USDA Agency Priority Goal for Water
Pilot Projects Final Report

Abstract

This report presents the U.S. Department of Agriculture's (USDA) findings and recommendations for assessing natural resource conditions and evaluating the effectiveness of conservation efforts. Drawing upon the two USDA project studies, St. Joseph River Watershed Project in Indiana and Cienega Creek Watershed Project in Arizona, as well as prior USDA research and assessment activities, the report emphasizes the need for multiple types of assessment approaches specific to the water resource concern and hydroclimatic setting, geographic location, and spatial and temporal scales.

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Summary

What is the Issue?

The availability and protection of clean water is critical to the country's drinking water supply and crop production capacity. The Environmental Protection Agency (EPA) recently released an assessment indicating that 23 percent of nation's rivers and streams were rated in fair condition, and 55 percent were rated in poor condition. USDA could positively affect 87 percent of America's surface supply of drinking water by assisting with conservation on lands upstream. If conservation treatments and locations are carefully selected, the investments in USDA conservation programs have an even stronger positive impact on the nation's water quality.

Determining the right approach involves accurate evaluation of water quality and conservation impacts, using ecosystem science and timesaving innovations. A combination of modeling and monitoring will be required to most efficiently assess a variety of landscapes and situations. Modeling and monitoring efforts should be focused on addressing the objectives of the assessment and the specific water resource concern to tailor the best-suited approach for that watershed. Approaches to modeling and monitoring must be research-based with available ecosystem data and targeted conservation efforts and address the appropriate scale of the assessment need. For example, this report is specific to smaller watershed scale outcome assessment and so is most applicable to case studies or regional collections thereof. (For national-scale reporting, approaches should be modified accordingly to available data and models, e.g. CEAP Cropland National Assessment.) It is also important to note that not all watersheds should be expected to monitor or model effects of conservation efforts, as this is cost-prohibitive and not technically feasible. Successful watershed monitoring and modeling efforts currently require a significant amount of well-placed infrastructure as well as a high level of scientific and technical expertise (Osmond, et al. 2012a). Therefore, a carefully selected subset of watersheds, where USDA can focus investments and resources on long-term assessment, research capacity and infrastructure as well as focused conservation implementation and program delivery would be the recommended approach for future watershed scale efforts to document conservation impacts. That said, to more fully accomplish the interagency objectives of the Agency Priority Goal for Water, more coordination and new resources would be needed, particularly where missions are delivered on different land uses or ownerships, as the two do not often intersect given different agency emphases.

What did the Projects find?

Building on years of advances by USDA conservation and science agencies, USDA is providing results-based, landscape scale conservation investment that will protect water resources more efficiently and effectively, and encourage innovations that attract private capital and create non-regulatory incentives for a variety of stakeholders to invest in sustainable water resource management practices.

To this end, USDA selected two project watersheds, the St. Joseph River Watershed Project in Indiana and the Cienega Creek Watershed Project in Arizona. These selected priority watersheds include a high proportion of agricultural and forest lands in need of conservation or restoration. USDA considered

watersheds in good condition where protection would benefit public health, economic viability, cultural heritage, and ecosystem sustainability. Selection criteria included a combination of factors such as the number of USDA agencies investing in a watershed, the potential for significant water quality improvements, and the sufficiency of data both from monitoring and in characterizing watershed condition.

Water Quality Results

In the St. Joseph River Watershed, agricultural drainage ditches were selected and monitored, as well as applying the Agricultural Policy/Environmental eXtender (APEX) model to assess the impacts of conservation practices applied to fields in the watershed, as well as the Soil and Water Assessment Tool (SWAT) model to assess the impacts of conservation practices for the whole watershed. Water quality monitoring indicated different results for different pollutants and methods of transport and data presented challenges due to sample design. APEX-modeled data that relied on assumptions to address issues of scale demonstrated a 51% decrease in sediment load, 30% decrease in phosphorus and 42% decrease in nitrogen load modeled at the field scale. SWAT modeling for the Cedar Creek subwatershed of the St. Joseph River watershed showed similar trends for the entire watershed with approximately 5% reductions in each pollutant. The watershed condition was assessed with respect to impairments, but out of 58 impairments, only a few will have links to agricultural activities.

For the more arid, range landscape of the Cienega Creek Watershed, a different approach was needed. Due to the ephemeral nature of streams in the watershed, in-stream water quality monitoring is not done nor is it historically available. However, good historical data are available on rangeland condition, ecological site descriptions, and plant community status and condition. In addition to remotely sensed data, these data were used in conjunction with watershed and hydrologic soil erosion models to assess the effectiveness and impacts of conservation activities. The hillslope scale Rangeland Hydrology and Erosion Model (RHEM), coupled within the KINEROS2 (Kinematic Runoff and Erosion Model) watershed model and the AGWA (Automated Geospatial Watershed Assessment) Tool, was used to estimate runoff, erosion, and sediment losses from hillslopes, small watersheds, and the entire Cienega Creek Watershed. A comparison of model results from the Pre-Conservation Condition to the Current Conservation Condition documented that there have been reductions in erosion and sedimentation as a result of conservation and management actions in Cienega Creek and the subwatersheds of Cienega Creek in spite of recent drought. There are still some areas of the larger watershed in need of additional conservation treatment. Modeling scenarios indicate that sediment yields for a subwatershed, Gardner Canyon, have decreased by between 4 and 33% from Pre-Conservation to Current Conditions.

Considerations and Recommendations

There are three primary findings for outcome-based performance reporting along with best-practice recommendations. The three considerations and summary recommendations are:

1. ***Common Water Quality Measures are Necessary* -** There are many possible measures, indicators, and assessments that can be used for water quality and watershed condition, such as common pollutants like nitrogen, phosphorous, and sediment. The major challenge is to find

enough locations and data to support the analysis of watershed condition and water quality changes for the same common measures. This becomes more challenging as we mix land uses, land ownerships, and agency missions, which are designed to limit overlap by either land use or geography.

2. ***How to Measure Water Quality Outcomes: Challenges and Best Practices –*** Measuring changes in water quality and watershed condition requires that watershed monitoring locations and frequencies (schedules) be selected in such a way as to distinguish among various influences on water quality parameters such as pollutant behavior, hydrologic regime, watershed and land treatment, significant land use changes, and climate effects among others (Osmond, D. 2012a). The number and extent of practices applied greatly influences the ability to measure a response to treatment. Data collection and assessment require a scientific approach to ensure there is a credible methodology to measuring impacts. Field scale observations can complement watershed scale monitoring (in-stream and the overall watershed with remote sensing) and are important to understanding the impacts of practices.

3. ***Spatial and Temporal Considerations: Impact on Assessing Water Quality -*** There is a significant lag time between conservation implementation on the land and observing water quality benefits or improved land cover in rangelands (Meals et al. 2010 and STAC 2013). Further compounding the time lapse are the many things that affect watershed condition and water quality between the point where conservation is applied in a landscape and the point where downstream water quality is measured. The issues of time and space create a variety of complexities in measurement that all influence our ability to observe improvements in water quality or availability as a result of USDA Program investments and practices applied.

   Biophysical simulation modeling can be very helpful in attempting to quantify water quality impacts of conservation and management, given the challenges associated with monitoring (expense, expertise, and approach). However, the modeling must still rely on good flow and water quality monitoring data in order to calibrate the models used. Modeling is a good approach for national or large regional (basin or sub-basin) scale assessments as monitoring data is not available for all small watersheds and conservation effects are not always additive across small watersheds. The summing effect from numerous smaller watersheds is usually not feasible nor advisable to attain national coverage in many cases. Smaller scale assessments are very important in benchmarking progress and validating modeled estimates with observations and measurement, and so must continue to be supported or expanded. Small watershed scale assessments also are important because they are often conducted at the scale that can inform local conservation planning and watershed management strategies.

These three considerations have been evaluated through this study to conclude that a combined water quality and watershed condition monitoring and modeling approach is needed to document water resource outcomes. The application of these approaches can prioritize locations and increase the effectiveness of conservation and management actions to protect or restore clean water.

Introduction

The availability and protection of clean water is critical to the country's drinking water supply and crop production capacity. The EPA recently released an assessment indicating that 23 percent of the nation's rivers and streams were rated as in fair condition, and 55 percent were rated as in poor condition. USDA could positively affect 87 percent of America's surface supply of drinking water by assisting with conservation on lands upstream. If conservation treatment methods and locations are carefully selected, the investments in USDA conservation programs have an even stronger positive impact on the nation's water quality.

Policymakers and conservationists increasingly recognize that broad and unsystematic implementation of conservation practices across a watershed is not adequate to affect water quality improvement. To make informed decisions with public funding and target conservation practices and water quality improvements, the focus must be on assessing water quality and watershed condition with a scientific connection to the effectiveness of conservation and management actions. This combination offers the potential to achieve more economic and sustainable solutions to protect and increase clean water.

Background

In the last 30 years, USDA has undertaken several programs focused on assessing the relationship between conservation and water quality in agricultural and rural watersheds. All these efforts have built on previous experiences, but all had slightly different foci in terms of the scale of the evaluation, length of time of assessment, key questions addressed, and certainly the state of the science at the time of the assessments. These numerous prior efforts include the USDA-US EPA Model Implementation Program (1978-1982), the USDA-US EPA Rural Clean Water Program (RCWP, beginning in 1980), the Management Systems Evaluation Area (MSEA, beginning in 1990), and the USDA Water Quality Program – Hydrologic Unit Area and Demonstration Projects (commonly referred to as the HUA and Demos involving USDA Natural Resources and Conservation Service (NRCS) and USDA Cooperative Extension Service, 1991-1995) (Osmond, D. 2010a).

Currently, USDA conducts the Conservation Effects Assessment Project (CEAP), which aims to quantify the effects of conservation practices and programs on environmental quality (Duriancik, et al., 2008). CEAP is a multi-agency effort led by NRCS in partnership with several other USDA and other Federal agencies (including USDA Agricultural Research Service (ARS), National Institute of Food and Agriculture (NIFA), Farm Service Agency (FSA), and in some studies U.S. Forest Service (USFS) and stakeholders. Developed into a comprehensive assessment effort over time spanning USDA conservation activities, CEAP assessments include a range of scales from watershed (including some field scale efforts) up to regional or basin-scale assessments and multiple resource concerns (water quality and availability, soil quality, and wildlife resources) on several key land uses (cropland, grazing lands and wetlands). Studies in CEAP focus on documenting conservation practice effects through application of complex process modeling and selective monitoring. Given the watershed or larger scale of CEAP studies, there is some analysis relevant to watershed condition, though the focus is on how to improve watershed condition through future focused conservation efforts (targeting conservation treatment to more effectively address remaining conservation needs).

The USFS also is currently utilizing a recently developed approach to assessing watershed condition, the Watershed Condition Framework (WCF). The Watershed Condition Framework is utilized by USFS employees and experts in the field to systematically evaluate watershed condition, based on a range of characteristics and indicators, and then rank watersheds according to their priority for restoration.

Approach

The basis for this report is in response to the "Agency Priority Performance Goal Framework Document" (Sulafsky, 2011). Building on years of advances by USDA conservation and science agencies, USDA is providing results-based, landscape scale conservation investments that will protect water resources more efficiently and effectively, and encourage innovations that attract private capital and create non-regulatory incentives for a variety of stakeholders to invest in sustainable water resource management practices.

To this end, USDA selected two project watersheds, the St. Joseph River Watershed Project in Indiana and the Cienega Creek Watershed Project in Arizona. These selected priority watersheds include a high proportion of agricultural and forest lands in need of conservation or restoration. USDA considered watersheds in good condition where protection would benefit public health, economic viability, cultural heritage, and ecosystem sustainability. Selection criteria included a combination of factors such as the number of USDA agencies investing in a watershed, the potential for significant watershed and water quality improvements and the availability and sufficiency of data both from monitoring and in characterizing watershed condition.

The St. Joseph River watershed is primarily a cropland agricultural landscape where it is possible to evaluate water quality outcomes through FSA and NRCS programs. The Cienega Creek watershed is primarily rangeland with USFS and NRCS programs. Both project watersheds enabled USDA to capitalize on ongoing work with similar objectives and prior investments. These projects leveraged ongoing and prior investments in both monitoring and science to understand the interaction of watershed hydrology, rangeland health, water quality, and conservation practices on the landscape.

To report both the practice effectiveness as well as watershed condition assessments proposed in the Agency Priority Goal Framework, USDA used a multi-scale combined monitoring and biophysical modeling approach. The monitoring provided observations of practice effectiveness and watershed condition measures. Modeling was used to help account for the portion of changes attributable to conservation practices and long-term producer stewardship management efforts.

The research from the projects demonstrates why both condition and effectiveness frameworks consisting of monitoring are needed to assess and evaluate watershed condition and water quality improvements. These approaches will enable USDA agencies and their partners to build performance measures into their programs and use the results to improve their work and guide future investments to more efficiently and effectively achieve the nation's water goals.

Projects and Findings

St. Joseph River Watershed

Watershed Description: The total drainage area of the St. Joseph River watershed is approximately 694,000 ac overlapping Michigan, Indiana, and Ohio, emptying into the Maumee River in Ft. Wayne, Indiana (Figure 1, Hydrologic Unit Code (HUC) 04100003). Within the 8-digit HUC St. Joseph River watershed, there are 45 12-digit HUCs ranging in size from 6,200 to 32,000 ac (ac). The area monitored by ARS is in the Cedar Creek watershed, encompassing 175,000 ac, defined from the confluence of Cedar Creek into the St. Joseph River, just northeast of Ft. Wayne, Indiana. There are two 10 digit HUCs in Cedar Creek (0410000306 and 0410000307) and eleven 12-digit HUCs within the Cedar Creek watershed. The majority of this watershed is within DeKalb County, Indiana within the 0410000306 HUC. Three small sub-watersheds have been selected for detailed monitoring (edge-of-field as well as in-stream) where specific practices or suites of practices will be evaluated, and are described in detail below (Figure 2).

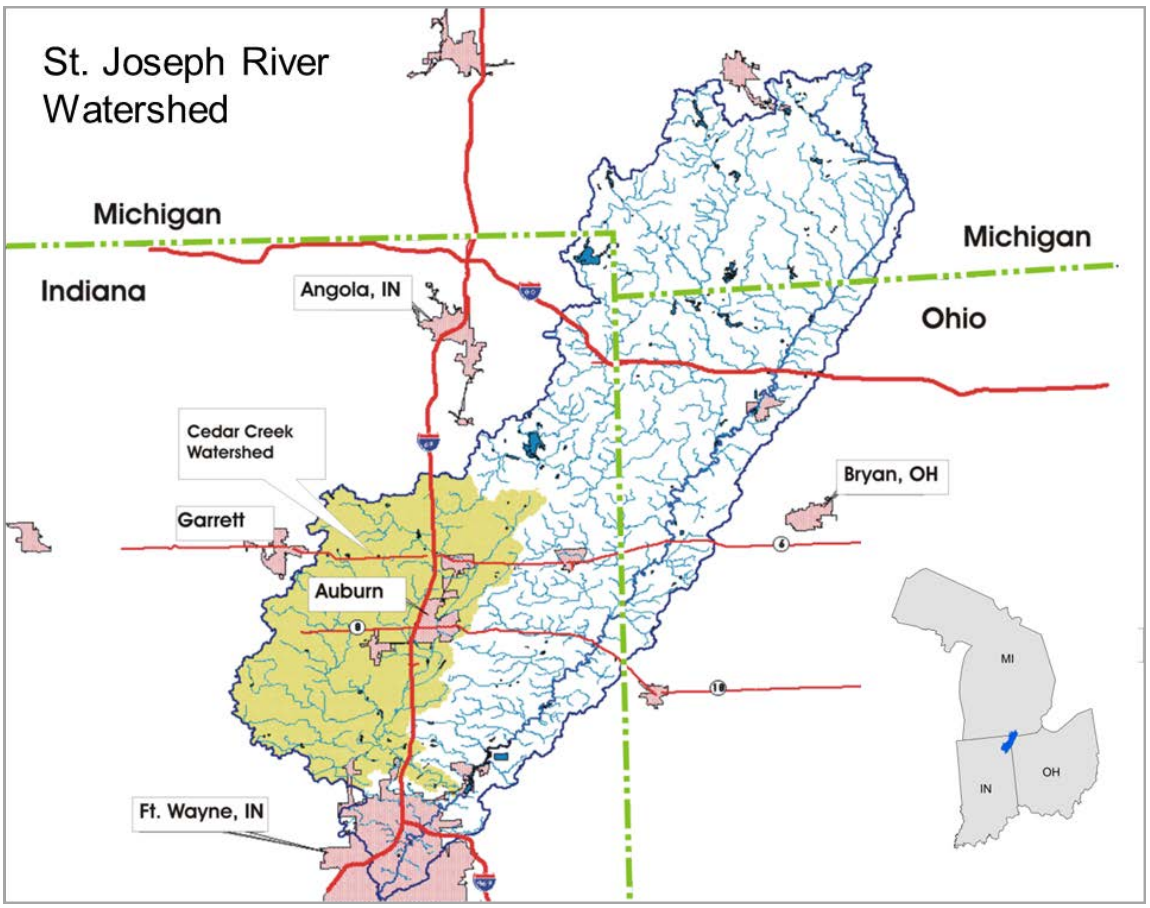


Figure 1. St. Joseph River Watershed (HUC 04100003) encompasses a total of approximately 694,000 ac in Michigan, Ohio, and Indiana. The Cedar Creek Watershed (HUC 0410000306 and 0410000307) and three smaller sub-watersheds within that area are the focus of CEAP studies and will be the focus of this project.

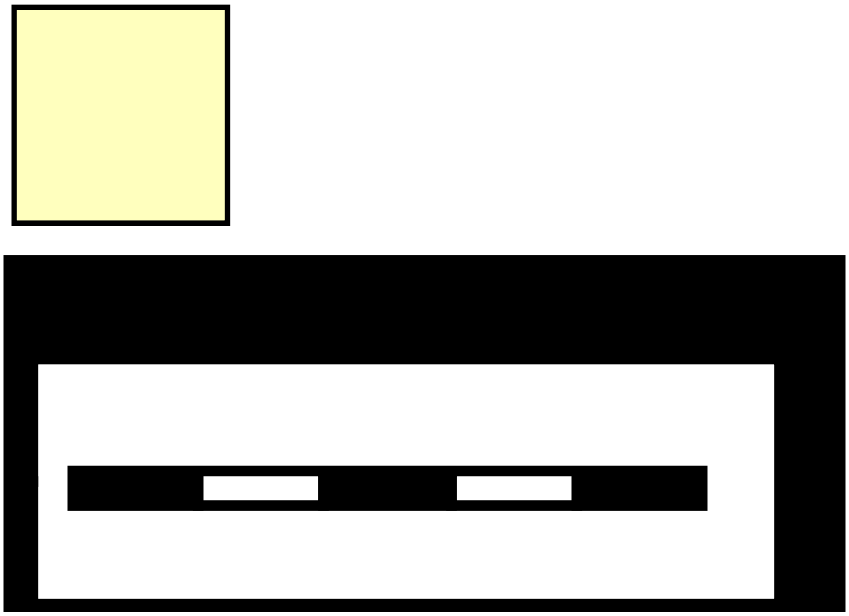


Figure 2. Map of the St. Joseph River watershed and the monitoring sites used for the CEAP – Watershed Assessment Study in the Cedar Creek subwatershed of the St. Joseph River.

The St. Joseph River watershed is primarily agricultural, with approximately 64% in cropland and 15% in pasture or forage. Woodlands and wetlands are found on 10%, while the remaining 11% consist of urban, industrial, farmsteads, airports, golf courses, and other land uses. Of the cropland, approximately 54% is in corn, 37% in soybeans, and 9% in wheat. Primary cropping consists of corn/soybean rotations and varying tillage practices. The primary water resource concerns in this watershed are phosphorus (total and soluble phosphorus) that contribute to algal blooms in the Western Lake Erie Basin; nitrates and pesticides that can lead to drinking water quality concerns in the cities of Ft. Wayne, Indiana and Defiance, Ohio; and sediment which is a primary concern to the shipping channel for the Port of Toledo in Lake Erie.

The St. Joseph River watershed is one of the ARS Benchmark CEAP watersheds, part of the CEAP Watershed Assessment Studies (WAS). This is the only ARS CEAP WAS in the Great Lakes region. The St. Joseph River watershed study was established in 2001 as the Source Water Protection Initiative, as Ft. Wayne was identified as having the second highest levels of atrazine in polished drinking water (Environmental Working Group, 1995). Monitoring of agricultural drainage ditches began in 2002, and monitoring of agricultural fields began in 2004. ARS has worked closely with national, state, and local NRCS offices with this project. ARS has also worked closely with the local Soil and Water Conservation Districts and local landowners and farmers for the CEAP WAS.

Data collection and models: Monitoring for the St. Joseph River Watershed CEAP WAS uses a paired, nested watershed research design. This means that each three agricultural drainage ditches are monitored at two locations, one draining approximately 700 ac, and another location draining approximately 3,500 ac (Figure 2). Additionally, in one of these agricultural drainage ditches, four fields

(5-12 ac) are monitored as one site that drains an entire 12-digit HUC (HUC 041000030603; 10,600 ac). Two of the monitored fields are in a corn/soybean rotation, while the other two monitored fields are cropped with a corn/soybean/wheat/oat rotation.

For the St. Joseph River watershed CEAP WAS, two models were applied for water quality assessments. The Agricultural Policy/Environmental eXtender (APEX) model was used to assess the impact of single and multiple conservation practices applied to fields in the watershed. This is a field scale model, and the impact of conservation practices were compared to a baseline scenario of a corn/soybean rotation with tillage between each crop.

To make assessments at the St. Joseph River watershed scale, the Soil and Water Assessment Tool (SWAT) model was used. The impact of modeled conservation practices was assessed at the watershed outlet for individual conservation practices and the cumulative effect for conservation practices applied to the watershed, and compared to the same baseline scenario as was employed during the APEX modeling.

The primary questions addressed through monitoring were to compare the impacts of conservation practices applied at the field scale. The practices tested include no-tillage (Conservation Practice 329), grassed waterways (CP 412), conservation crop rotation (CP 328), and a modification to the underground outlet practice standard (CP 620), known as a blind inlet.

The questions addressed by the modeling studies were to compare the impact of all known conservation practices placed on the ground through conservation programs on water quality at the field and watershed scale. This was accomplished by obtaining the conservation practice placement data, and feeding that information into the APEX or SWAT models, for field and watershed scale modeling, respectively. The predicted outputs from the models were compared to the results of the baseline scenario, corn/soybean rotation, with tillage between each crop and no other conservation practices applied.

Conservation Placement: Based on results from the 2013 windshield survey (Smith et al., 2013) of the monitored portion of the watershed, approximately 13.7% of the row crop agriculture was conventionally tilled, 66.7% was planted using no-till with the remainder being planted using conservation tillage methods. Corn represented 36.9% of the agricultural ground, 44.2% planted to soybeans, 7.8% in small grains and 7.8% was estimated to be in the Conservation Reserve Program (predominately stream buffers and grassed waterway).

Monitored Water and Soil Quality Results: Field scale water quality monitoring should be considered within context. The water quality monitoring program used in these fields was designed primarily to capture pesticide losses (Apr. 1 – Nov. 15), so a period of low pesticide transport but potentially high nutrient transport for each year (Nov. 16 to Mar. 31) was not monitored due to difficulty in sampling during freezing weather. In addition, the data represent surface runoff from 2004 to 2012 and tile discharge only from 2008 to 2012.

Single conservation practices rarely address all water quality resource concerns (Smith et al., 2013). For example, No-till (CP 329) reduced nitrogen load (33-51%), sediment load (94%), and total phosphorus load (70%; Figure 3). However, soluble phosphorus loads increased in this case by 81% with this practice (Smith et al., 2013). This can be important because soluble phosphorus is the form most readily available to algae, and increased soluble phosphorus loading since the mid-1990's has been identified as a primary contributor to algal blooms in Lake Erie (Richards et al., 2010; Stumpf et al., 2012). Grassed waterways (CP 412) reduced nitrogen (36 to 77%), total phosphorus (52%), and sediment loads (93%), but increased soluble phosphorus loading by 160% (Smith et al., 2013). Conservation Crop Rotation (CP 328) decreased phosphorus (50-53%) and sediment loading (29%) but increased nitrogen loading (1-120%). One likely reason for increased nitrogen loading from Conservation Crop Rotation is that a higher percentage of the total discharge in the two fields with this practice was through subsurface tile, a known conduit for nitrate-nitrogen. Furthermore, these two fields are roughly twice as large as the fields with the conventional rotation, so there may be an artificial impact of scaling. Blind inlets, a modification of the Underground Outlet (CP 620; Smith and Livingston, 2013) resulted in decreased nitrogen (10-66%), soluble phosphorus (11%), total phosphorus (25%), and sediment loading (72%). The Indiana NRCS has recently adopted this practice as a practice available for cost share through Environmental Quality Incentives Programs (EQIP), and the Ohio NRCS is in the process of adopting this practice for cost share.

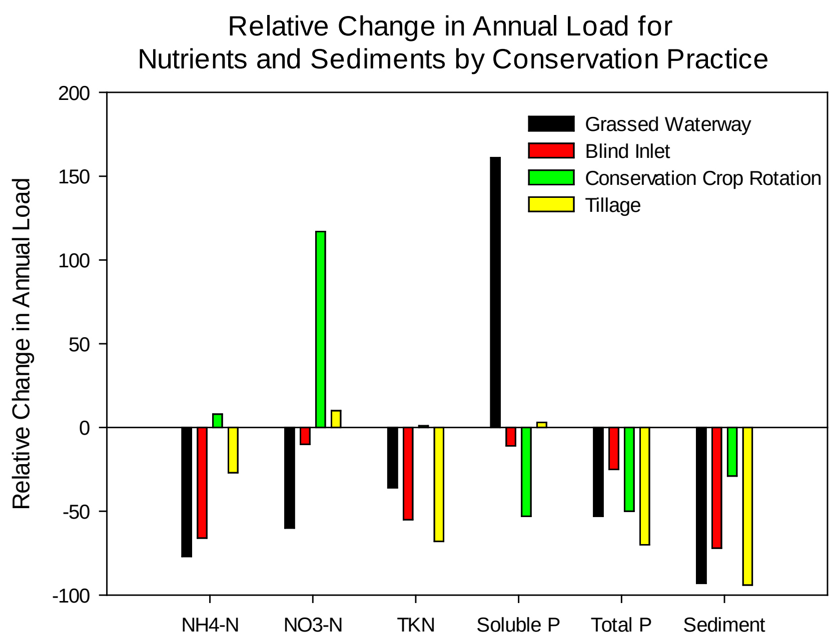


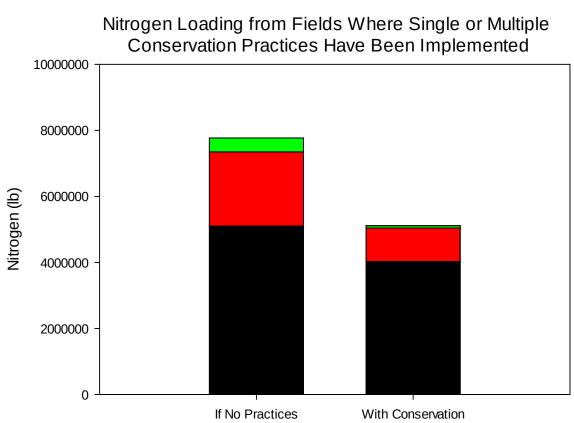
Figure 3. Relative changes in annual nutrient loads resulting from adoption of conservation practices in monitored fields in the St. Joseph River watershed.

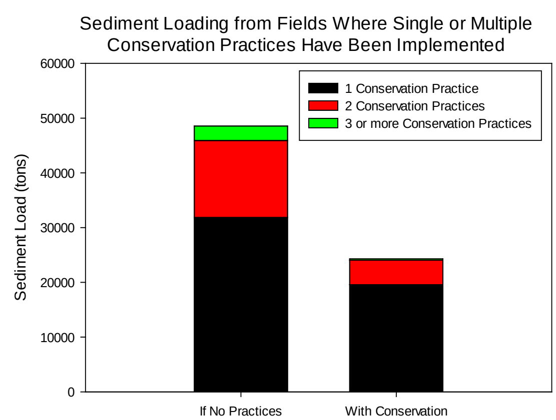
Soil quality was monitored in several fields within the St. Joseph River watershed (Stott et al., 2013). Sampling was carried out to evaluate a variety of cropping systems, and samples were analyzed for physical (i.e. soil texture), and chemical (i.e. pH and nutrient) properties. Results were entered into the Soil Management Assessment Framework (SMAF) to assess soil quality. Overall soil quality scores suggest that corn/soybean rotation resulted in the lowest soil quality, while practices such as Conservation Crop Rotation (CP 328), that add crops such as wheat or alfalfa to the rotation, improve soil quality. Further, grasslands, such as those enrolled in Conservation Reserve Program (CRP), have the overall highest soil quality.

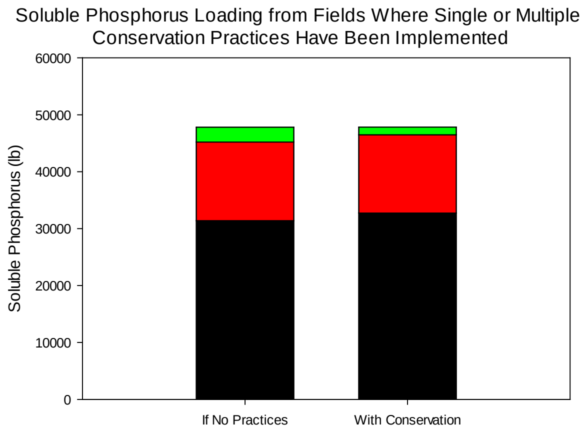
Field Scale Modeling Results: Conservation practices were placed in fields individually and in combination with other conservation practices in the St. Joseph River watershed. Field scale modeling was conducted to represent this level of conservation practice adoption. As many as possible of the conservation practices placed in the watershed were modeled at the field and/or watershed scale.

Based on the field scale modeling, conservation practices placed in the St. Joseph River watershed retained approximately 27,200 tons of sediment, 35,300 lb of phosphorus and 3,310,000 lb of nitrogen in agricultural fields, and thus out of the streams and Lake Erie (Francesconi and Smith, 2013). This corresponds to a 51% decrease in sediment load, 30% decrease in phosphorus and 42% decrease in nitrogen load at the field scale (Figure 4).

Based on this analysis, no-till reduces sediment loads by 56% compared to tilled fields (Francesconi and Smith, 2013). APEX modeling also suggests that no-till (CP 329) or mulch till (CP 329B) will increase soluble P loading 11-22% compared to a tilled system. The best performing conservation practices for sediment according to APEX modeling were Forage (CP 511/512) with a 91% reduction, Conservation Cover (CP 327) with a 91% reduction, and Cover Crop (CP 340) with an 88% reduction in sediment. For total phosphorus, the highest performing conservation practices were Forage (CP 511/512) with an 82% decrease in phosphorus load, and Cover Crop (CP 340) with an estimated 80% decrease in phosphorus load. Cover Crop (CP 340) is predicted to reduce nitrogen loading the most (76%) followed by Conservation Crop Rotation (CP 328; 46%).







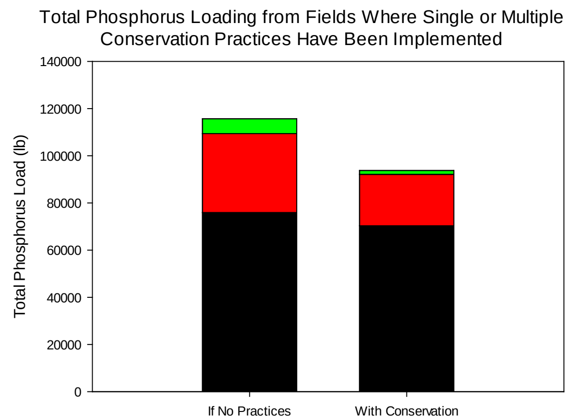


Figure 4. Cumulative impact of applying individual or multiple conservation practices on field nutrient or sediment losses, as calculated by APEX modeling. Portions of the bar with the same color represent the comparison of loads when conservation practices are applied to individual fields relative to the same fields with no conservation practices over the same period.

As with monitored data results, APEX modeling results suggest that when conservation practices are placed individually within fields all the resource concerns are rarely addressed. However, when two conservation practices are placed in a field, the results improve, and when three or more conservation practices are placed within a field, most resource concerns seem to be optimized (Figure 4; Francesconi and Smith, 2013).

Watershed Modeling Results: SWAT modeling for the Cedar Creek subwatershed of the St. Joseph River watershed used remotely sensed data to identify CRP grasslands, including grassed buffers of streams and forest buffers of streams. At the Cedar Creek scale, CRP grassland represented 6.6% of the watershed, of which 3.1% were grassed buffer strips and 2.1% were forested buffers. Together, these conservation lands decreased total phosphorus loading by 7.7% in the Cedar Creek watershed (Larose et al., 2011).

SWAT modeling of specific conservation practices applied during the 2005 through 2013 period at the watershed scale, shows similar results to reported field scale reductions from the APEX modeling efforts (Her et al., 2013). When expanded to the watershed scale, Conservation Crop Rotation (CP 328) appears to demonstrate the greatest reductions in nitrogen (2.3%), phosphorus (2.0%), and sediment (1.5%) at the outlet of the St. Joseph River watershed. The SWAT model also predicts load decreases of 1.1% for nitrogen, 1.5% for phosphorus, and 1.3% for Cover Crop (CP 340). Overall, SWAT predicts reductions of 228,000 lb of nitrogen (4.7%), 24,700 lb of phosphorus (5.9%), and 22,500 tons of sediment (5.0%) at the drainage outlet for all the practices implemented in the St. Joseph River watershed from 2005 to 2013.

Watershed condition: The St. Joseph River watershed is very sensitive, since contaminants of concern include pesticides and nitrates because the river is a drinking water source for the cities of Ft. Wayne, IN and Defiance, OH. Being a headwater for the Western Lake Erie Basin, water quality concerns include sediment, phosphorus, and nitrogen. Improvements are being made with respect to the loading of the herbicide Atrazine to the watershed; however, this is likely due to the decreased use of this herbicide in this watershed. Conservation practices are decreasing sediment and nutrient loading from fields within this watershed, as documented above. Field scale data have been able to document improvements, although this cannot yet be observed through monitoring at the 12-digit HUC scale. Lag times between implementing conservation practices at the field scale and when water quality improvements are observed are common (Meals et al., 2010). Additionally, other actions within a watershed can often mask improvements made through conservation activities. For example, dredging of agricultural drainage ditches has been shown to alter nutrient fate and transport in these ditches (Smith and Pappas, 2007; Smith and Huang, 2010). Further, other forces within the watershed, such as increased commodity prices, have led to intensification of agriculture in the watershed, as evidenced by more irrigation in the watershed now than was present five or ten years ago. Overall, the vast majority of stream/ditch miles in the watershed are well buffered (Smith et al., 2008; Larose et al., 2011). While water quality assessments are ongoing, the ecological integrity of streams and ditches in the watershed do not appear to be impaired by nutrients or sediments as much as they are by in-stream habitat (i.e. stream depth, stream velocity, bed sediment particle size; Robert Gillespie, personal communication).

The St. Joseph River has 35 stream segments in Indiana, one in Michigan and three in Ohio listed as impaired, with 58 impairments at 39 sites (SJRWI, 2006). This includes 22 impairments for pathogens, 19 fish consumption advisories for PCBs or mercury, 9 impaired biotic communities, 2 sites listed for habitat alterations, and 1 site each for algal growth, mercury, salinity, total dissolved solids, siltation, and nutrients. Thus, of the 58 impairments, only one can potentially be listed as impaired due to agricultural activities (on the list for nutrients), while four may be indirectly impaired because of agricultural activity (listed for siltation, algal growth or habitat alteration). Bacterial source tracking and modeling in the watershed both indicate the primary pathogen sources are from wildlife and homesteads, instead of agricultural activities (Rice, 2007).

While there is still room for improvement, conservation practices are working and conservation programs are having a positive impact on the St. Joseph River watershed. Opportunities exist to continue working on water quality and watershed condition by mitigating soil erosion and nutrient transport from agricultural activities. Current efforts are focused predominately on in-field and edge-of-field practices. Greater, and possibly more immediate water quality improvements, may be realized if these practices are coupled with near-stream or in-stream practices (Tomer and Locke, 2011; Kroger et al, 2013; McLellan et al., 2013).

Applying the Findings of the Project: This project has led to a greater understanding of how contaminants of concern, particularly phosphorus in this case, are transported through the landscape. As a result of the collaboration between NRCS, ARS, and Soil Water Conservation Districts, specific conservation practices, such as the blind inlet (IN CP 620), have been developed and implemented to target conservation to specific areas of concern within fields. Broader teams of scientists and conservationists have also begun work to target conservation in the watershed. Researchers from Purdue University worked collaboratively to provide SWAT modeling assessments of conservation practices and conducted social indicators studies in the St. Joseph River watershed. The Environmental Defense Fund, through a contribution agreement with NRCS, has started work to initiate landscape scale conservation practice implementation. The outcomes of this project could be adopting practices at field, edge-of-field, and in-stream to target removal of contaminants at as many locations along the flow-path as possible. NRCS is also working closely with ARS to apply the APEX model to the lake plain soils, a prominent feature in the Western Lake Erie Basin. The Indiana NRCS has designated the St. Joseph River watershed as being eligible for the Water quality monitoring Conservation Activity (201/202), so field scale testing of conservation practices is possible in the future through this CEAP WAS.

Cienega Creek Watershed

Watershed Description: The total drainage area of the Cienega Creek Watershed is 387,800 ac, but analysis will focus on the upper 126,720 ac of the basin upstream of U.S. Geological Survey (USGS) gage 9484550. Principal geographic features, communities, and surface water features are shown in Figure 5. The watershed has no major reservoirs or impoundments, but does have more than one hundred stockponds for grazing and wildlife. It lies in the Basin and Range geologic province that is characterized by a series of mid- to high-elevation mountain ranges separated by broad low-elevation basins. Vegetation includes plains, great basin, and semi-desert grasslands, Chiuahuan desertscrub, madrean evergreen woodlands, and a small portion of Rocky Mountain and montane conifer forest. It includes limited reaches of riparian vegetation adjacent to perennial streams consisting of mixed broadleaf trees, mesquite, and relatively dense understory. The watershed has a mix of private, state, and Federal land ownership that is common in the West and consists of approximately 28% USFS, 22% State Trust, 20% Private and 30% Bureau of Land Management (BLM) land. Primary land uses for the different ownership parcels consist of grazing, recreation, and fuelwood cutting on USFS lands; recreation and grazing on BLM lands; grazing on State Trust lands; and domestic ranching and farming on Private lands.

This watershed has been the focus of a long-term conservation planning process that has resulted in the adoption and implementation of numerous NRCS and USFS grazing land management and soil erosion control conservation activities. In addition, there are substantial efforts to address fire severity and the adverse impacts on watershed condition and sediment discharge through fuels treatments and fire management practices that can also be evaluated.

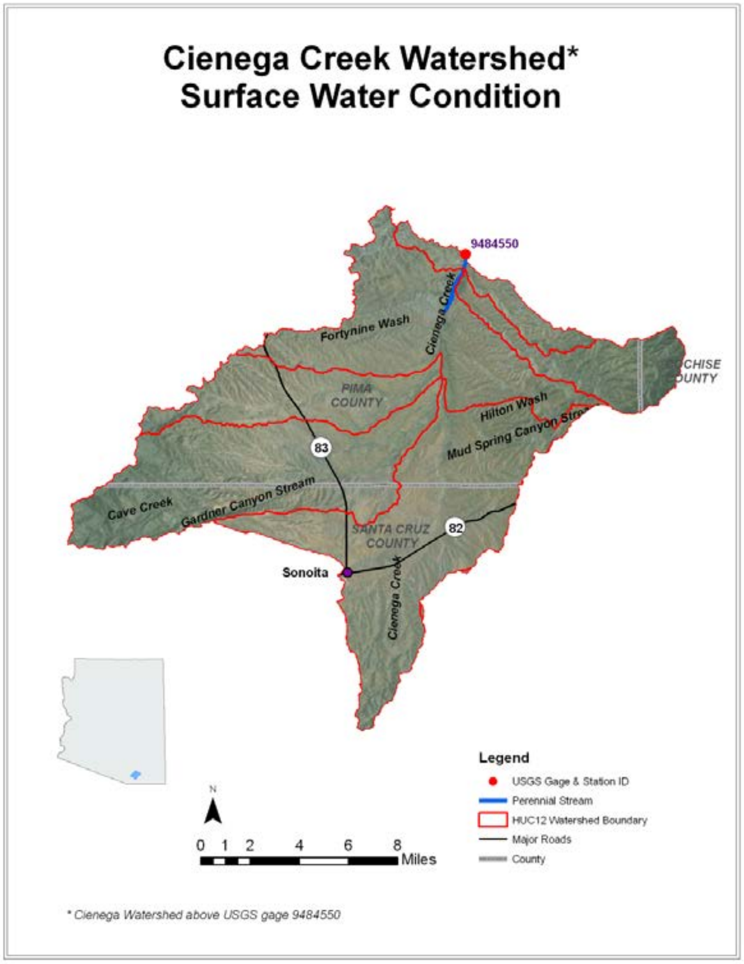


Figure 5. The Cienega Creek Watershed (HUC 1505030201) is in the southeastern corner of Arizona. Only a portion of the Cienega Creek Watershed (134,705 ac upstream of USGS gage 9484550, depicted by a red dot on the map) will be the focus of the analysis in this Agency Priority Goal pilot project (including the following 6 HUC 12 watersheds: Gardner Canyon (HUC 150503020101), Smith Canyon-Cienega Creek (HUC 150503020102), Empire Gulch (HUC 150503020103), Mattie Canyon (HUC 150503020104), Forty-nine Wash-Cienega Creek (HUC 150503020105), Fresno Canyon-Cienega Creek (HUC 150503020107).

Conservation Practices and Placement: Primary conservation and management practices include prescribed grazing (including practices to control the amount and timing of grazing such as fencing and watering points), and prescribed fire and brush management to increase forage and reduce losses of soil and nutrients. Rangeland conservation spending in Arizona began to steadily ramp up from roughly 1994-96 and peaked in 2009-2010. Earlier conservation practices deployed in the NRCS database only contain a point location of where a practice was implemented without the specific area over which it was applied. The Forest Service has geo-referenced polygons for the location of both prescribed fires and wildfires. High quality records of cattle numbers, where they grazed, and for what duration are not available from NRCS or USFS. Starting in 1995 detailed grazing and conservation placement and spending data are available on the Empire Ranch, managed by BLM as part of the Las Cienegas National Conservation Area and in collaboration with the Cienega Watershed Partnership (USFS is a partner and

NRCS provides technical assistance). Relatively extensive conservation and management practices have been conducted on the Empire Ranch (e.g. over $1.2 million, primarily stimulus funds, was spent on mechanical brush removal on over 2980 ac in 2010 and 2011). Conservation practices must be implemented as part of a comprehensive system to integrate practices and provide ongoing management to be effective. Due to high climatic variability, water-limited vegetation production, and low nutrient soils, rangeland condition change typically takes multiple years.

Monitored Watershed Condition Results: Due to the ephemeral nature of streams in the watershed, in-stream water quality measurements are neither collected nor historically available. Watershed condition is primarily assessed by monitoring the vegetation type, canopy cover, ground cover, and soil properties, which are used to estimate the susceptibility of watershed hillslope areas to erosion and therefore their long-term sustainability. NRCS collects these data as part of the National Resource Inventory (NRI) (Herrick et al. 2010). Vegetation transects collected for the NRI provide nationally consistent ground-sampled data on the status, condition, and trends of land, soil, water, and related resources on the Nation's non-Federal lands since 1982 (grazing lands since 1991 and select BLM-managed non-forested lands since 2011). The USFS also collects vegetation and soils information using a sampling method that is not consistent with NRCS and BLM NRI methods. Examination of repeat USFS observations data from 1958 to 2009 indicate general trends of increasing litter cover and decreasing bare soil suggesting improved rangeland condition.

There was only one NRI sample within the Cienega Creek Watershed but 134 NRI sample segments in the major land resource area (MLRA 41 - Southeastern Arizona Basin and Range) and 41 segments in Pima and Santa Cruz counties where the Cienega Creek Watershed is located. Similarities in soils, climate, and ecology were used to estimate conditions and hillslope runoff and erosion model parameters for the Cienega Creek Watershed from all the NRI samples in this MLRA. For the purpose of this project, the Pre-Conservation Condition (PCC) is defined as the Cienega Creek Watershed rangeland condition prior to substantial application of rangeland conservation practices conservation spending. The PCC Cienega Creek Watershed condition will be based on 1992 NRI samples. The Current Condition (CUR), after substantial conservation investments, will be based on 2006 NRI samples. Rangeland watershed condition at any given time is often compared to the Historical Reference Condition (HRC) characterized by the least disturbed vegetation community examples from specific type locations.

Qualitative NRI assessments concluded the trend in rangeland condition for both 1992 PCC and 2006 CUR was "moving slightly away from the HRC" for Pima and Santa Cruz County NRI samples. Another metric of rangeland watershed condition is the Similarity Index (SI). SI expresses the current species composition by weight as a percentage of the historic plant community species composition as described in the ecological site description. SI determinations in the Cienega Creek Watershed have shifted slightly from 30% in 1982 (1992 SI not available) to 28% in 2006. The average similarity index for Pima and Sana Cruz counties in 2006 was 30%, not significantly different from 1982. In addition, average woody plant cover decreased to 11% in 2006 compared to 16% in 1992. Cover of non-woody plants was not collected in the NRI process during 1982 to 1992. However, in 2006, average plant cover values were 50% and total ground cover (litter, cryptogams, basal plant, and rock) was 71%. Overall, this indicated a stable to improved rangeland condition from the PCC to the CUR. Rangeland health indicators were collected in the new on-site NRI (2003-06) samples and all three attributes (biotic integrity, soil and surface stability, and hydrologic function) were in the none-to-slight departure from the historic reference category.

This is very encouraging given that about half of the 23 driest seasons in the 117-year precipitation record from 1895 to 2012 have occurred during the 16-year period from 1997 to 2012 where conservation spending was focused. Remote sensing methods using freely and nationally available Landsat imagery dating from 1984, have been successfully developed and tested on the Cienega Creek Watershed to estimate both green and senescent brush and grass canopy cover. The remotely derived estimates of grass and forb canopy cover (an indication of improved rangeland condition) increased by statistically significant amounts after the implementation of burning and mechanical brush removal conservation practices. These observations imply that implementation of rangeland conservation practices including prescribed grazing has overcome the negative impacts to rangeland condition due to severe and extended drought.

Hillslope Scale Modeling Results: The RHEM (Rangeland Hydrology and Erosion Model; Nearing et al., 2010) was specifically designed to use data collected as part of the NRCS Rangeland NRI. Three conditions were modeled using RHEM to provide estimates of runoff, erosion, and sediment yield for various hillslopes and small watersheds within the CCW. The three conditions included are the HRC, the PCC – derived from 1992 NRI data prior to substantial conservation spending, and the CUR - derived from 2006 NRI data, the most recent data available, after substantial conservation spending.

A small watershed (297 ac) within the Cienega Creek Watershed was modeled with RHEM as three hillslopes draining into a small stock pond (<2 ac-ft capacity) for the three conditions described above using design storm rainfall that occurs on average of every 2, 5, 10, and 25 years. For the 10-year storm, the RHEM results for sediment yield with and without the stock pond are illustrated below (Figure 6). There were decreases in sediment yield of 6% without the pond and 16% with the pond from the PCC to the CUR again indicating improved rangeland condition resulting from conservation practices and management. However, there were profound reductions in sediment yield due to the stock pond trapping sediment (74% for the PCC and 77% for the CUR). This is important, as stockponds are ubiquitous in Arizona with an estimated 25,000 stockponds in the 37 million acre Gila River basin,129 stock ponds are present in the Cienega Creek Watershed alone, a tributary to the Gila River Basin). While NRCS treats stockponds primarily as a water supply practice for cattle and wildlife they are not often implemented for water quality purposes, but should be considered as such due to their direct impact in reducing surface runoff and sediment (Nichols, 2006).

If not properly maintained, sediment accumulation behind earthen dams can become an unmanaged source of sediment loading that directly impacts downstream water quality if a dam fails. In southeastern Arizona, reliance on stockponds for livestock water supply is being diminished as more dependable water pumping and distribution through pipelines become more common. As a result, there is a potential for stockponds that are not maintained to become a threat to release sediment after failure. Stock tanks also serve an important role providing water for wildlife habitat and are recognized as the primary sites for the recovery of the threatened Chiricahua leopard frog in the U.S. Fish and Wildlife Service's species Recovery Plan (2007).

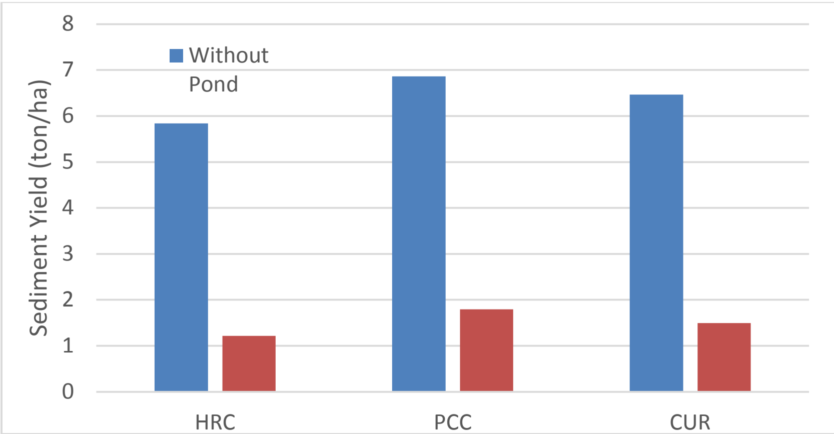


Figure 6. Simulated sediment yield (ton/ha) from a small watershed (297 ac) within the Cienega Creek Watershed for the HRC, the PCC, and the CUR modeled with and without a stock pond at the outlet of the watershed.

Watershed Modeling Results: The RHEM model was integrated into the USDA-ARS KINEROS2 watershed model (Goodrich et al., 2012) which is part of the AGWA (Automated Geospatial Watershed Assessment) Tool (Miller et al., 2007). AGWA enables rapid watershed model parameterization, execution, and visualization of KINEROS2 simulation results in a Geographic Information Systems (GIS) environment using nationally available data sets of topography, soils, and land cover. The Cienega Creek Watershed is made up of six HUC12 watersheds. A variety of simulation scenarios were investigated using different levels of information representing watershed topography, storms, and observations of ground cover and condition for the HRC, PCC, and CUR conditions. At the simplest, a single representative hillslope within a HUC12 with an average design storm and RHEM parameters from NRI data is employed. At the most complex, but more site-specific level, the HUC12 is broken into hundreds of hillslopes, with topography of the hillslopes described by 10 meter digital elevation model data, a design storm at the center of each hillslope with RHEM parameters derived from Landsat remotely sensed vegetation cover data, NRI data, and local vegetation transects.

A summary of the average sediment yield for the 10 year, 1 hour design storm for the Gardner Canyon HUC 12 appears in the following table for three levels of information (Table 1). For the simple and intermediate case where the RHEM parameters are based on NRI data there are substantial reductions in average sediment yield from the PCC to the CUR rangeland condition. For the most complex case, where the current condition simulations used ground observations and 2007, 2009, and 2011 Landsat scenes to derive RHEM parameters, the average sediment yield was four percent less than the pre-conservation condition. While the improvement is small, it is very encouraging that there was any improvement given the substantially hotter and drier climatic conditions in recent years as compared to the pre-conservation period.

A visual representation of the differences in sediment yield between current conditions represented by the 2007 (top), 2009 (middle) and 2011 (bottom) RHEM parameters and pre-conservation conditions is easily generated by AGWA in the following figure for all 974 hillslopes in the Gardner Canyon HUC12 (Figure 7). Figure 7 depicts the percent change in hillslope sediment yield from the pre-conservation to the current condition simulations (negative percent changes indicate a decrease in sediment yield from the PCC to the CUR – the larger the decrease the greener the color). Red hillslopes indicate the largest percent increase in sediment yield. These hillslope areas might be prioritized for implementation of future conservation practices.

Table 1. Simulated sediment yield (SY - kg/ha) from the Gardner Canyon HUC-12 subwatershed within the Cienega Creek Watershed for HRC, the PCC, and the CUR modeled with increasing levels of input information to derive the model input parameters as well as the average percentage change in SY from the PCC to the CUR condition.

Gardner Canyon HUC12 - 10 year, 1 hour storm					
(Area = 25,040 ac)					
		Sediment Yield (kg/ha)			
		Condition			
Level of Information	No. Hillslopes	HRC	PCC	CUR	% change from PCC to CUR[5]
Simplest[1]	1	346	763	513	-33
Intermediate[2]	974	449	948	671	-29
Most Complex[3]	974	N/A	430	413[4]	-4

[1] RHEM parameters from NRI; RHEM simulation for each ecosite, area weighted average by ecosite across HUC12, uniform storm, 50m planar hillslope

[2] RHEM parameters from NRI, spatially variable storms, complex slope profile from AGWA

[3] RHEM parameters from NRCS soils, ground plus remote sensing observations, spatially variable storms, complex slope profile from AGWA

[4] The average from the three recent Landsat derived cover parameters (438 kg/ha in ‘07; 435 kg/ha in ’09; 365 kg/ha in ’11)

[5] A negative percent change signifies a decrease in sediment yield from PCC to the CUR

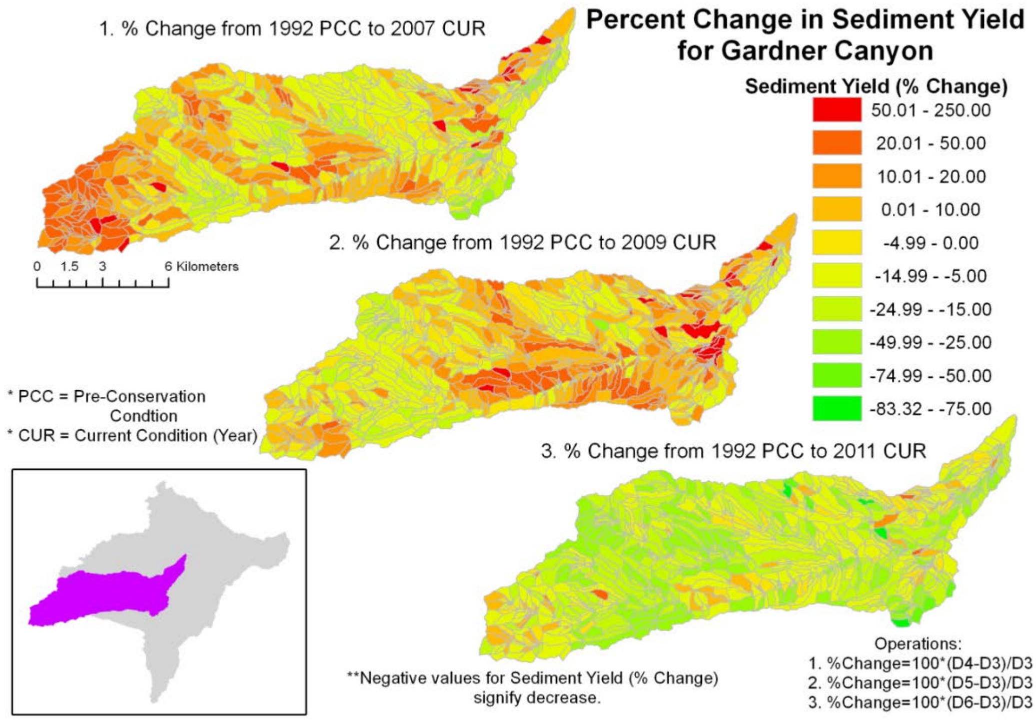


Figure 7. Spatial display of the percent change SY from PCC to three cases of the CUR with model input parameters derived using 2007, 2009, and 2011 Landsat imagery for all 974 hillslope modeling elements in the Garden Canyon HUC-12 subwatershed of the Cienega Creek Watershed for the 10-year one hour design storm.

Figure 8 illustrates the percent change in SI for all 3577 hillslopes in the Cienega Creek Watershed as well as for each of the six HUC12, which make up the CCW for the intermediate information level simulations. The greener the hillslope the greater the decrease in SI indicating improvement in rangeland condition after substantial conservation spending. Red hillslopes indicate that SI increased by up to ten percent between the PCC and CUR. Future conservation spending and management might be targeted in these areas.

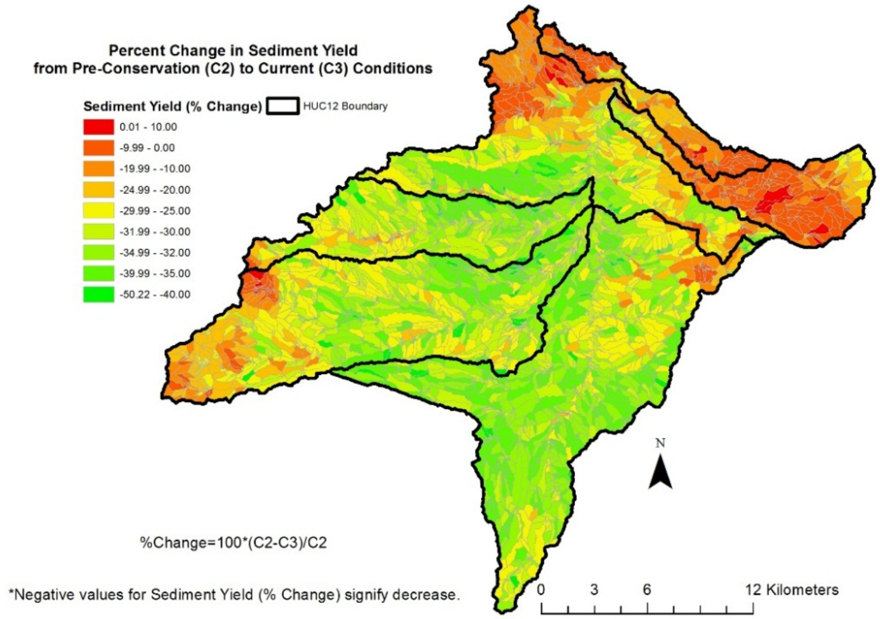


Figure 8. Spatial display of the percent change in SY from PCC to CUR with model input parameters derived using NRI data (1992 for PCC; 2006 for CUR), and nationally available digital topographic and NRCS soils data for all 3577 hillslope modeling elements in the Cienega Creek Watershed

It should be noted that the intermediate and complex cases utilize several different nationally available data sets (topography, NRCS soils, and land cover from Landsat remotely sensed imagery) to conduct conservation assessments at a scale allowing for identification and prioritization of areas to implement conservation practices commensurate with typical rangeland management and planning activities. Results can also be easily aggregated for reporting at the HUC12 watershed scale.

__Watershed condition:__

There is no widely accepted procedure for definitively assessing rangeland watershed condition. The Forest Service has a reconnaissance-level approach to assessing watershed condition known as the Watershed Condition Framework. In that framework, roughly 35% of the Cienega Creek Watershed is rated as “Functioning Properly” and roughly 65% as “Functioning at Risk,” in large measure due to problems associated with the risk to animals and plants associated with riparian/wetland areas. According to Figures 7 and 8, there have been substantial reductions in the simulated sediment yields between the pre-conservation and current periods across much of the watershed. The areas with a slight increase or small decrease in SI had steeper slopes and rockier soils, so they would be expected to show drought effects on vegetation before the flatter, deeper soils closer to Cienega Creek. The Arizona Department of Environmental Quality's 2010 Assessment for Streams and Lakes in the Santa Cruz Watershed show all of Cienega Creek in the "Attaining" water quality status. As part of an adaptive management process for the Las Cienegas National Conservation Area, a public review is held each spring and fall to assess actions needed to achieve the objectives defined in the 2003 Resource Management Plan. Over the past decade, the Las Cienegas National Conservation Area has generally been meeting the defined objectives. In summary, conditions across much of the watershed are improving in spite of the recent drought. However, areas that are not buffered by significant soil water holding capacity or are dependent on receiving additional water from runoff are at risk of losing function.

Applying the Findings of Project: This project led to increased collaboration among the NRCS, ARS, and USFS. Some of the outcomes of discussions and work in selecting and carrying out the project include a greater understanding across agencies of how ephemeral and intermittent streams function in the Western U.S., how each agency tracks changes in the quality or condition of water and soil resources and plant communities, and what the various approaches are that are used to assess the condition of water resources in the arid or semi-arid West. Also discussed, as part of the recommendations and considerations, were the potential benefits of more common methods of data collection on the condition of various resources. In the future, this would enable a more complete landscape-wide assessment in the west where mixed public-private grazing lands are common.

Because contaminants of concern, primarily sediment in this case, are transported through the watershed in such a different way in these intermittent and ephemeral streams (episodic sediment movement), the focus in these range and forested landscapes is on limiting soil erosion by restoring plant communities and cover. As a result, future collaboration between NRCS, ARS, and USFS will focus on applying the findings of this project to the Cienega Creek Watershed to reduce soil erosion and increase resilience to drought conditions. In addition, the new RHEM model will be applied to both rangelands and forested lands, particularly to prioritize rangeland conservation and management and following wildfire or prescribed fire to assess impacts. RHEM can be used to evaluate risk for erosion, and when coupled with the AGWA tool, it can aid conservationists, as they work to prioritize areas in greatest need of or yielding greatest benefits from additional conservation treatment. For example, a new CEAP project is expected to begin next year to carry on the work of this CEAP study and examine how model use and results can be integrated into the existing NRCS conservation planning process on rangelands to help prioritize lands for conservation implementation. The RHEM model can be used to examine hillslope scale or can be integrated into watershed-scale models such as KINEROS2/AGWA, as was done in this analysis. As part of a watershed planning approach, it could be used to assess how far we have come with prior conservation efforts as well as used to determine areas of the watershed that can benefit the most from additional future treatment, and therefore is crucial to more precise targeting of conservation practices over a broad landscape. More analysis of data sources and remotely sensed data options in comparison to ground-based data are needed to prepare for extending the use of the tool to other watersheds or regions in the West.

Considerations and Recommendations: Assessment and Performance Reporting

The basis for the report above was a response to the “Agency Priority Goal Framework Document” (Sulafsky, 2011). However, given USDA’s experience in responding not only to this recent document framing watershed evaluation but also to current and prior experiences to assess our impact, there are some lessons learned that could be used to help shape future similar undertakings. Those insights in particular are discussed in this section reviewing considerations and recommendations.

This report’s focus is on data collection, monitoring, and modeling for water resources draws on project studies and USDA research. The two watershed-scale projects for the Agency Priority Goal drew heavily on existing CEAP Watershed Studies (the St. Joseph River in IN and the San Pedro-Wilcox and Santa Cruz Watersheds in AZ) and a related project for CEAP Grazing Lands (the Cienega Creek Watershed, a subwatershed of the Santa Cruz River, AZ). The WCF was also carried out by USFS in 2011 in the Cienega Creek Watershed and contributed information and analysis to this effort.

Below is a review of three primary items for further consideration in future water outcome-based performance reporting efforts and some related suggestions based on current and prior USDA experience.

What to Measure: Common Water Resource Outcome Metrics

Many possible measures, indicators, and assessments can be used for water quality and watershed condition. However, it is a major challenge to find enough locations and data to substantiate claims of water quality improvements using the same measures. Both of the pilot watersheds used in this study had relatively abundant observations and records of conservation practices as compared to typical HUC12 watersheds. A focus of the Agency Priority Goal for Water was to explore potential common measurements to evaluate the water resource impacts of USDA programs and conservation efforts. Concerning water quality observations, there is certainly a common subset of metrics that could be explored in many locations around the country, namely nitrogen, phosphorous, and sediment reductions at the edge-of-fields or rangeland hillslopes and loads. These are the set of metrics that the Agency Priority Goal for Water commonly worked towards. However, assessments of conservation effects and watershed condition should be focused on the primary pollutant of concern in that specific watershed; as well, conservation and restoration efforts should be directed toward the pollutant of concern. In addition, the primary pollutant may differ from watershed to watershed. While this small subset of metrics is of great shared importance to watershed managers, conservationists, producers and citizens across the Nation, it is challenging to find a set of locations that has a water quality or vegetative cover monitoring record of sufficient length and quality to allow differentiation of conservation impacts on watershed and water resource conditions from other impacts.

For example, most USFS and private lands agricultural watersheds (where NRCS programs would be applied) do not have watershed water quality monitoring programs in place. Of those that do, most are not in places where both USFS and NRCS are actively working simultaneously. Additionally, in many cases, the pollutants of concern in arid versus humid watersheds differ. This is because of differences in dominant hydrologic pathways and pollutant biogeochemistry, which affect the fate and transport of different pollutants. For example, often nitrogen loads are a concern in many humid, eastern agricultural watersheds where fertilization and cultivation are common. However, in many western watersheds (where precipitation is low and variable or where drought is present) stream flow is intermittent or ephemeral, and agricultural chemicals are rarely applied, so measuring in-stream water quality contaminant loads is often not possible (Figure 8). However, vegetative community condition and soil erosion are concerns that are frequently the focus of many monitoring, conservation and assessment efforts in both range and forested settings.

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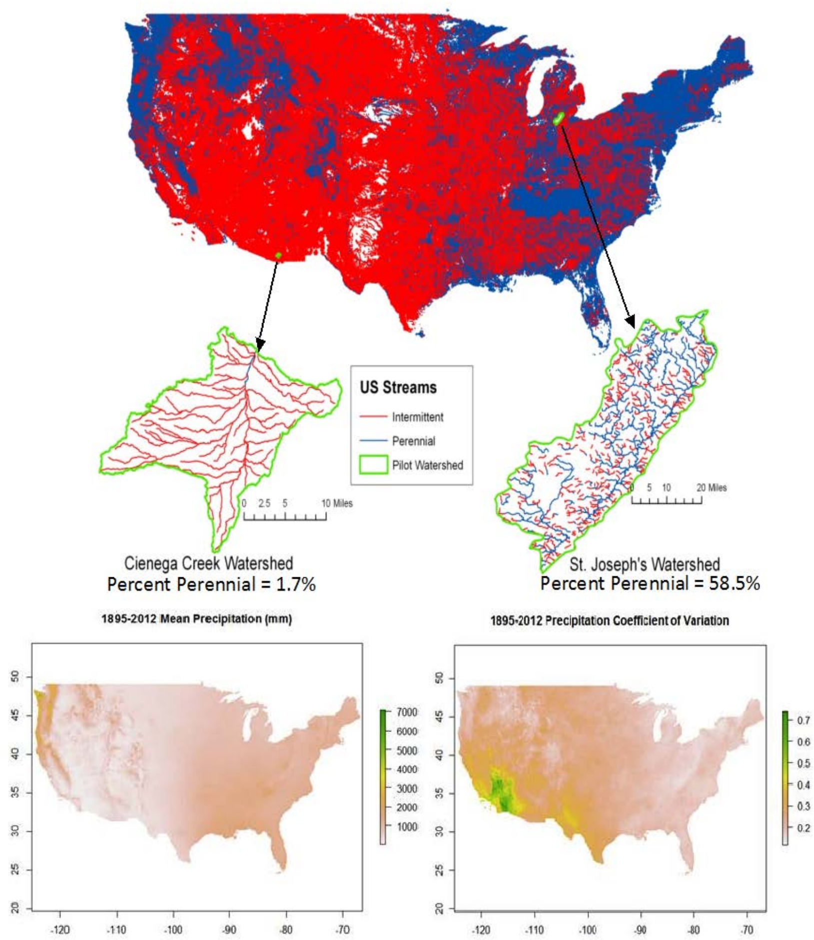

Figure 8. Upper - Map of the Continental United States showing the National Hydrography Dataset (NHD) intermittent/ephemeral (red) and perennial (blue) streams. Lower – Maps of mean precipitation and the precipitation coefficient of variation (equal to the standard deviation divided by the mean) of annual precipitation from 1895-2012.

How to Measure Water Quality Outcomes: Challenges and Best Practices

What measurable impact does USDA conservation program investment have on watershed condition and water quality? Although there may be volumes of data available on water quality and conservation, most existing data were not collected to help answer this question. Some existing data may not be usable.

Watershed condition and water quality monitoring programs need to be robust enough to perform statistical analysis as well as be planned in conjunction with the implemented conservation. In many cases, agencies implementing water quality monitoring programs (e.g., EPA, USGS) are not the same agencies implementing conservation practices. While coordination is always an objective, often watershed monitoring programs are not or were not established specifically to document changes because of conservation implementation. In addition, watershed monitoring locations and frequencies need to be selected in such a way as to distinguish among various influences on watershed condition and water quality parameters such as land treatment, significant land use changes, and climate effects. Because high-quality monitoring and data collection are expensive, they cannot be implemented across a broad spectrum of locations and practices. However, it is recommended that a small percentage of conservation dollars be dedicated to high quality, intensive monitoring, and evaluation of conservation practice effectiveness at a selected subset of representative locations for common conservation practices. A more lengthy discussion of factors to consider when attempting to measure water quality change as a result of conservation implementation is available in a related CEAP publication (Meals, et al. 2012).

Because research-based relationships between conservation or management and water or soil quality have been defined based on locations with high-quality monitoring, we can also use biophysical models to predict water resource outcomes at locations and for practices where the models were validated with excellent observations. Mechanistic simulation modeling can be applied at both field and watershed scales to determine the impacts of conservation and management actions on watershed condition and water quality, where confidently validated by representative monitoring. Model predictions of conservation effectiveness for practices or conditions where high-quality observations are not available are more uncertain. In addition to water quality monitoring, which is also used to calibrate and validate predictions from the simulation models, modeling can help to isolate the effects of water quality protection efforts and yield insights into the impacts of agriculture and conservation in a watershed versus other factors influencing the quality or availability of water. This is a particularly important and helpful approach in efforts aimed at assessing conservation practice effectiveness at field and watershed scales.

Research has illustrated that watershed condition and water quality monitoring combined with and modeling approaches are most effective at elucidating the effects of conservation and management actions to protect or restore water quality than either approach alone (Easton, et al. 2008; Osmond et al. 2012a). The USDA CEAP is well positioned to successfully document water quality outcomes because it employs both biophysical modeling and long-term watershed water quality monitoring approaches. Applying these approaches through the CEAP Watershed Assessment Studies, we have been able to document water quality improvements as a result of conservation (Tomer and Locke 2011; Osmond et al. 2012b).

For rangelands, there are some additional considerations given the unique nature of range ecosystems as well as the ephemeral and intermittent nature of streams in the western United States (Figure 8), where persistent droughts are common. There has been significant progress in developing interagency (BLM, NRCS, USFS) approaches to rangeland management including the definition of a qualitative approach that reflects departure from reference conditions known as Rangeland Health (Pellant et al., 2005) and an Interagency Handbook (2013) describing how to develop Ecological Sites as the basis for improving the science used in rangeland management. Yet much work remains to integrate expert opinion, field monitoring, simulation models and remote sensing to better inform rangeland management for resource conservation. The broad outlines of a more mature scientific foundation to rangeland watershed management are clear. Ecological sites should be mapped much more comprehensively, ecological state and transition models defined, especially to include an understanding about how climate and management practices interact to cause transitions, with a better ability to estimate the effects of changes in vegetative composition on simulation model parameters to estimate impacts on variables of management interest. Using freely and nationally available Landsat imagery, remote sensing methods were also found to be effective in monitoring changes in watershed condition from brush removal conservation practices (prescribed fire and mechanical removal) in the Cienega Creek Watershed Pilot effort and should be further evaluated for broader use across the western United States.

Spatial and Temporal Considerations: Impact on Assessing Water Quality

It is often the case that a significant time lapse exists between when conservation is implemented on the land and when changes in watershed condition and water quality are observed. There are also many things that affect water quality between the point where conservation is applied in a landscape and downstream water quality. The factors of time (temporal variations) and space (spatial variations) must be considered in determining how to best approach the monitoring and assessment of impacts from conservation, protection, or restoration actions. Spatial and temporal variations are both considerations relating to scale.

Scale is a critical factor to consider because it becomes increasingly challenging to document the impact of a conservation action the farther the distance from where the conservation and the water resource interact. This is because there are many other factors occurring within a watershed that likewise have an impact on the resource quality (e.g., urbanization or development, other large-scale land use changes, and climatic variability). Unless the extent and density of the conservation or restoration is substantial enough, it is challenging to measure a response in the larger watershed. Therefore, it is important, in assessing the effects of conservation on environmental quality, to include field (for cropland or pastureland settings) or hillslope (for rangeland settings) scales to increase the probability that you will be able to measure a response to the nearby conservation treatment. In the case of these Agency Priority Goal for Water projects, monitoring and modeling activities and analysis at the edge-of-field (cropland) or at hillslope scale (rangeland) as well as at watershed scale were included in an effort to report on measured water quality changes.

Challenging as that may be, it is also important to assess any changes in watershed condition and water quality. While the conservation actions of producers may be driven by very localized conservation needs that they witness or perceive on their land (at the edge-of-field, hillslope, and larger scales), as conservation-minded stewards they also commonly share with others in the community broader goals of contributing to protecting or restoring the overall watershed or a nearby water body of concern. As previously discussed, a high quality experimental design and appropriate equipment are needed in order to document changes in watershed condition or water quality over time. While there are several different approaches to this task of watershed condition and water quality monitoring (pre- and post-, nested, etc.), it is the general consensus in the scientific community that, where possible, a paired treatment-control watershed design is most effective in documenting change to water quality as a result of conservation implementation (Meals et al. 2012). This is obviously challenging to do both logistically, particularly at the scale of a watershed (as opposed to a smaller catchment), and politically, as it implies one location or producer may receive conservation practice support while another will not.

Modeling is a particularly good approach when performance assessment requires national coverage or large regional (basin or sub-basin) scale assessments, because it can be performed consistently across a large area since monitoring data is not available in all small watersheds across the nation and nationally available databases can also be used. While this approach provides consistent results, the results are quantitatively more uncertain due to the lack of observations for calibration but can be employed for relative area to area and basin to basin comparisons over longer time intervals. Because conservation effects are not necessarily always additive across watersheds (since other transformations and processes can occur within a basin that would influence results), summing effects from numerous smaller watersheds is usually not feasible nor advisable (depending on approach) to attain national coverage. Although, smaller scale assessments are important in benchmarking progress and validating modeled estimates. Small watershed scale assessments also are important because they are often conducted at the scale that can inform local conservation planning and watershed management strategies.

Temporal effects also have significant impacts on efforts to discern the outcomes of conservation. This is particularly true for watershed condition and water quality effects of conservation, as some of these changes can occur on multi-annual or even decadal time scales. For example, given the processes that govern the fate and transport of pollutants, climate is a factor with great influence on watershed cover and water quality parameters. For example, in examining the record of mean annual precipitation for the Cienega Creek Watershed, it is evident that there have been numerous cycles of wet and dry periods over a 100 plus year record (1895-2012) (Figure 9). These more lengthy periods of either greater or lesser than average precipitation have obvious implications for the performance of installed conservation practices on water resources and, in this case, on vegetative cover and erosive processes as well. Therefore, an answer to the question of how effective conservation is would differ depending on what time period (within the available record) you are using to answer that question. Lag time is another phenomenon that affects the ability to measure impacts of conservation on watershed condition and water quality (STAC, 2013). In cases where subsurface flow is present, it can take years or even decades to see the effects on water quality (Meals et al. 2010). Similar lag effects have been documented with regards to historical or legacy sediment loads in streams, which affects the ability to document a sediment load decrease in a stream even when contributing loads from upland erosion have been reduced (Brooks et al. 2010). In arid and semiarid rangeland watersheds, where plant growth is water limited and slow as compared to humid environments, significant changes in watershed condition (plant cover and form) can take many years.

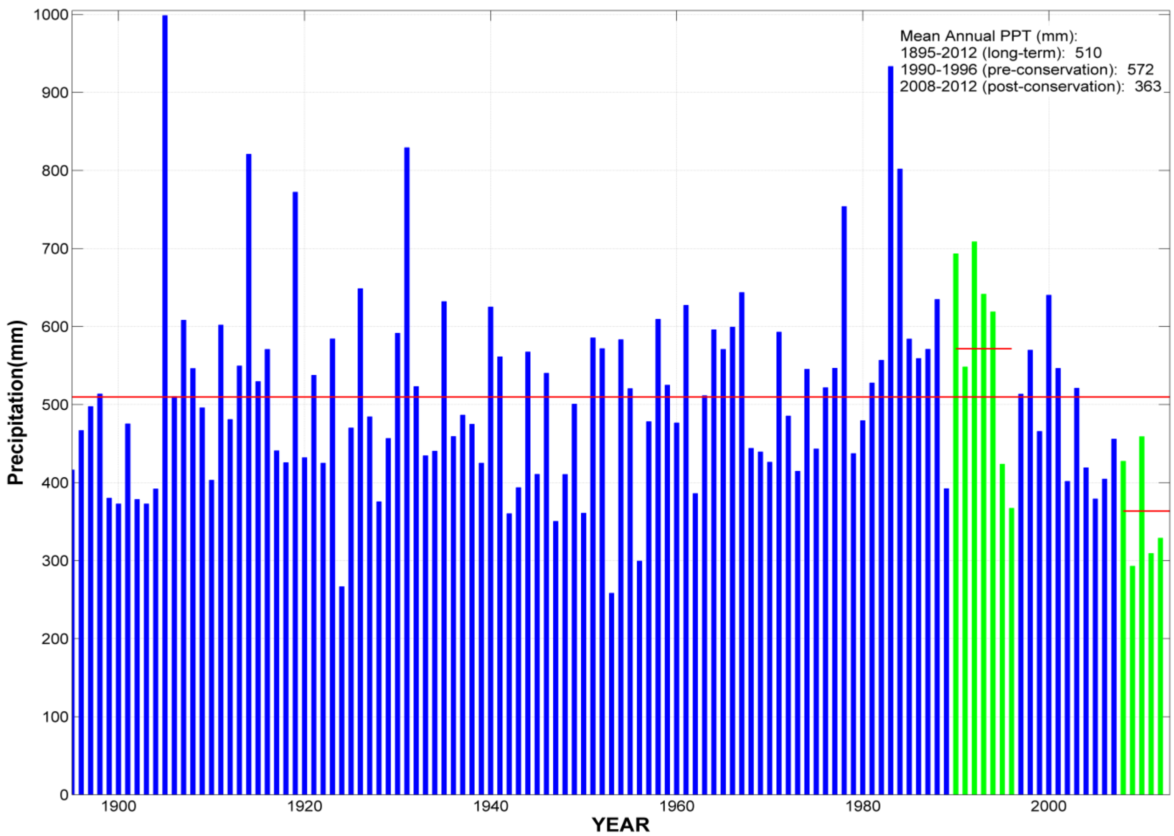

Figure 9. Long-term precipitation record at Cienega Creek Watershed. Green bars indicate periods of pre-conservation, post-conservation, and red lines indicate average precipitation for different periods. Data was derived from PSRIM (Parameter-elevation Regressions on Independent Slopes Model, http://www.prism.oregonstate.edu/).

Therefore in CEAP, to more accurately analyze these effects, we have opted for longer time periods as the basis for our assessments of conservation benefits. However, this means that conducting a short-term (e.g., 2 or 3 year) case study with no prior data is not recommended. For assessing conservation effects over time it is scientifically credible to rely on a longer-term, established, well-studied collection of locations as “Benchmarks.” This is particularly important when you are interested in measuring outcomes through monitoring in addition to modeling impacts. USDA must continue supporting a set of watersheds around the country with existing resources and historical understanding of the climate and land use history for the purposes of assessing conservation effects over time (Tomer and Locke, 2011, Duriancik, L.F. 2013). In CEAP, we have carefully drawn on a subset of fourteen ARS long-term watersheds now referred to as the CEAP Benchmark Watershed Assessment Studies (Richardson et al., 2008). Many of these sites include valuable field-scale analysis as well as watershed scale monitoring to assess conservation impacts. In addition, rigorous selection criteria implemented through a competitive grant process yielded a complementary set of locations in the NIFA CEAP Watershed Assessment Studies (Duriancik et al. 2008). Many of these projects, both ARS and NIFA-funded, had the advantage of participating in some of the prior efforts mentioned earlier aimed at examining relationships between practices and water resources (RCWP, MSEA, HUA-Demos) (Osmond et al., 2012b). However, syntheses of findings from these projects determined that even among these carefully selected sites, some are better suited than others at evaluating the effects of conservation on watershed condition and water quality at the scale of a watershed. Likewise, a subset of these locations would be critical resources to consider maintaining into the future, despite current funding constraints, as high quality and long-term benchmarks to assess progress. This is an explicit goal of the Administration endorsed Long Term Agro-Ecosystems (LTAR) research network (Walbridge and Shafer, 2011 also see - ars.usda.gov/ltar).

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