The Society for engineering in agricultural, food, and biological systems

An ASAE Meeting Presentation

Paper Number: 052040

SWAT Application for Conservation Effects Assessment in the Southeastern Coastal Plain

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Written for presentation at the
2005 ASAE Annual International Meeting
Sponsored by ASAE
Tampa Convention Center
Tampa, Florida
17 - 20 July 2005

Abstract. *The Soil Water Assessment Tool (SWAT) was used to examine the impacts of alternate land management practices on water quantity and quality within a Coastal Plain Watershed. Runoff, sediment, and pesticide loadings were examined. SWAT simulations indicate a linear decrease in sediment and pesticide yields will be observed if conservation tillage is implemented on the cotton acreage within this watershed. For sediment, a 20% reduction in loss can be obtained through implementation of conservation tillage on 15% of the watershed area. SWAT simulations indicated that a 45% reduction in the simulated pesticides can be expected when the conservation practices are implemented on the same acreage. However, the model did simulate an increase in water yields from the watershed when these practices were implemented, likely due to increases in infiltration in the uplands. This increase in infiltration and subsequently streamflow could result in greater losses of soluble chemicals, nitrate in particular.*

Keywords. *Forested watersheds, hydrology, land-use changes*

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SWAT Application for Conservation Effects Assessment in the Southeastern Coastal Plain[1,2]

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Introduction

Conservation programs developed and implemented by the U.S. Department of Agricultural have led to large-scale conversion of marginal farmland into conservation tilled and non-tilled acreages. Through the Conservation Reserve Program (CRP) alone, over 13 million ha (34 million acres) of highly erodible and environmentally sensitive cropland has been converted into non-tilled land since 1985 (USDA, 2004). The Conservation Security Program (CSP), a program to be implemented in 2005, will likewise encourage conversion of marginal cropland within sensitive watersheds.

While it is widely recognized that these conservation programs will protect millions of acres from soil erosion, enhance water and air quality, promote wetland and wildlife habitat restoration and preservation, and conserve agricultural water use, the environmental benefits have not been adequately quantified and reported. Tracking the environmental benefits of these programs in terms of the environmental benefits will allow policy-makers and program managers to implement and modify existing programs and design new programs to more effectively and efficiently meet the program goals.

The USDA has implemented the Conservation Effects Assessment Program (CEAP) to better quantify the effects of these conservation programs. One of the methods which will be used within CEAP is the utilization of watershed scale computer simulation models. The models will be used to predict the long-term environmental impacts of USDA conservation programs. In this effort we used the Soil Water Assessment Tool (SWAT) (Arnold et al., 1998) to examine the impacts of implementing conservation tillage within a Coastal Plain Watershed.

Methods

Computer simulations will be used to assess the long-term effects of implementing conservation tillage within the Little River Experimental Watershed. For this analysis we examined the impact of the best management practice (BMP) conservation tillage on watershed runoff, sediment yield, and pesticide losses.

Watershed Description

Data for this analysis were collected on the 334 km^2 Little River Experimental Watershed (Fig. 1) *(Sheridan et al., 1982; Sheridan, 1997)*. The Watershed is in the headwaters of the Suwannee River Basin, a major interstate basin that begins in Georgia and empties into the Gulf of Mexico. The Suwannee River Basin is completely contained in the Coastal Plain Physiographic Region. The Southeast Watershed Research Laboratory (USDA-ARS) has collected hyrdrologic and water quality data from this watershed for over 35 years. The LREW

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[1] Contribution from the USDA-ARS, Southeast Watershed Research Laboratory, P.O. Box 946, Tifton, GA 31793, in cooperation with Univ. of Georgia Coastal Plain Exp. Stn.

[2] All programs and services of the U.S. Department of Agriculture are offered on a nondiscriminatory basis without regard to race, color, national origin, religion, sex, age, marital status, or handicap.

is instrumented to measure rainfall and streamflow for the primary watershed as well as for seven subwatersheds that range from approximately 3 km^2 to 115 km^2.

For purposes of this analysis, we selected the 22.1 km^2 subwatershed J in the headwaters of the watershed (Fig. 1) where higher resolution input data were available. The channel length for this watershed is approximately 10 km, and the average channel slope is 0.4%. This watershed is approximately 30% row crop, 2% pasture, and 67% forest. The remainder is water and pecan orchards.

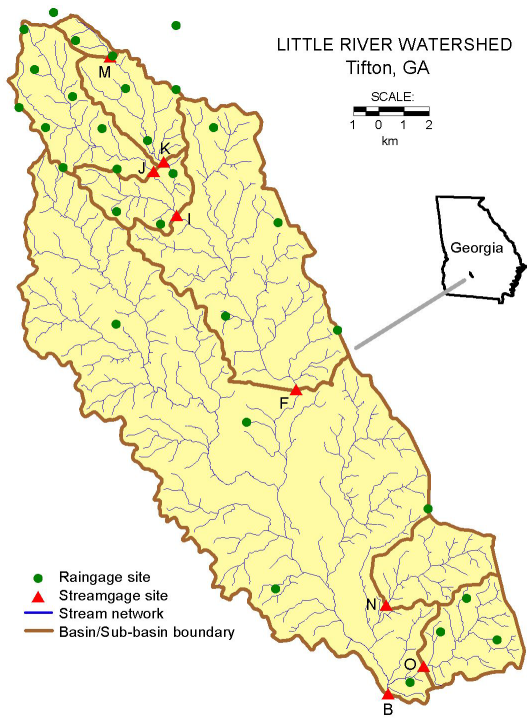

Figure 1. Little River Experimental Watershed.

Simulation Model

Watershed models are valuable tools for examining the impact of land-use on hydrology and water quality. The model selected for this analysis was the Soil Water Assessment Tool (SWAT) (Arnold et al., 1998). The model has been applied to watersheds throughout the world (Srinivasan et al., 1997; Spruill et al., 2000; Kirsch et al., 2002; Bingner, 1996; Bosch et al., 2004). In most cases, the prediction accuracy has been satisfactory to obtain working knowledge of the hydrologic system and the processes occurring in the watersheds. The accuracy of the model is generally better when comparisons are made to annual and monthly data rather than to daily values.

SWAT 2000 (AVSWAT2000) was used to simulate hydrologic and water quality processes for the 2246 ha Little River Watershed J. The model was used to assess varying levels of conservation practices. The simulation was set up as described by Bosch et al. (2004). The simulation used observed (watershed weighted) precipitation data for 1995 to 2003 and climatic data from the University of Georgia Tifton weather station (www.griffin.peachnet.edu/bae), which is located on the lower end of the Little River watershed. The simulation was run for the entire period, 1995 to 2003. In the process of defining the weather database, the U.S. database

provided with ArcSWAT was selected and served as the base for simulation of solar radiation, wind speed, and relative humidity. The observed land use from 2003 was used for the entire 9 year simulation period (Fig. 2). Major crops in the 2246 ha watershed were forest/evergreen (1521 ha, 68%), cotton (330 ha, 15%), and peanuts (179 ha, 8%) (Table 1). Annual data from each of the 9 years as well as the 9 year average results were examined.

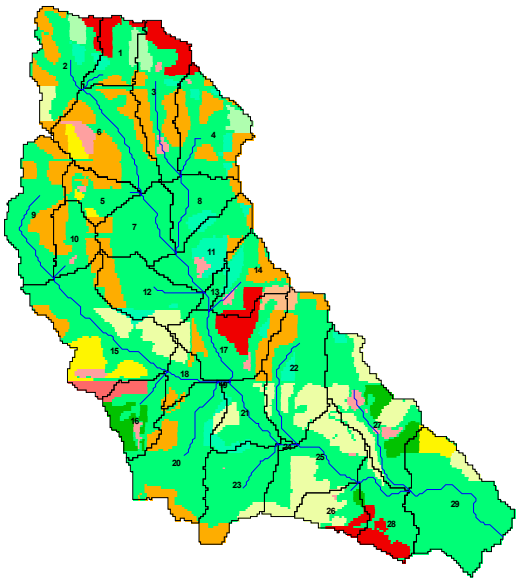

Figure 2. Watershed J 2003 land-use cover (forest in green, cotton in dark brown, peanuts in light brown, generic agriculture in red), with the sub-basin boundaries and numbers.

Table 1. Land use distribution following SWAT reclassification for Watershed J in 2003.

Land Use	Acreage (ha)	Percentage (%)
Forest/evergreen	1521	67.66
General Agriculture	92	4.09
Soybeans	6	0.26
Cotton	330	14.69
Peanuts	179	7.98
Pines	38	1.69
Corn	32	1.40
Pasture	41	1.82
Orchard	9	0.42

Selection Criteria for BMPs

The impact of implementing conservation tillage on the cotton acreage in Little River Watershed J was examined by changing the input parameters to reflect this practice for each of the sub-basins containing cotton. The BMPs were introduced to each hydrologic response unit (HRU)

which contained cotton in the order determined through a sediment ranking procedure. This BMP reduced the curve number from 77 to 70 in each of these HRUs and reduced the practice factor from 1.0 to .5. In addition, a winter cover crop (small grain) was introduced in each of these HRUs and the primary tillage changed from disk harrow to conservation tillage.

In order to determine where the BMPs were to be installed on the watershed the sediment yields from each of the sub-basins were examined. The predicted sediment yields for the 2003 simulation from the upland portion of each sub-basin were ranked from the highest to the lowest yield. The ranking based upon sediment yield provided an order and an acreage for implementation of the BMPs. The BMPs were implemented in order of the most erosive sub-basin to the least.

Model Calibration

Observed hydrologic data for 2003 were compared to the simulated data and parameter adjustments made to obtain an approximate fit of the surface runoff, the baseflow, evapotranspiration, and the total water yield for the watershed. Results of the fitting process are shown in Table 2.

Table 2. Hydrologic results for 2003 following calibration of the SWAT model for the Little River Watershed J using the 2003 land use data.

	Precipitation (mm)	Surface runoff (mm)	Baseflow (mm)	ET (mm)	Water Yield (mm)
Observed	1022.53	114.18	212.05	696.95	326.24
Simulated	1045.14	118.41	238.26	695.65	364.72

Pesticide Characteristics

The basic management for all of the cotton acreage in the watershed was altered to incorporate the simulation of the pesticides Prowl and Cotoran. Both of these are pre-emergence herbicides frequently used on Cotton. The basic management for the Cotton acreage was altered to introduce disk-harrowing prior to planting and application of both of the herbicides at planting. The rates for the Cotoran were 1.46 kg/ha at planting and 1.1 kg/ha 6 weeks after planting, and for Prowl 0.95 kg/ha at planting only. The default pesticide characteristics within the SWAT model were assumed for the simulations (Table 3). The pesticide yields from the watershed were then examined to evaluate the impact of the various levels of BMPs.

Table 3. Default pesticide characteristics in the SWAT simulation.

Trade Name	Common Name	Koc (ml/gm)	Wash-off Fraction	Foliar Half Life (days)	Soil Half Life (days)	Water Solubility (mg/L)
Cotoran	Fluometuron	100	.5	30	85	110
Prowl	Pendimethalin	5000	.4	30	90	0.275

Results

One HRU at a time, the BMPs were introduced and a SWAT simulation conducted. The order of implementation was determined from gross upland erosion within each sub-basin. The sub-basin yielding the greatest upland erosion was treated first. Then the sub-basin yielding the second greatest upland erosion was treated in addition to the first. The final simulation assumed 100% BMPs for all of the cotton acreage in the watershed. The cumulative acreage in BMPs is illustrated in Figure 3.

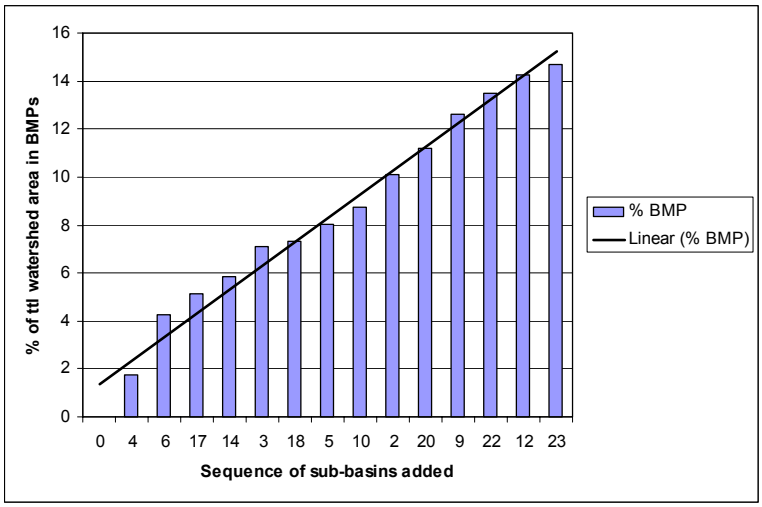

Figure 3. Cumulative % area in BMPs for the SWAT simulations.

The impact of the BMPs on the streamflow, the sediment yield, and the pesticide loadings were examined. Figure 4 illustrates the reduction in streamflow (as compared to the streamflow without any BMPs) obtained through introducing the BMPs over the 9 year simulation period and the average reduction for all 9 years (labeled 9 on the plots). For most years, and on the average, introducing the BMPs increased streamflow (negative reduction). This appears to be due to increased baseflow caused by greater infiltration in the sub-basins with the BMPs. The greatest change was observed when the BMPs were introduced on sub-basin 6, the second sub-basin to receive BMPs, but the one with the greatest cotton acreage. This may be a consequence of the proportionally greater cotton acreage in sub-basin 6 (Fig. 2).

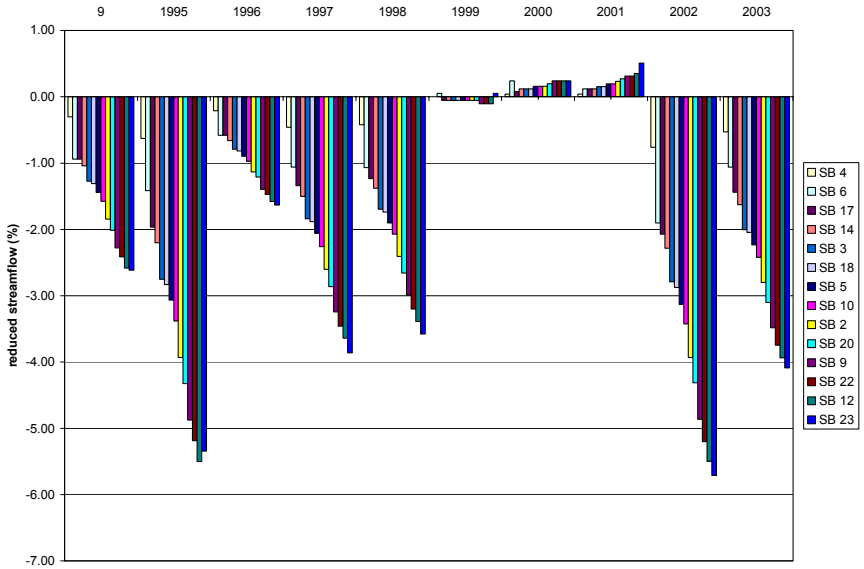

Figure 4. Impact of introduction of the BMPs on the reduction in streamflow.

Figure 5 illustrates the reduction in sediment yield (as compared to the sediment yield without any BMPs) obtained through introducing the BMPs over the 9 year simulation period and the average reduction for all years. For all years introducing the BMPs reduced the sediment load. Reductions as large as 32% were obtained when BMPs were simulated on all of the cotton acreage, which was just 15% of the watershed. This is to be expected since the practice factor was reduced significantly, from 1. to .5 for the cotton acreage.

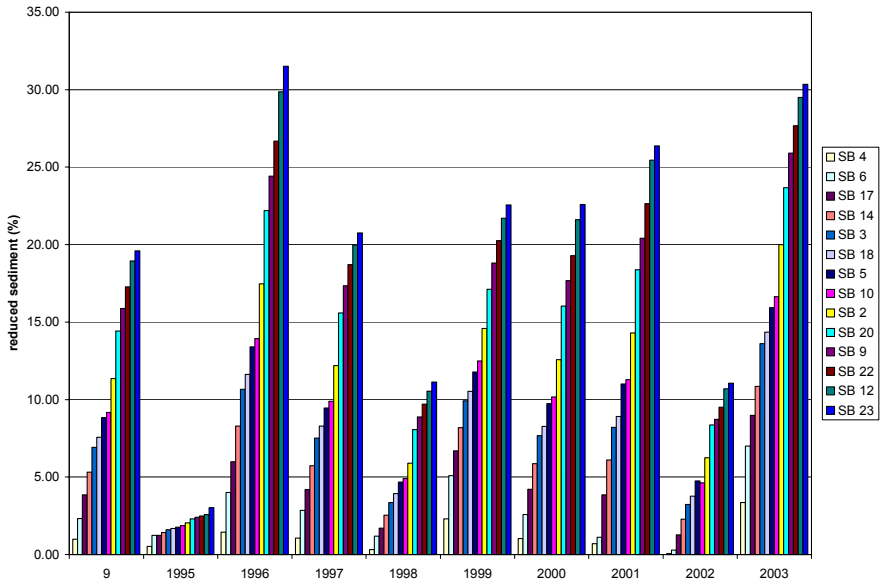

Figure 5. Reduction in sediment yield at the outlet obtained by introducing the BMPs.

Figure 6 illustrates the reduction in soluble cotoran yield (as compared to the yield without any BMPs) obtained through introducing the BMPs over the 9 year simulation period and the average reduction for all years. For all years introducing the BMPs reduced the soluble pesticide load. Reductions approaching 100% were obtained when BMPs were simulated on all

of the cotton acreage. However, these pesticides were only applied to the cotton acreage. The decrease was approximately linear.

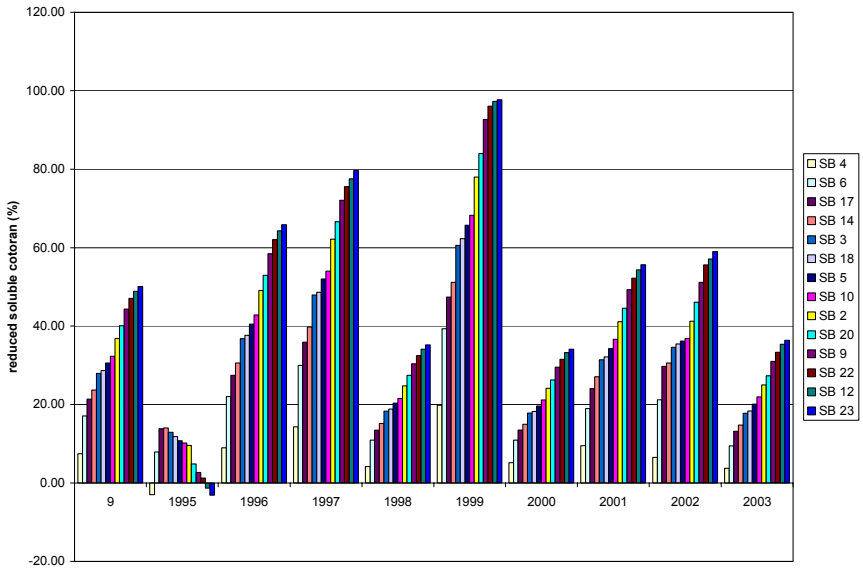

Figure 6. Reduction in soluble cotoran at the watershed outlet as a response to increases in BMP acreage.

The average reduction for the 9 years of simulation in streamflow, sediment yield, and soluble cotoran yield was plotted versus the acreage in BMPs to examine the expected return from introduction of conservation tillage (Fig. 7). As illustrated by the figure, the return for each variable is approximately linear. The greatest reductions were observed for cotoran.

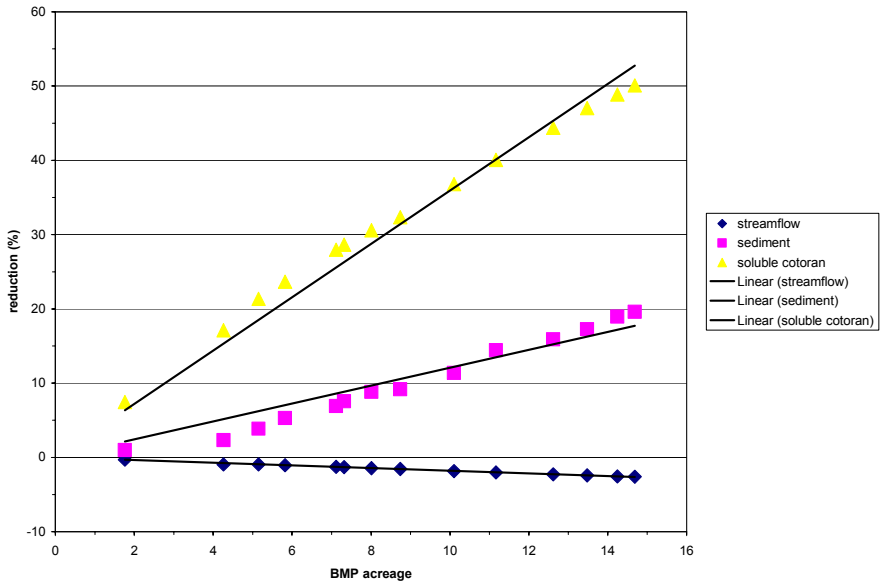

Figure 7. Reduction in streamflow, sediment, and soluble cotoran yield as a response to increases in BMP acreage.

Simulations were also conducted to examine the reduction in pesticide loading at the watershed outlet for the pesticide Prowl. As with Cotoran, the default pesticide characteristics within SWAT were assumed (Table 3). The adsorption rate for Prowl is considerably higher than that for Cotoran while the solubility is much lower. Thus, the primary transport mechanism that would be expected for Prowl would be through sediment.

While prowl was transported to the stream in both the soluble and the sorbed phases, the sorbed phase quickly went into solution within the channel system. Because of the relatively large volumes of water and low mass of the compounds, the model simulated the compounds going into solution rapidly. At the watershed outlet, only the dissolved phase and no sorbed phases were simulated.

The yields of the prowl simulated at the watershed outlet are illustrated in Figure 8. The mass loading for the prowl was considerably less than that simulated for cotoran, but the reduction patterns observed through integration of the BMPs was similar. Interestingly, the observed reductions in prowl transported from the watershed due to increasing the BMP acreage in the watershed were very similar to those observed for Cotoran (Fig. 9).

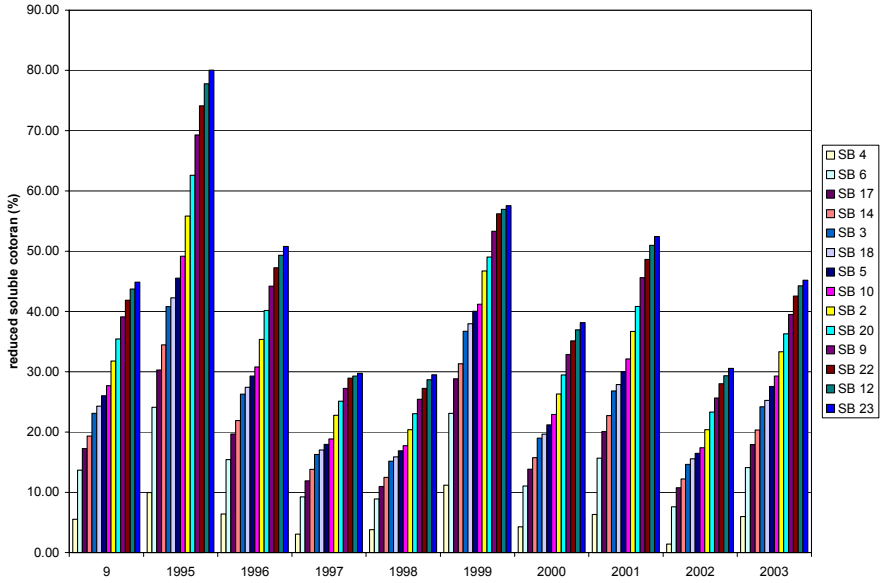

Figure 8. Reduction in soluble prowl at the watershed outlet as a response to increases in BMP acreage.

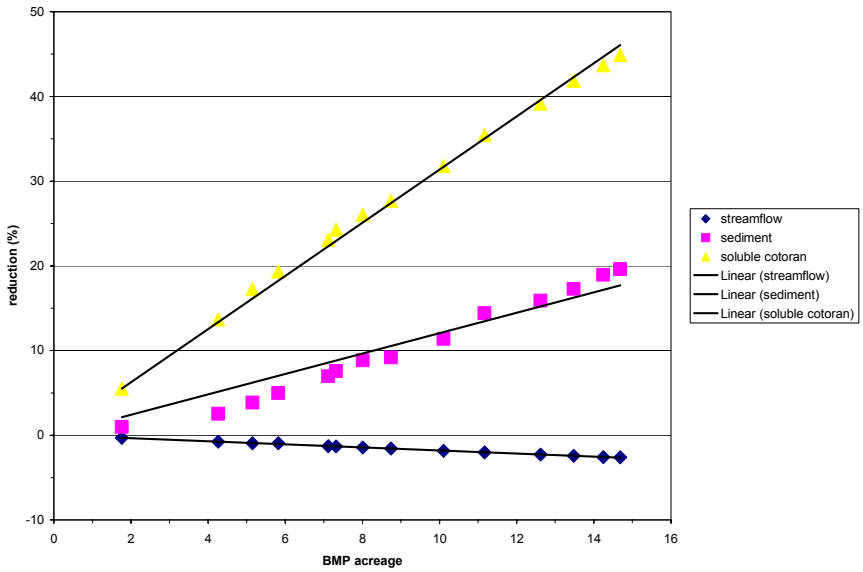

Figure 9. Reductions observed for the prowl simulations.

Table 4 illustrates the simulated results for each of the pesticides applied within the watershed. These results represent the totals from each of the simulated sub-basins within the watershed. As expected, the primary transport mechanism for the cotoran is through surface runoff. While considerably more of the prowl is transported attached to the sediment than is cotoran, it is also transported via surface runoff. While the solubility of the prowl is low, the volume of surface runoff is sufficient to dilute the concentrations to the point where it can be transported in the dissolved phase.

The simulated average annual water yield for the watershed was 421 mm. For the watershed coverage area of 22.46 km^2, the average annual water yield is 9.5×10^6 m^3. Using these values and those presented in Table 4 would yield an average concentration of 0.006 mg/L for cotoran and 0.001 mg/L for prowl, well below the solubility's for these compounds (Table 3).

Table 4. Average annual pesticide results from the simulations for watershed J.

Pesticide	Applied (mg/ha)	Decayed (mg/ha)	Transported dissolved in surface runoff to the stream (mg/ha)	Transported sorbed with sediment to the stream (mg/ha)	Leached out of soil Profile (mg/ha)	Transported dissolved in lateral subsurface flow to the stream (mg/ha)
Cotoran	281963	248671	26533	105	1428	558
Prowl	104635	94241	5533	3548	0	43

Conclusion

SWAT simulations indicate a linear reduction in sediment and pesticide yields will be observed if conservation tillage is implemented on the cotton acreage within this watershed. For sediment, a 20% reduction in loss can be obtained through implementation of conservation tillage on 15% of the watershed area. A greater decrease can be expected with the pesticides. SWAT simulations indicated that a 45% reduction in the simulated pesticides can be expected when the conservation practices are implemented on the same acreage.

However, the model did simulate an increase in water yields from the watershed when these practices were implemented. This is likely due to greater baseflow resulting from increased infiltration in the upland fields. This increase in infiltration and subsequently streamflow could result in greater losses of soluble chemicals, nitrate in particular. Additional work is necessary to quantify these effects.

References

Arnold, J. G., R. Srinivasan, R. S. Muttiah, and J. R. Williams. 1998. Large-area hydrologic modeling and assessment: Part I. Model development. *J. American Water Res. Assoc.* 34(1): 73-89.

Bingner, R. L. 1996. Runoff simulated from Goodwin Creek watershed using SWAT. *Trans. ASAE* 39(1): 85-90.

Bosch, D.D., J.M. Sheridan, H.L. Batten, and J.G. Arnold. 2004. Evaluation of the SWAT Model on a Coastal Plain Agricultural Watershed. Trans. Am. Soc. of Agr. Eng. 47(5):1493-1506.

Kirsch, K., A. Kirsch, and J. G. Arnold. 2002. Predicting sediment and phosphorus loads in the Rock River basin using SWAT. *Trans. ASAE* 45(6): 1757-1769.

Sheridan, J.M. 1997. Rainfall-streamflow relations for coastal plain watersheds. Applied Engineering in Agriculture. 13(3):333-344.

Sheridan, J.M., C.V. Booram, Jr., and L.E. Asmussen. 1982. Sediment-delivery ratios for a small Coastal Plain agricultural watershed. Trans. of the ASAE. 25(3):610-615, 622.

Spruill, C. A., S. R. Workman, and J. L. Taraba. 2000. Simulation of daily and monthly stream discharge from small watersheds using the SWAT model. *Trans. ASAE* 43(6): 1431-1439.

Srinivasan, R., T. S. Ramanarayanan, R. Jayakrishnan, and H. Wang. 1997. Hydrologic modeling of Rio Grande/Rio Bravo basin. ASAE Paper No. 972236. St. Joseph, Mich.: ASAE.

U.S. Department of Agriculture. 2004. Conservation Reserve Program 2003 Fiscal Year Summary. U.S.D.A. Farm Service Agency. 26 pp. Available at: http://www.fsa.usda.gov/dafp/cepd/stats/FY2003.pdf. Accessed 10 May, 2005.