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Evaluating Economic and Environmental Benefits of Soil and Water Conservation Measures Applied in Missouri

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Evaluating Economic and Environmental Benefits of Soil and Water Conservation Measures Applied in Missouri

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Executive Summary

This study used a combination of methods to evaluate the value of Missouri's Department of Natural Resources (MODNR) conservation programs for the affected regional economies. It was used to estimate water quality, soil conservation and rural life enhancement resulting from the Missouri Parks, Soils and Water Sales Tax funded conservation efforts abbreviated to (MO-PS&W-Sales-Tax) in figure and table titles in this report. The analyses are split into four components:

1. **analysis of financial and physical Missouri Soil and Water Conservation program data** to select practices to be evaluated and to tabulate the extent of those practices,
2. **regional economic assessment** of the value of MODNR's soil and water conservation projects for the affected regional economies,
3. **environmental assessment of the water quality impacts** of pond and terrace conservation practices at the field and regional scale, and
4. **farm-level economic assessment** of the economic viability of Missouri soil and water conservation program practices with and without cost-share.

Analysis of financial and physical Missouri Soil and Water Conservation Program data found that sediment retention and water impoundment structural conservation practices accounted for 30-40 percent of the state cost-share dollars. Surface-drained and tile-drained terraces also accounted for the same percentage, bringing the total of the four practices to 70-80 percent. The environmental analyses focus on these four practices.

Regional economic assessment found that over the 1997-2007 period, public and private investment in cost-shared practices initiated by the MO-PS&W-Sales-Tax funded conservation programs totaled nearly $400 million. This led to business sales of over $500 million, the creation of over 1000 jobs each year, nearly $80 million in labor income and over $110 million in property-type income. Over $14 million dollars of indirect business taxes were produced for local and state governments. In summary, the Missouri Soil and Water Conservation program value added after adjusting for the public and private investments was over $200 million for the 1997-2007 period.

Environmental assessment of the water quality impacts found that all four practices (sediment retention structures, water impoundment structures, surface-drained terraces and tile-drained terraces) are very effective measures for reducing sediment organic materials that move with sediment. The practices and their benefits are concentrated in the areas of Missouri with the most cropland. Cropping increases the land vulnerability to erosion and contains nutrients needed to grow crops.

Over a 10-year simulated period, these practices trapped 9.3 million tons of sediment, enough sediment to cover 4,759 miles of 30 foot wide streambeds 6 inches deep in sediment. Many Missouri streams flow into reservoirs that supply water for urban and rural citizens. Reservoirs are designed to last many years, with most having a life expectancy of 50 to 100 years.

Clarence Cannon reservoir (Mark Twain Lake) is an example of a Missouri lake that receives indirect benefits from the Missouri Parks, Soil and Water Tax Funded Conservation Programs. The lake is designed to provide drinking and industrial water supplies, hydroelectric power generation, recreation, navigation, fish and wildlife enhancement, and flood control. Annual benefits were estimated to be nearly $20 million per year.[1] The predicted rate of sediment deposition when the lake was designed was 11,500 acre feet per year. A survey completed in 1997 found the computed rate of sedimentation to be only 290 acre-feet per year or an average storage depletion rate of 0.02 percent per year.[2] Much of the East Central Claypan region drains into Mark Twain Lake. The sediment trapped by the four practices (sediment retention structures, water impoundment structures, surface-drained terraces and tile-drained terraces) installed in that region is equivalent to more than ten percent of the original rate of sediment deposition. Just the sediment trapped in this region potentially extends the life expectancy of the lake by at least 10 years at nearly $20 million per year.

The nutrients and chemicals attached to sediment are also trapped by sediment retention and water impound structures and by terraces. The estimated nitrogen trapped over the ten year simulated period is equivalent to the nitrogen needed to fertilize over 150,000 acres of corn yielding 150 bushels per acre. The estimated phosphorus trapped over the same period is equivalent to the phosphorus needed to fertilize over 500,000 acres of corn yielding 150 bushels per acre. The trapped nitrogen and phosphorus also enhance lake water quality by reducing potential eutrophication.The cost of removing nutrients from drinking water is also reduced.

The estimated carbon trapped across the state over a 10-year period is equivalent to the amount of carbon that would degrade over 17 trillion gallons of water. That is equivalent to almost 100 times the joint use storage capacity of Clarence Cannon reservoir.

Ponds and terraces trap a smaller fraction of the dissolved nutrients and other dissolved chemicals than those attached to sediment. However, dissolved nutrients account for a small percentage of the nutrient load in runoff. Trapping dissolved pollutants means either trapping the water or removing the pollutants from the water. Trapping the water would reduce stream flows, which is not desirable. However, retention by pond structures allows nutrients and other chemicals to precipitate, biodegrade, and be utilized by aquatic life before continuing downstream.

Farm-level economic assessment found that although farmers can expect to benefit in terms of long-term productivity and short term reductions in tillage required to smooth erosion-created rills and gullies, these benefits are small relative to terrace installation costs. Cost-sharing is necessary to encourage adoption of Missouri Soil and Water Conservation practices and to reap the offsite benefits.

[1] US Army Corps of Engineers, 1989.
[2] US Army Corps of Engineers, 2000.

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Introduction

Evaluating Economic and Environmental Benefits of Soil and Water Conservation Measures Applied in Missouri

Missouri loses millions of tons of soil each year. The loss of topsoil affects all Missourians. Everyone's food, forages for livestock and timber come from the soil. Thinner topsoil decreases the productivity of soil. Less production means lost income to the landowner and higher prices for the consumer. Soil erosion also creates other environmental problems. Soil from the land often washes into rivers and streams. Chemicals also can wash into the water with the soil. Soil conservation decreases the amount of soil washed into streams, improving water quality and the health of the environment.

Missouri citizens support soil conservation efforts. They voted for a 0.1% Parks, Soils and Water Tax in 1984, 1988, 1996 and 2006. This tax finances Missouri's soil and water conservation program activities. Various forms of financial and technical assistance are available to landowners for implementation of water quality and soil conservation practices. The Special Area Land Treatment (SALT) program is a watershed-based program administered by the Missouri Department of Natural Resources (MODNR) in which Soil and Water Conservation Districts (SWCDs) direct technical and financial assistance to landowners within prioritized watersheds for reduction of agricultural nonpoint source pollution. Cost-share is used by landowners, in cooperation with local SWCDs, to apply conservation practices.

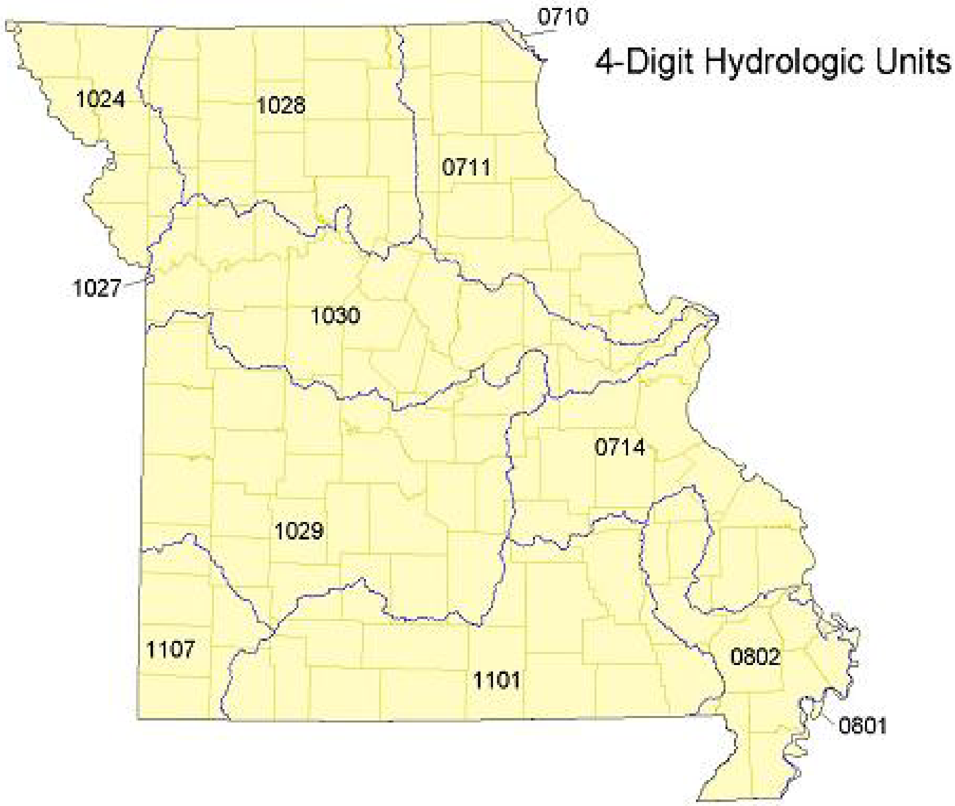
Soil erosion reduction from implemented practices, as well as water quality improvement and economic benefits from these practices were assessed by this study. This study used a combination of methods to evaluate the value of MODNR's Missouri Parks, Soil and Water Tax (MO-PS&W-Sales Tax) funded conservation programs for the affected regional economies and to estimate water quality, soil conservation and rural life enhancement resulting from the Missouri soil and water conservation efforts. The analyses are split into four components:

1. **analysis of financial and physical Missouri Soil and Water Conservation program data** to select practices to be evaluated and to tabulate the extent of those practices,
2. **regional economic assessment** of the value of MODNR's Missouri Soil and Water Conservation projects for the affected regional economies,
3. **environmental assessment of the water quality impacts** of pond and terrace conservation practices at the field and regional scale and
4. **farm-level economic assessment** of the economic viability of Missouri soil and water conservation practices with and without cost-share.

Analysis of Financial and Physical Missouri Soil and Water Conservation Program Data

The first step in the analysis was to determine which of several regional delineations to use. One option considered strongly was watersheds as shown in figure 1.

Figure 1. 4-digit Hydrologic Areas



Crop reporting districts and other groupings of counties were considered. The relationship between soil and conservation practice selection led to the selection of regions that are modified Major Land Resource Areas (MLRA) (figures 2a and 2b). Adjustments were made to group along county lines assigning counties to the dominant MLRA for each county. MLRA 108 was grouped with MLRA 107. MLRA 134 was grouped with MLRA 131 resulting in seven regions for this assessment.

Figure 2a. Major Land Resource Areas

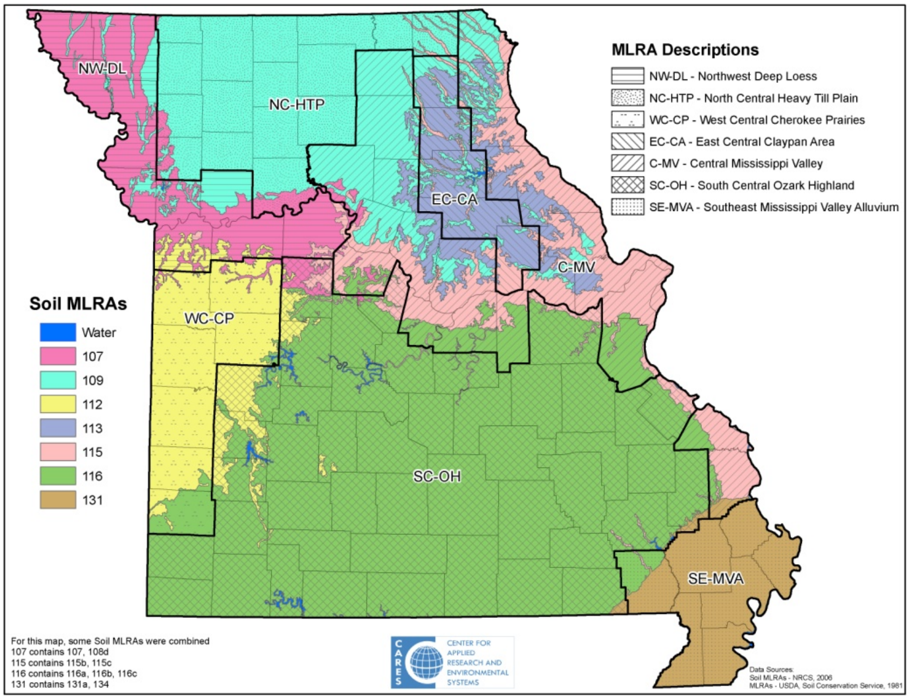
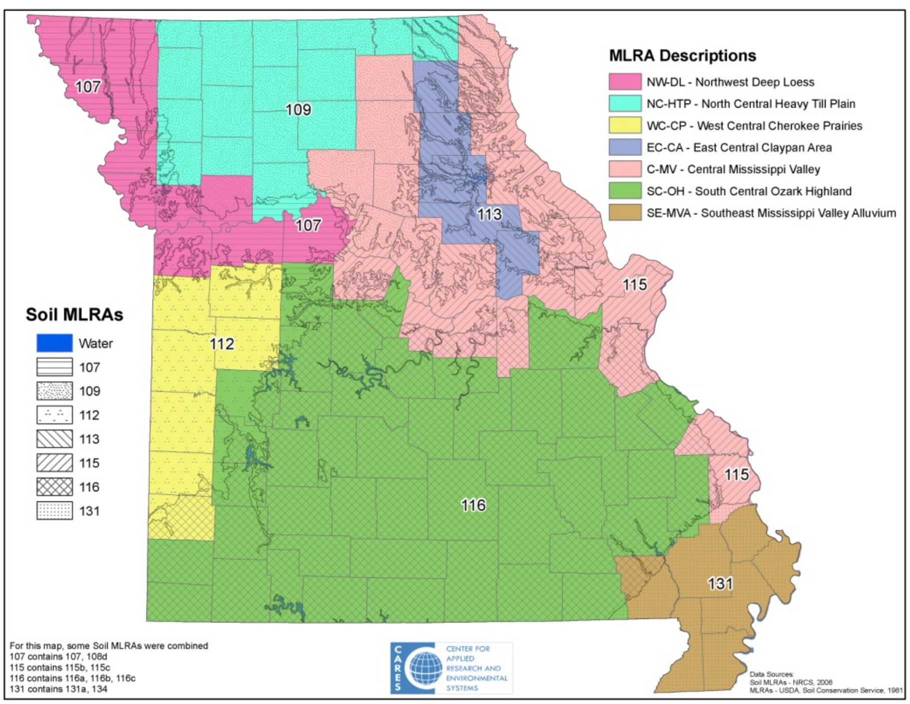


Figure 2b. Study Regions



Descriptions of the seven county-bounded MLRA regions[3] and key characteristics that determine the potential need for conservation practices follow:

1. MLRAs 107 and 108 will be referred to as Northwest Deep Loess (NW-DL) in this study. This region is characterized as rolling to hilly with deep medium-to-fine textured soils with drainage that varies from somewhat poorly drained flat uplands to well drained soils on gentle to steep slopes to somewhat poorly or poorly drained soil in bottom lands. The potential erosion hazard is severe, particularly in the MLRA 107 part of the region.

2. MLRA 109 will be referred to as North Central Heavy Till Plain (NC-HTP) in this study. This region is characterized as rolling to hilly with deep, medium-textured surface soils and fine-textured subsoils. The soils are somewhat poorly drained in the flat uplands and somewhat poorly or poorly drained in the bottom lands.

3. MLRA 112 will be referred to as West Central Cherokee Prairies (WC-CP) in this study. This region is characterized as gently sloping to rolling with shallow to deep medium textured and moderately fine textured soils. The soils are somewhat poorly drained in the flat uplands to moderately well to well-drained on the gentle slopes.

4. MLRA 113 will be referred to as East Central Claypan Area (EC-CA) in this study. This region is characterized as nearly level to gently sloping with deep medium-textured surface soils and fine-textured and moderately-fine-textured subsoils. The soils are poorly to somewhat poorly drained on the level lands to moderately well to well-drained on the gentle slopes.

5. MLRA 115 will be referred to as Central Mississippi Valley (C-MV) in this study. This region is characterized by ridgetops, steeply sloping valley sides and broad floodplains along the major rivers. Soils are deep medium textured and moderately fine textured soils. The soils are moderately well to well-drained. The hazards of erosion and sedimentation are severe in urban areas and on cropland.

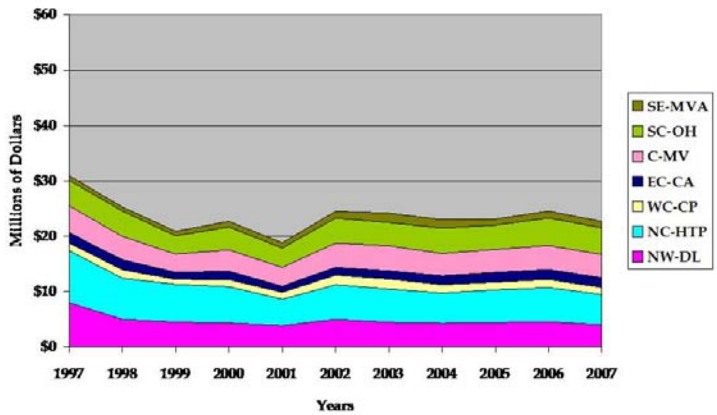
6. MLRA 116 will be referred to as South Central Ozark Highland (SC-OH) in this study. This region is characterized by narrow ridgetops, steeply sloping valley sides and narrow floodplains in stream valleys. Soils are deep to moderately-deep medium-textured to fine-textured, cherty, limestone soils. The soils are mostly well drained.

7. MLRAs 131 and 134 will be referred to as Southeast Mississippi Valley Alluvium (SE-MVA) in this study. This region is characterized as level to gentle sloping broad flood plains and low terraces. Soils are deep medium to fine texture soils that often require drainage.

[3] USDA, Soil Conservation Service, 1981.

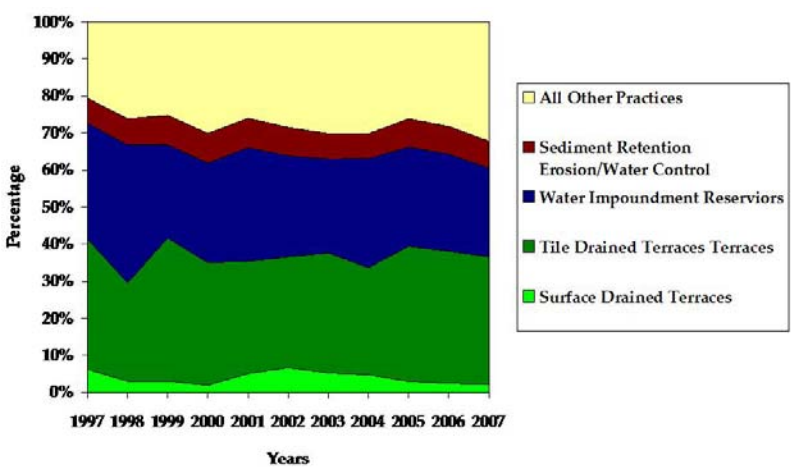
Financial summaries of Missouri cost-share dollars by region by year from 1997 to 2007 show considerable variation between the regions (figure 3). The difference is primarily due to topography and soil characteristics that dictate the need for various conservation practices.

Figure 3. MO-PS&W-Sales Tax Cost-Share by Region for 1997-2007



Sediment retention and water impoundment ponds conservation practice adoption accounted for 30-40 percent of the state cost-share dollars. Surface-drained and tile-drained terraces also accounted for 30-40 percent, bringing the total for the four practices to 70-80 percent (figure 4). The environmental analyses focus on these four practices.

Figure 4. Percentage of MO-PS&W-Sales Tax Cost-Share by Practice



The farm-level analysis focuses on the economic viability of terraces as an indicator of the need for state cost-share to stimulate Missouri Soil and Water Conservation practice adoption.

Regional economic Assessment

The **regional economic assessment** of the value of the MODNR's Missouri Soil and Water Conservation programs was conducted by the Community Policy Analysis Center (CPAC). CPAC reviewed the soil and water conservation activities of MODNR's conservation programs to determine the types and geographical locations of activities that have been undertaken. CPAC collected information on the type of construction and operations expenditures that are funded by earmarked Parks, Soils and Water Sales Tax revenues. The geographic incidence of the construction and operations expenditures were assessed to estimate the amounts spent locally (within the region where the projects were located), the funds expended in the remaining portions of Missouri, and funds spent elsewhere.

CPAC constructed a region social accounting matrix (SAM) for each county in Missouri. County models can be summed to estimate the regional and statewide economic impacts due to construction and operations expenditures for Parks, Soils and Water Tax funded conservation projects included in this study.

The input/output analyses estimate economic and employment impacts of the estimated actual costs from the MODNR database. The actual costs were used because the program stimulated private, federal, and other investment, in addition to the Missouri cost-share. Also, CPAC made adjustments for the economic impacts of the loss of consumption due to the Parks, Soils and Water Sales Tax.

Figures 5 and 6 present the total public and private investments and the number of claims filed by region for 1997 to 2007, respectively.

Figure 5. Regional Public and Private MO-PS&W-Sales Tax Investment

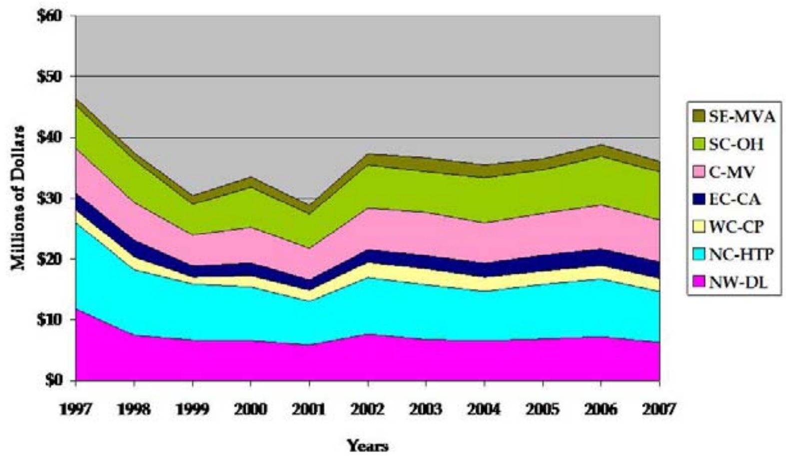


Figure 6. Number of MO-PS&W-Sales Tax Claims Filed by Region

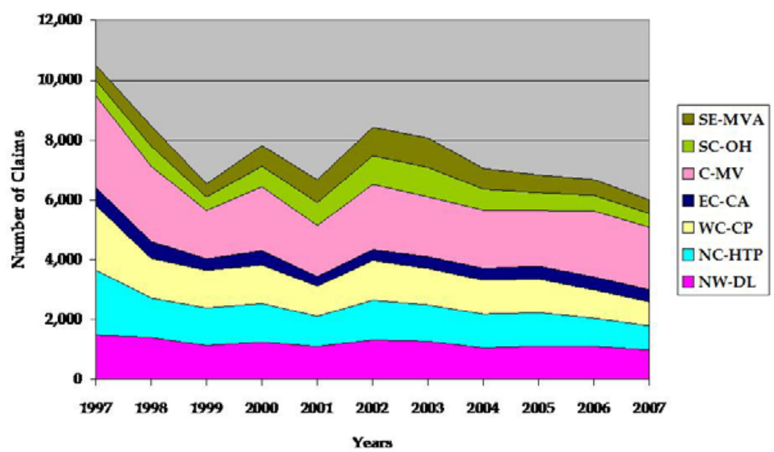


Figure 7. MO-PS&W-Sales Tax Funding Sources

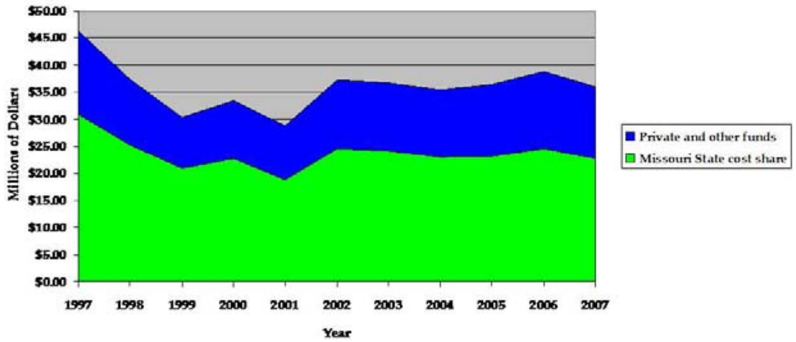


Figure 7 shows the funding source by year. The estimated total annual business sales resulting from program investments by region are shown in figure 8.

Figure 8. MO-PS&W-Sales Tax Business Sales by Region

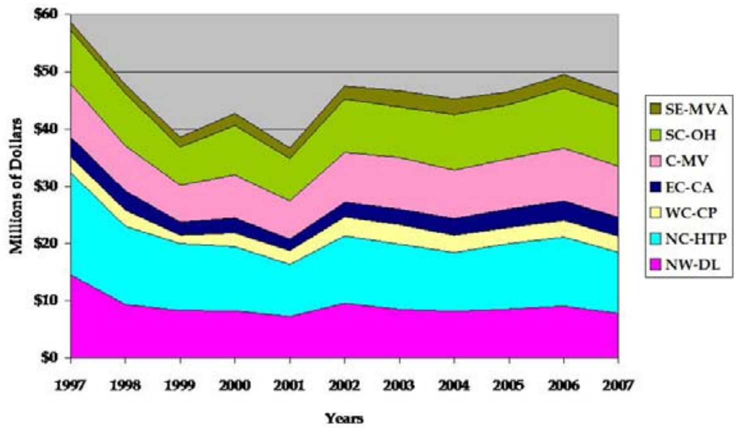
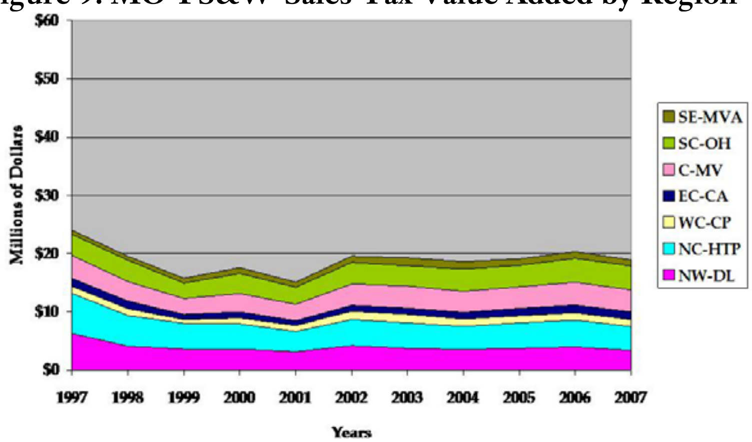


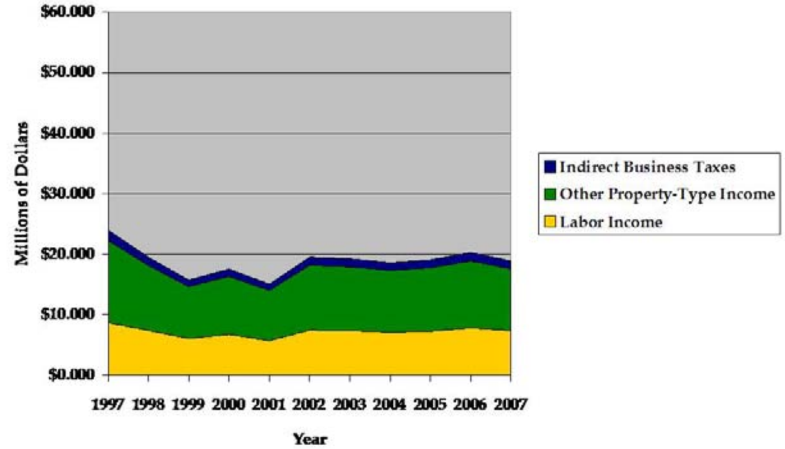
Figure 9. MO-PS&W-Sales Tax Value Added by Region



Business sales potentially double count the impact of the investments. A more accurate estimate of the increased economic production by region is what economists define as "Value Added," (figure 9).

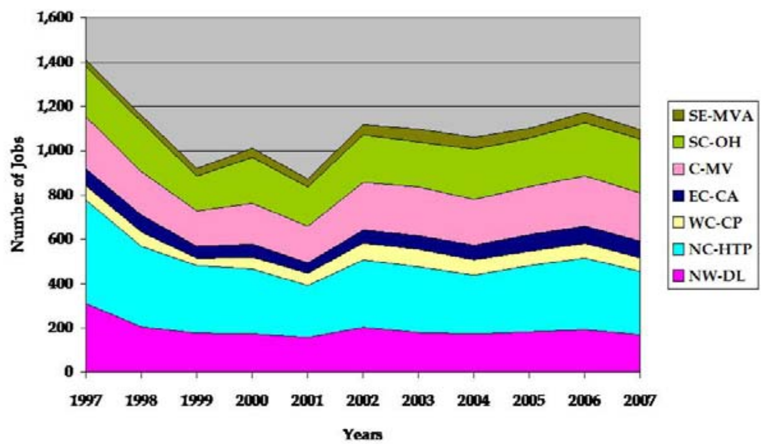
Figure 10 presents the value added by source. Value added is the sum of labor income, other property-type income and indirect business taxes.

Figure 10. MO-PS&W-Sales Tax Value Added by Source



The labor income comes from the jobs created by the public and private investment in Missouri soil and water conservation (figure 11). Appendix table A-1 presents the numerical data shown graphically in figures 5, 8, 9, 10 and 11.

Figure 11. Jobs Created by MO-PS&W-SALES TAX Conservation Programs



Regional Economics Summary

Over the 1997-2007 decade, public and private investment in the Missouri Soil and Water Conservation Program cost-shared practices totaled nearly $400 million. Those investments led to business sales of over $500 million, created over 1000 jobs each year, resulted in nearly $80 million in labor income and over $110 million in property-type income. Over $14 million dollars of indirect business taxes were produced for local and state governments. In summary, the MO-PS&W-SALES TAX Conservation Programs value-added after adjusting for the public and private investments was over $200 million for the 1997-2007 period. These figures show that the MO-PS&W-SALES TAX Conservation Program is reaching thousands of users across Missouri, stimulating private investment in conservation.

The next section will address the environmental benefits that result from the MO-PS&W-SALES TAX Conservation Programs. The economic value of environmental benefits was not included in the preceding economic analysis.

Environmental Impact Assessment

Historically, conservation benefits have often been expressed in terms of the number of practices installed or the acres enrolled. These are not measures of benefits, but rather indicators of potential conservation benefits. The change in the amount of soil erosion that occurs on a field or sediment trapped have been the primary indicators of the environmental benefits of conservation practices.

The Food and Agricultural Policy Research Institute at the University of Missouri (FAPRI–MU) just completed an assessment of the environmental benefits of the national Conservation Reserve Program for USDA. The environmental assessment of the water quality impacts focused on field and farm level environmental modeling. The environmental benefit assessment of the MO-PS&W-SALES TAX Conservation Programs used similar methods to evaluate the impact of currently installed Missouri Soil and Water Conservation practices.

FAPRI–MU used the MO-PS&W-SALES TAX Conservation Programs claims database to identify the dominant types of MO-PS&W-SALES TAX soil and water conservation practices applied. FAPRI–MU found that sediment retention structures, water impoundment ponds, surface-drained terraces and tile-drained terraces accounted for 70-80 percent of the cost-share investments. The environmental analyses focus on these four practices.

Watershed and field environmental impact modeling

FAPRI–MU chose the Agricultural Policy Environmental eXtender (APEX) model to analyze the environmental impacts of the MO-PS&W-SALES TAX Conservation Programs. APEX was developed and has continued to be enhanced by Dr. Jimmy R Williams at Blackland Research Center, Texas Agricultural Experiment Station, Temple, Texas, in cooperation with numerous governmental agencies and universities. APEX is a continuous simulation, daily-time-step, process-based model that calculates crop yields and grazing productivity as well as environmental indicators such as water, sediment, pesticide and nutrient yields. APEX daily estimates allow the analyses to examine the distribution of impacts from weather events as well as the average annual impacts.

Figure 12 presents an example of daily simulated rainfall and runoff for a single year. Only a few of the rainfall events per year result in much runoff. These few runoff events carry sediment and nutrients from the field to streams and lakes. The number and size of runoff events vary considerably from year to year.

Figure 12. One year of daily rainfall and runoff simulated for a field in NW-DL region

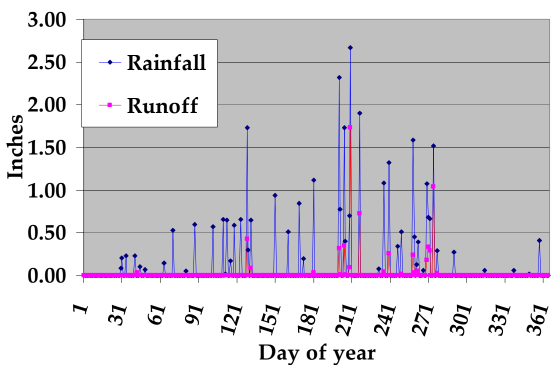


Figure 13 presents an example of daily simulated rainfall and runoff for ten years. This study uses 30 alternative daily ten year weather sequences to capture the variability of weather and the related crop growth, runoff, erosion, nutrient loss, carbon loss and sequestration and water impoundment.

Figure 13. Ten Years of Daily Rainfall and Runoff Simulated for a Field in NW-DL Region

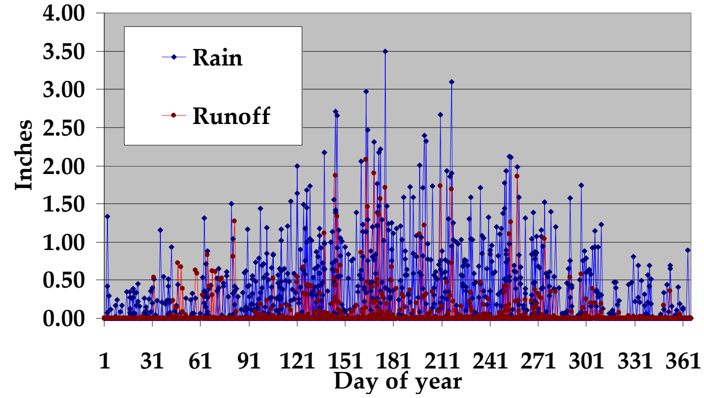


Figure 14 presents the estimated annual rainfall and sediment leaving the example field for 30 alternative ten-year weather sequences with and without tile-drained terraces installed. The distribution of impacts as well as the average helps us understand the nature of the problem and the potential impact of the conservation practice installed.

Figure 14. Estimated sediment leaving example NW-DL field per year for 300 alternative years of weather

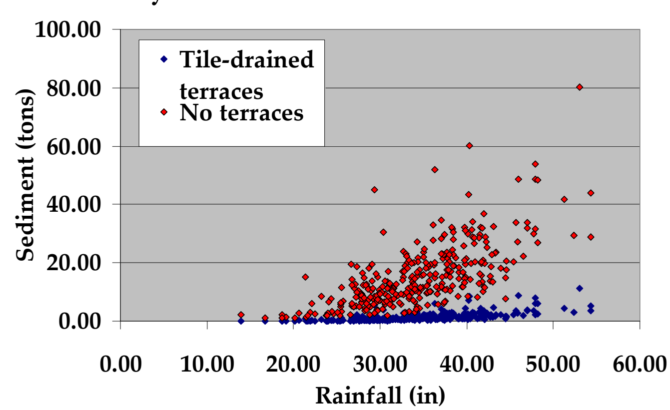
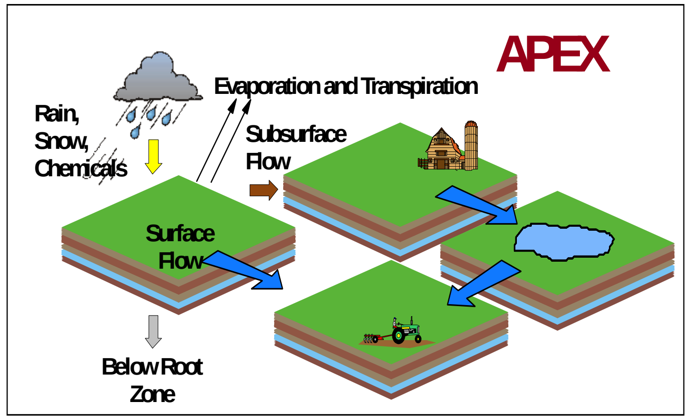


Figure 15 lists the comprehensive set of processes simulated by the APEX model. It is the interaction of these many processes that allows APEX to produce logical reproductions of real world events and their impacts.

Figure 15. APEX Process Model

APEX: a farm/watershed scale model



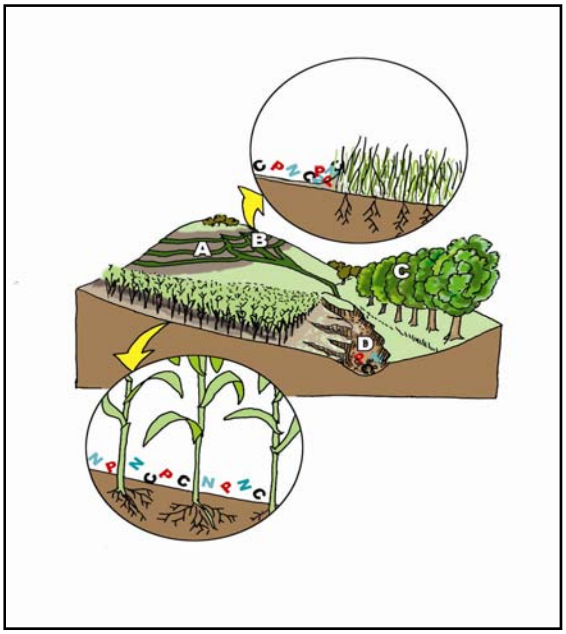
- Weather (simulated or actual)
- Heat transfer to the soil
- Runoff
- Percolation
- Evapotranspiration
- Snowmelt
- Erosion (wind & water)
- Crop growth
- Crop rotations & inter-cropping
- Weed competition
- Fertilization/nutrient movement
- Tillage
- Irrigation and furrow diking
- Pesticide application & movement

Drainage
- Grazing
- Manure application & movement
- Ponds and reservoirs
- Buffer strips & waterways
- Surface & subsurface flows between subbasins

Source: FAPRI-UMC Report #01-07

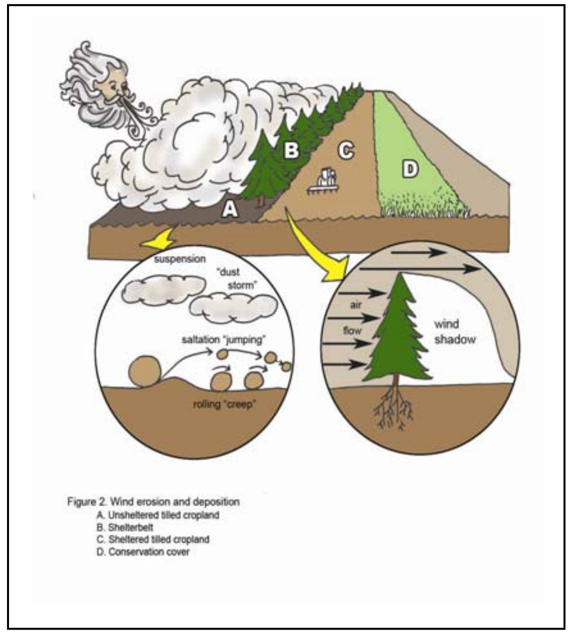
Figures 16-22 present artistic representations of the processes most directly related to the conservation impact assessment. Figure 16 presents an artistic rendering of some of the water conservation practices modeled by APEX to assess the impacts of the water erosion control practices. Cropland buffers (A), grassed waterways (B) and riparian tree buffers (C) trap some sediment and nutrients as illustrated; however, some sediment nutrients continue to flow toward streams. Ponds enclose the channel and allow sediment and nutrients to settle, volatilize and be consumed by aquatic life. Figure 17 presents an artistic rendering of some of the wind conservation practices modeled by APEX. Figure 18 illustrates the carbon cycling processes modeled to assess carbon sequestration impacts.

Figure 16. Water Erosion Control Practices



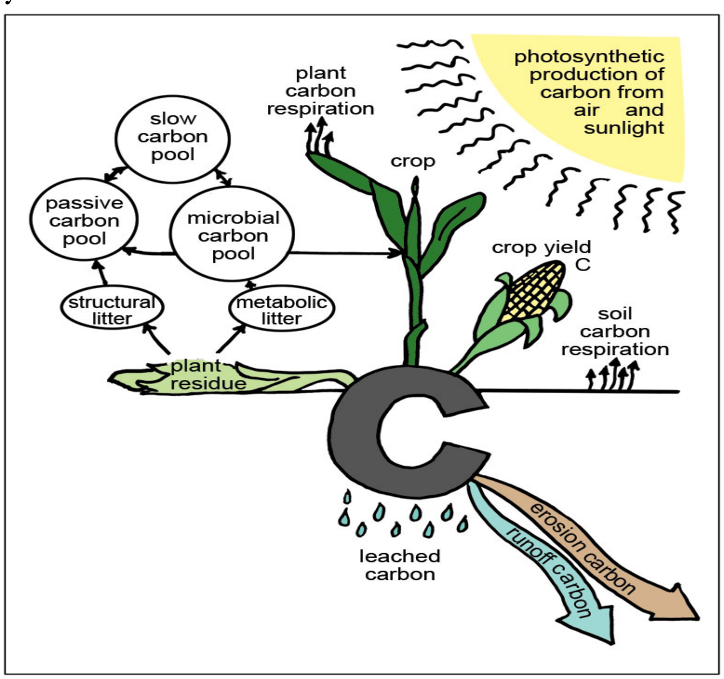
Source: FAPRI-UMC Report #01-07

Figure 17. Wind Erosion Processes and Conservation Practices



Source: FAPRI-UMC Report#01-07

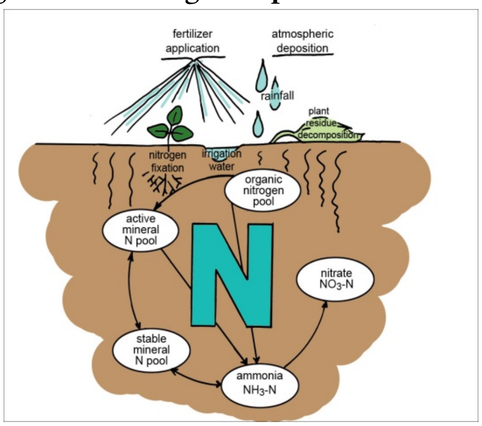
Figure 18. Carbon Cycle Processes



Source: FAPRI-UMC Report #01-07

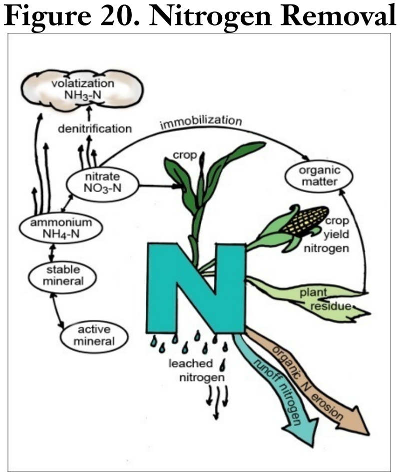
Crop fertilization and nutrient runoff control require a balance between nutrient management to produce economically viable crop yields and conservation practices to minimize nutrients in runoff. APEX simulates nitrogen inputs applied by the landowner and livestock as well as natural sources such as rainfall, biological fixation and residue decomposition (Figures 19 and 20). APEX also simulates nitrogen removal with crop yield, runoff, erosion, leaching, volatilization and immobilization.

Figure 19. Nitrogen Inputs



Source: FAPRI-UMC Report #01-07

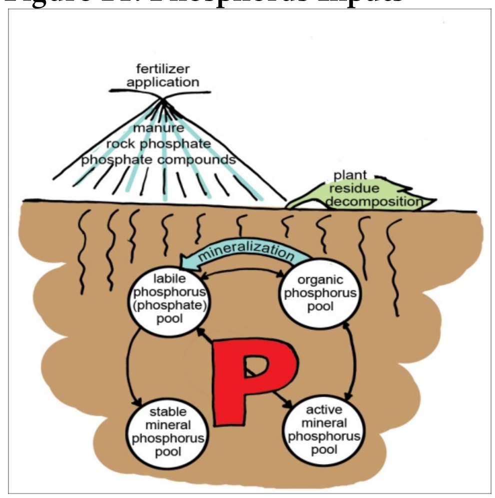
Figure 20. Nitrogen Removal



Source: FAPRI-UMC Report #01-07

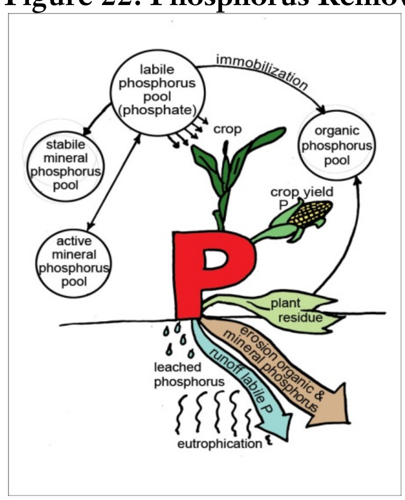
APEX simulates phosphorus input processes such as nutrient application, residue decomposition and manure from grazing animals; and processes that remove phosphorus such as crop uptake, runoff, leaching, erosion and sediment loss, and phosphorus in residue (Figures 21 and 22).

Figure 21. Phosphorus Inputs



Source: FAPRI-UMC Report #01-07

Figure 22. Phosphorus Removal



Source: FAPRI-UMC Report #01-07

APEX model developers and users have compiled considerable soil, weather, crop, management, pesticide and nutrient data inputs over the last 30 years of modeling with APEX and related models. The files included with the APEX model contain:

- equipment data (tillage, planting, fertilizing, harvesting, irrigation, and cost and repair characteristics for a few hundred pieces of equipment),
- crop data (crop growth, nutrient uptake, erosion, stress, photosynthetic productivity, plant population, grain yield, forage yield, leaf area development and temperature characteristics for over 100 crops, grasses and trees),
- pesticide data (cost, solubility, degradation and soil binding characteristics for nearly 300 pesticides), and
- fertilizer data (cost and mineral and organic nutrient content for nearly 100 fertilizers and manures).

The watershed area draining into the pond is split into sub-areas by weather, topography, soil type and land use. Each watershed is defined by a set of data files that include:

- a site file (latitude, longitude, weather, elevation, CO^2, nitrogen content in rainfall and irrigation water, watershed hydrology and spatial weather information),
- a sub-area file (soil numbers from soil list and management numbers from the list of alternative management systems; livestock information for grazing, feeding and manure application; initial snow and residue conditions as the simulation begins; latitude and longitude of the sub-area centroids; a number of watershed and stream hydrologic characteristics; reservoir/pond capacities and spillway release rates; irrigation, manure, lagoon and fertilization parameters used by the stress-driven automatic application systems; and livestock grazing limits to control automatic grazing management.)

Lists of soil filenames, weather filenames, wind filenames and alternative management filenames are included as are the soil, weather, wind and management files listed.

The model has a set of files that contain all of the basic control information to make a set of simulations for each type of analysis. The list of the simulation names, site file numbers, weather and wind station numbers and the sub-area number for each simulation to be made are entered into the "APEXRUN.DAT" file. The analytical parameters, such as number of years of simulation, beginning year, month and day, type of outputs created, method of evapotranspiration estimation used, method of erosion estimation used and many other parameters are entered into the "APEXCONT.DAT" file. Most of control file parameters have default or recommended values.

For additional information on the APEX model, please consult the "**A**gricultural **P**olicy/**E**nvironmental E**x**tender Model Theoretical Documentation and User Guide" by Evelyn Steglich and J.R. Williams.

Initial analyses examined the program claims databases to estimate the characteristics of the ponds and terraces in order to determine the data inputs for the APEX model. The analyses determined that the databases did not include adequate information to build the APEX data sets to simulate the MO-PS&W-SALES TAX conservation programs water quality and erosion impacts. In the absence of adequate data available on a practice-by-practice basis, FAPRI–MU used Geological Information System (GIS) data available at FAPRI–MU and the Center for Agricultural, Resource and Environmental Systems (CARES) to select representative sites based on photographic images, GIS topography, soil maps and secondary data sources. Major soil types, crop rotations and farm management practices were identified for each region and APEX data sets were built. Figure 23 is an example of the combination photographic images and digital elevation data used to define pond watersheds. The example pond watershed area in Figure 23 is identified with a light green outline. Figure 24 is a similar example for a terraced field. The terrace watershed is identified with a yellow outline. This information is connected to GIS soil maps to determine the fractions of the watershed by dominant soils.

Figure 23. Example Pond Illustration

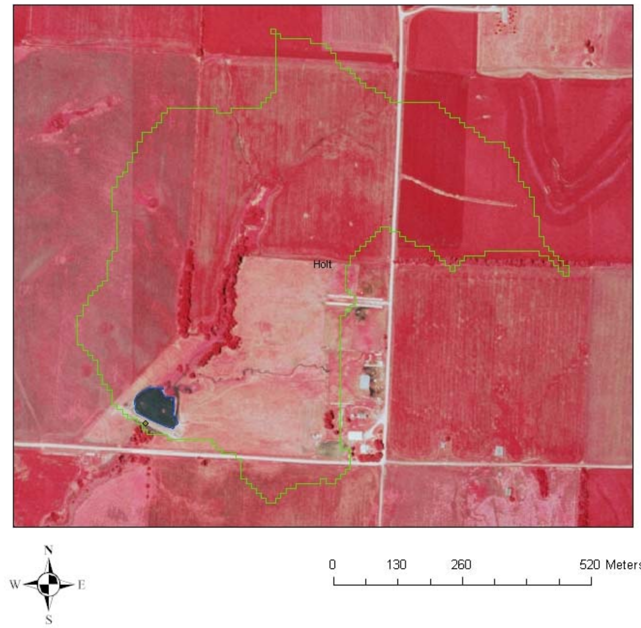
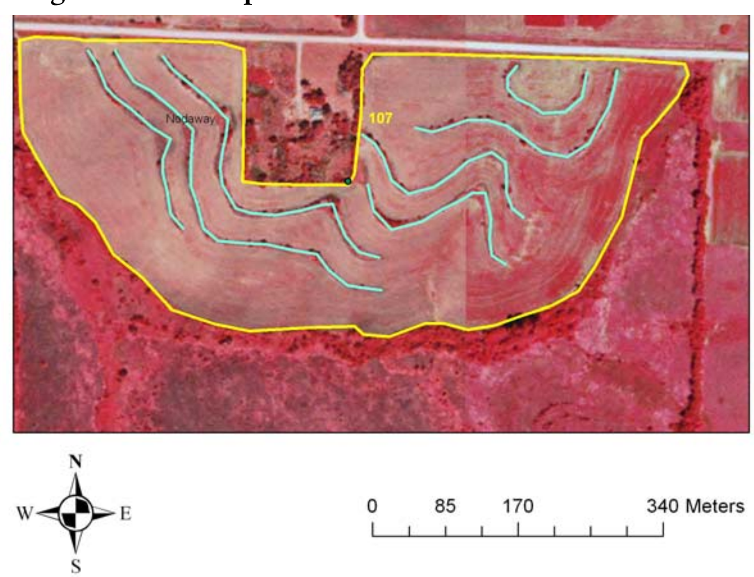


Figure 24. Example Terraced Field



A soil database built to meet the needs of APEX and related models that contains physical and chemical characteristics for over 15,000 soils was used to build the APEX soil input files. Soil and topographic data were used to develop the hydrologic input files for APEX. These hydrologic characteristics, the NRCS engineering guides for pond and terrace design and the photographic data were used to divide the watersheds into sub-watersheds. Each sub-watershed had a single soil and crop rotation or grass cover. Management files for the crops were set up to be conservation tillage with conservative nutrient management. The crop rotations and the cropland versus grass cover acreages were based on county average land use data from the 2002 Agricultural Census. Land use was adjusted between surface-drained terraces and tile-drained terraces to reflect the reduced need for grassed waterways with tile-drained terraces.

The results of these analyses are presented in practice-by-practice analyses. Water impoundment and sediment retention reservoirs are treated as one type of practice because:

- APEX model sediment and nutrient trapping processes for the two practices are very similar and
- most of the installed pond practices were water impoundments.

The pond designs represent water impoundments that retain some water for livestock or other uses.

Most of the installed terrace practices were tile-drained terraces. Surface-drained terraces and tile-drained terraces were analyzed separately because there are differences in crop versus grassed waterway acreage: the sediment and nutrients are trapped by somewhat different physical processes so trapping takes place in different parts of the landscape.

Water Impoundment and Sediment Retention Ponds

Ponds are designed with principal and emergency spillways. Emergency spillways are seldom used because the pond capacity at the emergency spillway is designed to contain all but the largest storm events. The principal spillways are designed to allow water to drain down to the principal spillway level within about three days making emergency capacity available for the next storm. Because the landscape varies considerably from site to site, pond design also varies.

This analysis uses the 44 representative ponds listed in table 1 to estimate the average water quality impacts for a pond in each region. Table 2 presents a summary of cost and size (measured in cubic yards of earth moved) for MO-PS&W-SALES TAX Conservation Programs cost-shared water impoundments. Table 3 contains the same information for sediment control structures.

Table 1. Representative Pond and Watershed Characteristics for 44 Ponds

Region	Surface Area of Pond (acres)	Watershed Drainage Area (acres)	Average Watershed Slope (percent)	Capacity at Emergency Spillway (acres-feet)	Capacity at Principal Spillway (acres-feet)
NW-DL	1.16	111.61	6.71	22.88	10.83
NW-DL	5.96	84.80	8.06	17.38	8.23
NW-DL	0.39	79.83	7.66	16.36	7.75
NW-DL	2.31	100.88	7.34	20.68	9.79
NW-DL	1.80	53.92	8.03	9.57	4.24
NW-DL	8.66	197.69	7.32	47.80	24.48
NW-DL	1.23	33.33	9.09	6.83	3.24
NW-DL	1.43	130.60	7.08	26.77	12.68
NC-HTP	2.84	62.29	4.28	15.53	8.13
NC-HTP	0.92	64.65	5.40	16.12	8.44
NC-HTP	1.34	38.20	3.63	9.53	4.99
NC-HTP	0.69	12.89	12.21	2.56	1.20
NC-HTP	1.17	57.83	5.59	13.99	7.16
NC-HTP	2.22	111.46	2.47	26.95	13.80
WC-CP	0.88	63.52	3.61	20.25	11.21
WC-CP	2.69	38.20	1.16	10.90	6.01
WC-CP	1.02	23.79	0.58	7.58	4.20
WC-CP	1.46	19.51	2.73	5.44	2.81
WC-CP	2.78	56.16	2.74	17.06	9.12
WC-CP	0.71	45.24	2.00	13.74	7.34
EC-CA	3.41	65.31	2.69	17.38	9.67
EC-CA	1.34	52.69	2.13	14.02	7.80
EC-CA	4.11	82.58	0.74	21.97	12.23
EC-CA	0.80	36.26	1.90	9.92	5.61
EC-CA	1.09	40.05	2.36	10.96	6.20
EC-CA	2.00	38.67	3.26	10.58	5.99
C-MV	1.60	35.20	6.60	6.21	3.15
C-MV	1.74	41.40	12.24	7.31	3.71
C-MV	2.80	35.87	6.03	6.33	3.21
C-MV	2.89	113.36	10.87	27.41	14.80
C-MV	3.05	110.48	3.21	26.72	14.42
C-MV	6.43	87.67	6.00	21.20	11.44
SC-OH	7.62	274.31	9.91	60.14	34.43
SC-OH	1.09	25.68	6.94	5.44	2.94
SC-OH	3.26	19.04	4.56	4.03	2.18
SC-OH	1.34	12.62	8.91	2.84	1.46
SC-OH	1.22	42.73	4.08	9.62	4.93
SC-OH	6.11	27.01	3.16	6.28	3.28
SE-MVA	0.26	3.54	5.41	0.53	0.25
SE-MVA	1.70	9.08	4.63	1.66	0.87
SE-MVA	0.54	7.08	5.26	1.65	0.94
SE-MVA	1.38	19.93	2.60	5.12	3.00
SE-MVA	0.82	6.42	4.34	1.65	0.97
SE-MVA	0.85	26.79	0.83	7.76	4.73

Table 2. MO-PS&W-Sales Tax Water Impoundments, Cubic Yards Installed and Cost by Region

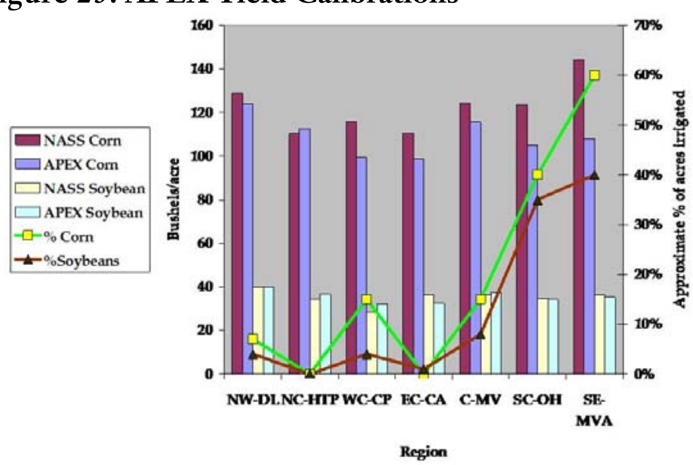
Region	Number of cubic yards Installed	Number of claims	Actual Cost	State Cost Share
Northwest-DL	4,059,987	965	8,748,303	5,166,509
North Central-HTP	27,482,148	6,312	53,034,096	33,330,789
West Central-CP	2,584,604	693	6,125,678	3,425,273
East Central-CA	3,325,258	786	6,262,226	3,826,003
Central-MV	11,532,301	2,596	22,988,577	12,920,161
South Central-OH	7,263,051	1,579	15,035,465	8,769,956
Southeast-MVA	1,065,153	244	1,799,946	1,111,051

Table 3. MO-PS&W-Sales Tax Sediment Retention Ponds, Cubic Yards Installed and Cost by Region

Region	Number of cubic yards Installed	Number of claims	Actual Cost	State Cost Share
Northwest-DL	2,588,705	1,367	8,039,588	5,505,944
North Central-HTP	980,537	938	3,253,892	2,154,856
West Central-CP	127,565	94	506,149	304,931
East Central-CA	66,792	104	337,331	228,084
Central-MV	1,056,560	960	3,599,425	2,292,050
South Central-OH	475,702	929	1,631,197	1,135,840
Southeast-MVA	2,972,338	5,560	9,325,396	5,990,966

Initial APEX simulations are used to debug data inputs and to calibrate the model to local conditions. Simulated crop yields are often used as one indicator of model accuracy because yields reflect crop, soil, weather and nutrient management accuracy in a single measure. Figure 25 compares corn and soybean yields simulated by APEX to United States Department of Agriculture (USDA) Missouri crop yield estimates for the last ten years. Only dryland production was simulated. However, the USDA estimates include both irrigated and dryland production. Percentage of acres irrigated by region is an indicator of which regional study yield estimates should be expected to be lower than USDA estimates because considerable irrigation is present, but not modeled.

Figure 25. APEX Yield Calibrations



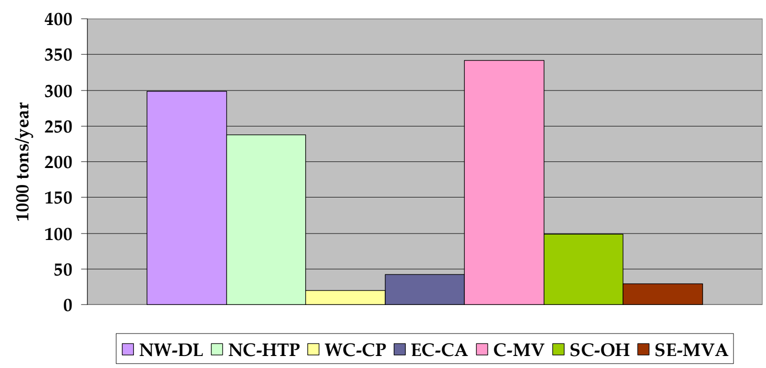
The initial simulation results indicate that the model is functioning logically and is producing reasonable results. Since no measured information exists on a pond-by-pond basis, and the cost and time to collect such information is prohibitive, simulation is the only reasonable way to estimate the benefits of water impoundments and sediment retention ponds. However, model simulations are only as good as inputs and the logical structure of the analyses.

This study used 44 existing ponds to represent the ponds built in the 1997 to 2007 time period. Each simulation was for a period of ten years. Thirty alternative 10-year weather sequences were simulated for each pond watershed with and without the pond to establish a distribution of alternate outcomes. The distributions were used to estimate the average environmental benefits from each pond and the average for all ponds in each region.

The average pond size based on the claims data for each region was then used to calculate the estimated environmental benefits per cubic yard of ponds installed and per dollar of cost-share funds expended. The aggregate estimates by region are based on this set of simulations and logic. It is believed to be credible and unbiased.

Estimated sediment trapped is the estimated soil leaving the watershed without a pond at the outlet, less the sediment estimated to pass through the principal and emergency spillways of the installed ponds. The estimated tons trapped per year in each region is based on the average of the ponds simulated adjusted to reflect the total cubic yards of ponds installed in that region. The estimated tons of sediment trapped by region vary with the number of ponds built, soil and landscape susceptibility to erosion and the land use (figure 26).

Figure 26. Estimated Tons of Sediment Trapped by MO-PS&W-Sales Tax Ponds



Estimated nutrients trapped with sediment are either bound to the sediment or to organic matter and residue moving with sediment. Figures 27 and 28 present the estimates of organic nitrogen (N) and organic phosphorus (P) trapped per year by MO-PS&W-SALES TAX ponds in each region. Almost all organic material is trapped by ponds, thus almost all organic N and P is trapped.

Figure 27. Estimated Tons of Organic N Trapped by MO-PS&W-SALES TAX Ponds

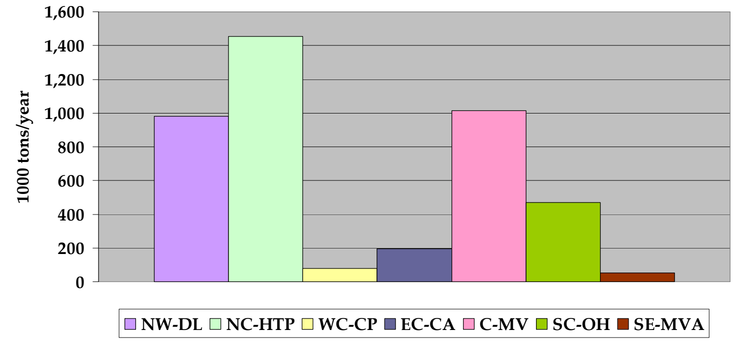
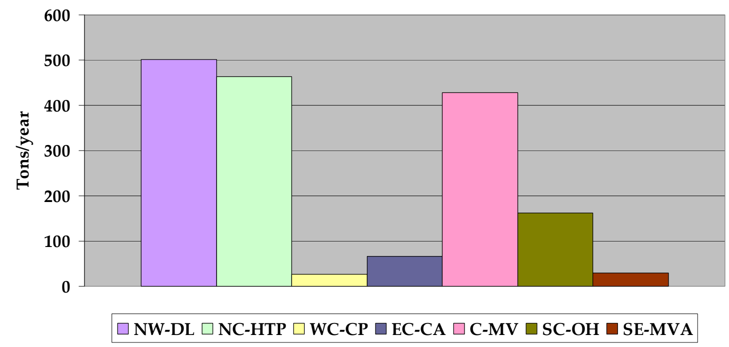
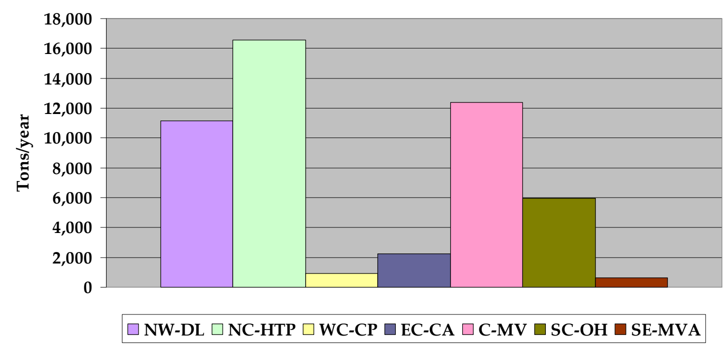


Figure 28. Estimated Tons of Organic P Trapped by MO-PS&W-Sales Tax Ponds



Estimated Carbon trapped is a component of the organic matter from eroded soils and within residue. Figure 29 presents the estimated carbon trapped by Missouri cost-share funded ponds per year for each region.

Figure 29. Estimated Tons of Carbon Trapped by MO-PS&W-Sales Tax Ponds



Estimated manure and manure P trapped are estimated separately by APEX from sediment; however, the processes are similar as are the impacts. Manure was not applied to either cropland or grassland, but the grassland was assumed to be grazed and the manure excreted by livestock was estimated and applied to the grassland on a daily basis (figures 30 and 31).

Figure 30. Estimated Manure Trapped by MO-PS&W-Sales Tax Ponds

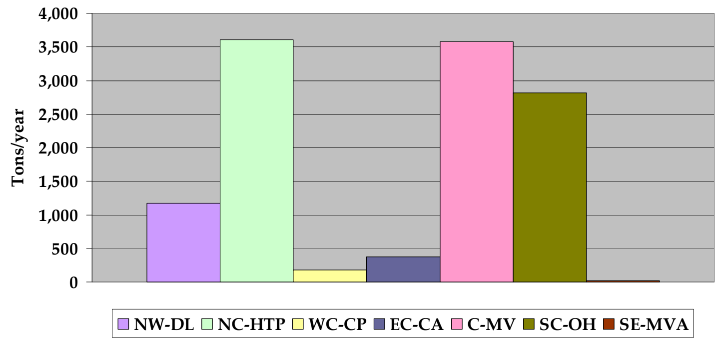
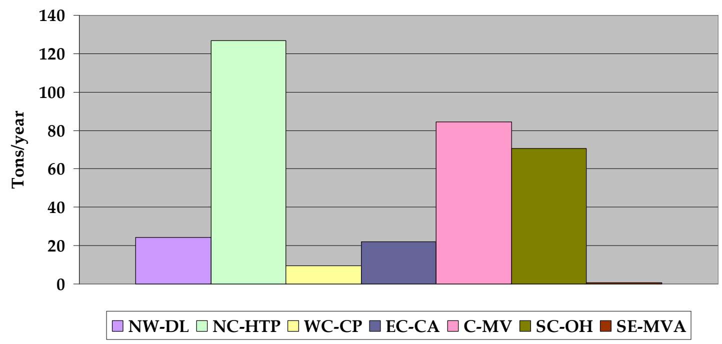
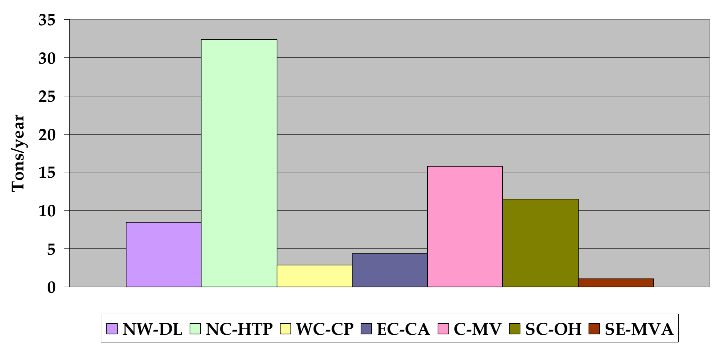


Figure 31. Estimated Manure P Trapped by MO-PS&W-Sales Tax Ponds



Estimated water runoff trapped is based on estimated runoff leaving the watershed without a pond at the outlet less the runoff estimated to pass through the principal and emergency spillways of the installed ponds. The estimated runoff water trapped per year by region is based on the average of the ponds simulated adjusted to reflect the total cubic yards of ponds installed for each region. The estimated runoff water trapped in ponds by region varies with the number of ponds built, the soil and topography and the land use (figure 32).

Figure 32. Estimated Acre-feet of Water Trapped by MO-PS&W-Sales Tax Ponds



The water that leaves through pond spillways leaves behind most of the suspended nutrients, soil and carbon. Nutrients in solution are more likely to move with the runoff water; however, they may be precipitated with other materials, consumed by aquatic life, or be volatilized. They are often at least an order of magnitude less than the nutrients moving with sediment (figures 33 and 34).

Figure 33. Estimated Tons of N in Runoff Trapped by MO-PS&W-Sales Tax Ponds

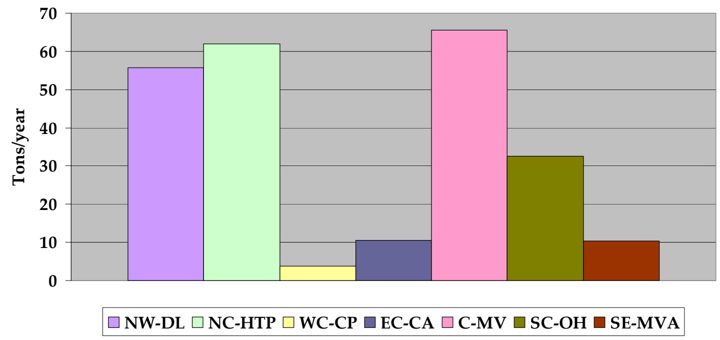


Figure 34. Estimated Tons of P in Runoff Trapped by MO-PS&W-Sales Tax Ponds

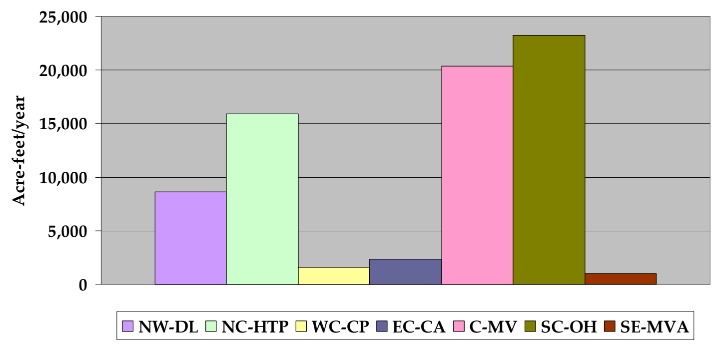
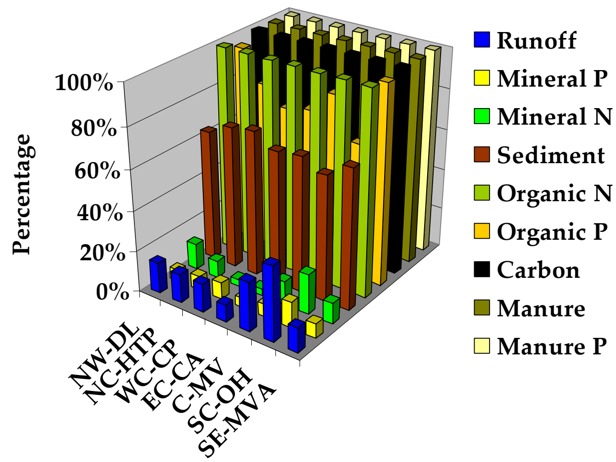


Figure 35 summarizes the trapping effects of ponds in terms of percent of sediment, nutrients, carbon, manure and water trapped by MO-PS&W-SALES TAX ponds by region. The simulations indicate that ponds are very effective conservation measures for trapping sediment and suspended material. The simulations also indicate that much of the dissolved material is trapped.

Figure 35. Estimated Percent of Pollutants and water Trapped by MO-PS&W-Sales Tax Ponds



Terraces Drained by Surface Waterways

Terraces drained by surface waterways are designed to trap soil and nutrients and to break up the concentrated water flows. This study assesses the impact of Missouri cost-share investments in two types of terraces, surface-drained and tile-drained terraces. Surface-drained terraces are drained by surface waterways that often have permanent vegetative cover. In recent years tile-drained terraces have become more common. Tile-drained terraces will be examined later in the report.

This analysis uses the 24 representative terraced fields listed in table 4 to estimate the average water quality impacts of surface-drained terraced fields in each region.

Table 4. Characteristics for Surface-drained Terraced Fields

Study Region	Field	Crops	Grass	Field
		(acres)	(acres)	(acres)
NW-DL	1	46.3	4.6	50.9
NW-DL	2	44.5	4.5	48.9
NW-DL	3	113.1	8.8	121.9
NW-DL	4	54.3	5.5	59.8
NC-HTP	1	60.6	6.1	66.6
NC-HTP	2	36.7	3.7	40.4
NC-HTP	3	42.0	4.2	46.2
NC-HTP	4	133.2	9.8	143.1
WC-CP	1	69.3	6.9	76.3
WC-CP	2	37.4	3.7	41.1
WC-CP	3	22.8	2.3	25.1
WC-CP	4	70.4	7.0	77.5
WC-CP	5	72.1	7.2	79.4
WC-CP	6	35.7	3.6	39.3
EC-CA	1	60.8	6.1	66.9
EC-CA	2	96.6	7.1	103.8
EC-CA	3	40.1	4.0	44.1
EC-CA	4	66.1	6.6	72.6
C-MV	1	103.1	7.7	110.8
C-MV	2	42.7	4.3	47.0
C-MV	3	51.1	5.1	56.2
C-MV	4	28.9	2.9	31.8
SC-OH	1	35.4	3.5	39.0
SC-OH	2	78.3	7.8	86.1

Each of these fields is divided into multiple sub-areas to capture the runoff hydrology as water moves down the field slopes into the terraces and then across the fields to the grassed waterways. Each sub-area has a dominate soil that describes percolation, runoff, water storage, erosivity and nutrient characteristics. Most of the fields simulated had only two dominate soils, but had 7 to 18 sub-areas to capture the field hydrology.

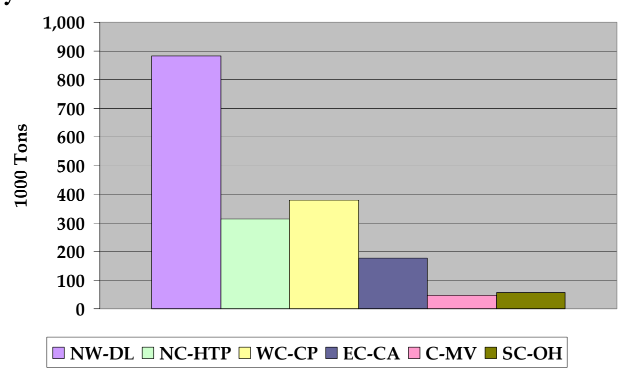
This study used 24 representative fields to simulate the environmental benefits of surface-drained terraces built in the 1997 to 2007 time period. Each simulation was for a period of ten years. Thirty alternative ten-year weather sequences were simulated for each field with and without surface-drained terraces to establish a distribution of alternate outcomes. The distributions were used to estimate the average environmental benefits from terracing each field. The average simulated benefits for each region were then converted into benefits per foot of surface-drained terrace simulated in the representative fields for each region. The number of feet of surface-drained terraces was then used to calculate the estimated environmental benefits per foot of surface-drained terrace installed and per dollar of cost-share funds expended. The number of feet of surface-drained terraces installed and the cost for each region is presented in table 5.

Table 5. MO-PS&W-Sales Tax Surfaced-drained Terraces by Region

Region	Number of feet Installed	Number of claims	Actual Cost	State Cost Share
Northwest-DL	5,937,306	1,570	5,619,157	3,927,210
North Central-HTP	2,593,853	891	3,825,439	2,631,487
West Central-CP	2,945,782	843	2,301,719	1,484,859
East Central-CA	885,021	387	1,261,218	873,937
Central-MV	487,957	241	1,005,428	674,133
South Central-OH	761,550	225	516,322	362,650

Estimated sediment trapped is the estimated soil leaving the watershed without surface-drained terraces less the sediment estimated to leave the field via the grassed waterways of surface-drained terraces. The estimated tons trapped per year by region are based on the simulated benefits per foot of surface-drained terraces times the feet of surface-drained terraces installed in the region. The estimated tons of sediment trapped by region vary with the number of feet of surface-drained terraces installed, soil and landscape susceptibility to erosion and the land use (figure 36).

Figure 36. Estimated Tons of Sediment Trapped by MO-PS&W-Sales Tax Surface-drained Terraces



Estimated nutrients trapped with sediment by terraces are either bound to the sediment or to the organic matter and residue moving with sediment. Figures 37 and 38 present the estimates of organic nitrogen (N) and organic phosphorus (P) trapped per year by MO-PS&W-SALES TAX surface-drained terraces in each MLRA. Most of the organic material is trapped by terraces, thus almost all organic N and P is trapped.

Figure 37. Estimated Tons of Organic N Trapped by MO-PS&W-Sales Tax Surface-drained Terraces

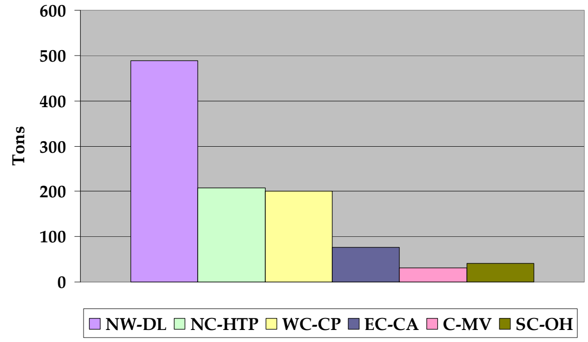
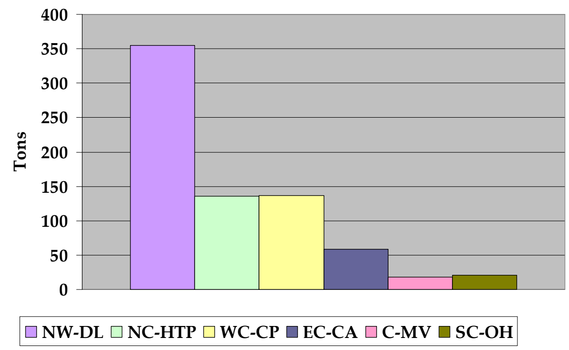
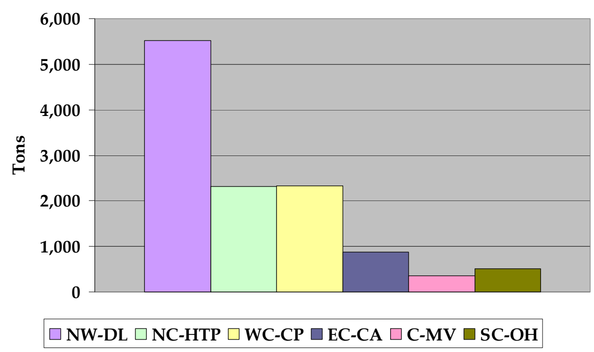


Figure 38. Estimated Tons of Organic P Trapped by MO-PS&W-Sales Tax Surface-drained Terraces



Estimated Carbon trapped is a component of the organic matter from eroded soils and within residue (figure 39).

Figure 39. Estimated Tons of Carbon Trapped by MO-PS&W-Sales Tax Surface-drained Terraces



Estimated water runoff trapped is based on estimated runoff leaving the field without surface-drained terraces less the runoff estimated leaving through the grassed waterways. The estimated runoff water trapped by surface-drained terraces is a function of the soil permeability, topography and the land use (figure 40).

These characteristics determine the rate of water flow across the landscape and the water infiltration rate, which determines the opportunity time for the water to infiltrate as it moves through the terraces and grassed waterways.

The water that leaves the grassed waterways that drain the terraces leaves behind most of the suspend nutrients, soil and carbon. Nitrogen and phosphorus in solution are more likely to move with the runoff water; however, they may be precipitated with other materials or be volatilized (figures 41 and 42).

Figure 40. Estimated Acre-feet of Water Trapped by MO-PS&W-Sales Tax Surface-drained Terraces

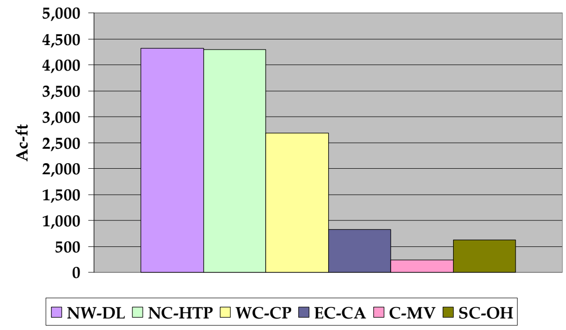


Figure 41. Estimated Tons of N Dissolved in Runoff Trapped by MO-PS&W-Sales Tax Surface-drained Terraces

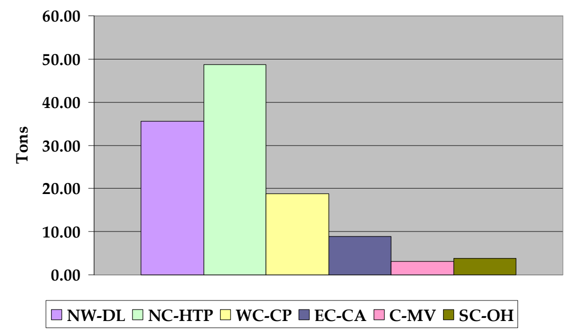


Figure 42. Estimated Tons of P Dissolved in Runoff Trapped by MO-PS&W-Sales Tax Surface-drained Terraces

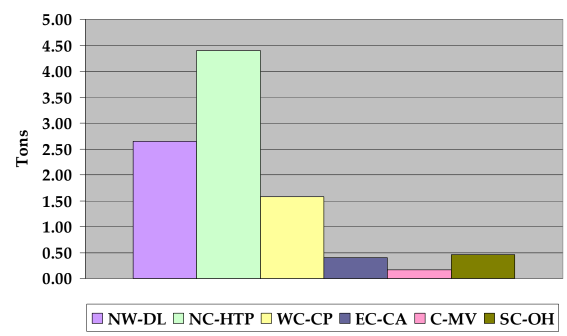
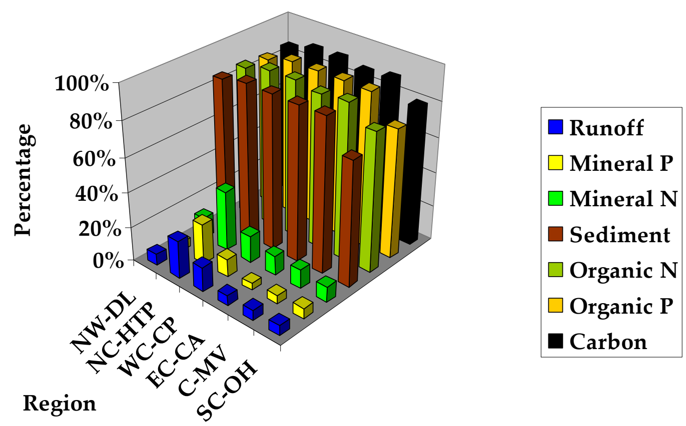


Figure 43 summarizes the trapping effects of surface-drained terraces in terms of percent of sediment, nutrients, carbon, manure and water trapped by MO-PS&W-SALES TAX surface-drained terraces by region. The simulations indicate that surface-drained terraces are very effective conservation measures for trapping sediment and suspended material. The simulations also indicate that some of the dissolved nutrients are trapped.

Figure 43. Estimated Percent of Pollutants and Water Trapped by MO-PS&W-Sales Tax Surface-drained Terraces



Tile drained terraces

In recent years farmers have installed tile-drained terraces versus surface-drained terraces with grassed waterways. Tile is used to drain water from terraces directly to the edge of the field. Grassed waterways are eliminated and the entire field is cropped.

This analysis uses the same 24 representative surface-drained terraced fields listed in table 4 with the exceptions that the grassed areas are planted to crops and each simulated terrace segment is tile drained to the edge of the field. Each of these fields is divided into multiple sub-areas to capture the runoff hydrology as water moves down the field slopes into the terraces. Like the surface-drained terrace fields, each sub-area has a dominant soil that describes percolation, runoff, water storage, erosivity and nutrient characteristics. The tile-drained terrace segments are treated like small sediment trapping structures that are entirely emptied in 36 hours or less.

The average simulated benefits for each region were converted into benefits per foot of tile-drained terrace simulated in the representative fields for each region. The feet of surface-drained terraces were then used to calculate the estimated environmental benefits per foot of tile-drained terrace installed and per dollar of cost-share funds expended. The number of feet of tile-drained terraces installed and the cost for each region is presented in table 6.

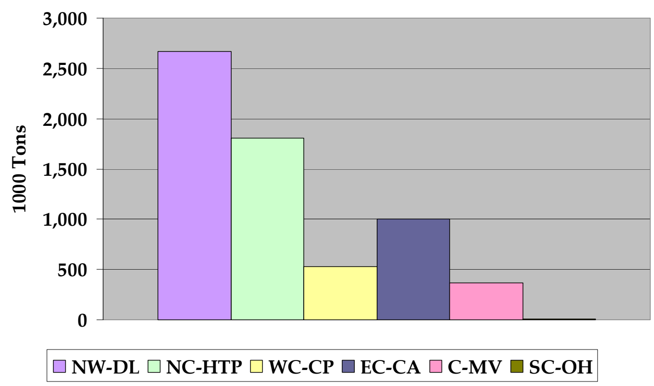
Table 6. MO-PS&W-Sales Tax Tile-Drained Terraces by Region

Region	Number of feet Installed	Number of claims	Actual Cost	State Cost Share
Northwest-DL	18,018,842	5,063	38,890,320	26,183,764
North Central-HTP	16,663,270	4,898	41,445,416	28,717,020
West Central-CP	4,229,894	1,129	8,821,859	5,541,993
East Central-CA	5,224,434	1,999	14,011,186	9,641,830
Central-MV	3,967,009	1,370	11,160,933	7,545,812
South Central-OH	74,104	30	146,285	95,720

Estimated sediment trapped is the estimated soil leaving the watershed without tile-drained terraces less the sediment estimated to leave the field via the tile drains. The estimated tons trapped per year by region are based on the simulated benefits per foot of tile-drained terraces times the feet of tile-drained terraces installed in the region.

The sediment, organic nutrients and carbon tend to precipitate from the runoff before being transported to the field edge by the tile. The estimated tons of sediment trapped by region vary with the number of feet of tile-drained terraces installed, soil and landscape susceptibility to erosion and the land use (figure 44).

Figure 44. Estimated Tons of Sediment Trapped by MO-PS&W-Sales Tax Tile-drained Terraces



Estimated nutrients trapped with sediment by terraces are either bound to the sediment or to the organic matter and residue moving with sediment. Figures 45 and 46 present the estimates of organic nitrogen (N) and organic phosphorus (P) trapped per year by MO-PS&W-SALES TAX tile-drained terraces in each region. Most of the organic material is trapped by terraces, thus almost all organic N and P is trapped.

Estimated Carbon trapped is a component of the organic matter from eroded soils and within residue (figure 47).

Figure 45. Estimated Tons of Organic N Trapped by MO-PS&W-Sales Tax Tile-drained Terraces

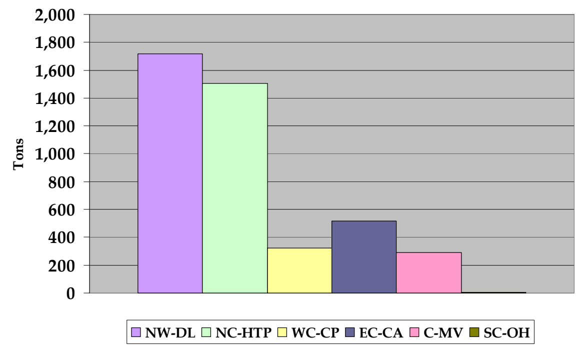


Figure 46. Estimated Tons of Organic P Trapped by MO-PS&W-Sales Tax Tile-drained Terraces

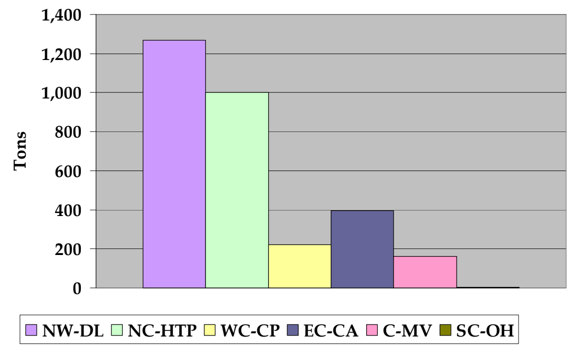
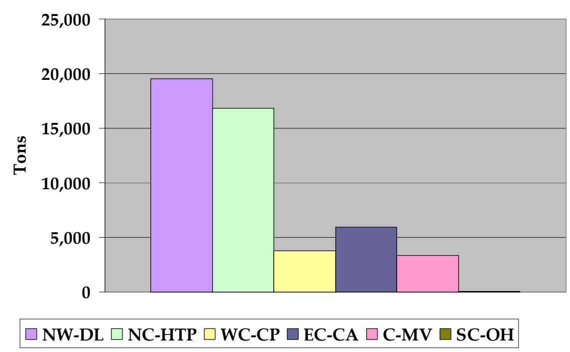


Figure 47. Estimated Tons of Carbon Trapped by MO-PS&W-Sales Tax Tile-drained Terraces



Estimated water runoff trapped is based on estimated runoff leaving the field without tile-drained terraces less the runoff estimated leaving through the tile drains. The estimated runoff water trapped by tile-drained terraces is a function of the soil permeability in the terraces, as seen in figure 48. The water infiltration rate and the time required for the tile to drain the terrace determine the amount of runoff trapped. The water that is drained by the tile leaves behind most of the suspended nutrients, soil and carbon.

Nitrogen and phosphorus in solution are more likely to move with the runoff water; however, they may be precipitated with other materials or be volatilized (figures 49 and 50).

Figure 48. Estimated Acre-feet of Water Trapped by MO-PS&W-Sales Tax Tile-drained Terraces

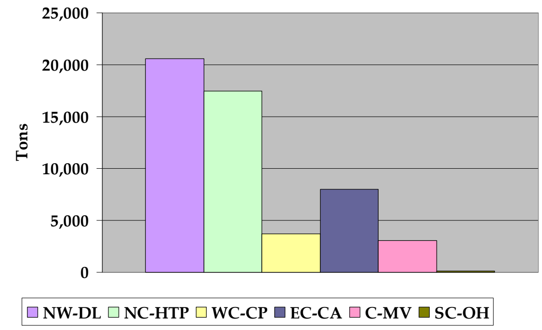


Figure 49. Estimated Tons of N Dissolved in Runoff Trapped by MO-PS&W-Sales Tax Tile-drained Terraces

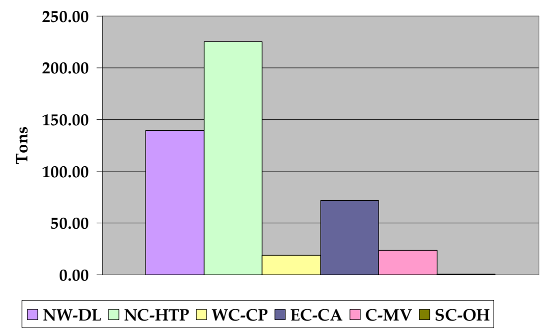


Figure 50. Estimated Tons of P Dissolved in Runoff Trapped by MO-PS&W-Sales Tax Tile-drained Terraces

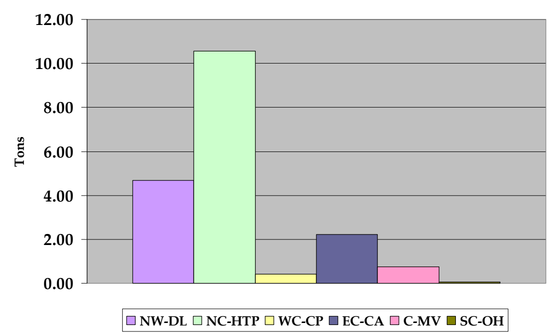
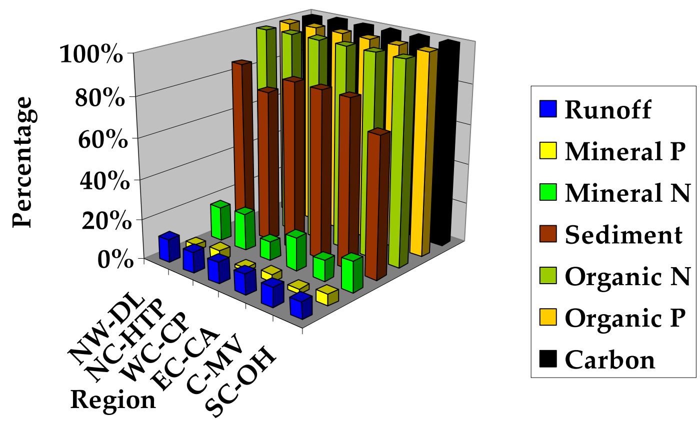


Figure 51 summarizes the trapping effects of tile-drained terraces in terms of percent of sediment, nutrients, carbon, manure and water trapped by MO-PS&W-SALES TAX tile-drained terraces by region. The simulations indicate that tile-drained terraces are very effective conservation measures for trapping sediment and suspended material. In addition, some of the dissolved nutrients are trapped.

Figure 51. Estimated Percent of Pollutants and Water Trapped by MO-PS&W-Sales Tax Tile-drained Terraces



Environmental Impact Summary

The environmental analyses focused on four practices: sediment retention ponds, water impoundment ponds, surface-drained terraces and tile-drained terraces. They account for 70-80 percent of the MO-PS&W-SALES TAX Conservation Programs investment in conservation practices. All four practices are very effective measures for reducing sediment and organic materials that move with sediment. The reductions of these potential pollutants are summarized in table 7. The practices and their benefits are concentrated in the areas of Missouri with the most cropland. Raising crops increases the land vulnerability to erosion and requires nutrient application to grow most crops.

Table 7. Estimated Suspended Pollutants Trapped per Year by MO-PS&W-Sales Tax Terraces and Ponds

Study Region	Sediment (1000 tons)	Organic N (tons)	Organic P (tons)	Carbon (tons)
NW-DL	3,846.6	3,187.6	2,123.8	36,192.3
NC-HTP	2,358.5	3,167.2	1,599.1	35,701.1
WC-CP	927.1	602.4	384.7	7,027.4
EC-CA	1,223.1	786.2	519.4	9,077.3
C-MV	757.5	1,335.2	607.9	16,076.5
SC-OH	161.2	514.5	185.6	6,533.7
SE-MVA	28.8	52.5	29.3	644.7
TOTAL	9,302.8	9,645.7	5,449.8	111,253.0

Citizens of Missouri may find these measures of accomplishment difficult to evaluate. What does 9.3 million tons of sediment trapped mean? It's enough sediment to cover 4,759 miles of streambeds 30 feet wide with a depth of 6 inches in sediment. Many Missouri streams flow into reservoirs that supply water for urban and rural citizens. Reservoirs are design to last many years, but most have life expectancies of 50 to 100 years. That means that they were expected to fill with sediment over their lifetime. A United States Geological Survey (USGS) study of reservoir sedimentation[4] of four Kansas watersheds found sediment deposition in the reservoirs ranging from less than two percent in 42 years to 27 percent in 37 years. The authors suggest that small impoundments played an important role in the watershed with less than two percent sediment deposition because there were more than 800 small impoundments.

Clarence Cannon reservoir (Mark Twain Lake) is an example of a Missouri lake that receives benefits from the MO-PS&W-SALES TAX Conservation Programs. The lake has three levels of storage: an inactive portion below withdrawals for water supply and hydroelectric power generation; a joint use pool for water supply, hydroelectric power generation, recreation, navigation and fish and wildlife enhancement; and a flood control pool. Annual benefits were estimated to be nearly $20 million per year.[5] The predicted rate of sediment deposition when the lake was designed was 11,500 acre feet per year. A sedimentation survey completed in 1997 found the computed rate of sedimentation to be only 290 acre-feet per year. The joint use pool is estimated to have lost only 0.7 of its capacity in 1997.[6]

[4] USGS.
[5] US Army Corps of Engineers, 1989
[6] US Army Corps of Engineers, 2000

Much of the East Central Claypan region drains into Mark Twain Lake. The estimated sediment trapped from that region is equivalent to more than ten percent of the original rate of sediment deposition resulting in an extended life expectancy of the lake of at least ten years at nearly $20 million per year.

The nutrients trapped with sediment greatly enhance the water quality in streams and reservoirs. The estimated nitrogen trapped is equivalent to the nitrogen needed to fertilize over 150,000 acres of corn yielding 150 bushels per acre. The estimated phosphorus trapped is equivalent to the phosphorus needed to fertilize over 500,000 acres of corn yielding 150 bushels per acre. This trapped nitrogen and phosphorus also enhances the recreation, fish and wildlife habitat, and reduces the cost of providing drinking from lakes like Mark Twain Lake.

The estimated carbon trapped across the state is equivalent to the amount of carbon that would degrade over 17,000 billion gallons of water. That is equivalent to almost 100 times the storage capacity of Clarence Cannon reservoir at the joint water supply-hydroelectric storage level.

Ponds and terraces trap much less of the dissolved nutrients and other dissolved chemicals. However, dissolved nutrients account for a small percentage of the nutrient load in runoff. Trapping dissolved pollutants means either trapping the water or removing the pollutants from the water, table 8. Trapping the water would reduce stream flows, which is not desirable.

Table 8. Estimated Dissolved Pollutants Trapped by MO-PS&W-Sales Tax Terraces and Ponds

Study Region	Runoff (ac-ft)	Nitrogen (tons)	Phosphorus (tons)
NW-DL	33,532.1	230.9	15.8
NC-HTP	37,651.4	335.8	47.3
WC-CP	7,961.2	41.7	4.9
EC-CA	11,132.9	91.2	6.9
C-MV	23,669.9	92.3	16.6
SC-OH	23,954.5	37.3	12.0
SE-MVA	1,016.0	10.3	1.0
TOTAL	138,918.0	839.5	104.6

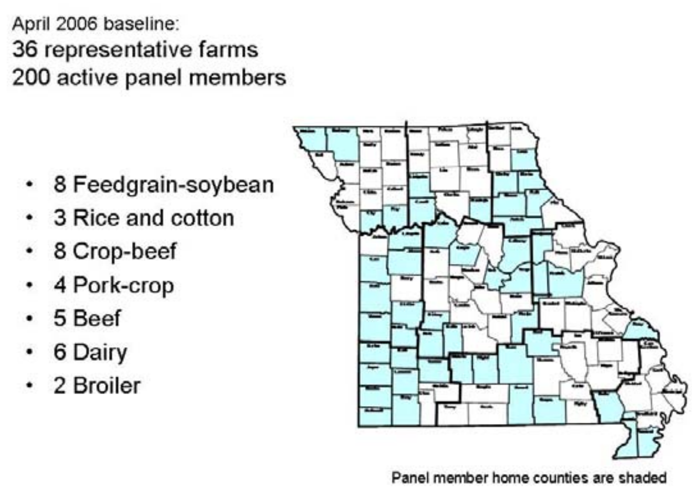
Farm Level Economic Assessment

Farm level economic assessment determines the likely farmer response to farm policy. Representative farms—also referred to as panel farms, rep farms, or sentinel farms—are constructed to simulate historical and future economic performance of a defined farm business under certain economic and environmental conditions. To measure impact, a baseline reflecting current conditions is estimated and published semi-annually. The simulation produces a set of financial statements for each scenario.

The rep farm approach treats a farm business unit as a unique system characterized by local features and resources that are adapted to by the farm manager. Primary data are initially developed and continuously validated by Missouri producers via a consensus process.

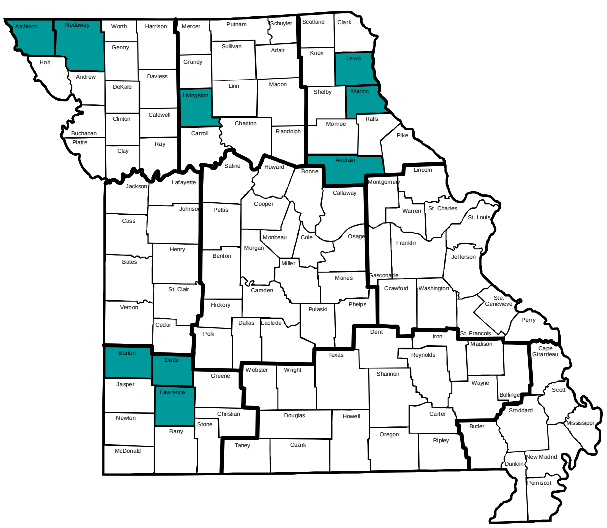
Producers establish farm structure, size, farming practices, costs of production, and associated financial requirements for the representative farm based on their individual operations. In some cases, data points are cross-referenced with published sources to test assumptions or to verify and explain differences. Farm financial statements are generated using the Farm Level Income Simulation Model (FLIPSIM) software. National price estimates are generated by the FAPRI consortium of universities at MU and Iowa State University. The accounting method used to model rep farm financials is a cash-basis, whole-farm, after-tax approach. Business size, structure, and management practices are held constant for the simulation period. The cash flow statement is the primary tool of this analysis and returns to family living are considered to be the bottom line, i.e., cash *available* for owner withdrawal from *current year* earnings. Figure 52 shows the location of the panel farms in Missouri. Shaded areas are the home counties of representative farm panel members. Bolded lines on the map are boundaries for USDA-Missouri Ag Statistics Service crop reporting districts which correspond to rep farm regions.

Figure 52. Location of active representative farms in 2006.



This study simulated installation of tile terrace on the six representative farms shown in figure 53. The study compared

Figure 53. Location of six study farms



installation with and without cost-share over time and under risk based on a 2004 installation date. The analysis quantifies the value of the cost-share program to the farmer relative to his/her level of net farm income. Terraces are expected to result in only a minor increase in market value of land. Yields were assumed to be unchanged. A farm was selected from each of the six regions where terraces were evaluated in this study. Cropland acres per farm ranged from 240 to 2600 acres. Terraces were installed on one 40 acre field of each representative farm. The analysis used the state average installation cost and cost-share rate, respectively ($578 per acre or $23,120) and ($393 or $15,720 at 68 percent cost-share rate). Terrace maintenance cost was assumed to be equivalent to the pre-terrace cost of repairing ephemeral gully and sheet and rill erosion damage.

A sample of farm level results for one of the six farms follows to illustrate the methodology. The sample farm is located in the Northeast Claypan Area in Audrain County. The farm has 1300 acres cropland of which 32 percent is owned. The farm raises 325 acres corn, 235 acres sorghum and 740 acres soybeans.

A summary of example farm economic returns is presented in table 9. The Audrain representative farm is a modest sized farm, historically on the financial edge. Terraces were installed on 40 acres. Although 40 acres is a small portion of cropland (three percent), relative to farmer's net return, installation cost is expensive.

Even with strong market outlook, installation is a big chunk of farmer's net return. The last line in table 9 shows what percent of family income would be required for each potential year of installation without cost-share from the MO-PS&W-SALES TAX Conservation Programs. These estimates illustrate how the difficulty of paying for terrace installation varies from year to year as droughts occur or market prices go up and down.

The fraction of family income required in the year of installation to install terraces on only 40 acres without cost-share is presented in table 10 for all six farms. Very few farmers would be expected to give up such a large percentage of their family income to install terraces. Cost-sharing increases the viability of terraces.

Table 9. Summary of Farm Level Economic Returns for Example Farm

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2004-13 Cumul.
Total cash receipts												
No cost-share	300.6	417.93	261.86	400.27	445.09	472.58	467.67	485.19	477.09	490.26	494.03	
With cost-share, $ chg		15.72	0	0	0	0	0	0	0	0	0	15.72
Net cash farm income												
No cost-share	69.0	146.1	10.22	132.44	174.68	203.61	201.33	221.63	212.8	221.84	227.75	
With cost-share, $ chg		15.72	1.18	1.48	1.37	1.5	1.39	0.99	0.48	0.38	0.19	24.68
Return to family living												
No cost-share	32.9	74.45	-34.07	57.64	98.64	106.1	98.51	105.4	68.87	89.53	90.36	
With cost-share, $ chg		15.72	1.18	10.84	0.92	0.97	0.88	0.55	0.13	0.04	-0.08	31.15
Installation costs, as percent of return to family living												
	70.3%	31.1%	-67.9%	40.1%	23.4%	21.8%	23.5%	21.9%	33.6%	25.8%	25.6%	

Table 10. Six Representative Farms and Family Living Impact of Terrace Installation

Crop acres	240	1,100	1,300	1,485	2,500	2,600
County	Dade	Barton	Audrain	Livingston	Nodaway	Marion
Region	SC-OH	WC-CP	EC-CA	NC-HTP	NW-DL	C-MV
	Installation costs as a percent of return to family living					
2003	55.4%	29.7%	70.3%	29.6%	43.1%	24.2%
2004-2013	54.6%	21.4%	30.6%	18.8%	12.4%	13.1%

Farm Level Summary

Much of the benefit of terraces accrues to the community as a whole. Although farmers can expect to benefit in terms of long term productivity and short term reductions in tillage required to smooth erosion created rills and gullies, these benefits are small relative to terrace installation costs. Cost sharing allows the offsite beneficiaries to encourage adoption of Missouri Soil and Water Conservation practices for their own benefit.

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Appendix

Table A-1. Missouri Soil and Water Conservation Public and Private Investment and Impact by Region: 1997-2007

	Major Land Resource Area	Fiscal Year										
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Conservation Public and Private Investment*	NW-DL	$11.80	$7.43	$6.66	$6.56	$5.86	$7.64	$6.74	$6.55	$6.84	$7.21	$6.26
	NC-HTP	$14.15	$10.77	$9.26	$8.86	$7.21	$9.31	$9.02	$8.14	$9.00	$9.50	$8.42
	WC-CP	$2.10	$2.15	$1.11	$1.83	$1.84	$2.55	$2.63	$2.32	$2.16	$2.23	$2.15
	EC-CA	$2.81	$2.73	$1.86	$2.12	$1.64	$2.07	$2.19	$2.35	$2.63	$2.73	$2.70
	C-MV	$7.35	$6.18	$5.07	$5.88	$5.22	$6.81	$7.08	$6.59	$6.88	$7.22	$6.92
	SC-OH	$7.00	$7.03	$5.06	$6.58	$5.62	$7.12	$6.69	$7.40	$7.15	$8.02	$7.89
	SE-MVA	$1.19	$1.16	$1.42	$1.67	$1.47	$1.83	$2.30	$2.16	$1.81	$1.89	$1.75
	Entire State	$46.39	$37.45	$30.43	$33.49	$28.86	$37.32	$36.66	$35.51	$36.48	$38.80	$36.09
Business Sales*	NW-DL	$14.57	$9.37	$8.31	$8.25	$7.28	$9.58	$8.50	$8.17	$8.57	$9.08	$7.80
	NC-HTP	$17.87	$13.66	$11.70	$11.22	$9.09	$11.75	$11.38	$10.27	$11.41	$12.06	$10.67
	WC-CP	$2.75	$2.81	$1.46	$2.38	$2.40	$3.32	$3.42	$3.02	$2.82	$2.91	$2.79
	EC-CA	$3.47	$3.38	$2.29	$2.62	$2.03	$2.56	$2.71	$2.91	$3.25	$3.38	$3.35
	C-MV	$9.29	$7.88	$6.43	$7.49	$6.66	$8.69	$9.03	$8.44	$8.78	$9.24	$8.87
	SC-OH	$9.29	$9.18	$6.62	$8.67	$7.39	$9.34	$8.80	$9.74	$9.40	$10.47	$10.41
	SE-MVA	$1.47	$1.46	$1.77	$2.10	$1.84	$2.29	$2.87	$2.70	$2.29	$2.37	$2.17
	Grand	$58.71	$47.73	$38.58	$42.73	$36.69	$47.52	$46.70	$45.24	$46.52	$49.50	$46.07
Full- & Part-Time Jobs	NW-DL	311	206	177	174	157	203	180	173	183	192	170
	NC-HTP	466	363	306	292	235	304	297	266	299	324	285
	WC-CP	64	65	33	54	55	76	79	69	64	66	61
	EC-CA	77	77	54	59	47	59	62	66	76	78	77
	C-MV	234	195	160	184	165	215	220	205	216	226	217
	SC-OH	226	225	157	207	177	214	202	227	219	240	243
	SE-MVA	29	29	35	41	37	46	58	54	45	46	44
	Grand	1,408	1,160	921	1,011	873	1,118	1,098	1,061	1,102	1,173	1,096
Labor Income*	NW-DL	$2.06	$1.58	$1.28	$1.35	$1.11	$1.56	$1.38	$1.25	$1.33	$1.44	$1.19
	NC-HTP	$2.62	$2.01	$1.77	$1.65	$1.29	$1.71	$1.70	$1.48	$1.70	$1.91	$1.67
	WC-CP	$0.50	$0.47	$0.27	$0.41	$0.41	$0.56	$0.56	$0.50	$0.49	$0.49	$0.49
	EC-CA	$0.36	$0.34	$0.25	$0.28	$0.21	$0.27	$0.28	$0.31	$0.35	$0.36	$0.36
	C-MV	$1.35	$1.25	$0.99	$1.19	$1.06	$1.37	$1.44	$1.42	$1.40	$1.54	$1.53
	SC-OH	$1.42	$1.38	$1.05	$1.36	$1.17	$1.42	$1.31	$1.46	$1.40	$1.49	$1.58
	SE-MVA	$0.36	$0.37	$0.44	$0.52	$0.46	$0.57	$0.71	$0.68	$0.60	$0.59	$0.54
	Grand	$8.67	$7.41	$6.05	$6.76	$5.71	$7.45	$7.39	$7.09	$7.26	$7.82	$7.36
Other Property-Type Income*	NW-DL	$3.77	$2.25	$2.08	$2.03	$1.83	$2.36	$2.10	$2.06	$2.15	$2.26	$1.96
	NC-HTP	$3.74	$2.82	$2.30	$2.32	$1.92	$2.43	$2.33	$2.15	$2.32	$2.36	$2.10
	WC-CP	$0.62	$0.65	$0.32	$0.54	$0.55	$0.76	$0.79	$0.69	$0.64	$0.66	$0.62
	EC-CA	$0.91	$0.88	$0.59	$0.68	$0.53	$0.67	$0.71	$0.76	$0.85	$0.88	$0.87
	C-MV	$2.29	$1.85	$1.54	$1.76	$1.56	$2.04	$2.10	$1.93	$2.04	$2.12	$2.00
	SC-OH	$1.96	$2.02	$1.42	$1.84	$1.57	$2.01	$1.93	$2.10	$2.04	$2.32	$2.23
	SE-MVA	$0.32	$0.29	$0.37	$0.43	$0.37	$0.47	$0.59	$0.55	$0.45	$0.49	$0.46
	Grand	$13.61	$10.76	$8.62	$9.60	$8.34	$10.74	$10.56	$10.24	$10.50	$11.09	$10.24
Indirect Business Taxes*	NW-DL	$0.44	$0.28	$0.25	$0.25	$0.22	$0.29	$0.26	$0.25	$0.26	$0.27	$0.23
	NC-HTP	$0.53	$0.41	$0.35	$0.34	$0.27	$0.35	$0.34	$0.31	$0.34	$0.36	$0.32
	WC-CP	$0.08	$0.08	$0.04	$0.07	$0.07	$0.10	$0.10	$0.09	$0.08	$0.08	$0.08
	EC-CA	$0.10	$0.10	$0.07	$0.08	$0.06	$0.07	$0.08	$0.08	$0.09	$0.10	$0.10
	C-MV	$0.27	$0.23	$0.19	$0.21	$0.19	$0.25	$0.25	$0.24	$0.25	$0.26	$0.25
	SC-OH	$0.25	$0.24	$0.17	$0.23	$0.19	$0.24	$0.23	$0.26	$0.25	$0.27	$0.28
	SE-MVA	$0.04	$0.04	$0.04	$0.05	$0.05	$0.06	$0.07	$0.07	$0.06	$0.06	$0.05
	Grand	$1.71	$1.37	$1.11	$1.22	$1.05	$1.36	$1.33	$1.28	$1.33	$1.41	$1.31
Value Added Total*	NW-DL	$6.27	$4.11	$3.61	$3.62	$3.16	$4.20	$3.73	$3.55	$3.74	$3.98	$3.39
	NC-HTP	$6.89	$5.24	$4.41	$4.30	$3.48	$4.49	$4.38	$3.94	$4.36	$4.63	$4.09
	WC-CP	$1.20	$1.20	$0.64	$1.02	$1.03	$1.41	$1.46	$1.28	$1.21	$1.24	$1.19
	EC-CA	$1.37	$1.32	$0.90	$1.04	$0.81	$1.02	$1.07	$1.15	$1.29	$1.33	$1.33
	C-MV	$3.92	$3.33	$2.71	$3.16	$2.81	$3.66	$3.80	$3.58	$3.69	$3.92	$3.78
	SC-OH	$3.63	$3.64	$2.64	$3.43	$2.93	$3.67	$3.47	$3.81	$3.69	$4.08	$4.08
	SE-MVA	$0.71	$0.70	$0.85	$1.00	$0.89	$1.10	$1.37	$1.29	$1.11	$1.14	$1.05
	Grand	$23.99	$19.53	$15.78	$17.58	$15.10	$19.55	$19.28	$18.61	$19.09	$20.31	$18.91

*Monetary values in millions of current dollars were computed using IMPLAN.