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What Else Can Surface Water Buffer Systems Do?—Exploring Multiple Ecosystem Services[1]

Lei Wu, Rafael Muñoz-Carpena, and Yuncong Li[2]

Introduction

Riparian buffers and Vegetative Filter Strips (VFSs) are both Best Management Practices (BMPs) recommended by USDA and EPA because of their potential for nonpoint source pollution control (USDA-NRCS 1999; EPA 2006). The purpose of these buffers is to improve water quality by intercepting and slowing runoff. While their primary functions are the same, their practice definitions are different. VFSs are mostly implanted vegetation areas that require regular maintenance to preserve the dense vegetation. They are usually located within and between agricultural fields and the water courses (rivers and streams). Riparian buffers, which tend to be larger than VFSs, can be established or spontaneous, containing mostly brushy or woody vegetation that emerges near streams or channels. Despite decades of research on these buffers, the primary focus has been on controlling pollutant removal. However, as society confronts the consequences of global warming, deteriorating water quality, and impoverished biodiversity, there is a growing urgency to develop and expand these buffers' multifunctional ecosystem services. In this context, these buffers should not be seen as operating independently from the surrounding land; instead, they must be regarded as an integrated part of the landscape. Figure 1 illustrates riparian buffer systems as the "engine that drives important natural functions like food availability and quality, access to clean water and habitat diversity" (Southeastern Wisconsin Regional Planning Commission 2010). Based on this concept, there is a need to change the way buffers are designed and evaluated in order to maximize their broader benefits to our society.

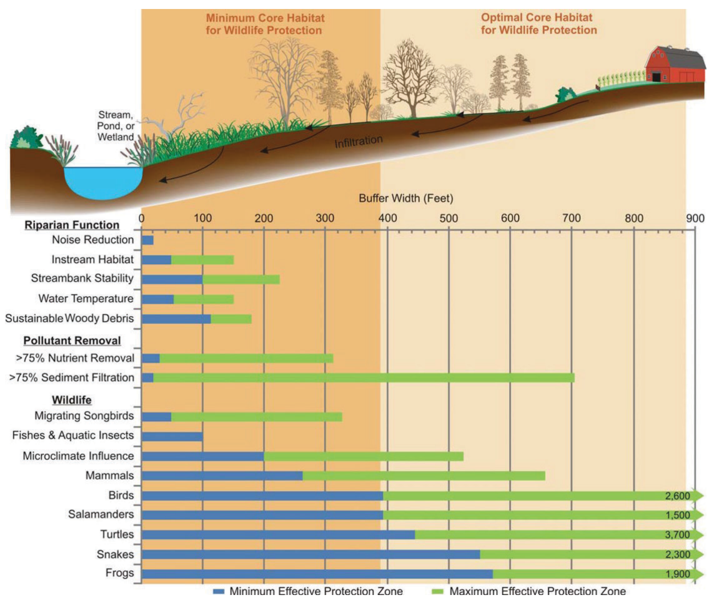

Figure 1. Multi-functions of a riparian buffer system.
Credits: Southeastern Wisconsin Regional Planning Commission

One of the key ecosystem functions that buffer systems support, namely, the ability to trap nutrients, sediments, or pesticides, has been documented extensively in scientific literature. However, limited information is available on other potential co-benefits associated with the use of

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buffers, particularly VFSs. This publication is intended to provide information on buffers' multiple ecosystem benefits (e.g., niche products production, carbon sequestration, and flood risk mitigation). Recommendations on future research needs necessary to enhance multiple ecosystem services and benefits of buffers are also provided.

Buffers' Multiple Ecosystem Services

Niche Products Production

Buffer strips are generally located along or around streams, lakes, ponds, or wetland. Many of these areas feature high soil moisture and nutrient availability. Trees and shrubs are commonly incorporated with buffers as beneficial components of the filter system, especially in a riparian zone. In addition to intercepting and filtering pollutants, trees can also be harvested, providing additional value as a renewable fuel source, timber for construction, fruits, nuts, and other products for small growers. This additional value can represent a different kind of opportunity for farmers who want to supplement their income. Table 1 lists tree species which could be incorporated into filter systems in the southeast region of the United States. For more information, please visit the UF/IFAS Extension site (http://smallfarms.ifas.ufl.edu/).

Table 1. Typical tree species in the Southeast US suggested by Center for Subtropical Agroforestry.

Species	Products
Maple	Timber/firewood, charcoal
Pecan	Nuts
Hickory	Nuts/timber, charcoal
Ash	Timber, tool handles
Black cherry	Timber, firewood
Alder	Smoke/flavor wood, honey
Pawpaw	Fruit, jellies

Carbon Sequestration

There is a growing awareness of the adverse impact of greenhouse gas (GHG) emissions and their potential impact on climate change. Recent studies suggest a few of the challenges of climate change can be effectively overcome by the storage of carbon in terrestrial carbon sinks via plants and soils. Compared to other Natural Resources Conservation Service (NRCS) practices, such as tree/shrub establishment, the potential to sequester large amounts of carbon in buffers is not well understood (Figure 2). For more information, please visit the following website: http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/air/?cid=stelprdb1044982.

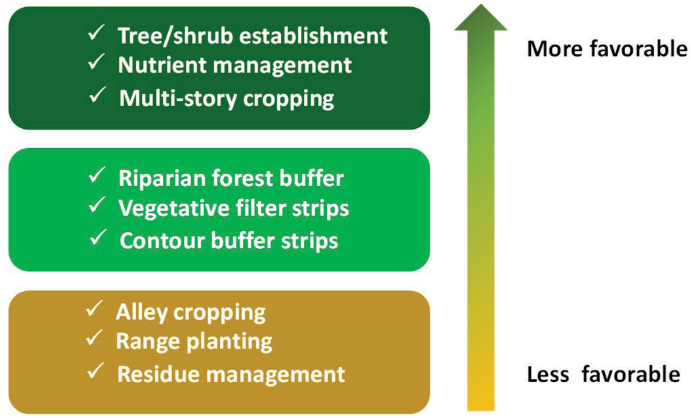

Figure 2. GHG and carbon sequestration ranking of typical NRCS practices.
Credits: L. Wu

Although carbon sequestration in traditional buffers (i.e., without perennial or woody vegetation) can be a challenge based on current understanding, a number of approaches have the potential to improve the capacity of buffers to sequester carbon. One promising approach is to incorporate perennial vegetation into traditional buffer systems since perennial plants sequester and store greater amounts of carbon than annual plants do. A recent study indicates that a riparian buffer system consisting of mixtures of annual and perennial species sequestered significantly greater amounts of carbon compared with crop fields or an annual grass buffer alone (Fortier et al. 2015). This finding provides further evidence that incorporating perennial vegetation in strategic locations within traditional buffer systems creates opportunities to expand the systems' capacity for carbon sequestration. The use of soil amendments such as the charcoal by-product biochar presents another potential means of promoting greater carbon sequestration through buffer systems. Since biochar is highly resistant to degradation, it can provide a long-term sink for carbon storage in the soil. In addition, recent studies also indicate that biochar can be effective in controlling the fate of fertilizer-nitrogen and reducing the unintended environmental consequences associated with N losses via nitrogen oxide gas emission, overland flow, and leaching.

Flood Risk Mitigation

Buffers, specifically VFSs, have become one of the most frequently used stormwater management tools in urbanized areas. Many stormwater practitioners perceive VFSs mostly as a water quality management practice and underestimate the value of VFS systems as effective tools for peak discharge control, channel protection, and bank stabilization. While research data related to this function are still limited, the computational and modeling results clearly indicate that VFSs can be effective in controlling peak discharge

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rates and mitigating flood risks. For example, a recent study (Ballinger 2011) indicates that although VFSs represent a relatively small portion of land, they can help mitigate the impact of intense rainfall, especially in drier summer months (e.g., subtropical storms). Similarly, researchers in another study (Liu et al. 2014) developed a community scale simulation model to quantify the effectiveness of different Green Infrastructures (GI) on reducing the volume and peak flow of urban flooding. The outcomes show that vegetated surfaces make the greatest contribution to the storm runoffs in the community. That said, the reduction capacity for a single GI facility is limited, especially in bigger storm events. However, integrated GI configuration (e.g., incorporating the hedgerows of native perennial plants with traditional VFSs) has shown significant reduction capability by reducing the total runoff and peak flow rate by more than 25% and 10%, respectively. This study suggests that integrated VFS systems have the potential to act as a low-impact development and resilient management practice in urban areas. In Florida, VFSs have been used as a stormwater management practice to preserve or restore predevelopment hydrology, increase dry weather base flow, and reduce bankfull flooding frequency (Figure 3).

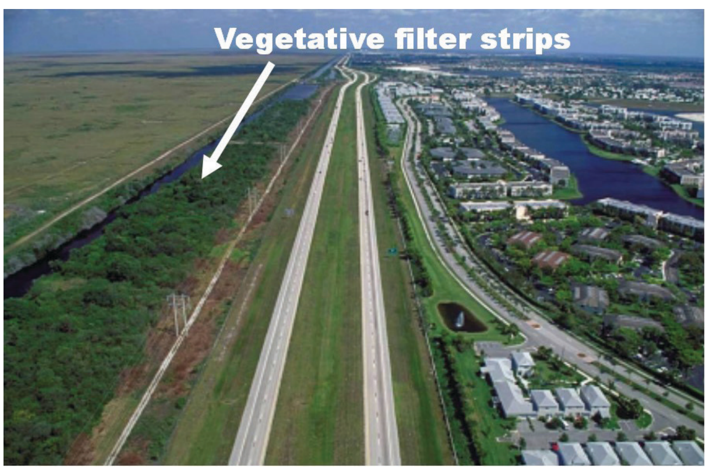

Figure 3. Vegetative filter strips used as a stormwater management practice in south Florida.
Credits: South Florida Water Management District

Summary and Recommendations

Generally, addressing other ecosystem functions of buffers implies a trade-off in terms of total land that must be retired from production in favor of protection, especially in an agricultural context. The arguments in this paper support the hypothesis that buffers, if properly managed, should not be considered as unproductive landscape designed for water quality control, but as part of a productive landscape with multiple ecosystem functions and potential economic benefits (Figure 4).

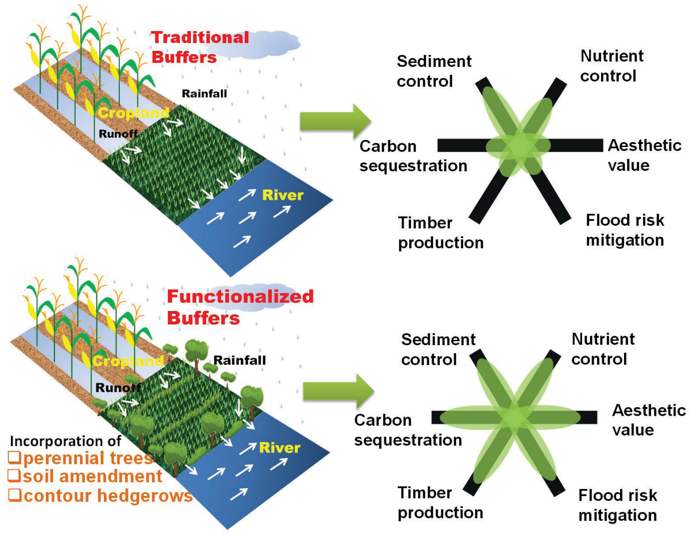

Figure 4. Conceptual framework for comparison of multiple ecosystem services between traditional and functionalized buffers. The provision of multiple ecosystem services by the two buffer systems can be illustrated with these two "flower" diagrams, in which the magnitude of each ecosystem service is indicated along each axis.
Credits: L. Wu

Enhancement of the efficacy of buffers' multiple ecosystem services requires additional research and development of more effective management strategies. The following list of items, intended to present challenges for researchers, engineers, and decision makers, was designed to meet these goals.

1. For researchers, there is a critical need to understand the *functions, conflicts, and interactions between diffuse pollution and other services*. This will allow the development of improved and more effective strategies that can maximize the benefits of buffers to our society. For example, there is a need to look into mechanisms which control the nutrient cycling process in buffer systems. This fundamental knowledge is important for us to better manage buffer soil to provide a wide range of ecosystem services, such as pesticide degradation, carbon sequestration, and high biodiversity support. There is an additional need to quantify carbon and nitrogen sequestration in buffer systems.

2. For engineers or farmers, there is a need to embrace *the complexities of managing unfamiliar integrated buffer systems*. Unlike conventional buffer systems, they are not designed to be fully controlled. Managing integrated buffer systems requires more flexibility, effective communication, and risk management.

3. For decision makers, there is a need to *encompass measures of performance beyond the finances of a single utility or political entity*. New tools will be needed to

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quantify non-monetary benefits and create incentives for organizations to adopt approaches that lead to better overall outcomes. For example, an ecological-economic model using the Bayesian belief network (a statistical model which uses a directed acyclic graph to represent the conditional dependencies of each variable) should be considered to assess and value the delivery of ecosystem services from the buffer system.

4. For educators, there is a need to provide interdisciplinary education in multiple areas. Successfully managed integrated buffer systems will require the integration of knowledge and tools from basic sciences, such as hydrology, microbiology, ecology, and geochemistry, with applications of computer skills.

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