Assessing performance of conservation-based Best Management Practices: Coarse vs. fine-scale analysis

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Abstract:

Background/Questions/Methods

Animal agriculture in the Spring Creek watershed of central Pennsylvania contributes sediment to the stream and ultimately to the Chesapeake Bay. Best Management Practices (BMPs) such as stream bank buffers are intended to intercept sediment moving from heavy-use areas toward the stream. The placement of BMPs on a farm is generally based on untested assumptions about flow paths. Most often, a straight-line distance from the heavy-use area to the stream is assumed to be correct. Our objective was to compare the straight-line path to hydrologic flow paths calculated from fine-, medium- and coarse-grained Digital Elevation Models (DEMs; 1m, 10m, 30m) for 471 mapped heavy-use points within 100m of the stream. The 30m DEMs are the most widely available and require the least processing time. We anticipated that the flow path distance would be longer than the straight-line distance in all cases, that the finest resolution would lead to the most accurate measurement, but that the difference might not be great enough to justify the increased costs. Understanding the changes in path length and direction calculated using more complex methods and higher-resolution source data will enable us to make recommendations on methods to be used in developing conservation management plans.

Results/Conclusions

The medium-(10m DEM) and fine-resolution data (1m DEM) had the smallest differences between the hydrologic flow path and straight-line path: median differences in path length of 20 m for both the 1m and 10m DEMs, and 51m for the 30m DEM. Hydrologic flow paths were significantly longer than straight-line paths for all three scales; BMP placement based on straight-line distances may not be the most effective. Although the overall difference was significantly positive, calculations on the 30m DEMs sometimes produced straight-line paths that were longer than the hydrologic flow paths, apparently due to inaccuracies in the data. Where fine-scale DEMs are available, BMPs might be more effectively situated by considering the corresponding drainage pathways. The very different results produced at the three scales demonstrate that using the finest-grained elevation data may substantially improve placement of BMPs intended to mitigate for heavy animal use areas. The use of 30m DEMs for this purpose should be avoided. Fine-grained data such as 1m-resolution LiDAR-derived DEMs are available for Pennsylvania through PAMAP, and can be incorporated in the planning stages of BMP placement ultimately resulting in reducing agricultural sediment and nutrient loadings into local watersheds and the Chesapeake Bay.

Problem: Intensive animal-based agriculture releases sediments into Spring Creek **impairing streams** and depressing Brown Trout populations.

Feed Heavy Use Area

Photo: M. Sanderson USDA-ARS

Shade Heavy Use Area

Photo: S. Goslee USDA-ARS

Best **M**anagement **P**ractices (**BMP**s) such as bank stabilization, buffer strips and stream crossings **mitigate impacts** of grazing animals, but BMP placement is usually done only using **on-site estimation**.

Cattle Crossing

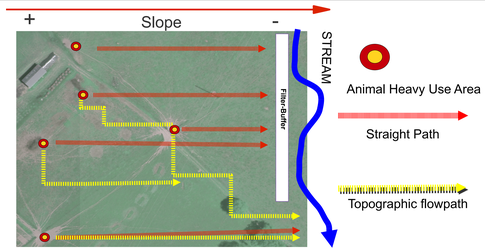
Photo: S. Yeiter

Streambank Fencing

Photo: S. Yeiter

Problem: BMPs are placed downslope from animal heavy use area **without** considering local **topographic features** (NRCS: Heavy Use Area Protection (PA561)).

Figure 1: Downslope & topographic flow-paths.



Objectives:

- Compare the flow path length (FP) with straight path length (SP) from the heavy-use points to the stream ((FP-SP)/SP)*100 = **Adjusted Difference %**).
- Compare **along-stream difference** between flow path and straight path stream entry points.
- Evaluate effect of DEM resolution on above calculations by comparing coarse (30m), medium (10m), and fine (1m) elevation maps.

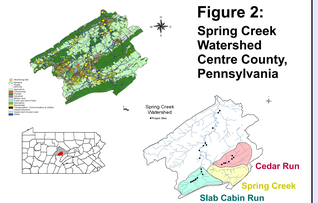


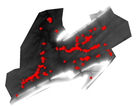
Figure 2: Spring Creek Watershed Centre County, Pennsylvania

Background:

- Spring Creek drains to the Chesapeake Bay via the South Branch of the Susquehanna River.
- An EPA ruling described portions of Spring Creek as impaired in 1995.
- We studied three sub-sheds within the Spring Creek Watershed. All are >625 ha. (Fig 2.)
- Animal-based agriculture is most prevalent in Slab Cabin and Cedar Run, and upper Spring Creek is mostly forests (Fig 2.).

Figure 3a: Riparian Zone

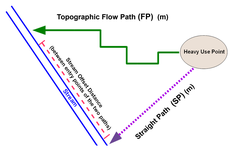
Figure 3b: Heavy Use Pts.



Methods:

- A 100m riparian buffer was made around the PA State Plane Stream Layer (Fig 3a.)
- Centroids of 471animal heavy use areas were marked using high-resolution aerial photography. (Fig 3b.)
- All points in 30m DEM (55,580 points), and the same number of randomly selected points in the 1m and 10m DEMs, were used as comparative distributions.
- We defined streams and topographic flow paths by processing the three DEM resolutions (30m, 10m, and 1m) using ArcHydro Tools in ArcInfo.

Figure 4: Diagram of straight path and topographic flow paths, and an example applied across DEM grains.



Adjusted Difference (%) = ((***FP – SP***) / ***SP***) * **100**

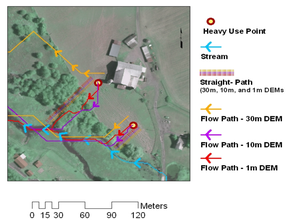
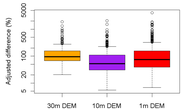


Figure 5a: Path length of heavy use points.



The difference between the flowpath length estimates can be large.

The flow path (FP) distance had a median value of 20m longer than the straight path (SP) for both the 1m (73%) and 10m (52%) DEMs, and 50m longer for the 30m DEM (94%) (**Fig 5a & 5b**).

Figure 5b: Path length of random points.

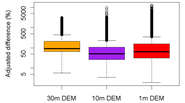
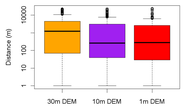


Figure 6a: Along stream difference for heavy use points.

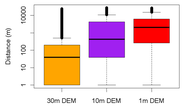


Along stream differences are considerable.

Median along-stream differences of heavy use points were 281m for the 1m DEM, 256m for the 10m DEM, and 1198m for the 30m DEM (**Fig 6a**).

Median along-stream differences of random points increased with increasing DEM resolution (**Fig 6b**). Random points have more topographic variability than the heavy use points. This variability is enhance by the resolution of the DEM.

Figure 6b: Along stream difference for random points.



Conclusions:

Visual assessments and straight paths from heavy use areas to streams often give **misleading estimates** of flow path lengths and stream entry points, resulting in inefficiently placed BMPs.

The **actual point** where water flowing from a heavy use area enters the stream **may be nowhere near the straight path entry point**, thus by-passing the BMP entirely.

The **most accurate flow paths** were given by the **1m DEMs, but 10m DEMs** were **suitable for** farm **planning**. The **30m DEMs are highly inaccurate** and should be **avoided**.

Fine-grained data such as 1m resolution DEMs **are available** for Pennsylvania through PAMAP, and **can be incorporated in the planning stages of BMP placement** ultimately resulting in reducing agricultural sediment and nutrient loadings into local watersheds and the Chesapeake Bay.

References:

NRCS Conservation Practice Standard: Heavy Use Area Protection (Code 561). Technical Guide Section IV, Pennsylvania, March 2008.

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