# APEX SIMULATION: ENVIRONMENTAL BENEFITS OF AGROFORESTRY AND GRASS BUFFERS FOR CORN-SOYBEAN WATERSHEDS

**G.M.M.M. Anomaa Senaviratne[a*], Ranjith P. Udawatta[ab], Stephen H. Anderson[a], Claire Baffaut[c] and Shibu Jose[b]**

**[a]Dept. of Soil, Environmental and Atmospheric Sciences, [b]The Center for Agroforestry, [c]USDA-ARS Cropping Systems and Water Quality Research Unit, University of Missouri, Columbia.**

## INTRODUCTION

- **Existence of an argillic claypan horizon at shallow depths in soils of the claypan region in Central U.S. restricts downward water movement and increases surface water runoff and non-point source pollution (NPSP) from agricultural watersheds.**
- **A 19-year-old study conducted at Greenley Memorial Research Center, Knox County, Missouri has shown 28-30% reductions in sediment, 11-13% reductions in total nitrogen, and 22-26% reductions in total phosphorous loadings after eleven years of establishment of grass and agroforestry (tree+grass) buffers in corn-soybean watersheds (Udawatta et al., 2002, 2011).**
- **Long-term environmental benefits of buffers and effects of agroforestry buffers on large watersheds have not been evaluated, thus restricting adoption of agroforestry buffers on large watersheds for environmental benefits.**
- **This also hinders development of guidelines for the placement and design of agroforestry buffers for optimum environmental benefits while minimizing the amount of land taken out of production.**
- **In order to investigate long-term benefits and to understand the effect of width and placement of grass and agroforestry buffers, a study was initiated to simulate watersheds using the Agricultural Policy Environmental eXtender (APEX) model (Williams et al., 2008).**

## OBJECTIVES

1. **Calibrate and validate the APEX model for runoff, sediment, total phosphorous (TP), and total nitrogen (TN) losses from small corn-soybean watersheds with grass and agroforestry buffers at the Greenley Memorial Research Center.**
2. **Use the calibrated and validated model to quantify NPSP reduction efficiencies of varying buffer widths and placement combinations.**
3. **Determine the effectiveness of cover crops on NPSP reductions.**

## MATERIALS AND METHODS

- **The paired watersheds for the study were located at the University of Missouri, Greenley Memorial Research Center (Fig. 1a,b).**
- **No-till, row crop, corn-soybean rotational cultivation is carried out in the three adjoining watersheds; West with grass buffers (3.16 ha), Center with agroforestry buffers (4.44 ha), and East, the control (1.65 ha).**
- **Contour Grass strips (CGS) of 4.5 m widths were established in 1997. Single row of pin, bur, and swamp white oak trees were planted at 3-m intervals at the center of the grass buffers in the agroforestry buffer watershed (AGF; Fig. 1c,d).**
- **The three watersheds were simulated using ArcAPEX with APEX software and custom created subareas, stream networks, land-use, soils, and DEM (Digital Elevation Model) maps.**

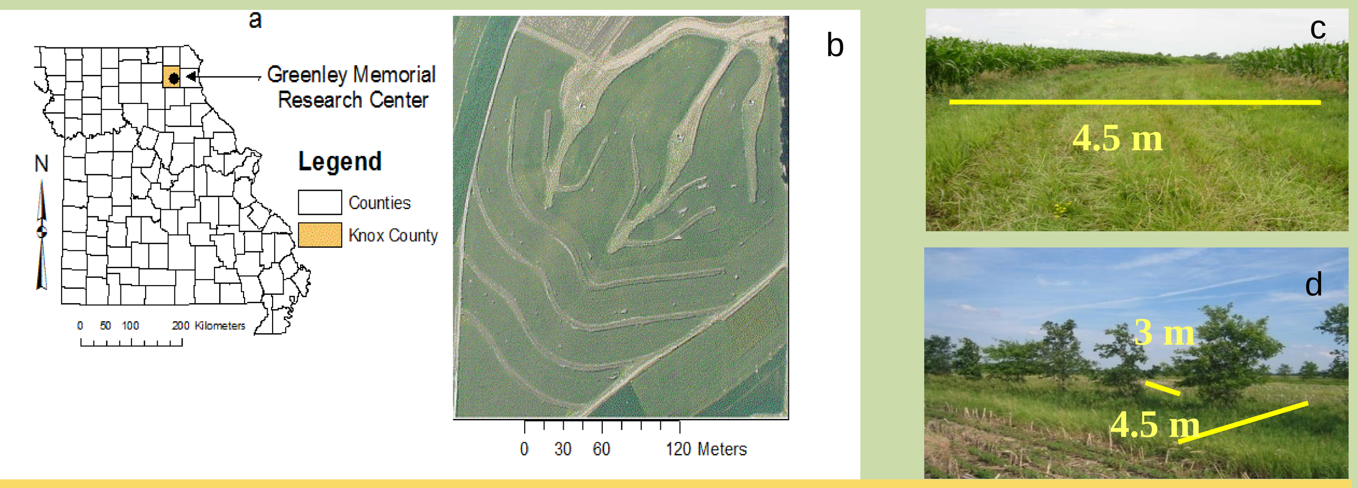


**Fig. 1. a. The location of Greenley Memorial Research Center in Knox County of Missouri, b. Aerial view of the study watersheds, c. Grass buffer, and d. Agroforestry buffer.**

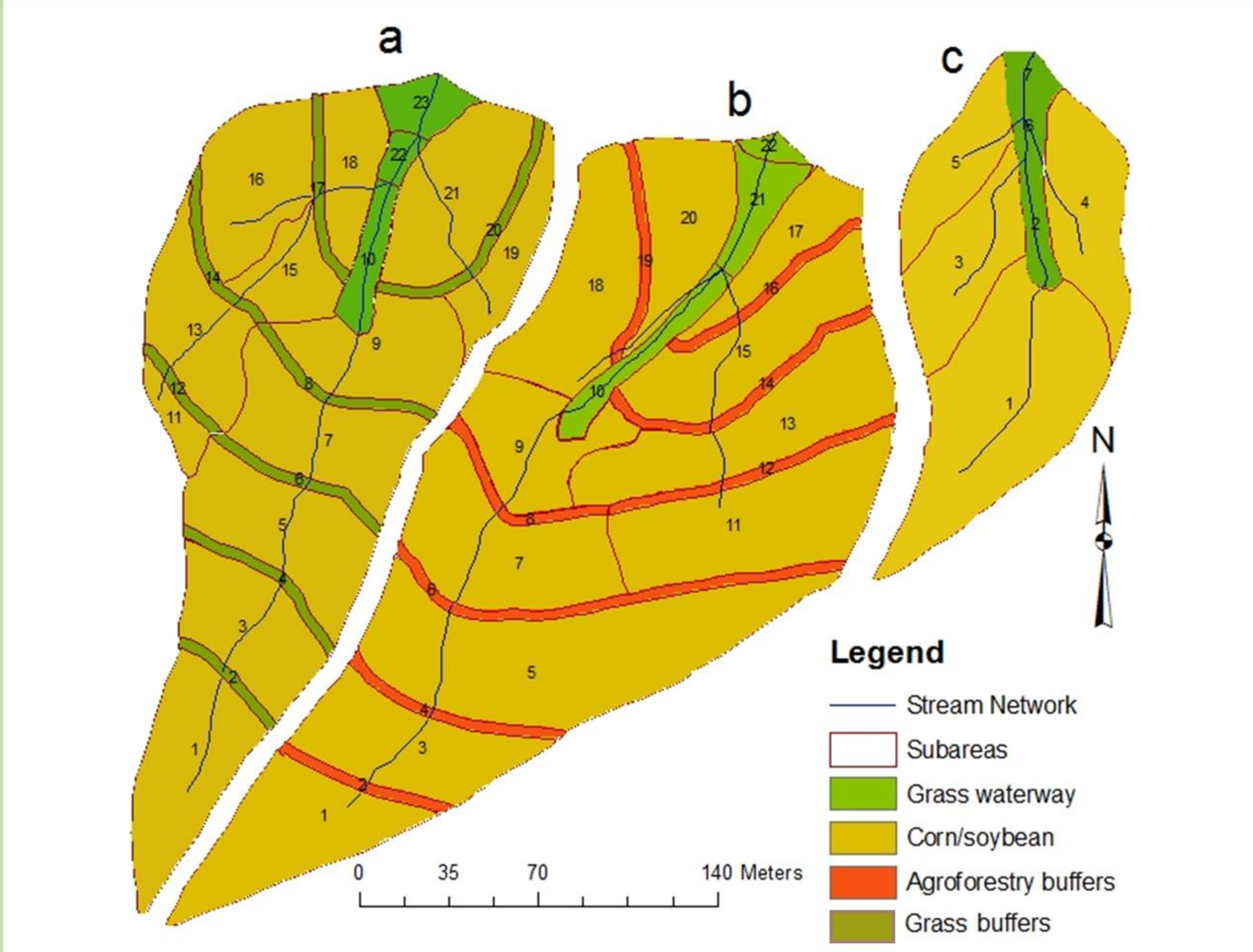


**Fig. 2. APEX simulated a. grass, b. agroforestry and c. control watersheds at Greenley Memorial Research Center, Missouri.**

- **Detailed soil categorization was done based on the depth to claypan and measured soil physical and chemical characteristics available for the watersheds.**
- **Subareas and stream networks (Fig. 2) were created manually based on the depth to claypan, land-use, soil, and contour maps available for the site, using ArcGIS 9.0 software.**
- **The models for agroforestry, grass buffer, and control watershed were calibrated using data from 1998 to 2001 and validated using data from 2002 to 2008.**
- **Calibrated and validated models were used to predict long–term effects of increased buffer widths (5.5 and 7.5 m) and different placement options for buffers in the watershed.**
- **Models also were used to simulate output parameters with winter cover crop (winter wheat) to evaluate its effect on NPSP.**

## RESULTS AND DISCUSSION

***APEX model calibration and validation*:**

- **Simulated corn and soybean yields were within ±13% and ±27% of the measured yields, respectively, except for the validation period by the grass buffer watershed.**
- **The $r^2$ and Nash-Sutcliffe Coefficient (NSC) values were over 0.5 for event runoff and TP for calibration and they were over 0.4 for validation (Figs. 3 & 4).**
- **The model did not calibrate well for event sediment and TN probably due to low concentrations as a result of the buffers, as well as low intensity rainfall events during the study periods.**

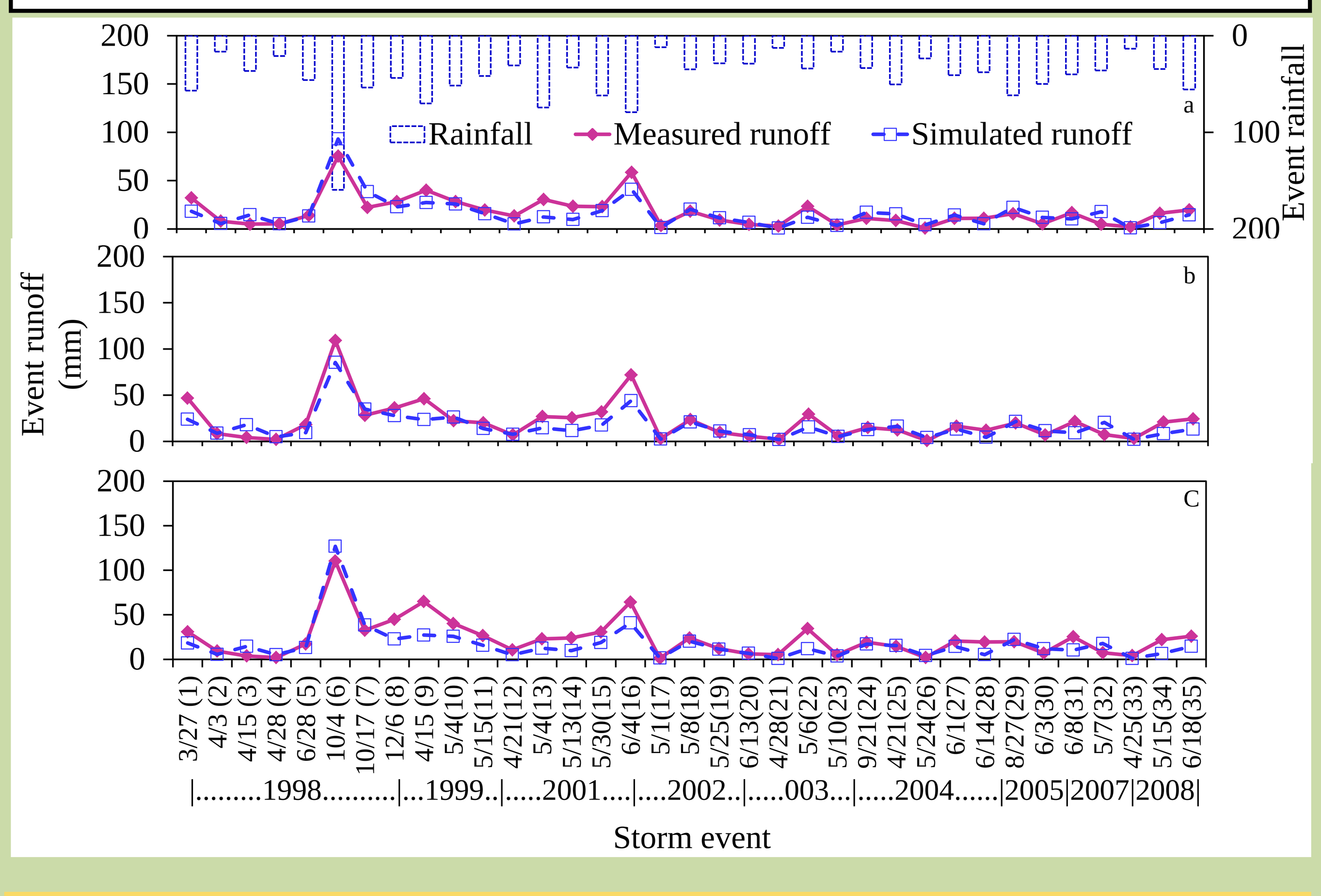


**Fig. 3. Measured & simulated runoff of a. agroforestry, b. grass buffer, and c. control watersheds during calibration (events 1 to 14; 1998-2001) and validation (events 15 to 35 ; 2002-2008) for the APEX model.**

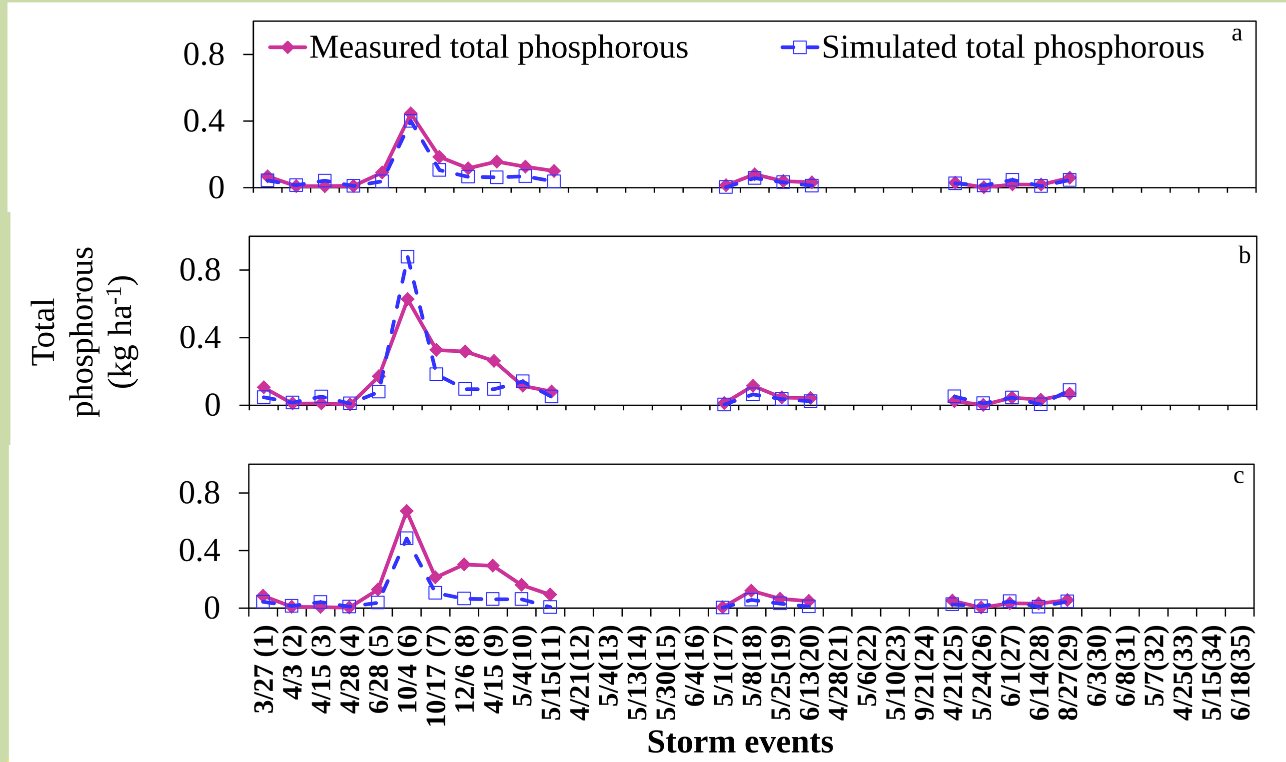


**Fig. 4. Measured & simulated event total phosphorous of a. agroforestry, b. grass buffer, and c. control watersheds during calibration (events1 to 14; 1998-2001) and validation (events 15 to 35; 2002-2008) for the APEX model.**

- ***Scenario analysis:***
- **Long-term scenario analysis showed 4.3 to 5.2% reductions in average annual runoff and 12.5 to 44.5% reductions in average annual TP loadings due to the presence of buffers.**
- **Higher reduction values for both annual runoff and TP loadings were obtained for the CGS buffer watershed.**
- **Long-term scenario analysis of increasing buffer width from 4.5 to 5.5 m and 7.5 m showed no significant reduction in annual runoff or TP loads.**
- **The buffers at the shoulder and back slopes of the landscape of the AGF watershed contributed to 62% of the total reduction of annual TP loadings. Simulation of a winter wheat cover crop did not reduce runoff but contributed to further reduction in annual TP loads by 15-24% (Fig. 5).**

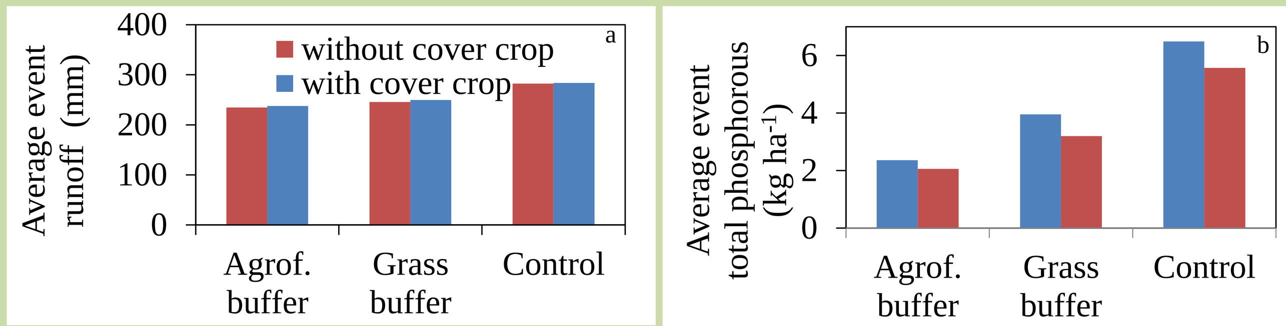


**Fig. 5. Simulated average annual runoff (a) and total phosphorous (b) with and without a winter wheat cover crop.**

## CONCLUSIONS

- **The APEX model was reasonably calibrated and validated for crop yield, event-based runoff ($r^2$ and NSC values were over 0.5) and event-based TP loadings ($r^2$ and NSC values were over 0.4) for the long-term monitored study watersheds located at the Greenley Memorial Research Center, in Northeast Missouri. These watersheds contained upland contour agroforestry buffers, grass buffers, or a control (without buffers).**
- **Long-term scenario analysis showed 4-5% reduction in annual runoff and 13-45% reduction in annual TP loads due to upland buffers. Simulated winter cover crop (winter wheat) reduced annual TP loads by 15-24%.**
- **Results of this unique study demonstrated that the APEX can be used to evaluate environmental benefits of upland filter strips and winter cover crops, provided sufficient long-term data are available for calibration and validation.**

**References**

Udawatta, R.P., J.J. Krstansky, G.S. Henderson, and H.E. Garrett. 2002. Agroforestry practices, runoff, and nutrient loss: A paired watershed study. J. Environ. Qual. 31:1214-1225.

Udawatta, R.P., H.E. Garrett, and R. Kallenbach. 2011. Agroforestry buffers for nonpoint source pollution reductions from agricultural watersheds. J. Environ. Qual. 40(3): 800–806.

Williams, J.R., R.C. Izaurralde, and E.M. Steglich. 2008. Agricultural policy/environmental extender model: User's manual version 0604. BREC Report #2008-16. Blackland Research and Extension Center.p. 222.Available at http://epicapex.brc.tamus.edu/downloads/usermanuals.aspx.Accessed on 3/28/2011.

**Acknowledgements**

University of Missouri, Center for Agroforestry for funding this project. Dr. Verel Benson and Dr. J. Williams for support on APEX modeling.

**Contact email:** gs2n8@mail.missouri.edu

The Center for Agroforestry
University of Missouri