Chapter 3

Conservation Practice Implementation and Maintenance: National Institute of Food and Agriculture–Conservation Effects Assessment Project

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Land treatment is the implementation of conservation practices to achieve water quality or agricultural goals. Edge-of-field research on the effectiveness of conservation practices has been conducted for decades, and there is a large body of knowledge gained from these efforts. Hundreds of research projects and their associated journal articles relate, with varying degrees of uncertainty, potential environmental benefits with specific conservation practices. The volume of research available is evident in the compilation of bibliographies by the Water Quality Information Center at the National Agricultural Library, in conjunction with the USDA, to support the Conservation Effects Assessment Project (CEAP). Two bibliographies describe considerable literature related to agricultural conservation and the protection of natural systems (Gagnon et al. 2004; Gagnon et al. 2008). Subsequent bibliographies on other conservation practices, such as wetlands (Maderik et al. 2006b), grazing lands (Maderik et al. 2006a), and effects of conservation practices on fish and wildlife (Gagnon et al. 2008) have also been compiled. These bibliographies, collectively, include thousands of scientific citations on the effects of conservation practices.

Another effort to compile publications on conservation practice effectiveness in the protection of water quality was through a 11-year series of articles that highlighted numerical pollutant reductions from nonpoint sources, including agriculture (Line et al. 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002; Gale et al. 1993). As expected, the range in effectiveness for a given practice or system of conservation practices varied from negative effectiveness to 100%, based on agroecological region, site specific characteristics (soil, slope, etc.), experimental design, and other factors.

When conservation practice effectiveness data are compiled through literature reviews, results show that the effectiveness range for a given conservation practice varies widely, as developers of watershed-scale decision support systems or conservation practice effectiveness tools have found (Osmond et al. 1997; Gitau et al. 2005). Despite the range of measured effectiveness values, the majority of the data confirm the value of individual conservation practices at reducing pollutant export from agricultural land at the field scale, especially when used as a system (i.e., multiple conservation practices to affect the same pollutant).

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In addition to edge-of-field documentation, research on effectiveness of conservation practices has occurred at the watershed scale; much of this work has been conducted through specific programs such as the Rural Clean Water Program (RCWP), Hydrologic Unit Area (HUA), and US Environmental Protection Agency (USEPA) Section 319 National Nonpoint Source Monitoring Program (NNPSMP), as discussed in Chapter 1. In determining conservation practice effectiveness at a watershed scale, the major lessons learned relative to land treatment in the RCWP (Gale et al. 1993) follow:

1. Land treatment should be targeted to critical areas contributing the greatest pollutant load to the receiving waters.
2. A high level of critical area implementation of practices is necessary to effect a significant water quality change.
3. Nutrient and pesticide management and conservation tillage were the most cost-effective in terms that they cost the least for the greatest potential for water quality benefits.
4. Greater emphasis should be placed on management and maintenance of conservation practices.
5. Allowing flexibility in conservation practice implementation helped increase adoption.
6. All confined animal feeding operations or animal feeding operations in the watershed must have conservation practices implemented to reduce agricultural pollutants.

As noted in Chapter 1, one of the follow-up programs to the RCWP was the USEPA Section 319 NNPSMP. A number of watershed projects in the NNPSMP have demonstrated significant reductions of agricultural pollutants; two of the National Institute of Food and Agriculture–Conservation Effects Assessment Project (NIFA–CEAP) watershed studies were part of this protocol (Iowa and New York) (Spooner et al. 2010). Groundwater nitrogen (N) was reduced through the use of crop rotations in the Eastern Snake River Plain Groundwater Project in Idaho. In Illinois, most sediment was derived from stream banks rather than agricultural fields, and sediment basins significantly reduced the sediment entering Lake Pittsfield. In Long Creek, North Carolina, there were 75% and 70% decreases in median annual total phosphorus (TP) and fecal coliform levels, respectively, at downstream stations due to conservation practice implementation. Additionally, 43%, 75%, 74%, and 85% reductions in weekly nitrate + nitrite (nitrate-nitrogen [NO_3-N]), total Kjeldahl N, TP, and total suspended sediment loads, respectively, were documented in a small stream draining a dairy pasture after the stream was fenced. Exclusion fencing resulted in decreases in stream N-species, TP, and suspended-sediment concentrations, but dissolved phosphorus (P) concentrations increased in the Pequea and Mill Watersheds in Pennsylvania. In the Lake Chaplain area of Vermont, mean TP, total Kjeldahl N, and total suspended sediment loads were reduced by 49%, 38%, and 28%, respectively, when livestock were excluded from the streams in selected areas, riparian zones were created or improved, degraded stream banks were revegetated, stream crossings were constructed, and heavy-use areas were improved or eliminated. Other projects were not able to demonstrate water quality improvements due to the implementation of conservation practices as clearly.

Tomer and Locke (2011) published a review of the USDA Agricultural Research Service (ARS) Benchmark Watershed studies that were part of CEAP. Four of the fourteen watersheds were also NIFA–CEAP watersheds: Goodwater Creek, Missouri; Little River, Georgia; Town Brook, New York; and Walnut Creek, Iowa. The authors demonstrated again how difficult it is to relate implementation of conservation practices to water quality change.

The effectiveness of land treatment relates to the technical role of conservation practices (as discussed above). However, equally or potentially more important is the role of sociologi-

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cal and economic factors; conservation practices are no better than their implementation and maintenance by farmers. As with the science on conservation practice effectiveness, a large body of work has been developed to assess these important human dimension characteristics. Makuch et al. (2004) have also developed a bibliography listing research studies related to the human dimension of implementing agricultural conservation systems through the Water Quality Information Center at the National Agricultural Library in support of the CEAP. Specific literature for the social dimension can be found in Chapters 2 and 6 of this synthesis.

Limited understanding of water quality changes associated with conservation practice implementation is not from lack of effort over the years as seen from this very brief introduction on the effects of conservation practices. In order to relate conservation practice effectiveness with changes in aggregate water quality, it is necessary to relate conservation practice implementation at the watershed scale with water quality changes over time. Because there is significantly less knowledge about these relationships at the watershed scale, the NIFA–CEAP was expected to add to this body of knowledge.

Role of Land Treatment in the National Institute of Food and Agriculture–Conservation Effects Assessment Project

The overall long-term goal of the NIFA–CEAP effort was to understand how to optimize the achievement of locally defined water quality goals by selecting a suite of applicable conservation practices, distributing these practices strategically in a watershed, and implementing them in a timely manner (Duriancik et al. 2008). Clearly, the entire focus of the effort was aimed at determining the effectiveness of conservation practices (land treatment) in protecting water resources at a watershed scale.

Most previous research could not integrate landscape effects and timing of conservation practice implementation on water quality changes because it was often conducted at a plot or field scale. Thus, NIFA was interested in expanding agricultural conservation practice research in order to evaluate the impacts of interactions among conservation practices and their biophysical setting, including spatial and temporal characteristics, on water quality changes at the watershed scale for predominantly agricultural watersheds.

The protocol for the NIFA–CEAP was designed to be retrospective in order to account for the lag time between land treatment and water quality response (Meals et al. 2009) and thus was based on existing land treatment at the watershed scale. It was assumed that land treatment practices would include erosion control structures and tillage management, nutrient and animal waste management, water management (both irrigation and drainage), riparian buffers, and pest management. It was also expected that there would be a minimum of five years of land-use history and georeferenced conservation practice data available to each NIFA–CEAP. Furthermore, all the NIFA–CEAP watershed studies were expected to answer four major questions about land treatment:

1. Within the hydrologic and geomorphic setting of a watershed, how do the timing, location, and suite of implemented agricultural conservation practices affect surface and/or groundwater quality at the watershed scale?
2. What are the relationships among conservation practices implemented in a given watershed with respect to their impact on water quality? Are the effects additive, contradictory, or independent?

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3. What social and economic factors within the study watershed either facilitate or impede implementation or proper maintenance of conservation practices?
4. What is the optimal set or suite of conservation practices and what is their optimal placement within the watershed in order to achieve water quality goals or to provide acceptable reductions in water quality impairments?

The first two questions were expected to be addressed by relating land treatment and water quality monitoring data, spatially and temporally. The economic portion of question three and the last question were expected to be addressed primarily through modeling. The sociological factors affecting conservation practice adoption were typically explored by most of the projects through surveys of farmers and other stakeholders.

Summary of Land Treatment Activities in the National Institute of Food and Agriculture–Conservation Effects Assessment Project

The principal land treatment activities for each of the 13 NIFA–CEAP watershed studies are summarized in table 3.1. Specific land treatment details for each project are included in Part II: Chapters 9 to 21 of this book.

Four of the NIFA–CEAP watershed studies (Georgia, Missouri, Ohio, and Oregon) relied exclusively on the USDA Natural Resources Conservation Service (NRCS) or farmer-implemented watershed-scale conservation practices that were part of normal planning and implementation, and as such, the majority of the practices focused on sediment and erosion control (terraces, grassed waterways, and/or conservation tillage). In the Eagle Creek Watershed, Indiana, USEPA Section 319 funds were used to augment USDA NRCS conservation practice funding for conservation tillage, nutrient management, cover crops, and filter strips (Chapter 13). Other NIFA–CEAP studies, however, implemented conservation practices that were part of special program or project efforts, as well as using standard USDA NRCS programs. Long-term USDA ARS plot- and/or field-research augmented conservation practice effectiveness results from the Georgia and Missouri NIFA–CEAP studies.

The Paradise Creek Watershed in Idaho was located within the Palouse region of the Pacific Northwest, which is known for extremely high erosion rates. To combat excessive erosion, the Solutions to Environmental and Economic Problems (STEEP) research and education program began in 1976 as a partnership between USDA ARS and state agricultural experiment stations (Idaho, Oregon, and Washington). Research and outreach focused on conservation practices that included reduced-tillage or no-tillage and changes in cropping systems. As a consequence of the STEEP efforts and in association with USDA NRCS conservation programming, estimated or computed cropland erosion rates were reduced by over 75%. In addition to the ongoing STEEP program, the Paradise Creek Watershed used USEPA Section 319 funding to install more diverse conservation practices, such as riparian buffers, structural improvements, gulley plugs, and stream and wetland restoration. Some urban practices (stream and riparian restoration and wetland construction) were also installed with the funding (Chapter 12).

Watersheds with nutrient impairments generally focused on practices to reduce nutrient losses rather than on sediment and erosion control practices. An Iowa paired-watershed study compared the water quality of streams draining two watersheds, one in traditional corn and soybean row crops (Squaw Creek) and the other in a slow transformation from row crop to tall grass

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Table 3.1
Summary of principal land treatment activities of the Conservation Effects Assessment Project.

Project	Principal activities
Arkansas	• Over 20 years of nutrient management focus from the USDA NRCS and extension. • Conservation practices were monitored via land-use maps over six years by conducting an inventory of farm-level best management practice implementation and recordkeeping and by meeting with farmers to collect information. • Focused on nutrient management of broiler litter.
Georgia	• Conservation practices documented by obtaining as a digital data set from USDA Soil Conservation Service/NRCS files for the 1980 to 2005 time period. • The most dominant conservation practice was natural riparian forest buffers, which simply existed as landscape features and were not intentionally installed. • Implemented conservation practices with the largest number of acres were nutrient management, pest management, grassed waterways, and tree plantings, but many other practices were used.
Idaho	• Crop rotations, tillage practices, and conservation practices were documented on a field-by-field basis. • Land treatment (crop rotation, tillage practices, and conservation practices) was monitored by starting with yearly land-use digital maps in 1995 to determine the practices implemented. Additional practices were added to the record when practices were implemented through the US Environmental Protection Agency Section 319 funds. • Many sediment-reducing conservation practices were developed and introduced through the federally funded Solutions to Environmental and Economic Problems project to reduce soil erosion in the Palouse Region. Practices included three-year or longer conservation cropping rotations, conservation tillage, and direct seeding. • Additional conservation practices were installed in Paradise Creek Watershed as part of a US Environmental Protection Agency Section 319 project (gully plugs, conservation tillage, buffer installation, stream and wetland restoration, and land conversion using the Conservation Reserve Program); many of the conservation practices were installed as a suite of practices.
Indiana	• USDA NRCS records, landowner interviews, and spatial analysis were combined to identify, inventory, and locate the installation and operation of conservation practices. • Predominant conservation practices were grassed waterways, filter strips, cover crops, and conservation tillage.
Iowa	• Land-use practices for both creeks were recorded on an annual basis during the life of the project, and historical land use in the watersheds (prerestoration) was compiled from aerial photography. • Since 1993, row crop production decreased as prairie conversion occurred on 23% of the treatment watershed (Walnut Creek). Row crop production increased by 71% to 80% in the control (Squaw Creek).
Kansas	• Data on conservation practices, their locations, and times of implementation from 1994 to 2006 were primarily obtained from a stakeholder database. • Some conservation practices were implemented through standard USDA NRCS programs, while other practices were funded by the City of Wichita through the Citizen Management Committee, composed of local farmers. • Primary conservation practices were cover crops, filter strips, crop rotations, management intensive grazing systems, strip cropping, no-tillage production, grassed waterways, terraces, and permanent grass plantings (Conservation Reserve Program).
Missouri	• Crop history in the watershed was developed from Farm Service Agency records in combination with aerial and satellite images and other sources. Because access to conservation practice information was denied by the Farm Service Agency, data were developed from resource and/or district conservationists with the use of aerial photographs. Management practices were assessed in 2006 through a survey of individual farmers in the watershed. • Primary conservation practices include grassed waterways and terraces (with and without underground outlets) and conservation tillage.

Continued

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Table 3.1 Continued

Project	Principal activities
Nebraska	• Conservation practice implementation was tracked uniquely in this project. Since 1988, the farmers in the Buffalo-Hall County Phase III area have been required to file detailed annual reports for each well and report nitrogen in irrigation well water, residual soil nitrogen, and quantity of water applied. • Conservation practices focused on fertilizer and irrigation management activities, which are closely monitored and/or regulated by the Central Platte Natural Resources District.
New York	• Field-scale, detailed land-use data, including conservation practice implementation, were held by the Watershed Agricultural Council. There were no corresponding dates for installation of practices. When the data were transferred to other parties, such as researchers, the conservation practices were located by 11-digit HUCs only and were no longer-field specific. If there were six or less coded practices, then no data were transferred. The National Institute of Food and Agriculture–Conservation Effects Assessment Project received only censored data, except for the two farms where research was conducted. • Whole-farm planning was used in the Cannonsville Reservoir Watershed to select and locate conservation practices, which had to include a nutrient management plan. Other conservation practices (barnyard improvements, exclusion fencing, riparian buffers, veal barns, etc.) were selected based on farmer preference. All practices were cost shared at 100%, mostly by the New York City Watershed Program. • Conservation planning was locally led by dairy farmers, who had a significant voice in the conservation practice selection and adoption.
Ohio	• Data on watershed-wide agricultural trends were obtained from the National Agricultural Statistics Service, Conservation Technology Information Center, and the Ohio Department of Agriculture. Acquisition of data on crop type through interpretation of satellite imagery was tried, with little success. There was no concurrent monitoring of land treatment practices as water quality data were collected. Thus, conservation practice data could not be attributed spatially. • Primary conservation practices were conservation tillage, no-tillage, grassed waterways, and land conversion using the Conservation Reserve Program and the Conservation Reserve Enhancement Program.
Oregon	• Land use/land cover geographical information system data were obtained for the Calapooia Basin by using existing USDA NRCS, Oregon State University Extension, and USDA information, along with farmer interviews, aerial photographs, and site visits. From 2004 to 2010, a technician cataloged agricultural practices on 4,800 fields annually to document crop species grown, tillage practices, and residue left on 100% of the farmed land in the watershed. The cataloged practices were then distributed into 56 classes relative to vegetative cover and time, and all data were georeferenced and entered into a geographical information system database. • Conservation practice implementation consisted of buffers and conservation tillage.
Pennsylvania	• Conservation practice implementation occurred from 1992 to 1995 for the Slab Cabin reach and from 1993 to 1998 for the Cedar Run reach. The location of the practices was noted. • Practices consisted of exclusion fencing, stream crossings, stream bank armoring, and naturally revegetated buffers. Installation was done at no cost to the landowners, who were required to sign agreements ensuring maintenance of all improvements for 10 years.
Utah	• Conservation practice implementation and maintenance were tracked retrospectively by using past USDA NRCS paper records and following up with site visits and interviews. • Practices were installed during the Hydrologic Unit Area (1990s) and consisted of waste management systems, livestock exclusion, stream bank stabilization, riparian buffers, improved grazing management, and furrow- to sprinkler-irrigation conversion.

Note: NRCS = Natural Resources Conservation Service.

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prairie (Walnut Creek). The conservation practice brought a complete change in cropping system by restoration to native prairie. Agriculture in the Lincoln Lake Watershed in Arkansas was dependent on beef cows and broiler operations, with the broiler litter applied to pastures. Excess P from these operations is of concern as Oklahoma and Arkansas are involved in litigation to limit the amount of P delivered from Arkansas in to Oklahoma from the Illinois River Watershed. The focus of conservation practices has been on use of nutrient management, including soil and litter testing, and management of animal waste (including stream fencing, riparian area plantings, and poultry litter storage). The only groundwater NIFA–CEAP was located in the Central Platte Region of Nebraska and was part of a large 30-year effort to reduce groundwater NO_3-N concentrations through the use of nutrient and water management. Quasi-regulatory programs were implemented in this watershed that included attendance at educational programs and annual reporting of irrigation use and quality. Millions of dollars have been targeted toward conservation and educational programs to reduce groundwater NO_3-N concentrations in this region.

The Spring Creek Watershed in Pennsylvania was a paired-watershed study that sought to determine the effectiveness of exclusion fencing, crossings, and rock armoring of streams abutting pastures. Conservation practices were promoted by the university faculty member who devised this study.

Two NIFA–CEAP studies were in watersheds that served as the source of drinking water for urban areas (New York City, New York, and Wichita, Kansas), where the cities funded agricultural conservation programs to protect water quality and thereby reduce treatment costs of water. New York City paid for many nutrient-reducing conservation practices throughout the watershed supplying its reservoirs (see Chapter 17). The water quality monitoring portion of the Cannonsville Reservoir Project in New York was conducted prior to the NIFA–CEAP efforts, mostly through the USEPA Section 319 NNPSMP (Spooner et al. 2010). Multiple conservation practices were installed on a single dairy farm—from barnyard improvements to a nutrient management plan that focused manure applications on fields less likely to generate surface runoff. Adaptive management was used so that as the stream was monitored and additional sources were identified, more conservation practices were added. In Kansas, the City of Wichita provided additional cost share to farmers for conservation practices over and above the land treatment funded by the USDA NRCS. Practices funded by both groups included land retirement (Conservation Reserve Program [CRP]), terraces, grassed waterways, nutrient management, conservation tillage, and other typical conservation practices.

Results: Contributions to Knowledge/Science from Land Treatment

Although implementation of conservation practices occurred prior to most of the CEAP periods, analysis of land treatment accomplishments did make some important contributions to knowledge about watershed land treatment for water quality improvement.

Several of the NIFA–CEAP watershed studies demonstrated that conservation practice implementation may have unintended consequences. Monitoring results from the 1991 to 2001 Iowa paired-watershed comparison demonstrated that in a watershed where the predominant conservation systems were terraces with drain outlets, water yield increased 12%, turbidity levels decreased by 46%, but suspended sediment concentration was unchanged, and NO_3-N concentrations increased by 37% (Spooner et al. 2011). The terraces probably

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decreased turbidity, while the outlets increased NO_3-N. These contradictory effects on different pollutant types were also observed in the Goodwater Creek Project in Missouri, where terraces increased NO_3-N losses. This relationship between terraces, sediment or turbidity reductions, and NO_3-N increases is well-established and was noted in a RCWP project (Gale et al. 1993). When conservation practices affect pollutants differently, tradeoffs must be considered; there has to be a decision as to which pollutant is more critical to control.

Three projects (Ohio, Kansas, and Missouri) determined that conservation tillage does not always reduce pollutant load(s). In the Rock Creek Watershed in Ohio, conservation tillage decreased sediment and particulate P losses but is believed to be at least partially responsible for increases in dissolved P concentrations in runoff, probably due to changes in timing (fall rather than spring) and placement (surface rather than incorporated) of P fertilizer application; increases in tile drains may also be a factor. Researchers in Kansas and Missouri found that runoff actually increased from claypan soils under conservation tillage. As a consequence, losses of surface-applied chemicals, such as pesticides, were increased. The Goodwater Creek Project in Missouri experienced a major issue in establishing conservation practices that could find a balance between reducing erosion through tillage practices versus controlling herbicide losses (soil incorporation of herbicides decreased losses by 39% to 55%). During the Cheney Lake Project in Kansas, experimental work demonstrated that terraces were significantly more effective in reducing ephemeral gully erosion than conservation tillage. However, many terraces are currently being removed in this watershed as they interfere with modern large agricultural equipment.

Buffers were found to be effective in reducing pollutants in several projects, although from the farmers' perspective, this was often the most disliked conservation practice. In the Cannonsville Reservoir Watershed in New York, researchers were able to show that Conservation Reserve Enhancement Program buffers reduced total P loading by 33%, primarily by keeping pollutants (e.g., animal waste) out of the stream corridor rather than acting as a filter (Flores-Lopez et al. 2010). Riparian forest buffers were common in the Georgia Project area; most are natural and exist in areas of hydric soils that historically have been too wet to farm. The performance/value of these buffers for protecting water quality has been well documented from prior research in Georgia and elsewhere (Lowrance 1992; Lowrance et al. 1995; Smith et al. 2006). Thus, naturally occurring buffers may be more important to maintaining water quality in some regions than conservation practices. However, implementing buffers on productive land is much more difficult, as in Indiana, where farmers did not like filter strips because they perceived that too much land was removed from production.

Researchers in the Spring Creek Project in Pennsylvania were able to show that buffers were potentially poorly located because they were not placed to capture the majority of the runoff. By comparing digital elevation models from conventional and light detection and ranging (LiDAR) measurements, it was determined that mapped topographic flow paths from a 10 m (32.8 ft) digital elevation model are sufficient to reveal pathways where concentrated runoff from source areas would bypass buffer filter strip zones. This process can be used to identify/locate critical source areas and improve the location of intercepting treatment measures.

In Iowa, the importance of stream bank/streambed erosion as a sediment source was documented by stream walk surveys and the use of beryllium/lead ratios. These measures determined that for one small event in Walnut Creek, 76% of suspended sediment came from bed and bank sources, while only 24% came from overland flow. Bank erosion was primarily from areas with established riparian forest and was higher than rates from stream reaches in grassland or

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pasture riparian land use. Streams in forested areas were generally more incised. This counter-intuitive observation suggested landscape position is important as forested areas tend to be lower in the Iowa Walnut Creek Watershed and, therefore, are more affected by the impact of upstream channelization on stream power. Researchers in other watersheds (Idaho and Indiana) also identified sediment sources primarily derived from historical stream sediments and stream bank erosion rather than current erosion from cropland.

To assess implementation and maintenance of conservation practices installed during the HUA, Utah NIFA–CEAP staff conducted a series of field visits and extended structured interviews with the approximately 90 landowners who participated in the Little Bear River watershed protection projects since 1990 (Jackson-Smith et al. 2010). The interviews evaluated both direct and indirect implementation of prescribed agricultural conservation practices. The dataset obtained from this work is unique and insightful. The interview rate was 61%, and from these interviewees, it was determined that 35% of the conservation practices were structural practices (e.g., fences, waste storage, sprinklers), 47% were management practices (e.g., irrigation, nutrient management, waste utilization), 16% were planting practices (e.g., grasses, filter strips, trees), and 2% were clearing practices (e.g., clearing and snagging, land clearing). Survey results indicated that 75% of management conservation practices, 13% of planting conservation practices, and 4% of structural conservation practices were not fully implemented, even though the farmers thought they were doing a very good job. Reasons cited for not fully implementing practices ranged from "did not remember" (46%), to "ignored full implementation" (15%), to "practice failed" (9%). In addition, 61% of management practices, 4% of planting practices, and 35% of structural practices were not maintained/continued. Overall, management practices had lower rates of maintenance than did structural or planting practices.

The Little Bear River Project in Utah used stream bank/stream channel condition assessment as an alternative indicator of response to conservation practices. This process compared 1992 to 2007 aerial video imagery to analyze for changes in riparian zones. Results noted significant vegetation growth and changes in stream morphology associated with reaches treated with riparian vegetation. Riparian restoration did work in some areas but did not work in the lower reaches of the watershed because the stream was already too incised.

The critical area of the New York single-farm paired-watershed study (Bishop et al. 2005) was the entire farm (~140 ha [346 ac]). Conservation practices included a comprehensive nutrient management plan, crop rotations, strip cropping, riparian buffers and associated cattle exclusion from the riparian areas, alternative water development using springs, barnyard improvements including the development of a lagoon, filter areas for barnyard runoff, relocation of the stream and the silage storage area, targeted manure spreading schedule, and interceptor drainage ditches to reduce flow to frequently saturated areas (Spooner et al. 2008). As conservation practices were implemented, cow numbers were increased by about 30%, which could offset some gains via the implemented conservation. Using water quality monitoring data and adaptive management, additional conservation practices (precision feeding, an additional stream crossing, and stream bank restoration) were added to the farm. The suite of conservation practices had a positive effect on water quality: ammonia and soluble P loads were reduced by 64% and 53%, respectively, while particulate P and sediment losses were reduced by 36% and 28%, respectively (Spooner et al. 2011).

The suite of conservation practices used in the Walnut Creek, Iowa, paired watershed study described in this book was cropland conversion (from soybeans and corn to tall grass prai-

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rie—23% of the watershed) combined with removal of fertilizer and drain plugging of these lands. In addition, cropland remaining in the Walnut Creek Watershed reduced N and pesticide applications by 21% and 28%, respectively, while N applications increased 13% in the control watershed. Project results indicated that prairie restoration in an agricultural watershed improved water quality with regard to NO_3-N concentrations and loads (reduction of NO_3-N of ~1.2 mg L^{-1} over 10 years), while NO_3-N concentrations increased 1.9 mg L^{-1} in the control watershed (Schilling and Spooner 2006). In addition, a smaller subbasin was monitored within the control watershed for land-use change (~25% increase in row crop production as CRP grassland was converted), and the corresponding increase in NO_3-N loading was 10 mg L^{-1} or greater over the baseline concentrations. Phosphorus loads did not change in any of the main stem streams in either Walnut Creek or Squaw Creek, probably due to the episodic transport and variability in P concentrations detected.

In the Spring Creek, Pennsylvania, paired-watershed study, exclusionary fencing (1 to 3 m [3 to 9.8 ft] from the stream bank), stream crossings, and stream bank armoring was implemented to reduce stream sediment caused by direct cattle access, with the expected benefit of improving stream habitat. Total suspended solids and fine sediments declined following the implementation of the suite of practices. Baseflow and stormflow concentrations of total suspended sediment decreased from preimplementation to postimplementation in Cedar Run (17.8 to 1.0 mg L^{-1}) and Slab Cabin Run (29.3 to 1.0 mg L^{-1}), with a significant decline in percent soil fines in both treatment streams: Cedar Run (~26% to ~10%) and Slab Cabin Run (~25% to ~15%). The temporal response of the two streams to a reduction in fines seemed related to stream type and climate—one was a losing stream (the water flows from the stream back into the land) and was more affected by drought, which made detection more difficult. Macroinvertebrate habitat (decrease in fine sediments) and densities (number of organisms per area) improved, whereas fish community structure did not change nor was there any apparent increase in reproductive success. Nutrient concentrations remained unchanged. This result differs from the Cannonsville Reservoir Project in New York, which documented P reductions due to exclusionary fencing (Flores-Lopez et al. 2010).

Lessons Learned

Conservation Practice Selection

This synthesis examined how the experiences of the CEAP case studies inform our understanding of selecting conservation practices in order to protect water quality.

Before any conservation practices are planned, it is critical to first identify the pollutant(s) of concern so that land treatment targets the appropriate pollutants. Three of the watershed projects primarily targeted erosion, using conservation practices, such as grassed waterways, terraces, or conservation tillage. However, the primary pollutants of concern were herbicides in Missouri and Indiana and nutrients in Indiana. In the Goodwater Creek Watershed in Missouri, researchers found soil incorporation of herbicides decreased losses by 39% to 55%, but the focus was on erosion control, not herbicide reduction, so conservation tillage was continued. These watersheds were not able to show reductions in the primary pollutants of concern.

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It is equally important to the success of watershed projects to determine the source of pollutants because the best conservation practices simply will not work if they do not treat the problem. Two examples are provided below:

- Automatically focusing on agriculture, while overlooking wastewater discharges (municipal facilities and rural septic systems), urban storm water, or construction impacts seriously misdirects attention and conservation efforts, as demonstrated by several projects.
- As noted previously, several NIFA–CEAP watershed studies identified stream bank erosion as the major source of sediment after land treatment efforts had targeted upland erosion (Indiana, Iowa, and Idaho). For example, sediment export from a watershed may or may not be related to erosion control practices implemented on uplands. Soil loss calculations using the Revised Universal Soil Loss Equation (RUSLE) indicated gross erosion increased by 3,447 Mg y^{-1} (3,800 tn yr^{-1}) in Squaw Creek (+15%) and decreased by 12,066 Mg y^{-1} (13,300 tn yr^{-1}) in Walnut Creek (–37%). However, monitoring data showed no change in sediment export from either watershed. The Iowa Project attributed the lack of differences in sediment export to multiple factors: no change in flow regime, especially stream power; the importance of bank erosion; and legacy sediment stored in floodplains, behind debris dams, and in streambeds.

Practice Implementation

This synthesis has examined how CEAP experiences can inform future implementation of watershed conservation projects and programs.

Many barriers still exist for implementation of conservation practices at the field scale. These barriers include but are not limited to sociological factors, real or perceived economic costs, programmatic issues, and lack of understanding about the impacts of various management practices. (See Chapters 2 and 6 for more details on barriers.)

Ultimately conservation practices only work if they are adopted. As one farmer from Kansas stated, "Farmers make conservation practices work, and if he isn't interested, they won't work regardless of whether the land is owned or rented." Understanding the human dimension aspect of conservation practice adoption and implementation is essential. There are multiple reasons and incentives for adoption:

- Reasons for lack of adoption are not always clear and often are very difficult to understand. For example, a farmer who served on his Soil and Water Conservation District board did not switch to direct seeding because he supported two other families in the farm operation. Direct seeding would reduce the need for personnel (by replacing labor with money/machinery). This farmer had been intimately involved in the watershed project for years and would like to make changes in his farming practices but did not because of family considerations.
- Nutrient management was discontinued in the Cheney Lake Watershed Project in Kansas. Neither certified crop advisors nor farmers supported the nutrient rate recommendations from Kansas State University. In addition, farmers did not like the regulatory requirements to show fertilizer receipts that were often generated for multiple fields and did not correspond with applications to individual fields.
- It is important to identify multiple functions of conservation practices to make them more palatable to farmers because agency perspectives of conservation practices can differ dramatically from farmers. For instance, farmers in the Cannonsville Reservoir Watershed in New York stated that calf barns were important for farmers because they

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promoted calf health and greater weight gains and they were perceived as a sign of affluence for the farmer; project personnel, however, promoted calf barns because they reduced pathogen loads to streams compared to open barnyards.

- Some farmers viewed conservation practices as inconvenient and costly.
- Other farmers did not recognize landscapes in greater need of conservation practice adoption. In Idaho, farmers stated that buffers, gulley plugs, and conservation tillage were only slightly more effective as slope increased, although research data demonstrated that the importance of these practices increased sharply as slope increased.
- It can take a generation or more to change behavior. Even after decades of extension activity and cost-share programs to promote conservation tillage in the Palouse (Paradise Creek Watershed in Idaho), some farmers were still using conventional tillage.

Conservation practice adoption was affected by many factors, including the following:

- Threat of regulation, as well as availability of cost share is an important incentive for adoption of conservation practices. In Lincoln Lake, Arkansas, exceptional adoption rates were achieved due to litigation, the threat of further regulations, and outstanding support, in the form of one extension agent who was fully devoted to helping ~70 farmers. Conversely, in Utah, which retrospectively analyzed conservation practice adoption under an HUA project, it was determined that education was not a key factor in shaping the decisions to enroll in the program for the subset of farmers who actually participated in the HUA project. It was the social networking with conservation program staff and the "fit" between production goals and the available conservation practices eligible for project funding that caused implementation of conservation practices.
- Trust in a product can increase conservation adoption. In the Rock Creek Watershed in Ohio, farmers more readily switched to minimum and conservation tillage the year after John Deere introduced their "green drill." Farmers then viewed the technology as acceptable.
- Increased farm size, fuel costs, and lowered labor requirements often increased adoption of conservation tillage. In Kansas, larger farms adopted conservation tillage because no additional labor or fixed costs (tractors, etc.) were needed.
- Yields, rather than net profits, were often the main focus for farmers. Farmers in Ohio and agency staff in Kansas reported that farmers compared yields with each other but did not discuss profit or return on investment. Practices that can increase yields may be more readily accepted than practices that improve profitability at the expense of yield. This point was underscored by Indiana researchers, who found that when farmers were mostly interested in economic return, adoption was generally lower than when farmers were more concerned with off-farm impacts of practices. The greatest adoption tended to be among those farmers to whom stewardship was important (Reimer et al. 2011).
- Genetic modification of crops allowed farmers to shift production and implement conservation practices. Farmers in the Cheney Lake Watershed in Kansas diversified from continuous wheat and plowing (to reduce disease) to corn, soybeans, and wheat. Multiple crops suppress diseases, allowing farmers to use conservation tillage. The introduction of corn and soybeans was a result of their much greater yield potential (i.e., greater income) relative to wheat and increased ability to withstand drought; the genetic yield potential of wheat has not increased relative to corn and soybeans.

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- Instrumentation of irrigation wells with meters (versus manual readings) in Nebraska provided valuable feedback to the farmers; much more water has typically been used than farmers recognized, and this knowledge is enabling them to reduce water usage.
- Nonfarmer landowners may be an impediment to conservation practice adoption in urbanizing landscapes. In Pennsylvania, these groups did not understand the importance of buffer adoption in part because there were few programs for outreach and education or federal cost-share programs to help them adopt the practice. Additionally, development pressures in rapidly urbanizing watersheds, such as Eagle Creek in Indiana, may discourage conservation practice adoption because of the encumbrance of long-term (e.g., 10 year) contracts.
- In Pennsylvania, the willingness of landowners to adopt riparian buffers appeared to be related to perceived knowledge of stream water quality and in-stream fish habitat, to the proportion of neighbors considered to be close friends, and to a landowner's belief that buffers provide water quality benefits.
- Horse owners in the Eagle Creek Reservoir Watershed in Indiana (who were classified as nonagricultural) were not necessarily anticonservation but had little or no knowledge that their operations can cause problems. They were also uninformed about how to solve the problems, having been overlooked in previous educational or extension efforts.
- Renaming conservation practices (e.g., calling a constructed wetland a bioswale or a wet buffer) may increase acceptance because using a value-laden term like "wetland" may deter farmers.

Most watersheds have significant amounts of rented land in agriculture, and ownership affected conservation practice implementation. In Kansas, landowners pay one-third of production costs and receive one-third of the commodity produced. As a result, many absentee landowners were reluctant to make even minimal investments in their lands, e.g., to purchase lime. However, in Georgia, where renters pay a per-acre rental fee, tenants were willing to help pay for terrace construction, as long as they could be assured of a long-term lease (i.e., five years or greater). Communication may be more important to adoption on rented lands than rent structure as conservation practice adoption may be inhibited if farmers and owners of rented land do not communicate. In Indiana, discussions with both renters and tenants revealed each thought the other would not want the conservation practices.

Some practices installed by farmers on their own may not meet the USDA NRCS standards and may or may not affect pollutant losses. Many farmers believe USDA NRCS design and construction standards are excessive and result in practices that are too rigid, too over-built, and too costly. In Pennsylvania, the ~1 m (~3 ft) grass buffers implemented by land owners were narrower than the minimum USDA NRCS standard, but there was some water quality and habitat restoration improvement. Without the narrower buffer allowance, no buffers would have been established.

Experience with financial incentives to increase user adoption has been mixed among the NIFA–CEAP watershed studies:

- Some farmers are simply not interested in conservation practices. Even with 100% or near 100% cost share (due to matching offered by the city of Wichita), many priority farms in the Cheney Lake Watershed in Kansas did not participate in conservation programs.
- In the Cannonsville Reservoir Watershed in New York, 100% cost share was critical to the implementation and maintenance of practices. Most NIFA–CEAP watershed stud-

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ies determined that cost share was necessary but was not sufficient to ensure adoption of many conservation practices.

- Two trends have been driving change from furrow irrigation to sprinkler irrigation in Nebraska: an increase in labor costs and an increase in cost share. Initially, the USDA NRCS would only cost share one center pivot system per farmer per lifetime for US$3,000. After adoption leveled off, the USDA NRCS began cost-sharing one center pivot system per farmer per year for US$7,500. There was little incentive for farmers to change to center pivot because the groundwater was available and was relatively shallow, meaning pumping costs were fairly low. The combination of increased cost share and rising fertilizer costs contributed to increased adoption.

Conservation is a complex multivariate choice—not an either/or decision. Conservation tillage in the Goodwater Creek, Missouri, region reduced sediment loss but increased pesticide delivery. Currently, farmers must choose either to control erosion (often an obvious, local problem) or reduce pesticide loss (sometimes a more distant, abstract issue). Farmers were resistant to incorporating pesticide management because of soil loss potential.

Implementation of conservation practices by itself is not a behavior change. Implementation often occurs in response to aggressive outreach (sales) programs and the availability of incentives, such as cost share. This short-term encouragement does not necessarily induce a sustained behavior change on the part of the farmer that would lead to long-term practice operation and maintenance, especially of management-based practices. Efforts to market conservation practices should stress two primary issues: the relative advantages offered to farmers on their farms by using the practices, e.g., the direct benefits of conservation tillage (reduced input and labor costs) or nutrient management (reduced fertilizer costs); and the need to address perceived issues of incompatibility among practices (e.g., manure and/or fertilizer incorporation versus reduced tillage) or lack of need for the practice.

Traditional conservation planning may be difficult to reorient. Researchers in the Cannonsville Reservoir Watershed in New York found it was initially challenging to overcome traditional beliefs by farmers and agency personnel that soil erosion was the only issue of concern. This was not unique to the New York NIFA–CEAP; several other watersheds used primarily sediment-reducing conservation practices, although nutrients were the principal problem. This may be related to other observations that locally visible environmental problems (like gulley erosion) tend to be of greater concern to farmers than far off-site problems (like nutrient enrichment of a distant reservoir).

Attitudes toward the USDA NRCS varied among projects. Some project participants (e.g., Kansas) believed that the USDA NRCS should work with farmers when installing conservation practices to ensure implementation of practices that will perform as expected. In other projects (e.g., Missouri), many farmers felt the USDA NRCS practices were overengineered and overpriced and suggested that less "bullet-proof" practices were needed. The USDA NRCS plans were often criticized as broader than farmers wanted or were willing to accept. Acceptance of some conservation practices would increase if farmers could choose the practices they wanted rather than the "take it or leave it" package of conservation practices being promoted by the USDA NRCS. On the other hand, farmer-selected conservation practices may be insufficient to protect water quality. Finally, it was reported during several site visits that the direct, on-site relationship between the farmer and the USDA NRCS conservation planner had suffered

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because of budget cuts and the proliferation of special programs, resulting in more generic conservation planning "by laptop."

Practice Documentation and Monitoring

This synthesis has examined how CEAP experiences can improve the documentation and tracking of conservation practices in future watershed conservation projects and programs.

Goals for land treatment should be set for watershed conservation projects. Only one of the NIFA–CEAP watersheds had set quantitative goals for land treatment implementation during the time that conservation practices were implemented. The Utah HUA Project determined and stated the number and types of practices expected for implementation to change water quality. Projects did not generally report the level of treatment achieved by implementation of conservation practices in their watersheds, especially with respect to treatment needs. Thus, in cases where little or no water quality response was observed, it was difficult to ascertain whether this was due to insufficient treatment or to some other cause. The success of any land treatment program must be measured against the goals and objectives set for land treatment. Water quality response (or the lack of response) must be understood in the context of selecting the appropriate practices, siting the practices in critical areas, and implementing sufficient practices to treat the pollutant sources in the watershed.

Data on land use and agronomic management are critical to understanding the relationships between conservation practices and water quality. However, collecting retrospective data on farming systems and conservation practices is extremely challenging. Lack of good contemporary land-use data can impair detection and understanding of trends observed in water quality data. Examples from the NIFA–CEAP watershed studies follow:

- The USDA records on conservation practice implementation (when available) are extremely important but need to be augmented with additional information, such as farmer interviews. In Indiana, many of the of implemented practices were identified only from government records, even with intensive investigation of other information sources (farmer surveys and remote sensing). Because government records are so important for conservation practice identification, restrictions on access or release of only general aggregated data can lead to erroneous conclusions of the effects of conservation on water quality at the project level. The Utah Project, through careful delineation of data collection goals, use, and farmer protection mechanisms, was able to obtain permission to access farmer data first from the USDA NRCS state office and then from the USDA NRCS federal office. However, struggles with variable and antiquated USDA NRCS reporting formats increased the workload for the project. Likewise, Indiana was able to develop a database of the nature, location, and status of conservation practices in the project watershed, but it required considerable work because the USDA NRCS database of implemented practices was incomplete and failed to completely match verified land-use information with other sources. Farmer interviews and remote sensing data were important additional sources of data.
- Several projects were able to collect data on structural practices but not management practices. The Little River Experimental Watershed Project in Georgia was able to collect only structural information concerning USDA NRCS practices, thereby missing all the management practices. The Walnut Creek Project in Iowa augmented aerial photography with windshield surveys by an agronomist equipped with a laptop computer and

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electronic field maps. These were annotated with information about buffers, waterways, tillage, etc. The result was an extensive, spatially explicit database on land use/land cover and the existence of obvious structural practices. However, no conservation management information could be ascertained with this method. In Missouri, the absence of change in in-stream atrazine concentrations could be due to application rates or management. However, data on these aspects of the farming system were insufficient because, like all of the NIFA–CEAP watershed studies, Missouri personnel collected conservation practice information retrospectively, and the specificity of management data needed was not available.

- The USDA NRCS practice codes are, in some cases, too broad for water quality work. For instance, the code for fencing does not distinguish between upland fencing and riparian stream fencing.
- Several projects reported difficulty in determining if conservation practices had been implemented as planned, maintained, or continued. It was widely reported that the USDA NRCS system that accounts and tracks conservation practices was weak and needed to be updated and that USDA NRCS should use additional funding to follow up on practice implementation and operation, even after the contract is complete.

Confidentiality restrictions on conservation practice implementation and land management data were a major impediment to understanding how timing, location, and suite of implemented agricultural conservation practices affect water quality at the watershed scale among the NIFA–CEAP studies. The success of individual projects in obtaining necessary and useful land-treatment data depended on history, luck, and personal contacts, although recent changes in USDA NRCS policies on data sharing should improve data acquisitions and sharing between agencies. Examples from the NIFA–CEAP watershed studies follow:

- In the Cannonsville Reservoir Watershed in New York, conservation practices and management data were aggregated by the local agricultural council and were purged of location. As a result, the project could not relate conservation practice implementation with water quality changes in the basin.
- The Goodwater Creek Project in Missouri was able to collect data concerning past conservation practice implementation from local USDA NRCS technical staff, while agreeing to protect confidentiality. The result was a database of monthly conservation implementation.
- Researchers in Nebraska were given permission by the Central Platte Natural Resources District (the regulating agency) to use land-use records, which are mandatory for the farmers to submit. Subsequently, the Natural Resource District found that they could not follow-up on farmer's management reports because of changes in USDA privacy regulations after the last farm bill. The farmers learned about these new regulations, and as a result, their levels of compliance diminished. The Natural Resource District has started using other publicly available records to glean basic information.
- Data-censoring by the National Agricultural Statistical Service can affect the quality of land-use data by not releasing information from counties with a few (potentially large) farmers.
- The Eagle Creek Watershed Project in Indiana tried for several years to obtain land-use data without success. Toward the end of the project, they were successful because of initiatives by the USDA NRCS and other agencies to make data sharing easier.

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The NIFA–CEAP watershed studies encountered additional problems trying to document land-use practices:

- Even when land-use data were accessible, counting only cost-shared acres of conservation practices frequently caused practices to be underreported. For example, some farmers independently installed grassed waterways in the Goodwater Creek watershed in Missouri. In the Little River Watershed in Georgia, natural riparian buffers are believed to provide more protection than other practices, but they are unreported.
- Several projects reported difficulty in determining if conservation practices had been implemented as planned, maintained, or continued. It was widely reported that the USDA NRCS system that accounts and tracks conservation practices was weak and needed to be updated and that the USDA NRCS should use additional funding to follow up on practice implementation and operation, even after the contract period is complete.
- Educational programs need to continually address maintenance and management of conservation practices.
- Lack of reliable information on practice operation and maintenance and reliance on the assumption that practices continue to operate as designed significantly compromises the ability to relate water quality to land treatment, especially in retrospective projects.

Even when land uses are well-documented, changes in land use can confound the assessment of water quality changes due to conservation practice implementation:

- Changes in urban/rural land use made it difficult to determine water quality trends in the Lincoln Lake Watershed in Arkansas.
- Researchers at the Eagle Creek Reservoir in Indiana found it was important to track land-use changes frequently (e.g., annually) because of changes in urban and rapidly developing areas.
- Increases in corn acreage (and therefore, herbicide application) in the Goodwater Creek Watershed in Missouri masked the impact of potential changes in herbicide management.

Few conservation programs ensure long-term effectiveness of practices. Examples from the NIFA–CEAP watershed studies follow:

- In New York, the Watershed Agricultural Program has an ongoing program to evaluate conservation practices coming out of contract. The Watershed Agricultural Program will reinvest in and restore (if necessary) the practice(s) and seek a new contract with the farmer, both to maintain the original practice(s) and to meet evolving USDA NRCS practice standards.
- In contrast, previously implemented conservation practices installed during a HUA project were evaluated in the Little Bear River Project in Utah, and many practices had been discontinued or poorly maintained. They no longer provided effective treatment.
- Changes in land ownership and management can affect conservation practice operation and maintenance. In Pennsylvania, when land changed ownership, new owners changed the riparian exclusion practices by allowing livestock to graze in the riparian buffer area; there was no follow-up with these new landowners to explain the importance of the buffers.

Many projects reported that the USDA NRCS and cooperative extension must work together for conservation practice implementation. Extension can help target conservation practices through visits to particular farmers, while the USDA NRCS can provide technical assistance. Unfortunately, extension resources have been significantly reduced in many watersheds.

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National Institute of Food and Agriculture–Conservation Effects Assessment Objectives Relative to Land Treatment

As noted previously, two of the CEAP questions were expected to be addressed by relating land treatment and water quality monitoring, spatially and temporally:

1. What are the effects of timing, location, and suite of implemented agricultural conservation practices on water quality at the watershed scale?
2. What are relationships among conservation practices—additive, contradictory, or independent?

Only a few NIFA–CEAP studies were able to specifically address the effects of location and suite of implemented agricultural conservation practices on water quality at the watershed scale; none were able to address the effects of timing.

To obtain full benefit from conservation practices, critical areas must be identified prior to implementation, and the majority of practices need to be targeted to these critical areas (effects of location). Due to the voluntary nature of most conservation practice implementation (farmers choose to implement with the help of federal or state dollars or farmers implement on their own), land treatment was rarely focused to the most sensitive areas of the watershed. Retrospective analyses of critical areas and conservation practice adoption in three NIFA–CEAP watershed studies (Kansas, Missouri, and Utah) confirmed that past land-treatment implementation programs were not well-targeted. For example, in Utah, critical area determination was done during the NIFA–CEAP using distance to surface water as the major consideration. Practices installed during the HUA, a decade earlier, were installed on only 25% of the critical area; most of the implementation occurred on lands that likely contributed little P to the stream. Similar conclusions were reached in the Goodwater Creek Watershed in Missouri, where retrospective modeling of critical source areas based on soil and terrain features suggested that about half of conservation practices had been placed on critical source areas and that a substantial quantity of critical areas were still in need of treatment. Using geographical information system and RUSLE analysis retrospectively, the Cheney Lake Project in Kansas determined that for the most part, conservation practices were not implemented in priority areas. There was a slightly higher proportion of CRP acres implemented on priority areas (13%), probably because the CRP siting process focused on high-risk land. Regardless of whether land treatment was implemented through regular federal programs or special USDA programs, such as HUA or Management Systems Evaluation Area, critical areas are not being targeted for conservation practices.

No NIFA–CEAP was able to demonstrate additive or independent relationships among conservation practices, but several projects were able to show contradictory relationships of conservation practices. These examples already have been discussed and include terraces that reduce sediment while increasing NO_3-N and conservation tillage that decreases sediment but increases surface-applied pesticides or nutrients.

Recommendations: What Would Improve Land Treatment?

Based on the lessons learned from the case-study NIFA–CEAP watershed studies, this synthesis recommends the following steps to improve the effectiveness of conservation practice implementation in protecting water quality.

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Agencies and organizations designing programs and organizations implementing projects must follow these steps:

1. Identify impairments and pollutant(s) of concern before selecting conservation practices
2. Identify pollutant source(s) before selecting conservation practices
3. Match conservation practices to pollutant(s) of concern and the corresponding source(s)
4. Determine critical source areas and target conservation practices to those areas; ensure sufficient coverage
5. Set goals for implementing conservation practices on a sufficiently large scale to influence water quality
6. Monitor and track the location and timing of conservation practice implementation
7. Ensure farmer operation and maintenance of conservation practices over the long term

These are not new recommendations. Similar recommendations were drawn from the RCWP experience (Gale et al. 1993). Specific to the NIFA–CEAP watershed studies, there was little systematic effort by the USDA NRCS to implement land treatment in the watersheds using the steps already listed. The exceptions were the Utah and Nebraska NIFA–CEAP studies, where water quality data from previous projects were used in implementing conservation practices. With reductions in federal and state funding for conservation planning and practices, it is critical that resources be used as effectively as possible to protect water quality. All agencies implementing practices will need to change conservation programming so that it targets specific problems and watershed locations.

The findings in the NIFA–CEAP study are echoed by findings from the USDA ARS–CEAP watershed studies (Tomer and Locke 2011):

1. Conservation practices were not targeted at critical sources/pathways of contaminants.
2. Sediment in streams originates more from channel and bank erosion than from sediment loss from agricultural fields.
3. Timing lags, historical legacies, and shifting climate combined to mask effects of practice implementation.
4. Water quality management strategies addressed single contaminants with little regard for trade-offs among contaminants.

As a whole, this synthesis found that management practices, such as nutrient management and water table management, are more difficult for farmers to implement and are more often abandoned (Jackson-Smith et al. 2010), especially nutrient management. Furthermore, most implemented conservation practices target erosion and sediment abatement (Richards et al. 2010), and it is hard to shift the focus of agencies and farmers from sediment to nutrients. Farmers may adopt conservation practices based on their recognition of local problems and their best knowledge of the field-scale benefits of the practices more than as a response to less personally relevant or distant issues (watershed-scale). This has important ramifications for the control of nonpoint sources of agriculturally derived nutrients.

Lastly, conservation practice adoption is a complex multivariate decision, not a binary option for farmers who must implement and maintain the practices. Cost share is usually necessary but is typically not sufficient to ensure practice adoption. Farming is a business, and the economics and time management requirements of conservation practices must be recognized. Education must be tailored to work with farmers on a one-to-one basis and must be provided through highly coordinated efforts between extension and the USDA NRCS, along with their Soil and Water Conservation District affiliates to be effective. In addition, farmers and farm groups (such

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as the ones developed in the Cheney Lake or Cannonsville Reservoir Watersheds) should play a very important role in education and outreach as models for their peers and must be used by agency personnel to increase outreach effectiveness. Agencies should be more cognizant of the human dimensions that affect conservation practice decision-making by farmers and landowners and leverage that knowledge in order to increase participation. In other words, a more personalized approach is recommended when working with farmers and landowners, though this is more expensive and time consuming in an era with dwindling resources. However, to best use our limited conservation dollars, and most importantly, to ultimately achieve water quality goals, it is imperative that the correct practices be placed in the most strategic locations on the landscape and that these practices be properly implemented and maintained. This will take all parties—agencies, farmers, and agribusiness—working in a coordinated fashion for a common good.

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