv. | 2.34 | 3.84 | 3.19 | 2.96 |
| Ridge | 1.92 | 4.08 | 2.68 | 2.73 |
| Strip | 3.02 | 3.13 | 2.46 | 2.17 |
| Strip/r | 2.41 | 3.43 | 1.69 | 2.11 |
| | ---tillage along the contour--- | | | |
| Conv. | 3.12 | 4.15 | 3.79 | 3.35 |
| Ridge | 2.76 | ------* | 2.89 | 2.86 |
| Strip | 2.89 | 3.99 | 2.77 | 2.89 |
| Strip/r | 3.00 | ------* | 3.05 | 2.99 |
| No-till | 3.43 | 3.51 | | |

* No runoff after 60 minutes of simulated rainfall

but only 10 percent of the variation in the Bray P-1 enrichment ratio could be explained by linear or non-linear regression with soil loss and average sediment concentration. For any tillage treatment, the greatest Bray P-1 enrichment ratio was at cultivation time during corn production in 1986, perhaps in part because soil loss tended to be lower at that time than at other times. Other causes of variation in enrichment ratio have not been identified.

When soil loss was greater than 6 t/ha, equation (1) over estimated TKN enrichment ratio (Figure 2). At any level of soil loss, equation (1) tended to under estimate Bray P-1 enrichment ratio, possibly because equation (1) was derived largely from total P and N enrichment ratios. Bray P-1 enrichment ratios are expected to be greater than total P enrichment ratios because Bray P-1 tends to be more concentrated in the more readily transportable clay particles (Logan, 1982). Massey & Johnson (1952) reported average enrichment ratios of Bray P-1 of 3.4 and presented an equation which predicted enrichment ratios slightly greater than equation (1), but less than the enrichment ratios measured in this study.

Much of the variation in enrichment ratios measured remains to be explained. Possibly, sediment transport models which incorporate sediment size distribution coupled with chemical concentrations of particle sizes may provide a better understanding of the variations in enrichment ratios.

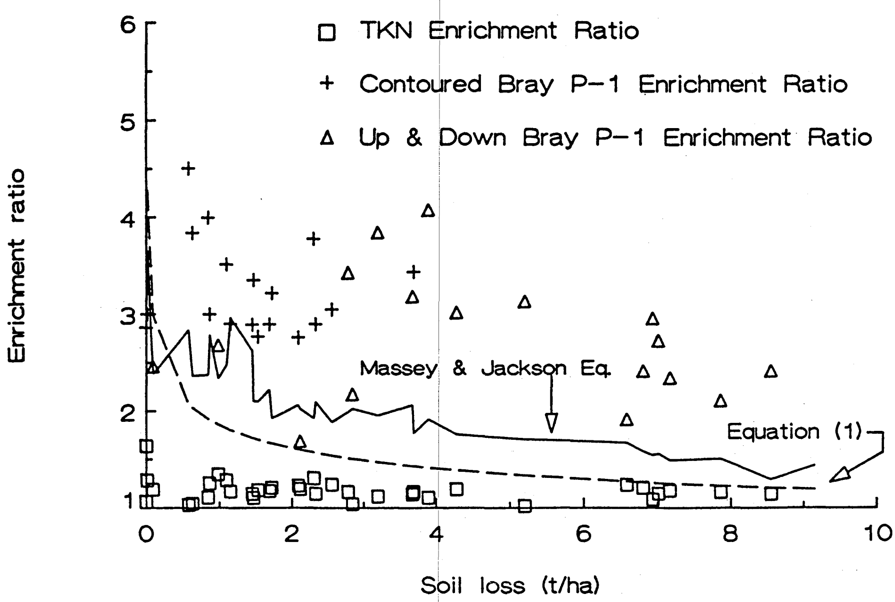


**Figure 2** TKN(+) and Bray P-1 enrichment ratios.

CONCLUSIONS

Tillage treatment and contouring significantly affected runoff, soil loss and nutrient loss. No-till following soybeans had significantly greater losses than other tillage treatments on the contour. Sediment bound TKN and Bray P-1 loss from alternative tillage treatments were well correlated with soil loss. The concentration of Bray P-1 in the soil and eroded sediment was significantly reduced by moldboard plowing. Enrichment ratios for TKN and Bray P-1 were less than and greater than, respectively, that predicted by equation (1), and were not well correlated with soil loss or sediment concentration.

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