Comparison of Models for Estimating the Efficiency of Vegetative Buffer Strips

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Introduction

Vegetated buffer areas established between agricultural fields and receiving waters have long been recommended as a best management practice to reduce the amount of sediment, nutrients, and pesticides entering water bodies. Recently, intensively managed vegetated filter strips have been mandated as requirements on labels for plant protection products in both Europe and North America. Also recently, models have been developed to predict the amount of active ingredients and their metabolites removed from runoff flowing through these strips. This research has shown that the removal efficiency is a function of several parameters and must be predicted on an event basis. A recent project (Winchell and Estes, 2009) reviewed five models (APEX, PRZM, REMM, SWAT, and VFSMOD-W) which can be used to predict the reduction in pesticide loss in runoff passing through a vegetative buffer strip. The work of the recently completed comparison project is in the process of being extended by comparing predictions of four of these models on two common data sets. This poster shows some of the results of these comparisons.

Models Tested

The predictions of four field scale runoff buffer models were compared with runoff, sediment, and pesticide flux data from two experimental sites. The models tested were APEX, PRZM-BUFF, REMM (2008), and VFSMOD-W.

APEX (Williams et al., 2008) is a farm/small watershed scale model for simulating the effects of agricultural management practices on environmental quality and agricultural productivity. It is a physically-based, continuous, distributed parameter model which can be used to model up to 4,000 distinct and hydrologically connected "subareas".

PRZM-BUFF is a modified version of the field scale model PRZM to evaluate the effectiveness of vegetative filter strips and unmanaged buffers in reducing pesticide runoff flux, pesticide erosion flux, and pesticide spray drift to downstream areas. PRZM-BUFF is configured as a run-off / run-on model with main field water and chemical mass from runoff and erosion input as boundary condition inflows into adjacent untreated areas. Multiple PRZM simulations are performed to simulate various portions of the field and surrounding areas.

REMM (Lowrance et al., 2002) is a field scale model for evaluating the movement of water and nutrients in riparian zones adjacent to agricultural fields and includes subsurface lateral flow and ground water in addition to overland runoff. REMM 2008 includes simulation of pesticide behavior.

VSFMOD-W links a field-scale, storm based numerical simulation model for flow through vegetative filter strips (Muñoz-Carpena et al., 1999) with a pesticide trapping equation (Sabbagh et al., 2009). The model is capable of simulating hydrology, sediment transport, and pesticide trapping through vegetative filter strips in numerous hydrologic settings.

Data Sets

Two data sets, one from Europe and the other from North America, were used for the comparison of model predictions. The sites differ in their soil, topographic, and climatic characteristics, as well as the environmental fate properties of the pesticides modelled.

Velbert-Neviges is in North Rhine-Westphalia, Germany as described in Pätzold et al. (2007). The buffer modelled was a three meter wide grass filter strip (field to buffer area ratio of 2.3) on a silty loam soil with a 10% slope. The plot draining to the buffer received simulated rainfall representing six events spread over two years (1998 and 1999). The reduction in runoff, sediment, and pesticide (pendimethalin, a highly sorbed compound) was simulated by each of the models and compared with the reductions observed in the field for each event.

Gibbs Farm is near Tifton, Georgia, USA where US Department of Agriculture experiments (Lowrance et al, 1997) were conducted. The Gibbs Farm site is situated on a more permeable loamy sand soil on a 2.5% slope. The buffer is an eight meter wide grass filter strip (field to buffer area ratio of 11.5). The site was monitored continuously for three years from 1992 through 1994. Field measurements were compared with simulations of the runoff, sediment, and pesticide (alachlor and atrazine, more soluble and less strongly sorbed than pendimethalin) fluxes into and out of the buffer from natural rainfall events.

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The model simulations were performed by the following people
- APEX: Michael Winchell, Stone Environmental
- PRZM-BUFF: Amy Ritter and Mark Cheplick, Waterborne
- REMM: Tamara Estes, Stone Environmental
- VSFMOD-W: George Sabbagh, Bayer CropScience

Additional information on the data sets was provided by the following people:
- Velbert-Neviges: Christine Klein, SCC Scientific Consulting
- Gibbs Farm: Richard Lowrance and Randy Williams, USDA/ARS

References

Lowrance RR, Altier LS, Williams RG, Inamdar SP, Bosch DD, Sheridan JM, Thomas DL, Hubbard RK (2002). The Riparian Ecosystem Management Model: simulator for ecological processes in riparian zones. USDA-ARS Conservation Research Report 46.

Lowrance RR, Vellidis G, Wauchope RD, Gay P, and Bosch DD (1997). Herbicide transport in a managed riparian forest buffer system. Transactions of the ASAE 40(4):1047-1057.

Muñoz-Carpena R, Parsons JE, Wendell GJ (1999). Modeling hydrology and sediment transport in vegetative filter strips. J. of Hydrol. 214:111-129.

Pätzold S, Klein C, Brümmer GW (2007). Runoff transport of herbicides during natural and simulated rainfall and its reduction by vegetated filter strips. Soil Use and Management 23:294-305.

Sabbagh GJ, Fox GA, Kamanzi A, Roepke B, Tang JZ (2009). Effectiveness of vegetative filter strips in reducing pesticide loading: Quantifying pesticide trapping efficiency. J. Environ. Qual. 38(2):762-771.

Winchell M, Estes T (2009). A Review of Simulation Models for Evaluating the Effectiveness of Buffers in Reducing Pesticide Exposure, Report No. # 09-2136-F, Stone Environmental, Montpelier, VT, USA.

Williams JR, Izaurralde RC, E. M. Steglich EM (2008). Agricultural policy/environmental extender model theoretical documentation. BREC Report #2008-17. Blackland Research and Extension Center.

Results

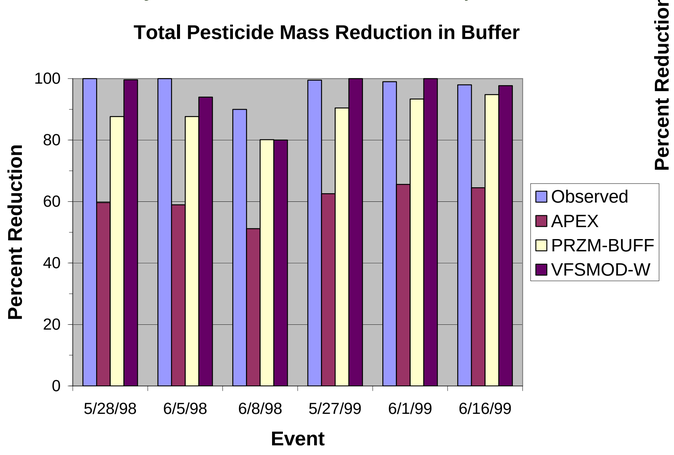
Velbert-Neviges Study Site

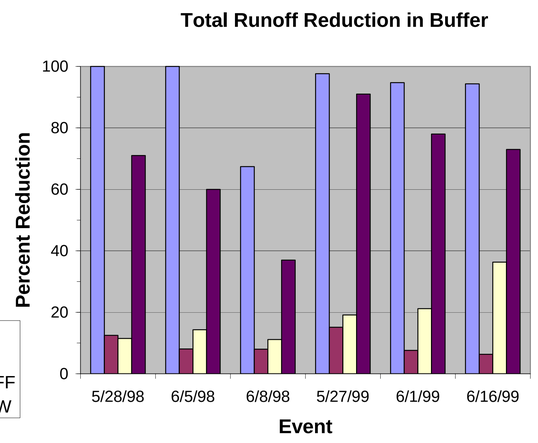
Model input parameters were derived from information in Pätzold et al., (2007) and supplementary data from the study authors. These inputs were kept as consistent as possible between the models. The pesticide, runoff, and sediment loadings into the buffer were based on the observations reported in Pätzold et al., (2007). The three-meter grass buffer at the Velbert-Neviges site was modeled for three simulated rainfall events in 1998 and three events in 1999 (the APEX and PRZM-BUFF models were run continuously between 1998 and 1999).

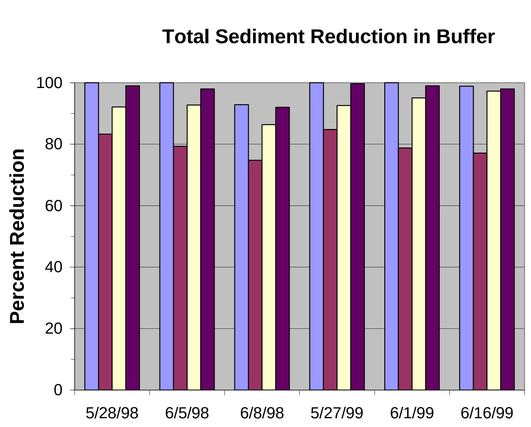
Simulated Rainfall Events

Event	Rainfall (mm)	Duration (hr)	Runoff (mm)
5/28/98	66	1.5	25
6/5/98	65	1.5	36
6/8/98	71	1.5	46
5/27/99	70	2	21
6/1/99	60	2	38
6/16/99	70*	2	44

*3-m buffer received only 57 mm



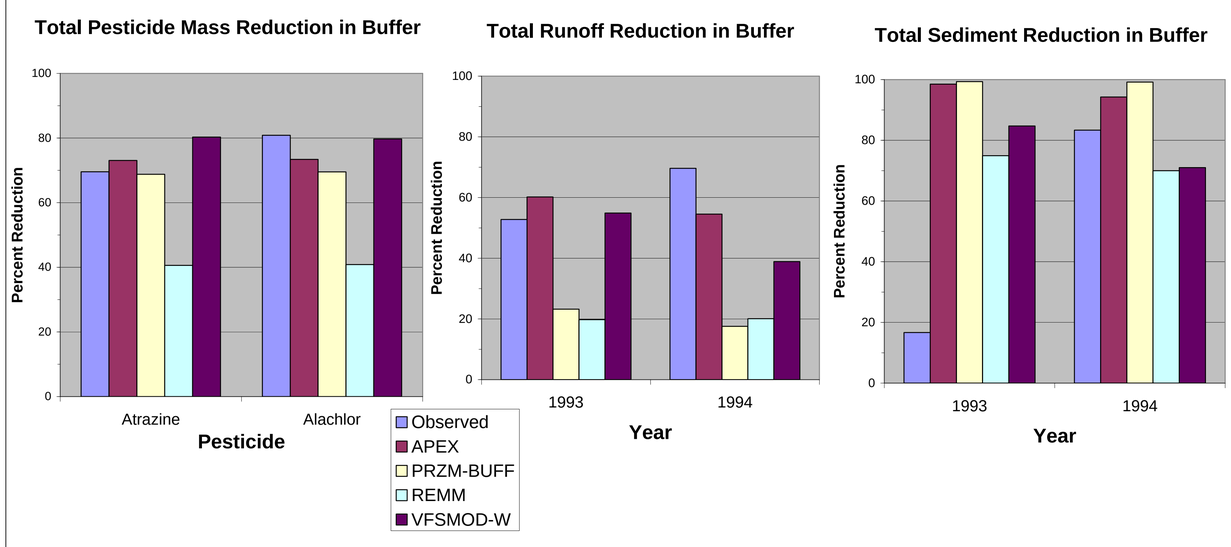




The pesticide reductions observed in the field were all greater than 90%. VFSMOD-W predicted the highest pesticide reductions, which were also closest to the observations. The other models consistently under predicted the observed reductions. For runoff reductions, all models were too low in their predictions. For sediment reductions, APEX PRZM-BUFF, and VFSMOD-W were generally within 20% of the observed sediment reductions, all of which were greater than 92%. The relatively strong performance of the models in predicting sediment reduction is largely responsible for the reasonable pesticide reduction predictions, as pendimethalin is strongly sorbed to sediment. The rather significant differences in the models' predictions of runoff reduction will be investigated further.

Gibbs Farm Study Site

Input parameters for each of the models were derived from information in previous publications on the study. The pesticide, runoff, and sediment loadings into the buffer were generated using the PRZM model with observed weather conditions and pesticide application dates. The four models tested were run continuously for a three year period from January 1st 1992 through December 31st 1994. The daily mass of pesticide entering and leaving the buffer was summed for the entire three year period to calculate the total percent reduction.



Because of the similarities in the environmental fate parameters for atrazine and alachlor, all four models predict that the percent reductions in both pesticides will be nearly the same. APEX, PRZM-BUFF, and VFSMOD-W are each within approximately 10% of the observed pesticide reductions. APEX is the highest of the models in terms of runoff reduction and closest to the observed reductions. PRZM-BUFF and REMM are the lowest in terms of runoff reduction. All four models predict significant sediment capture in the buffer, with PRZM-BUFF predicting nearly 100% capture. The observations from 1993 were judged to be unrealistic, so looking only at 1994, all four models all produce reasonable results which are within 16% of the observed reductions.

Conclusions

All four models predicted significant reductions of pesticides in the buffer consistent with the observed reductions, providing strong support for the use of these models as tools for estimating buffer effectiveness. All of the models evaluated were found to be sensitive to key inputs (for example saturated hydraulic conductivity and runoff curve number), and selection of different values (yet within their acceptable range) would produce different results. The next step in this study will be to evaluate the effects of parameter estimation uncertainty on model results and performance.

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