Riparian Buffer Science: Status and Research Needs

A summary of research, applications to management and the new Minnesota buffer rule

Status of the science: What do we know?

Erosion and nutrient loss from upland areas, streambanks, bluffs, ravines, and river banks have been contributing to water quality problems throughout the state. Furthermore, changes to the structure and vegetation of waterbodies have impacted the health of aquatic life over the years.

Impairments from these changes are associated with problems pertaining to aquatic life, drinking water, and algal blooms in Minnesota's water bodies and water in other states downstream. In order to improve waters across the state and water discharging into neighboring states, Minnesota has been implementing best management practices (BMPs). Riparian buffers are one type of BMP being used to reduce contaminants released into the state's waterways.

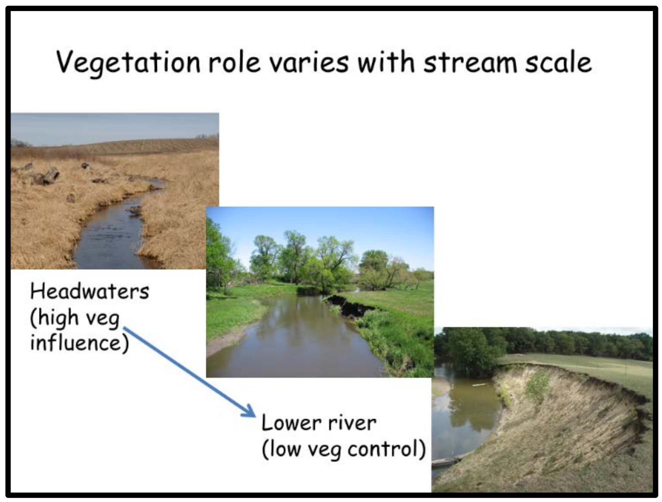
Riparian buffers are referred to by many names. They are sometimes called filter strips, wildlife corridors, greenways, vegetated riparian zones and more. While their water quality benefits are most well-established, they also may improve biodiversity and soil productivity while supporting economic opportunities, public safety, aesthetic values, and outdoor recreation (Bentrup, 2008). They can be defined as land with perennial vegetation bordering rivers, streams, lakes, and other waterways. Vegetation can vary from grasses, forbs, shrubs, trees, or a mixture of vegetation, although the majority of buffers in the Midwest are planted to grass for maintenance reasons.

Vegetation slows water flowing across the surface of the land through increased surface roughness. It traps sediment and contaminants, such as phosphorus, attached to sediment, and allows for infiltration of water and associated nutrients as long as water is flowing across neatly as sheet flow (Hoffmann, Kjaergaard, Uusi-Kämppä, Hansen, & Kronvang, 2009; Liu, Zhang, & Zhang, 2008; Lowrance et

al., 1997). Vegetation also assists in nutrient uptake and removal from surface and subsurface water flowing through the riparian zone. Plant roots can take up nutrients and stabilize soil with attached nutrients. Plants also increase carbon input to the soil improving the denitrification potential provided by bacteria.

Due to the heterogeneity of soil types, topography, tillage practices, stream order, watershed size, geology, vegetation, and climate within the state, buffer effectiveness varies from site to site. Not only do sites differ within the state, but buffer effectiveness may vary along a single buffer. Therefore, buffers are most effective when designs include adjustments within a site to account for some of the variability in the parameters mentioned above. Optimal buffer width will vary based on the heterogeneity of the site.

On a landscape scale, buffers can improve biodiversity by improving the connectivity of habitats, protecting remnant habitat, creating a corridor, and reducing an edge effect (Nieber, Arika, Lenhart, Titov, & Brooks, 2011; Shaw, 2016). Locally, buffers provide habitat within the buffer and within the waterway next to the buffer. Woody debris provides habitat within the waterway, and fallen leaves, twigs, stems, etc. provide important nutrients for animals in the water. Furthermore, shade can improve temperatures in the water for fish communities.



Vegetation in riparian buffers can also provide some economic value to landowners. The vegetation stabilizes soil to prevent the loss of productive land. Furthermore, various types of plant communities can be harvested. Some of these communities are even profitable to sell as edibles, decoratives, and biofuels.

Buffers are already one of the most widely used BMPs for improving water quality. Many landowners in Minnesota already voluntarily have native shoreline vegetation. In a survey of over 800 shoreline homeowners in East Otter Tail County, over 70% already had native shorelines (Eckman & Henry, 2012). With the signing of the Minnesota Buffer Law in 2015, efforts have increased to learn more about their optimal function, benefits, and optimal design and placement. Research will improve the effectiveness of existing buffers and new buffers installed as a result of the new law. Establishment of multi-purpose buffers in response to the new buffer law will offer opportunities to evaluate their multiple benefits (e.g. water quality, productivity, and habitat).

Recent Research

Much has been discovered in recent years on the potential for using buffers to remove more nitrogen from tile drainage water. Saturated buffers are buffers in which tile drainage is directed below the ground within a buffer so it flows perpendicular to the waterway through the width of the buffer.

These systems are limited by capacity, but designs recently studied indicate a high reduction of the nitrate from tile drainage (Jaynes & Isenhart, 2014; Utt, Jaynes, & Albertsen, 2015).

More research has been conducted in recent years on how well various genotypes of biofuel crops perform at local sites. There has been increasing potential for new crops and varieties to be planted along buffers for biofuel, pest control, water quality, and more. Some of the recent species of interest are hybrid poplars, willow, elderberry, hazelnut, black chokeberry, intermediate wheatgrass, switchgrass, and others. A variety of species have been successfully established in research plots around the state and new processing facilities have been constructed (Bongard & Wyatt, 2010).

The primary role of buffers in reducing phosphorus discharge into waterways is via erosion prevention and particulate phosphorus deposition prior to entering the water. Recent studies show that much more dissolved phosphorus enters waterways through subsurface drainage and groundwater than originally thought (King et al., 2015; Smith et al., 2015; Young & Briggs, 2008). While buffers can be sources of phosphorus due to a release of phosphorus when the buffer is saturated, some work has shown that lime or iron could be implemented into saturated buffers to reduce phosphorus (Kirkkala, Ventelä, & Tarvainen, 2012; Uusi-Kämppä, Turtola, Närvänen, Jauhiainen, & Uusitalo, 2012).

Berms are sometimes developed due to soil deposition along buffers or from dredge spoils during construction. Buffers perform well at removing sediment, particularly in sandy to loamy soils, from field runoff. However over time berms form along the buffer, and water can no longer flow as sheet flow through the buffer. Concentrated flow paths are developed when water flows through the point of least resistance on the berm. From that moment on, the majority of flow through the buffer occurs in rills or gullies. Some concentrated flow paths also occur from incision or head cutting from the creek backward. These areas create problems for filtering sediment from surface water and need to be considered for design and management of buffers (Dosskey, Helmers, Eisenhauer, Franti, & Hoagland, 2002; Pankau, Schoonover, Williard, & Edwards, 2012; Vieira & Dabney, 2012).

Key questions that still remain

Much remains to be learned about the design of optimal management practices. For example, what types of vegetation harvest are acceptable in each buffer design? How will deposited sediment be removed when berms start to develop and create concentrated flow paths without disrupting the function of the buffer?

Research on saturated buffers in recent years has expanded the literature on buffers' nutrient removal potential in subsurface flow. However, more needs to be learned about the dynamics of subsurface flow in buffers from groundwater, bank infiltration during high stream flow, shallow subsurface flow, and surface water infiltration. Is shallow groundwater which is being treated within the root zone of the buffer impacted by water in the stream or river that infiltrates back into the bank during high flows? Will higher flows in a changing climate impact this subsurface treatment? How do vegetative community types influence this hydrology?

Agroforestry practices have great potential as a productive option in buffers. However, more research is needed on their economic viability and their impact on yields of adjacent crops. Some concerns are raised when trees shade or compete with crops for water and nutrients (Senaviratne, Udawatta, Nelson, Shannon, & Jose, 2012). They also may contribute to increased erosion and channel width increase on small prairie streams < 10 m wide (Anderson et al. 2004). Many of the potential impacts can be mitigated by proper management but research is needed to define BMPs.

More needs to be learned about management techniques for reducing phosphorus (especially dissolved phosphorus) loads in particular. Forested buffers likely reduce phosphorus loads from bank erosion better than other buffers (Kronvang, Audet, Baattrup-Pedersen, Jensen, & Larsen, 2012), but grass strips tend to reduce surface flow and sediment deposition in streams better (Pankau et al., 2012). Management strategies, which may combine forested and grass buffers, need to be improved for reducing phosphorus loads through prevention of bank erosion, reduction in surface runoff, and removal of phosphorus in dissolved forms.

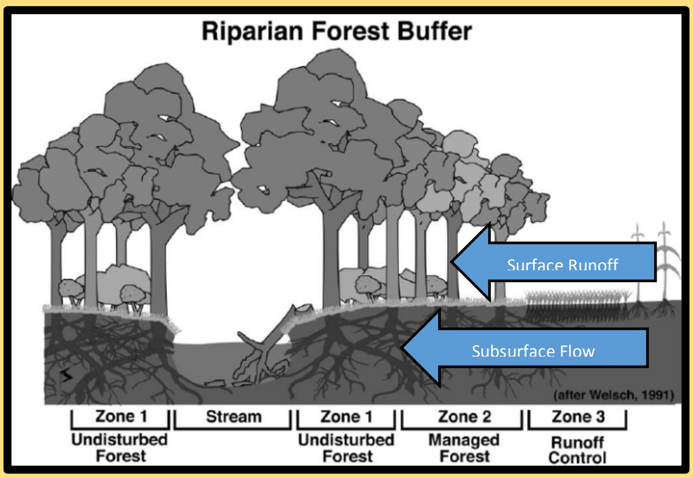


Figure 1. Three-zone riparian buffer system. Zone 3 reduces surface runoff with grasses and herbs. Zone 2 is a managed forest which reduces sediment and nutrients from runoff and subsurface flow. Zone 1 is an undisturbed forest which provides nutrients and cover for animals in the stream. Figure adapted from Schultz et al. (2004). See Bongard (2010) for vegetation types fitting for each zone.

What is important to know for design and the buffer rule?

Design requires site-specific assessment. It is a good idea to assess issues with soil productivity, soil loss, water quality, wildlife habitat, public safety, and economics. Goals should also be listed to determine if other items such as aesthetics or recreation should be part of the design. The watershed, soil type, and historic flow paths should be determined in order to design a buffer that addresses the heterogeneity of the site. In many cases, the three-zone buffer system can be followed (Figure 1) in order to address multiple issues. However, the wooded buffers are not always recommended in small streams or ditches (Anderson, Bledsoe, & Hession, 2004). Furthermore, Tomer et al. (2015) created a design framework considering the size of the watershed and its slope along with the width of shallow groundwater (<1.5 m deep) to determine the width of buffer needed or if stream bank stabilization within the channel is preferred. Adjustments should be made according to each site's needs and goals.

Contributors

Brad Gordon[1], Chris Lenhart[1], Ann Lewandowski[2], Gary Wyatt[3], and Dean Current[4] ([1]University of Minnesota Department of Bioproducts and Biosystems Engineering, [2]Water Resources Center, [3]McLeod County Extension Office, and [4]University of Minnesota Department of Forest Resources)
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