Water Quality Runoff and the South Tobacco Creek

David Green, Water Quality Management, Manitoba Conservation

Background

A three-year study was conducted in the South Tobacco Creek Watershed from the fall of 1997 to 2000 to gain a better understanding of differences in quality of runoff from fields treated with inorganic commercial fertilizers during the spring seeding period to a field treated with an organic fertilizer (hog manure) the preceding fall. Relatively rapid expansion of the hog industry in Manitoba in recent years and subsequent increase in manure application to land created public concern about potential impacts to ground and surface waters. A key question was whether a common practice used in many agricultural operations such as fall application of hog manure by broadcast spreading and incorporation provides adequate protection against excessive bacteria and nutrient loss in surface runoff events.

The study was undertaken with the collaboration of producers in the watershed and agencies that included Manitoba Conservation, Environment Canada, Manitoba Agriculture, Prairie Farm Rehabilitation Administration, and Manitoba Pork Est. The South Tobacco Creek Watershed was considered a good starting point because some infrastructure and other projects that were of benefit to this study were already established.

Water quality comparisons were made between fecal coliform bacteria, nutrient (phosphorus and nitrogen), organic carbon, and suspended solid concentrations in runoff water leaving fields. Discussion in this presentation focused on the key variables of fecal coliform bacteria, nitrogen and phosphorus.

Project area

The study locations occur within the South Tobacco Creek Watershed on the Manitoba Escarpment just west of the community of Miami in southern Manitoba, Canada (Figure 1). Organic (hog manure) and inorganic commercial fertilizer were applied to the Manured Watershed and Twin Watershed sites, respectively. Background data was also collected from two sites that drained a natural wooded area and a forage field on the Escarpment near the headwaters of the South Tobacco Creek (Figure 1).

The Manured Watershed study unit occurs at approximately 98°22’13” longitude, 49°23’55” latitude (NE17-5-7W) and drains into the North Arm of South Tobacco Creek. The drainage area of the Manured Watershed study field is approximately 0.892 ha (2.2 acres) with an approximate slope of 1.3%. The Twin Watershed monitoring sites are located on one of the feeder tributaries of the South Arm at approximately 98°21’45” longitude, 49°20’24” latitude (NE29-4-7W). The study site is separated into two sub-watershed units referred to as the Conventional-till field and Zero-till field.

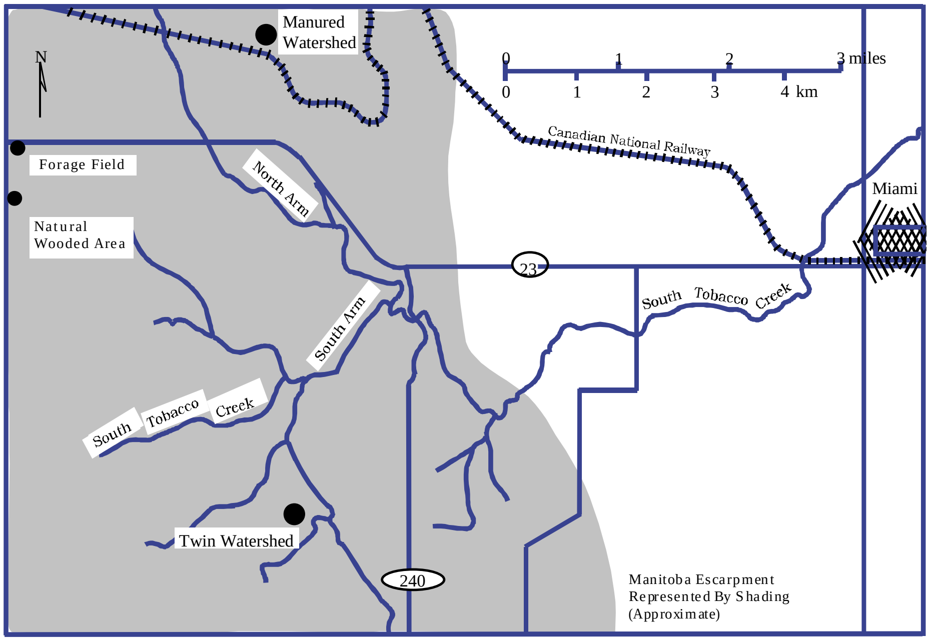

Figure 1. Study locations within the South Tobacco Creek Watershed.

The Conventional-till field is approximately 4.24 ha (10.5 acres), while the Zero-till field is approximately 5.64 ha (13.9 acres). Slopes of the field units average approximately 2%.

V-notch weirs designed to capture all runoff leaving the field and automatic water samplers were located at the drainage outlet passage of the Manured field and each Twin Watershed field unit. Grab water samples were also periodically collected at weir locations, especially if runoff flows were not sufficient to trip the automated samplers.

The intent of this study was to gain information on the field scale utilizing methods commonly used by producers. Inorganic commercial fertilizer applications were usually applied to the Twin Watershed sites during the spring crop-seeding season after the spring runoff period. However, commercial anhydrous ammonia inorganic fertilizer was also applied one fall to the Twin Watershed conventional-till field. Organic fertilizer (hog manure) applications on the Manured Watershed site occurred in fall. Hog manure was applied by broadcast spreading and incorporated by deep tillage and harrowing within approximately 48 to 72 hours. Soils samples were collected from each of the fields during the fall. Nutrient analysis of manure was done to determine the application rates for the Manured Watershed field.

Overview

Presented information is mainly from the 1998 and 1999 runoff period since these were the only years with adequate amounts of runoff for collecting water samples and obtaining flow/volume measurements. There was not any measurable runoff from the Manured Watershed or Twin Watershed conventional-till fields during spring 2000. Measurable runoff from the Twin Watershed zero-till field during 2000 was less than half of what occurred in 1998. Runoff volumes from the Manured Watershed field were also very low (1% or less) compared to Twin Watershed fields during 1999.

Fecal coliform bacteria contamination from fall application of hog manure was found not to be any more of a concern during spring runoff than from other areas with no manure applications. Mean values from the Manured Watershed field were well under the guideline value of 200 organisms/100 mL for primary recreational activities involving skin contact or body immersion in water. They were also within ranges of values from the natural wooded area, forage field or fields fertilized with commercial inorganic fertilizers (Fig 2). Exposure to sunlight and other elements from the fall to spring period appeared adequate to reduce most fecal coliform counts to very low values.

There was considerable variability between runoff nutrient concentrations of the Manured Watershed field and Twin Watershed fields and between years. Reasons for the variability are not fully known but were considered to be due to several factors. These would include differences in soil nutrient values, variations in runoff volumes as well as other non quantified factors such as soil microbial and other process activities that can be affected by soil pH, temperature and moisture content.

Mean total nitrogen concentrations from the Manure Watershed field during spring 1998 were fairly high (18.4 mg/L) compared to the other sites (<3.0 mg/L; Figure 3). This was considered to be mainly due to the much higher soil nitrogen values in the top 15 cm (146 kg/ha) in the Manured Watershed field compared to the Twin Watershed fields (11-13 kg/ha). Although nitrogen values in the top 15 cm of soil in the Manured Watershed field were similar in the falls preceding spring melt in 1998 and 1999, the mean nitrogen concentration during spring runoff 1999 (4.5 mg/L) was only about one-quarter that of 1998 (Figure 3). The reason for this is not fully known other than the runoff volume from the Manured Watershed field in 1999 was <2% of that in 1998. Although it could be expected that a reduced volume of snowmelt would cause an increase in concentrations due to less dilution factor, this much lower volume may have actually reduced the pickup and transport of nutrients from soils. This would be especially true for runoff that would normally travel from further reaches of the field and accumulate nutrients as it traveled towards the weir.

The Twin Watershed conventional-till field applied with inorganic commercial fertilizer in the fall of 1998 was also found to have increased nitrogen concentrations occur during spring runoff. During spring 1999, the mean nitrogen concentration (16.4 mg/L) from the Twin Watershed conventional-till field was almost as high as what occurred from the Manured Watershed field the previous year (Figure 3). This value was attributed to the fall application of anhydrous ammonia fertilizer (approximately 67 kg/ha).

The mean total nitrogen concentration from the Twin Watershed zero-till field during spring 2000 was the same (6.2 mg/L) as in 1999. These values were more than double the mean concentration in 1998 (Figure 3). It was not clear what caused these higher concentrations in the spring of 1999 and 2000. It did not appear to be only related to soil residual values. For example, fall soil residual values in the top 15 cm preceding spring runoff 1998 and 2000 were 11 and 13 kg/ha, respectively, yet the nitrogen concentration in the 1998 spring runoff was half that of 2000. The fall soil value preceding spring runoff 1999 was only 2.4 kg/ha and the nitrogen value in this spring runoff was the same as in 2000. This relationship also existed down to 60 cm. Nutrient concentrations may have also been increased due to breakdown of organic plant matter left on the zero-till field. This would mean more "trash" (crop straw) was left on the zero-till field during the fall of 1998 and 1999 or conditions for breakdown were better than in fall 1997. Crop type or straw management practices between the fall of 1997 and 1998 alone did not seem to account for the differences in nitrogen concentrations during the following spring runoff period since the crop grown on this field in 1997 and 1998 was flax. As well, the straw was baled in both years. During the fall of 1999, "trash" was probably more available since the wheat straw was chopped onto the field during harvest. This may have helped increase spring runoff concentrations somewhat in that year.

Runoff volumes from the Twin Watershed zero-till field during 1999 and 2000 were about 40 – 60% of what occurred in spring 1998. These lower volumes may have also increased nutrient concentrations somewhat. This is contrary to what was suggested may have caused reduced nitrogen concentrations in the Manured Watershed field during 1999. However, compared to the Manured Watershed field situation, there was still about 330 – 460 m^3/ha of runoff from the Twin Watershed zero-till field that could pick up, transport and accumulate nutrients from a greater surface area. This compared to only about 8 m^3/ha from the Manured Watershed field during 1999, and field observations indicated this amount probably only reflected runoff from close proximity to the weir.

Mean concentrations of total nitrogen from the natural wooded area and forage field were <3.5 mg/L, and concentrations in corresponding years were lower than for runoff from the fertilized fields (Figure 3).

Mean total phosphorus concentrations were higher from the Manured Watershed field than either Twin Watershed field during spring runoff 1998 and 1999. Similar to nitrogen, the mean value from the Manured Watershed field (2.26 mg/L) was more than four times higher than either Twin Watershed field during spring 1998 (Figure 4). This higher value from the Manured Watershed field than Twin Watershed fields was attributed to the much higher phosphorus content in the top 15 cm of soil from the previous fall. The mean phosphorus value in runoff from the Manured Watershed field during 1999 (1.27 mg/L) was also lower than in 1998. This occurred despite soil phosphorus values (including manure-added phosphorus) in the top 15 cm actually being higher during the fall 1998 (127 kg/ha) compared to the fall 1997 (94 kg/ha). As with nitrogen, lower mean values from this field in 1999 were probably due to the very low runoff volumes compared to 1998.

Mean phosphorus concentrations from the natural wooded area were comparatively low (0.09 and 0.24 mg/L in 1999 and 1998, respectively). Mean phosphorus concentrations from the forage field were also very low in 1998 (0.08 mg/L; Figure 4). However, during 1999 the mean phosphorus concentration from the forage field and Manured Watershed field were very similar at about 1.3 mg/L. The mean phosphorus value from the forage field in spring 2000 was also approximately 1.34 mg/L. The mean value (1.51 m/L) from the Twin Watershed zero-till field in spring 2000 was about 85% higher than what occurred in 1999 (0.81 mg/L; Figure 4). As with nitrogen, an increased phosphorus value from the zero-till field during spring 2000 may be partially due to more organic matter (straw) left on the field the previous fall.

Concentrations of nutrients provide an indication of losses from fields but they can also sometimes be misleading, especially when runoff volumes vary considerably between different sites and field sizes are different. In order to compensate for some of these differences, nutrient losses per unit area (areal loss in kg/ha) were calculated. The estimated total nitrogen (7.50 kg) and total phosphorus (1.09 kg) losses from the Manured Watershed field in 1998 were in the ranges of total nitrogen (7.51 – 9.68 kg) and total phosphorus (0.96 – 2.03 kg) losses found from the Twin Watershed fields despite being only about one-quarter the size. Compensating for the smaller field size indicated that areal loss of nitrogen from the Manured Watershed field in 1998 was actually about 8.63 kg/ha compared to only about 1.72 – 1.77 kg/ha from the Twin Watershed fields (Figure 5). Phosphorus loss was also greater from the Manured Watershed field (1.25 kg/ha) compared to only 0.23 – 0.36 kg/ha from the Twin Watershed fields. However, areal loss of nitrogen (0.011 kg/ha) and phosphorus (0.007 kg/ha) from the Manured Watershed field during 1999 was <1% of that found in 1998. Again, the very low runoff volume during spring 1999 (7.75 m^3) was considered a key factor for such low nutrient values since it was <2% of what occurred in 1998 (428 m^3). As noted previously, very low runoff probably reduced the opportunity for nutrient pickup, accumulation and transport off field since nitrogen values in the top 15 cm of soil during fall prior to 1998 and 1999 were fairly similar at about 146 kg/ha to 157 kg/ha, respectively.

Application rates to the Manured Watershed field were higher than intended and exceeded recommended guidelines in the top 60 cm profile for the type of soils and crops grown. Provided runoff volumes were low enough, it would appear concentrations of nutrients from the Manured Watershed field could remain within ranges found from a non-fertilized forage field and from a zero-tilled field that receives inorganic commercial fertilizer. However, if runoff volumes were high enough during spring thaw, it would appear that addition of nutrients to soils in excess of requirements become fairly mobile and may cause much greater nutrient loss than from non-manured areas.

There were a few rainfall events of sufficient size in the 1999 and 2000 growing season to determine nutrient concentration loading rates. Nutrient loads from precipitation events were usually lower or at least within the daily ranges observed during spring runoff. Since there were fewer days of runoff compared to spring, overall loading from these events during the growing season also tended to be lower than in spring. An exception occurred for one event from the Twin Watershed conventional-till field during May 1999. This event was actually large enough (500 m^3 of runoff in one day with a phosphorus concentration greater than in spring runoff) to produce a phosphorus load (0.436 kg) greater than the whole spring load (0.318 kg).

Fall residual soil nitrogen values for all fields were variable between 1997 to 2000 and did not show a consistent increasing or decreasing trend. Soil nitrogen values for the Manured Watershed field were highest in the fall of 1997 and 2000 with relatively equal but lower values in the fall of 1998 and 1999 (Figure 6). Residual soil nitrogen values for the Twin Watershed fields were considerably lower than the Manured Watershed field in fall and also fluctuated between years (Figure 7). Likewise, soil phosphorus values from the Twin Watershed fields were varied with no visible trend (Figure 8). There was, however, an apparent slightly increasing trend in phosphorus soil values from the Manured Watershed field between 1997 - 2000. Consecutive annual applications of hog manure to this field in this time period appeared to cause a slight increase in soil total phosphorus, especially in the top 15 cm (Figure 9). Variations in nutrient values between years will depend upon crop uptake as well as other factors. Since application rates are usually based upon nitrogen requirements, phosphorus additions greater than the crop needs will probably occur from manure applications. The extent of these additions may vary from one operation to the next. Phosphorus additions through inorganic fertilizer can usually be better controlled since only the needed amount can be determined and added.

Analyses of manure prior to spreading also showed variability in the content of nutrients between years. The first two years of analyses indicated total nitrogen values were fairly similar at 1.95 to 2.3 kg/1000 L, respectively (Figure 10). Total manure nitrogen values were about 40% less (1.2 kg/1000 L) in fall 1999 and more than double (4.8 kg/1000 L) in fall 2000. Total phosphorus in manure samples appeared slightly more consistent for the first three years (0.41, 0.53, and 0.40 kg/1000 L), but also was more than double in the fall of 2000 (1.06 kg/1000L; Figure 10). It is often considered that the manure content from a hog operation can be relatively consistent provided operational procedures remain consistent. The higher concentration in 2000 may be caused by manure not being fully agitated in the storage prior to spreading and the batch of manure for this application happened to have higher concentrations. The results do show though, that nutrient content of manure from a single operation may vary between years and this should be considered when spreading to fields. Simply assuming a nutrient content based upon past operation history may provide an under- or over-estimate of the manure requirements for appropriate application rate needs.

Conclusions

- Fecal coliform contamination did not appear to be any greater in spring runoff from fall application and incorporation of hog manure than what occurred from other sites that had no applied hog manure.
- Application of an organic (hog manure) fertilizer in fall appeared to provide greater opportunity for nutrient loss in spring runoff than fields applied with fertilizers after spring runoff.
- Application of an inorganic nitrogen commercial fertilizer in fall also appeared to provide more opportunity for nitrogen loss in the following spring runoff than for fertilizer applied after spring runoff.
- It could not be determined if manure applied in the fall at recommended rates caused excessive nutrient loss in spring runoff compared to non-manure applied areas since application rates to the Manured Watershed field exceeded recommended guidelines. Provided runoff volumes are sufficient, however, applications above the recommended guidelines did cause excess nutrients to be transported off field.
- Per unit area of nitrogen and phosphorus loading from the Manured Watershed field during 1998 was about four times higher than from the Twin Watershed fields. Higher than recommended application rates to the Manured Watershed field was considered to be a major factor causing these results.
- Runoff volumes from field sites appeared to influence nutrient concentrations in spring runoff water. A very low runoff volume from the Manured Watershed field in 1999 produced fairly low nutrient concentrations in runoff despite relatively similar soil nutrient values in the top 15 cm of soil for the 1998 and 1999 spring runoff years. It was beyond the scope of this study to be able to determine what threshold volume of runoff from the Manured Watershed field would cause greater nutrient loss than from the other fields.
- Mean nitrogen and phosphorus concentrations in spring runoff from the natural wooded area were relatively low compared to other sites.
- Nutrient loads leaving fields due to rainfall events occurring in the growing season were usually lower than the spring runoff nutrient load. One exception occurred with a phosphorus load from a single and fairly significant rainfall event at the Twin Watershed conventional-till field in 1999. This event produced as much phosphorus load from this field as what occurred during the entire spring runoff period in that year.
- Consecutive annual manure applications to fields appear to cause gradual accumulations of phosphorus in soil.

Considerations for future study work

- Continued study on broadcast spreading and incorporation in fall and keeping fertilization rates within recommended guideline values.
- Spring soil testing after fall application of fertilizers to estimate loss during the spring runoff.
- Evaluating broadcast spreading and incorporation of hog manure in spring following spring runoff period instead of fall application.
- Evaluating injection of hog manure in fall and subsequent spring runoff losses.

- Weir infrastructure setup on non-cultivated sites such as natural wooded area and forage field to determine loading rates for comparisons with tilled and fertilized land.

Acknowledgements

This project could not have been done without the valued cooperation and assistance of local producers in South Tobacco Creek Watershed, the Deerwood Soil & Water Management Association, Environment Canada, Prairie Farm and Rehabilitation Administration, Manitoba Agriculture, and Manitoba Pork Est. The efforts of Bill Turner and Loni Scott at collecting hog manure samples in windy conditions are especially appreciated!!

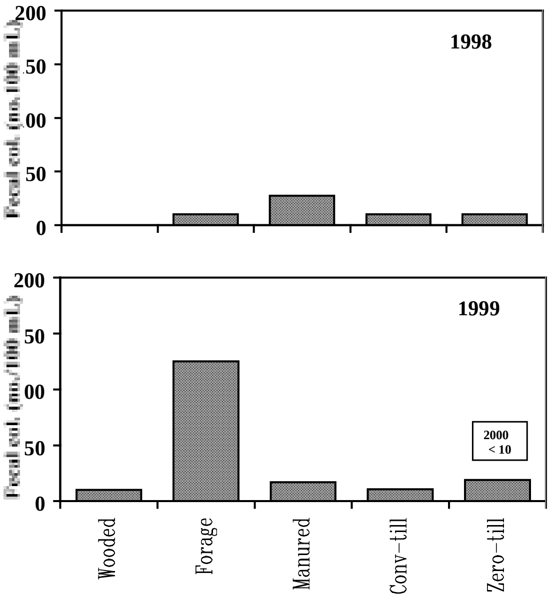

Figure 2. Fecal Coliform counts.

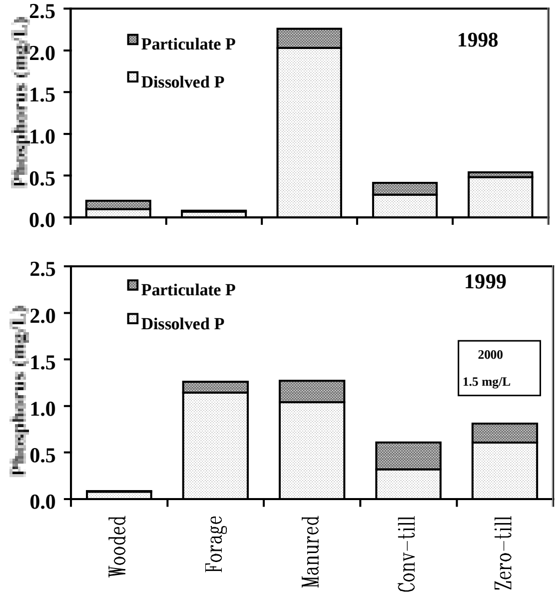

Figure 4. Total Phosphorus concentrations.

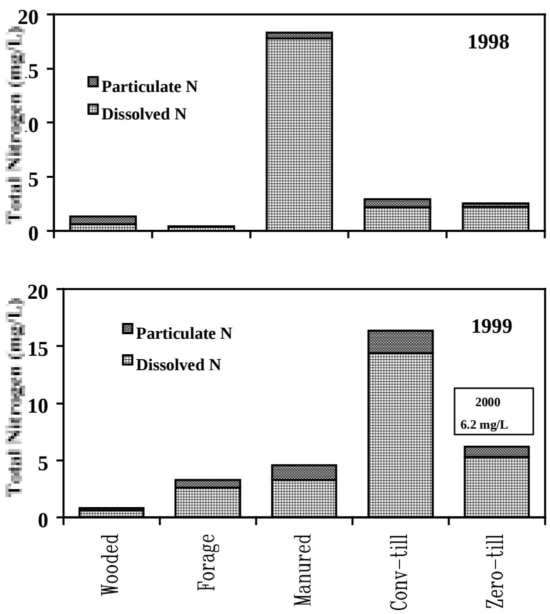

Figure 3. Total Nitrogen concentrations.

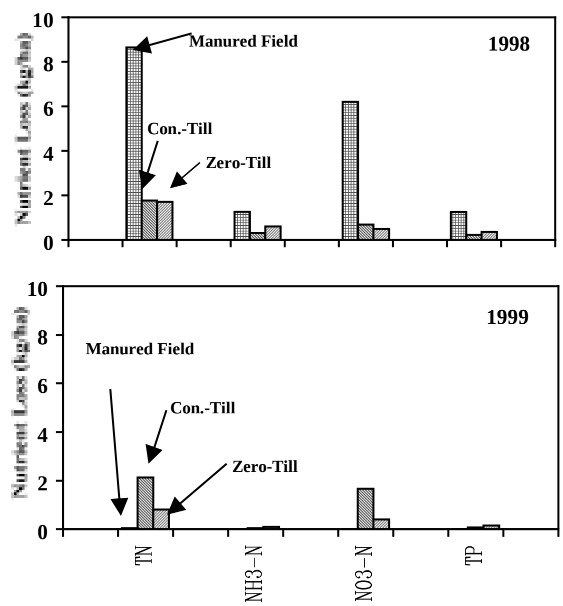

Figure 5. Per unit area loss.

Note: Mean concentrations from the zero-till field in 2000 are shown above bar on the 1999 graphs. There was no runoff data from the Manured Watershed or Twin Watershed conventional-till field during spring runoff 2000.

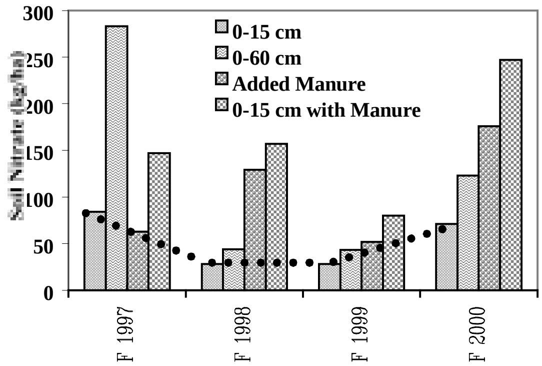

Figure 6. Manured Watershed field soil nitrogen values.

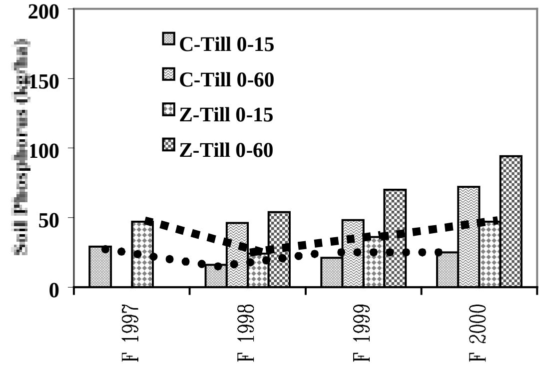

Figure 8. Twin Watershed fields soil phosphorus values.

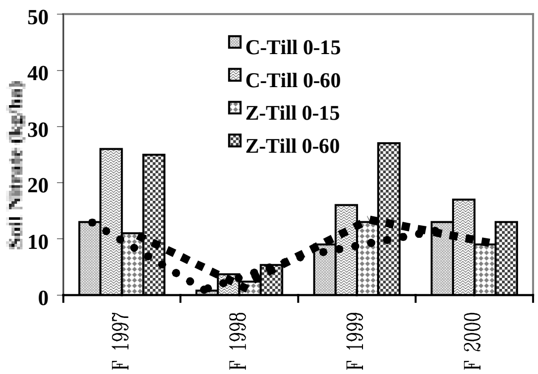

Figure 7. Twin Watershed fields soil nitrogen values. Note: Y-axis scale is 1/6 that of scale for Manured field in Figure 6.

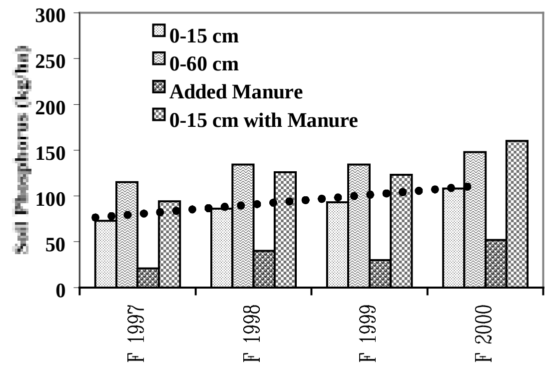

Figure 9. Manured Watershed field soil phosphorus values.

C-Till = Twin Watershed conventional-till field
Z-Till = Twin Watershed zero-till field

F 1997 = Fall 1997, etc.
Dotted lines show trend in top 15 cm of soil.

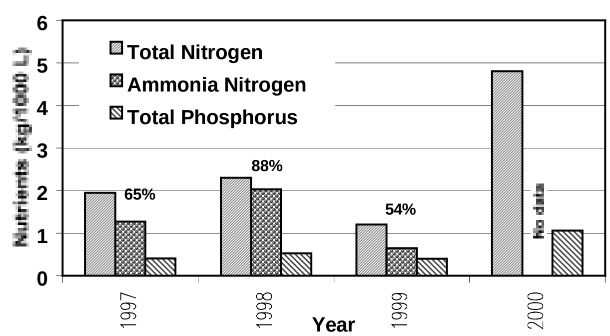

Figure 10. Manure analyses results.
% represents ammonia proportion of manure total nitrogen