INDEXES FOR TARGETING BUFFER PLACEMENT TO IMPROVE WATER QUALITY

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ABSTRACT

The effectiveness of vegetative buffers for improving stream water quality in agricultural watersheds has long been regarded as being greater in some locations than in others within watersheds (Walter et al., 2007). Many approaches have been advanced for identifying more-effective locations in order to target the installation of buffers and enhance their environmental performance.

The simplest targeting model places vegetative buffers along the downhill margins of agricultural fields. In these locations, they are more likely to intercept and retain pollutants in runoff. This model can be refined by focusing on cultivated and manure-applied fields, particularly ones that are steep and highly-erodible, because these fields tend to contribute greater pollutant load to runoff than other fields do. Other simple models focus on landscape position, such as riparian areas through which runoff is expected to pass before entering streams, or site conditions, such as wetland soils which offer more favorable slope and soil chemistry for retaining and transforming pollutants in runoff. Each of these examples represent one of the three characteristics of a well-targeted vegetative buffer: (i) downhill from larger sources of pollutant load; (ii) in the pathway of runoff flow from sources to streams, and; (iii) where site characteristics are more-favorable for immobilizing pollutants with a buffer.

The emergence of GIS technology and widespread availability of digital spatial databases on land uses (National Land Cover Database), streams (National Hydrography Dataset), and soils (SSURGO) have enhanced planners' ability to use these simple categorical models in various combinations for targeting buffers in large planning areas.

These categorical models, however, lack sufficient spatial resolution for effectively managing runoff with vegetative buffers. Resolution at the scale of whole fields, stream networks, and soil map units fail to account for field runoff that converges into concentrated flow paths and traverses only small portions of field margins and riparian zones and for wetlands that do not lie in those paths (Dosskey et al., 2002). Buffer area that does not intercept runoff is not very effective.

Newer models employ digital topography in the form of digital elevation models (DEMs) for determining runoff pathways and slope conditions at horizontal resolutions as fine 1 m^2. The simplest of these indexes, Wetness Index (Moore et al., 1991), employs only the DEM to identify where flow converges from larger source areas to flatter locations. It has been interpreted variously to indicate where more runoff accumulates and either infiltrates and deposits its sediment (Tomer et al., 2003), raises the water table into interaction with the rooting zone (Burkart et al., 2004), or exfiltrates into erosive overland flow (Walter et al., 2002), depending upon local hydrologic circumstances. The Topographic Index (Walter et al., 2002) refines the Wetness Index to more-accurately identify the exfiltration-prone sites by accounting for soil properties. The Water Inflow Index (Dosskey et al., 2011) combines size of source area with soil properties to more-accurately gauge where the amount of overland flow from source areas would be greater while its partner Sediment Retention Index gauges the corresponding amount of sediment that would be deposited in a vegetative buffer at those locations. The DEM provides a grid framework and spatial resolution that better matches the needs for managing agricultural runoff.

Our comparison of results using these four DEM-based indexes on the same watersheds showed that they tend to target similar locations. We trace this similarity to the disproportionate importance of intercepting runoff from larger source areas to the ranking by each index. Larger source area correlates very strongly with larger runoff volume and the potential for retaining pollutants from that runoff with a buffer. The size of source area to individual grid cells ranged 6 to 7 orders of magnitude throughout our study watersheds while other factors in these mathematical indexes such as slope, soil depth, and erodibility do not vary to this degree.

While DEM-based indexes promise greater spatial precision and accuracy than the categorical models, they can be more complicated to use. Among other challenges, DEM-derived flow patterns may need manual adjustment for drainage modifications that are not indicated in the DEM, and, threshold index values must be determined that distinguish appropriate sites for buffers from those where stream channels occur. Consequently, greater skill will be required of planners to effectively employ the DEM-based targeting indexes.

Keywords: Precision agriculture, Precision conservation, Agricultural runoff, Vegetative buffer, Digital elevation model, Environmental performance, Watershed.