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U.S. DEPARTMENT OF AGRICULTURE

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Characteristics and Trends of U.S. Soybean Production Practices, Costs, and Returns Since 2002

Kate Vaiknoras and Todd Hubbs

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Abstract

The United States is a major global soybean producer. In the past 20 years, U.S. soybean acreage has grown 18 percent, from 74 million to 87 million acres. Soybean yields have also increased. This study uses nationally representative survey data of U.S. soybean farmers (along with costs and returns data) to examine how production practices, export demand, public policy, and environmental factors have changed over the past 20 years. We find that soybean farming has become more input-intensive, which likely explains some of the yield gain. The use of fertilizer, fungicides, insecticides, and precision agriculture practices have increased since 2002, and genetically engineered seed variety adoption has become nearly universal. These changing practices have contributed to an increase in per-acre production costs over the period. However, the unit cost of producing a bushel of soybeans, when adjusted for inflation, has fallen from $10.21 in 2002 to $9.07 in 2018 due to increasing yields that offset increasing per-acre costs. Thus, soybean productivity has increased over time. Our analysis of developments in the production of soybeans, the second-most planted crop in the United States, has crucial relevance for understanding U.S. agriculture in the 21st century.

Keywords: Soybeans, farm characteristics, agricultural production practices, commodity costs and returns, Agricultural Resource Management Survey (ARMS).

Acknowledgments

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A report summary from the Economic Research Service *June 2023*

Characteristics and Trends of U.S. Soybean Production Practices, Costs, and Returns Since 2002

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What is the Issue?

Soybean is a major U.S. crop, with 87 million planted acres in 2022, making it the second-most planted crop after corn. Soybean is a key source of livestock feed and also an export crop. The U.S. soybean industry has grown over the past two decades in terms of acreage, yield, and production. Many factors influencing soybean production and soybean markets have changed since the last major USDA, Economic Research Service (ERS) report that examined the crop. These factors include technology and production practices, export demand, environmental concerns, public policies, and weather events. This report contributes to the literature on U.S. crop farming by identifying major trends in soybean farming in recent decades and examining their causes and implications. The report also analyzes how costs, returns, and productivity have evolved in response to shifting prices and production practices.

What Did the Study Find?

Over the past two decades, U.S. soybean acreage, yields, and exports increased while prices trended upward:

- Soybean planted acreage grew 18 percent between 2002 and 2022. While planted acreage lagged that of corn in most years, soybean acreage grew at a faster rate than corn during the period.
- U.S. soybean exports increased over time as a share of total U.S. production but fell in 2018 due to trade restrictions. In the 2017/18 marketing year, which runs each year from September to August, exports were 48.4 percent of production, but the following year fell to 39.6 percent. Soybean prices and acreage also fell that year. Soybean exports quickly rebounded, and in 2020/21, equaled 53.7 percent of production.
- Yield trended upward but was affected by pest and weather events, including aphid infestations in 2003 and a drought in 2012.
- Prices trended upwards over the past two decades but there was fluctuation between years. Nominal soybean prices peaked in 2012 at $14.40 per bushel.

ERS is a primary source of economic research and analysis from the U.S. Department of Agriculture, providing timely information on economic and policy issues related to agriculture, food, the environment, and rural America.

Soybean production has become more input intensive and the adoption of new technologies has expanded:

- Genetically engineered seed varieties became commercially available in 1996. Adoption of herbicide-tolerant genetically engineered soybean varieties was nearly universal by 2006. The most common type of seed is tolerant to glyphosate, a widely used herbicide.

- Demand for other herbicides, such as dicamba, has grown due to the spread of glyphosate-resistant weeds. Dicamba-tolerant soybean varieties became commercially available in 2016. By 2018, 43 percent of soybean acres in the United States were planted with dicamba-tolerant seed, though the acres were not all treated with dicamba.

- A greater share of soybean acres were treated with fertilizer, insecticide, and fungicide in 2018 than in 2002, while the use of precision agriculture technology also grew. Usage varies by region.

Costs of soybean production, as well as net returns and productivity, have changed over time:

- Changing soybean production practices contributed to an increase in the cost of producing an acre of soybeans, as well as yields, and productivity. The unit cost of producing a bushel of soybeans, adjusted for inflation, fell from $10.21 in 2002 to $9.07 in 2018. Of the years 2002, 2006, 2012, and 2018, this cost was lowest in 2006 at $8.93 per bushel.

- From 2002 to 2022, net financial returns were highest in 2012—a major drought year when soybean prices were relatively high, and lowest in 2019, a year when soybean prices were relatively low. Net soybean returns were positive in more years than for corn and wheat, which may explain the growth in soybean acreage relative to those crops.

How Was the Study Conducted?

This study uses data from USDA, National Agricultural Statistics Service (NASS) on soybean acreage, prices, and yields from 2002 to 2022 and from the U.S. Census of Agriculture in 2002, 2007, 2012, and 2017 to summarize broad trends in the U.S. soybean industry from the past two decades. The study also uses data from USDA, ERS *Oil Crops Yearbook* from 2002 to 2022 to describe the increase in U.S. soybean exports during that period. Data from the USDA, ERS and USDA, NASS Agricultural Resource Management Survey (ARMS) of soybean fields from the years 2002, 2006, 2012, and 2018 are used to examine changes in technology used in soybean production over time and by region. The ARMS provides nationally representative information on production practices and input use on soybean fields. Finally, data from the annual USDA, ERS Commodity Costs and Returns estimates from 2002/22 are used to analyze changes to costs and returns to soybean production, as well as economies of size and productivity in soybean production. Much of the data are summarized for the major soybean-producing regions.

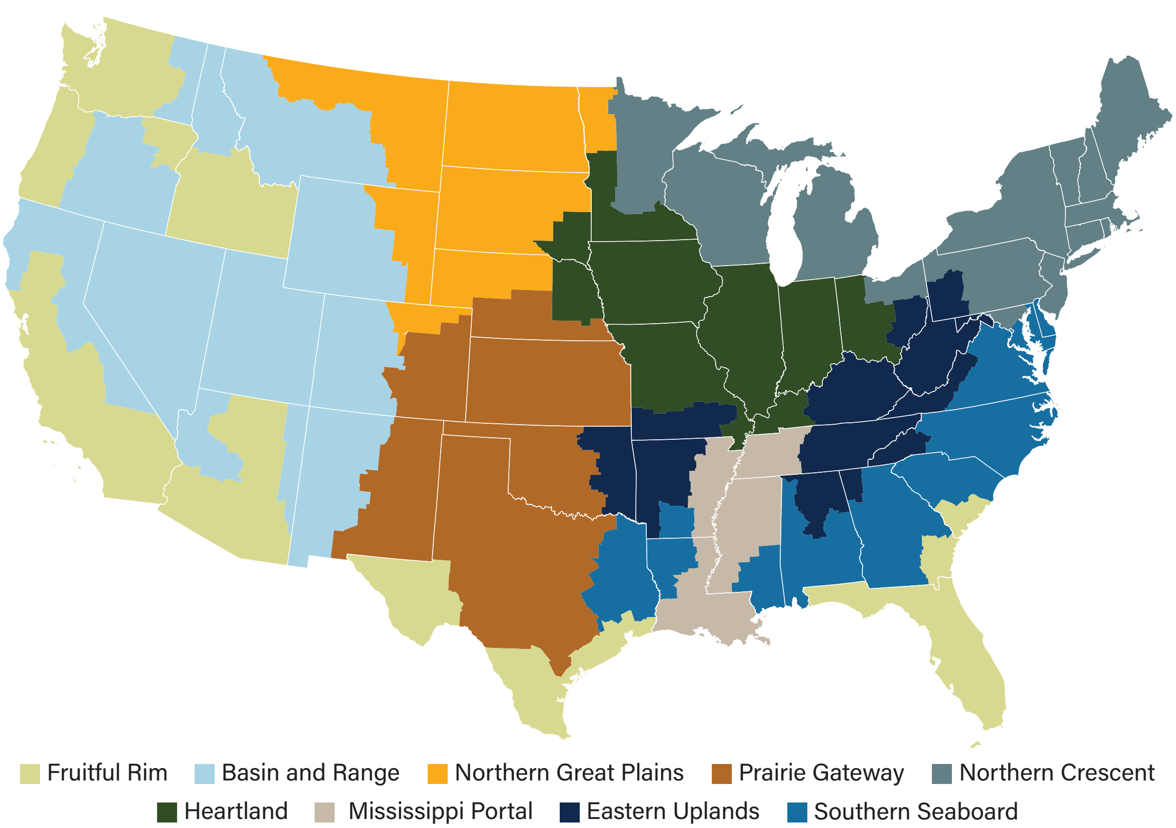
Characteristics and Trends of U.S. Soybean Production Practices, Costs, and Returns Since 2002

Introduction

This study examines U.S. soybean production since 2002—summarizing changing trends in acreage, yield, prices, and production costs and returns. The study also analyzes how production practices have shaped these trends—along with growing export demand, weather events, pests, and diseases. The authors define a soybean farm as one that grows soybeans in a particular year and expects to sell, or would normally sell, at least $1,000 worth of agricultural products. This definition includes farms that produce other agricultural commodities in addition to soybeans.

Many of the trends described in this report are summarized by USDA, Economic Research Service (ERS) farm resource regions, which include nine production regions based on similar production conditions and farm characteristics, as shown in figure 1. Much of the data in this report comes from the seven regions that produce the most soybeans in the United States: the Heartland, Northern Crescent, Northern Great Plains, Prairie Gateway, Eastern Uplands, Southern Seaboard, and Mississippi Portal regions.

Figure 1
USDA, Economic Research Service farm resource regions



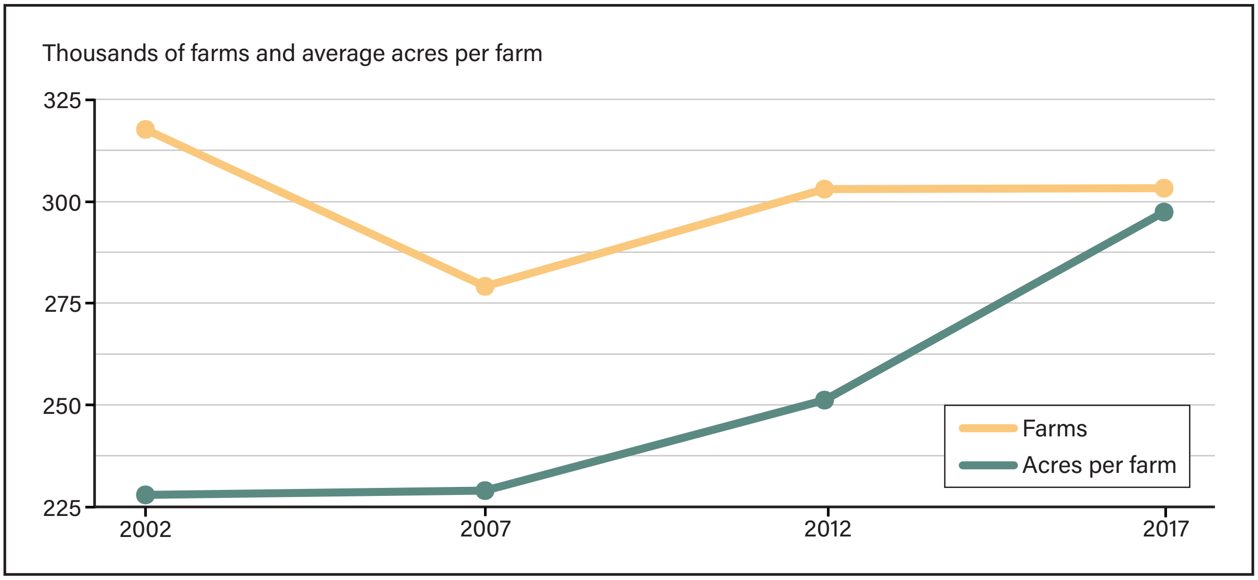
Source: USDA, Economic Research Service farm resource regions.

Data used in this report come from several sources. The first is USDA, National Agricultural Statistics Service (NASS) acreage and yield reports, as well as input price indices. The second is USDA's Agricultural Resource Management Survey (ARMS) of soybean producers conducted in 2002, 2006, 2012, and 2018. The third is the USDA, ERS Commodity Costs and Returns data product. Additional data also come from the U.S. Census of Agriculture and the ERS *Oil Crops Yearbook.*

Number of Farms Producing Soybeans

Agricultural Census data indicate 317,611 farms in the United States harvested soybeans in 2002; by 2017, this number had dropped 5 percent to 303,191 farms (figure 2). The number of soybean acres harvested per farm in the United States increased by 30 percent from 2002 to 2017, from 228 to 297 acres.

Figure 2
Number of soybean farms in the United States and average acres harvested per farm



Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, Agricultural Census 2002, 2007, 2012, and 2017.

Total U.S. Acreage

The total planted acreage of soybeans in the United States grew from 74 million acres in 2002 to 87 million acres in 2022, an increase of 18 percent (figure 3). This increase has not been steady over time. From 2002 to 2006, growth was modest, followed by a sharp acreage decline in 2007; acreage shifted to corn that year, likely due to a biofuel policy (see box, "Soybean Marketing and Major Uses of Soybeans").

Following 2007, soybean planted acreage grew in most subsequent years, peaking in 2017 at 90 million acres. Acreage fell in 2018 and 2019 to 76 million acres, its lowest since 2011. This decrease was likely due to falling exports to China as a result of trade restrictions, along with low soybean prices (see section, Soybean Trade). In addition, heavy spring rains in 2019 led to many unplanted acres (USDA, FSA, 2019). Acreage partially recovered in the following years.

In most years from 2002 to 2022, soybeans had the second-highest planted acreage of any U.S. crop behind corn. Only in 2018 was soybean acreage higher than that for corn. Acreage of both crops has trended upward over time, though less for corn (12 percent growth) than for soybeans (18 percent). By contrast, planted acres of wheat declined by 22 percent from 2002 to 2022 (figure 3).

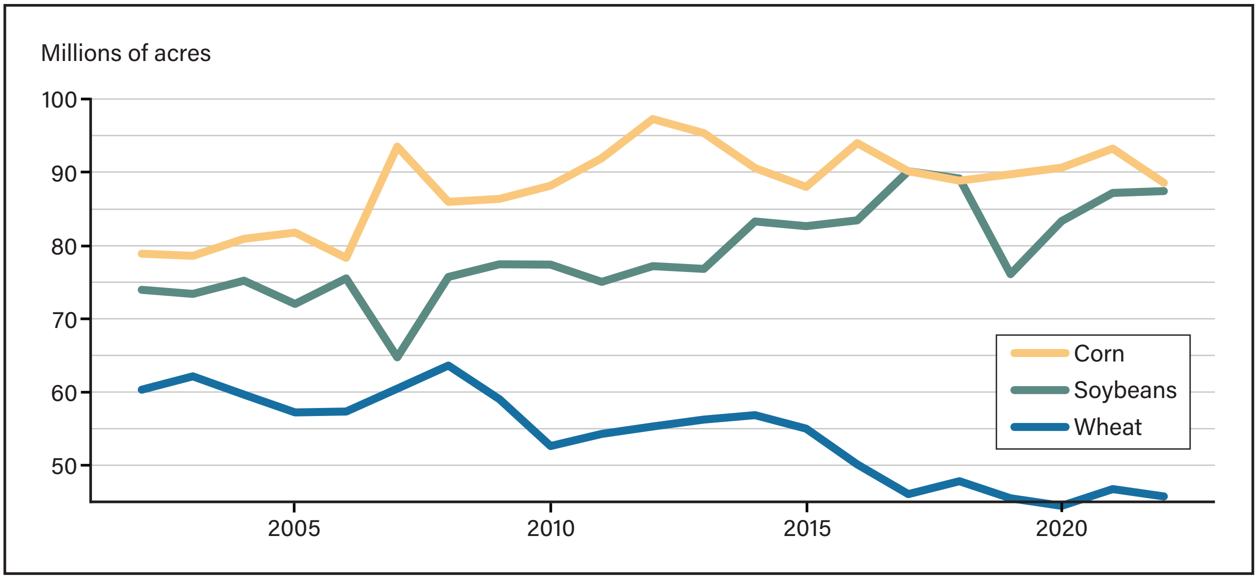
Soybean Marketing and Major Uses of Soybeans

Soybeans were first grown in the United States during the 19th century. Soybean demand grew in the mid-20th century, coming from the U.S. processing industry and livestock farms. Today, the United States, Brazil, and Argentina are the world's largest soybean producers.

Most soybeans, whether exported or used domestically, are processed into soybean meal and oil in a process called crushing. The hull of the soybean is removed, and the soybean is processed into flakes and soaked in a solvent to extract the oil. The leftover flakes are then made into soybean meal. One bushel of soybeans yields approximately 44 pounds of soybean meal and 11 pounds of oil. Soybean meal is used as livestock feed—while soybean oil can be made into vegetable oil for human consumption, various industrial uses, or biofuels. The USDA lists three uses for soybeans: crush; exports; and seed, feed, and residual. In the 2021/22 marketing year, which runs each year from September to August, most soybeans were crushed domestically (2,204 million bushels) or exported whole (2,158 million bushels)—while 102 million bushels were used as seed, feed, and residual. Some soybeans are kept as stocks (274 million bushels in 2021/22).

The U.S. Renewable Fuels Standard, created under the Energy Policy Act of 2005, requires a given volume of renewable fuel to replace petroleum-based fuels. Recently, some States implemented programs—such as California's Low Carbon Fuel Standard—to reduce carbon intensity in fuel by using life-cycle greenhouse gas emission models. Tax incentives, increased production capacity, and high crude oil prices contributed to an increase in U.S. biofuel production. While the production of ethanol—mostly from corn—grew, biodiesel fuel made from soybeans also had strong growth (Westcott, 2007). Prior to the 2004/05 marketing year, less than 1 percent of U.S. soybean oil was used for biofuels. This share grew to more than 15 percent in the 2007/08 marketing year, after which the share dipped for the next few years before continuing its upward trajectory. Forty percent of U.S. soybean oil was used for biofuels in 2021/22, with further growth expected due to demand for vegetable oils in the expansion of renewable diesel and jet fuel production (USDA, ERS, 2022b).

Figure 3
Total soybean, corn, and wheat planted acreage in the United States

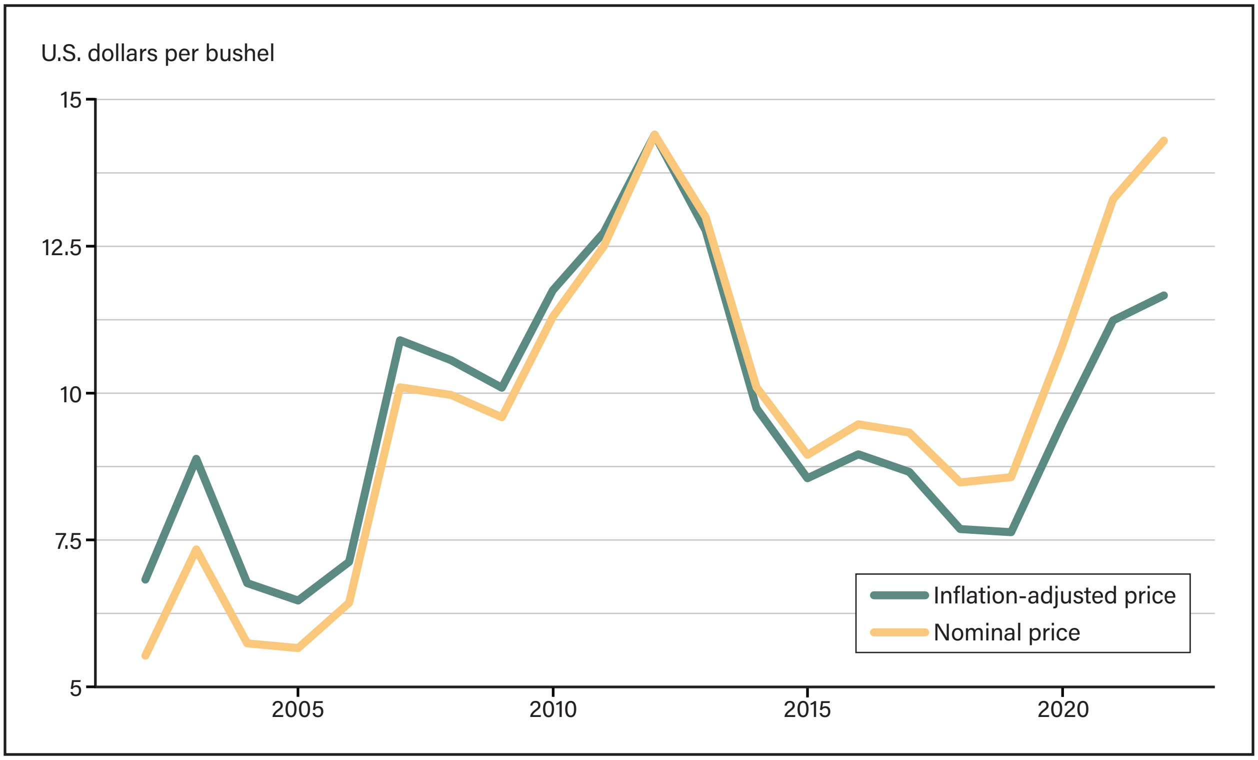


Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, *Crop Production*.

Prices

In 2002, the nominal (i.e., not adjusted for inflation) marketing year season average price of soybeans was $5.53 per bushel; this price increased by 159 percent to $14.30 in 2022 (figure 4). The price peaked in 2012 at $14.40 per bushel. In 2012, U.S. production suffered from a drought throughout the Midwest that lowered yields and increased prices (Ash, 2012). The price then fell for many of the subsequent years as production increased, reaching a low of $8.48 in 2018 when the industry suffered from trade restrictions, demonstrating the importance of export markets to the U.S. soybean price and industry. Between 2002 and 2022, the real price of soybeans (adjusted for inflation) rose 71 percent.

Figure 4
Soybean price in the United States



Note: Inflation prices are adjusted using the Gross Domestic Product (GDP) Implicit Price Deflator to reflect 2012 dollars.

Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, *Agricultural Prices.*

Soybean Trade

U.S. soybean exports (as a share of total production) have increased over time, from 37 percent in 2001/02 to 48 percent in 2021/22 (figure 5), with China dominating global soybean imports. In 2002, China joined the World Trade Organization (WTO), which eliminated quantitative restrictions on imports. Around this time, China also expanded its oilseed crushing capacity, and rising Chinese living standards led to an increased demand for meat and edible oils, increasing Chinese demand for soybeans (Ash et al., 2006).

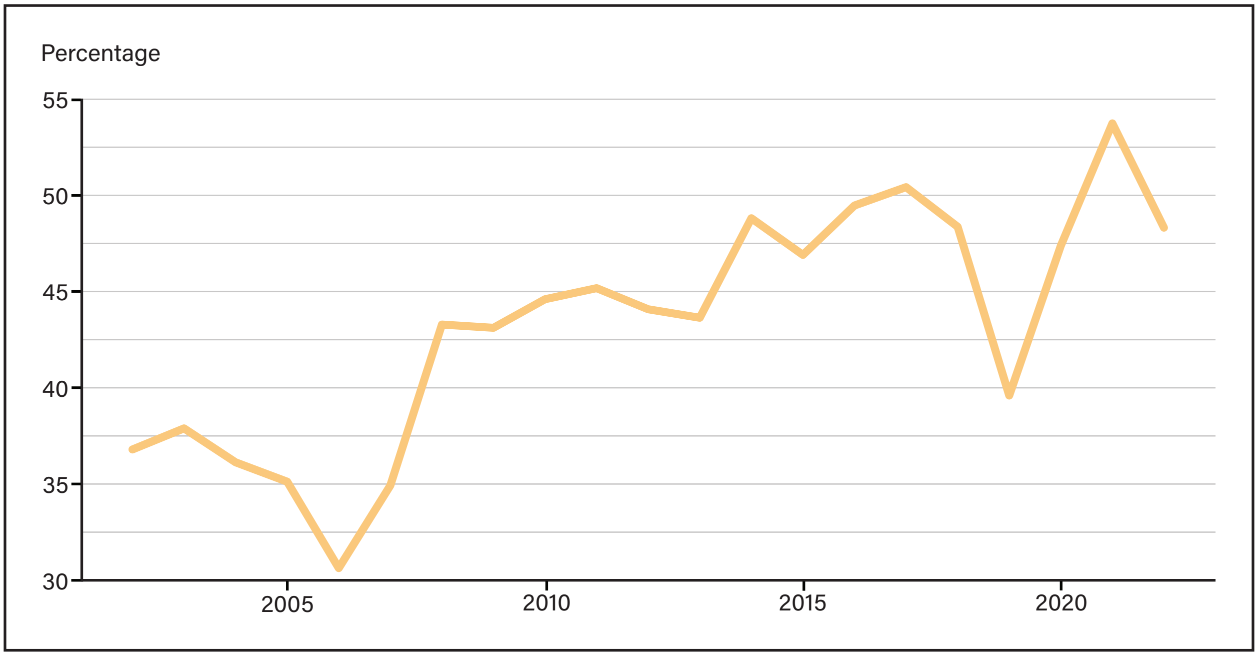
In 2018, several U.S. trading partners imposed retaliatory tariffs on U.S. exports in response to U.S. tariffs on steel and aluminum imports. It is estimated that from mid-2018 to the end of 2019, these retaliatory tariffs reduced the value of U.S. agricultural exports by more than $27 billion total, or $13.2 billion in annualized losses (Morgan et al., 2022). Much of this loss was due to reduced exports to China. The majority of the loss (71 percent, or 9.4 billion dollars in annualized losses) was concentrated in the soybean industry. In 2018/19, the impact of trade restrictions on the United States from U.S. trading partners can be seen from the sharp decline in exports that year.

In 2020, U.S. agricultural exports to China increased with the signing of a new trade agreement (Morgan et al., 2022). Exports subsequently climbed, peaking in 2020/21 at 54 percent of total production. Exports declined to 48 percent of total production in the following year, as total global exports and imports declined (figure 5; USDA, ERS, 2022c).

The United States imports a small quantity of soybeans (16 million bushels in 2021/22) (USDA, ERS, 2022c). Much of this quantity is used to satisfy the demand for organic soybeans, which has increased for use in processing and animal feed, and a majority of the U.S. supply of organic soybeans comes from imports.

While planted acreage of U.S. organic soybeans has grown, the acreage remains small (less than 0.5 percent of acres in 2019) (Raszap Skorbiansky et al., 2021).

Figure 5
U.S. soybean exports as a share of total production



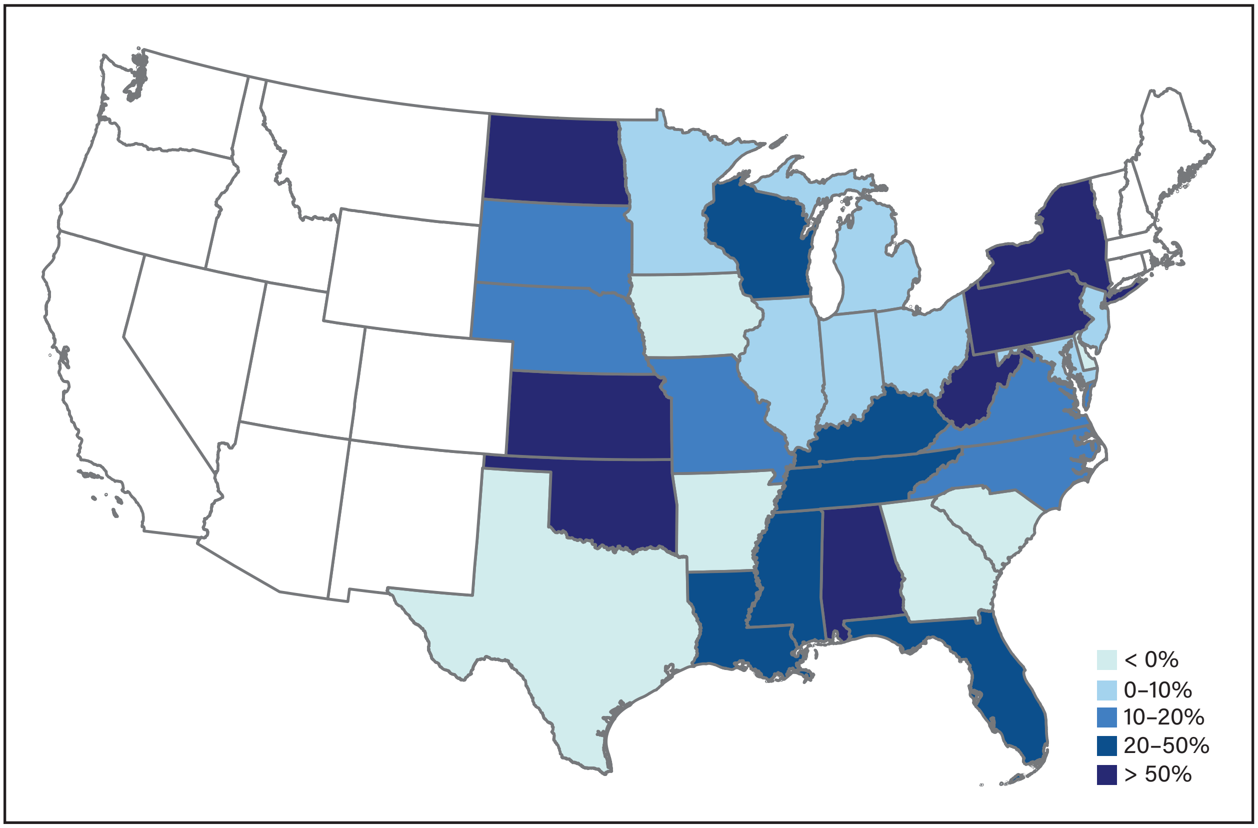
Source: USDA, Economic Research Service, *Oil Crops Yearbook*.

U.S. State Acreage

To examine trends in State planted acreage over time, the 5-year moving average acreages of 2002 and 2020 (the last year for which a 5-year average can be calculated) for major U.S. soybean-producing States are used (figure 6). For this report, the average for 2002 in each State is the average acreage from 2000 to 2004, and for 2020, the acreage is the average across the years from 2018 to 2022. This is to give a more accurate picture of trends than individual-year data since acreage will vary from year to year.

Of the States for which USDA, NASS provides data, most had an increase in soybean acreage. The largest acreage decline was in Iowa, falling by 8 percent from 10.6 million to 9.8 million acres (the largest percentage decline was in Texas, where acreage declined 50 percent). The largest acreage increases were in North Dakota, with 129 percent growth (from 2.7 million acres to 6.2 million acres), and in Kansas, with 72 percent growth (from 2.8 to 4.8 million acres) (figure 6). This demonstrates the expansion of soybean production into wheat-producing regions, as wheat acreage fell and soybean acreage increased (figure 3; Ash et al., 2006). In 2002, Iowa grew the most soybeans. In 2020, Illinois was the top-acreage State, with 10.5 million acres. Several States with low acreage had large percentage increases between 2002 and 2020, including New York, where acreage grew by 107 percent from 151,000 to 312,000 acres.

Figure 6
Percentage change in soybean acreage, 2002 to 2020 by State



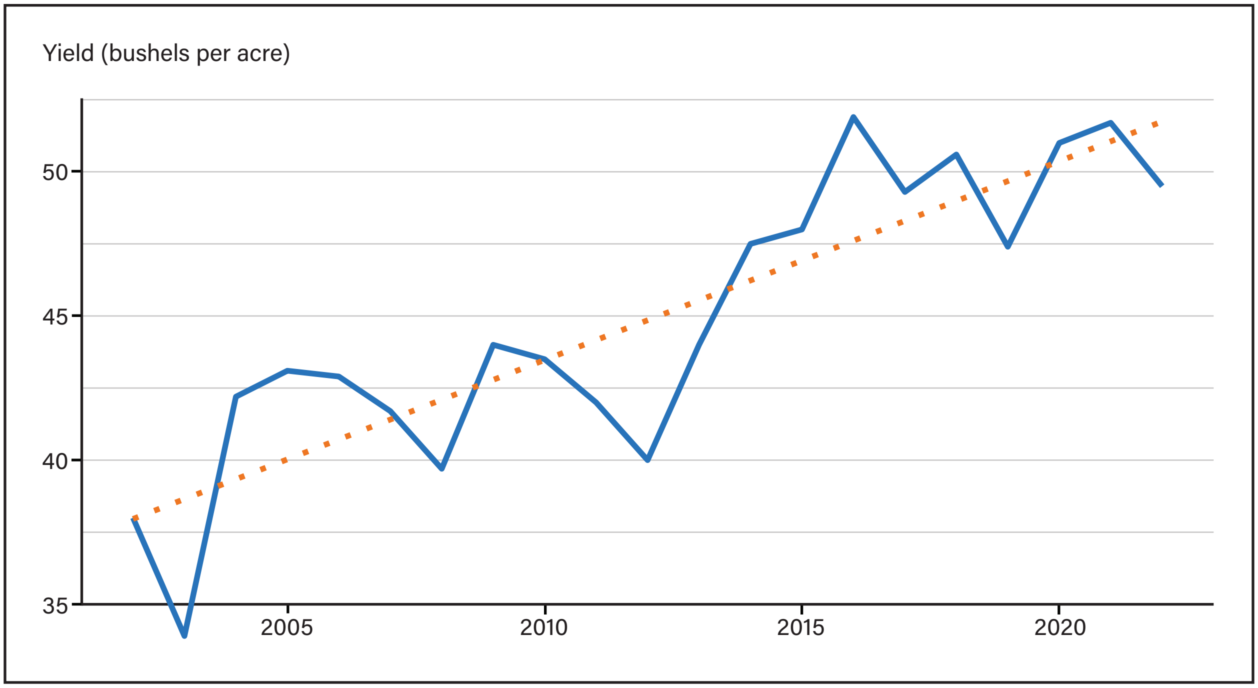
Note: White areas indicate States for which no data was available.

Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, *Crop Production*.

Yield and Production

Soybean yield in the United States increased by 30 percent, from an average of 38 bushels per acre in 2002 to 49.5 bushels per acre in 2022 (figure 7). This increase was not steady; some years it declined. The largest declines occurred in 2003 due to drought and aphid infestations and in 2012 when much of the central United States experienced severe drought (Mondesir, 2020).

Figure 7
Soybean yield in the United States, 2002 to 2022



Note: Solid blue line represents annual yield. Dotted orange line represents trend line from 2002 to 2022.

Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, *Crop Production*.

From 2002 to 2022, total soybean production grew by 54 percent, from 2.8 billion bushels in 2002 to 4.3 billion bushels in 2022, due to increasing acreage and yield (figure 8). Production trends follow acreage and yield trends; for instance, production declined in 2003 and increased in 2004 due to a yield decline and subsequent recovery, and production declined in 2019 when acreage declined.

Figure 8
Total soybean production in the United States, 2002 to 2022

Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, *Crop Production*.

Structural Change

This section summarizes data from the 2002, 2006, 2012, and 2018 ARMS soybean commodity surveys. The data provide information on structural change in the soybean industry, as well as information on technological change driving the industry.

Agricultural Resource Management Survey (ARMS) Data

The USDA, Economic Research Service (ERS) and USDA, National Agricultural Statistics Service jointly implement the annual Agricultural Resource Management Survey (ARMS) to collect nationally representative data on U.S. farm producers. Part of the ARMS is a commodity-specific survey that cycles each year through different commodities. The soybean-specific survey targets the minimum number of States that together represent 90 percent of all U.S. soybean acreage. Farms are eligible if they grow soybeans in the target year and expect to sell, or would normally sell, at least $1,000 worth of products. Eligible farms are identified in Phase 1 of the ARMS, which is a screening survey. Phase 2 of the survey asks producers to provide detailed information on inputs, production practices, and costs for one randomly selected soybean field on their farm. Finally, Phase 3 collects data on farm-level finances. The USDA, ERS commodity costs and returns data product is developed using data from the commodity-specific ARMS.

The four most recent soybean-specific ARMS surveys were conducted in 2002, 2006, 2012, and 2018. The analysis in this section is based mostly on Phase 2 observations from these years, which includes 2,480 observations in 2002; 3,042 in 2006; 2,472 in 2012; and 2,273 in 2018. The following States were surveyed in each of these years: Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Nebraska, North Carolina, North Dakota, Ohio, South Dakota, Tennessee, Virginia, and Wisconsin; Maryland was surveyed in 2002. Weights are assigned to each observation so that the sample can be expanded to 90 percent of the U.S. soybean farm acreage.

Farm and Operator Characteristics

Table 1 provides information on farm and operator characteristics for soybean farms surveyed via ARMS for 2002, 2006, 2012, and 2018. Between 2002 and 2018, per farm acreage of soybeans grew, while total operated acres (which include but are not limited to soybean cultivation) fluctuated and declined. The average U.S. farm size has not changed much in recent years and decades, while cropland has been consolidated into larger farms (USDA, NASS, 2022d; MacDonald et al., 2013). Per farm cultivated soybean acreage is slightly higher than the number of harvested acres per farm (figure 2); not all cultivated acres may be harvested.

In 2018, 75 percent of soybean farms also grew corn, 1 percent grew rice, 2 percent grew cotton, and 21 percent grew wheat. Most farms had grown corn in the previous spring/summer growing season on their 2018 soybean field. Farms that double-cropped soybeans with wheat, which can reduce yields due to delayed planting, declined from 2002 to 2018 (Rod et al., 2021). More than half (52 percent) of surveyed soybean farms in 2018 were in the Heartland region. The share of soybean farms in the Heartland and Southern Seaboard declined over time but increased in all other regions and doubled in the Northern Great Plains and Eastern Uplands regions. From 2002 to 2018, the average total value of soybean production more than doubled and became a larger share of the total value of farm production on farms that grow soybeans. As shown in table 1, in 2018, the average soybean farm operator was older and more likely to have a college degree than in 2002.

Table 1

Average characteristics of U.S. soybean farms and farm operators

Variable	2002	2006	2012	2018
Total operated acres	770	763	812	709
Total owned acres	300	303	343	317
Cultivated soybean acres	268	303	273	314
The farm also planted the following in 2018:	**Percent of farms**			
Corn	82	81	83	75
Rice	1	1	1	1
Wheat (spring or winter)	31	27	22	21
Cotton	1	2	1	2
Planted previous season on field:				
Corn	65	72	65	63
Soybeans	21	17	22	27
Rice	1	1	1	1
Spring wheat	2	2	1	2
Cotton	1	1	1	1
Double-cropped with winter wheat	9	4	9	6
Total cultivated soybean acres:				
<200 acres	33	31	35	32
200–499 acres	33	32	27	27
500–749 acres	14	14	12	12
750–1,499 acres	14	15	16	18
>1,500 acres	6	8	9	12
Percent of farms in the following regions				
Heartland	57	58	54	52
Northern Crescent	13	14	14	14
Northern Great Plains	3	4	5	6
Prairie Gateway	6	7	6	7
Eastern Uplands	2	2	3	4
Southern Seaboard	12	8	9	9
Mississippi Portal	7	8	9	8
Operator Characteristics				
Age of principal operator (years)	53	55	57	59
Principal operators with a college degree (percent)	18	23	21	24
Value of production	**U.S. dollars**			
Total value of soybean production	$47,957	$69,275	$110,593	$120,461
Total value of farm production	$215,037	$251,083	$474,225	$385,588

Note: Spring wheat includes durum wheat and other spring wheat.

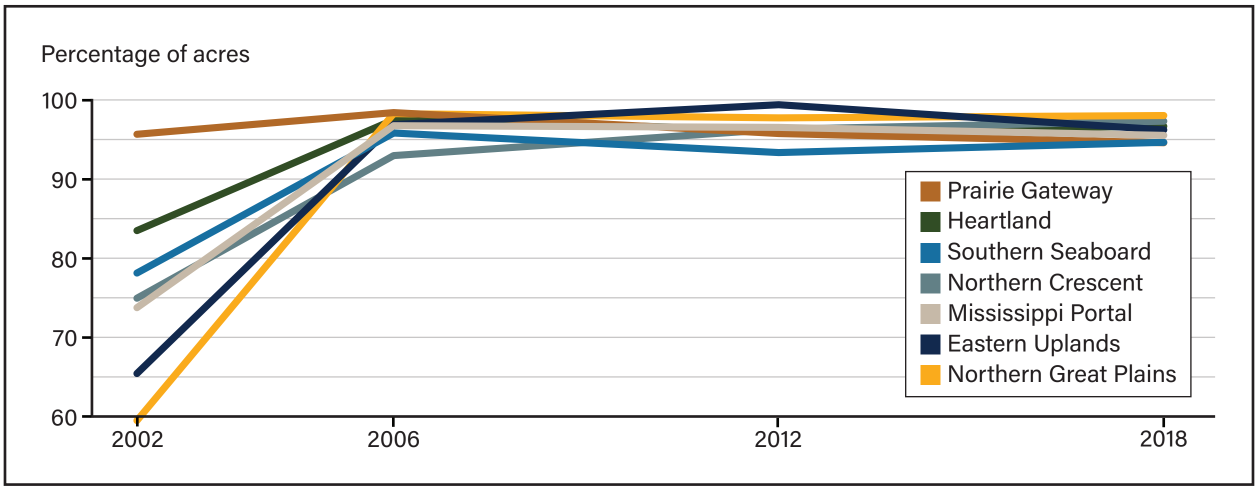
Source: USDA, Economic Research Service (ERS) estimates based on the 2002, 2006, 2012, and 2018 Agricultural Resource Management Survey (ARMS) and USDA, ERS Commodity Costs and Returns. ARMS is jointly administered by USDA, ERS and USDA, National Agricultural Statistics Service.

Technology, Production Practices, and Inputs

Seed

Genetically engineered seed varieties first became commercially available in the United States for major crops in 1996. By 2000, more than half of U.S. soybean acres were planted with genetically engineered varieties (Fernandez-Cornejo et al., 2014a). Most genetically engineered soybeans are herbicide-tolerant (HT), meaning the soybeans have traits to allow them to tolerate certain herbicides such as glyphosate, dicamba, and glufosinate. Some genetically engineered soybean seeds have stacked traits making the seeds tolerant to more than one herbicide. The use of genetically engineered crops can increase yields by preventing yield loss (due to pests) and can simplify weed management by allowing farmers to use one product on a wide range of areas (Fernandez-Cornejo et al., 2014a). In 2002, 81 percent of soybean acres were planted with genetically engineered seed nationally. Regionally, the adoption ranged from 60 percent in the Northern Great Plains region to 96 percent in the Prairie Gateway region (figure 9). In 2006, 2012, and 2018, at least 93 percent of acres in every region were planted with genetically engineered seed.

Figure 9
Adoption of genetically engineered soybean seed by region



Source: USDA, Economic Research Service (ERS) estimates based on the 2002, 2006, 2012, and 2018 Agricultural Resource Management Survey, jointly administered by USDA, ERS and USDA, National Agricultural Statistics Service.

The most common type of herbicide-resistant genetically engineered soybean seed varieties grown in 2018 were glyphosate-tolerant seed varieties (figure 10). Glyphosate is a herbicide that kills broad-leaf weeds and grasses. Glyphosate-tolerant varieties allow farmers to apply glyphosate to kill weeds without harming the soybean plant. In 2018, glyphosate-tolerant varieties were planted in a majority of acres in all regions.

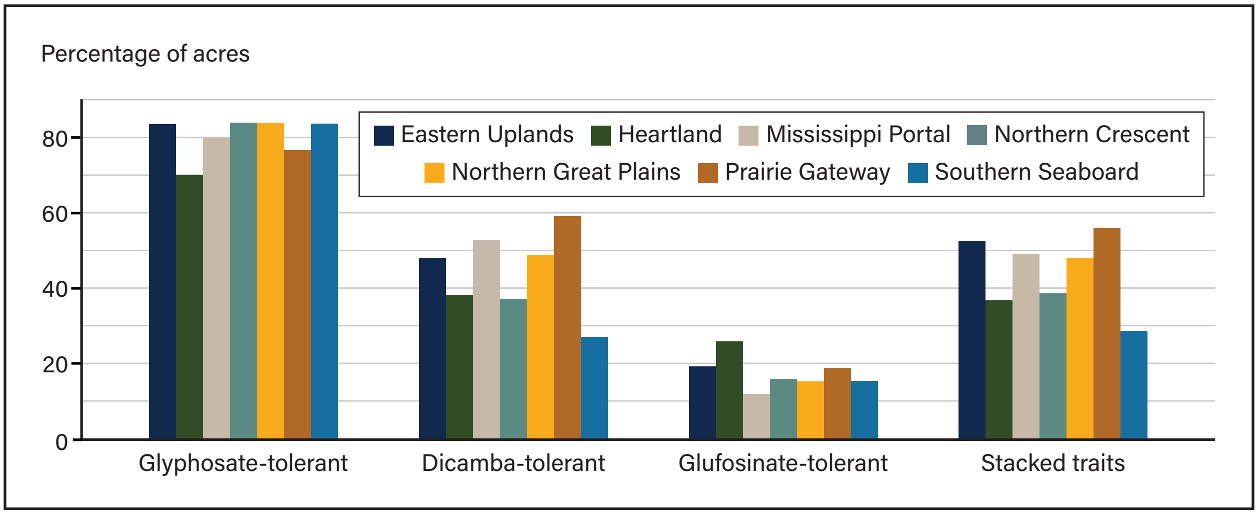
Over time, populations of some weed species have evolved a resistance to glyphosate. Of the major soybean-producing States, glyphosate-tolerant weed species are particularly prevalent in Missouri, Mississippi, Tennessee, and Kansas—which each had nine or more glyphosate-tolerant weed species as of 2022 (Heap, 2022). This development has led to the use of different herbicides to treat weeds in soybean fields, as well as the development of new seed types resistant to these herbicides, such as dicamba (Wechsler et al., 2019).

Dicamba-tolerant seeds were commercialized in 2016, and adoption has been rapid. The Prairie Gateway region, which had the highest adoption of genetically engineered seeds in 2002, also had the highest percentage of acres planted to dicamba-tolerant seeds in 2018, at 59 percent. The regions with the greatest number of acres planted to dicamba-tolerant seeds contain some of the States with the highest number of glyphosate-tolerant weeds.

When dicamba is applied to fields, dicamba can move off the treated field to other plants or crops and injure them. In 2018, the Federal Government and some States imposed restrictions on dicamba use to limit this problem. For more information on dicamba and restrictions on its use, see the U.S. Environmental Protection Agency webpage entitled "Registration of Dicamba for Use on Dicamba-Tolerant Crops" (EPA, 2022).

Seeds tolerant to glufosinate were the next most commonly planted and most popular in the Heartland region (figure 10). The regional distribution of stacked traits is similar to that of dicamba-tolerant traits, in part because most of the dicamba-tolerant seed varieties used were stacked with other traits.

Figure 10
Traits of soybeans in main U.S. planted regions, 2018



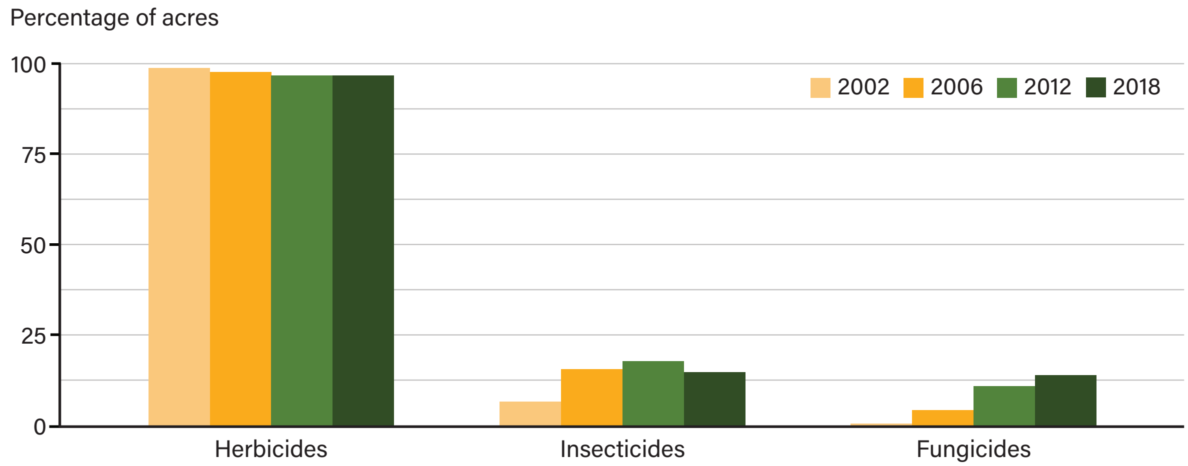
Source: USDA, Economic Research Service (ERS) estimates based on the 2018 Agricultural Resource Management Survey, jointly administered by USDA, ERS and USDA, National Agricultural Statistics Service.

Chemicals

Pesticides (in the form of herbicides to control weeds, insecticides to control insects, and fungicides to control fungi and other pathogens) can indirectly increase yields by reducing pest pressure. Pesticides can also potentially reduce other costs of production, such as labor used to control pests, and tillage costs. Herbicides are applied to nearly all U.S. soybean acres (figure 11). The adoption of genetically engineered seeds since 1996 has shifted the composition of herbicides applied to soybean, as well as corn and wheat fields, toward glyphosate and away from many other chemicals (Fernandez-Cornejo, 2014b).

In 2018, farmers applied foliar insecticides and fungicides (liquids sprayed on leaves) to 15 and 14 percent of soybean acres, respectively. In 2002, farmers applied fungicides to 1 percent of soybean acres. Soybean rust (a disease that can cause yield losses if untreated) was first discovered in the United States in 2004 in Louisiana (Ash et al., 2006). This likely played a role in the increase of fungicide use over time. Previous research has found that usage is highest in years of wet weather and widespread disease (Bandara et al., 2020). The share of soybean acres treated with insecticides also increased after 2002.

Figure 11
U.S. soybean acres receiving herbicides, insecticides, and fungicides



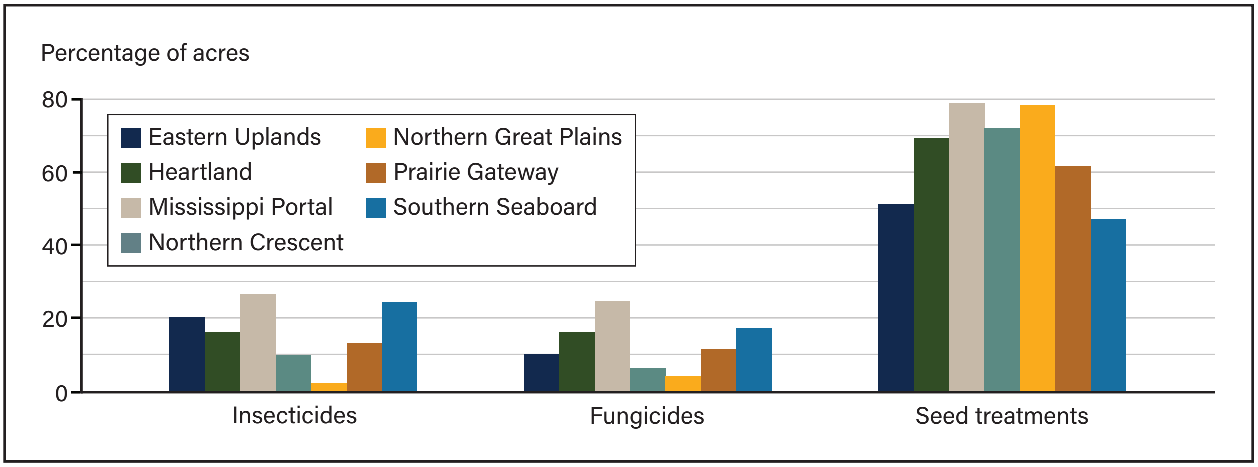
Source: USDA, Economic Research Service (ERS) estimates based on the 2002, 2006, 2012, and 2018 Agricultural Resource Management Survey, jointly administered by USDA, ERS and USDA, National Agricultural Statistics Service.

Insecticides and fungicides were applied to the highest share of acres in the Mississippi Portal region and the lowest share in the Northern Great Plains region (figure 12). This is consistent with previous literature, which found foliar fungicide use higher in southern States than northern ones. This finding could be due to the southern region's longer period of soybean planting from March to June and the longer period of warm, wetter weather, which is conducive to disease compared to the northern region (Bandara et al., 2020).

Soybean seeds can also be treated with pesticides to protect them from seedling diseases that can cause poor emergence and reduced yields. Treated seeds are particularly helpful in cool, wet soil—which can be present when soybeans are planted early and in no-till fields where soils remain cooler (Specht et al., 2018). Treated seeds were more common in 2018 than insecticides or fungicides (figure 12). Seed treatments were most prevalent in the Mississippi Portal region, where foliar insecticides and fungicides were also most common, and in the Northern Great Plains region, where foliar insecticides and fungicides (sprayed on leaves) were least common.

Figure 12

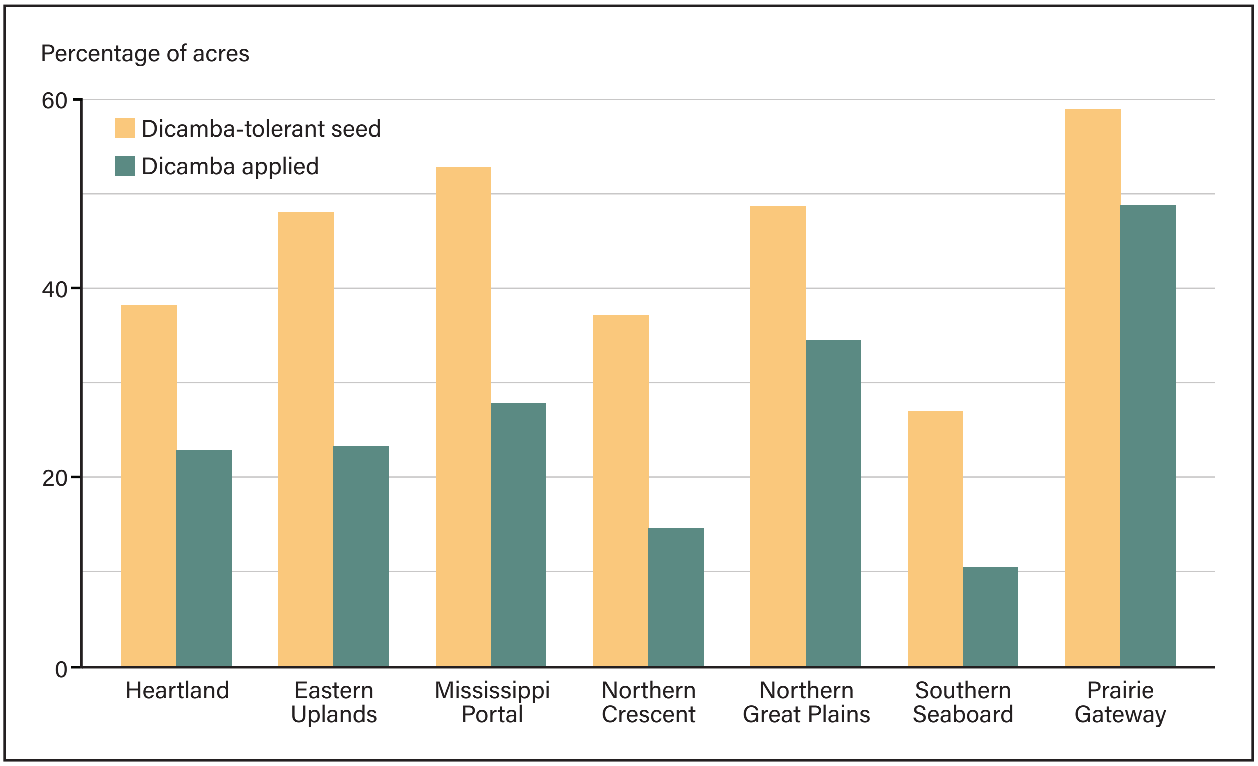
U.S. soybean acres receiving insecticides, fungicides, and planted with treated seeds in main growing regions in 2018



Source: USDA, Economic Research Service (ERS) estimates based on the 2018 Agricultural Resource Management Survey, jointly administered by USDA, ERS and USDA, National Agricultural Statistics Service.

Regions with the highest rate of adoption of dicamba-tolerant seeds also had the highest percentage of acres treated with dicamba, although in each region, fewer acres were treated with dicamba than were planted with dicamba-tolerant varieties (figure 13). This finding is consistent with State-level findings in Wechsler et al. (2019). For instance, in the Prairie Gateway region, 59 percent of acres were planted with dicamba-tolerant varieties while 49 percent of acres received dicamba treatments (a gap of about 10 acres). The largest such gap was in the Mississippi Portal region, where farmers planted dicamba-tolerant seed varieties on 53 percent of acres and applied dicamba to 28 percent of acres. After application, dicamba can drift from the fields it was applied to into other nearby fields, causing damage to crops that are not genetically engineered to be resistant. Farmers may plant dicamba-tolerant seeds without applying dicamba because the farmers are concerned about harm to their crops due to exposure from the off-target movement of dicamba from other sources. Farmers may also prefer the seed variety for other seed traits. Alternatively, farmers may only plan to apply dicamba if they encounter glyphosate-tolerant weeds in their fields; planting dicamba-tolerant seeds gives the farmers this option (Wechsler et al., 2019).

Figure 13
Dicamba-tolerant seed and dicamba applications on U.S. soybean acreage in 2018



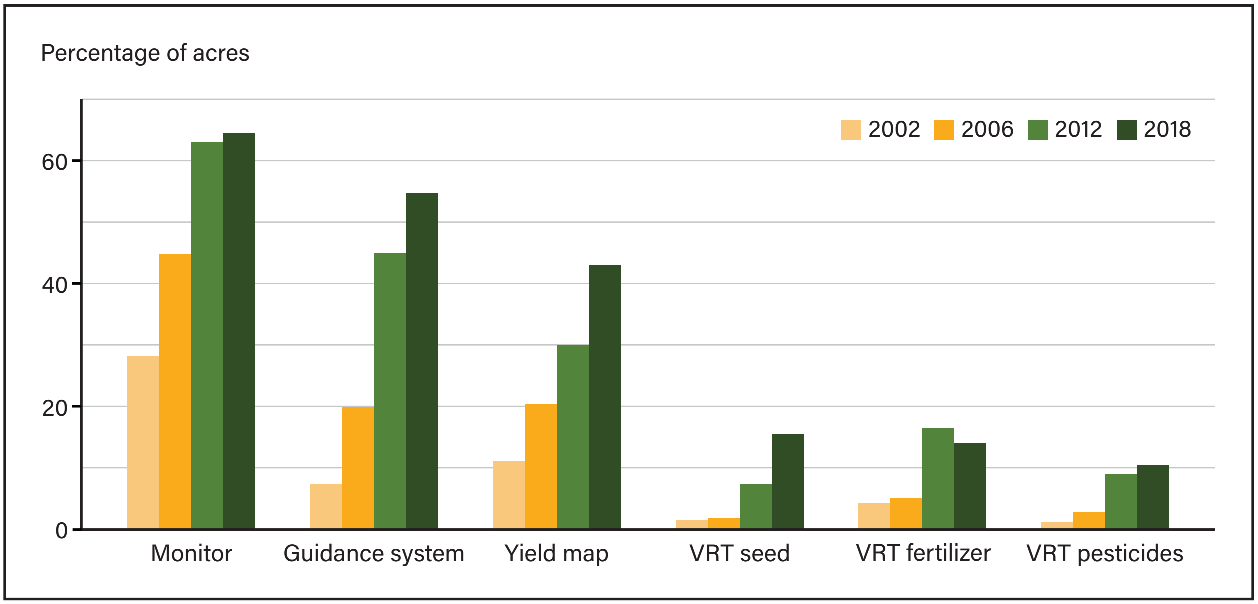
Source: USDA, Economic Research Service (ERS) estimates based on the 2018 Agricultural Resource Management Survey, jointly administered by USDA, ERS and USDA, National Agricultural Statistics Service.

Precision Agriculture

There are many different types of precision agriculture technologies used in soybean farming. Yield monitors and yield maps can identify high- and low-yielding parts of fields, allowing farmers to adjust management decisions accordingly. Guidance systems are GPS-guided, enabling auto-steering combines and tractors, which can improve the application of sprays and align the seeding of field crop rows. Finally, variable-rate technology can vary the rate of input applications over a field based on geolocation data from yield or soil maps. Precision agriculture technologies can have high up-front costs but can reduce variable input costs and increase yields. Precision agriculture technology adoption is positively associated with large farm sizes. The technology has been found to have a small positive impact on net returns and operating profits on average-sized U.S. corn farms, which may help to explain its growing adoption (Schimmelpfennig, 2016).

In 2018, yield monitors were the most commonly used precision agriculture technology on soybean farms (used on 65 percent of soybean acres), followed by guidance systems (55 percent) (figure 14). The use of each of these technologies has grown between every survey year except for VRT fertilizer (Variable Rate Technology fertilizer allows crop producers to apply different rates of fertilizer at each location across fields), which declined slightly from 2012 to 2018. High fertilizer prices in 2012 may be responsible for the higher rate of VRT fertilizer in 2012 than in 2018, as farmers may have needed to apply fertilizer more efficiently (USDA, NASS, 2022c).

Figure 14
Use of precision farming technologies on U.S. soybean acreage

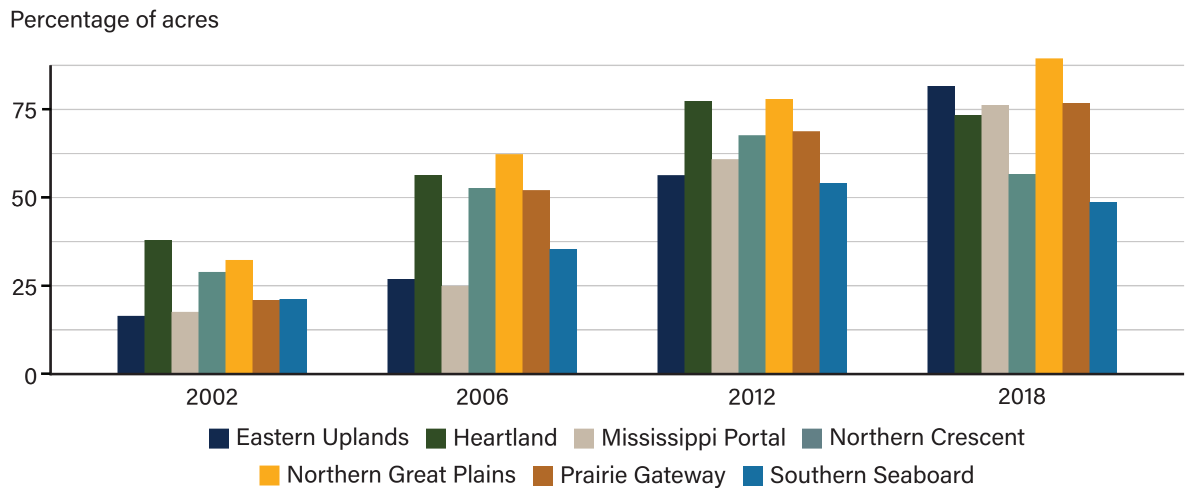


Note: Monitor refers to yield monitor. VRT stands for variable rate technology.

Source: USDA, Economic Research Service (ERS) estimates based on the 2002, 2006, 2012, and 2018 Agricultural Resource Management Survey, jointly administered by USDA, ERS and USDA, National Agricultural Statistics Service.

In 2018, precision agriculture adoption was highest in the Northern Great Plains region (used on 89 percent of acres) and lowest in the Southern Seaboard (on 49 percent of acres). This adoption could be due in part to farm size; the average soybean farm in the Northern Great Plains cultivated 655 soybean acres compared to 209 in the Southern Seaboard (USDA, ERS, 2022a). The use of precision agriculture technologies declined between 2012 and 2018 in the Heartland, Southern Seaboard, and Northern Crescent regions. These declines were spread across different types of technologies; it is possible that these declines relate to the decline in total operated acres of soybean farms from 2012 to 2018 (table 1), the high price of fertilizer in 2012, and/or the higher soybean price in and immediately prior to 2012 compared to 2018.

Figure 15
Use of precision farming technologies on U.S. soybean acreage

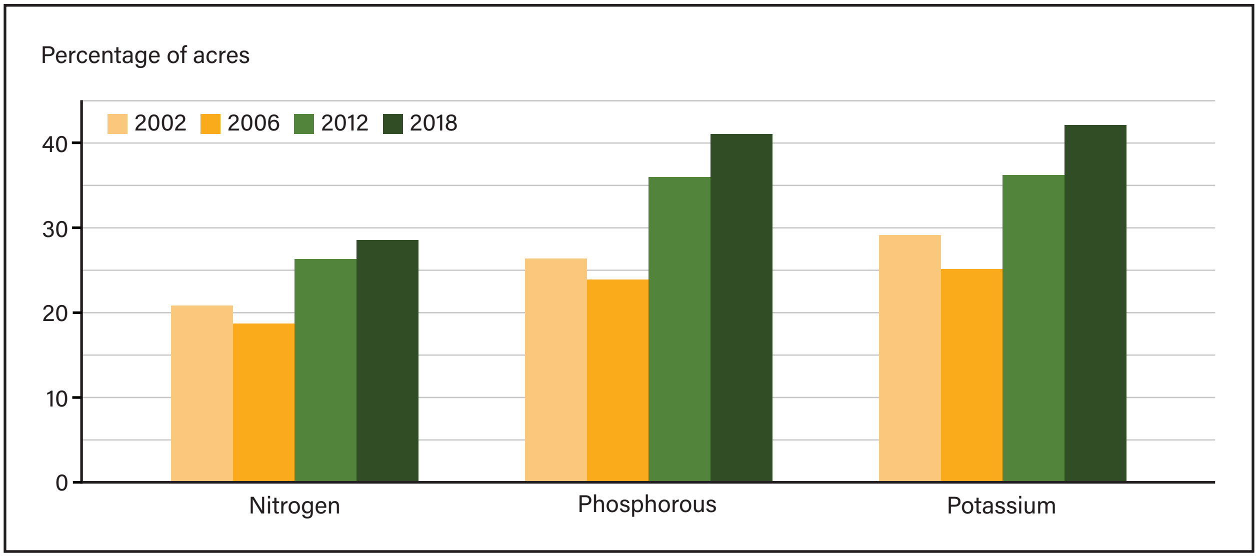


Source: USDA, Economic Research Service (ERS) estimates based on the 2002, 2006, 2012, and 2018 Agricultural Resource Management Survey, jointly administered by USDA, ERS and USDA, National Agricultural Statistics Service.

Fertilizer

Fertilizer is applied to crops to try to increase the quantity of nutrients in the soil in order to boost yields. The percentages of soybean acres receiving fertilizer in the form of nitrogen (N), phosphorous (P), and potassium (K) each declined from 2002 to 2006 but have increased since. In each year, potassium was applied to the most acres (42 percent in 2018), followed by phosphorous (41 percent in 2018), and then nitrogen (29 percent in 2018) (figure 16). As legumes, soybeans benefit from nitrogen fixation performed by bacteria that live in nodules on the roots of the soybean plant. These bacteria produce nitrogen that is then absorbed by the soybean plant. Nitrogen fertilizer is sometimes applied at soybean planting before the soybean plant begins to fixate nitrogen; applying too much nitrogen, however, can disrupt the nitrogen-fixation process of the plant (Flynn and Idowu, 2015). As a result, farmers typically apply less nitrogen to soybeans compared to other crops such as corn (Saavoss et al., 2021). It is likely that nitrogen is sometimes applied to soybeans because nitrogen is included in commonly used phosphorous fertilizers, diammonium phosphate (DAP) and mono-ammonium phosphate (MAP).

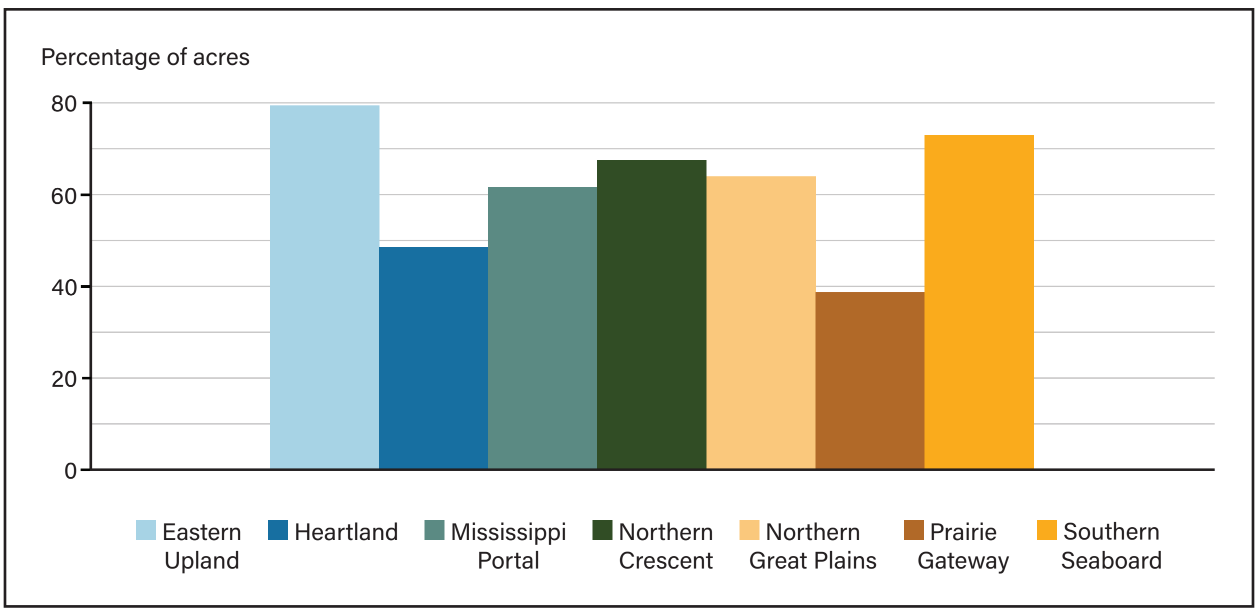
Figure 16
U.S. soybean acres receiving nitrogen, phosphorus, and potassium



Source: USDA, Economic Research Service (ERS) estimates based on the 2018 Agricultural Resource Management Survey, jointly administered by USDA, ERS and USDA, National Agricultural Statistics Service.

In 2018, fertilizer use was most prevalent in the Eastern Uplands region, where 79 percent of acres received a commercial nutrient or fertilizer, followed by the Southern Seaboard (figure 17); this use could be indicative of low soil fertility in these regions. Fertilizer was the least commonly used in the Prairie Gateway region, where 39 percent of acres received fertilizer.

Figure 17
U.S. soybean acres receiving fertilizer in 2018



Source: USDA, Economic Research Service (ERS) estimates based on the 2018 Agricultural Resource Management Survey, jointly administered by USDA, ERS and USDA, National Agricultural Statistics Service.

Tillage

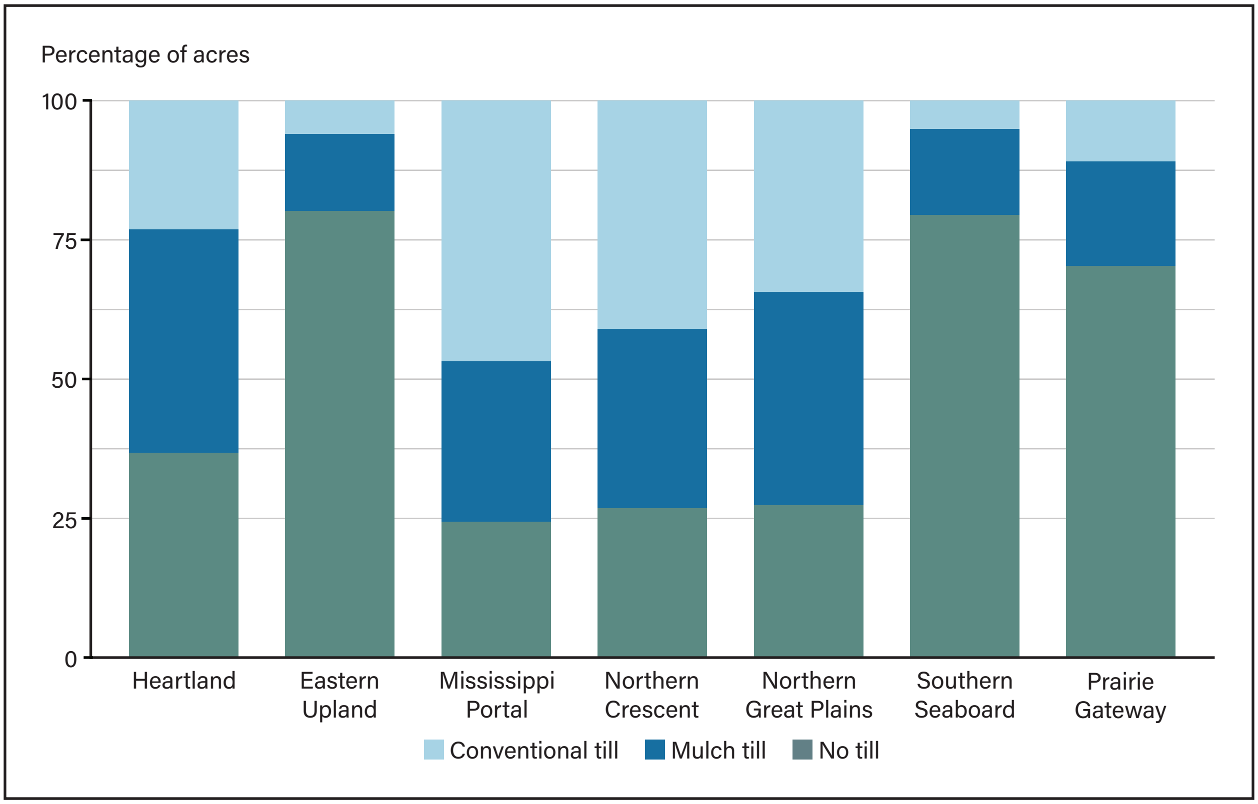
Conservation tillage practices, which reduce soil disturbance compared with conventional tillage and keep the soil covered with crop residue, can improve soil health. Using reduced tillage can also reduce costs associated with tillage, such as fuel and labor. Conservation tillage includes no-till (where the soil is not tilled at all between the harvest of the previous crop to the harvest of the current crop) and reduced tillage practices such as mulch or strip-till (Claassen et al., 2018).

In 2012, 70 percent of soybean acres nationally were cultivated using conservation tillage, including 40 percent of acres cultivated under a no-till system. The percentage of U.S. soybean acres cultivated under no-till increased from 2002 to 2006, then decreased slightly from 2006 to 2012. Conservation tillage was also used on a majority of wheat and corn acres in recent years (Claassen et al., 2018).

In 2018, farmers in the Southern Seaboard region cultivated 95 percent of soybean acres under conservation tillage, the highest of any region, followed by the Eastern Uplands and Prairie Gateway regions (figure 18). Conservation tillage was least common in the Mississippi Portal region, where it was used on 53 percent of acres.

Conservation tillage practices have become more popular with the availability of herbicide-tolerant seed, which allows greater application of pesticides, reducing the need for tillage to control weeds. Conversely, research has found that the presence of glyphosate-resistant weeds reduces farmers' usage of conservation tillage (Van Deynze et al., 2022). There was no clear regional relationship in 2018 between tillage practices and the adoption of different types of herbicide-tolerant seed varieties or with the use of dicamba, which may indicate the presence of glyphosate-resistant weeds. For instance, the share of acres planted with dicamba-tolerant varieties was highest in the Prairie Gateway region and lowest in the Southern Seaboard region, both regions where conservation tillage is popular (figures 13 and 18). Similarly, there was no clear relationship between regional use of seed treatments and conservation tillage, even though no-till soils can remain cooler and increase the need for pesticide seed treatment (Specht et al., 2018). In fact, the regions with the greatest use of no-till (Southern Seaboard and Eastern Uplands) had the smallest share of acres planted with treated seeds (figure 12).

Figure 18
Tillage practices on U.S. planted soybean acreage in 2018



Source: USDA, Economic Research Service (ERS) estimates based on the 2018 Agricultural Resource Management Survey, jointly administered by USDA, ERS and USDA, National Agricultural Statistics Service.

Production Costs

Table 2 shows the nominal cost of producing one acre of soybeans in survey years 2002, 2006, 2012, and 2018. Between 2002 and 2018, the national average total costs increased 114 percent, from $232 to $496. Almost all individual cost categories increased between these years. Operating costs increased as a share of total costs, while allocated overhead costs declined as a share of total costs. Fertilizer cost share tripled from 3 percent of total costs in 2002 to 9 percent in 2012, then decreased to 6 percent in 2018. The cost shares also increased of capital recovery for machinery and equipment, chemicals, repairs, and seed. While the use of these inputs has increased—the prices of fertilizer, chemicals, seed, and machinery also increased between 2002 and 2018. The price of fertilizer was particularly high in 2012, which likely explains why fertilizer made up such a large share of costs in that year (USDA, NASS, 2022c).

Commodity Costs and Returns Estimates

USDA, Economic Research Service calculates commodity costs and returns for 12 commodities. Survey-year estimates are calculated using data from the commodity-specific Agricultural Resource Management Survey (ARMS) and supplemental data on prices, machinery, and other costs. In off-survey years, the estimates are updated using data on yields, prices, and input price indices.

The costs and returns estimates include operating costs and allocated overhead costs. Operating costs include seed; fertilizer; chemicals; custom services; fuel, lubricant, and electricity; repairs; purchased irrigation water; and interest on operating capital. Allocated overhead costs include hired labor, the opportunity cost of unpaid labor, capital recovery of machinery and equipment, the opportunity cost of land, taxes and insurance, and general farm overhead. Many cost categories, such as seed and fertilizer, are variable costs that farmers must pay each year. Other costs (such as the cost of land) can be opportunity costs if, for example, the farm household owns its land. Thus, the commodity costs include the full economic cost of producing one acre of the commodity.

Many cost categories (including seed, fertilizer, chemicals, and custom services) are estimated via direct costing, meaning that farmers were specifically asked in ARMS how much they spent on these inputs. Other costs are estimated by valuing input quantities; this is true for labor and interest on operating capital. Interest on operating capital is calculated using total operating costs and the 6-month treasury-bill interest rate. Labor costs are calculated by determining how many labor hours (paid and unpaid) were required to work the field and multiplying this by the wage rate (for paid labor) or an opportunity wage rate based on the farm operator's age, education, and other characteristics (for unpaid labor). Land costs are calculated using the direct cost of rent if the land is rented or by valuing input quantities to estimate the opportunity cost of land that is owned.

Estimates for fuel, lube, and electricity; repair costs for machinery; and capital recovery costs are made by indirect costing—using information from ARMS on machinery usage in field operations, as well as additional data on machinery, such as prices and fuel needs. Finally, general farm overhead costs and taxes and insurance are based on allocating whole-farm expenses; information on these costs is collected for the whole farm, and the portion allocated for a particular crop is then estimated.

For soybeans, returns are based on soybean yields and prices. Government payments are not included in returns. Estimates include total net returns, which equal total returns less total costs, and net operating returns equal to total returns less operating costs. Because total costs include some opportunity costs (such as the opportunity cost of land and unpaid labor), as well as costs of machinery depreciation, negative total returns do not necessarily imply that farmers are incurring negative accounting profit.

Table 2
Nominal per acre costs of soybean production, 2002, 2006, 2012, and 2018

	2002		2006		2012		2018	
Item	**Cost**	**Percent of total cost**	**Cost**	**Percent of total cost**	**Cost**	**Percent of total cost**	**Cost**	**Percent of total cost**
Seed	$25.45	11	$32.30	12	$55.32	13	$62.39	13
Fertilizer	$7.30	3	$13.05	5	$37.54	9	$29.17	6
Chemicals	$17.12	7	$14.46	5	$26.38	6	$37.30	8
Custom services	$6.16	3	$6.01	2	$9.41	2	$12.45	3
Fuel, lube, and electricity	$6.98	3	$13.51	5	$21.24	5	$15.78	3
Repairs	$9.76	4	$11.80	4	$22.23	5	$28.13	6
Purchased irrigation water	$0.12	0	$0.11	0	$0.06	0	$0.01	0
Interest on operating capital	$0.61	0	$2.17	1	$0.11	0	$1.93	0
Total, operating costs	$73.50	32	$93.41	34	$172.29	39	$187.16	38
Hired labor	$1.84	1	$1.78	1	$2.81	1	$4.72	1
Opportunity cost of unpaid labor	$15.59	7	$15.20	5	$16.76	4	$16.26	3
Capital recovery of machinery and equipment	$43.30	19	$60.38	22	$81.16	19	$107.55	22
Opportunity cost of land	$80.74	35	$86.17	31	$137.55	31	$150.33	30
Taxes and insurance	$5.66	2	$7.93	3	$9.58	2	$11.96	2
General farm overhead	$11.37	5	$13.22	5	$17.44	4	$17.88	4
Total, allocated overhead	$158.50	68	$184.68	66	$265.30	61	$308.70	62
Total, costs listed (per acre)	$232.00	100	$278.09	100	$437.59	100	$495.86	100
Price per bushel	$5.20		$5.54		$14.21		$8.61	
Gross returns per acre	$208.00		$254.84		$596.82		$458.91	
Net returns per acre	-$24.00		-$23.25		$159.23		$-36.95	

Source: USDA, Economic Research Service, Commodity Costs and Returns.

In both 2002 and 2018, the Mississippi Portal region had the highest nominal costs per acre (tied with the Northern Crescent region in 2002), while the Northern Great Plains had the lowest (USDA, ERS, 2022a). High chemical costs in the Mississippi Portal region are reflected in its high use of fungicides, insecticides, and seed treatments. The Northern Great Plains region had particularly low chemical costs, in keeping with its low use of chemicals (USDA, ERS, 2022a; figure 12).

Between 2002 and 2018, costs increased in all regions. The biggest rise occurred in the Eastern Uplands region, where operating costs, including fertilizer, seeds, and repairs, were particularly high (table 3). This increase reflects the region's relatively high fertilizer use in 2018, as well as the region's large increase in genetically engineered seed adoption and precision agriculture technology since 2002 (figures 9, 15, and 16). The Eastern Uplands region also had the highest yield increase of any region, likely due in part to these changing practices.

The smallest rise in cost was in the Prairie Gateway and Northern Crescent regions, which had relatively low cost increases in many categories. The large reduction in precision agriculture technology adoption in the Northern Crescent region from 2012 to 2018 may have contributed to its low increase in capital recovery costs compared to other regions.

Table 3
Percentage changes in nominal per acre soybean production costs, 2002 to 2018

Item	Eastern Uplands	Heartland	Mississippi Portal	Northern Crescent	Northern Great Plains	Prairie Gateway	Southern Seaboard
Seed	170	142	181	151	174	113	113
Fertilizer	451	312	372	193	178	387	416
Chemicals	112	129	164	74	54	146	104
Custom services	76	126	110	78	55	71	51
Fuel, lube, and electricity	151	123	329	85	96	13	201
Repairs	207	208	140	120	204	148	213
Purchased irrigation water	0	0	0	0	0	-95	0
Interest on operating capital	260	220	263	177	187	158	218
Total, operating costs	202%	162%	195%	123%	134%	110%	164%
Hired labor	211	139	243	-41	117	144	137
Opportunity cost of unpaid labor	11	4	45	-6	7	-22	29
Capital recovery of machin-ery and equipment	121	164	89	92	189	130	129
Opportunity cost of land	91	98	88	89	103	73	85
Taxes and insurance	145	108	105	80	137	172	166
General farm overhead	50	59	23	90	57	68	105
Total, allocated overhead	91%	103%	86%	75%	123%	81%	97%
Total, costs listed	132%	121%	124%	91%	127%	91%	125%
Yields	76%	35%	43%	24%	11%	52%	70%

Note: White indicates a smaller increase in the cost category or yield relative to other regions; darker blue indicates a larger increase in the cost category or yield relative to other regions.

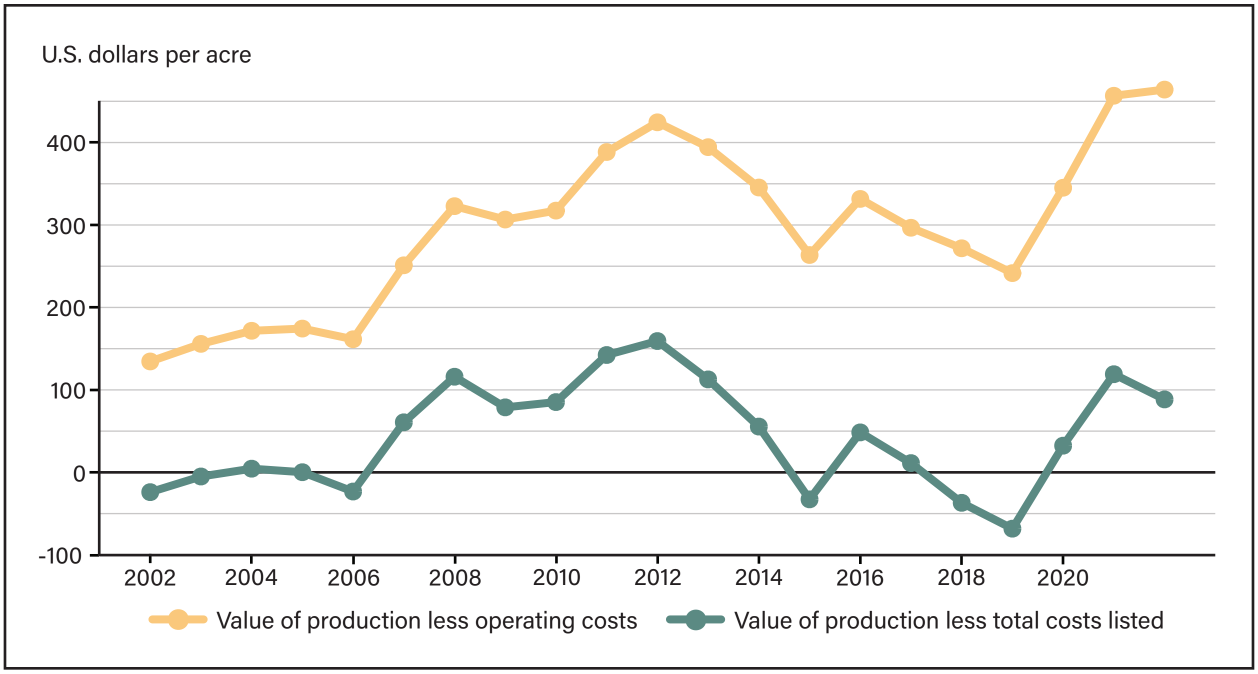
Source: USDA, Economic Research Service Commodity Costs and Returns.

Producer Profitability

The value of soybean production has exceeded total operating costs in every year since 2002 (figure 19). However, the value of production less total costs was negative in 6 of the years between 2002 and 2022. Net returns were highest in 2012, at $159, due to high prices that offset low yields due to drought. Net returns were lowest in 2019, at -$68.30, due to low soybean prices stemming from trade disputes (see section on Soybean Trade).

Compared to corn and wheat (the two other largest crops in terms of U.S. acreage), soybean net returns since 2002 have been relatively strong. Net returns for corn were negative in 12 of the years from 2002 to 2022, while wheat net returns were negative in all years except 2008 and 2012 (USDA, ERS, 2022a). This finding may explain in part why U.S. soybean-planted acreage has had a higher growth rate than that for corn and why wheat-planted acreage has fallen steadily (figure 3).

Figure 19
U.S. average nominal net returns to soybean production



Source: USDA, Economic Research Service, Commodity Costs and Returns.

Productivity

Unit Costs

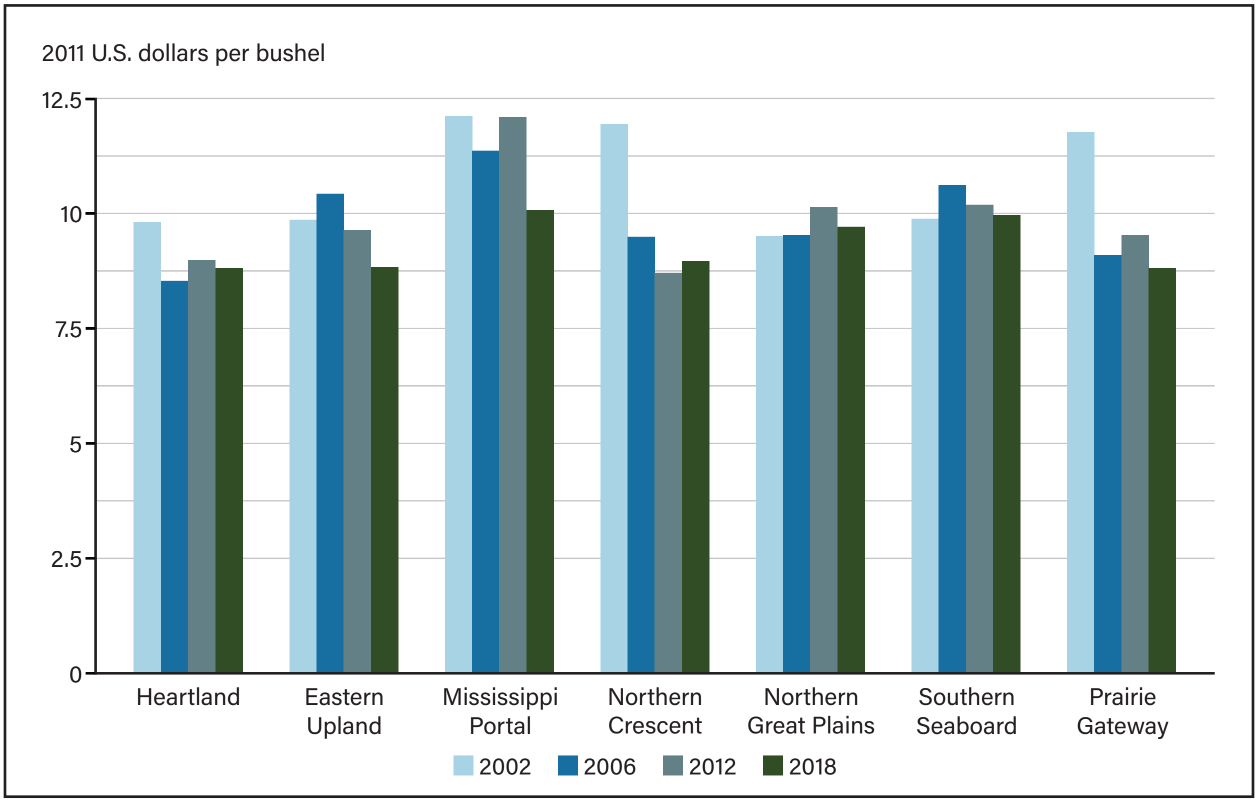
Productivity can be defined as the quantity of inputs required to produce a set quantity of outputs; more productive farms require fewer inputs. In this report, we measure productivity change as the change in the total unit cost of producing one bushel of soybeans over time, calculated as the total cost of producing one acre of soybeans divided by the average yield. As unit costs decline, productivity increases. Total costs are deflated, or adjusted for inflation, using the USDA, NASS production input prices index for 2011 because input prices change over time (Saavoss et al., 2021; McBride et al., 2019; USDA, NASS, 2022c). In addition, yields are normalized to minimize the effect of their annual variation. To normalize yields, the 5-year average yield surrounding each survey year is used; for instance, the 2002 yield used here is the average of the yield from 2000/04. Productivity can increase either from increased yield in soybeans per acre and/or reduced costs per acre and can stem from management decisions, weather, changing farm size, and/or natural resource effects such as soil fertility.

The unit cost of producing 1 bushel of soybeans in the United States was $10.21 in 2002, $8.93 in 2006, $9.26 in 2012, and $9.07 in 2018. The drop in productivity in 2012 was partly due to a drop in yields caused by drought. Yields rose again in 2018, but costs continued to rise as well, and the unit cost was slightly higher than in 2006. Between 2002 and 2018, deflated total costs per acre rose 11 percent, while normalized yields increased 25 percent. Thus, yield gains outpaced increases in per-acre costs, resulting in net productivity gains. Changes in production practices (such as increased use of genetically engineered seed, fertilizer, pesticides, and precision agriculture) have likely contributed to these yield and productivity gains. Changing weather patterns also play a role, as evidenced by the drop in yields and productivity in 2012. The increase in per farm cultivated soybean acres has likely also played a role; Key (2019) found a positive relationship between farm size and total factor productivity in the Heartland region from 1982 to 2012.

From 2002 to 2018, unit costs fell in all regions except for the Northern Great Plains and Southern Seaboard, where costs rose slightly (figure 20). The Northern Great Plains region had relatively low yield increases, hampering productivity growth (table 3). Although the Southern Seaboard had relatively high yield growth from 2002 to 2018 (table 3), yields in this region were very low in 2002 (23 bushels per acre) compared to the 5-year normalized yield (34 bushels per acre). When normalized yields were used, the Southern Seaboard region's yield growth was only 18 percent. The regions with the greatest productivity gains were the Northern Crescent and Prairie Gateway. These were both relatively high-cost regions in 2002 (figure 20) but had the lowest increase in per-acre production costs (table 3).

In 2018, the Mississippi Portal and Southern Seaboard regions had the highest unit costs ($10.10 and $10.00, respectively). These regions overlap some of the same States (including Mississippi and Louisiana) and thus may experience similar weather, pest pressures, and other effects; for instance, both regions apply chemicals to relatively large shares of their soybean acres. The Mississippi Portal region has the highest per-acre costs, despite having the largest number of cultivated soybean acres per farm (959 acres), as well as yields equal to the U.S. average (53 bushels per acre). The Mississippi Portal region also has the highest share of acres under irrigation (53 percent in 2018). The Southern Seaboard (by contrast) has relatively low per-acre costs and low yields, with fewer cultivated soybean acres per farm (209 acres) and only 2 percent of acres under irrigation. The lowest cost regions were the Heartland and Prairie Gateway ($8.84 per bushel). The Heartland region was also the lowest unit-cost region for corn production in 2016, possibly due to high soil fertility, good drainage, and flat land (Saavoss, 2021). The Heartland has the highest yields of any region, likely due to high soil fertility, while the Prairie Gateway region achieves relatively high yields with relatively low per-acre costs.

Figure 20
Inflation-adjusted average U.S. soybean total costs per bushel by region



Note: Costs are deflated using the 2011 production input prices from USDA, National Agricultural Statistics Survey, Prices Paid Surveys and Indexes.

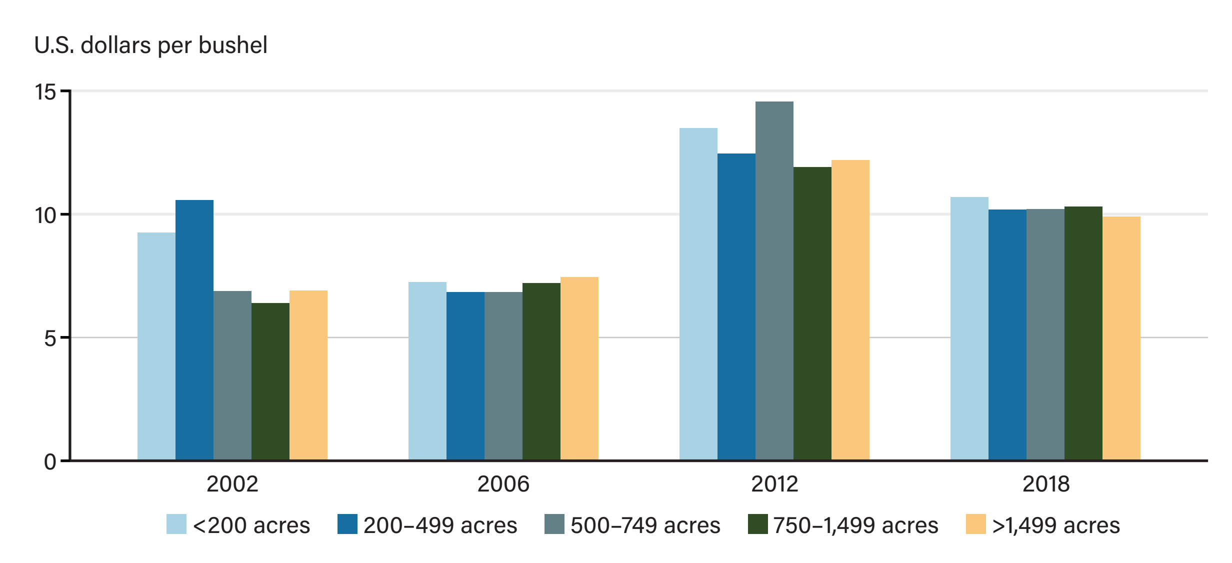
Source: USDA, Economic Research Service (ERS) estimates based on USDA, ERS, Commodity Costs and Returns.

Economies of Size

Economies of size exist if unit costs decline as the size of the operation increases. To examine economies of size associated with U.S. soybean production, total nominal costs per bushel were averaged across operation size groups, measured as the total number of soybean acres planted on a farm. In 2018, unit costs were lowest ($9.89) for the largest size group examined (>1,499 acres) and highest ($10.69) for the smallest group examined (<200 acres). This number indicates the presence of economies of size, though unit costs did not consistently decline for the intermediate group sizes (figure 21).

The ratio between the total costs per bushel of the smallest and the largest farm size categories can be compared over years to evaluate the change in economies of size. This ratio was 1.34 in 2002, 0.97 in 2006, 1.11 in 2012, and 1.08 in 2018. Thus, compared to 2002, economies of size were lower in 2018 and lowest in 2006. If instead the two smallest categories are compared to the two largest in the same way, then the decline in economies of size appears larger; in 2002, the ratio of the two smallest farm groups' unit costs to the two largest farm groups' unit costs was 1.49, and in 2018, it was 1.03. Figure 21 shows how unit costs compare among all five size groups in 2002, 2006, 2012, and 2018.

Figure 21
Nominal unit costs of soybean production by size of farm



Source: USDA, Economic Research Service (ERS) estimates based on the 2002, 2006, 2012, and 2018 Agricultural Resource Management Survey, jointly administered by USDA, ERS and USDA, National Agricultural Statistics Service.

Characteristics of High and Low Unit-Cost Farms

To examine how high- and low-cost soybean farms differ, ARMS survey respondents were divided into quartiles based on total nominal costs per bushel in 2018. The lowest cost quartile had average nominal costs of $6.75 per bushel, while the highest had costs of $15.36 per bushel (table 3). The highest cost quartile had yields 35 percent lower and total per-acre costs 39 percent higher than the lowest cost quartile. Profitability also varied; only the two lowest cost quartiles had positive net returns in 2018.

The lowest cost group consisted of larger farms compared to the highest cost group, measured by total acres and soybean acres. However, the middle-cost groups were both larger on average than the lowest cost group. In general, larger farms have an advantage because they can spread fixed costs over a larger number of acres and may be able to negotiate for lower input prices. Precision agriculture technology is used more by the lowest cost group than any other group. A higher share of low-cost farms used dicamba-tolerant seed varieties and applied dicamba and fungicides. A higher share of high-cost farmers applied fertilizer; it is possible that high-cost farms suffer lower soil fertility and have a greater need for fertilizer. Irrigation may have driven some farm cost differences, as the share of irrigated acres increases as costs increase.

Table 4

Nominal 2018 production costs and characteristics of high and low unit-cost soybean farm operations, by quartile

	Lowest cost	Second-lowest cost	Second-highest cost	Highest cost
Yield, bushels per acre	62	56	50	41
	U.S. dollars			
Cost per bushel	6.75	8.59	10.33	15.36
	U.S. dollars per acre			
Gross returns	537.3	483.74	429.02	350.91
Total operating costs	161.56	185.28	202.96	230.19
Total allocated costs	256.62	294.02	310.04	352.78
Total costs	418.18	479.31	513.00	582.98
Gross returns minus operating costs	375.74	298.46	226.05	120.72
Gross returns minus total costs	119.12	4.43	-83.99	-232.06
Seed	57.06	60.24	64.65	66.94
Fertilizer	24.13	34.77	40.32	49.00
Chemicals	32.94	35.88	37.07	41.94
Custom services	13.27	11.97	14.96	16.07
Fuel, lube, and electricity	10.64	14.04	15.99	22.09
Repairs	21.79	26.47	27.88	31.77
Water	0.05	0.00	0.00	0.02
Interest on operating capital	1.66	1.91	2.09	2.37
Hired labor	2.63	3.74	3.88	7.55
Opportunity cost of unpaid labor	14.38	17.27	20.25	41.62
Capital recovery of machinery and equipment	88.48	102.12	107.24	118.44
Opportunity cost of land	125.71	143.4	146.08	142.18
Taxes and insurance	10.17	11.09	11.24	16.48
General farm overhead	15.25	16.4	21.35	26.51
Technology use and farm characteristics				
Percentage of farms:				
Used glyphosate-tolerant seeds	74	72	76	75
Used dicamba-tolerant seeds	43	39	35	33
Used glufosinate-tolerant seeds	22	24	21	20
Used seeds with stacked genetic traits	43	38	34	32
Applied dicamba	25	21	21	18
Applied insecticides	12	11	14	12
Applied fungicides	15	11	9	8
Applied fertilizer	45	59	64	69
Used precision agriculture technology	70	68	58	50

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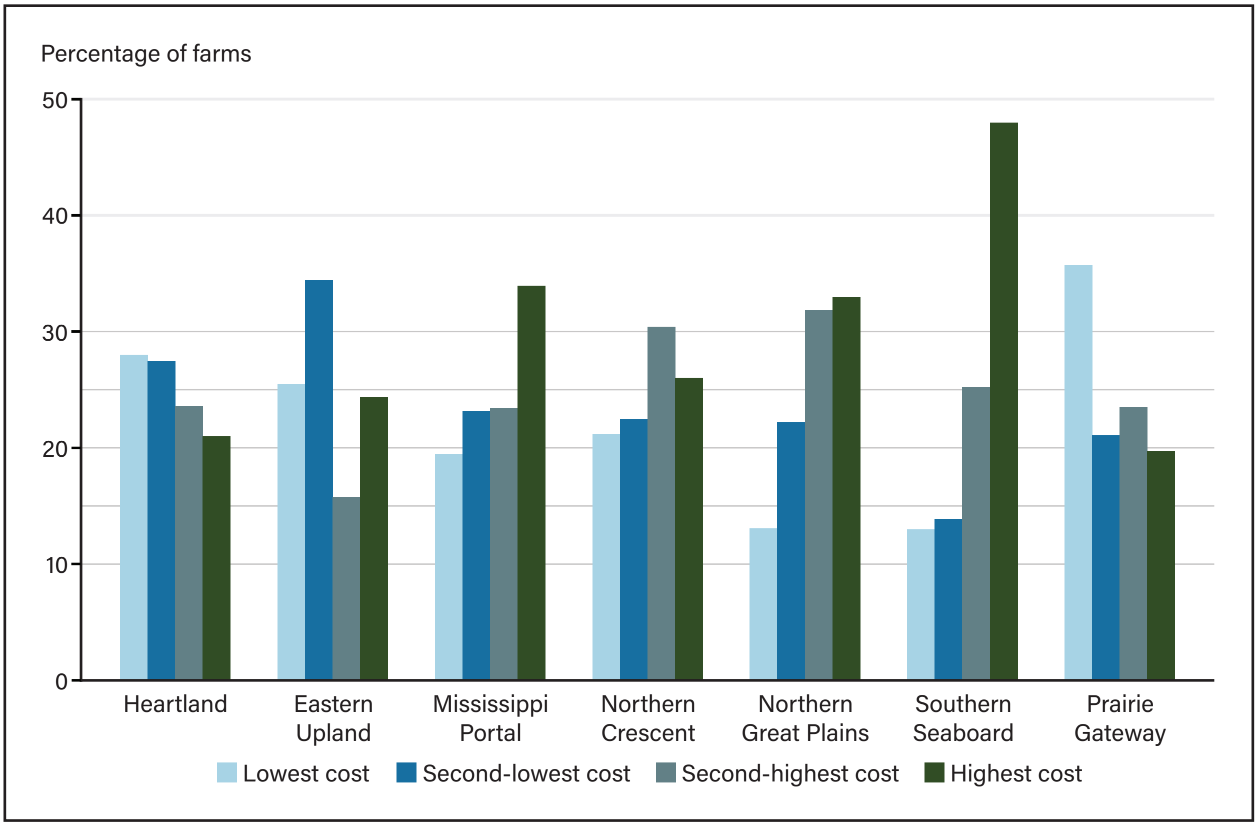
Table 4
Nominal 2018 production costs and characteristics of high and low unit-cost soybean farm operations, by quartile—continued

	Lowest cost	Second-lowest cost	Second-highest cost	Highest cost
Technology use and farm characteristics				
Irrigated (percent of acres)	2	5	7	9
Total operated acres	744	910	748	534
Cultivated soybean acres	339	364	342	249

Source: USDA, Economic Research Service (ERS) estimates from the 2018 Agricultural Resource Management Survey (ARMS), jointly administered by USDA, ERS and USDA, National Agricultural Statistics Service.

The Heartland, Prairie Gateway, and Eastern Upland regions (which are low-cost regions) had more farms in the lowest cost groups than in the highest cost groups. The Southern Seaboard region had the highest percentage of its farms in the highest cost region compared to other regions, followed by the Mississippi Portal and Northern Great Plains (figure 22).

Figure 22
Distribution of soybean farms by region and unit-cost quartile in 2018



Source: USDA, Economic Research Service (ERS) estimates based on the 2002, 2006, 2012, and 2018 Agricultural Resource Management Survey, jointly administered by USDA, ERS and USDA, National Agricultural Statistics Service.

Conclusions

The past two decades of U.S. soybean farming have been characterized by growth in prices, acreage, and yield. Total planted acreage has grown in absolute terms and relative to other major crops (corn and wheat). Higher prices have likely been driven in part by increased export demand; this relationship is highlighted by the drop in export demand in 2018/19 that was accompanied by reductions in price and total acreage. Biofuel policy may have also played a role in increasing demand—and price—for soybeans.

Environmental issues have also influenced the soybean industry. A drought in 2012 contributed to a drop in yields and productivity that year. Glyphosate resistance in weeds has likely driven demand for dicamba and dicamba-tolerant seeds and may influence the adoption of conservation tillage as well. These issues can affect production practices, profitability, and the environmental impacts of soybean farming in the United States.

Production has become more input-intensive over time; since 2002, genetically engineered seeds have become nearly universally adopted—and the use of fertilizer, insecticides, fungicides, and precision agriculture has increased. These changes contributed to the increase in total cost per acre of producing soybeans and to soybean yields and productivity over time.

Trade and biofuel policy, input prices, weather, and other environmental concerns such as crop diseases will continue to influence the industry. Export demand will be crucial as well; if the demand continues to rebound and grow after the export reductions in 2018, then soybean price and acreage may also continue to increase. New technologies, and the production practices farmers use to address environmental concerns, will also be important.

This report is unable to identify the precise impacts of these factors. Future research can help determine how policies, weather, and new technologies will affect yields and farmers' decisions in determining acreage and production practices. In addition, more research on the environmental impacts of production practices and new herbicides may influence future policy, which will, in turn, affect the industry.

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