Comment on "Major Factors Influencing the Efficacy of Vegetated Buffers on Sediment Trapping: A Review and Analysis," by Xingmei Liu, Xuyang Zhang, and Minghua Zhang in the *Journal of Environmental Quality* 2008 37:1667–1674

Dear Editor,

Liu et al. (2008) provide a general overview of many of the physical factors affecting sediment removal by vegetated buffers, including soil, buffer width, area ratio, flow, buffer slope, rainfall intensity, and vegetation. The authors also present data from over 80 scientific studies on buffer characteristics and their trapping efficacy for sediment. While it is good to see the use of published data rather than focus on new, extensive field studies, it is discouraging to see continued statistical analyses that attempt to relate physical characteristics of the buffer system (i.e., slope, vegetation, area ratio, and buffer width) to sediment and/or contaminant removal. For example, the authors rely specifically on regression models that attempt to predict sediment removal as functions of either buffer width or slope. Their regression equations have low to moderate statistical strength, as quantified through coefficients of determination (R^2 of less than 0.35). The authors also developed a regression equation between sediment removal and the two variables of slope and buffer width. The results from the regression analyses suggested that removal efficacy is greatest for a 9% slope, but the authors offer no physical or theoretical explanation for this result. More likely is that the maximum efficiency at this slope is a product of the data sources and the relatively fewer data points in their database for slopes between 6 and 10%.

The authors correctly conclude that "…other factors might also be important for the efficacies of vegetated buffers for sediment removal." Attempts to predict reductions in sediment and contaminants relative to vegetative filter strip (VFS) physical characteristics alone (such as width, slope, area ratios, and/or vegetative types) are inadequate. Physical characteristics of the buffer system are not driving sediment and contaminant reductions. Rather it is the hydrologic impacts of these physical characteristics on the VFS system that drive sediment and contaminant removal. Consider for example that the presence of sheet versus concentrated flow will significantly impact the resulting sediment and/or contaminant removal efficiencies.

Instead of attempting to develop equations relating physical characteristics of the buffer to the sediment reduction, two alternative approaches seem more reasonable. First, in the desire to develop empirical equations, variables of primary interest should be those that quantify the hydrologic response of the system. A new study by Sabbagh et al. (2009) in the *Journal of Environmental Quality* highlights the robustness of empirical equations for predicting pesticide removal based on hydrologic response. The resulting empirical equations for pesticide trapping proposed by Sabbagh et al. (2009) are elegantly simple in that they are based on runoff reduction/infiltration (ΔQ), sediment reduction (ΔE), a phase distribution factor, and the percent clay content of the incoming sediment.

In fact, using the data reported by Sabbagh et al. (2009), a relationship between the hydrologic response and sediment reduction can be derived with an R^2 of 0.51 (Fig. 1), based on an exponential relationship of the following form (Fig. 1):

$$\Delta E = 100\%[1 - \exp(-b\Delta Q)] \quad [1]$$

where b is a regression parameter (approximately 0.04 for this dataset). The improved R^2 in this relationship increases further (R^2 = 0.65) if one ignores the data point with approximately 90% flow reduction and 0% sediment removal. However, such data points indicate that depending on empirical equations alone can be an issue.

The second alternative is to use a hydrologic simulation model capable of predicting sediment transport. In fact, Sabbagh et al. (2009) suggest linking an empirical pesticide trapping efficiency equation with a hydrologic simulation model capable of predicting both runoff reduction (i.e., infiltration) and sediment reduction. They used the Vegetative Filter Strip Modeling System, VFSMOD, a finite-element, field-scale, storm-based model developed to route the incoming hydrograph and sedigraph from an adjacent field through a VFS and to calculate the resulting outflow, infiltration (based on the Green-Ampt equation for unsteady rainfall), and sediment trapping (based on GRASSF) (Munoz-Carpena et al., 1999; Munoz-Carpena and Parsons, 2004). Researchers have demonstrated the model's ability to predict reductions in runoff volume and sediment concentration moving through buffers. Such numerical models can account for site-specific conditions not able to be cap-

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677 S. Segoe Rd., Madison, WI 53711 USA

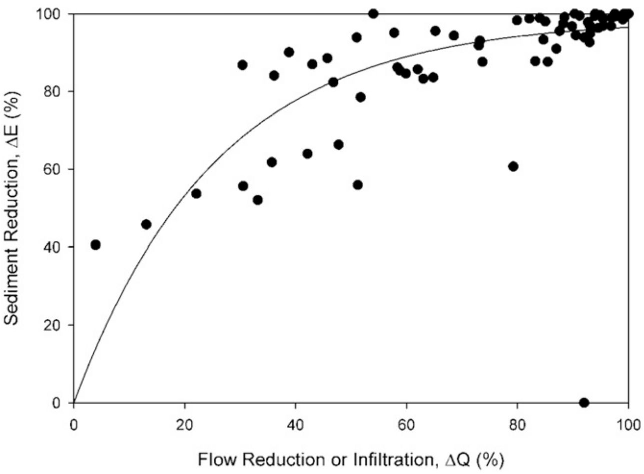

Fig. 1. Relationship between sediment reduction (Δ*E*, %) and the flow reduction or infiltration (Δ*Q*, %) for vegetative filter strip studies published by Hall et al. (1983), Arora et al. (1996), Patty et al. (1997), Barfield et al. (1998), Tingle et al. (1998), Schmitt et al. (1999), Arora et al. (2003), Krutz et al. (2003), Popov (2005), and Patzold et al. (2007).

tured by the empirical models. The linked empirical pesticide trapping equation and physically based hydrologic/sediment transport model have proven effective for both uniform and concentrated flow conditions.

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Garey A. Fox and George J. Sabbagh

G.A. Fox,
Dep. of Biosystems and Agricultural Engineering
Oklahoma State Univ.
Stillwater, OK 74074
G.J. Sabbagh
Bayer CropScience and Texas A&M Univ.
17745 South Metcalf
Stilwell, KS 66085
(george.sabbagh@bayercropscience.com; garey.fox@okstate.edu).

Reply

We appreciate the interest of Fox and Sabbagh in our published paper in JEQ and the willingness to share their scientific contributions on analysis methodologies. While their comments contain some positive feedback, we nevertheless find it necessary to respond to some of their more critical remarks.

Our paper contained data from more than 80 studies on the efficacy of vegetative buffer strip management practices to reduce sediment runoff. As best management practices (BMPs) become important mitigation methods, more and more agricultural practitioners are interested in utilizing these BMPs to reduce the loads of potential pollutants running off their fields. One of the recommended practices for reducing pollutant loads is installing vegetative buffer strips. While the efficacy of this BMP has been widely acknowledged, information about the optimal length and slope of the buffer and the effects of soil and vegetation type on removal efficacy have yet to be explored in detail. This information, however, is critical for informing farm managers about the optimal design of vegetative buffers. Our paper aimed to provide this information to agricultural practitioners.

Given our large sample size, the regression model we used in the paper is very appropriate. Our previous analyses, with limited data, showed that soil type was not statistically significant while vegetation type was significant in sediment removal. However, data on both buffer width and buffer slope were available from every reviewed literature and these two variables were significantly related to sediment removal efficacy. Then we further quantified the correlations between buffer width and slope. Both variables are independent factors. Therefore, we used linear regression models for each of these two factors without considering an interaction component. For our regression model that combined both factors, the coefficient of determination was 0.43. While this determination coefficient might seem relatively low, it does indicate that 43% of the variation in sediment removal efficacy can be explained by only two factors: buffer width and slope. With the data from the literature covering a wide range of study designs and locations, one could expect a larger variation. In this context, our results are remarkably good. Sabbagh et al. (2009) found slightly higher R^2 values in their model. A relationship based on a data set from the five papers listed in Table 1 of Sabbagh et al. (2009) could result in higher R^2 values because of a smaller sample size. The coefficient of determination is only useful for comparison between different data sets, when the sample size is similar and the two compared models share the same type of variables (Barclay, 1991; Fonticella, 1998).

In addition, Sabbagh et al. (2009) may need to consider possible correlations between buffer width and their main explanatory variable, infiltration quantity (Q). In fact, such correlations are to be expected. Almost all previous studies have already pointed out that the buffer/filter strip width was an important factor affecting pollutant removal (Lowrance et al., 1984; Peterjohn and Correll, 1984; Pinay and Decamps, 1988; Gharabaghi et al., 2006).

Fox and Sabbagh question our conclusion that 9% slope may be optimal for removing sediment, attributing it to a small sample size in that range. In our database, the number of data points with slopes between 6 and 10% was not small, as shown in Table 1 and Fig. 3 of our paper. A vegetated buffer with slight slope is ideal for sediment removal as a slight slope would facilitate runoff flow and encourage laminar flow over the buffer. In contrast, further increased steepness could increase the flow velocity of the runoff water, reducing residence time of runoff water and therefore reducing sediment trapping efficacies. Very small gradients, on the other hand, might lead to rapid sediment deposition and the formation of preferential flow paths through the buffer. These scientific insights are widely utilized by California growers in installing vegetative buffer strips.

Fox and Sabbagh criticize our exclusive focus on the physical characteristics of buffer strips for predicting sediment reduction. While this comment has merit, our paper does provide agricultural practitioners with the needed information for designing vegetative buffer strips, which can be expected to optimize the efficiency of sediment removal. We agree that a hydrological response model, such as that suggested by Sabbagh et al. (2009), can provide useful information for understanding the hydrological processes taking place in sediment reduction. For farm managers, however, such a model has very limited applicability. Our paper and the study by Sabbagh et al. (2009) thus target different audiences, and they serve different purposes.

Our research on the effectiveness of vegetative buffer strips in removing environmental contaminants is ongoing, and we expect to obtain further results in the near future. We will be happy to share our results with Fox and Sabbagh and other researchers on vegetative buffer strips, hopefully leading to collaborative efforts to elucidate the mechanisms of contaminant removal and to identify optimal physical and hydrological characteristics of this valuable management tool.

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