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Modeling Vegetative Buffer Performance Considering Topographic Data Accuracy

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Abstract. *Riparian buffers are a promising tool in efforts to reduce sediment contribution to streams. Models that predict the capacity of buffers to trap sediment have recently been developed. A number of parameters that are required to conduct such modeling efforts are derived from the topography of the site. In this study, three topographic data sources were used to generate the model input for an agricultural field with a riparian buffer. The runoff and sediment transport in the system was then simulated for three years. As a result, the area that contributed runoff and sediment to the buffer was substantially different for each of the topographic data sources. In addition, the predicted runoff and sediment loss from the field was different for each case. Finally, the predicted sediment delivered to the stream was substantially affected by the accuracy of the topographic data source.*

Keywords. Riparian buffers, Hydrologic modeling, Topographic data accuracy.

Introduction

Riparian buffer systems have recently become recognized as promising tools in the conservation management of soil, water, and biological resources. Riparian buffer systems can be defined as ecosystems adjacent to a stream, river, or other body of water that are populated with species that are distinct from upland ecosystems. Some of the benefits associated with riparian buffer systems include water quality improvement, erosion control, aquatic and terrestrial wildlife habitat improvement, stream bank stabilization, and aesthetic enhancement. The basic philosophy behind construction of riparian buffer systems is to exploit the processes by which naturally occurring riparian ecosystems moderate the interactions between aquatic and upland ecosystems. Riparian ecosystems are able to effectively reduce the amount of sediment in overland runoff (Sheridan et al., 1999). Because of these capabilities, initiatives have been developed by government agencies, private industries, and non-profit organizations to encourage the adoption of riparian buffer systems.

As the result of recent interest in riparian buffer installation, modeling tools have been developed to aid in the design and placement of these systems (Xiang, 1993,1996; Inamdar, 1993). These models rely heavily on input from a topographic data source, and usually use a Digital Elevation Model (DEM), or a similar product from the USGS. Because of the importance of topographic information in these tools, the accuracy of this data is a possible limitation on the effectiveness of these models.

Our hypothesis is that maps with different degrees of topographic data accuracy will produce dissimilar runoff patterns in riparian buffers. The goal of this study was to determine the effect that topographic data accuracy in model input has on predictions of riparian buffer performance in an agricultural watershed with respect to sediment trapping and runoff hydrology.

Site Description

The site is located on the Rogers Memorial Research Farm, near Lincoln, Nebraska. Rogers Farm is owned and operated by the University of Nebraska, Department of Biological Systems Engineering. The field that was used in this project has an area of 5.67 hectares, and is located on the terrace of a third order stream. The field is isolated from upland runoff by a conservation terrace that drains upland runoff into a grassed waterway. This field contains silt loam soils of the Judson and Kennebec series, and generally exhibits slopes of three percent or less. The cultural system in this field is non-irrigated, and includes corn and soybean rotation using no-till practices. The local climate at this site is sub-humid, with an annual average precipitation of 76.0 cm.

Because the field is adjacent to the stream, a riparian buffer was established. The stream banks are populated by a mature native deciduous forest. A 0.23-hectare, 14-meter wide strip of native grasses was established in 1998 in a previously cropped area adjacent to the forest. The grass mixture includes big bluestem (*Andropogon geradii*), Indiangrass (*Sorghastrum mutans*), and switchgrass (*Panicum virgatum*). The forested portion of the buffer is not considered to be effective due to the presence of a pronounced gully. Concentrated flow through this gully compromises the effectiveness of a buffer (Dillaha et al., 1989).

Methods

The first procedure in this project was to obtain topographic data at three different levels of accuracy. In order to evaluate the accuracy of topographic data, the USGS National Map Accuracy Standards were used. Topographic data sources were compared using the standard for elevation. This standard states that 20 or more random points on a map are to be field-tested. The elevation of 90% of these points must be within half of the contour interval that is used on the map (USGS, 1999).

At this site, three independent sources of topographic data were available. The most accurate data source available was a detailed survey that we conducted using a laser level and a Global Positioning System (GPS). Using standard topographic survey techniques, closure of elevation data to within 1.5 cm was achieved. Using ArcView 3.2, the survey points were used to develop a raster-based topographic surface, with 1 square meter cells. The topographic map that was developed from this survey adheres to National Map Accuracy Standards for 0.5 ft. contour intervals (±0.25 ft.). This map is shown in Figure 1.

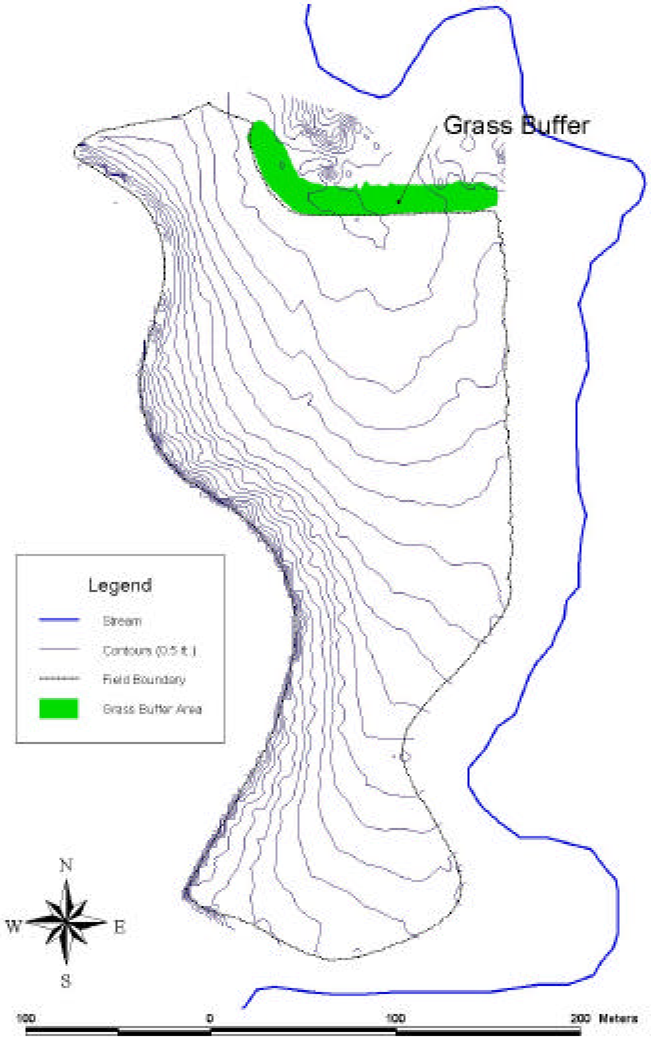

Figure 1: Topographic map produced from the laser/GPS survey.

The second topographic data source was a map that was produced by the Soil Conservation Service (SCS), using aerial photogrammetry. This map is drawn using a 1-ft. contour interval, and appears to meet the National Map Accuracy Standard at this level (±0.50 ft.). This source was chosen because it exhibited an intermediate level of accuracy and uses a common method of topographic data collection. Digitized contours from this source are shown on the map in Figure 2.

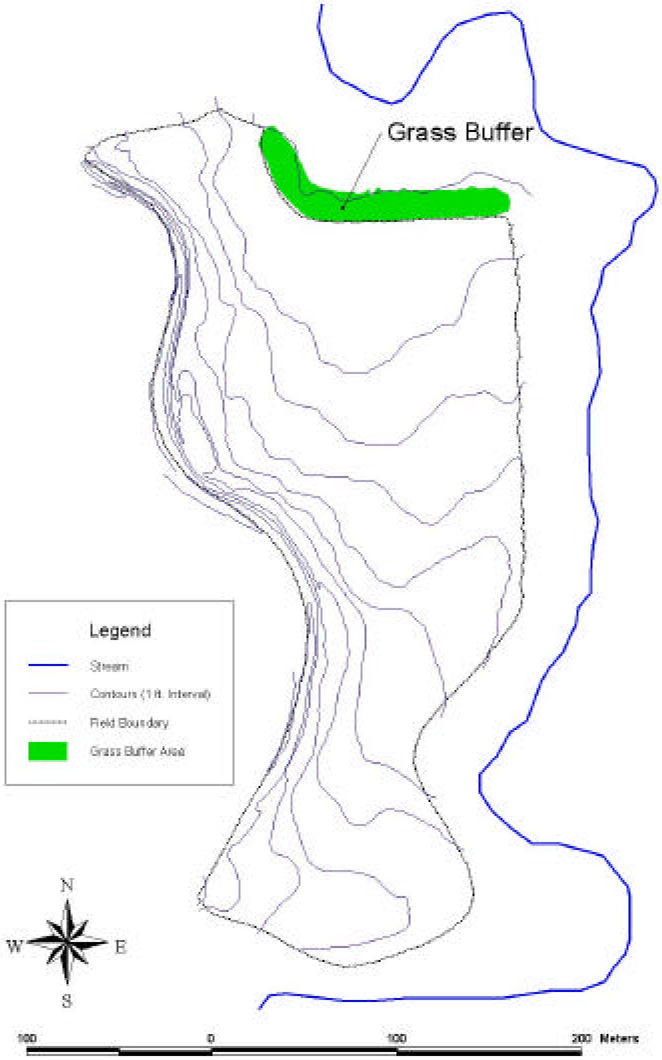

Figure 2: SCS 1'-Contour map.

The third source of topographic data is the USGS- Digital Elevation Model (DEM) for this region. This data source is not a map in itself, rather it is a three dimensional surface composed of square cells in which elevation is represented by a single value that is applied to each 30 m x 30 m cell. Because USGS-DEMs are not maps, and do not have contour intervals, National Map Accuracy Standards are not applicable, however, USGS-DEMs are derived from USGS 7.5 minute quadrangle maps, which adhere to the standard for 10-ft. contour intervals (±5.00 ft.). Because of this, the DEM is assumed to be no more accurate than the 7.5 minute quadrangle. The DEM was chosen instead of the 7.5 minute quadrangle because several runoff models, such as AnnAGNPS and SWAT, have incorporated their use through a GIS interface. A topographic map that was generated from this source is shown in Figure 3.

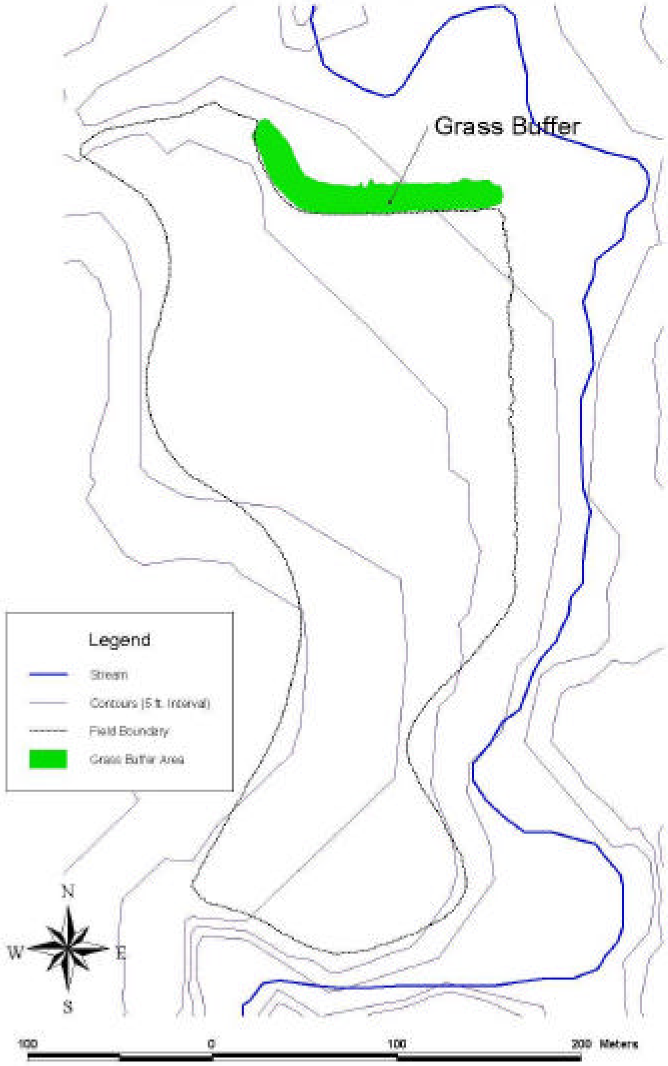

Figure 3: Topographic map produced from the USGS-DEM.

Using the three chosen topographic data sources, runoff and sediment loss from the field was simulated for each case. In the three trials, all model inputs remained constant, with the exception of those parameters that were affected by changing topographic data sources. All simulations for this project were made for the years of 1990 –1992, which exhibited slightly below average precipitation totals.

Three different computer models were used together for the simulation. Table 1 shows a few of the input parameters for this simulation. The models and their usage are as follows:

> **ArcView 3.2** was used to process topographic and soils data to generate many of the sub-basin parameters that were needed for watershed simulation. For example, the area, average slope and average flow length of each sub-basin was

determined using ArcView. Also, the runoff contributing area for the buffer was determined for each scenario.

SWAT 99.2 (Soil and Water Assessment Tool, Arnold et al., 1998) was used to simulate site hydrology and sediment transport. The resulting runoff and sediment were either routed to the stream or through the riparian buffer, depending on what the topographic map indicated. Many of the input parameters for this model, such as SCS curve number, Manning's roughness coefficient, and USLE crop and practice factors were obtained from the User's Guide for the GLEAMS (Knisel, 1991) model. Climate data was obtained from the High Plains Regional Climate Center.

REMM (Riparian Ecosystem Management Model, Lowrance et al., 2000) was used to simulate the hydrology and sediment trapping within the riparian buffer. Soil properties such as bubbling pressure, pore size distribution, and bulk density were obtained from the REMM User's Guide. The nutrient cycling portion of the REMM input was left at default values, while climate data from the site and runoff and sediment contribution from SWAT simulations provided the remaining parameters.

Table 1: Selected model input parameters for SWAT and REMM.

SWAT	
SCS Curve Number	78
Field Slope (Percent)	1.0-3.1
Length (m)	65-213
USLE K Factor	0.28-0.37
USLE C Factor	0.1
Manning's n	0.08
REMM	
Porosity	0.48
Field Capacity	0.33
Wilting Point	0.15
Manning's n	0.046

Results and Discussion

The maps produced by the three different topographic data sources exhibit contours that suggest different runoff patterns for each data source. This caused differences in the area which contributed runoff and sediment to the buffer. Table 2 summarizes these findings.

The runoff depth that occurred in the field as predicted by SWAT varied slightly with each topographic model. This was probably due to the fact that locations of sub-basin boundaries were unique to each topographic data source. This caused a shift in the distribution of dominant soil type within several sub-basins. However, the volume of runoff that was predicted to enter the buffer, as opposed to directly entering the stream, varied dramatically. This is a result of the drastic differences between areas that contributed runoff to the buffer that were predicted by each topographic data source.

Table 2: Predicted area contributing runoff and sediment to the buffer for three topographic data sources.

	USGS-DEM	SCS 1'-Contour Map	Laser/GPS Survey
Total Field Area (ha)	5.67	5.67	5.67
Field Area Contributing Runoff to Buffer (ha)	1.93	3.79	5.40

The USGS-DEM scenario predicted 1093 m^3 of runoff entering the buffer during the simulated period, while the SCS map and the laser/GPS survey predicted 2600 m^3 and 3239 m^3 of runoff, respectively, entering the buffer. Also, the DEM scenario predicted a decrease in runoff inside the buffer, while the other two trials predicted an increase in runoff. Figure 4 summarizes the runoff hydrology in this study. The fact that the buffer increased runoff volume in the simulations using the laser/GPS survey and the SCS map while reducing runoff in the DEM simulation is likely caused by saturation by the volume of runoff entering the buffer in the first two cases.

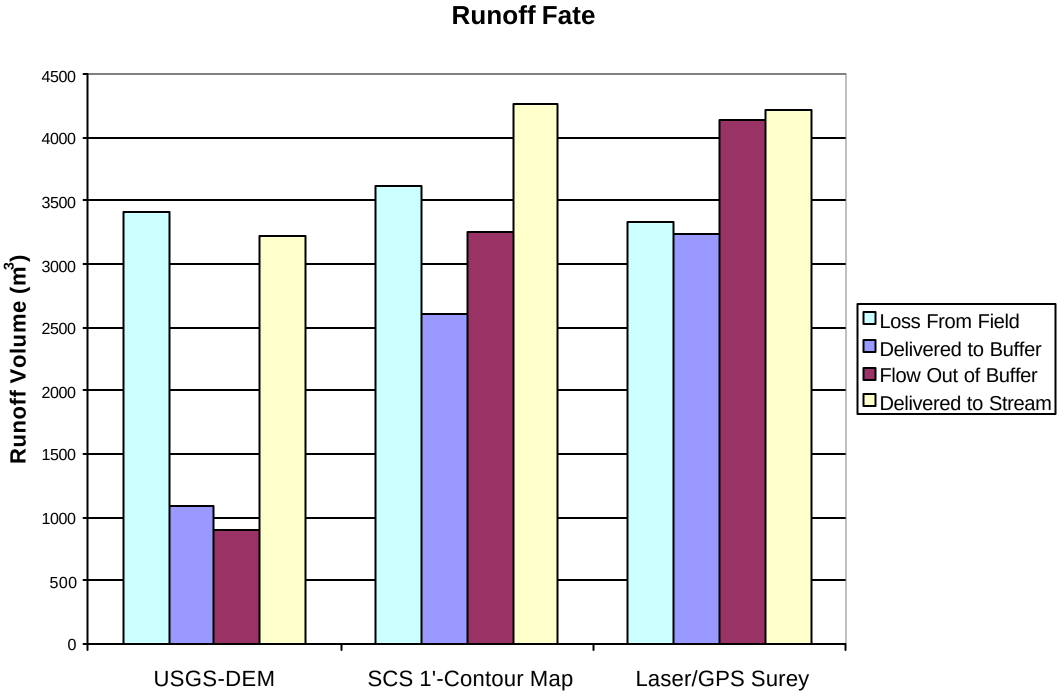

Figure 4: Predicted runoff fate for a field with three topographic data sources.

Sediment loss also exhibited substantial differences between the modeled conditions. Loss of sediment from the field was substantially less in the case of the laser/GPS survey as compared to the other two cases. The field was predicted to lose 4583 kg of sediment when the DEM was used, whereas sediment loss using the SCS map and the laser/GPS survey was predicted to be 4074 kg and 2093 kg respectively. Although sediment delivery to the buffer is highly variable, the buffer is able to trap a sizeable portion of the sediment it encounters in all cases. In fact the trapping efficiency for the buffer in the DEM, SCS map, and laser/GPS survey simulations are 59%, 66%, and 62%, respectively. As a result, sediment accumulation within the buffer is also highly variable with topographic data accuracy. Figure 5 shows the results for sediment accumulation in this study. Figure 6 summarizes the sediment fate results of this study. Interestingly, sediment loss from the field showed much more variation than runoff. It is believed that this was caused by differences in average slope, slope length, and soil type distribution within the sub-basins. The fact that the trapping efficiency of the buffer is relatively constant in all cases suggests that increasing sediment loads did not overwhelm the trapping ability of the buffer.

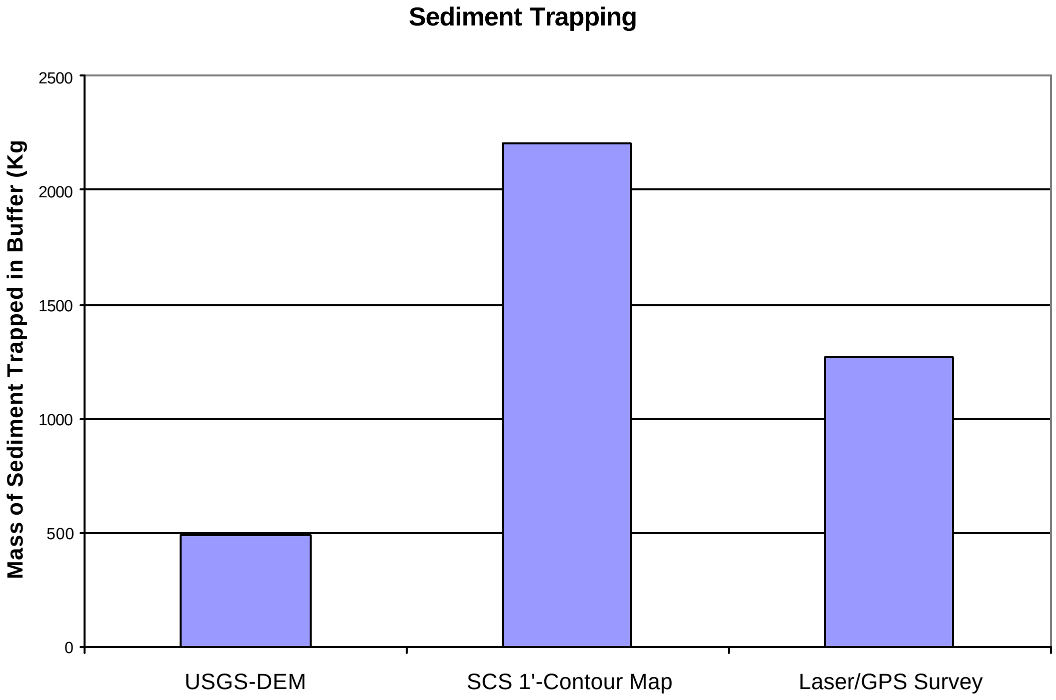

Figure 5: Predicted sediment trapping in a buffer using three topographic data sources.

The most striking difference among the simulations in this project is the difference in the amount of sediment delivered to the stream. Examination of Figure 6 indicates that sediment delivery to the stream in the simulation using the DEM is dominated by the portion of sediment

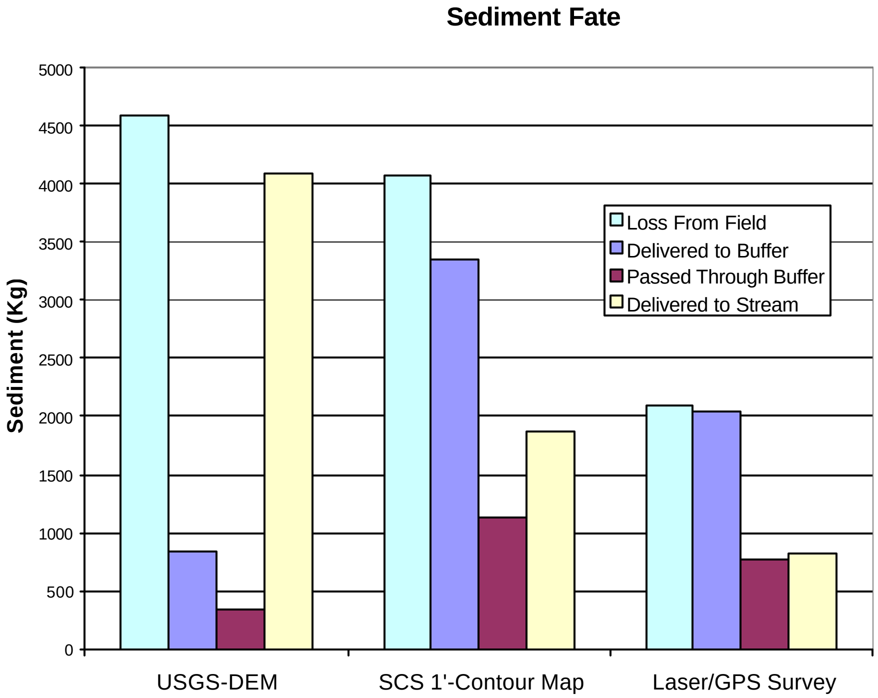

Figure 6: Sediment fate predictions for a field using three topographic data sources

that does not pass through the buffer. The logical conclusion in this case is that the buffer is only marginally effective in reducing the field contribution of sediment to the stream, as the buffer only traps 10.7% of the sediment lost from the field. By comparison, the sediment delivery to the stream in the simulation using laser/GPS data is dominated by the portion of sediment that has passed through the buffer. In fact, the buffer was predicted to reduce the contribution of sediment from the field to the stream by 60.4%. The SCS 1'-Contour Map prediction gave intermediate results, as 54.2% of the sediment lost from the field was trapped.

Conclusions

The results of study suggest that topographic data accuracy has a strong influence on the results of riparian buffer performance simulation. Most of this influence is due to differences in predicted runoff patterns. The predicted sediment delivery to the stream was substantially affected by topographic data accuracy. The model predictions indicated that at a lower degree of topographic data accuracy, the sediment loading in the stream is controlled by the amount of sediment that is able to bypass the buffer. In contrast, at a high degree of topographic accuracy, sediment loading is controlled by the amount of sediment that is not trapped in the buffer. In addition, the buffer was able to trap roughly 60% of the sediment that passed through it, despite high variability in the amount of sediment that was delivered to the buffer.

This study found that topographic data accuracy can have a very substantial impact on the predicted results of riparian buffer performance modeling. While it is logical to assume that more accurate input data will lead to more accurate simulation results, the findings of this study should be tested at other sites and should be verified with field experimentation.

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