Minnesota Pollution Control Agency

Regional Division

Feedlot Program

Runoff reductions with incorporated manure
- A Literature Review

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Introduction

The land application of manure has long been viewed to improve crop production and soil properties such as infiltration, aggregation, and bulk density due to the presence of nutrients and organic matter. It is generally accepted that the resulting soil properties from manure application can decrease runoff and soil erosion. In an effort to verify these claims and to quantify the reduction in runoff and soil loss, several manure application runoff studies have been completed in the United States, including Minnesota. This review provides a summary of these studies and the results.

Plot Descriptions

Gilley and Risse [2000] summarized the results of eight manure application studies from seven locations: Bethany, Missouri; Clarinda, Iowa; La Crosse, Wisconsin; Marlboro, New Jersey; Morris, Minnesota; Moscow, Idaho; and State College, Pennsylvania. The period of research for these studies varied from the 1930s to 1974. All of the research compared runoff quantity and soil loss from plots where manure was incorporated to control plots that did not receive manure. Manure was applied either annually or intermittently (every two to three years). Manure application rate varied from 5 to 20 tons/acre. Slopes ranged from 8 percent to 16 percent, with slope lengths of approximately 70 feet. Crop types, soils, and tillage varied from study to study. Crops included corn, hay, grain, vegetables, and fallow. Manure types included solid dairy manure and barnyard manure.

Ginting et al. [1998a, 1998b] examined the effect of a single 1992 application of solid beef manure upon runoff volume, sediment, and phosphorus loss from plots in Morris, Minnesota from 1992 to 1994. This study also researched the effect upon runoff of ridge tillage versus moldboard plow. Plots 72 feet long with a slope of 12 percent were planted with continuous corn and were cultivated with moldboard plow and ridge tillage parallel to the slope. Plots that were tilled with a moldboard plow resulted in a loose soil structure with less than 10 percent residue. Ridge till plots produced residue greater than 30 percent.

Many studies evaluated the application of solid manure, which typically includes livestock bedding such as straw. However, to see if runoff reductions also apply to liquid manure that does not contribute to surface residue, Gessel et al. [2004] evaluated the incorporation of liquid swine manure. The location of the study was Morris, Minnesota, using the same plots as Ginting et al. [1998a, 1998b]. This study included a seasonal analysis – spring (March, April, includes snowmelt) and summer (June, July, and August) – of runoff from a corn/soybean rotation from 1998 to 2001. Liquid swine manure was broadcast once each year in the fall and immediately incorporated using a chisel plow parallel to the slope. Manure was applied on different plots at 0 (control), ½, 1, and 2 times the recommended agronomic rate.

Daverede et al. [2004] performed a very detailed runoff study in Monmouth, Illinois from 1999 to 2001. This research examined the effects of annual application of surface-applied and injected liquid swine manure and incorporated triplesuperphosphate (TSP) fertilizer upon time-to-runoff, runoff

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volume, and runoff sediment and phosphorus concentration. Additional variables evaluated in the research were tillage, residue, manure application rate, and time-after-application. Manure was surface applied and row injected in the fall of 1999 and 2000 at rates of 21 tons/acre and 42 tons/acre. A rainfall simulator was used to simulate precipitation upon plots with a slope of 5.5 percent and a slope length of 29 feet. The study compared the effects of incorporated TSP and liquid swine manure to surface applied TSP and liquid swine manure, as well as the comparison of plots with manure and fertilizer application to no-till and chisel-plow control plots with no amendment. The control and TSP plowed plots were chisel plowed perpendicular to the slope.

Runoff Volume

The application and incorporation of manure results in a substantial reduction in measured runoff volume. The summary of research compiled by Gilley and Risse [2000] showed that for plots which received annual applications of manure, the runoff reduction was from 2 percent to 62 percent compared to plots that did not receive manure. At the Clarinda, Iowa site, the effect of doubling the manure application rate from 8 tons/acre to 16 tons/acre for 9 percent slopes 72 feet long was examined. Doubling the annual manure application rate further increased infiltration, so that runoff reductions jumped from 12 percent to 32 percent as compared to plots which did not receive manure. The Marlboro, New Jersey site was the only study examined by Gilley and Risse which researched the effect of slope length upon runoff volume and soil loss**.** Manure was applied to 4 percent slopes with lengths of 68 feet, 141 feet, and 210 feet and runoff volume was measured and compared to slopes with the same gradient and length which did not receive manure. The study showed that reductions in runoff volume were not significantly affected by increases in slope length, with reductions of 49 percent, 23 percent, and 38 percent in runoff volume for the three increasing slope lengths which received manure as compared to those slopes which did not receive manure. The study with the steepest slope that was included in the summary by Gilley and Risse is located in La Crosse, Wisconsin. Barnyard manure was applied at a rate of 8 tons/acre to cropped plots and 5 tons/acre to fallow plots with slope lengths of 72 feet and gradients of 16 percent. Measured reductions in runoff volumes were 8 percent for the cropped plots and 2 percent for the fallow plots as compared to plots which did not receive manure.

For plots in Morris, Minnesota, Ginting et al. [1998a] found that the application beef manure reduced runoff from plots that received manure as compared to plots that did not receive manure in both moldboard plow and ridge till systems. In the high rainfall years of 1993 and 1994, the ridge till and moldboard plow plots which received manure in 1992 were found to have 50 percent and 80 percent less runoff compared to counterpart plots which did not receive manure. The application of manure reduced runoff from plots with moldboard plow tillage for a rainfall event of 0.8 inches, but had little effect upon runoff for a rainfall event of four inches due to lack of surface residue. By contrast, the addition of manure to ridge till plots resulted in a reduction in runoff for the four-inch rainfall compared to the control plot which did not receive manure. There was little runoff for either the manured or non-manured plots for the ridge till system for the 0.8 inch storm. The ridge till plot had sufficient residue to store water for infiltration from the large storm event. The application of manure provided greater infiltration capacity to the soil.

A more recent study by Gessel et al. [2004] at the same Morris, Minnesota location found that summer runoff from plots which received liquid swine manure was less than that from plots which did not receive manure, with the greatest reduction occurring from the plots which received manure at twice the agronomic rates. This reduction may be due to increased canopy for plots with greater manure application rates, or due to changes in soil properties due to manure addition. Spring runoff during snowmelt conditions was comparable between manured and unmanured plots, with a net effect of a reduction in annual runoff for plots which received manure at 0.5 and 2 times the agronomic rates.

Time-to-runoff, as well as runoff volume, was measured by Daverede et al. [2004] for one month and six months after manure and phosphorus fertilizer (TSP) application. Time-to-runoff averaged one hour for incorporated TSP and injected manure, as compared to an average time–to–runoff of nine minutes for surface applied amendments for a rainfall simulation one month after application. The chisel plowed control plot had the longest time to runoff of 129 minutes, while the injected high manure application

rate (HM) plot resulted in a time to runoff of 82 minutes. The injected low manure application rate (LM) plot had a time-to-runoff of 114 minutes. This order reversed after six months, with the HM plot having the longest time to runoff of 47 minutes, and the chisel plow incorporated TSP plot having a time-to-runoff of 27 minutes – comparable to the HM surface applied manure plot time-to-runoff. Correspondingly, the runoff volume after one month of application for the incorporated and injected amendments was 79 percent less than the surface applied amendments. After six months, the plots which received incorporated and injected amendments had 38 percent less runoff volume than the surface applied plots. This study also showed the importance of reduced tillage when attempting to increase infiltration.

Gilley and Risse [2000] summarized the compiled research on the reduction in runoff volume due to manure application as compared to tilled plots which did not receive manure by development of an equation which relates the manure application rate in Mg/hectare to the reduction in runoff from a field which has received incorporated manure:

$$\text{Runoff Reduction} = 0.0123\left(\text{Manure Application Rate}\right)$$

This equation is based upon data from sites which received an annual application of manure to slopes with lengths of 69 to 79 feet. The equations are valid for application rates from 11 to 45 Mg/hectare (5 to 20 tons/acre). The monitoring results summarized in the above equation included a variety of soil types; precipitation volumes, durations, and intensities. It is important to note that for all of the sites, the runoff and erosion was less for the plots to which manure was applied as compared to plots to which no manure was applied.

Soil Loss

The effects of manure application upon soil erosion are influenced by the time required for the organic matter to become incorporated in the soil and subsequently impact the soil properties [Chandra and De, 1982]. The summary of research compiled by Gilley and Risse [2000] showed that for plots receiving annual applications of manure, the soil loss reduction was from 15 percent to 65 percent compared to plots which did not receive manure. At the Clarinda, Iowa site, the effect of doubling the manure application rate increased the reduction in soil loss from 21 percent to 37 percent as compared to plots which did not receive manure. At the Marlboro, New Jersey, site, the increase in slope length caused a consistent decrease in the reduction in soil loss from plots that received manure as compared to plots that did not receive manure, with soil loss reductions of 65 percent, 30 percent, and 17 percent for slope lengths of 68 feet, 141 feet, and 210 feet, respectively. The reduction in soil loss for the 16 percent slope in La Crosse, Wisconsin was found to be 15 percent for manure applied annually to a fallow plot and 27 percent for a cropped plot.

Ginting et al. [1998a] found that runoff sediment loads were greater from plots to which manure was not applied as compared to plots to which manure was applied. As compared to plots that did not receive manure, a one-time application of manure in 1992 reduced annual soil loss by 67 percent in 1993, with negligible reductions in 1994. In comparing plots that received manure that were subject to moldboard plow versus ridge tillage, the soil loss from moldboard plow plots was 53 times larger in 1993, and 12 times larger in 1994.

The seasonal analysis of Gessel et al. [2004] found that soil loss in runoff occurred predominately in the summer. The quantity of total solids in runoff was greatest in plots which received manure at 1/2 of the agronomic rate. However, a significant reduction was seen in plots that received manure at twice the agronomic rates as compared to the unmanured control plot. The fall-applied manure did not show soil loss reductions during periods of spring runoff over frozen soil conditions.

Daverede et al [2004] studied the effect of both injected manure and incorporated TSP fertilizer versus surface applied amendments and unfertilized control plots. The research illustrated that runoff sediment concentration was highest for the chisel plowed control plot that did not receive amendment and the incorporated TSP fertilizer plots. The injected low rate (LM) and high rate (HM) liquid manure plots had runoff sediment concentrations 34 percent and 56 percent less than the chisel plowed plots that did not receive manure. However, all no-till plots had lower soil losses compared to tilled plots, irregardless of the manure applications. The no-till plots that received

surface applied amendments had a residue of 92 percent, while the chisel plow plots had a surface residue of 37 percent, and the plots that received injected manure had a surface residue of 61 percent. The surface applied TSP and manure plots had lower runoff sediment concentrations than the untilled control plot, with the surface applied HM plot having the lowest concentrations.

Gilley and Risse [2000] summarized the compiled research on the reduction in soil loss due to manure application as compared to tilled plots which did not receive manure by development of the following equation which relates the manure application rate in Mg/hectare to the reduction in soil loss for fields that have incorporated manure.

$$\text{Soil Loss Reduction} = 0.0120(\text{Manure Application Rate})$$

The same caveats that apply to the runoff reduction equation given above also apply to the soil loss reduction equation.

Phosphorus

Ginting et al. [1998b] also examined the effect the incorporation of beef manure upon runoff phosphorus concentrations from plots in Morris, Minnesota. The annual loss of total phosphorus and particulate phosphorus from plots which received manure was either similar or lower than plots that did not receive manure or other phosphorus amendments. Precipitation-driven runoff from plots that received manure had lower particulate phosphorus, slightly higher soluble reactive phosphorus, and, resultantly, lower total phosphorus than plots that did not receive manure. Under normal rainfall events, the runoff total phosphorus loadings from plots that received manure was less than plots that did not incorporate manure. The loadings of dissolved reactive phosphorus from ridge till systems were higher for those plots that received manure than for the plots that did not receive manure. This was due to the accumulation of phosphorus near the soil surface for manured ridge-tilled plots. This condition did not hold true for moldboard plow plots that received manure, where runoff dissolved reactive phosphorus concentrations were similar between plots which received manure and which did not receive manure.

For particulate phosphorus, the annual loss from ridge till systems was less than that from moldboard plow systems. These results correspond to results obtained for runoff sediment loads. Runoff from plots subject to ridge tillage had lower total phosphorus loadings than plots that were tilled by moldboard plow, which illustrates that the higher dissolved reactive phosphorus loadings from ridge-tilled systems as compared to moldboard plowed systems is offset by lower particulate phosphorus loadings.

Gessel et al. [2004] also studied phosphorus loadings due to liquid swine manure applications onto the same plots in Morris, Minnesota as Ginting et al. Annual runoff total phosphorus loads were similar for the control plots that did not receive manure or commercial fertilizer phosphorus, and the plots that received manure at various application rates. Dissolved phosphorus runoff loadings were constant for the various manure application rates during the summer season. However, during the spring snowmelt period when runoff is controlled by frost depth, dissolved phosphorus loadings were four times greater from the plots that received manure at twice the agronomic rate as compared to plots that received no manure or manure at ½ the agronomic rate. Annual total phosphorus levels are similar to plots that did not receive manure due to the reduced erosion and consequently lower particulate phosphorus loss during the summer for plots that received manure.

The research completed by Daverede et al. [2004] found that for one month after manure application, runoff total phosphorus concentration and loads from plots to which swine manure was injected did not differ from plots to which no manure was applied. For plots that received surface-applied TSP fertilizer and liquid swine manure, high dissolved reactive phosphorus and total phosphorus runoff loads were found to exist as compared to the unamended control plot one month after amendment application. In comparison of injected plots versus plots with surface applied swine manure with no tillage, the soil injection of swine manure resulted in a 93 percent reduction in the runoff concentration of dissolved reactive phosphorus, a 99 percent reduction in dissolved reactive phosphorus load, an 82 percent reduction in total phosphorus concentration, and a 94 percent reduction in total phosphorus load. However, soil extractable phosphorus levels were higher in injected plots that received higher manure application rates. A linear

relationship was found to exist between the Bray P1 soil extraction value and runoff dissolved reactive phosphorus concentrations from injected swine manure plots. For this reason, the study recommends that Bray P1 soil extraction levels should be maintained below 100 mg/kg at the 0 to 2.5cm depth. Also, to reduce potential particulate phosphorus loadings, the study concluded that erosion control is the main target for agricultural soils where nutrients have been applied.

Conclusions

It is important to remember that each study had specific soil, crop, climatic, tillage, residue, slope, and slope length conditions. All of the studies found that, compared to tilled plots that did not receive manure, the incorporation of manure into soil can significantly reduce runoff volume and soil loss and does not increase runoff phosphorus levels on an annual basis. It was clearly demonstrated that it is necessary to incorporate manure to prevent the direct surface runoff of solids and phosphorus. However, plots that incorporate manure through tillage have higher soil loss than untilled control plots. Therefore, it is important to perform incorporation in such a manner as to maintain surface residue through such minimum tillage methods as knifing or injection. Repeated manure applications can result in an increase in soil phosphorus levels. This increase can cause increases in dissolved reactive phosphorus concentrations in surface runoff, especially during late winter and early spring runoff. Therefore, preventing soil phosphorus accumulations will also serve to minimize phosphorus in runoff.

For more information

For more information, contact Dave Wall at 651-296-8440, or Nick Gervino at 651-296-8847. Information on the MPCA feedlot program can be found on the Web at: http://www.pca.state.mn.us/hot/feedlots.html

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