# WATERSHED ASSESSMENT THROUGH ECOLOGICAL RESEARCH/FARMERS ACTIVE IN RESEARCH

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**Abstract.** Producers in the Southern Piedmont graze and manage their lands in a variety of ways across watersheds and across individual farms. These land management practices may have an impact on the nitrogen (N) and phosphorus (P) concentrations in stream base flow and storm flow. A group of producers, researchers and educators (WATER/FAIR) pulled together to assess stream nutrient concentrations relative to land management practices in two typical Southern Piedmont watersheds. The objective of this paper is to increase awareness of participatory monitoring and of the spatial and temporal distribution of stream nutrients (N & P) at watershed and farm levels. Results showed that dissolved reactive P (DRP) concentrations were highly variable depending on the management system. Stream base flow nitrate concentrations were lower leaving farms than going into farms more than more than 75 percent of the time and were 16 percent lower in 2000 than in 1999. These lower concentrations coming out of farms could suggest that these management systems are not losing nutrients to aquatic systems but rather utilizing them on the farm.

## INTRODUCTION

Producers in the Southern Piedmont graze and manage their lands in a variety of ways across watersheds and across individual farms. A typical whole farm management system in the Southern Piedmont often consists of both hay lands and grazing lands and less often croplands are present. These farmers may fertilize grasslands with either mineral fertilizer or animal manures depending on availability, costs and perceptions. These land management practices may have an impact on the N and P concentrations in runoff and streams.

In an effort to determine the impact of agriculture in the Southern Piedmont, a group of producers, researchers and educators (WATER/FAIR) joined to assess stream nutrient concentrations relative to land management practices in two typical Southern Piedmont watersheds (Rose and Greenbrier Creek watersheds). Project participants wanted to determine which practices were most effective in sustaining and improving water quality and if there was room for improvement.

## OBJECTIVE

The overall goal of this project was to determine which management practices are working in the Southern Piedmont. The specific goals of this paper are to increase awareness of participatory monitoring, as well as spatial and temporal distribution of nutrients (N & P).

## MATERIALS AND METHODS

This participatory watershed assessment project, WATER/FAIR (Watershed Assessment Through EcologicalResearch/Farmers Active in Research) began in 1996. Participants decided that we should first increase all entities' understanding of nutrient cycling in agroecosystems. Researchers and educators worked together to create a workbook focusing on Southern Piedmont agroecosystems and aquatic systems. The workbook titled: *Nutrient cycles in the Southern Piedmont*, was reviewed by farmers, educators, and researchers for both content and readability. All WATER/FAIR participants attended a nutrient cycling workshop and received a workbook and a colorimeter with reagents. Farmers participating in the project managed stream-side fields and were interested in water quality as well as the impact different management practices had on the nutrient contents in adjoining aquatic systems. Farmers were located by attending local agricultural gatherings and knocking on doors within the Rose and Greenbrier Creek watersheds. Each participant in WATER/FAIR was asked to fill out a questionnaire.

The project premise was that informed decision-makers fashion better decisions and that intangible information (nutrients leaving the field) is better communicated with a "seeing-is-believing" format (darker, bolder colors in colorimeter samples mean more nutrients are being lost). This type of on-going informative decision-making may lead to adaptive management; nutrient losses may then be reduced and water quality improved.

**Table 1. Management demographics for both watershed level and farm level from December 1998 to January 2001. Global indicates that runoff occurred on all farms.**

| Management Demographics | | |
|---|---|---|
| | **Watershed level** | **Farm level** |
| **Management systems** | 3 crop, 5 hay, 12 pasture | hay and pasture |
| **Fertilizer Source** | 3 dairy slurry, 5 mineral, 12 broiler litter | mineral and broiler litter |
| **Rainfall** | 44 events, 8 global | only base flow presented |
| **Case Study specific management** | | fencing, pond, and both litter and mineral fertilizers. |

In this paper, we will present watershed results for stream base flow and storm flow on various management systems (Table 1) as well as results for stream base flow from one of the participating farms. Base flow results presented are for year 1999 and storm flow results are for years 1999 and 2000. The limited rainfall during this portion of the study resulted in drought conditions. To better understand nutrient distributions it is helpful to study them on different scales. Rose and Greenbrier Creeks are fourth-order watersheds with gently rolling to steep uplands. Average annual rainfall is 1250 mm and soils are well drained kanhapludults. Seventeen stream sampling sites were located on the Rose Creek and 18 stream sampling sites on the Greenbrier Creek. Management systems were crop, hay and pasture. These systems were fertilized with dairy slurry, mineral fertilizers, or broiler litter.

The case-study farm system utilizes four practices: 1) hayed/grazing land fertilized with inorganic fertilizer (mineral), 2) grazing land fertilized with broiler litter, 3) limited stream access by cattle, and 4) farm pond as a filter system (Fig. 1). Nutrients are measured in runoff from each of the fields as well as upstream and downstream of each stream-side field. Field **Ø** is fertilized with inorganic fertilizer and closely resembles a P-based nutrient management strategy. This field has also been designated as a hay field; however, due to more than a two-year drought, the field has been occasionally grazed. Cattle do not have access to the stream from this field. Field **Ù** is identical to Field **Ú** , except that cattle had limited access to the stream. Field **Ú** is pasture or grazing lands fertilized with broiler litter, and Field **Û** has a pond which is to be utilized as a filter system for sediment and nutrients as well as a water source for cattle. A riparian buffer with an average width of 100 ft (30 m) is present along all stream corridors but not on the pond perimeter. In late summer/early fall the riparian buffer was thinned (all large pines were removed) and in late 2000 the riparian buffer and stream were fenced.

Five stream collectors were installed. Stream sampling Site 1 is a measure of upstream rural inputs, Site 2 is a measure of inorganic fertilizer with no stream access,

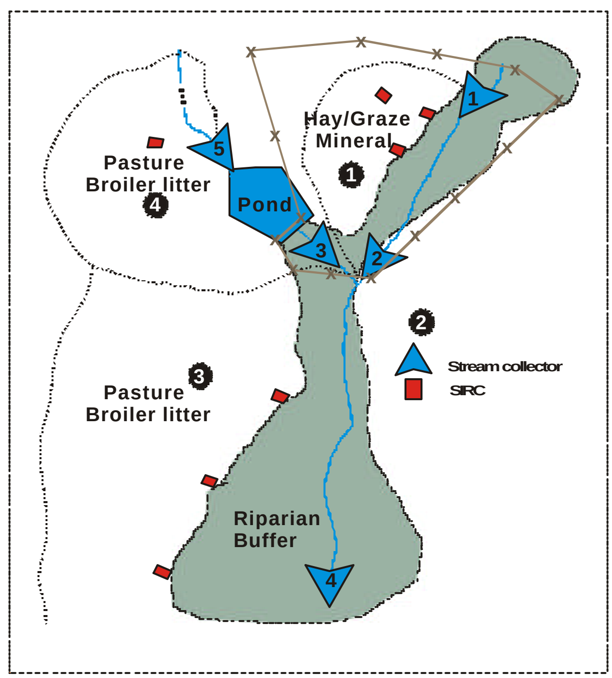


**Figure 1. Whole farm management system with 5 stream samplers. Stream flows toward the bottom of page.**

Site 3 is a measure of pond effectiveness, and Site 4 is whole farm discharge with limited stream access by cattle. Site 5 is a spring upstream from pond.

**Base Flow Sampling**

Bi-monthly base-flow sampling began in December 1998 and continued throughout 2001. Prior to each sampling, bottles were conditioned in-stream with Athree bottle fills@. Collected samples were filtered in the field through 0.45-Fm filters (CNA), placed in dark iced coolers and transported to an analytical laboratory for analysis.

**Storm Flow Collection**

In addition to base flow sampling, storm flow was collected from rising-flow stream collectors (Gordon et al.) and runoff was collected with small in-field runoff collectors (SIRC, Franklin et al., 1999). Runoff information is not the focus of this paper. Stream collectors were inspected and cleaned if necessary at least twice monthly. The morning following a rainfall event, sites were inspected for runoff and if runoff was present, stream samples were collected. Collected samples were placed in dark iced coolers and transported to an analytical laboratory for analysis. In the laboratory samples were filtered through 0.45-Fm Cellulose Nitrate (CNA) membranes.

**Laboratory analysis**

Water samples were analyzed for dissolved reactive phosphorus (DRP) and nitrate. The DRP was determined colorimetrically using the molybdate blue method (Murphy and Riley, 1962) and nitrate ($NO_3^-$ + $NO_2^-$)-N was measured with the Griess-Ilosvay method (Keeney and Nelson, 1982), after reduction of $NO_3^-$ to $NO_2^-$ with a cadmium column.

**Statistical Analysis**

Univariate analysis (SAS Inst. Inc., 1994) was executed to summarize descriptive statistics and to determine likelihood of a normal distribution for base flow data. Though several land uses were represented, land uses were classified into land management systems. The land management systems analyzed were pasture, crop, hay, and forest. Analysis of variance with PROC GLM and PROC ANOVA were also executed to explore relationships between base flow nutrient concentrations and management systems. Since the data within groups were not normally distributed, rank transformation/ANOVA was used in this study.

RESULTS AND DISCUSSION

**Watershed Level**

The results presented are from 20 farm fields from December 1998 to February 2001. Overall stream nitrate and DRP stream base flow concentration were lower in 2000 than in 1999 (Table 2). The Greenbrier Creek was found to have lower concentrations of nitrate and higher concentrations of DRP than the Rose Creek (Table 2). Pooled annual medians for nitrate were always higher than the US EPA proposed nutrient criteria (0.17mg $NL^{-1}$), while phosphorus pooled annual medians were always lower than the proposed US EPA stream nutrient criteria (0.037g $PL^{-1}$) for Ecoregion IX.

Stream-side fields with crop, hay and forest management systems had significantly lower ($p < 0.05$) stream base flow DRP concentrations than stream-side fields with pastures or the upstream source (Fig. 2A). Stream nitrate concentration for base flow for crop, forest, hay and pasture management systems were significantly lower than the upstream source (Fig. 2B, p

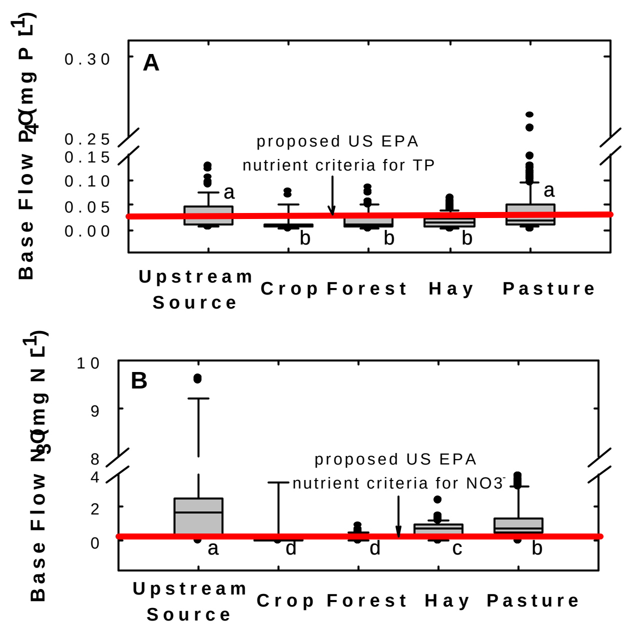


**Figure 2. Boxplots of dissolved reactive phosphorus (A) and nitrate (B) for management systems. Center line in each boxplot marks the median value. Upstream source management system indicates rural housing. Unlike lower case letters indicate medians are significantly different (Fisher's LSD, p < 0.05). Note US EPA nutrient criteria are for Ecoregion IX.**

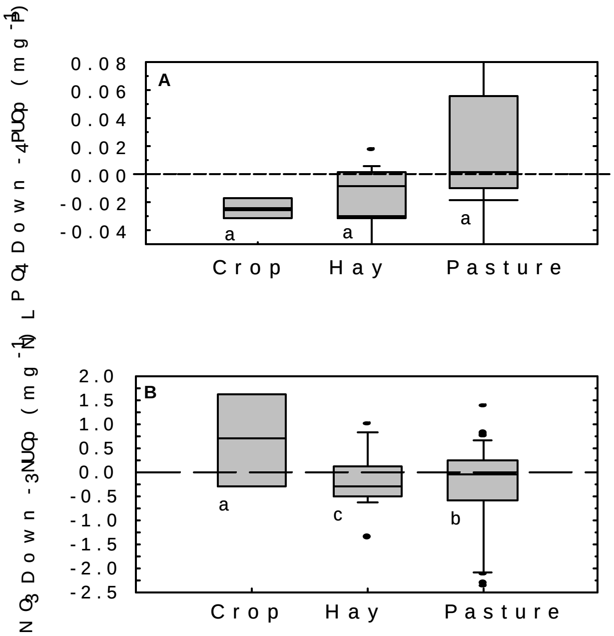


**Figure 3. Boxplots of median differences (downstream - upstream) in stream storm flow dissolved reactive phosphorus (A) and nitrate (B) for management systems. Unlike lower case letters indicate median rankings of concentration are significantly different (Fisher's LSD, p < 0.05).**

< 0.05). Pasture streams had higher nitrate concentrations than hay which was higher than both crop or forest streams. For both systems, pastures had the most variability and room for improvement. The variability may indicate possible solutions exist. It is also important to note that for both N and P many of the base flow concentrations were lower coming out of farms and that these lower concentrations were higher than the proposed stream nutrient concentration for Ecoregion IX. Both these points have several implications which will be discussed later.

No significant differences between land management systems were found for either N or P for storm flow, though as in base flow, pastures had the greatest variability (data not shown). Differences (downstream - upstream) in stream storm flow DRP concentrations were predominantly negative. Negative differences indicate that nutrient (in this case DRP) storm flow concentrations are lower leaving management system than coming into the management system. Differences in stream storm flow DRP concentrations were not affected by management systems (Fig. 4).

Differences (downstream - upstream) in storm nitrate concentrations were also predominantly negative, especially when stream-side fields were in hay and pastures (Fig. 3). Some positive differences were observed when stream-side fields were in crops.

These lower concentrations coming out of farms could suggest that these management systems are not losing nutrients to aquatic systems but rather utilizing them on the farm. These decreases in concentration could also be a result of dilution or transformations taking place within the stream and/or riparian buffers.

## Farm level

Overall, nitrate concentrations in stream base flow were highest coming into the farm (Stream Site 1, Fig. 4) and lowest leaving the whole farm system (Stream Site 4, Fig. 4). This was not always the case within the farm. Between sites 2 and 4 note that nitrate levels were often lower at site 4 but they also tended to spike above site 2 on several dates. Cattle had access in this segment of the stream making it difficult to identify fertilization as the source of these spikes though one spike did occur immediately following fertilization. The seasonal trends should be noted. Nitrate stream base flow concentrations were almost two times higher in the winter months than in the summer months. Farm out flow for nitrate concentrations in base flow were always above the

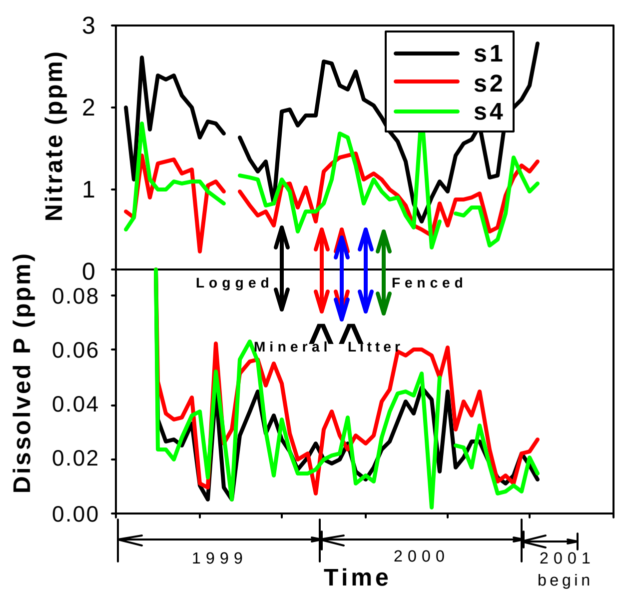


**Figure 4. Stream base flow nitrate (upper) and DRP (lower) concentrations from December 1998 to January 2001. Note that s1 indicates stream site 1 (coming into farm), s2 is midway (above which cattle have no access to stream), and s4 is exiting farm.**

Table 2. Median base flow nutrient concentrations for the Greenbrier and Rose Creeks

| Year | Greenbrier | Rose | p>\|t\| | Pooled Data |
|---|---|---|---|---|
| | -- mg $NO_3$-N $L^{-1}$ -- | | | --mg $NO_3$-N $L^{-1}$ -- |
| 1999 | 0.51 | 0.83 | 0.0001 | 0.62 |
| 2000 | 0.47 | 0.60 | 0.0001 | 0.52 |
| | --- mg DRP $L^{-1}$ --- | | | --- mg DRP $L^{-1}$ --- |
| 1999 | 0.023 | 0.014 | 0.0001 | 0.017 |
| 2000 | 0.013 | 0.007 | 0.0001 | 0.010 |

† Probability for comparison of ranked stream nutrient concentrations between Greenbrier and Rose creeks according to Fisher's LSD.

proposed US EPA criteria.

Pond management system did not appear to be a very effective management tool for the reduction of nitrate (Field Û, Site 3, Fig. 5) nor were seasonal trends as prominent. On many of the collection dates nitrate in base flow was slightly higher leaving the pond than entering the pond. Logging was done (Fig. 5, note arrow) in late 1999 throughout the riparian area. It appears to have reduced nitrate in base flow but this reduction was not found to be significant. Stream base flow DRP concentrations were lower in the winter than in all other seasons. No differences between incoming and outgoing DRP concentrations were found (stream site 1 and stream site 4). Within the farm, however, stream site 2 was almost always higher than both stream sites 1 and 4. As with nitrate, seasonal trends were not noteworthy in the pond management system. Farm out flow for DRP concentrations in base flow (s4) oscillated just above and just below the proposed US EPA proposed criteria (Fig. 4). In late summer and fall, DRP base flow concentrations crept above the criteria.

The pond management system was dramatically effective for DRP reduction**.** Pond outflow DRP concentrations were consistently at least six times lower than stream base flow DRP concentrations above the pond.

## General Discussion

Both at the watershed scale and at the farm scale nitrate concentrations tended to be lower coming out of farms. This indicates that some mechanism is reducing nitrate concentrations. If that mechanism is dilution then what the farmer has done to date has kept

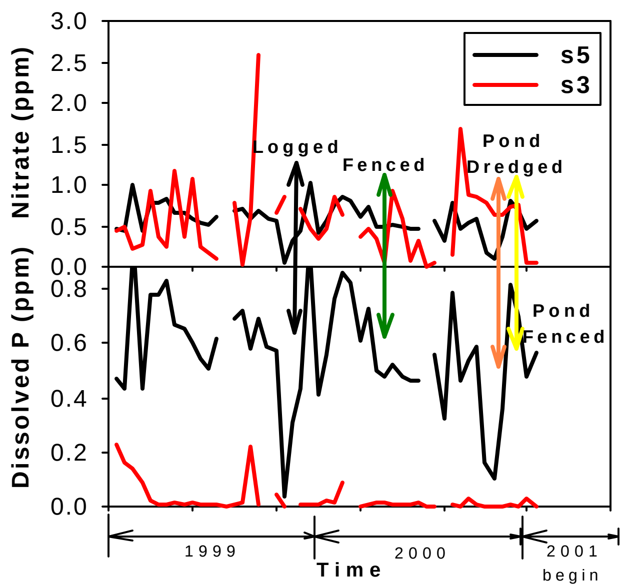


**Figure 5. Stream base flow nitrate (upper) and DRP (lower) concentrations from December, 1998 to January, 2001. Note that stream site s5 is coming into pond and s3 is exiting the pond.**

nitrate out of subsurface flow that becomes base flow. If it is not dilution, then it is some mechanism either within the riparian area or within the stream itself. Within the riparian area it could be plant uptake or denitrification. In that after logging stream nitrate concentrations tended to be lower (though not significantly), this might suggest that uptake is occurring That is, younger, faster growing vegetation tends to consume and store more nutrients than older, slower growing trees. We should again point out that the logging carried out on this riparian area was a selective cut of predominantly older pines and hardwoods with diameters (dbh) of 24 inches (60 cm) or greater.

Of importance, is the concern that US EPA proposed nutrient criteria are lower than the nutrient concentrations coming out of many of the farms even though concentrations are higher before reacting the farms. Each state has until 2004 to produce a viable plan developing State Nutrient Criteria that are acceptable to the US EPA. This report points out that nutrients are higher leaving farms than the proposed criteria. This could result in potential fines or mandates for management placed on these farms, regardless of the quality of water before it reaches farms. Thus, the State Nutrient Criteria should consider concentration changes within the farm or parcel, not just absolute concentrations leaving the farm or parcel. Fines or mandates should not be placed on those landowners that "improve" the water. Seasonal considerations should also be made in the criteria developed at the state level. Similar provisions should probably be made for total maximum daily loads.

## CONCLUSIONS

Through the participatory process, farmers, educators, and scientists are working together to understand the impact of management on stream water quality. Many farms are improving in-stream nutrient concentrations for both base and storm flow in the Rose and Greenbrier Creek watersheds. Yet, nitrate levels in base flow are higher than the proposed US EPA stream nutrient criteria for Ecoregion IX. In contrast, DRP concentrations in base flow are lower than the proposed US EPA stream nutrient criteria. Because of this, states developing Nutrient Criteria should consider concentration changes within the farm or parcel, not just absolute concentrations leaving a parcel.

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