APPLIED NUTRIENT MANAGEMENT RESEARCH AT PIONEER FARM

C.A. Baxter[1] and L.W. Good[2]
[1]University of Wisconsin – Platteville, Platteville, WI
[2]University of Wisconsin – Madison, Madison, WI

Abstract

As part of the Wisconsin Agricultural Stewardship Initiative (WASI), Pioneer Farm serves as an applied systems research and education farm with a mission to collect and disseminate high-quality environmental and economic baseline data to students, producers, and regulatory personnel. This paper outlines the current farm operations, methods and types of data collection, current results from ongoing monitoring projects and research, and details how the data is being used to support science-based public policy through efforts to refine and calibrate the Wisconsin P Index.

Introduction

Located approximately 6 miles southeast of Platteville, **Wisconsin**, Pioneer Farm is a 430 acre farm with 330 acres of tillable fields and dairy, beef, bull test and swine operations. Pioneer Farm is owned and operated by the University of Wisconsin – Platteville and until recently, the farmed served primarily as a facility for demonstrating production agriculture techniques. In 2000, the mission of Pioneer farm was expanded to include applied systems research. Stakeholders that included producer groups, regulatory personnel, and scientists were asked to identify research priorities for Pioneer Farm. These included:

1. Baseline measurements: environmental & farm management
2. Water quality - soil conservation practices, erosion & sediment delivery
3. Nutrient management
4. Manure Management
5. Air quality and odor control

In 2001, Pioneer Farm received funding to implement a sampling program and install water quality monitoring equipment. These data are used for accurately assessing nutrient mass balance and evaluating the impact of nutrient management on water quality. Since that time, Pioneer Farm has continued to expand data collection efforts and implement research to address issues important to Wisconsin Farmers.

Farm Operations

Dairy

The dairy facility includes a free-stall and tie-stall facility capable of housing 100 cows, a solar calf-raising barn, and a heifer lot. Current operations use a double-5 herringbone parlor for milking. Current manure management includes gutter and floor scrapers and a 1,000,000 gallon lagoon for storage of liquid manure. Pack manure from outdoor lots is stacked or composted on an earthen pad. Plans are underway to double the size of the dairy herd and build a new dairy facility that includes robotic milkers, liquid-solid manure separation, and treatment to reduce odor from the liquid waste stream.

Beef and Bull Test Station

Pioneer Farm maintains a beef herd of approximately 40 cows and steers, which are pastured from May – October and maintained on lots for the remainder of the year. Pioneer Farm also operates a bull test station with 100-150 beef bulls housed from November – April. During the winter, animals are kept on open lots. Lot runoff is collected and stored in an aboveground tank. Pack manure is stacked or composted on an earthen pad.

Swine

The recently completed farrow-finish swine facility will house up to 1400 wean-finish animals at full capacity. All manure from the facility is composted. The two-level facility houses animals on the upper level and manure falls through a slatted floor onto a bed of cornstalks on the lower level. The manure is periodically turned and dried using forced air, and eventually transferred to a covered compost pad to finish the composting process. Current plans are to transfer all of the swine manure off-farm as finished compost.

Crops

Pioneer Farm manages roughly 330 acres of cropland in 26 fields (Figure 1). Crops grown are corn, oats, and alfalfa-bromegrass hay in a 3 years corn – oats (alfalfa-brome seeding) – 3 years hay rotation. All fields are managed to meet "T" as defined in an approved conservation plan. Conservation practices include broad- and narrow-base terraces and contour strip cropping. In 2003, the farm produced 135 acres corn grain, 32 acres of corn silage, 139 acres of hay and 21 acres of oats. Average yields in 2003 were 179 bu/acre corn grain, 6.9 T/acre corn silage, 5.4 T hay, and 106 bu/acre oats. All of the crops grown are fed to livestock on-farm.

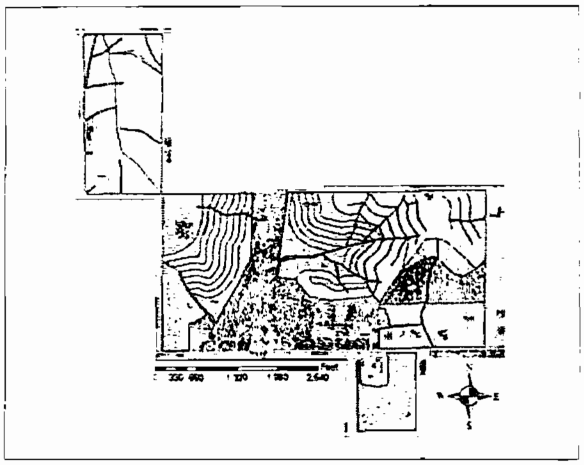


Figure 1. Pioneer Farm Field Layout

Nutrient Management

Pioneer Farm developed a Certified Comprehensive Nutrient Management Plan (CNMP) in 2003 and is currently managing nutrients according to the Natural Resources Conservation Service Conservation Practice Standard Code 590 (NRCS, July 2002). Soils are sampled annually and nutrients are managed with the SNAP-Plus software tool, which provides nutrient recommendations and an evaluation of potential P loss using the Wisconsin P Index (http://wpindex.soils.wisc.edu/). Like many

Table 1. Pioneer Farm mass balance

Nutrient	2002	2003
	---- Mass balance (lb/acre/yr) ----	
N	93	96
P	21	8
K	43	24

farms with livestock, Pioneer Farm operates under a positive mass balance of N, P, and K (Table 1.). This positive mass balance has undoubtedly contributed to the rise in average soil test P and K observed on the farm since 1968 (Figure 2). With recent expansion of the swine facilities and future expansion of the dairy facilities, this mass balance will increase unless alternative manure management practices are used.

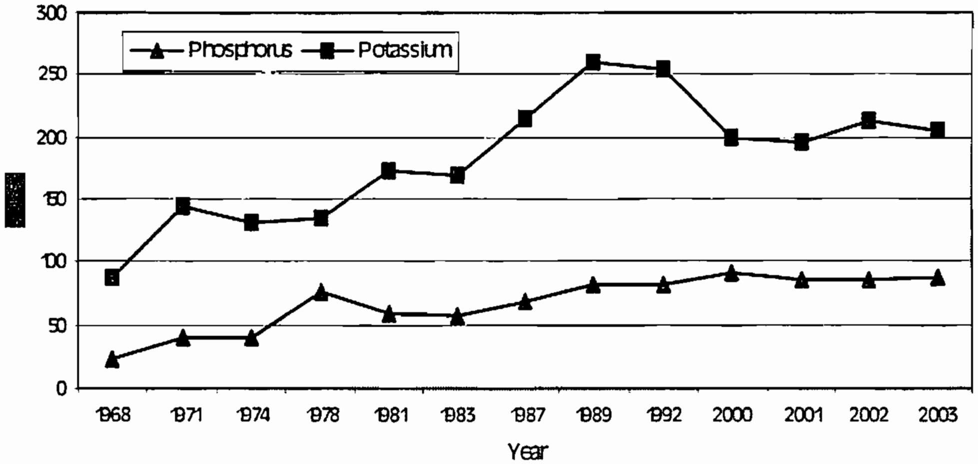


Figure 2. Trends in average soil test P and K at Pioneer Farm (year axis not scaled).

Data Collection

Nutrient Analysis Data

Nutrient analysis data provides the information essential for accurate calculation of nutrient mass balances, livestock rations, crop nutrient needs, and for answering long-term research questions. Crops are sampled as they are harvested from each field and yields are recorded. All purchased and raised feed (including premixes and mineral additives), bedding materials, milk and manure are sampled and analyzed. Feed, bedding and milk are analyzed for dry matter, crude protein, and total P, K, Ca, and Mg. Manure samples are collected at the time of application and analyzed for dry matter and Total N, P_2O_5, K_2O, and S. The UW Soil and Forage and Analysis Lab in Marshfield, Wisconsin perform all nutrient analysis.

Runoff / Water Quality Monitoring

Pioneer Farm monitors runoff and water quality at ten stations (Figure 3). Sites 1-4 were installed and fully operational in 2002, and the remaining sites were installed in 2003. All ten record flow volume, and nine stations include automatic samplers for collecting samples during runoff events. One monitoring station periodically collects samples directly from the Galena River at baseflow. At all sampling stations, multiple samples are collected during runoff events, and flow-weighted

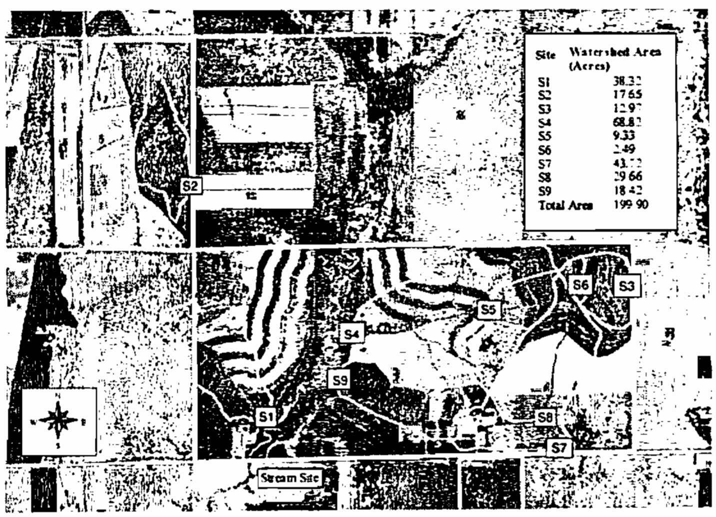


Figure 3. Location of water monitoring stations.

composites are prepared in the lab to produce one sample per runoff event.

Through a partnership with Pioneer Farm, the United States Geological Survey (USGS) installed all the runoff monitoring stations and compiles all runoff data. Runoff samples are analyzed for sediment concentration, dissolved NO_3^- and NH_4^+, total Kjedahl Nitrogen (TKN), dissolved reactive P, total dissolved P, and total P. The Water and Environmental Analysis Lab in Stevens Point, Wisconsin analyzes all water quality samples. Though still in the early stages of data collection and interpretation, Pioneer Farm has already begun to use the data collected to help answer some of the questions facing producers and researchers in the area of Nutrient Management and Water Quality.

Ongoing Research Projects

Impact of Runoff Volume and Sediment on Nutrient Loads

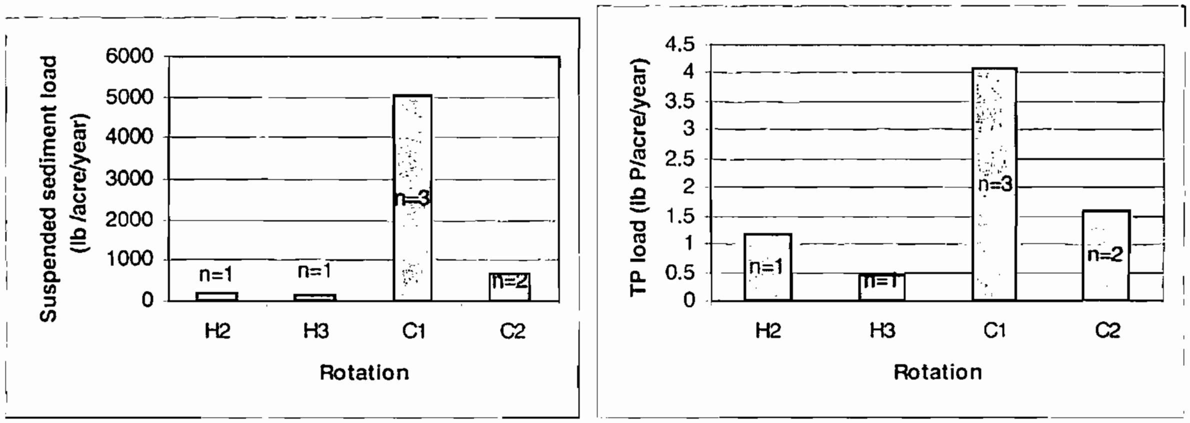
Preliminary data indicate that a reduction in sediment concentrations in runoff would likely have a greater impact than an overall reduction in runoff volume for reducing nutrient loads. While there were positive , but for the most part weak, linear relationships *(are these all significant?)* between runoff volume and total P (TP) and total Kjeldahl nitrogen (TKN) loads at all monitoring sites evaluated, the relationships between suspended sediment (SS) loads and TP and TKN were stronger ($r^2 > 0.8$) at all monitoring sites except 8 (Table 2). This indicates that while reducing total runoff volumes may decrease soil loss and nutrient loading under some conditions, significant sediment and nutrient losses reductions can be achieved without reducing runoff completely.

Table 2. Linear regression coefficients relationships between total runoff volumes, suspended sediment (SS) loads, total P loads (TP) and total Kjeldahl Nitrogen loads (TKN).

	Relationship between runoff volume and:			Relationship between SS and:	
Monitoring Site	SS	TP	TKN	TP	TKN
	---- Linear regression coefficient (r^2) ----				
2 (n = 51)	0.17	0.32	0.27	0.82	0.74
3 (n = 28)	0.46	0.69	0.52	0.84	0.95
5 (n = 28)	0.37	0.54	0.39	0.94	0.98
8 (n = 31)	0.74	0.94	0.91	0.81	0.66

Cropping Systems and Manure Managements Impact on Runoff Quality

Sites two, three, five, and eight monitor runoff quality in subwatersheds that are included within a single field or in multiple fields under the same rotation schedule. Thus, they are useful in evaluating how crop type impacts runoff quality. Although data is preliminary, available runoff quality data and field observations have shown that fall-killing hay with a burndown herbicide application before rotation into corn produces the largest sediment and total P losses compared to H-H or C-C rotations (Figures 4 and 5). In fact, the three greatest annual sediment and total P loads recorded from single-crop subwatersheds have been from those in the first year of corn following hay. These data are supported by low surface residue cover (10% average) measured in the spring after planting first year corn. Best management practices to decrease erosion and increase surface residue should be targeted at this year in the cropping sequence.



Figures 4 and 5. Cropping effect on sediment and total P load. H2=2nd year hay, H3=3rd year hay, C1=1st year corn following fall hay burndown, C2=2nd year corn.

The effect of manure application on sediment and P loads is also being investigated. Of particular interest are the effect of solid vs. liquid manure applications and the relationship between winter manure applications and P losses in snowmelt runoff. Current research is underway to evaluate the effects of surface-applied solid manure and subsurface injected liquid manure on subwatershed-scale nutrient losses.

Supporting Science-Based Public Policy: Calibrating and Refining the Wisconsin P Index

In order to evaluate the relative risk of P contamination from varying agricultural management practices on a given field, the Wisconsin P Index (WPI) makes a gross calculation of the annual P delivery from that field to the nearest surface water body. The general equation for the WPI is as follows:

$$WPI = [PP + SP + AP] \times TPDR$$

Where: *PP* is the particulate P loss from the edge of the field,
SP is the dissolved P loss from the edge of the field,
AP is an acute (single-event) P loss from the edge of the field from surface-applied (unincorporated) nutrients, and
TPDR is the total P delivery ratio from the edge-of-the field to the surface water.

A description of the equations used to develop the components of the WPI can be found at the WPI website: (http://wpindex.soils.wisc.edu). Since the WPI uses a quasi-modeling approach to estimate the potential losses of P from agricultural fields, numerous assumptions were made where data was lacking or limited. For example, AP losses are estimated under "worst-case" instead of "average" climatic conditions. The WPI's predictive ability is also limited by the need to use input data that is readily accessible to producers and/or agricultural consultants. These data include:

- Slope (%) and slope length
- Soil test P and Organic Matter
- Tillage (type and timing)
- Crop and yield goal
- Manure and Fertilizer Applications (timing, rate, and incorporation)

The WPI uses the above factors, climatic data, and RUSLE2 soil loss to estimate a total edge-of-field P delivery, which is then adjusted by a total P delivery ratio (TPDR) which takes into account below field slope and distance to surface water to estimate the amount of P that could potentially reach a surface water body.

As the WPI has been determined for all fields on Pioneer Farm and the single-crop subwatersheds provide an ideal condition for measuring edge-of-field losses, researchers are using the monitoring data to calibrate and refine the equations used to estimate edge-of-field P loss. Index values have been compared to preliminary annual total P loads from seven single-crop watersheds in 2003 and 2004 (through August). In all but one year for one of the subwatersheds, WPI values were higher than, but roughly proportional to, the measured annual total P load. The one exception was one of the first year corn sites in a year with abnormally heavy spring rainfall (Site 2 in 2004). The lack of residue cover caused by fall hay burndown and the heavy rains which occurred in spring and early summer of 2004 caused significant erosion and failure of grassed waterways at Site 2, which led to high sediment and P loading. This data suggests that an adjustment of the parameters used to predict soil loss with RUSLE2 or the WPI itself may be necessary to account for the potential P losses under this type of cropping system.

In addition to relating WPI values to annual P loads, the runoff data collected at Pioneer farm is being used to answer several more specific questions related to the WPI. Some of the questions currently being addressed are:

1) ***Does the WPI method for estimating soluble P delivery accurately predict actual soluble P losses from subwatersheds?***
   In the absence of surface P applications, the soluble P delivery is based on the relationship between soil test (Bray P1) and runoff P concentrations developed using small plot ($1m^2$) data. Data gathered at Pioneer Farm can help determine if the relationship holds true for sub-watershed scale runoff. Additionally, two single crop subwatersheds have been intensively sampled (100' grid) for soil test P and small plot runoff collectors have been placed within the boundary of the subwatershed to determine if small plot runoff collectors can be used to predict subwatershed-scale soluble P concentrations.

2) ***Does the following WPI assumption hold true: in the absence of unincorporated nutrient applications, winter (frozen soil) runoff dissolved P concentrations are not different than those at other times of year?***
   Preliminary data from Pioneer Farm suggests that this assumption may need to be adjusted for certain cropping systems, because of the differences in dissolved P concentrations observed at different times of year at Sites 2 and 8 (Table 3). These data suggest that crop type and season may affect runoff dissolved P concentration, even in the absence of P applications.

3) ***Is the WPI assumption that sediment P (in the absence of manure application) can be determined directly from soil total P valid?***
   It has been observed that as sediment loads decrease, runoff sediment-bound P concentrations become enriched with respect to the bulk soil. However, in simulated and

natural rainfall experiments conducted in Wisconsin, this relationship has not been observed. Currently, the WPI uses a placeholder of 1 for the sediment P enrichment ratio. Preliminary data collected at Pioneer Farm may suggest that an enrichment factor would provide more accurate prediction of watershed-scale P loss, but more analysis is needed before the enrichment ratio can be determined.

4) ***Does the WPI accurately predict the impact of acute (single runoff event) losses from unincorporated manure and fertilizer?***

Currently the WPI estimates acute losses based on a limited amount of available data and factors that vary by season. Because Pioneer Farm has not had a uniform, unincorporated manure application in a single-crop watershed since runoff monitoring began, researchers have not been able to answer this question. In the winter 2004-2005 surface applications of manure will be made in Site 2 to gather data on acute losses.

Table 3. Average dissolved P concentrations in single-crop watersheds that did not receive manure in 2004.

Season (2004 crop year)	Site 2 (1st year corn)	Site 8 (1st year hay)
	------------- Average dissolved P concentration (mg/L) --------	
Fall (harvest- Nov. 15)	0.50 (n=4)	N/A
Winter (snowmelt and winter precipitation)	0.43 (n=20)	2.35 (n=23)
Spring (April 1 – June 1)	0.46 (n=13)	0.57 (n=6)
Summer (June 1 - harvest)	0.42 (n=8)	1.57 (n=2)

Summary

Though still in the early stages of data collection, Pioneer Farm has already begun to answer some of the questions facing producers and researchers concerned with nutrient management in Wisconsin. Baseline data collected thus far has begun to provide insight into the nutrient and sediment losses associated with cropping systems, seasonal fluctuations, and manure management. The data has suggested best management practices (i.e. sediment control structures or cover crops) that could be tested to determine the impact on actual sediment and nutrient loads. The data generated by Pioneer Farm is providing a solid platform for the Wisconsin P Index, which will direct agricultural nutrient management in Wisconsin's future.

PROCEEDINGS OF THE

THIRTY-FOURTH NORTH CENTRAL EXTENSION-INDUSTRY SOIL FERTILITY CONFERENCE

Volume 20

November 17-18, 2004
Holiday Inn Airport
Des Moines, IA

Program Chair:
Bob Hoeft
University of Illinois
Urbana, IL 61801
(217) 333-9480

Published by:
Potash & Phosphate Institute
772 – 22nd Avenue South
Brookings, SD 57006
(605) 692-6280
Web page: www.ppi-ppic.org