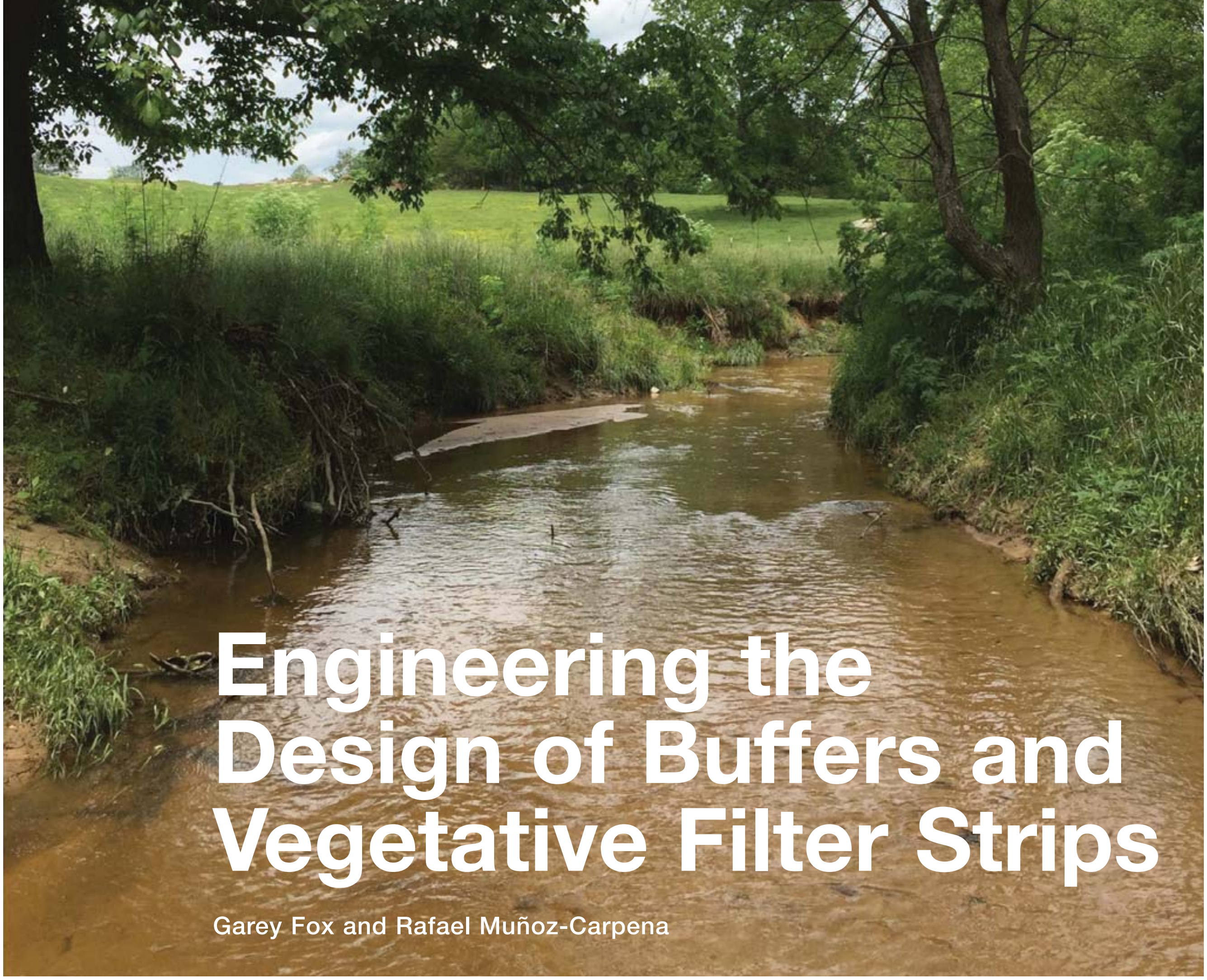

Engineering the Design of Buffers and Vegetative Filter Strips

Garey Fox and Rafael Muñoz-Carpena

A riparian buffer along Millstone Creek in North Carolina. ***Photo by Celso Castro Bolinaga, North Carolina State University.***

As the protection of sensitive water supplies becomes increasingly important, research conducted by agricultural and biological engineers is leading the way in improving how buffers are designed and analyzed. Buffers are a best management practice (BMP) aimed at controlling pollution in the surface runoff from agricultural fields, construction zones, and urban areas. Buffer types include spray drift buffers, field borders, riparian buffers, and vegetative filter strips.

Understanding the performance of buffers for runoff mitigation has typically been frustrating. For typical buffer widths, the effectiveness in removing sediment, nutrients, and pesticides ranges between 0% and 100% depending on the incoming flow characteristics and the hydrologic and sediment transport conditions in the buffer, which are partly controlled by land use. Small runoff events may be entirely captured by the buffer and prevent transport out of the buffer, while a subsequent large storm event may allow complete transport through the buffer. Time-varying factors, such as land use, infiltration capacity of the soil, shallow groundwater tables, and the roughness of the vegetation, all significantly influence a buffer's performance.

Building upon engineering fundamentals, mechanistic approaches are required due to the dynamic nature of these BMPs under the time-variable hydrologic and sediment transport conditions that a buffer may experience. This has been the goal of our ongoing research. In particular, our field, laboratory, and computer modeling studies have focused on pesticide fate and transport in vegetative filter strips (VFS) for environmental exposure assessments. In addition, through collaborations with Bayer CropScience, DOW Chemical, Waterborne Environmental, Inc., and European partners, our team has demonstrated how VFS can be incorporated into an environmental exposure assessment strategy for pesticides.

What's unique about our approach to predicting pesticide transport through buffers is the focus on the forces and mechanisms that engineers are trained to consider. Our approach has been adopted by the European Union as part of its exposure assessment for pesticide regulation, and it's currently being considered by the U.S. Environmental Protection Agency. This focus on system dynamics works not only for pesticides but also for analyzing the transport of phosphorus and bacteria through buffers, as well as for emerging contaminants like nanoparticles and colloids.

A vegetative filter strip study at the University of Florida. ***Photo by Rafael Muñoz-Carpena.***

Conventional buffer design typically uses qualitative guidance by specifying a conservative buffer width. In our dynamic approach, systems analysis is used to predict the complex performance of a buffer based on appropriate equations for infiltration, sediment transport, and contaminant transport processes. Instead of predicting buffer performance based on simple features such as width or vegetation type (which can't explain the huge variations in buffer performance reported in the literature), focusing on integrated process variables, such as infiltration and sediment reduction, can explain the wide range of efficiencies observed in previous studies. These integrated process variables can be predicted by our advanced and well-tested VFS model, called VFSMOD, which was originally developed in the Department of Biological and Agricultural Engineering at North Carolina State University and has been improved over the last 15 years at the University of Florida. Recent improvements to VFSMOD include the ability to analyze shallow groundwater tables and pesticide degradation between events.

Adding to this body of knowledge, a new USDA National Institute for Food and Agriculture (NIFA) foundational grant will allow us to focus on preferential flow processes in buffers. Preferential flow is hypothesized to be important in riparian zones and in well-established buffers.

The effectiveness of buffers for runoff mitigation depends on maintaining a well-performing buffer that limits the concentration of flow pathways. Maintaining uniform sheet flow across the buffer is important. Our team has demonstrated the capability of our modeling tools to analyze buffers for concentrated flow pathways. High-performance computing and sophisticated analysis tools allow us to understand how important individual factors are in the overall design process for both event-based and long-term simulations.

To protect the environment while growing the food needed to support a growing population, engineering principles must be used to understand the dynamics of natural systems. Agricultural and biological engineers are uniquely qualified to understand natural systems in terms of mechanistic processes, and this focus will lead to transformational research with worldwide benefits. Our research is an example of applying engineering principles to such systems to better understand and predict their behavior.

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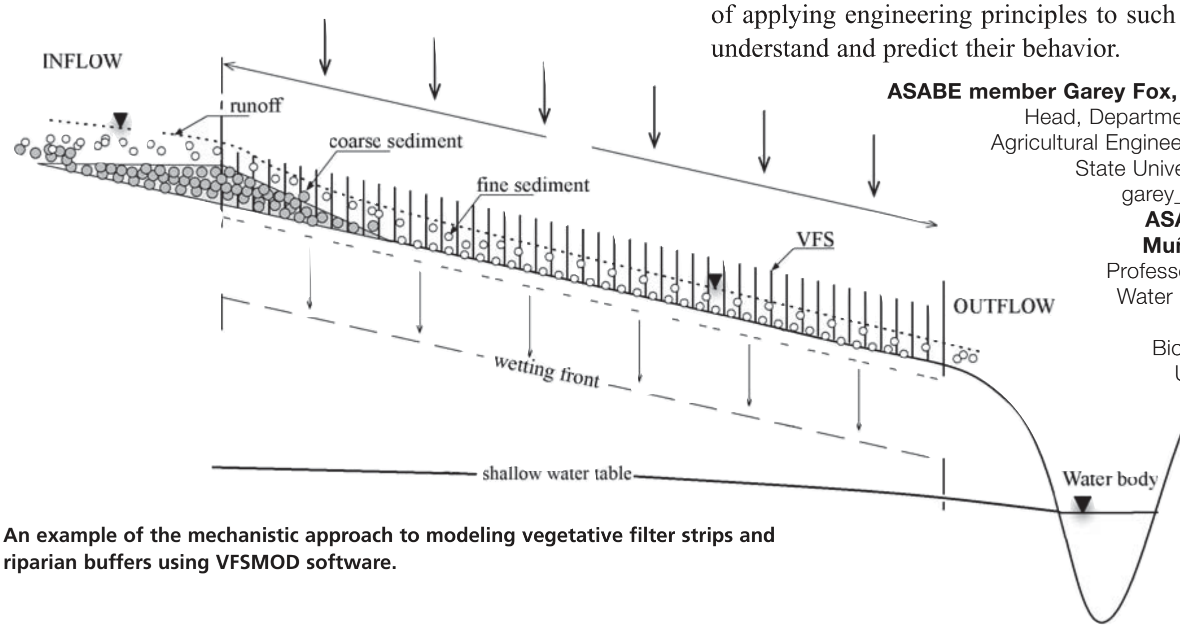

An example of the mechanistic approach to modeling vegetative filter strips and riparian buffers using VFSMOD software.