Chapter 9

Lincoln Lake Watershed, Arkansas: National Institute of Food and Agriculture–Conservation Effects Assessment Project

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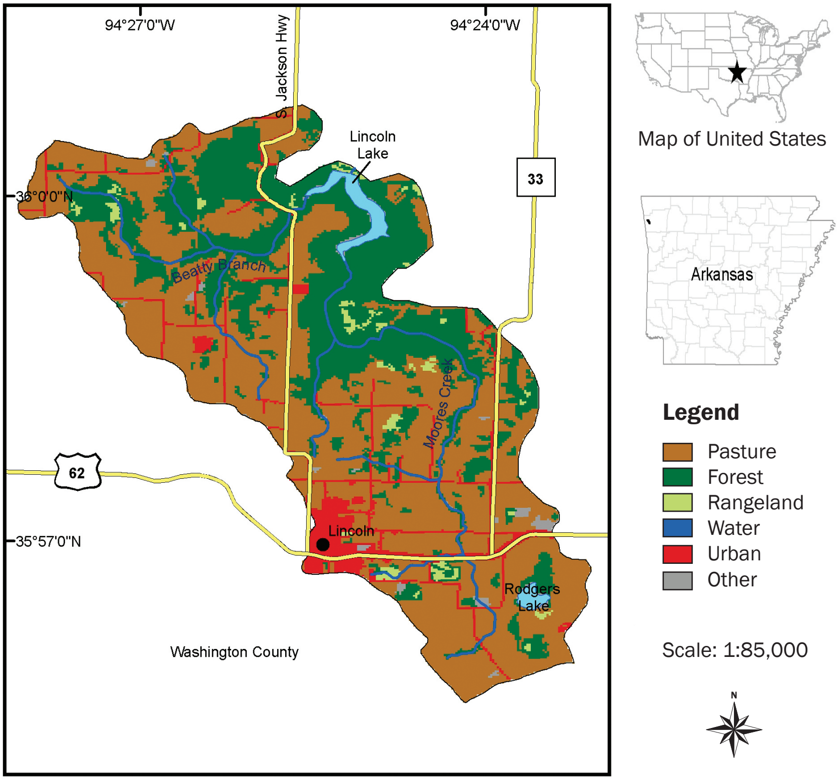
The overall goal of the Arkansas National Institute of Food and Agriculture–Conservation Effects Assessment Project (NIFA–CEAP), Effectiveness and Optimization of Best Management Practices (BMPs) in Improving Water Quality from an Agricultural Watershed, was to quantify how implementation of various BMPs, timing of BMPs, and spatial distribution of BMPs within a pasture-dominated agricultural watershed affect reductions in sediment and nutrient transport. The following objectives were completed to address this goal:

1. Synthesize historic watershed BMPs, land use, and water quality data in a geographic information system–linked database to explore relationships between BMPs and their influences on water quality at the watershed scale.
2. Quantify linkages among nutrient management, land use, BMP implementation, water quality, and ecosystem response at the watershed level.
3. Develop comprehensive cost-benefit analyses of the water quality management practices to optimize BMP implementation, animal manure application, and water quality improvement at the watershed level.
4. Develop education and demonstration programs to educate stakeholders (farmers, extension agents, and state and federal agencies) on linkages among BMPs and watershed-scale water quality response.

Watershed Information

The Lincoln Lake Watershed is in the Ozark Highlands ecoregion of northwest Arkansas and is part of the Illinois River Watershed (hydrologic unit code #11110103). This 2,590 km^2 (1,000 mi^2) watershed is shared between Arkansas (64% or 1,645 km^2 [636 mi^2]) and Oklahoma (36% or 945 km^2 [364 mi^2]). The watershed is typical of the Ozark Highlands, with rolling pastures intermixed with woodland, and is densely populated with poultry (broiler) operations that use litter as a fertilizer for pastures. The two primary tributaries that feed Lincoln Lake are Moores Creek (21 km^2 [8 mi^2]) and Beatty Branch (11 km^2 [4.5 mi^2]). The total Lincoln Lake Watershed drainage area is 32 km^2 (12 mi^2). Land use in 2008 consisted of 37% pasture, 39%

Figure 9.1
Lincoln Lake Watershed, Arkansas, land use and stream networks.



forest, 12% urban, 10% transitional, and 2% poultry facilities (figure 9.1) (Gitau et al. 2010; Chiang et al. 2010).

Waters of the Illinois River and many of the lakes on its tributaries are eutrophic from excessive nitrogen (N) and phosphorus (P), while additional impairment has been related to bacteria. In November of 2007, the attorney general for Oklahoma filed a motion in federal court requesting a moratorium on all poultry litter applications within the Illinois River Watershed. This motion was based on the assumption that nutrients and pathogens from poultry litter applications were causing high levels of nutrients and pathogens in the surface waters of the Illinois River, which were stated to cause "an imminent threat to human health." The TP water quality criterion in Oklahoma is 0.037 mg L^{-1}, and due to a US Supreme Court ruling, the portion of the Illinois River leaving Arkansas and entering Oklahoma at the Highway 59 Bridge must meet this criterion.

The resulting litigation between the State of Oklahoma and several poultry integrators in the Illinois River Watershed makes this National Institute of Food and Agriculture–Conservation Effects Assessment Project (NIFA–CEAP) study watershed unique among the other funded projects. Not only does the litigation bring increased awareness of water quality issues within the watershed, but it also highlights differences among stakeholders' beliefs within the watershed with respect to nutrient sources, their relative contributions and importance, and the implied responsibility for clean-up.

The Lincoln Lake Watershed is located in one of the top two poultry-producing counties in Arkansas and is in the top cattle-producing county in the state. Because the Illinois River Watershed is designated as a nutrient surplus watershed, all poultry operations are required to prepare nutrient management plans (NMPs) that determine an acceptable rate for land application of poultry litter, or other acceptable use approved by the Arkansas Natural Resources Conservation Commission, based on the risk of P loss in runoff.

There is minimal cropping in the watershed due to shallow, inherently low fertility soils, which was the main reason for the development and rapid intensification of broiler production in this region, synergistically with beef cattle grazing. Agricultural production is now dominated by poultry operations integrated with cattle grazing and beef production. Farms typically have four to six poultry houses with an approximate 20,000 to 25,000 bird capacity per house. Beef cattle are grazed, and the poultry litter is applied to pastures to supply N and P for warm and cool season grass production for grazing and forage cutting. The litter from the poultry houses is either land applied according to an approved NMP or is exported out of the watershed.

Watershed topography is composed of broad upland divides separated by areas of rolling hills with slopes ranging from 0% to 14%. Elevations in the watershed range from 350 m (1,148 ft) above sea level at the watershed outlet to 480 m (1,575 ft) above sea level at the headwaters. Watershed soils are a mixture of silt loam, gravelly loam, loam, stony fine sandy loam, and fine sandy loam, dominated by the Hector and Enders series covering about 44% of the watershed.

Average 10-year precipitation in this region is approximately 1,100 mm y^{-1} (43 in yr^{-1}). Precipitation occurs throughout the year, with long-term monthly averages ranging between 60 mm (2.5 in) in August and 150 mm (5.9 in) in May. The watershed is characterized by moderate to high temperatures, with a long-term average ranging from about 5°C (41°F) in December to 24°C (75°F) in June.

Water Quality Information

In Oklahoma, the Illinois River is listed as a scenic river, and the principal pollutants are nutrients (N and P) and sediment, as related to biological productivity or trophic state of Lincoln Lake. Agricultural and urban runoff are the main sources of these pollutants. The principal concern in this watershed was degrading water quality from P contained in land-applied animal manure.

Flow and water quality monitoring have been performed at various sites in the watershed since 1991. Streamflow and water quality data were collected at two sites in Moores Creek and at one site in Beatty Branch. At all the sites, streamflow was monitored continuously using a pressure transducer to measure flow depth and depth-discharge relationships at each site. Water quality data for sediment, N, and P were collected separately during storm and base flow conditions. Flow-weighted composite samples were collected during each storm event using an autosampler. Water quality during base flow conditions was quantified by grab samples collected every two weeks. All water samples were analyzed using standard methods of analyses. Details of flow and water quality monitoring are provided by Vendrell et al. (1997, 2000) and Nelson et al. (2008).

Land Treatment

The project studied conservation practices already in place in the watershed and increased practice implementation during the project. Conservation practices were already implemented by farmers based on NMP requirements and USDA Natural Resources Conservation Service (NRCS) cost share programs over the last 20 years. Conservation practice locations were determined by the USDA NRCS and extension personnel working with individual farmers. In this watershed, land owners played a key role in selection of appropriate or approved conservation practices available from USDA NRCS standards and codes. Feedback from farmers was positive and was used to enhance conservation practice adoption within the watershed.

Adoption of conservation practices was assessed via land use and land cover maps for 1992, 1994, 1996, 1999, 2001, and 2004 by conducting an inventory of farm-level conservation practice implementation and record keeping, and through face-to-face meetings with farmers to collect information. Based on data derived from land-use maps, conservation practice implementation increased from 1% to 34% over the 12 years of land-use assessment (1992 to 2004), with 53% of all pastures having one or more practices installed by the end of the period.

Conservation practices implemented in the watershed included the following:

- Adoption of an approved NMP (USDA NRCS Conservation Practice Standard 590: Nutrient Management)
- Soil testing (USDA NRCS Conservation Practice Standard 590: Nutrient Management)
- Litter application based on soil test P results (USDA NRCS Conservation Practice Standard 590: Nutrient Management)
- Reduced litter applications (USDA NRCS Conservation Practice Standard: 590 Nutrient Management)
- Use of legumes to decrease or offset decreased applications of N in poultry litter (USDA NRCS Conservation Practice Standard 512: Forage and Biomass Planting)
- Rotational or controlled grazing (USDA NRCS Conservation Practice Standard 528: Prescribed Grazing)
- Amendment of poultry litter with alum to decrease ammonia volatilization and sequester P (USDA NRCS Conservation Practice Standard 591: Amendments for Treatment of Agricultural Waste)
- Use of poultry litter storage or staking sheds (USDA NRCS Conservation Practice Standard 313: Waste Storage Facility)
- Filter strips and riparian areas (USDA NRCS Conservation Practice Standard 390: Riparain Herbaceous Cover)
- Stream fencing to exclude grazing cattle (USDA NRCS Conservation Practice Standard 382: Fence; and USDA NRCS Conservation Practice Standard 578: Stream Crossing)
- Construction of detention ponds (USDA NRCS Conservation Practice Standard 378: Pond)

Growers were reluctant to adopt new practices at first, but farmer-to-farmer word of mouth increased adoption as growers discovered from soil tests that they did not need to add as much fertilizer and litter and that reduced applications saved them money. Soil nutrient testing was the primary conservation practice because it made an economic impact for the growers. Conveniently, it provided an environmental benefit via decreased fertilizer and litter applications. Another very important factor was that the region hired a dedicated extension agent who was able to work with 63 of the 75 farmers who lived in the watershed. This locally based individual was able to overcome the social barriers of distrust widely held by producers.

There were significant changes in land use over the 12 years of investigation (1992 to 2004). Although there was no change in forest area, there was a reduction in pasture land (from 49 to 37%) as residential areas (from 3% to 12%) expanded over the same period. Surveys of producers and residents in the area (described later) suggested varying opinions on the relative contributions of agriculture and other players (construction, industry, households, etc.) to water quality issues in the area.

Water Quality Response

This project was not able to show a definitive response to the implementation of conservation practices in monitored sediment and nutrient concentrations in tributaries of the Lincoln Lake Watershed. This was mainly due to the rapidly changing landscape during the 12-year period, 1992 to 2004, that confounded concurrent implementation of conservation practices. There was a systematic gain in urban areas (9%) at the expense of pastureland in the watershed, with urban land tending to directly replace pastureland (Gitau et al. 2010).

The project relied on simple linear regressions of mean annual sediment and nutrient concentrations against time, without correction for changes in weather, streamflow, or land use, for analysis of possible water quality trends. This analysis suggested that mean annual total suspended solids, nitrate-nitrogen, and total P (TP) concentrations in the Upper Moores Creek may have declined from 2000 to 2007; there is also an indication that mean annual stream discharge increased over the same period. Other data showed mixed results, with baseflow concentrations of total suspended solids and nitrate-nitrogen decreasing in Upper Moores Creek (1996 to 2007), while stormflow concentrations showed no trend. In Lower Moores Creek (1991 to 1998), no changes in nutrient or sediment concentrations were observed during baseflow, but the data suggested that TP and nitrate-nitrogen levels increased during stormflow.

Additional analysis during 2002 to 2004 demonstrated that light, not nutrients, are limiting algal production in Moores Creek. Benthic sediments were sources of dissolved P in two of the monitored sites, probably due to disturbance of bed sediments by cattle access.

Model Application

Modeling was used to assess the effectiveness of various land management options for improving streamwater quality (sediment and nutrient loadings). The Soil and Water Assessment Tool (SWAT) model was used with a stakeholder-driven risk-based nutrient management decision process.

Three distinct conservation practices were modeled: nutrient management, riparian buffer zones, and pasture and grazing management. Grazing intensity scenarios consisted of no grazing, optimum grazing, and overgrazing, while buffer width scenarios were set at 0, 15, and 30 m (0, 50, and 100 ft).

Litter scenarios (nutrient management) were more complex, consisting of three rates, two timings, two grass types, two poultry litters, and a control (no litter application). The two poultry litter types were normal poultry litter and alum-amended (reduced available P) poultry litter.

The total number of litter application scenarios was 19 (three nutrient application rates × three application timings × two litter types, plus one no-litter application scenario):

- For warm season grasses, there were three litter application rates consisting of 2.47, 3.71, and 4.94 t ha^{-1} (1, 1.5, and 2 tn ac^{-1}) and two application times (surface applied in the spring or summer).
- For cool season grasses, there were three rates consisting of 4.94, 6.18, and 7.4 t ha^{-1} (2, 2.5, and 3 tn ac^{-1}), with only one application surface applied in the fall (October 15th).

The 19 nutrient management scenarios were combined with buffer and grazing scenarios for a total of 171 different conservation practice scenarios. Baseline management practices were set to reflect watershed management that occurred in 2004. The SWAT model was used to quantify practice effects on forage production and water quality. The model results were compared to historical data to determine which conservation practices would have improved water quality significantly in the watershed.

A digital elevation model at 30 m (100 ft) resolution, land use and land cover at 28.5 m (93.5 ft) resolution, and SSURGO soils data were used to delineate the watershed and subwatersheds. Land use and soil thresholds of 0% and 0% were used to define hydrologic response units in the SWAT model. The resulting watershed configuration consisted of 72 subbasins and 1,465 hydrologic response units.

The SWAT model was calibrated and validated to simulate streamflow and water quality (total suspended solids, total nitrogen [TN], TP, and soluble P losses) in the watershed. Uncertainty in future weather conditions was quantified by generating 250 realizations of future weather. The same weather scenario was used for evaluations of all 171 conservation practice scenarios. This resulted in 43,000 SWAT runs.

Results from the modeling were evaluated using a five-way analysis of variance (ANOVA) to determine the effects of the conservation practices—nutrient management (litter application rate, type, application timing), grazing management, and buffer management. Not surprisingly, TN and TP losses increased as litter application rates increased. The model suggested that fall litter application led to greater TN losses but had no effect on TP losses. As buffer width increased or grazing intensity decreased, nutrient losses decreased. Modeled results found buffers to be the most effective conservation practice to control TP (99%) losses. Most other practices individually or combined had almost no effect on TP losses. However TN losses were most affected by three conservation practices: application timing, buffers, and grazing management (29%, 28%, and 28% reductions respectively).

Analysis of impacts of uncertainty in weather indicated a four-fold range of nutrient losses. Because of uncertainty in future weather conditions, even if no conservation practices were added, pollutant losses would be highly variable due to weather. The modeling suggested that variability in weather (particularly rainfall) may cause nutrient loads to exceed the capacity of conservation practices to retard nutrient transport.

When pollutant losses were compared for overgrazed conditions under different weather conditions, modeled results suggested that loading from overgrazed pastures would overwhelm any conservation practices. Conversely, nutrient loading was always reduced under uncertain weather conditions when pastures were optimally grazed or when there was no grazing and when buffers were used. Taken as a whole, the modeling suggests that the most important conservation practice is buffer strips, followed by good pasture management, and spring-applied litter application at appropriate rates.

Socioeconomic Analysis

There were multiple distinct components to the socioeconomic activities of the Lincoln Lake NIFA–CEAP, which included a stakeholder survey, an input-output contribution of agriculture study, risk assessment of conservation practices, and optimization of conservation practices in the watershed.

Stakeholder Survey

Objectives of the survey were to collect stakeholders' (farmers, nonagricultural watershed residents, and water quality experts) perceptions of watershed water quality and sources of water pollution; to understand how stakeholders view the roles of local, county, state, and federal officials in meeting water quality objectives; and to determine how that information can be used to help move stakeholders from conflict to cooperation in meeting desired water quality goals. Surveys of agricultural stakeholders were conducted at meetings and at their homes. Sixty-three of the 75 (84%) of the agricultural stakeholders in the watershed took the survey. This high response rate is likely due to the relationships established with the extension agent funded through this project.

Results showed that 39% of responding farmers indicated that they had a NMP, while 48% said they had adopted at least one conservation practice. Interestingly however, some producers were unaware of some of the conservation practices that could address water quality issues in the region. Farmers' opinions often differed from those of water quality specialists regarding the effectiveness of conservation practices. Other social factors that limit adoption of conservation practices were listed by participants as a lack of knowledge (54%), a belief that conservation practices increase further regulation (32%), lack of equipment (22%), the belief that the Environmental Quality Incentives Program (EQIP) does not meet their needs (22%), and the belief that practice were too expensive (22%).

Nonagricultural stakeholders (nonagricultural) and the water quality experts (experts) were surveyed by mail. Response rates were 26% (68 of the 243) for the nonagriculture stakeholders and 49% (78 of the 160) for the water quality experts who were sent a survey. Most (81%) of the nonagricultural stakeholders held land in the watershed as their primary residence. The rest owned the land for business, as rental property, or for land preservation uses. The experts represented the University of Arkansas Experiment Station (11%), University of Arkansas Cooperative Extension Service (29%), conservation districts (8%), the USDA NRCS (25%), Arkansas Department of Environmental Quality (8%), and Arkansas Natural Resources Commission (19%).

All three stakeholder groups shared their perceptions of water quality issues in the surveys. As expected, agricultural stakeholders believed that their contributions to water quality problems were smaller than those of nonagricultural stakeholders. Agricultural stakeholders, therefore, believed the primary responsibility for cleaning up any problems belonged to nonagricultural stakeholders, while nonagricultural stakeholders believed the responsibility belonged to farmers. Experts' opinions fell between those of the agricultural and nonagricultural stakeholders. Most importantly, however, all three surveyed groups believed that existing water quality problems were generated by multiple sources (agriculture, industry, new construction, city sewer, households), and therefore, all sources had a responsibility to contribute to cleanup. However, both agricultural and nonagricultural stakeholders felt disengaged from the policy process. Very few believed they were ever invited to participate in the process, and even if they were invited, they felt their voices were rarely heard. Most of these results were expected, but this is the first time these observations were recorded in the watershed.

The survey process generated a number of lessons. First and foremost, to address water quality issues in the watershed, it is essential to build trust. As such, an approach that includes all stakeholders is better than a government-directed approach to project management. The extension program established in this watershed, which was sensitive to farmers' schedules, was critical to the collaboration of agricultural stakeholders in the survey and later to outreach efforts within the watershed.

Contribution of Agriculture to the Washington County Economy

The economic contributions of Washington County's Agricultural Sector for 2007 were modeled using the Impact Analysis for Planning (or IMPLAN) System, input-output modeling software. Results showed that the agricultural sector contributed 15,937 jobs (13% of county employment). Agriculture paid US$616 million (13%) of total county labor income and contributed US$0.9 billion (13%) of county value added. The livestock sector was the dominant agricultural activity, generating over half of the agricultural jobs, income, and value added. The contributions of agriculture are far reaching throughout the economy. The top sectors where agriculture generated jobs and value added in Washington County were: manufacturing agriculture, forestry, fishing, and hunting; retail trade; wholesale trade; health and social services; and transportation and warehousing. These results highlight the importance of agriculture to the local economy.

Optimization of Conservation Practices in the Watershed

The Arkansas NIFA–CEAP also applied three types of analysis to evaluate economic and environmental tradeoffs, measured as changes in TP and sometimes nutrient loading (N and P) at the watershed level. This study applied a genetic algorithm to compare economic and environmental objectives over 171 conservation practices, with various combinations of buffer zones, pasture management, and litter application practices in the Lincoln Lake Watershed. The nondominated sorting genetic algorithm technique allowed the authors to compute the economic and environmental impacts for a subset of the entire population of conservation practices, fields, and crops. The solution is plotted along an underlying Pareto efficiency frontier. The genetic algorithm assures that only Pareto optimal points—systems that improve at least one objective and do not decrease the other—are plotted, thus reducing the number of systems that need to be considered. The resulting frontier shows the tradeoffs between the two objectives.

The cost per unit to reduce P, the cost per unit to reduce N, and the cost per unit to reduce P and N jointly were compared. As with the other methods, a few conservation practices were consistently ranked at the top of all three analyses. With regard to tradeoffs, the low cost conservation practices scenario could reduce TP by 76%, while increasing costs by 2%, about US$5.40 ha^{-1} (US$2.91 ac^{-1}). Total P can be reduced further with the medium and high cost options, but the cost would more than triple for the medium scenario and would increase by over tenfold for the high cost option. The best-ranked systems commonly recommended optimal grazing practices, a buffer zone, the lower rate of litter application, no alum, and spreading in the summer.

Risk Assessment of Combinations of Conservation Practices

Economic analyses also included the ranking of conservation practice alternatives with regard to risk using Simulations and Econometrics to Analyze Risk (SIMETAR). To evaluate potential effects on net returns and water quality, estimated N and P loadings for conservation practices alternatives were combined with a risk model using stochastic dominance with respect to a function and stochastic efficiency with respect to a function.

The analysis used data from SWAT (bermudagrass yield and water quality associated with each conservation practices combination) as well as bermuda hay prices, production costs, and conservation practice costs data to create net returns distributions. For each conservation practice combination, N and P loadings and net returns were simulated to evaluate the impact of decision makers' risk attitudes on scenario preferences under net returns, TP, and TN runoff reductions. While the resulting order of the rankings at the watershed and the subbasin levels were very consistent, rankings differed dramatically depending upon whether the analysis was conducted based on environmental or economic goals. In general, the preferred scenarios to reduce P or N runoff decreased net returns considerably. Consequently, producers might be reluctant to adopt scenarios that reduce net returns, regardless of their water quality benefits. Producers' attitudes towards risk had an impact on selecting scenarios. There were some conservation practices that sustained water quality and were profitable for agricultural producers. In addition, the analysis showed that cost and net risk cannot be ignored when selecting conservation practices. Risk-neutral, slightly risk-averse, and extreme risk-averse producers would prefer different conservation practices. In other words, producers' risk attitudes matter, and this can influence adoption of conservation practices in the watershed.

Outreach

The specific outreach objectives for the Lincoln Lake Watershed NIFA–CEAP were to initiate stakeholder input on collection of new data and availability and quality of historic data, collect stakeholder feedback on modeling scenarios, and develop education and demonstration programs to educate watershed stakeholders and state agency personnel.

In order to meet the outreach objectives, a new county extension agent was hired to work exclusively in the Lincoln Lake Watershed. This was the only NIFA–CEAP to hire an extension agent to work with stakeholders. Initially, the new agent worked with a well-respected agricultural agent in order to meet key stakeholders and to gain acceptance within the watershed. The new agent conducted farm visits and educational workshops, collected survey feedback, pasture and nutrient management records, and developed fact sheets, trainings, and numerous newspaper articles.

Because of long-term nutrient issues in the watershed, multiple extension outreach and education activities occurred in this watershed years before the NIFA–CEAP began, which included material development, extension presentations, and approaches to encourage conservation practice adoption. These earlier extension efforts made the NIFA–CEAP extension efforts easier. Prior to the NIFA–CEAP, watershed and county extension councils were formed; a similar format was continued in the Arkansas NIFA–CEAP. A watershed focus group and steering committee was formed that consisted of five farmers, two nonfarmers, a county judge, and a conservation district board member. This group helped guide the outreach component

Figure 9.2
Environmental stewardship sign that was prepared and distributed to the farmers who met conditions for implementing conservation practices on their fields.

of the project and the development of the stakeholder survey. The watershed focus group was critical to the outreach success.

This NIFA–CEAP was initially announced to the watershed stakeholders through a mailing to each business, farm, or residence in the rural portion of the watershed. The mailing contained information about the project and two initial project meetings; only 20 of 318 stakeholder families attended. There were several subsequent news releases that highlighted the project to the community. About the same time, farmers began speaking to each other about the project and the conservation practices, and requests for farm visits increased. As a result of farmer-to-farmer referrals and a highly effective one-on-one education program led by the NIFA–CEAP extension agent, almost all of the targeted agricultural producers ultimately participated in project activities, which resulted in a high adoption level of one or more conservation practices.

The NIFA–CEAP extension agent used results from the stakeholder survey to develop new educational materials along with specific programs: nutrient management trainings, conservation practice field days, beef cattle short courses, pesticide applicator trainings, one-on-one farm visits, and a stewardship recognition program. The stewardship recognition program recognized producers within the Lincoln Lake Watershed that were using three or more conservation practices on their farms, and there were 54 farms recognized as environmental stewards (figure 9.2). This program, in turn, spawned the development of a stewardship program by Audubon, Arkansas, in the Upper White River Watershed. As the project progressed, outreach efforts reached business, households, and agricultural communities and organizations, such as the local rotary clubs, farm bureau, cattlemen's association, and the Southeast Asian American Farmers Association.

The NIFA–CEAP extension agent was able to build trust with the producers he served. This was critical in increasing conservation practice adoption. This trust allowed the Lincoln Lake Project team to obtain information from 37 of 45 preexisting NMPs in the watershed for modeling. Additionally, 18 NMPs were created and were also used in the modeling. Furthermore, 39 additional NMPs were developed outside of the Lincoln Lake Watershed as a direct result of the project's related educational programming. In all, NMPs were written for over 3,525 ha (8,710 ac) within and adjacent to the watershed.

The combination of working with key and informed stakeholders, with a stakeholder steering committee, in one-on-one settings, and in large groups with indirect and direct educational methods resulted in high adoption levels of one or more conservation practices and high quality data collection and retrieval for use in other aspects of the project. Additionally, reaching more than 1,000 farmers from other places within the county with project education and outreach led to adoption of conservation practices beyond the Lincoln Lake and Illinois River Watershed boundaries.

Lincoln Lake Watershed National Institute of Food and Agriculture–Conservation Effects Assessment Project Publications

This project's results have been published in numerous journal articles, abstracts, and other publications. The list of these publications is provided below.

Journal Articles

Chaubey, I., L. Chiang, M.W. Gitau, and M. Sayeed. 2010. Effectiveness of BMPs in improving water quality in a pasture dominated watershed. Journal of Soil and Water Conservation 65(6):424-437, doi:10.2489/jswc.65.6.424.

Gitau, M.W., L. Chiang, M. Sayeed, and I. Chaubey. 2011. Computational approaches to evaluating BMP scenarios considering stochasticity of weather. Simulation doi:10.1177/0037549711402524.

Pennington, J.H., M.A. Steele, K.A. Teague, B. Kurz, E. Gbur, J. Popp, G. Rodríguez, I. Chaubey, M. Gitau, and M.A. Nelson. 2008. Breaking ground: A cooperative approach to collecting information on conservation practices from an initially uncooperative population. Journal of Soil and Water Conservation 63(6):208A-211A, doi:10.2489/jswc.63.6.208A.

Popp, J., G. Rodríguez, E. Gbur, and J. Pennington. 2007. Stakeholders' perceptions in addressing water pollution. Journal of Environmental Monitoring and Restoration 3:255-263, doi:10.4029/2007jemrest3no15.

Rodriguez, H.G., J. Popp, E. Gbur, and I. Chaubey. 2011. Environmental and economic impacts of reducing total phosphorous runoff in an agricultural watershed. Agricultural Systems 104(8):623-633, doi:10.1016/j.agsy.2011.06.005.

Rodriguez, H.G., J. Popp, C. Maringanti, and I. Chaubey. 2011. Selection and placement of best management practices used to reduce water quality degradation in Lincoln Lake Watershed. Water Resources Research 47:W01507, doi:10.1029/2009WR008549.

Abstracts

Chaubey, I., M. Gitau, D. Ennannay, M. Nelson, E. Gbur, J. Popp, and J. Pennington. 2006. Effectiveness and optimization of BMPs in improving water quality impacted by land application of animal manure. Abstract published in the proceedings of the workshop called Managing Agricultural Landscapes for Environmental Quality: Strengthening the Science Base. Kansas City, MO. October 11-13, 2006.

Chaubey, I., M.W. Gitau, J.H. Popp, E. Gbur, J. Pennington, M.A. Nelson, L. Chiang, and G. Rodríguez. 2008. BMP effectiveness assessment for a pasture dominated watershed: Results from two years of CEAP assessment. Abstract published in the proceedings of the 2008 USDA Cooperative State Research, Education, and Extension Service National Water Conference, Sparks, NV.

Popp, J., and G. Rodríguez. 2007. The role of stakeholders' perceptions in addressing water quality disputes in an embattled watershed. Abstract. Journal of Agricultural and Applied Economics 39(2):418.

Popp, J., G. Rodríguez, J. Pennington, and E. Gbur. 2008. Factors that influence stakeholder groups perceptions of water quality: Lessons for policy makers. Abstract. Journal of Agricultural & Applied Economics 40(2):738.

Popp, J., G. Rodríguez, J. Pennington, G. Gbur. M. Steele, I. Chaubey, and M. Gitau. 2006. From conflict to cooperation: Enlisting stakeholders to address water quality disputes in an embattled watershed. Abstract published in the proceedings of the workshop called Managing Agricultural Landscapes for Environmental Quality: Strengthening the Science Base. Soil and Water Conservation Society Managing Agricultural Landscapes Conference. Kansas City, MO. October 11-13, 2006.

Rodríguez, H.G., J. Popp, C. Maringanti, and I. Chaubey. 2010. Selection and placement of best management practices used to reduce total phosphorous runoff in the Lincoln Lake watershed in northwest. Abstract. Journal of Agricultural and Applied Economics 42(3):598.

Conference Papers, Posters, and Presentations

Chaubey, I. 2007. Nutrient limitation, nutrient retention, and sediment nutrient interactions in an agriculturally dominated watershed. Hydraulics Group Seminar Series, Purdue University. March 5, 2007.

Chaubey, I. 2008. BMP effectiveness assessment for a pasture dominated watershed: Results from two years of CEAP assessment. Improving Indiana Waters: Using monitoring data to show change. Indianapolis. December 3, 2008.

Chaubey, I. 2009. BMP effectiveness evaluation in a pasture watershed: What have we learned from CEAP evaluation? USDA Agricultural Research Service National Soil Erosion Laboratory Seminar Series. May 13, 2009.

Chaubey, I. 2009. Effectiveness of BMPs in controlling nonpoint source pollutants from a CEAP watershed. 2009 International SWAT Conference, Boulder, CO. August 5-7, 2009.

Chaubey, I., L. Chiang, M.W. Gitau, and J.H. Pennington. 2009. BMP effectiveness evaluation in a CEAP watershed: What have we learned from watershed modeling? 2009 USDA Cooperative State Research, Education, and Extension Service National Water Conference, St. Louis, MO. Lincoln Lake CEAP Final Report Page 34. Feb 8–12, 2009.

Chaubey, I., E. Gbur, B. Kurz, M. Nelson, J. Popp, M. Steele, and K. Teague. 2006. Effectiveness and optimization of BMPs in improving water quality from an agriculturally dominated watershed. San Antonio, TX: USDA Cooperative State Research, Education, and Extension Service National Water Quality Conference.

Chaubey, I., M. Gitau, L. Chiang, J.H. Popp, E. Gbur, M.A. Nelson, J. Pennington, G. Rodriguez, and B. Kurz. 2008. BMP effectiveness assessment for a pasture dominated watershed: Results from two years of CEAP assessment. Annual Conference of the USDA Cooperative State Research, Education, and Extension Service. Sparks, NV. February 4 – 7, 2008.

Chiang, L., and I. Chaubey. 2009. Quantifying the impacts of land use changes on BMP performance in a pasture dominated watershed. Paper No. 097437, Annual Conference of the American Society of Agricultural and Biological Engineers, Reno, NV.

Chiang, L., and I. Chaubey. 2010. Hindcasting of sediment and nutrient losses from a dynamic land use watershed. Paper No. 1009162, Annual Conference of the American Society of Agricultural and Biological Engineers, Pittsburgh, PA.

Chiang, L., M. Gitau, and I. Chaubey. 2008. Effectiveness of BMPs considering uncertainties in weather patterns in a pasture dominated watershed. Paper No. 083549, Annual Conference of the American Society of Agricultural and Biological Engineers, Providence, RI.

Gbur, E.E., M.W. Gitau, I. Chaubey, and J.H. Pennington. 2009. Water quality trend in a CEAP watershed. 2009 USDA Cooperative State Research, Education, and Extension Service National Water Conference, St. Louis, MO.

Gitau, M., I. Chaubey, and J.H. Popp. 2007. Effectiveness and optimization of BMPs in improving water quality from agriculturally dominated watersheds. Annual Conference of the USDA Cooperative State Research, Education, and Extension Service, Savannah, GA. January 28-31, 2007.

Gitau, M., L. Chiang, I. Chaubey, and S. Mohammed. 2007. Evaluating best management practice impacts on water quality considering stochasticity of weather. Poster presented at the CRI, High Performance Computing Seminar, Purdue University. October 25, 2007.

Gitau, M., L. Chiang, I. Chaubey, and M. Sayeed. 2008. Computational approaches to evaluating BMPs considering stochasticity of weather. Paper No. 083577, Annual Conference of the American Society of Agricultural and Biological Engineers, Providence, RI.

Gitau, M.W., I. Chaubey, M.A. Nelson, and J.H. Pennington. 2007. Analyses of BMP and land use change effects in a northwest Arkansas agricultural watershed. Paper No. 072244, American Society of Agricultural and Biological Engineers, St. Joseph, MI.

Gitau, M.W., L. Chiang, I. Chaubey, and M. Sayeed. 2008. Evaluating BMP scenario under CEAP: Approaches to handling a multitude of runs and large datasets. Annual Conference of the USDA Cooperative State Research, Education, and Extension Service. Sparks, NV. February 4–7, 2008.

Merriman, K., M. Gitau, and I. Chaubey. 2006. A tool for estimating best management practice effectiveness in Arkansas. Soil and Water Conservation Society Managing Agricultural Landscapes for Environmental Quality: Strengthening the Science Base. Kansas City, MO. October 11-13, 2006.

Pennington, J., J. Popp, H.G. Rodriguez, E. Gbur, I. Chaubey, M.W. Gitau, L. Chiang, and M.A. Nelson. 2009. Cooperative stakeholder engagement and participation for gaining effective Lincoln Lake CEAP Final Report Page 35 results. Poster presented at the 2009 USDA Cooperative State Research, Education, and Extension Service National Water Conference, St. Louis, MO. February 8–12.

Pennington, J., J. Popp, H.G. Rodriguez, E. Gbur, I. Chaubey, M.W. Gitau, and M.A. Nelson. 2007. Lincoln Lake Watershed Project a Conservation Effectiveness Assessment Project. Arkansas Water Resources Conference, Fayetteville, AR.

Popp, J., and H.G. Rodríguez. 2007. The role of stakeholders' perceptions in addressing water quality disputes in an embattled watershed. Selected paper presentation for the Southern Agricultural Economics Association Meetings. Mobile, AL. February 5-7, 2007.

Popp, J., H.G. Rodríguez, J. Pennington, and E. Gbur. 2007. How attitudes of important stakeholder groups can influence effective water quality management. Selected paper for the American Agricultural Economics Association. Portland, OR. July 29–August 1, 2007.

Popp, J., H.G. Rodríguez, J. Pennington, and E. Gbur. 2007. The role of stakeholders' perceptions in addressing water quality disputes in an embattled watershed. Selected paper for the National Conference on Agriculture & Natural Resources Conservation & Management. Dover, DE. February 22-24.

Popp, J., H.G. Rodríguez, J. Pennington, and E. Gbur. 2008. Factors that influence stakeholder groups perceptions of water quality: Lessons for policy makers. Poster Southern Agricultural Economics Association annual meetings, Dallas, TX. February 3-7, 2008.

Popp, J., H.G., Rodríguez, J. Pennington, and E. Gbur. 2009. What factors influence water quality in Lincoln Lake Watershed? Perceptions of important stakeholders. Annual Conference of the USDA Cooperative State Research, Education, and Extension Service. St. Louis, MO. February 8–12, 2009.

Popp, J., H.G. Rodríguez, J. Pennington, E. Gbur, and I. Chaubey. 2006. Poster: From conflict to cooperation: Enlisting stakeholders to address water quality disputes in an embattled watershed. National Public Policy Education Fayetteville, AR. September 17-20.

Popp, J., H.G. Rodríguez, J. Pennington, E. Gbur, and I. Chaubey. 2006. Poster: From conflict to cooperation: Enlisting stakeholders to address water quality disputes in Lincoln Lake Watershed. Arkansas Watershed Advisory Group: Clean Water, Stronger Communities, Fayetteville, AR. November 2-4.

Popp, J., H.G. Rodríguez, J. Pennington, E. Gbur, M. Steele, I. Chaubey, M. Gitau. 2006. From conflict to cooperation: Enlisting stakeholders to address water quality disputes in an embattled watershed. Presentation at the Soil and Water Conservation Society Managing Agricultural Landscapes Conference. Kansas City, MO. October 11-13.

Rodríguez, H.G., and C. Maringanti. 2009. Selection and placement of best management practices used to reduce total phosphorous runoff in the Lincoln Lake Watershed in northwest Arkansas. Poster presented at the Annual Research and Watershed Conference. Arkansas Water Resources Center. Fayetteville, AR. April 14-15, 2009.

Rodríguez, H.G., J. Popp, E. Gbur, and I. Chaubey. 2010. Evaluation of best management practices under net cost risk. Selected poster presented at the American Agricultural Economics Association Annual Meeting. Denver, CO. July 24-27, 2010.

Rodríguez, H.G., J. Popp, E. Gbur, and I. Chaubey. 2011. Selection of best management practices to control non-point sources of pollution under environmental and economic uncertainty. Poster presented at the American Agricultural Economics Association Annual Meeting, Pittsburgh, PA. July 25-27, 2011.

Rodríguez, H.G., J. Popp, C. Maringanti, and I. Chaubey. 2010. Selection and placement of best management practices used to reduce total phosphorous runoff in the Lincoln Lake Watershed in northwest Arkansas. Selected poster presented at the Southern Agricultural Economics Association annual meeting. Orlando, FL. First Place Winner. February 7-9, 2010.

Zhao, L., K.S. Subramanian, C.X. Song, S. Kumar, V. Merwade, C. Maringanti, I. Chaubey, M. Sayeed, and R.S. Govindaraju. 2009. A Web-interface for SWAT modeling on the TeraGrid. 2009 International SWAT Conference, Boulder, CO. Lincoln Lake CEAP Final Report Page 36. August 5-7, 2009.

Theses and Dissertations

Chiang, L. 2010. Evaluation of the Effectiveness of BMPs for Improving Water Quality in a Pasture Dominated Watershed. PhD dissertation. Purdue University, West Lafayette, IN.

Rodríguez, H.G. 2009. Evaluation of Best Management Practices to Reduce Nutrients Runoff in Watersheds in Arkansas. PhD dissertation. University of Arkansas, Fayetteville, AR.

Fact Sheets

Pennington, J., M. Daniels, and A. Sharpley. 2008. Best management practices for livestock farms. Fact sheet no. FSA9527. University of Arkansas-Division of Agriculture.

Pennington, J., M. Daniels, and A. Sharpley. 2008. Using the watershed approach to maintain and enhance water quality. Fact sheet no. FSA9526. University of Arkansas-Division of Agriculture.

Press Articles Written by John Pennington

- Farmers work hard improving water quality. *In* The Lincoln Leader 08/13/08.
- Cost share assistance for implementing best management practices. *In* Ozarks Farm & Neighbor 08/11/08.
- Disposal of dead animals. *In* Ozarks Farm & Neighbor 07/03/08.
- Streambank erosion: Prevention equals protection. *In* Ozarks Farm & Neighbor 05/19/08.
- Fertilizers: Apply with care. In 06/09/08.
- Streambank erosion: Prevention equals protection. *In* Ozarks Farm & Neighbor 05/19/08.
- Water Source Options. *In* Ozarks Farm & Neighbor 04/28/08.

- A no-cost to low-cost way to maintain high water quality. *In* Ozarks Farm & Neighbor 02/25/08.
- Save money with nutrient management. *In* Ozarks Farm & Neighbor 02/04/08.
- Watershed what? Stakeholder who? *In* The Lincoln Leader 12/07/2007.
- Controlled grazing adds value. *In* Ozarks Farm & Neighbor 11/12/07.
- Money for farm BMP till there. *In* The Lincoln Leader 10/03/2007.
- No better time to lime. *In* Ozarks Farm & Neighbor 10/01/07.
- There's more to record keeping: Advantages of detailed record keeping on the farm. *In* Ozarks Farm & Neighbor 09/12/07.
- Lincoln Lake Watershed Project identifies 10 affordable best management practices for northwest Arkansas farmers. *In* Ozarks Farm & Neighbor 08/20/07.
- A cheap source of nitrogen still exists. *In* Ozark Farm & Neighbor 07/30/07.
- Invest now or pay later: Basing fertilization on soil test recommendations. *In* Ozarks Farm & Neighbor May 28, 2007 and Farm Talk 06/13/07.
- You might not know manure. *In* The Lincoln Leader 06/06/07 and in Ozarks Farm & Neighbor 06/18/ 2007.
- The ABC's of BMPs: What are they and why are they important? *In* Ozarks Farm & Neighbor 07/09/2007 and Farm Talk June 2007.
- Good manure management explained. *In* The Lincoln Leader 03/14/07.
- Soil test before you fertilize to help maintain water quality. *In* The Lincoln Leader 02/07/07.
- A new nutrient management regulation for the new year. *In* White River Current 01/11/2007. Lincoln Lake -CEAP Final Report Page 37.
- Farmers stewarding watersheds *In* The Lincoln Leader 12/13/06.
- Lincoln Lake Watershed surveys important. *In* The Lincoln Leader 08/09/06.

Newspaper Articles Written by Others

- Study shows opinions toward water quality in Washington County. *In* Northwest Arkansas Times 04/24/08.
- Farmers, others talk grazing methods. *In* Northwest Arkansas Times 11/07/07.
- Farmers recognized as environmental stewards. *In* Northwest Arkansas Times 10/30/07.
- Best management policies urged. *In* The Lincoln Leader 08/15/07.
- Farmers, residents blame each other for water woes. *In* The Arkansas Democrat Gazette 07/30/2007. Lincoln Lake CEAP Final Report Page 38.

Funding

Funding for this project was provided by the USDA NIFA–CEAP (Award No. 2005-48619-03334).

Project Personnel

Indrajeet Chaubey, at Purdue University, was the project director, and Jennie Popp, Marc Nelson, and Edward Gbur (University of Arkansas) were coproject directors. Graduate students included Li-Chi Chiang and German Rodriguez. Margaret Gitau was a postdoctoral research associate, and John Pennington was the extension agent on this project, continues to work with Arkansas Cooperative Extension.

This project was a cooperative effort between the University of Arkansas, Purdue University, the University of Arkansas Cooperative Extension Service, the USDA NRCS, and the Arkansas Natural Resources Commission.

References

Chiang, L., I. Chaubey, M.W. Gitau, and J.G. Arnold. 2010. Differentiating impacts of land use changes from pasture management in a CEAP watershed using the SWAT model. Transactions of the American Society of Agricultural and Biological Engineers 53(5):1569-1584.

Gitau, M.W., I. Chaubey, E. Gbur, J.H. Pennington, and B. Gorham. 2010. Impact of land-use change and best management practice implementation in a Conservation Effects Assessment Project watershed: Northwest Arkansas. Journal of Soil and Water Conservation 65(6): 353-368, doi:10.2489/jswc.65.6.353.

Nelson, M.A., L.W. Cash, and G.K. Trost. 2008. Water quality monitoring of Moores Creek above Lincoln Lake 2006 and 2007. University of Arkansas, Fayetteville (unpublished).

Vendrell, P.F., M.A. Nelson, L.W. Cash, K.F. Steele, R.W. McNew, and J.F. Murdock. 1997. Continuation of the Illinois River water quality monitoring of Moores Creek. Non-Point Source Final Report. Submitted to Arkansas Soil and Water Conservation Commission. Arkansas Water Resources Center Publication No. MSC-213.

Vendrell, P.F., K.F. Steele, M.A. Nelson, L.W. Cash, and R.W. McNew. 2000. Extended water quality monitoring of the Lincoln Lake Watershed. Final Report. Submitted to Arkansas Soil and Water Conservation Commission. Arkansas Water Resources Center Publication No. MSC-296.