ASSESSING THE WATER QUALITY IMPACT OF A RESTORED RIPARIAN WETLAND FOREST

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INTRODUCTION

Recent research has shown that riparian ecosystems can also be used to control nonpoint pollution. Lowrance et al. (1984, 1985a, 1985b) and Peterjohn and Correll (1984) demonstrated that riparian forest ecosystems of coastal plain agricultural watersheds are excellent nutrient sinks which buffer the nutrient discharge from surrounding agroecosystems. Lowrance et al. (1984), Peterjohn and Correll (1984), and Lowrance (1992) showed that nutrient uptake and removal by soil and vegetation in the riparian forest ecosystem prevented agricultural upland outputs from reaching stream channels. They concluded that the riparian ecosystem can serve as both a short and long-term nutrient filter and sink if above-ground vegetative biomass is periodically harvested to ensure a net uptake of nutrients. Riparian wetlands have also been shown to function as nutrient sinks and filters for land-treated waste application of municipal sewage (Turner et al., 1976; Sloey et al., 1978).

Although mature riparian forests have been shown to be excellent nutrient sinks and buffers, little research has been conducted on the short-term effectiveness of newly established riparian forests. Licht and Schnoor (1990) used densely planted poplar trees (*Populus spp.*) to provide a riparian buffer strip for conventional row crop agricultural land in Iowa. They found that in some instances, the reestablished riparian forest decreased nitrate concentrations in the shallow soil profile from 25 mg N-NO_3/kg dry soil to 5 mg N-NO_3/kg dry soil during the first year of reestablishment. However, information on storage and removal of nutrients migrating through the riparian zone is still lacking for wetlands during the first years following restoration.

This work reports on the first year of a study designed to examine the feasibility and effectiveness of restoring a riparian wetland and using it as a bioremediation site for nutrients moving downslope from an animal waste application site. In question is the short-term effectiveness of the restored wetland in enhancing the quality of the water leaving the site.

DESCRIPTION OF STUDY AREA

A new research facility at the University of Georgia's Coastal Plain Experiment Station in Tifton, Georgia, provided the opportunity to conduct the research. The facility is primarily used to evaluate the water quality impact of liquid dairy manure applied to a year-round minimum tillage forage production system (Vellidis et al., 1991a). The land is typical of a new dairy site and was not previously used for disposal of animal wastes.

A 5.6 ha center pivot irrigation system applies liquid manure derived from flush cleaning of dairy cow facilities onto a year-round forage production system. A detailed monitoring program is used to determine the concentrations and cumulative amounts of NO_3-N, NH_4-N, Total N, PO_4-P, Total P, Ca, K, Mg, and Na applied through the waste, assimilated by the crops, stored in the soil, or leached to shallow ground water.

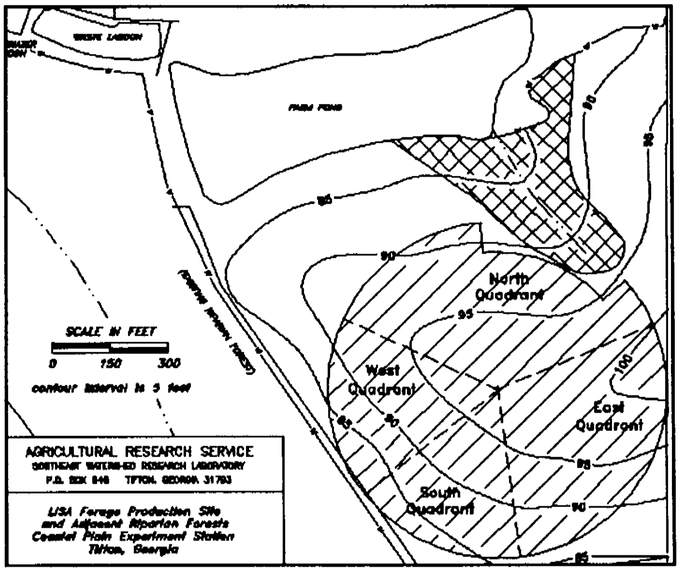

Figure 1 Dairy Wetland Restoration research facilities. The circle indicates the area irrigated by the center pivot waste application system. The wetland is the cross-hatched area.

The north quadrant (2 ha) of the pivot which receives an application rate of 600 kg N/ha-yr drains downslope directly into an adjacent wetland (Figure 1). Surface runoff and ground water from this quadrant flow through the wetland before being discharged to the first order stream which drains the wetland. The stream feeds a constructed farm pond.

The wetland (0.92 ha), which was forested until 1985, is easily distinguished from the surrounding agricultural area by its vegetation, which consists mostly of wetland grasses and rushes (*Juncus sp.*), and its soil, which is Alapaha loamy sand, a deep, poorly drained soil commonly found along drainageways. Plinthite is found below a depth of 0.6 m and typically acts as an aquitard.

An upland pasture on the east side of the wetland (Figure 1) and the forage production site are comprised primarily of Tifton loamy sand soil with a plinthic layer at a depth of 1-1.5 m. As in the wetland, the plinthite typically acts as an aquitard and during periods of high rainfall, is responsible for the formation of transient perched water tables. Water movement to the wetland from the upslope areas occurs primarily through subsurface flow. In the summer and autumn, surface runoff generally occurs only during intense rainfall events. During the winter months, when the soil profile is often saturated, runoff events are frequent and stream flow through the wetland is evident.

The surface topography of the field site and the physical location of the wetland with respect to the upland waste application system limit waste-impacted hydrological inputs to the west side of the wetland (Figure 1). The east side of the wetland is impacted by the upland pasture which does not receive animal waste except as drift. The pasture receives inorganic fertilizer as recommended by the University of Georgia Cooperative Extension Service. Waste application began in July, 1991.

The wetland was partially restored in February 1991 by reintroducing a combination of native trees on 0.47 ha (Figure 2). The trees will be eventually harvested for pulp wood or timber wood. Slash pine (*Pinus elliottii* Engelm.), yellow poplar, (*Liriodendron tulipifera* L.), blackgum (*Nyssa sylvatica* Marsh.) and green ash (*Fraxinus pennsylvanica* (Borkh.) Sarg.) were selected as a combination that would provide fast growth and year-round nutrient uptake. The pines were planted on the upslope portions of the wetland while the poplars were planted in the lower and wetter areas. The trees were planted with 1.5 m spacing within rows and 3 m spacing between rows to permit seasonal mowing for biomass removal. Native grasses were permitted to establish themselves along the perimeter of the wetland (0.45 ha) as a transitional zone between the forage production system and the riparian forest (Figure 2).

METHODS

Water Quality Measurement. A combination of surface runoff collectors, flumes, and monitoring wells were installed to monitor surface runoff and shallow ground water in the restored riparian wetland and the agricultural uplands (Figures 2). The resulting data are expected to provide specific information on nutrient uptake and removal processes in the riparian wetland and on changes in nutrient content of surface runoff and

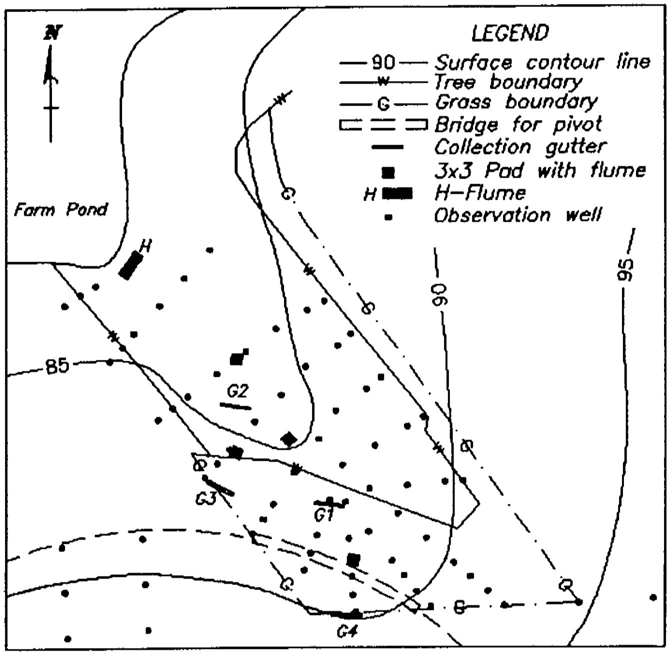

Figure 2. Map of the Dairy Wetland Restoration site showing the network of monitoring wells and the location of the 4 collection gutters and flumes.

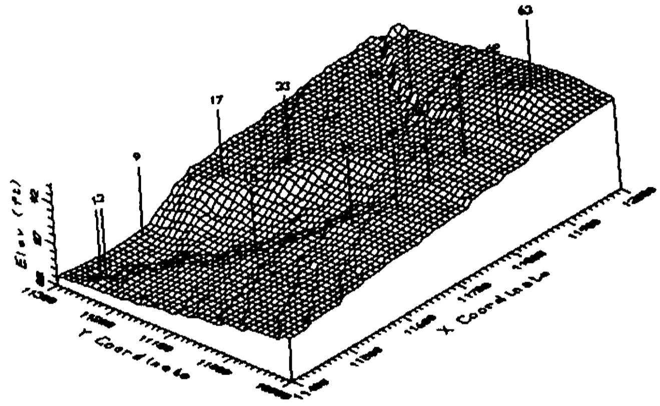

Figure 3. Three-dimensional image of the restored wetland's surface topography. Labels indicate the location of shallow ground water wells on the periphery of the wetland.

shallow ground water moving through the riparian zone.

Nutrient concentrations in shallow ground water are sampled in the north quadrant of the agricultural upland with 18 monitoring wells installed at depths of 3 and 6 m (Vellidis et al., 1991b). In the wetland, ground water is monitored with 63 wells located within the wetland and on its perimeter on a 10 m grid (Figure 2). The wells were installed to the plinthic layer (from 0.6 to 1.2 m in depth) and screened from 50 mm below the soil surface.

The well network was designed to intercept shallow ground water inputs into the wetland from both the waste application site and upland pasture on the east side of the wetland. To illustrate the extent of the well network with respect to surface topography, a three-dimensional image of the wetland was created (Figure 3). The numeric labels indicate the locations of 13 of the 17 perimeter wells. The other 46 wells were located within the perimeter. The view is from the northwest and elevations are relative to a local benchmark. A rigid biweekly sampling schedule is used to sample the wells and to measure the depth to the water table.

Surface runoff is sampled at two locations entering the wetland, and at two locations near the stream flow. At each location, the runoff is collected in a gutter, passed through a 200 mm modified Tucson flume, and redistributed through a slotted gutter. Collection gutters G4 and G3 (Figure 2) were installed at the boundary of the wetland and the agricultural area and sample runoff leaving the forage production system. Collection gutter G1 was located downslope from G4 at the boundary of the perennial grass zone and the hardwoods to sample surface water that has traveled approximately 20 m through the wetland. Gutter G2 was located downslope from G3 at the boundary of the pines and hardwoods to sample water that has passed through approximately 25 m of wetland.

A 600 mm H-flume installed at the wetland outlet is used to measure surface water quality and quantity discharged into the farm pond. The location of the flume is denoted by the letter *H* in Figure 2. Tapered earthen berms approximately 10 m long were constructed on either side of the H-flume to route surface flow leaving the wetland through the flume.

The paired surface water collectors are expected to provide specific information on nutrient uptake and removal by wetland soil and vegetation types as the nutrient front discharged from the land application site migrates through the wetland. The outlet flume is expected to provide data on the overall effectiveness of the wetland.

Composite water samples are collected from the four modified Tucson flumes and the H-flume with battery-powered peristaltic pumps. During runoff events, the pumps are switched on by electro-optic liquid level switches installed in the flume stilling wells. To prevent overflow of the 13.5 L glass sample bottles during extended runoff events, the pumps were also furnished with a programmable time-out circuit that forces them to operate for 15 seconds out of every hour during the winter when runoff events commonly last 2 or 3 days. In the summer, when runoff events from thunder storms are typically short lived, the timer is reprogrammed to be on for 15 seconds out of every 5 minutes. Hinged sheet metal covers fabricated in the dimensions of the concrete pads completely enclose all instrumentation on the pads. The design of the surface runoff collectors is described in detail by Vellidis et al. (1992).

Samples from each runoff event and from the biweekly sampling of the monitoring wells are analyzed for nutrient concentrations (NO_3-N, NH_4-N, Total N, PO_4-P, and Total P). Water samples from the stream at the wetland outlet are collected periodically and compared to background level samples collected before waste application began to evaluate nutrient loading of the stream.

DISCUSSION

Monitoring Wells. The high degree of spatial and temporal variation resulting from the dynamic nature of the controlling factors such as rainfall, hydraulic gradients, and subsurface topography make it difficult to observe trends by comparing time-series graphs from individual wells. However, three-dimensional surface representations of concentration versus space allow the progression of nutrient plumes to be readily observed as illustrated by Figures 4 and 5.

Figure 4 shows NO_3-N concentrations in the wetland on 12 April 1991. The view is from the northwest, as in Figure 3, and shows a large mound of NO_3-N, with a mean concentration of 10 mg/L, on the western side of the wetland. Figure 5 presents NH_4-N concentrations in the wetland on the same date. As expected, very low levels were detected in the majority of the wells.

Surface Water Collectors. Although most studies have shown that wetlands were processing and storing nutrients in surface runoff, reported nutrient retention differed greatly among wetland types and for each nutrient because

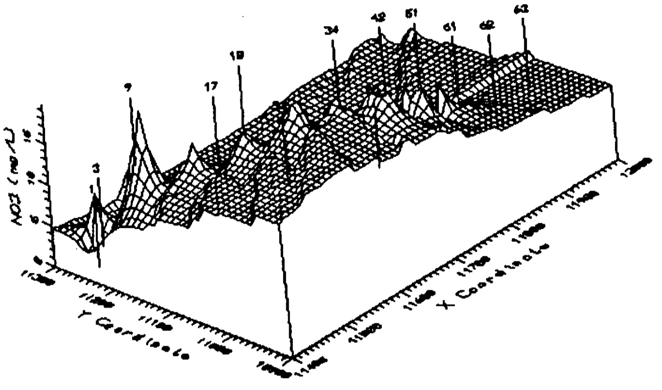

Figure 4. NO_3-N concentrations in shallow ground water on 12 April 1991.

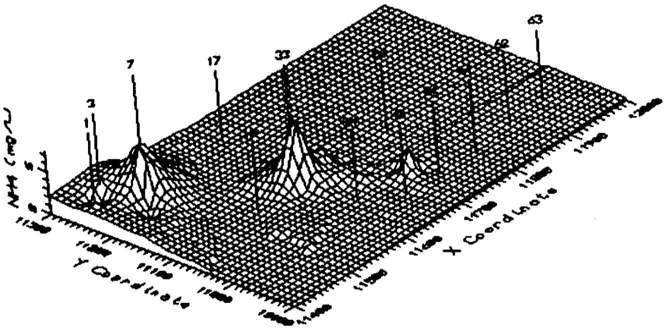

Figure 5. NH_4-N concentrations in shallow ground water on 12 April 1991.

the processes were biologically controlled to a great degree and output concentrations varied seasonally. In this study, the runoff collectors were paired to provide data on nutrient retention by the soil and vegetation as surface runoff from the land application site migrated through the wetland.

Initial evaluation of field performance indicates that composite water samples were collected from the four runoff collectors for each event registered by the flume stage recorders. Volumes varied with location but were proportional to the recorded hydrograph. The paired gutters also appear to be successfully quantifying nutrient concentration changes in surface runoff.

SUMMARY

The instrumentation that was designed and installed to monitor the nutrient assimilation capacity of the restored riparian wetland has performed well and has met expectations. Little maintenance has been required.

In addition to successfully monitoring nutrient concentrations in surface and subsurface flow, the overall sampling strategy appears to be effectively quantifying the role of several key ecosystem processes in the restored wetland. Because of the labor intensive nature of the study, however, other important processes are not currently being addressed. These include the role of microbial organisms and algae on short-term uptake of nutrients from surface and subsurface flow and the contribution of litter to overall nutrient storage and removal. As resources become available, additional research components are added. A study on the role of microbes in P retention is currently in the planning stages. The initial phase of the study will be concluded in 1994 at which time the impact of the restored wetland on water quality will be evaluated based on the collected data.

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