Final Report: Use of remote-sensing data and sediment traps to evaluate erosion in zero-order streams

Bucknell University, Summer of 2022

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Transport of sediment through small streams is linked to agricultural soil loss, erosion and deposition in stream channels, and ultimately to the sediment that is choking parts of the Chesapeake Bay. Earlier research at Bucknell developed GIS (Geographic Information Systems) tools to calculate, based on a high-resolution digital elevation model (DEM), a sediment transport capacity index, T_c for any point along a stream or concentrated flow path. It is defined as the product of the land area contributing runoff at a point and the slope of the channel at that point (Moore and Wilson, 1992).

Earlier work showed a significant correlation between T_c at a point along a flow path and another variable dependent only on DEM data. That other variable is based on the difference between the land surface elevations measured by LIDAR in 2006 and in 2017 (E_{dif}), where positive values indicate erosion and negative values indicate deposition. In a channel transporting large amounts of sediment, erosion and deposition likely occur repeatedly over storms, seasons, and years, with some parts of a reach showing deposition and others erosion. A strong case can be made that high variability in E_{dif} within a reach corresponds to large flows of sediment in the reach, and high sediment flow should correspond to high T_c values. Specifically, the earlier work showed that the standard deviation of E_{dif}, that is, std(E_{dif}), is significantly and positively correlated with T_c. Figure 1 describes how the E_{dif} layer can inform the evolution of the thalweg (the path of the deepest part of the channel).

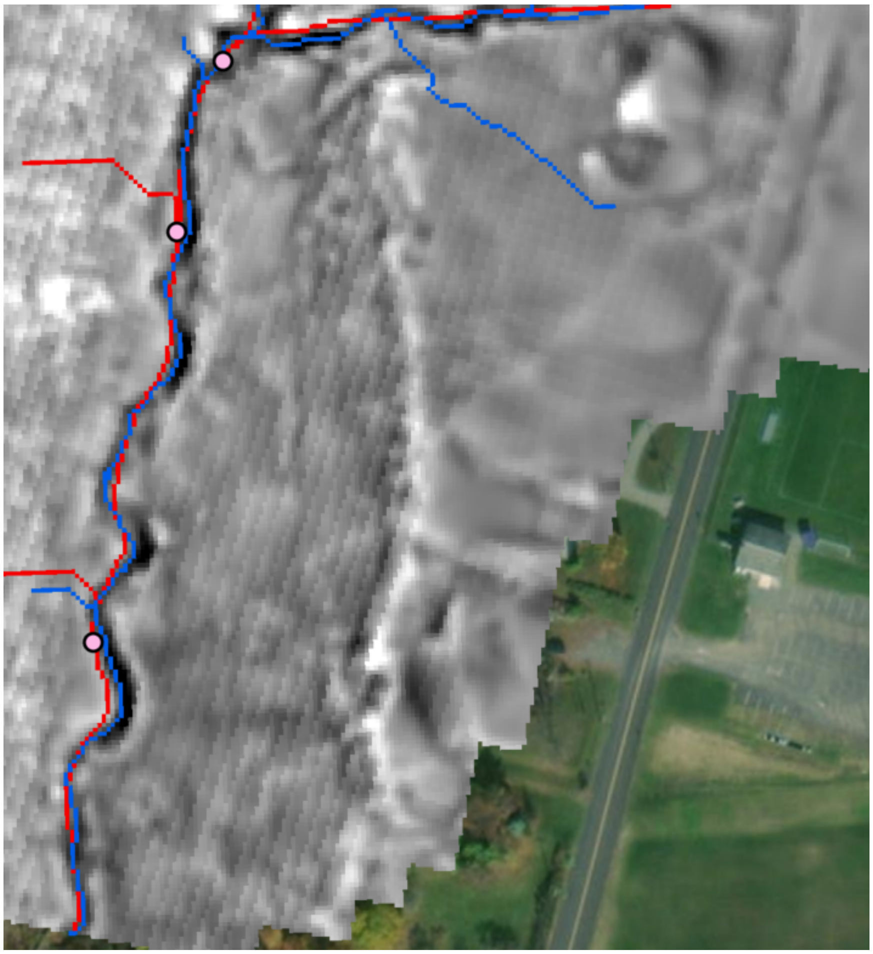

Figure 1. Example of the E_{dif} layer on a black (deposition) to white (erosion) color scale, along with the concentrated flow path from 2006 (in blue) and 2017 (in red). Note that in nearly all bends of the channel, the 2017 channel is straighter than the 2006 one. E_{dif} on the outside of the bends is black, indicating deposition, which pushes the stream channel towards the inside of the bend, thus straightening it. The pink dots are carpet locations. Scale of the map can be inferred from the two-lane road and parking lot visible in the aerial photo visible on the right side of the figure.

Over the summer of 2021, a local land-owner allowed six sediment traps (shag carpet rectangles which were weighed in advance) to be placed in flow paths located using GIS. After several weeks, they (and the sediment on them) were collected, dried and weighed to determine the mass of sediment collected and the mass per unit rug area. Preliminary results indicated a positive correlation between T_c and the mass per unit area of carpet.

For the summer of 2022 a more robust sampling plan with twelve carpet sites was planned, with trap locations planned in advance using GIS. The goal was to link T_c, std(E_{dif}) and sediment mass per unit area of carpet. Installation and retrieval of the carpets is labor intensive, and sites were limited to those on the landowner's property. Two of the sites turned out to be inaccessible due to dense undergrowth, and two other carpets got washed downstream, leaving only eight trap sites. Figure 2 shows the relationships among the variables. The left column of panels uses the averages of T_c and of std(E_{dif}) in a 5-m radius circle around the carpet. The right column uses reach-averages of the same two variables.

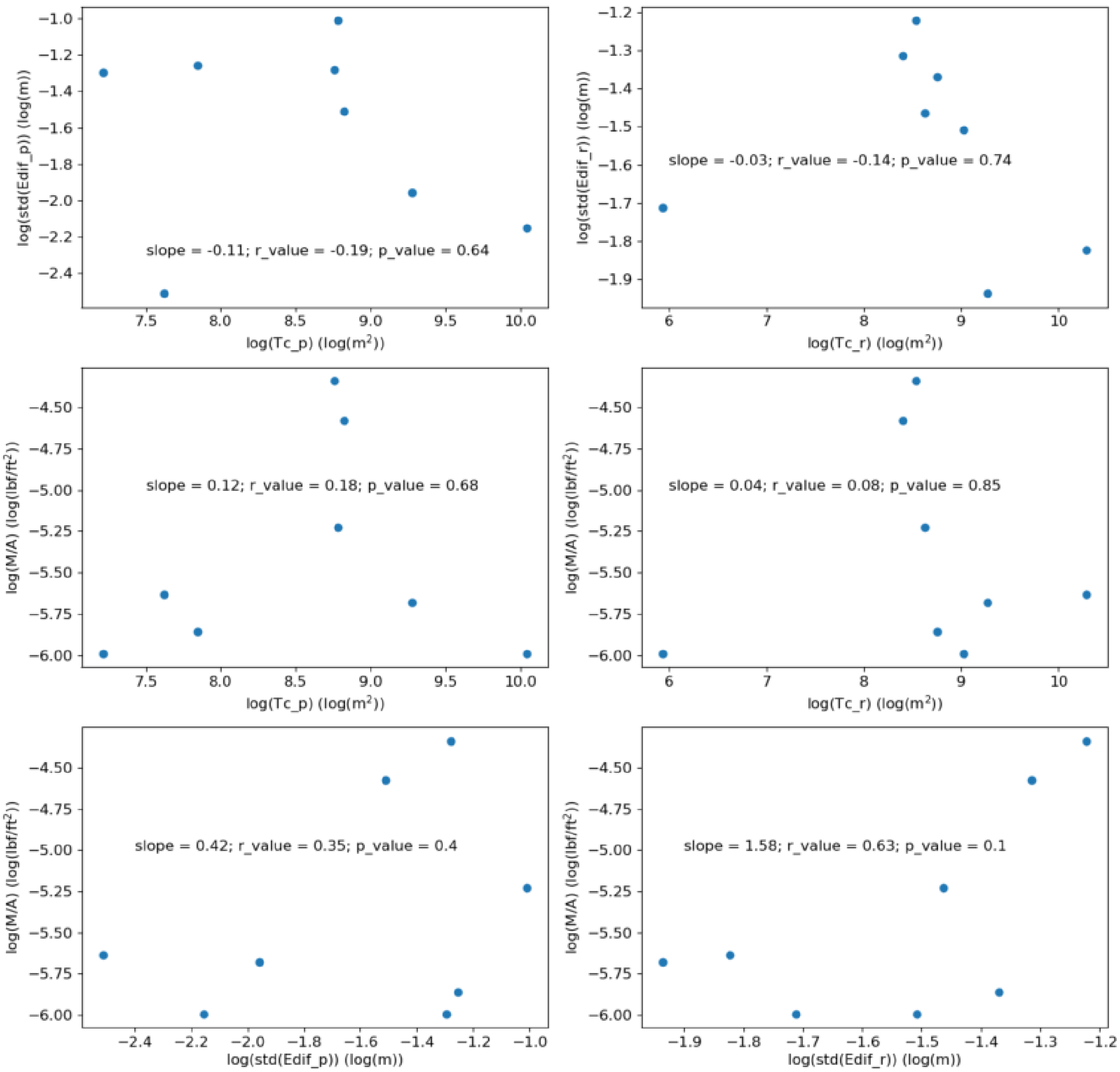

Figure 2. Comparisons among std(E_{dif}), T_c, and mass per unit area of carpet (M/A) at the carpet sites. For std(E_{dif}) and T_c the subscript p (panels on the left side of the figure) represent means in a circle around the carpet with a 5-m radius, while subscripts r represent means over a reach. The slope of the linear regression line, the correlation coefficient, and the p-value are provided for each panel. None of the correlations are significant at the 5% level.

Figure 2 shows only weak relationships, if any, among the variables tested. Two likely reasons are: 1) A sample size of only eight makes it hard to establish a robust relationship and 2) There is a mismatch in scale between T_c and std(E_{dif}) on the one hand (which represent scales on the order of tens of meters), and carpet sediment loads on the other (which represent a scale on the order of 1 m). Because of the mismatch, two (hypothetical) carpets in the same reach could have significant differences in sediment load (for example, if one was in a pool and the other in a riffle).

An additional part of the planned work was to apply the GIS analysis to Bull Run (a mostly-urbanized watershed containing Lewisburg, PA and most of the Bucknell campus) and to Buffalo Creek (a much larger and mostly rural watershed). For Bull Run, std(E_{dif}) had a statistically-significant relationship to T_c, but the correlation was not as large as for more rural watersheds. This is not surprising since stormwater cannot erode paved channels, gutters and storm sewers, so the causal link between the two variables is weakened in urban areas. Comparison of the two variables for Buffalo Creek was not possible because parts of the watershed fell outside the range of one of the LIDAR datasets.

In conclusion, the work done in the summer of 2022 confirmed the link between T_c and std(E_{diff}). However, the further link to "ground truth" measurements remains elusive. Cross-sectional and/or longitudinal surveys of elevation for key reaches over a period of years could potentially provide ground truth.

Acknowledgments

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References

Moore, I. D., and Wilson, J. P., Length-slope factors for the Revised Universal Soil Loss Equation: Simplified method of estimation, *J. Soil and Water Conserv.* 47(5), 423-428, 1992.