Soil & Nutrient Losses from Small Sprinkler & Furrow Irrigated Watersheds in Southern Idaho

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Abstract. *Sediment and associated nutrients flowing to the Snake River with furrow irrigation runoff and unused irrigation water have been a concern in the Twin Falls irrigation tract in southern Idaho. Converting furrow irrigated fields to sprinkler irrigation is one practice that has been promoted, and received financial assistance, to reduce sediment loss. Five small watersheds (330 to 1480 acres) with 10 to 70% sprinkler irrigation were monitored from 2005 to 2008 to determine if converting to sprinkler irrigation reduced sediment and nutrient losses from these watersheds. Eliminating runoff from furrow irrigated fields by converting to sprinkler irrigation will reduce sediment and nutrient losses from fields. However, there were no significant correlations between the amount of sprinkler irrigation and the sediment or nutrient loads from these watersheds. Potential reasons for these results are the flow rate allocation system used by the TFCC, the amount and location of furrow irrigated fields in each watershed, and the management of furrow irrigated fields within each watershed. One significant correlation was decreasing dissolved phosphorus concentrations as relative amount of sprinkler irrigated land increased, presumably because less water flowed across fields in furrows as sprinkler irrigated area increased. A water quality model for irrigated watersheds is needed for more thorough assessment of the variety conditions and management practices within these watersheds.*

Keywords. Irrigation Erosion, Furrow Irrigation, Sprinkler Irrigation, Best Management Practices.

Introduction

Soil erosion from furrow irrigated fields has been the primary natural resources concern in the Twin Falls irrigation tract in southern Idaho since the 1970's. Water flowing in irrigation furrows detaches and transports soil. It is impractical to contain irrigation runoff on furrow irrigated fields in this area because field slopes are typically 1 to 2% and some irrigation runoff is desired to achieve acceptable irrigation uniformity. Berg and Carter (1980) found that 20 to 50% of applied irrigation water ran off furrow irrigated fields in the Twin Falls tract. Soil loss from these fields varied from 0.4 to 63 ton/acre annually. In a more recent study, annual soil loss of 0.9 to 15 ton/acre was measured on six commercial furrow irrigated fields (Bjorneberg et al., 2007). In 1971, Carter et al. (1974) measured a net loss of 460 lb/a of sediment from the watershed during the irrigation season (May through September). Eroded sediment and associated nutrients return to the Snake River with furrow irrigation runoff and unused irrigation water. The NRCS provided more than $4 million through the Environmental Quality Incentive Program (EQIP) for conservation practices in this area between 2002 and 2006, with approximately 90% of these funds used to convert from furrow irrigation to sprinkler irrigation (Bjorneberg et al, 2008).

The Upper Snake Rock (USR) Watershed was one of eight NRCS Special Emphasis watersheds selected for the Conservation Effects Assessment Project (CEAP) in 2004. One primary objective of this project was to determine if converting from furrow irrigation to sprinkler irrigation improved surface water quality in the watershed. Monitoring for this project focused on the Twin Falls irrigation tract, a 202,000 acre watershed that receives irrigation water from the Snake River through canals managed by the Twin Falls Canal Company (TFCC). The objective of this paper is to compare sediment and nutrient losses from five small watersheds within the Twin Falls tract that have different amounts of sprinkler irrigation. We hypothesized that watersheds with greater amounts of sprinkler irrigation will lose less sediment and nutrients.

Materials and Methods

Five small watersheds within the Twin Falls irrigation tract were chosen for monitoring based on each having a well defined inflow boundary and a single outlet. It is common within the Twin Falls irrigation tract for unused irrigation water and field runoff to be diverted from drainage channels to other fields, making the surface water hydrology very complex in some areas. Field runoff was not re-diverted within these sub-watersheds, which varied from 330 to 1480 acres and had 10 to 70% of the cropland sprinkler irrigated in 2005 (table 1). Soils in all watersheds were silt loams, predominantly Portneuf silt loam. One watershed (EC) contained subsurface drains that continued to flow after the irrigation season until early January.

Table 1. Watershed Characteristics.

		Sprinkler Irrigated Area		Average
	Size	2005	2008	Field Slope
Watershed	(acre)	(%)	(%)	(%)
EC	1480	11	22	2 to 8
PC1	600	10	10	0 to 2
PC2	1020	41	52	0 to 2
TF1	430	19	33	2 to 4
TF3	330	63	70	2 to 4

The five watersheds were monitored from 2005 to 2008 during the irrigation season (May 1 to September 30). Crop production and irrigation practices on the five sub-watersheds were recorded through monthly field surveys during the irrigation season. Outflow from each sub-watershed was measured with a flume. A data logger with a pressure transducer measured water stage every minute and recorded the hourly average stage and flow rate. The data logger also calculated cumulative flow volume every minute to trigger water sample collection. An automatic sampler, controlled by the data logger, collected flow proportional samples with a goal of 4 to 5 samples bottles per week. Ten, 0.2-L sub-samples were composited in each 2 L sample bottle. The data logger triggered the sampler after 650 to 3000 m^3 of flow. These trigger volumes were equivalent to 0.2 to 0.6 mm of flow from each sub-watershed. The data loggers also recorded cumulative flow volume for each sub-sample and sample.

All monitoring sites were visited weekly while water was flowing to collect water samples, record flow stage and download flow data. Water samples were refrigerated until processed the day after collection. During sample processing, samples were stirred for 1 to 2 min before measuring pH and electrical conductivity (EC). A 50 ml aliquot was taken for total N and P analysis. A second 20 ml aliquot was filtered (0.45 micron) and analyzed for dissolved nutrients (NO_3, P). A third aliquot was used to determine sediment concentration by filtering a known volume (approximately 100 ml) through 0.45 micron filter paper and weighing the dried filter paper. The filtered water sample was analyzed by inductively coupled plasma-optical emission spectroscopy (ICP-OES) for P and by flow injection analysis (FIA) for NO_3-N concentrations. An aliquot (~25 ml) of the unfiltered water sample was digested with a Kjeldahl procedure (USEPA, 1983) and analyzed by ICP-OES for total P and by FIA for NH_4-N for total N.

Flow volume for each water sample was multiplied by parameter concentrations from laboratory analysis to calculate mass loads. Loads were summed over the irrigation season and the month of July. Flow-weighted concentrations were calculated by dividing the mass load for a time period by the total flow volume for the same period.

Linear correlations were used to compare water quality parameters with the relative amount of sprinkler irrigation in each watershed (i.e. percent sprinkler irrigated area). Water quality parameters were also correlated with the relative amount of furrow irrigated row crops in each watershed, assuming that the greatest sediment loss occurs from furrow irrigated row crop fields. Correlation coefficients (r) were considered significant for $P<0.05$ (Little and Hills, 1978).

We also evaluated the effectiveness of converting to sprinkler irrigation by comparing predicted soil loss under current conditions with predicted soil loss assuming the entire watershed was furrow irrigated. Soil loss from furrow irrigated fields was predicted with the SISL model (Bjorneberg, et al., 2007). The SISL model is an empirical model with form similar to the Universal Soil Loss Equation (USLE). A base soil loss value is multiplied by several factors to account for variations in soil erodibility, previous crop, conservation practices, and irrigation management.

Results and Discussion

Watershed outflow was lowest in 2005 (Table 2) because above normal precipitation in the watersheds reduced the need for irrigation in May. Furthermore, below normal snowpack reduced water available for irrigation and caused the TFCC to restrict irrigation allocations during the summer. Net water use for watersheds (inflow-outflow) could not be calculated because watershed inflow data have not been analyzed yet. Inflow will be determined from daily TFCC records for each headgate delivering water to fields in these watersheds.

Table 2. Measures flow, sediment load and dissolved phosphorus load flowing from watersheds during 2005-2008.

Watershed	2005	2006	2007	2008
	------------------ Watershed Outflow (ft) ------------------			
EC	1.05	2.00	1.68	1.51
PC1	0.43	0.60	0.64	0.49
PC2	1.50	1.87	1.84	1.56
TF1	0.73	1.21	1.54	1.91
TF3	0.79	1.48	0.73	0.89
	------------------ Sediment Load (lb/acre) ------------------			
EC	1218	1945	1527	2106
PC1	694	1067	474	840
PC2	1487	2328	1045	774
TF1	2011	8406	4516	9062
TF3	1756	6548	1573	4644
	---------- Dissolved Phosphorus Load (lb/acre) ----------			
EC	0.42	0.36	0.47	0.42
PC1	0.19	0.12	0.16	0.16
PC2	0.48	0.34	0.39	0.34
TF1	0.45	0.42	0.56	0.96
TF3	0.31	0.40	0.20	0.18

There were no statistically significant linear correlations between the relative amount of sprinkler irrigation in a watershed and the amount of water flowing from the watershed during the four irrigation seasons for individual watersheds or all five watersheds combined (data not shown). Watershed outflow also did not correlate with the relative amount of sprinkler irrigation during July when irrigation demand was greatest (Figure 1). Outflow could be watershed dependent so combining results from five watersheds would include factors in addition to irrigation type that could affect watershed outflow. However, analyzing each watershed independently did not result in any significant correlations ($-0.24<r<0.81$). While correlations were not significant for individual watersheds, the general trends indicated greater flow as sprinkler irrigated area increased ($r>0$) in four of the watersheds. One possible reason for this trend is that the TFCC allocates water on a flow rate basis, not volume basis, so farmers have little incentive to stop water delivery when they are not irrigating. The flow rate allocation is used because the original TFCC water rights are natural flow rights in the Snake River. On sprinkler irrigated fields, irrigation water flows from the headgate into a pond where it is pumped to the sprinkler system. When the sprinkler system is not running, water often spills from the pond and flows through the watershed with runoff from furrow irrigated fields, especially in the spring and fall when irrigation demand is lower. In addition, much of the outflow from these watersheds is re-diverted to other fields within the Twin Falls tract so the TFCC is not concerned about this unused water.

Sediment loads in water flowing from these watersheds varied considerably each year, especially for TF1 and TF3 (Table 2). Similar to watershed outflow, sediment load was not significantly correlated with the relative amounts of sprinkler irrigation during July ($r=0.15$) or during the irrigation season ($r=0.28$). The positive correlation coefficients indicate that sediment loss tended to increase as sprinkler irrigated area increased. This was not expected because converting from furrow irrigation to sprinkler irrigation reduces soil loss from individual fields by eliminating irrigation runoff. Part of the variability was likely caused by the variability in watershed outflow. Correlating flow weighted sediment concentration instead of sediment load did not improve the correlations for July (Figure 2) or the irrigation season ($r=0.30$).

One possible explanation for the unexpected trend in sediment load is the amount of furrow irrigated row-crops in each watershed. Table 3 shows the correlation coefficients between the percent furrow irrigated area in each watershed versus the flow-weighted sediment concentration or sediment load in watershed outflow. Two watersheds (PC2 and TF3) have good correlations between furrow irrigated row crop area and sediment concentration or load. These two watersheds also have the greatest amount of sprinkler irrigation (Table 1). Positive correlation coefficients indicate that sediment concentration or load increased as the amount of furrow irrigated row crops increased.

The location of the furrow irrigated fields within each watershed will potentially affect sediment load as some sediment may deposit in channels before reaching the watershed outlet. TF3, for example, had dry bean planted in the furrow irrigated field adjacent to the watershed outlet in 2006 when sediment load was two to four times greater than the others years (Table 2). An irrigated watershed model is needed to more fully consider the various combinations of irrigation systems and crop types within each watershed.

Table 3. Correlation coefficients between furrow irrigated row crop area and sediment concentration or load flow from the watershed during the irrigation season.

	Correlation Coefficient for Furrow Irrigated Row Crop Area vs.	
Watershed	Sediment Concentration	Sediment Load
EC	-0.42	-0.26
PC1	-0.21	0.27
PC2	0.90	0.80
TF1	0.28	-0.13
TF3	0.63	0.94

Coefficients are significant at P=0.10 if r>0.90 for n=4.

Total phosphorus (P) load was directly related to sediment load during the irrigation season (r=0.99) and during July (r=0.99), because 70 to 90% of the total P was associated with soil particles. Thus, total P followed the same trends as sediment. There was a significant correlation between percent sprinkler irrigated area and flow weighted dissolved P concentrations in July (Figure 3). Dissolved P concentration decreased as the relative amount of sprinkler irrigation increased. A similar trend occurred during the irrigation season but the correlation was not significant (r=-0.22). Dissolved P concentrations increase as water flows across the field in furrows (Bjorneberg et al., 2006) so reducing the furrow irrigated area should reduce dissolved P concentrations. The dissolved P load, however, did not correlate with the relative amount of sprinkler irrigation, probably because flow was not related to the amount of sprinkler irrigation in each watershed.

Furrow irrigation management is another potential reason for the lack of significant correlations between sediment or nutrient loads and sprinkler irrigation. One poorly managed furrow irrigated field can add more sediment to the irrigation return flow than is removed by converting fields to sprinkler irrigation. It is also possible that the better irrigation managers have tended to convert to sprinkler irrigation.

The SISL model was applied to furrow irrigated fields in PC1, TF1 and TF3 to estimate annual soil loss from each field and the entire watershed assuming no deposition before the watershed outlet. Predicted sediment load correlated reasonably well with measured sediment load (Figure 4) considering the simplicity of the SISL model and this analysis. SISL predicted sediment load was about four times greater than measured load for PC1 and twice for TF1 during the four irrigation seasons. Predicted sediment load was only 50% greater than measured for TF3, indicating that furrow irrigation erosion was greater or sediment deposition was less in this watershed, assuming SISL predictions are representative of actual soil loss. The only time measured sediment load exceeded predicted load was for TF3 in 2006, when the furrow irrigated field adjacent to the watershed outlet was planted to dry bean.

Conclusion

Eliminating runoff from furrow irrigated fields by converting to sprinkler irrigation will reduce sediment and nutrient losses from fields. However, simple linear regressions with data from five small watersheds during four irrigation seasons did result in significant correlations between the amount of sprinkler irrigation and the sediment and nutrient loads from these watersheds. Potential reasons for these results are the flow rate allocation system used by the TFCC, the amount and location of furrow irrigated fields in each watershed, and furrow irrigation management within each watershed. One significant correlation was decreasing dissolved phosphorus concentrations as relative amount of sprinkler irrigated land increased. This presumably occurred because less water flowed across fields in furrows as sprinkler irrigated area increased.

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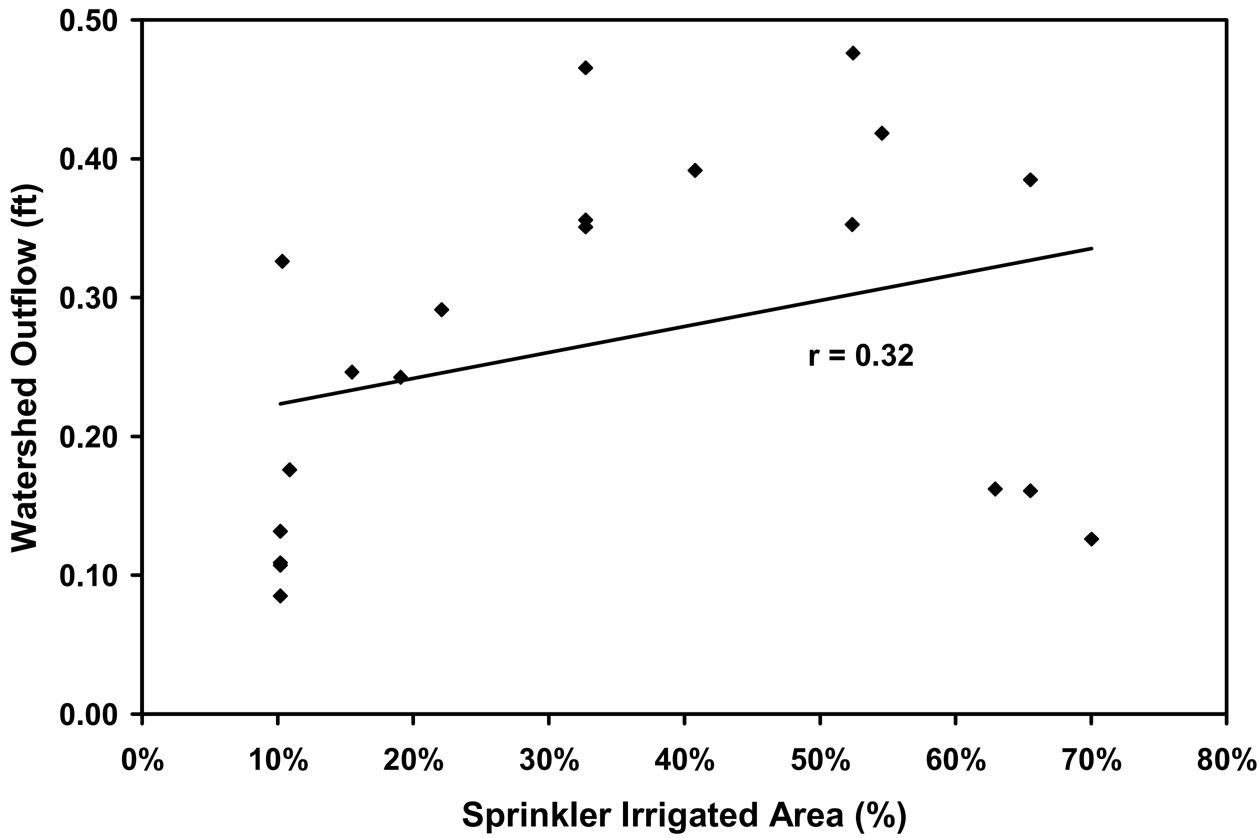

Figure 1. Correlation between sprinkler irrigated area and watershed outflow during July for 2005 to 2008.

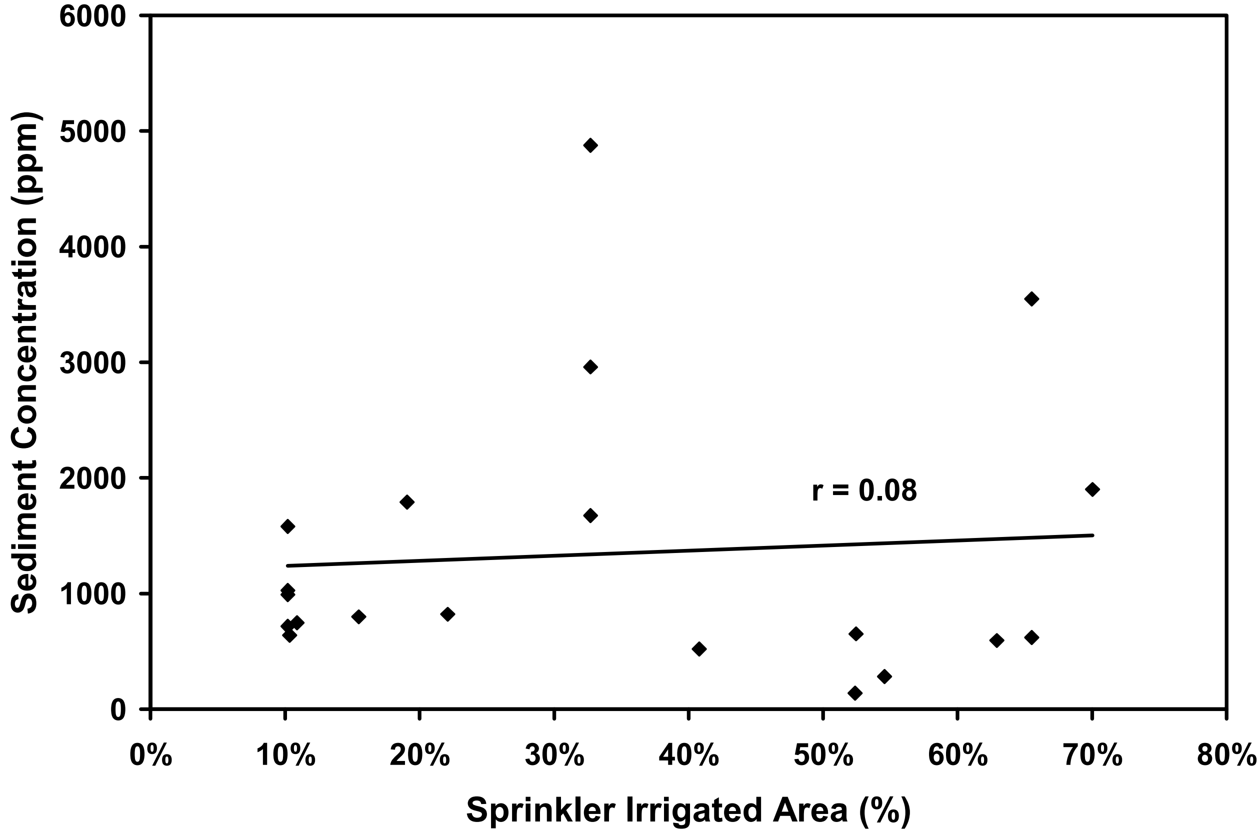

Figure 2. Correlation between sprinkler irrigated area and flow weighted sediment concentration during July for 2005 to 2008.

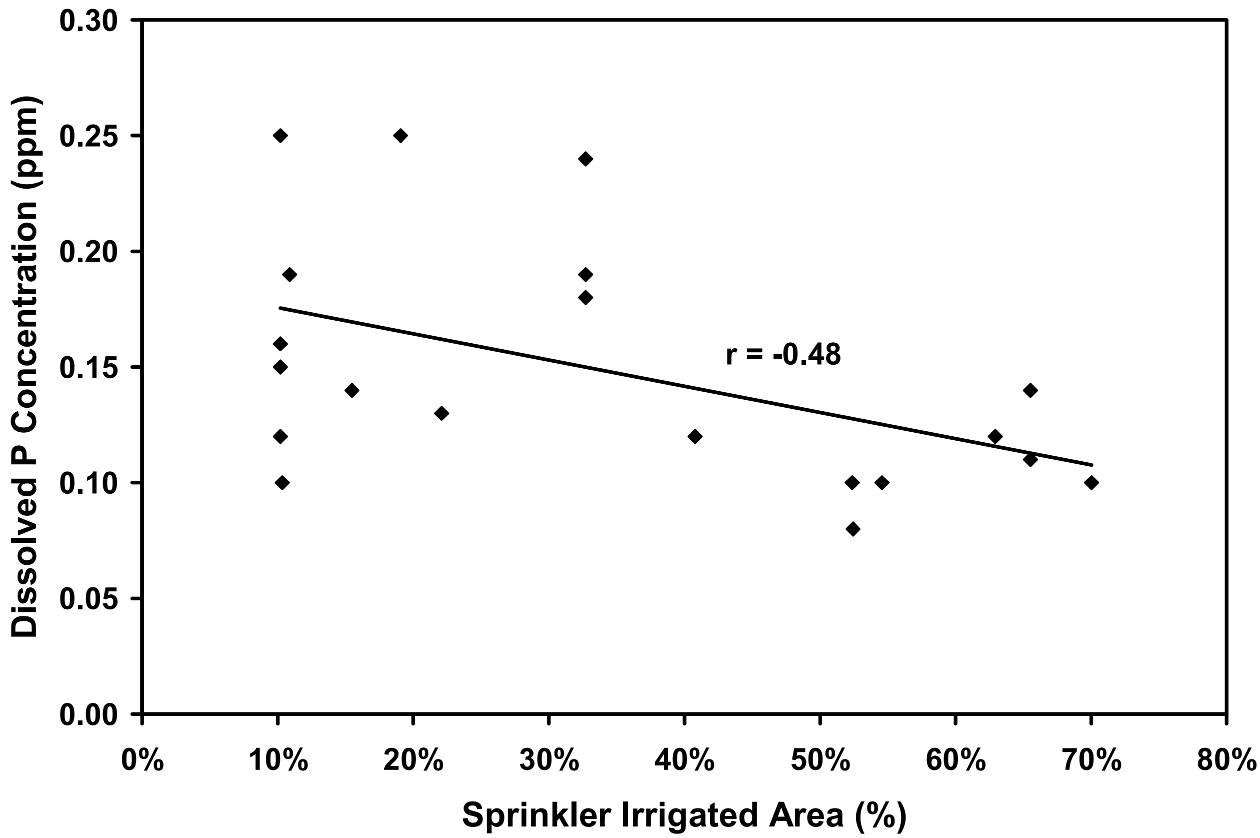

Figure 3. Correlation between sprinkler irrigated area and flow weighted dissolved phosphorus concentration during July for 2005 to 2008. (r = -0.48 significant at $P<0.05$)

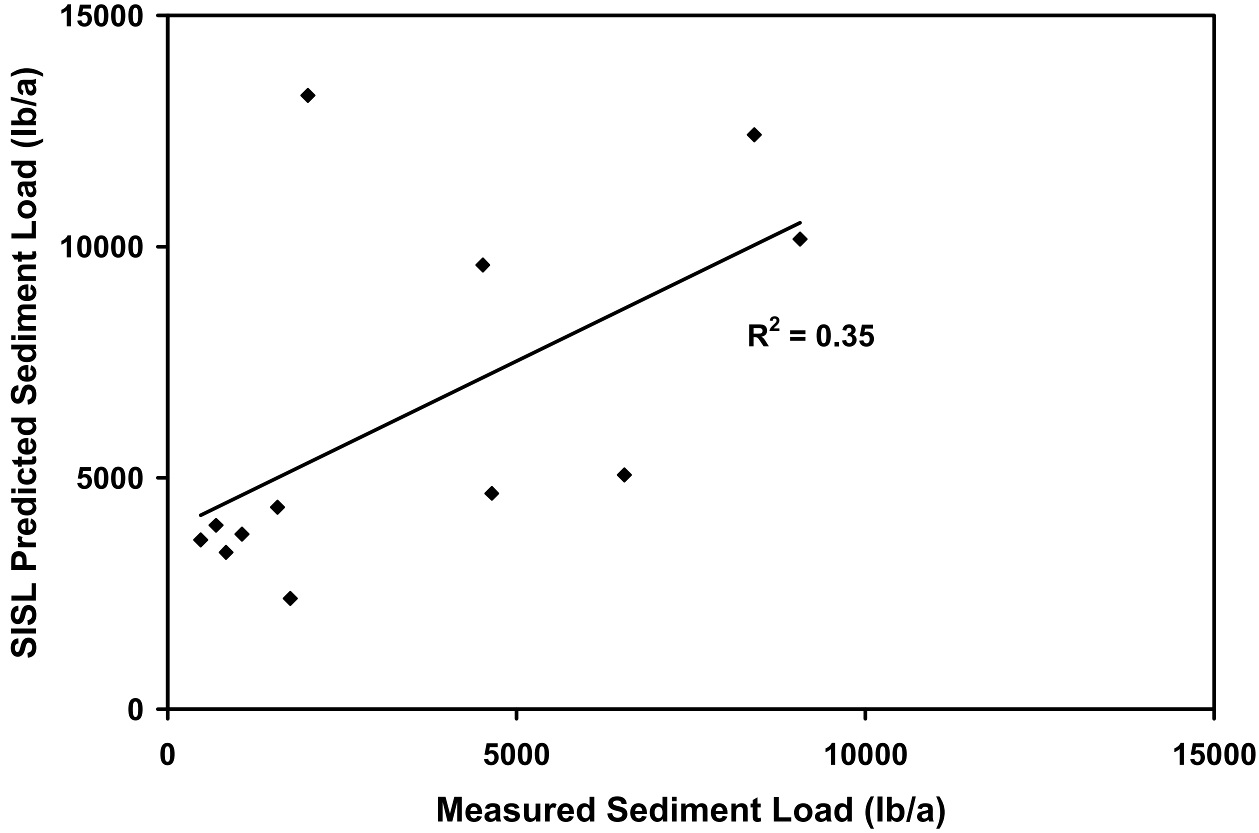

Figure 4. Measured versus SISL predicted sediment load for PC1, TF1 and TF3 watersheds for 2005 to 2008. (R^2=0.35 is significant at P<0.05)