Vegetative Filter Education and Assessment in the State of Iowa

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Abstract
Vegetative filter is one of the agricultural best management practices that helps reduce the deterioration of the surface waters. These filters use natural processes to remove a portion of the sediment and other pollutants carried by runoff before the water enters a water-body. The project aims at gathering elevation data in field-scale vegetative filters with the help of Geographic Positioning Systems (GPS) and analyzes the flow accumulation with the help of Geographic Information Systems (GIS). The overall vision and objectives for this project include (1) To determine the effectiveness of VFS by visual field observation and validation by flow mapping procedures in ArcGIS 9, (2) To compare the area ratios and percentage of flow along each stream segment at The authors are solely responsible for the content of this technical presentation. The technical presentation does not necessarily reflect the official position of the American Society of Agricultural and Biological Engineers (ASABE), and its printing and distribution does not constitute an endorsement of views which may be expressed. Technical presentations are not subject to the formal peer review process by ASABE editorial committees; therefore, they are not to be presented as refereed publications. Citation of this work should state that it is from an ASABE meeting paper. EXAMPLE: Author’s Last Name, Initials. 2006. Title of Presentation. ASABE Paper No. 06xxxx. St. Joseph, Mich.: ASABE. For information about securing permission to reprint or reproduce a technical presentation, please contact ASABE at rutter@asabe.org or 269-429-0300 (2950 Niles Road, St. Joseph, MI 49085-9659 USA). various resolutions (5X5, 10X10, 20X20 and 30X30) for different sizes of the survey data sets, (3) Compare the flow routing for USGS 7.5 Quad Angle values and spatial analysis of the elevation data at resolution of 30X30. This study is of great significance in regard to key water quality and surface runoff issues, which are gaining broad awareness while developing consciousness about effective management practices and good land stewardship values. This paper will present the data and results for this study, which is still on going.

Keywords
Vegetative Filter strips, impaired water bodies, water quality, nutrients, sediment, surface runoff, GIS

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Introduction

Water is the most precious natural resource that exists on our earth. At present, quality of water is the largest issue globally, with concerns for alarming death rate of aquatic organisms, human health hazards, and aesthetic beauty of world’s famous water bodies. With respect to growing public awareness to combat water pollution, the U.S. Environmental Protection Agency enacted a law called Clean Water Act (CWA) in 1972, as an establishment towards surface water quality protection in the United States. Non Point Source (NPS) pollution is a major cause of degradation of surface water quality. NPS pollution is caused by water movement over and through the surface of the land (Subra and Waters, 1996). Sediments and a range of applied agrochemicals are transported from the agricultural fields into the surface water bodies, which is one of the major environmental threats.

In order to combat pollution resulting from diffuse sources, the U.S. government is taking considerable measures towards mitigation by means of employing Best Management Practices (BMPs). Vegetated filter strips (VFS) form a practice that helps reduce the transport of these substances to receiving waters. VFS are the bands of planted or indigenous vegetation situated down slope of cropland or animal production facilities to filter nutrients, sediment, organics, pathogens and pesticides from agricultural runoff before it reaches a water system (Dillaha et al., 1989). These have been considered to be effective in reducing the sediment delivery by slowing down the runoff velocity and filtering sediment (Neibling and Alberts, 1979; Van Dijk et al., 1996). VFS provide an impediment to the movement of the suspended material such as soil particles and plant residue in the runoff, hence promoting their settling through sedimentation.

Various studies have been conducted in past decades to determine the effectiveness of VFS. It has been found that the effectiveness of VFS is influenced by factors like length of the vegetative strip, type of vegetation, slope of strip, sediment size distribution in the runoff and concentration of flow. Length of the strip is considered in many studies as the most important parameter that affects its sediment removal efficiency. Studies have concluded that increasing the flow length beyond 10m doesn’t help increasing the VFS efficiency by large margins (Gharabhaghi et al., 2001; Lee et al., 2003; M. Abu Zreig et al., 2004). Ree et al. (1949) studied the sediment trapping efficiency of grass filters of length 1, 4-5 and 10 m and recorded efficiencies as 50-60, 60-90, and 90-99 percent respectively. Gharabhaghi et al. (2001) studied the variations in sediment removal efficiency by varying lengths of vegetative strips from 2.44 to 19.52 m for a 1.22 m wide field with a slope 5.1 to 7.2% and it was concluded that the first five
meters play a significant role in removal of the suspended solids and aggregates greater than 40 microns in runoff. M. Abu Zreig et al. (2004) conducted twenty field experiments with filter lengths of 2, 5, 10, 15 m. and slopes of 2.3 and 5%. An exponentially decreasing trend between sediment trapping efficiency and length beyond 10m was seen. The field studies indicate that the submergence of vegetation lowers the Manning's coefficient which decreases the VFS efficiency to a great extent (Ree et al., 1949; Van Dijk et al., 1996). Van Dijk et al. (1996) indicated that retardation of flow and filtration of pollutants is more efficient with older and denser grasses. Denser vegetation leads to higher Manning's coefficient which results in greater contact time between the runoff and vegetation, eventually leading to lesser erosive power and lesser transport capacity of the runoff, and therefore, greater trapping efficiency. Another important factor that affects the performance of the filters is the sediment size distribution of the incoming runoff. Studies like Meyer et al. (1995) and Gharabhaghi et al. (2001) indicated that smaller sized sediments take longer to separate out, therefore, requiring a longer filter. In the study by M. Abu Zreig (2001), trapping efficiencies of 0% and 47% for clay particles over filter lengths of 1 m and 15 m, respectively, were observed. Lee et al. (2003) installed three plots where each of the cropland source area was matched with no buffer strip, switchgrass buffer (7m), and a switchgrass/woody plant buffer strip (16.3m) to determine the effectiveness riparian buffer strips in removing pollutants carried by cropland runoff. Efficiencies higher than 92% and 97% were seen for the switchgrass and switchgrass/woody buffer respectively. It was concluded that the switchgrass was an effective measure for removing coarse particles, unlike the switchgrass/woody buffer, which is more suitable for finer particles. It was also noticed that more than 90% of the sediment in the surface runoff from the buffered plots was in the <0.05 mm size fraction. During infiltration of nutrients, suspended fine soil particles with adsorbed chemicals also enter the profile, thus decreasing the surface runoff and sediment transport capacity. For VFS to function properly, achieve high pollutant removal efficiencies, uniform distribution of flow (generally referred as sheet flow) is important. Undulating surfaces and slopes >6% lead to flow concentration, erosion and loss of water quality benefits, eventually lowering of sediment removal efficiency of the VFS. When flow concentrates, it moves too rapidly to be effectively treated by a grassed filter strip. Dosskey et al. (2002) installed four study fields for studying the impact of the flow on sediment trapping efficiency. The four fields were evaluated with the help of a numerical model using regression equations based on the ratio of the buffer area to field runoff area. Area ratios were considered between 0.02 to 0.48 and 0.01 to 0.03 for uniform and non-uniform flow conditions, respectively. The model yielded trapping efficiencies of 99%, 67%, 59% and 41% in contrast to 43%, 15%, 23% and 34% for uniform and
non-uniform flow conditions respectively; all other parameters held constant. Area ratio, defined as the ratio of drainage area to buffer area is another factor that can lead to channelization activities in the field resulting in flow concentration. Large area ratios, like 40:1, force greater amounts of flow through the buffer strip which renders them ineffective due to high flow concentration during large rainfall-runoff events. In this case, the effective area of buffer is much less than the gross area. Studies have indicated that although higher area ratios lead to lower removal efficiencies, no appreciable differences were noticed in the performance of buffer strips (Arora et al., 1996; Arora et al., 2003; Boyd et al., 2005).

One disadvantage that VFS practice is that its employment displaces land that typically could be cropped, therefore, minimizes the crop production. Therefore, it is important to assess the effectiveness of the VFS in removal of the sediments and nutrients from the runoff. The major objectives of this study are outlined as follows:

1. To determine the effectiveness of VFS by visual field observation and validation by flow mapping procedures in ArcGIS 9.
2. To compare the area ratios and percentage of flow along each stream segment at various resolutions (5X5, 10X10, 20X20 and 30X30) for different sizes of the survey data sets.
3. Compare the flow routing for USGS 7.5 Quad Angle values and spatial analysis of the elevation data at resolution of 30X30.

METHODS AND MATERIALS

VFS at Rock Creek watershed near Newton, Iowa were selected for this study. The study was focused on a field, owned by Dave Kaisand, located in Jasper county of Iowa. The agricultural runoff from this field transports sediment and agrochemicals to Rock Creek Lake. Erosion and chemical transport from this field and other fields in the watershed led to deterioration of surface water quality of the lake. A stream that joins to the lake runs through the middle of this field. A 35 m wide VFS was placed on both the sides of the stream immediately downslope of the cropland by Natural Resources Conservation Services in year 2000 to help reduce the transport of nutrients, pesticides and sediments through runoff. The natural vegetation for the watershed is categorized as Prairie with soil types known as Ackmore, Ely, Downs, Tama, Colo and Ackmore-Colo complex. These soils have an average infiltration rate of 0.6-2 in/hr and fall under hydrologic group B. The texture of these soils consists mainly of silt
loam, loam, silty clay loam. The field was found to have best management practices like terraces and grassed waterways in addition to VFS, as shown in Figure 1. The presence of a major grassed waterway and a stream divides the field into three sub-watersheds as shown in Figure 2. The spatial data for these three subwatersheds is analyzed separately.

Through visual observation and in-field surveying, it was found that the buffer strips are ineffective in sediment and chemical retention, as the surface runoff does not flow through the VFS. Owing to the presence of undulations in the field, the flow leads towards the natural vegetation instead of draining into buffer strips which led to significant growth in this region. Some traces of sedimentation at the buffer edge were seen which makes it evident that there were times when runoff reached the buffer strips, but from the topographic observations, it is possible only in case of larger rainfall event. The stem count per square feet for the VFS beginning edge, mid point and ending edge of buffer is 24, 78 and 56 respectively.
Site surveys were carried out for recording the elevations throughout the field. This was collected by the local NRCS office staff using Global Positioning System (GPS) Real Time Kinematics (RTK) equipment capable of receiving L1 and L2 Signals. A base station, Trimble 4800 receiver with a Trimark-3 24-Watt radio was set up on site along with a 3.66 m radio tower to increase the line of sight. Both the base station and radio tower were powered using a 12-Volt battery. A Trimble 5700 receiver with a Zypher antenna mounted on an All Terrain Vehicle (ATV) was used to collect elevation data on roughly a five-meter distance. A Trimble 5800-R8 receiver was used as a handheld receiver to collect elevation data for points where ATV could not access the terrain, especially at the edge of the creek and the bottom elevation of the flow line in the creek. Both handheld and mounted receivers were individually attached to Trimble TSE data storage collectors. These collectors operating on Trimble Survey Software collected specific GPS coordinates and elevation data. Data from the collectors was transferred onto a computer using Trimble Geomatics Office software. Three different data sets were extracted out.
of the data set that was collected keeping the size of collected data > data set 2 > data set 3 > data set 4.

Geographic Information Systems (GIS) was employed for validation of the visual observation regarding the flow accumulation and outlets points in the field. This software combines the site evaluation data of each point on the field into layers of information at that point on the map of the watershed to give a better understanding of the runoff hydrology at that point. The technique of Digital Elevation Model (DEM) helps obtain the digital representation of the topographic surfaces as a regular grid of spot heights. In this case, elevation data for the field was used to obtain the flow routing in ArcGIS 9, and validate our visual observation regarding the effectiveness of the buffer strip. Elevations at equal and uniform intervals in the watershed were interpolated from the collected data (which was at unequal spacing) through a method called Kriging. DEM helped identify the sinks in the drainage area, generate flow accumulation and drainage/stream network of the watershed for the collected data through ArcView 3.3. The stream network delineated by the software, shown in Fig 3, was found in congruence with the visual observation. As per the objectives, stream network for four different resolutions of DEM, namely 5X5, 10X10, 20X20 and 30X30 was also delineated. The stream network for sub watershed 1 has been delineated for all four datasets at a resolution of 5X5 of the collected data. These layers were laid on top of one another, as shown in Fig.4. We can clearly see the difference in the stream network delineation for four datasets at same resolution. We aim to quantify these differences in terms of area ratios and percent of flow along each stream segment for four different sizes of the dataset.

Another objective aimed at comparison of the flow routing for USGS 7.5 Quad Angle values and spatial analysis of the elevation data of the field at a resolution of 30X30. The DEM of USGS 7.5 Quad Angle 30X30 values were extracted from Iowa data found at ftp://gis.iastate.edu and the stream network was delineated in ArcView 3.3. Flow routing for this showed well-organized streams heading towards the buffer before draining into streams. This was laid on top of 30X30 resolution of the collected data, as shown in Fig. 5. Apparently, delineated stream network for collected data was far different from that of USGS data at resolution of 30X30. But it was seen that the delineated stream network for dataset 4, the smallest data size, at resolution of 30X30 was close to that of USGS 30X30, as shown in Fig. 5. This clearly implies that number of data points for USGS 30X30 lies close to the number of data points in Set 4.
Figure 3 The overlay of stream network for Subwatershed 1 (generated through flow mapping at DEM resolution of 5X5 in ArcView 3.3) and the field.

Fig. 4 Stream network for all four datasets at 5X5 resolution
Conclusions

The differences in the flow accumulation at various resolutions (5X5, 10X10, 20X20 and 30X30) of the different survey data sets for the field will be quantified in terms of area ratios and percentage of flow along each segment. The work is under progress and we will have more results to share at the meeting.
References

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