


Environmental Impact of Missouri Crop Production

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1 Introduction

Most persons in the U.S. are three generations away from the farm. Memories of their ancestors' farms invoke images of practices that are uncommon now. One hundred years ago, soybeans were not a cash crop; today, more acres of soybean are planted in Missouri than any other crop. Multiple passes of tillage equipment prior to planting, which were common 50 years ago, are rare in Missouri today. One hundred years ago, the quantity of food produced was the biggest concern. Today, minimizing environmental impact and providing environmental amenities are major interests of farmers.

This report has five sections. The section titled *Crop Industry in Missouri* presents the long view of crop production. Data from the past 50 years to 100 years are used to illustrate how agriculture has changed over time. Soybean, corn, hay, wheat, cotton, sorghum and rice have been major crops grown in Missouri. The five-year peak harvested acre periods for corn, cotton and wheat were before 1950. Hay, soybeans and rice are near, but not exceeding, their five-year peak harvested acreage totals. Privately owned acres in forest and grass have increased. Publically owned acres in parks and wildlife areas have increased.

Crop yield per acre has increased dramatically during the past 100 years. The increase in yields can be traced to the development of hybrid seeds, the use of commercial fertilizers and chemicals, and the adoption of genetically modified crops. Although acres harvested have decreased over time, total tons produced have increased. USDA data indicate that use of inputs other than land to produce crops — inputs such as fuel, labor and equipment — have also decreased over time. Missouri farmers are producing more with less and allocating resources to other desires.

The section titled *Trends in Crop Production Affecting the Environment* looks at the past 25 years, when possible. The period from 1990 to 2015 provides a picture of the latest developments in agriculture and the environment. Predominantly, statewide data are shared. National research results and U.S. agricultural trends supplement the trends found in Missouri-specific data. Missouri is a state with a diverse ecosystem. Trends in different regions of the state are rarely recorded due to available data.

This section is organized by the decisions farmers make about practices such as tillage, fertility and pest management. In each subsection, trends of farmer decisions are presented along with their impact on water, air and soil quality. Decisions regarding one aspect of crop production affect other decisions. For example, the adoption of herbicide-resistant crops creates less demand for tillage but more demand for herbicide use.

This section reports that farmers are:

- Actively participating in available state and federal conservation programs.
- Using less tillage and planting more cover crops;
- Increasing fertilizer efficiency and improving their nutrient management practices;
- Using more pounds of herbicides;
- Using fewer pounds of insecticides;
- Planting mostly genetically modified corn, soybeans and cotton;
- Adopting precision agriculture where it is appropriate for their farms; and
- Using the same amount of irrigation since 2000, but note a significant increase in irrigation development occurred before that year.

The measures of environmental benefits of these activities include:

- Less erosion;
- Improved soil health;
- Less fuel use;
- Fewer greenhouse gas emissions;
- Steady to fewer pounds of fertilizers applied in excess of fertilizer nutrients removed by crops, leaving less to escape into the environment;
- The acute hazard quotient associated with herbicides increased for winter wheat, but it decreased for corn, soybean, cotton and rice;
- The chronic hazard quotient associated with herbicides remained relatively flat for corn and winter wheat, but it increased for cotton and decreased for soybean and rice;
- Lower environmental impact measures for insecticides; and
- Improved wildlife habitat resulting in increasing wildlife populations.

The section entitled *Special Topics: Atrazine and Wildlife Population Trends* gives information on two areas of particular environmental interest. The available data indicate:

- Atrazine detects in raw water exceeding the finished water standard of three ppb ranged from zero in 2004 and 2012 to 52 in 2006.
- The overall state wildlife population has increased over the last 40 years for deer, turkey and most furbearing animals.

The section titled *Challenges and Opportunities* highlights some important areas to address. Despite a generally favorable improvement in the environmental impact associated with crop production, some recent indications point to areas of environmental concern from Missouri crop production.

The increase in rainfall events greater than three inches in a 24-hour period can cause serious erosion problems. Although fertilizer efficiency is improving, not all water quality measures are improving. Research indicates it may take decades of increasing fertilizer efficiency to improve the hypoxia zone in the Gulf of Mexico. The nutrient management standard proposed by the USEPA is estimated to be 20 times more expensive than the standard proposed by the Missouri Department of Natural Resources.

Weed resistance to an increasing number of herbicides is creating multiple challenges. The latest tillage estimates are up slightly. More pounds of herbicides are being used. Introducing dicamba-resistant crops has been accompanied by significant off-target injury to crops and trees.

Federal and state budgets are limiting the amount available to assist farmers in improving the environment. CRP acreage is decreasing. Regulatory uncertainty impacts farmers in ways that do not foster improved environmental quality.

The last section of this report, *Public Perceptions on Agriculture*, gives a brief overview of several surveys that indicate consumers are interested in how food and fiber are produced. They want sustainable agriculture. At the same time, consumers don't have a clear definition of "sustainable" and do not understand the improvements that accompany efficient production practices.

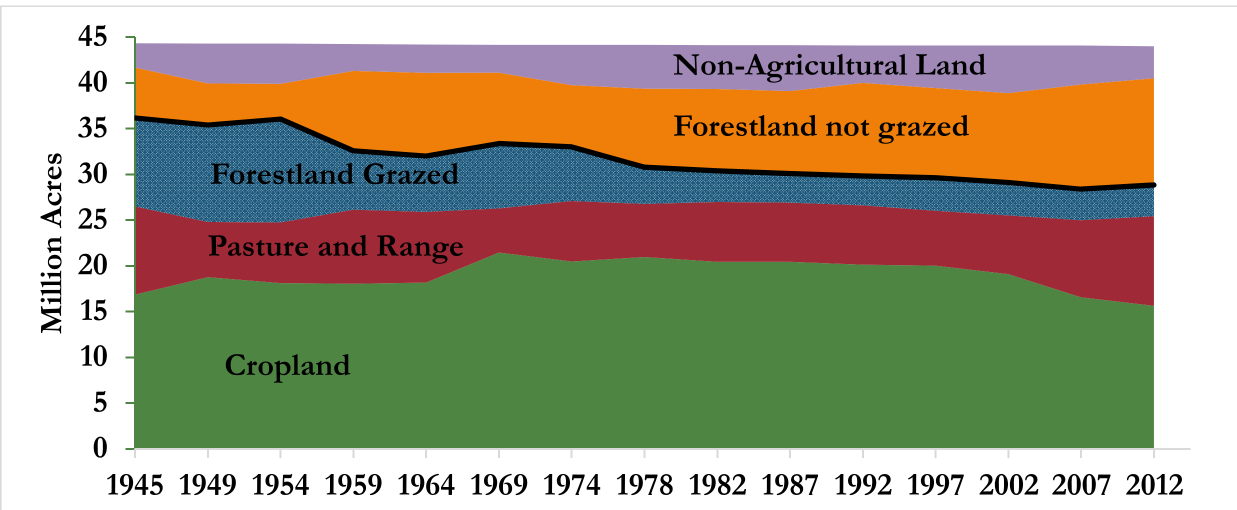
2 Crop Industry in Missouri

2.1 Major Land Uses

Missouri has 44 million acres of land, 64 percent of which is listed as agricultural land. Taking the long view of land use clarifies the impact of agriculture on the environment. The USDA Census of Agriculture has published the number of acres in major land use categories since 1945. Exhibit 2.1 shows that the number of acres in cropland reached a maximum of 21.5 million acres in 1969. Since then, land dedicated to crop production decreased to 15.6 million acres in 2012. The black line in Exhibit 2.1 shows that the amount of land used for crop and livestock production decreased from 36.2 million acres in 1945 to 28.8 million acres in 2012.

Using less land for crop and livestock production has resulted in an additional 6.2 million acres of forestland not grazed and an additional 700,000 acres of parks and wildlife areas.

Exhibit 2.1 - Missouri Land Uses, 1945-2012

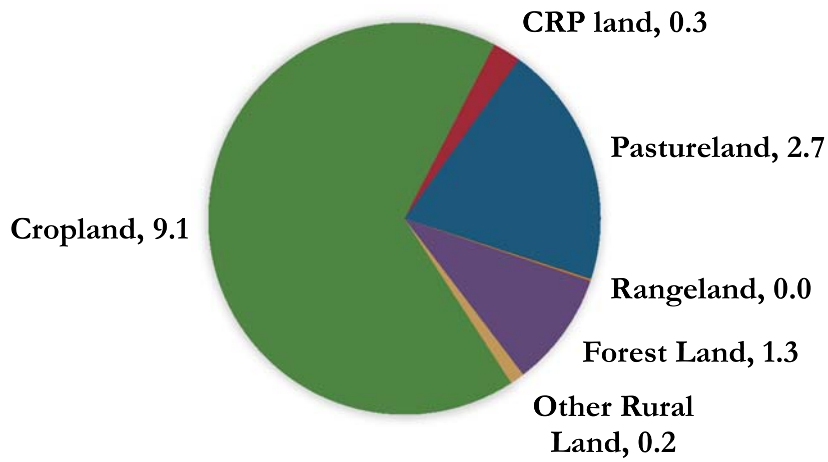


Source: USDA Economic Research Service, Major Land Uses

The USDA National Resource Inventory defines prime farmland as "land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is also available for these uses." This dataset reports that in 2012, Missouri had 13.6 million acres of prime farmland. Of this prime farmland, 67 percent was cropland, 20 percent was pastureland, and the remaining land was not used for crop and livestock production; see Exhibit 2.2.

The USDA National Resource Inventory reports that Missouri wetland modestly increased in all categories from 1.567 million acres in 1992 to 1.650 million acres in 2012. Approximately 25 percent of these wetlands were on cropland, pastureland and CRP land. Wetlands provide fish and wildlife habitat, protect and improve water quality and abate flooding.

Exhibit 2.2 - Missouri Prime Farmland by Land Cover, 2012, Million Acres



Source: USDA NRCS, National Resource Inventory

2.2 Cropping History

During the past century, the quantity of various commodities produced by Missouri farmers has changed. Exhibit 2.2.1 reports the peak five-year average of acres harvested, the five-year period during which the peak was recorded, acres harvested on average from 2012 to 2016 and the harvested acreage change recorded during the two periods — the peak five-year period and the 2012-to-2016 period. Acres harvested of corn, wheat, barley, cotton, oats, rye, grain sorghum and tobacco all decreased at least 46 percent between their peak five-year period and the 2012-to-2016 period.

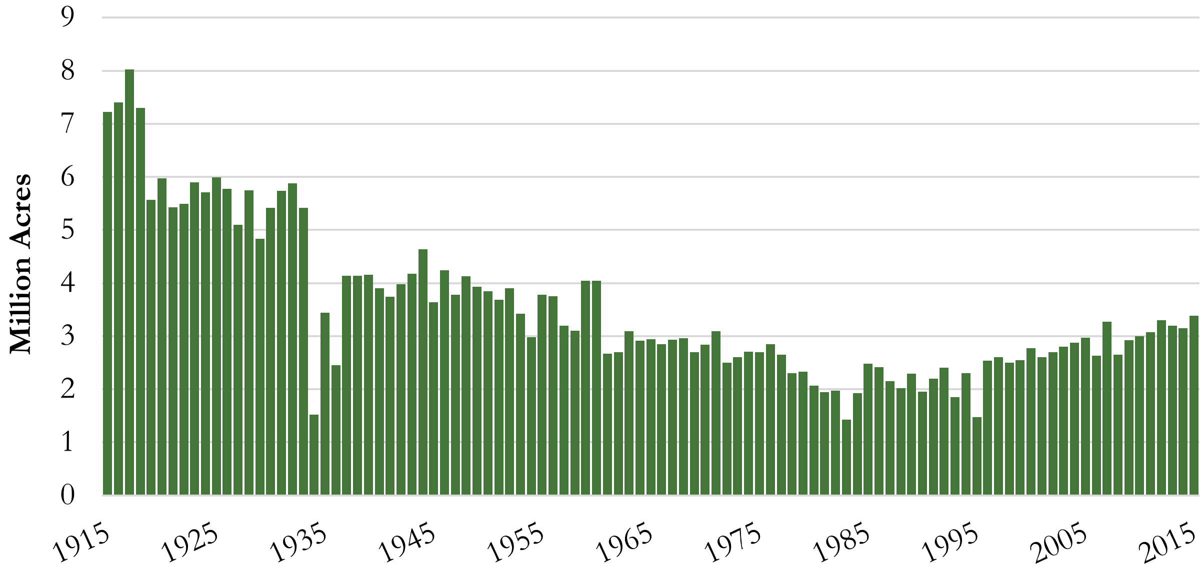
Exhibit 2.3 - Changes in Individual Crop Harvested Acres

Crop	Peak Acres Harvested (5-Year Average)	5-Year Period of Peak Acres Harvested	Acres Harvested (2012-2016 Average)	Change in Acres Harvested
Barley	397,800	1954-1958	1,236*	-396,564
Corn	6,852,400	1916-1920	3,292,000	-3,166,600
Cotton	527,000	1949-1953	252,400	-274,600
Hay	4,244,000	2000-2004	3,388,000	-856,000
Oats	2,004,400	1939-1943	11,400	-1,993,000
Rice	208,400	2006-2010	190,200	-18,200
Rye	63,000	1954-1958	1,115*	-61,885
Sorghum	1,080,000	1982-1986	76,389	-1,003,612
Soybeans	5,500,000	1978-1982	5,296,000	-204,000
Tobacco	6,920	1929-1933	427*	-6,493
Wheat	3,402,400	1918-1922	717,000	-2,685,400

*Data available from 2012 census only
Source: USDA National Agricultural Statistics Service, 1917-2016 census and survey data

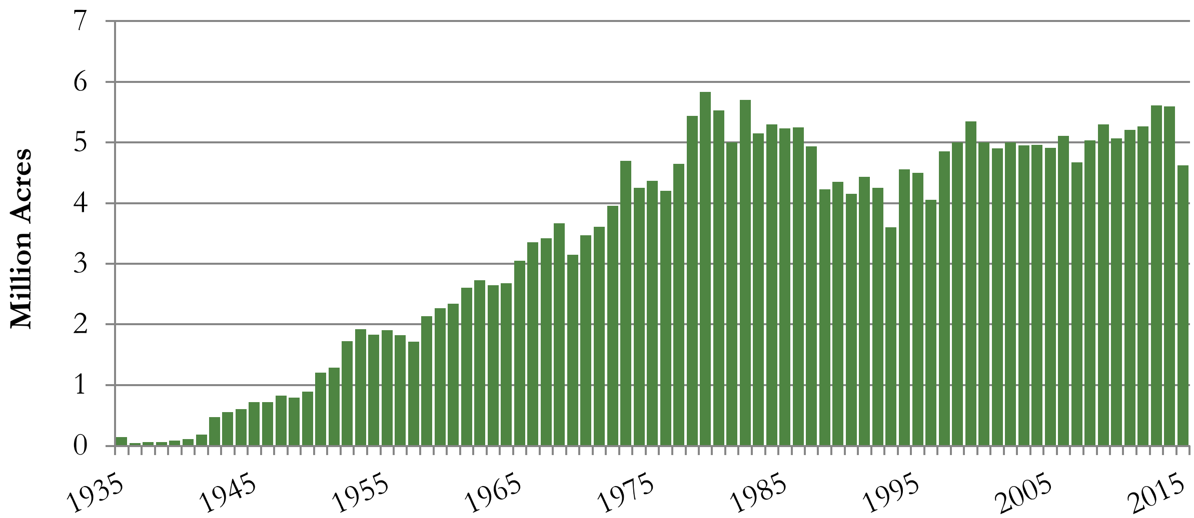
Corn production went from a high of 8.0 million acres in 1917 to 3.4 million acres in 2015. See Exhibit 2.4. Soybean production increased from 0.47 million acres in 1942 to 5.59 million acres in 2014. Weather problems in 2015 caused abnormally low soybean acres, so 2014 is reported as more characteristic; see Exhibit 2.5. Rice production rose from 18,000 acres in 1975 to 169,000 acres in 2015. In 1949, 600,000 cotton acres were harvested compared with 266,000 acres in 2016.

Exhibit 2.4 - Missouri Corn Acres Harvested, 1915-2015



Source: USDA National Agricultural Statistics Service

Exhibit 2.5 - Missouri Soybean Acres Harvested, 1935-2015



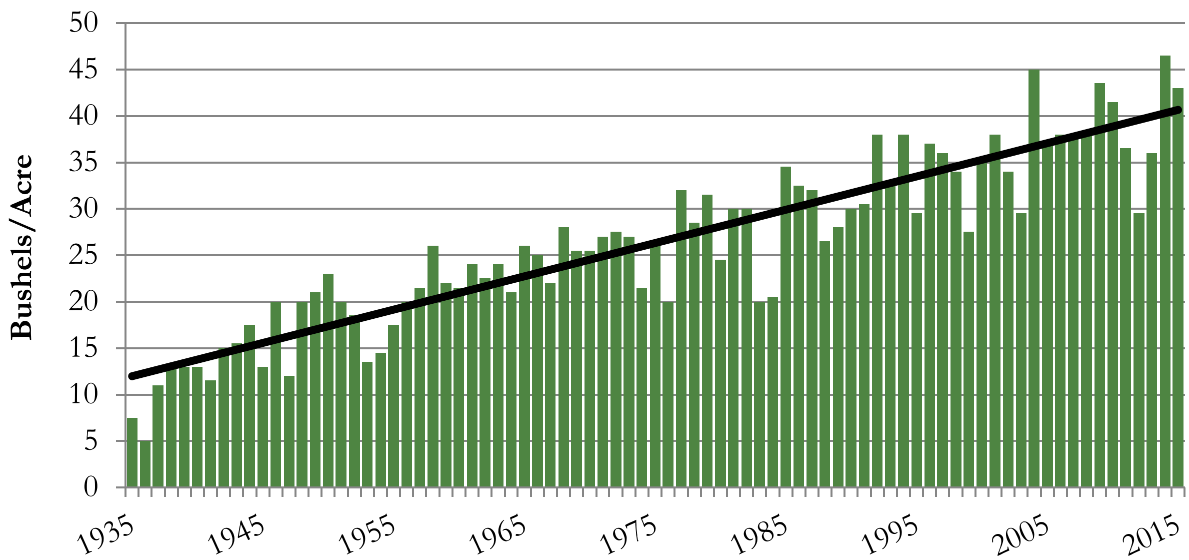
Source: USDA National Agricultural Statistics Service

Corn, soybean, grain sorghum, wheat, rice and cotton yields per acre all increased during the past century. For corn and soybeans, the total amount produced in Missouri has increased over time, despite relatively flat corn and soybean acres harvested since 1980. The increased production is a result of increased bushels harvested per acre; see Exhibit 2.6 and Exhibit 2.7.

Soybeans yields increased by 0.4 bushels per acre per year, and corn yields increased by 1.2 bushels per acre per year during the period from 1935 to 2015. Although total production of Missouri wheat, grain sorghum, cotton and rice did not increase in the past several decades, their yields per acre have increased. Wheat yields increased by 0.6 bushels per acre per year; grain sorghum, 0.1 bushel per acre per year; rice, 94.8 pounds per acre per year; and cotton, 21.5 pounds per acre per year during the period from 1990 to 2015.

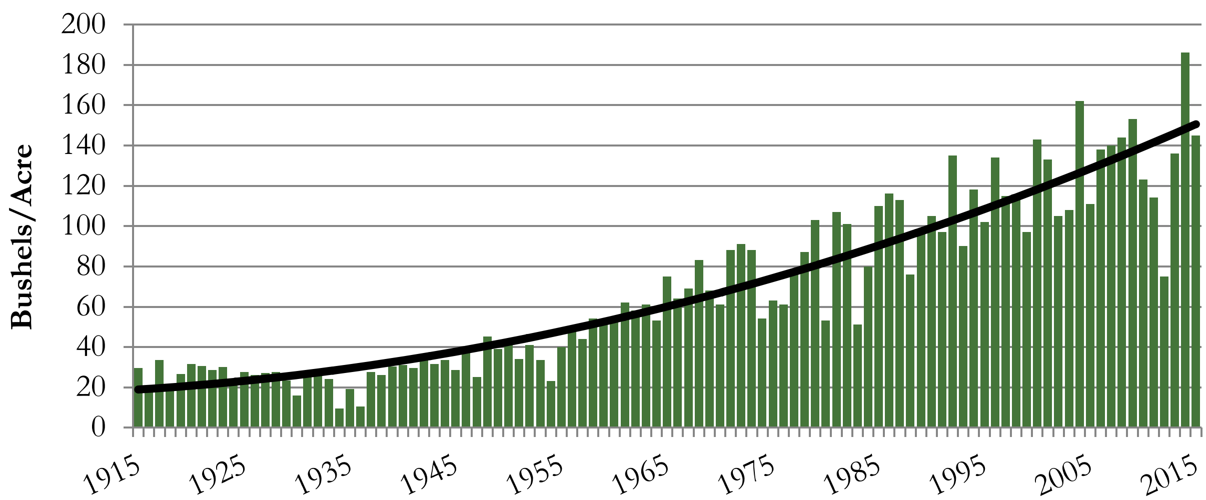
Among field crops, corn and soybean percentage yield increases have risen faster than wheat and grain sorghum yield increases. Also, the acreage of wheat and grain sorghum has declined since the 1980s.

Exhibit 2.6 - Missouri Soybean Yields (Bushels Per Acre), 1935-2015



Source: USDA National Agricultural Statistics Service

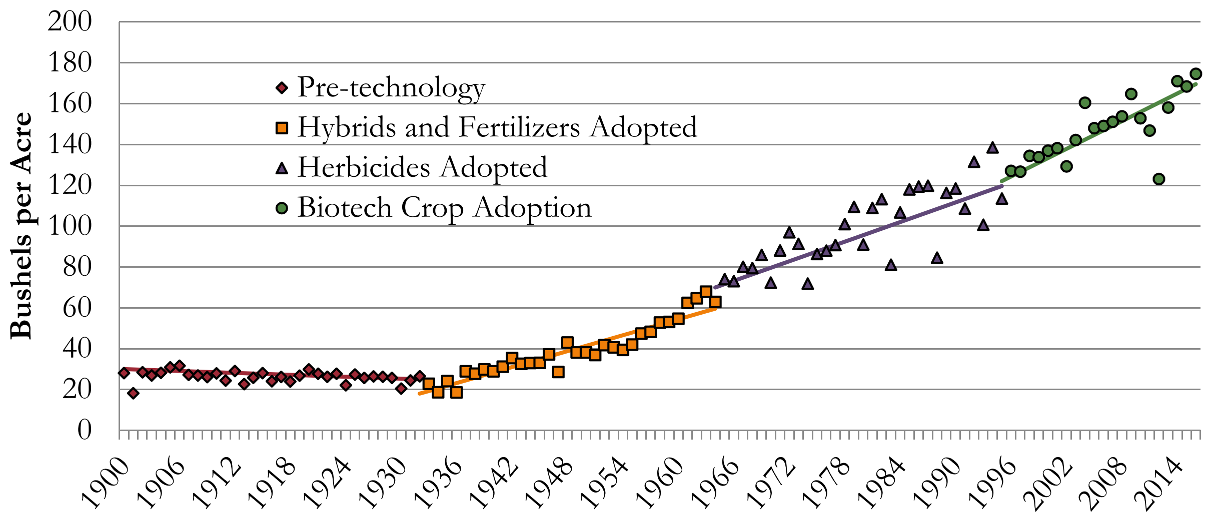
Exhibit 2.7 - Missouri Corn Yields (Bushels Per Acre), 1915-2015



Source: USDA National Agricultural Statistics Service

The importance of improved technology to crop production can be illustrated by the trend in U.S. corn yields per acre since 1900. See Exhibit 2.8. Absent significant soil, technology or genetic improvements, from 1900 to 1930 corn yields actually decreased 0.1 bushel per acre per year. In the 1930s, commercial fertilizers and improved hybrids began being widely adopted. Yields began increasing 1.3 bushels per acre per year. Herbicides were widely adopted in the 1970s, and annual yield increases grew to 1.6 bushels per acre per year. When biotechnology traits began imparting pest and pesticide resistance benefits, yields began increasing at the rate of 1.9 bushels per acre per year.

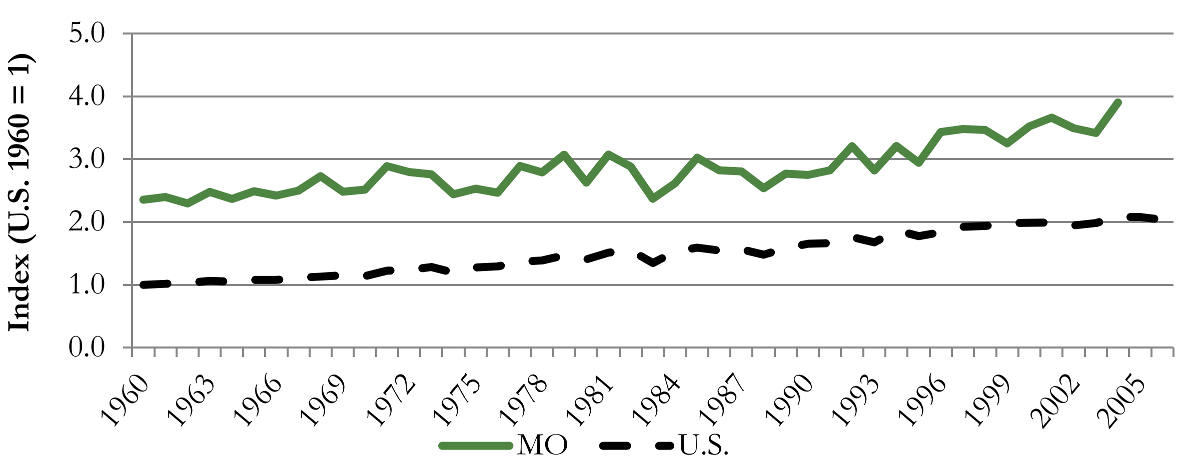
Exhibit 2.8 - U.S. Corn Productivity Showing Technology Impacts, 1900-2016



Source: USDA National Agricultural Statistics Service

The USDA documents this increased productivity for the entire agricultural sector in its Agricultural Productivity Indices. Exhibit 2.9 shows that both the U.S. and Missouri total agricultural output has increased over time. The U.S. data exist for 1950 to 2015; Missouri data only exist for 1960 to 2004. The exhibit shows that Missouri output growth (1.4 percent per year) closely followed U.S. output growth (1.1 percent per year). Although the data do not exist for the most recent decade, it is likely that Missouri has continued to experience increasing agricultural output growth.

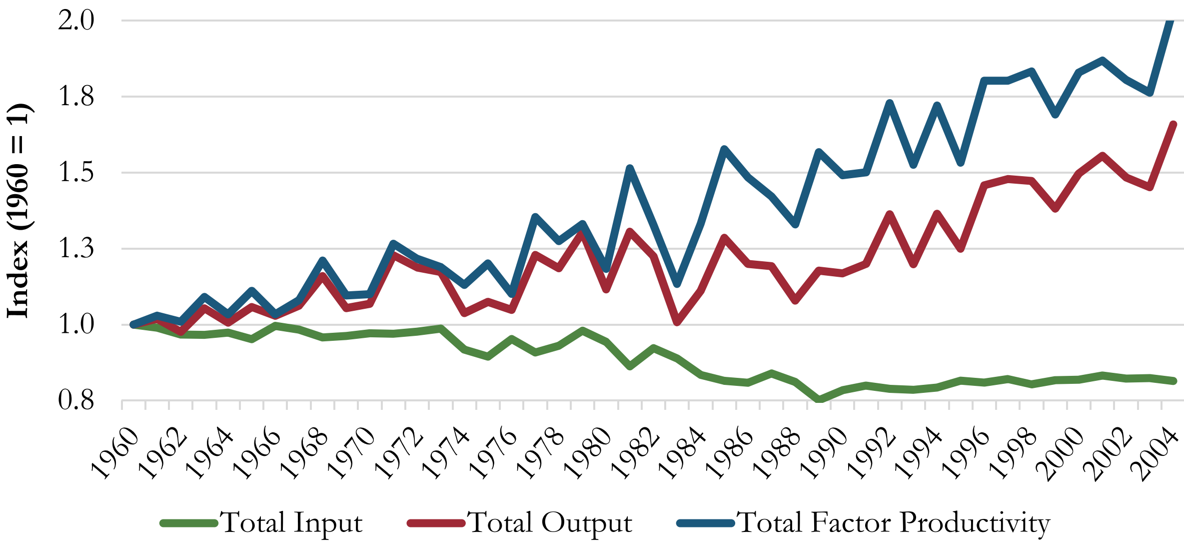
Exhibit 2.9 - Agricultural Output, U.S. and MO, 1960-2006



Source: USDA Economic Research Service

A look at the details of Missouri productivity data show that increased output has been accompanied by decreased input; see Exhibit 2.10. Missouri agricultural output in 2004 was 165 percent of the output in 1960 (rising from an index of 1.0 to an index of 1.65). Agricultural inputs decreased by 15 percent as the index dropped from 1.0 to 0.85 during the same 54-year period. This results in what the USDA calls an increasing total factor productivity — more goods are being produced with fewer inputs. During 2004, Missouri produced agricultural products twice as efficiently (index rising from 1 to 2) as it did in 1960.

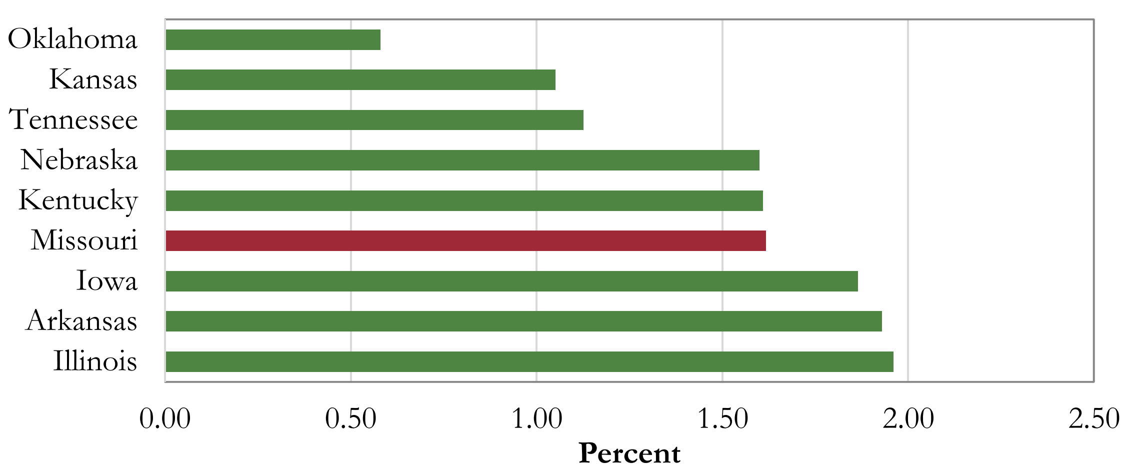
Exhibit 2.10 - Missouri Agricultural Output, Input and Total Factor Productivity, 1960-2004



Source: USDA Economic Research Service

Exhibit 2.11 shows the average annual change in total productivity for Missouri and its seven adjoining states. Missouri's total factor productivity has increased 1.62 percent annually on average. Missouri, Kentucky and Nebraska all had productivity growth rates of about 1.6 percent annually. Three adjoining states — Illinois, Arkansas and Iowa — had higher growth rates, and three states — Oklahoma, Kansas and Tennessee — had lower productivity growth than recorded for Missouri.

Exhibit 2.11 - Agricultural Productivity Growth for Missouri and Adjoining States



Source: USDA Economic Research Service

Production efficiency is a key to achieving environmental improvement. When the majority of inputs are transformed into output, fewer inputs are used, and fewer are released into the environment. Both of these effects lead to better environmental quality.

Throughout this report, it will be discussed how increased crop production efficiency has an impact on environmental quality. Already, this report mentioned fewer acres are necessary for crop production, so more acres are available to parks and forests. Later, production efficiency also will be addressed with regard to fertilizers, pesticides and other measures that affect environmental quality.

3 Trends in Crop Production Affecting the Environment

This section presents various trends in crop production that may affect environmental quality. It is organized by the decisions farmers make rather than by environmental quality measures. When possible, the section summarizes data for Missouri, but in some cases, data for the U.S. or the appropriate regions within the U.S. (e.g. Midwest U.S. or Mississippi River Basin) are reported. The section also summarizes research literature that draws correlations between agricultural production decisions and environmental quality.

This report attempts to report data for 1990 to 2015, a 25-year period that illustrates trends and recent changes in technology use and decision-making. In some instances, data were not available for the entire 1995-to-2015 period, so only the data that were available are reported.

Agricultural production is a system. Tillage can be traded for herbicides. Crop rotation can manage pests and fix nitrogen. Tillage can affect erosion, which affects fertilizer and chemical loss that ultimately affects yield. The following section discusses the environmental impacts of production agriculture and is organized according to certain decisions producers make about practices such as tillage, chemicals and fertilizer. Because of the systems characteristic of agricultural production, some topics overlap and will be repeated.

3.1 Tillage Practices

Highlights:

- Farmers are using less tillage today than in previous years.
- Adoption of less tillage is related to the adoption of herbicide-tolerant crop varieties.
- Less tillage benefits the environment by reducing fuel use, decreasing greenhouse gas emissions, sequestering more carbon, improving soil health and reducing erosion.

Modern crop production uses less tillage and reduces soil erosion relative to crop production in past decades. Prior to the adoption of herbicides, organic practices for weed control was used. Insights into tillage practices over time can be accomplished by comparing organic crop production to current crop production. Iowa State University crop production budgets expect the following seven tillage activities on organic corn and soybean production: plow, tandem disk, field cultivate, rotary hoe (two times) and row cultivate (two times). Their same budgets for conventional crop production expects the use of a chisel plow, tandem disk and field cultivator – four fewer tillage activities (Chase, 2017).

The USDA Agricultural Resource Management Survey (ARMS) the number of tillage operations on planted corn acres declining from 3.0 in 1996 to 1.4 in 2010. For soybeans, the ARMS survey shows number of tillage operations decreasing from 3.1 in 1997 to 1.1 in 2006.

TILLAGE DEFINITIONS

Traditional Tillage

- **Conventional Till**: <15% residue cover after planting
- **Reduced Till**: 15%-30% residue cover after planting

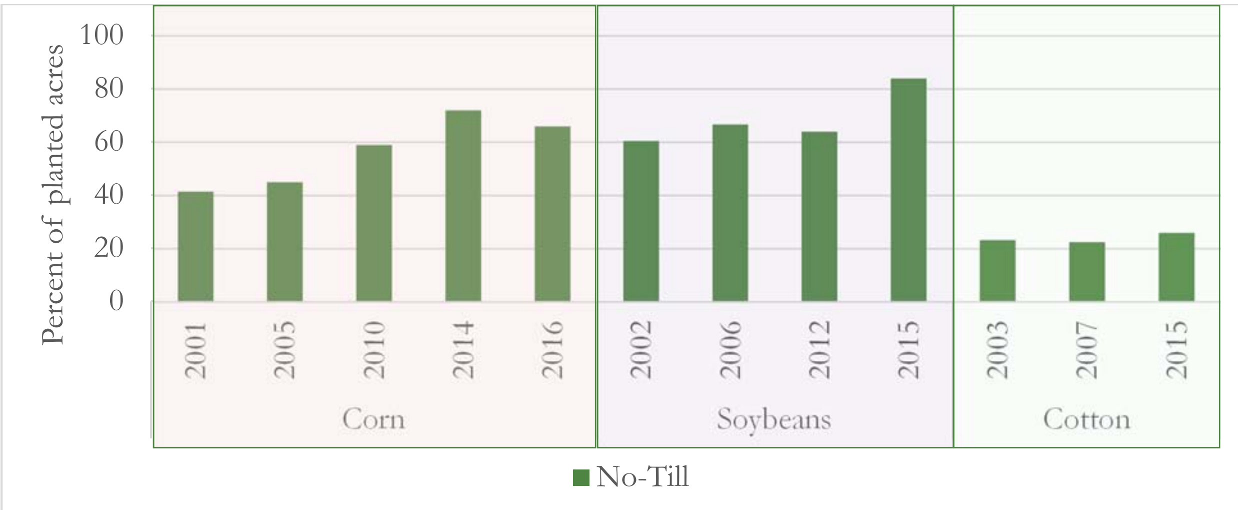
Conservation Tillage (>30% residue cover after planting)

- **Mulch Till**: full width tillage involving one or more trips
- **No-Till**: soil left undisturbed from harvest to planting except for strips up to 1/3 of the row widths

The ARMS survey also reports the percentage of acres that are planted using conservation tillage, defined as no-tillage or tillage leaving 30% of residue. The ARMS data are taken at certain years for certain crops so there is not a continuous data over time.

Exhibit 3.1. shows that conservation tillage in Missouri rose from 41% in 2001 to 72% in 2014. In 2016, the latest date for which ARMS data exist indicates that it was at 66%. Tillage can fluctuate from year to year depending on field and environmental conditions. Soybean adoption of conservation tillage also rose from 2002 to 2015 where it was estimated that 84% of soybean acres used it. Cotton adoption of conservation tillage is around 25% for the period 2003 to 2015.

Exhibit 3.1 – Conservation Tillage Acres for Corn, Cotton and Soybeans Acres in Missouri



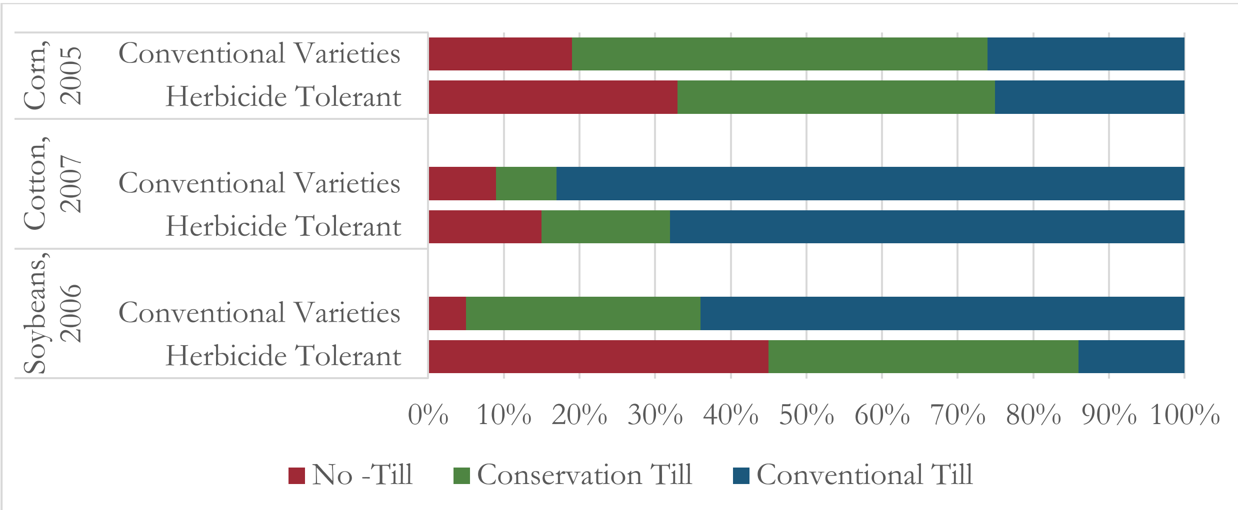
Source: Horowitz, et al and USDA ARMS.

In addition to reducing soil erosion, Horowitz, Ebel and Ueda (2010) stress that the number of no-till acres is reducing greenhouse gas emissions by sequestering more CO_2. They also report that within the Mississippi River Basin, approximately 13 percent of cropland acres in 2009 were in no-till for at least three consecutive years.

Planting herbicide-tolerant varieties of corn, soybean and cotton has facilitated wider conservation tillage adoption. Research from the USDA Economic Research Service and U.S. Environmental Protection Agency assessed the relationship between soybean seed choice — herbicide-tolerant or conventional — and conservation tillage use. Their work found choosing herbicide-tolerant soybeans was linked to an increased likelihood of adopting conservation tillage (Fernandez-Cornejo, Hallahan, Nehring, & Wechsler, 2012).

Exhibit 3.2 summarizes USDA Agricultural Resource Management Survey (ARMS) data that measured conservation and no-till adoption based on whether acreage had conventional or herbicide-tolerant seeds planted. The data support that herbicide-tolerant crop acreage has used more conservation tillage and no-till practices. As an example, conservation tillage was practiced on roughly 86 percent and 32 percent of herbicide-tolerant soybean and cotton planted acreage, respectively. Soybean data were from 2006, and cotton data were from 2007. By comparison, just 36 percent and 17 percent of conventional soybean and cotton planted acreage, respectively, had adopted conservation tillage. Similar trends were noted for no-till adoption in soybeans and corn — acreage planted with herbicide-tolerant seed was more likely to use no-till methods (Fernandez-Cornejo, Wechsler, Livingston, & Mitchell, 2014).

Exhibit 3.2 - Share of Herbicide-Tolerant or Conventional Crop Planted Acreage Using Tillage Practices



Source: USDA Economic Research Service (Fernandez-Cornejo et al. 2014)

The USDA Energy Estimator estimates mulch till and ridge till methods use 20 percent less energy than conventional tillage, and no-till uses 50 percent less energy (USDA NRCS, n.d.). The adoption of conservation tillage practices and improvement in tractor fuel efficiency over time indicates that fuel consumption per unit of production has decreased. This would mean less air pollutants and fewer greenhouse gases emitted in agricultural production.

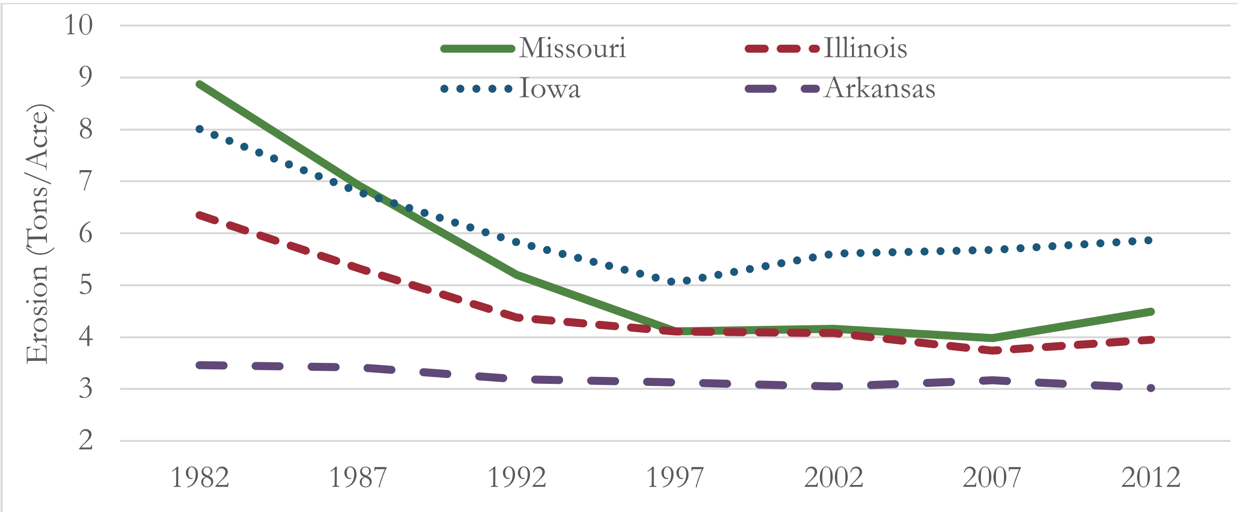
Adoption of herbicide-tolerant crops reduces greenhouse gas emissions and supports soil carbon sequestration as choosing such crop varieties enables producers to use less tillage. From a greenhouse gas perspective, growing soybeans and choosing no-till instead of conventional tillage may decrease fuel used for cultivating and preparing the seedbed by 2.9 gallons per acre. Using reduced tillage would reduce fuel consumption by 1.1 gallons per acre. Relative to conventional tillage, no-till may cut 6.4 gallons of fuel use per acre when raising corn, and reduced tillage would save 0.8 gallons per acre. Assuming that using a gallon of tractor diesel releases 22.3 pounds of carbon dioxide, reduced tillage and no-till can cause carbon dioxide emissions to decline (Brookes & Barfoot, 2016). Several other environmental benefits linked to conservation tillage are decreased soil erosion, improved water retention and reduced soil degradation (Fernandez-Cornejo, Wechsler, Livingston, & Mitchell, 2014).

Research from the University of Nebraska reports farm diesel use per acre declined from 1992 to 2012. The research team divided diesel fuel on farms reported by the U.S. Energy Information Agency by harvested acres in the U.S. to quantify this decline (U.S. Energy Information Administration, n.d.).

Erosion is one measure of agriculture's environmental impact. The USDA National Resource Inventory estimates the erosion per acre for cropland in various states. Their estimate is based on cropping practices, management practices and inherent resource conditions. The USDA changed from using the Universal Soil Loss Equation (USLE) to the revised USLE (called RUSLE2) to estimate soil erosion in 2008.

From 1982 to 2012, erosion rates on cropland decreased from an estimated 8.9 tons per acre to 4.5 tons per acre. This decrease in cropland erosion was greater than that for the surrounding states of Iowa, Illinois and Arkansas (see Exhibit 3.3).

Exhibit 3.3 - Estimated Average Annual Erosion on Cropland, 1982-2012



Source: USDA National Resource Inventory

3.2 Crop Residue Practices and Cover Crops

Highlights:

- Farmers are planting more cover crops.
- Farmers planting cover crops indicate they reduce other inputs such as fertilizer and pesticides and they improve soil health.

The Sustainable Agriculture Research and Education program conducts annual surveys of farmers to discover producers' use of tillage and cover crops. Eighty-eight percent of the farmers that responded to the 2016-2017 survey indicated they plant cover crops. The average area planted in cover crops per responding farmer was 400 acres (Sustainable Agriculture Research and Education, 2017).

Environmental benefits attributed to cover crop adoption include reduced erosion from wind and water, increased soil health and organic matter content, weed suppression, improved soil moisture use efficiency, biological nitrogen fixation in soils and reduced soil compaction. Additionally, cover crops can provide forage and grazing value for livestock producers.

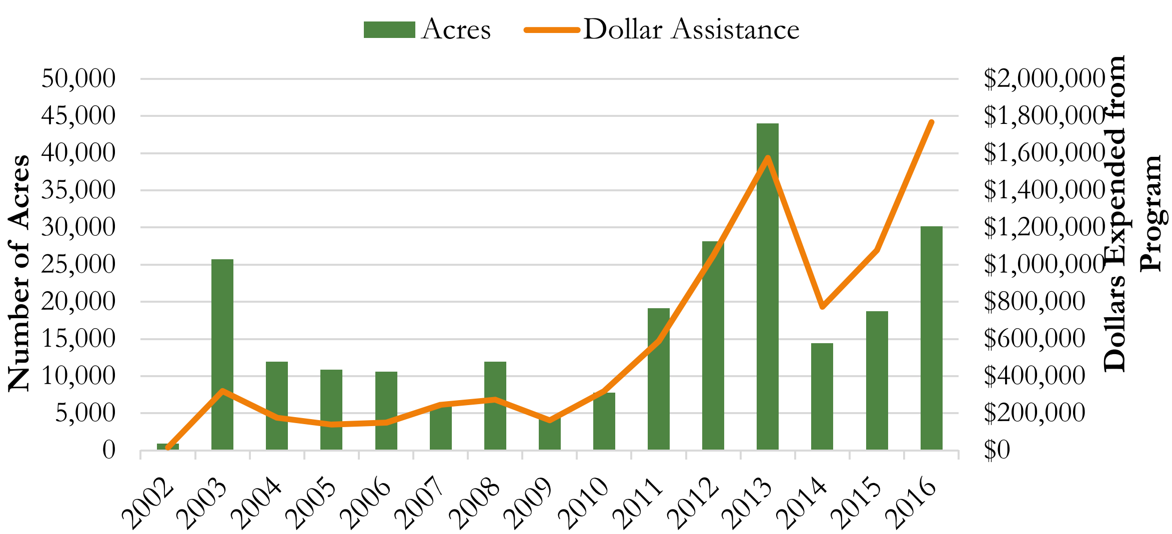
A broad range of cover crops are available to farmers. Cool-season cover crops, which can be planted in fall or early spring, include annual ryegrass, cereal rye, hairy vetch, crimson clover, forage turnips, oilseed radishes, oats, triticale and wheat. Warm-season cover crops, which can be planted in the summer, include buckwheat, cowpea, pearl millet, sorghum-sudangrass, sunflower and sunn hemp.

Farmers select the appropriate cover crop or crop mix by identifying the objectives or benefits they want to achieve and considering a crop's fit with their cropping and tillage systems, location and soil characteristics. Cover crops can be established with conventional row-crop planting machinery (planter or drill) or seeded by broadcast or aerial application. Most cover crops need proper termination by chemical or mechanical methods prior to planting the next crop (corn, soybeans, etc.).

Both state and federal agencies encourage cover crop plantings in Missouri. The Missouri Soil and Water Conservation Program reports that a cover crop practice was applied to 34,218 acres from 1990 to 2005, when the practice ended. A new cover crop practice was implemented statewide in 2015 and has since been applied to 211,289 acres (Plassmeyer, 2018).

The Environmental Quality Incentives Program (EQIP) has also been instrumental in encouraging cover crop adoption. This voluntary program is operated through USDA National Resources Conservation Service (NRCS), and it offers financial assistance to agricultural producers. Producers apply for EQIP funding to plant cover crops. The NRCS ranks the applications based on local, state and national priorities. If accepted, the farmers receive payments for adopting the cover crop practice. The history of the NRCS cover crop assistance program in Missouri is reported in **Error! Reference source not found.**. Acres supported were the highest in 2013 with 44,006. In 2016, Missouri farmers received approximately $1.8 million in EQIP cover crop payments to support 30,163 acres. This year would be the largest financial support provided during the years observed.

Exhibit 3.4 - Missouri EQIP Cover Crop Management Program, Acres and Cost, 2002-2016



Source: USDA National Resources Conservation Service

Farmers plant more acres to cover crops than the EQIP data reveal. EQIP assistance is limited to three payments per acre within the contract period, and the cover crop must not be hayed. The intention is to have farmers recognize the benefits of cover crops and continue using them after the three-year period ends. According to the Sustainable Agriculture Research and Education Cover Crop Survey, 63 percent of farmers who have tried cover crops have used them for four years or more (Sustainable Agriculture Research and Education, 2017).

Cover crop adopters report the following environmental benefits associated with cover crop use:

- Forty-seven percent agree or strongly agree with the statement "Using cover crops has helped me reduce my overall crop inputs (fertilizer, insecticide, herbicide, etc.)."

- Eighty-six percent of users agree or strongly agree with the statement "Using cover crops has improved soil health on my farm."

Although cover crops help with soil health and input use efficiency, note they do require additional fuel and chemicals for planting and termination.

Another project helping farmers improve soil health is the Soil Health Partnership administered by the National Corn Growers Association. Six Missouri farmers have joined more than 100 farmers from a 10-state Soil Health Partnership region in an effort to foster sustainable crop production by emphasizing soil health. Other organizations involved in the Soil Health Partnership include the Walton Family Foundation, the Midwest Row Crop Collaborative, Monsanto, General Mills, the USDA, The Nature Conservancy and the Environmental Defense Fund.

3.3 Fertilizer Usage and Efficiency

Highlights:

- Fertilizer efficiency is increasing as farmers produce more units of crops per unit of fertilizer.
- Farmer-documented adoption of improved nutrient management practices is low, but it is likely increasing.
- The amount of nitrogen fertilizer applied in excess of crop removal has been steady over time, and the quantity found in Missouri rivers has been fairly constant over time.
- The amount of phosphorus fertilizer applied in excess of crop removal has been decreasing over time, but the quantity found in Missouri rivers has been trending up over time.

Fertilizers are essential for sustainable crop production, and worldwide, nearly 40 percent of the protein consumed by humans is derived from food which had synthetic nitrogen fertilizers applied (Smil, 2002). The development and adoption of modern, high-concentration fertilizers after World War II contributed directly to the rapid increase in the yields of corn, soybean and other grain crops.

Adoption of Improved Management Practices

The 4R's philosophy promotes practices associated with increased nutrient stewardship and efficiency. It encourages farmers to apply nutrients of the right source at the right rate, right time and right place. Practices promoted in this program include incorporating a nitrogen stabilizer, using grid soil sampling, implementing variable-rate technology, splitting nitrogen applications, testing plant tissue, operating equipment with GPS guidance and adopting satellite imaging (The Fertilizer Institute).

Limited current data describe farmer adoption of 4R practices. Exhibit 3.5 highlights Missouri adoption of several 4R practices between 2006 and 2010 based on data from recent USDA Agricultural Resource Management Surveys. Nitrification inhibitor use was most widespread in rice, 39 percent of 2006 planted acreage, followed by cotton and corn, an estimated 21 percent and 12 percent of planted acreage, respectively. The USDA data indicate testing plant tissues and applying fertilizer with variable-rate technology had relatively limited adoption before 2010. Guidance or auto-steering systems, which can assist in the right placement of fertilizers, were used on more than one-third of Missouri corn acres during 2010 compared with an estimated 12 percent of sorghum planted acreage in 2003 (USDA ERS, 2017). It is recognized that these data are seven years to 14 years old. Anecdotal evidence, such as the increased number of variable-rate fertilizer applicators and sales of auto-steering systems, indicates adoption is likely higher now.

Exhibit 3.5 - Missouri 4R Nutrient Stewardship Practice Adoption Rates, Percent of Planted Acres

	Corn, 2010	Cotton, 2007	Rice, 2006	Sorghum, 2003	Soybeans, 2006	Winter Wheat, 2009
Nitrification inhibitor	12%	22%	39%	5%	NA	NA
Plant tissue test	NA	9%	5%	NA	NA	NA
VRT for fertilizing	NA	2%	NA	NA	3%	7%
Guidance or auto-steering system	35%	NA	NA	12%	NA	NA

NA: Estimate does not comply with NASS disclosure practices, is not available or is not applicable.
Source: USDA Agricultural Resource Management Survey (2017)

Application timing is another consideration. Twenty percent of 2010 corn acreage received nitrogen fertilizer in the fall, when it is at greatest risk to escape into the environment. Eighty percent of corn acreage received nitrogen fertilization in the spring before planting, at planting or after planting (USDA ERS, 2017).

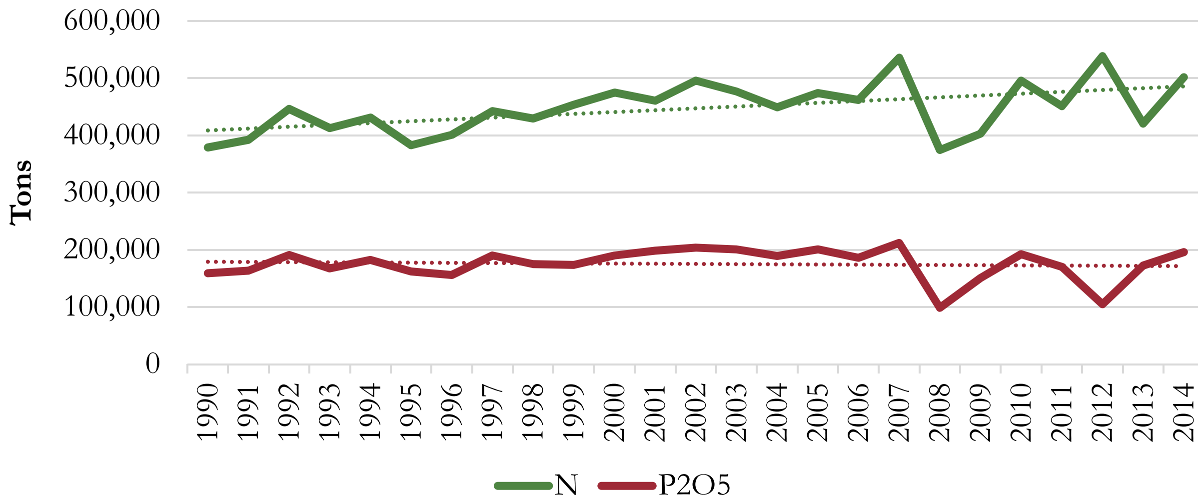
Nutrient Efficiency

Missouri Plant Food Control Service data in Exhibit 3.6 document that the quantity of nitrogen fertilizer shipped in Missouri increased by about 20 percent from 1990 to 2014, and the tons of phosphate fertilizer shipped in Missouri has remained constant (University of Missouri, 2014). During the same time period, yields and associated nutrient removal in the grain increased — by 25 percent for soybean and nearly 40 percent for corn. See Exhibit 2.6 and Exhibit 2.7 in an earlier section.

For phosphorus, the apparent fertilizer nutrient balance per acre averaged about zero in the decade since 2004, down from a historic average (1990-2004) of 10 pounds of phosphate fertilizer above crop removal; see Exhibit 3.7. These simple comparisons imply Missouri farmers improved the fertilizer use efficiency and gained more yield per unit of commercial fertilizer sold during this observed time period.

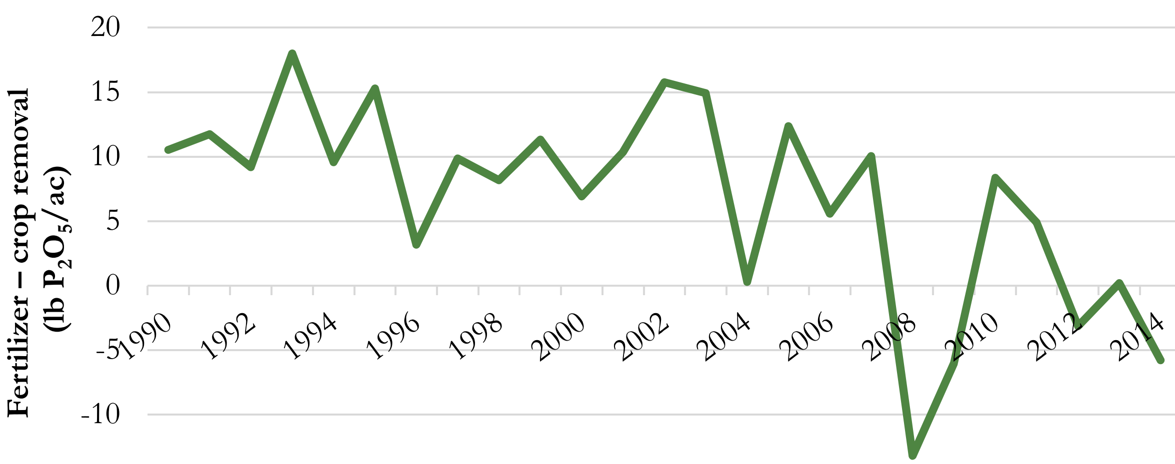
There are limits to using fertilizer data alone to assess crop nutrient efficiency. The first assumption is all phosphorus fertilizer used in Missouri is for row-crop production. This overestimates the phosphorus applied to row crops because nutrients applied to pasture and hay ground are attributed to row crops. A second assumption is the only source of phosphorus applied to cropland is commercial fertilizer. This underestimates the phosphorus applied to row crops because some phosphorus is supplied by manure. The USDA data for Missouri indicated that in the period from 2006 to 2010, eight percent of wheat acres, five percent of corn acres and two percent of soybean acres received manure applications (USDA ERS, 2017).

Exhibit 3.6 - Tons of Commercial Fertilizer Nutrients Shipped in Missouri, 1990-2014



Source: Missouri Plant Food Control Service

Exhibit 3.7 - Estimated Net Phosphorus Balance Per Planted Cropland Acre in Missouri, 1990-2014

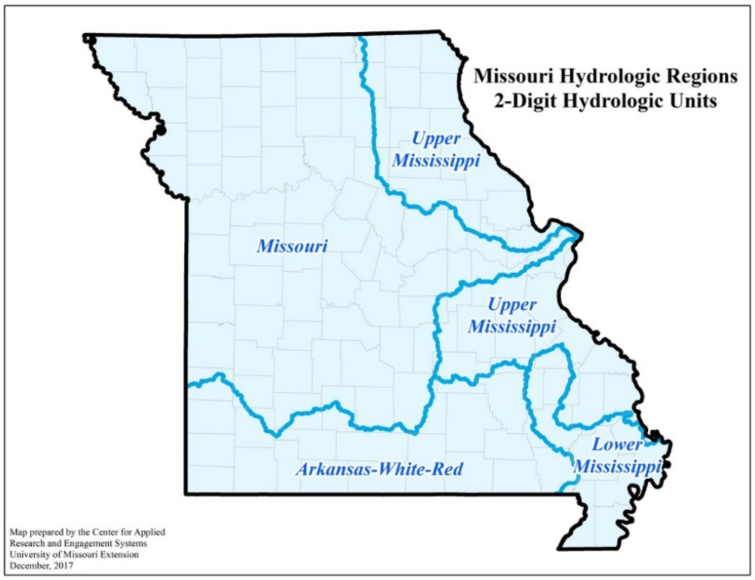


Source: Missouri Fertilizer Tonnage Report, 2014 and data from USDA QuickStats.

The International Plant Nutrient Institute (IPNI) suggests that partial nutrient balance (PNB) is the relevant measure of fertilizer efficiency for environmental nutrient risk assessments (IPNI Scientists, 2014). The partial nutrient balance for nutrients is defined as quantity of nutrient supplied by commercial fertilizers, manure and biological fixation processes less the quantity of nutrients removed by crop harvest. When nitrogen and phosphate applied as fertilizer equal the amount removed by crops, additions of nutrients to the environment from agriculture are minimized.

In a 2017 report, IPNI reported the partial nutrient balance for both nitrogen and phosphorus for the five sub-basins of the Mississippi River Basin. Three of those basins include most of the row-crop production in Missouri; see Exhibit 3.8. The Missouri River sub-basin covers much of the productive cropland of western Missouri. The lower Mississippi sub-basin covers the productive cropland of southeast Missouri. The Upper Mississippi sub-basin includes the two easternmost tiers of counties in Missouri where significant crop production occurs. The areas of Missouri found in the Arkansas/Red River sub-basin are predominately pasture, hay and forestland, so the Arkansas/Red River sub-basin is not included in this report. Reported partial nutrient balances are for the entire sub-basin areas, including land not in Missouri. However, they are the most comprehensive published nutrient balances available that include Missouri cropland.

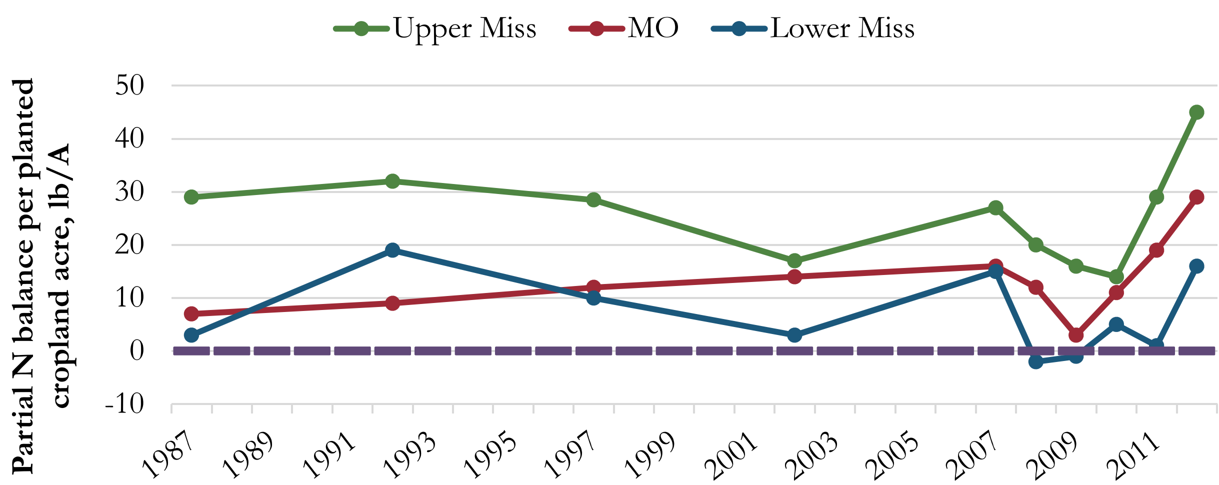
Exhibit 3.8 - Mississippi River Sub-basins in Missouri



Source: University of Missouri Extension

Exhibit 3.9 shows the estimated partial nutrient balance for nitrogen for the various Mississippi River Basin sub-basins. Note each of these sub-basins contain part of Missouri, but they also contain cropland from several other states. The results below are for the entirety of the sub-basin rather than just the portions in Missouri.

Exhibit 3.9 - Net Nitrogen Balance Per Planted Cropland Acre, Pound Per Acre, 1987-2012

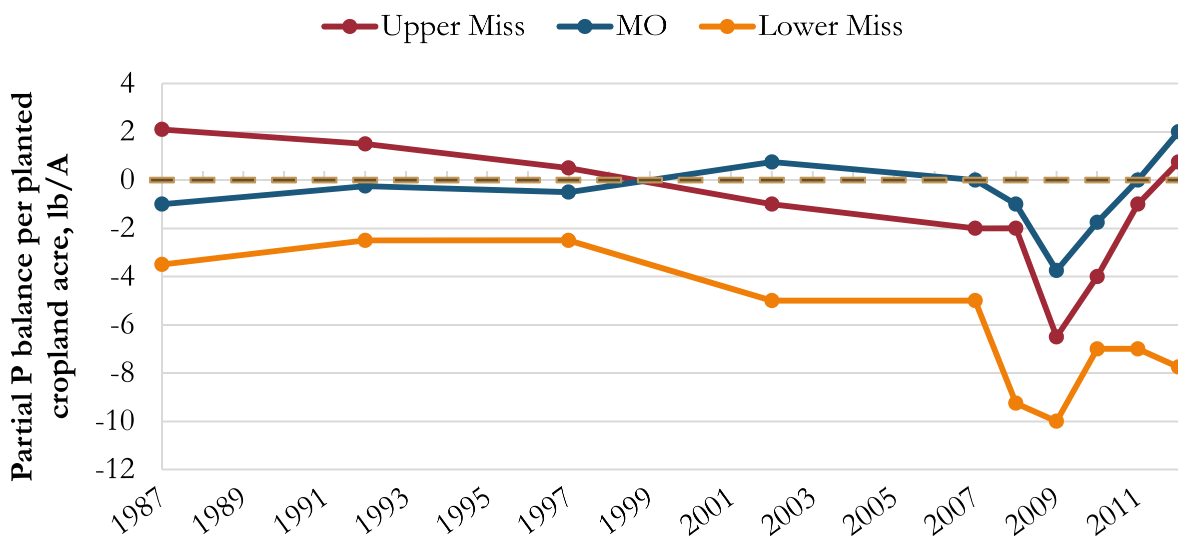


Source: Snyder, C., 2017

The three relevant Mississippi river basins document a negative trend in phosphate partial nutrient balance averaging less than zero across the three sub-basins. See Exhibit 3.10. The partial nutrient balance for nitrogen averaged 14 pounds nitrogen per acre for 1987 to 2011 with no strong positive or negative trend.

Annual variability in the partial nutrient balance in Exhibit 3.9 and Exhibit 3.10 illustrates the impact of fertilizer applied and yield. Increasing global fertilizer prices in 2007-2009 resulted in less fertilizer applied and lower partial nutrient balances during that period. The high partial nutrient balances in 2012 were due to dramatically reduced yields related to the severe drought experienced by the U.S. Corn Belt. (Snyder, 2017).

Exhibit 3.10 - Net Phosphorus Balance Per Planted Cropland Acre, Pound Per Acre, 1987-2012



Source: Snyder, C., 2017

Generally, state fertilizer use statistics and regional partial nutrient balances support the claim that nutrient use efficiency has remained constant or improved and that row-crop yields continue to increase over time.

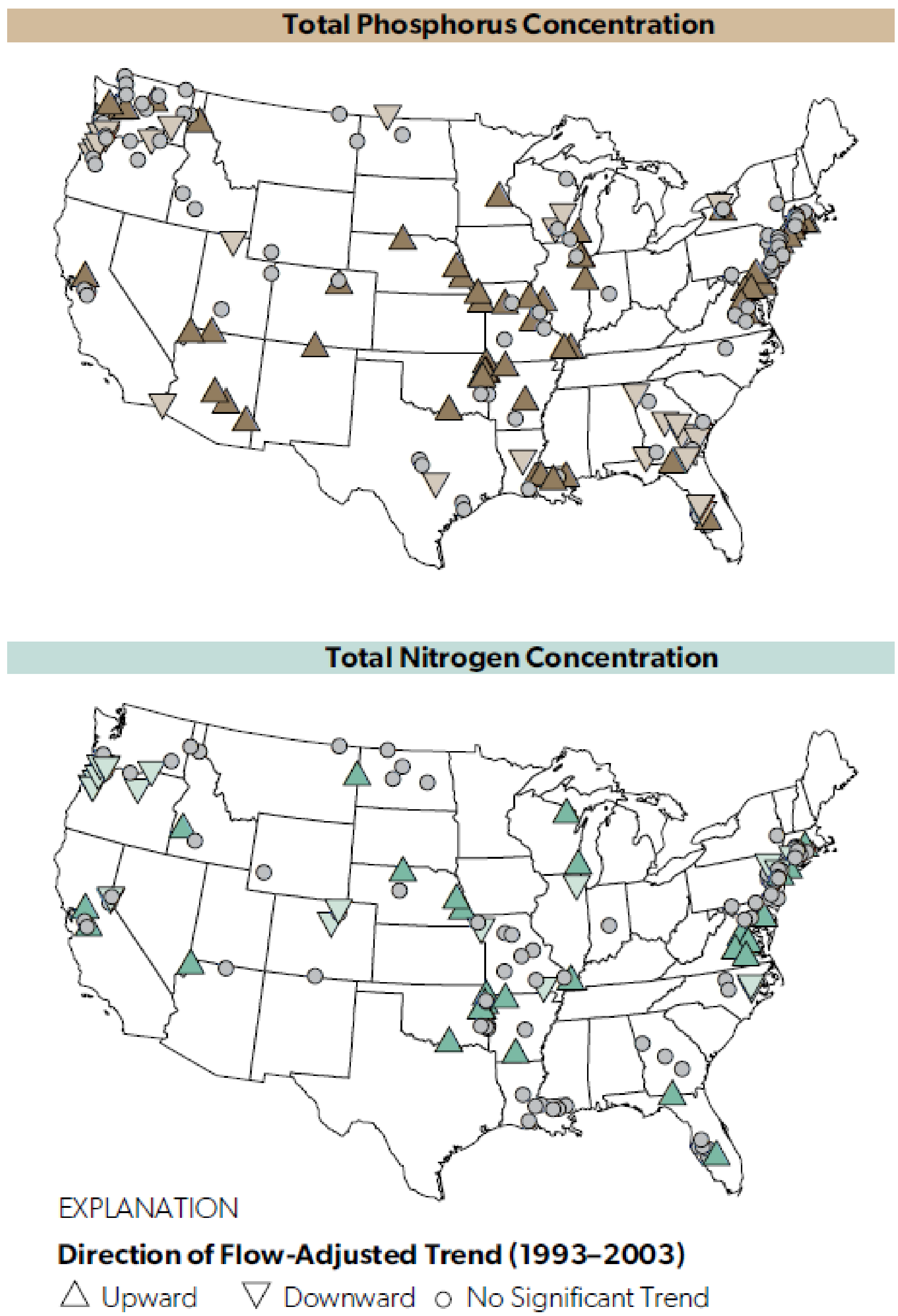
Impacts of Nutrients on Water Quality

Farmers seek to keep applied fertilizers on the fields so the nutrients are available for crop production. As more applied fertilizers are taken up by crops, less is available to move from the land into the water or air. Fertilizer which is applied to cropland and subsequently enters water can cause various negative impacts. Most generally, fertilizer in water can cause excessive plant and algal growth, called eutrophication. This may result in dissolved oxygen depletion affecting aquatic life, and in the most extreme cases, it may lead to the release of compounds toxic to animals.

Crop nutrients, particularly nitrogen and phosphorus, which leave the field and enter waters may eventually flow into the Mississippi River and enter the Gulf of Mexico. The increase in nutrients in the Gulf of Mexico has created a "dead zone" caused by low oxygen conditions, called hypoxia.

The U.S. Geological Survey monitors water flow and nutrient concentrations within the Mississippi River Basin (Dubrovsky, 2010). Exhibit 3.11 shows the direction of the flow-adjusted trend of nitrogen and phosphorus at various locations in the U.S. between 1993 and 2003. Phosphorus concentration in Missouri rivers trended upward or remained constant from 1993 to 2003. On the other hand, nitrogen concentrations in Missouri rivers held constant or trended downward from 1993 to 2003.

Exhibit 3.11 - Measured Phosphorus and Nitrogen Concentrations in U.S. Waters



Source: Dubrovski and Hamilton.

Another study by the USGS analyzed nitrogen concentrations in rivers in the Mississippi River Basin from 1993 to 2003 (Murphy, 2013). The report found that the concentration at the Hermann, MO monitoring site was among the lowest in the study that monitored sites in Iowa, Illinois and Louisiana. However, they also found that the Hermann, MO monitoring site had a substantial increase in the flow-adjusted trend of nitrogen. The concentration rose from about 1 mg/l to 1.5 mg/l.

Murphy et al. (2013) suggest that legacy nutrients may be responsible for increases in nitrogen and phosphorus concentrations over time even while net nutrient balances are decreasing. Legacy nutrients are nutrients added to the system earlier which are belatedly showing up in water samples due to release of groundwater or erosion of stream banks.

Nitrogen and phosphorus contributing to hypoxia in the Gulf of Mexico comes from different sources. Robertson and Saad (2013) estimated that 60 percent of nitrogen and 48 percent of phosphorus loading in the Mississippi-Atchafalaya River Basin are from agricultural sources.

Missouri Innovations

In addition to river water quality monitoring, personnel in the Missouri NRCS developed a protocol for edge-of-field monitoring used by several states in the Mississippi River Basin. The protocol helps provide qualitative data to determine the amount of nitrogen and phosphorus runoff entering the Mississippi River through sediment (USDA NRCS, n.d.).

To further sustainable fertility practices, the University of Missouri under the supervision of Dr. John Lory obtained monies from the USDA Agricultural Food and Research Initiative, the Missouri Corn Growers and the Missouri Soybean Merchandising Council. The work will dramatically expand the predictive value and decision power of data collected in on-farm experiments, which are often called on-farm strip trials, by applying the newest methods of data analysis based on spatial statistics. The research is expected to reduce the amount of phosphorus applied to cropland without sacrificing yield.

3.4 Chemical and Pesticide Use

Highlights:

- Farmers are using more pounds of pesticide.
- Almost 100 percent of crop acres have some type of pesticide applied to them.

Pesticides invoke images of killing because, by definition, “cide” means “killer.” Pesticides used in agriculture include fungicides, herbicides, insecticides, rodenticides and nematicides.

The proper use of pesticides has helped crop production become more efficient and sustainable. Herbicide use allows for less tillage. Insecticide use allows crops to yield more per plant and acre. Fungicide use allows grain to be in better condition and maintain its nutritional and processing quality for longer periods of time.

PESTICIDES IN AGRICULTURE

- **Fungicides**
- **Herbicides**
- **Rodenticides**
- **Nematicides**
- **Soil fumigants**
- **Plant growth regulators**
- **Defoliants**
- **Desiccants**

The quantity of pesticides used is increasing and is likely to continue to increase. Factors contributing to increased pesticide use include the introduction of invasive species of pests, the development of pesticide resistance in pests formerly controlled and the development of new pesticides for previously uncontrolled pest problems (Council for Agricultural Science and Technology, 2014).

Several factors have contributed to changes in U.S. pesticide use. For example, as pesticide effectiveness improves, application rates shift. Adopting integrated pest management (IPM) practices, such as rotating crops, alternating chemistries and using enhanced spray technologies, has affected pesticide needs. Additionally, evolving pesticide use has been attributed to farms adopting genetically modified crops, implementing conservation methods, responding to regulatory changes and changing their planted acreage allocations (Fernandez-Cornejo, et al., 2014).

The USDA NASS Agricultural Chemical Use Survey tracks pesticide adoption by crop for key production regions (not exclusive of Missouri). Exhibit 3.12 summarizes the share of planted U.S. corn, cotton, rice, soybean and winter wheat acreage which had various treatments in years with the most recent data available. Note Agricultural Chemical Use surveys are not conducted each year for every crop. For four of the five crops, the table shows that more than 90 percent of U.S. planted acreage had some type of pesticide applied during the most recent year for which data is available. Winter wheat was the exception (USDA NASS, various).

During recent years, herbicide treatments had the most extensive use on U.S. acreage; in most cases, more than 90 percent of planted acreage was treated with herbicide. In cotton, insecticide use was prevalent during 2015, and other crops used insecticide to a lesser degree. Fungicide applications have been most common in rice, an estimated 49 percent of planted acreage in 2013, and winter wheat, an estimated 19 percent of planted acreage in 2015. Seventy six percent of U.S. cotton planted acreage in 2015 had been treated with "other" pesticides, such as growth regulators and defoliants (USDA NASS, various).

Exhibit 3.12 - Estimated Share of U.S. Planted Crop Acreage Treated with Any Pesticide

Crop (data year)	Insecticide	Herbicide	Fungicide	Other
Corn (2016)	16%	97%	12%	1%
Cotton (2015)	40%	92%	1%	76%
Rice (2013)	28%	97%	49%	4%
Soybeans (2015)	22%	96%	11%	1%
Winter wheat (2015)	5%	61%	19%	NA

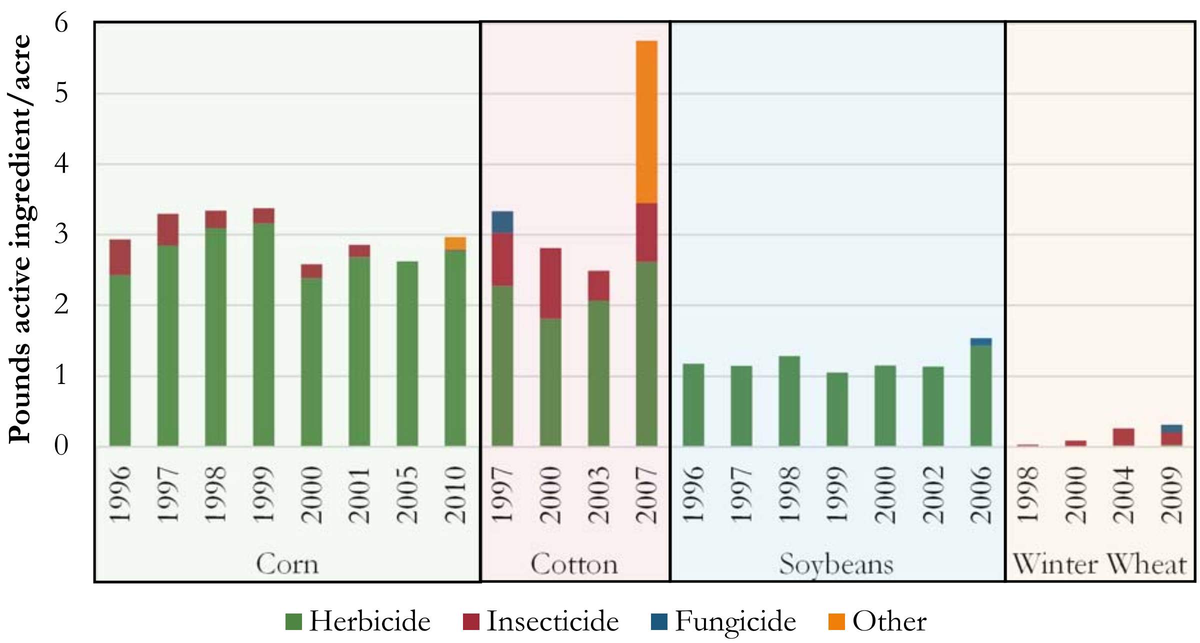
NA: Estimate doesn't comply with NASS disclosure practices, is not available or is not applicable.
Source: USDA NASS Agricultural Chemical Use Survey (multiple years)

When the USDA data are available for Missouri only, it reveals that MO is similar to the U.S. Trends over time indicate that Missouri corn and soybean acres that have been treated with herbicides has remained over 90 percent almost every year since 1990. Missouri wheat acres receiving herbicides have risen from between 10 percent in 1990 to 40 percent in 2015. Insecticide-treated acres in corn dropped from a high of 44 percent in 1998 to 16 percent in 2012. Insecticide-treated acres in wheat increased from a low of 8 percent in 2004 to 22 percent in 2015 (USDA NASS).

USDA ARMS data document the amount of pesticides applied in Missouri. Exhibit 3.13 shows the quantity of pesticides applied for principal crops grown in Missouri. Herbicide use in corn reached a maximum in 1999, decreased in 2000 and trended upward until 2010, the last year reported. Corn use of insecticides decreased from 1996 to 2001, after which insufficient data exist to estimate applications (USDA ERS, 2017).

Missouri soybean acreage has had a slight uptick in the use of pesticides. The USDA documented the quantity of fungicide applied to soybean for the first time in 2006. Use of pesticides on cotton trended downward until 2007 when it had a sharp upturn. The majority of the increase was due to increases in other pesticides — defoliants and plant growth regulators — which were reported for the first time in 2007. It is unclear whether these "other pesticides" were included in previous estimates. Winter wheat, which uses the least amount of chemicals per acre, has also seen an increase in the quantity of pesticides applied since 1998. Increases in insecticides and fungicides in 2009 accounted for much of the increase in wheat pesticide use in Missouri (USDA ERS, 2017).

Exhibit 3.13 - Chemical Applications Per Acre by Crop in Missouri, 1996-2010



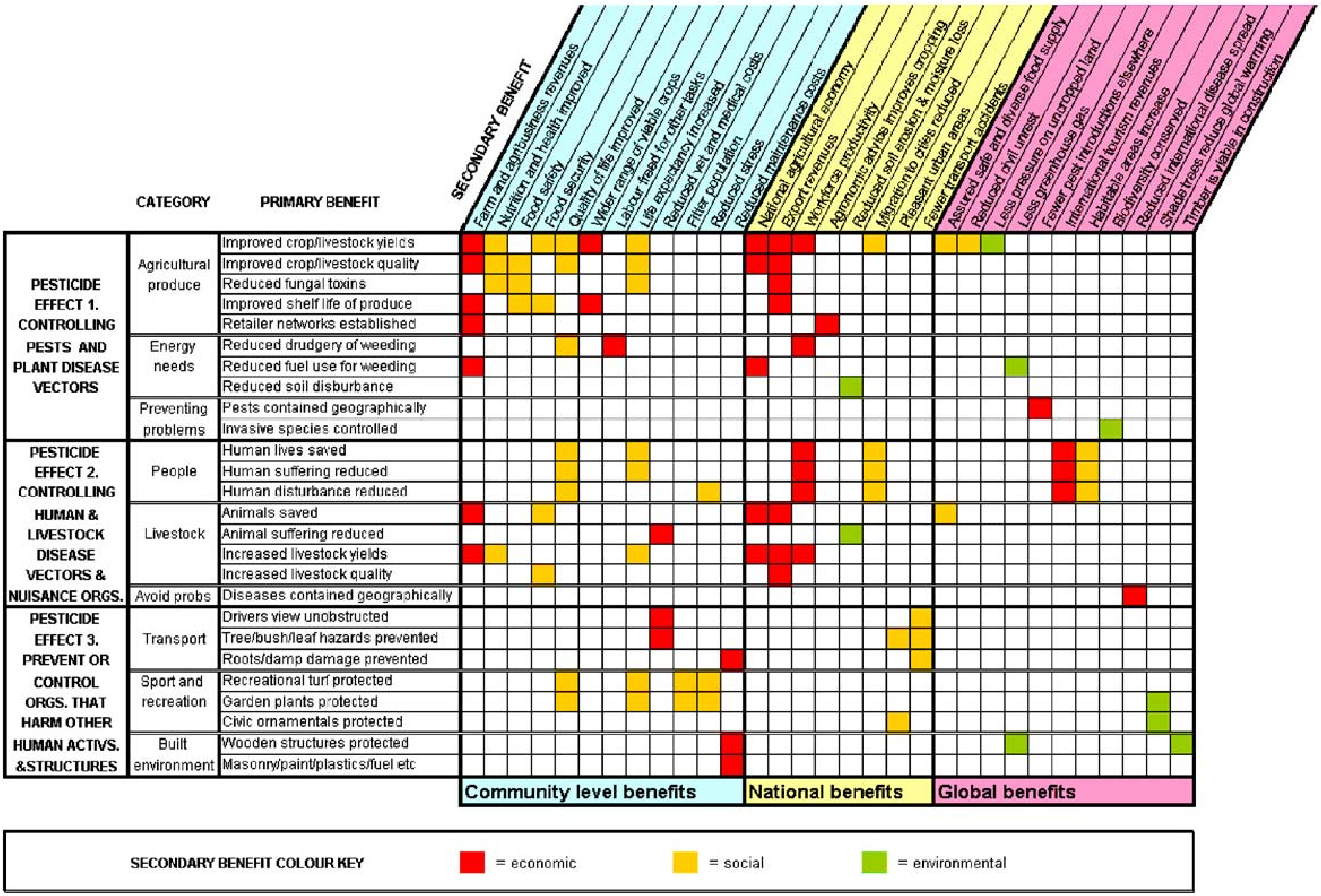
Source: USDA ARMS Survey

Exhibit 3.14 summarizes the economic, social and environmental benefits of various types of pesticides (Cooper & Dobson, 2007). The primary benefit refers to benefits that are immediate and incontrovertible. Secondary benefits are longer term and more difficult to establish causality.

Crop Life America estimates that 32% of field crop value, defined as yield times price, is attributable to crop protection products such as herbicides, fungicides and insecticides. Their analysis attributes insecticide use with 4% of this benefit; fungicide use with 3%; and herbicide use with 25% in Missouri.

Gianessi and Reigner (2006) estimate the percent of yield attributable to fungicides for various U.S. crops to be 19% for wheat and soybeans, and 14% for cotton (Gianessi & Reigner, 2006). In another journal article, Gianessi and Reigner (2007) estimate percent of yield attributable to herbicides for various U.S. crops. They estimate yield gains of 20% for corn, 26% for sorghum and soybeans, 25% for wheat and 27% for cotton (Gianessi & Reigner, The Value of Herbicides in U.S. Crop Production, 2007).

Exhibit 3.14 - Benefits of Pesticides



Source: Jerry Cooper and Hans Dobson, Crop Protection 26 (2007) 1337–1348

Herbicides have also been found responsible for increasing corn yields up to 8% by allowing earlier planting of full season hybrids because mechanical destruction of weeds prior to planting is not necessary (Council for Agricultural Science and Technology, 2014).

3.4.1 Herbicides

Highlights:

- Farmers are using more pounds of herbicide.
- The acute hazard quotient associated with herbicides increased for winter wheat but decreased for corn, soybean, cotton and rice from 1990 to 2015.
- The chronic hazard quotient associated with herbicides remained relatively flat for corn and winter wheat but increased for cotton and decreased for soybean and rice from 1990 to 2015.
- Herbicide resistance in weeds is creating challenges for Missouri farmers.
- Without herbicides, crop production would become less efficient, and acreage would have greater erosion problems.

Herbicide use in row-crop production has increased during the past 10 years in Missouri and the rest of the U.S. Corn, soybean and cotton are predominately glyphosate-resistant crops. The Union of Concerned Scientists (2012) has blamed the increased use of herbicides on glyphosate-resistant crop production. However, data indicate herbicide applications to rice and wheat, which have no GMO varieties, have also increased.

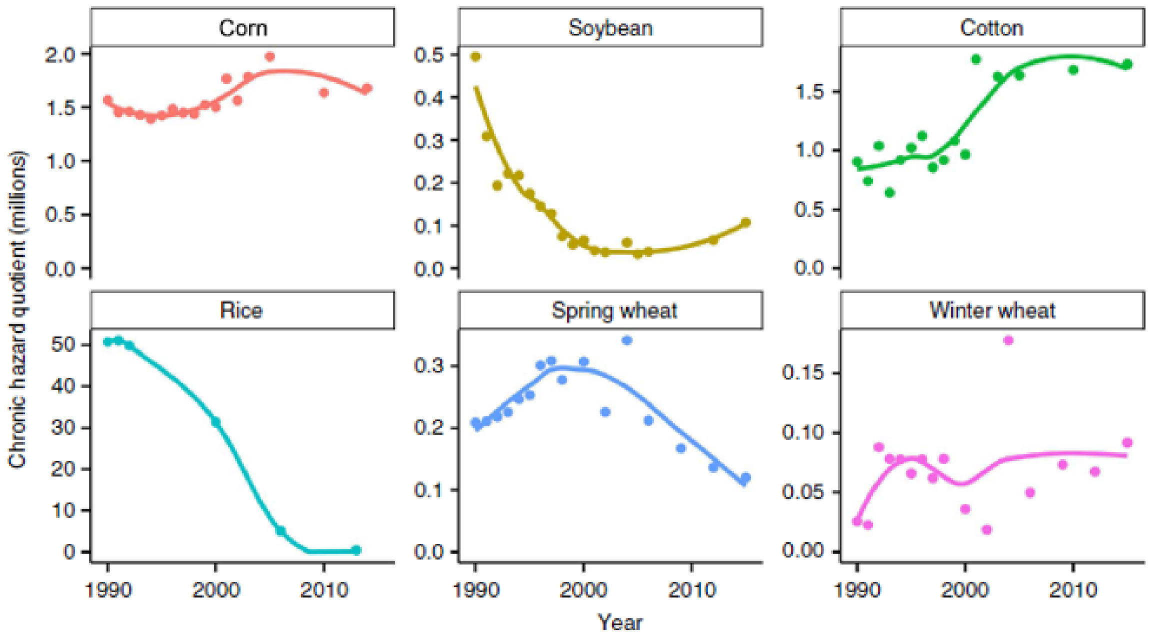
The environmental impact of the increased herbicide use is best measured using a hazard quotient approach. The toxicity of each herbicide represents the hazard, and the amount of the herbicide applied represents an estimate of exposure. Chronic toxicity is measured as the 24-month oral rat no observable effect level (NOEL). See Exhibit 3.15. Acute toxicity is measured by the oral dose that kills 50 percent of rats (LD50). See Exhibit 3.16.

For corn, the herbicide chronic hazard quotient from 1990 to 2015 initially increased but declined more recently. The herbicide acute hazard quotient, however, decreased significantly during the observed period. Both chronic and acute hazard quotients decreased markedly in soybean and rice production. Cotton's herbicide chronic hazard quotient increased from 1990 to 2015. The cotton herbicide acute hazard quotient decreased from a peak in 1994, increased later in the observed period but is still lower than it was in 1990. Winter wheat herbicide chronic and acute hazard quotients rose from 1990, dipped in the early 2000s and later increased.

Herbicides benefit farmers by providing better, more reliable weed control at a lower cost than tillage. Better weed control results in higher yields and increased incomes. Herbicide use has also reduced farm-related injuries from hoeing and use of farm equipment (Harman, Regier, Wiese, & Lansford, 1998). University of Missouri research documented that farmers stopped cultivating between corn rows because it was time-consuming and inefficient (Rikoon, Vickers, & Constance, 1993).

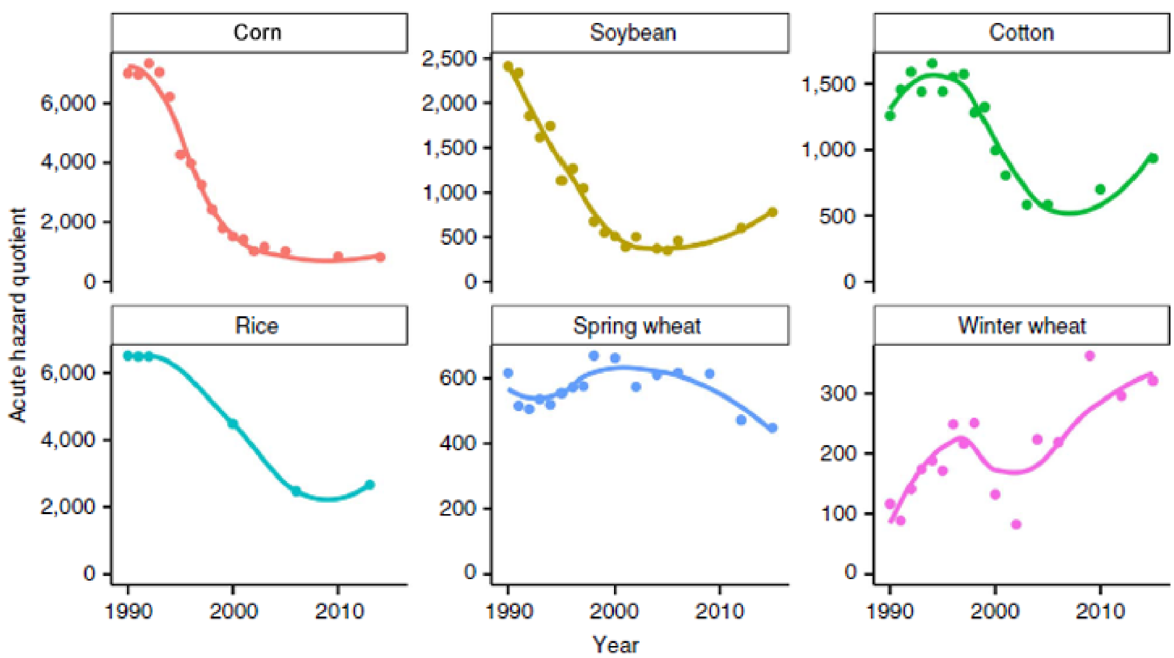
Apart from the toxicity measure, herbicides also benefit the environment. Replacing cultivation with herbicides has resulted in lower carbon emissions from both less fuel use and greater carbon sequestration, less soil erosion, less soil compaction and less water use.

Exhibit 3.15 - Herbicide Chronic Hazard Quotient, 1990-2015



Source: Kniss, Nature Communications

Exhibit 3.16 - Herbicide Acute Hazard Quotient, 1990-2015



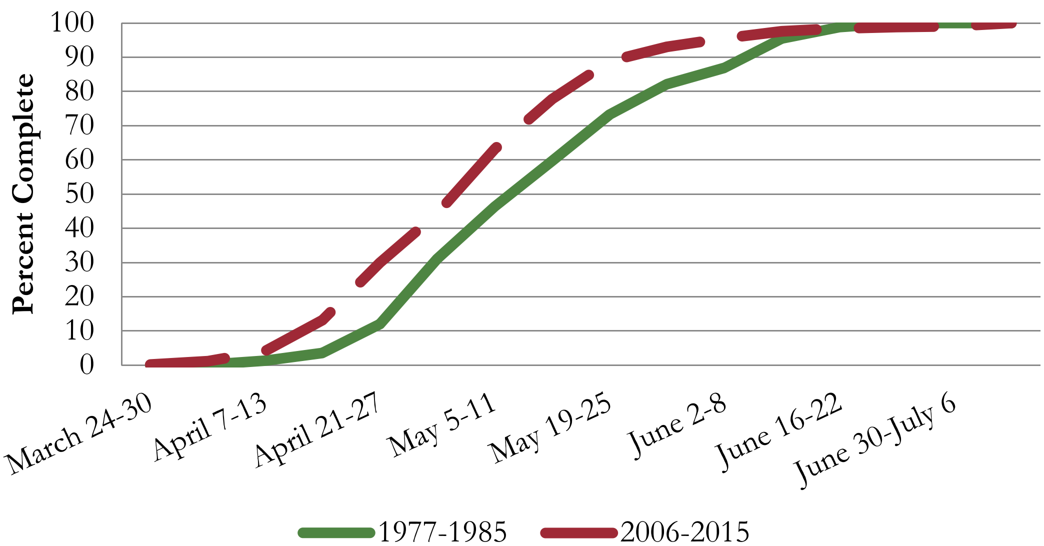
Source: Kniss, Nature Communications

Herbicide use has also allowed producers to choose higher-yielding, full-season corn hybrids. With herbicide applications as a possible production tool, producers may plant before the first population of weeds germinate. Exhibit 3.17 illustrates how planting dates at the 50 percent planting mark are about 10 days earlier in northwest Missouri, a finding consistent with other crop reporting districts in

Missouri. This has contributed to the ability to produce more crops on an acre of land and allocate other land tracts to purposes such as growing pasture and trees.

The Weed Science Society of America estimates weed interference in soybean production without weed control measures (tillage or herbicides) caused an average 52.1 percent yield loss from 2007 to 2013 in the U.S. and Canada. The society estimated the loss in Missouri to be 100 million bushels per year. This loss dramatizes the importance of tillage or herbicide use in sustainable soybean production. Any estimate of the environmental risk of weed control practices needs to be considered in light of the benefit from those practices (Soltani, et al., 2017).

Exhibit 3.17 - Corn Planting Progress in Northwest Missouri



Source: USDA Crop Progress and Condition Reports

Dicamba injury to nonresistant plants occurred in both 2016 and 2017. In 2017, the Missouri Department of Agriculture investigated complaints of dicamba injury to soybeans, tomatoes, watermelons, cantaloupes, organic vegetables, pumpkins, peaches, grapes, mums, residential gardens and pecan and apple trees.

Dicamba movement during the growing season can harm not only row crops but also tree species such as oak and elm (Bradley, 2017). Dicamba in the salt form is not expected to harm birds; in the acid form, however, it is slightly to moderately toxic to birds. It is not likely to harm fish (National Pesticide Information Center, 2012). Pollinators can be affected due to dicamba drift because the drift may delay and reduce flowering of nontarget plants (Jeunesse, 2015).

University of Missouri scientists have been at the forefront of efforts to document dicamba drift and have created a website that records and reports temperature inversions in an effort to reduce dicamba movement (University of Missouri Extension, n.d.).

3.4.2 Insecticides

Highlights:

- Farmers are using fewer pounds of insecticide.
- Farmers have adopted better management practices called integrated pest management.
- Chemical companies have developed safer insecticides, which have a less significant environmental footprint.

Concerns with the use of insecticides abound. Contamination of water and soil resources can negatively affect birds, fish and mammals. Agricultural worker and food safety concerns also arise.

The USDA reports insecticide use peaked in 1972 with 158 million pounds being used. In contrast, 29 million pounds were used in 2008 (Fernandez-Cornejo, et al., 2014).

The level of testing required to introduce a new insecticide along with the safeguards enforced by state and federal regulatory agencies have mitigated many of these concerns. During the past 30 years, new pesticides have been introduced to be safer to use, have a lower environmental footprint, be more pest-specific and be more precisely applied at extremely low rates (Council for Agricultural Science and Technology, 2014).

Crop producers now use integrated pest management (IPM) extensively in row-crop production. Insecticides that had high environmental concerns (e.g. organochlorines) and high toxicity have been, and are continuing to be, replaced by lower risk, biological and user-friendly materials. Insect growth regulators take advantage of pest biology to provide improved management of pests. This improved management reduces losses due to pests and minimizes the effect on nontarget organisms and the environment. Introducing genetically modified crops that confer pest resistance (e.g. Bt corn and cotton) also reduces dependence on chemical controls.

The ability of pests to develop resistance to IPM tactics, including pesticides and genetically modified crops, requires the continual development of pest management tools. The USDA fostered the adoption of IPM tactics by providing financial assistance from 1997 to 2012.

Knutson and Smith (1999) estimated eliminating organophosphates and carbamates, common in insecticides, would have the following effects on north central U.S. and Mississippi River Delta crop production. For corn, cotton, rice, soybeans and wheat, crop yields would decrease, and costs of production would increase. The economic impact originates from using more expensive pesticides and recording decreased yields. These factors increase the cost of production per unit.

Exhibit 3.18 - Impact of Eliminating Organophospates and Carbamates on Row Crops

Measure	Corn[1]	Cotton[2]	Rice[2]	Soybeans[1]	Wheat[1]
Yield	-3.8%	-8.0%	-5.3%	-6.0%	-0.1%
Total variable cash expense ($/unit produced)	5.6% ($/bu)	13.8% ($/lb)	5.6% ($/cwt)	9.5% ($/bu)	0.1% ($/bu)

[1]North Central U.S. [2]Mississippi River Delta
Source: Knutson and Smith

3.5 Biotechnology Use and Adoption of GE Crops

Highlights:

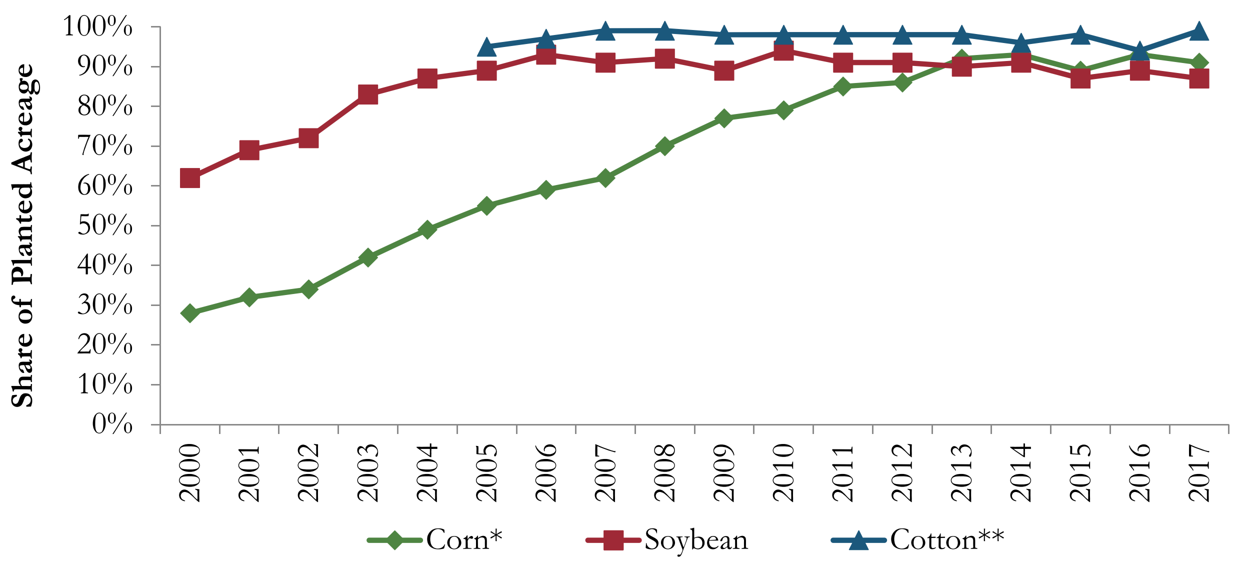
- Farmers have widely adopted genetically modified corn, soybeans and cotton.
- The adoption of herbicide-resistant crops has led to more herbicide use but a smaller environmental impact.
- The adoption of insect-resistant crops has led to less insecticide use and a smaller environmental impact.

Two types of genetically modified crops are common in U.S. agriculture: herbicide-tolerant crops and insect-resistant crops.

Missouri producers extensively adopted genetically modified crop varieties during the past two decades. Exhibit 3.19 charts the share of Missouri planted corn, soybean and upland cotton acreage that used genetically modified varieties from 2000 to 2017. In 2017, 99 percent of Missouri upland cotton planted acreage used genetically modified seed. Missouri soybean and corn producers used genetically modified varieties to a slightly lesser extent. Eighty-seven percent of Missouri soybean planted acres in 2017 used genetically modified seed, and genetically modified seed was used for 91 percent of Missouri corn planted acreage (USDA ERS, 2017).

The chart shows more than half of Missouri soybean acreage has been planted with genetically modified seed since 2000. However, note genetically modified soybeans' share of total planted acreage was highest — 94 percent — in 2010. Since 2015, genetically modified seed has been used to plant less than 90 percent of Missouri soybean acreage. For corn, genetically modified variety use increased from 28 percent in 2000 to 91 percent in 2017. It was highest — 93 percent — in 2014 and 2016. Since 2005, Missouri cotton producers have annually planted more than 90 percent of upland acreage with genetically modified seed (USDA ERS, 2017).

Exhibit 3.19 - Missouri Genetically Modified Variety Adoption by Crop, 2000-2017



* All genetically modified varieties
** Missouri-specific cotton acreage data were first released in 2005.
Source: USDA Economic Research Service (2017)

Depending on the crop, producers have accepted some biotech traits more than others. Exhibit 3.20 summarizes Missouri and U.S. genetically modified variety adoption data for 2017. Missouri and U.S. corn acreage tended to use stacked gene varieties instead of varieties that conferred only insect resistance or only herbicide tolerance. During 2017, 81 percent and 77 percent of Missouri and U.S. planted corn acreage, respectively, used stacked gene varieties. For soybeans, all genetically modified varieties are those that offer herbicide tolerance. Like for corn, genetically modified cotton varieties may offer insecticide resistance, herbicide tolerance or stacked traits. In Missouri, stacked cotton varieties have not been used as broadly as they have in the U.S. as a whole. During 2017, 58 percent of Missouri upland cotton acreage used stacked gene varieties, but such varieties were planted on 80 percent of total U.S. upland cotton acreage. Cotton varieties with only herbicide tolerance have been relatively popular in Missouri. Thirty-six percent of Missouri planted upland cotton acreage used only herbicide-tolerant varieties in 2017. Eleven percent of U.S. upland cotton acreage had only herbicide-tolerant seed planted (USDA ERS, 2017).

Exhibit 3.20 - Types of Genetically Modified Crop Varieties Planted in Missouri and U.S., 2017

	Missouri	U.S.
Corn		
Insect-resistant (Bt) only	2%	3%
Herbicide-tolerant only	8%	12%
Stacked gene varieties	81%	77%
All genetically modified varieties	91%	92%
Soybeans		
Herbicide-tolerant only	87%	94%
All genetically modified varieties	87%	94%
Cotton		
Insect-resistant (Bt) only	5%	5%
Herbicide-tolerant only	36%	11%
Stacked gene varieties	58%	80%
All genetically modified varieties	99%	96%

Source: USDA Economic Research Service

In some cases, interest in environmental sustainability has encouraged genetically modified crop adoption. Soybeans provide an example. Agribusinesses began releasing herbicide-tolerant soybean varieties during the mid-1990s. Shortly after being commercialized, Roundup Ready soybeans were widely adopted. Like other post-emergence herbicides, Roundup could be applied throughout the season to soybeans modified to have tolerance to the product. Herbicide tolerance enabled growers to integrate more conservation tillage into their farms and plant narrower rows. For weed control, farms could spray herbicides and rely less on cultivation. In addition, the narrower rows would encourage a crop canopy to develop early and deter late season weed pressure (Carpenter & Gianessi, 1999).

Other research has measured whether genetically modified crops have enabled growers to apply less herbicide and pesticide. Analysis of a farm-level, commercial dataset from 1998 to 2011 revealed the following observations about the quantity of herbicides used: 1) glyphosate-tolerant soybean adopters used 28 percent more herbicide than farms that didn't use glyphosate-tolerant varieties and 2) for corn, adopters of glyphosate-tolerant and insect-resistant varieties decreased herbicide and insecticide use by 1.2 percent and 11.2 percent, respectively. When the environmental impact quotient (EIQ) rather than pounds of product were evaluated, genetically modified adopters and nonadopters used relatively the same amount of herbicides for soybeans and 9.8 percent less herbicide and 10.4 percent less insecticide for corn. The EIQ considers a product's effect on farmworkers, consumers, and ecology such as fish, birds and bees (Perry, Ciliberto, Hennessy, & Moschini, 2016).

Brookes and Barfoot found that the adoption of herbicide-tolerant crops has influenced the mix and total amount of herbicides used and resulted in changing environmental impact quotients. Due to the development of herbicide-resistant weeds, the amount of herbicide active ingredient applied and number of herbicides used in many regions has increased, and the EIQ indicator has deteriorated. However, the environmental profile of herbicide-tolerant crop use continues to provide an improved EIQ compared with the conventional alternative (Brookes & Barfoot, 2013).

Brookes and Barfoot (2013) also found that insect-resistance technology has reduced the use of insecticides to control crop pests. In the U.S. from 1996 to 2011, insect-resistant technology in corn was estimated to have removed 90 million pounds of insecticide active ingredient and improved the EIQ by 36.5 percent. For cotton, insect-resistant technology was responsible for reducing active ingredient use by 24 million pounds and improving the EIQ by 16.1 percent.

Brookes and Barfoot (2013) estimated that total fuel saved due to U.S. adoption of biotech soybeans from 1996 to 2009 was 220.4 million gallons. They estimated this fuel savings resulted in an estimated 2.5 million tons of CO_2 not being released into the environment. Adding in the impact of carbon sequestration due to no-till and reduced-till made possible by biotech soybeans, an estimated 41.6 million tons of CO_2 was not released into the environment.

3.6 Precision Ag Tools

Highlights:

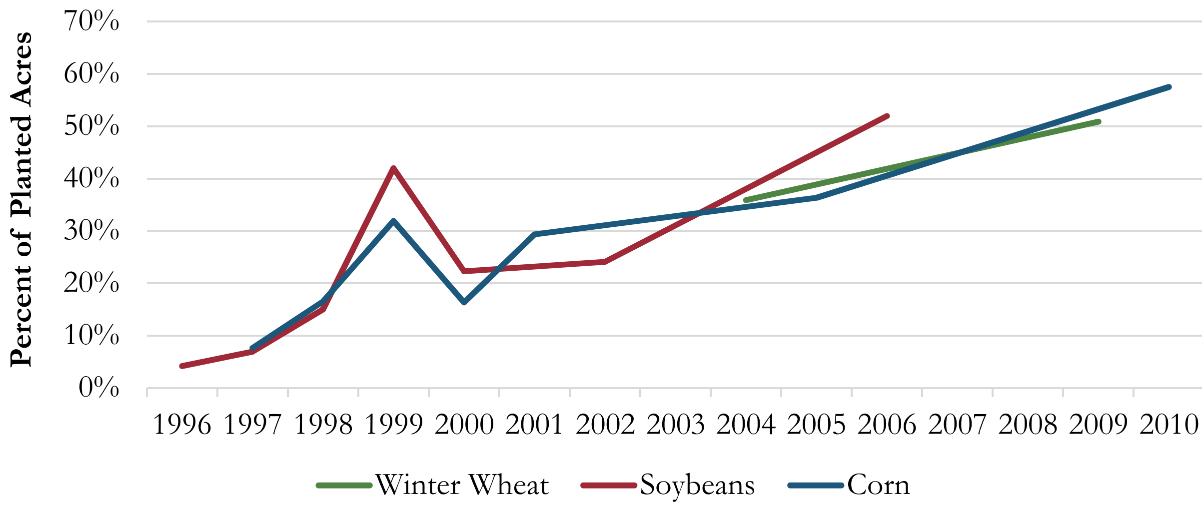
- Farmer use of precision agricultural technology is increasing at different rates for different technologies, and adoption varies by farm size.
- Precision agriculture technologies help farmers reduce use of inputs such as fuel and fertilizer.

Farmers can use precision agriculture technology to fine-tune their production practices and gain detailed in-field information. This information can be used to decrease input costs, increase yields and potentially reduce a farm's environmental impact. Precision agriculture tools include yield monitors, control systems, sensors, drones, guidance and auto-steering systems, GPS-based soil sampling and variable-rate technology (VRT).

In the U.S., adoption rates of precision agriculture vary significantly across technologies. A USDA Economic Research Service report about precision agriculture adoption at the national level states that adoption rates on the largest corn farms, defined as those with more than 2,900 acres, is double the adoption rate found on all farms. The adoption rate of individual precision agriculture technologies is generally less than 50 percent, and VRT adoption lags the use of all other technologies.

Overall adoption rates of precision agriculture practices are lower in Missouri than the U.S. as a whole. Exhibit 3.21 shows the trends in precision agriculture adoption between 1996 and 2010. This shows the percentage of acres that have adopted any type of precision agriculture technology. The most recent data show more than 50 percent of acres planted in corn, soybeans and winter wheat used at least one type of precision agriculture technology. In 2010, 57.5 percent of acres of planted in corn had some type of precision agriculture technology used. In 2009, 50.9 percent of acres planted in winter wheat used some type of precision agriculture technology. In 2006, 51.9 percent of acres planted in soybeans used some form of precision agriculture technology.

Exhibit 3.21 - Adoption Rates of Precision Agriculture Technologies in Missouri, 1996-2010



Source: USDA Agricultural Resource Management Survey (2017)

Exhibit 3.22 highlights Missouri adoption of several precision agriculture technologies. During the most recent year with data available, yield monitors were relatively popular. More than half of 2006 planted rice acreage had applied the technology. Using yield monitors was also relatively common when raising Missouri corn, winter wheat and soybeans during 2010, 2009 and 2006, respectively. Yield maps were less commonly used than yield monitors. More than one-third of Missouri corn acres during 2010 used guidance or auto-steering technology; an estimated 12 percent of sorghum planted acreage in 2003 used the technology. VRT has had little adoption in Missouri for any crops (USDA ERS, 2017).

Precision agriculture technologies increase efficiency of agricultural inputs so fewer inputs are "wasted." Although quantifiable results were not available, several research articles have noted the ability of precision agriculture technologies to enhance environmental conditions (Schieffer and Dillon, 2014; Schimmelpfennig, 2016; Bonogiovanni and Lowenberg-Deboer, 2004). Guidance systems save money and reduce chemical and fuel use by better aligning the seeding of field crop rows and reducing overapplication and underapplication of sprays. VRT can be used to apply fertilizer and pesticides at different rates throughout a field. Better placement should keep more of the fertilizer and pesticides on their intended target and out of waters. It can also assist in accurately observing and recording nutrient management plan compliance.

Exhibit 3.22 - Precision Agriculture Tools Used in Missouri, Percent of Planted Acres

	Corn (2010)	Cotton (2007)	Rice (2006)	Sorghum (2003)	Soybeans (2006)	Winter Wheat (2009)
Yield monitor	48%	6%*	53%	33%	45%	45%
Yield map created	16%	NA	10%	11%	15%	8%
GPS device used to create soil properties map	5%	NA	NA	14%	8%	3%
Guidance or auto-steering system used	35%	NA	NA	12%	NA	NA
VRT used for any purpose	1%	NA	NA	7%	6%	7%

* Statistically unreliable due to a low sample size.
NA: Estimate does not comply with NASS disclosure practices, is not available or is not applicable.
Source: USDA Agricultural Resource Management Survey (2017)

The adoption of precision agriculture technologies has been accompanied by the rise of companies that offer services to farmers related to big data. These companies provide high-resolution climate information, storage of management decisions such as planting date and hybrid/variety, contemporaneous yield estimates and yield mapping. Three precision agriculture/big data companies serving Missouri farmers are Climate Corp (Fieldview), Pioneer (Encirca) and Farmobile (Farmobile). In addition, farmer coops and agribusinesses offer services such as intensive soil sampling and variable rate applications that ensure that nutrients and chemicals are put where they are needed for efficient crop production.

3.7 Irrigation and Water Use Efficiency

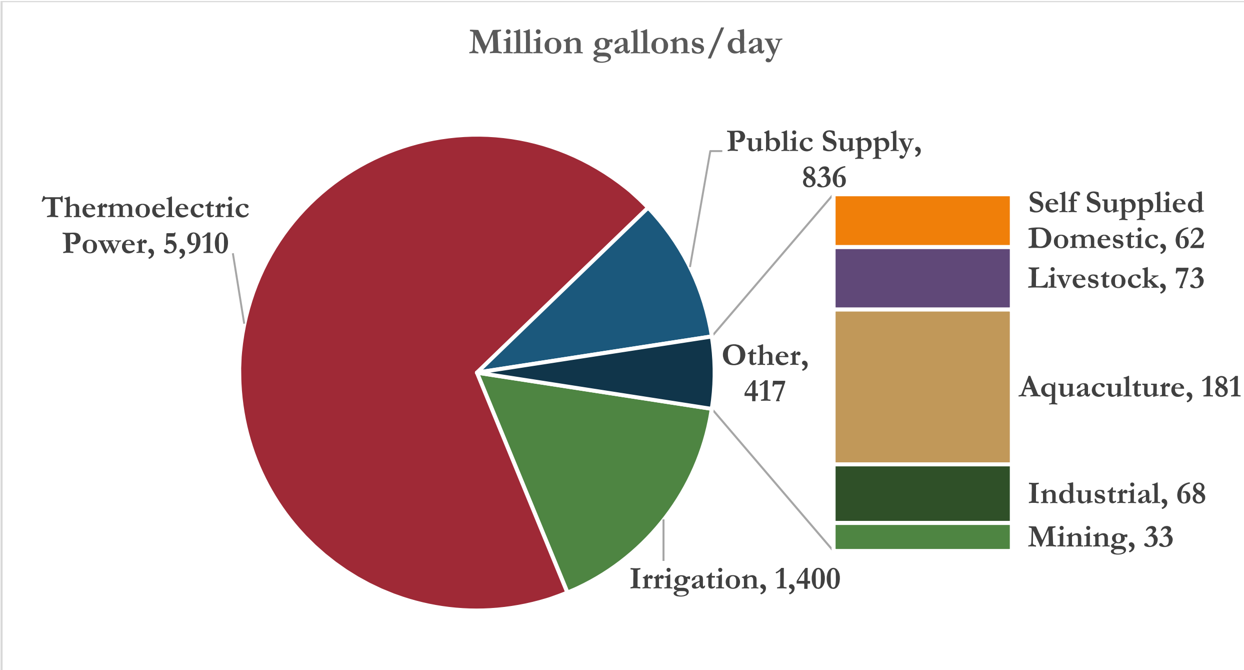
Highlight:

- Irrigation water use in Missouri increased from 1990 to 2000. Since that time, it has remained fairly constant.

Total Missouri water withdrawals from groundwater and impounded surface water sources in 2010 were estimated to be 8,570 million gallons per day (Mgal/d). Water used for irrigation accounted for 16.3 percent (1,400 Mgal/d) of total water used in Missouri during 2010. This was a 2.5 percent decrease from 2005 levels. Irrigation is the second-highest use of water in Missouri. Thermoelectric power, which uses 5,910 Mgal/d, was the leading Missouri water consumer during 2010 (USGS, 2014). See Exhibit 3.23.

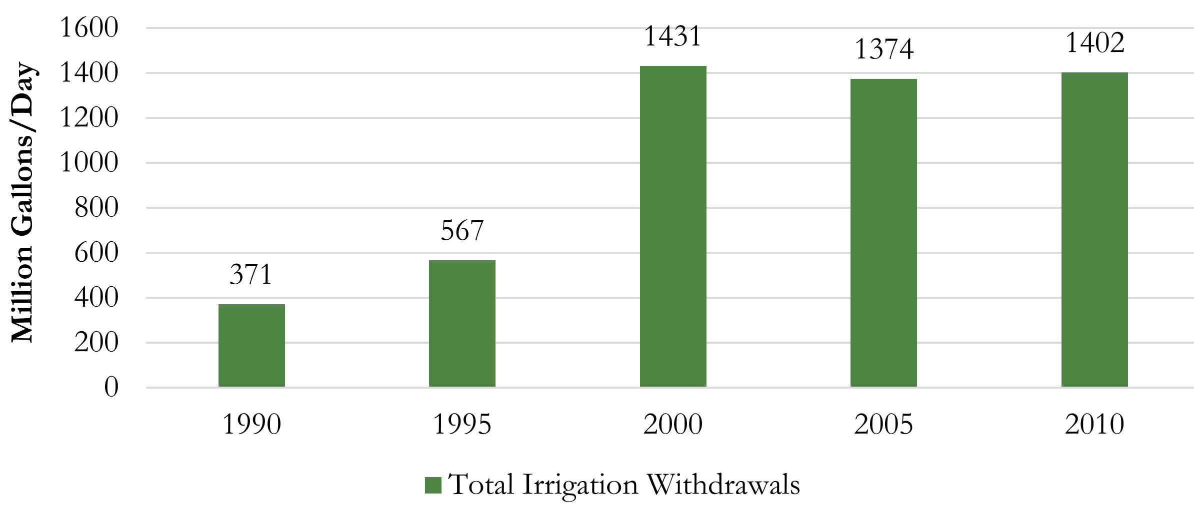
From 2000 to 2010, the amount of water withdrawn for irrigation in the U.S. decreased by 17.3 percent from a high of 139 billion gallons per day (Bgal/d) to 115 Bgal/d (USGS, 2014). Exhibit 3.24 shows how water withdrawals for irrigation changed from 1990 to 2010 in Missouri. Between 1995 and 2000, Missouri irrigated acreage increased by 68.6 percent — 786,100 acres to 1.3 million acres. During that time, water withdrawals for irrigation increased by 152.4 percent — 567 Mgal/d to 1325.4 Mgal/d. Between 2000 and 2010, Missouri irrigation withdrawals were relatively stable (USGS).

Exhibit 3.23 - Total Water Use in Missouri, 2010



Source: USGS, Estimated Use of Water in the United States in 2010. Irrigation includes urban irrigation such as golf courses and parks.

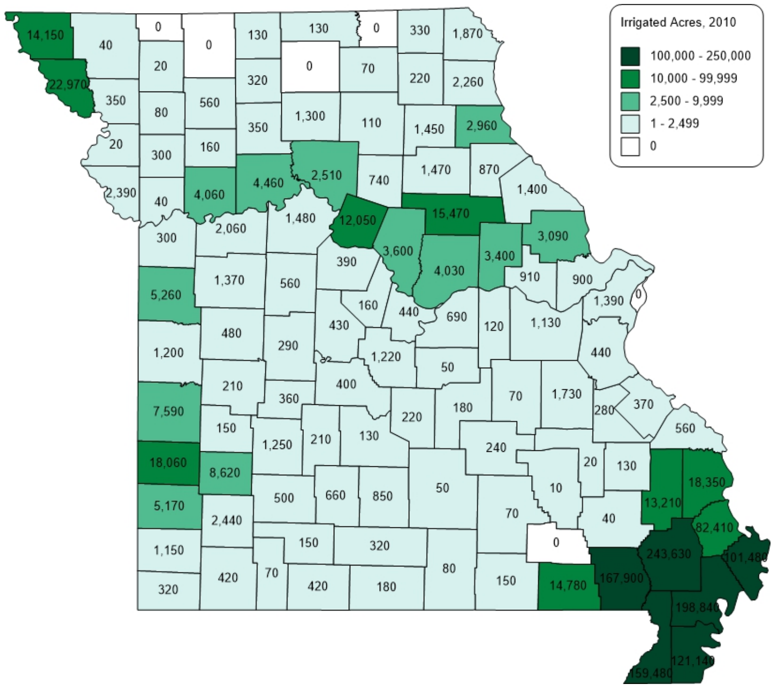
Exhibit 3.24 - Irrigation Use in Missouri, 1990-2010



Source: USGS, Water Use Data 1990-2010. Irrigation includes urban irrigation such as golf courses and parks.

In 2013, Missouri had 1.2 million acres of irrigated farmland (USDA, 2014). Exhibit 3.25 maps irrigated acres by county in Missouri during 2010. The majority of irrigated acres were located in southeast Missouri and along the Missouri River. The 10 counties which make up the bootheel region of Missouri — Bollinger, Butler, Cape Girardeau, Dunklin, Mississippi, New Madrid, Pemiscot, Ripley, Scott and Stoddard — accounted for 85.8 percent of Missouri's irrigated acres (USGS, 2014).

Exhibit 3.25 - Map of Irrigated Acres in Missouri by County, 2010

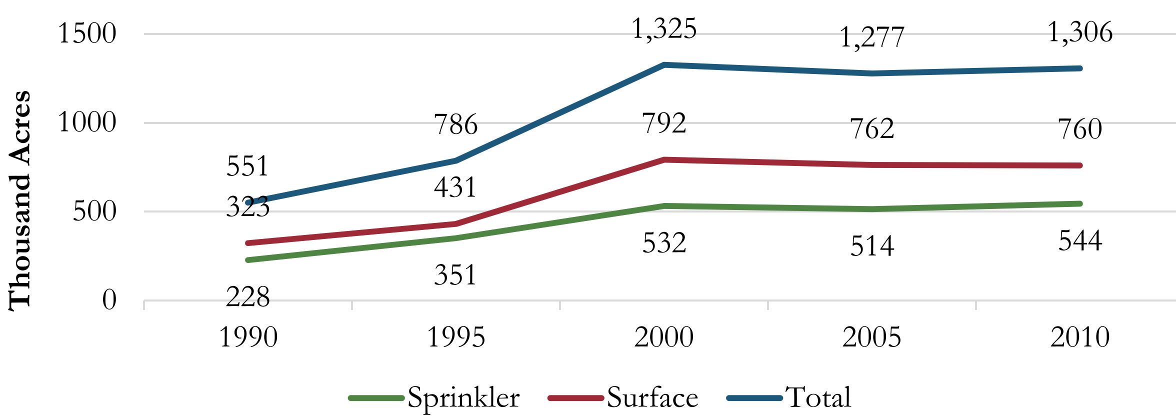


Source: USGS, Water Use Data 2010. Irrigation includes urban irrigation such as golf courses and parks.

The three main types of irrigation systems used in Missouri are surface, sprinkler and micro-irrigation. In 2010, the majority of irrigated acres in Missouri (58 percent) were irrigated using surface irrigation. Sprinkler and micro-irrigation systems, which use water more efficiently than surface irrigation systems, were used on 42 percent of irrigated acres in Missouri. Micro-irrigation was only used on 2,100 acres in Missouri, 0.2 percent of irrigated land. Nationwide, sprinkler and micro-irrigation systems are used more often than in Missouri (USGS, 2014).

Exhibit 3.26 shows irrigation system usage from 1990 to 2010 in Missouri. Between 2005 and 2010, irrigated acres grew by 2 percent. Acreage irrigated by sprinkler systems increased by 6 percent, and a one percent decrease was recorded for the number of acres irrigated by surface irrigation (USGS, 2014).

Exhibit 3.26 - Irrigated Land by Type of Irrigation in Missouri, 1990-2010



Source: USGS, Water Use Data 1990-2010. Irrigation includes urban irrigation such as golf courses and parks.

Missouri farmers have a long history of scheduling irrigation using various MU programs. Dr. C. M. Woodruff developed the Woodruff chart with support from the Missouri Soybean Merchandising Council in the 1960s. The Woodruff chart was intended to help farmers manage irrigation to prevent both under-watering and overwatering. More recently, Dr. Gene Stevens helped to develop the online and phone app called Crop Water Use Program for Irrigation. It incorporates plant stages, current weather information and previous water applications to help farmers apply correct amounts of water.

Any surface or groundwater user that has the capacity to withdraw or divert more than 70 gallons per minute from any water source is required by law to report his or her water use to the Missouri Department of Natural Resources. In 2014, the department estimated 50 percent to 60 percent of registered major water users reported their annual water use data.

3.8 Farmers Participation in Conservation Programs

Highlight:

- Missouri farmers extensively use USDA and Soil and Water Conservation Programs to improve crop production and environmental amenities.

Missouri farmers, agricultural organizations and government entities voluntarily cooperate with several USDA conservation programs to improve water quality and wildlife habitat and maintain agricultural production. The USDA Regional Conservation Partnership Program is a locally led, partner-driven approach to conservation. Since 2014, the USDA has contributed more than $35 million to advance 10 projects involving 114 partners. One project targets soil health, two projects target water quantity and drought, three address water quality, and four foster wildlife habitat. State agencies collaborating with the USDA include the Missouri departments of agriculture, natural resources and conservation. Soil and water districts and county agencies are also participating. Ducks Unlimited is a private group contributing to an individual project.

The USDA Natural Resources Conservation Service (NRCS), along with other conservation partners, developed the Missouri River Basin Healthy Watersheds Initiative. Funding from sources such as the Environmental Quality Incentives Program, the Wildlife Habitat Incentive Program and the Wetlands Reserve Enhancement Program is directed to previously selected watersheds. Farmers in these watersheds voluntarily implement land management practices that avoid, control and trap runoff and improve wildlife habitat while maintaining agricultural production. Missouri has participated in this program since 2012, and it currently has several active Missouri River Basin Healthy Watershed Initiative Projects. Although not specifically noted below, many of the acres enrolled in projects detailed below are part of this initiative.

The Missouri Department of Natural Resources Soil and Water Conservation Program estimates that since 1986 it has distributed $732 million dollars in assistance to landowners that resulted in 182 million tons of soil saved on over 5 million acres.

The following sections use NRCS participation data to report how many acres have been enrolled in various conservation programs. The trends are difficult to generalize because the enrollment covers several farm bills (1990, 1996, 2002, 2008 and 2014). Different farm bills emphasize different priorities. At times, various programs are coupled, so if a farmer participates in one, then he or she is required to participate in another.

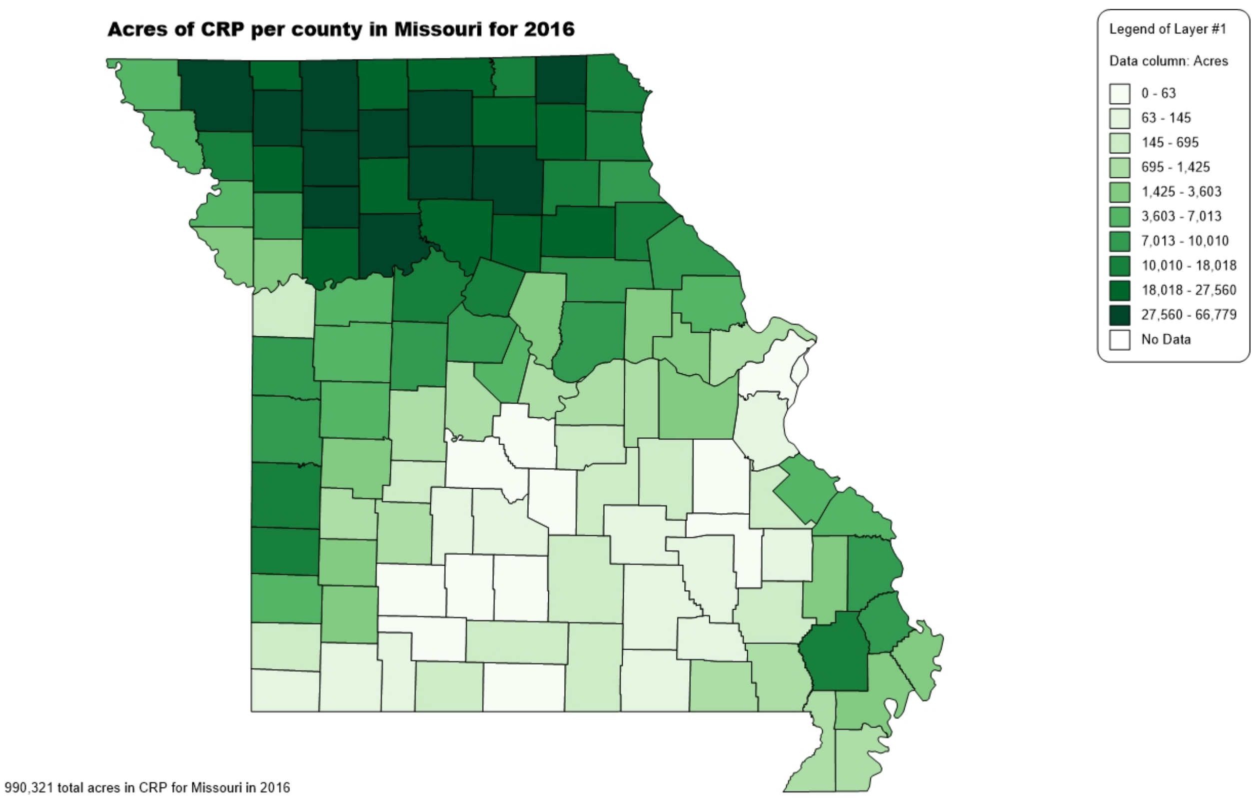
In addition to the USDA metrics below, data from the Missouri Department of Natural Resources Soil and Water Program has been aggregated, where possible. This program is funded by a portion of the parks, soil and water sales tax. Similar to some USDA assistance programs, the Missouri Soil and Water Program provides cost-share dollars for farmers who adopt soil and water conservation practices.

This section attempts to group several programs into categories aligned with their primary conservation goal. It is recognized that all programs achieve multiple conservation goals.

3.8.1 Conservation Reserve Program

The Conservation Reserve Program (CRP) has played an important role in transitioning marginal land from crop production to conservation. Farmers sign 10- to 15-year contracts with the USDA Farm Service Agency to switch land from crop production to conserving use in exchange for yearly program payments. The CRP area under contract in the U.S. was 23.4 million acres in 2017, down from the maximum of 36.8 million acres in 2007. As of July 2017, Missouri had a total of 29,344 contracts on 17,447 farms that covered 976,252 acres. Exhibit 3.27 displays where the CRP acres are located in Missouri (USDA FSA, 2017).

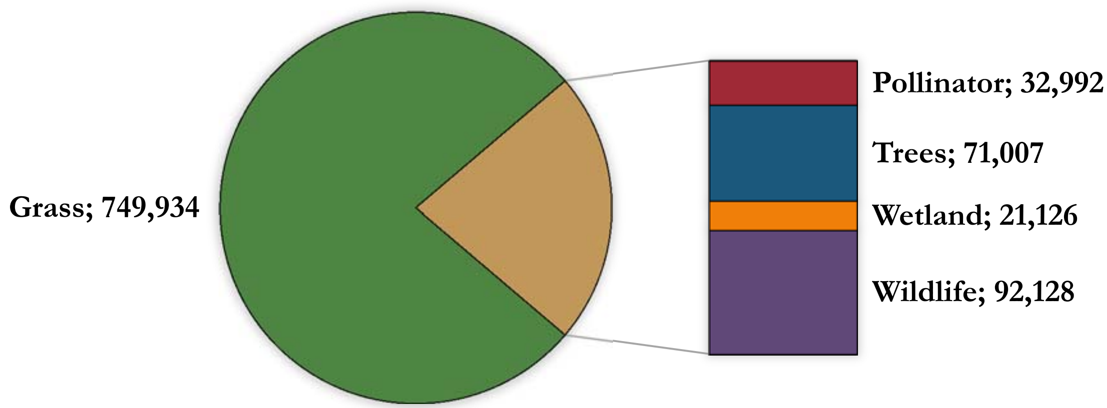
Exhibit 3.27 - Acres of Conservation Reserve Program (CRP) Per County in Missouri, 2016



In 2016, Missouri farmers received $102,027,564 in CRP rental payments. Missouri's average rental payment in 2016 was $110.94 per acre (USDA FSA, 2017).

Sixty-two percent of Missouri land enrolled in CRP is highly erodible land with an erodibility index greater than 20 (USDA FSA, 2017). The USDA uses various CRP conservation practices to obtain objectives that benefit the environment and wildlife. Exhibit 3.28 shows the number of acres in general categories of CRP conservation practices. In 2016, Missouri ranked seventh in the U.S. for the number of acres enrolled in continuous CRP, a program targeting the most environmentally sensitive farmland. It ranked fifth for acres enrolled in the Upland Bird Habitat Buffer CRP Initiative. The National Sustainable Agriculture Coalition specifically draws attention to Smithville Lake Watershed where 175 farmers enrolled 6,700 acres in CRP; the enrollment resulted in an average 16 percent reduction in pesticide application. Data do not exist for Missouri alone, but the USDA estimates that CRP in the U.S. in 2016 reduced sediment loss by 190 million tons, prevented 514 million tons of nitrogen and 102 million tons of phosphorus from entering waterbodies and sequestered 34 million tons of CO_2 (USDA FSA, 2017).

Exhibit 3.28 - CRP Acres by General Conservation Practice, 2017

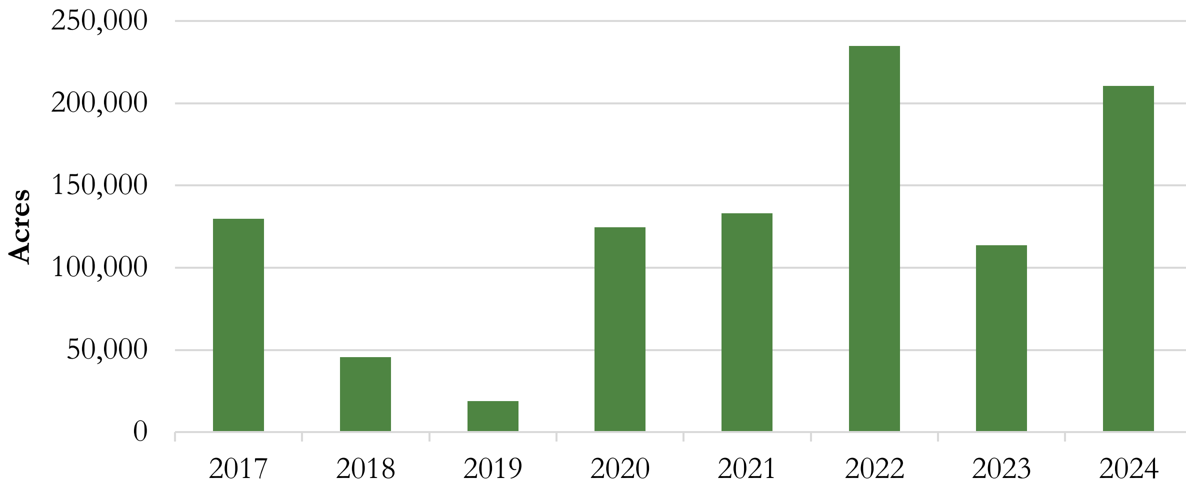


Source: Conservation Reserve Program, Monthly Summary – July 2017
Notes: Grass contains practices CP1, CP2, CP6, CP8, CP10, CP15, CP21, CP28, CP87 and CP88; Trees contains practices CP3, CP5, CP11, CP16, CP22, and CP32, Wetland contains practices CP23, 30 and 40; Wildlife contains practices CP4, CP9, CP12, CP25, CP29 and CP38; Pollinator is practice CP42.

Exhibit 3.29 shows CRP expirations for Missouri. In 2017, 129,656 CRP contracted acres were set to expire in Missouri (USDA FSA, 2017). Although 2018 and 2019 will see minor impacts in acres coming out of CRP, years 2020 and beyond may see land use changes in Missouri as more than 100,000 acres are set to expire each year. These acres have the potential to be re-enrolled in CRP, become pasture or hay land or revert back to cropland.

The opportunity to re-enroll CRP acres or gain new acres may be hindered in the future. The cap on the number of acres fell from a high of 39.2 million acres in the 2007 farm bill to 24 million acres in the 2014 farm bill. In addition, spending caps at the federal level may prevent some acres from re-enrolling. Current debate on the Farm Bill indicates that the number of acres allowed into CRP will increase from 24 million to 29 million. However, in order to save money, the rental payment offered to farmers for putting land into CRP would be limited to 80% of the rental value in a county (Gullickson, 2018).

Exhibit 3.29. Missouri CRP Expiration Acres by Year, 2017-2024



Source: USDA Farm Service Agency

3.8.2 Wildlife Conservation Practices

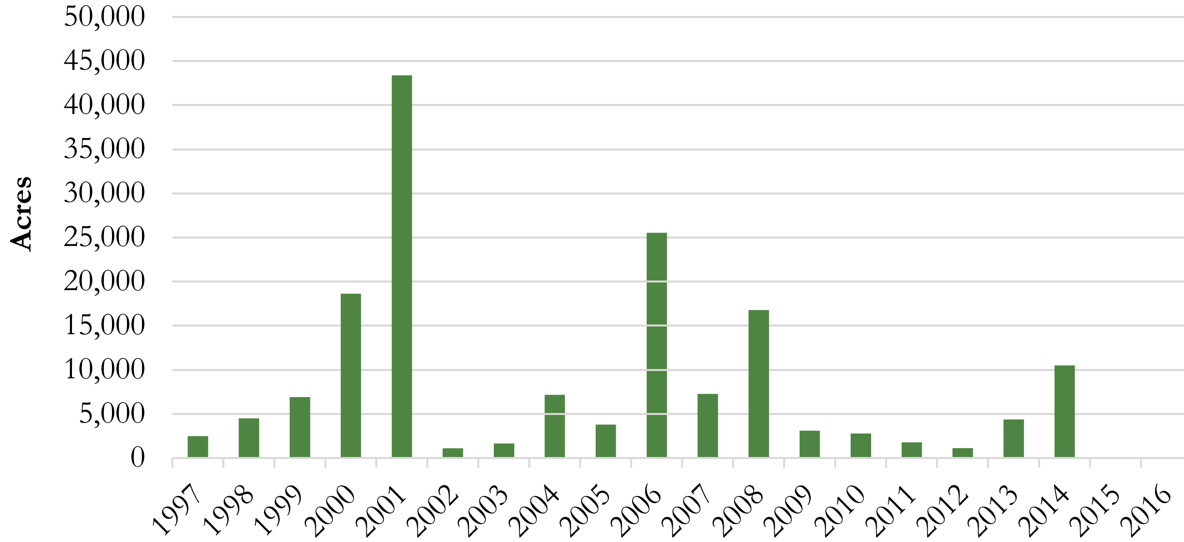
During the 20 year period from 1997 to 2006, Missouri farmers have adopted a variety of practices that have benefited the environmental ecosystems for wildlife and fish on 478,111 acres. USDA NRCS programs and initiatives such as the Environmental Quality Incentives Program (EQIP), Wildlife Habitat Incentive Program (WHIP) and Conservation Security Program (CSP) have enabled producers to receive cost-share assistance for implementing environmentally sound practices. The following sections will discuss background and adoption of wildlife conservation-related practice standards in Missouri.

Upland Wildlife Habitat Management (NRCS Practice Standard 645)

Background: The practice is to provide and manage upland habitats and connectivity within the landscape for wildlife. Structural, vegetative or management measures to improve food and cover for the desired wildlife species are identified. Examples include creating food plots and planting warm- or cool-season grasses or legumes, forbs, trees or other woody vegetation. This practice has a lifespan of one year.

Adoption: From 1997 to 2016, 162,986 acres in Missouri adopted this practice. Missouri farmers were provided $4,465,681 in financial payments from NRCS during this time period. Exhibit 3.30 details the Missouri adoption rate trends from the past 20 years. Peak enrollment was in 2001 with 43,386 acres being put under contract.

Exhibit 3.30 - Missouri Upland Wildlife Habitat Management Adoption, 1997-2016



Source: USDA National Resources Conservation Service

Tree Shrub Establishment (NRCS Practice Standard 612)

Background: This standard focuses on establishing woody plants by planting seedlings or cuttings, using direct seeding or supporting natural regeneration. Conservation benefits include establishing forest cover, enhancing wildlife habitat, controlling erosion, improving water quality and conserving energy. The practice lifespan is 15 years.

Adoption: From 1997 to 2016, 151,349 acres in Missouri adopted this practice. Of these acres, 130,030 were enrolled in 2002. From 2007 to 2016, new program usage of the tree shrub establishment program averaged 232 acres per year. Missouri farmers were provided $904,210 in financial payments from NRCS from 1997 to 2016.

Shallow Water Development and Management (NRCS Practice Standard 646)

Background: The purpose of the standard is to provide habitat for wildlife such as shorebirds, waterfowl, wading birds, mammals, fish, reptiles, amphibians and other species that require shallow water for at least a part of their life cycles. This practice is applied where water can be impounded or regulated by diking, excavating, ditching or flooding. This practice is authorized up to three payments per acre within the contract period.

Adoption: From 1997 to 2016, a total of 105,845 acres in Missouri adopted this practice. Of these acres, 76,601 were enrolled in 2010. During the past five years, typical Missouri program usage was 2,978 acres per year. Missouri farmers were provided $4,571,067 in financial payments from NRCS from 1997 to 2016.

Riparian Forest Buffer (NRCS Practice Standard 391)

Background: The purpose of the standard is to establish a riparian forest buffer (trees or shrubs) located adjacent to a body of water. The vegetation extends outward for a specified distance necessary to provide a minimum level of protection. The project lifespan is 15 years. NRCS financial incentives are only paid in the enrollment year.

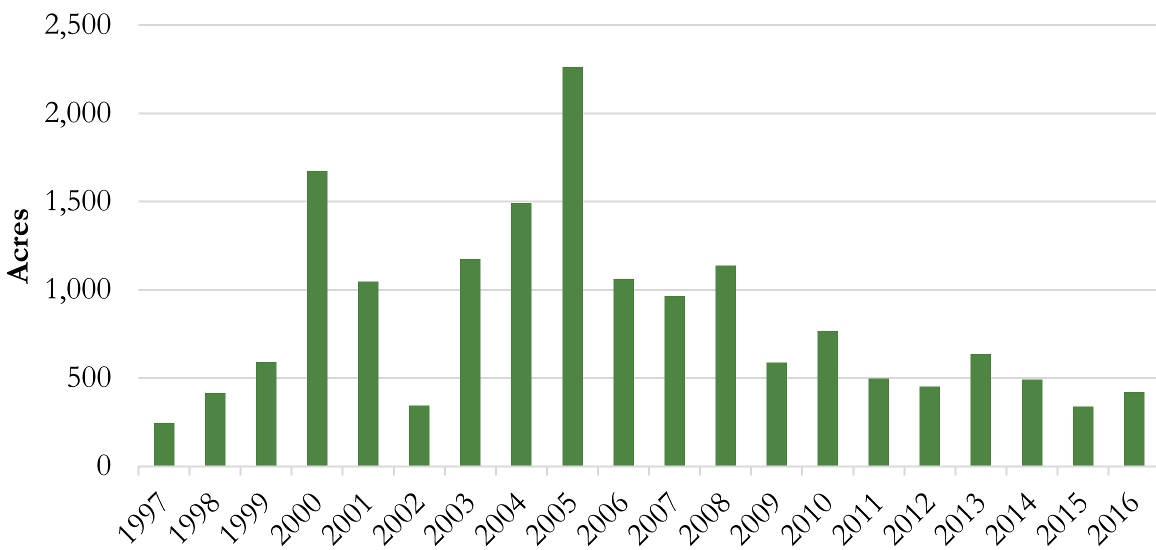
Adoption: From 1997 to 2016, 26,257 acres in Missouri adopted this practice. Of these acres, 14,607 were enrolled in 2001. Since 2010, enrollment occurred in only two years for tracts less than two acres. Missouri farmers were provided $86,584 in financial payments from NRCS from 1997 to 2016.

Conservation Cover (NRCS Practice Standard 327)

Background: This goal of this standard is to establish and maintain perennial vegetative cover to protect soil and water resources on lands needing permanent protective cover that will not be used for forage production. Project lifespan is five years. Payment rates to farmers vary by species introduced (native, pollinator, monarch, etc.).

Adoption: From 1997 to 2016, a total of 16,597 acres in Missouri adopted this practice. Missouri farmers were provided $1,736,700 in financial payments from NRCS during this time period. Exhibit 3.31 details the adoption trends from the past 20 years in Missouri. The historical high in enrollment was in 2005 with 2,262 acres being put under contract.

Exhibit 3.31 - Missouri Conservation Cover Adoption, 1997-2016



Source: USDA National Resources Conservation Service

Wetland Wildlife Habitat Management (NRCS Practice Standard 644)

Background: This practice is used to create or improve habitat for waterfowl, furbearers or other wildlife. It can be applied on or adjacent to wetlands, rivers, lakes and other water bodies where wetland-associated wildlife habitat can be managed. Application of this practice may include adding structures, seasonal water depths, plant species or vegetation management for specific wildlife species.

Adoption: From 1997 to 2016, a total of 15,078 acres in Missouri adopted this practice. No usage of the program has occurred since 2008. Missouri farmers were provided $47,072 in financial payments from NRCS between 1997 and 2008.

3.8.3 Soil and Water Conservation, Soil Erosion

Missouri farmers have adopted a variety of practices that have improved soil and water conservation. USDA NRCS programs and initiatives such as EQIP, WHIP and CSP have enabled producers to receive cost-share and technical assistance for implementing environmentally sound practices. The USDA provided assistance on 3,679,059 acres in Missouri from 1997 to 2016. The following sections share background and adoption of soil and water conservation practice standards in Missouri.

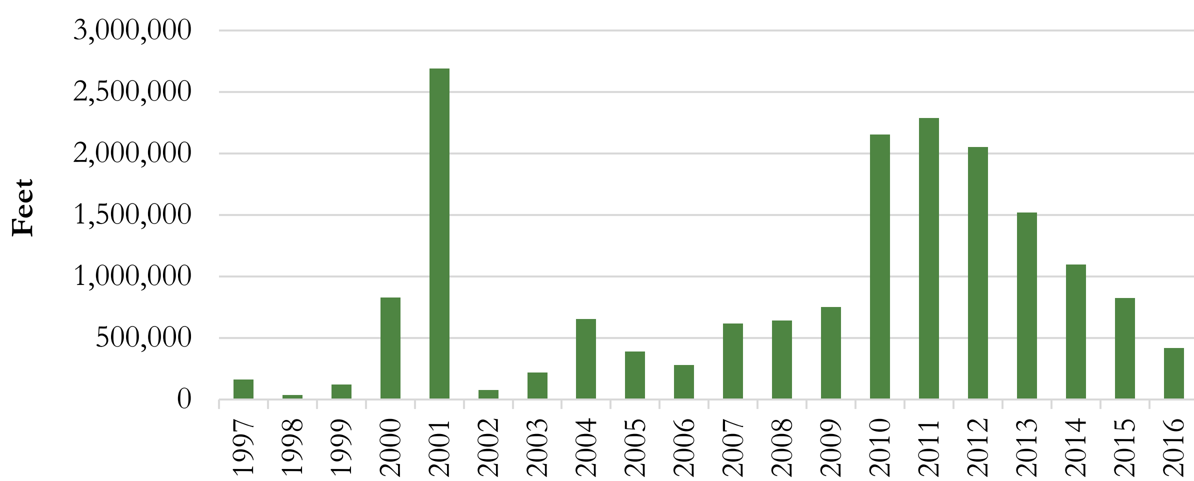
Terrace (NRCS Practice Standard 600)

Background: Under this practice, terraces are installed to control erosion and runoff, trap sediments, conserve moisture, prevent gully formation and alter the land surface to improve farmability. The practice has a minimum expected life of 10 years.

Adoption: From 1997 to 2016, 17,810,390 feet of terraces were added to Missouri farms with assistance from NRCS funding. Missouri farmers were provided $24,391,268 in NRCS financial payments during this time period. Exhibit 3.32 details adoption trends from the past 20 years in Missouri. The historical high in enrollment was in 2001 as 2,690,355 feet were enrolled in this practice.

The Missouri Soil and Water Conservation Program also assists in terrace adoption. Since 1990, they have assisted in installing over 39 million feet of terraces without tile and over 125 million feet of terraces with tile (Plassmeyer, 2018).

Exhibit 3.32 - Missouri Terrace Adoption, 1997-2016



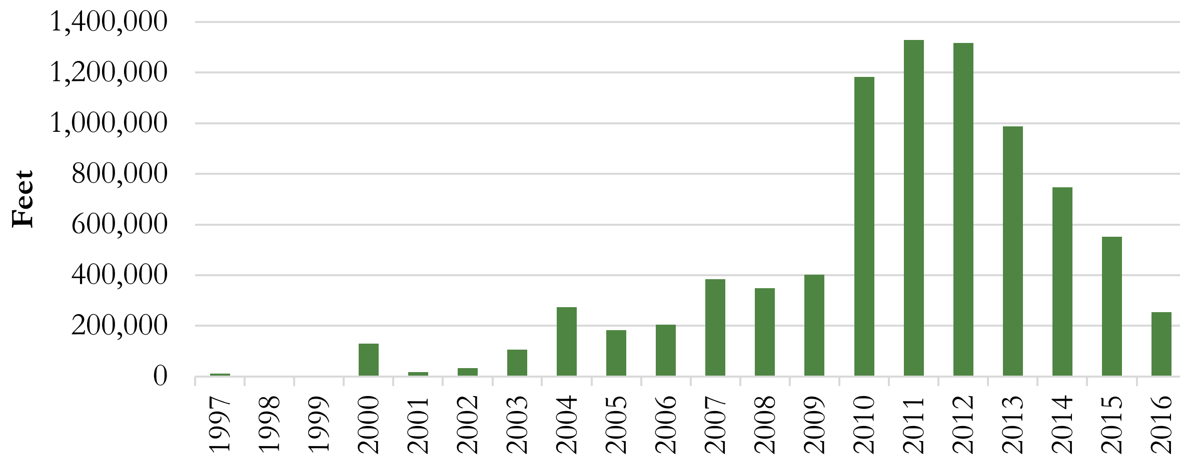
Source: USDA National Resources Conservation Service

Underground Outlet (NRCS Practice Standard 620)

Background: This standard's purpose is to carry excess water to a suitable outlet from terraces, water and sediment control basins, diversions, waterways, subsurface drains, surface drains or similar practices without causing erosion or flooding. Projects have an expected lifespan of 20 years.

Adoption: From 1997 to 2016, 8,452,597 feet in underground outlets were added to Missouri farms with assistance from NRCS funding. Missouri farmers were provided $19,425,901 in NRCS financial payments during this time period. Exhibit 3.33 details the adoption trends from the past 20 years in Missouri. The historical high in enrollment was in 2011 with 1,328,548 feet being enrolled in this practice.

Exhibit 3.33 - Missouri Underground Outlet Adoption, 1997-2016



Source: USDA National Resources Conservation Service

Drainage Water Management (NRCS Practice Standard 554)

Background: This standard seeks to manage water discharges from surface or subsurface agricultural drainage systems with water-control structures. Projects have an expected lifespan of one year.

Adoption: From 2010 to 2013, 11,000 acres in drainage water management were added to Missouri farms with assistance from NRCS funding. No usage of the program has occurred since 2013. Missouri farmers were provided $89,351 in NRCS financial payments during the observed time period.

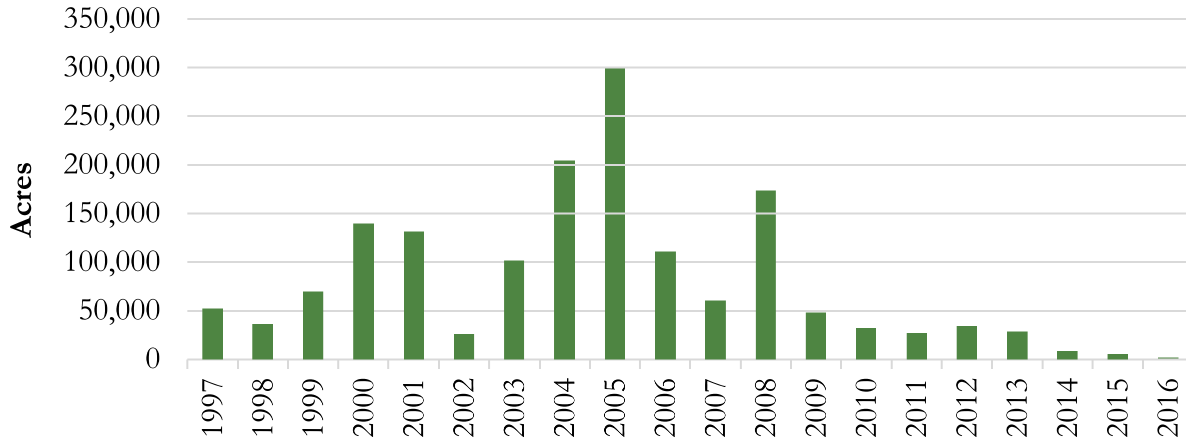
Nutrient Management (NRCS Practice Standard 590)

Background: The purpose of this standard is to manage the amount, placement, and timing of plant nutrients to obtain optimal yields and minimize the risk of surface and groundwater pollution. To receive payment for this practice, an approved nutrient management plan is required. This project has an expected lifespan of one year.

Adoption: From 1997 to 2016, 1,591,276 acres in nutrient management practices were added to Missouri farms. Missouri farmers were provided $14,927,282 in NRCS financial payments during the observed period. Exhibit 3.34 details the Missouri adoption trend from the past 20 years.

The Missouri Soil and Water Conservation Program also assists in helping farmers with nutrient management. Their nutrient management practice has been implemented on 293,189 acres in Missouri since 1990 (Plassmeyer, 2018).

Exhibit 3.34 - Missouri Nutrient Management Adoption, 1997-2016



Source: USDA National Resources Conservation Service

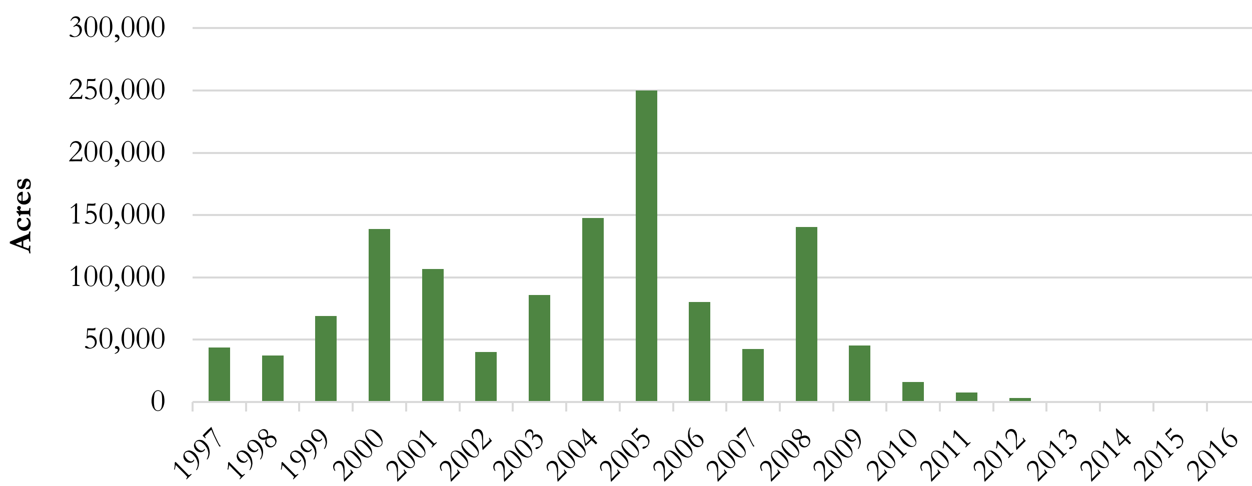
<u>Integrated Pest Management (NRCS Practice Standard 595)</u>

Background: This practice develops a plan to prevent or mitigate pest management risks for identified natural resource concerns. Strategies that keep pest populations below economically damaging levels and minimize pest resistance are utilized. This practice has a lifespan of one year.

Adoption: From 1997 to 2016, 1,254,404 acres in Missouri adopted integrated pest management practices with assistance from NRCS funding. Missouri farmers were provided $6,378,433 in NRCS financial payments during the observed time period. Exhibit 3.35 details the Missouri adoption trend for the past 20 years. The peak in enrollment was 2005 with approximately 250,000 acres. Program usage declined in more recent years.

The Missouri Soil and Water Conservation Program also assists in helping farmers with pest management. Their pest management practice has been implemented on 464,380 acres in Missouri since 1990 (Plassmeyer, 2018).

Exhibit 3.35 - Missouri Integrated Pest Management Adoption, 1997-2016



Source: USDA National Resources Conservation Service

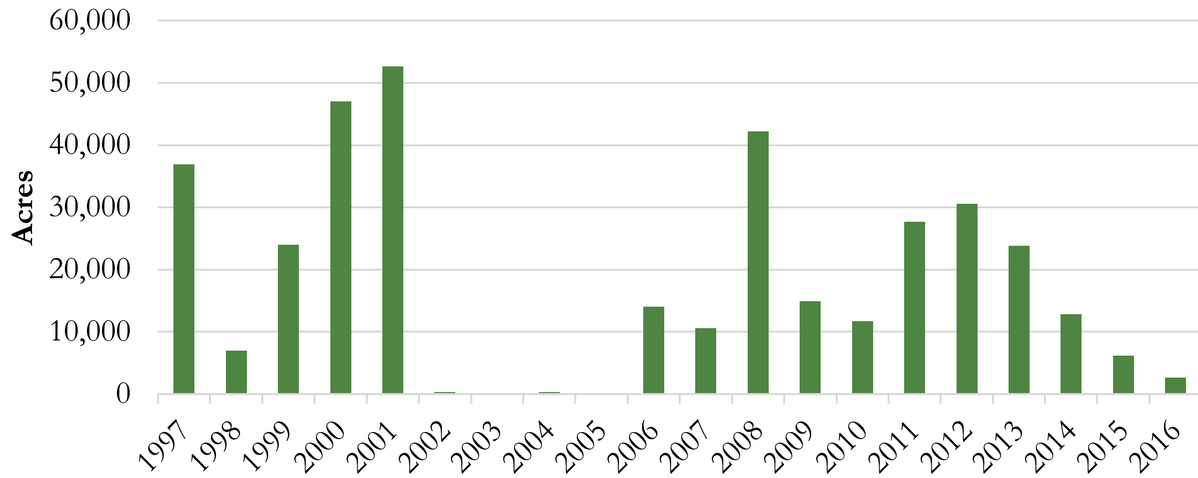
Irrigation Water Management (NRCS Practice Standard 449)

Background: This practice addresses the process of determining and controlling the volume, frequency and application rate of irrigation water in a planned and efficient manner. An irrigation-scheduling plan is the important component of this practice. The practice has a lifespan of one year.

Adoption: From 1997 to 2016, 365,276 acres in Missouri adopted irrigation water management practices with assistance from NRCS funding. Missouri farmers were provided $1,386,347 in NRCS financial payments during this period. Exhibit 3.36 details the Missouri adoption trend from the past 20 years.

The Missouri Soil and Water Conservation Program has assisted irrigation farmers increase water efficiencies by replacing above ground pipe with underground pipe on 679,982 irrigated acres from 1990-2017. They have assisted with other water conserving measures on over 75,000 acres from 1990-2017 (Plassmeyer, 2018).

Exhibit 3.36 - Missouri Irrigation Water Management Adoption, 1997-2016



Source: USDA National Resources Conservation Service

Conservation Crop Rotation (NRCS Practice Standard 328)

Background: Conservation crop rotation refers to growing a planned sequence of various crops on the same piece of land for conservation purposes. Crop rotations vary by soil type, crops produced, farming operations and how the crop residue is managed. This practice has a lifespan of one year.

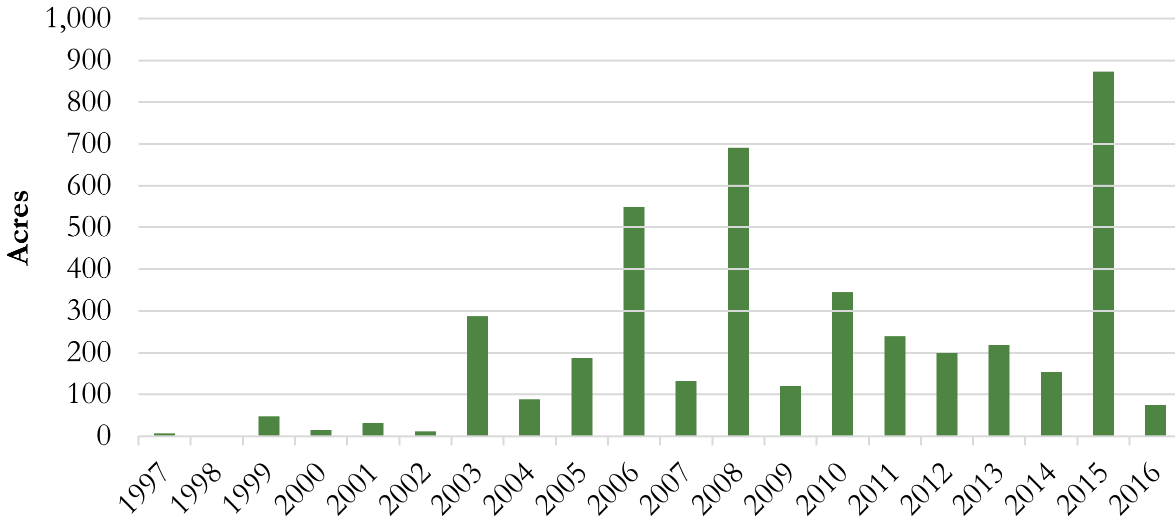
Adoption: From 1997 to 2016, 305,203 acres in conservation crop rotation were added to Missouri farms with assistance from NRCS funding. During the past five years, program usage averaged about 1,706 acres enrolled per year. Missouri farmers were provided $854,638 in financial payments during this period.

Critical Area Planting (NRCS Practice Standard 342)

Background: Critical area planting establishes permanent vegetation on sites that have or will have high erosion rates and sites that have conditions that prevent the establishment of vegetation with normal practices. Plant materials such as grass, trees, shrubs and vines can be used to establish vegetation. This practice has a lifespan of 10 years.

Adoption: From 1997 to 2016, 4,271 acres in Missouri adopted critical area planting practices with assistance from NRCS funding. Missouri farmers were provided $585,418 in financial payments during this observed time period. Exhibit 3.37 details the Missouri adoption trend from the past 20 years.

Exhibit 3.37 - Missouri Critical Area Planting Adoption, 1997-2016



Source: USDA National Resources Conservation Service

Filter Strip (NRCS Practice Standard 393)

Background: This practice involves adding a filter strip to the lower edge of a field. A filter strip is an area of vegetation established for removing sediment, organic material and other pollutants from runoff and wastewater.

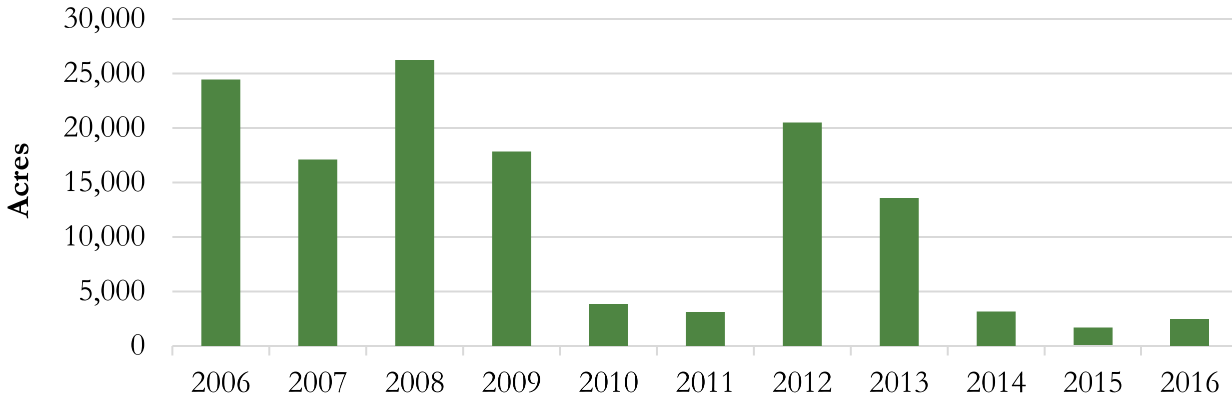
Adoption: From 1997 to 2016, 4,505 acres in filter strips were added to Missouri farms with assistance from NRCS funding. Since 2009, program usage in Missouri has been very limited. Missouri farmers were provided $53,914 in financial payments during the observed time period.

Residue and Tillage Management, No Till (NRCS Practice Standard 329)

Background: This practice includes maintaining most of the crop residue on the soil surface throughout the year; it is commonly known as no-till. Benefits to soil include increased organic matter, improved soil tilth and increased productivity. This practice has a lifespan of one year, and the practice is authorized up to three payments per acre within the contract period.

Adoption: From 2006 to 2016, 133,789 acres in Missouri adopted residue and tillage management (no-till) practices with assistance from NRCS funding. Missouri farmers were provided $2,178,073 in financial payments during this time period. Exhibit 3.38 details the Missouri adoption trend from the past 11 years.

Exhibit 3.38 - Missouri Residue and Tillage Management, No-Till Adoption, 2006-2016



Source: USDA National Resources Conservation Service

<u>Field Border (NRCS Practice Standard 386)</u>

Background: This practice involves adding field borders, which are strips of permanent vegetation (grasses, legumes, forbs, or shrubs) established on one or more sides of a field. Different scenarios and payment rates are available for adding introduced species, native species or pollinator vegetation. This practice has a lifespan of 10 years.

Adoption: From 1997 to 2016, 4,929,695 feet in field border area were added to Missouri farms with assistance from NRCS funding. Approximately 65 percent of those feet were added in 2005. Missouri farmers were provided $1,719,105 in financial payments during the observed time period.

<u>Grassed Waterway (NRCS Practice Standard 412)</u>

Background: Waterways control gullies or improve the water quality of downstream water bodies by reducing the sediment carried by runoff water. This practice has a minimum expected life of 10 years.

Adoption: From 1997 to 2016, 9,337 acres in grassed waterway area were added to Missouri farms with assistance from NRCS funding. Approximately 63 percent of those acres were added in 2002. Missouri farmers were provided $1,398,670 in financial payments during the observed time period.

4 Special Topics: Atrazine and Wildlife Population Trends

This section looks at two environmental quality measures for which data are available in Missouri. The first is atrazine detects in surface water, which gives an indication of water quality. The second is wildlife population trends in Missouri, which are impacted by production agriculture.

4.1 Atrazine Detects in Surface Water

Highlight:

- Atrazine detects in raw water exceeding the finished water standard of three ppb ranged from zero in 2004 and 2012 to 52 in 2006. All samples were below the observable adverse effect level found in studies on rats.

Of particular interest in Missouri has been the levels of atrazine in drinking water sources. Atrazine is labeled by the USEPA as a restricted use pesticide. Farmers and private applicators must undergo training and certification on how to safely use, handle, store, and dispose of restricted use pesticides before they can legally purchase and apply them. The USEPA set the safety standard for atrazine in *finished* drinking water at three parts per billion (ppb). This level was determined by finding the no observable adverse effect level on rats and dividing it by 10 for extrapolation to humans and 10 for human variability in sensitivity. In other words, the observable adverse effect level of 300 ppb in rats was divided by 100 to determine the 3 ppb threshold for humans.

Missouri has 62 surface water intakes that could be subject to atrazine contamination. The USEPA conducts an atrazine monitoring program on 23 of those that have a history of potential issues. The remaining 39 have not exhibited a history of atrazine detects and are therefore not included in the monitoring program. Water samples are collected weekly throughout the year.

This report summarizes aggregate data of *raw* and *finished* water samples collected and used as part of the USEPA's 2016 re-authorization of atrazine in the United States, see Exhibit 4.1. *Raw* samples are from untreated water that has not been through a public drinking water supply treatment facility. *Finished* samples are from treated water that has been through a public drinking water supply treatment facility. The data are from 23 water treatment plants that have at least three years of data during the period 2003 to 2012. Water entering the treatment plant at less than the EPA threshold of three ppb is still treated for a host of other conditions to make the water safe. Some atrazine is removed during this treatment. The goal is always to have finished water below three ppb.

Four percent of the 4,303 raw water samples taken at the 23 water treatment plants tested above three ppb atrazine. The water treatment plant had to conduct processes that would result in finished water with less than three ppb atrazine. These atrazine detects above three ppb occurred in 14 of the 23 locations. Two had *average* annual atrazine levels exceeding three ppb in raw water: Wyaconda in 2005 with an average of 11.06 ppb and Drexel in 2010 with an average of 4.98. There is a downward trend in the number of atrazine detects in raw water since 2006.

One percent of the 4,016 finished water samples taken at the 23 water treatment plants tested above three ppb atrazine. Five of the water treatment facilities exceeded the atrazine limit of three ppb in at least one sample during the period 2003 to 2012. None of the locations had average annual atrazine levels above three ppb in finished water. The highest level of atrazine monitored in drinking water was 30 ppb, 10 times less than the observable adverse effect level experiments on rats.

Exhibit 4.1 - Count of Atrazine Samples at 23 Missouri Water Treatment Facilities That Exceeded the EPA Finished Drinking Water Limit of Three ppb

Year	Finished Water	Raw Water
2003	0	11
2004	0	0
2005	14	48
2006	7	52
2007	7	14
2008	3	20
2009	1	7
2010	20	28
2011	0	13
2012	0	0
Total	**52**	**193**

Source: U.S. EPA

4.2 Wildlife Population Trends

Highlight:

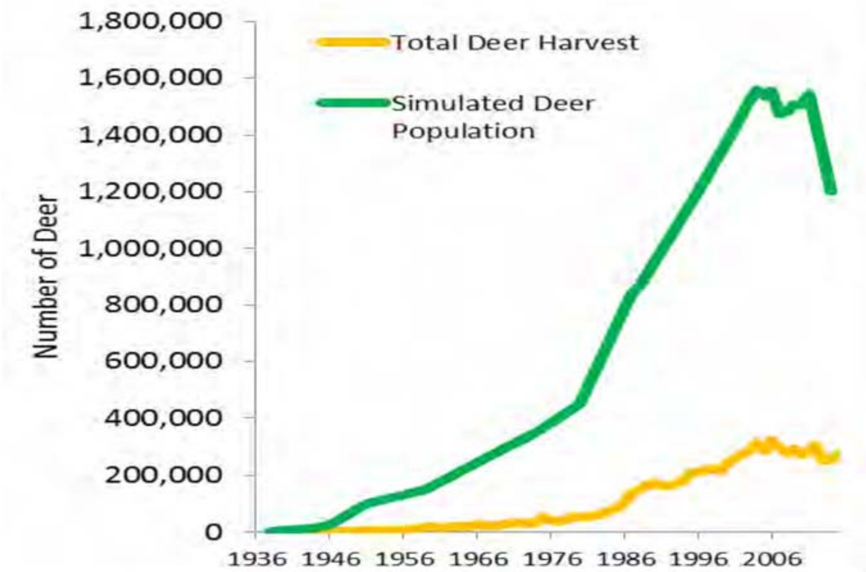
- Wildlife population trends vary by county. The overall state wildlife population has increased over the last 40 years for deer, turkey and most furbearing animals.

The Missouri Department of Conservation (MDC) annually issues reports on 1) deer population, 2) wild turkey population and 3) the furbearer program.

Keller and Marshall (2016) report the simulated population of Missouri deer from 1936 to 2016 Exhibit 4.2. The deer population in Missouri was estimated at less than 1000 in 1935 and has risen to over 1.5 million recently. Lombardo and Haslag (2017) report that the trends in deer population are decreasing in three Missouri counties, stable to decreasing in mostly northern Missouri counties, stable to increasing in six southeast Missouri counties and stable elsewhere in the state (Exhibit 4.3). The MDC attributes the loss in deer populations in many central, northern, and western Missouri counties in recent years to liberal antlerless permit availability, severe hemorrhagic disease outbreaks, and changes in habitat availability (Keller and Marshall, 2016).

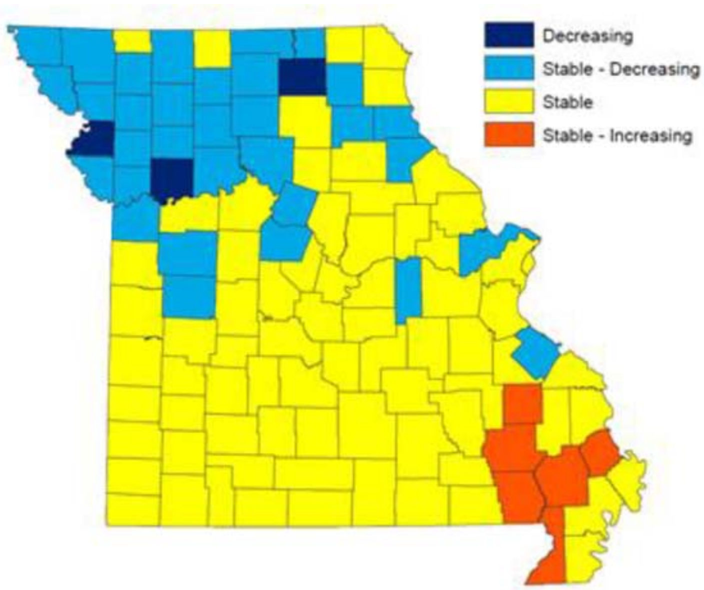
Elk were native to Missouri prior to the mid-1800's, after which none were sighted. Between 2011-2013, elk were reintroduced into Carter, Reynolds and Shannon counties of Missouri. One reason these three counties were chosen was because of low row crop acreage (Lombardo and Haslag, 2017). USDA records show that the number of crop and hay acres harvested has decreased from 116,640 acres (8% of land area) in 1919 to 52,000 acres of hay and no crop acres in 2008. The USDA does not report any crop or hay acres by county in this region since 2008. Increased crop productivity per acre has augmented the reduction of cropped acres in regions such as south central Missouri, allowing the successful reintroduction of elk.

Exhibit 4.2 - Simulated Deer Population in Missouri, 1936-2016.



Source: Keller and Marshall, 2016

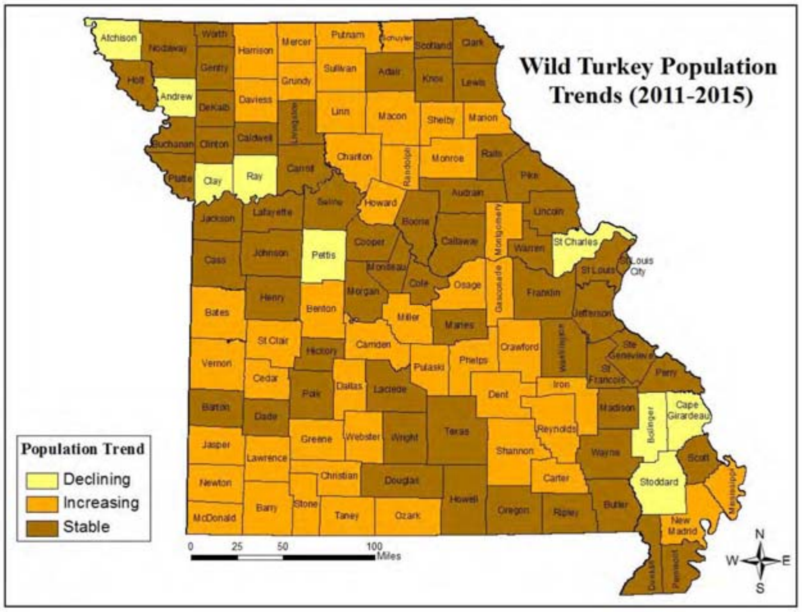
Exhibit 4.3 - County-specific deer population trends in Missouri, 2016.



Source: Lombardo and Haslag, 2017

The Missouri Department of Conservation (2016) estimates the wild turkey population is declining in 9 counties but increasing or remaining stable in the other 114 counties (Exhibit 4.4).

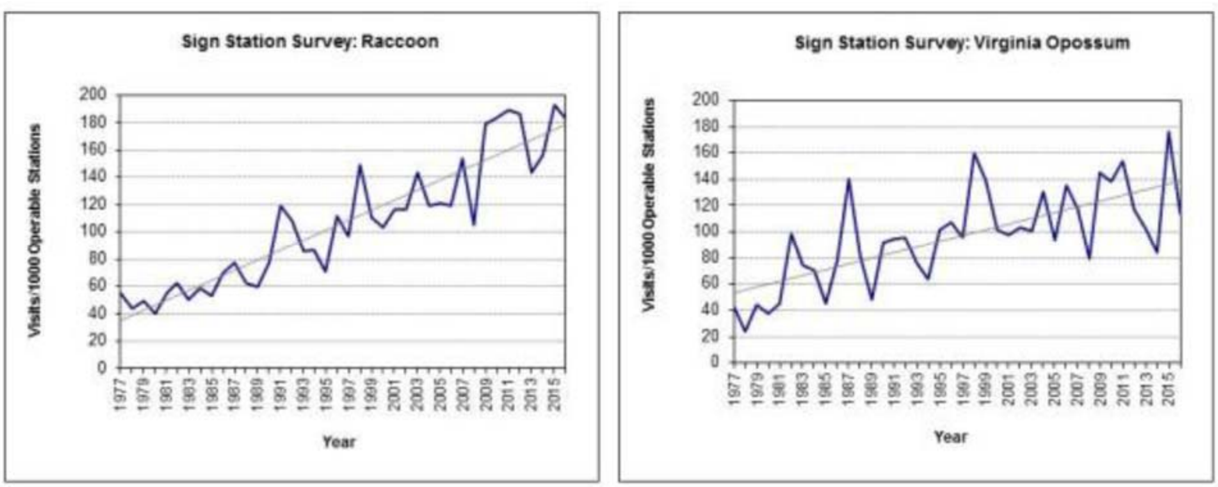
Exhibit 4.4 - Wild Turkey Population Trends in Missouri, 2011-2015.

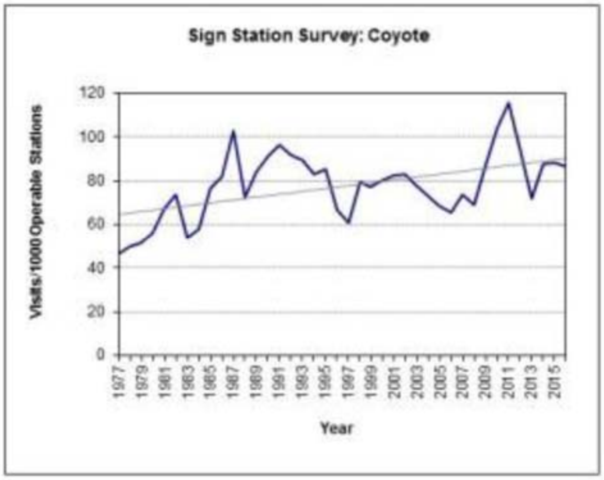


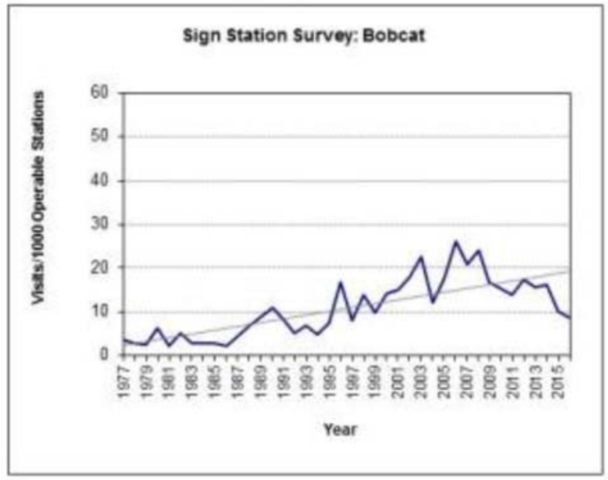
Source: Missouri Department of Conservation, 2016

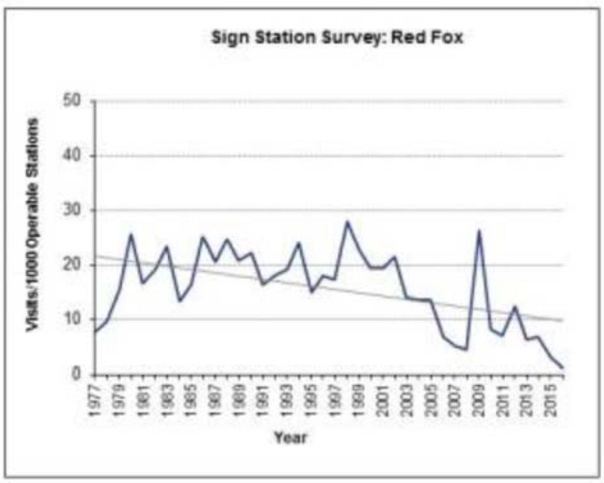
The MDC also reports the populations of many furbearing animals in Missouri. Conlee and Johnston (2018) report that the population of raccoons, opossums, coyotes, bobcats and striped skunks have risen based on sign station surveys since 1977. Red and gray fox populations have declined since 1977 based on sign station surveys (Exhibit 4.5). Harvest data, rather than population data, is reported for other species, such as muskrat and beaver, but recognized to be influenced by the market price for pelts.

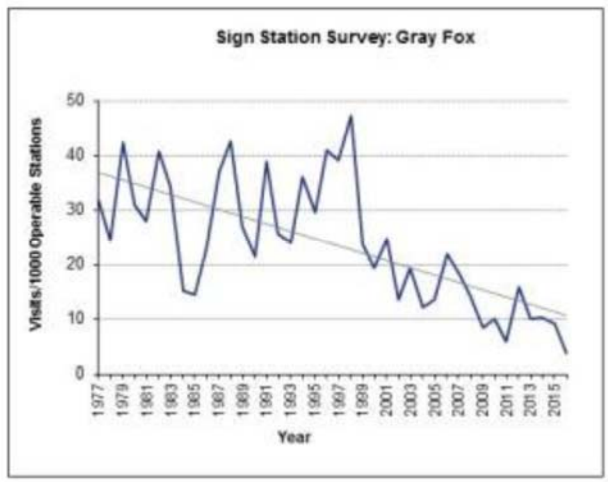
Exhibit 4.5 - Sign Station survey data used to estimate populations of furbearing animals in Missouri, 1977 - 2016.

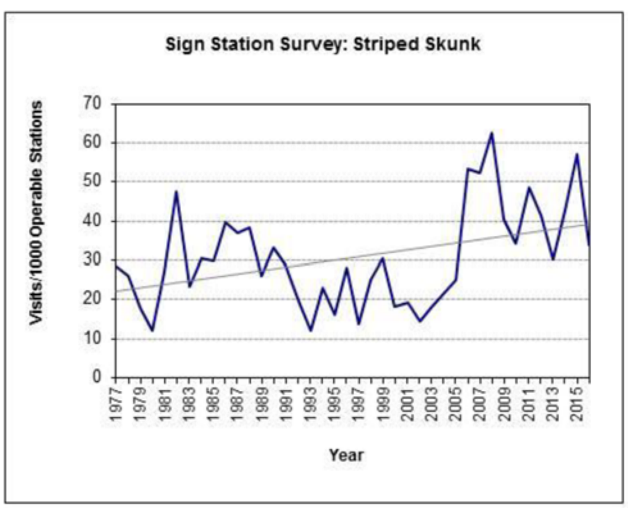












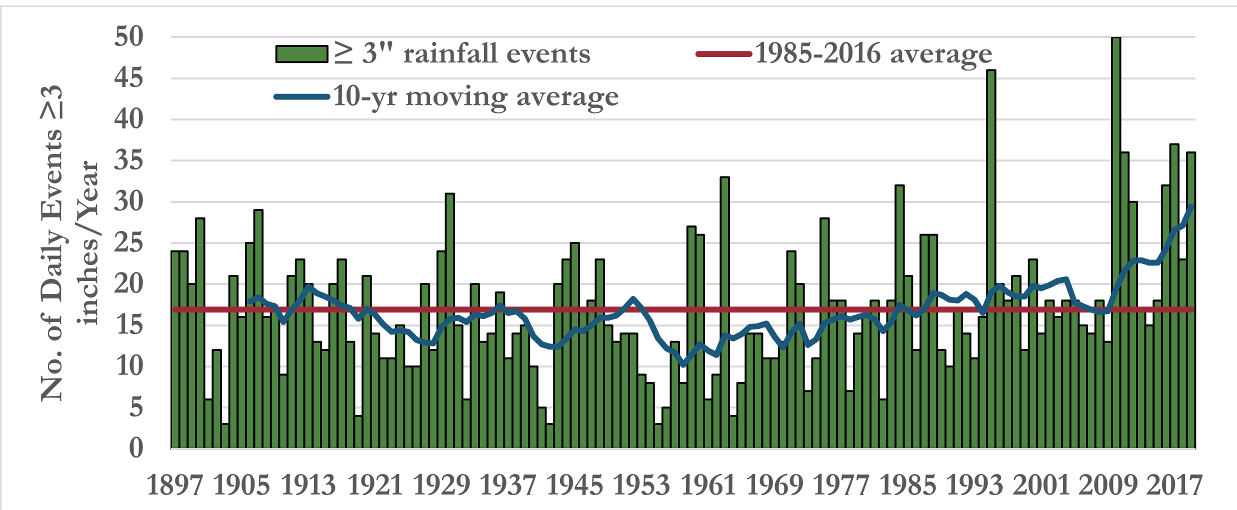
Source: Conlee and Johnston, 2017

5 Challenges and Opportunities

5.1 Impact of Major Weather Events (Changing Climate, More Intense Storms)

Missouri farmers have been adopting reduced tillage practices and cover crop plantings, which lead to reduced erosion. These practices are likely to increase in importance if the number of daily rainfall events exceeding 3 inches continues to rise. Exhibit 5.1 tracks extreme rainfall events from 1895 to 2017. Extreme rainfall events create field runoff that can remove substantial amounts of soil from a field. Missouri Climate Center analysis indicates that the number of 3-inch rainfall events averaged 20 events during the past 30 years. That exceeds the long-term average of 17 by three.

Exhibit 5.1 – Missouri Extreme (≥ 3 Inches/Cay) Rainfall Events, 1895-2017



Source: NOAA/Missouri Climate Center

5.2 Herbicide Resistance in Weeds

At least six weed species have developed glyphosate resistance in Missouri: waterhemp, giant ragweed, marestail, common ragweed, palmer amaranth and annual bluegrass (Bradley, 2014). Herbicide resistance in weeds causes increased herbicide applications, which can cause the environmental impact quotient to increase. It could also increase demand for tillage, which would increase erosion, reduce soil health and increase fuel use.

Dicamba-resistant cotton and soybean varieties are new technologies introduced to fight herbicide-resistant weeds. Their introductory rollout has been accompanied by multiple off-target movement concerns. The University of Missouri estimated that 325,000 acres of soybeans experienced dicamba injury in 2017. As of October 15, 2017, the Missouri Department of Agriculture (MDA) received 310 dicamba injury complaints affecting 108,758 acres of soybeans, 770 acres of peach and apple trees, 134 acres of watermelons, cantaloupes and pumpkins, 132 acres of vineyards, 130 acres of rice, 24 acres of certified organic vegetables, and numerous commercial and residential gardens. The MDA issued a special use label for dicamba formulations sprayed in-season to address the off-target injuries.

Focusing increased attention on best management practices that prevent the development of herbicide-resistant weeds, such as using herbicides with multiple modes of action, will be critical to continued efficient and sustainable agricultural production.

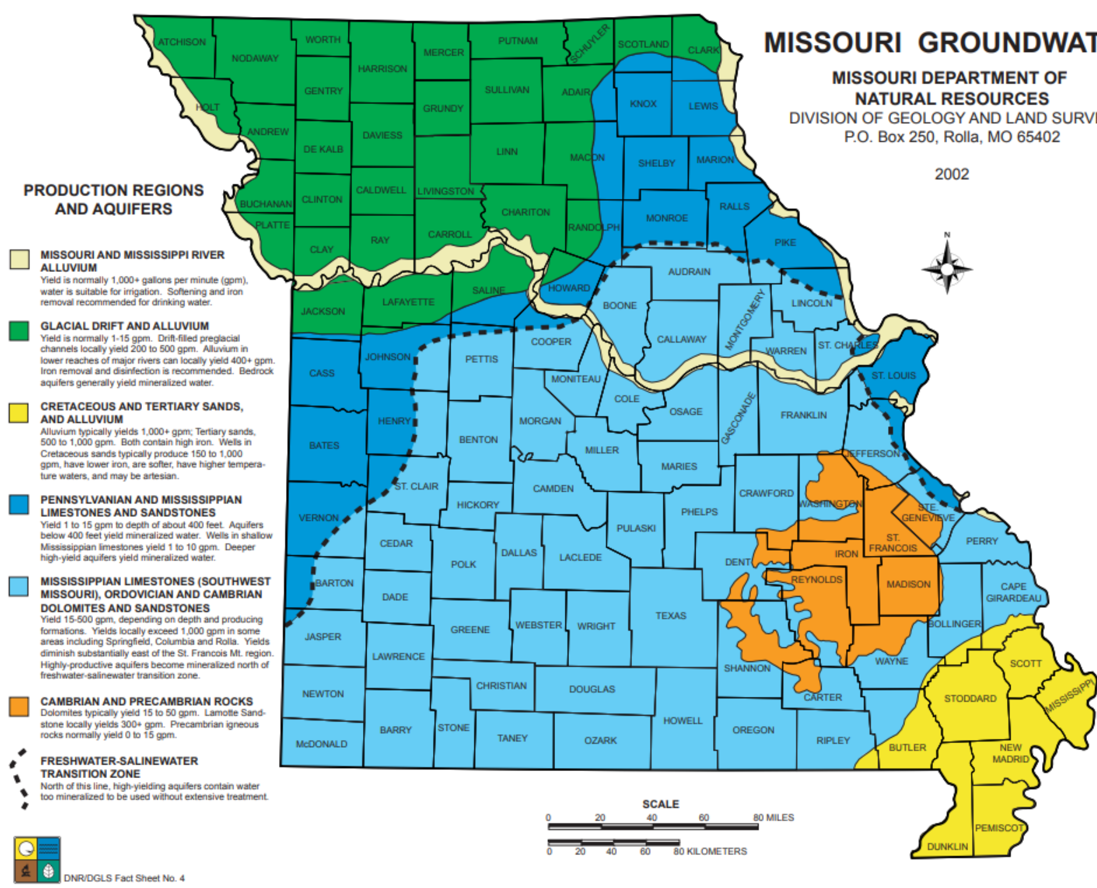
5.3 Water Availability

Missouri is a riparian water law state, so landowners may reasonably use water sources that are touching or underneath their land. Under this law, a landowner can withdraw as much water as needed as long as the withdrawals do not adversely impact the water use of other individual water users. The U.S. Army Corps of Engineers has jurisdiction over navigable waters, such as rivers and streams.

Missouri is a water-rich state with both the Missouri and Mississippi rivers and an average annual rainfall of 43 inches. High-yielding dryland crop production is common in much of the state. Water for irrigation and livestock tends to be from surface water or shallow groundwater sources. This allows Missouri farmers to have low pumping costs.

Missouri has significant groundwater production regions and aquifers; see Exhibit 5.2. The dotted line delineates the freshwater-saline water transition zone. North of this line, high-yielding aquifers contain water too mineralized to be used without extensive treatment. The light blue area south of the line contains most of the deep wells used for crop and livestock production.

Exhibit 5.2 - Missouri Groundwater Production Regions and Aquifers



Source: Missouri Department of Natural Resources

Western U.S. states are experiencing significant water challenges. The 2012 drought caused Texas, Oklahoma and Missouri cattle producers to cull cows and market their calves earlier in the summer. Many California dairies have moved to access better water resources at a more reasonable cost. Missouri is considered a desirable location to move livestock because of its water availability. Also, processing plants that require water consider Missouri as a possible site. This potential increased demand for water could become an area of concern.

5.4 Waters of the U.S. Rule

The definition of "waters of the U.S." was first promulgated in 1986. In 2015, the Environmental Protection Agency revised the definition. This revision was challenged in court and issued a stay. In February 2018, the EPA finalized a WOTUS applicability rule that delays the implementation of the 2015 redefinition of Waters of the U.S. until February 2020. Although many farmers laud the delay of the implementation of the rule, the rule's fate remains uncertain as several court challenges have been filed. This uncertainty prevents efficient decision-making and improvements in environmental quality.

Hendricks (2017) contends that the regulatory uncertainty is burdensome due to 1) uncertainty of jurisdiction without obtaining a jurisdictional determination by the Army Corp of Engineers, 2) concerns about how agricultural exemptions may be determined given vague language in the applicable legislation, 3) large fines for violations and 4) permitting requirements that create significant application costs and delays.

Hendricks also asserts that the Clean Water Act has been ineffective in reducing nonpoint source pollution affecting the hypoxia zone in the Gulf of Mexico. He states that "the WOTUS rule would have little to no impact on improving water quality," and he proposes that to improve water quality, "The government simply needs to clearly define the property rights for agricultural nonpoint emissions" and rely on markets to trade pollutants.

If property rights are used to reduce nonpoint source pollution, then certain decisions would become important. For example, would farmers have a right to pollute or water users have a right to water without nutrients? What level of pollutant release would be the baseline? How would releases and sequestrations be monitored?

5.5 Missouri Nutrient Management Standard

In 2016, the EPA agreed in a consent decree, to propose criteria for MO lakes and reservoirs or accept a revised MDNR proposal that addressed the issues stated in the EPA's 2011 disapproval of MDNR's earlier proposal. The MDNR submitted a revised state nutrient rule to the EPA and the EPA proposed its own nutrient rule. The EPA is under court order to finalize a water quality rule by December 15, 2018.

The MDNR and EPA proposed nutrient rule for Missouri Lake Ecoregions are summarized in Exhibit 5.3. The EPA rule joins the Ozark Border and Ozark Highland Lake Ecoregions of the MDNR rule into a single Ozark Lake Ecoregion. The MDNR rule has a set criterion for chlorophyll-a which, if exceeded, designates a waterbody as impaired. The EPA and MDNR rules set screening or protection values for waterbodies for phosphorus, nitrogen and chlorophyll-a. If a screening or protection value is exceeded, other tests are taken to determine if the waterbody is impaired.

Exhibit 5.3 – MDNR and USEPA proposed nutrient rule for water quality screening values and criterion in Missouri Lake Ecoregions.

Lake Ecoregion	Regulatory Agency	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll-a (µg/L)	
				Screening or protection value	Criterion
Plains	MDNR*	49	843	18	30
	EPA**	44	817	14	
Ozark Border	MDNR*	40	733	13	22
	EPA**	23	500	7.1	
Ozark Highland	MDNR*	16	401	6	15
	EPA**	23	500	7.1	

Source: (U.S. Federal Register, 2017)

*MDNR rule proposes *screening values* for total phosphorus, total nitrogen and chlorophyll-a with a hard criterion for chlorophyll-a.

**EPA rule proposes *protection values* for total phosphorus, total nitrogen and chlorophyll-a.

An analysis of affected lakes indicates that the MDNR rule would designate 34 lakes as impaired; the EPA rule would list 113 lakes as impaired. The cost for implementing the MDNR rule is estimated at $83 million while the EPA rule would cost 20 times more at $1.7 billion (Missouri Department of Natural Resources, 2018). The average cost per impaired lake for the EPA rule would be $15 million; for the MDNR rule, it would be $2.4 million. Impairment designations can affect the land management decisions within the watershed of an impaired waterbody.

The Missouri Coalition for the Environment, which originally brought the suit against the EPA, which resulted in the current consent decree, argues that both the EPA and MDNR rules are insufficient to protect water quality (US EPA, 2018).

Many state Hypoxia Task Force Nutrient Reduction Strategies present various methods for reducing nitrogen and phosphorus from reaching the Gulf of Mexico. Some researchers have found that more strategic targeting of government programs to landscapes that most affect the nutrient concentrations found in the Mississippi River Basin are necessary (Zilberman, Khanna, & Lipper, 1997). Others suggest transitioning to perennial crops such as miscanthus, which has positive soil and nutrient retention properties (Friedrich, Derpsch, & Kassam, 2012). Such solutions would have significant impacts on land management options available to farmers.

6 Public Perceptions on Agriculture and the Environment

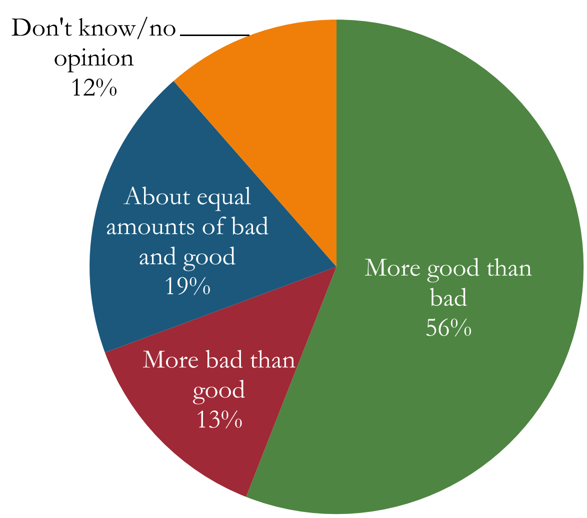
Improving the environmental footprint of crop production needs to be accompanied by communicating that improvement to consumers and voters. The term "sustainability" is often connected to agriculture's environmental effects. Farmers may hold different perceptions about sustainability and agriculture's relationship with the environment than consumers.

According to a survey conducted in 2014, consumers tended to associate sustainability with fewer specifics than farmers. For example, 22 percent of consumers defined sustainable agriculture as "environmentally friendly," and 18 percent indicated it meant the "ability to produce sufficient food to feed the population" (Wurth, 2014).

In contrast, farmers who responded to the same survey described specific elements of environmental stewardship when asked to define sustainable agriculture. Forty percent shared that sustainable agriculture would emphasize soil protection, 27 percent stressed land use as a sustainability factor, and 27 percent noted water use as a component of sustainable agriculture. For 25 percent of farmer-respondents, "biodiversity protection" was an environmental aspect that they named (Wurth, 2014).

Exhibit 6.1 highlights the extent to which registered voters viewed agriculture and farming as bad or good with respect to environmental sustainability. More than half of the responding registered voters indicated that they viewed agriculture and farming as more good than bad for environmental sustainability; however, 13 percent shared that the industry was more bad than good, and 19 percent viewed the industry as about equal parts good and bad (Morning Consult, 2017).

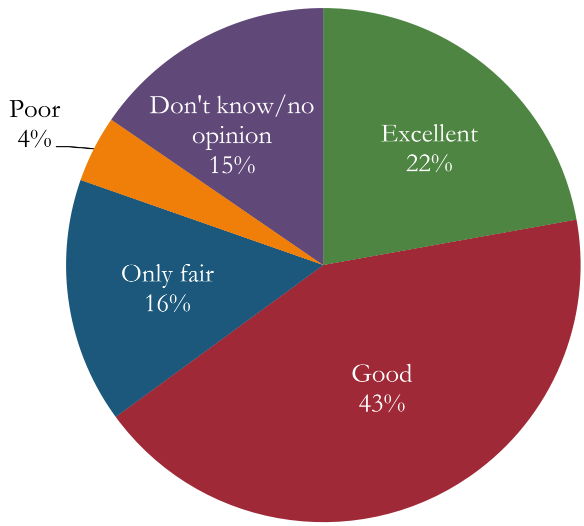
Exhibit 6.1 - Registered Voter Views of Agriculture and Farming as Good or Bad for Environmental Sustainability*



* Question: Do you think each of the following industries or sectors is more good than bad, more bad than good, or equal amounts of good and bad when it comes to environmental sustainability? Agriculture and farming (n=1,971)
Source: Morning Consult (2017)

The same survey indicates that nearly two-thirds of the respondents rated the sustainability *practices* of agriculture and farming as excellent or good; see Exhibit 6.2. Twenty percent assigned an only fair or poor rating to the industry's sustainability practices (Morning Consult, 2017).

Exhibit 6.2 - Registered Voters' Rating of Agriculture and Farming Industry's Sustainability Practices*



* Question: How would you rate the sustainability practices of each of the following industries or sectors? Agriculture and farming (n=1,971)
Source: Morning Consult (2017)

Based on insights from a survey conducted in 2016, sustainability perception does have some impact on food and beverage purchase decisions. However, it is not the driving force that motivates decision-making. Consumers noted that the most important characteristics influencing food and beverage purchase decisions were taste, price, healthfulness and convenience. Sustainability has been a relatively important purchase driver for some consumers. In 2011, 52 percent of respondents indicated that sustainability was a factor affecting their food and beverage decisions; in 2016, this fell to 41 percent (Raymond, Smith Edge, & Sanders, 2016).

Other notable findings from this survey were:

- Thirty-eight percent of the respondents said that they would pay more for foods and beverages that were produced sustainably, but 28 percent indicated that they would not pay more.
- "Conserving the natural habitat (water, land, rainforests, etc.)" and "reducing the amount of pesticides used to produce food" were cited by more than 40 percent of the respondents as the most important aspects of sustainable food production.
- "Ensuring an affordable food supply" and "ensuring a sufficient food supply for the growing global population" were cited by more than one-third of the respondents (Raymond, Smith Edge, & Sanders, 2016).

A targeted study of persons likely to influence others in food conversations found that the elements of food sustainability most important to them were 1) soil health and conservation and 2) water quality, pollution and runoff (U.S. Farmers & Ranchers Alliance, 2015).

A 2015 survey reported that 42 percent of consumers strongly agreed or somewhat agreed that GMO crops are not safe for the environment (Watson, 2015). The amount of scientific research that contradicts public perceptions about the benefit of GMO crops reinforces the need to educate consumers about food production and the changes farmers are adopting to benefit the environment.

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