Missouri Department of Natural Resources

FINAL REPORT

COMPUTER BASED EVALUATION OF THE AGNPS-SALT PROJECT

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The Food and Agricultural Policy Research Institute at the University of Missouri (FAPRI) is charged with providing objective, quantitative analysis to decision makers. Since 1984, this service has been provided to Congress and national trade associations, and has focused on commodity policy issues.

In 1995, the unit was asked to expand its focus and begin to bring the same level of effort to environmental issues, that of providing objective, analytical support. The unit spent considerable time examining the problems and determined the area most lacking analysis was at the local level; the farm, the watershed, and the local community.

Similar to the extensive peer-review effort the unit goes through on national commodity policy issues, the environmental analysis effort recognizes the strong need for local involvement. If the local people who must live with the analysis have doubts about the way the analysis was developed, then the effort is wasted. Consequently, the process FAPRI brings to the table also incorporates extensive local input with respect to data sources and model calibration.

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EXECUTIVE SUMMARY

The agricultural sector is a major contributor to the Missouri's economy. Along with the economic impact, environmental concern on the water quality degradation due to the nonpoint source pollutants from agricultural related activities has been rising. To improve, maintain, and protect the water quality, the Agricultural Nonpoint Source-Special Land Area Treatment (AgNPS-SALT) program has been proposed. The intent of the program is to develop watershed based projects that include a combination of education, training, and best management practices implementation aimed at reducing agricultural nonpoint source pollution. In this study, an environmental simulation tool, the Soil and Water Assessment Tool (SWAT), developed by the USDA Natural Resource Conservation Service, was adapted to Missouri resource needs by developing a set of weather, soil and management databases that can be directly used to model characteristics of watersheds in Missouri. This study applied the computer based simulated model to predict the expected environmental outcomes due to the adopting of the Best Management Practices (BMPs) proposed in AgNPS-SALT program projects. The process was based on data developed for six watersheds representing a cross-section of Missouri conditions.

The six watersheds included in this study were Flat Creek (Barry County), Jenkins Basin (Stoddard County), Long Branch (Macon and Adair Counties), Miami Creek (Bates County), and upper and lower Big Maries River (Maries and Osage Counties). The potential water quality problem is unique to each watershed due to the variations in agricultural activities and physical characteristics such as land use, hydrology, topography, soil and climates. Sediment and nutrient runoffs to surface water due to improper grazing management were major concerns in most watersheds where the primary land uses were pastures with cattle grazing. For the watershed such as the Flat Creek where a large number of poultry operations are located, the water quality degradation due to phosphorus runoff from the poultry litter is a main cause of concern. Nitrogen leaching to groundwater from the cropland posted a major concern to the Jenkins Basin watershed where the primary land use is cropland. This watershed locates on top of the shallow aquifer which is primary source of drinking supplies and irrigation.

The purpose of this study was to assess the change in nutrient, sediment, and pesticide loads using the SWAT model when the BMPs proposed by the AgNPS-SALT program are implemented. Major environmental concerns among the six watersheds are sedimentation, nutrient runoff, and pesticides. A number of BMPs have been proposed to address these concerns; effectiveness of the BMPs was unique to each watershed. Factors contributing to the environmental outcomes included the topography, soil types, land use, agricultural practices, hydrology, and climate. Factors contributing to the effectiveness of the BMPs were the amount of acres protected by each BMP and the condition of the land on which the BMPs were implemented, and the initial condition of the watershed. When all the proposed BMPs were simultaneously implemented, the sediment, nitrogen, and phosphorus were reduced by 6-40%, 4-20%, and 10-43%, respectively, across all the six watersheds.

The SWAT model can be an effective tool to quantify the amount of sediment, nutrient, and pesticide loads that vary due to agricultural management practices and physical characteristics. The information on pollutant load reductions from implementing conservation practices can be useful for the agencies in prioritizing the practices to achieve the optimal environmental impact under the constrained resources.

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Environmental concerns

Agriculture is an important sector to the state of Missouri and has been significantly contributing to the state's economy over a long period of time. In the mean time environmental nonpoint source pollution in associated with agricultural activities has been raising concerns and causing water quality degradation. To improve, maintain, and protect the water quality, the Agricultural Nonpoint Source-Special Land Area Treatment (AgNPS-SALT) program has been proposed. The intent of the program is to develop watershed based projects that include a combination of education, training, and best management practices implementation aimed at reducing agricultural nonpoint source pollution. In this study, an environmental simulation tool, the Soil and Water Assessment Tool (SWAT), developed by the USDA Natural Resource Conservation Service, was adapted to Missouri resource needs by developing a set of weather, soil and management databases that can be directly used to model characteristics of watersheds in Missouri. This study applied the computer based simulated model to predict the expected environmental outcomes due to the adopting of the Best Management Practices (BMPs) proposed in AgNPS-SALT program projects. The process was based on data developed for six watersheds representing a cross-section of Missouri conditions. These watersheds include Jenkins Basin, Flat Creek, Long Branch, Miami Creek, upper Big Maries River, and lower Big Maries River watersheds (Figure 1). The variations in landuses, hydrology, topography, soils, climates, and agricultural activities influence the potential environmental concerns which are unique to each watershed.

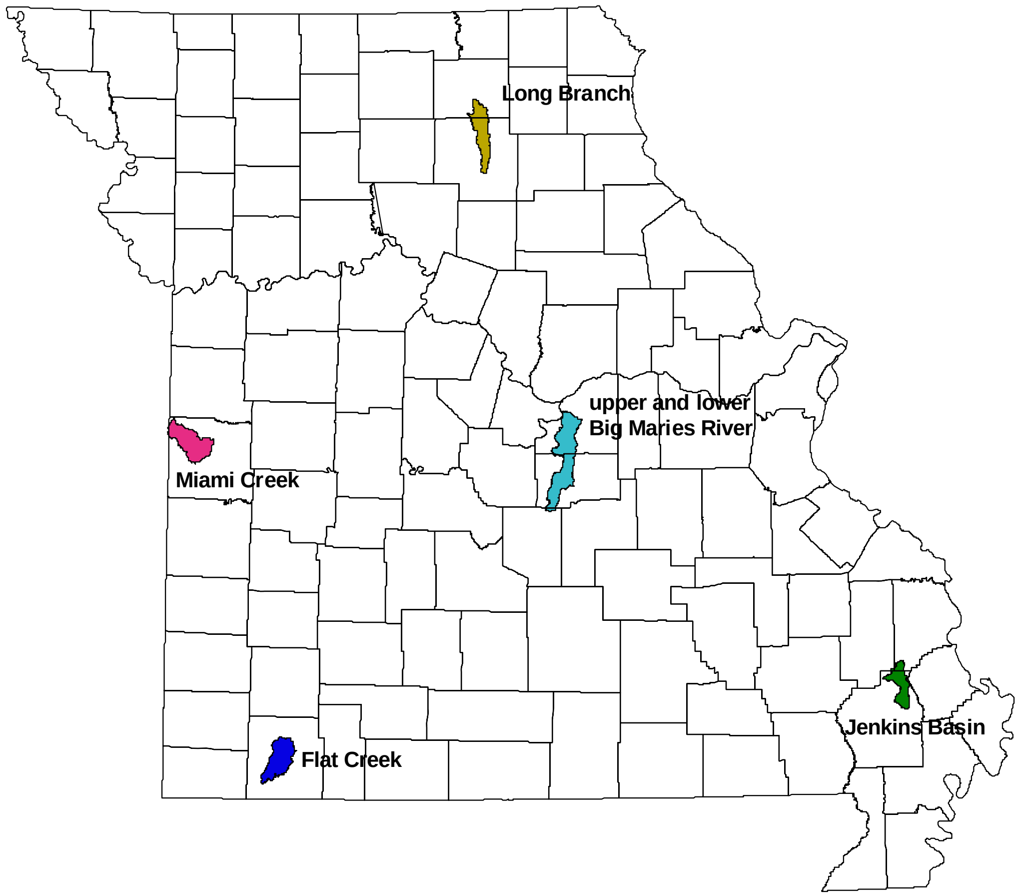

Figure 1. AgNPS-SALT watershed location.

The Jenkins Basin watershed located in south east Missouri covers 42,522 acres with the primary agricultural land uses of cropland (73%), grassland (16%), and forest (10%). The watershed sits on the shallow aquifer which is the primary source for public and private drinking supplies and for irrigation. The natural springs and seeps produce small streams and creeks which feed into the ditches that drain the lowland areas. Sediment and nutrient loads in the aquifer and in the ditches from cropland (rice, soybeans, and wheat) and pasture land (cattle grazing) are the primary concerns.

Unlike the Jenkins Basin, the other five watersheds are not irrigated. The primary agricultural activities include the production of crops and grazing. The Flat Creek watershed located in south west Missouri covers 72,990 acres with the primary land use of pasture (78%) and woodland (16%). In addition, the number of poultry growers continues to increase. Over 20 million birds produce over 940,000 pounds of elemental phosphorus annually. Improper cattle grazing management and poultry operations cause concerns on nutrient and sediment loadings to Flat Creek which eventually flows to the James River and Table Rock Lake.

The Long Branch watershed is located in north-central Missouri. In these 66,683 acres, the primary land uses are grassland (39%), cropland (25%), and forest (24%). The East Fork of the Little Chariton River and the Long Branch Creek drain the basin and feed Long Branch Lake that supplies drinking water and provides fishing and other recreational activities. Improper cattle grazing management and traditional cropping practices which cause excessive sediment, nutrient, and pesticide loadings in the reservoir are the primary environmental concerns in this watershed.

The Miami Creek watershed (84,240 acres) is located in the north-west Missouri. Miami Creek and its tributaries flow in a southeasterly direction to the Marais des Cygnes River, Osage River, and eventually into the Truman reservoir. The primary agricultural land uses are allocated to cropland (56%), grassland (36%), and forest (8%). Some confinement operations are included in the watershed. Major water quality concerns in the Miami Creek are excessive sediment, nutrient, and pesticide loads, and stream bank instability due to improper storage and excess application of animal manure, poorly managed and overly grazed pastures, erosion and high pesticide runoff from some cropland, and inadequate protection of the stream riparian zones.

The upper and the lower Big Maries River watersheds, geographically, are adjacent to each other. The streams run from the south to the north (from the upper to the lower) and drain to the outlet located a few miles north of Westphalia at the confluence with the Osage River. The upper watershed contains 61,689 acres including pasture (55%) and woodland (45%). The 67,863 acres of the lower watershed include pasture (39%) and woodland (54%). The remaining acres are towns and a small fraction of cropland. The major agricultural activities for both watersheds are cattle grazing. The environmental concerns in these two watersheds are associated with improper grazing management which causes excessive nutrient and sediment loads, stream bank instability, diminishing dissolved oxygen, and bloom of filamentous algae.

To improve the water quality, the AgNPS-SALT program sponsored a number of conservation practices through technical and financial assistance through the Soil and Water Conservation Districts (SWCDs). The AgNPS-SALT program focused on agricultural and land management activities that influence sediment, nutrient loading and pesticide through agricultural conservation practices.

BMP Implementations

Individual reports for each of the watershed describe in detail the management practices proposed in these watersheds, their goals, and the target acreages. Table 1 presents the management practices implemented in each watershed. It is followed by a short description of each practice.

Table 1. Best management practices proposed in each AgNPS-SALT project.

BMP	Lower Maries	Upper Maries	Flat Creek	Long Branch	Miami Creek	Jenkins Basin
Irrigation management						√
Nutrient management			√	√	√	√
Pesticide management				√	√	
Grazing management	√	√	√	√	√	
Waste transport			√			
Pasture management	√	√			√	
Erosion control			√	√		
Riparian corridor management			√			
Woodland management	√	√	√	√		
Cover enhancement				√		
Residue management					√	
Tillage management					√	
Buffers and filter strips					√	
Terraces				√	√	
Conservation rotation					√	

Irrigation management techniques improve the water delivery system and thus reduce the water application rates. The purpose of nutrient management is to optimize nutrient application rates while ensuring that crop have the required nutrients to grow at their full potential and minimizing nutrient loading to the streams. Pesticide management includes reducing pesticide application rates, modifying their timing, and filtering the runoff so that the pesticide dissolved in it does not enter the streams.

Grazing management consists in shorter, more frequent grazing periods at higher grazing intensities which help improve grass cover and reduce sediment and nutrient runoff. Waste transport is key to manage large surplus of poultry litter out of a watershed such as the Flat Creek watershed, where large amount of poultry are produced. An improvement of pasture condition via permanent vegetation establishment and improvement under pasture management cause a reduction in sediment and nutrient runoff. Erosion control by using ponds to trap sediment from the gully erosion contributes to lower sediment yields. Riparian corridor management reduces sediment and nutrient runoff from surface water and in shallow ground water flow by protecting stream banks and filtering surface runoff. To protect the woodland acres that are susceptible to erosion, under woodland exclusion management, cattle which are usually left in the forest during the winter would be permanently removed from the woodland. Residue management, tillage management, and conservation rotations reduce sediment and nutrient loadings by providing more ground cover with additional residue or vegetation. Stream exclusion prevents the cattle to access the streams to improve the stream bank stability. The purpose of the stream bank stabilization is to protect the stream banks from accelerated erosion by providing adequate stream bank vegetation. Terraces and permanent vegetative cover are also key management tools to control erosion.

Analytical tool

The Soil and Water Assessment Tool (SWAT) was used as a tool to simulate and to estimate the impact of the BMPs associated with the AgNPS-SALT program on the six watersheds. The model input requirements were electronic land cover and soil maps, digital elevation model (DEM), soil database, climate data collected from nearby weather stations, and information about the land management (Figure 2).

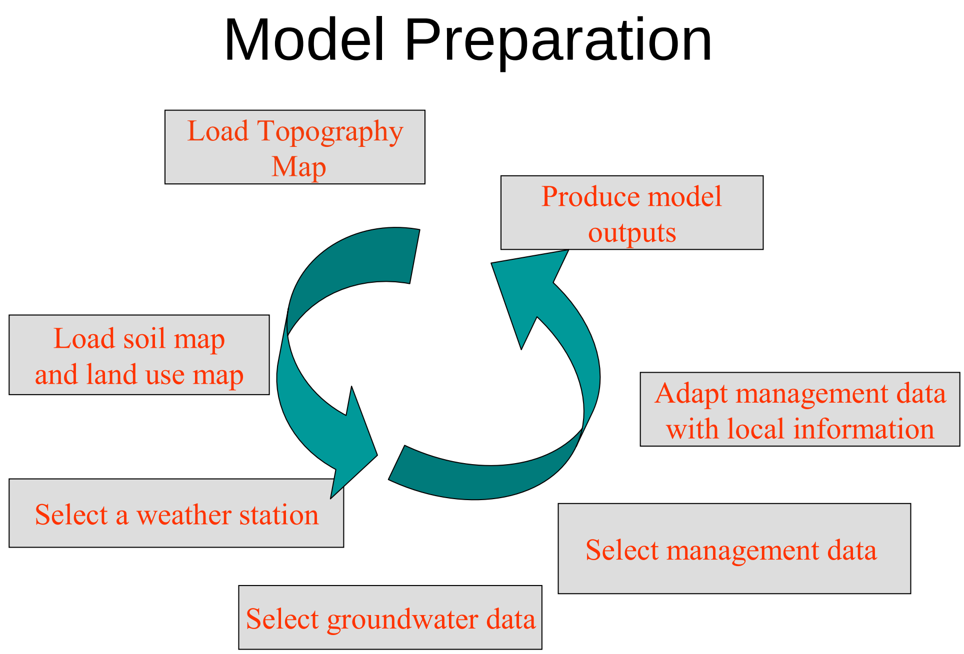

Figure 2. SWAT simulation procedure

The information on typical agricultural land management for the baseline scenario was gathered from meetings with the watershed steering committees. The committees consisted of landowners in the watersheds who participated in the AgNPS-SALT program and members of the boards of the county SWCDs.

The SWAT simulation model has the capacity to simulate most of the BMPs proposed in the AgNPS-SALT project, particularly the ones associated with the agricultural land and crop management. However, due to limitations of the SWAT model or because of a lack of information, some proposed practices were fully addressed. Table

2 lists the practices that SWAT could fully address, those that were partially addressed, and those we could not simulate. It also includes a short description of the main reason why the BMP could not be fully simulated.

Table 2. BMP simulation using the SWAT model

Category	**Practice**	**Reason**
BMPs fully simulated with SWAT	Erosion control through tillage and terraces	
	Grade stabilization structures (ponds)	
	Woodland protection (livestock exclusion)	
	Grassland establishment / improvement	
	Pasture management	
	Poultry litter export	
BMPS partially simulated with SWAT	Pesticide management	No pest stress on crops
	Nutrient management	No variable P fertilization
	Irrigation management	Cannot represent the heterogeneity in water depth across a field
	Rotational grazing	Cannot represent the heterogeneity in grazing pressure across a pasture
	Field borders	Incomplete science
	Riparian buffers	Incomplete science; requires area filtered by the buffer.
	Stream protection (livestock exclusion)	Additional information needed
BMPS not simulated with SWAT	Groundwater protection	Does not fully track groundwater quality
	Well decommissioning	Does not fully track groundwater quality
	Spring development	Benefit in that cattle do not go to the stream
	Waste management when applied to only a few operations.	Requires the definition of the management prior to BMP implementation
	Critical areas planting	No good way to simulate a small critical area

The SWAT model cannot estimate how education and training efforts affect the behavior of the producers and land managers. An evaluation of the impact of meetings, education, training, and farm visits was not included in the study.

AgNPS-SALT program effectiveness

On the Jenkins Basin watershed, a large fraction of the cropland was irrigated. The BMPs proposed by the AgNPS-SALT program and considered in this study were irrigation management, nutrient management on irrigated land, and nutrient management on grassland. Irrigation management did not seem to produce the expected results related to nitrate leaching. Nutrient management and grassland management along with irrigation management resulted in phosphorus reductions five times higher than with irrigation management alone. It also showed higher reduction rates of leached nitrogen. Reduction rates in sediment and surface nitrogen were similar. Due to a lack of flow and water quality data, the model could not be calibrated. Results were compared to the estimations provided in the Jenkins Basin SALT proposal. These results should be reviewed when data become available to calibrate this model. When all the proposed BMPs simultaneously implemented, the reduction rates were up to 24 %, 20%, and 43% on sediment, surface nitrogen, and phosphorus, respectively (Figure 3). The average reductions rates were smaller, 6%, 6%, and 15% for sediment, surface nitrogen, and phosphorus, respectively.

The main agricultural activities on the other five watersheds were cattle grazing, poultry growing, and cropland. Unlike the Jenkins Basin, there is no irrigation in these watersheds. The BMPs proposed by AgNPS-SALT and examined in this study were grazing management, erosion control, woodland management, riparian corridor management, tillage management, conservation rotation, grassland improvement, stream exclusion, irrigation management, waste management, and nutrient management.

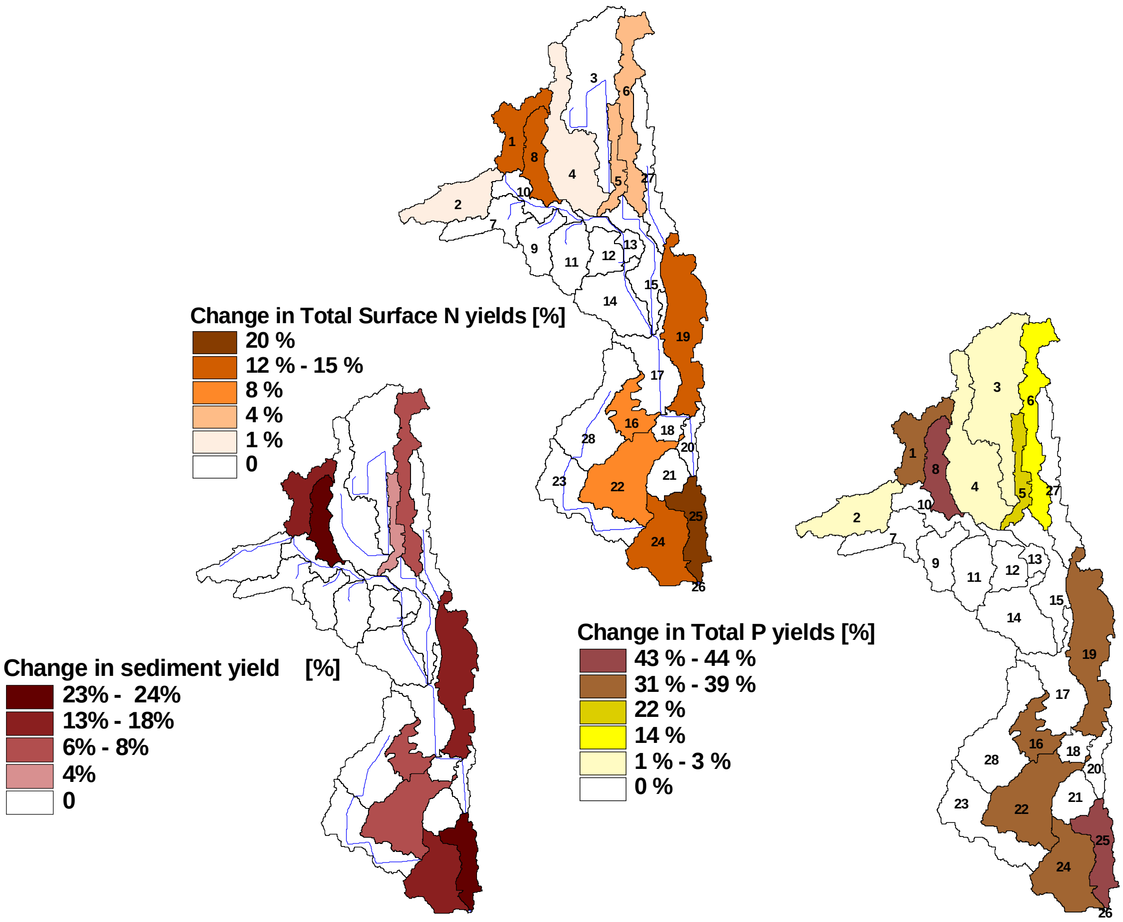

Figure 3. Environmental impacts from combined BMPs in the Jenkins Basin watershed.

In the Flat Creek watershed, nutrient management and waste transport were among the most effective practices to reduce phosphorus and nitrogen. On sediment loadings, grazing management and riparian corridor management resulted in the highest reductions of sediment loadings. The effectiveness of the AgNPS-SALT program is represented by the combined BMPs scenario which aggregated the environmental impacts when all the proposed BMPs were simulated. In comparing with the baseline, the combined BMPs showed average reductions of 6%, 9%, and 14% in sediment, surface nitrogen, and phosphorus, respectively (Figure 4).

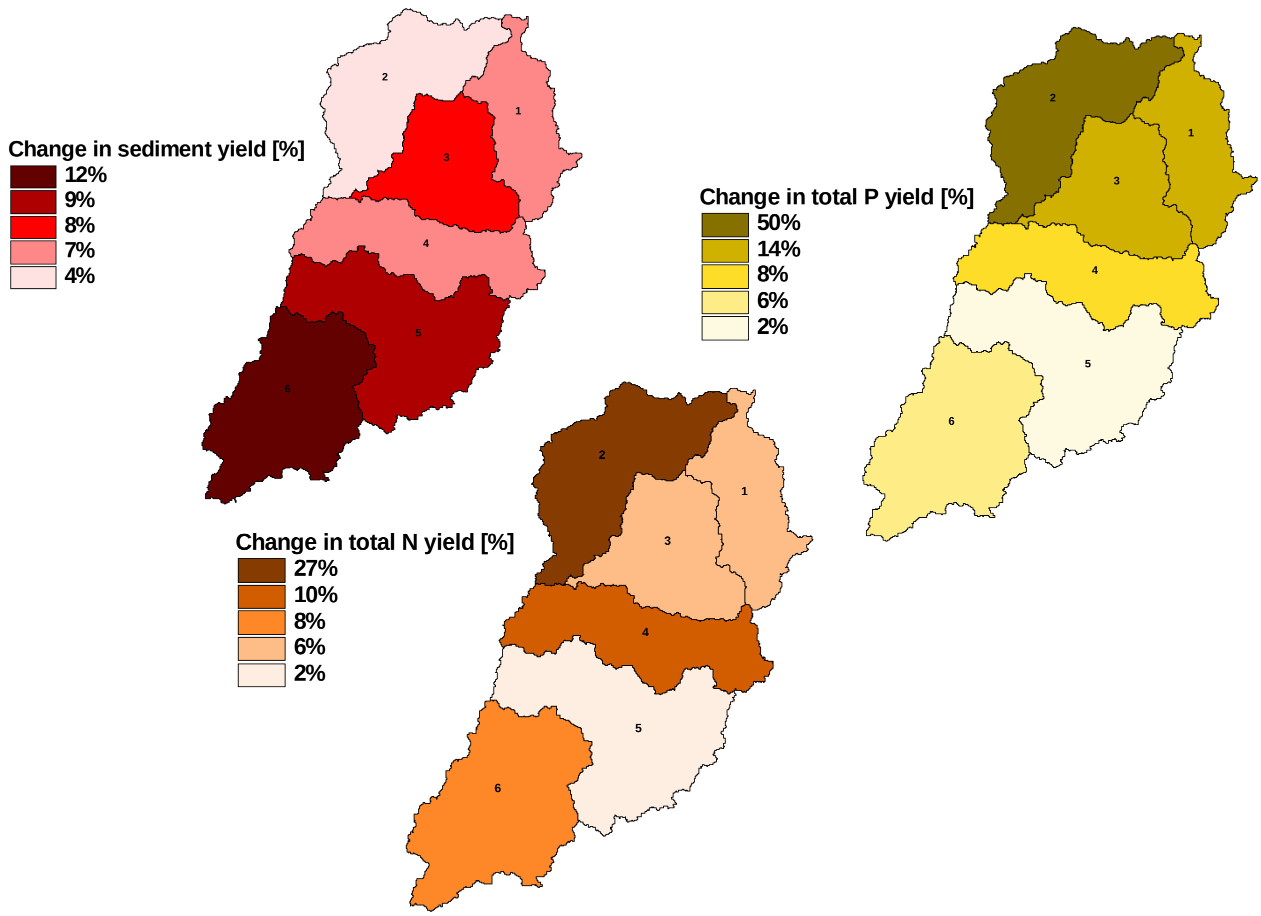

Figure 4. Environmental impacts from combined BMPs in the Flat Creek watershed.

In the Miami Creek watershed, tillage management and the implementation of buffers and filter strips appeared to be the most efficient practices to reduce sediment loadings. Pasture and grazing management contributed to significant reductions in phosphorus, while tillage management was the most effective practice to reduce nitrogen. Reducing the amount of atrazine applied resulted in the highest atrazine loading reduction with the next most effective management practice being buffers and filter strips. Compared to the baseline, the combined BMPs resulted in average reductions of 39%, 4%, 25%, and 10% of sediment, nitrogen, phosphorus, and atrazine, respectively (Figure 5).

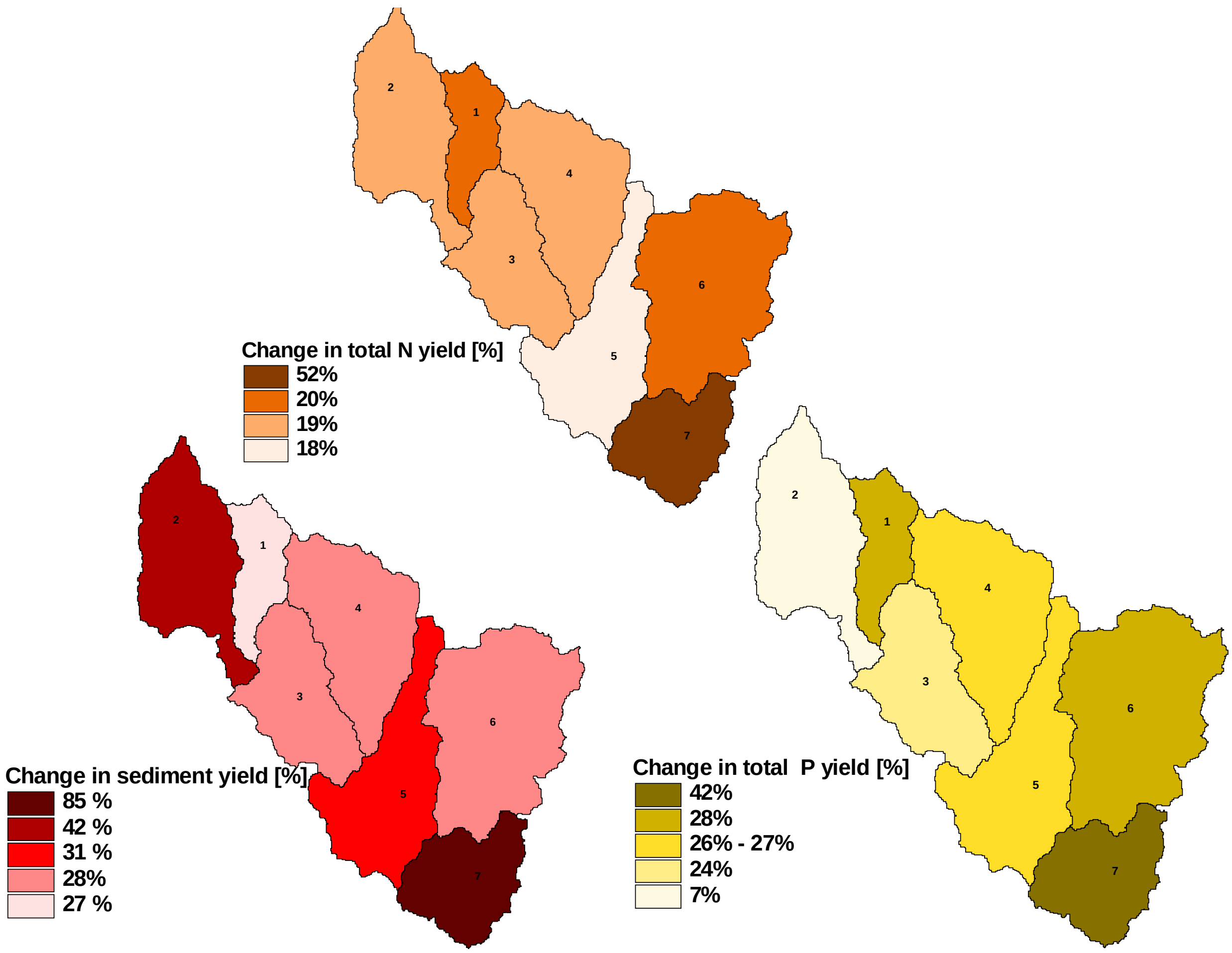

Figure 5. Environmental impacts from combined BMPs in the Miami Creek watershed.

In the Long Branch watershed, erosion control and grazing management were the most effective BMPs to reduce the sediment as well as nutrient runoff. Nutrient and pest management and erosion treatment also contributed to the reduction in atrazine.

Compared to the baseline environmental impacts, the combined the BMPs resulted in 13%, 8%, 10% and 29% reduction on sediment, nitrogen, phosphorus, and atrazine, respectively (Figure 6).

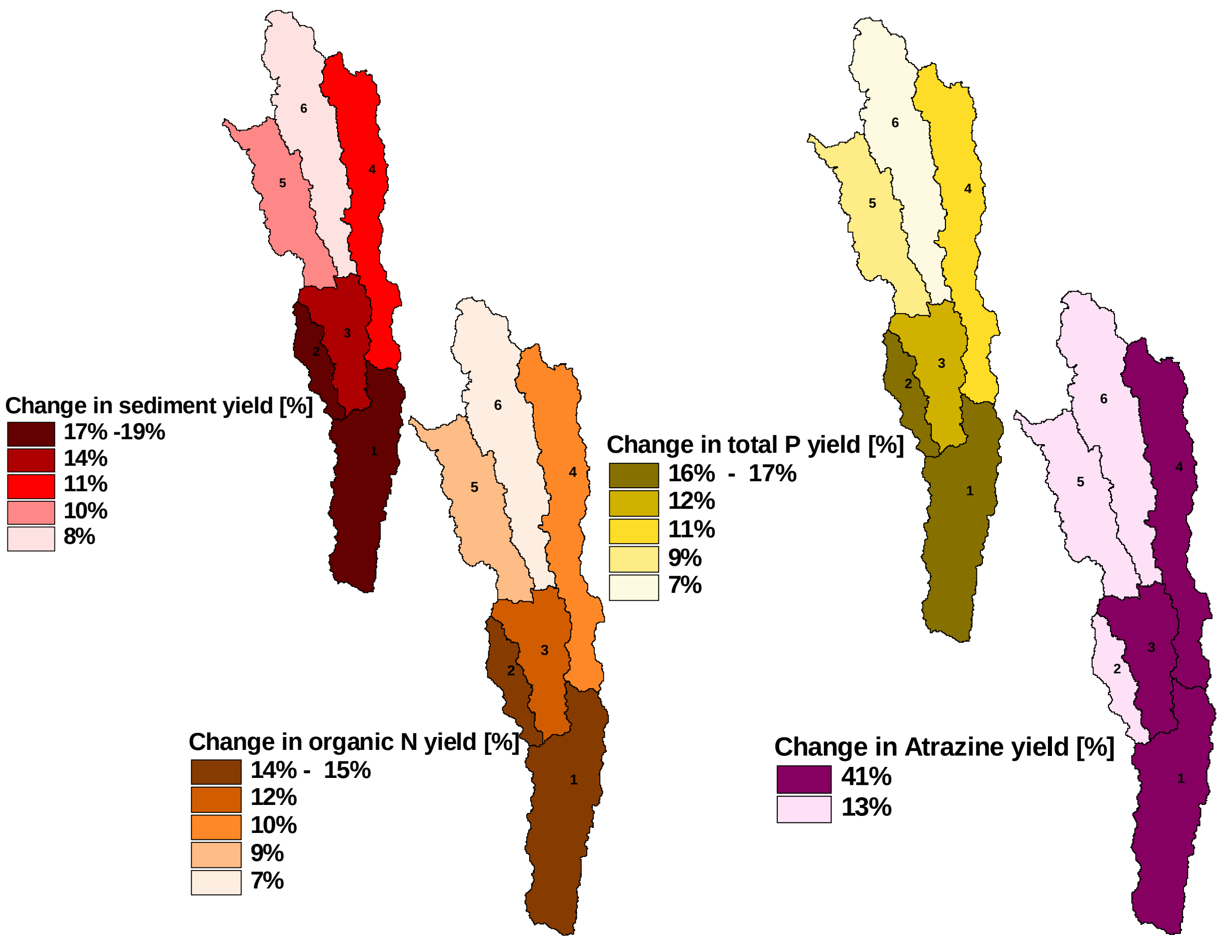

Figure 6. Environmental impacts from BMPs in the Long Branch watershed.

In the upper Big Maries River, grazing and grassland managements resulted in the highest sediment reduction. Grazing management contributed to the highest reduction rate in nutrients. At the lower Maries River, grazing management was the most effective BMP to reduce sediment and nutrient runoff at the subbasin and the outlet. At the outlet, stream bank exclusion showed the highest sediment reduction rate as contributed by grazing management. The environmental impacts of the combined BMPs of the upper and the lower Big Maries River watersheds in comparing with the baseline are presented in Figure 7.

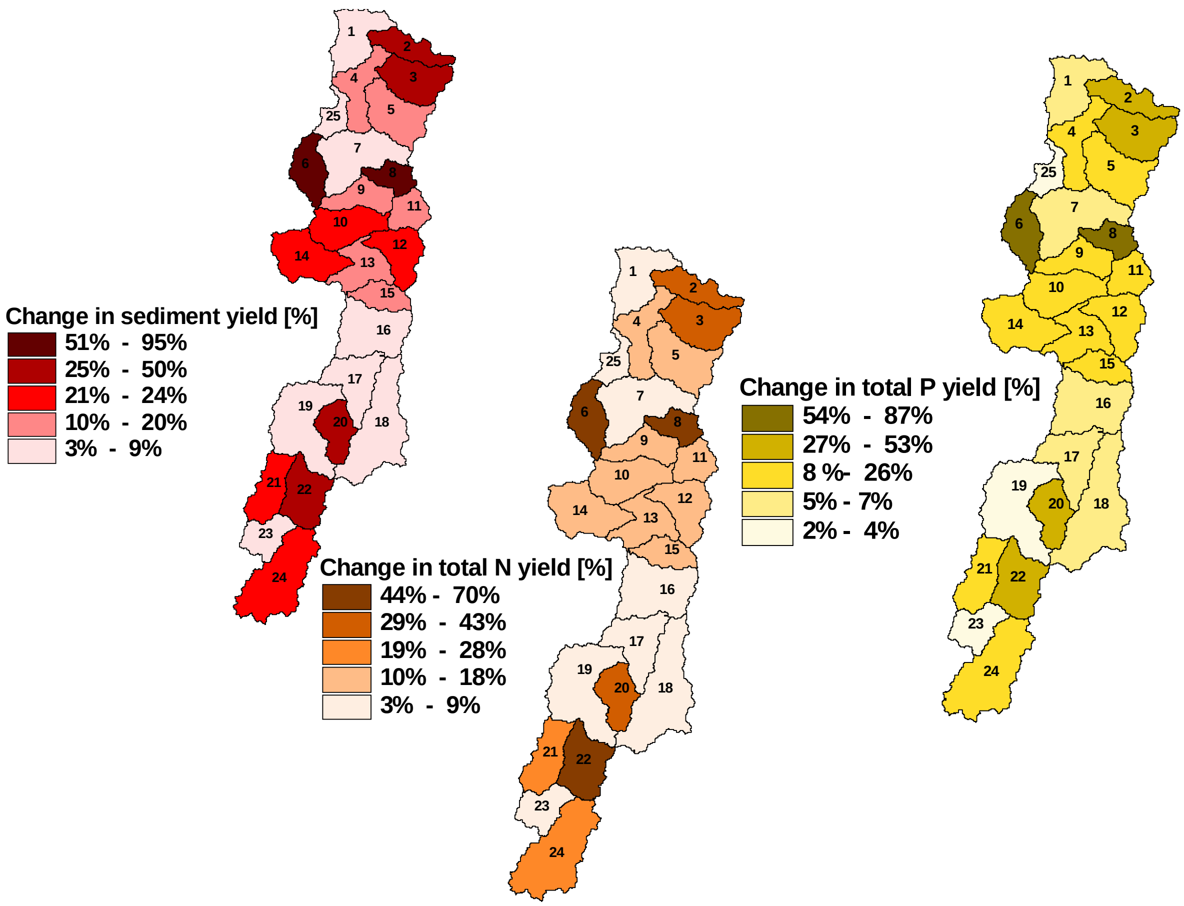

Figure 7. Environmental impacts from BMPs in the upper and the lower Big Maries River watersheds.

Conclusions

The major environmental concerns among the six watersheds are sedimentation, nutrient runoff, and pesticides. A number of BMPs have been proposed to address these concerns; effectiveness of the BMPs was unique to each watershed. Factors contributing to the environmental outcomes included the topography, soil types, land use, agricultural practices, hydrology, and climate. Factors contributing to the effectiveness of the BMPs were the amount of acres protected by each BMP and the condition of the land on which the BMPs were implemented, and the initial condition of the watershed. On the watersheds where the primary land use was pasture and the major agricultural activity was cattle grazing, grazing and pasture management were among the most effective BMPs to reduce the sediment and nutrient runoff. On the watershed where the poultry operations were heavily concentrated, nutrient management and waste transport were among the most effective practices to reduce phosphorus and nitrogen.

When all of the BMPs were implemented simultaneously on the target acres under the AgNPS-SALT program, the pollutant reductions ranged from 6-39%, 6-20%, 10-25%, and 10-29% for sediment, nitrogen, phosphorus, and atrazine, respectively. The comparisons were based on long-term (30 years) averages.

Even though the SWAT model could not fully address all the BMPs, it proved to be an effective tool to quantitatively estimate the amount of nutrient and sediment loads as they are affected by agricultural management practices and physical characteristics. The information on pollutant load reductions from implementing conservation practices can be useful for the agencies in prioritizing the practices to achieve the optimal environmental impacts under the constrained resources.