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Effectiveness of filter strips for nutrient removal

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Introduction

A riparian filter strip (RFS) is a vegetative zone that is intended to serve as a "buffer" between cultivated land in the upland and a down gradient water resource. The water resource may be a surface water feature such as a stream, lake, or ditch; or an access point to ground water such as a sinkhole. A RFSs is generally planted to grass and herbaceous plants, although trees or shrubs may sometimes be included. The major function of a RFS is to remove sediment and other waterborne pollutants (especially N and P) from runoff. Secondary considerations include stream bank stabil-ization and the creation of wildlife habitat. It is important to recognize that a RFS is just one tool that is intended to reduce non-point pollution and should be used with upland management practice that reduce soil erosion and runoff (e.g., conservation tillage, contour strip cropping, diversions and waterways, and crop rotations).

Ideally, runoff flow through a RFS should be dispersed as sheet flow to allow sediment to settle-out and to encourage infiltration. This is accomplished by selecting an adequate width to slow and disperse runoff, using effective vegetation types that are dense and remain erect during runoff events, and maintaining the RFS in proper condition. Undersized RFSs will not adequately disperse runoff and remove pollutants, while very large RFSs will be unacceptable to farmers because of the acreage taken out of production (Castelle et al., 1994). Dosskey et al. (1997) has suggested a "minimum acceptable buffer width" that should integrate factors such as the filtering of sediment and soluble pollutants, modification of runoff temperature, aquatic and terrestrial wildlife habitat, riparian stabilization, flood protection, and economics and aesthetics. Table 1 summarizes this interpretation for these specific benefits. Their assessment shows that relatively small widths of grass are needed to remove sediment, but that the removal of dissolved contaminants will require a much greater width because the runoff must be allowed to infiltrate.

Table 1. Relative effectiveness of width and vegetative type on the performance of riparian filter strips (adapted from Doskey et al., 1997).

Benefit	Width (ft.)	Grass	Shrub	Tree
Bank stability	20	low	high	high
Sediment filtering	25	high	low	low
Soluble filtering	50-100	medium	low	medium
Aquatic habitat	30-50	low	medium	high
Grassland wildlife	40-70	high	medium	low
Forest wildlife	40-70	low	medium	high
Economic products	--	medium	low	medium
Visual diversity	--	low	medium	high
Flood protection	--	low	medium	high

Factors that affect the rate of infiltration in a RFS include soil texture, porosity, structure, slope within the riparian area, age of the RFS, vegetation type, and runoff volume. Pollutants deposited in a RFS will be subjected to processes such as microbial degradation, denitrification, fixation by soil minerals or organic matter, and plant uptake.

Nitrogen

Wenger (1999) suggested that RFSs efficiently remove nitrate-N through a combination of plant uptake and denitrification. Nitrate enters the soil through leaching in the cropland and moves into the buffer through subsurface flow of soil water. Denitrification will be most effective in the rootzone layers of the soil where carbon sources are available for denitrifying bacteria. Ten studies that evaluated nitrate-N removal from the shallow groundwater showed an average reduction of 90% (range = 78 to 99%). These data are shown in Table 2. The nitrate-N reduction was attributed mainly to denitrification. Widths ranged between 53 and 200 ft. This review did not find a correlation between these widths and nitrate-N removal from subsurface flow possibly because the buffer widths examined were relatively large. Gilliam et al. (1997) summarized the work of several researchers and found that much of the denitrification occurred in the first 15 feet of the buffer. They suggest that denitrification may remove between 18 and 55 lb N/acre/year.

Denitrification would not be effective for the removal of dissolved ammonium and organic-N contained in runoff. These two forms of N represent most of the N in runoff (total N) and would be expected to be relatively high in runoff through barnyards or following manure application. The removal of total N is influenced by RFS width. Wenger (1999; Table 2) cited four studies that compared the effectiveness of 15- and 30-foot widths. The average removal of total N from the 15- and 30-foot RFS was 35 and 62%, respectively. Another review conducted by Canadian scientists (Findlay et al., 1991) discussed a study that showed higher ammonium-N concentrations as the RFS widths increased, presumably because of mineralization of organic N that had previously accumulated in the filter. Clearly nutrient cycling will be dynamic within a RFS.

Table 2. Average and range of nutrient removal from runoff by riparian filter strips (adapted from Wenger, 1999).

Nutrient	Number of sites	Average	Low	High
		---------------- % Removal --------------		
Nitrate-N	10 †	90	78	99
Total N	8 ‡	48	0	74
Total P	8 ‡	54	18	79

† Widths ranged from 53 to 200 feet.

‡ Average of 15- and 30-foot widths.

Filter strips may be especially useful adjacent to areas where animal manures are applied (i.e. field edges, barnyards, feedlots). Table 3 shows the effect of filter strip length on the transport of both ammonium and total N over a length of 50 ft (Chaubey et al., 1995). This study confirmed that much of the nutrient removal occurs in the first 20 ft. of the strip. Ammonium-N was removed in relatively greater amounts compared to the total N.

Table 3. Mass transport of nutrient pollutants through varying lengths of a grass filter strip following poultry litter application (after Chaubey et al., 1995).†

	Filter strip length (ft)					
Nutrient	0	10	20	30	40	50
	------------------------------ lb/acre ---------------------------					
NH_4-N	3.4	2.0	1.2	0.9	0.3	0.1
Total-N	14.0	8.3	6.4	4.6	3.8	3.1
PO_4-P	2.3	1.4	1.0	0.6	0.4	0.3
Total-P	3.6	2.1	1.4	0.8	0.6	0.4

† Runoff collected for 1 hour following artificial rainfall applied at 2 inches/

hour.

Uptake and storage of nitrogen by woody vegetation is suggested justification for including trees and shrubs in an RFS. The amount of uptake will vary between vegetation types, age, and soil factors. Gilliam et al. (1997) uptake and storage by trees ranged between 10 and 90 lb N/acre/year.

Phosphorus

The removal of P from runoff is impacted greatly by sediment removal because the majority of the total P in runoff is attached to soil particles. Sediment removal is directly related to RFS width (Wenger, 1999). This review, shown in Table 2, compared data from eight studies. Widening the RFS from 15 to 30 feet resulted in increases in removal from 70 to 85%. Increasing the width out to 200 feet increased removal to 90%. Because most P would arrive in the riparian zone on sediment surfaces, P will accumulate and presumably be cycled within the soil and vegetation.

The removal of soluble P will require the infiltration of runoff by the RFS because P dissolved in the runoff will flow to the stream or other feature. Findlay et al. (1991) cited a study that showed that increasing the width from 2 to 13 feet increased soluble P removal from 9 to 62% because of infiltration. It is imperative that channelized flow from the upland be converted to sheet flow in the RFS to remove soluble P. Daniels and Gilliam (1996) found that nutrient concentrations remained constant through the runoff sampled in an upland channel. In their study, 80% of the soluble P entering a RFS passed through the filter in the channelized flow.

The study conducted by Chaubey et al. (1995) also examined the ability of a filter strip to remove P. Their paper did not discuss whether soil was dislodged and trapped in the filter strip. They did indicate that runoff infiltration was the main process by which transport was reduced. Both forms of P were reduced to about 10% of their initial amount following transport through the 50-foot length. As with N, over 50% of the P was removed in the first 20 feet of the filter strip.

Other Considerations

The USDA-NRCS Standard 393 outlines the criteria for the establishment and maintenance of filter strips, as well as the conditions where the practice should be applied. This standard should be followed when designing and maintaining a filter strip, and will likely be required where federal cost sharing is requested.

The most important vegetation type in a RFS is grass, but often limited direction is provided on grass species selection. Reed canary grass is endemic in most riparian areas and will compete strongly with planted species. This species is not recommended for a RFS because it is subject to lodging and therefore loses its filtering ability. It does produce considerable biomass and can accumulate a con-siderable amount of nutrients. An ideal grass species has both an erect growth characteristic and stiff straw that will resist lodging throughout the cold months. Bunch grasses are also less desirable, but not excluded from planting mixes, because of space between plants. Choices are either cool-season species (timothy or brome) or warm-season (switchgrass, indian grass, and big bluestem). Advan-tages for cool season grasses include ready availability of seed through agronomic outlets, typically lower cost, and faster establishment. Advantages to warm season grasses are persistence, greater biomass production, and aesthetic quality.

Regardless of the grass type chosen, maintenance will be necessary to keep a RFS functioning properly. Mowing should be conducted every few years at a height not shorter than 6 inches to remove woody weeds and to encourage vigorous regrowth. Mowing time is restricted to limit interference with nesting birds. When possible, the grass should be removed to prevent loss via transport of soluble nutrients leached from the cut material. If a program permits, this vegetation can be used as animal feed. Grazing in a RFS, although permitted, should be discouraged because of compaction and damage to stream banks. If sediment is being deposited in an RFS, a small berm may develop that will have to be scraped occasionally and re-seeded. Under no circumstances should a RFS be used a vehicle travel lane because of the potential reduction in infiltration capacity.

Filter strips will have the greatest impact on water quality if installed in the upper reaches of watersheds where runoff may first contact ephemeral streams and unnamed tributaries. Where limited funding is available priority should be given to these areas rather than along named streams and rivers. Therefore, a prioritization of RFS installation should be made for any agricultural watershed where the practice is to be employed.

Summary

The notion that a "one-size-fits-all" should not be applied to riparian filter strips. Every landscape is different because of soil type, topography, size, vegetation, etc. Planning goals should place RFSs in the upper region of watersheds and not in the valleys. A RFS should be considered as part of an overall conservation strategy. Obviously, when soil is being deposited in a buffer, it has been lost from the crop land. It is important that flow entering a RFS must be converted from its channelized nature in the waterway. This will encourage infiltration and allow for greater contact with the soil and vegetation in the RFS. Occasional mowing and the removal of cut vegetation is a must to maintain filter strips. Livestock and vehicles should be excluded from the RFS if possible to maintain a high infiltration capacity. Research studies show that a properly designed and maintained RFS can remove 90% or more of the incoming pollutants.

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