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Effectiveness of vegetative filter strips

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Effectiveness of vegetative filter strips

Abstract
The use of close-growing plants, such as in grass sod, is a long-established technique for controlling soil erosion. This approach serves two purposes: (1) the fine root system of sod holds soil in place, thereby reducing its susceptibility to erosion, and (2) the plants slow the velocity of water flow, which reduces the sediment-carrying capacity of the water.

Keywords
Agronomy, Water quality quantity and management

Disciplines
Agricultural Science | Agriculture | Agronomy and Crop Sciences | Water Resource Management

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Background and goals

The use of close-growing plants, such as in grass sod, is a long-established technique for controlling soil erosion. This approach serves two purposes: (1) the fine root system of sod holds soil in place, thereby reducing its susceptibility to erosion, and (2) the plants slow the velocity of water flow, which reduces the sediment-carrying capacity of the water.

Despite its benefits, this approach is used little with intensive row-crop production, except for grass waterways. The use of vegetative filter strips (VFS), bands of close-growing plants, offers distinct advantages for reducing the sediment-carrying capacity of runoff water compared to other erosion control measures. Relative to most structures, VFS establishment is inexpensive, can be easily removed and reestablished if desired, and can also serve as favorable wildlife habitat. In addition, depending on the species used, VFS can be mowed and harvested for forage.

Although the efficiency of this system is not yet proven, evidence suggests that VFS, when properly used, may reduce sediment loads in runoff water. For controlling agricultural nonpoint source pollution, these strips appear advantageous both from the economic and ease-of-use perspectives just mentioned. But to optimize the effectiveness of this system, more knowledge is needed about the effect of slope, vegetation density, rainfall intensity, and vegetation type on sediment trapping. The goals of this study were to determine sediment concentration in runoff water flowing through a VFS as a function of distance from the edge of the filter, slope steepness, and rainfall and runoff amount.

Approach and methods

Investigators established two research plots on C (7%) and D (12%) slope Fayette (fine-silty, mixed, mesic Typic Hapludalfs) silt loam soils to study the effects of VFS on sediment concentration in runoff water. These soils were 77% silt and 18% clay with 2% organic matter. The dimensions of each plot were 31 meters (m), approximately 102 feet, perpendicular to the slope by 36.6 m parallel to the slope. The upper portion of the plot was managed as a continuous fallow strip and was tilled as weather permitted every three weeks from April through August. The final tillage passes on these strips were done parallel to the slope to prevent concentration of the runoff before it reached the VFS. The lower portion of the plot was maintained as a bromegrass filter strip. Investigators surveyed the research sites and established the plots on uniform grades. They used survey information to determine the orientation of the plots and collectors. Rain gauges recorded rainfall amounts.

The collection apparatus consisted of a 20.3-cm (8-inch) diameter polyvinyl chloride (PVC) pipe, 4.25 m in length, and associated splitters. A one-quarter section was cut from the circumference at the pipe’s midsection such that from the end, the pipe looked like a "C," with the open portion or slot representing the removed section. Investigators positioned this pipe perpendicular to the flow of runoff water. Each pipe was partially buried so the slot opening was directed upslope and the lower edge of the slot was flush with the ground level. A 1.5% grade was established on the pipe to direct the runoff collected to an elbow; additional PVC pipe was used to carry the runoff to a series of sample splitters and collectors.
A series of splitters was connected to the collection pipe and placed parallel with the slope such that water flowed through them. The function of each splitter was to divide the sample water volume in half, discard half of the runoff into a container, and transmit the remaining runoff onto the next splitter. Thus, after several splits, a representative and manageable sample volume was collected for heavy rainfall events, and for lighter events the representative sample was collected from one of the initial splits.

The splitters, which formed an equilateral triangle in cross section, were made from thin acrylic sheets 12 m long. One side of this cross-sectional triangle was horizontal and on top, with the opposite vertex on the bottom. Water flow occurred along the lower vertex of this triangle. A 46-cm-long (18 in.) acrylic sheet (divider) extended axially into the splitter from the downslope end of the splitter. This divider bisected the upper horizontal side of the cross-sectional triangle and the opposite or bottom vertex. Water entered the upslope end of the splitter and the acrylic divider split the water flow in half (see Fig. 1). One half of the original volume entering the splitter was discarded from one side of the divider; this portion of the splitter water was dumped into a container, while the other half entered the next splitter.

A series of five splitters was used on the 7% slope with 20-L (liter) buckets at each of the intermediate splits and a 200-L tank at the end. A series of four splitters was used on the 12% slope with 20-L buckets at the intermediate splits and a 400-L tank at the end. Theoretically, this setup could collect all the runoff from a 60-70 mm rainfall event if no infiltration occurred. Neither the buckets nor the tank was covered, so the volume of water in the bucket attributed to runoff had to be corrected for the amount of rain falling directly into the buckets. Sample volume was determined by measuring the depth of water in the bucket or tank and using a calibration curve that related water depth to volume for each container. The collector-splitter assemblies were positioned at six distances from the edge of the fallow strip: 0, 3.1, 6.1, 9.1, 12.2, and 18.3 m on both slopes.

For each rainfall event, the quantity of rain was recorded and rainfall intensity was subjectively classified. Investigators also recorded the depth of samples in all buckets and tanks that had not over-filled, and after stirring to get all solids in suspension, they took a one-L subsample for analysis from the fullest bucket or tank that had not over-filled. The total volume of runoff was calculated on the basis of water volume in containers that had not over-filled. From these subsamples investigators determined the mass of sediment per runoff volume. Rainfall intensity was classified as low (L), medium (M), high (H), or very high (VH). For analysis purposes, L and M events were combined. Runoff samples were collected from 13 rainfall events from August 1990 to September 1991. Runoff volume collected within the VFS was corrected to reflect only that rain which fell on the fallow area. Sediment concentration, runoff distribution, and soil loss were calculated for each event and slope. Soil loss calculations were based on sediment concentrations and flow volumes at each position.
Findings

Table 1 summarizes the rainfall events in relation to the most recent tillage event.

### Table 1. Storm characteristics.

<table>
<thead>
<tr>
<th>Date</th>
<th>Rainfall (mm)</th>
<th>Soil loss (Mg/ha)</th>
<th>Soil loss (Mg/ha)</th>
<th>Storm intensity</th>
<th># of storm after tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-24-90</td>
<td>54</td>
<td>0.01</td>
<td>0.04</td>
<td>H</td>
<td>2</td>
</tr>
<tr>
<td>8-25-90</td>
<td>72</td>
<td>3.65</td>
<td>6.54</td>
<td>VH OW</td>
<td>3</td>
</tr>
<tr>
<td>4-27-91</td>
<td>17</td>
<td>&lt;0.01</td>
<td>0.29</td>
<td>H OW</td>
<td>2</td>
</tr>
<tr>
<td>4-29-91</td>
<td>20</td>
<td>0.73</td>
<td>1.14</td>
<td>H OW</td>
<td>2</td>
</tr>
<tr>
<td>5-5-91</td>
<td>25</td>
<td>0.02</td>
<td>0.21</td>
<td>M OW</td>
<td>2</td>
</tr>
<tr>
<td>5-13-91</td>
<td>14</td>
<td>&lt;0.01</td>
<td>0.80</td>
<td>H OW</td>
<td>2</td>
</tr>
<tr>
<td>5-30-91</td>
<td>52</td>
<td>12.99</td>
<td>26.64</td>
<td>VH OW</td>
<td>2</td>
</tr>
<tr>
<td>5-31-91</td>
<td>18</td>
<td>3.72</td>
<td>8.63</td>
<td>VH</td>
<td>2</td>
</tr>
<tr>
<td>6-1-91</td>
<td>10</td>
<td>0.03</td>
<td>0.22</td>
<td>H</td>
<td>4</td>
</tr>
<tr>
<td>6-15-91</td>
<td>34</td>
<td>0.02</td>
<td>&lt;0.01</td>
<td>L</td>
<td>5</td>
</tr>
<tr>
<td>9-11-91</td>
<td>72</td>
<td>1.56</td>
<td>17.06</td>
<td>VH</td>
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</tr>
<tr>
<td>9-14-91</td>
<td>16</td>
<td>0.02</td>
<td>0.08</td>
<td>M</td>
<td>2</td>
</tr>
<tr>
<td>9-16-91</td>
<td>42</td>
<td>3.74</td>
<td>3.46</td>
<td>VH</td>
<td>3</td>
</tr>
</tbody>
</table>

1 Megagram per hectare  
2 OW = over-winter

The VH events accounted for 67% of the rainfall for the period. Intensity was not related to rainfall amount, though H and VH events had greater per-storm rainfall than LM events. Soil loss was greater when VH events occurred as one of the first storms after tillage.

Data from both slopes were analyzed. Because of many similarities in the trends, the results from the 12% slope will be emphasized. Table 1 indicates the soil loss differences on the two slopes. Runoff distribution and sediment concentration differences between positions were similar to those of soil loss. The average runoff distribution (see Fig. 2) was calculated as the ratio of the total runoff volume collected to the volume of rain that fell on the continuous fallow strip. The negative slopes on the lines in Fig. 2 indicated that the VFS encouraged infiltration of water into the soil. The first 3 m was the most effective in decreasing the runoff volume, and little change occurred beyond 9 m. The VFS on the 7% slope transmits a larger proportion of the total runoff downslope, while on the 12% slope a larger proportion of incident rainfall was infiltrated in the first 9.15 m of the VFS.

Figure 3 shows the sediment concentrations within the VFS for the five VH events. The variability of sediment concentration with rainfall amount and distance within the VFS is apparent here.

Figure 4 shows the effect of slope, while Fig. 5 indicates the effect of rainfall intensity on sediment concentration. The 12% slope had much greater sediment concentrations, runoff volumes, and therefore soil losses for most events. The average sediment concentrations for the 12% slope were nearly twice those from the 7% slope at the edge of the fallow strip. The five VH and five H events accounted for 75% and 20% of the soil loss on both slopes, respectively. Three storms accounted for 65% of total soil loss, and eight of the 13 accounted for 93%.

![Fig. 2. (left) Average runoff distribution (12% slope).](image1)

![Fig. 3. (right) Sediment concentrations for very high intensity storms (VFS on 12% slope).](image2)
In all storms, the sediment concentrations in the runoff decreased greatly in the initial 3 m, and few changes in sediment concentration were observed beyond 9 m. The initial 3 m of VFS removed more than 70% and 80% of the sediment on the 7% and 12% slopes, respectively, and more than 85% was removed in 9 m of VFS.

Two mechanisms contribute to the effectiveness of VFS in decreasing sediment concentrations in runoff. First, VFS decrease the velocity of runoff, thus decreasing the transport capacity of the runoff and resulting in the deposition of the sediment. Second, VFS decrease the volume of runoff by increasing infiltration. Conditions in the VFS that promote infiltration include the decreased runoff velocity and the more stable soil structure maintained by vegetation cover. Although VFS removed 4% more sediment on the 12% slope than on the 7% slope, more total sediment remained in the runoff from the 12% slope.

In this study, there was no apparent decrease in effectiveness of the VFS with time. The final series of storms in September 1991 was filtered as effectively as the others (Fig. 3). Even though sediment deposition occurred, the effectiveness of this bromegrass filter strip did not appear to be affected.

**Implications**

Erosion control techniques must be designed to handle very high rainfall events. This research indicates that VFS can limit sediment loading of streams from cropland runoff. Within the first 3 m, most sediment was removed; beyond 9 m, very little change in sediment concentration of runoff water was observed. These favorable results apply to VFS treatment of runoff water for non-concentrated water flow.

Filter strips can play an important role in soil conservation in a variety of settings. The low cost and simplicity involved in establishing VFS, and the efficiency with which they function, suggest that VFS can be implemented to reduce soil erosion on Conservation Reserve Program land if it is returned to row-crop production. Filter strips placed strategically in positions to intercept sheet flow, as opposed to concentrated flows, could save millions of tons of topsoil in Iowa every year.

Now, research must address the effect of vegetation density and type on soil erosion control. The interaction of these variables with slope differences is another area that requires additional study.

In addition to presentations at professional society meetings, the investigators disseminated information about this project at two field days.