The Conservation Effects Assessment Project

Watershed Assessment Studies Network

A network of watershed studies to quantify the effects of conservation practices on water quality, water availability, and soil health within small watersheds.

USDA

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Clean, available water and healthy soils are vital to our well-being and existence. We rely on these to ensure we have adequate and nutritious food and clean water to drink and recreate. Conservation practices in agricultural watersheds are key to helping us protect and restore our watersheds' water quality.

Agricultural producers, as well as conservation and watershed planners, need to know what benefits we can achieve from implementing conservation practices. That has been the focus of our work under the Conservation Effects Assessment Project (CEAP), USDA's flagship natural resources assessment and research program. Under CEAP, we are developing the science base, methods and tools for managing productive agricultural landscapes while ensuring environmental quality.

Partnerships are vital to accomplishing these technically challenging objectives, and through CEAP, we are building capacity and leveraging the resources needed to carry out these cutting-edge scientific assessments of environmental effects. Together, with agricultural producers and our partners, USDA is making conservation count! Because of that, this cooperative CEAP approach has been recognized as an "Exemplary Collaborative Case Study" by the Natural Resources Roundtable of the American Association for the Advancement of Science (AAAS).

Ultimately, the knowledge gained through these studies is being used to help us build more resilient agricultural systems, inform watershed and conservation planning at local levels, and program design and delivery approaches at larger scales.

We invite you to read and learn more about our joint efforts to measure conservation effects in watersheds and improve the efficacy of our practices for better water resources.

The Conservation Effects Assessment Project – Watershed Assessments

Following the passage of the Farm Security and Rural Investment Act of 2002, also known as the "2002 Farm Bill," which significantly increased funding for conservation programs, the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), the USDA Agricultural Research Service (ARS) and other USDA agencies created the Conservation Effects Assessment Project (CEAP) in 2003. The goal of CEAP is to measure the effects of agricultural conservation practices and develop the science-base for managing agricultural landscapes for environmental quality. The CEAP Watershed Assessment Studies, a partnership between NRCS, ARS, and numerous other federal and university partners, quantify the effects of conservation practices on water quality, water availability, and soil health within small watersheds. Field and watershed studies also help build understanding of the processes that are influenced by or that drive conservation practice effects.

Sediment retention pond in Beasley Lake watershed

Earlier plot and field scale studies have documented that conservation practices improved water quality at the edge of a field, but water quality improvements in a watershed have been difficult to observe in large streams and rivers. The efforts described in this brochure are innovative in that they identify more effective conservation practices, enhanced monitoring designs and more accurate simulation models. New understandings of the interactions between conservation practices and novel comprehensive conservation planning approaches help define which fields or areas within a field need conservation practices and what practices can be combined together in a field or watershed to improve water quality.

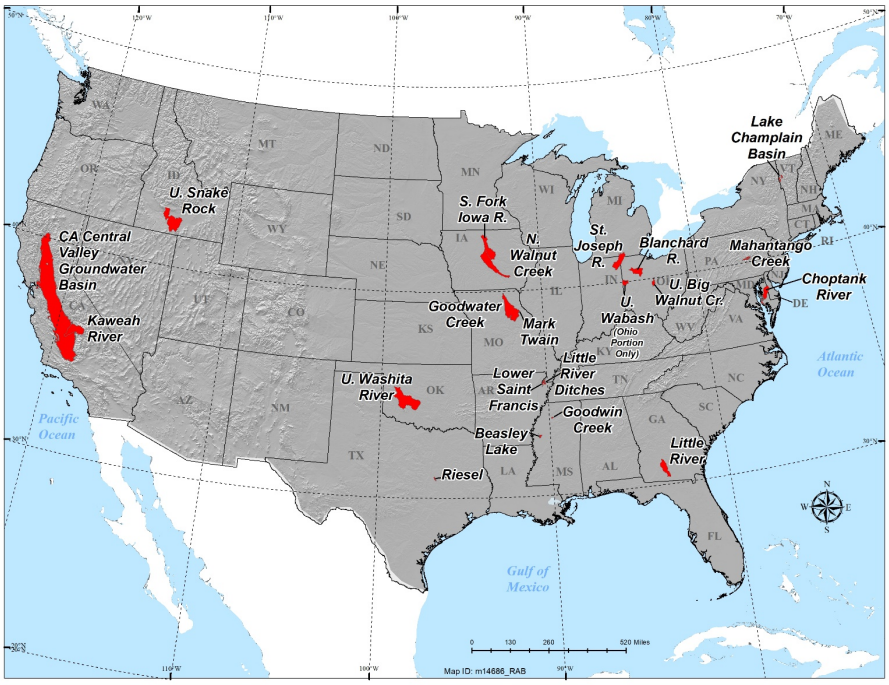
CRP in early spring in Beasley Lake watershed

This brochure describes the currently active 23 watershed studies at 18 locations and the research findings to date. These findings, the improved simulation models, and the newly developed conservation practices and assessment tools contribute towards more effective conservation strategies to address goals and document outcomes for the USDA Mississippi River Basin Healthy Watersheds Initiative, the Great Lakes Restoration Initiative, the Chesapeake Bay Watershed Initiative, the Lake Champlain Basin Initiative, and local source water protection efforts.

Summer cover crops in Goodwater Creek watershed

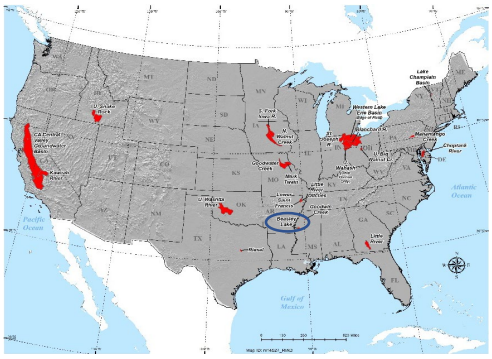
The Conservation Effects Assessment Project – Watershed Assessments Network

As described later in this publication, conservation practice evaluation and development progressed independently at each watershed research site. However, an important aspect of the CEAP Watershed Assessments network is the collaboration across this network of studies, the sharing of data, and the evaluation of practices and tools for everyday use by conservation planners. One major accomplishment is the development of the publicly accessible STEWARDS database, which contains the data collected at these sites, along with descriptions of the data. These data sets, along with expert knowledge and models, have been used in evaluating and developing enhancements for several CEAP-developed precision conservation tools such as the Soil Vulnerability Index and the Agricultural Conservation Planning Framework tool across CEAP Watershed sites. A number of process-based models have been evaluated under the CEAP Watersheds network. Current focus is on the Agricultural Policy Extender (APEX) and Soil and Water Assessment Tool (SWAT). Prior assessments of sediment source tracking, climate effects on conservation practice effectiveness, and soil health assessment framework at watershed scales over time, have all been completed at sites across the CEAP Watersheds network. A new on-going network-wide effort seeks to quantify the time it takes for water percolating through the soil to get to the stream. A good understanding of this lag time will help researchers, conservationists and stakeholders understand the time it takes for newly implemented conservation practices to produce cleaner water flowing to the stream.



The CEAP watershed sites (see map) in Oklahoma, Mississippi, Arkansas, Missouri, Iowa, Texas, and two watersheds in Ohio are located in the Mississippi River Basin. Waters flow from these sites toward the Gulf of Mexico. Those in northern Indiana and one watershed in Ohio drain toward Lake Erie. One watershed in Mississippi, the one in Vermont, and the one in Missouri also drain into fresh water lakes affected by algae blooms. Those in Pennsylvania and Maryland lie within the Chesapeake Bay drainage area. Finally, the California and Idaho sites focus on western water concerns. The waters of the Georgia site flow toward the Atlantic. Findings across sites within a region are often synthesized by researchers and NRCS staff to help inform effective strategies for conservation programs and planning to advance progress on water resource concerns in that region.

Beasley Lake Watershed

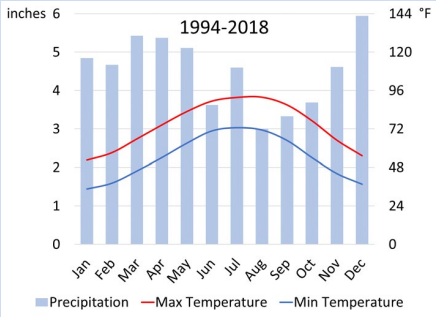


A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the Agricultural Research Service and the Natural Resources Conservation Service

Location

Beasley Lake Watershed is 2.4 mi^2 and is located in western Mississippi along the Lower Mississippi Alluvial Plain. The lake is used primarily for fishing, hunting, and recreation.

Temperature and Precipitation



Major land uses

Cropland: Corn, Soybean, Cotton, Sorghum, Wheat.
Riparian Woodland

Data collection

Beginning in 1995, lake surface water quality was assessed seasonally for sediment, nutrients, and algae. Since 1996, lake water quality has been monitored biweekly. Lake pesticide monitoring began in 1998 to assess a suite of herbicides and insecticides commonly used in the watershed. Starting in 2005, storm runoff water was collected with automated samplers within Conservation Reserve Program acreage. Runoff monitoring expanded in 2008 to include edge-of-field buffers, and, in 2011, runoff through a sediment retention pond. Lake ecology is assessed by monitoring algal blooms, fishery production, and biochemical processes.

Concerns

Soils in the watershed range from sandy loam to heavy clays and are vulnerable to erosion and loss of soil organic carbon and soil structural stability under conventional farming practices.

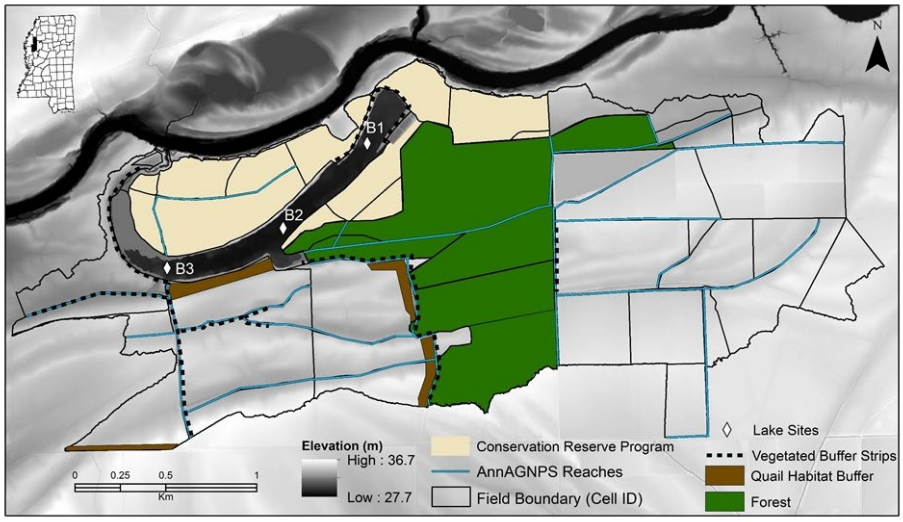
Regionally, high precipitation with highly erodible soils creates runoff with high sediment, nutrient, and pesticide transport to surface water.

Lake water quality and fish habitat degrade with sedimentation and increased eutrophication, causing harmful algal blooms and altering lake productivity. Excess nutrients and sediments from watersheds in the Lower Mississippi River can contribute to hypoxia in the Gulf of Mexico.

Main conservation practices used

Several conservation practices have been implemented over time, including vegetated drainage ditches and conservation tillage. Multiple studies have assessed effectiveness of practices for improving both runoff and lake water quality, such as:

- edge-of-field grass filter strips, late 1990's;
- 215-acre Conservation Reserve Program (CRP) and constructed wetland, 2004-2005;
- mixed-vegetated quail habitat buffer, 2008; two-stage sediment retention pond, 2010.



Beasley Lake Watershed

Outcomes/Findings

Plot and field scale

- CRP reduced runoff sediment by more than 90% and reduced Total Nitrogen (TN) and Total Phosphorus (TP) by 50-100%. Mixed vegetation buffers reduced runoff sediment by 34-70% but TN and TP reductions varied greatly.
- Integrated conservation practices of vegetated drainage ditches and a sediment retention pond reduced runoff sediment by 69% while TN and TP reductions were 30-50%.
- A three-stage vegetated constructed wetland reduced runoff herbicides atrazine by 70-89% and fluometuron by 58-81% and reduced runoff of the insecticide diazinon by over 95%.

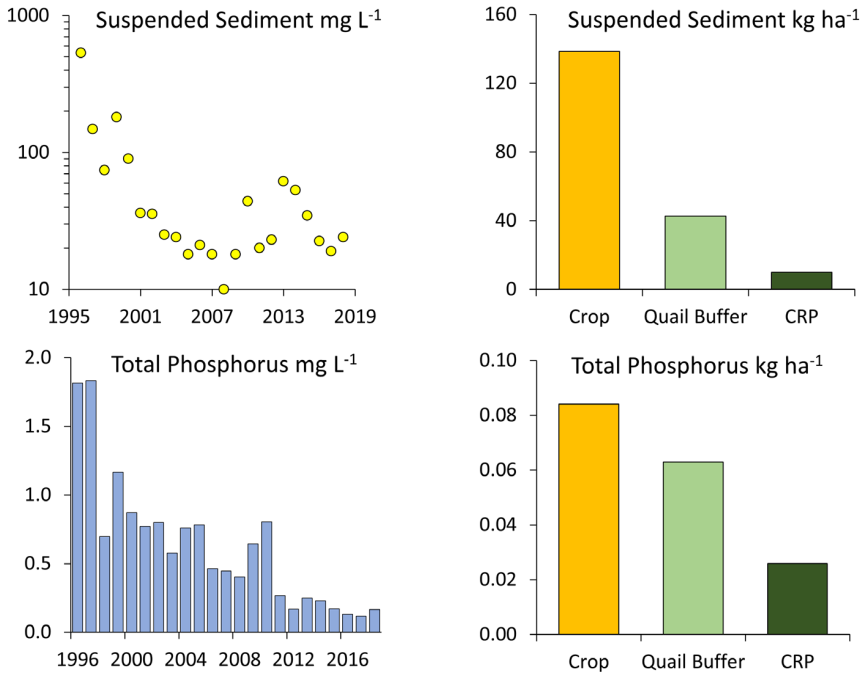
Watershed scale

- Multiple integrated conservation practices implemented across the watershed reduced lake suspended sediment by more than 60% and increased water clarity by more than 100%.
- Watershed-wide conservation practices reduced lake water TP by 50-70% and nitrate-nitrogen by more than 80%, but TN was unaffected.
- The Annualized Agricultural Non-Point Source (AnnAGNPS) model predicts that no-till and cover crops will reduce runoff sediment and nutrients by 20-75% even with the coming climate change.

Ecology

- Conservation practices more than doubled lake fishery production and the lake currently supports a healthy self-sustaining bass population.
- Conservation practices decreased pesticide toxicity in lake sediments by 40-70% and reduced pesticides in crustacean tissues by more than 80%.

Clockwise from left: Jason Taylor measures lake fishery production, Wade Steinriede collects lake water samples, Richard Lizotte measures wetland plant diversity, view of Beasley Lake from an edge-of-field buffer.



Collaborators and Stakeholders

More Information

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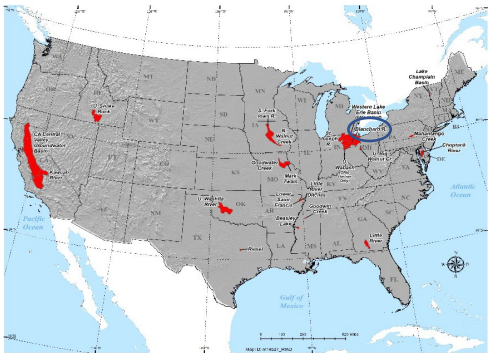
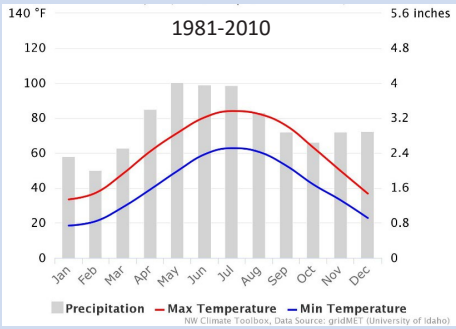
Blanchard River Watershed



Location

Two sub-watersheds (<19 mi^2) in the headwaters of the Blanchard River, which is a tributary to Maumee River whose loads drive the severity of Lake Erie algal blooms.

Temperature and Precipitation



Major land uses

Cropland: Corn, Soybean, Wheat.

Data collection

In the small paired watersheds, USGS stream gages were installed in August 2018 and measure discharge every 15 minutes. Weekly grab samples started May 2018, and by October 2019 the stations were built out to include refrigerated automatic samplers. Three samples per day are analyzed for suspended solids and nutrients during high flow; otherwise only one sample a day is analyzed. There are a multitude of other stream gaging stations and water quality monitoring stations throughout the Blanchard and Maumee watersheds. The USDA-ARS SDRU has 38 paired edge-of-field monitoring locations, a majority of which are in the Western Lake Erie Basin, and about 6 are near the CEAP watersheds.

A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration with Heidelberg University, the Agricultural Research Service, and the Natural Resources Conservation Service

The 2011 harmful algal bloom in the Western Basin Satellite of Lake Erie via satellite

Concerns

The western basin of Lake Erie has been plagued by intense harmful algal blooms (HABs) over the past 15 years, and they pose a substantial human health risk in the region. The HABs in Lake Erie are closely associated with bioavailable phosphorus (P) loading from Maumee River during the period of March through July, and this loading is primarily associated with agricultural runoff. Recent research has also shown that precipitation and discharge have increased in the past decade, which accounts for ~35% of the increase in loading since 2002.

Research at the edge of the field found that total and dissolved P concentrations are higher in surface runoff than in subsurface drainage, yet most of the water discharge and P loads are delivered through subsurface tile drainage. These subsurface losses are associated with preferential flow through macropores, a common occurrence in these clayey soils. A study of over 1,500 fields in the region also identified a vast prevalence of soil P stratification associated with rotational no-till and broadcasting P fertilizer, which likely contributes to P losses.

Main conservation practices used

Starting in the 1980s, practices to control soil erosion were increasingly prevalent throughout the Western Lake Erie Basin (WLEB), including conservation tillage and rotation no-tillage, buffer strips and grassed waterways, and taking highly-erodible land out of production (CRP). These practices continue to be the most common best management practices (BMPs) implemented, though incentives for nutrient management plans have been popular recently. Other BMPs that are promoted heavily include controlled drainage structures and cover crops, though these practices make up <10% of implemented BMPs. There is also interest in gypsum applications and precision fertilizer application.

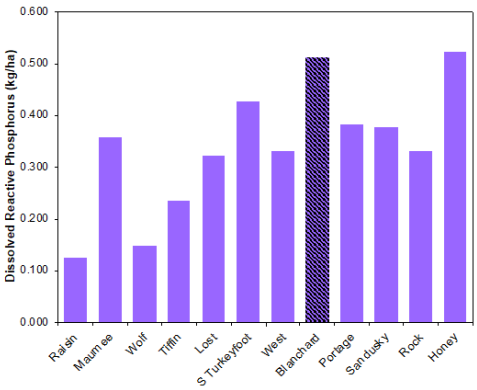
For this study, the most promising practices include those that reduce the risk of dissolved P runoff (e.g., nutrient management/4R nutrient stewardship and P removal structures) and those that will retain water on fields to reduce watershed flashiness (e.g., drainage water management, cover crops, blind inlets, gypsum application, and two-stage ditches).

Blanchard River Watershed

Outcomes/Findings

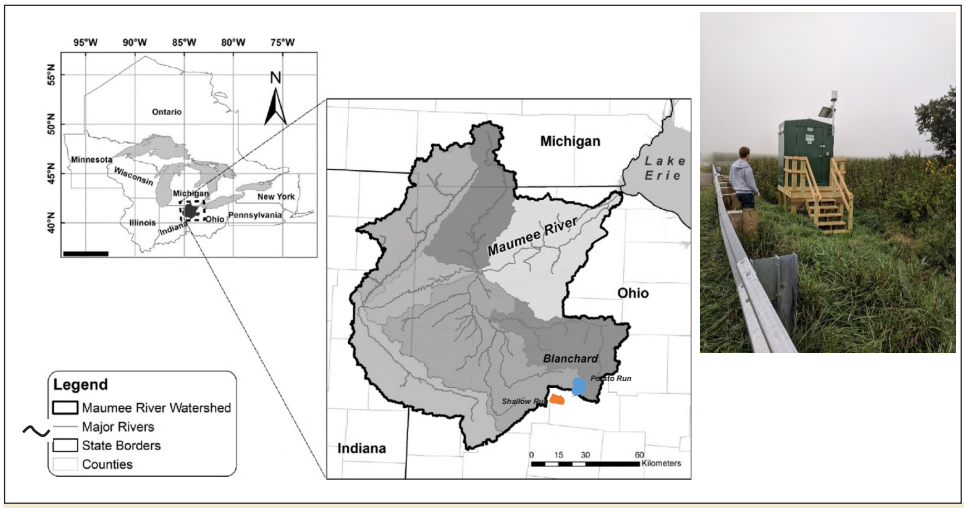
Preliminary Results

- Compared to other watersheds in the Western Lake Erie Basin, the Blanchard has the second highest 5-year mean unit area load for dissolved reactive phosphorus (DRP) (0.5 kg/ha, see below).

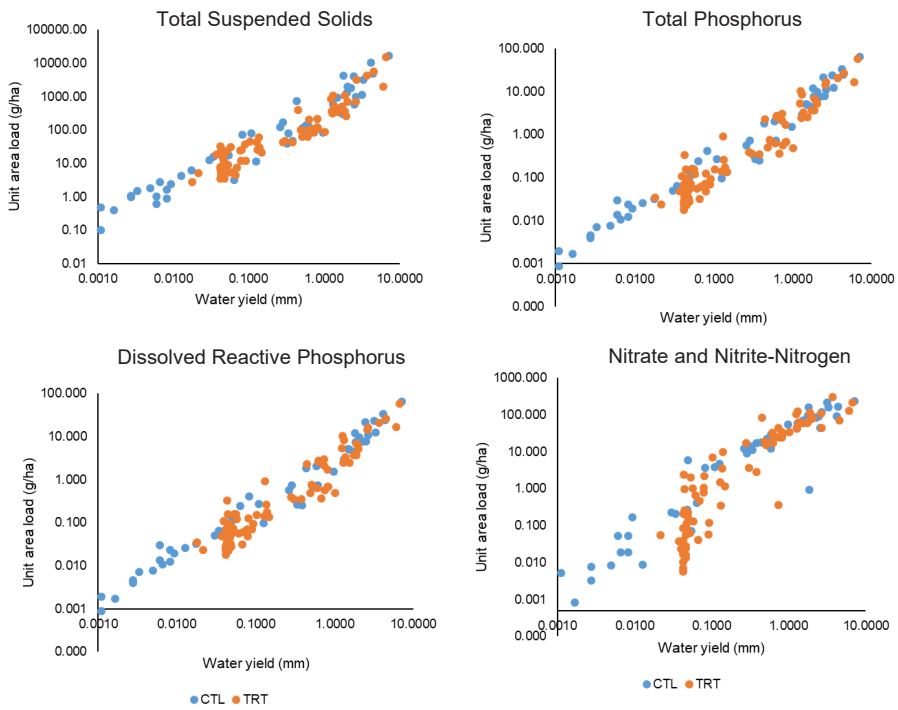


- Preliminary flow-weighted mean concentrations are very similar between the paired watersheds for all major analytes. Similarly, unit area loads for the control and treatment watersheds are not significantly different from each other when corrected for water yield (see right).
- The treatment phase began in the 2020 water year with prioritized NRCS EQIP and CRP practices in the treatment watershed (see those listed on page 1).

View upstream of the sampling location in the treatment watershed, Shallow Run.



Watershed map of the Maumee River. Each HUC-8 subwatershed is indicated in varying shades of gray. Located in the Blanchard River watershed, the paired subwatersheds are shown in orange (treatment, Shallow Run) and blue (control, Potato Run). The photo on the right shows the sampling station at Potato Run (control).



Collaborators and Stakeholders

National Center for Water Quality Research, Heidelberg University

USGS science for a changing world

Blanchard River Watershed Partnership BRWP Clean Water, Bright Future

Great Lakes Restoration

More Information

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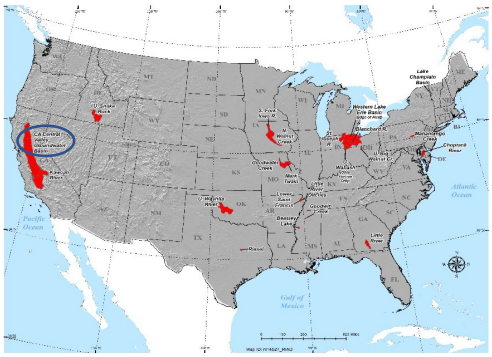
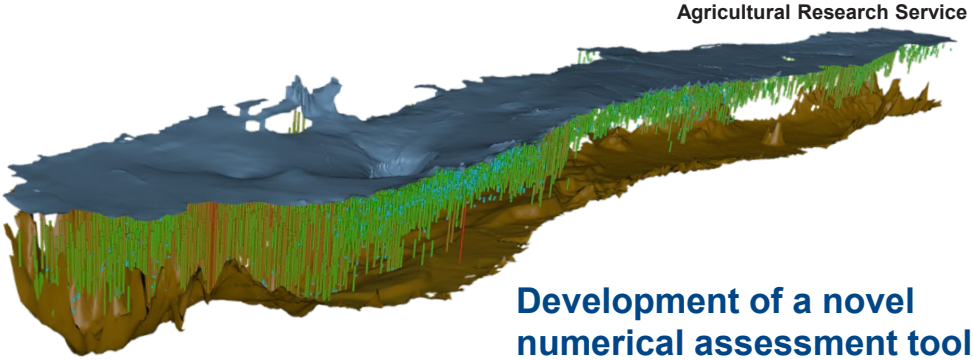
NCWQR website: ncwqr.org ARS website: ars.usda.gov NRCS website: nrcs.usda.gov
CEAP website: nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/

California Central Valley Groundwater Basin: Nonpoint Source Pollution Assessment Tool

A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the University of California–Davis, the Natural Resources Conservation Service, and the Agricultural Research Service

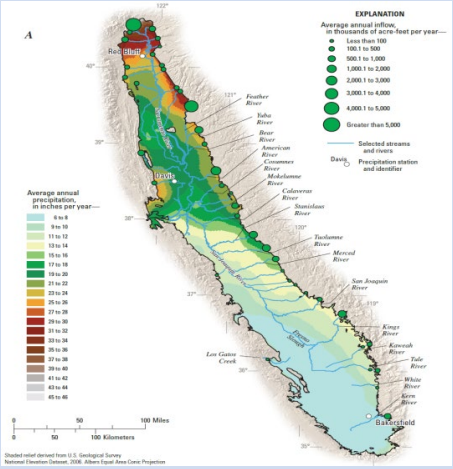




Location

This assessment project encompasses the entire 20,000-mi^2 Central Valley groundwater basin in California.

Temperature and Precipitation



Mediterranean climate with dry summers (May-Oct). Average winter precipitation increases south to north from 6 to 30 inches per year. Average lows/highs: January 38°F/56°F and July 66°F/98°F.

Major land uses

Agriculture: ~$45B with ~250 irrigated crops on ~ 8M acres. Largest acreage is in nuts, tree-fruit, citrus, grapes, rice, vegetables, forage (corn, grain, alfalfa); dairy farming (~20% of US).

Data Tool Being Evaluated

The novel NSPAT tool we developed expands on existing numerical models:

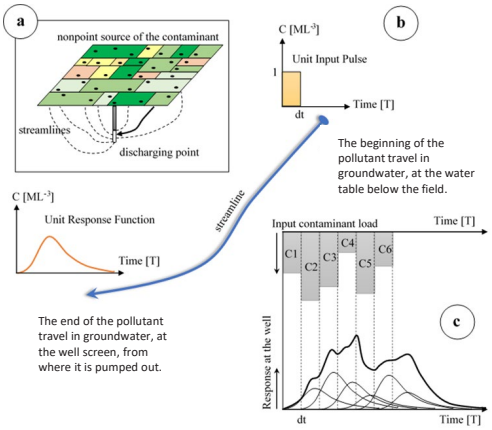
- USGS Central Valley Hydrologic Model (CVHM)
- CDWR Groundwater Model "C2VSim"
- UC Davis Groundwater Nitrogen Loading Model (GNLM)

Concerns

Nitrate nonpoint source contamination of groundwater is widespread across the globe and is the leading cause of water quality degradation in California.

Due to the considerable time lag between management actions and groundwater system response (baseflow, well water quality) - often on the order of several decades - decision makers must rely on simulation models to evaluate future water quality improvements from proposed practices.

Existing contaminant simulation approaches are often ill-suited for simulating nonpoint source (NPS) pollution at sufficient resolution of source and aquifer variability across large regions, and too expensive as decision-support tools.



Development of a novel numerical assessment tool

A novel groundwater modeling framework was developed to assess and evaluate the dynamic, spatio-temporally distributed linkages between nonpoint sources above a groundwater basin and groundwater discharges to wells, streams, or other compliance discharge surfaces (CDSs) within a groundwater basin. The framework, the Nonpoint Source Pollution Assessment Tool (NSPAT), allows for computationally efficient evaluation of NPS pollution scenarios and of their effects on improving pollution at CDSs.

The core of NSPAT is a detailed physically based groundwater flow and contaminant transport simulation model. Under the assumption of steady state flow, the flow and transport processes can be tackled separately. An adaptively resolved flow simulation accounts for detailed flux variations near flow sources and sinks (e.g., wells, streams) and due to aquifer heterogeneity is used to identify the pathways of contaminants to wells. The transport simulation is divided into multiple 1D transport computations, each solving for a unit input contaminant mass over one year ("unit source loading function"). The output of the pollutant simulation is a database library ("unit response functions"). The library is used to compute hundreds of years of pollutant breakthroughs at receiving wells and streams from salt and nitrate loading scenarios across a region, also accounting for historic pollutant loading (legacy contamination).

Central Valley Nonpoint Source Pollution Tool

Outcomes/Findings

Application of the numerical tool to local scale basins

- Tule River Basin, 770 mi^2 sub-basin: 9,000 individual nitrate sources were linked to 2,000 agricultural and public water supply wells for statistical assessment of future water quality.
- Modesto, 1,000 mi^2 sub-basin: NSPAT simulated pollution levels over several decades in 3,900 wells and provided statistic measures of nitrate contamination in individual stream segments.
- Tulare Lake Basin, 8,220 mi^2 sub-basin: NSPAT simulated nitrate transport to 7,800 wells and found good agreement with actual historic nitrate data.
- The NSPAT online tool is in development for the entire Central Valley and will allow for prediction of future nitrate at various spatial scales: township, county, sub-basin, management zone, region, study area.

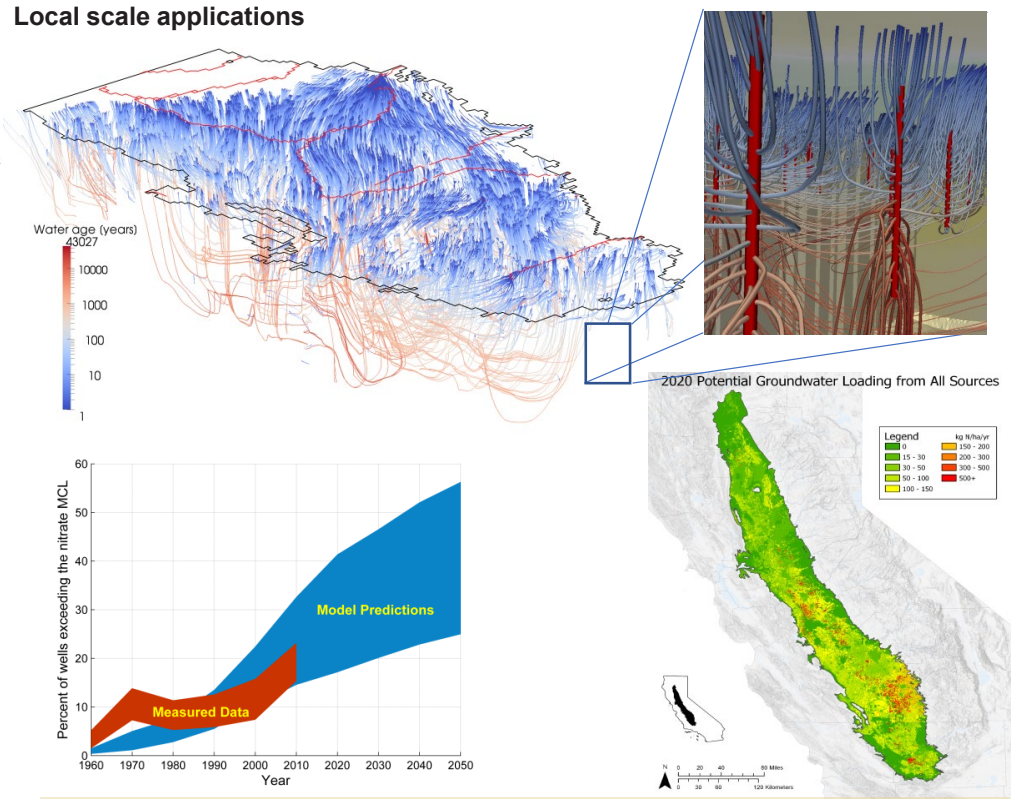
Validation of modeling framework

- We developed extensive "teaching and understanding" examples of nonpoint source pollution in fully 3D, heterogeneous alluvial aquifers.
- The modeling approach was validated against standard modeling tools (MODFLOW-MT3D).
- Evaluation of time and spatial scales was performed to obtain accurate nonpoint source simulation results.
- A web-based user interface is being developed: User-defined scenarios of future agricultural practices and prediction of nitrate distribution in domestic, public, and irrigation supply wells of an area can be quickly assessed over the next 200 years.

Next steps

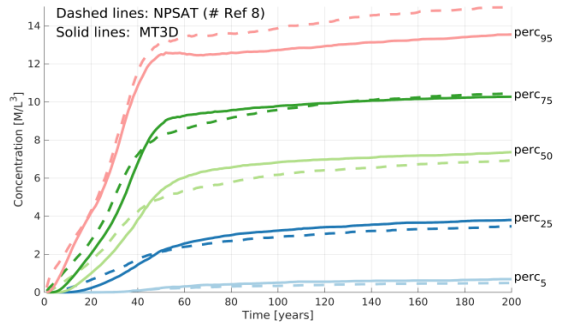
- Simulate the entire Central Valley using NSPAT.

Local scale applications



Clockwise from top left: Contaminant pathways in the 8,220 mi^2 southern Central Valley, close-up of simulated flow paths from the land surface (mostly irrigated agriculture) to well screens (red) with age of the flowpath since recharge (blue = young, red = over 100 years old), potential nitrate loading to groundwater (kg N/ha/year), excess nitrate predicted by NSPAT vs. measured in wells in the southern Central Valley.

- Develop a library of representative flow and transport models based on CVHM and C2VSim for different hydrologic conditions (typical, wet, arid).
- Develop an online platform to be used for predictions by stakeholders.



Comparison of assessment tool against the standard USGS software (MODFLOW with MT3D).

Collaborators and Stakeholders

California Water Boards Central Valley - R5
The Southern San Joaquin Valley Management Practices Evaluation Program
Northern California Water Association
Westside San Joaquin River Watershed Coalition
cdfa
california almonds Almond Board of California
East San Joaquin Water Quality Coalition
San Joaquin County & Delta Water Quality Coalition

More Information

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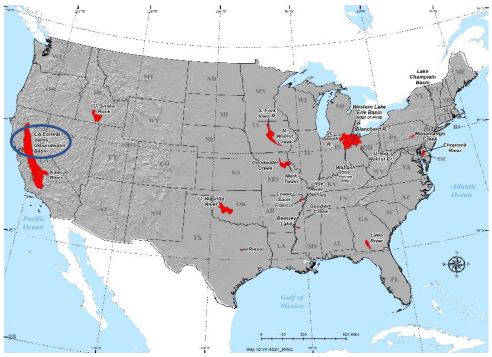
California Central Valley Groundwater Basin: Nitrate Leaching Field Scale Assessment Tools

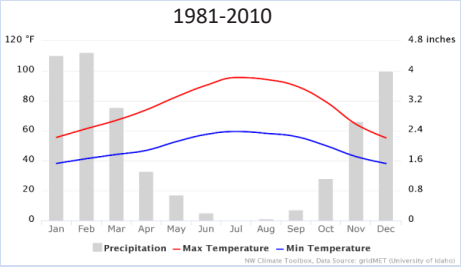
A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the University of California–Davis, the Natural Resources Conservation Service, and the Agricultural Research Service



Location

The 90-acre field is located in Yolo County, California.

Temperature and Precipitation



Major land uses

Cropland: Processing tomato rotation with hybrid seed production.

Data collection

Ten boreholes were drilled and the profiles characterized by soil texture, water content, ammonia, nitrate, total N and C contents, chloride, and sulfate in November 2019.

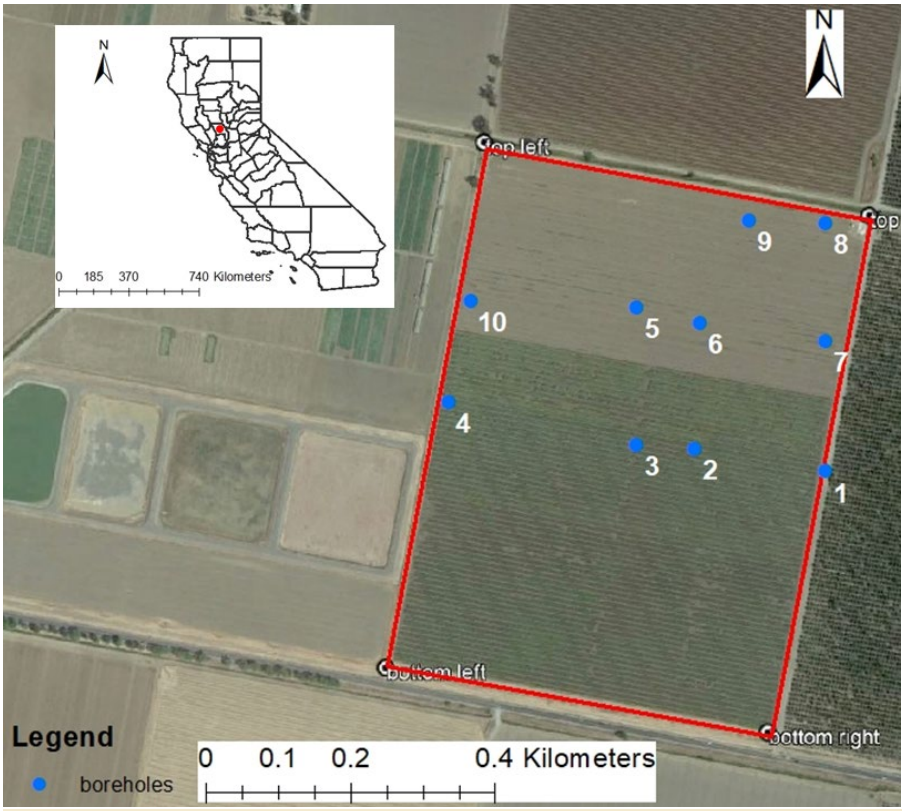
Historic water and nitrogen mass balances were performed using grower information, remote sensing, meteorological data, and nitrogen uptake coefficients.

Water and nitrogen inputs will be continuously measured.

Evapotranspiration will be monitored with remote sensing and soil water mass balance techniques.

Nitrate leaching will be monitored using a deep vadose zone monitoring system. Plant nitrogen removal from the field will be measured.

Groundwater level and quality will be intensively monitored with a high resolution well network.



Field location in Yolo County, California. Sampling locations and field delineation.

Issues

Most California drinking water suppliers depend partially or entirely on clean groundwater. Nitrate continues to be the most widespread contaminant, and nitrate levels are trending higher in agricultural regions. Domestic wells, common in rural areas, are also widely affected by nitrate contamination.

Excess nitrogen from agricultural activities is one of the most prominent sources of groundwater nitrate. Nitrogen not used by plants is leached with excess irrigation water or precipitation recharge to groundwater as nitrate.

Main conservation practices used

Irrigation and nitrogen are applied jointly and more accurately to specifically meet plant demands, at the right time, place, and amount.

Nitrogen is injected into irrigation water ("fertigation"), which increases uptake efficiency.

Winter cover crops prevent nutrient losses during California's rainy season (November – April).

Soil tests are performed before planting, and initial mineral nitrogen in the soil is accounted for in fertilizer applications.

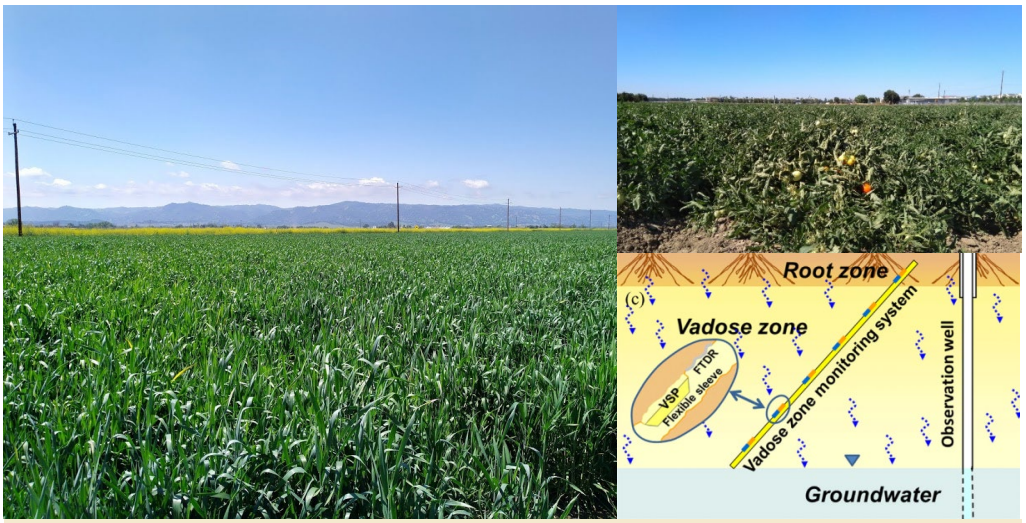
Nitrate concentrations in irrigation water from a groundwater source are accounted for as part of the fertilization budget.

Outcomes/Findings

Central Valley Nitrate Leaching Field Assessment

Watershed scale

- The USDA SWAT model and other modeling tools will be evaluated against field-measured data.
- The models will allow us to simulate nitrogen leaching from other agricultural lands in the Central Valley, CA, with different soils, management, and climate.
- Nitrogen mass balance at the field level will be compared to vadose zone measurements of nitrogen leaching to confirm robustness of this approach.

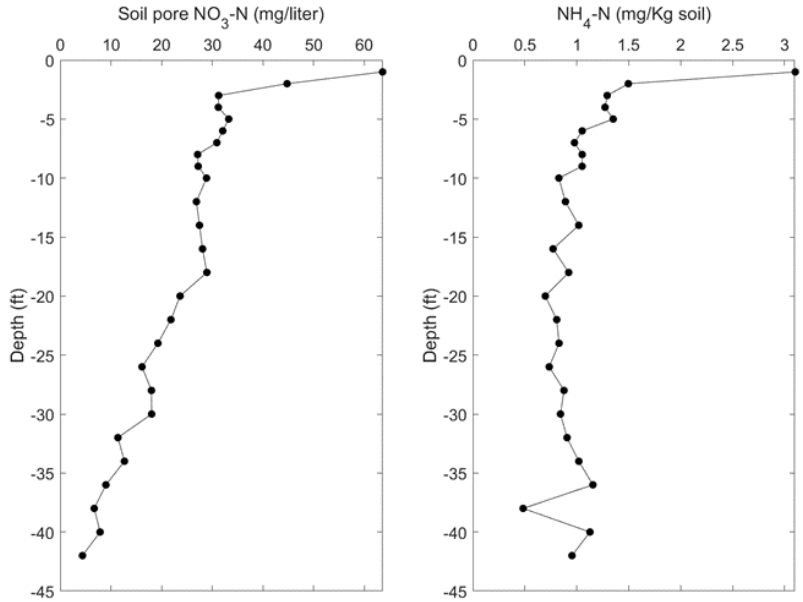


On the left: field in Spring 2020. Triticale was seeded in November 2019 as a winter cover crop, after processing tomato harvest. On the right: deep vadose-zone monitoring system to be installed in March 2020. This system will measure soil water content and will allow for soil pore water sampling from the root zone and up to the groundwater table. Nitrate concentrations will be measured all year round in two profiles.

Plot and field scale

- Nitrate concentrations in the soil pore water exceeded the maximum contaminant level (MCL) (10 ppm NO_3-N) to a depth of 36 ft.
- Both ammonium (NH_4-N) and nitrate (NO_3-N) are higher in the active root zone (0-3 ft) than in the lower profile, showing residuals from fertilization during the growing season (See graphs on the right).
- Groundwater monitoring wells will be installed at the edge of the field, down gradient to the general groundwater flow. Water levels and nitrogen concentrations will be measured every six weeks.
- Two deep vadose zone monitoring systems will be installed from the root zone and up to the groundwater level. Water content and soil solution nitrogen concentrations will be measured weekly all year round. Changes in vadose zone nitrogen concentrations will reflect changes in management practices as well as nitrogen leaching potentials.
- Water fluxes below the root zone will be measured by potential differences using tensiometers.
- Nitrogen loads at the bottom of the root zone will be calculated by multiplying concentration by flux.

Mineral nitrogen in the soil profile in November 2019



Collaborators and Stakeholders

UC DAVIS UNIVERSITY OF CALIFORNIA

CALIFORNIA WATER BOARDS Central Valley - R5

THE SOUTHERN SAN JOAQUIN VALLEY MANAGEMENT PRACTICES EVALUATION PROGRAM

California Tomato Research Institute

cdfa

california almonds Almond Board of California

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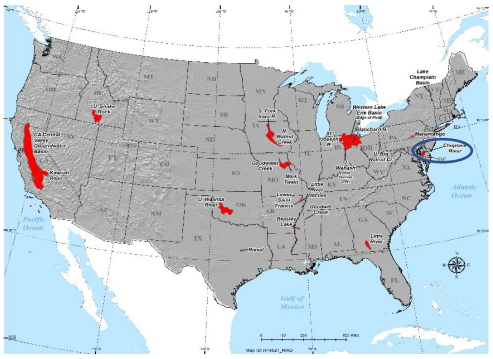
Choptank River Watershed

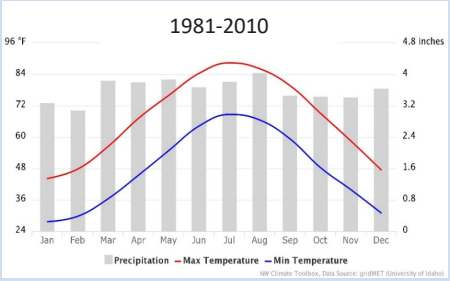
A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the Agricultural Research Service and the Natural Resources Conservation Service



Location

The approximately 2,600 km^2 Choptank River Basin is a major tributary of the Chesapeake Bay. Approximately 60% of land area is in cropland and 40% in forest.

Temperature and Precipitation



Major land uses

Cropland: Corn, Soybean, Wheat.
Grassland: Pasture and Hay.
Woodland: Forested wetlands.

Data collection

This site is a testbed for demonstrating new agronomic and conservation practices on-farm and for evaluating crop residue mapping techniques, air and water modeling efforts, and wetland ecosystems, as well as for developing advanced geospatial tools.

This CEAP study started in 2004: Satellite images monitor winter cover crop performance and reduced tillage management. Real time in situ sensors monitor water quality at two USGS gage stations. Extensive time series datasets on wetland hydroperiod have been established.

Concerns

The Choptank River Watershed contains a large estuarian embayment that drains directly into the Chesapeake Bay estuary. Health of both ecosystems are highly impacted by nutrients and sediment.

Nearly 50 percent of wetlands that once dominated the landscape have been drained to make way for crop production during 400 years of ditch drainage history.

An intensive poultry production industry on the Delmarva Peninsula creates a lot of poultry litter typically used for fertilizer, leading to excess phosphorus levels in soils.

Poultry houses are major sources of ammonia and other atmospheric contaminants that can degrade air quality and lead to excess nutrient deposition on sensitive ecosystems.

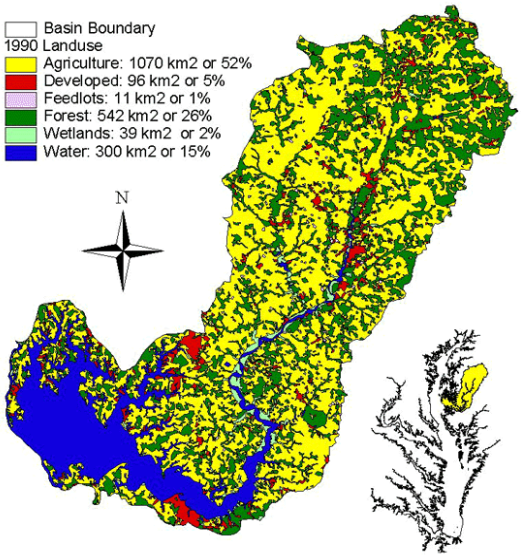
Extensive ditch drains allow rapid movement of agricultural nutrients to sensitive waterways.

A water deficit for summer crop production is common, and farmers rely increasingly on irrigation for production on cropland.

Main conservation practices used

To meet non-point source water quality regulations, Maryland and Delaware depend increasingly on conservation practices of reduced tillage and winter cover crops. Other practices include:

- Improved management of manures.
- Use of buffers for water quality and stream health.
- Increased riparian buffer acreage.
- Improved drainage management.

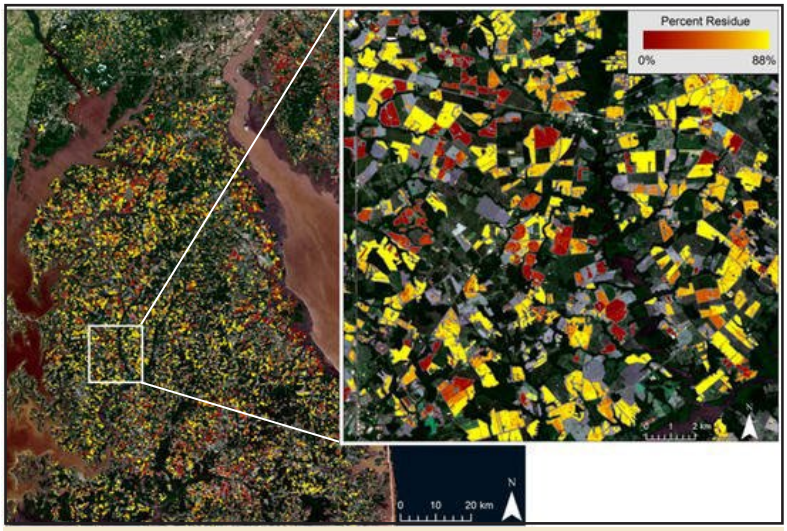


Choptank River Watershed

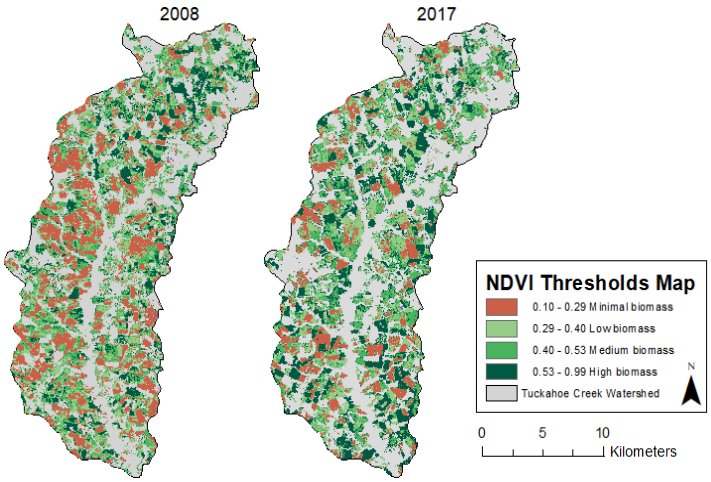
Choptank River Watershed

Outcomes/Findings

- Technology was developed to use satellite data for monitoring winter cover crop performance. The Maryland Department of Agriculture now routinely uses remote sensing to manage their winter crop program and Delaware is following suit.
- Remote sensing approaches for monitoring tillage intensity using World View 3 and Landsat data were successfully demonstrated.
- Watershed research has led to development of a novel transient tracer for measuring watershed lag time, an important parameter in assessing performance of conservation practices.
- In situ water quality sensor data from the watershed provide more accurate and robust estimates of nitrogen fluxes using high frequency measurements compared to estimates often obtained with the LOADEST model.
- Vegetative buffers around poultry houses captured 20 to 70 percent of particulate emissions depending on meteorological conditions and reduced net downwind ammonia dispersion by 51 percent.
- The Choptank River Watershed has been an important testbed for development of advanced geospatial tools using remote sensing inputs for monitoring the performance of conservation practices such as residue management, winter cover crops, riparian buffers, and wetland restorations.
- Tillage intensities can be estimated from a satellite-generated map of percent crop residue cover on non-vegetated agricultural fields, overlaid on a natural-color Landsat 8 imagery.



Increased Use of Reduced Tillage and Winter Cover Crops, comparing 2008 and 2017



- Wintertime vegetation classification for cropland in the Tuckahoe Creek sub-watershed based upon composite satellite Normalized Difference Vegetation Index (NDVI) threshold values for minimal, low, medium, and high levels of green vegetation. Increased adoption of cover crops reduced nitrate leaching by 25% over 10 years.

Collaborators and Stakeholders

More Information

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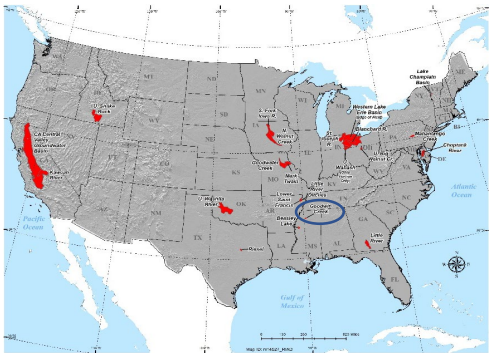
Goodwin Creek Experimental Watershed

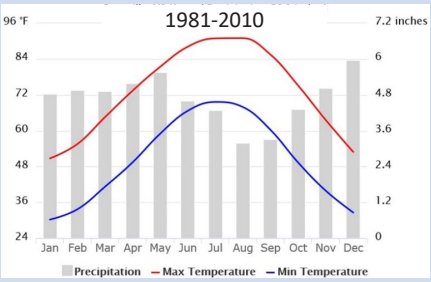
A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the Agricultural Research Service and the Natural Resources Conservation Service



Location

The Goodwin Creek Experimental Watershed (GCEW) was established as a part of the "Stream-Bank Erosion Control Evaluation and Demonstration Project" authorized by Section 32 of U.S. Public Law 93-251. This 8-mi^2 watershed was chosen for its mixed land use, active upland erosion, and steep degrading channels with unstable banks. The watershed is a tributary of the Yazoo River, which ultimately flows into the Mississippi River.

Temperature and Precipitation



Average annual rainfall is 53.5", with most runoff events occurring in the winter and spring. The difference of elevation in the watershed is 190 feet with soil types closely following topography.

Major land uses

Cropland: Cotton and Soybean.
Grassland: Pasture and Hay.
Woodland: Pines and Hardwoods.

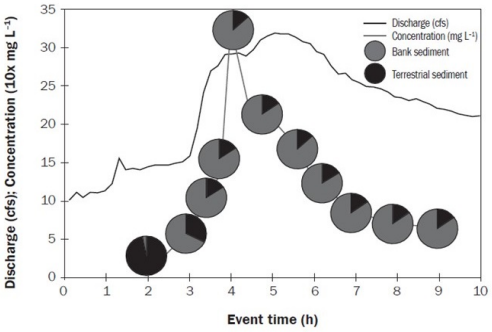
Data collection

The watershed has 19 stations that measure flow and water quality, 32 rain gauges, and one station that measures multiple weather variables.

Concerns

Sheet and rill erosion were historically the major source of sediment in Goodwin Creek. Row crop agriculture was historically practiced over the majority of the watershed, including the sloping uplands. Conservation practices have reduced row crop use to just 6% of the area, and only in the flatter part of the alluvial plains. The hillslopes were converted to forest and pasture lands, which occupy 96% of the watershed.

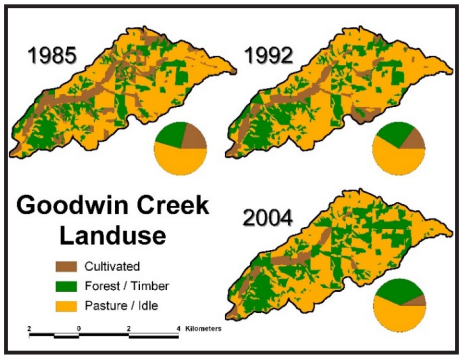
With the shift in landuse, sheet and rill erosion has been effectively controlled. However, gully erosion remains a significant problem.



Sediment sources identified using ratios of naturally-occurring radionuclides ^{7}Be and ^{210}Pb on the GCEW demonstrate that currently the major source of sediment is streambank failure and gully erosion.

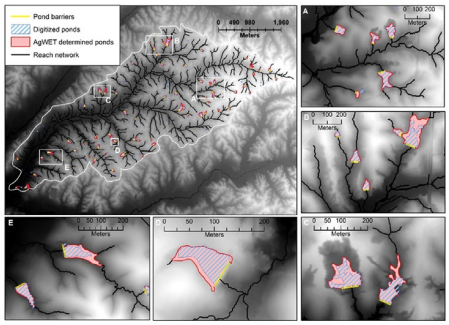
Main conservation practices used

The large land use shift that occurred between 1985 and 2004 (See land use maps below) was enabled by enrolling land in the Conservation Reserve Program (CRP). Forest restoration has resulted in 47.5 miles of riparian buffers along stream channels.



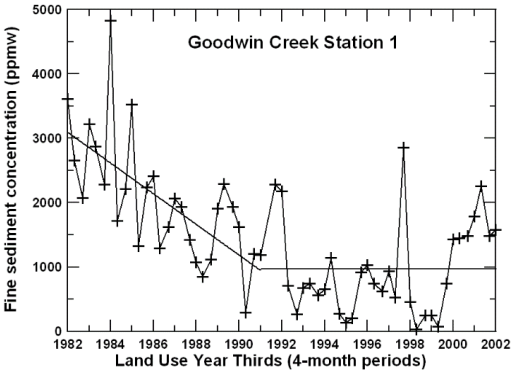
In addition in-stream structures were installed, which drain areas ranging from less than a square mile to the whole watershed (8 mi^2).

Sixty seven field ponds collect 20% of watershed runoff.



Outcomes/Findings

- The in-stream structures at several locations in GCEW have reduced total and fine sediment yields. Reductions ranged from 10% to 70%. These structures had a greater impact on sediment yields and bank stability in the upstream portions of the watershed.
- Sediment concentrations decreased from 3,000 to 1,000 ppm from 1982 to 1990 and have remained flat since 1990. This trend corresponds closely with the shift of cropland to forest and pasture and shows that CRP conditions provide long-term control of sediment .



- 78% of the fine sediment reaching the channels were derived from channel sources. This shows that total watershed erosion control requires consideration of concentrated flow sources from channels and gullies.
- Field ponds reduced the annual average runoff volume by 4% and the average peak flow by 36%. The hydrologic impacts of ponds should be considered when there are a significant number of ponds in a watershed.
- Riparian buffers reduce sediment by 60%. The reduction varies by particle size: 38% for clay, 62% for silt and 70% for sand.

Goodwin Creek Experimental Watershed

Clockwise from top: A hillslope pasture used as an edge-of-field monitoring site. Dr. Tianyu Zhang surveying an ephemeral gully in crop land. Typical failing streambank.

Mechanistic field studies on subsurface erosion

GCEW has identified subsurface erosion, i.e. piping, as a major contributor to ephemeral gully erosion and streambank failure. Piping can involve flow through large lateral pores called "soil pipes" or seepage out of bank faces. Flow through soil pipes causes erosion of the inside of pipes that leads to collapse of the soil above, which forms sinkholes and gullies. Sinkholes intercept runoff that generates additional pipeflow velocities and enhanced erosion.

Collaborators and Stakeholders

US Army Corps of Engineers®

NOAA

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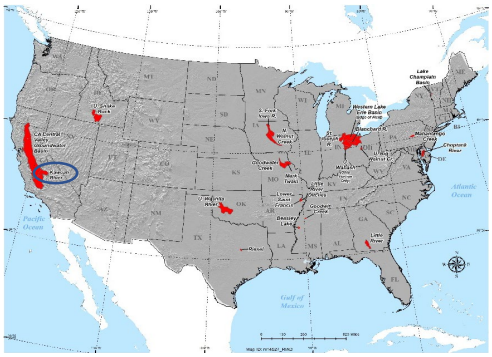
Kaweah River Watershed

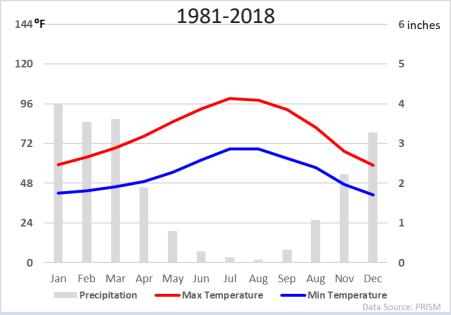


A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the University of California–Riverside, the Natural Resources Conservation Service, and the Agricultural Research Service

Location

The 1,550-mi^2 Kaweah River Watershed on the western slopes of the southern Sierra Nevada in California extends to the agricultural regions of the Tulare basin in the Central Valley.

Temperature and Precipitation



Major land uses

Cropland: Citrus, fruit and nuts, grapes.
Grassland: Pasture and hay.
Forest: Evergreen needle leaf and mixed conifer forests.

Data collection

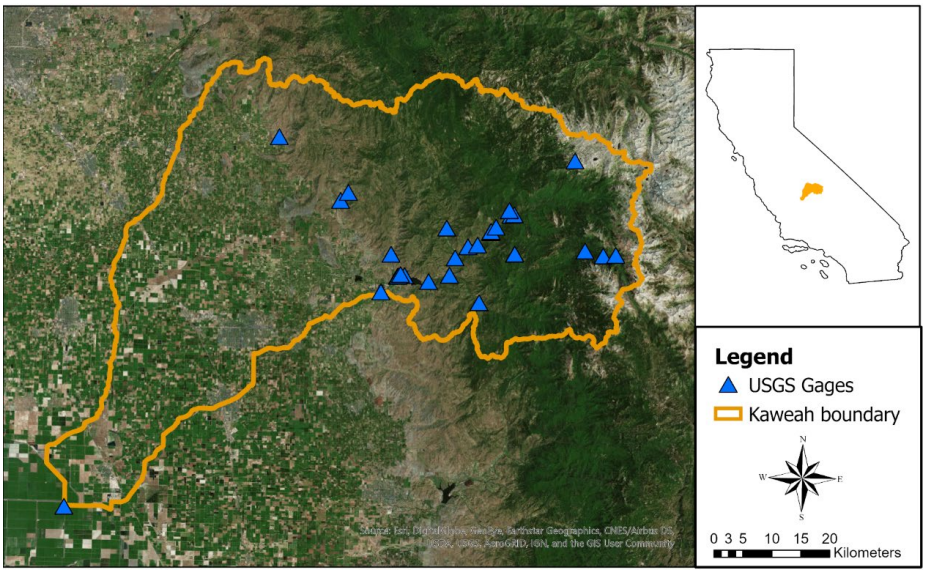
Since 1901, USGS stream gauges across the basin measure daily discharge. Hourly meteorological variables (precipitation, temperature, atmospheric pressure, wind speed, specific humidity, and solar radiation) are available from North American Land Data Assimilation System project phase 2 (NLDAS-2) (Xia et., 2012). Daily precipitation data is from the Parameter elevation Regression on Independent Slopes Model (PRISM) at 4 km resolution. The Kaweah Basin Water Quality Association and Kaweah Delta Water Conservation District have monitoring programs for surface water and groundwater quality and quantity.

Concerns

Groundwater pumping in the Kaweah watershed has caused significant overdraft. Therefore, efforts are underway to improve conjunctive water-use in the watershed and build more recharge basins for managed aquifer recharge. A major uncertainty in quantifying groundwater availability on the eastside of the Central Valley is recharge at the mountain front that supply water to the agricultural lands of the valley floor. Furthermore, limited knowledge is available on the impacts of on-farm irrigation practices and infiltration ponds on groundwater recharge in irrigated agricultural lands.

Main conservation practices used

A number of conservation practices are already used in the watershed. The Terminus Dam and Reservoir at the mountain front was built in 1962 for flood control and irrigation water storage. Recharge basins are also constructed in the valley floor for managing aquifer recharge and reducing groundwater overdraft. Deficit irrigation has been recommended as a conservation practice to reduce water use while maintaining the same level of crop productivity. We will assess the impact of deficit irrigation using simulation scenarios.



Kaweah River Watershed

Planned Research

Plot and field scale

- Transducers will be installed at selected existing wells in the watershed above mountain front to periodically monitor groundwater levels. These data will help to constrain mountain front recharge estimates and accurately close the basin water budget.
- Measured evapotranspiration estimates will be obtained from two towers that will be installed in the citrus orchards.
- These data along with recent streamflow and groundwater observations will be used for validating the hydrologic model of the study watershed.

Clockwise from top: Citrus groves in the watershed, Lake Kaweah is at the intersection of mountain front and valley floor, Marble Fork of Kaweah River in the mountains.

Watershed scale

- An integrated groundwater-land surface model (ParFlow.CLM) will be set up for the Kaweah watershed to estimate groundwater recharge on the agricultural lands below Lake Kaweah under actual and simulated irrigation and recharge practices.
- When possible, remotely sensed evapotranspiration and snow water equivalent data will be used for model evaluation.
- By simulating surface water/groundwater interactions in a fully integrated manner, valuable information regarding the watershed water balance and conjunctive surface water/groundwater use will be obtained.

Modeling Scenarios

- Deficit irrigation is a potential means of water conservation, especially for permanent crops in water-starved arid and semi-arid regions such as the California Central Valley.
- We perform model simulations by applying irrigation at 100% and 75% crop evapotranspiration to represent actual and deficit irrigation scenarios, respectively to assess their impacts on groundwater recharge.
- To assess the impacts of recharge from infiltration ponds, two scenarios will be used in model simulation: 1) recharge from existing infiltration ponds, and 2) recharge from existing plus 30% additional infiltration ponds.
- The Sustainable Groundwater Management Act (SGMA) in California was created to initiate sustainable conjunctive water-use management. The Kaweah River model provides a valuable tool to examine the impacts of various management decisions such as changes in groundwater pumping and land cover on streamflow and groundwater levels.

Collaborators and Stakeholders

Kaweah Delta Water Conservation District

Kaweah Basin Water Quality Association

Xia, Y. et al. (2012). Continental-scale water and energy flux analysis and validation for the North American Land Data Assimilation System project phase 2 (NLDAS-2): 1. Intercomparison and application of model products, *Journal of Geophysical Research* 117, D03109, doi:10.1029/2011JD016048.

More Information

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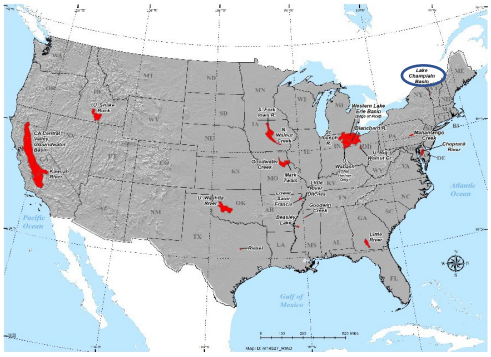
Lake Champlain Basin

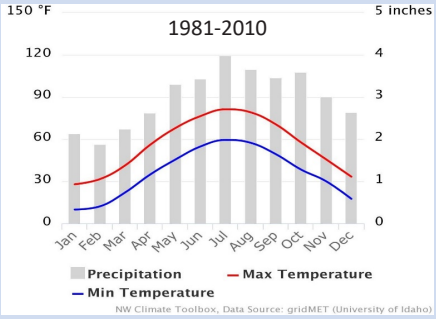


A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the University of Vermont, the Natural Resources Conservation Service, and the Agricultural Research Service

Location

The Lake Champlain Basin (LCB) is 8,170 mi^2 and drains portions of Vermont, New York, and the province of Quebec. The surface area of Lake Champlain itself is 435 mi^2 and is regionally important as a water supply and for recreation.

Temperature and Precipitation



Major land uses

Cropland: Corn silage, Soybean
Grassland: Pasture and Hay

Data collection

This study started recently, so data collection just began in late 2019. A 'control' (Dead Creek) and 'treatment' (Headwaters Little Otter Creek) watershed were both selected within the LCB and instrumented with stream gages and automated water sampling stations. Discharge is measured every 15 minutes, and samples are collected during storms and every two weeks during baseflow. Water is analyzed for phosphorus, nitrogen, and sediment to be used as key indicators of water quality and conservation practice effectiveness.

Concerns

Many farmed soils in the study area are heavy clay. These soils often have poor drainage and high runoff, transporting nutrients to surface waters and increasing sheet and rill erosion. Increased frequency of heavy storms and more overall annual precipitation exacerbate these issues.

As a result of poor drainage and wetter conditions, artificial subsurface drainage (i.e., tile) is being implemented on many farms to maintain productivity. It is not clear how this increased drainage and altered field hydrology affects the overall transport of nutrients, especially phosphorus to surface waters.

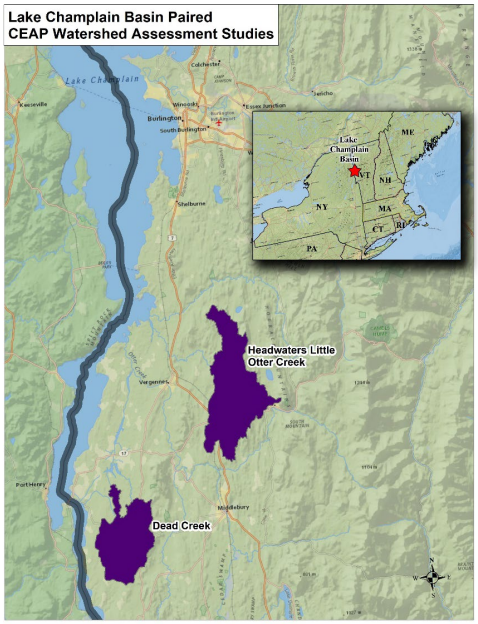
The heavy clay soils also affect crop production. Wet conditions can delay planting and lead to deep soil compaction that reduces yields and is difficult to remediate.

Efforts to reduce nutrient transport to the lake have accelerated significantly in the LCB after a new Total Maximum Daily Load (TMDL) was issued in 2016, focused on phosphorus loading for the lake.

Main conservation practices used

A number of conservation practices are regularly used in the watershed. These practices include no-till, winter cover crops, manure incorporation, and crop rotation. Adoption of manure injection in both corn fields and hayland is increasing rapidly.

Newer conservation practices to be studied include manure phosphorus removal systems and tile outlet phosphorus removal filters.



Lake Champlain Basin

Planned Research

Plot and field scale

- Evaluate the cumulative effect of using multiple conservation practices for reducing phosphorus loss and delivery to surface waters. This study will align with NRCS's Avoid-Control-Trap (ACT) framework, and will evaluate phosphorus sources vulnerable to loss, in-field practices for controlling export, and edge-of-field practices for trapping any phosphorus that does leave the field.
- Evaluate innovative edge-of-field practices for treating phosphorus inside tile drains. Project personnel are collaborating closely with ARS scientists to design, implement, and test at least one type of phosphorus removal structure for tile drainage water treatment. If conducive site conditions exist, a phosphorus removal structure will also be evaluated for treatment of surface runoff.
- Evaluate edge-of-field field-scale hydrology and total phosphorus loss in surface and subsurface runoff from tile-drained fields following manure injection to the field. A field-scale paired-watershed study will compare injection to surface application of manure in heavy clay soils typical of the LCB.
- Evaluate soil health, water quality, and crop yield implications following application of a low-phosphorus fertilizer source. Low-phosphorus effluent from a manure phosphorus removal system will be applied at a rate to meet the crop nitrogen requirements, but without adding meaningful amounts of phosphorus to the soils. This fertility source will be evaluated in large plots in the treatment watershed.

Clockwise from top left: Tile drainage monitoring station on Dead Creek, edge-of-field surface runoff monitoring flume, flow measurement instrumentation on a monitored tile outlet, newly installed USGS flow gage on East Branch of Dead Creek.

Watershed scale

- A paired watershed study will evaluate the effectiveness of conservation practices at the watershed-scale. This will include a 1- to 2-year calibration period before an accelerated implementation of conservation practices occurs in the treatment watershed.
- Practices targeted for accelerated implementation will be determined through consultation with a stakeholder advisory committee, but will likely include manure injection, no-till, cover cropping, and changes in timing of manure application to avoid high runoff time periods.
- Phosphorus removal performance of two innovative systems designed to extract phosphorus from liquid dairy manure will be compared. Low-phosphorus effluents will be evaluated in the treatment watershed.
- Collaboration with NRCS and ARS scientists to evaluate the Agricultural Conservation Planning Framework (ACPF) planning tool within the LCB.
- Evaluation of watershed water quality outcomes of various future conservation scenarios using 1) the APEX model with NRCS scientists, and 2) the SWAT model in collaboration with Virginia Tech scientists.

Collaborators and Stakeholders

VERMONT AGENCY OF AGRICULTURE, FOODS & MARKETS
VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION
USGS science for a changing world
COLLEGE OF ENGINEERING
COLLEGE OF AGRICULTURE AND LIFE SCIENCES
BIOLOGICAL SYSTEMS ENGINEERING
VIRGINIA TECH.

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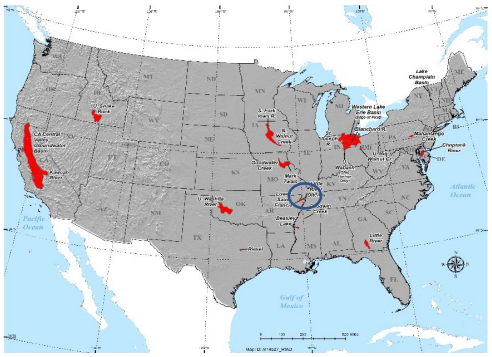
Little River Ditches & Lower St. Francis Watersheds

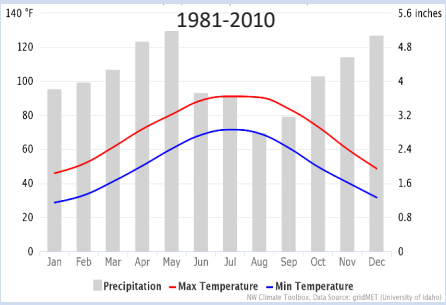


A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the Agricultural Research Service and the Natural Resources Conservation Service

Location

The Lower Mississippi River Basin (LMRB) is the lowest elevation of the basins of the Mississippi-Atchafalaya River Basin. The narrow band along the Mississippi River Alluvial Plain in the LMRB is considered the Delta Region. The region is characterized by humid subtropical climate with long, hot summers, and mild winters.

Temperature and Precipitation



Major land uses

Cropland: Rice, Soybean, Cotton, Peanut, Corn, Sorghum, Wheat.
Grassland: NA
Woodland: NA

Data collection

The two study watersheds were established in 2014. Little River Ditches (LRD) in Mississippi County and Lower St. Francis (LSF) in Poinsett County each had five instream water quality monitoring stations. The watersheds complement ongoing edge-of-field (EOF) monitoring studies that measure nutrients and sediment from agricultural fields as part of a state-wide monitoring network.

Concerns

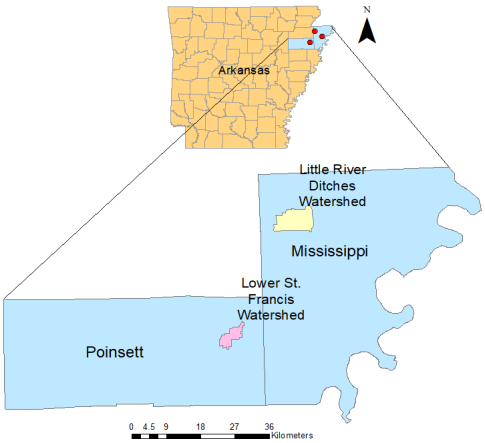
Non-point source pollution from agriculture is the leading source of water quality impairment in U.S. water resources. Nutrients and sediment lost in runoff from agricultural fields can impact water quality in downstream waterways. Such losses present both an agro-economic and environmental challenge.

When agricultural managers apply fertilizers in fields, their expectation is that those nutrients will contribute to farm profits through improved crop performance and not be lost in surface water runoff. Instead, losses of excess nutrients occur in turbid, hypoxic (low oxygen) and anoxic (no oxygen) waters, and erosion contributes to sediment buildup in water resources.

Hypoxia in the Gulf of Mexico due to nutrient loading from the Mississippi River watershed is well documented. Non-point source pollution from agriculture and urban activities are primary contributors to the hypoxic zone in the Gulf of Mexico and local waterways.

Main conservation practices used

A number of conservation practices are regularly used in the watershed. These practices include irrigation water management (e.g., row rice irrigation, alternate wetting and drying rice irrigation, irrigation termination, and computerized hole selection), nutrient management (e.g., conservation tillage, winter cover crops, grid soil sampling with variable rate fertilizer applications, in-field and EOF buffers), as well as shallow water management for waterfowl during the winter season and surface water storage for irrigation.



Little River Ditches & Lower St. Francis Watersheds

Site Description

Edge-of-field Sites

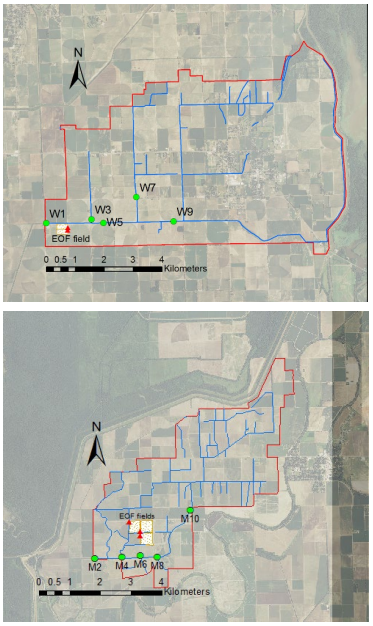
- The statewide network of edge-of-field sites includes all major commodities of Arkansas, with ARS and partners staffing sites in rice, cotton, and soybean.
- The sites consist of pairs of fields similar in soil type and size. For each pair, one of the fields is managed conventionally, while the other has a suite of conservation practices. Runoff quantity and quality are measured at both.

Outcomes/Findings

Plot and field scale

- The non-growing season loads and concentrations of several measured components were higher than those measured during the growing season, lending support to the need for off-season practices such as winter cover crops and shallow water management for waterfowl during the winter.
- Lower concentrations and loads of nutrients and sediment were observed from rice compared to cotton and soybean systems. These differences are likely due to soil type but are also related to the water management system of flooded rice fields compared to furrow irrigated row-crops.
- Cover crops effectively reduced concentrations of dissolved nitrogen by 85% and dissolved phosphorus by 53% at a cotton edge-of-field location.
- Runoff water quality after irrigation was not different from that after rainfall.
- Given the proximity of the sites to the Mississippi River and the northern Gulf of Mexico, baseline runoff water quality data from this generally under-studied region will help inform regional budgets of nutrients and sediment loss.

Clockwise from top left: Water quality sonde deployed, installation of water quality sonde, automated sampler at LRD outlet location, and monitoring site in the LSF watershed.



Sampling sites in Little River Ditches (top) & Lower St. Francis Watersheds (bottom).

Outcomes/Findings

Watershed scale

- Source control in spring and late fall could be more effective in reducing sediment and nutrient losses coming off agricultural fields.
- Differences in sediment and nutrient loads were compared between the two CEAP watersheds, and differences were primarily due to cropping practices and soil type.
- Sediment and nutrient loadings increased from upstream to downstream in LSF. In LRD, nutrient loadings increased but sediment loadings showed no change in spite of measured edge-of-field reductions in conjunction with conservation practice adoption.

Collaborators and Stakeholders

Collaborating Producers

More Information

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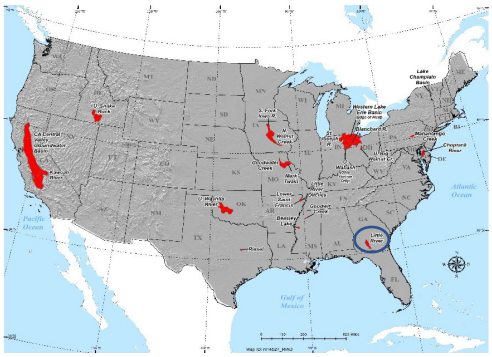
Little River Watershed

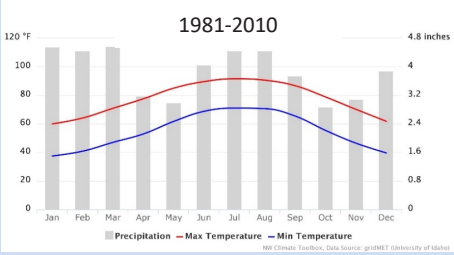


A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the Agricultural Research Service and the Natural Resources Conservation Service

Location

The 129-mi^2 Little River Watershed is at the headwaters of the Suwannee River Basin in South-central Georgia and North Florida.

Temperature and Precipitation



Major land uses

Cropland: 37% Cultivated Crops (Cotton, Peanut, Corn)
Grassland: 14% Pasture and Herbaceous
Woodland: 29% Forest and Shrubs
Wetland: 14%, Predominantly Forest
Urban: 5%
Open Water: 1%

Data collection

Beginning in 1967, stream discharge has been measured every 5 minutes. Automated samplers have collected flow weighted composite water samples since 1974. Plot and field studies have been conducted since 1969. Sediment, nitrogen, phosphorus, and herbicide concentrations have been characterized at the watershed and field scales. Rain gauges have been installed since 1968, soil moisture probes since 2001, and meteorological stations since 2003.

Concerns

Riparian buffers throughout the watershed are a key component to maintaining watershed health, occupying up to 14% of the watershed area. Decreasing profit margins are leading to increased irrigation, which leads to reduced riparian acreage. In addition, increased irrigation can lead to reduced aquifer levels.

Conservation tillage is seen as important for improving soil health and reducing environmental impact. However, the use of conservation tillage has recently been threatened by an evolution of herbicide-resistant weeds. New farming systems are necessary to overcome this issue. Furthermore, most soils in the watershed have restrictive subsoils, which promote shallow lateral flow during saturated periods. Reduced percolation makes local soils more susceptible to spring erosion and increased peak flow.

Riparian buffers can be an effective tool for reducing sediment, nutrient and pesticide transport. However, high water loss can lead to high levels of nutrient loss even at low concentrations. Because of this, new systems are needed to reduce overall agrichemical losses.

Main conservation practices used

A number of conservation practices are regularly used in the watershed. Several have been studied and assessed. These practices include riparian buffers, grass water-ways, strip-tillage, and winter cover crops.

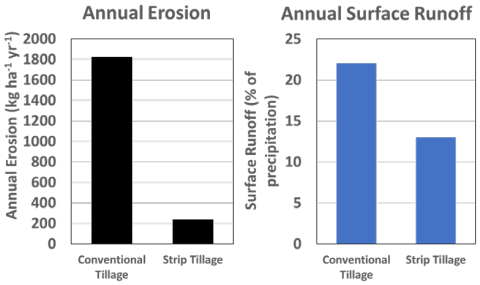
Other practices used in the watershed include nutrient management, pest management, contour farming, seasonal residue management, and terraces. Riparian buffers, although prevalent throughout the watershed, are naturally occurring and largely unsupported by government programs.

Little River Watershed

Outcomes/Findings

Plot and field scale

- Strip tillage reduced surface runoff (2X) and losses of sediment (7X), total pesticide (2X), and total nutrients (0.5X).

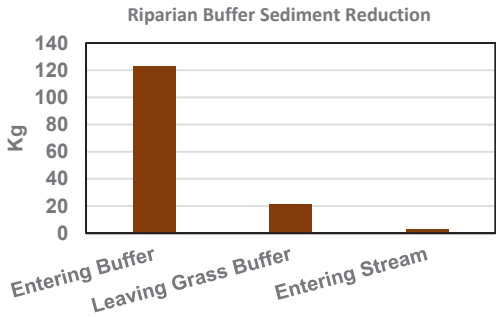


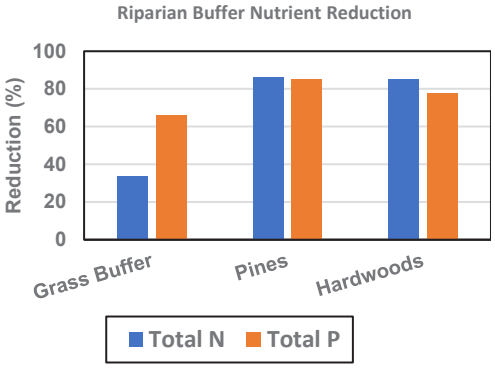
- Strip tillage enriched total organic nitrogen (1.5X) and total organic carbon (1.5X) in surface runoff.
- Winter cover crops reduced sediment losses during spring periods of high runoff (4X) and increased soil carbon (1.2 X).
- Characterization of water losses indicated that while strip tillage significantly reduced surface runoff and transport of agrichemicals, subsurface water and soluble agrichemical losses increased (1.5X) due to higher infiltration.

Left: Collecting water quality measurements. Right: Little River Station F.

Watershed scale

- The primary runoff-producing areas within regional watersheds are the low-lying, poorly drained, near-stream areas.
- Riparian buffers can reduce sediment transport, nutrient mass, and herbicide concentrations associated with surface runoff each by a factor of 10 (see charts on right).
- Baseflow accounts for 53% of all Little River Streamflow.
- A methodology for assessments of conservation tillage mapping was developed with 71–78% accuracy.
- Successful delineation of conservation vs. conventional tillage regimes within the LREW was completed.





Collaborators and Stakeholders

USGS science for a changing world
Georgia Cotton Commission
Georgia Conservation Tillage Alliance
University of Georgia

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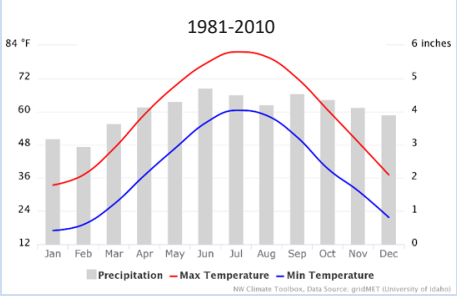
Mahantango Creek Watershed

A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the Agricultural Research Service and the Natural Resources Conservation Service

Location

The 420-km^2 Mahantango Creek Watershed (MCW) lies in the Appalachian Valley and Ridge Physiographic Province of the Upper Chesapeake Bay Watershed. Long-term monitoring is focused in WE-38, a 7.3-km^2 subbasin of Mahantango Creek.

Temperature and Precipitation



Major land uses

Cropland: Corn, Soybean, Small Grains.
Grassland: Pasture and Hay.
Woodland: Mixed hardwood.

Data collection

Flow from WE-38 is continuously monitored via tandem broad-crested and v-notched weirs established in 1968. Since 1981, water quality samples have been collected thrice weekly. Recently, Mahantango Creek joined other CEAP partners in testing real-time sensors for high-frequency water quality monitoring. NRCS-SCAN and ARS weather stations are located at the Mahantango Creek field station. Also, three rain gauges are dispersed across WE-38 (two since 1968, and a third since 1978). WE-38 farmers share management information annually, aiding interpretation of monitored data.

Concerns

Concerns over the health of the Chesapeake Bay have guided most conservation priorities in recent decades, with an emphasis on mitigating nitrogen, phosphorus, and sediment losses from the 166,000 km^2 Watershed to the Bay.

Given concerns over water quality, nutrient runoff via surface and subsurface hydrological flow pathways has been the primary resource concern. Improved mapping of soil layers that restrict downward water movement is key to identifying soils where excessive soil moisture can promote surface runoff.

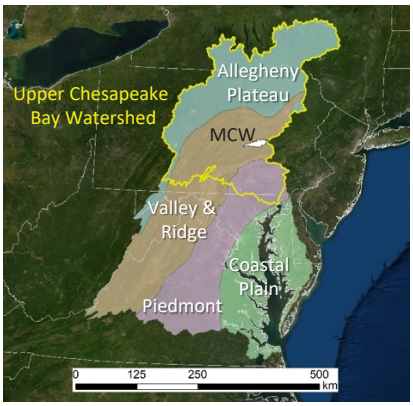
Increasingly, there is an association between emergent groundwater flows from seeps in lower landscape positions and nitrate-nitrogen losses to headwater streams.

These resource concerns converge in the riparian area, intersecting with riparian and aquatic ecosystem health. Grazing options for the riparian area are seen as a priority for livestock farmers in the region and conservation practices that restrict grazing are a barrier to their adoption.

Main conservation practices used

The main practices advocated for agriculture are no-till, winter cover crops, and 4R nutrient stewardship. The Chesapeake Bay TMDL identifies many other practices, all of which are vetted by the Chesapeake Bay model and prescribed by the State Watershed Implementation Plan. Farmer field days, hosted by NRCS, educate and problem solve locally.

Strategies to target and prioritize conservation practices include critical source area identification with the Phosphorus Index, and watershed planning under the Agricultural Conservation Planning Framework.



Location of Mahantango Creek Watershed (MCW) in the Upper Chesapeake Bay Watershed.

Mahantango Creek Watershed

Outcomes/Findings

Plot and field scale

- Manure applied to no-till soil exacerbates dissolved phosphorus (P) losses in runoff, increasing losses from critical source areas.
- In sloping landscapes, saturation excess runoff processes tend to override management factors in P mobilization and transport from agriculture to headwater streams.
- Added to soils high in P, gypsum decreases P solubility, improves infiltration, and reduces dissolved P losses in runoff.
- When simulated on historic, local crop rotations, the BMPs shown below reduced N, P, and sediment losses by 3 to 120, 4 to 22, and 9,300 to 17,400 lb/ac, respectively.

	N	P	Sed.
Cover crop*	15.8	15.8	3.2
Grass buffer	1.5	2.9	4.3
Land retirement	7.0	13.9	23.1
Manure injection	0.8	5.5	
No-till	0.1	0.5	0.8
Wetland restoration	9.5	19.9	35.7

* does not include benefit from residual N, forage use, or weed prevention.

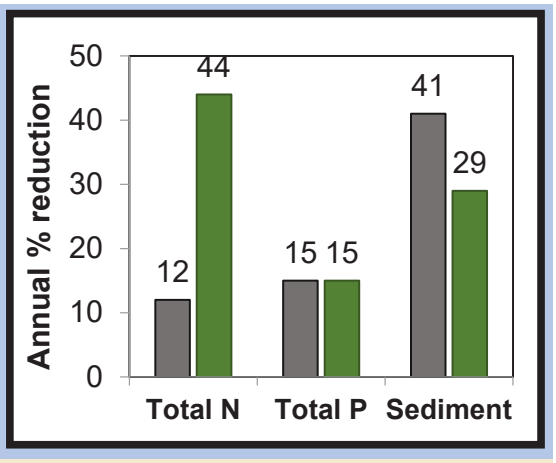
BMP cost-effectiveness ($/lb)

Watershed scale

- CRP-funded riparian buffers across the region have reduced N and P levels in surface runoff by about 12 and 35%, respectively.
- Since the late 1900s, increasing focus on conservation tillage and on-contour strip cropping of row crops with grasses has reduced annual overland losses of N, P and sediment by up to 26 kg/ha, 4.3 kg/ha, and 3.6 t/ha, respectively.
- Implementation of critical source area management strategies can achieve nutrient management objectives of the Chesapeake Bay TMDL at less cost than can strategies not prioritizing location.

TMDL Watershed Plan Scenario
BMPs (e.g., nutrient management, land retirement, stream buffers, wetland restoration) placed randomly by field to meet area allocation of Plan, **without** attention to critical source areas.

Cost-effective Targeting Scenario
BMPs highly cost-effective in reducing losses (e.g., 4R nutrient stewardship, cover crops) placed preferentially by field-level critical source areas to meet N and P reduction levels of TMDL Watershed Plan Scenario.



Two BMP placement scenarios of Mahantango Creek Watershed, simulated with the Soil & Water Assessment Tool, demonstrate environmental and economic watershed-level trade-off impacts in management decision-making. For 30% of the cost of the *TMDL Watershed Plan Scenario*, the *Cost-effective Scenario* reduced three times more nitrogen (N) and similar levels of phosphorus (P) annually from the watershed, leaving money for focusing on sediment control practices. (Methods described in: Amin, M.G.M., Veith, T.L., Shortle, J.S., Karsten, H.D., and Kleinman, P.J.A. 2020. Addressing the spatial disconnect between national-scale total maximum daily loads and localized land management decisions. *J. Environ. Qual.* 2020:1–15)

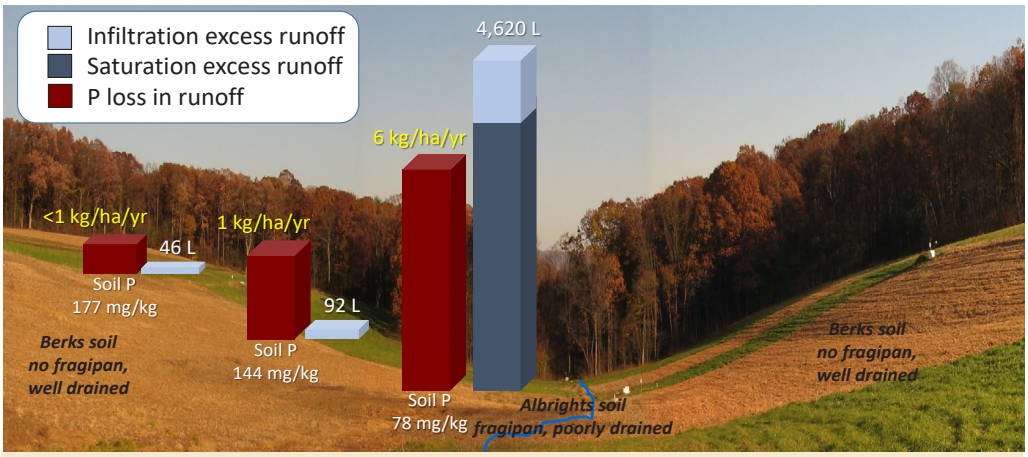


Illustration of the critical source area concept in the Mattern experimental watershed, part of CEAP's Mahantango Creek Watershed. Columns emphasize the contribution dissimilarities of well-drained and somewhat poorly drained soils to surface runoff and total phosphorus (P) loss in surface runoff over 2.5 years of monitoring. Soils above restrictive fragipan layers have the highest runoff potentials and, thus, contribute overwhelmingly to P loads. (Source: Buda, A.R., Kleinman, P.J.A., Srinivasan, M.S., Bryant, R.B. and Feyereisen, G.W. 2009. Factors influencing surface runoff generation from two agricultural hillslopes in central Pennsylvania. *Hydrol. Process.* 23:1295-1312)

Collaborators and Stakeholders

USGS science for a changing world
PennState

More Information

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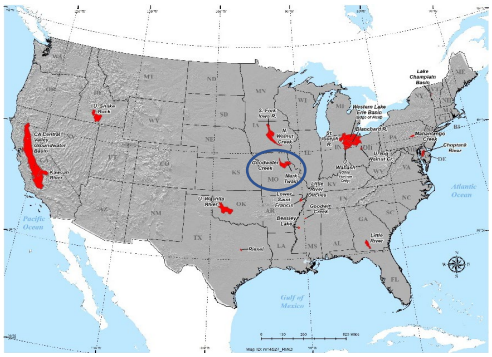
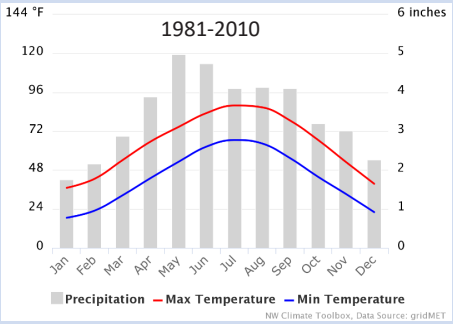
Mark Twain/Salt River and Goodwater Creek Watersheds



Location

The slightly under 2,300-mi^2 Salt River Basin is the drainage area for Mark Twain Lake, in Missouri. The lake was built for flood control and drinking water supply. Goodwater Creek is a headwater stream.

Temperature and Precipitation



Major land uses

Cropland: Corn, Soybean, Sorghum, Wheat.
Grassland: Pasture and Hay.
Woodland

Data collection

As early as 1971, stream gauges measure discharge every 5 to 15 minutes. Automated samplers collect water samples during storm events with additional samples collected every one or two weeks. Since 1991, monitoring equipment measure discharge and collect water samples from plots and fields. Measurements of sediment, nitrogen, phosphorus, and herbicides concentrations in these samples assess water quality. Rain gauges since 1971 and a meteorological station since 1993 measure precipitation, temperature, relative humidity, and solar radiation.

A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the Agricultural Research Service and the Natural Resources Conservation Service

Concerns

Most soils in the Salt River Basin and in Goodwater Creek Watershed have a restrictive layer (the claypan). This layer reduces percolation and the storage of soil water. Reduced percolation causes excessive soil moisture in the spring and increases the peak flow of area streams.

High levels of soil moisture result in increased water erosion of soil, increased sediment transported to surface water, excessive agricultural nutrients and pesticides transported to surface water, organic matter depletion, and poor soil health. Increased peak flows in streams cause higher rates of stream bank erosion.

The thin top soil also affects grain production. Excessively wet fields can delay planting, and in the worst case, make it impossible, because equipment cannot enter the fields. During dry and hot summer periods, there is a potential for insufficient soil moisture for plant growth.

Excess nutrients and pesticides in the water entering Mark Twain Lake have increased treatment costs for the water supply facility. Excess nutrients leaving the lake contribute to Gulf hypoxia.

Main conservation practices used

A number of conservation practices are regularly used in the watershed. Several have been assessed and developed during the studies. These practices include no-till; winter and summer cover crops; timing of nitrogen, phosphorus, and pesticides applications; nitrogen injection into soils as opposed to broadcast surface application; strategic conservation tillage to incorporate pesticides (rotary harrow); vegetated upland buffers; and targeting practices to the most vulnerable land.

Other practices used in the watershed include terraces, grassed waterways, riparian buffers, streambank protection, and conservation tillage.

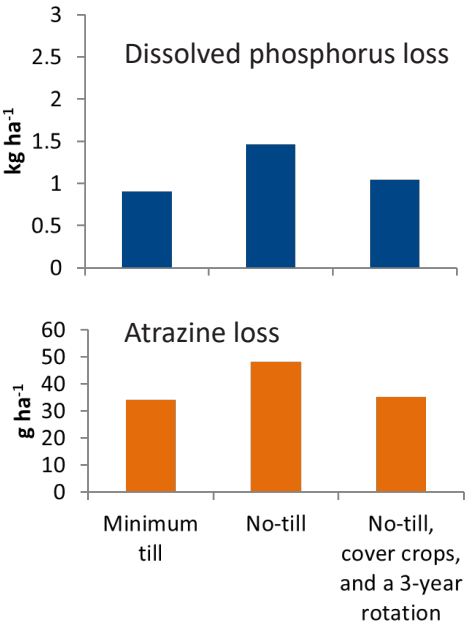
Mark Twain/Salt River and Goodwater Creek Watersheds

Outcomes/Findings

Plot and field scale

- No-till does not reduce runoff volume and doubles or triples atrazine and dissolved phosphorus losses on claypan soils.
- Light tillage with a rotary harrow incorporated herbicides without destroying residue cover. This reduced edge-of-field atrazine losses from fallow plots by 50% compared to losses from no-till plots.
- Vegetated buffers reduced sediment losses by 65% and herbicides by 20-30% by trapping sediment, increasing infiltration, increasing adsorption, and enhancing degradation.
- A precision agriculture system (PAS, no-till, cover crops, cropping systems defined by zones, and precision applied inputs) reduced soil loss by 85%, and surface runoff nitrogen loss by 40%.
- Although no-till alone, on claypan soils, increased herbicide and dissolved P losses, PAS mitigated these negative effects (see graph at right), and maintained crop yields compared to a minimum-till system.
- No-till with cover crops and a 3-year rotation increased soil organic carbon in the topsoil by 32% relative to no-till alone. No-till alone increased soil organic carbon in the topsoil by 22% relative to mulch till.
- In annual cropping systems, reducing soil disturbance, using longer rotations, and incorporating cover crops improves soil function and soil health scores.
- Overall, perennial systems improve soil function and soil health scores over annual cropping systems.

Clockwise from left: Measuring flow at Young's Creek, plot monitoring infrastructure in the winter, Mark Olson takes a water quality sample in Goodwater Creek.



Watershed scale

- Stream bank degradation produces 65-85% of the stream sediment in streams of Mark Twain Lake watershed.
- Effective sediment, herbicide, and nutrient stream load reduction requires targeting of practice implementation.
- The Soil Vulnerability Index identifies the vulnerability to losses of sediment, nutrients, and pesticides as a function of slope and select soil properties. For mild slopes (<2%), accounting for the depth to the claypan may improve the usefulness of the index.

Collaborators and Stakeholders

More Information

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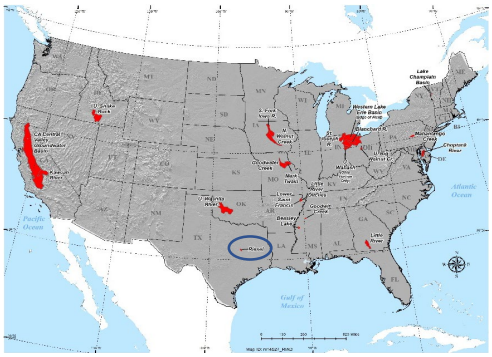
Riesel Watersheds/Grassland Research

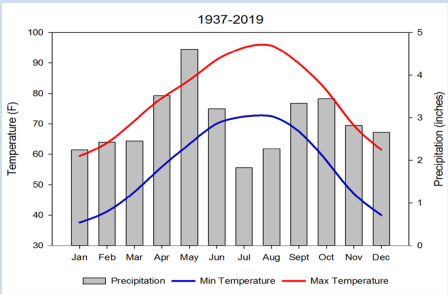


A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the Agricultural Research Service and the Natural Resources Conservation Service

Location

The Grassland Research Station in Riesel, TX encompasses 820 acres of Blackland Prairie. Riesel, TX is the last of three research stations that were opened in the mid 1930s to study soil erosion.

Temperature and Precipitation



Major land uses

Cropland: corn, oats, wheat, cotton, no-till cover crops
Grassland: pasture, hay production, remnant native prairie
Woodland

Data collection

The first runoff samples were collected manually in 1937. Chickasha samplers were used from the mid 1970s to 2001. Automated ISCO samplers were installed in 2001 and are still in use. Flow gauges measure discharge every 5 to 10 minutes. Automated samplers collect water samples during storm events with the addition of manual base flow samples. Measurements of sediment, nitrogen, and phosphorus concentrations in these samples assess water quality. Rain gauges since 1939 and a meteorological station since 1990 measure precipitation, temperature, relative humidity, and solar radiation.

Concerns

The soils in the Riesel Watershed are dominated by Houston Black clay soil that is recognized as the classic Vertisol. These highly expansive clays shrink and swell with changes in soil moisture.

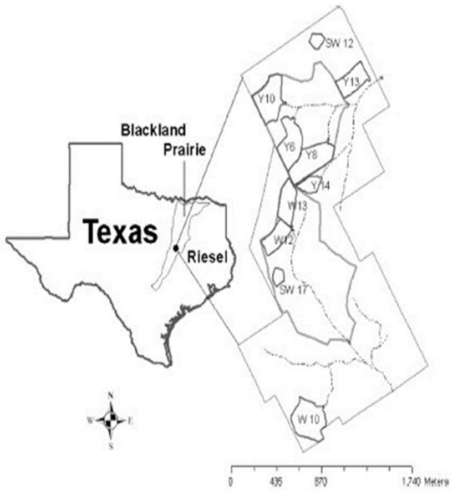
High levels of soil moisture result in decreased infiltration rates, which increase soil erosion. Conversely, low levels of soil moisture result in increased infiltration rates. Preferential flow becomes common when soils dry and large cracks form.

High clay soils can impact crop production. Excessively wet fields can delay planting and in some years prevent planting altogether. During drought, the clay soils in the Blackland Prairie can become so compact that equipment cannot penetrate, making field preparation and planting troublesome. Strategies to mitigate excessive water (e.g., artificial drainage) are largely impractical due to the extensive droughts that are common during the summer months.

Land holdings are typically small, and high variability in crop yields can result in unpredictable profit margins.

Conservation Practices

A number of conservation practices are regularly used in the watershed. These practices include broad-base terracing, contour farming, crop rotation, and grassed waterways. Both organic fertilizer (e.g., turkey litter), and inorganic commercial fertilizers (e.g., urea ammonium nitrate, or UAN) are used on conventionally tilled land. Broadcast surface applications of litter or commercial fertilizers are often lightly disked in within 24 hours to incorporate nutrients and reduce losses through runoff or volatilization.

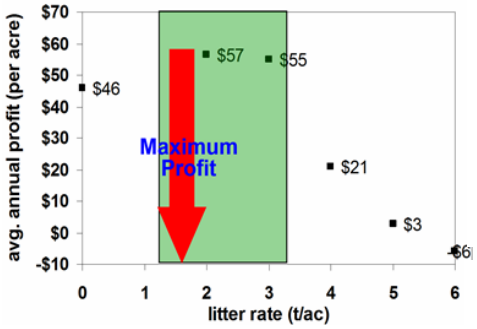


Outcomes/Findings

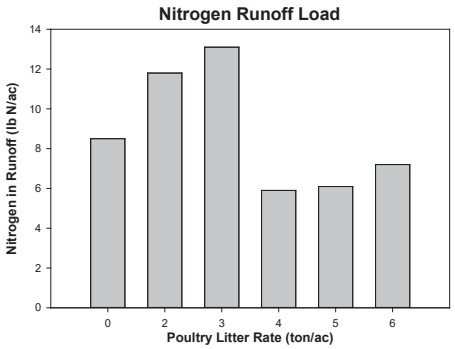
Riesel Watersheds

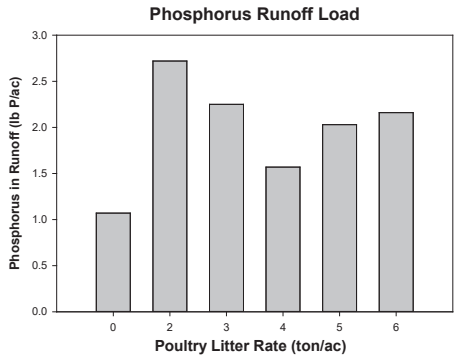
Plot and Field Scale

- For cultivated land in the Blackland Prairie region of Texas, litter rates of up to 2 tons/acre are acceptable for maintaining water quality.
- On cultivated land, litter application increased runoff phosphorus (P) but decreased runoff nitrogen (N), particularly at extremely high rates (see charts at right). Litter applications of 3 tons/acre and greater caused P runoff to exceed ideal limits. On pasture, litter application increased both P and N in runoff.
- Runoff N and P concentrations generally decreased during the year as time since fertilizer application increased, but few long-term trends in N and P runoff occurred in spite of soil P buildup due to the dynamic interaction between transport and source factors.
- Litter application had no effect on *E. coli* in surface waters. *E. coli* count was highest in grazed pastures due to cattle. Native prairie had higher *E. coli* in runoff compared to cultivated lands due to wildlife.
- Poultry litter applied at 2 or 3 tons/acre maximized average annual profit, which was greater than with commercial fertilizer. Litter rates above 3 tons/acre diminished return on investment or even caused a net loss.



Clockwise from left: planting a crop on one of the gaged watersheds, applying poultry litter prior to planting a crop, runoff at a gaging station following a storm.





Watershed Scale

- Conventional practices increased runoff by 56% compared to native prairie. Conservation practices increased runoff by 19% compared to native prairie. Conservation practices overall decreased total runoff, peak runoff, and soil loss. Small grain crops (e.g., wheat) reduced soil erosion compared to row crops (e.g., corn) due to greater soil cover.
- A few intense events (10% of precipitation events) caused more than half of all soil loss via water erosion.

Collaborators and Stakeholders

More Information

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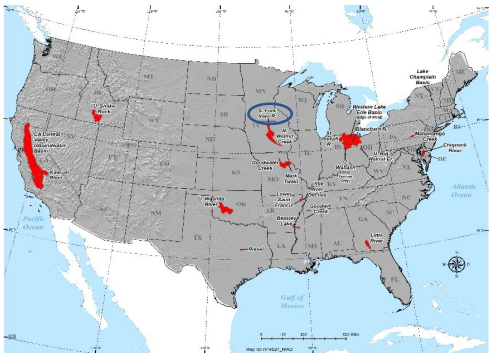
South Fork, Iowa River Watershed

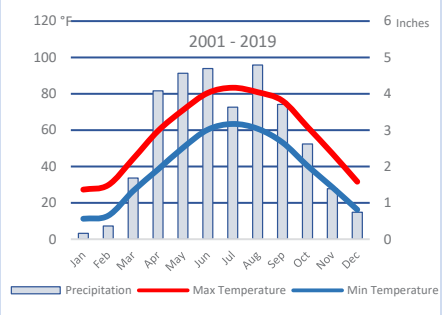


A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the Agricultural Research Service and the Natural Resources Conservation Service

Location

The South Fork of the Iowa River drains 780 km^2 (193,000 acres) in Iowa. The watershed is an area of intensive production of row-crops and livestock.

Temperature and Precipitation



Major land uses

Cropland: Corn & Soybean production occurs on about 90% of the watershed. **Pasture, Livestock facilities, Farmsteads, Woodlands, Roadways, and Towns** comprise the remainder.

Data collection

Stream monitoring began in 1996 and was expanded to multiple stream gauges in 2001. Continuous discharge data are aggregated on 30-minute intervals. Automated samplers collect water samples during storm events with additional samples collected every week during the growing season. Water quality sondes have been in place since 2007 to collect continuous data on water temperature, dissolved oxygen, and nitrate concentrations.
Two meteorological stations measure precipitation, temperature, relative humidity, and solar radiation.

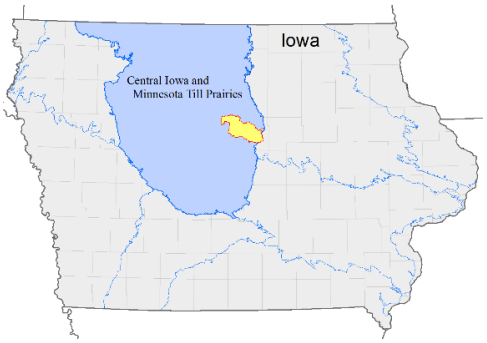
Concerns

The SFIR watershed is in the Des Moines Lobe of north central Iowa and southern Minnesota, an area of recent glaciation that exhibits limited stream development and poor soil drainage. The loam textured soils are high in organic matter, which, combined with a humid temperate climate, make the area one of the world's most productive agricultural regions. Hydric soils occupy 54% of the watershed. Artificial (tile) drainage systems were installed beginning in the early 1900s and are being updated on an ongoing basis. About 84% of the watershed is tile drained, and 2/3 of stream discharge originates via tiles.

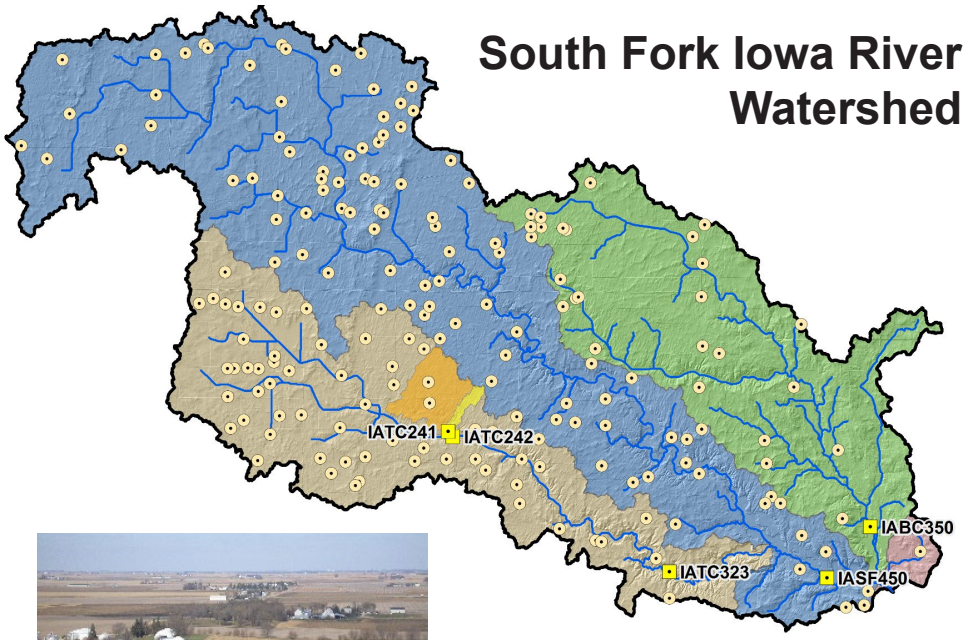
The drainage water carries substantial nitrate loads, which have averaged around 30 kg ha^{-1} in recent years. Soil temperatures are cool in the spring, and farmers use tillage to help warm them for planting. The resulting poor residue cover increases soil erosion, especially in spring when periods of wet weather have delayed planting in recent years. There are >100 livestock facilities, most producing swine. Most manure is applied in fall, which challenges beneficial re-use of manure nutrients.

Main conservation practices used

Most producers address water quality risks by managing timing and rate of fertilizer and pesticide applications. But wet weather can reduce flexibility of operations. Producers are being encouraged to implement practices to reduce nitrates in tile drainage, including controlled drainage, bioreactors, saturated buffers, and wetlands. Locations suited for placement of these and other practices have been identified using the Agricultural Conservation Planning Framework (ACPF), and farmers can view suggested practice placements, by field, on a story map website. Surface inlets found in glacial depressions can have filter practices installed, but only in fields where tillage is restricted.



South Fork Iowa River Watershed



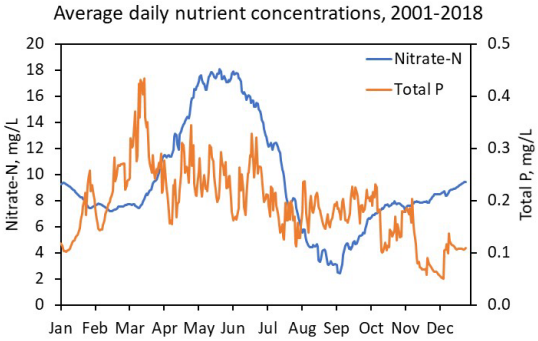
The watershed has many confined animal feeding operations (circles), most producing swine. Drainage areas above gage stations (labeled) include streams and tile outlets.

Outcomes/Findings

Plot and field scale

- Existing conservation practices (grassed waterways, WASCOBs, terraces) were mapped from1930 to 2016. Distribution of these conservation practices are related to erosion. Grassed waterways were the predominate conservation practice. In recent decades installation of new conservation practices tends to balance loss of conservation practices.
- Existing conservation practices are ineffective for reducing nitrate and *E. coli* in this tile-drained and manured watershed. Sources of nitrate are fertilizer, animal manure, and soil organic matter.
- Monitoring of this watershed showed that annual nitrate loss ranges from 8.4 to 58.9 kg/ha, which varies with rainfall. Streamflow varies seasonally with about 50% of the annual nitrate loss occurring during spring and early summer. Phosphorus losses are episodic; peak losses come from snowmelt in some years (see chart at right).
- The watershed would benefit from implementation of saturated buffers and wood-chip bioreactors. Wood – chip bioreactors host bacteria that convert nitrate in water to nitrogen gas in the atmosphere. Bioreactors occupy only 0.3% of a treated field's area and can reduce annual nitrate loads by 20%.
- Concentrations of two antibiotics used in swine production were detected in 69% of the water samples from streams and tile drains.
- Monitoring data has been used to test and calibrate watershed simulation models. Research has focused on testing tile drainage routines and evaluating benefits of perennial bioenergy crops.

Typical farmlands after harvest.



Restored prairie pothole wetland.

Watershed scale

- Practices to treat tile drainage can be used to reduce nitrate loads. Using the ACPF, we estimate that saturated buffers could treat drainage from 101,736 acres, bioreactors could treat drainage from 24,194 acres, and controlled drainage could be used on 44,933 acres in the watershed.
- Glacial depressions (prairie potholes) are common. The watershed has 4,775 potholes covering 19,710 acres, which could store 25,820 acre-ft of water if all were filled. In some years potholes are highly productive and not visible.

Collaborators and Stakeholders

Southfork Watershed Alliance Inc.
Iowa Soybean Association
Iowa Department of Agriculture & Land Stewardship
Antares Group Incorporated
USGS science for a changing world
DNR Iowa Department of Natural Resources
Agricultural Conservation Planning Framework

More Information

CEAP Site Lead: Rob Malone, rob.malone@usda.gov
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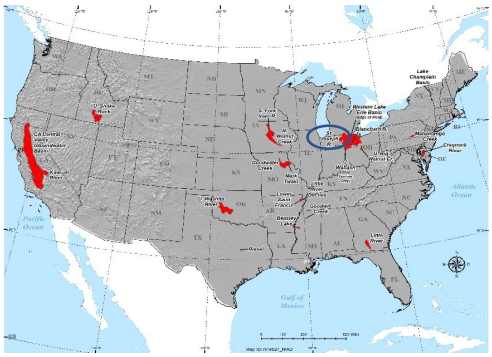
CEAP website: nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/

St. Joseph River Watershed

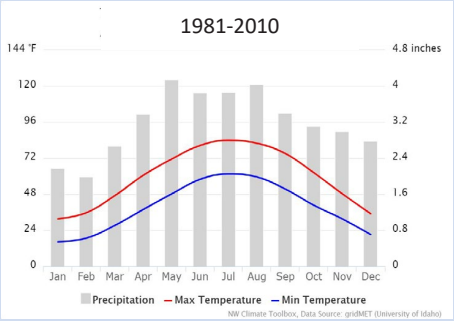
A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the Agricultural Research Service and the Natural Resources Conservation Service



Location

The St. Joseph River Watershed (1,093 mi^2) located in northeastern Indiana is part of the Maumee Basin (6,354 mi^2), which drains into Lake Erie near Toledo, Ohio.

Temperature and Precipitation



Major land uses

Cropland: Corn, Soybean, Wheat.
Grassland: Pasture and Hay.

Data collection

Beginning in 2002, stream gauges measure discharge every 10 minutes. Automated samplers collect water samples from most flowing sites on a daily basis, with additional samples collected during high-flow events on some stream locations. Since 2004, monitoring equipment measure discharge and collect water samples from multiple fields. Sediment in runoff is measured from some field sites; nitrogen, phosphorus, and herbicide concentrations in runoff are measured from all sites. Meteorological stations since 2004 measure precipitation, temperature, relative humidity, and solar radiation.

Concerns

Closed depressions or "potholes" dominate the watershed area and must be artificially drained to support agricultural crop production. Poorly drained soils combined with depressional topography result in increased runoff, increased sediment transported to surface waters via surface inlets and direct overland flow, excess agricultural nutrients and pesticides transported to surface water via subsurface tile and surface runoff, organic matter depletion, and poor soil health. Increased peak flows in streams cause higher rates of stream bank erosion.

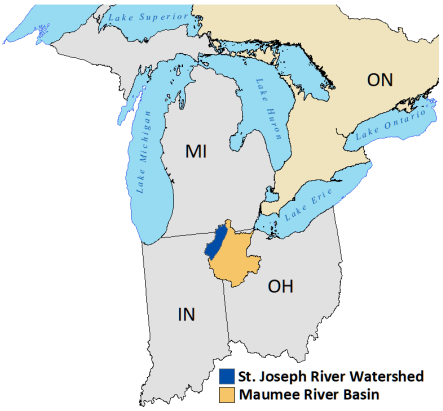
Poorly drained soils also affect grain production. Excessively wet fields can delay planting and, in some cases, make it impossible because farm equipment cannot enter fields. During dry and hot summer periods, there is a potential for insufficient soil moisture for optimum plant growth.

Water, sediment, and nutrients from the St. Joseph River Watershed flow into Lake Erie, which experiences annual harmful algal blooms caused by excess nutrients primarily from agricultural sources.

Main conservation practices used

A number of conservation practices are regularly used in the watershed. Several have been assessed and developed as part of CEAP research. These practices include no-till, conservation tillage, cover crops, grass waterways, fertilizer placement (broadcast vs. injection), fertilizer application rate, in-stream water treatment, alternative surface drainage inlets (blind inlets), and phosphorous removal structures.

Other practices used in the watershed include water and sediment control basins, riparian buffers, streambank protection, and precision fertilizer placement.



St. Joseph River Watershed

Outcomes/Findings

Plot and field scale research

Blind inlets

- Replacing tile risers with blind inlets resulted in a 78-79% reduction in sediment and total phosphorus losses in surface runoff.
- Blind inlets reduced atrazine (57%), 2,4-D (58%), metolachlor (53%), and glyphosate (11%) in surface runoff compared to tile risers.
- Blind inlets did not influence the frequency of flow, but may increase or decrease the length of ponding in fields compared to a tile riser.

Phosphorus removal structures

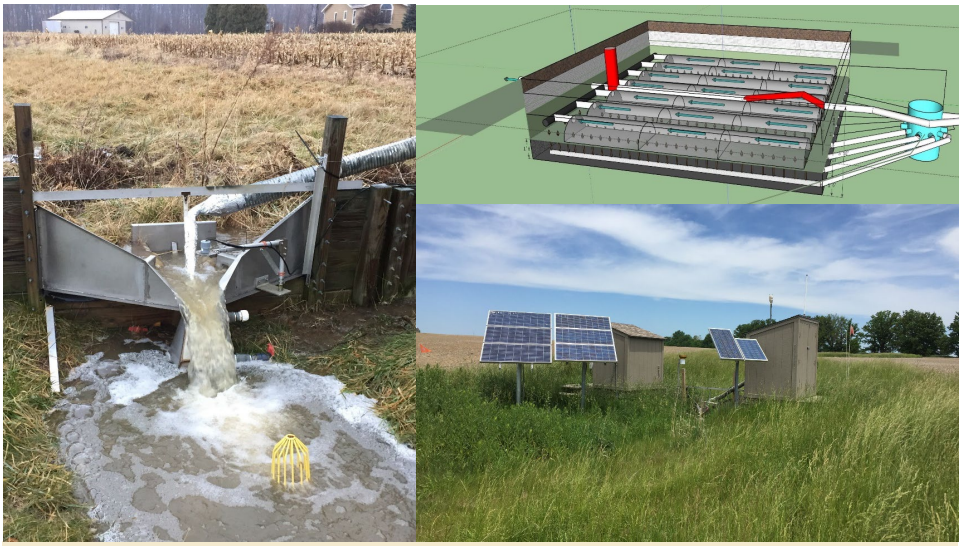
- A phosphorous removal structure utilizing steel slag as the phosphorus sorption material decreased soluble phosphorus load in surface and subsurface flow by 37 to 55%. (see graph on the right).

Tillage

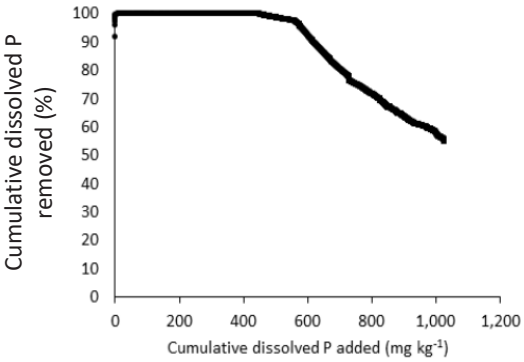
- Soluble phosphorous and nitrogen surface losses from no-till plots before and after fertilization were greater compared to tilled plots.
- Atrazine and glyphosate loads from no-tilled plots were higher than conventionally tilled plots.
- No-tillage doubled soluble phosphorus loading in surface runoff, but decreased total phosphorus loading by 69%.

Other practices

- Grassed waterways increased soluble phosphorus losses in surface runoff, but not total phosphorus.
- A corn-soybean-wheat rotation decreased soluble phosphorus (85%) and total phosphorus (83%) losses in surface runoff compared to a corn-soybean rotation.



Clockwise from left: Measuring surface runoff from an edge-of-field plot, in-field phosphorous removal structure designed to treat surface and subsurface flows, water quality monitoring site infrastructure.



Cumulative mass of dissolved P in drainage water per mass of steel slag in the structure (mg/kg)

Watershed scale research

- Ditch dredging activities resulted in stream reaches becoming net sinks for ammonium, soluble phosphorus, and total phosphorus within 12 months of dredging.
- Modeling studies indicated that cover crops and forage were most successful at reducing sediment and nutrient loss (56-88% and 28-91%, respectively).
- Compared to single practices, two and three practices resulted in greater sediment and nutrient reductions.
- Total phosphorus load decreased by 2-4% with the addition of vegetated buffer strips.
- Combining buffer strips with conversion to grassland, resulted in a 7% reduction in total phosphorus.

Collaborators and Stakeholders

DeKalb County SWCD DeKalb County farming community

More Information

CEAP Site Lead: Mark Williams, Mark.Williams2@usda.gov
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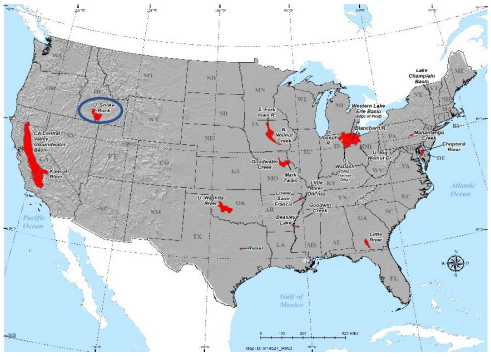
Upper Snake/Rock Watershed

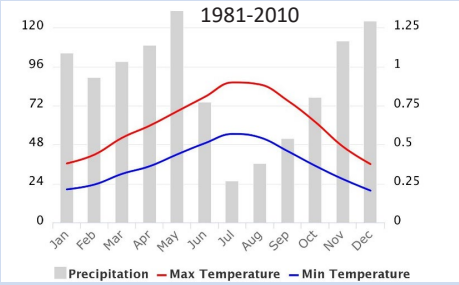


A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the Agricultural Research Service and the Natural Resources Conservation Service

Location

This assessment has focused on the Twin Falls irrigation tract within the Upper Snake/Rock Watershed in southern Idaho. The Twin Falls Canal Company (TFCC) diverts irrigation water from the Snake River, which flows to 205,000 acres of farmland.

Temperature and Precipitation



Major land uses

Cropland: Alfalfa, Corn, Dry Bean, Barley, Wheat, Sugar Beet, Potato.
Livestock: Dairy.

Data collection

Water quality analysis has focused on sediment, nutrients, and soluble salts. The first data set was collected in 1968-1971. In 1990, TFCC partnered with the University of Idaho and U.S. Bureau of Reclamation to sample the main irrigation return flow streams. From 2005-2008, ARS began measuring flow rate and water quality at 24 return flow and 2 inflow sites for an NRCS Special Emphasis CEAP-Watershed project. ARS continues to collect water samples at the inflow and eight return flow sites while Idaho Department of Water Resources measures flow rate.

Concerns

The Twin Falls irrigation project started in 1906. The watershed is bounded by the main irrigation canal on the east, highline irrigation canal on the south, Salmon Falls Creek canyon on the west, and Snake River canyon on the north. This is a highly managed watershed. Rock Creek is the only natural stream in the Twin Falls irrigation tract, and it generally does not flow during the summer. Water flowing in streams is irrigation water, furrow irrigation runoff, or subsurface drainage. Annual irrigation application on fields is two to three times greater than average annual precipitation.

Soils are silt loams with low organic matter and high erodibility. All crop land was initially furrow irrigated, causing chronic erosion problems and high sediment loads in irrigation return flow to the Snake River.

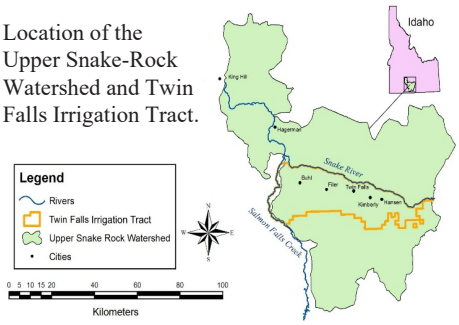
In the 1990s, farmers began converting from furrow irrigation to sprinkler irrigation with assistance from state and federal programs. During the same time, the dairy industry grew rapidly in Idaho, increasing the amount of corn grown and manure applied, which changed irrigation demand and nutrient management.

Main conservation practices used

Conversion from furrow irrigation to sprinkler irrigation has been the main practice. About 2,500 acres of crop land are converted to sprinkler irrigation each year. Many furrow-irrigated fields have sediment basins to trap sediment before tailwater flows from the field. Most farmers who furrow irrigate mix water soluble polyacrylamide (PAM) with irrigation water, which can reduce soil erosion 50-80%.

TFCC worked with state and local organizations to install more than 20 water quality ponds that capture sediment and nutrients before water flows back to the Snake River. These ponds are similar to constructed wetlands, but water continuously flows through them so retention time is less than 12 hours.

Location of the Upper Snake-Rock Watershed and Twin Falls Irrigation Tract.



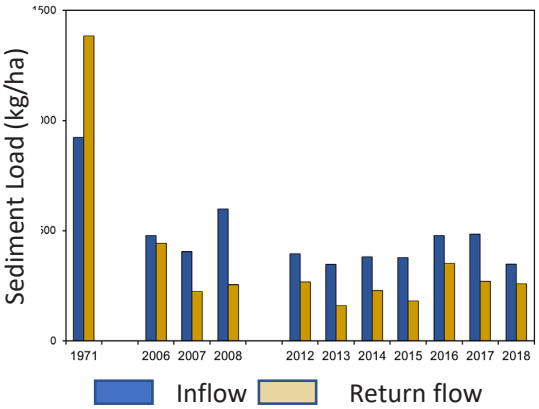
Upper Snake/Rock Watershed

Outcomes/Findings

Watershed scale

- The amount of irrigation water annually diverted into the watershed was 45 to 50 inches from 2006-2016, which was 3 to 9 times greater than annual precipitation.
- Irrigation return flow includes runoff from furrow-irrigated fields, unused irrigation water, and subsurface drainage. Return flow during the irrigation season is approximately 30% of the diverted irrigation water.
- Furrow irrigation has been steadily converted to sprinkler irrigation (45% of the crop land was sprinkler irrigated in 2006 vs. 60% in 2016). Irrigation project efficiency (evapotranspiration/diverted irrigation water) did not increase as more land was sprinkler irrigated. TFCC is a supply-based irrigation project that uniformly distributes available water to farms. Irrigation project efficiency in July, when crop water use is maximum, increased from 2006-2016.
- Annual sediment discharged to the Snake River has decreased from 1200 lbs./acre in 1971 to 230 lbs./acre in 2018. More sediment enters the watershed with irrigation water than is discharged to the Snake River with return flow, removing 15,000 tons of sediment from the river annually.
- Water quality ponds reduced sediment concentrations 36 to 75% (57% on average), total phosphorus 13 to 42% (27% on average) and dissolved phosphorus 7 to 16% (7% on average).
- Nitrate-nitrogen concentrations in shallow groundwater and return flow have increased from 3 mg/L in the late 1960s to 5 mg/L in the early 2000s.

Clockwise from left: Water quality pond, muddy irrigation return flow in the 1980s, sediment basin on a furrow-irrigated field, and untreated (left) and PAM-treated furrows.



Field scale

- Soil quality parameters were lower on the eroded, inflow ends of furrow-irrigated fields compared to the bottom end of the fields. Within three years of converting to sprinkler irrigation, soil quality parameters were no longer different between the top and bottom ends of the fields.
- Furrow-irrigated fields are often moldboard plowed. Increasing sprinkler irrigation has increased conservation tillage and a few farmers have started direct seeding.

Collaborators and Stakeholders

Twin Falls Magic Valley Canal Co.

IDWR

University of Idaho

More Information

CEAP Site Lead: Dave Bjorneberg, dave.bjorneberg@usda.gov
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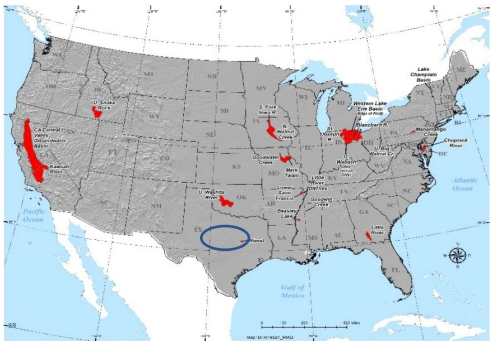
Upper Washita River Watersheds

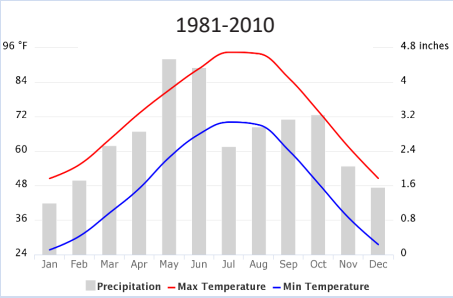


A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the Agricultural Research Service and the Natural Resources Conservation Service

Location

The Upper Washita River Watersheds (UWRW) consist of the Fort Cobb Reservoir Experimental Watershed (FCREW), the Little Washita River Experimental Watershed (LWREW), and one field study, all located in central Oklahoma.

Temperature and Precipitation



Major land uses

Cropland: Winter wheat
Grassland: Pasture

Data Collection

A precipitation gauge network was installed in the UWRW in 1961. At 5-minute intervals, a weather station measures air temperature, relative humidity, rainfall, solar radiation, and soil temperature at three depths. Soil moisture is measured at 30-minute intervals. The U.S. Geological Survey monitors streamflow in collaboration with the Oklahoma Water Resources Board and ARS. From 2004 to 2007, samples were collected at the FCREW gauging stations to measure water quality variables. Beginning in 1976, surface runoff samples were collected from 8 research plots for water quality analysis.

Concerns

The Fort Cobb Reservoir and contributing stream segments were selected for study because the lake was experiencing high sedimentation rates. In addition, seasonal phosphorus (P) and nitrogen (N) loads were excessive in some stream segments and contributed to poor lake water quality.

A rapid geomorphic assessment indicated that unstable stream channels dominated the stream networks. This led to stream bank erosion that contributed to sedimentation in water bodies.

Forty five flood-retarding structures were constructed by NRCS in the LWREW from 1969-1982, with a design life of 50 years. These aging structures and those installed around the country need assessment in terms of current storage capacity and degree of sedimentation that has occurred over the years.

In the nearby North Canadian River watershed, encroachment of invasive species such as red cedar into grasslands affects beef production as well as water resources.

Major applied conservation practices

The conservation practices (CPs) implemented by NRCS at the watershed scale apply to cropland and degraded grazing lands.

The NRCS cropland CPs include conservation cover, conservation crop rotation, contour farming, cover crop, critical area planting, diversion, forage and biomass planting, grade stabilization structure, grassed waterway, nutrient management, range planting, residue and tillage management, no-till, residue and tillage management, reduced till, residue management, mulch till, and terraces.

The NRCS CPs used on degraded grazing lands include brush management, fences, livestock pipeline, prescribed grazing, pumping plant, water well, and watering facility.

The CPs studied by ARS at plot scale include no-till systems that integrate cool season and warm season cover crop forages mixtures.

Upper Washita River Watersheds

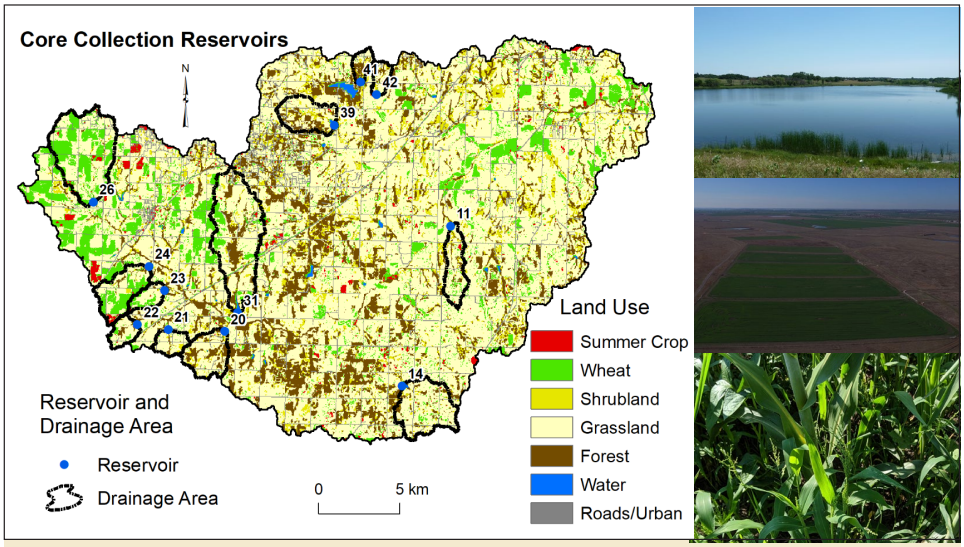
Outcomes/Findings

Field to sub-watershed scale

- Compared to conventional tillage, a minimum tillage system used with a summer forage cover crop reduced suspended sediments, total P, and total N by 7%, 19%, and 31%, respectively.
- Modeling results show that the multiple CPs implemented by NRCS between 1964 and 2003 reduced soil erosion rates of the 16-km^2 Bull Creek subwatershed by 77% compared with rates prior to this period.
- Modeling results in the 342-km^2 Cobb Creek subwatershed in the FCREW showed that application of a Bermuda filter strip (BFS) along cropland borders reduced the amount of eroded overland sediment delivered into the stream by 72%. Riparian forest buffer (RF) and combined RF and BFS reduced suspended sediment at the sub-watershed outlet by 68% and 73%, respectively.
- Planting vegetation in stream banks graded at 2:1 (horizontal:vertical) side slopes in the 110-km^2 Five Mile Creek subwatershed was the most cost-effective stabilization technique to reduce sediment loads.

Watershed

- Forty five flood-retarding structures were constructed by NRCS in the LWREW from 1969-1982, with a design life of 50 years. Bathymetric surveys carried out in 2012 showed that reservoir lifespans ranged from 45 to 118 years, with 11 of 12 reservoirs having a lifespan greater than the design period of 50 years (see table on the right). The higher projected lifespans were attributed to multiple CPs implemented over the years through NRCS programs.



Clockwise from top left: Drainage boundaries of surveyed reservoirs, photo of reservoir ID number 14, aerial photo of the Water Resources & Erosion (WRE) watersheds, mixed forage summer cover crop in one of the WRE watersheds.

Reservoir ID	Years of Operation on Survey Date	Sedimentation Rate ($m^3/km^2/year$)	Projected Lifespan (years)
11	42	181	**118**
14	37	368	61
20	33	526	61
21	45	294	88
22	38	873	**45**
23	44	305	96
24	39	265	89
26	44	557	51
31	38	423	64
39	38	288	77
41	46	410	64
42	46	320	93

Watershed continued

- SWAT model output showed that removal of the current 8% red cedar encroachment in the 1,802-km^2 North Canadian River Watershed would increase water supply to Oklahoma City by 5%.
- Multiple CPs have been implemented in the FCREW since the 1950s. Analysis of sediment transport at the watershed outlet showed that average annual sediment yield was reduced by 86% in 2004-2007 compared to 1943-1948, or from 760 to 108 metric tons/year/km^2.

Collaborators and Stakeholders

More Information

Site Lead: Daniel Moriasi, Daniel.Moriasi@usda.gov
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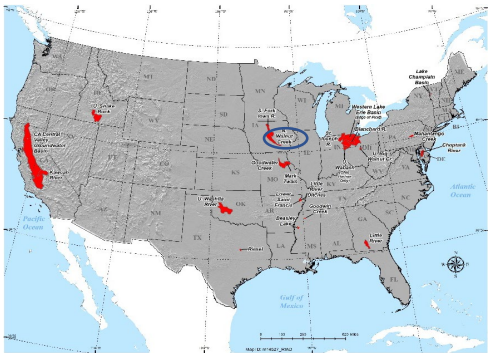
CEAP Network Website: nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/

Walnut Creek Watershed

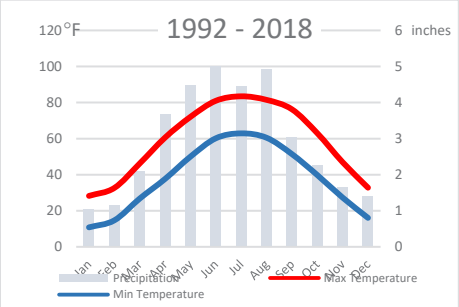


A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the Agricultural Research Service and the Natural Resources Conservation Service

Location

The slightly under 51.3-km^2 Walnut Creek Watershed is located on the Des Moines Lobe region of central Iowa. Walnut Creek flows into the South Skunk River just south of Ames, IA.

Temperature and Precipitation



Major land uses

Cropland: Corn & Soybean production occurs on about 90% of the watershed. **Pasture, Farmsteads, Woodlands, Roadways and Towns** comprise the remainder.

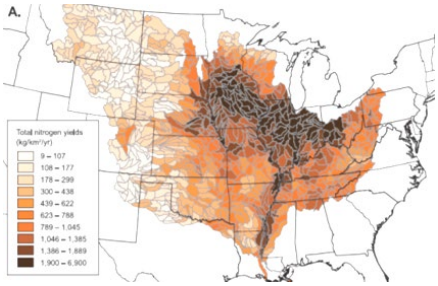
Data collection

Stream monitoring began in 1991. Continuous discharge data are aggregated on 5-minute intervals. Automated samplers collect water samples during storm events with additional samples collected every week. Water quality sensors have been in place since 2014 to collect continuous turbidity data and since 2016 to collect continuous nitrate concentration data. Two meteorological stations measure precipitation, temperature, relative humidity, and solar radiation.

Concerns

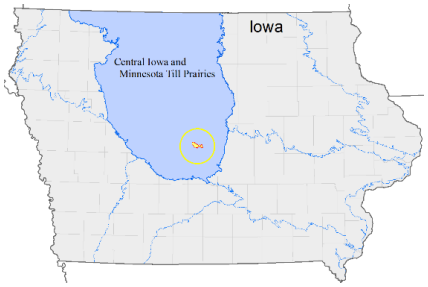
Soils in the watershed are deep, with high organic matter content formed over post-glacial deposits (till). The till forms a layer restricting deep percolation of water. This poor drainage is overcome by installing subsurface drains (tiles), which represent the main pathway for water in the watershed. These tiles eventually discharge into ditches or streams.

The corn-soybean cropping system covers most of the agricultural land. There are relatively few confined animal feeding operations (CAFO). Water quality issues include high nitrate loads from subsurface drainage, and to a lesser extent pesticides. Walnut Creek exports N loads to the Mississippi River, which drives up hypoxia in the Gulf of Mexico.



Main conservation practices used

Conservation practices used in the watershed include conservation tillage and nutrient management, with minor amounts of cover crops, no-till, and erosion control practices. Several practices have been identified that could reduce nitrate losses and provide other benefits. These include N fertilizer management, cover crops, wood-chip denitrification bioreactors, and saturated riparian buffers.



Walnut Creek Watershed

Outcomes/Findings

Plot and field scale

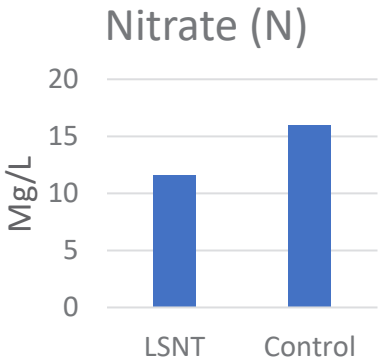
- Wood-chip bioreactors were evaluated on plots with individual tile drains. Bioreactors removed an average of over 25 kg N/ha/yr over 9 years of testing.
- At the same site, direct N_2O emissions were not reduced by the rye cover crop. However, the rye did reduce indirect emissions through reduction in nitrate leaching.
- Over 4 years under field conditions, corn-soybean nitrate-N losses ranged from 34 to 81 kg N/ha/yr compared to 11to 34 kg N/ha/yr losses from the corn-soybean with a winter rye cover crop system.
- Modeling studies showed that controlled drainage using water level control gates could reduce nitrate-N losses by 39% compared to the loss from free drained fields.
- Saturated buffers were identified as another tool for nitrate removal from tile drainage. Tile lines are intercepted and drainage water is redistributed laterally into riparian buffers. See photo of installation below. As the water seeps through the buffer, soil microorganisms remove the nitrate by denitrification. Nitrate removal by buffers ranged from 8 to 84% of nitrate leaving the field. Study used 6 different riparian buffers in central Iowa.

Lower Walnut Creek (left) and upper Walnut Creek (right). Upper Walnut Creek is sourced from tile discharge into ditches that join more natural stream channels.

Watershed scale

The Late Spring Nitrate Test (LSNT) predicts available N when corn most needs it. The test is usually done in late May and requires soil sampling, nitrate analysis, and application equipment. N management by LSNT was applied on one sub-basin in Walnut Creek on farmer fields and compared to sub-basins where farmers made their own N fertilizer decisions.

- LSNT-based management reduced nitrate loss by 30% without affecting corn yield.



Nitrate concentrations in Walnut Creek sub-basins with late spring N applications after LSNT or conventional N application.

Collaborators and Stakeholders

USGS science for a changing world
IOWA SOYBEAN Association
IOWA STATE UNIVERSITY
IOWA DEPARTMENT OF AGRICULTURE & LAND STEWARDSHIP

More Information

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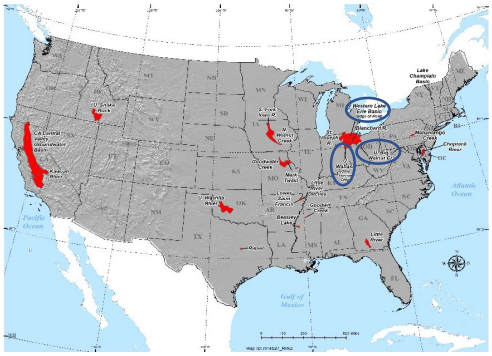
CEAP website: nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/

Western Lake Erie Basin, Upper Big Walnut Creek, and Upper Wabash River

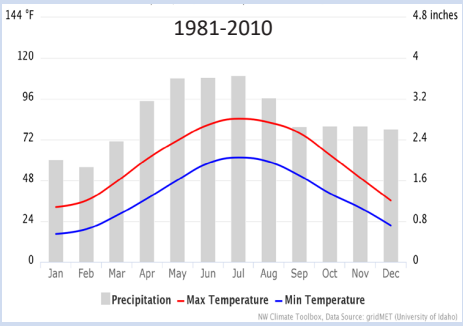


A Conservation Effects Assessment Project (CEAP) Watershed Assessment Study: A collaboration between the Agricultural Research Service and the Natural Resources Conservation Service

Location

CEAP-related research is occurring in the Western Lake Erie Basin (WLEB), Upper Big Walnut Creek (UBWC), and the Upper Wabash River (UW) watersheds.

Temperature and Precipitation



Major land uses

Cropland: Corn, Soybean, Wheat.

Data collection

Hydrology and water quality (nitrogen and phosphorus) data are collected year round from 40 private farm fields and streams within three Ohio watersheds. Fields are paired (20 pairs) in order to assess the impact of single and "stacked" practices. Field-scale data includes surface runoff and subsurface (tile) drainage discharge and nutrient loads. Within WLEB, there are fourteen paired edge-of-field sites. Within UBWC, there is one paired edge-of-field site and twelve ecological measurements locations. The remaining four paired field sites are located in the UW watershed.

Concerns

WLEB is comprised of about 6 million acres, the majority of which is used for agricultural production. Lake Erie has been identified as impaired due to excessive loadings of sediment and nutrients. The Maumee River watershed covers over half of WLEB and has been identified as the largest single contributor of P transport and focus of Lake Erie algal blooms.

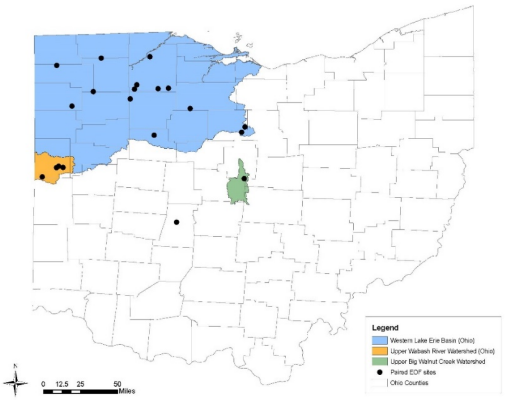
Located in Central Ohio, UBWC is about 122,000 acres and is comprised of 467 perennial and intermittent stream miles that drain into Hoover Reservoir, the water supply for 1.1 million Columbus residents. The primary land use of the watershed is row crop agriculture (55%) followed by woodlands (27%) and urban development (13%), but the watershed is rapidly urbanizing.

The UW watershed is characterized by extensive animal agriculture and row crop agriculture.

An extensive portion of WLEB, UBWC, and UW are systematically tile-drained. Without the tile systems, agricultural production would be limited. At the watershed scale, tile drainage represents about half of the discharge and nutrient load.

Primary conservation practices

CEAP-related research efforts within WLEB, UBWC, and UW are concerned with the edge-of-field and watershed scale water quality and ecological impacts of conservation practices. Studies continue to quantify the edge-of-field water quality impacts of conservation practices such as NRCS avoiding, controlling, and trapping practices, the 4R initiative (right source, rate, time, and place) and innovative practices such as P-removal structures, woodchip bioreactors, and 2-stage ditches. The ecological research is aimed at quantifying the effects of individual and combined conservation practices on different ecological metrics.



Location of ARS edge-of-field sites.

Western Lake Erie Basin, Upper Big Walnut Creek, and Upper Wabash River

Outcomes/Findings

In-Field Practices

- Two consecutive annual applications of gypsum significantly decreased combined surface and subsurface dissolved-P loadings by 36% (28.27g/ha).
- In one study, cover crops reduced discharge and nitrate loadings by 28% and 84% respectively, but phosphorus load reductions varied.
- Incorporating perennial crops (i.e. alfalfa) into the rotation reduced discharge and nutrient loadings.

4R Management Framework:

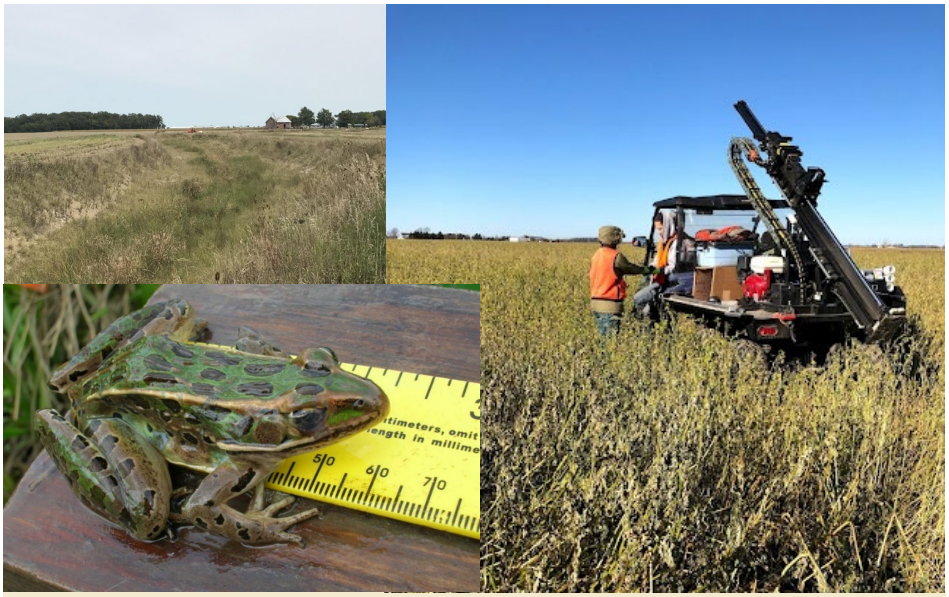
- Applying fertilizer at crop removal rates reduced risk of P loss.
- Greater P losses occurred with rainfall in the first five days following application.
- At a plot scale, injecting or tilling fertilizer into the soil reduced DRP concentrations by 66% and 75%, respectively, in subsurface discharge compared to broadcast applications.

Edge-of-Field

- Drainage water management provided a mechanism to store more water in the landscape, reducing discharge volume and N loading. The impacts on reducing P loss are not well defined.
- Stacked practices: An upland practice (in-field management) with an edge-of-field or structural type practice may further reduce agrichemical transport originating in crop production areas. Current research is documenting the benefits of stacked practices.

In-stream

- Two-stage ditches construct "mini-floodplains" within the stream channel and have effectively improved water quality, particularly during inundation or storm events, by increasing bank stability, reducing turbidity, enhancing denitrification, and reducing nutrient concentrations.



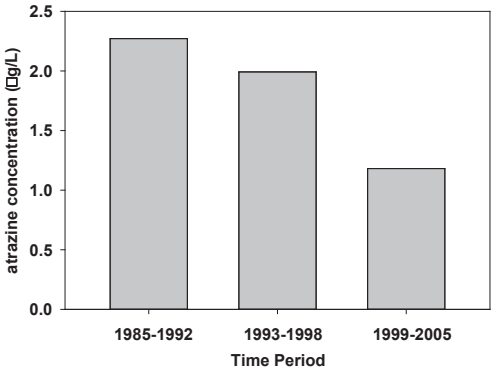
Clockwise from top left: 2-stage ditch, example of a well-established cover crop at an edge-of-field site in WLEB, Northern leopard frog *(Lithobates pipiens)* measured as part of CEAP ecological metrics.

Ecological Metrics

- Grass filter strips widened riparian habitat, but did not restore ecosystem structure in channelized agricultural headwater streams.

Watershed scale

- EQIP efforts reduced concentrations of Atrazine in drinking water for Columbus, resulting in $2.73 saved for every $1 spent on NRCS 595 Pest Management (see bar graph at right).



Mean monthly atrazine concentrations in Hoover Reservoir when no label restrictions were present (1985-1992), after label restrictions were applied (1993-1998), and following implementation of EQIP targeting atrazine reduction (1999-2005).

Collaborators/Funding Sources

More Information

CEAP Site Lead: Kevin King, kevin.king@usda.gov
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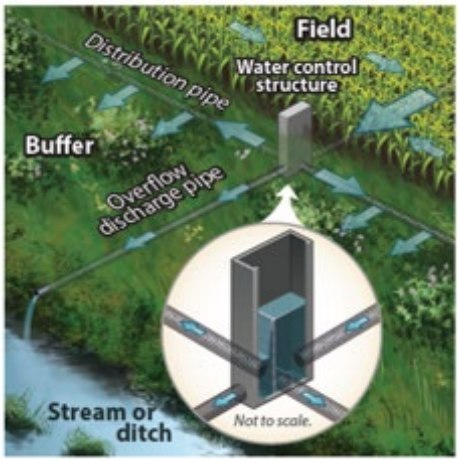
CEAP website: nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/

Future of CEAP Watershed Assessment Studies

Additional watershed assessment studies continue to be incorporated into the CEAP network. Simultaneously, several new network-wide projects are being initiated, which utilize the data from CEAP watersheds studies. We also look for opportunities to revitalize our current CEAP Watersheds sites, enhancing our ability to detect conservation effects at the watershed scale in support of USDA's outcomes documentation efforts, to better understand processes, to develop more effective practices, and to optimize their use and placement within watershed conservation strategies.

- New watershed assessment studies were added in 2020 in Florida to address water quality, HABs, and hypoxia and in California to address aquifer depletion concerns and evaluate new recharge strategies.
- Additional modeling activities will help synthesize and scale up the edge-of-field monitoring results to the watershed scale in the Western Lake Erie Basin and the Blanchard Creek watershed in Ohio, and in the Lake Champlain watershed in Vermont.
- A new regional assessment of legacy, or historical, sources of phosphorus is being conducted from plot to watershed scales among numerous sites in the Western Lake Erie Basin. Work will include identifying effective conservation options for these sources.
- Buffer management and potential for harvesting biomass on buffers will be evaluated for their ability to reduce legacy phosphorus and nitrogen runoff in the Chesapeake Bay.
- A new project utilizing the CEAP Watershed network among other sites in the Mississippi River Basin will measure legacy sediment sources and identify effective conservation opportunities to address them.
- Work on the Soil Vulnerability Index (SVI) will continue to draw on data from CEAP watersheds to support future enhancements.
- Further evaluation and identification of development opportunities of the Agricultural Conservation Practice Framework (ACPF) continues in the Eastern United States as well as selected other selected CEAP watersheds.

Excess nitrogen and phosphorus discharges cause hypoxia issues and harmful algal blooms in fresh and coastal waters.



Field drainage outlet discharges into a saturated buffer.

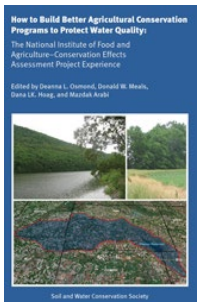
Software like ACPF can determine suitable locations of saturated buffers.

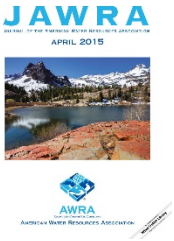
More information:

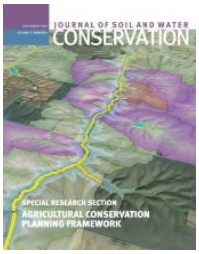
Those interested in the purpose and scope of the CEAP program can find information in the early foundational papers by Mausbach and Dedrick (2004), Duriancik et al. (2008), and Maresch et al. (2008).

The CEAP Watersheds webpage (***https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/ws/***) links to numerous products and articles, including the CEAP Watersheds Story Map, a map of current and past CEAP watershed studies, and numerous publications: special issues in 2008, 2010, 2014, and 2020; and the 2012 USDA NIFA-CEAP Watershed Synthesis Study. In addition, webcasts synthesize assessment results as of 2012, and after 10 years and 15 years of CEAP Watershed Studies.

Other special collections of papers focus on specific aspects of conservation assessment, placement, and outcomes such as modeling and assessment tools (2015) in the Journal of the American Water Resources Association, and edge-of-field monitoring (2018), the Soil Vulnerability Index (2020), and the Agricultural Conservation Practice Framework (2020) in the Journal of Soil and Water Conservation.







Foundational papers

Duriancik, L. F., Bucks, D. A., Dobrowolski, J. P., Drewes, T., Eckles, S. D., Jolley, L., . . . Weltz, M. A. (2008). The first five years of the Conservation Effects Assessment Project. *Journal of Soil and Water Conservation*, 63(6), 185A-197A. doi:10.2489/jswc.63.6.185A.

Maresch, W., Walbridge, M. R., & Kugler, D. (2008). Enhancing conservation on agricultural landscapes: A new direction for the Conservation Effects Assessment Project. *Journal of Soil and Water Conservation*, 63(6), 198A-203A. doi:10.2489/jswc.63.6.198A

Mausbach, M. J., & Dedrick, A. R. (2004). The length we go: Measuring environmental benefits of conservation practices. *Journal of Soil and Water Conservation, 59*(5), 96A-103A.

Special collections

2008 special collection:
https://www.jswconline.org/content/63/6
Introduction: Karlen, D. L. (2008). A new paradigm for natural resources research: The Conservation Effects Assessment Project. *Journal of Soil and Water Conservation*, 63(6), 220A. doi: 10.2489/jswc.63.6.220A.

2010 special collection:
https://www.jswconline.org/content/65/6
Introduction: Osmond, D. L. (2010). USDA water quality projects and the National Institute of Food and Agriculture Conservation Effects Assessment Project watershed studies. *Journal of Soil and Water Conservation*, 65(6), 142A-146A. doi:10.2489/jswc.65.6.142A.

2014 special collection:
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/ws/?cid=stelprdb1260812
Introduction: Arnold, J. G., Harmel, R. D., Johnson, M.-V. V., Bingner, R., Strickland, T. C., Walbridge, M., . . . Wang, X. (2014). Impact of the Agricultural Research Service Watershed Assessment Studies on the Conservation Effects Assessment Project Cropland National Assessment. *Journal of Soil and Water Conservation*, 69(5), 137A-144A. doi:10.2489/jswc.69.5.137A

2015 special featured collection: synthesis and analysis of conservation effects assessment projects for improved water quality. Jan Boll – guest coordinator:
https://onlinelibrary.wiley.com/toc/17521688/2015/51/2
Introduction: Boll, J., Steenhuis, T. S., Brooks, E. S., Kurkalova, L. A., Rittenburg, R. A., Squires, A. L., ... & Wulfhorst, J. D. (2015). *Featured collection introduction: synthesis and analysis of conservation effects assessment projects for improved water quality. JAWRA Journal of the American Water Resources Association, 51(2)*, 302-304. doi: 10.1111/1752-1688.12297

2018 special collection on edge-of-field monitoring:
https://www.jswconline.org/content/73/1
Introduction: Daniels, M. B., Sharpley, A., Harmel, R. D., & Anderson, K. (2018). The utilization of edge-of-field monitoring of agricultural runoff in addressing nonpoint source pollution. *Journal of Soil and Water Conservation*, 73(1), 1-8. doi:10.2489/jswc.73.1.1.

2020 special collection on the Soil Vulnerability Index:
https://www.jswconline.org/content/75/1
Introduction: Baffaut, C., Thompson, A. L., Duriancik, L. F., Ingram, K. A., & Lee Norfleet, M. (2020). Assessing cultivated cropland inherent vulnerability to sediment and nutrient losses with the Soil Vulnerability Index. *Journal of Soil and Water Conservation*, 75(1), 20A-22A. doi:10.2489/jswc.75.1.20A.

2020 special collection on the Agricultural Conservation Practice Framework:
https://www.jswconline.org/content/75/4
Introduction: Gesch, K., Kiel, A., Sutphin, T., & Wolf, R. (2020). Integrating farmer input and Agricultural Conservation Planning Framework results to develop watershed plans in Iowa. *Journal of Soil and Water Conservation*, 75(4), 101A-104A. doi:10.2489/jswc.2020.0226A

2020 special collection: synthesis of the first fifteen years:
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/ws/?cid=nrcseprd1589255
Moriasi, D. N., Duriancik, L. F., Sadler, E. J., Tsegaye, T., Steiner, J. L., Locke, M. A., . . . Osmond, D. L. (2020). Quantifying the impacts of the Conservation Effects Assessment Project watershed assessments: The first fifteen years. *Journal of Soil and Water Conservation*, 75(3), 57A-74A. doi:10.2489/jswc.75.3.57A

Books and webcasts

Osmond, D. L., Meals, D.W., Hoag, D. L. K., Arabi, M. (2012) How to Build Better Agricultural Conservation Programs to Protect Water Quality: The National Institute of Food and Agriculture-Conservation Effects Assessment Project Experience. Soil and Water Conservation Society, Ankeny, Iowa. E-book available at: ***https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/ws/?cid=stelprdb1047821***

USDA's NIFA-CEAP Watershed Synthesis: Lessons Learned. 2012 USEPA webcast available at: ***https://www.epa.gov/watershedacademy/usdas-nifa-ceap-watershed-synthesis-lessons-learned***

Watershed Academy Webcast: Ten Years of Watershed Assessment in CEAP: Insights and Lessons Learned. 2015 USEPA webcast available at: ***https://www.epa.gov/watershedacademy/watershed-academy-webcast-ten-years-watershed-assessment-ceap-insights-and-lessons***

NRCS Conservation Outcomes Webinar Series: Measuring and Understanding the Effects of Conservation within Watersheds. 2020 USDA NRCS webcast available at: ***https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?cid=nrcseprd1576043***

NRCS Conservation Outcomes Webinar Series: Development of the Agricultural Conservation Planning Framework (ACPF) and Use by NRCS for Watershed Planning. 2021 USDA NRCS webcast available at: ***https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?cid=nrcseprd1576043***

NRCS Conservation Outcomes Webinar Series: When it Rains, it Pours: Conservation Considerations for Resiliency in a Changing Climate. 2021 USDA NRCS webcast available at: ***https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?cid=nrcseprd1576043***

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