USE OF TURFGRASS SOD TO TRANSPORT MANURE PHOSPHORUS OUT OF IMPAIRED WATERSHEDS

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ABSTRACT

Agricultural best management practices (BMPs) can be used to improve the water quality of impaired watersheds where phosphorus (P) reduction is required by total maximum daily loads (TMDLs) regulation. Export of dairy manure through turfgrass sod may be a cost effective means to reduce nutrient loading on impaired watersheds. Previous plot-scale experiments indicated that 46 to 77% of the applied manure P was removed in a single sod harvest. New turfgrass research has been conducted at the field scale using composted dairy manure where two fields, 1.4 ha in size, have been instrumented to monitor surface runoff. One field received only inorganic fertilizer while the other field utilized composted dairy manure for turfgrass production. The surface runoff from each field was quantified and sampled for all runoff events to assess the transport of P to the surface water. Runoff and the mass of P in each field were compared and analyzed. Total dissolved P concentrations in the runoff were directly related to P concentrations in the soil. A total of 3.8% of the applied P from composted dairy manure was lost in the surface runoff.

KEYWORDS. Total maximum daily load, best management practices, turfgrass sod, dairy manure, phosphorus, surface runoff

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INTRODUCTION

Agricultural operations have become a contributor of nutrient pollutants to the nation's water bodies. Confined animal feeding operations (CAFOs) and other livestock operations are agricultural sources of nonpoint source (NPS) pollution with nutrient losses in runoff (Saleh et al., 2000). The Upper North Bosque River (UNBR) in central Texas drains into Lake Waco and may be impaired due to excess phosphorus (P). CAFOs have been identified as a possible source of the excess P. Continued application of manure to small plots causes the soil to have high level of nutrients. These excess nutrients are available for transport to surface water by runoff or for leaching into the groundwater. The Texas Natural Resource Conservation Commission (TNRCC) has issued a total maximum daily load (TMDL) requirement for a 50% reduction in total annual loading of P on the UNBR watershed (TNRCC, 2001). The U.S. Environmental Protection Agency (EPA) is currently subsidizing the removal of surplus manure nutrients out of the watershed. As part of this program, the Texas Department of Transportation is exporting composted dairy manure from the UNBR watershed to roadway embankments on highway construction sites for improving poor soils. The U.S. EPA subsidy program has resulted in a composting infrastructure in the region. This composting infrastructure has led researchers at Texas A&M University to examine the possibility of using composted diary manure to produce turfgrass sod. The transport of manure nutrients in turfgrass sod may be a sustainable way to remove manure nutrients from the watershed (Hanzlik et al., 2002).

MATERIALS AND METHODS

FIELD RESEARCH SITE

Two research fields, each 1.4 ha in size, at the Texas A&M University research farm were used for the turfgrass research. The soil at the research site is a ships clay. Clay berms, approximately 0.3 m high, were installed to divide the research field into North and South fields with a slope of 0.1%. This site has been instrumented for monitoring the movement of agricultural nutrients to surface water. The surface runoff instrumentation includes an ISCO bubbler flow meter used to monitor flow rates in a one-foot H-flume and an automated water sampler.

SOD FIELD ESTABLISHMENT AND MANURE APPLICATION

The turfgrass sod fields were planted on June 12, 2002. Each field received equal mowing, irrigation, and pest control treatments. Ammonium sulfate (21-0-0) was the primary nitrogen (N) source and was applied on both fields during the growing season to sustain maximum turfgrass growth. However, composted dairy manure was applied only to the North field. Table 1 shows the dates and rates of manure and N applications. Total nutrients applied to the North field from composted dairy manure were 75.0 kg/ha P, 130.4 kg/ha N and 212.3 kg/ha K. Total N applied to both the North and South fields from inorganic fertilizer was 290.3 kg/ha.

Table 1. The dates and application rates of composted dairy manure applied to the North field and nitrogen applied to both the North and South fields.

Manure Application[1]		Nitrogen Applications[2]	
Date	**P (Kg/ha)**	**Date**	**N (kg/ha)**
9/27/2002	25.8	7/8/2002	62.8
11/13/2002	18.6	7/23/2002	62.8
11/15/2002	19.3	8/13/2002	102.0
11/25/2002	11.3	9/18/2002	62.8

[1] North field only

[2] North and South fields

SURFACE RUNOFF SAMPLING AND ANALYSIS PROCEDURES

The surface runoff from each field was quantified and sampled for all rainfall events. The surface runoff flow rate was monitored at 5-minute intervals. Composite runoff samples were obtained throughout each runoff event using the automated samplers located at the outlet of each runoff field. Four 250ml samples were composited in one sample bottle at 10-minute intervals. The runoff samples were filtered (pore size = 1 micron) and the particulate and dissolved fractions were sent to the Texas A&M University Soil, Water, and Forage Testing Laboratory for analysis. P, N, and ammonium in the dissolved fraction were quantified using chemical analysis and inductively coupled plasma atomic emission spectrometry (ICP). In addition, the particulate fractions on the glass filters were digested to determine total P, K and total kjeldahl nitrogen (TKN). Total P and potassium (K) in digests of the particulate fraction were analyzed through ICP. The TKN in the digests and the nitrate-nitrogen (NO_3-N) and ammonium-nitrogen (NH_4-N) of the filtrate were measured in an auto analyzer. The NO_3-N in filtrate of the water samples was analyzed using cadmium reduction and NH_4-N of the particulate fraction was analyzed colormetrically (Vietor et al., 2002).

SOIL SAMPLING AND ANALYSIS PROCEDURES

Soil samples were taken from the turfgrass fields based on a grid of six rows and two columns. Soil samples were taken from either the individual grid points or as a composite of the twelve samples from all grid points on a field. Composite samples were taken with a hand probe and were 2.5 cm in diameter and 5 cm long. For individual grid point samples, a hydraulic probe was used to obtain soil cores with 3.8 cm in diameter and 90.0 cm long. Each core was then cut into five segments, 0-5 cm, 5-15 cm, 15-30 cm, 30-60 cm, and 60-90 cm in depth.

Soil from each field was sampled and analyzed prior to P and N imports in composed dairy manure. Extractable P and NO_3-N of the soil samples were analyzed at the Texas A&M University Soil, Water, and Forage Testing Laboratory. An acidified ammonium-acetate - ethylenediaminetetraacetic acid (EDTA) extractant was used to estimate plant-available P (Hons et al., 1990). The P extracted from the soil was analyzed through Inductively Coupled Plasma Optical Emission Spectroscopy (ICP). Soil NO_3-N was extracted using a modified version of Keeney and Nelson (1982).

QUANTIFICATION OF PHOSPHORUS LOSS IN SURFACE RUNOFF (SRO)

The trapezoidal rule, a numerical integration method, was used to calculate the volume of water from each SRO hydrograph. The time between samples (Δt, Figure 1) was used to determine the volume of runoff associated with that sample (cross-hatched area). The mass of P lost in the runoff was calculated by multiplying the P concentration in the sample times the volume of runoff. The total mass of P lost in each SRO event was calculated by adding up mass lost for each time step. The total P losses were comprised of particulate P lost in the sediment and dissolved P lost in the water.

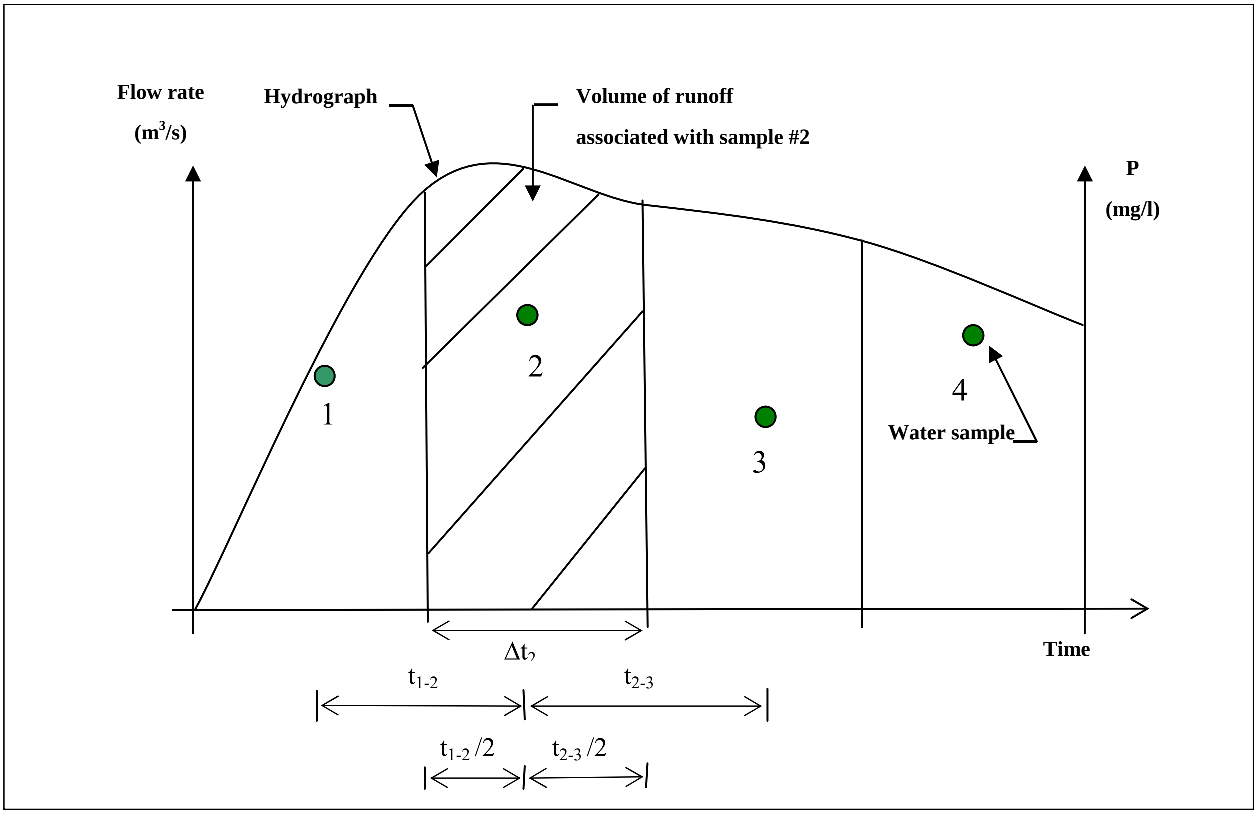

Figure 1. Quantification of P mass lost in surface runoff using the sample P concentration times the runoff volume associated with that sample.

RESULTS AND DISCUSSION

PHOSPHORUS LOSSES IN RUNOFF

There were 18 runoff events from September, 2002 to March, 2003 with a total rainfall of 652.3 mm. Table 2 shows the volume of runoff and the ratio of runoff to rainfall for each runoff event. The runoff volumes of South field were 19% greater than the North field that received the composted manure. The average runoff to rainfall ratio was 39% for the North field and 46% for the South field.

In the 16 surface runoff events that samples were obtained, total P (sediment P and dissolved P) was 6.4 kg/ha in the North field and 3.6 kg/ha in the South field (Table 3). The South field was used as a control (no P was applied to the South field) to determine the mass of P lost in the runoff that could be attributed to the manure P. As shown on Table 4, a total (sediment P and dissolved P) of 2.8 kg/ha of manure P was lost in the runoff events.

Table 2. Comparison of SRO volumes in the North and South fields.

Date	Duration of rainfall (hr)	Rainfall (mm)	Runoff North (mm)	Runoff South (mm)	Difference South-North (mm)	North Ratio : Runoff /Rainfall (%)	South Ratio : Runoff / Rainfall (%)
9/8/2002	13.8	31.75	6.93	10.63	3.7	21.8	33.5
10/1/2002	1	14.99	1.42	2.38	0.96	9.5	15.9
10/7/2002	3.1	22.1	1.07	1.95	0.88	4.8	8.8
10/19/2002	11.3	45.97	13.18	17.84	4.66	28.7	38.8
10/21/2002	35	34.29	12.29	15.47	3.18	35.9	45.1
10/24/2002	34.3	30.73	12.27	13.84	1.57	39.9	45
10/28/2002	4.8	14.73	4.52	4.39	-0.13	30.7	29.8
11/4/2002	25.3	110.24	56.79	67.64	10.85	51.5	61.4
11/26/2002	13.1	16.51	0.46	3.15	2.69	2.8	19.1
12/4/2002	12.5	56.64	27	26.88	-0.12	47.7	47.5
12/9/2002	15.8	25.4	14.23	12.83	-1.4	56	50.5
12/19/2002	1.3	9.4	0.03	0.26	0.23	0.3	2.8
12/23/2002	17.5	23.62	6.33	13.6	7.27	26.8	57.6
12/30/2002	8.2	25.65	14.43	14.7	0.27	56.2	57.3
1/11/2003	24.8	23.37	7.71	8.86	1.15	33	37.9
2/6/2003	3.4	14.22	0.89	1.98	1.09	6.2	13.9
2/20/2003	50.7	140.21	72.9	83.26	10.36	52	59.4
3/3/2003	8.3	12.45	0.99	2.21	1.22	8	17.8
Total	-	652.3	253.4	301.9	48.5	38.9 (avg.)	46.3 (avg.)

Table 3. Dissolved P, sediment P and total P losses in surface runoff of the North and South fields.

North Field

Date	Dissolved P in Runoff (kg/ha)	Sediment P in Runoff (kg/ha)	Total P in Runoff (kg/ha)
10/1/02	0.021	0.005	0.026
10/7/02	0.023	0.002	0.025
10/19/02	0.308	0.304	0.612
10/21/02	0.309	0.019	0.328
10/24/02	0.279	0.028	0.306
10/28/02	0.121	0.029	0.151
11/4/02	0.902	0.110	1.013
12/4/02	0.746	0.070	0.816
12/9/02	0.456	0.043	0.499
12/19/02	0.001	0.000	0.001
12/23/02	0.195	0.016	0.212
12/30/02	0.373	0.165	0.539
1/11/03	0.244	0.008	0.252
2/6/03	0.016	0.003	0.019
2/20/03	1.292	0.260	1.552
3/3/03	0.015	0.002	0.018
SUM	5.303	1.065	6.368

South Field			
10/7/02	0.019	0.006	0.025
10/19/02	0.164	0.035	0.199
10/21/02	0.141	0.043	0.184
10/24/02	0.173	0.024	0.198
10/28/02	0.032	0.018	0.050
11/4/02	0.736	0.085	0.821
11/26/02	0.027	0.004	0.032

12/4/02	0.216	0.040	0.256
12/9/02	0.076	0.023	0.100
12/19/02	0.006	0.004	0.010
12/23/02	0.107	0.038	0.146
12/30/02	0.176	0.063	0.238
1/11/03	0.105	0.018	0.122
2/6/03	0.021	0.004	0.025
2/20/03	1.008	0.137	1.145
3/3/03	0.027	0.004	0.031
SUM	3.034	0.546	3.580

Table 4. Total P losses in surface runoff from manure fertilizer in the North field by subtracting the total P losses in the South field from the total P losses in the North field.

Date	North Field Total P in Runoff (kg/ha)	South Field Total P in Runoff (kg/ha)	Manure Losses Total P in Runoff (kg/ha)
10/1/2002	0.026	N.S.[1]	-
10/7/2002	0.025	0.025	0.000
10/19/2002	0.612	0.199	0.413
10/21/2002	0.328	0.184	0.144
10/24/2002	0.306	0.198	0.108
10/28/2002	0.151	0.050	0.101
11/4/2002	1.013	0.821	0.192
11/26/2002	N.S.[1]	0.032	-
12/4/2002	0.816	0.256	0.559
12/9/2002	0.499	0.100	0.399
12/19/2002	0.001	0.010	0.000
12/23/2002	0.212	0.146	0.066
12/30/2002	0.539	0.238	0.300
1/11/2003	0.252	0.122	0.130

2/6/2003	0.019	0.025	0.000
2/20/2003	1.552	1.145	0.407
3/3/2003	0.018	0.031	0.000
SUM	6.368	3.580	2.820

[1]No sample.

COMPARISON OF SOIL TEST P AND TOTAL P LOSSES IN SURFACE RUNOFF

A total of five soil tests at the 0-5 cm depth were performed on the North and South field during this study (Table 5). The first soil sampling on 9/13/02 was prior to the first manure application and the soil sampling on 11/12/02 was just before the second manure. The average initial soil P levels (0-5 cm) in the South field (116mg/l) were much lower than in the North field (138mg/l). Even though no P was applied to the South field, the P in the surface soil increased (116 – 126 mg/l). This may be due to root extraction from deeper depths and deposition in the grass clipping that was left on the surface. The P levels in the surface soil in the North field increased (138 – 204 mg/l) due to the manure applications. The last manure application on the North field was on 11/25/02 and the next soil test on 1/10/03 yielded surface soil P levels of 185 mg/l. The next surface soil test on the North field on 3/12/03 yielded P levels at 204 mg/l. This soil P increase without any P applications may be attributed to microbial breakdown of organic P (from the manure) to inorganic P in the spring with warmer temperatures. Surface runoff events as close to the soil sampling dates as possible were selected to compare P concentrations in runoff with P concentrations in the soil (Table 5). To assess the relationship between P in the soil and in the runoff, the P concentrations in the soil and runoff were plotted in Figures 2 and 3. In the North field (Figure 2), runoff P concentrations increase linearly with increasing soil P concentrations up to the fourth soil sampling date (1/10/03). The final soil sampling date (3/12/03) showed increased soil P concentrations but sharply lower runoff P concentrations. In the South field (Figure 3), soil P concentrations increase slightly while runoff P concentrations remained relatively constant.

Table 5. Average P concentrations in runoff (dissolved P), sediment (sediment P) and combined dissolved and sediment P (total P) in five surface runoff events in the North and South field with associated average P concentrations in the soil at the 0-5 cm depth.

North Field					
Soil Test Date	Avg. Soil P (mg/l)	Runoff Date	Avg. dissolved P in Runoff (mg/l)	Avg. sediment P In Runoff (mg/l)	Avg. total P in Runoff (mg/l)
9/13/02	138.0	9/8/02	1.05	0.21	1.26

10/17/02	158.0	10/7/02	2.15	0.22	2.37
11/12/02	156.0	11/4/02	1.59	0.19	1.78
1/10/03	184.5	1/11/03	3.17	0.10	3.27
3/12/03	204.0	3/3/03	1.54	0.24	1.78
South Field					
Soil Test Date	Avg. Soil P (mg/l)	Runoff Date	Avg. dissolved P in Runoff (mg/l)	Avg. sediment P in Runoff (mg/l)	Avg. total P in Runoff (mg/l)
9/13/02	115.9	9/8/02	0.83	0.20	1.03
10/17/02	117.0	10/7/02	0.97	0.29	1.26
11/12/02	111.0	11/4/02	1.09	0.13	1.22
1/10/03	118.0	1/11/03	1.18	0.20	1.38
3/12/03	126.0	3/3/03	1.22	0.17	1.39

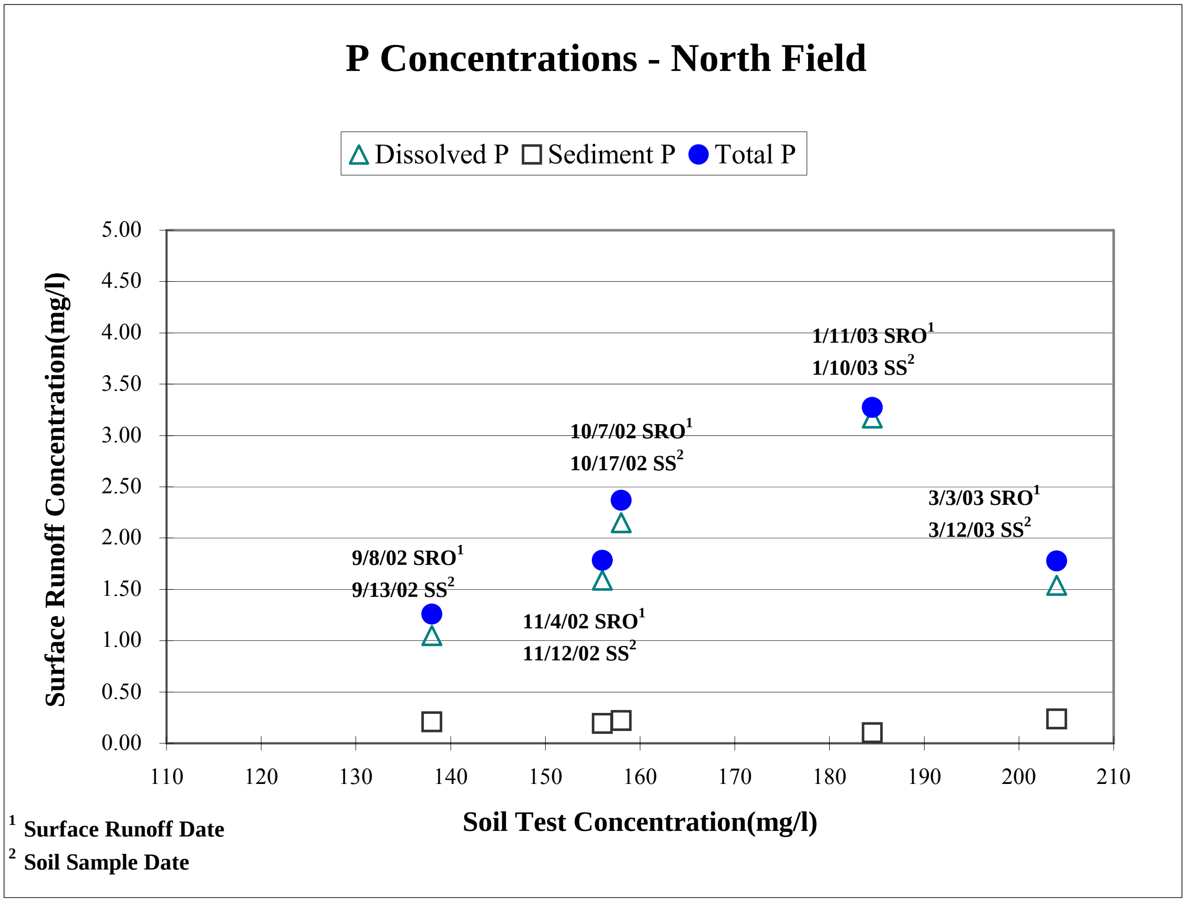

Figure 2. Average P concentrations in runoff (dissolved P), sediment (sediment P) and combined dissolved and sediment P (total P) in five surface runoff events in the North field with associated average P concentrations in the soil at the 0-5 cm depth.

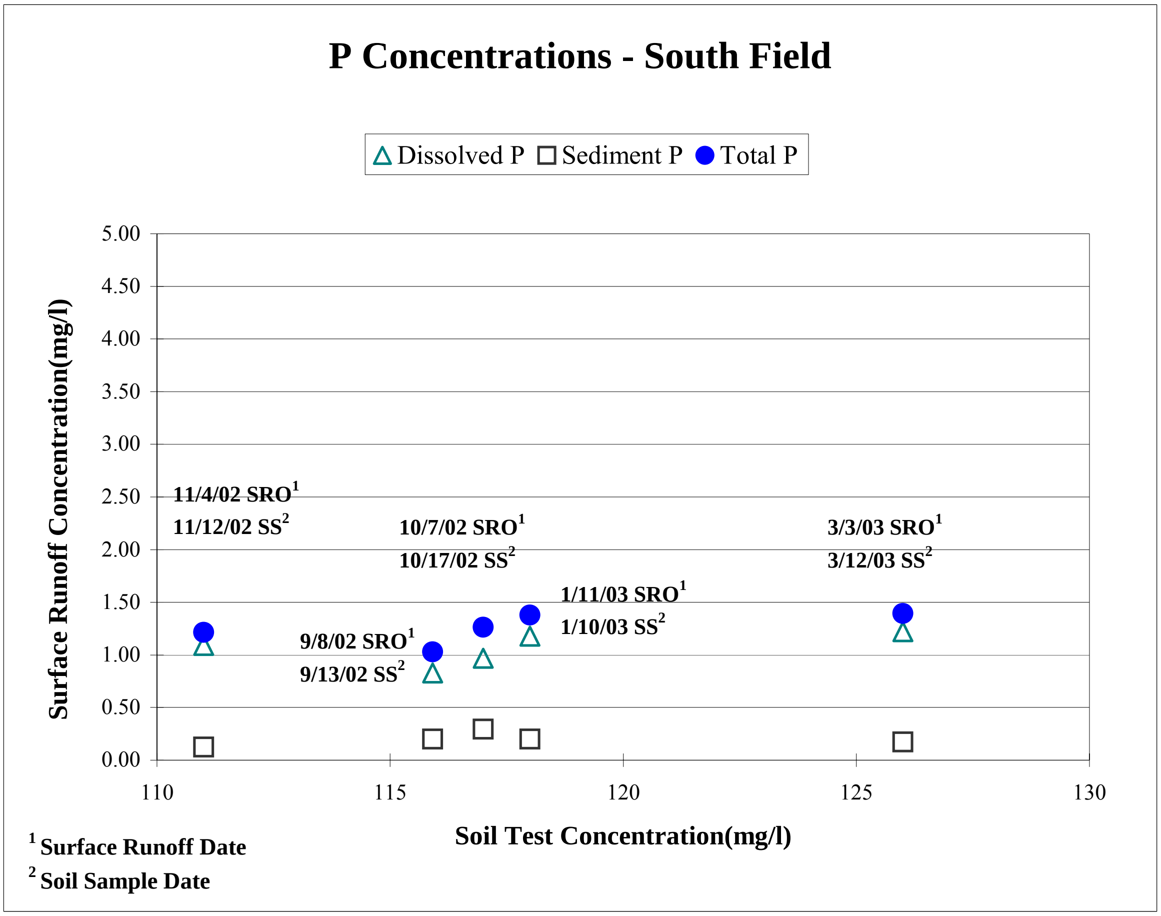

Figure 3. Average P concentrations in runoff (dissolved P), sediment (sediment P) and combined dissolved and sediment P (total P) in five surface runoff events in the South field with associated average P concentrations in the soil at the 0-5 cm depth.

CONCLUSIONS

The surface runoff from the South field (no manure applications) was 19% greater than in the North field (manure applied). A portion of the reduced runoff may be attributed to the use of composted manure that resulted in enhanced water holding capacity of the soil. Additional research into the question of runoff differences between the North and South field is on going. The total P losses in the runoff in the North field that were attributed to the manure was 2.8 kg/ha. This value is less than the total P lost from the South field (3.6 kg/ha) with no P applications. This indicates that the use of composted dairy manure is a viable environmental alternative for turfgrass sod production and is a sustainable BMP for exporting manure nutrients out of impaired watersheds.

ACKNOWLEDGEMENTS
Special thanks to George Stewart, Chad Richards and Brandon McDonald for sample and data collection

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