Controlling Nutrient Runoff from Golf Course Fairways using Vegetative Filter Strips

Oklahoma State University

Gregory E. Bell

Start Date: 2000
Number of Years: 3
Total Funding: $75,000

Objectives:

1. *Investigate the influence of multiple vegetative filter strips for reduction of nutrient runoff.*
2. *Determine if irrigation and natural rainfall differ in propensity for nutrient runoff.*
3. *Study the impact of antecedent soil moisture and application timing prior to rainfall on nutrient runoff potential. 4) Investigate the potential use of the PRZM-3 model for determining nitrogen fate under golf course conditions.*

Construction at the site is progressing. Projected target date for the completion of site construction is January 31 2001. That provides sufficient time to test the irrigation system, collection equipment, and moisture sensing devices before the bermudagrass growing season begins in May 2001.

A TDR 100 moisture sensing system was purchased from Campbell Scientific (funds provided by Oklahoma Agricultural Experiment Station) to monitor soil moisture content at the site. TDR sensors will be connected to a multiplexer that will coordinate signals to a data logger at the research site. A computer in the turfgrass research center will pole the data logger continuously through a modem connected by underground cable.

Automatic runoff collection units were purchased from ISCO (funds provided by the Oklahoma Turfgrass Research Foundation) to collect runoff during periods of natural rainfall or rainfall simulation. Model 6700 samplers will pump water from calibrated flumes constructed by the Oklahoma State University Biosystems and Agricultural Engineering Department. The samplers will collect water automatically in predetermined intervals. The flumes are calibrated to known water flow rates. Sensors monitor the depth of water in the flumes and flow rate is calculated on that basis. When runoff occurs the samplers are automatically activated by the sensors and collect up to 20 individual samples in 5-minute intervals. The flumes are continuously covered to prevent rainfall or irrigation entry. Water flows into the flumes through collection troughs at the base of each runoff plot. Research will begin in May 2001.

Progress Report: November 1, 2000

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Progress on the project is a season behind. It took several weeks to procure the moisture sensing equipment and several months to procure the runoff collection equipment. A graduate student has joined the program to lead this research through 2001 and construction at the site is progressing. Projected target date for the completion of site construction is January 31 2001. That provides sufficient time to test the irrigation system, collection equipment, and moisture sensing devices before the bermudagrass growing season begins in May 2001. The initial study to determine the effectiveness of graduated buffer strips will begin in 2001.

A TDR 100 moisture sensing system was purchased from Campbell Scientific (funds provided by Oklahoma Agricultural Experiment Station) to monitor soil moisture content at the site. As construction proceeds, CS-615 water content reflectometers will be placed 6 inches below the soil surface at three locations, high, mid, and low in each research plot to monitor soil moisture. These sensors will be connected to an AM 416 multiplexer that will coordinate signals to a CR10X data logger. A computer in the turfgrass research center will pole the data logger continuously through a modem connected by underground cable to research site. Using these measurements the irrigation system at the site will be activated either automatically or manually to maintain moisture content at field capacity continuously.

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Water flows into the flumes through collection troughs at the base of each runoff plot. These troughs are constructed of 3-inch polyvinylchloride pipe cut in half lengthwise. The troughs are mounted to 4 x 4 treated lumber posts to maintain slope. These posts are buried 24 inches into the ground and anchored with concrete. Troughs are mounted to half moon supports anchored to the top of the posts. Each trough is located below the thatch layer and covered to prevent rainfall or irrigation entry. These metal covers are specially designed to slope away from the runoff plot with raised extensions that extend over the plot to allow runoff to enter the trough. Steel angle (3 x 3 x ¼ inch) is laid beneath the thatch layer at the base of the plots and extends over the trough to prevent runoff from exiting under the trough. Aluminum angle overlaps the steel angle on the plot side with and its other side extends into the soil to prevent runoff under the steel angle. Research will begin in May 2001.

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Maintaining golf course turf at acceptable levels requires relatively high inputs of plant nutrients and water. Common bermudagrass (*Cynodon dactylon* L.), maintained as golf course fairway, requires as much as 48.8 kg ha^{-1} mo^{-1} (1 lb./1000 sq. ft.) nitrogen (N), 24.4 kg ha^{-1} mo^{-1} (1/2 lb./1000 sq. ft.) phosporus (P), and 48.8 kg ha^{-1} mo^{-1} potassium (K) to maintain color and density. Golf course fairways often border lakes, ponds, and streams. The potential for nutrient contamination of surface water from these sites is a subject of increasing environmental concern.

Runoff occurs when precipitation rate exceeds soil infiltration rate. Compacted fine soils, common on golf course fairways, increase runoff potential by reducing infiltration rate. The resulting runoff may carry nutrients in solution or nutrients adsorbed to soil particles (Liaghat 1996). The velocity of runoff also influences infiltration (Muscutt et al. 1993). As velocity slows, infiltration rate increases and physical filtering of chemicals and sediment in runoff increases.

Vegetated waterways and no-till vegetative filter strips (VFS) reduce surface runoff of chemicals in wetlands (Castelle et al. 1994) and agriculture (Felsot et al. 1990; Chaubey et al. 1994). Turfgrass VFS also have potential to filter and reduce chemical pollution (Cole et al. 1997; Gross et al. 1990; 1991). Cole et al. (1997) found no relationship between VFS length or VFS mowing height and nitrogen and pesticide concentrations in runoff from simulated golf course fairways. The presence of a VFS, however, significantly reduced chemical and nutrient concentrations in runoff water. These results suggested that the initial barrier provided by a VFS was more important for nutrient runoff reduction than the severity of the obstacle presented. It may be possible to further inhibit nutrient runoff by presenting a series of obstacles in the form of turfgrass VFS mowed at increasingly higher heights.

A predictive model, PRZM-3, was recently developed and released by the United States Environmental Protection Agency to determine pesticide and nitrogen fate in agricultural systems. This model is a combination of a refined PRZM model (Carsel et al., 1984) and the VADOFT model and can be used in a Monte Carlo, probabilistic simulation mode. Nitrogen and pesticide fate in the plant root zone and vadose zone are determined respectively by PRZM and VADOFT. The model also includes a hydrologic component for calculating runoff and erosion based on the Soil Conservation Service curve number technique and the Universal Soil Loss Equation. This model may have value for predicting nitrogen fate under golf course conditions.

The objectives of this study are to 1) Investigate the influence of multiple vegetative filter strips for reduction of nutrient runoff. 2) Determine if irrigation and natural rainfall differ in propensity for nutrient runoff 3) Study the impact of antecedent soil moisture and application timing prior to rainfall on nutrient runoff potential. 4) Investigate the potential use of the PRZM-3 model for determining nitrogen fate under golf course conditions.

Figure 1. Photo depicting the OSU runoff site.

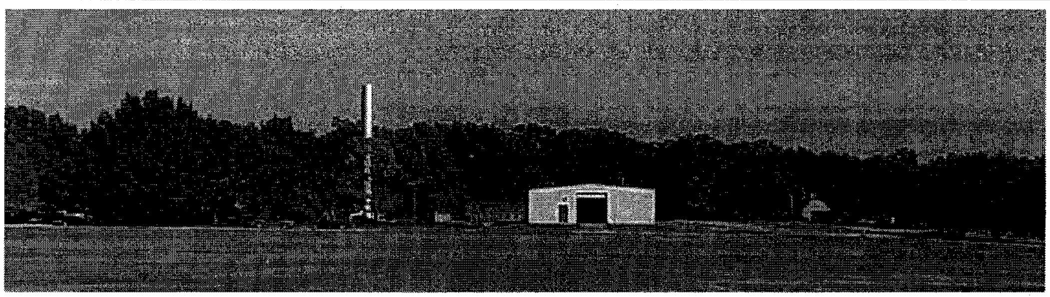
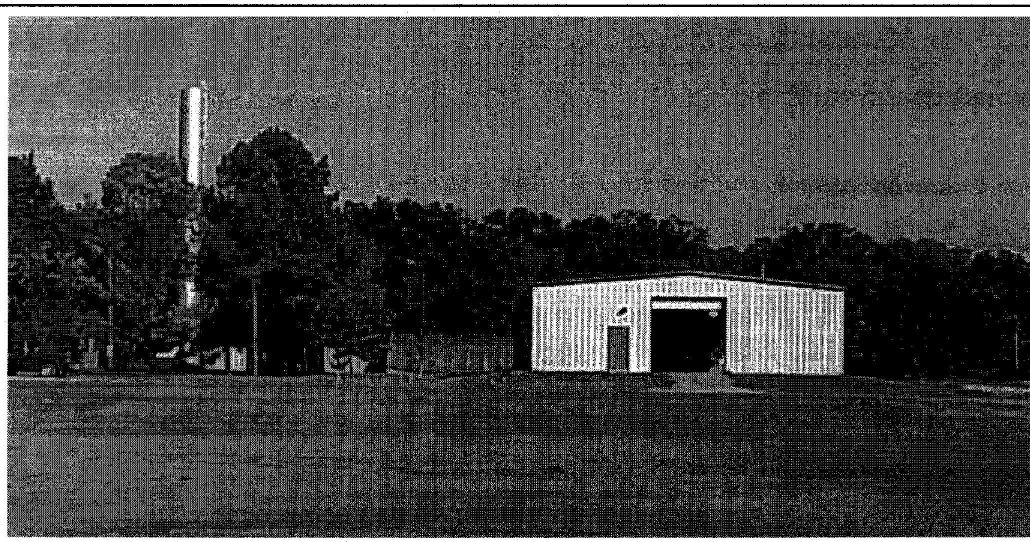


Figure 2. Photo depicting a single block of the OSU runoff site.



Procedures

A common bermudagrass area specifically designed for these studies was constructed at the Oklahoma State University Turfgrass Research Center (Figure 1, 2). The area is divided into three large blocks (595 m^2; 6400 sq. ft.) each consisting of two experimental units. Experimental units and blocks are separated by earthen mounds that confine runoff to the area under investigation. An overhead irrigation system capable of delivering a simulated rainfall event of up to 64 mm h^{-1} (2 ½ in. per hour) is located at the edge of each block separated from the block by earthen mounds. Soil at the site is silty clay loam with an infiltration rate less than 13 mm h^{-1} (½ in. per hour). Each experimental unit has a uniform slope of 5%, severe for a golf course fairway. A box blade and transit level were used for finish grading less than 24 h before each block was sodded with 'U-3' bermudagrass. Rainfall did not occur during the period between finish grading and sod installation so erosion did not affect finish grade. Once studies begin, daily rolling will help simulate cart traffic and daily irrigation will maintain soil moisture at 50% volumetric water content. The turf will be mowed at 12.7 mm (½ in.) across the upper sections of each experimental unit to simulate golf course fairway. These fairway sections will be 12.2 m (40 ft.) wide by 18.9 m (62 ft.) long down the fall line and will be bordered by lower VFS sections of 5.5 m (18 ft.). Covered troughs will collect runoff water from each experimental unit and channel the water to individual collection tanks by gravity flow. Water samples will be collected from this flow at pre-determined intervals and samples tested for concentrations of nitrate, ammonium, and phosphate. Time from rainfall initiation to runoff will be recorded for each rainfall event and flow rate will be measured periodically for the duration of the event. Total amount of runoff compared to precipitation will be calculated for each experimental unit.

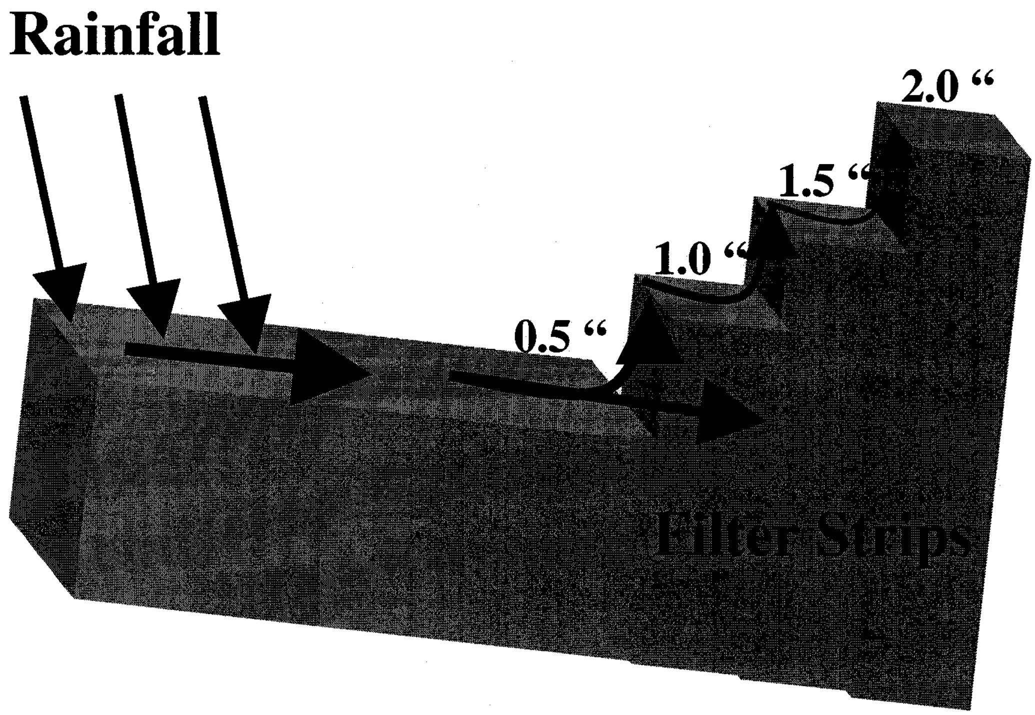
Time-domain-reflex probes will be permanently placed along the slope in each experimental unit to assess soil moisture content. These probes will be centered within each experimental unit at 2.1, 10.2, and 18.3 m (7, 33, and 59 ft.) from the top of the fall line. Each experimental unit will contain three probes. The units will be irrigated daily to 50% volumetric soil moisture based on the average measured by the three probes. Regulating irrigation in this manner will insure consistent soil moisture prior to all natural rainfall events and provide the basis for experiments concerning antecedent soil moisture. The higher elevations of sloped experimental units are expected to be drier than the lower areas. This natural condition does not require adjustment. Urea and super triplephosphate fertilizer will be tested for runoff potential. Nitrogen concentration and total nitrogen loss will be measured for 1 h following the initiation of runoff. Automatic sampling devices and collection tanks will be constructed for this purpose.

Prior to study initiation, coefficients of uniformity will be determined for irrigation in each experimental unit. These results will be compared to coefficients of uniformity determined after natural rainfall and the irrigation system will be adjusted to provide a close proximity to natural rainfall. Crop coefficients will be determined for the site monthly and evapotranspiration calculated daily.

Study 2000

The influence of multiple VFS compared to a single VFS (Objective 1) will be tested in year 2000. Each block will consist of a control experimental unit containing a single 5.5-m (18 ft.) wide VFS mowed at 38.1 mm (1 ½ in.) and an experimental unit containing three 1.8-m (6 ft.) bermudagrass VFS. These three VFS will be mowed progressively higher with decreasing elevation (Figure 3).

Figure 3. Concept of graduated vegetative filter strips.



The VFS bordering the fairway will be 25.4 mm (1 in.), the next highest 38.1 mm (1 ½ in.), and the final VFS, 50.8 mm (2 in.). Prior to simulated rainfall, fairway sections will be fertilized with 48.8 kg ha^{-1} (1 lb./1000 sq. ft.) N (urea) and 24.4 kg ha^{-1} (½ lb./1000 sq. ft.) P (triple superphosphate). Approximately 4 h after fertilization, a simulated rainfall event of 50 mm h^{-1} will be used to force water runoff. Variables will include the length of time and amount of water required to force runoff and the concentrations of nutrient (NO_3-N, NH_4-N, and PO_4-P) in runoff water over time. Nutrient concentrations will be measured every 5 min after runoff begins and total nutrient loss will be assessed after each rainfall event. Nutrient concentrations and total nutrient collected will be measured for 1 h following runoff initiation. The experiment will be repeated three times during the growing season (1 June – 30 Sept. 2000). Time series analysis will be used to determine nutrient runoff as a function of precipitation duration. Between simulated rainfall events, the same variables will be tested using runoff provided by natural rainfall.

Following simulated rainfall events, fertilizer will be reapplied when soil moisture has returned to 50% gravimetric content in all experimental units. Fertilizer type and rate will be the same as that applied prior to simulated rainfall. Subsequent natural rainfall events will be monitored and runoff data collected each time natural runoff occurs. Runoff from simulated and natural rainfall will be compared to determine differences between artificial and natural research methods. Plant tissue, thatch, and soil nutrient levels will be tested before and after each simulated rainfall. These data will be used to determine the fate of fertilizer nutrients, to provide a baseline for runoff potential during natural rainfall events, and to provide constants for PRZM-3. The PRZM-3 model will be used to predict nutrient fate for each experiment and results compared to data collected.

Study 2001 and 2002

In year 2001 and 2002, studies will investigate runoff response to antecedent soil moisture and adjustments in time between fertilizer application and beginning of precipitation. Results of these studies may help build a predictive model for nutrient runoff on golf course fairways and support the effectiveness of VFS. Simulated rainfall will be required to control timing, rate, and amount of water applied to the site. Information accumulated during Study 2000 will be used to adjust irrigation to closely match natural rainfall. Based on Study 2000, the most effective VFS method will be used to reduce runoff in these studies. In study 2002 the VFS will be eliminated providing only fairway-height turf and soil moisture will be held constant.

Antecedent soil moisture will be tested at 25, 50 and 75% volumetric content. Time between fertilizer application and rainfall event will be tested at 0, 1, and 2 DAT. Antecedent soil moisture will be tested using pair-wise comparisons. Soil moisture content at 25% will be tested against 50% and 75% in independent studies replicated in time and space. Moisture contents of 50% and 75% will be tested in the same manner. This same protocol will be used to test time between fertilizer application and rainfall event in year 2002.

Results

Many golf course fairways are bordered by sections of rough before draining into surface water. It has been demonstrated that these rough areas act as vegetative filter strips. We expect to enhance the filtering ability of these rough areas by increasing the number of VFS and varying VFS mowing height. If this procedure proves successful, the amount of N and P entering surface water through runoff can be reduced. Maintaining these VFS should not require a great deal more time and expense than current practices. We expect to demonstrate that turfgrass management on golf course fairways contributes little nutrient runoff to surface water. We also expect to demonstrate that enhanced maintenance procedures and proper fertilizer scheduling can reduce the amount of fertilizer in runoff water. Scheduling fertilizer applications during periods of low soil moisture and days before rain should result in negligible N and P losses even under severe precipitation. Severe losses may occur when proper fertilization practices are not followed.