MEASUREMENTS OF RUNOFF, SEDIMENT, AND PHOSPHORUS LOSSES FROM SEVERAL DISCOVERY FARM FIELDS[1]

C.C. Molling[2], J.M. Norman[3], C.A. Bonilla[3], P.S. Miller[4], J.C. Panuska[4], K.G. Karthikeyan[4], K. Manchikanti[3], J. Topel[3], J. Leverich[5], L. Ward-Good[3], K. Klingberg[5], and D. Frame[5]

Background

The quality of our surface waters is important to human, ecological, and economic health in our state. Certain agricultural practices can degrade surface waters by contributing excess amounts of sediment and phosphorus. If we wish to maintain or improve the quality of surface waters in the state of Wisconsin, or elsewhere, we need to find out how much sediment and phosphorus (P) is being lost by farm fields (a large fraction of the land use in Wisconsin) and the effectiveness of conservation techniques to reduce these losses.

Erosion research in the past has focused mainly on studies on small uniform plots. While this research has been very informative, it is difficult to scale up to entire fields, where topography and soil conditions are not uniform. The research described below is part of two related studies that seek to address the scaling up issue.

Study Objectives

The University of Wisconsin-Madison and Wisconsin's Discovery Farms Program are involved in a pair of studies related to surface water quality. The first is a study to quantify runoff, sediment loss, and P loss on working farm fields and to then use standard management changes to reduce the losses. The second study seeks to measure the effectiveness of vegetated buffers to reduce sediment and P delivery to surface waters. The first stage of these studies was to design and install runoff/sediment/P collectors on working farm fields. Measurements made from these collectors will be used to validate a precision-scale model, which will be capable of simulating runoff/sediment/P losses for individual events in a variety of landcape/management configurations. Once this precision-scale model is validated, it will be used to calibrate an annual-mean sediment/P loss model for use statewide.

This paper outlines findings from the first year of measurement of runoff, sediment and phosphorus from natural runoff events on four farms in Wisconsin's Discovery Farms Program and the Arlington Agricultural Research Farm.

Sites

The five sites used in this study are located in various landscape and soil types across the southern half of the state. The Bragger site, in Buffalo County, is located in the Driftless Area, with relatively steep slopes and silt loam soil. One corn field and one alfalfa field are being

---

[1] Funding agencies: USDA Water Quality Program, National Resources Conservation Service, Wisconsin Department of Natural Resources
[2] Cooperative Institute for Meteorological Satellite Studies, Space Science and Engineering Center, UW-Madison
[3] Department of Soil Science, UW-Madison
[4] Department of Biological Systems Engineering, UW-Madison
[5] Wisconsin Discovery Farms Program

monitored. The Knigge site is located in Winnebago County on red clay soils and contains an edge-of-field vegetated buffer on a corn field. The Opitz site, in Ozaukee County, is on sandy loam soil and also contains an edge-of-field vegetated buffer on a corn field. The Koepke farm, in Dodge County, is a loam soil with two collectors on an alfalfa field. The Arlington site is located on a silt loam soil with corn.

The data presented in this paper were collected between from July 2003 through June 2004. Table 1, below, summarizes the conditions at each site.

Table 1. Summary of collection sites

Site	Arlington	Bragger		Knigge		Koepke		Opitz	
Soil	Silt Loam	Silt Loam		Clay Loam		Loam		Sandy Clay Loam	
Crop	Corn	Alfalfa	Corn	Corn	Buffer	Alfalfa	Alfalfa	Corn	Buffer
Tillage	No Till	No Till		Mold Board		No Till		Chisel	
Slope, %	8	13	7	5	5	8	8	10	4
Contributing Area, ha	0.04	1.01	0.10	0.03	0.04	0.05	0.21	0.16	0.17
Rain, mm	564	907		1034		988		970	
Total Runoff, mm	34	51	64	40	32	6	6	158	138
Site Events	13	45		13		16		26	

Instrumentation

The study needed instrumentation that operated under the following requirements: no power source at the site; farm locations 1-3 hours travel distance from university; measurement near discharge location where slopes are small; contributing areas around 0.2 ha; total runoff volume and sediment/P mass per event. The instrumentation that fit these requirements is an adaptation of a design by Daniel Yoder, University of Tennessee.

The basic design consists of two main parts: a runoff collector and a flow sampler. The collector is a triangular piece of plastic sheeting inserted with its uphill edge embedded in the soil surface. The plastic has guides on the lower two edges that direct water flow into a plastic sewer pipe. The whole collector is covered with a tarp roof to prevent rainfall from entering the collector directly. The pipe conducts water to the flow sampler: a wooden box set into the ground a short distance down the slope.

The box contains a series of 4 buckets at four different elevations. The water from the pipe is directed into the first (highest) bucket, which has a volume of 5 gallons (19 liters). Atop the bucket is a divider head that splits any overflow into 12 equal portions. One-twelfth of the overflow (one divider section) is conducted into the next highest 5 gallon bucket. Overflow from the second bucket is divided with a 24 slot divider head. One-twenty-fourth of overflow from the second bucket is directed into an identical bucket with a 24 slot divider head. One-twenty-fourth of overflow from the third bucket is directed into a 20 gallon (76 liter) bucket. The system can sub-sample 540 m^3 (140,000 gallons) of runoff before overflowing the last bucket.

Overflow from the first three buckets is either drained or pumped out of the box back onto the ground surface. If a second runoff collector system is installed below the first, the overflow is spread out by a plastic flow diffuser, so that the water runs down toward the second collector as naturally as possible.

Using the volumes of water in each of the four buckets a simple equation can reconstruct the entire runoff volume, sediment mass and P mass for the runoff event. The collector cannot reconstruct the timing of the event.

Results from First Year

The figures below summarize the runoff, sediment loss, and P loss for the July 2003 through June 2004 sampling period, which includes more than 100 site-events. Runoff for the year and for snowmelt events is shown in Figure 1. Figure 2 shows sediment loss for storm (rainfall) and snowmelt events separately. Note that we use units of T/ac/year as these are the common units for tolerable soil loss "T". Figure 3 shows P loss for storm events in two forms, dissolved reactive P (DRP) and total P (TP). We show values in the commonly used lb/ac. Figure 4 shows the same for snowmelt events. In all figures sites are abbreviated as follows: A) Arlington, B1) Bragger alfalfa, B2) Bragger corn, C1) Knigge above buffer, C2) Knigge below buffer, D1) Koepke east, D2) Koepke west, E1) Opitz above buffer, E2) Opitz after buffer. Note the log scale on the y-axis differs on each figure.

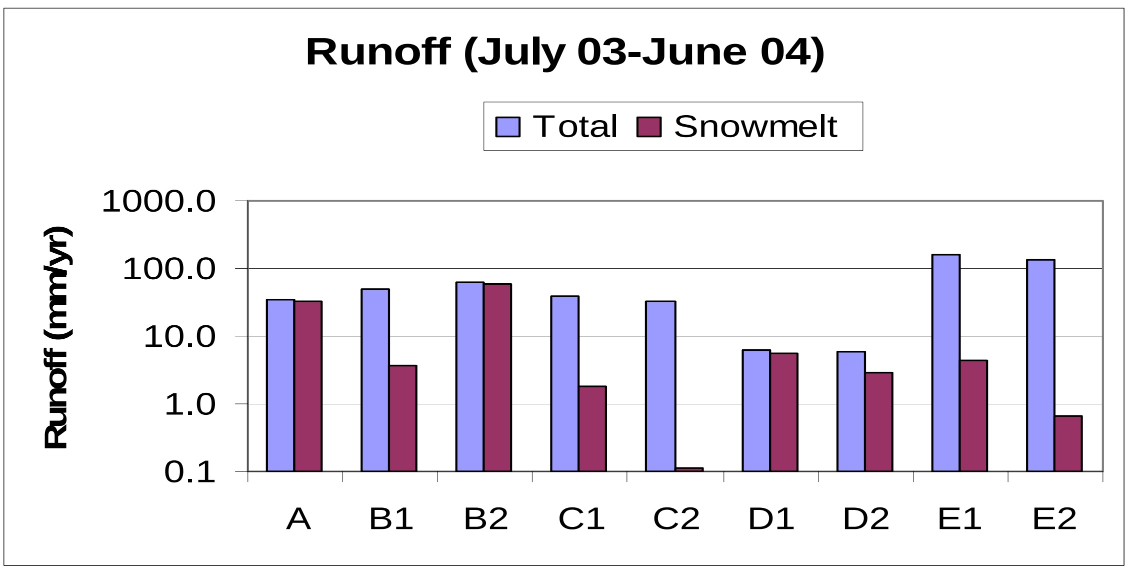

Figure 1. Runoff volume per unit contributing area. Light bars are runoff totals from storm and snowmelt events. Dark bars are from snowmelt only. Note log scale on y-axis. See text above for site abbreviation key.

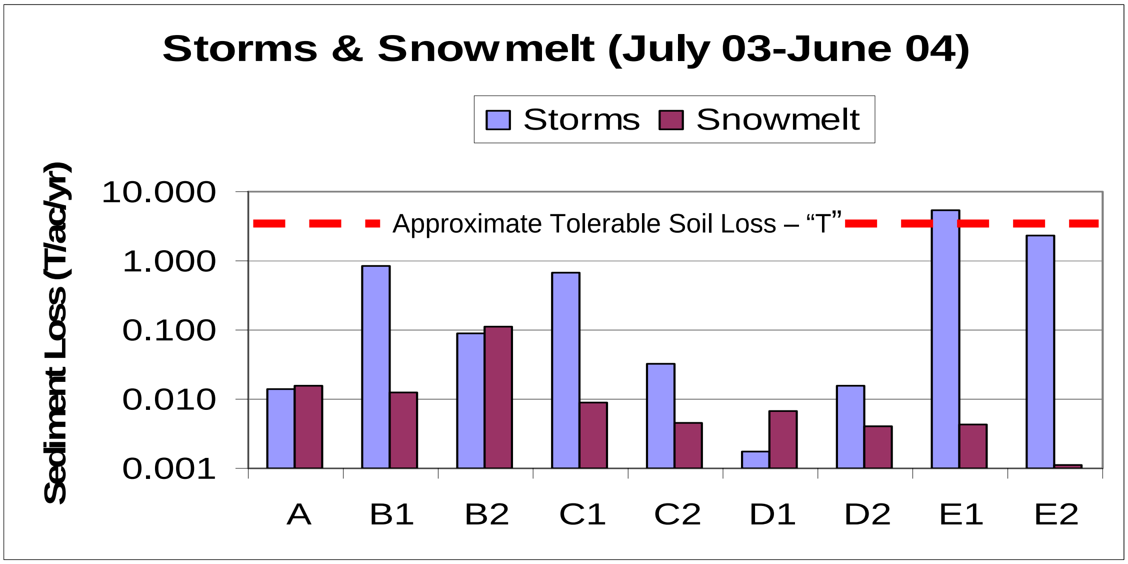

Figure 2. Sediment loss per unit contributing area. Light bars are runoff totals from storm events. Dark bars are from snowmelt events. Note log scale on y-axis. See text above for site abbreviation key.

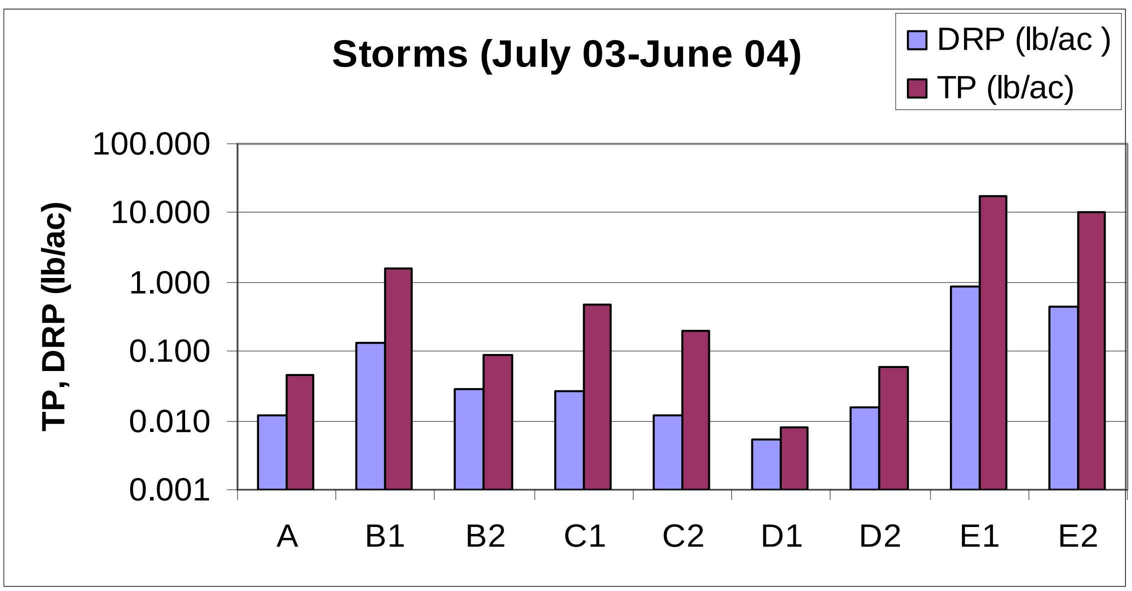

Figure 3. Phosphorus loss during storm events, per unit contributing area. Light bars are dissolved reactive P. Dark bars are total P. Note log scale on y-axis. See text above for site abbreviation key.

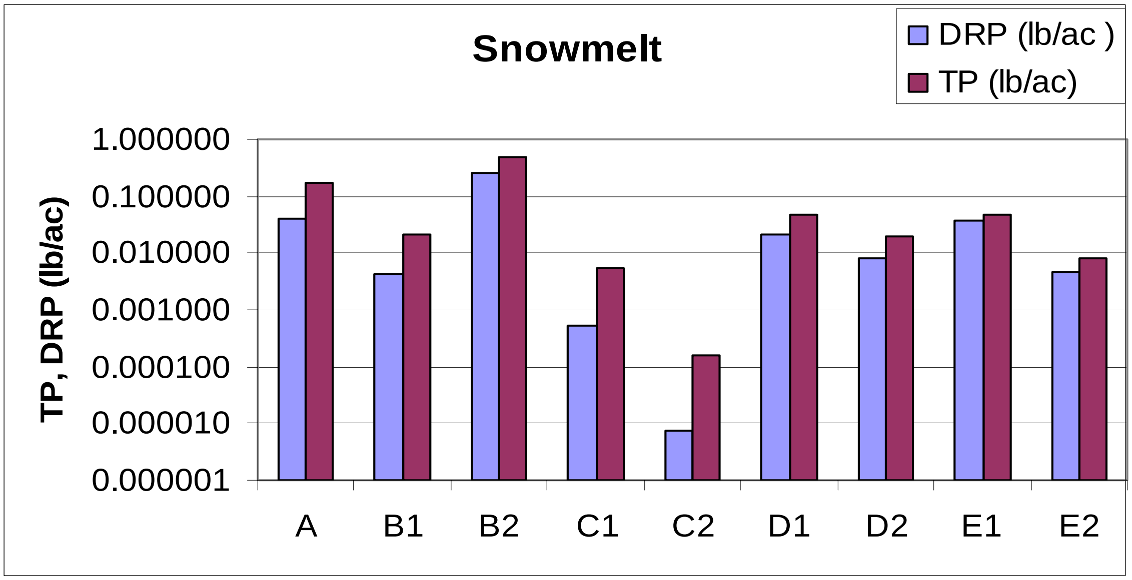

Figure 4. Phosphorus loss during snowmelt events, per unit contributing area. Light bars are dissolved reactive P. Dark bars are total P. Note log scale on y-axis. See text above for site abbreviation key.

Below are some features of the data to note:

In some cases snowmelt can contribute to more runoff at a site than rain-generated runoff. Snowmelt tends to be a larger fraction of runoff at the sites where minimal tillage is used. Of course, the amount of snowpack (not shown) vs. rainfall also plays a deciding role in the split. In general, however, snowmelt contributes much less to sediment and P loss than does rainfall.

Sediment loss is 30 times more variable across fields than runoff. Site conditions (soils, terrain, management) play an important role in controlling erosion.

While 2003-2004 was a year containing large rainfall events, erosion in general was less than “T” (tolerable soil loss) for all but one site. In only one site, Opitz, was the sediment loss greater than “T”. Half of the erosive events at Opitz occurred within one month of tilling the soil in preparation for planting – a worst case scenario. Even with this large sediment loss, the buffer was able to retain enough sediment to bring total contributing area sediment loss under “T”.

In snowmelt, sediment concentrations (mass per unit runoff volume) and P losses (mass per unit area) are an order of magnitude smaller than in storm runoff.

In sites with edge-of-field vegetated buffers (Knigge and Opitz), the buffer removed 13-20% of runoff, 90% of snowmelt sediment, 57-90% of storm sediment, 90-95% of snowmelt P, and 50% of storm P.

Comparisons with RUSLE2

RUSLE2 is a commonly used model that estimates annual mean sediment loss for use in conservation planning. As one of the goals of this study is to calibrate RUSLE2 to observations in Wisconsin, we compared estimated and observed sediment loss on two of our study sites.

At the Optiz site, "T" is estimated to be 5 T/ac/yr. We measured 5.5 T/ac/yr for 2003-2004, which had an erosivity index of 116. RUSLE2 uses an average erosivity of 120, and estimates sediment loss of 13 T/ac/yr.

At the Knigge site, "T" is estimated to be 3 T/ac/yr. We measured 0.67 T/ac/yr for 2003-2004, which had an erosivity index of 230. RUSLE2 uses an average erosivity of 110, and estimates sediment loss of 7.1 T/ac/yr.

RUSLE2 appears to greatly overestimate erosion for these sites. This may be due to the difficulty in scaling up observations on uniform "unit plots" (0.01 ha) to the field scale. More comparisons are needed before any tuning of RUSLE2 can occur.

Conclusions

In the first year of this study, we have measured runoff, sediment, and P losses from four Wisconsin Discovery Farms and one university research farm. We have measured more than 100 site-events including runoff generated by rainfall and snowmelt.

Sediment loss is 30 times more variable across the sites than is runoff. In all cases but one, sediment loss was less than "T". When vegetated buffers are considered, all losses were below "T". P losses varied from 0.01-10.0 lb/ac/yr.

Buffers removed from 50-90% of sediment, DRP, and TP.

RUSLE2 estimates of sediment loss are greater than observed.

Future Work

We will continue to collect runoff samples at these sites. We will use these observations to validate a precision-scale model, called PALMS, which can produce maps of runoff, sediment, and P losses on an event basis. This model produces output that can be compared directly to observations.

Because PALMS has extensive data needs, and runs slowly, we will use PALMS to calibrate SNAP+. SNAP+ uses RUSLE2 and the Wisconsin P Index top produce annual average estimates of sediment and P loss over multiple-year rotations. SNAP+ runs rapidly and uses readily available data. While SNAP+ can't be compared directly to observations, we will use PALMS simulations over several years and rotations to calibrate SNAP+ to observed data.

We will use PALMS and SNAP+ to design a package of management changes for each site in an effort to reduce sediment and P loss. We will continue to collect runoff at the sites to measure the impact of the management changes.

SNAP+ will also be relied on in the Wisconsin Buffer Initiative as a tool to guide the placement and design of vegetative buffers across the state.