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Chief Economist

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2017 Indicators of the U.S. Biobased Economy

Jay S. Golden, Robert Handfield, Janire Pascual-Gonzalez, Brandon C. Morrison

Executive Summary

The biobased economy is defined as the production of goods in ways that replace fossil carbon with biogenic carbon. This definition includes a wide variety of products such as biofuels from agriculture and forestry, biochemicals from enzymes, microorganisms or renewable sources, end-use consumer products from agriculture or renewable sources, and biopower from biomass, agriculture or forestry.

To further understand the impact that the biobased economy has in the America economy, this report collects and analyzes measures of bioindicators in four categories: field crops, bioenergy, bioproducts, and policy. This report analyzes field crops and leaves out specialty crops because it is focused on those agricultural products from which bioproducts can produce (i.e., biofuels from corn).

This report is the second in a series published by the office of The Chief Economist at the United States Department of Agriculture, beginning in 2017.

This report is divided into four main sections: (1) field crop indicators, (2) bioenergy indicators, (3) biobased products, and (4) policy. A brief summary of important findings for each section is provided below.

Field Crops

- The number of farms and acreage decreased during the period of 2008 to 2017. Despite this trend, the average size of farms increased by 5.5 percent, from 421 acres in 2008 to 444 acres in 2017.
- Geographical proximity plays an important role in agricultural trade. Most U.S. agricultural trade is with Mexico and Canada.
- Irrigation water accounted for 37 percent of total freshwater withdrawals in 2015. 81 percent of the total irrigation withdrawals and 74 percent of irrigated acres were in the western states, which are states with low average annual precipitation and need supplemental water to support crops.
- Corn is the dominant field crop in the United States, and its production is concentrated in the Midwest.
- Corn production in the United States surpassed 370 million metric tons in 2017. Nearly half of the corn consumed in the U.S. was used for ethanol production, and 27 percent of corn oil was used for biodiesel production.
- Production of wheat, which is primarily concentrated in the Midwestern United States, is two times greater than consumption, and remained almost constant from 2008 to 2017.
- Wheat exports accounted for 24 million metric tons in 2017, and Mexico was the largest market destination.
- In 2017, 73 percent of the United States barley was planted in just 3 states: Montana, Idaho and North Dakota.
- From 2008 to 2017, production and consumption of barley in the United States was very small in comparison with other crops and did not change over those years.
- The production of sorghum in the United States is very small and highly concentrated. In particular, 55.2 percent of total production is located in Kansas and 26 percent in Texas.
- In 2017, 5.8 million metric tons of sorghum were exported, 79 percent of which went to China.
- Soy, which is the second largest crop in the United States, is used as a primary feedstock for biodiesel production. Specifically, 52 percent of biodiesel in 2017 was produced from soybean oil.
- Production and consumption of soy increased from 80 to 119 million metric tons and from 48 to 57 million metrics tons, respectively, from 2008 to 2017.
- In 2017, 12.6 million acres of cotton were planted in the United States, 55 percent of which was planted in Texas.
- Production of cotton decreased to 4.87 million metric tons in 2017, compared to 5.98 million metric tons in 2008.

- The acreage of peanuts planted is very small in comparison with other crops, and 44.6 percent of acres in 2017 were planted in Georgia.
- During the period of 2008 to 2017, exports of peanuts increased from 0.3 million metric tons to 0.6 million metric tons.
- In 2017, the production of sunflowers reached 1.2 million metric tons, 80 percent of which was produced in North Dakota and South Dakota.
- Production and consumption of sunflowers in the United States are very similar, which means that the United States produces and consumes all sunflowers domestically.
- Canola is used as feedstock for biodiesel production, and it is primarily produced in North Dakota.
- In 2017, consumption of canola in the United States was 45 percent larger than production, which means that the United States is a net importer of canola.

Bioenergy

- The number of ethanol plants in the United States slightly increased from 204 plants in 2010 to 209 plants in 2017. This accounts for over 350,000 American jobs.
- Ethanol production and consumption in the United States are rising, achieving 16 billion gallons of ethanol produced and 14.4 billion gallons of ethanol consumed in 2017.
- In 2017, the United States, which is the world's leading ethanol producer, exported 1.4 billion of gallons of ethanol, primarily to Brazil and Canada. 76.6 million gallons of ethanol were imported from Brazil in 2017.
- The number of biodiesel plants in the United States decreased to 95 plants in 2017, accounting for almost 50,000 direct jobs.
- Biodiesel production increased from 0.3 billion gallons in 2010 to 1.6 billion gallons in 2017. However, consumption of biodiesel is greater than production, which means that the United States is a net importer of biodiesel.
- Imports of biodiesel reached 394 billion gallons in 2017 as compared to 24 billion gallons in 2010.
- The number of wood pellet plants in the United States increased to 148 production plants in 2017, and are primarily located in the southeastern United States. This accounts for almost 24,000 direct jobs.
- The United States is the world's leading wood pellets producer, achieving 6.3 million metric tons of wood pellets in 2017. Just one third of total production is consumed domestically, and it is used primarily for heating.
- Exports of wood pellets reached 5.2 million metric tons in 2017, in comparison with 1.9 million metric tons in 2012. The European Union is the market destination for American wood pellets, and they are used in coal-fired power plants for electricity generation to reduce greenhouse gas emissions.
- The generation of municipal solid waste in the United States increased by 3 percent between 2010 and 2014, with 12.8 percent combusted for energy recovery.
- In 2017, the number of waste-to-energy plants decreased to 70 plants in the United States. Most of the facilities are located in the northeastern United States, which is a densely populated region with little land availability for landfills.
- 154 BTUs of energy were generated from waste in the United States in 2016. The energy generated from waste is primarily used for electricity generation.
- In 2017, there were over 2,300 sites producing biogas in the United States: 250 anaerobic digesters on farms that produced 1.9 million metric tons of methane; 849 landfills gas projects that produced 2.6 million metric tons of methane; and 1,268 wastewater treatment facilities that produced 2.3 million metric tons of methane.
- Biogas production surpassed 285 billion cubic feet in 2017, compared with 225 billion cubic feet in 2010.
- The collection and use of biogas have direct benefits for the environment. In fact, biogas capture systems reduced greenhouse gas emission by more than 126 million metric tons in 2017.

Biobased Products

- More than 2,200 companies participate in the BioPreferred Program; California has the largest number of participating companies.
- The number of categories that qualify for mandatory federal purchasing increased from 32 categories in 2008 to 109 categories in 2017. In addition, the number of categories that are certified through the voluntary labeling initiative increased from 50 categories in 2011 to 100 categories in 2016.
- The BioPreferred Program estimates that the number of biobased products in the United States was greater than 40,000 products in 2014, compared to 17,000 products in 2008. This accounts for 4.5 million American jobs and 393 billion dollars in value added to the United States economy.
- The production of bioplastics at global scale increased from 0.18 million metric tons in 2008 to 2.05 million metric tons in 2017.
- Over 50 percent of global bioplastics were used for packaging in 2017.
- About 16 percent of global production of bioplastics occurs in North America.
- In 2017, the production of biobased chemicals in the United States was estimated at 750 thousand metric tons. This number is projected to grow to 3200 thousand metric tons in 2020.
- The biobased chemical industry created 18,000 American jobs in 2014.
- In 2014, the biobased chemical industry contributed 5 billion in value added to the United States economy.
- The global market of enzymes reached 5 billion dollars in 2016, in comparison with 2.9 billion dollars in 2008.
- The number of direct jobs created by the enzyme industry in 2014 was 3,970.
- The direct value added contribution to the United States economy from the enzyme industry in 2014 was 1 billion dollars.
- The largest forest products are paper products and wood-based panels, with a production of 239 million tons and 207 million cubic meters in 2017, respectively.
- Trade of forest products increased slightly from 2008 to 2017. Imports, increased by 1 billion dollars and exports by 6 billion dollars.
- In 2014, the forest product industry contributed to the United States economy by 1.1 million direct jobs and 93 billion dollars in value added.
- The number of jobs contributed to the United States economy by the biobased textiles industry in 2014 was 164,040.
- In 2014, the biobased textile industry contributed 10 billion dollars in value added to the United States economy.

Government Advisory Council

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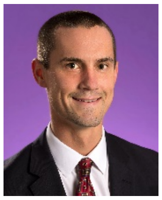

Dr. Brandon Morrison is the Director of Strategic Initiatives within the Division of Research, Economic Development, and Engagement at East Carolina University. He earned his Ph.D. in Earth and Ocean Sciences from the Nicholas School of the Environment at Duke University, where his dissertation research utilized lifecycle-modeling techniques to examine the sustainability implications of the industrialization of the Earth's resources. Dr. Morrison graduated from Franklin & Marshall College with his B.S. in Environmental Science and earned his Master of Environmental Management degree from Duke University.

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Glossary of Terms

Anaerobic digestion:	Collection of processes in which organic material is broken down by bacteria in the absence of oxygen.
Biobased chemical:	Chemical totally or partially produced from plants or renewable sources.
Biodegradable:	Can be degraded by naturally occurring microorganisms in a defined environmental and timescale.
Biodiesel:	Diesel fuel derived from vegetable oils, animal fats, or recycled grease. Chemically distinct from petroleum diesel.
Bioenergy:	Form of renewable energy derived from biomass.
Biofuel:	Fuel produced from biological or renewable materials. Examples include biodiesel and ethanol.
Biogas:	Mixture of gases, primarily methane and carbon dioxide, produced by anaerobic digestion from different waste sources.
Biogenic material:	Material made by or from living organisms (i.e., plants and animals).
Bioplastic:	Type of plastic that is partially or fully biobased and/or biodegradable.
BioPreferred Program:	A program administered by the U.S. Department of Agriculture with the goal of increasing the Federal purchase and use of biobased products. The program's purpose is to spur rural economic development, create new jobs and provide new markets for farm commodities.
Bioproduct:	Products derived in whole, or in significant part, from biological or renewable materials.
British Thermal Units:	Amount of heat needed to raise one pound of water at maximum density through one degree Fahrenheit.
Cellulosic material:	The world's most abundant biological material. Corn stover, switchgrass, or wood chips are some examples of cellulosic materials. Cellulose is a group of organic compounds with the formula $(C_6H_{10}O_5)_n$.
Cubic feet:	Volume of a cube with sides of one foot.
Enzyme:	Substance produced by living organisms that act as a catalyst on a specific biochemical reaction.
Fuel ethanol:	Motor gasoline blending component produced from fermenting biomass that is rich in starches and sugars. It is typically derived from corn and sugar cane.
Global warming potential:	Amount of heat a greenhouse gas traps in the atmosphere. Expressed in relation to carbon dioxide.

Gross domestic product:	Monetary value of all the finished goods and services produced within a country's borders in a specific period of time, usually a year.
Irrigation water:	Water applied to plants in controlled amounts at needed intervals.
Methane potential:	Amount of methane in the biogas produced during anaerobic digestion, expressed under Normal conditions of Temperature and Pressure.
Non-biogenic material:	Material of nonbiological origin such as plastics and synthetic materials made from petroleum.
Noncombustible material:	Material that does not support combustion such as glass and metals.
Organic material:	Material made from living organisms (i.e., plants and animals).
Waste-to-energy:	Production of energy or heat from waste.
Waste-to-energy plant:	Facility that incinerates waste for energy recovery. In these plants the waste is burned to capture the heat from the burning process and produce steam, which is used to generate electricity or heat.

1. FIELD CROP INDICATORS

1.1. Summary

Cropland in the U.S. ↓ 0.2% [Annual Change]

TOP 5 FIELD CROPS

2016 252M acres	2017 252M acres
Corn [94]	Corn [90]
Soy [83]	Soy [90]
Wheat [50]	Wheat [46]
Cotton [10]	Cotton [13]
Sorghum [7]	Sorghum [6]

TOP 5 STATES

2016 252M acres	2017 252M acres
Iowa [23]	Iowa [23]
Illinois [22]	Illinois [22]
Kansas [21]	Kansas [21]
North Dakota [20]	North Dakota [20]
Minnesota [18]	Minnesota [18]

Value of field crops in the U.S. ↓ 1.9 % [Annual Change]

TOP 5 FIELD CROPS

2016 111 B Dollars	2017 109 B Dollars
Corn [51]	Corn [48]
Soy [41]	Soy [41]
Wheat [9]	Wheat [8]
Cotton [6]	Cotton [7]
Sorghum [1]	Sorghum [1]

TOP 5 STATES

2016 111 B Dollars	2017 109 B Dollars
Iowa [14]	Iowa [14]
Illinois [14]	Illinois [14]
Nebraska [9]	Minnesota [9]
Minnesota [9]	Nebraska [9]
Indiana [7]	Indiana [7]

Value of field crops exported from the U.S. ↓ 4.5% [Annual Change]

TOP 5 FIELD CROPS

2016 40 B Dollars	2017 38 B Dollars
Soy [23]	Soy [22]
Corn [10]	Corn [9]
Wheat [5]	Wheat [6]
Sorghum [1]	Sorghum [1]
Peanuts [1]	Peanuts [1]

TOP 5 DESTINATIONS

2016 40 B Dollars	2017 38 B Dollars
China [29]	China [28]
Mexico [7]	Mexico [7]
Japan [3]	Japan [3]
South Korea [0.4]	South Korea [0.4]
Taiwan [0.3]	Taiwan [0.2]

Value of field crops imported into the U.S. ↑ **11.5%** [Annual Change]

TOP 5 FIELD CROPS

2016 1,361 M Dollars	2017 1,518 M Dollars
Wheat [471]	Wheat [689]
Soy [342]	Soy [367]
Corn [334]	Corn [274]
Barley [76]	Barley [81]
Peanuts [65]	Peanuts [51]

TOP 5 SOURCES

2016 1,361 M Dollars	2017 1,518 M Dollars
Canada [729]	Canada [929]
Turkey [223]	Turkey [164]
Argentina [109]	Argentina [130]
India [64]	India [99]
Mexico [49]	Mexico [54]

Corn produced used for ethanol production ↓

2016 44.2% VS **2017** 44.0%

Corn oil produced used for biodiesel production ↑

2016 24% VS **2017** 27%

Soy oil produced used for biodiesel production ↑

2016 25% VS **2017** 27%

Canola oil produced used for biodiesel production ↑

2016 19% VS **2017** 22%

Land Use

Photo 1. (16).

The number of farms in the United States decreased from 2.2 million farms to 2.0 million farms during the period of 2008 to 2017 (Figure 1.1.1). Although the number of farms has been reduced, the total land in farms has remained rather stable over the years, showing a reduction of just 0.9 percent from 2008 to 2017.

Despite a slight reduction in the total land in farms, the average size of farms increased by 5.5 percent, from 421 acres in 2008 to 444 acres in 2017. The main uses of the United States farmland are permanent pasture and cropland (Figure 1.1.2).

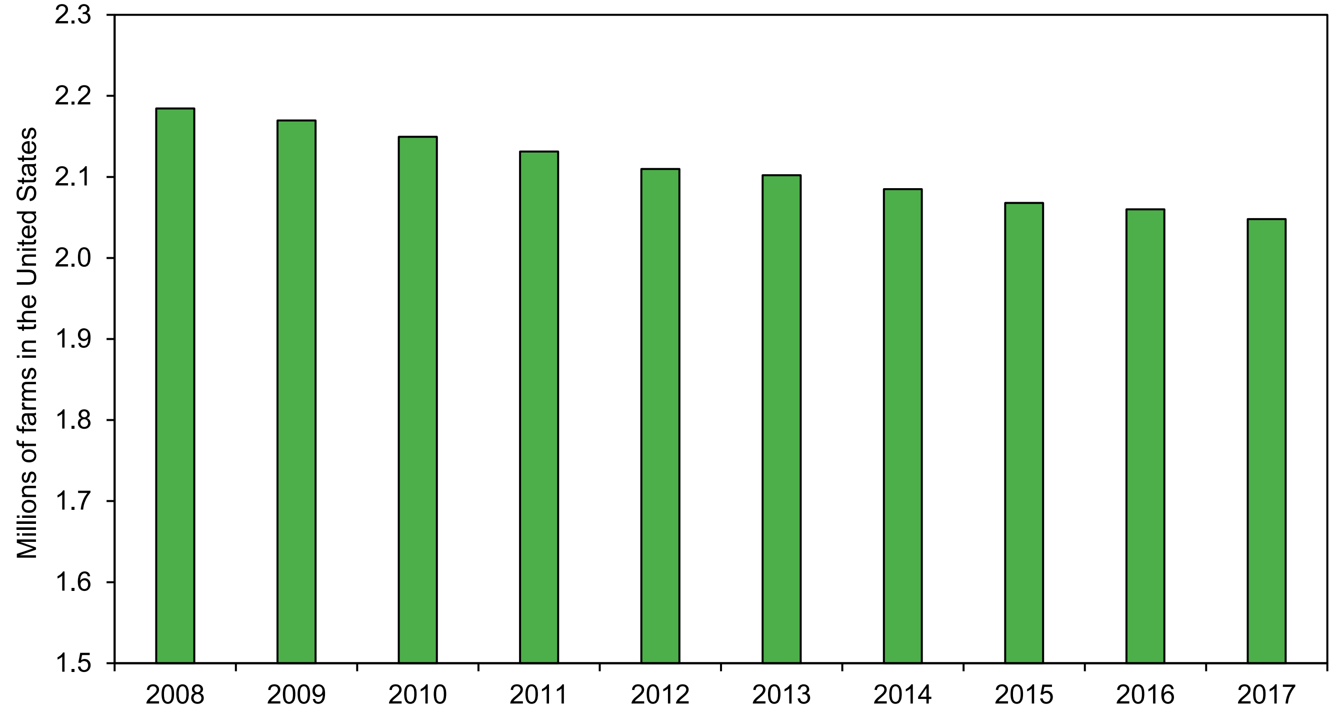

Figure 1.1.1. Total number of farms in the United States from 2008 to 2017 (in millions) (1).

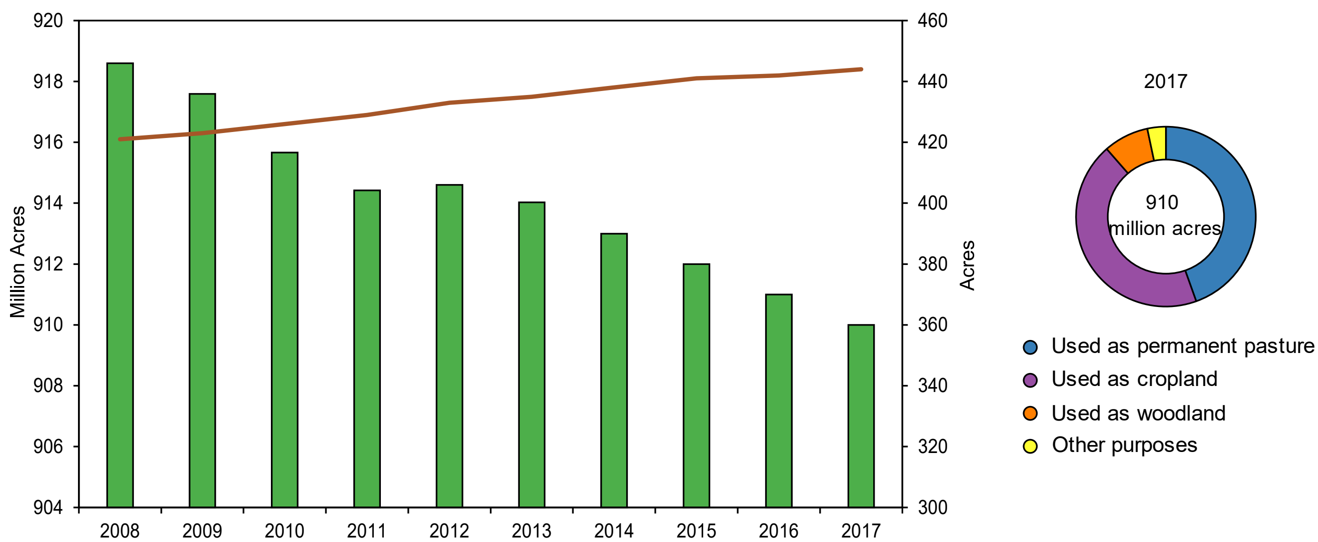

Figure 1.1.2. The bars represent the total land in farms in the United States from 2008 to 2017 (in million acres; left axis), and the line the average farm size in the United States from 2008 to 2017 (in acres; right axis) (1-3).

Cropland and total farms are focused primarily in the Midwest region of the United States (Figures 1.1.3 and 1.1.4). The top 5 states with highest cropland are Texas, Kansas, North Dakota, Iowa, and Illinois (see Table 1.1.1 for more detail). The 5 states with most farms are Texas, Missouri, Iowa, Oklahoma, and California (see Table 1.1.2 for more detail).

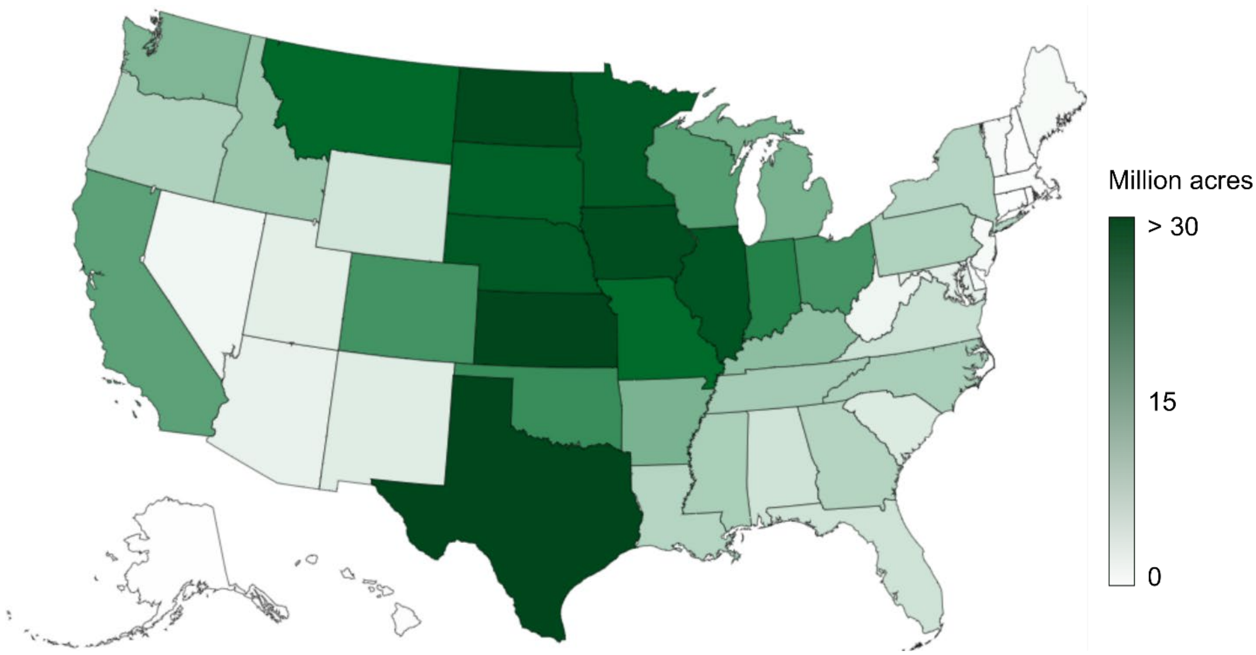

Figure 1.1.3. Total cropland in the United States by state in 2017 (in million acres) (3).

State	Million Acres	Percentage
Texas	29.4	7.4
Kansas	29.1	7.4
North Dakota	28.0	7.1
Iowa	26.5	6.7
Illinois	24.0	6.1

Table 1.1.1. 5 states with largest cropland in the United States in 2017 (in million acres) (3).
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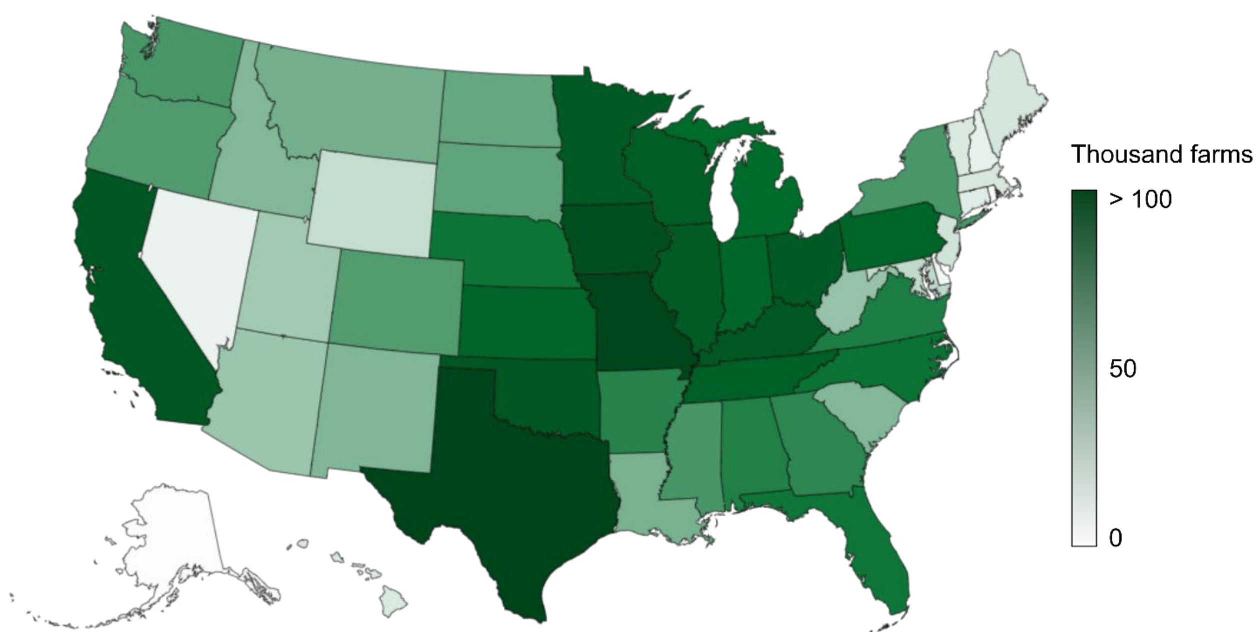


Figure 1.1.4. Total number of farms in the United States by state in 2017 (3).

State	Acreage	Percentage
Texas	240	11.7
Missouri	97.3	4.8
Iowa	86.9	4.2
Oklahoma	77.2	3.8
California	77.1	3.8

Table 1.1.2. 5 states with largest number of farms in the United States in 2017 (in thousand farms) (3).

Production

The value of U.S. agricultural production grew from 2008 through 2012, when it reaches its peak at 224 billion dollars. After that, the value of agriculture production goes through a brief decline through 2015 and then expanded slightly, to 186 billion dollars in 2016 (Figure 1.1.5).

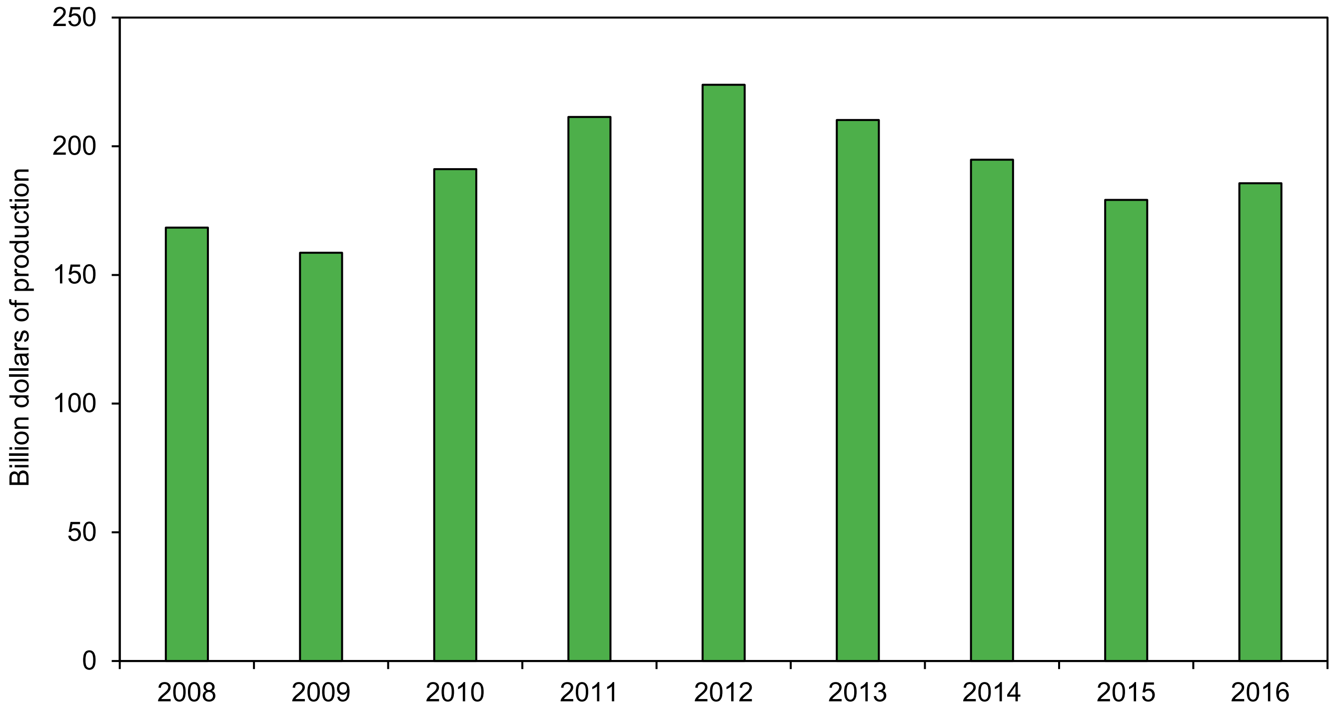


Figure 1.1.5. Agriculture production in the United States from 2008 to 2016 (in billion dollars) (4).

The value of exports increased until 2014 when it reached a maximum of 150 billion dollars. Exports dropped to 133 billion dollars in 2015 but recovered the positive trend with exports of 138 billion dollars in 2017. Canada is the country with the highest trade of agriculture goods with the United States, followed closely by China and Mexico (Figure 1.1.6).

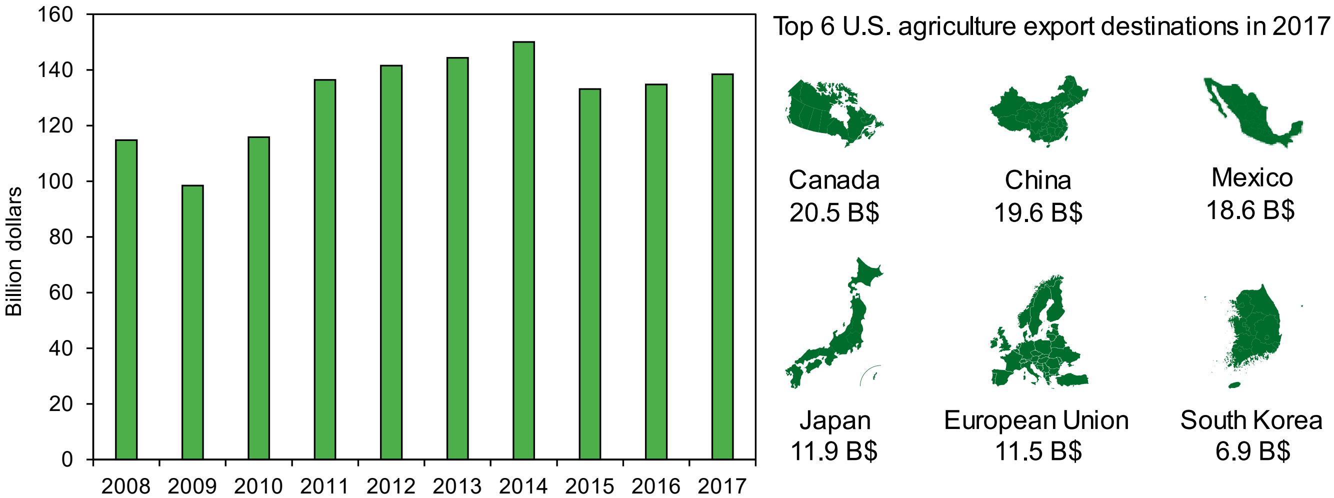


Figure 1.1.6. Exports of agriculture in the United States from 2008 to 2017 (in billion dollars) (5) and top 6 United States export destinations in 2017 (in billion dollars) (6).

The value of agricultural imports reached 121 billion dollars in 2017 compared to 80 billion dollars in 2008. Mexico, Canada and the European Union were the largest sources of agriculture products in 2017, well ahead of China, which is the fourth largest exporter to the U.S. (Figure 1.1.7).

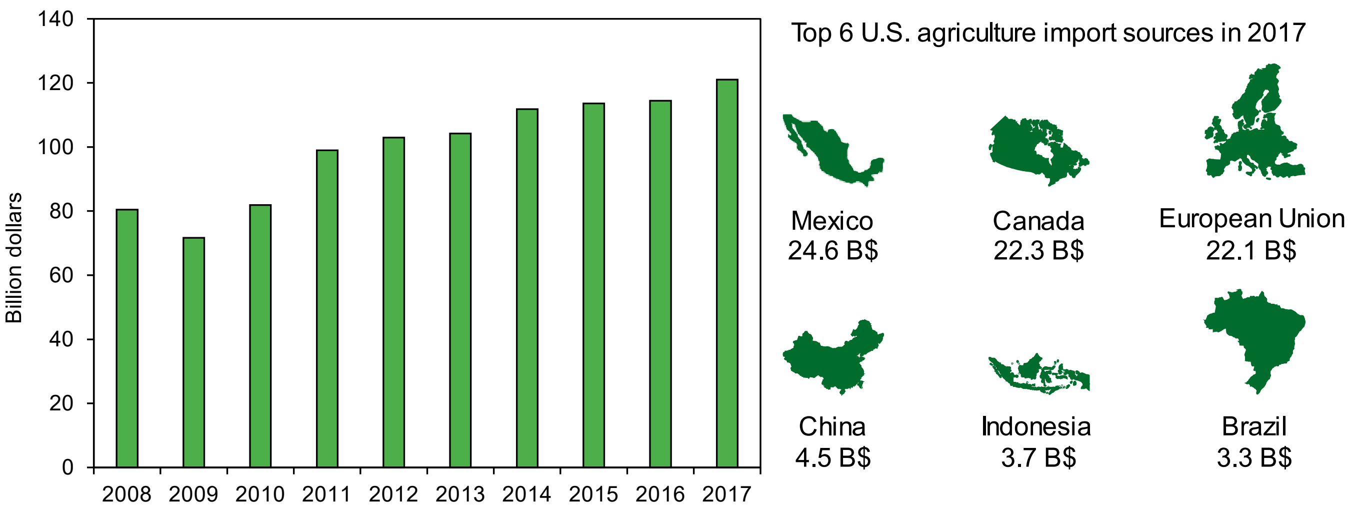


Figure 1.1.7. Imports of agricultural products in the United States from 2008 to 2017 (in billion dollars) (5) and top 6 United States import sources in 2017 (in billion dollars) (6).

Economics

Although the total agriculture acreage has remained constant over the years, the net farm income in the United States has dropped over 40 percent, from 2011 to 2017. In 2013, the net farm income reached a historic peak at 124 billion dollars compared with 64 billion dollars in 2017 (Figure 1.1.8).

Net cash income of farm operations is significantly higher in California and in the Midwest United States (see Figure 1.1.9 and Table 1.1.3 for more detail).

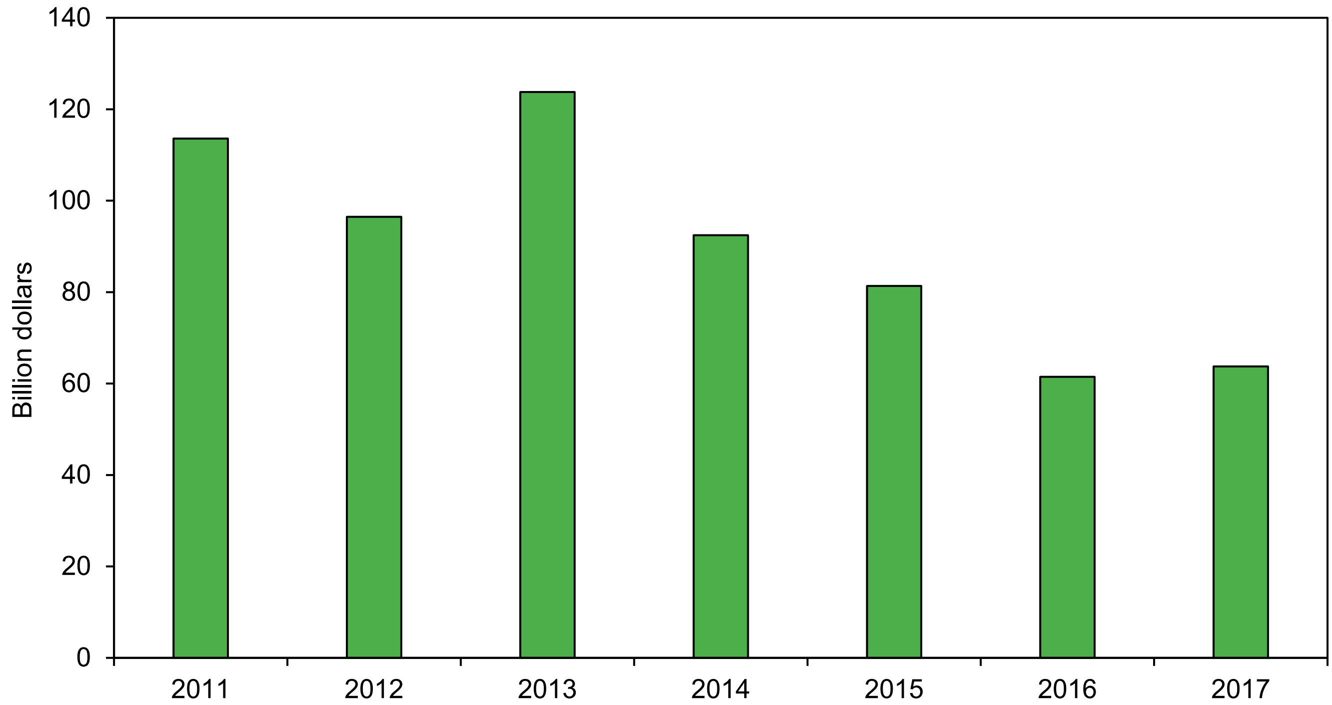


Figure 1.1.8. Net farm income in the United States from 2011 to 2017 (in billion dollars) (7).

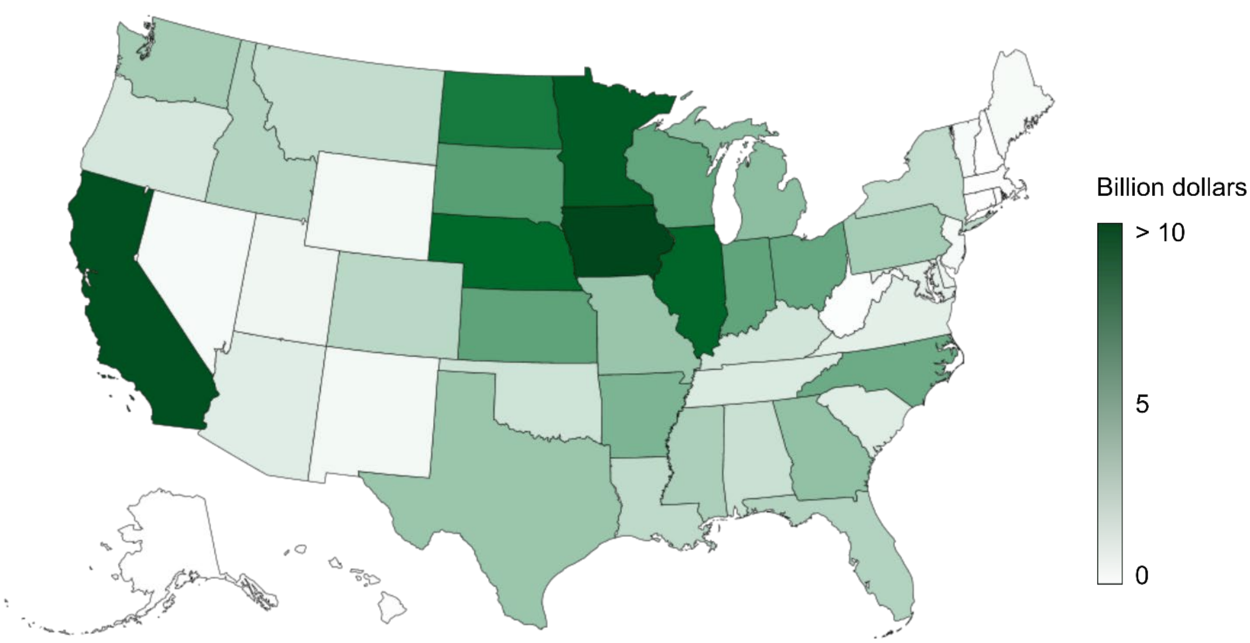


Figure 1.1.9. Net farm income in the United States by state in 2017 (in billion dollars) (3).

State	Net cash income	Percentage
Iowa	9.8	10.6
California	8.5	10.3
Minnesota	7.0	9.5
Illinois	5.9	8.9
Nebraska	5.4	8.9

Table 1.1.3. 5 states with highest net farm income in the United States in 2017 (in billion dollars) (3).

U.S. farm assets, farm equity and farm debt all increased by 31 percent from 2011 to 2017 (Figure 1.1.10).

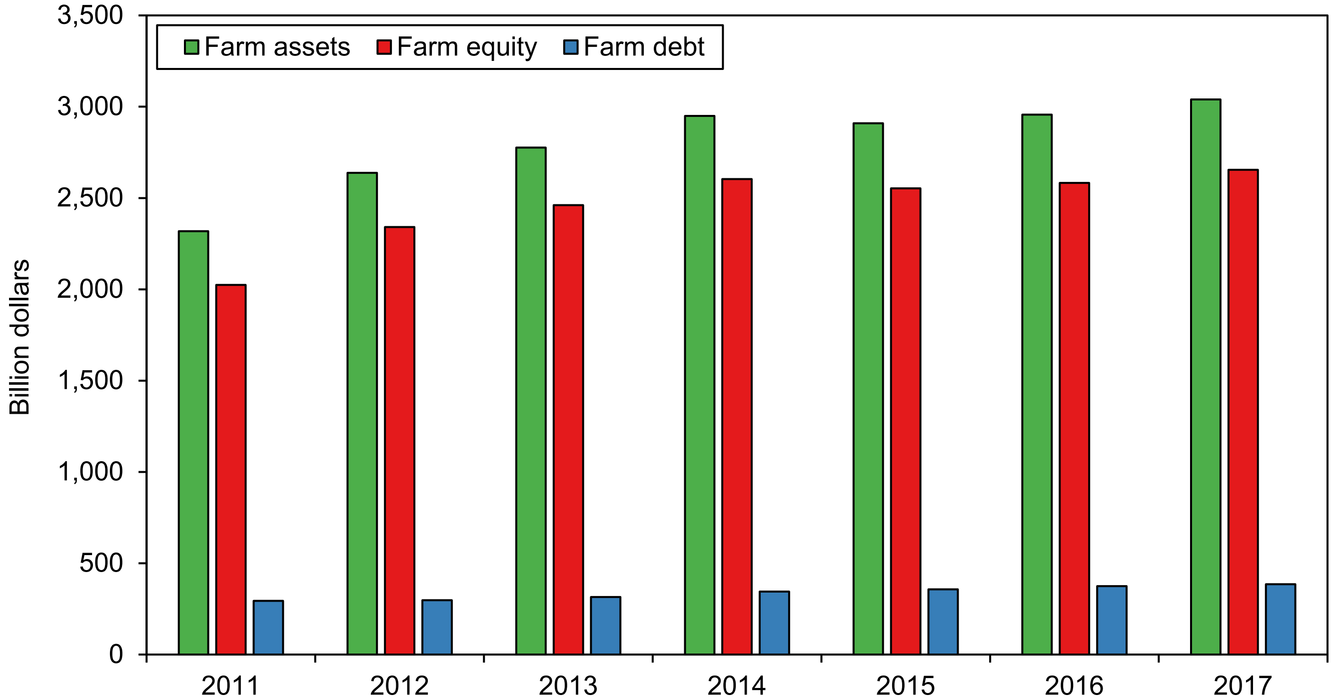


Figure 1.1.10. Total farm assets, debt and equity in the United States from 2011 to 2017 (in billion dollars) (7).

Environmental indicators

Agricultural production in the United States relies greatly on the country's land, water, and other natural resources, and subsequently has a direct impact on the quality of the surrounding environment (8). The following sub-sections present a brief overview of agriculture's requirements for water, fertilizer and pesticide use.

Water Use

The agriculture sector is a major user of both ground and surface water in the United States, historically accounting for approximately 80 percent of the country's consumptive water use (9).

The most recent Census of Agriculture, conducted in 2012, reported total U.S irrigated acreage at 55.8 million acres (3), while a more recent study conducted in 2015 reported the same metric at 63.5 million acres (10). Though the two studies were conducted in different years by different agencies, both documents are concurrent in noting that five states – Arkansas, California, Idaho, Nebraska, and Texas – account for over half of the nation's irrigated agriculture acreage. Nebraska (15.08%) and California (14.67%) together accounted for nearly 30 percent of the total U.S irrigated land area in 2015. (see Figure 1.1.11 and Table 1.1.4)

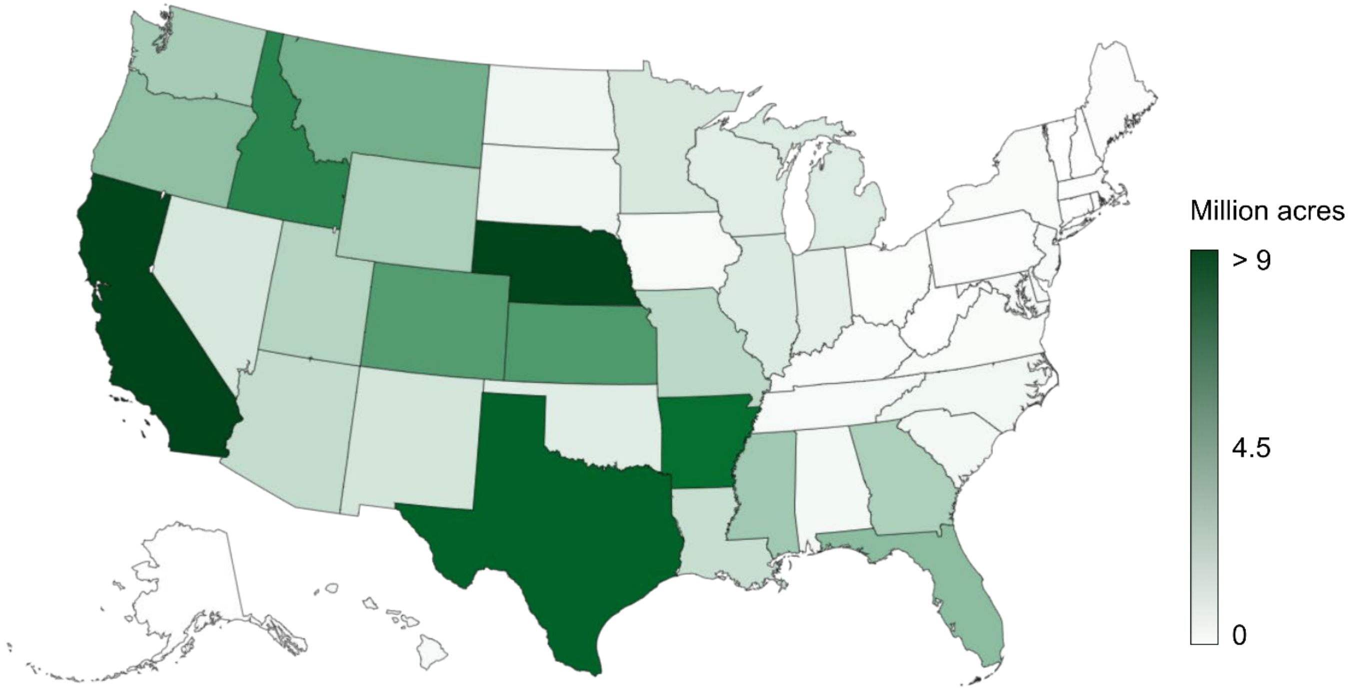


Figure 1.1.11. Irrigated land by state in the United States in 2015 (in million acres) (10).

State	Irrigated land	Percentage
Nebraska	9.6	15.1
California	9.3	14.7
Texas	5.7	8.9
Arkansas	4.4	7.0
Idaho	3.8	6.0

Table 1.1.4. 5 states with highest irrigated land by state in the United States in 2015 (in million acres) (10).

On a crop-level basis, corn (approximately 25% of total), soybeans (14%), cotton (7%), and wheat (7%) accounted for more than half of total U.S irrigated acreage harvested in 2012 (9).

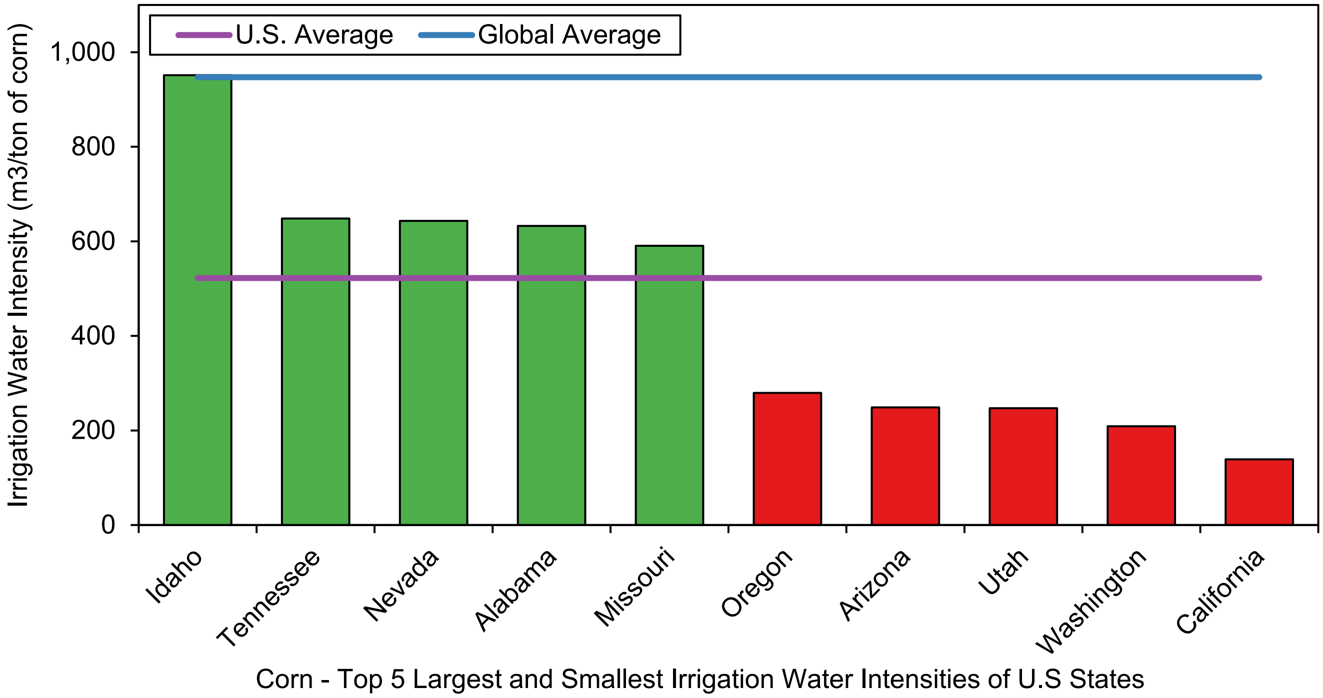


Figure 1.1.12. Top five states with the (a) highest and (b) lowest irrigation water intensities for growing corn. Water intensity is measure as the volume of water (m^3) required to produce one ton of crop (11).

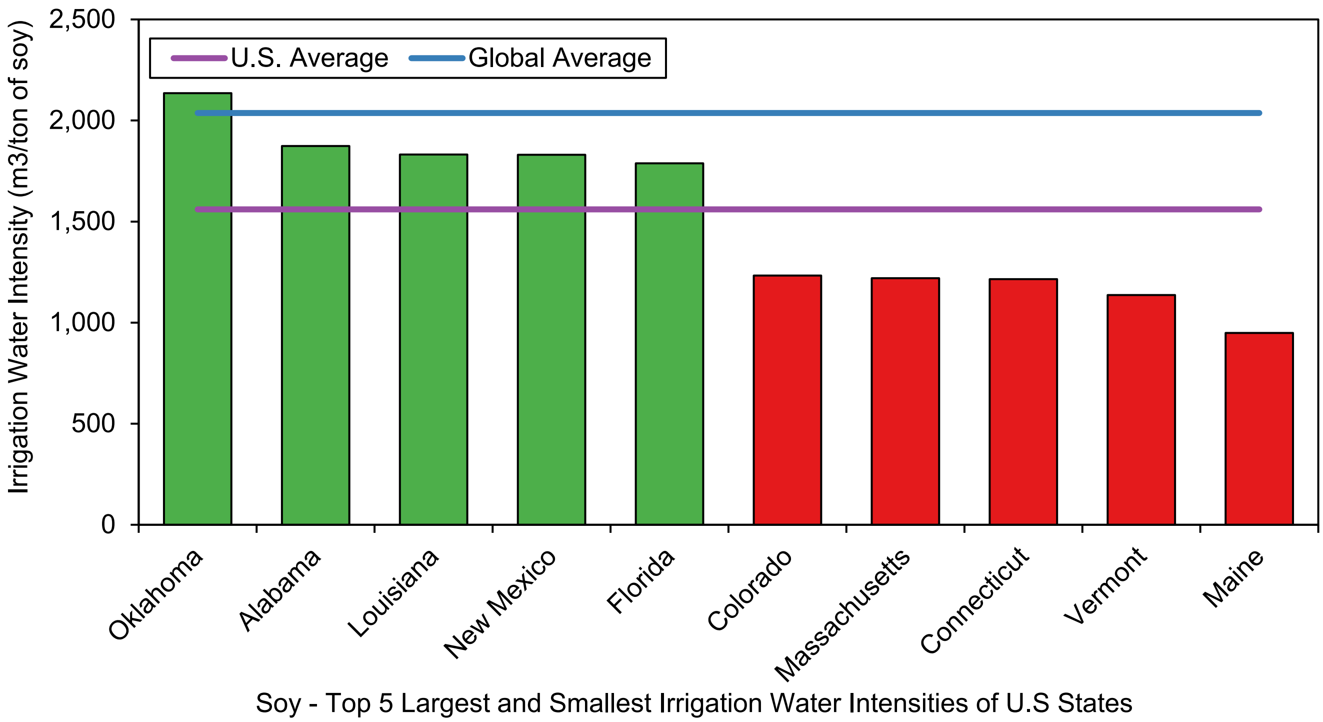
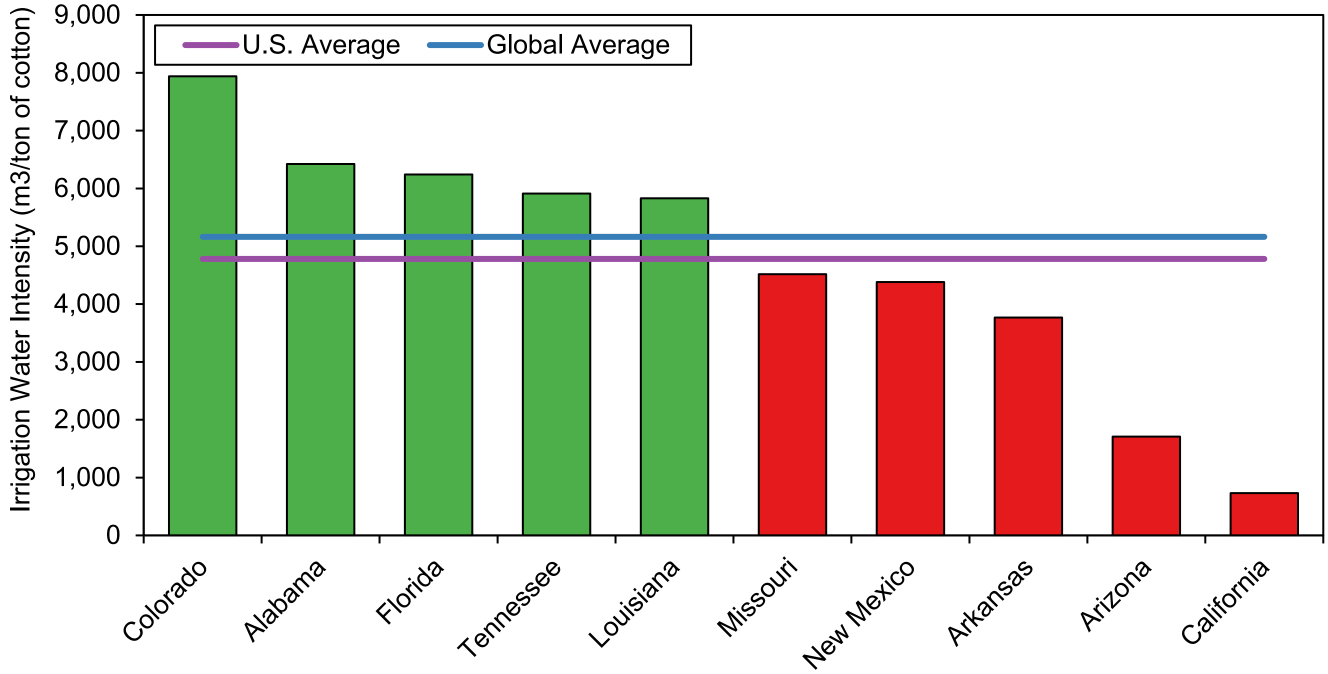
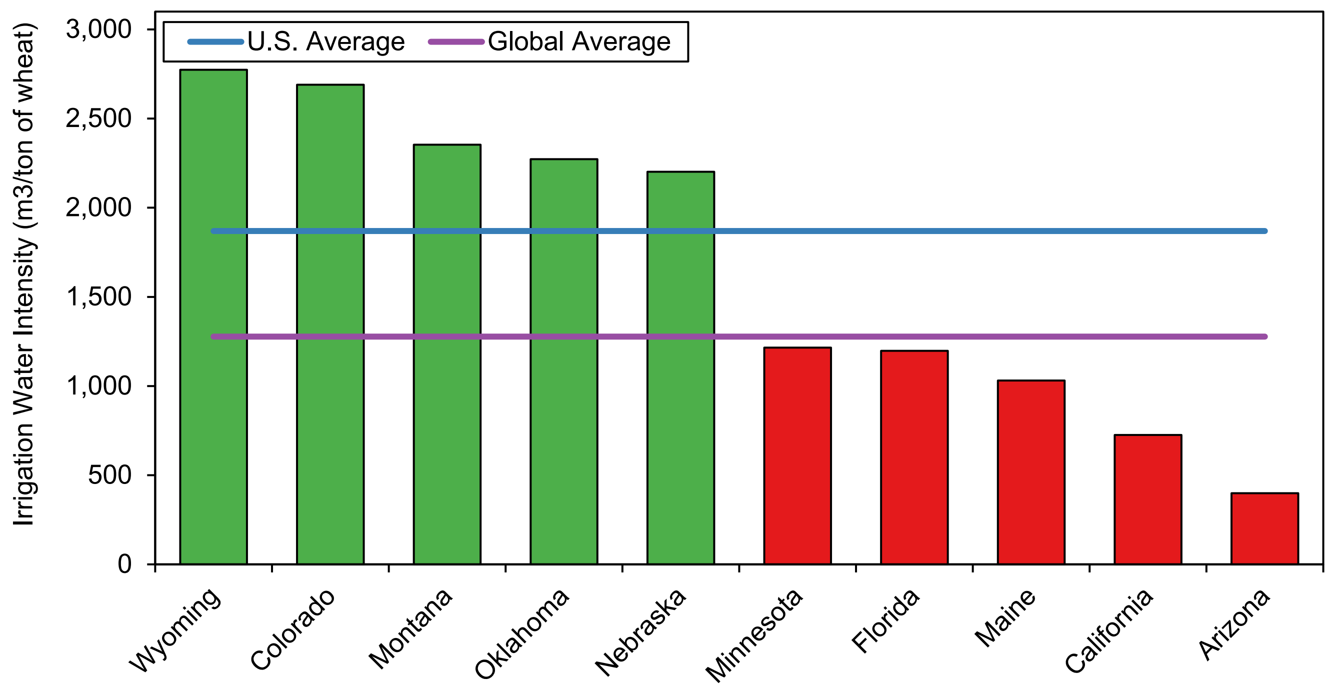


Figure 1.1.13. Top five states with the (a) highest and (b) lowest irrigation water intensities for growing soybeans. Water intensity is measure as the volume of water (m^3) required to produce one ton of crop (11).



Cotton - Top 5 Largest and Smallest Irrigation Water Intensities of U.S States

Figure 1.1.14. Top five states with the (a) highest and (b) lowest irrigation water intensities for growing cotton. Water intensity is measure as the volume of water (m^3) required to produce one ton of crop (11).



Wheat - Top 5 Largest and Smallest Irrigation Water Intensities of U.S States

Figure 1.1.15. Top five states with the (a) highest and (b) lowest irrigation water intensities for growing wheat. Water intensity is measure as the volume of water (m^3) required to produce one ton of crop (11).

Fertilizer Use

Nitrogen (N), phosphate (P2O5), and potash (K2O) are essential in the production of crops used for food, feed, fiber, fuel, and bioproducts (12). Since 1990, the NASS Agricultural Chemical Use Program has surveyed U.S farmers to collect information on the chemical ingredients that farmers apply to agricultural commodities through fertilizers and pesticides (13). This data relies on a sample of farmers, who participate voluntarily. Alternatively, the USDA Economic Research Service provides annual fertilizer use and price data at the national and State levels (14).

The amount of fertilizer applied to farms has remained nearly constant over the years, with no persistent trend save for a dip in total fertilizer consumption in 2009 (Figure 1.1.16). The decline in fertilizer consumption in 2009 is attributable to both record fertilizer prices in 2008 and impacts from the 2008-2009 economic crisis, which resulted in a weakening of global demand for U.S. agriculture (14, 15). Lower demand for crops, coupled with record fertilizer prices, led farmers to reduce their fertilizer usage the following year (see Figure 1.1.17).

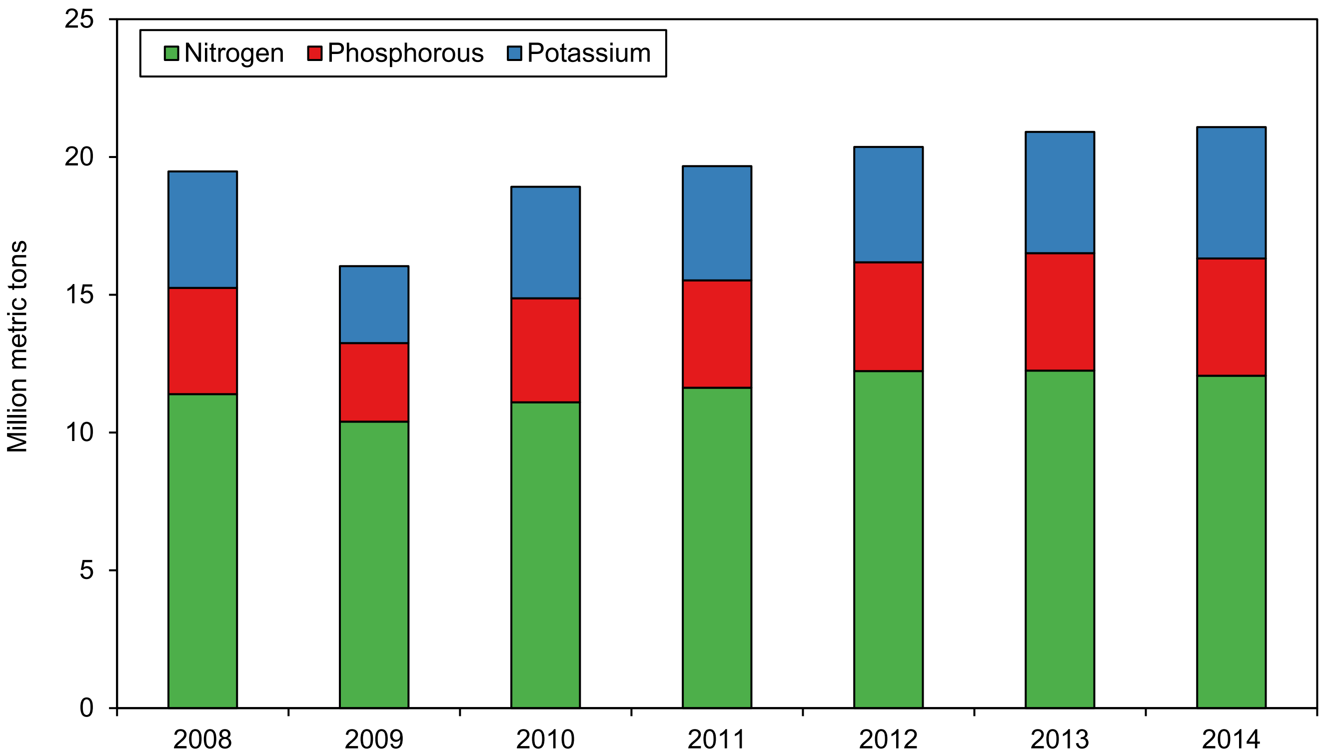


Figure 1.1.16. Total chemical fertilizers applied to farms in the United States from 2008 to 2014 (in million metric tons) (14).

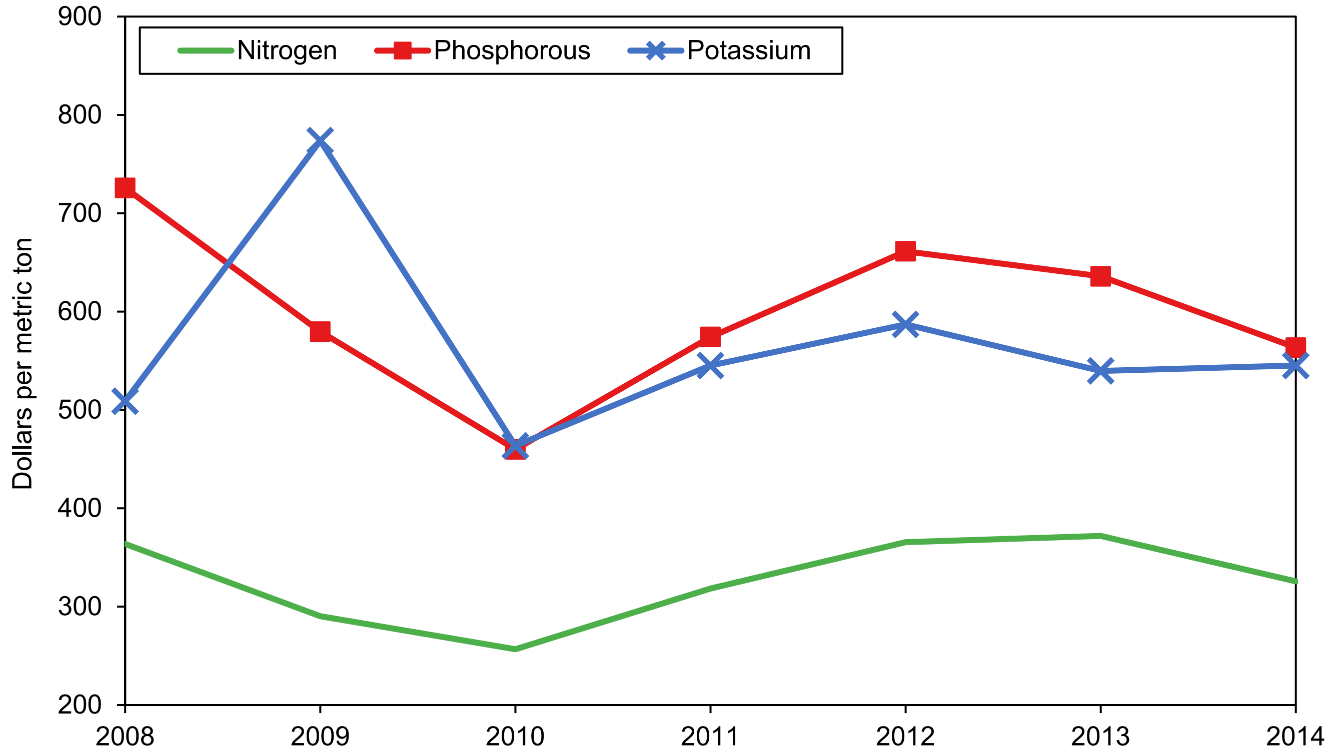


Figure 1.1.17. Average price for chemical fertilizers in the United States from 2008 to 2014 (in million metric tons) (14).

Fertilizer application rates vary state-to-state, influenced by factors such as soil type and nutrient ranges of various crops. Matching application rates to crop needs is an important component of optimizing crop production, in addition to reducing nutrient exports and loadings to nearby waterbodies. Average values for the United States are presented for four selected crops: corn, cotton, soybeans, and wheat (Table 1.1.5). The share of planted crop acreage receiving fertilizer, in addition to fertilizer application rates per acre, are shown (13).

	Nitrogen		Phosphate		Potash	
	Planted acres (%)	Average rate for year (lbs./acre)	Planted acres (%)	Average rate for year (lbs./acre)	Planted acres (%)	Average rate for year (lbs./acre)
Corn	97	145	79	61	65	80
Cotton	78	94	59	45	45	64
Soybeans	31	18	41	52	42	91
Wheat	52	48	73	53	72	44

Table 1.1.5. Fertilizer applied to planted acres for four selected crops: corn, cotton, soybeans, and wheat. Data presented is from the 2016 and 2017 Agricultural Chemical Use Surveys. Data for wheat is averaged for the year, given that application rates vary among winter wheat, spring (excl. durum) wheat, and durum wheat (13).

Nitrogen and Phosphate were most widely applied to corn, with Potash was applied most widely to wheat crops. The representative dataset of fertilizer application comes from selected surveyed states, which respectively represent: 92 percent of total planted corn acreage (2016 crop year); 89 percent of total planted cotton acreage (2017 crop year); 92 percent of planted soybean acreage (2017); and 90 percent of planted wheat acreage (2017).

Pesticide Use

Farmers in the United States employ a variety of practices to reduce crop yield losses to pests. Focus within this section is on chemical pesticide application, with data retrieved from the National Agricultural Statistics Services (NASS). The NASS has surveyed farmers since 1990 to collect information on the chemical ingredients that farmers apply to agricultural commodities.

Pesticides come in a variety of applications. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) includes four classes of pesticides that are included within the report: herbicides targeting weeds; insecticides targeting insects; fungicides targeting fungal disease; and other chemicals targeting all other pests and other materials, including extraneous crop foliage.

Four representative crops were selected to examine pesticide use: corn, cotton, soybeans and wheat. Data presented is from both the 2016 and 2017 Agricultural Chemical Use Surveys. More specifically, the values for corn are from the 2016 Agricultural Chemical Use Survey, while all other values displayed are from the 2017 survey. Herbicides targeting weeds were used most extensively across all four selected crops. For cotton, other chemicals such as desiccants were applied to nearly 70 percent of the planted acres (See Figure 1.1.18).

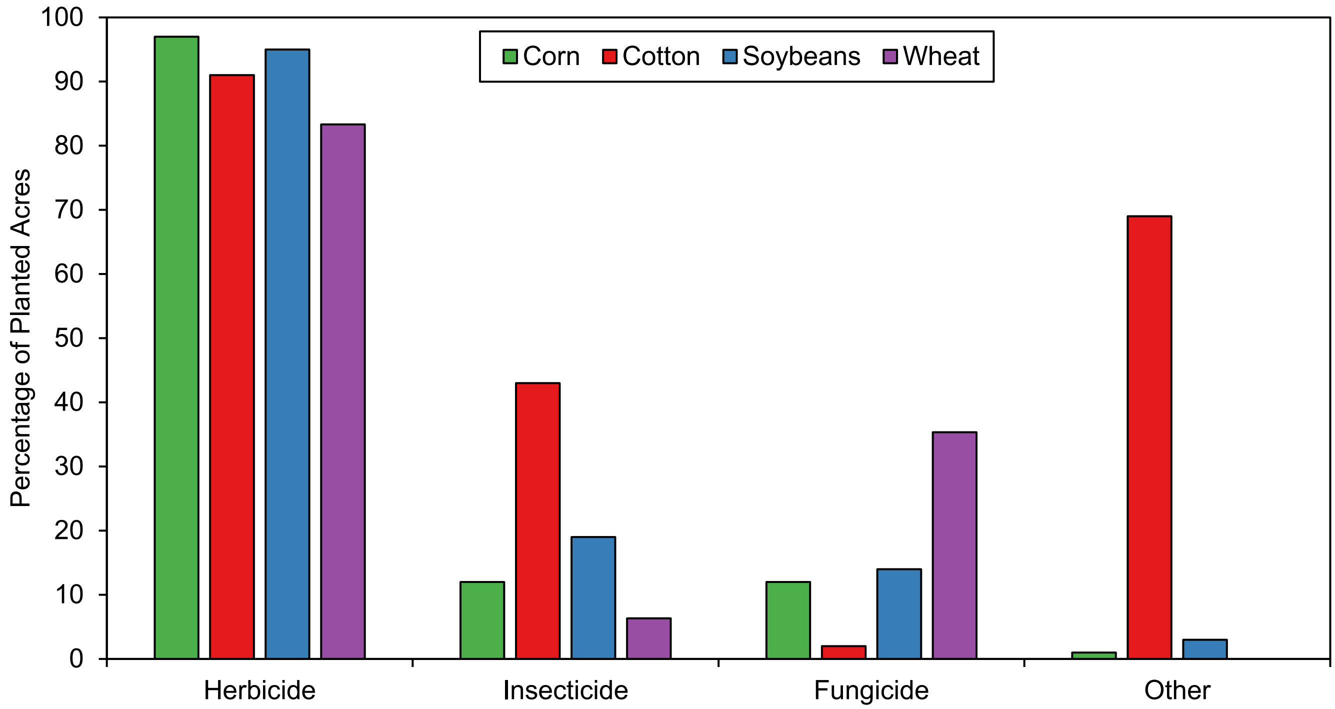


Figure 1.1.18. Pesticides applied to planted acres for four representative crops, 2016-2017 crop years. The values for wheat represent an annual average, given that pesticide use varies among winter wheat, spring (excl. durum) wheat, and durum wheat (13).

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1.2. **Corn**

Photo 2. (13).

Corn is the most abundant crop in the United Sates. Its production is concentrated in the Midwestern United States.

Almost half of the corn consumed in 2017 was used for ethanol production, and 27 percent of corn oil was used for biodiesel production, which makes corn the most relevant crop in terms of biofuel production.

The United States is a net exporter of corn (see Figure 1.2.8), with Mexico being the largest market destination.

Although the production of corn has remained nearly constant over the years, earnings from corn have been reduced in recent years due to the downward trend in corn prices.

In this section these trends are further analyzed according to three main categories, (1) land use, (2) production, and (3) economics.

Photo 3. (14).

Corn occupied the largest amount of acreage of the starch crops from 2008 to 2017, with wheat second. Corn slightly increased the number of acres planted over the years, from 86 million acres in 2008 to 90 million acres in 2017. (Figure 1.2.1). Most corn acreage, 83 percent of the total, is planted in the Midwest. Iowa, Illinois, Nebraska, Minnesota, and South Dakota are the top 5 states for corn planting (see Figure 1.2.2 and Table 1.2.1 for more details).

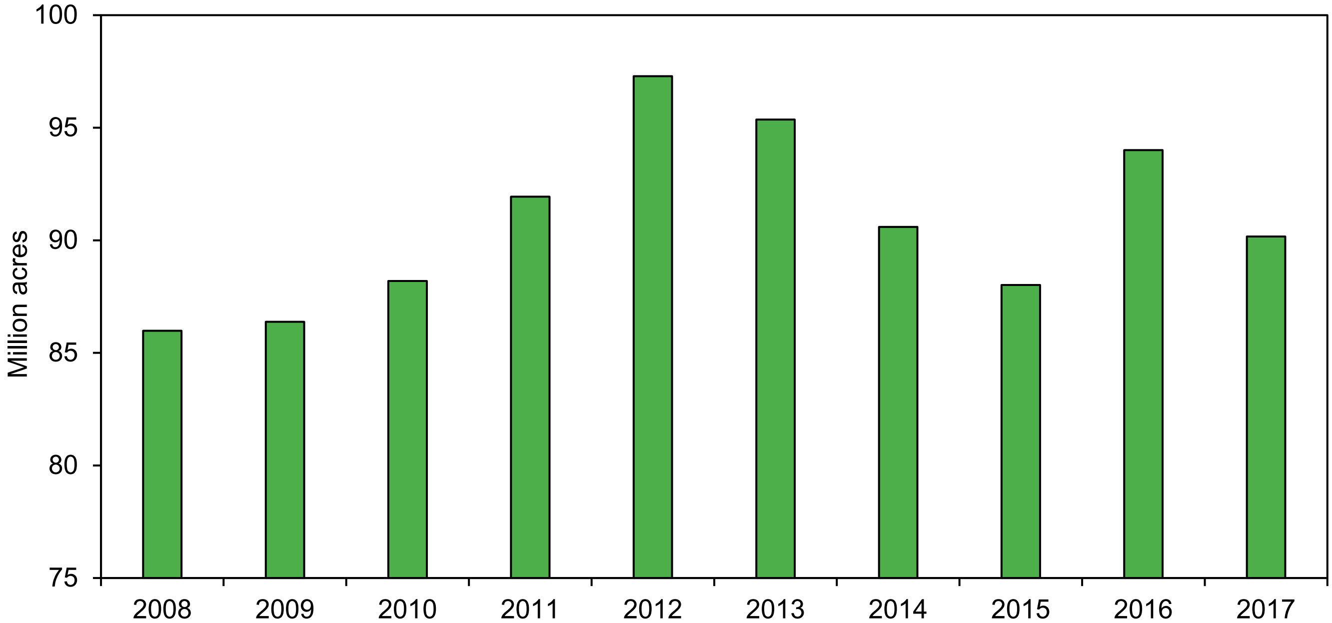

Figure 1.2.1. Total acreage of corn planted in the United States from 2008 to 2017 (in million acres) (1).

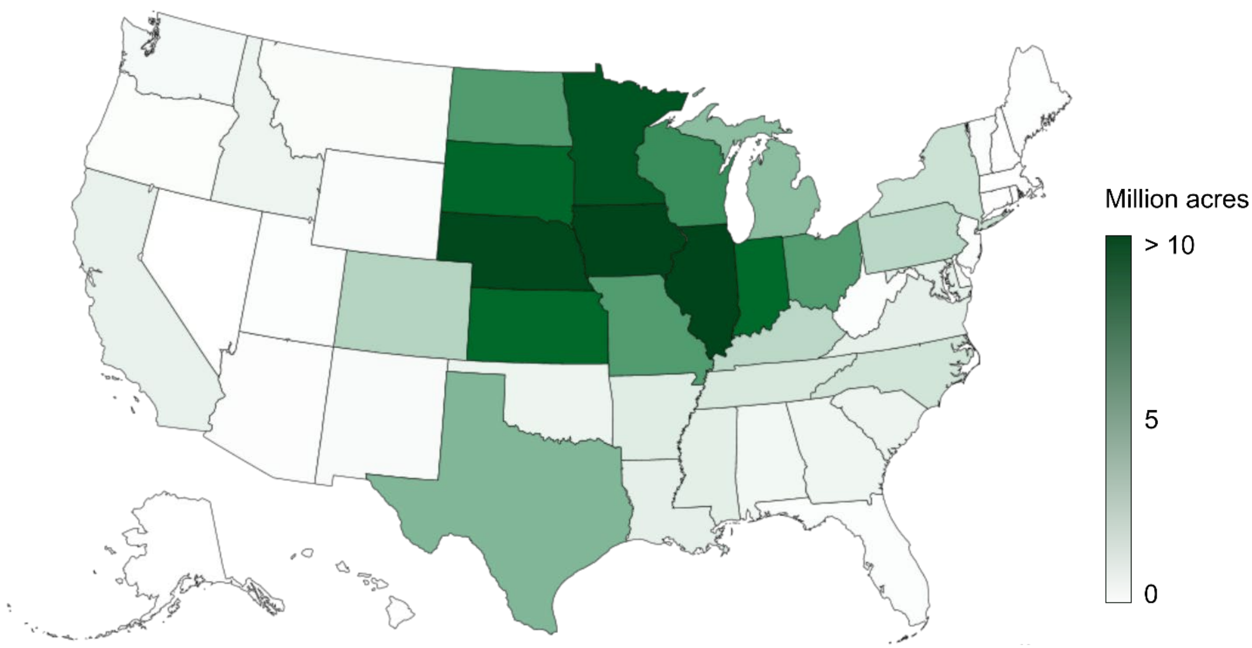

Figure 1.2.2. Total acreage of corn in the United States by state in 2017 (in million acres) (2).

State	Million Acres	Percentage
Iowa	13.3	14.8
Illinois	11.2	12.4
Nebraska	9.6	10.6
Minnesota	8.1	8.9
South Dakota	5.7	6.3

Table 1.2.1. 5 states with largest acreage of corn in the United States in 2017 (in million acres) (2).

Production

Most of the corn grown in the U.S. is used for feed, fuel alcohol and exports. In particular, 15 percent of corn produced in the U.S. is being exported, 37 percent of corn is used for ethanol production and 37 percent for animal feed in 2017. Note that the production of corn is higher than the consumption, which means that the United States is a net exporter of corn (Figure 1.2.3).

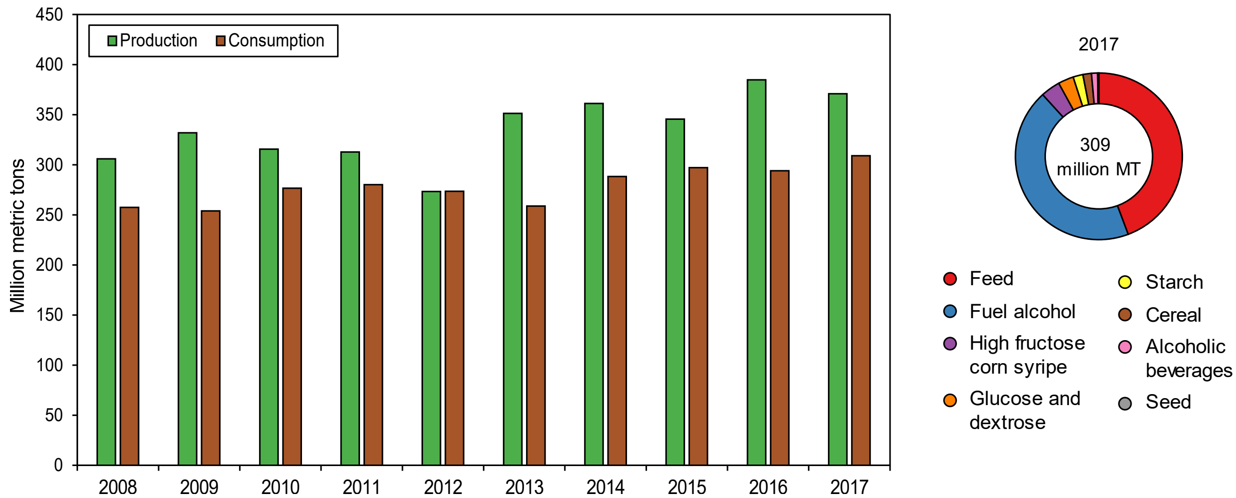

Figure 1.2.3. Total corn production versus total corn consumption in the United States from 2008 to 2017 (in million metric tons) and corn uses in the United States in 2017 (3, 4).

The value of U.S. corn production in billions of dollars from 2008 to 2017 is presented in Figure 1.2.4. Note that the production of corn reached a minimum in 2012 (Figure 1.2.3), which corresponds with the maximum earnings from corn. This is evidence of inelastic demand for corn during this time period (Figure 1.2.10). Between 2008 and 2017, 2012 was the year with the highest relative price of corn. This is because in 2012 there was a huge drought that reduced the production of corn, and since the demand remained strong, corn prices were very high.

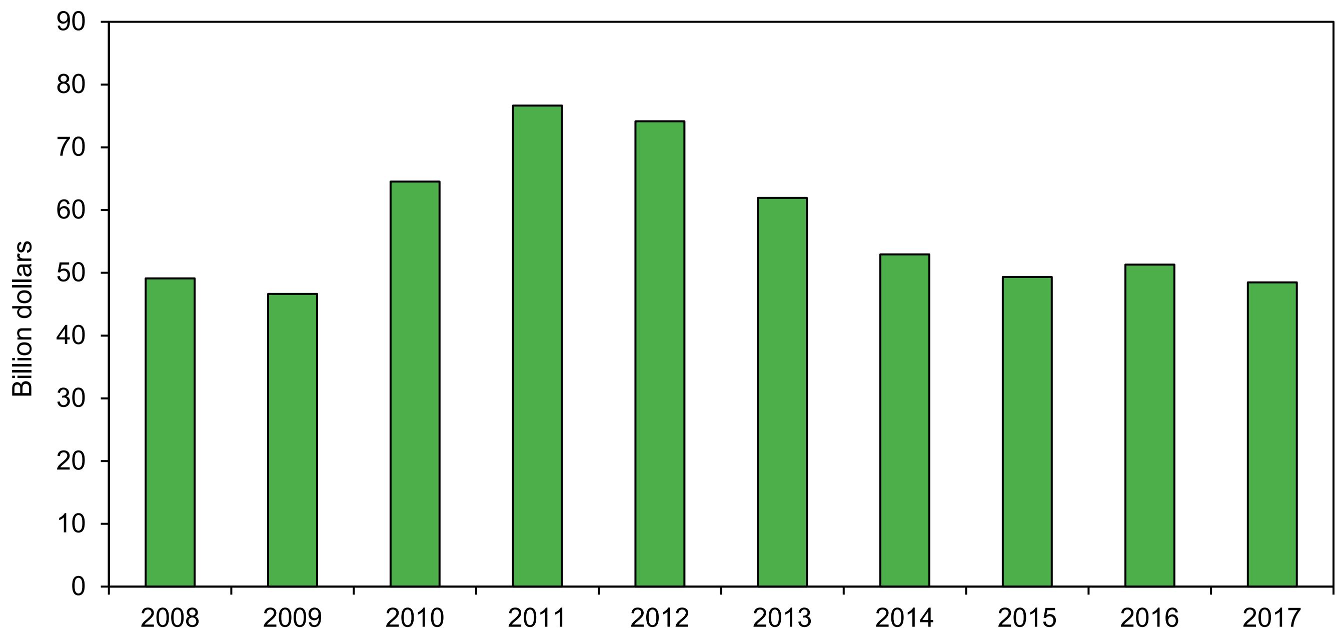

Figure 1.2.4. Production of corn in the United States from 2008 to 2017 (in billion dollars) (5).

Most corn production, 87 percent of the total, is produced in the Midwest. Iowa, Illinois, Nebraska, Minnesota, and Indiana are the top 5 states for corn production (Figure 1.2.5 and Table 1.2.1). This is consistent with the geographical information about corn acreage.

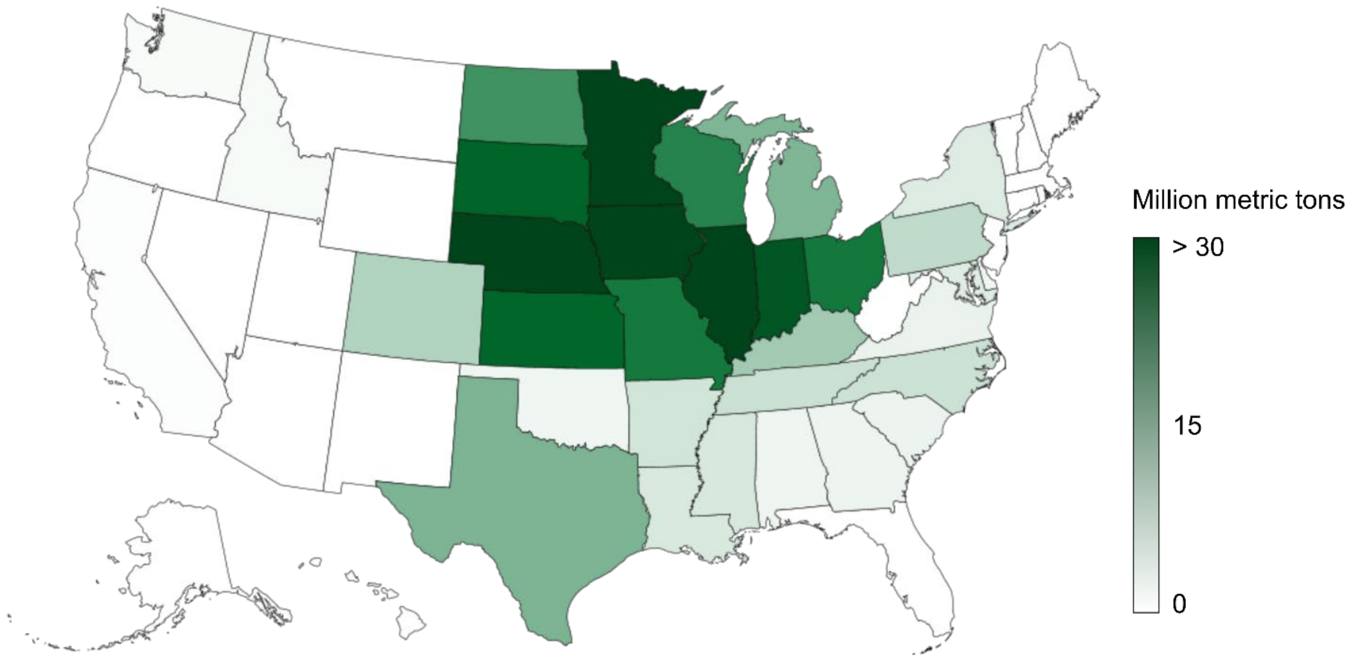

Figure 1.2.5. Total production of corn in the United States by state in 2017 (in million metric tons) (6).

State	Million metric tons	Percentage
Iowa	65	18.0
Illinois	55	15.2
Nebraska	42	11.6
Minnesota	37	10.2
Indiana	23	6.4

Table 1.2.2. 5 states with highest production of corn in the United States in 2017 (in million metric tons) (6).

Corn is the most versatile crop regarding biofuel production since corn starch is used for ethanol production, and corn oil is used to produce biodiesel. The use of corn for fuel ethanol production increased from 76 million metric tons in 2008 to 136 million metric tons in 2017 (Figure 1.2.6). This is equivalent to 30 percent of total corn used in 2008 and 44 percent in 2017, which is consistent with the increase in ethanol production (see Figure 2.1.3).

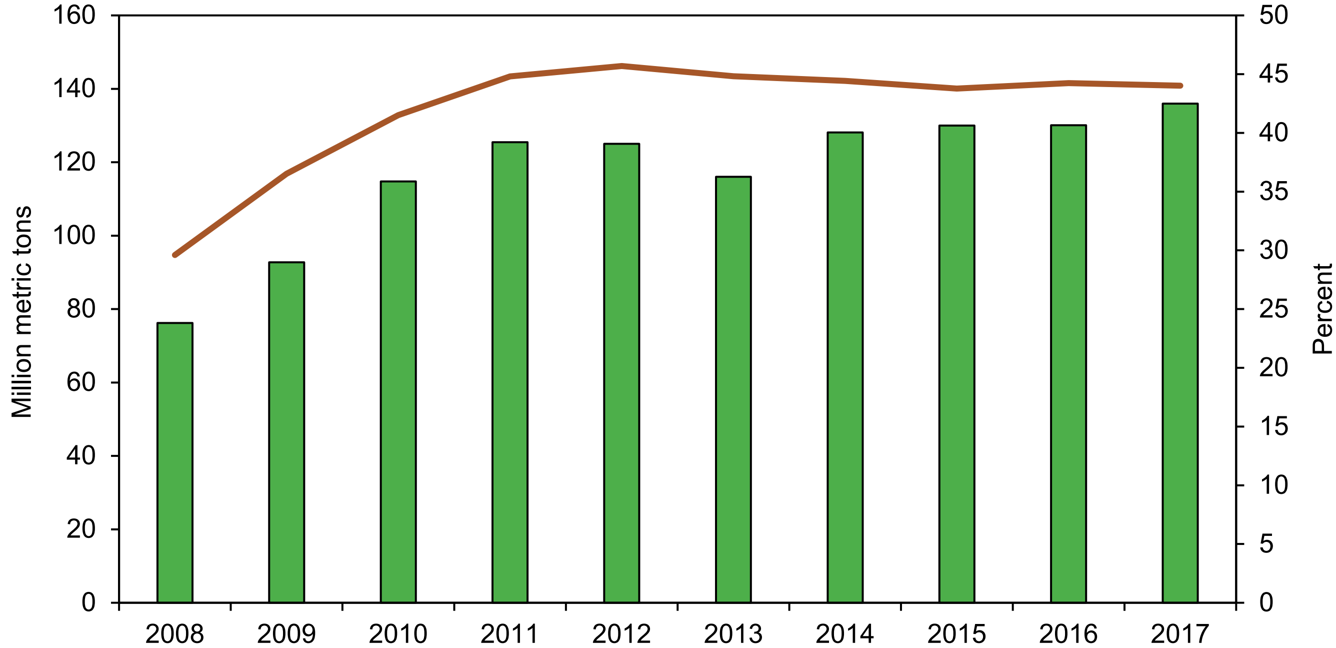

Figure 1.2.6. The bars represent the amount of corn processed into ethanol in United States from 2008 to 2017 (in million metric tons) (left axis) and the line the percentage of total corn consumption being devoted to ethanol from 2008 to 2017 (in percentage) (right axis) (3, 7).

The quantity of corn oil used as feedstock for biodiesel production increased considerably from 2009 to 2017; corn oil's share of biodiesel production grew from 3 percent in 2009 to 27 percent in 2017 (Figure 1.2.7 and Figure 2.2.3).

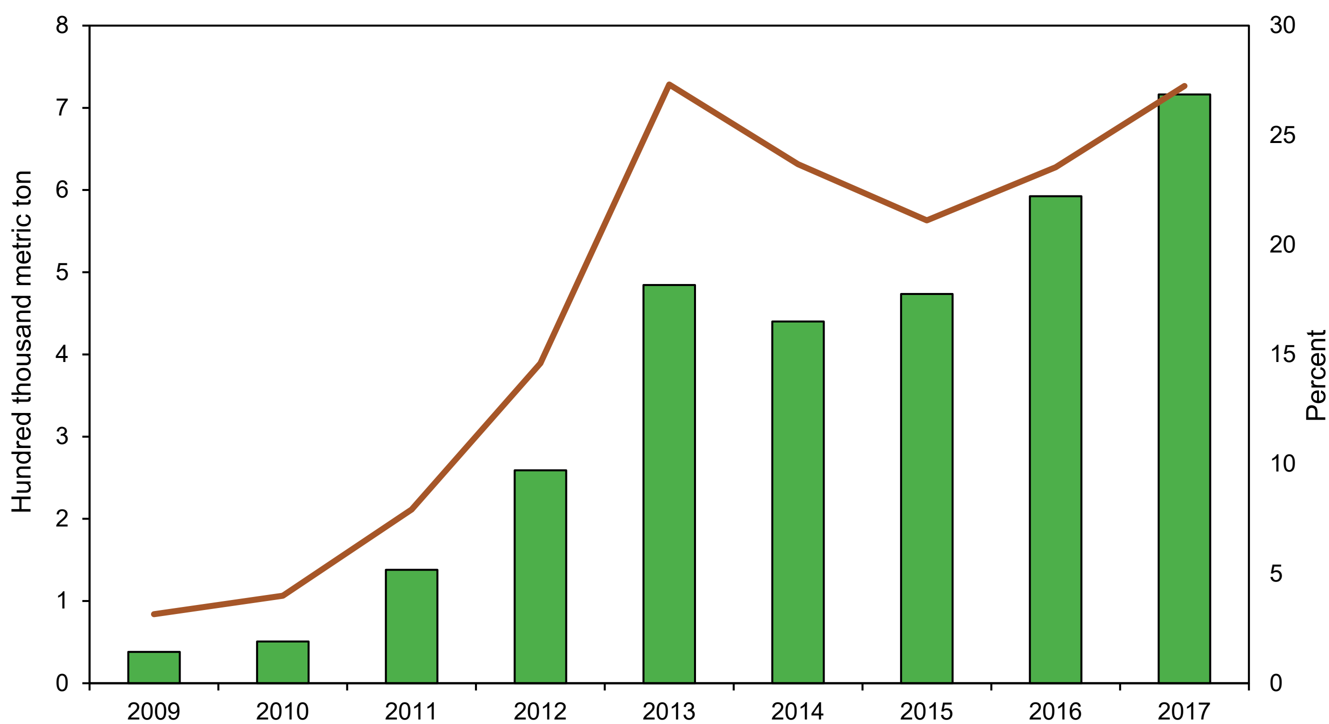

Figure 1.2.7. The bars represent the amount of corn oil processed into biodiesel in the United States from 2009 to 2017 (in hundred thousand metric tons) (left axis) and the line the percentage of total corn oil production being devoted to biodiesel from 2009 to 2017 (in percentage) (right axis) (7, 8).

Corn exports have varied since 2008 (Figure 1.2.8). Exports trended downward until 2012, when they reached a minimum of 21 million metric tons, and after that, the exports increased significantly with a volume of 55 million metric tons exports in 2017.

In 2017 Mexico was the largest market destination for corn, followed by Japan, with a total of 15 million metric tons and 12 million metric tons exported, respectively.

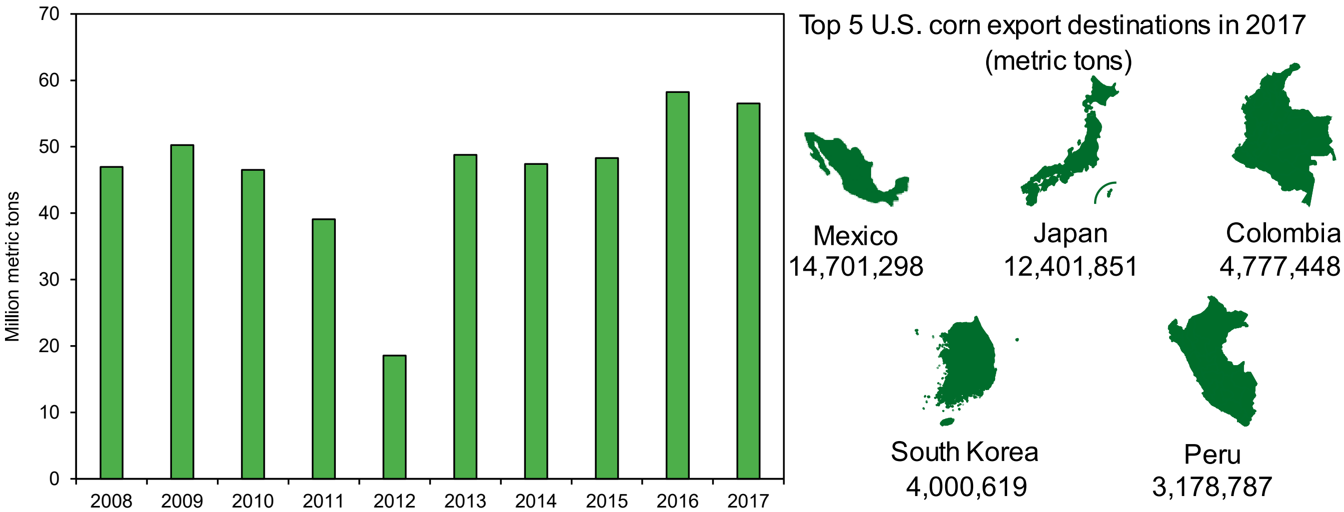

Figure 1.2.8. Exports of corn in the United States from 2008 to 2017 (in million metric tons) (3) and the top 5 United States export destinations in 2017 (in metric tons) (9).

Imports of corn are considerably lower than exports (Figure 1.2.9). In 2012 there is a peak in corn imports: 4.1 million metric tons compared with 1.3 million metric tons in 2017. Maximum corn imports therefore coincided with minimum United States corn production (Figure 1.2.3). Canada was the nation from which the United States imported the most corn in 2017. Most of the corn imported in the U.S. is organic corn and seed corn.

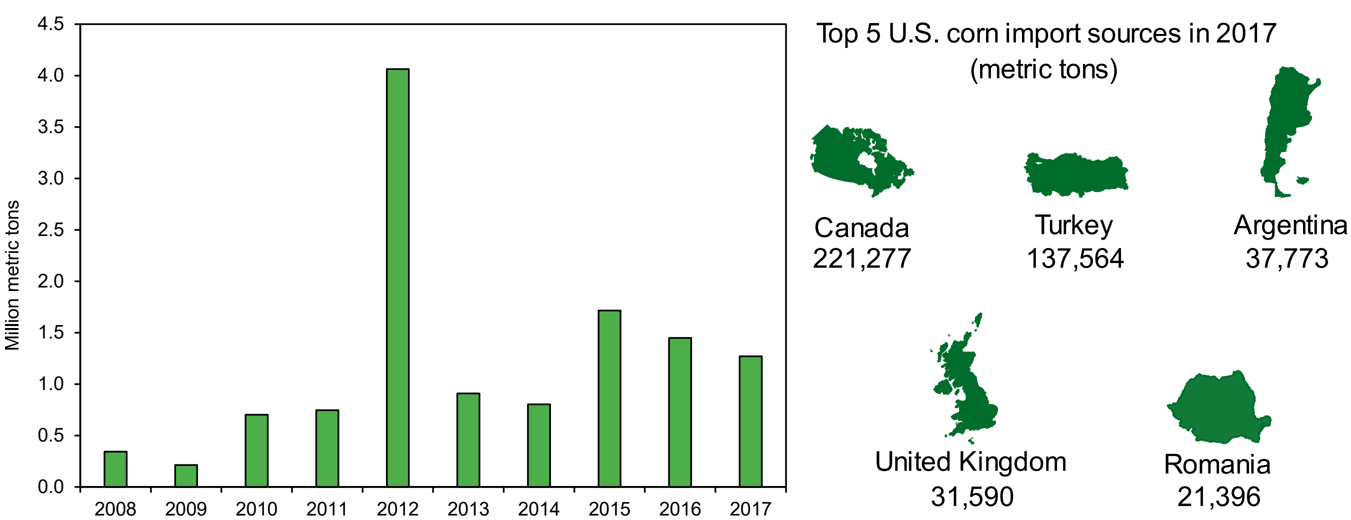

Figure 1.2.9. Imports of corn in the United States from 2008 to 2017 (in million metric tons) (3) and the top 5 United States import sources in 2017 (in metric tons) (9).

Economics

The farm price of corn decreased from 162 dollars per metric ton in 2008 to 134 dollars per metric ton in 2017 (Figure 1.2.10). Note that 2012 was the year with the highest corn price, which matches the year with the lowest production.

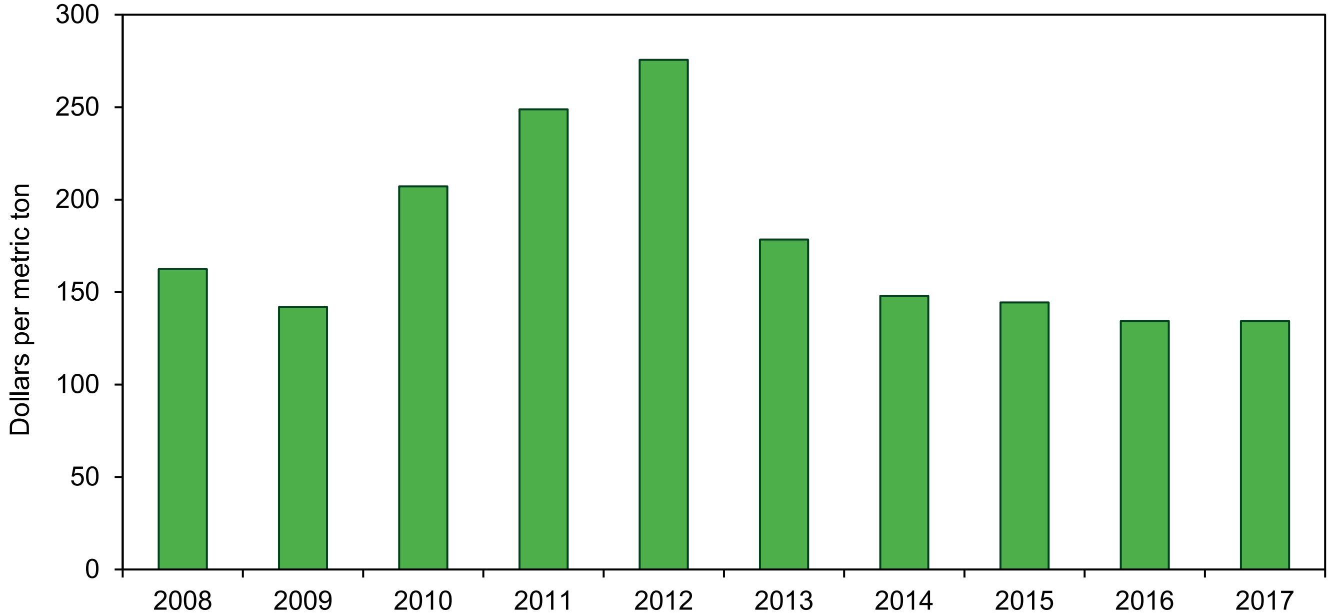

Figure 1.2.10. Farm price of corn from 2008 to 2017 (in dollars per metric ton) (10).

Most of the farmgate value of corn production accrues to counties in the Midwest, where production is concentrated. Iowa, Illinois, Nebraska, Minnesota and Indiana together accounted for 59 percent of the farm value of corn production in 2017 (see Figure 1.2.11 and Table 1.2.3 for more details). Note that these are also the states with highest acreage of corn and highest corn production.

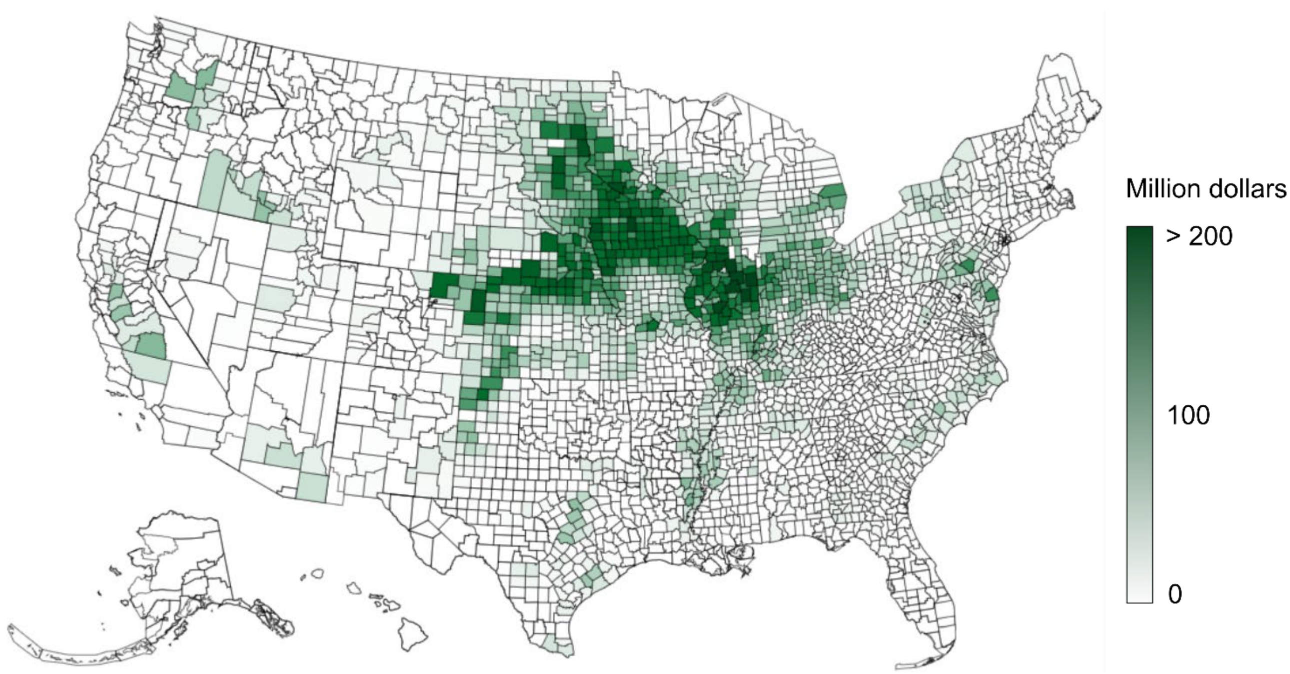

Figure 1.2.11. Total sales of corn in the United States by county in 2017 (in million dollars) (11).

State	Million dollars	Percentage
Iowa	8,463	16.6
Illinois	7,392	14.5
Nebraska	5,598	11.0
Minnesota	4,762	9.4
Indiana	3,353	6.9

Table 1.2.3. 5 states with highest sales of corn in the United States in 2017 (in million dollars) (11).

The value of corn used for ethanol grew rapidly from 2008 through 2012, peaking at 34 billion dollars in 2012. After that, the economic value of corn for ethanol decreased almost 50 percent to 18 billion dollars in 2017 (Figure 1.2.12).

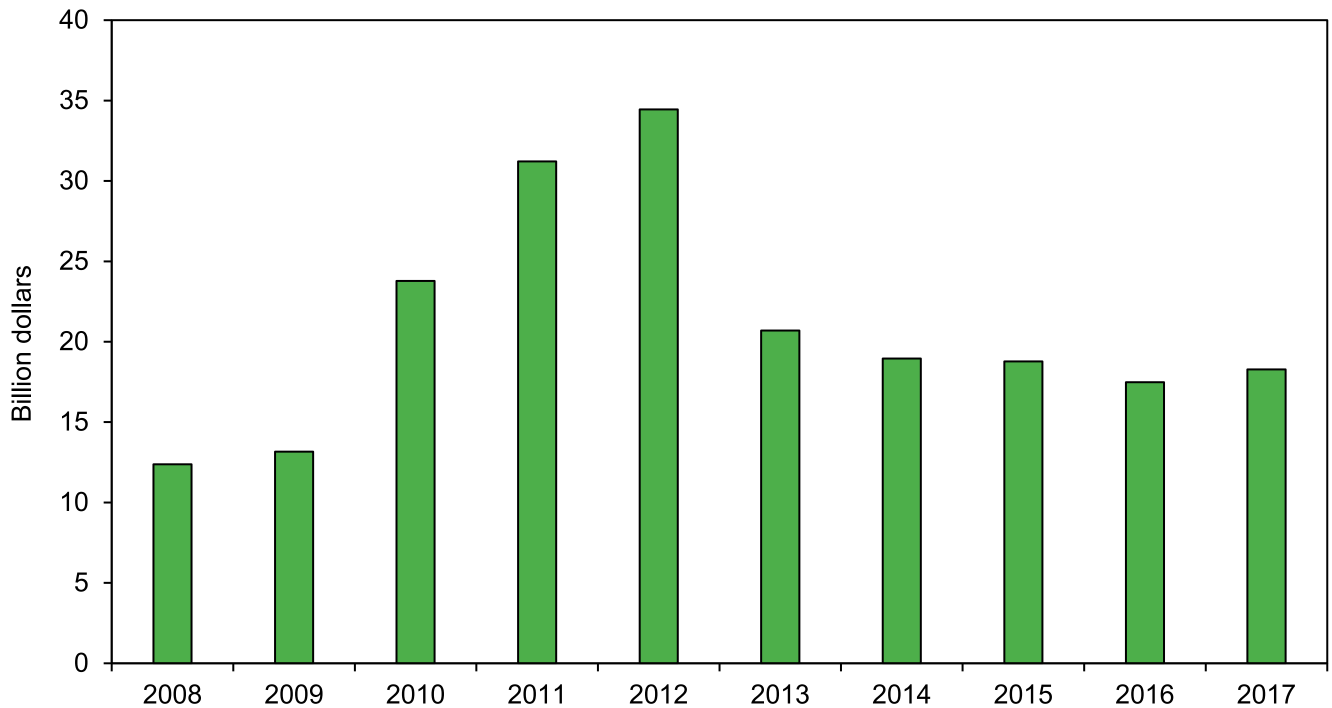

Figure 1.2.12. Economic value of corn being used for ethanol from 2008 to 2017 (in billion dollars) (7, 10).

The economic value of corn oil used for biodiesel production increased rapidly, from 28 million dollars in 2009 to 591 million dollars in 2017 (Figure 1.2.13).

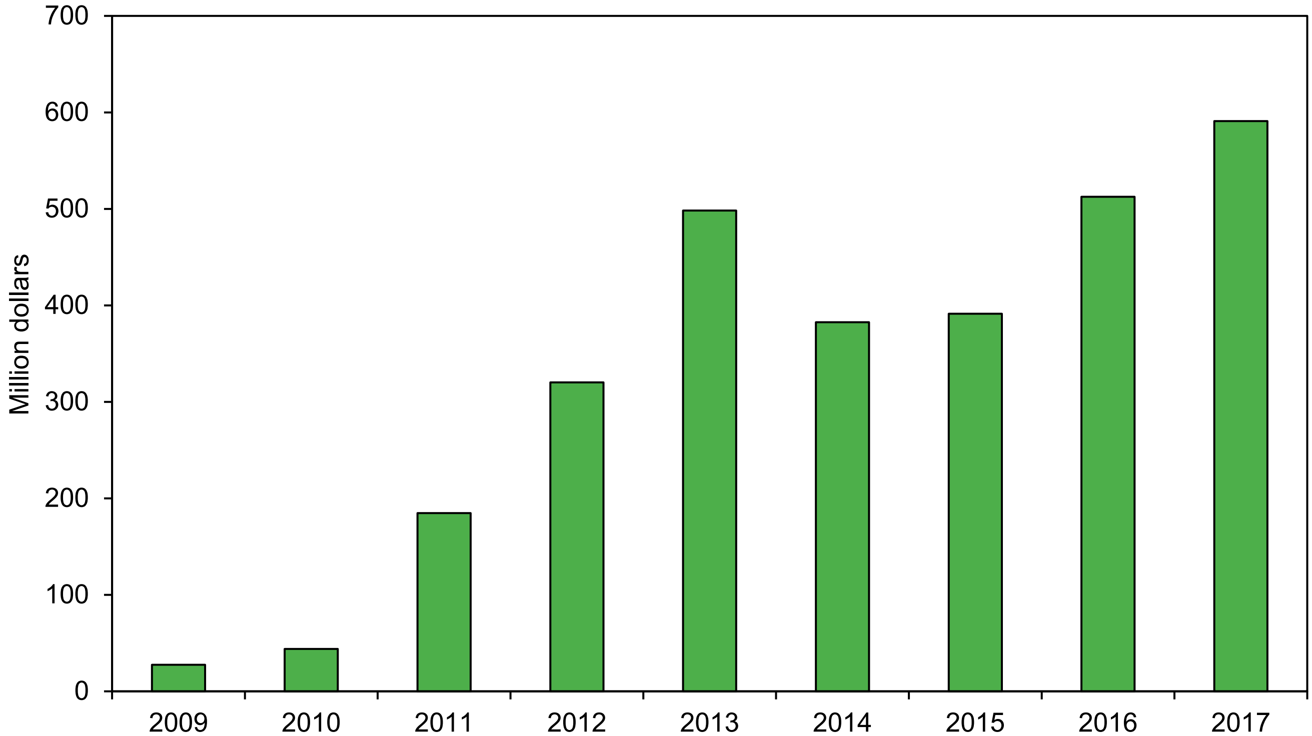

Figure 1.2.13. Economic value of corn oil being used for biodiesel from 2009 to 2017 (in million dollars) (8, 12).

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1.3. **Wheat**

Photo 4. (10).

Wheat is the second largest starch crop. Its production is concentrated in the Midwestern United States.

The production of wheat is two times higher than the consumption, and this has remained almost constant from 2008 to 2017.

The United States is a net exporter of wheat, with Mexico being the largest market destination in 2017.

The earnings from wheat are strongly correlated with the farm price, so the years with the highest price of wheat are those with the highest earnings.

In this section these trends are further analyzed according to three main categories, (1) land use, (2) production, and (3) economics.

Photo 5. (11).

Wheat occupies the second largest amount of acreage of the starch crops from 2008 to 2017. Acreage planted with wheat has dropped by 28 percent from 2008 to 2017, from 64 million acres in 2008 to 46 million acres in 2017 (Figure 1.3.1).

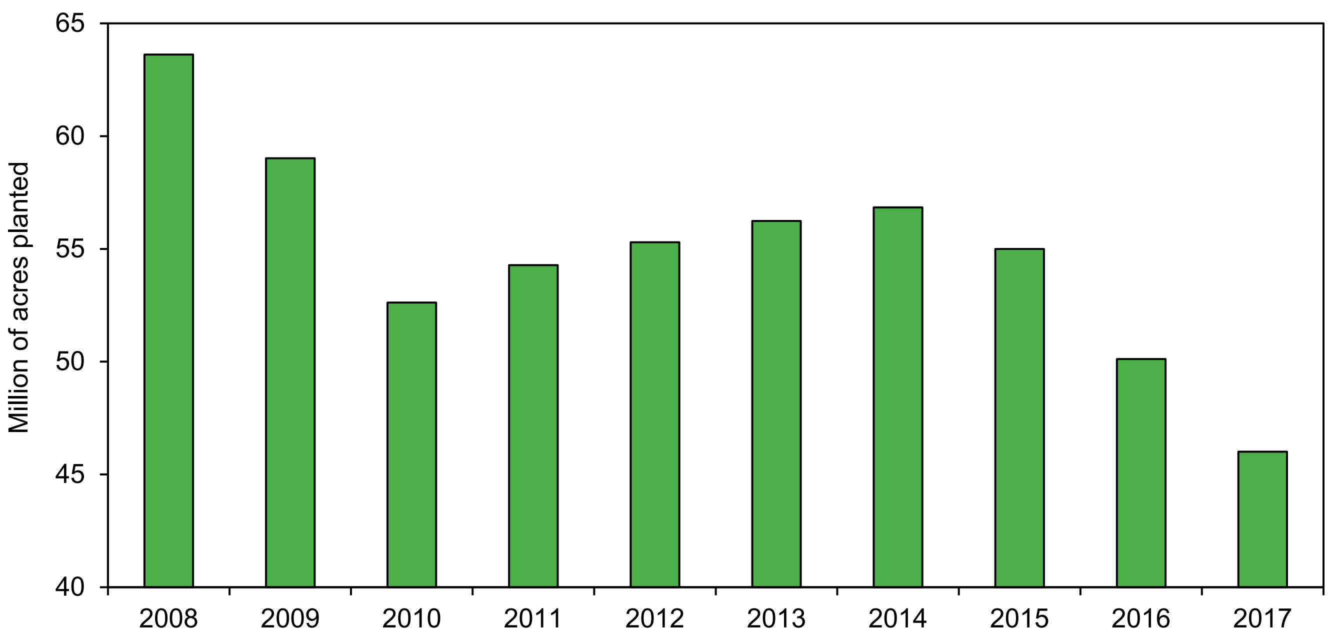

Figure 1.3.1. Acreage planted with wheat in the United States from 2008 to 2017 (in million acres) (1).

Most U.S. wheat is planted in the northwest and southwest, with 62 percent of total acreage planted concentrated in 5 states. Kansas and North Dakota are the top 2 states by wheat acres planted, closely followed by Montana, Texas and Oklahoma. (Figure 1.3.2 and Table 1.3.1)

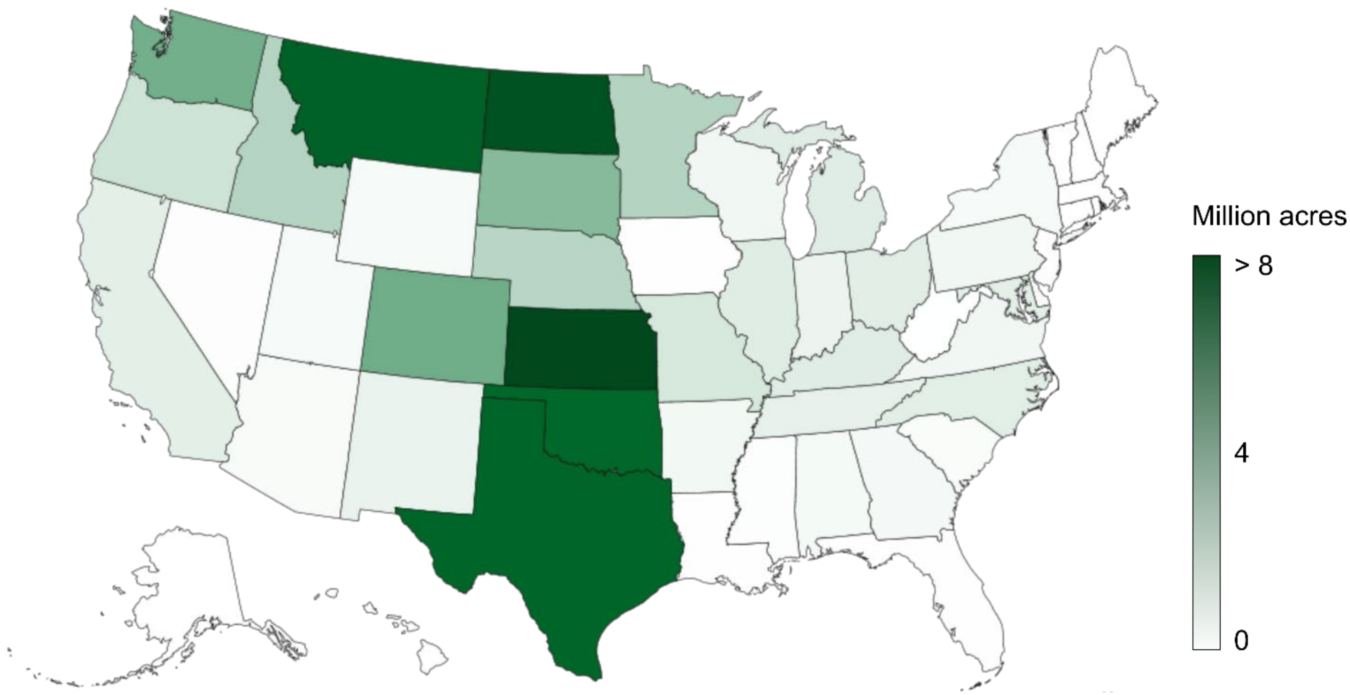

Figure 1.3.2. Total acreage of wheat in the United States by state in 2017 (in million acres) (2).

State	Million Acres	Percentage
Kansas	7.6	16.5
North Dakota	6.7	14.5
Montana	5.1	11.2
Texas	4.7	10.2
Oklahoma	4.5	9.8

Table 1.3.1. 5 states with largest acreage of wheat in the United States in 2017 (in million acres) (2).

Production

Similar to corn, the production of wheat is almost two times higher than the consumption, so the United States is a net exporter of wheat.

U.S. wheat production and consumption did not exhibit a clear trend from 2008 through 2017. Production and consumption in 2017, however, were 21 million metric tons and 5 million metric tons below their respective levels in 2008 (Figure 1.3.3).

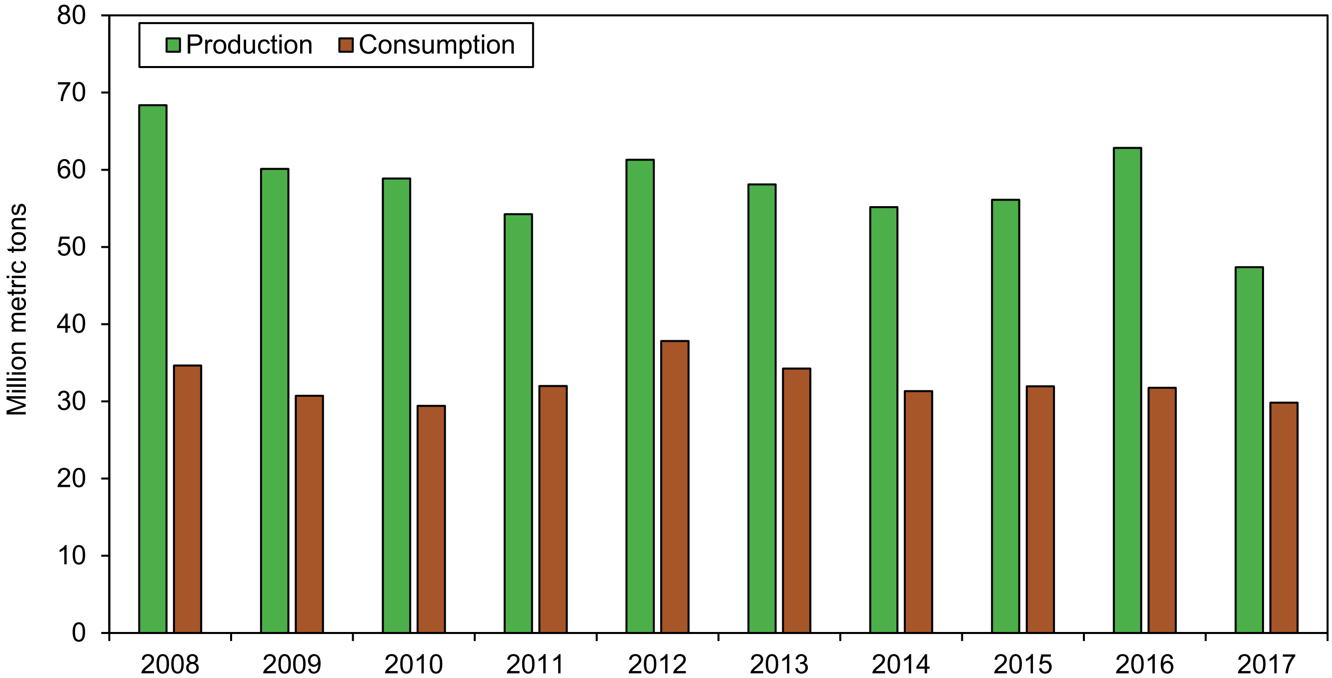

Figure 1.3.3. Total wheat production versus total wheat consumption in the United States from 2008 to 2017 (in million metric tons) (3, 4).

The value of wheat production from 2008 to 2017 is presented in Figure 1.3.4. As was the case with corn production, the earnings from wheat are highly correlated with the farm price (Figure 1.3.8). The years 2008 and 2012 had the highest wheat prices and greatest earnings from wheat.

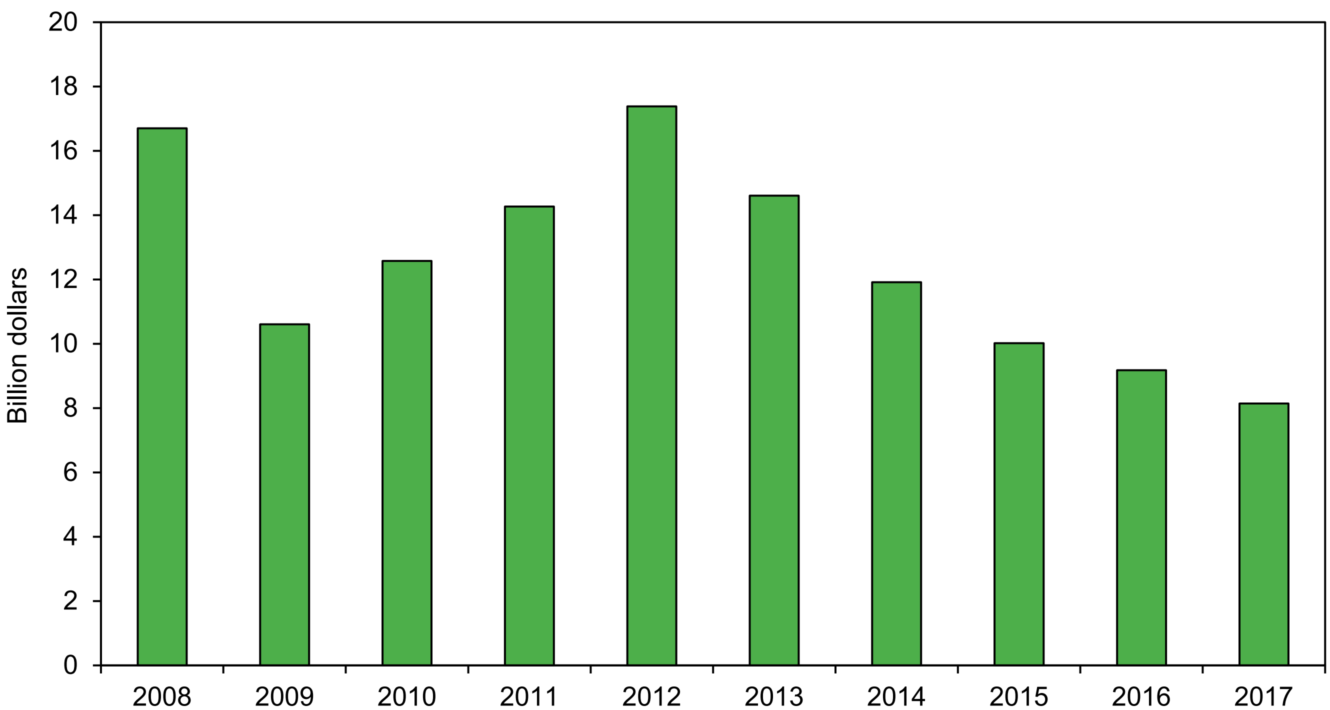

Figure 1.3.4. Production of wheat in the United States from 2008 to 2017 (in billion dollars) (5).

The production of wheat is highly correlated with the acreage planted; therefore, the geographical information and trends of wheat production are the same as the acreage trends (Figure 1.3.5 and Table 1.3.2).

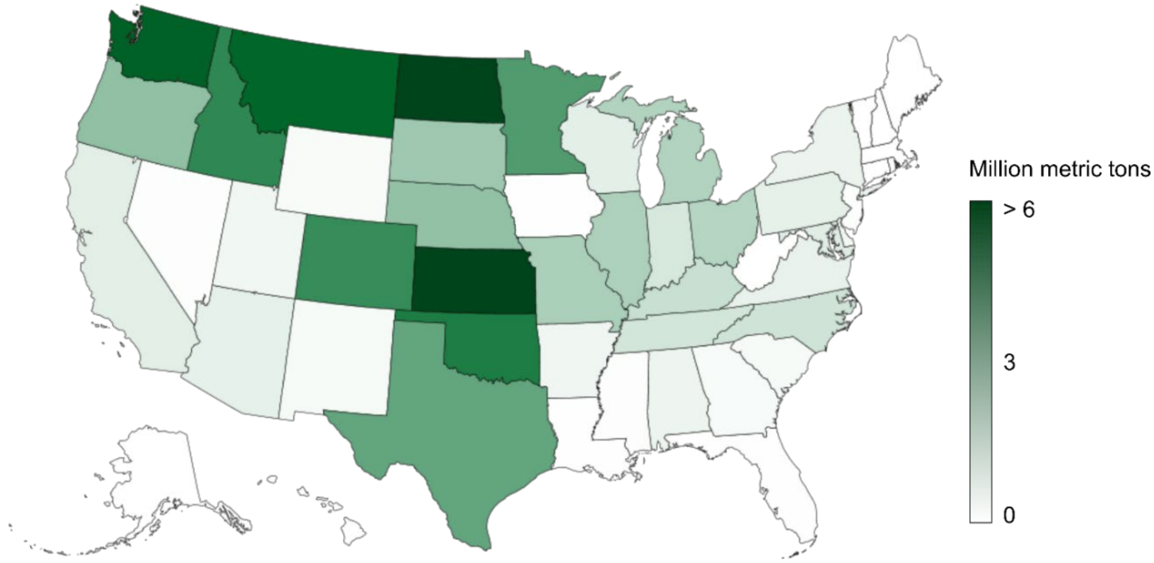

Figure 1.3.5. Total production of wheat in the United States by state in 2017 (in million metric tons) (6).

State	Million metric tons	Percentage
Kansas	9.0	19.2
North Dakota	6.4	13.7
Washington	3.8	8.2
Montana	3.4	7.3
Oklahoma	2.7	5.7

Table 1.3.2. 5 states with highest production of wheat in the United States in 2017 (in million metric tons) (6).

Wheat exports did not exhibit a clear trend between 2008 and 2017. Exports in 2017 were 24 million metric tons. Mexico is the largest market destination for wheat, followed by Japan, with totals of 3.7 million metric tons and 3 million metric tons imported from the U.S., respectively (Figure 1.3.6).

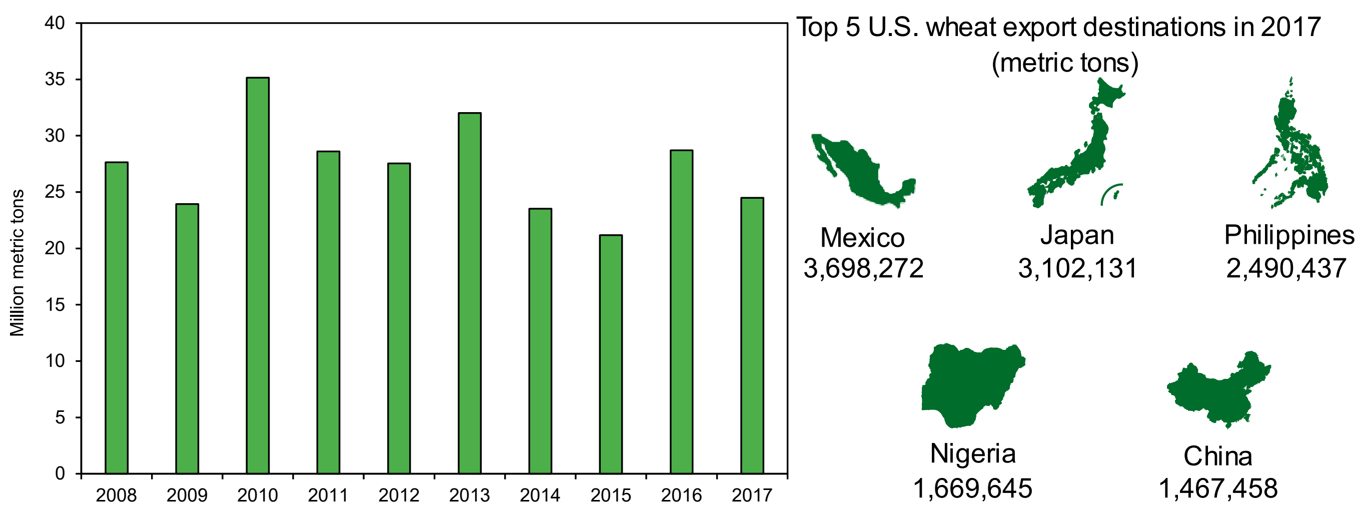

Figure 1.3.6. Exports of wheat in the United States from 2008 to 2017 (in million metric tons) (3) and top 5 United States export destinations in 2017 (in metric tons) (7).

Imports of wheat are considerably lower than exports, with a smaller variance. In particular, wheat imports slightly increased from 3.5 million metric tons in 2008 to 4.2 million metric tons in 2017 (Figure 1.3.7).

The United States imports more wheat from Canada in 2017, well ahead of Argentina, the second largest source of imports.

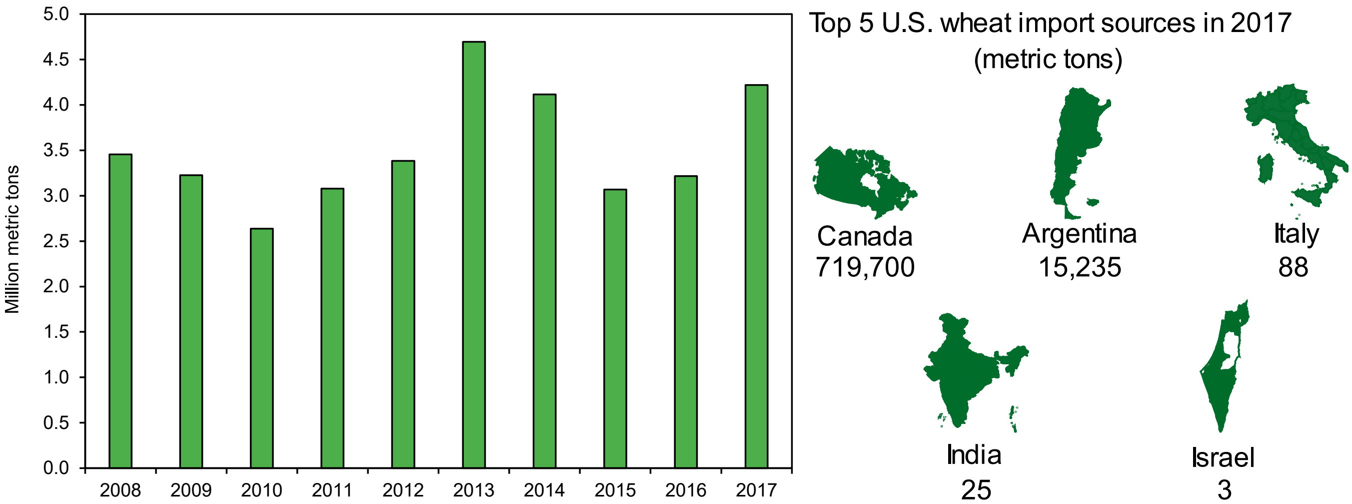

Figure 1.3.7. Imports of wheat in the United States from 2008 to 2017 (in million metric tons) (3) and top 5 United States import sources in 2017 (in metric tons) (7).

Economics

In 2012 the price of wheat reached its highest value of 288 dollars per metric ton. After that, it decreased to170 dollars per metric ton by 2017 (Figure 1.3.8).

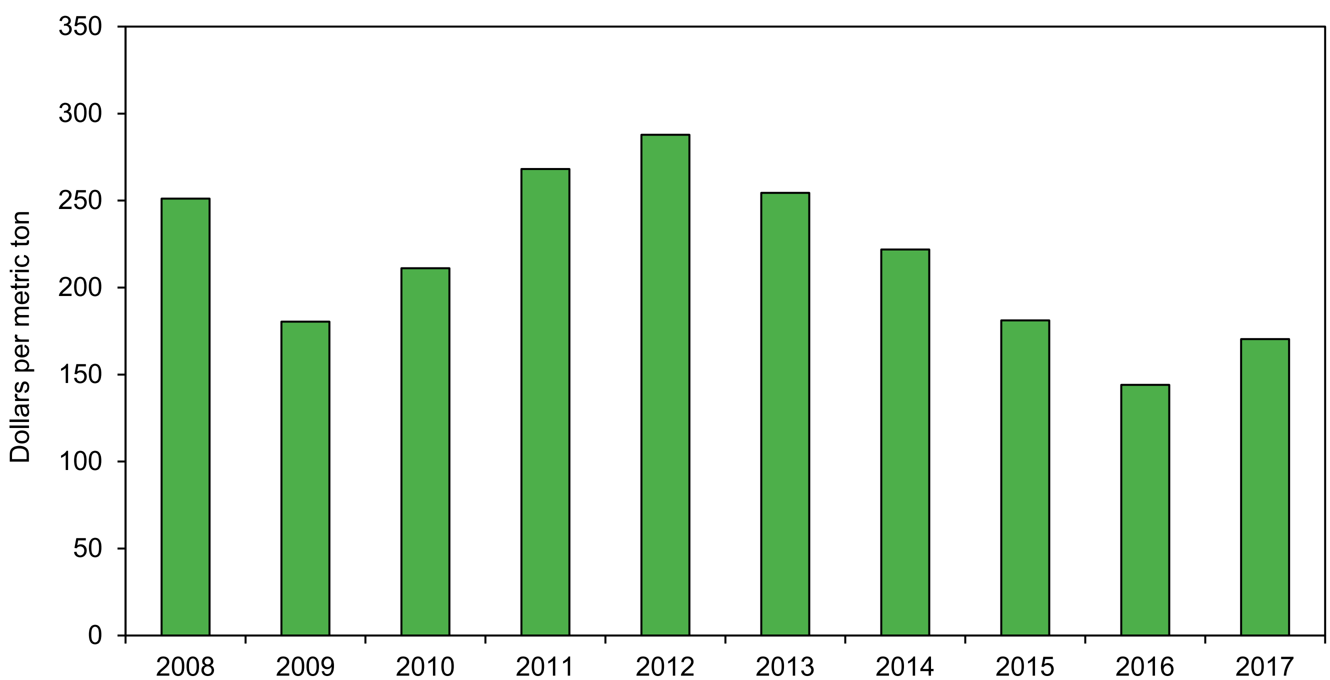

Figure 1.3.8. Farm price of wheat from 2008 to 2017 (in dollars per metric ton) (8).

Most of the farm value of wheat production accrues to the Midwest and west, with 5 states concentrating 56 percent of total sales. More wheat is sold in North Dakota and Kansas, followed by Montana, Washington and Minnesota (Figure 1.3.9 and Table 1.3.3).

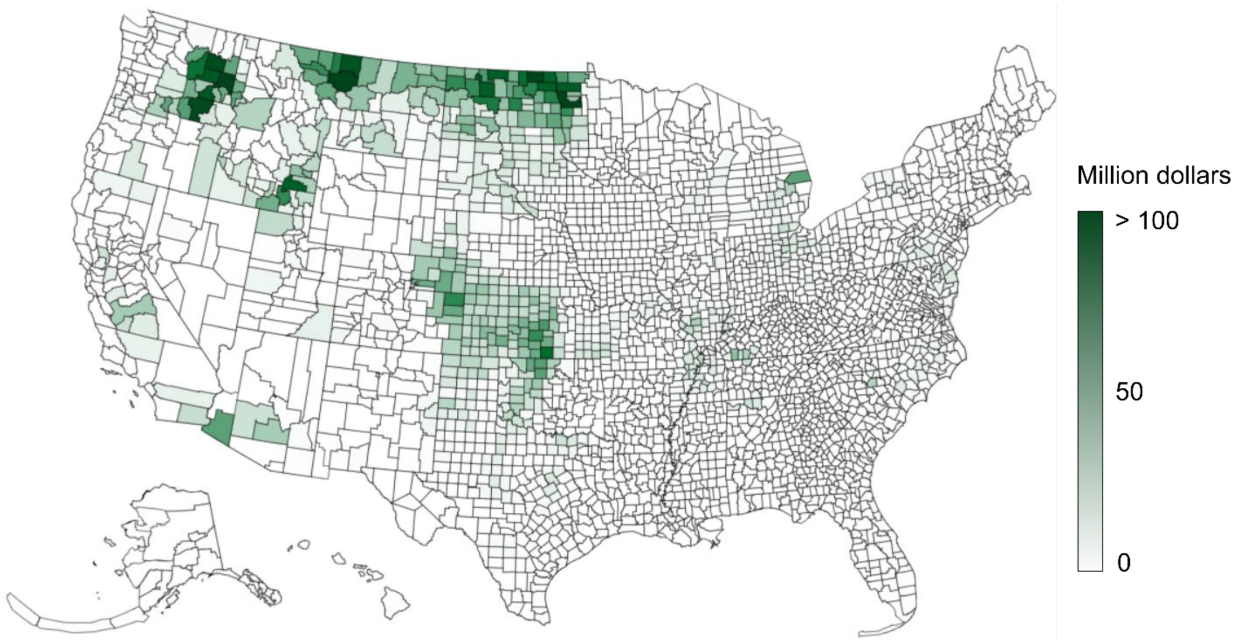

Figure 1.3.9. Total sales of wheat in the United States by county in 2017 (in million dollars) (9).

State	Million dollars	Percentage
North Dakota	1,348	17.8
Kansas	1,176	15.5
Montana	692	9.1
Washington	633	8.4
Minnesota	430	5.7

Table 1.3.3. 5 states with highest sales of wheat in the United States in 2017 (in million dollars) (9).

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1.4. **Barley**

Photo 6. (11).

Barley is a cereal plant of the grass family, and it is the fourth largest grain crop in the United States after corn, wheat and sorghum. Barley is commonly used as animal fodder, as a source of malt for beer production, and as a component of health products (1).

The number of acres planted of barley in the United States is very small and concentrated in three states: Montana, Idaho and North Dakota.

This section shows that the production and consumption patterns of barley are very similar, but much smaller in comparison with other crops.

The trade of barley with international markets is on the order of a few hundred thousand metric tons annually. In contrast to other crops, the imports of barley are higher than the exports, with Canada being the most important import source.

Since the production of barley is so small, the earnings from barley are also small compared to corn or wheat.

In this section these trends are further analyzed according to three main categories, (1) land use, (2) production, and (3) economics.

Photo 7. (12).

The number of acres planted with barley is small in comparison with corn or wheat acreage, which are in 2017 45 and 23 times greater, respectively. U.S. planting seems to follow a multiyear cycle. Acreage planted with barley in 2017 was 2 million acres; the high was 4 million acres in 2008 (Figure 1.4.1).

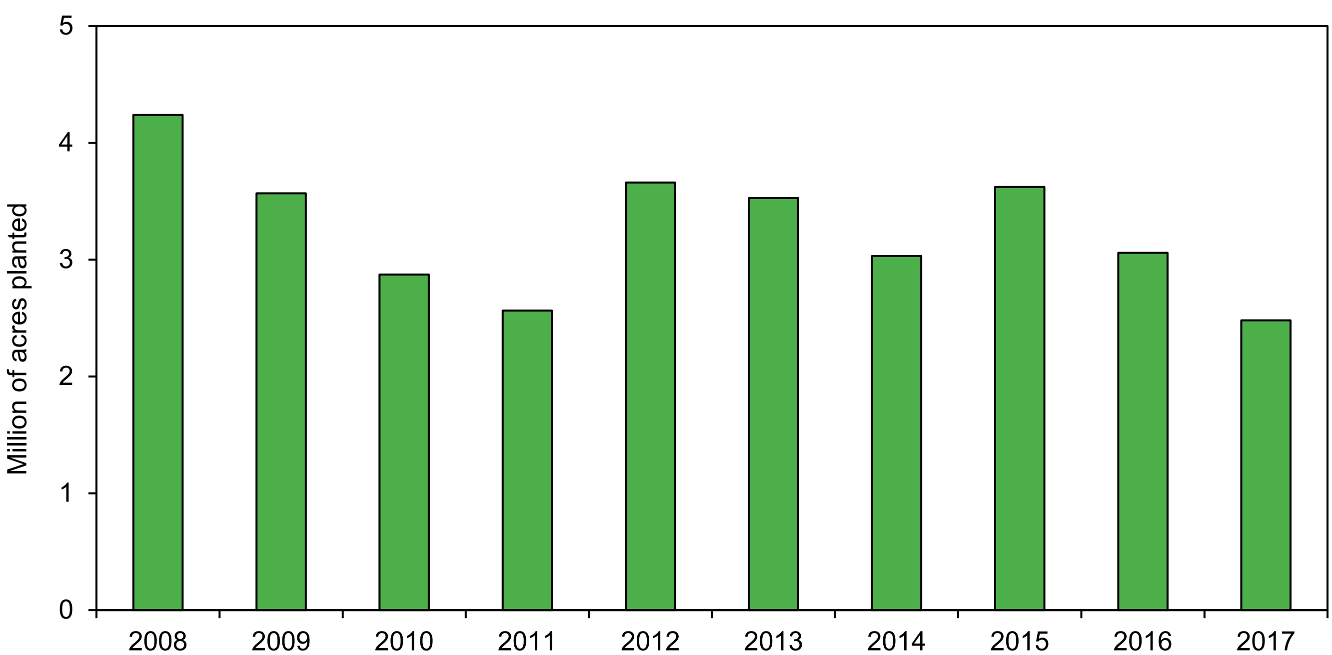

Figure 1.4.1. Acreage of barley planted in the United States from 2008 to 2017 (in million acres) (2).

The amount of barley planted in the United States in 2017 is very small, and it is concentrated. Montana, Idaho and North Dakota plant 73 percent of U.S. barley acreage (Figure 1.4.2 and Table 1.4.1).

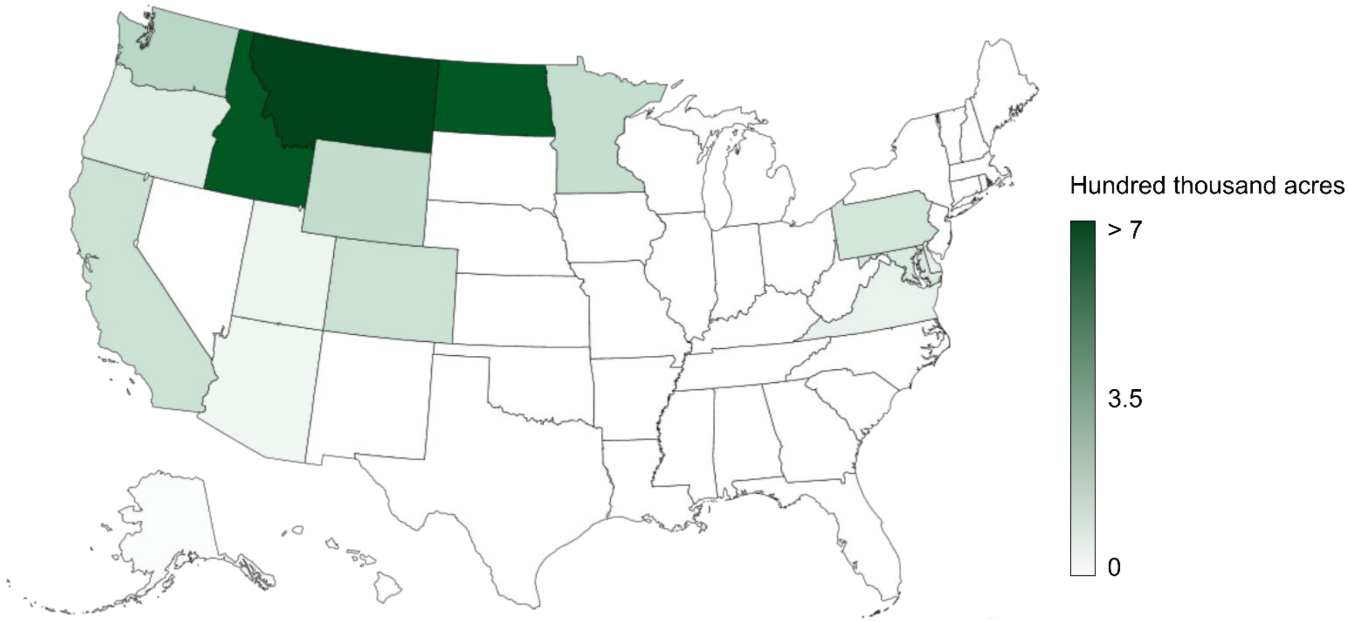

Figure 1.4.2. Total acreage of barley in the United States by state in 2017 (in hundred thousand acres) (3).

State	Hundred Thousand Acres	Percentage
Montana	7.7	31.0
Idaho	5.3	21.3
North Dakota	5.2	20.9
Washington	1.0	3.8
Wyoming	0.8	3.3

Table 1.4.1. 5 states with largest acreage of barley in the United States in 2017 (in hundred thousand acres) (3).

Production

Barley production and consumption are very small in comparison with other starch crops such as corn and wheat. In contrast to these other crops, U.S. production of barley may not meet U.S. demand for barley, which means that the United States is a net importer of barley. Note that the production and consumption of barley do not exhibit a clear trend from 2007 through 2017 (Figure 1.4.3).

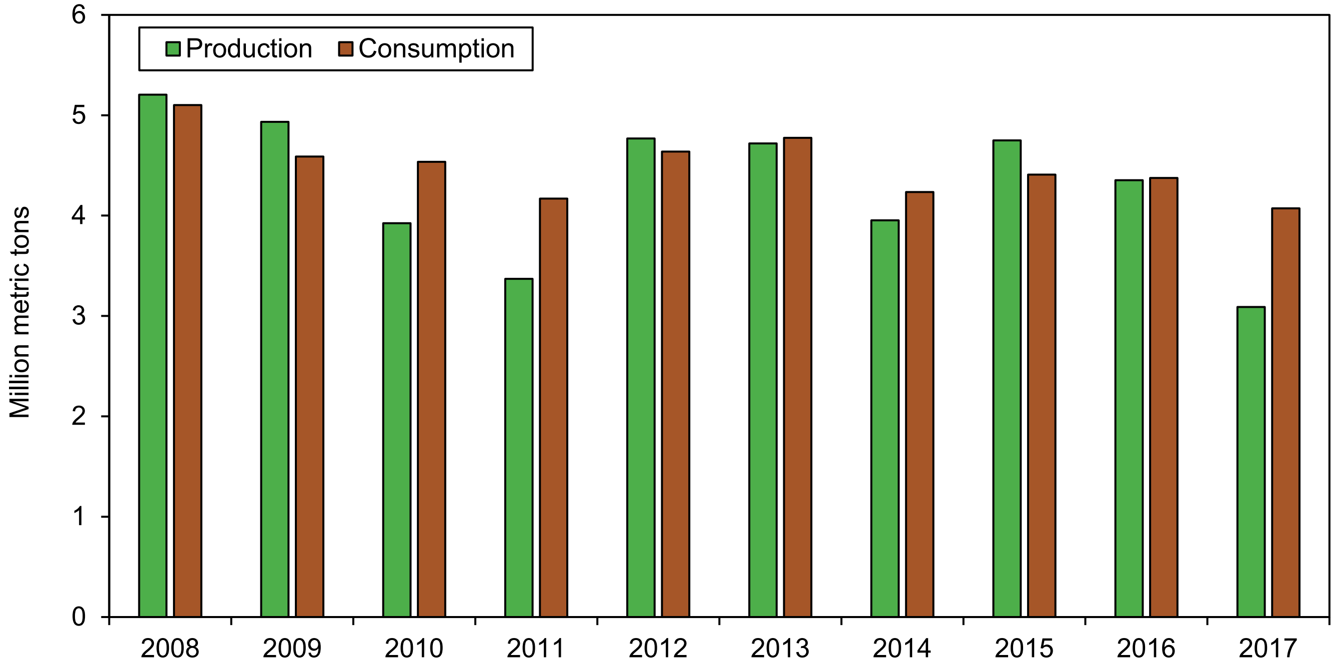

Figure 1.4.3. Total barley production versus total barley consumption in the United States from 2008 to 2017 (in million metric tons) (4, 5).

The value of barley production from 2008 to 2017 is presented in Figure 1.4.4. As with the other starch crops, farm revenue from barley is highly correlated with the farm price (Figure 1.4.8). Barley prices were highest in 2012, so that was also the peak revenue year for barley producers. Revenue from barley production in 2017 was more than 50 percent below its peak in 2012, falling from 1.4 billion dollars in 2012 to 600 million dollars in 2017.

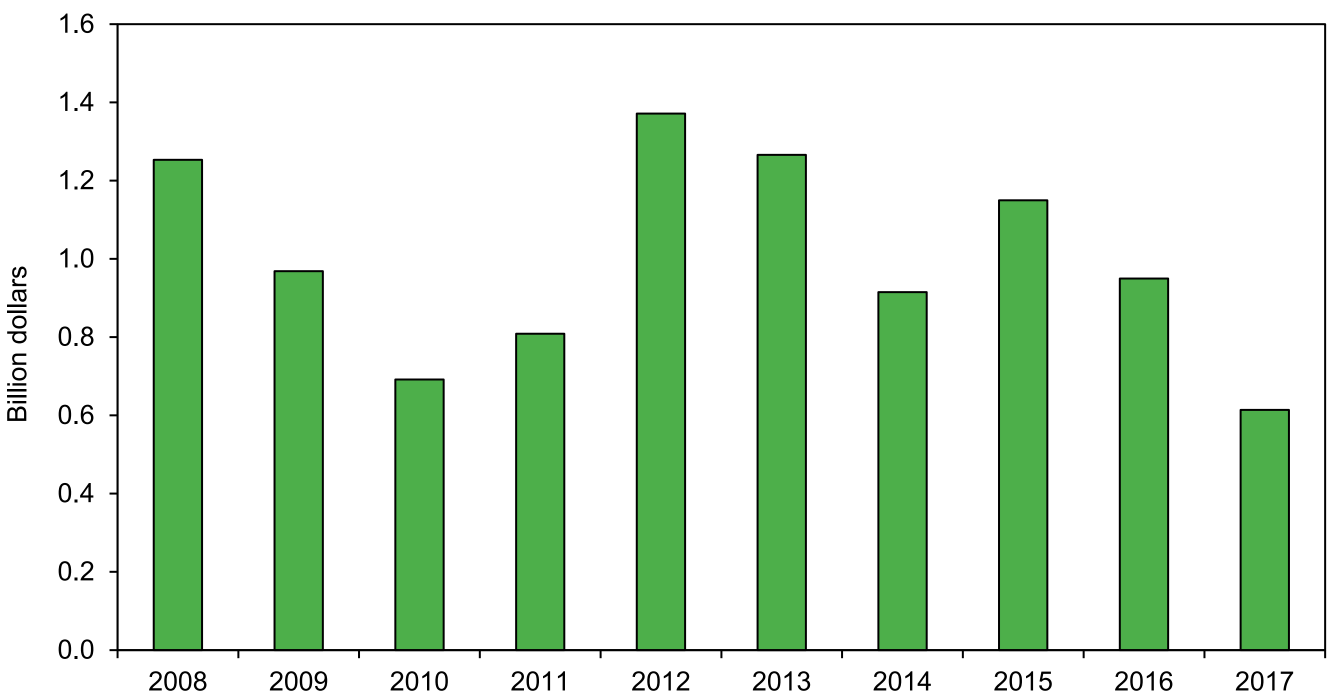

Figure 1.4.4. Production of barley in the United States from 2008 to 2017 (in billion dollars) (6).

Barley production is highly correlated with the acreage planted; therefore, the geographical information and trends of barley production are the same as the acreage trends (Figure 1.4.5 and Table 1.4.2).

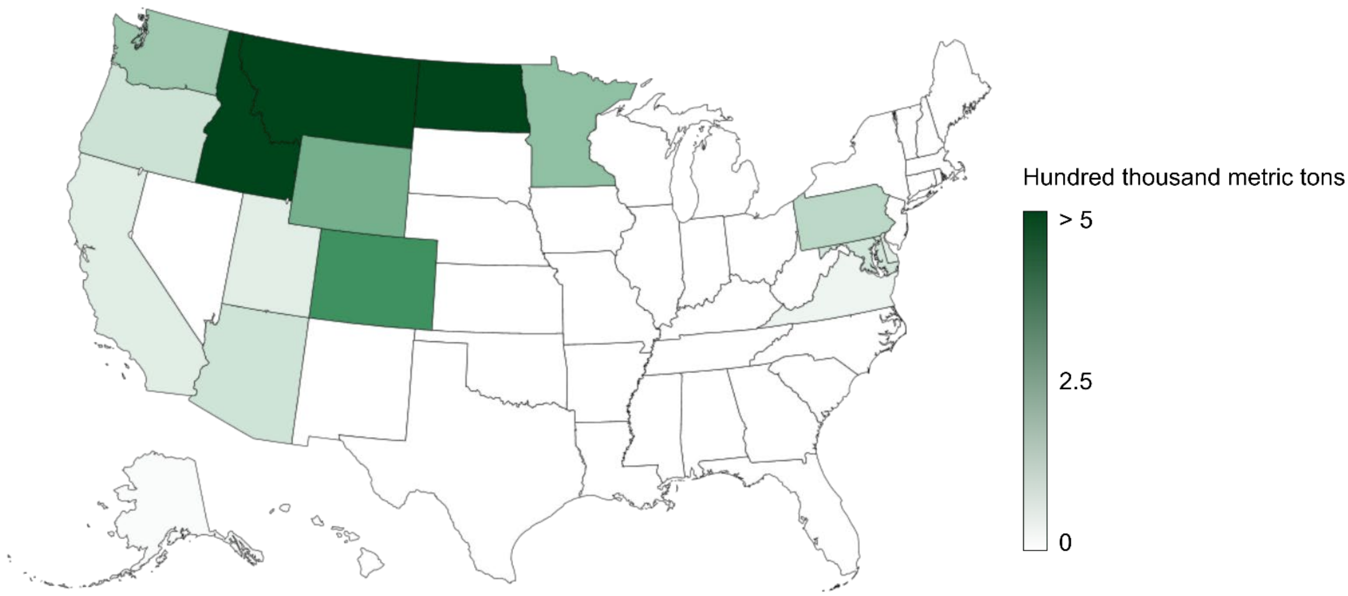

Figure 1.4.5. Total production of barley in the United States by state in 2017 (in hundred thousand metric tons) (7).

State	Million metric tons	Percentage
Idaho	1.0	34.1
Montana	0.6	20.3
North Dakota	0.5	17.5
Colorado	0.2	6.3
Wyoming	0.1	4.5

Table 1.4.2. 5 states with highest production of barley in the United States in 2017 (in million metric tons) (7).

Exports of barley were a little more than 130,000 metric tons in 2017. Canada is the largest export destination for barley, followed by Japan (Figure 1.4.6).

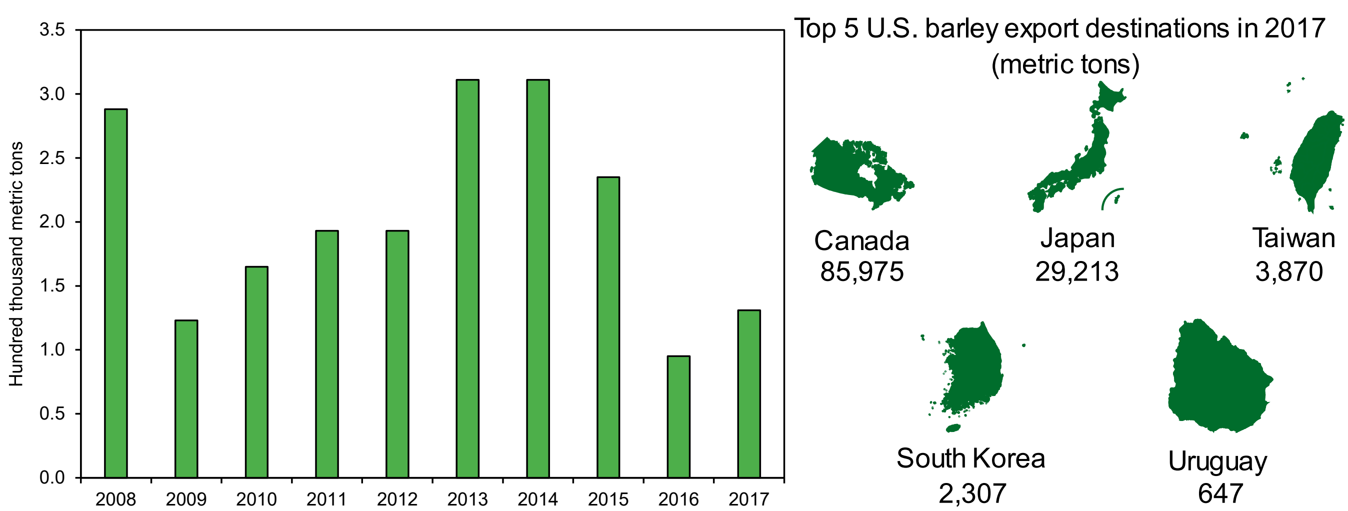

Figure 1.4.6. Exports of barley in the United States from 2008 to 2017 (in hundred thousand metric tons) (4) and top 5 United States export destinations in 2017 (in metric tons) (8).

Imports of barley are also very small; they were 218,000 metric tons in 2017. Note that imports of barley are higher than exports, which is consistent with the production-consumption patterns analyzed in Figure 1.4.3. Canada is the country from which the United States imported the most barley in 2017 (Figure 1.4.7).

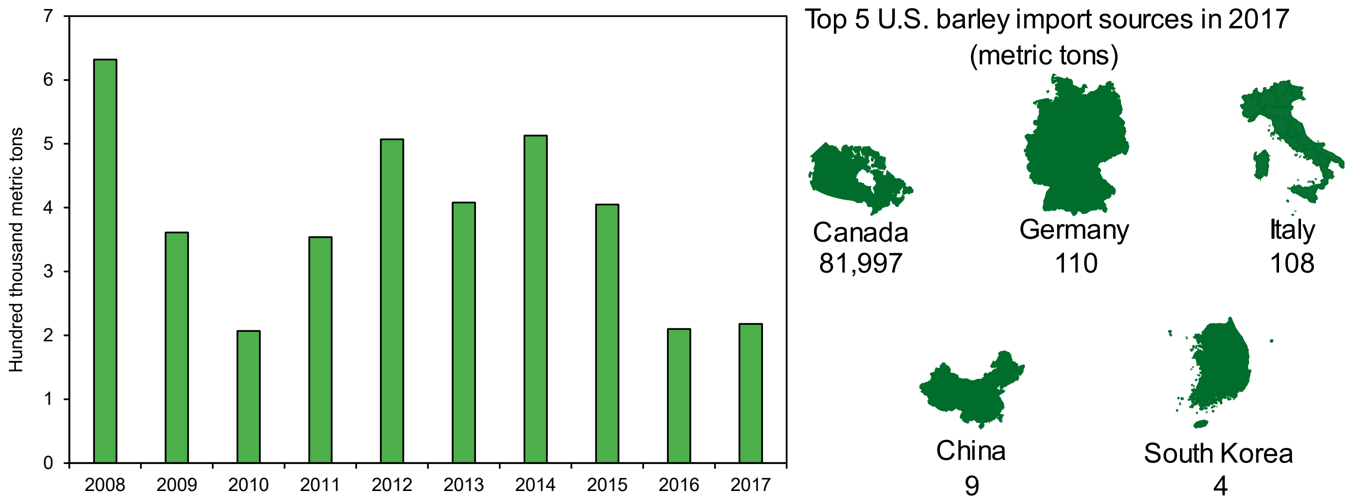

Figure 1.4.7. Imports of barley in the United States from 2008 to 2017 (in hundred thousand metric tons) (4) and top 5 United States import sources in 2017 (in metric tons) (8).

Economics

Barley is one of the highest-priced crops produced in the U.S. The farm price peaked at 306 dollars per metric ton in 2012. The price in 2017, at 212 dollars per metric ton, was 30 percent lower relative to 2012 (Figure 1.4.8).

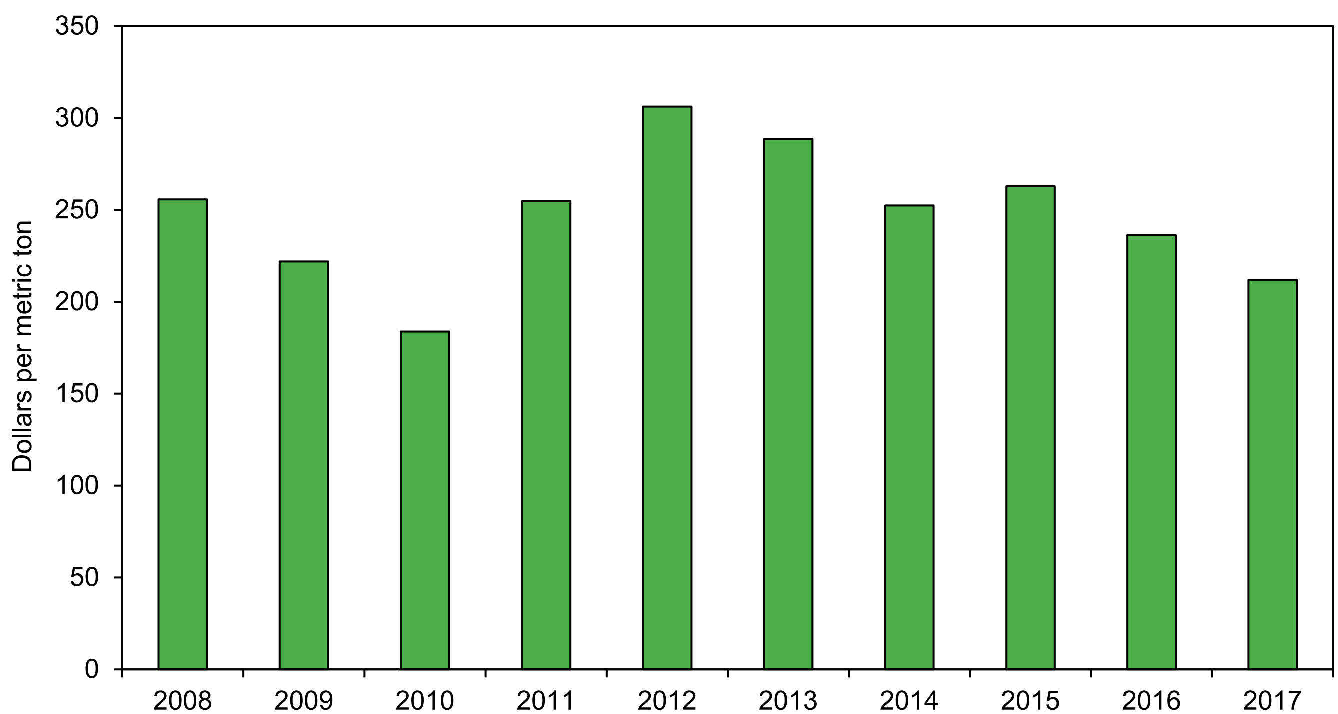

Figure 1.4.8. Farm price of barley crops from 2008 to 2017 (in dollars per metric ton) (9).

Most of the farm value of barley production accrues to the western United States, with three states, Idaho, Montana and North Dakota concentrating 74 percent of total sales (see Figure 1.4.5 and Table 1.4.2 for more details). Note that these are also the states with highest acreage and production of barley.

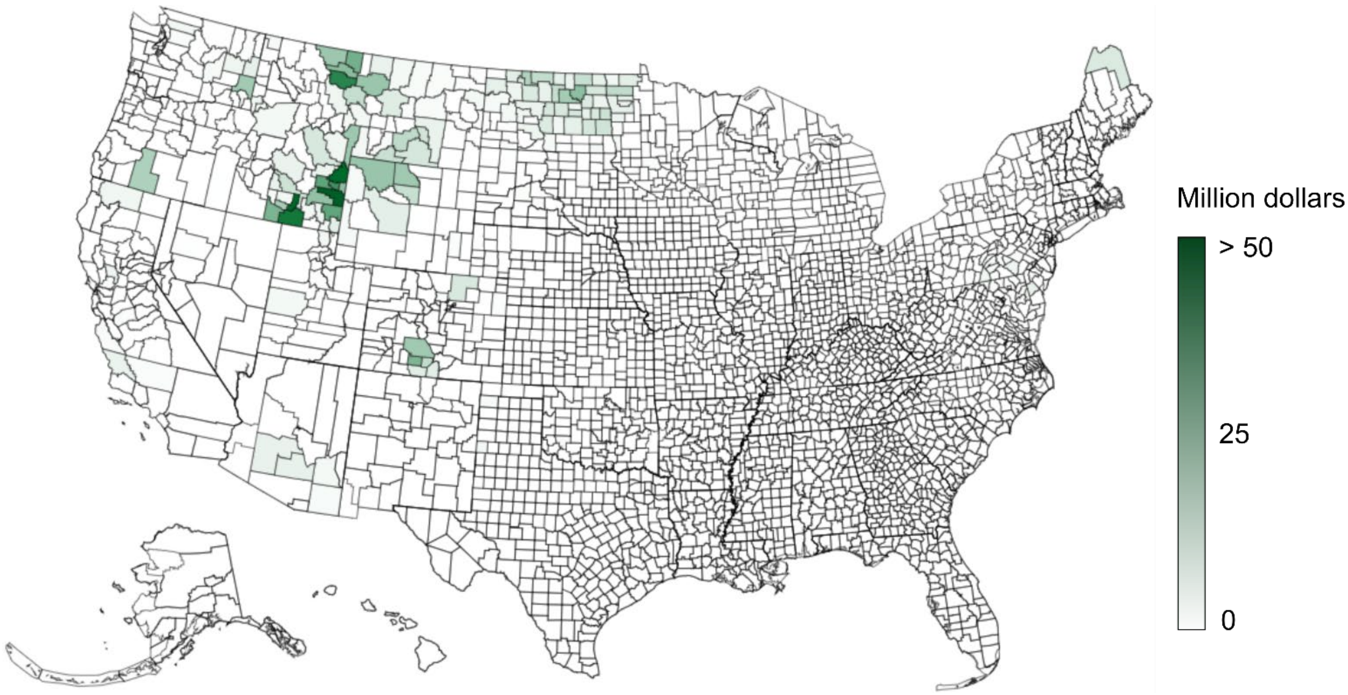

Figure 1.4.9. Total sales of barley at the farm level in the United States by county in 2017 (in million dollars) (10).

State	Million dollars	Percentage
Idaho	225	35.5
Montana	124	19.5
North Dakota	122	19.3
Colorado	38	6.1
Wyoming	29	4.6

Table 1.4.3. 5 states with highest sales of barley at the farm level in the United States in 2017 (in million dollars) (10).

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1.5. Sorghum

Photo 8. (11).

Sorghum is a cereal plant of the grass family and it is the third largest grain crop in the United States after corn and wheat. Sorghum, which is a gluten free grain, is commonly used for human consumption (i.e., flatbreads, cakes, sweetener), as animal fodder, to produce alcoholic beverages, and to produce fuel ethanol (1).

The number of acres planted with sorghum in the United States is very small and very concentrated. Almost half of the United States sorghum acreage is planted in Kansas.

Production of sorghum is higher than consumption, and it has varied significantly between 2008 and 2017.

The variability in the production is reflected in the exports, which do not show a clear trend from 2008 to 2017. The imports of sorghum are small.

Despite the variability in production, farm revenue from sorghum remained nearly constant from 2008 to 2017.

In this section these trends are further analyzed according to three main categories, (1) land use, (2) production, and (3) economics.

Photo 9. (12).

Like barley, the number of acres of sorghum planted are small in comparison with other crops such as corn and wheat. Like barley, sorghum acreage follows a cyclical pattern. The last high point was 8 million acres planted in 2015; planting in 2017 was 6 million acres (Figure 1.5.1).

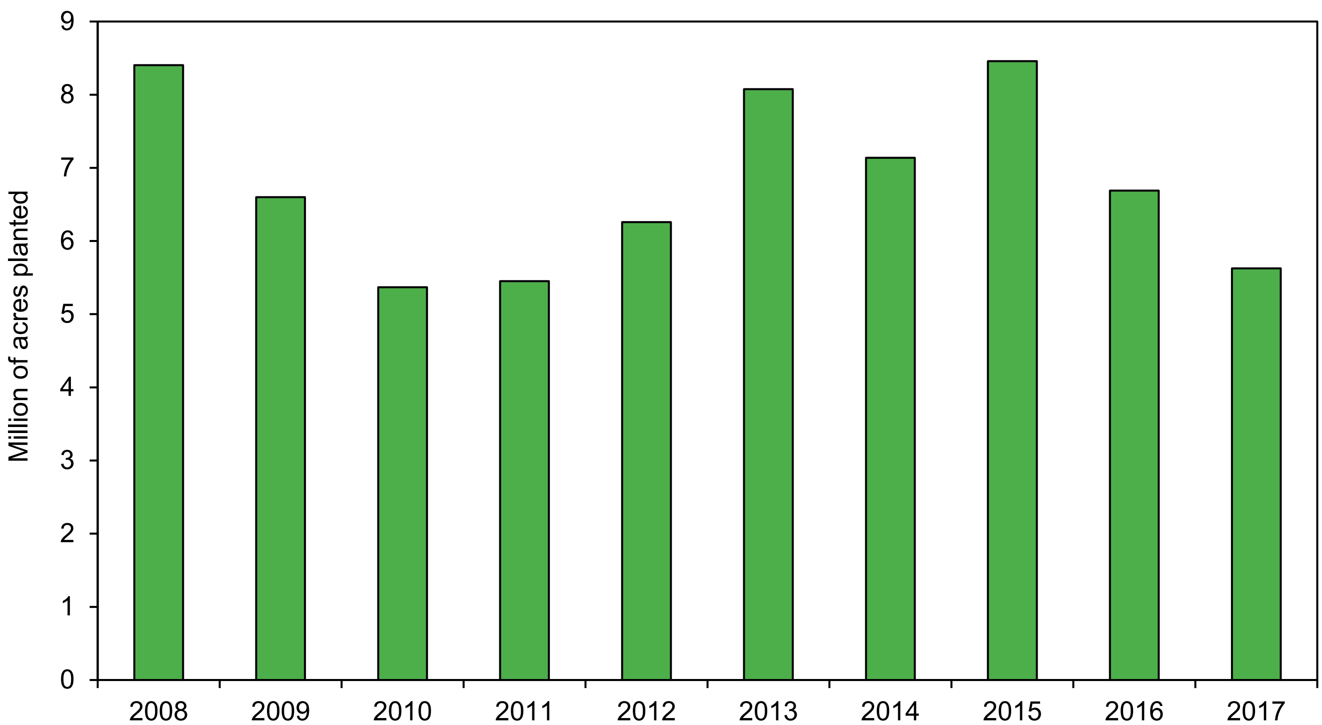

Figure 1.5.1. Acreage of sorghum planted in the United States from 2008 to 2017 (in million acres) (2).

Kansas and Texas are the states where most sorghum is planted, with 46 and 26 percent of the total acreage, respectively. Colorado, Oklahoma and South Dakota complete the top five but with a significantly smaller areas planted relative to the top two states (Figure 1.5.2 and Table 1.5.1).

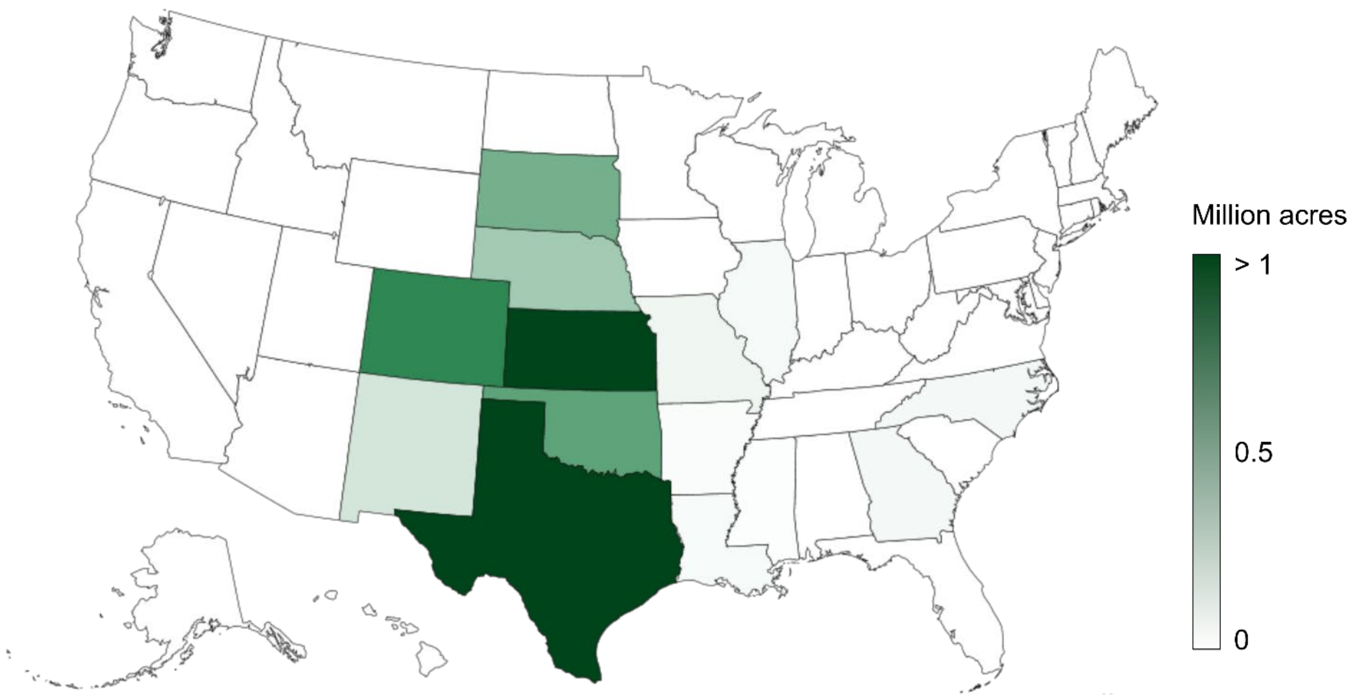

Figure 1.5.2. Total acreage of sorghum in the United States by state in 2017 (in million acres) (3).

State	Million Acres	Percentage
Kansas	2.6	46.2
Texas	1.7	29.3
Colorado	0.4	7.3
Oklahoma	0.3	5.6
South Dakota	0.3	4.8

Table 1.5.1. 5 states with largest acreage of sorghum in the United States in 2017 (in million acres) (3).

Production

The production and consumption of sorghum from 2008 to 2017 is presented in Figure 1.5.3, expressed in million metric tons. The production of sorghum is much smaller than the major starch crops but was about 50 percent greater than barley production in 2017. Production of sorghum is higher than the consumption, thus the United States is a net exporter of sorghum.

Annual sorghum production is highly variable. The production reached its minimum value in 2011 with 5 million metric tons; however, in four years the production multiplied by three, accounting for 15 million metric tons in 2015. After that, the production decreased to 9 million metric tons in 2017 (Figure 1.5.3).

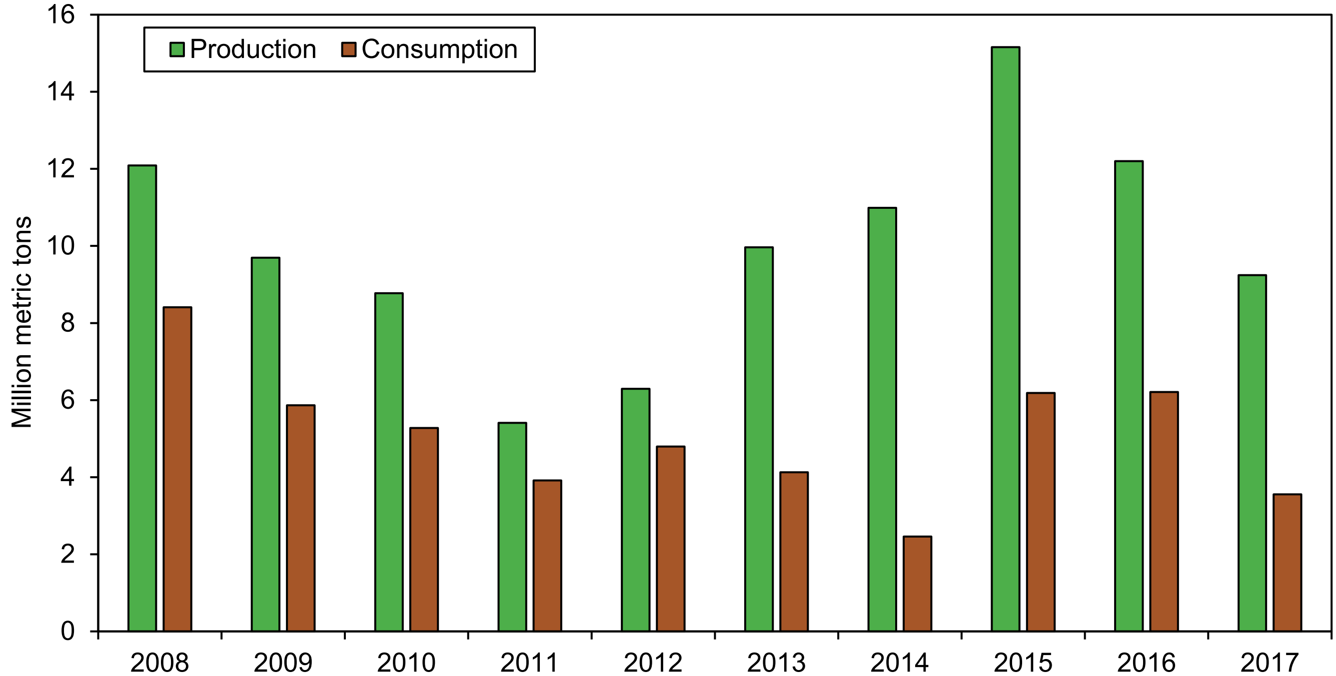

Figure 1.5.3. Total sorghum production versus total sorghum consumption in the United States from 2008 to 2017 (in million metric tons) (4, 5).

The value of sorghum production from 2008 to 2017 is presented in Figure 1.5.4. Revenue is less variable than tons of production. This is because the production of sorghum and its price (see Figure 1.5.8) are inversely proportional, and so they compensate for each other.

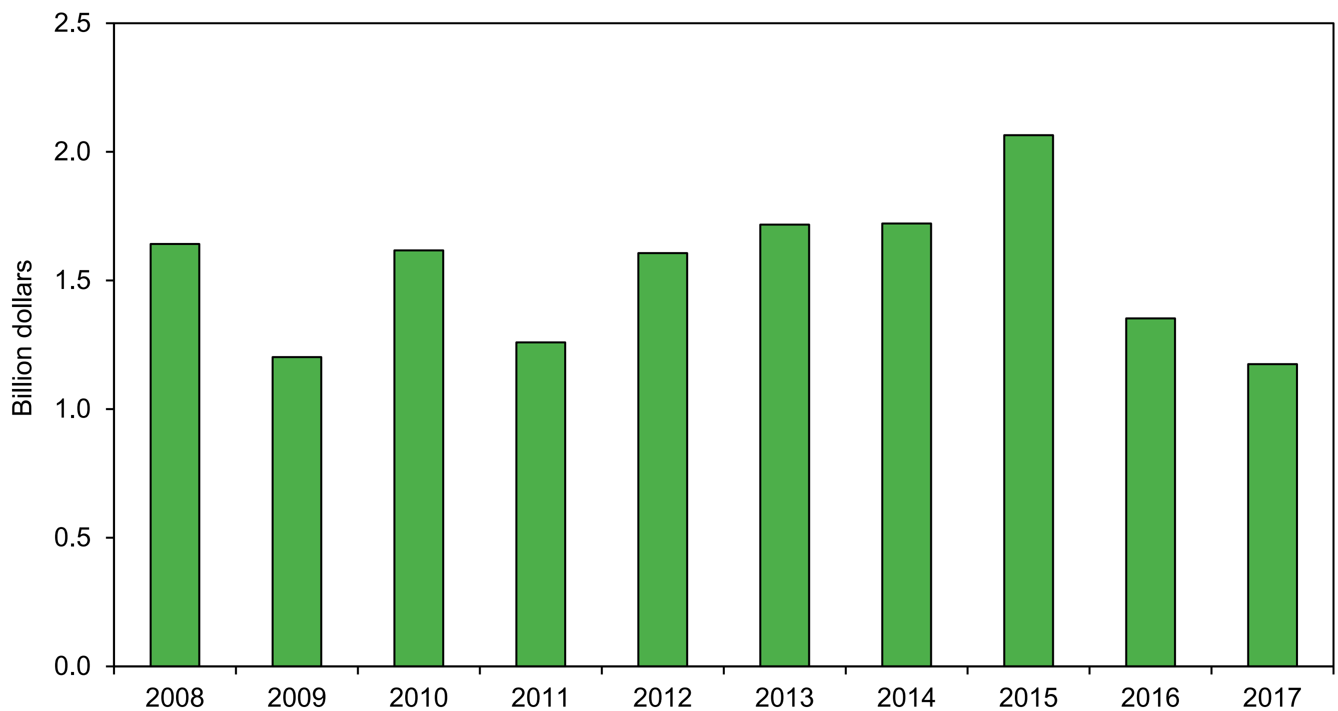

Figure 1.5.4. Production of sorghum in the United States from 2008 to 2017 (in billion dollars) (6).

The production of sorghum is highly correlated with the acreage planted: therefore, the geographical information and trends of sorghum crop production are the same as the acreage trends (Figure 1.5.5 and Table 1.5.2).

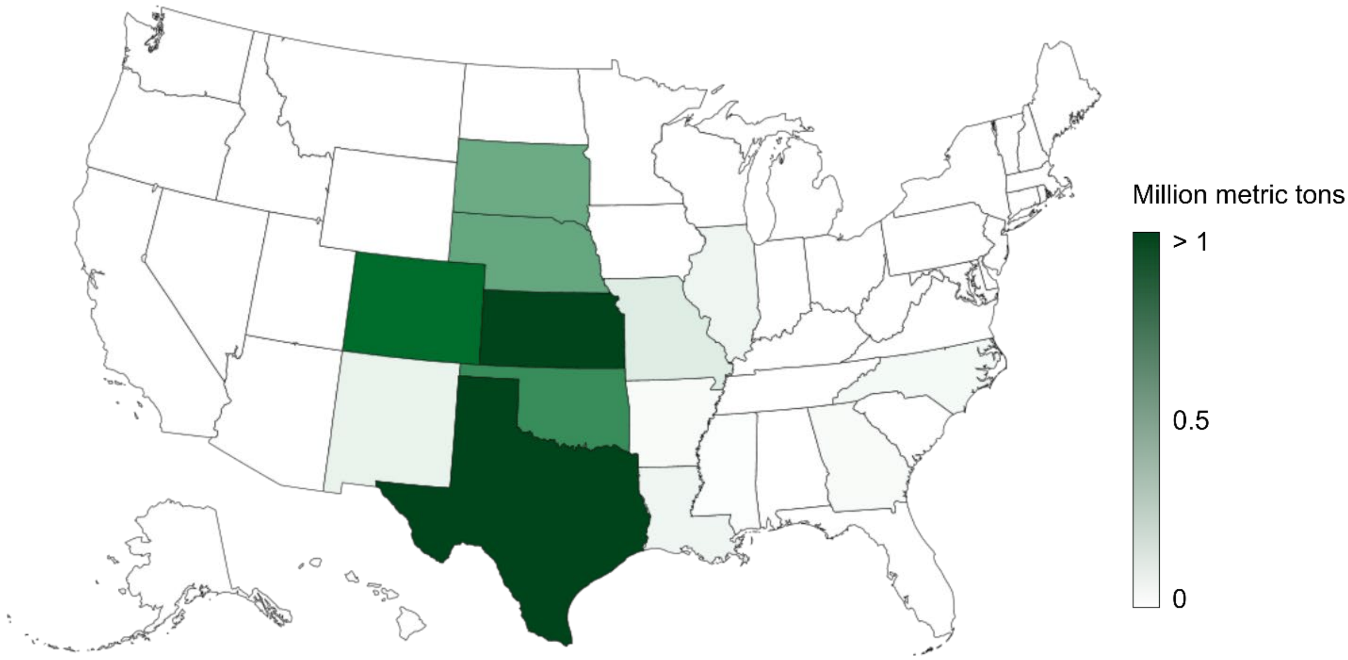

Figure 1.5.5. Total production of sorghum in the United States by state in 2017 (in million metric tons) (7).

State	Million metric tons	Percentage
Kansas	5.0	55.2
Texas	2.4	26.0
Colorado	0.5	5.6
Oklahoma	0.4	4.3
Nebraska	0.3	3.3

Table 1.5.2. 5 states with highest production of sorghum in the United States in 2017 (in million metric tons) (7).

Sorghum exports are correlated with the production of sorghum, so greater production of sorghum correlates to greater exports. China is the largest market destination for sorghum, more than ten times the second-largest importing country, Mexico (Figure 1.5.6).

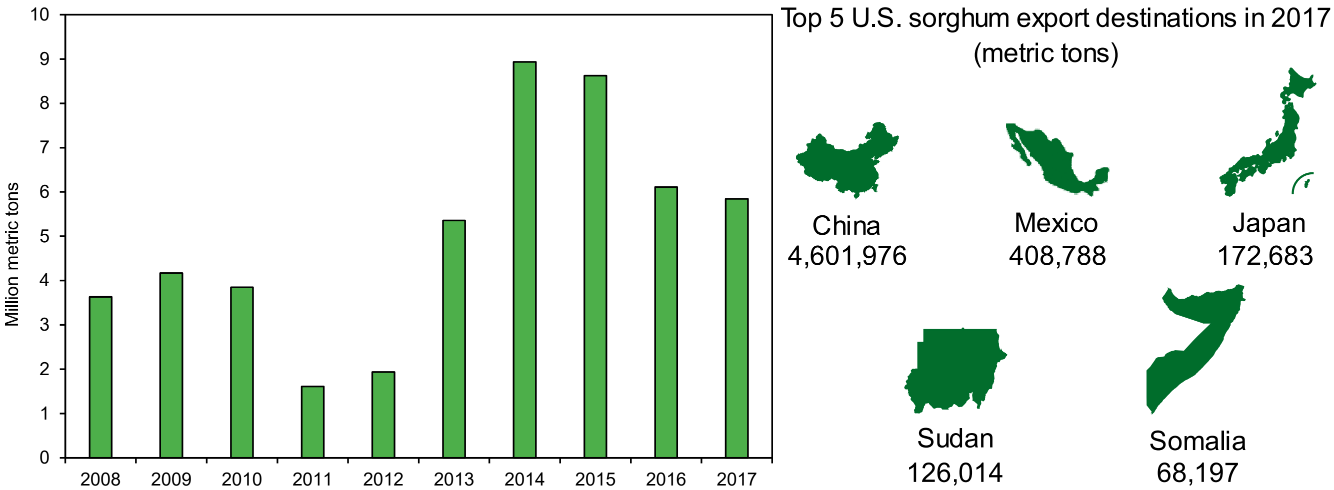

Figure 1.5.6. Exports of sorghum in the United States from 2008 to 2017 (in million metric tons) (4) and top 5 United States export destinations in 2017 (in metric tons) (8).

United States imports of sorghum were very small from 2008 to 2017. In fact, 2012, the year with the greatest imports, just 240,000 metric tons were imported to the United States. The United States imported 57,000 metric tons of sorghum from China and Canada in 2017 (Figure 1.5.7).

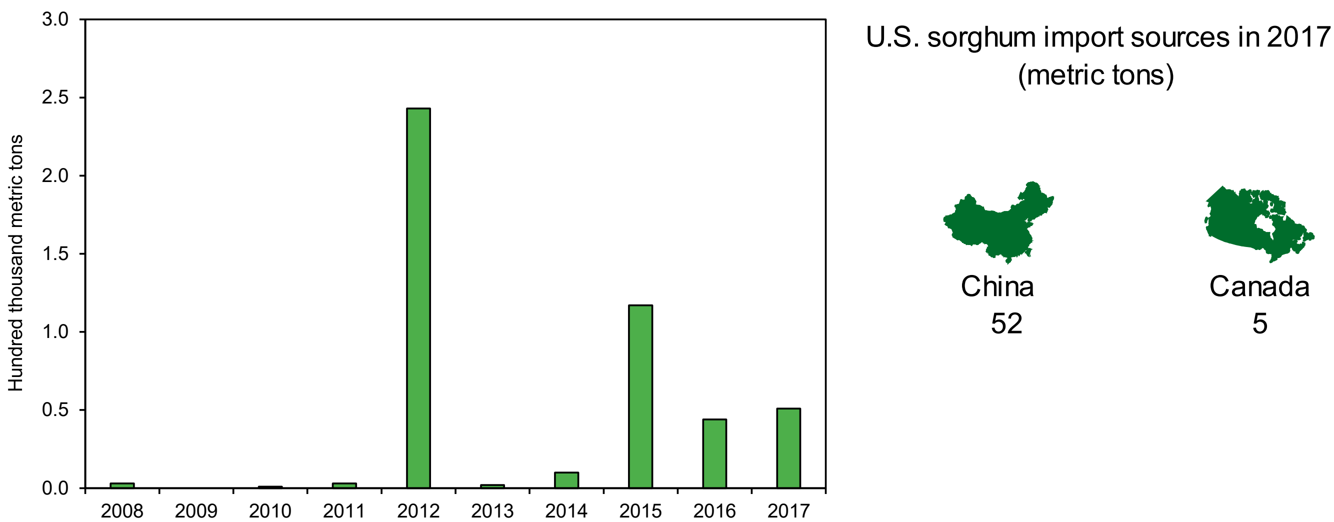

Figure 1.5.7. Imports of sorghum in the United States from 2008 to 2017 (in hundred thousand metric tons) (4) and the United States import sources in 2017 (in metric tons) (8).

Economics

The farm price of sorghum ramped up from 2008 through 2012. But by 2017, the farm price of sorghum was the same as the price in 2008, at 125 dollars per metric ton. The price of sorghum varied significantly from 2008 through 2017, reaching a maximum of 249 dollars per metric ton in 2012 (Figure 1.5.8).

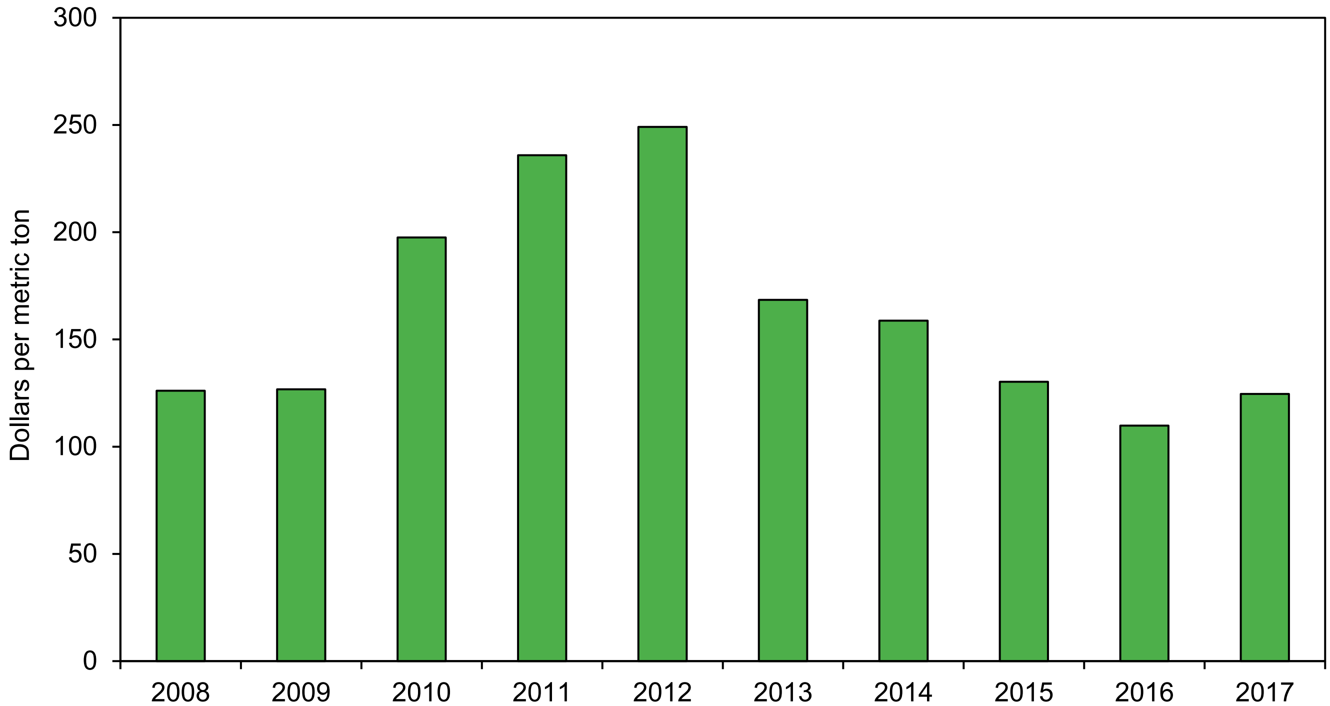

Figure 1.5.8. Farm price of sorghum from 2008 to 2017 (in dollars per metric ton) (9).

Kansas and Texas are the states where the most value from sorghum production is realized, 51 and 31 percent of total, respectively. This is consistent with the geographical information about sorghum acreage and production (Figure 1.5.9 and Table 1.5.3).

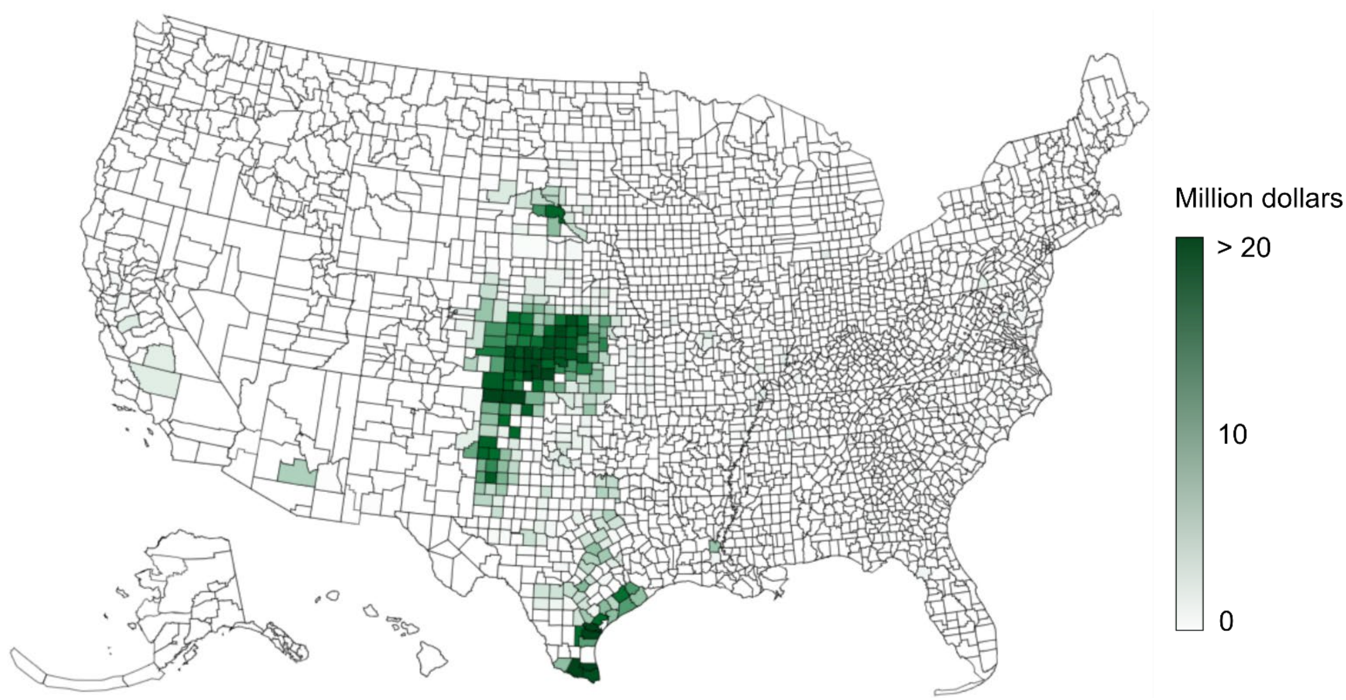

Figure 1.5.9. Total sales of sorghum in the United States by county in 2017 (in million dollars) (10).

State	Million dollars	Percentage
Kansas	753	50.7
Texas	465	31.3
Oklahoma	68	4.6
Colorado	60	4.1
South Dakota	46	3.1

Table 1.5.3. 5 states with highest sales of sorghum in the United States in 2017 (in million dollars) (10).

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1.6. Soy

Photo 10. (10).

Soy is the second largest lipid crop after corn, and its production is concentrated in the Midwest United States.

The production of soy has increased over the years. Soy is mostly used for crush.

Soy and corn can be substituted for one another for biodiesel production, which makes their production patterns highly correlated and in 2017, the pattern converged.

Soybean oil has an important role in biofuels production as it is used as the primary feedstock for U.S. biodiesel production. In 2017, 52 percent of biodiesel was produced from soybean oil.

The United States is a net exporter of soy; China, which is the world's top consumer of soy and imports about 60 percent of its consumption, is the largest market destination.

The earnings from soy have increased from 2009 to 2017 despite the downward trend in relative soy prices.

In this section, these trends are further analyzed according to three main categories, (1) land use, (2) production, and (3) economics.

Photo 11. (11).

Soy has historically occupied the second-largest acreage among lipid crops, after corn. By 2017, however, plantings of the two crops converged at 90 million acres each (see Figure 1.2.1 and Figure 1.6.1 for more details).

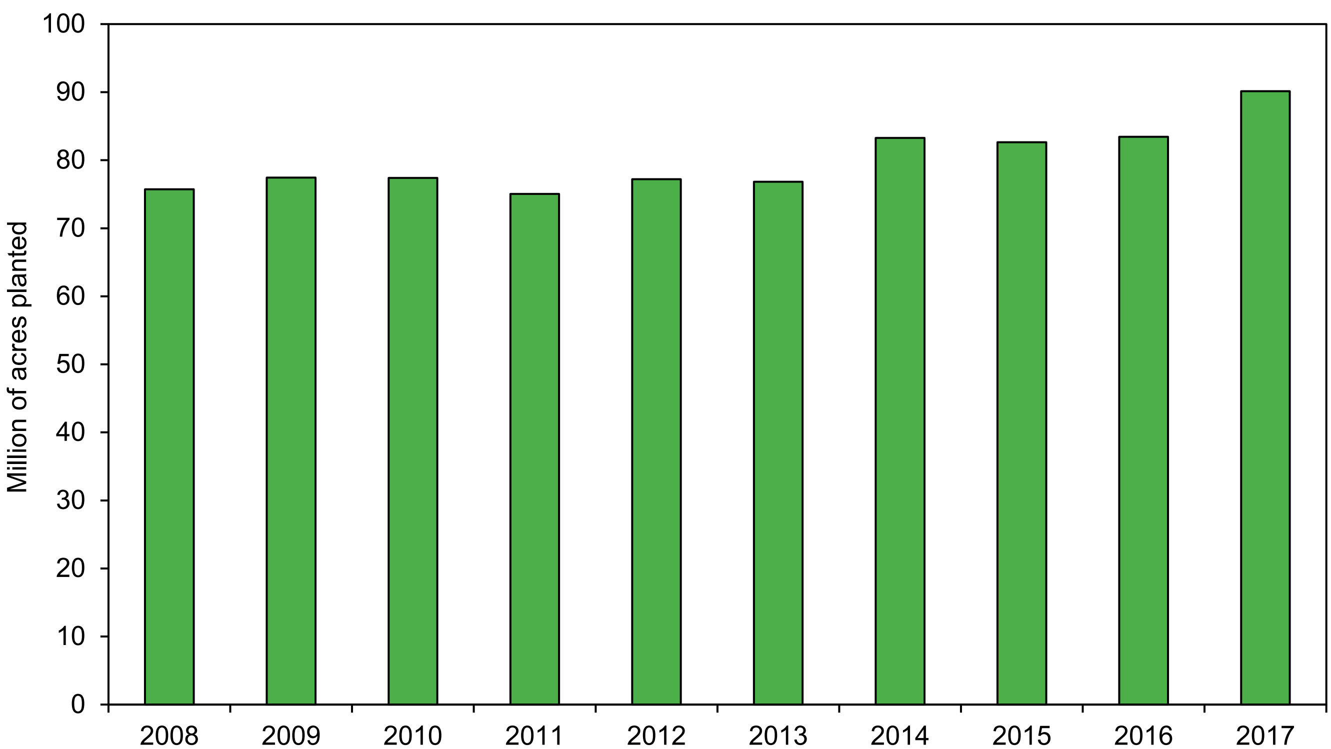

Figure 1.6.1. Acreage of soy planted in the United States from 2008 to 2016 (in million acres) (1).

Soy acreage exhibits the same patterns as corn. The Midwestern states encompass 82 percent of soy plantings. The top 5 states for soy acreage are Illinois, Iowa, Minnesota, North Dakota, and Indiana (Figure 1.6.2 and Table 1.6.1).

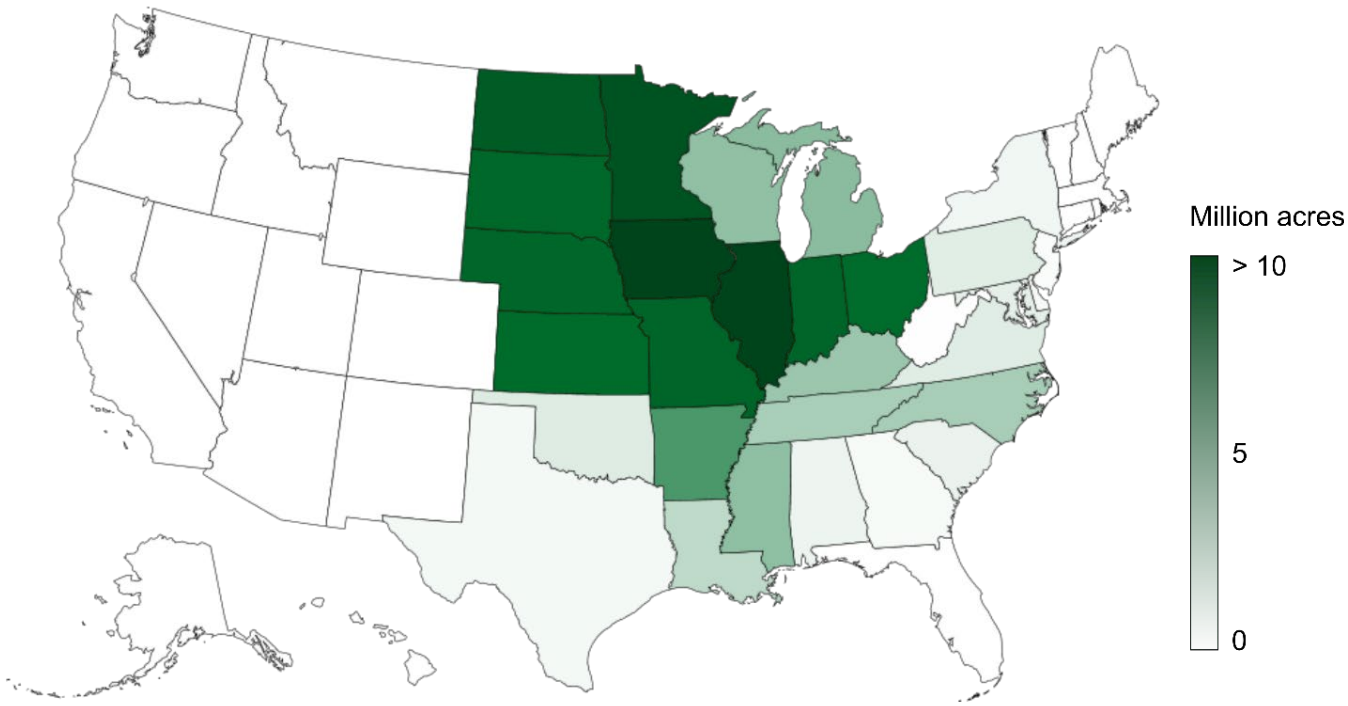

Figure 1.6.2. Total acreage of soybean in the United States by state in 2017 (in million acres) (2).

State	Million Acres	Percentage
Illinois	10.6	11.8
Iowa	10.0	11.1
Minnesota	8.2	9.0
North Dakota	7.1	7.9
Indiana	6.0	6.6

Table 1.6.1. 5 states with largest acreage of soybean in the United States in 2017 (in million acres) (2).

Production

Most soy is crushed to separate oil and meal; only 7 percent of the beans are used whole. The production and consumption of soy increased from 80 and 48 million metric tons in 2008 to 119 and 57 million metric tons in 2017, respectively. Production of soy is consistently higher than consumption, which means that the United States is a net exporter of soy (Figure 1.6.3). Farm revenue from soy peaked at 44 billion dollars in 2012 and 2013; revenue in 2017 was a little below this level, at 41 billion dollars (Figure 1.6.4)

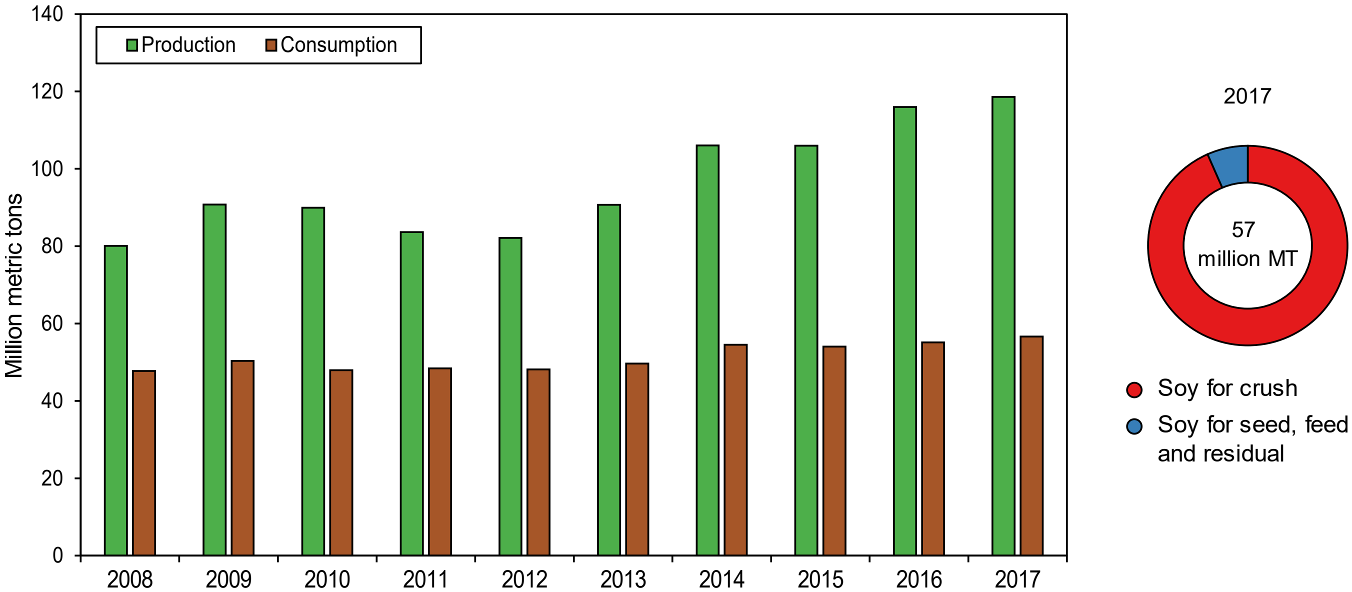

Figure 1.6.3. Total soy production versus total soy consumption in the United States from 2008 to 2017 (in million metric tons) and soy uses in the United States in 2017 (1).

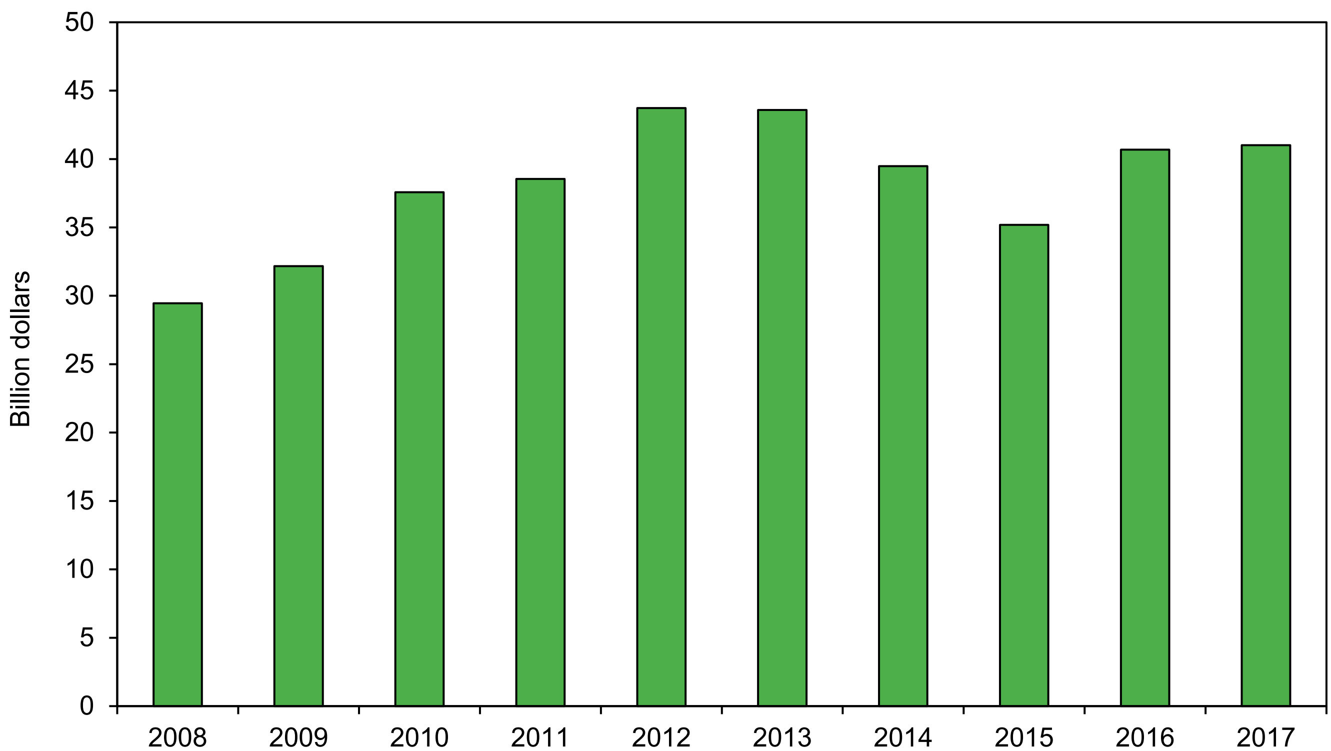

Figure 1.6.4. Total production of soy in the United States from 2008 to 2017 (in billion dollars) (3).

Similar to starch crops, soy production is highly correlated with acreage. Therefore, the geographical trends of soy production are the same as those analyzed in the Land Use section (see Figures 1.6.5 and Table 1.6.2).

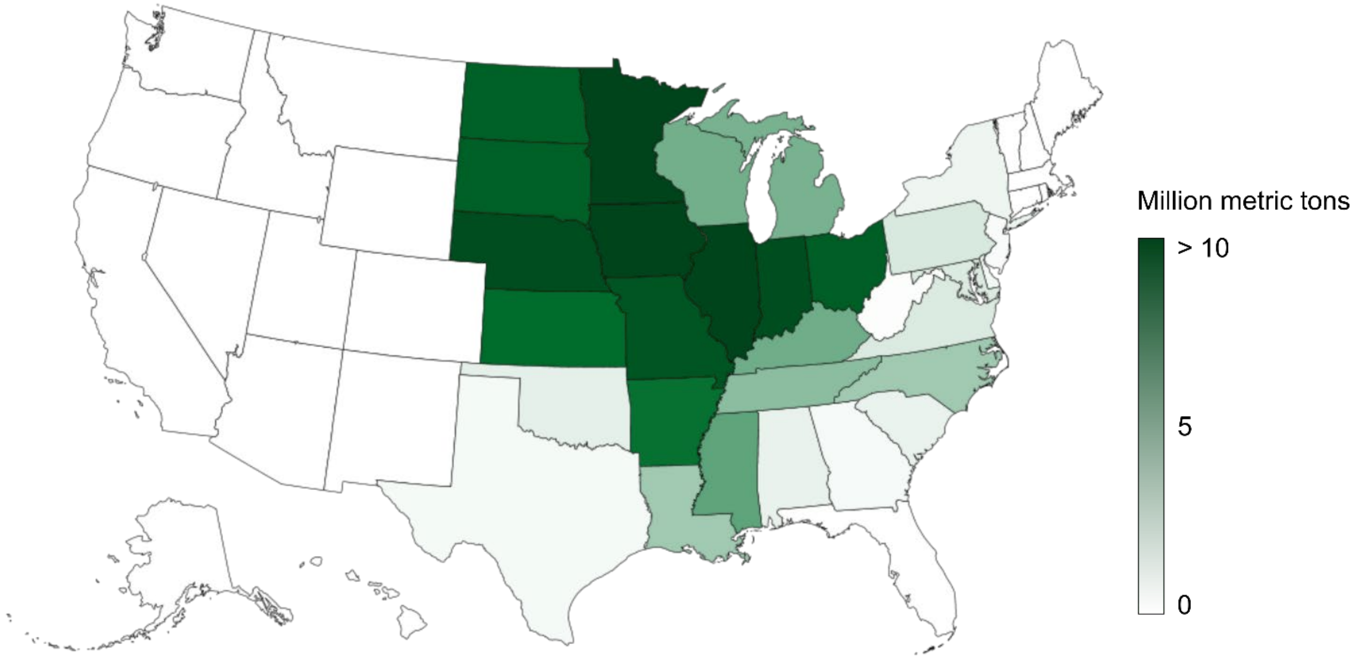

Figure 1.6.5. Total production of soybeans in the United States by state in 2017 (in million metric tons) (4).

State	Million metric tons	Percentage
Illinois	16.7	13.9
Iowa	15.3	12.8
Minnesota	10.3	8.7
Nebraska	8.9	7.4
Indiana	8.7	7.3

Table 1.6.2. 5 states with highest production of soybeans in the United States in 2017 (in million metric tons) (4).

Soybean oil plays an important role in biofuels production since it is used as primary feedstock for biodiesel production. In 2017, 52 percent of biodiesel was produced from soybean oil (5).

As the production of biodiesel increases (see Figure 2.2.3), the amount of vegetable oil used as feedstock increases as well. The amount of soybean oil used for biodiesel production surpassed 2.8 million metric tons in 2017, compared with just 1.5 million metric tons in 2008. In 2017, 27 percent of total soybean oil was used for biodiesel production (See Figure 1.6.6).

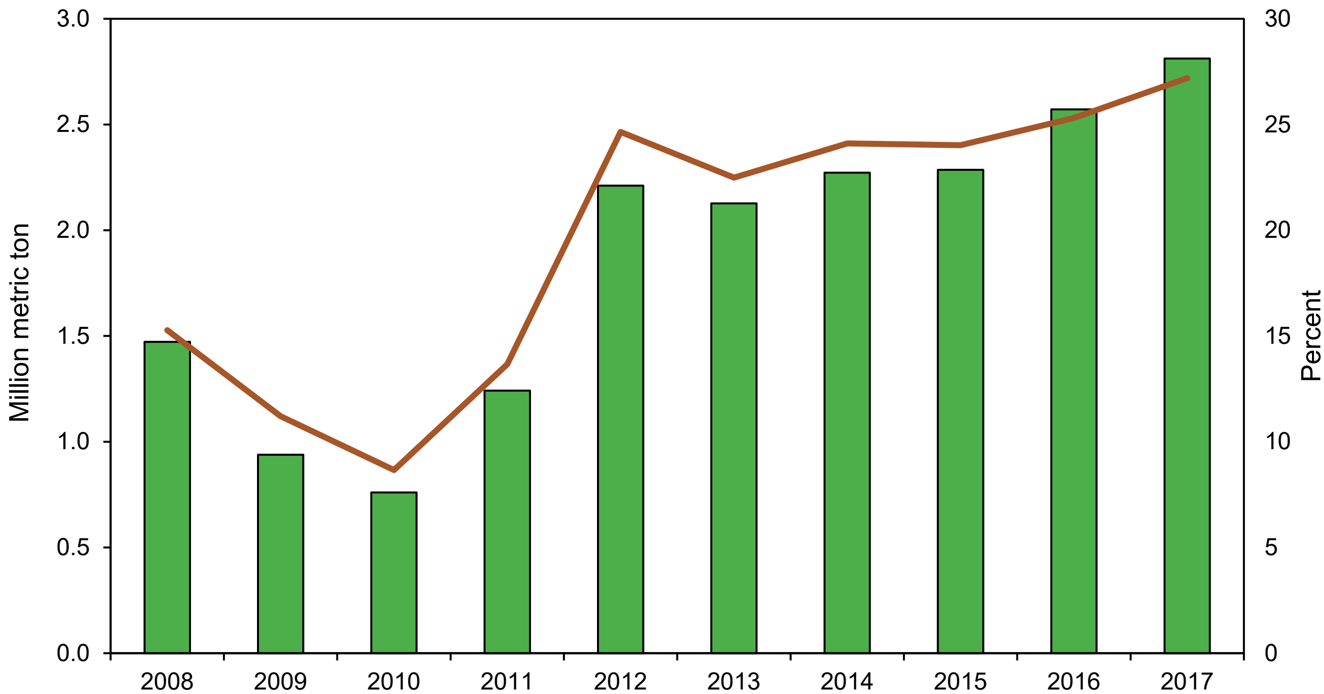

Figure 1.6.6. The bars represent the amount of soybean oil processed into biodiesel in United States from 2008 to 2017 (in million metric tons) (left axis) and the line the percentage of total soybean oil production being devoted to biodiesel from 2008 to 2017 (in percentage) (right axis) (6).

The variation in soy exports matches the variation in production, so the minimum exports in 2012 matches the minimum production of soy (Figure 1.6.7 and Figure 1.6.3). Exports of soy increased by 38 percent from 35 million metric tons in 2008 to 56 million metric tons in 2017. China is the largest market destination for the United States soybeans, receiving more than eight times as much U.S. soy as Mexico, the second-largest importing country (Figure 1.6.7).

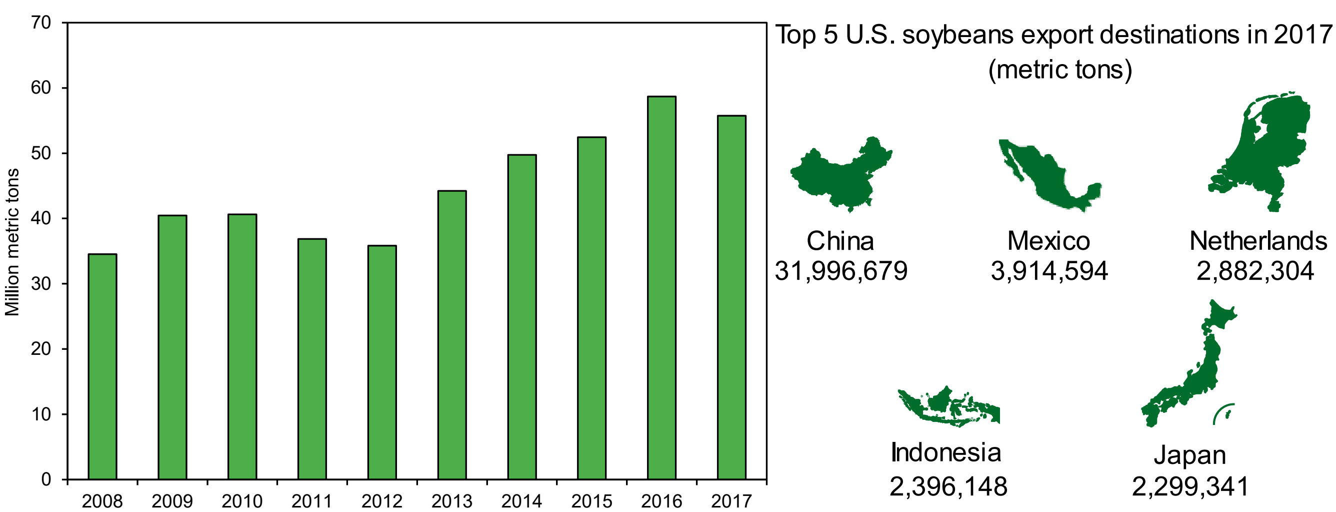

Figure 1.6.7. Exports of soy in the United States from 2008 to 2017 (in million metric tons) (1) and the top 5 United States export destinations in 2017 (in metric tons) (7).

Imports of soy are an order of magnitude smaller than exports. In 2013, soy imports peaked at 1.9 million metric tons compared with 0.7 million metric tons in 2017. Turkey is the largest source of imported soybeans from the United States, followed closely by Canada (Figure 1.6.8).

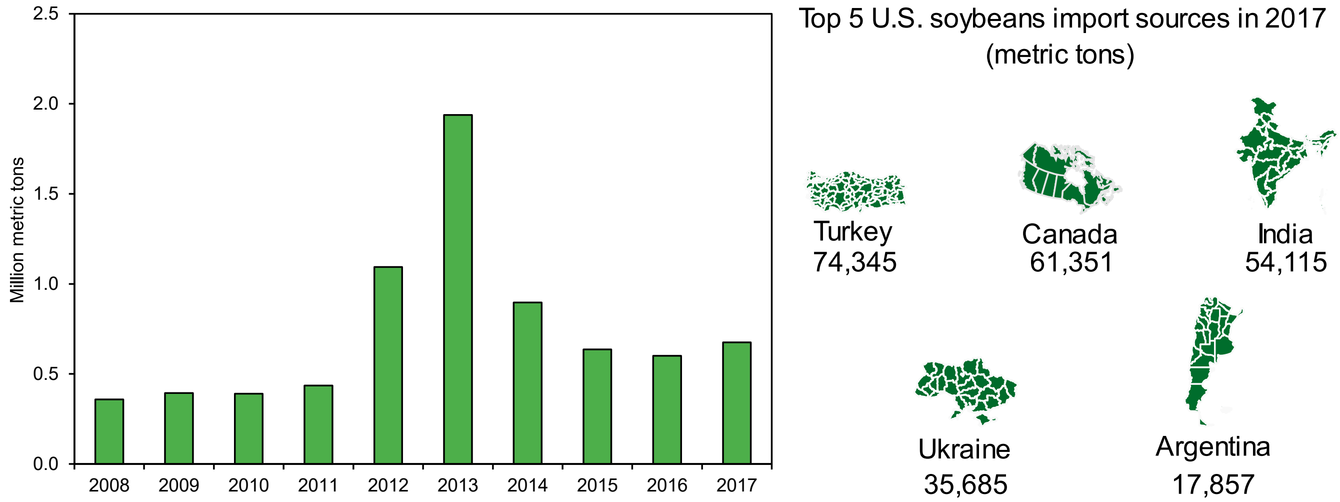

Figure 1.6.8. Imports of soy in the United States from 2008 to 2017 (in million metric tons) (1) and top 5 United States import sources in 2017 (in metric tons) (7).

Economics

The farm price of soy increased considerably in 2012 when it reached a peak of 533 dollars per metric ton. Once the drought ended and production increased, prices came down. By 2017, the price had decreased to 344 dollars. Soy prices tend to be higher in years with lower production. (Figure 1.6.9)

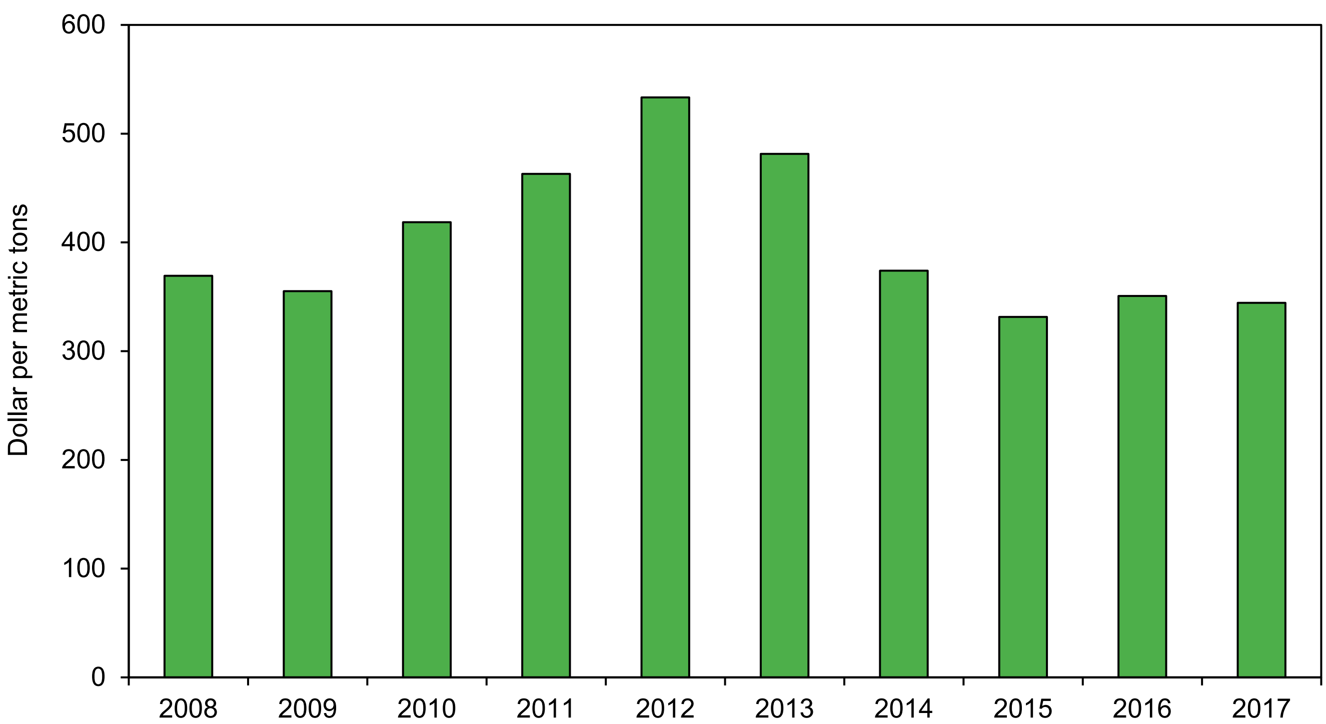

Figure 1.6.9. Farm price of soy from 2008 to 2017 (in dollars per metric ton) (8).

Midwestern farm sales of soy are about 83 percent of total farm sales of U.S soy. The top 5 states are Illinois, Iowa, Minnesota, Indiana, and Nebraska (see Table 1.6.3 for more details). This is consistent with the geographical information of soy acreage and production.

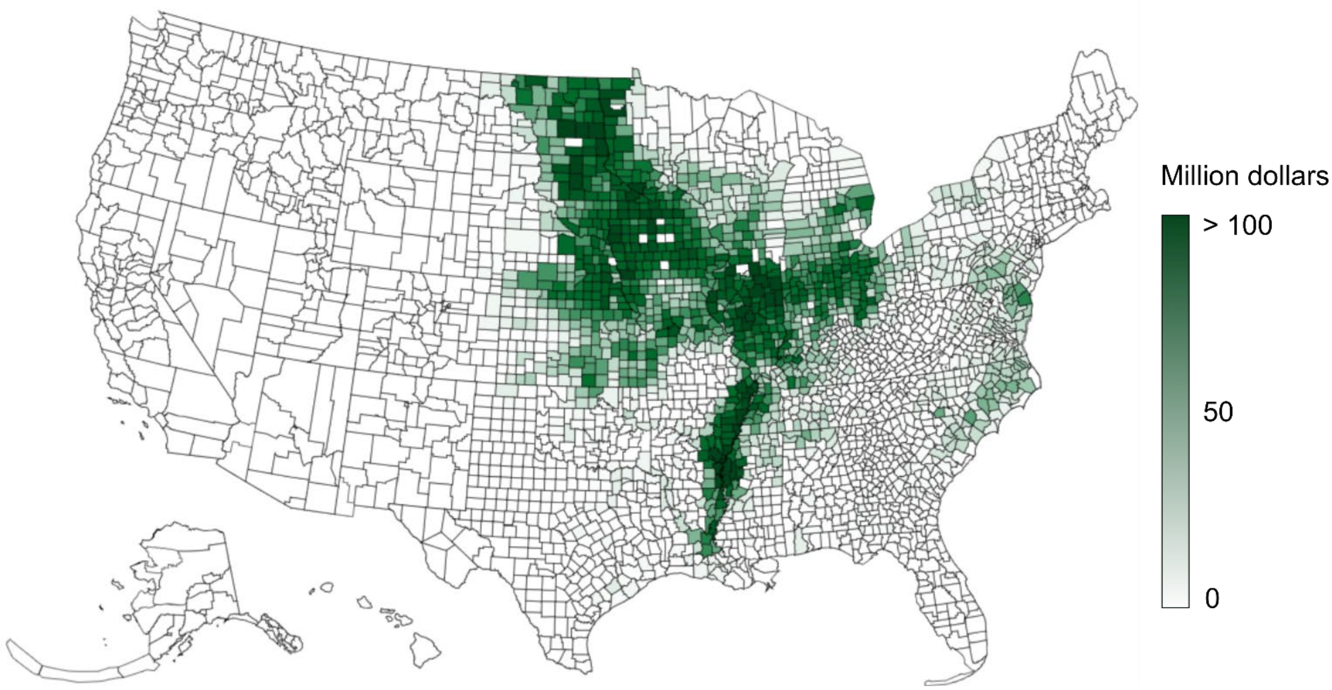

Figure 1.6.10. Total sales of soybean in the United States by County in 2017 (in million dollars) (9).

State	Million dollars	Percentage
Illinois	5,568	14.6
Iowa	4,768	12.5
Minnesota	3,445	9.0
Indiana	3,024	7.9
Nebraska	2,772	7.3

Table 1.6.3. 5 States with highest sales of soybean in the United States in 2017 (in million dollars) (9).

The economic value of soybean oils used for biodiesel production reflects both biodiesel production growth and soybean oil price variability. Between 2009 and 2012, biodiesel production and soybean oil prices were increasing, resulting in a steep increase in the value of soybean oil used for biodiesel production. It peaked at 2.5 billion dollars in 2012. After 2012, biodiesel production growth offset some of the reduction in value due to decreasing prices. The value of soybean oil used for biodiesel production in 2017 was 2 billion dollars (Figure 1.6.9).

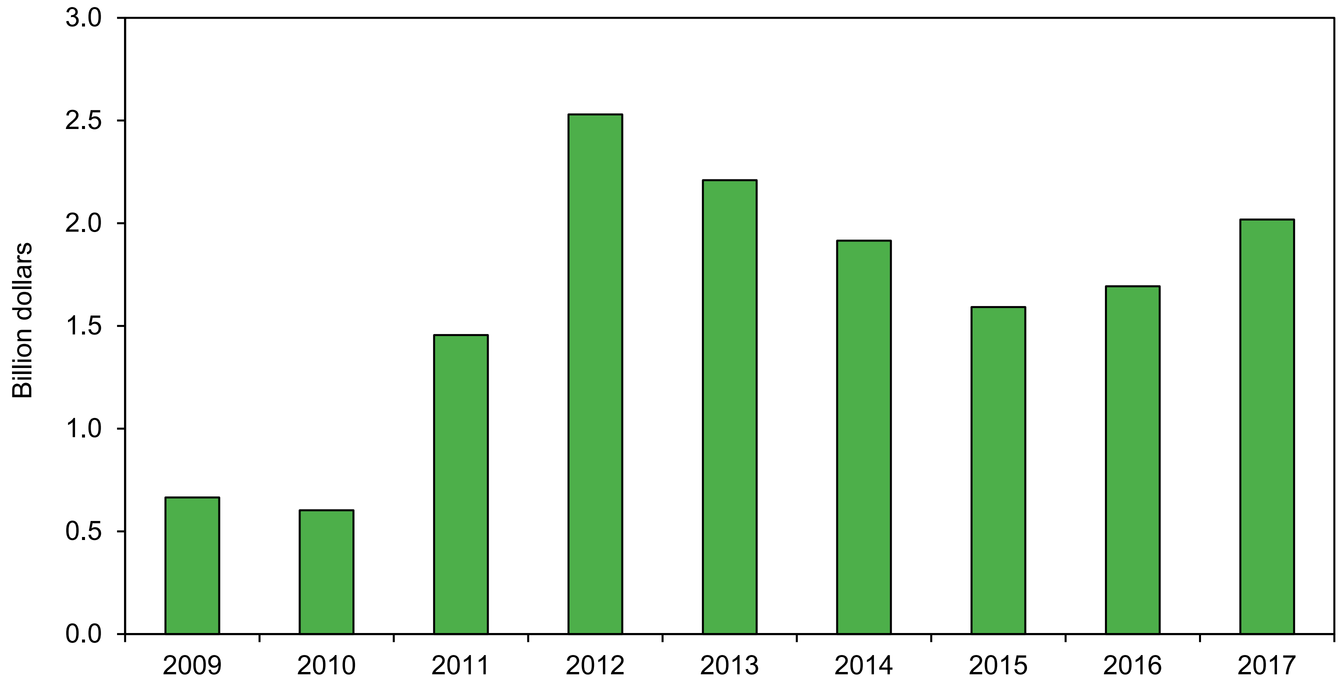

Figure 1.6.11. Economic value of soybean oil being used for biodiesel from 2009 to 2017 (in billion dollars) (6, 8).

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1.7. Cotton

Photo 12. (8).

Cotton is the third largest lipid crop, well behind corn and soy in acreage and tonnage produced. Its production is very concentrated: more than half of cotton is planted and harvested in Texas.

The production and consumption of cotton remained almost constant from 2008 to 2017. Also, production and consumption are very similar, which means that the United States produces and consumes the cotton domestically.

In this section, these trends are further analyzed according to three main categories, (1) land use, (2) production, and (3) economics.

Photo 13. (9).

The acreage to which cotton is planted is significantly smaller in comparison to corn or soy acreage. Cotton acreage peaked in 2011 at 15 million; in 2017, 13 million acres were planted (Figure 1.7.1).

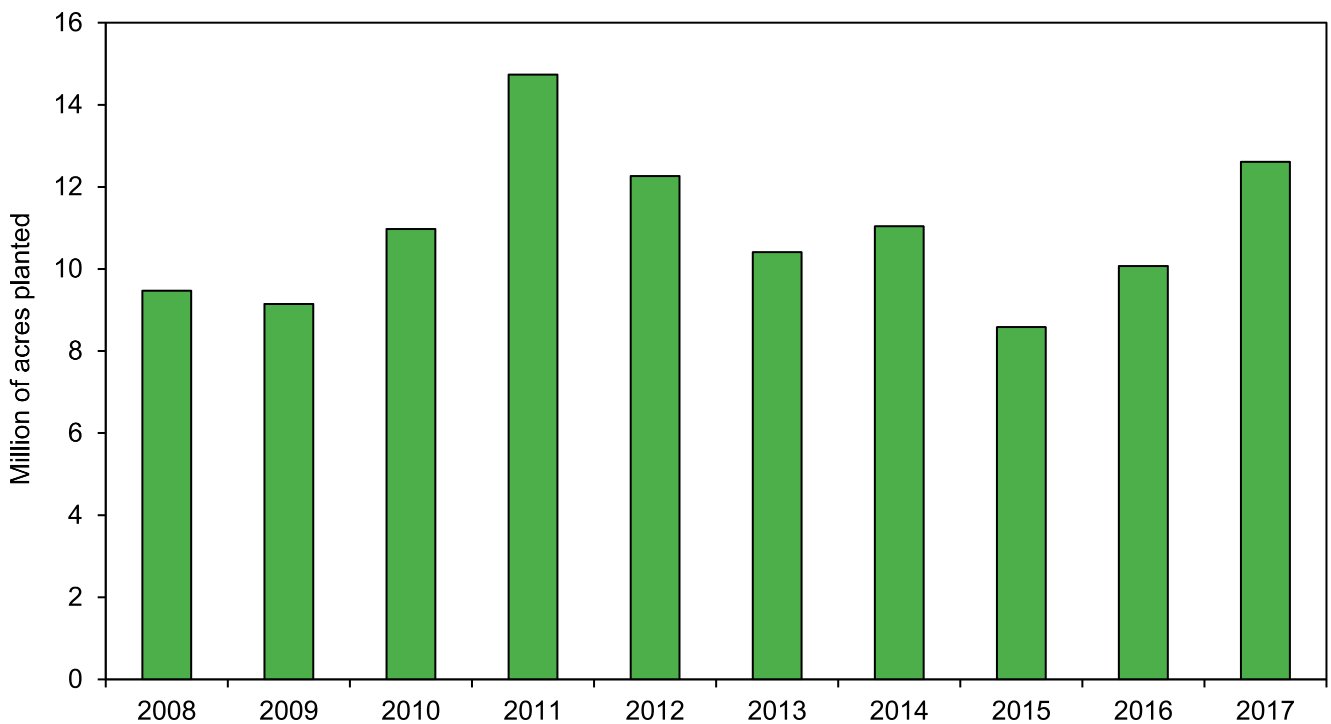

Figure 1.7.1. Acreage of cotton planted in the United States from 2008 to 2016 (in million acres) (1).

More than half of cotton is planted in Texas, with a total of 6.9 million acres. Georgia, Mississippi, Oklahoma, and Arkansas complete the list of the top 5 states. Together, they account for 78 percent of total cotton acreage (Figure 1.7.2 and Table 1.7.1).

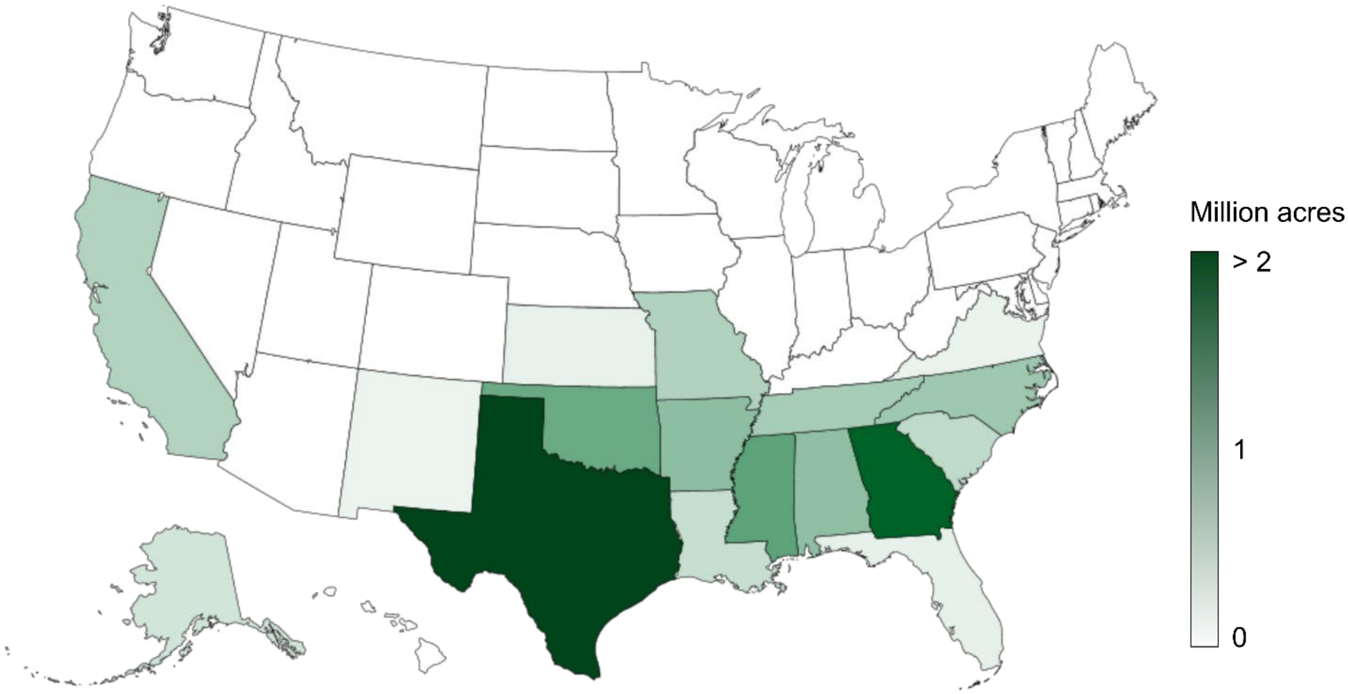

Figure 1.7.2. Total acreage of cotton in the United States by state in 2017 (in million acres) (2).

State	Million Acres	Percentage
Texas	6.9	54.8
Georgia	1.3	10.1
Mississippi	0.6	5.0
Oklahoma	0.6	4.6
Arkansas	0.4	3.5

Table 1.7.1. 5 states with largest acreage of cotton in the United States in 2017 (in million acres) (2).

Production

Cotton production and consumption are very small in comparison with other lipids crops such as corn and soy. Similar to barley, the production of cotton is equal than the consumption, which means that the United States produces and consumes nearly all of its cotton domestically. Production fluctuated around a downward trend, and between 2008 and 2017 (Figure 1.7.3).

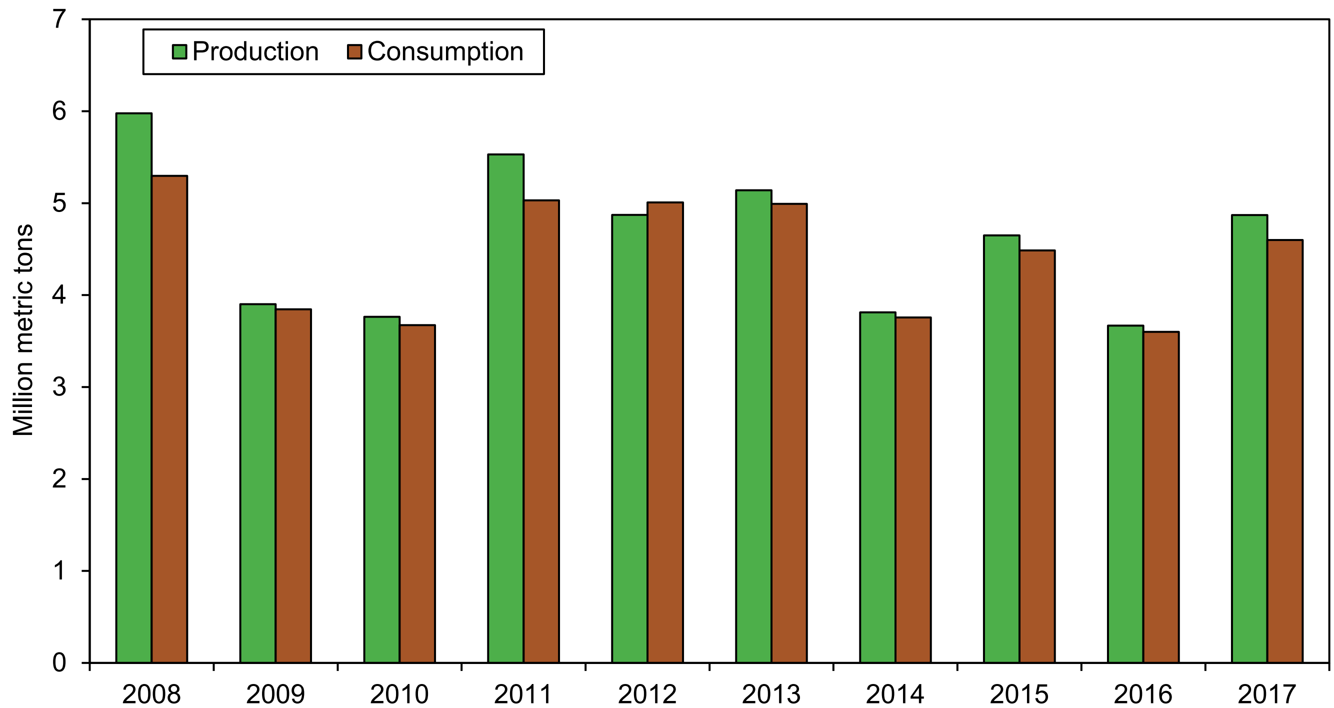

Figure 1.7.3. Total cotton production versus total cotton consumption in the United States from 2008 to 2017 (in million metric tons) (1).

The value of cotton production is presented in Figure 1.7.4. Farm sales of cotton in 2017 were approximately the same as the previous peak in 2010, at 7 billion dollars.

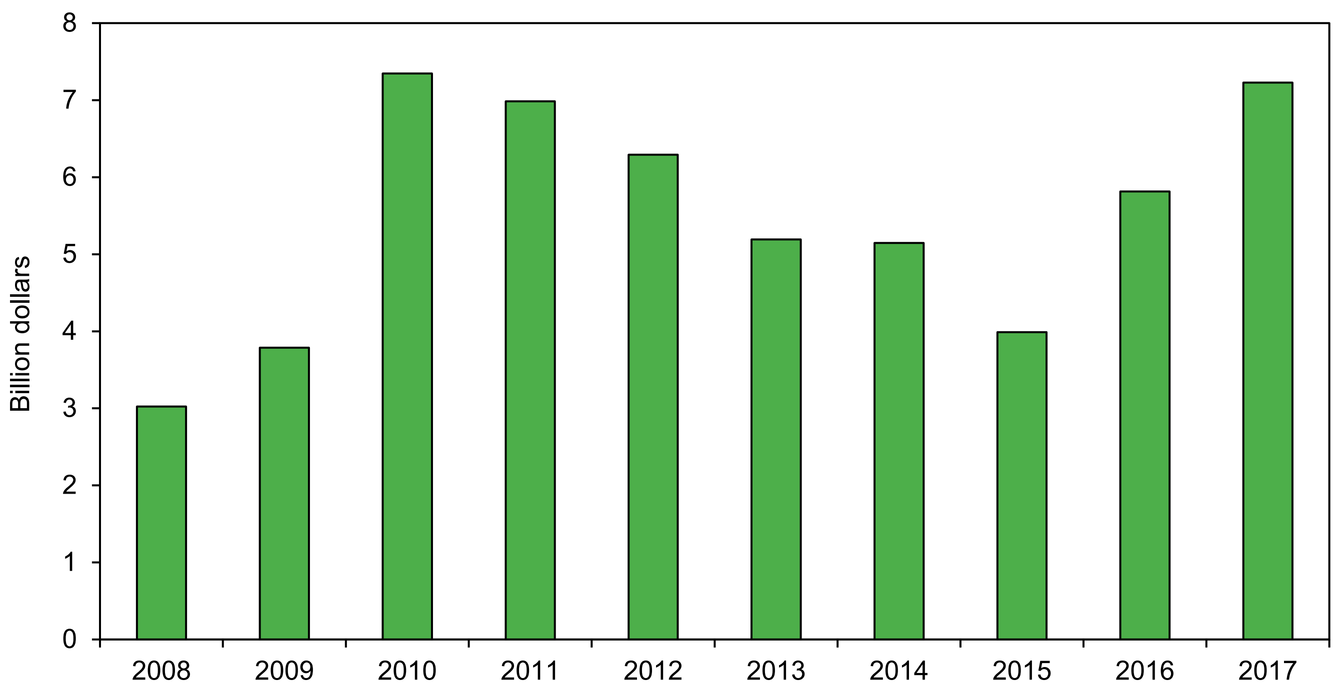

Figure 1.7.4. Total production of cotton in the United States from 2008 to 2017 (in billion dollars) (3).

Cotton production by state is highly correlated with acreage planted to cotton within the state; as a consequence, the geographical trends of cotton production are the same as those analyzed in the Land Use section (See Figure 1.7.5 and Table 1.7.2).

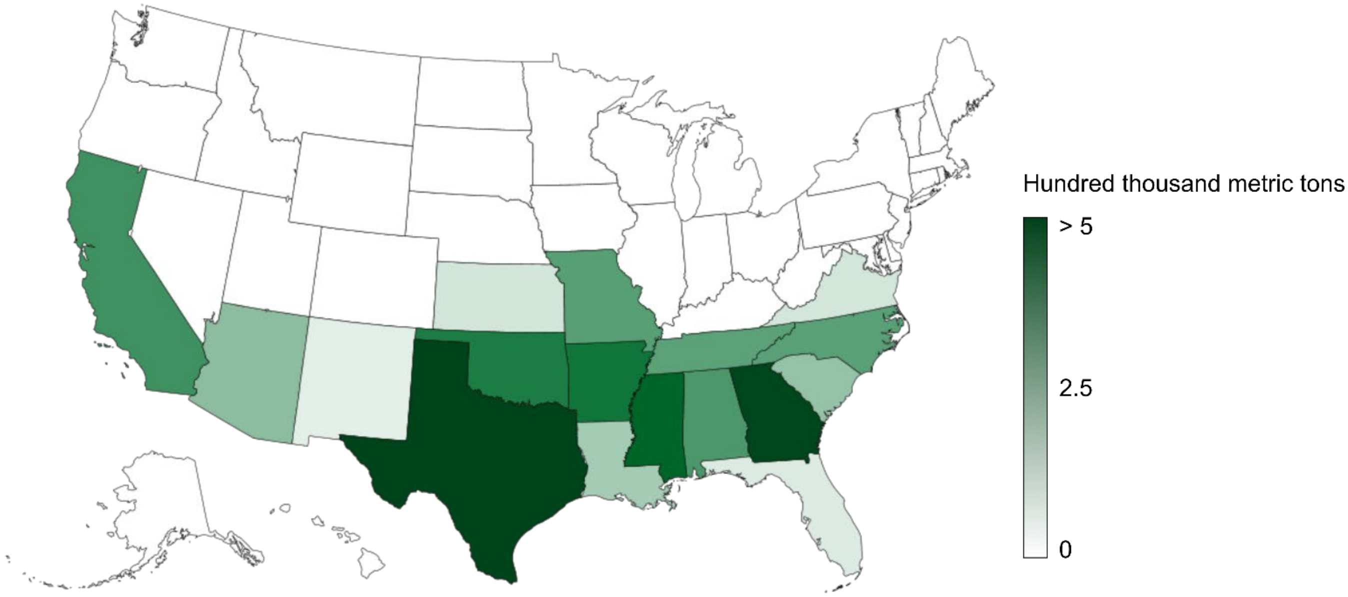

Figure 1.7.5. Total production of cotton in the United States by state in 2017 (in hundred thousand metric tons) (4).

State	Million metric tons	Percentage
Texas	2.02	44.4
Georgia	0.48	10.6
Mississippi	0.29	6.5
Arkansas	0.23	5.1
Oklahoma	0.22	4.9

Table 1.7.2. 5 states with highest production of cotton in the United States in 2017 (in million metric tons) (4).

Cotton exports are much smaller in volume than other crops, which is consistent with the patterns of production and consumption analyzed in Figure 1.7.3. South Korea is the largest market destination for United States cotton, with 124,000 metric tons exported, followed closely by Mexico with 120,000 metric tons of cotton exported (Figure 1.7.7).

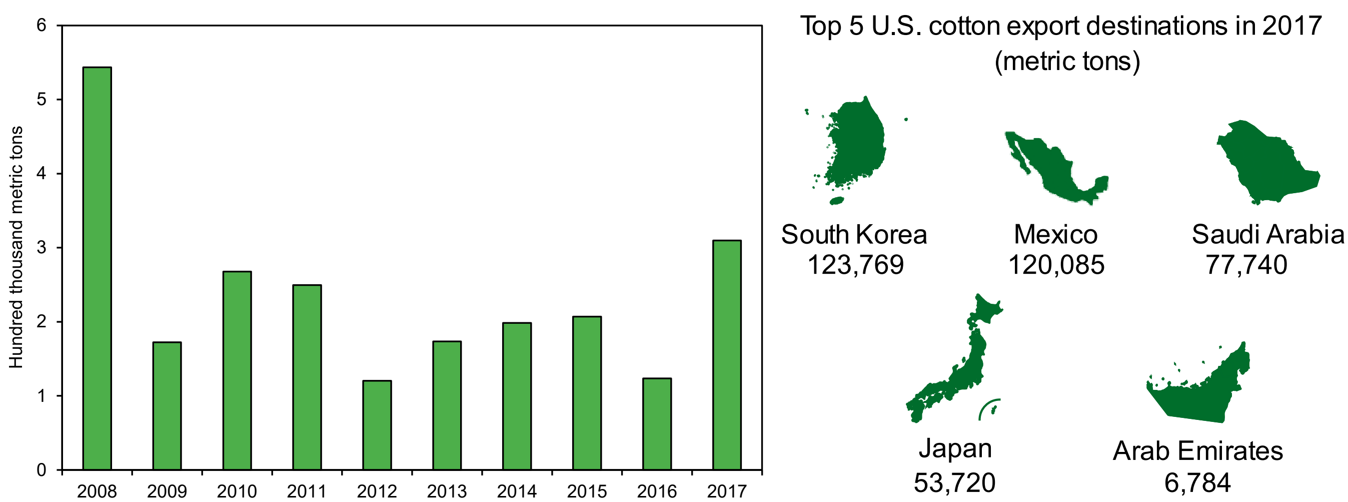

Figure 1.7.6. Exports of cotton in the United States from 2008 to 2017 (in hundred thousand metric tons) (1) and top 5 United States exports destinations in 2017 (in metric tons) (5).

Imports of cotton are even smaller than exports, on the order of 10s of thousands of tons rather than 100s of thousands of metric tons. Mexico is the only country from which the United States imported cotton in 2017 (Figure 1.7.7).

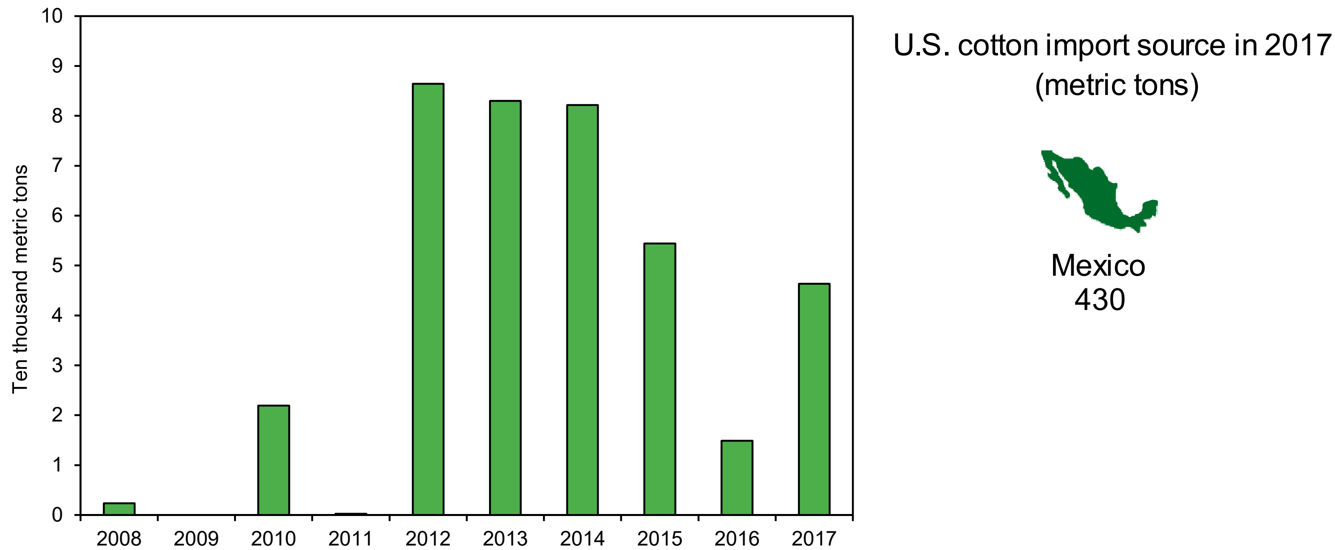

Figure 1.7.7. Imports of cotton in the United States from 2008 to 2017 (in ten thousand metric tons) (1) and United States import source in 2017 (in metric tons) (5).

Economics

The minimum price of cotton in the decade between 2008 and 2017 was 174 dollars per metric ton in 2010. Prices peaked at 287 dollars per metric ton in 2012 then trended downward. The farm price of cotton was 215 dollars per metric ton in 2017 (Figure 1.7.8).

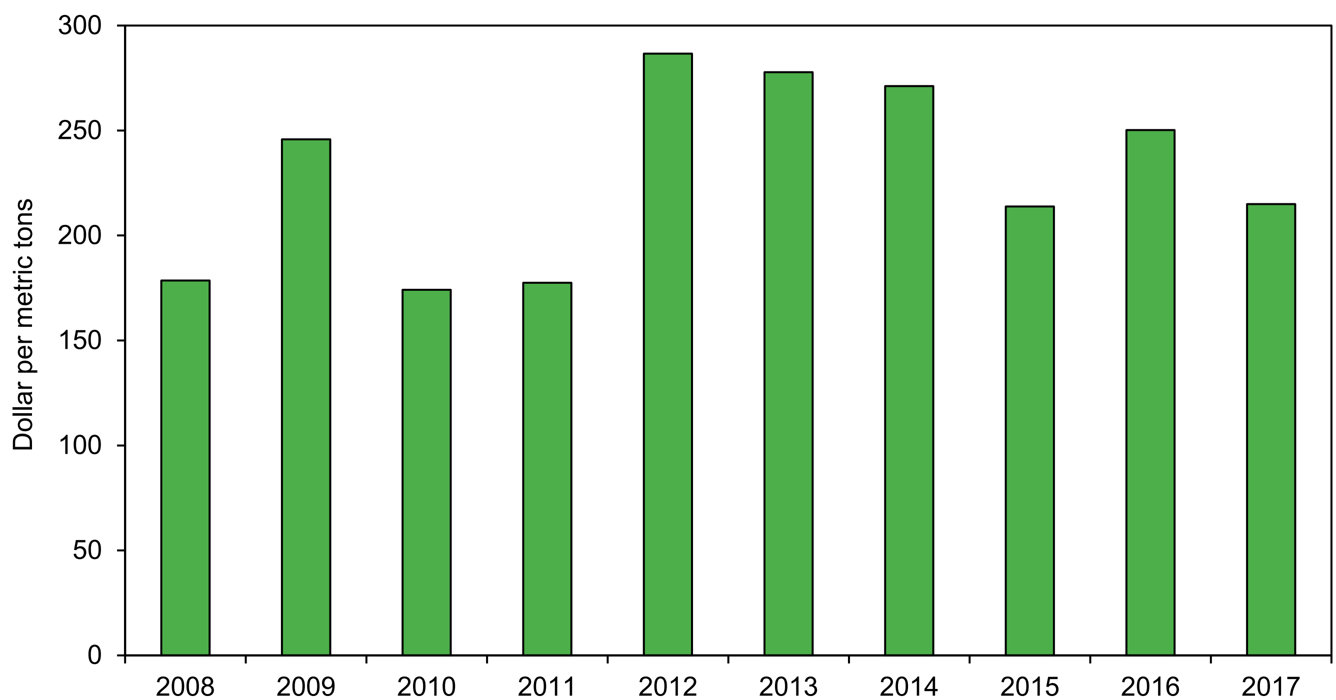

Figure 1.7.8. Farm price of cotton from 2008 to 2017 (in dollars per metric ton) (6).

The value of cotton sold in the United States in 2017 is very small in comparison with corn and soy sales. Most of the cotton is sold in the southern United States, with 5 states concentrating 82 percent of total sales. Texas and Georgia are the states where more cotton is sold, followed by California, Mississippi and Arkansas (Figure 1.7.9 and Table 1.7.3). These are the states with highest acreage of cotton and cotton production.

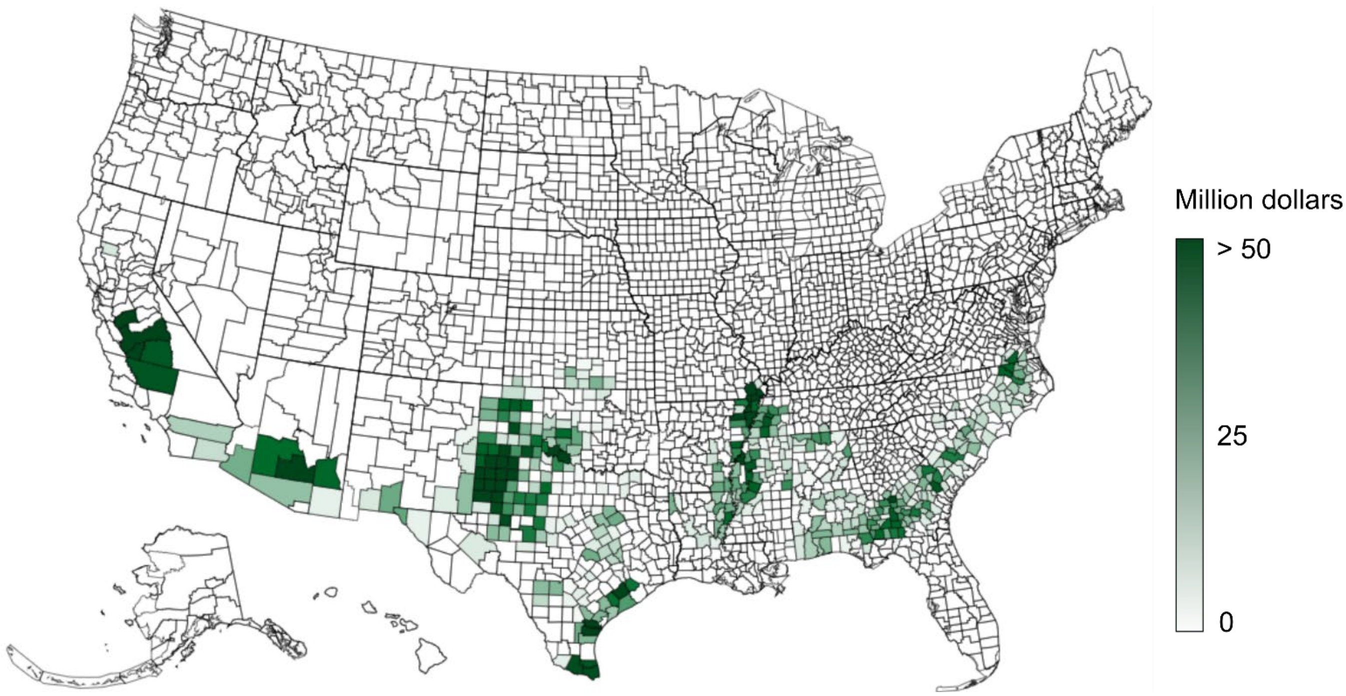

Figure 1.7.9. Total sales of cotton in the United States by county in 2017 (in million dollars) (7).

State	Million dollars	Percentage
Texas	2,604	46.6
Georgia	774	13.9
California	509	9.1
Mississippi	399	7.1
Arkansas	309	5.5

Table 1.7.3. 5 states with highest sales of cotton in the United States in 2017 (in million dollars) (7).

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1.8. **Peanuts**

Photo 14. (7).

As with cotton, the number of acres planted with peanuts in the United States is very small and very concentrated. Almost half of the peanuts planted in the United States are located in Georgia.

The production and consumption of peanuts are nearly the same and have not changed over the years. This implies that the United States produces and consumes peanuts domestically.

Although the exports of peanuts are very small, they have doubled in weight from 2008 to 2017, from 0.3 million metric tons to 0.6 million metric tons.

Peanut is the most expensive crop and, as with other crops, shows a high variability from 2008 to 2017.

In this section these trends are further analyzed according to three main categories, (1) land use, (2) production, and (3) economics.

Photo 15. (8).

The number of acres planted to peanuts is small in comparison with other crops. Nonetheless, the acreage of peanuts has slowly grown since 2008, increasing from 1.5 million acres in 2008 to 1.9 million acres in 2017 (Figure 1.8.1).

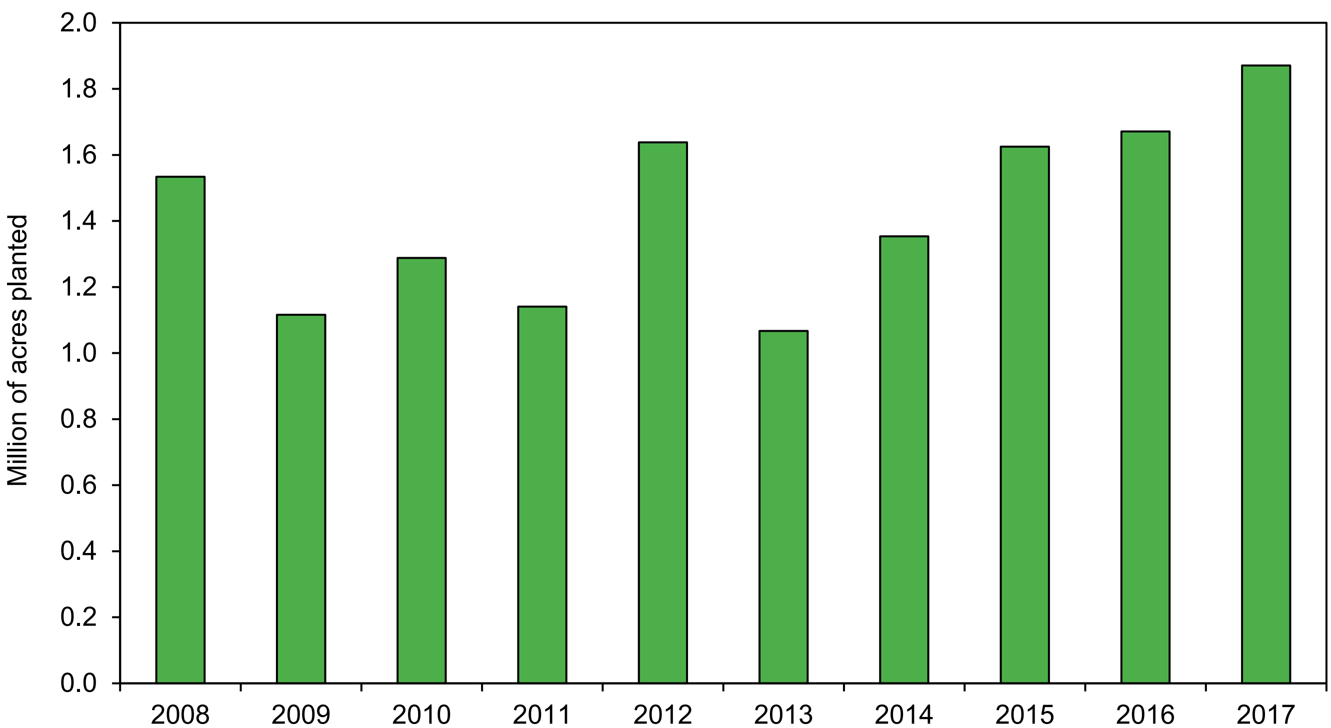

Figure 1.8.1. Acreage of peanuts planted in the United States from 2008 to 2016 (in million acres) (1).

The acreage of peanuts is not only very small but also very concentrated. Georgia, in particular, accounts for nearly half of peanut acreage, followed by Texas and Alabama which represent 14 percent and 10 percent of total acreage planted (Figure 1.8.2 and Table 1.8.1).

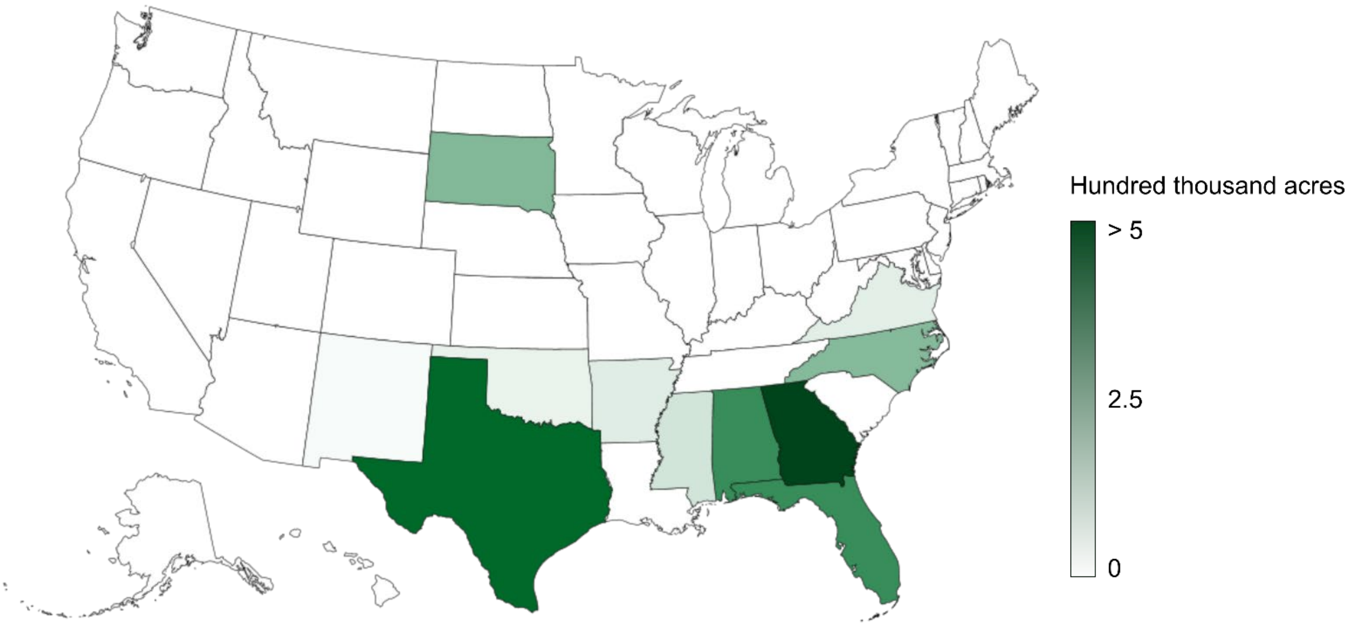

Figure 1.8.2. Total acreage of peanuts in the United States by state in 2017 (in hundred thousand acres) (2).

State	Hundred Thousand Acres	Percentage
Georgia	8.4	44.6
Texas	2.8	14.7
Alabama	2.0	10.4
Florida	2.0	10.4
South Dakota	1.2	6.5

Table 1.8.1. 5 states with largest acreage of peanuts in the United States in 2017 (in hundred thousand acres) (2).

Production

Peanut production and consumption are very small when compared with other crops. With the exception of 2013, when production was almost double consumption (3.1 million metric tons in comparison with 1.8 million metric tons), the production and consumption of peanuts is very similar, which means that the United States produces and consumes most peanuts domestically (Figure 1.8.3).

The greatest farm revenues from peanut production occurred in 2012, one year prior to the production peak. Revenue stayed low for several years after 2013 then recovered in 2017, to about 2 billion dollars (Figure 1.8.4).

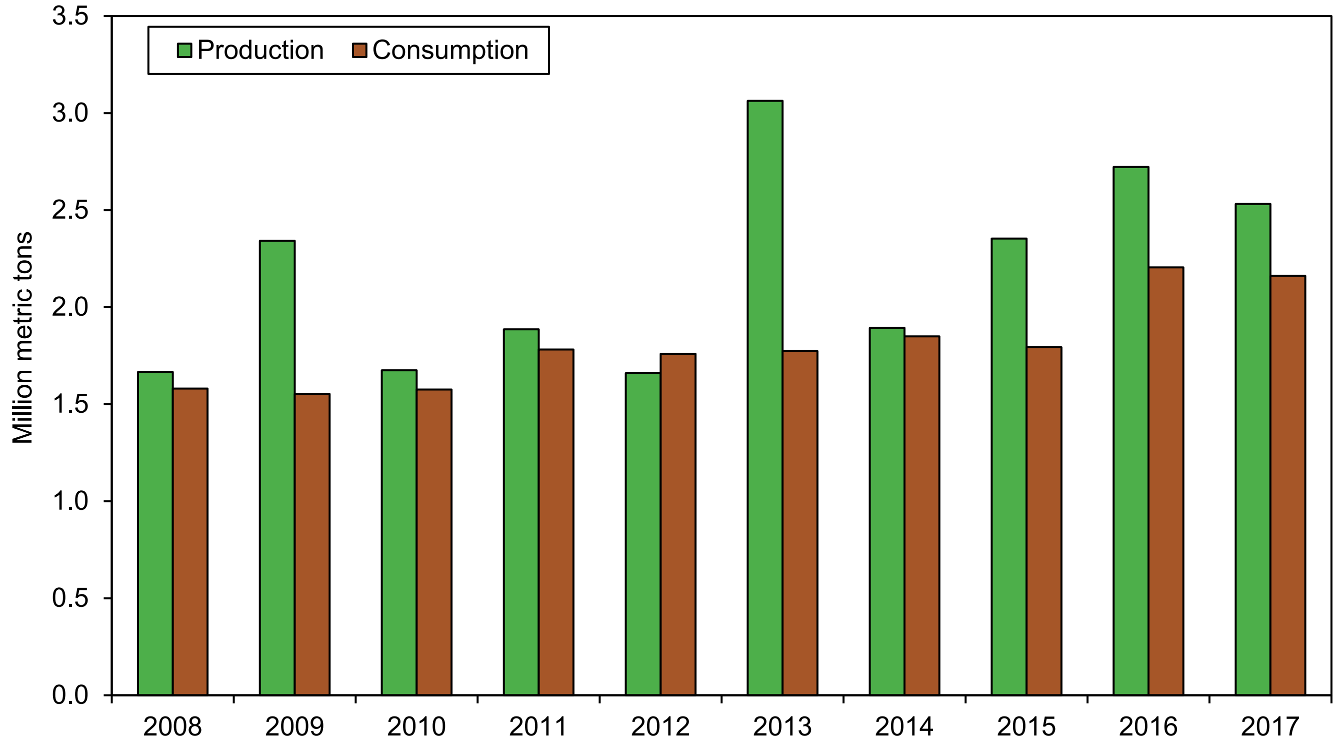

Figure 1.8.3. Total peanuts production versus total peanuts consumption in the United States from 2008 to 2017 (in million metric tons) (1).

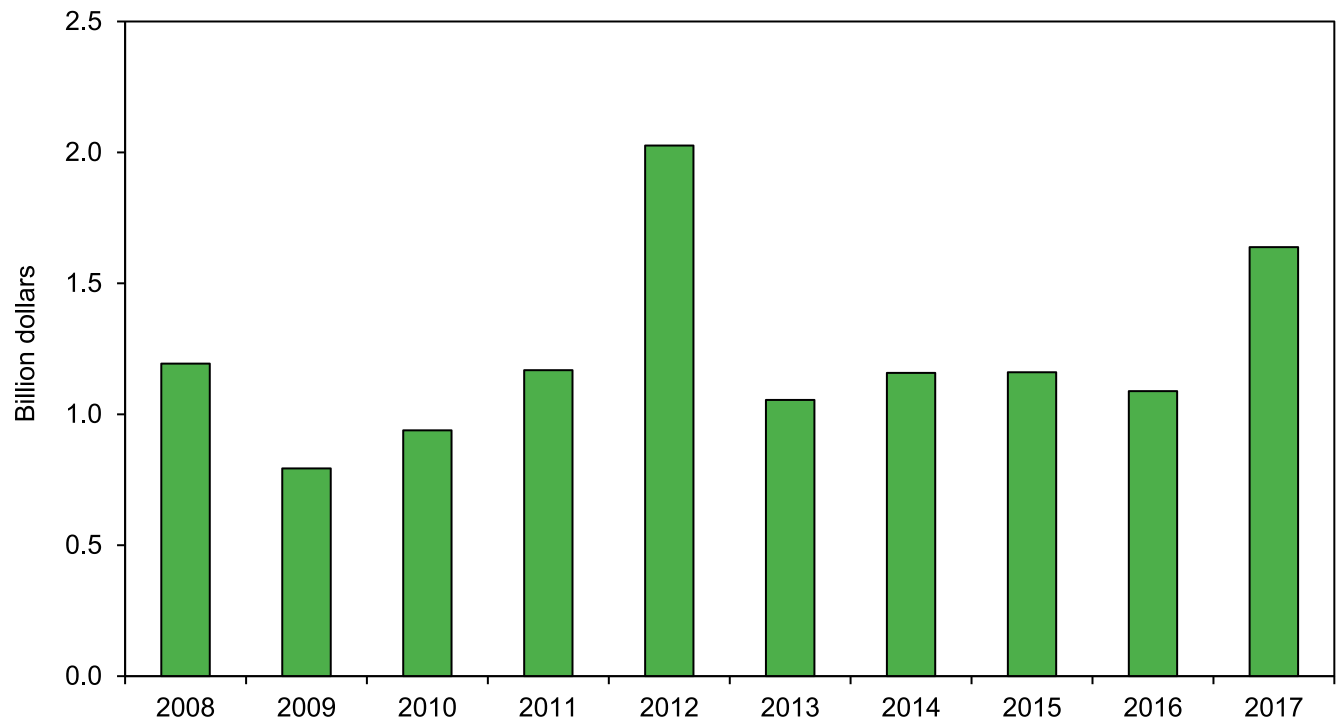

Figure 1.8.4. Total production of peanuts in the United States from 2008 to 2017 (in billion dollars) (3).

State production of peanuts is a function of acres planted within the state; as a consequence, the geographical trends of peanuts production are the same as those analyzed in the Land Use section (Figure 1.8.5 and Table 1.8.2).

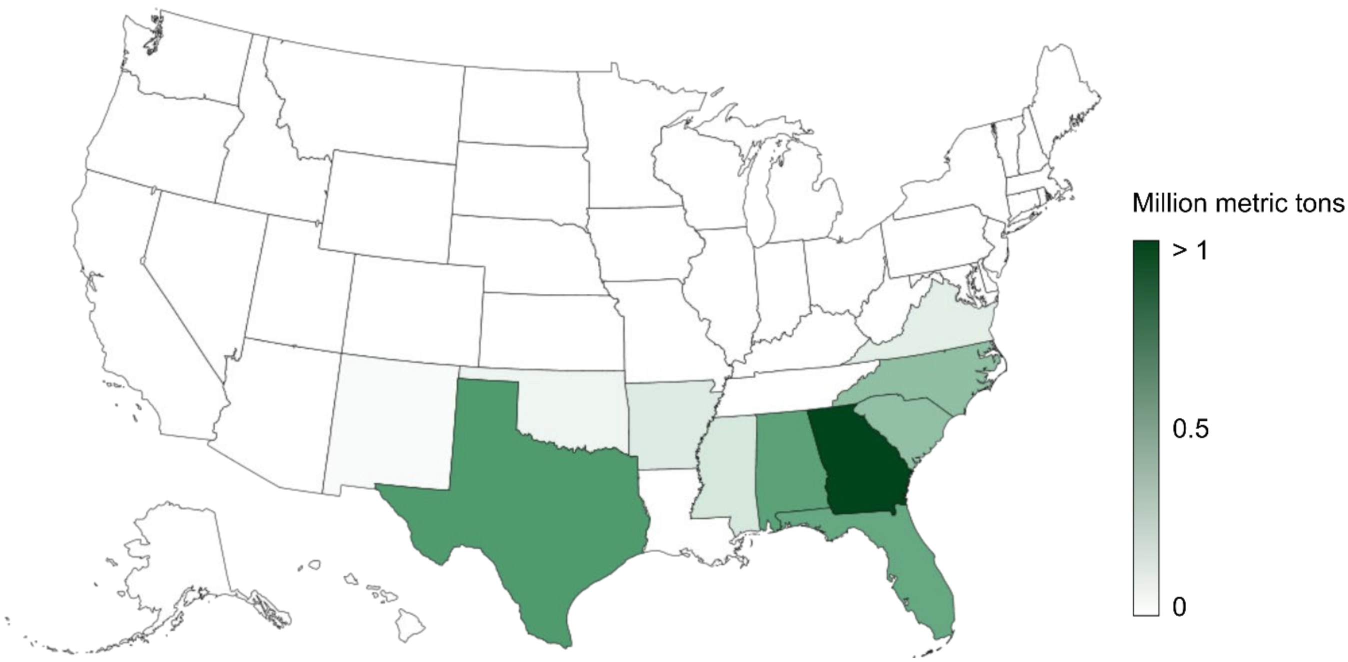

Figure 1.8.5. Total production of peanuts in the United States by state in 2017 (in million metric tons) (4).

State	Million metric tons	Percentage
Georgia	1.64	50.0
Texas	0.34	10.5
Alabama	0.32	9.7
Florida	0.30	9.1
North Carolina	0.22	6.6

Table 1.8.2. 5 states with highest production of peanuts in the United States in 2017 (in million metric tons) (4).

As with cotton, exports of peanuts are small in comparison with other crops. Although the exports are very small, they have shown a positive trend; increasing from 340,000 metric tons in 2008 to 602,000 metric tons in 2017. In 2017, Mexico was the largest market destination for United States peanuts, with about 105,000 metric tons exported, followed closely by Canada with 103,000 metric tons of peanuts exported (Figure 1.8.6).

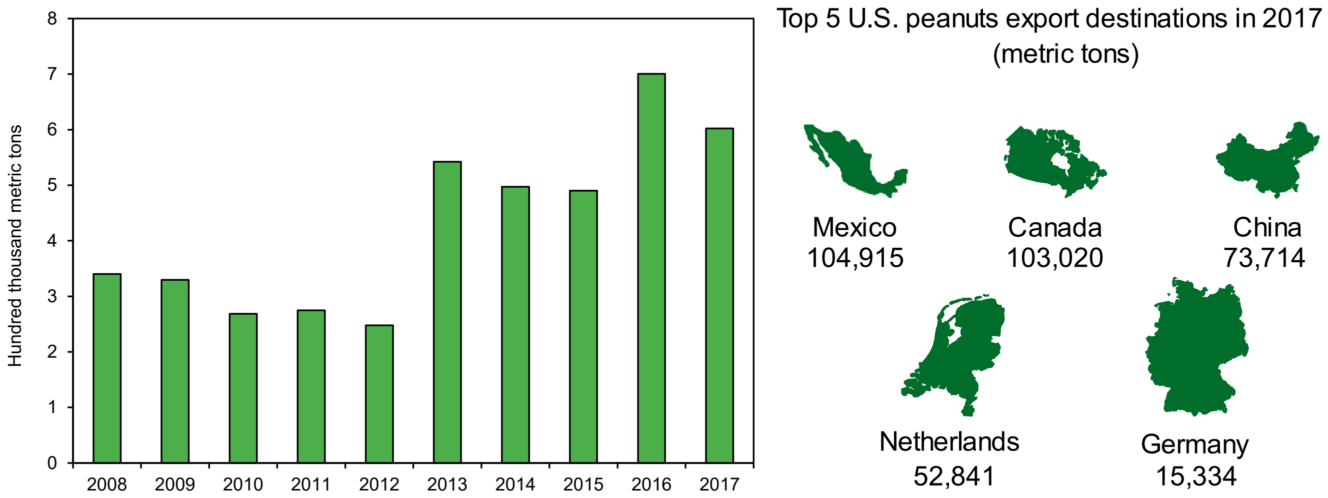

Figure 1.8.6. Exports of peanuts from the United States from 2008 to 2017 (in hundred thousand metric tons) (1) and top 5 United States export destinations in 2017 (in metric tons) (5).

Peanut imports are significantly lower than exports, typically about a tenth of the tonnage sent abroad. In 2012, there was a peak of peanuts imports of 115,200 metric tons; imports were 73,000 metric tons in 2017. Argentina and Mexico were the largest exporters to the United States with 8,000 and 5,000 metric tons, respectively (Figure 1.8.7).

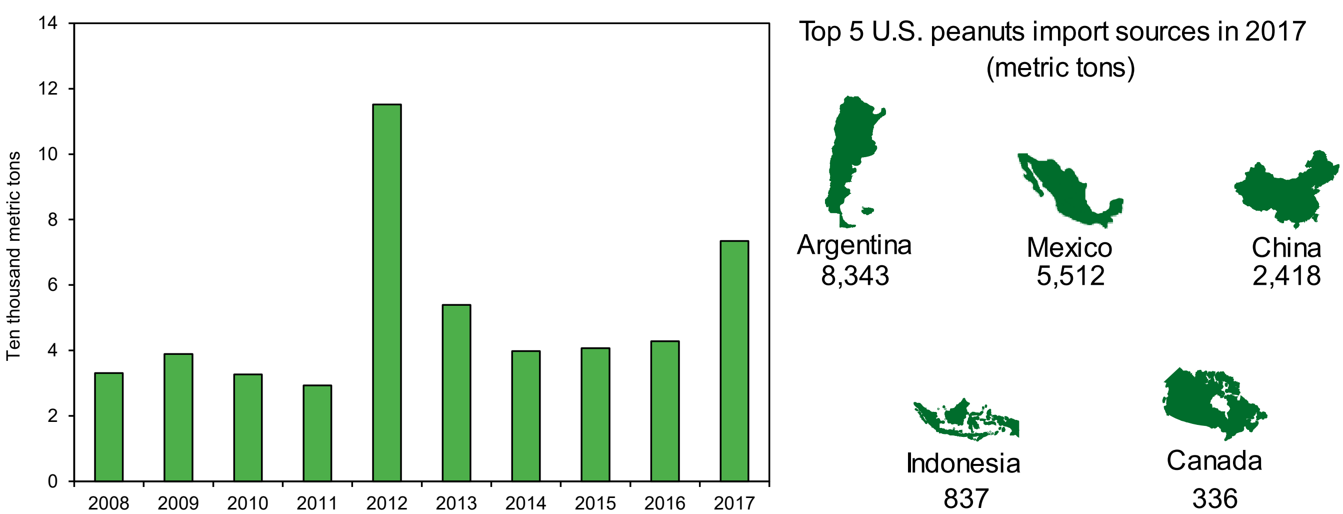

Figure 1.8.7. Imports of peanuts in the United States from 2008 to 2017 (in ten thousand metric tons) (1) and top 5 United States import sources in 2017 (in metric tons) (5).

Economics

Peanut is the most expensive of U.S. crops, and prices vary significantly year over year. The farm price of peanut in 2017 is almost the same as the price in 2008. In 2012, however, it reached its maximum with 701 dollars per metric ton (Figure 1.8.8).

Sales of peanuts by county are not available.

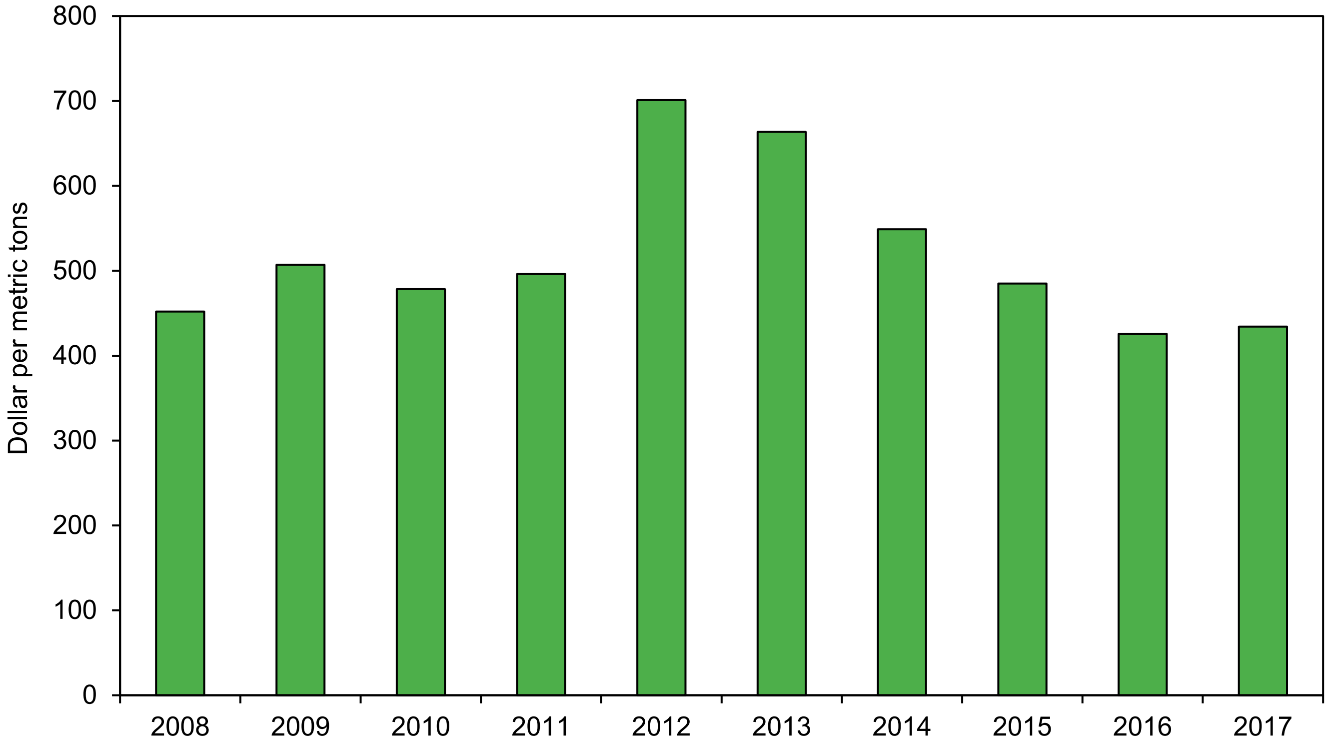

Figure 1.8.8. Farm price of peanut from 2008 to 2017 (in dollars per metric ton) (6).

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1.9. **Sunflowers**

Photo 16. (7).

Sunflowers are another U.S. lipid crop that grown in smaller quantities than other lipid crops. Production is concentrated in North Dakota and South Dakota.

The production and consumption of sunflowers are very similar, and they have not changed over the years. That implies that the United States produces and consumes sunflowers domestically.

The trade of sunflowers with international markets is very small. Although imports of sunflowers have remained almost constant over the years, exports show a downward trend.

As a general trend, the farm price of sunflowers has decreased from 2008 to 2017 by 25 percent.

In this section these trends are further analyzed according to three main categories, (1) land use, (2) production, and (3) economics.

Photo 17. (8).

Sunflower acreage was relatively small in 2008 and has trended downward since then; the number of acres planted decreased from 2.5 million acres in 2008 to 1.4 million acres in 2017 (Figure 1.9.1).

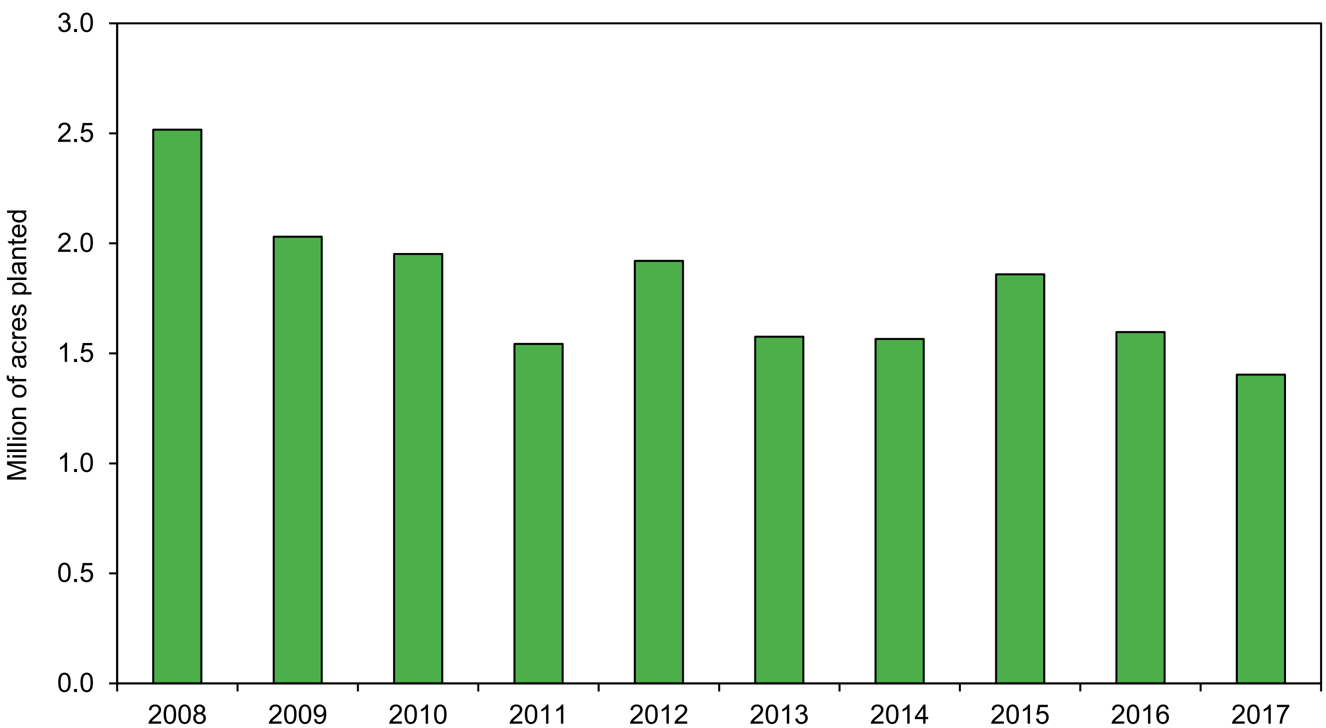

Figure 1.9.1. Acreage of sunflowers planted in the United States from 2008 to 2016 (in million acres) (1).

Sunflower acreage is not only very small but also very concentrated. Two states, South Dakota and North Dakota, account for 75 percent of sunflower acreage (Figure 1.9.2).

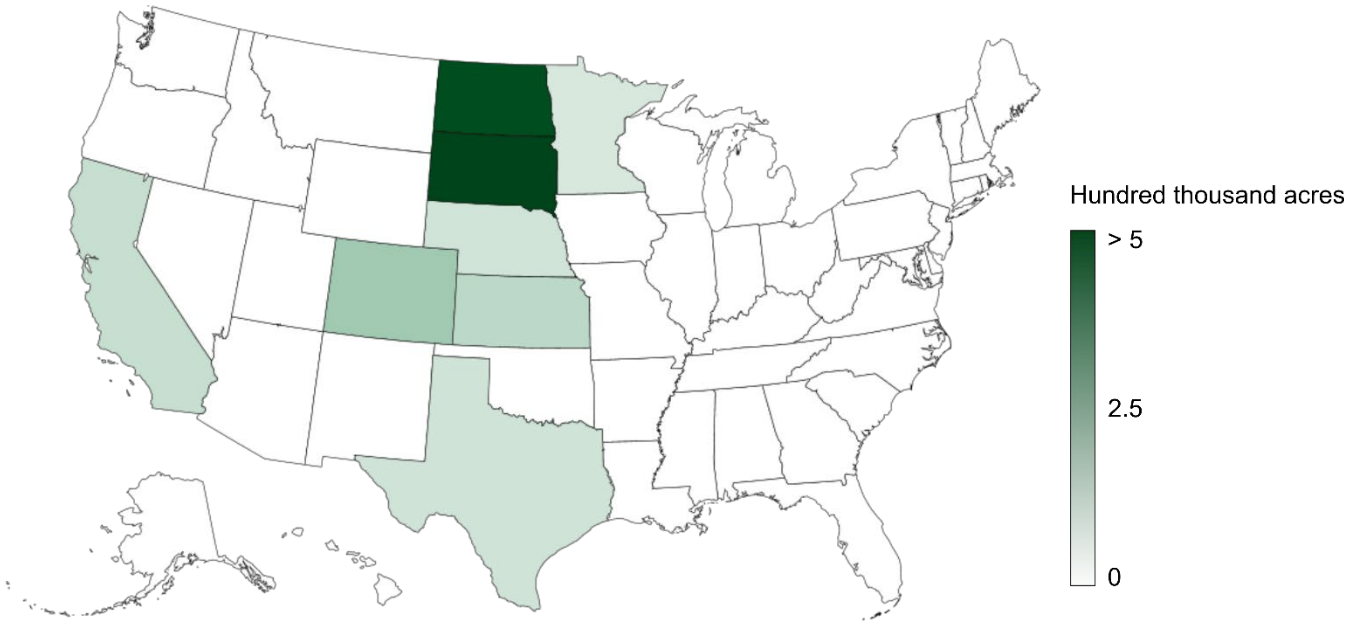

Figure 1.9.2. Total acreage of sunflowers in the United States by state in 2017 (in hundred thousand acres) (2).

State	Hundred thousand acres	Percentage
South Dakota	6.2	44.3
North Dakota	4.4	31.2
Colorado	0.9	6.6
Kansas	0.7	4.7
California	0.6	3.9

Table 1.9.1. 5 states with largest acreage of sunflowers in the United States in 2017 (in hundred thousand acres) (2).

Production

Production and consumption of sunflowers are very similar, which means that the United States produces and consumes most of its sunflowers domestically (Figure 1.9.3).

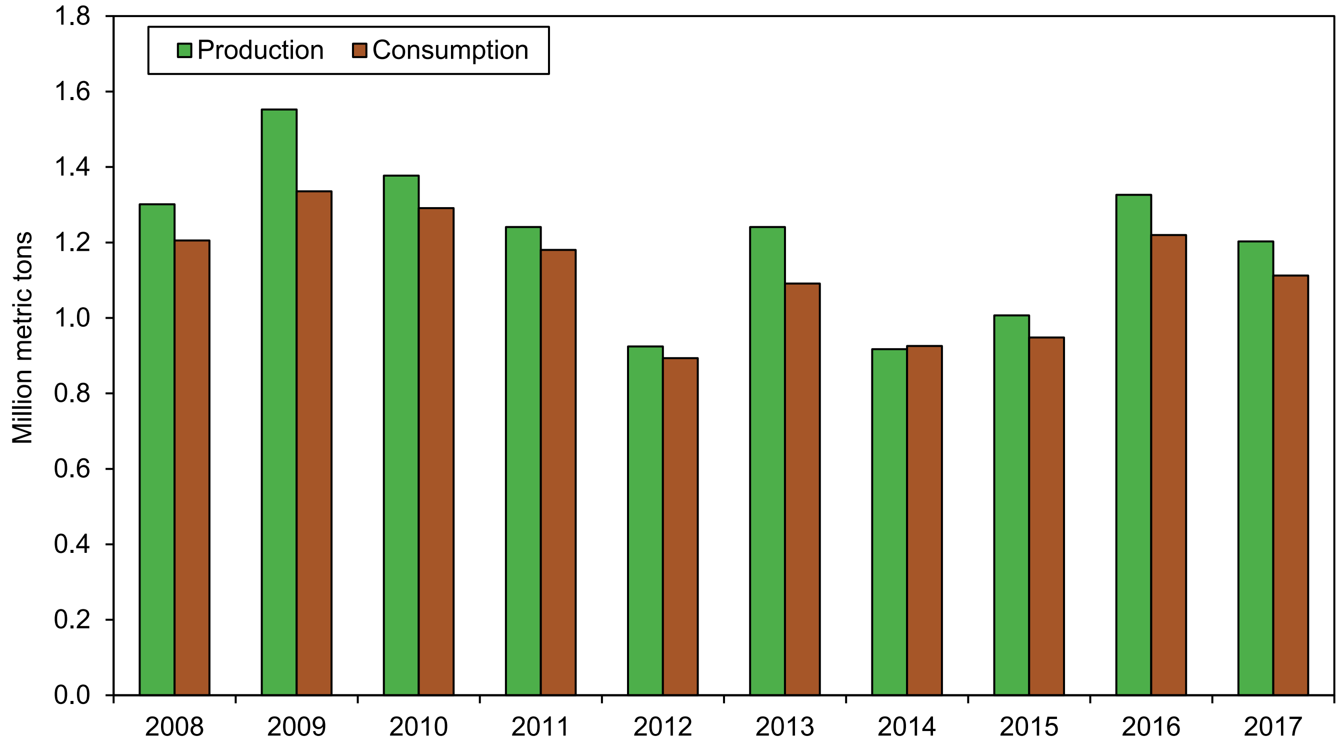

Figure 1.9.3. Total sunflower production versus total sunflower consumption in the United States from 2008 to 2017 (in million metric tons) (1).

Earnings from sunflowers varied between 389 million and 704 million dollars between 2008 and 2017 (Figure 1.9.4).

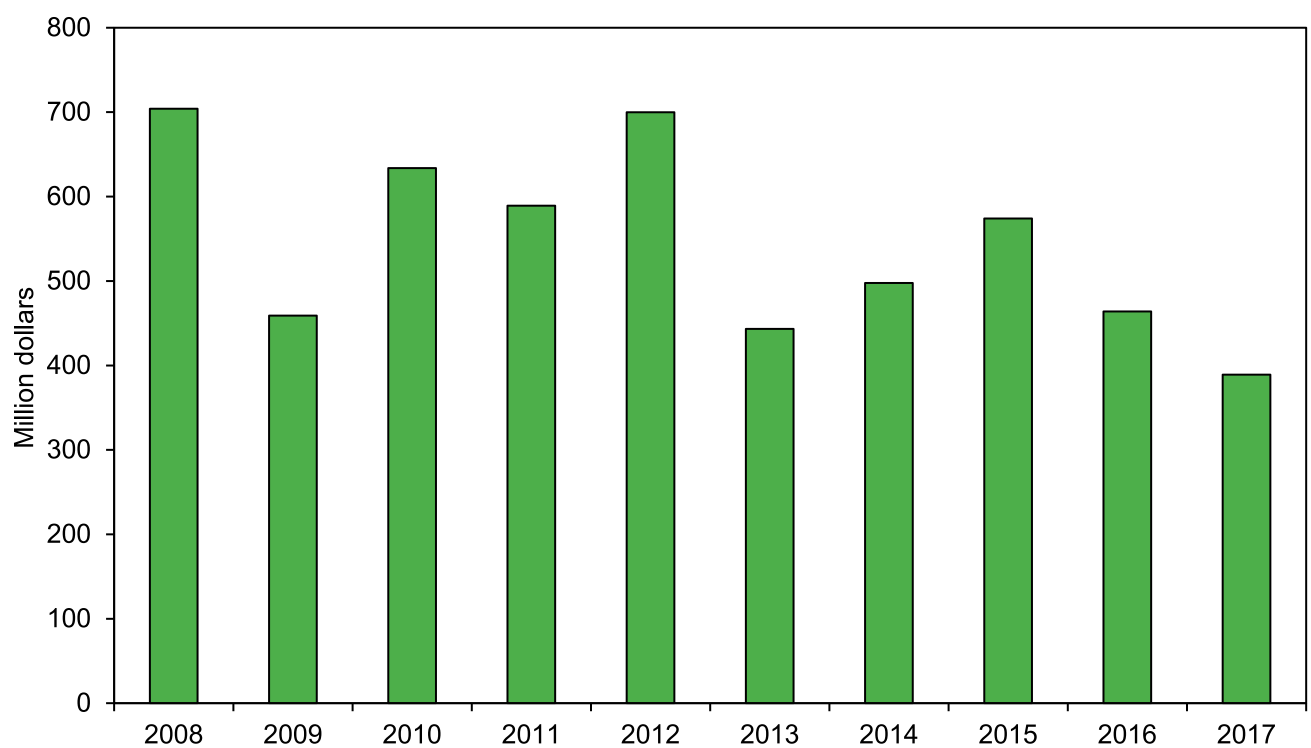

Figure 1.9.4. Total production of sunflowers in the United States from 2008 to 2017 (in million dollars) (3).

Like peanut farmers, sunflower growers earned relatively high revenues in 2012 and increased production in 2013 (Figure 1.9.4).

Production of sunflowers by state largely mirrors acreage by state; as a consequence, the geographical trends of sunflower production are the same as those analyzed in the Land Use section (Figure 1.9.5 and Table 1.9.2).

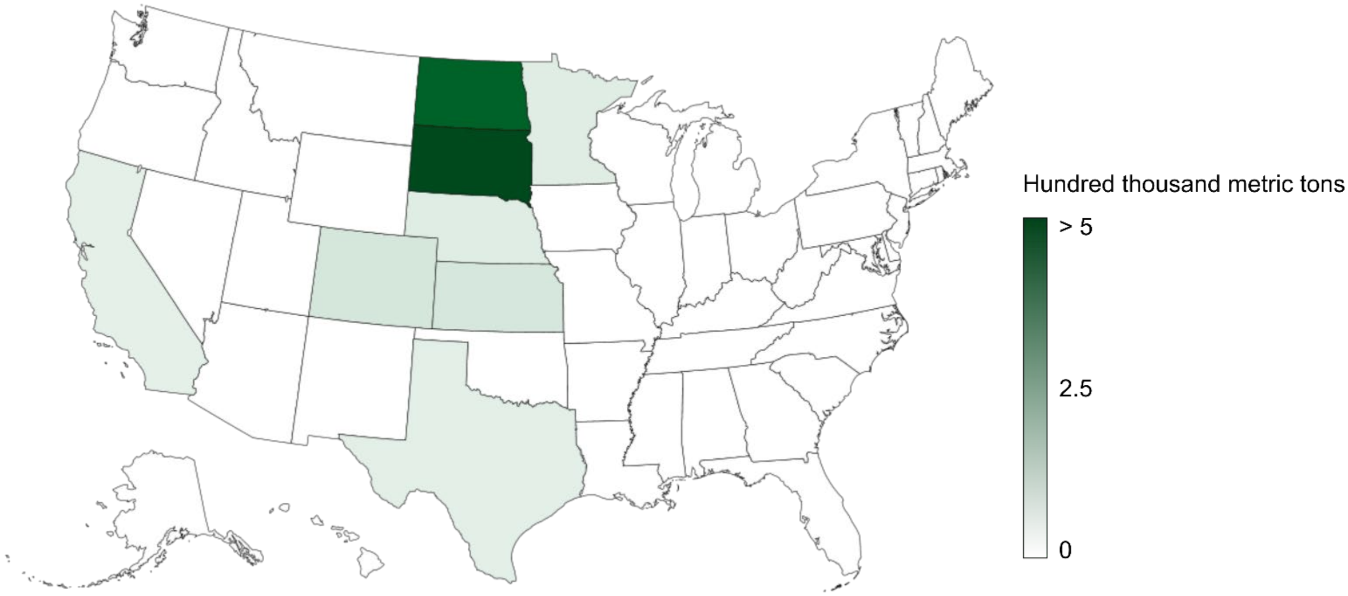

Figure 1.9.5. Total production of sunflowers in the United States by state in 2017 (in hundred thousand metric tons) (4).

State	Hundred thousand metric tons	Percentage
North Dakota	4.7	47.9
South Dakota	3.2	32.1
Colorado	0.4	4.2
Kansas	0.4	4.1
Nebraska	0.3	3.2

Table 1.9.2. 5 states with highest production of sunflowers in the United States in 2017 (in hundred thousand metric tons) (4).

Exports of sunflowers are very small in comparison with corn or soy. Exports have also shown a downward trend, decreasing from 200 thousand metric tons in 2008 to 90 thousand metric tons in 2017. In 2017, Mexico was the largest market destination for United States sunflowers, followed closely by Spain with 23,000 and 20,000 metric tons of sunflowers exported, respectively (Figure 1.9.6).

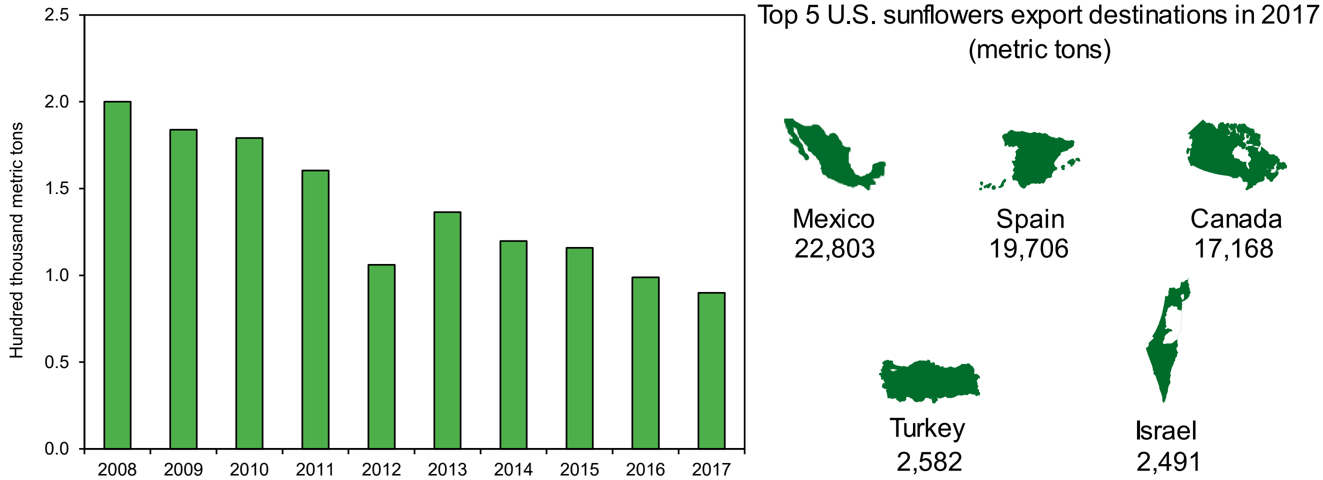

Figure 1.9.6. Exports of sunflowers in the United States from 2008 to 2017 (in hundred thousand metric tons) (1) and top 5 United States export destinations in 2017 (in metric tons) (5).

Imports of sunflowers are even smaller than exports. Exports reached a minimum in 2011 at 41 thousand metric tons and nearly doubled by the end of 2017. In 2017, Bulgaria was the largest exporter to the United States, followed closely by Canada (Figure 1.9.7).

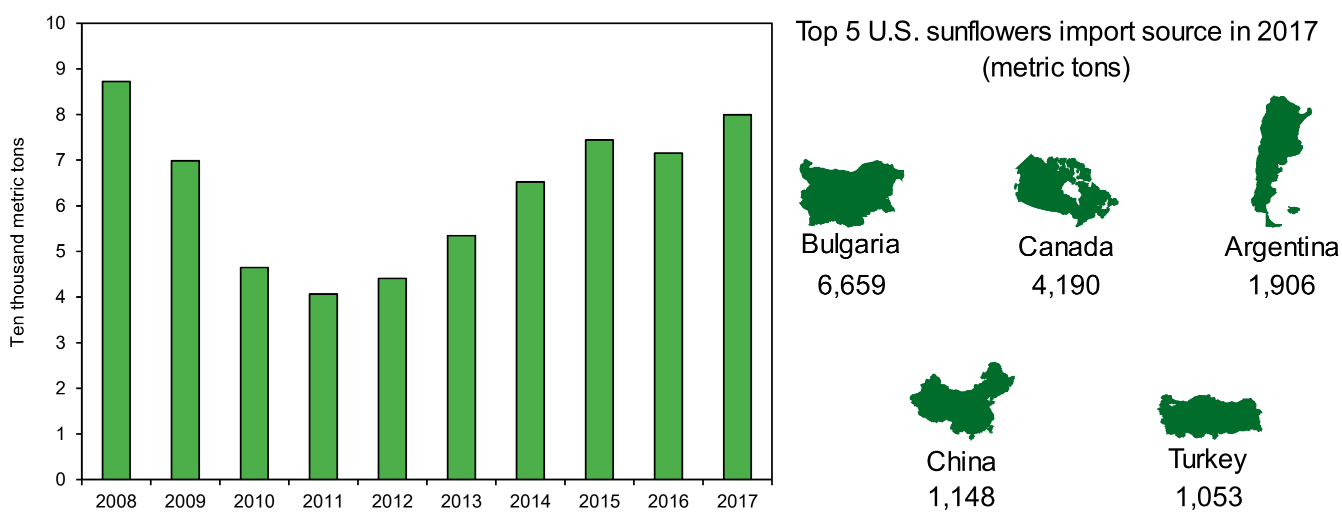

Figure 1.9.7. Imports of sunflowers in the United States from 2008 to 2017 (in ten thousand metric tons) (1) and top 5 United States import sources in 2017 (in metric tons) (5).

Economics

The price of sunflowers decreased in 2010 from the previous years, reaching a minimum of 297 dollars per metric ton. After that, the price increased to a value of 342 dollars per metric ton in 2017 (Figure 1.9.8).

Sales of sunflowers by county are not available.

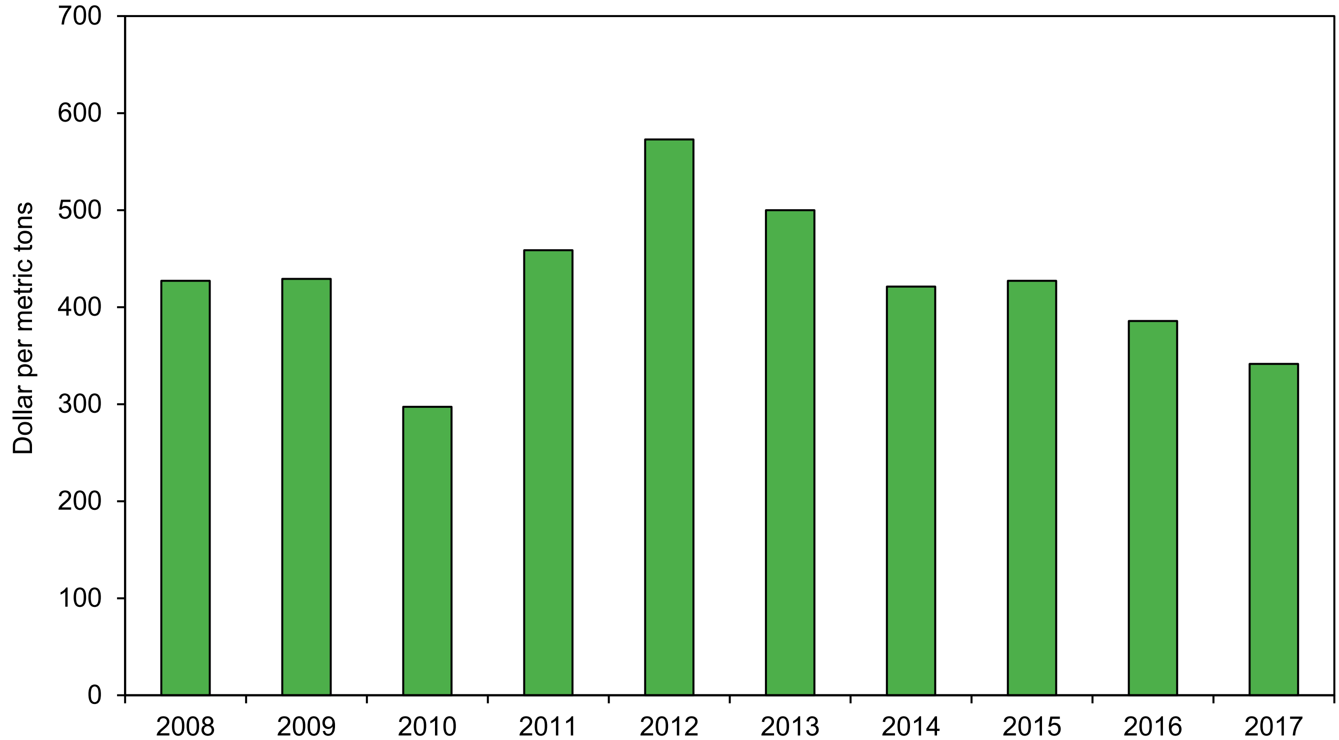

Figure 1.9.8. Farm price of sunflowers from 2008 to 2017 (in dollars per metric ton) (6).

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1.10. Canola

Photo 18. (10).

Canola is a plant between 3 to 5 feet tall and it is cultivated mostly for its oil rich seeds. Canola oil is commonly used in cooking, as an ingredient in soaps and to produce biodiesel (1).

Canola is the most concentrated crop by state, with more than 75 percent planted in North Dakota.

The consumption and production of canola is very small in comparison to other oilseeds. U.S. consumption is greater than production, which means that the United States is a net importer of canola. The production of biodiesel might explain this trend, since canola is used as a feedstock.

Canola oil, along with corn and soy, is used for biodiesel production; 13 percent of biodiesel was produced from canola oil in 2017.

The price of canola varies year-on-year and does not appear related to production levels. That most of canola used in the United States is imported might explain this, since local canola must compete with international markets.

In this section these trends are further analyzed according to four main categories, (1) land use, (2) production, and (3) economics.

Photo 19. (11).

Although the number of canola acres is small in relation to other oilseeds, it has increased from 1.2 million acres to 1.7 million acres in 10 years (Figure 1.10.1).

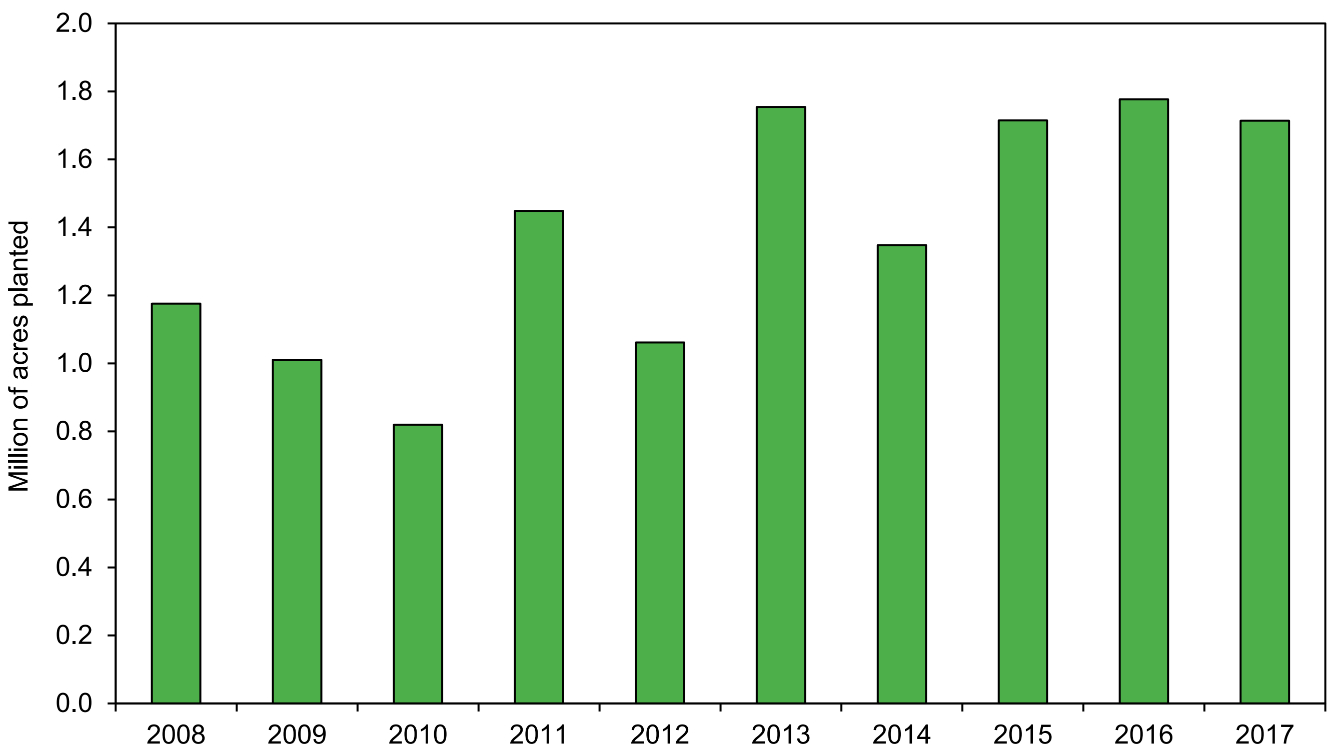

Figure 1.10.1. Acreage of canola planted in the United States from 2008 to 2016 (in million acres) (2).

Canola acreage at the state level is about as concentrated peanuts and sunflowers; 77 percent of canola is planted in just one state, North Dakota (Figure 1.10.2 and Table 1.10.1).

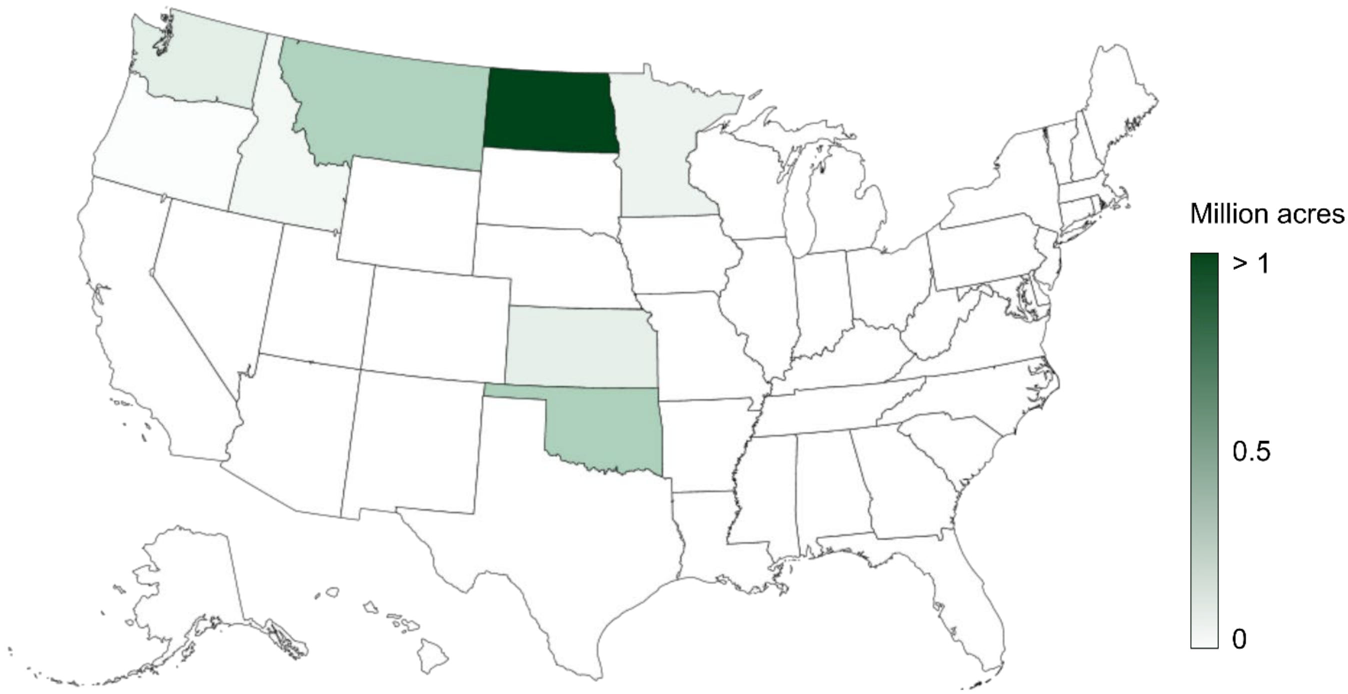

Figure 1.10.2. Total acreage of canola in the United States by state in 2017 (in million acres) (3).

State	Million Acres	Percentage
North Dakota	1.59	76.6
Oklahoma	0.16	7.7
Montana	0.16	7.5
Washington	0.06	2.6
Kansas	0.05	2.4

Table 1.10.1. 5 states with largest acreage of canola in the United States in 2017 (in million acres) (3).

Production

Consumption and production of canola are much smaller than soy or corn. However, both consumption and production have about doubled since 2008. The consumption of canola is consistently larger than the production, which means that the United States is a net importer (Figure 1.10.3). Canola is used as a feedstock for biodiesel production; biodiesel production growth is one factor in the growth of canola consumption.

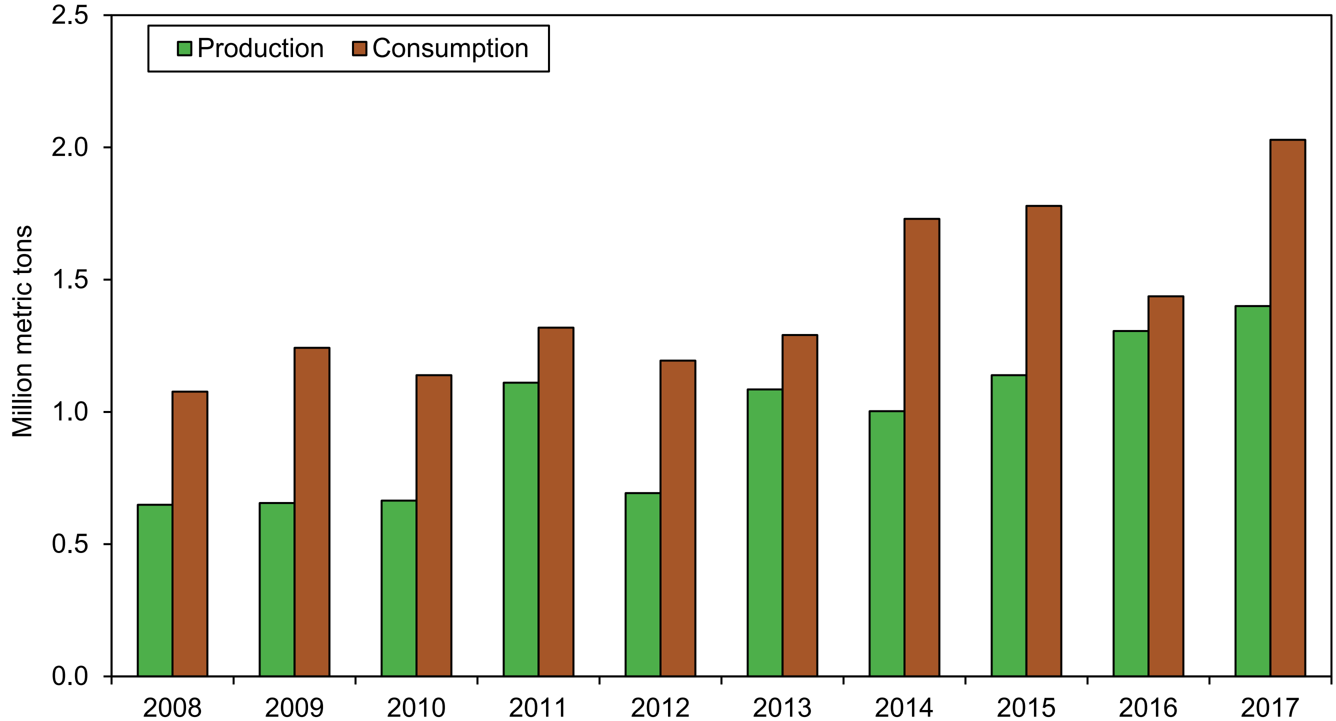

Figure 1.10.3. Total canola production versus total canola consumption in the United States from 2008 to 2017 (in million metric tons) (2).

As seen with other crops, farm earnings from canola are correlated with the crop price, so 2012 was the year with the highest canola price and with more earnings from canola (Figure 1.10.4).

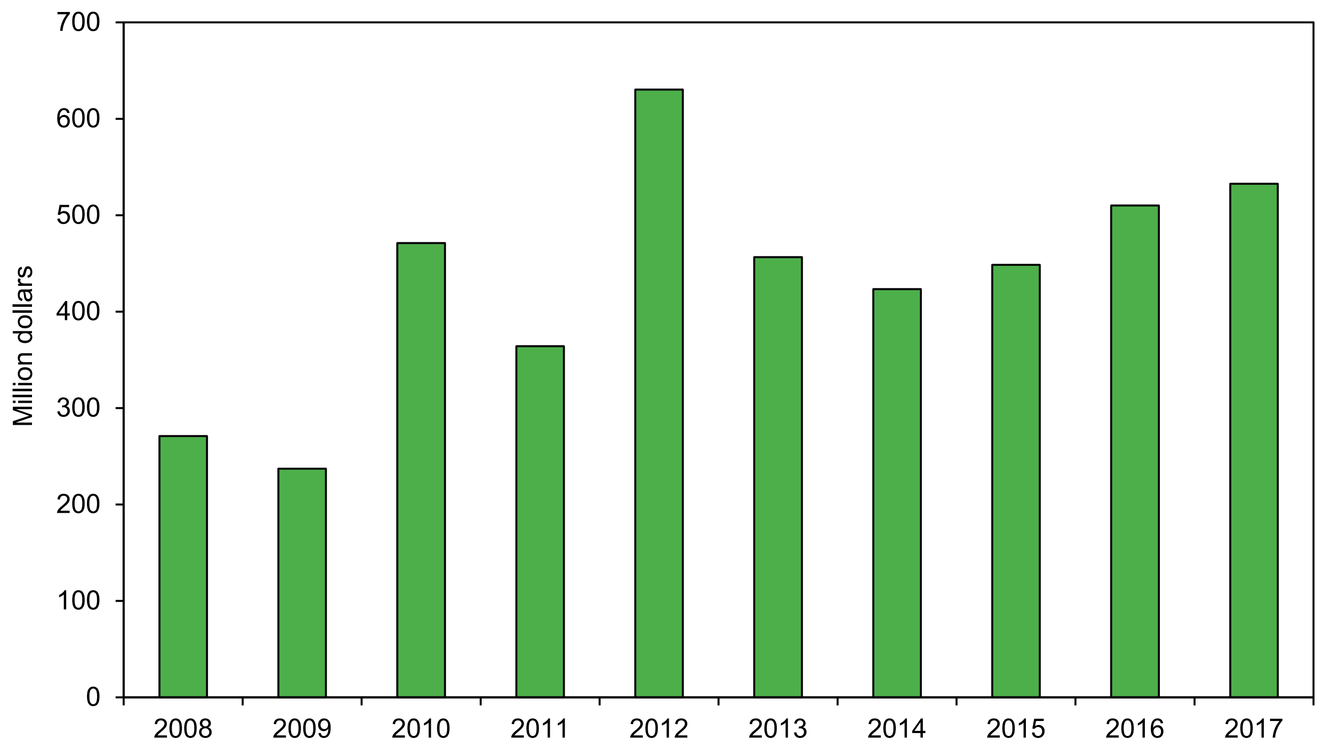

Figure 1.10.4. Total production of canola in the United States from 2008 to 2017 (in million dollars) (4).

Canola production by state is highly correlated with acreage by state; as a consequence, the geographical trends of canola production are the same as those analyzed in the Land Use section (Figure 1.10.5 and table 1.10.2).

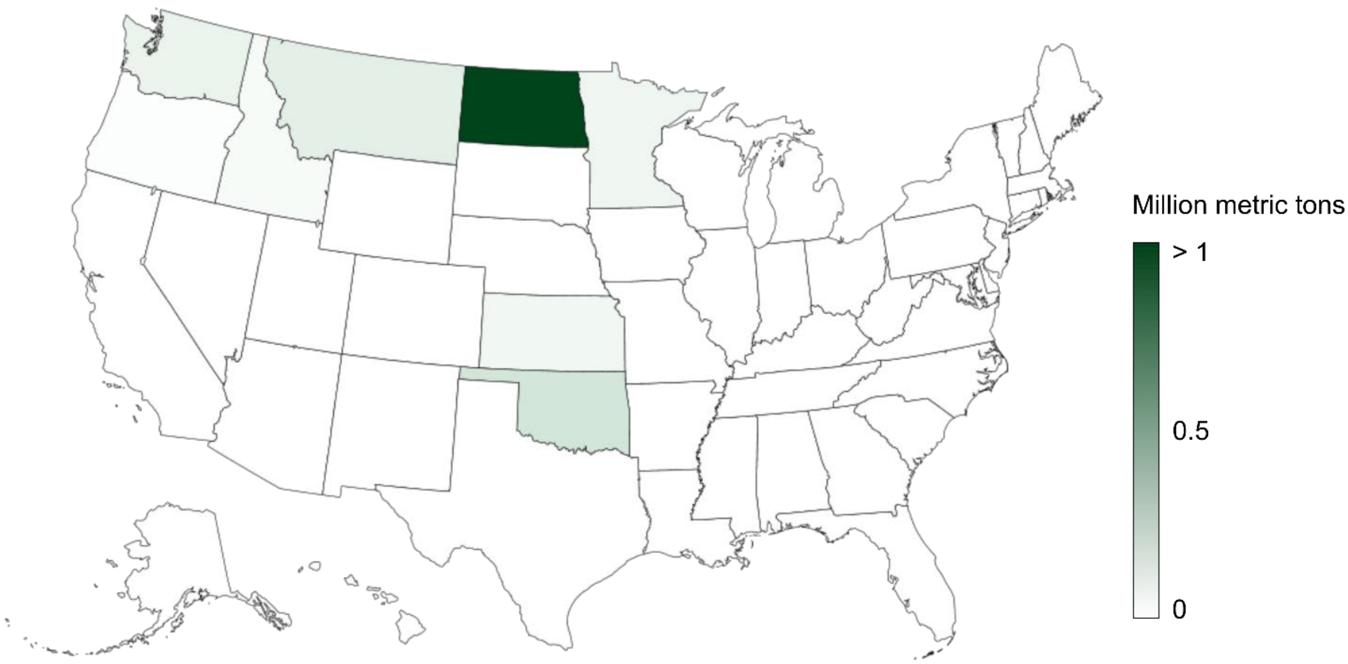

Figure 1.10.5. Total production of canola in the United States by state in 2017 (in million metric tons) (5).

State	Million metric tons	Percentage
North Dakota	1.15	81.5
Oklahoma	0.09	6.2
Montana	0.05	3.8
Washington	0.04	2.8
Minnesota	0.03	2.3

Table 1.10.2. 5 states with highest production of canola in the United States in 2017 (in million metric tons) (5).

Canola oil, along with corn and soy, is one of the vegetable oils used for biodiesel production.
According to the Energy Information Administration, 13 percent of biodiesel was produced from canola oil (6). The amount of canola oil used for biodiesel production is very small in comparison with soybean oil. Despite that, 22 percent of total canola oil produced in 2017 was used for biofuels production, compared with just 7 percent in 2010 (Figure 1.10.6).

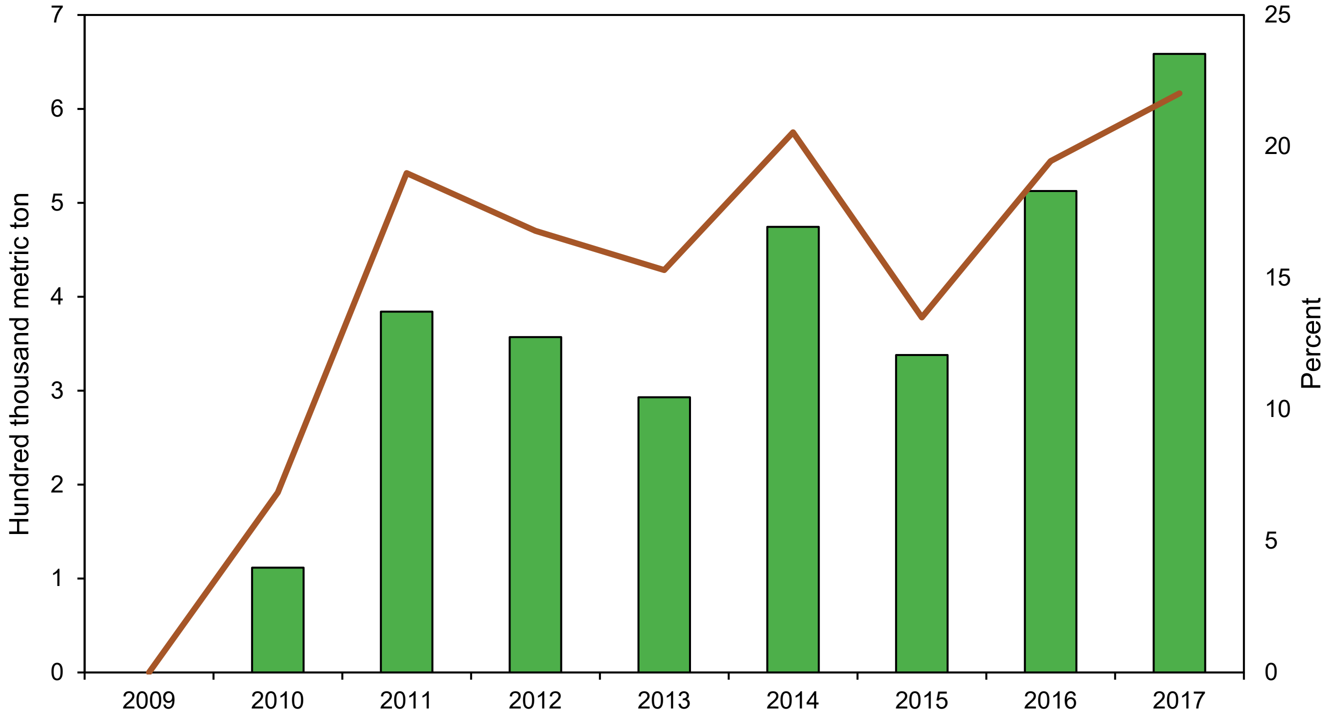

Figure 1.10.6. The bars represent the amount of canola oil processed into biodiesel in United States from 2009 to 2017 (in hundred thousand metric tons) (left axis) and the line the percentage of total canola oil production being devoted to biodiesel from 2009 to 2017 (in percentage) (right axis) (7, 8).

Although canola production is relatively small in the United States, the imports of canola are similar to soy imports and slightly lower than corn imports (see Figure 1.2.8 and Figure 1.6.7).

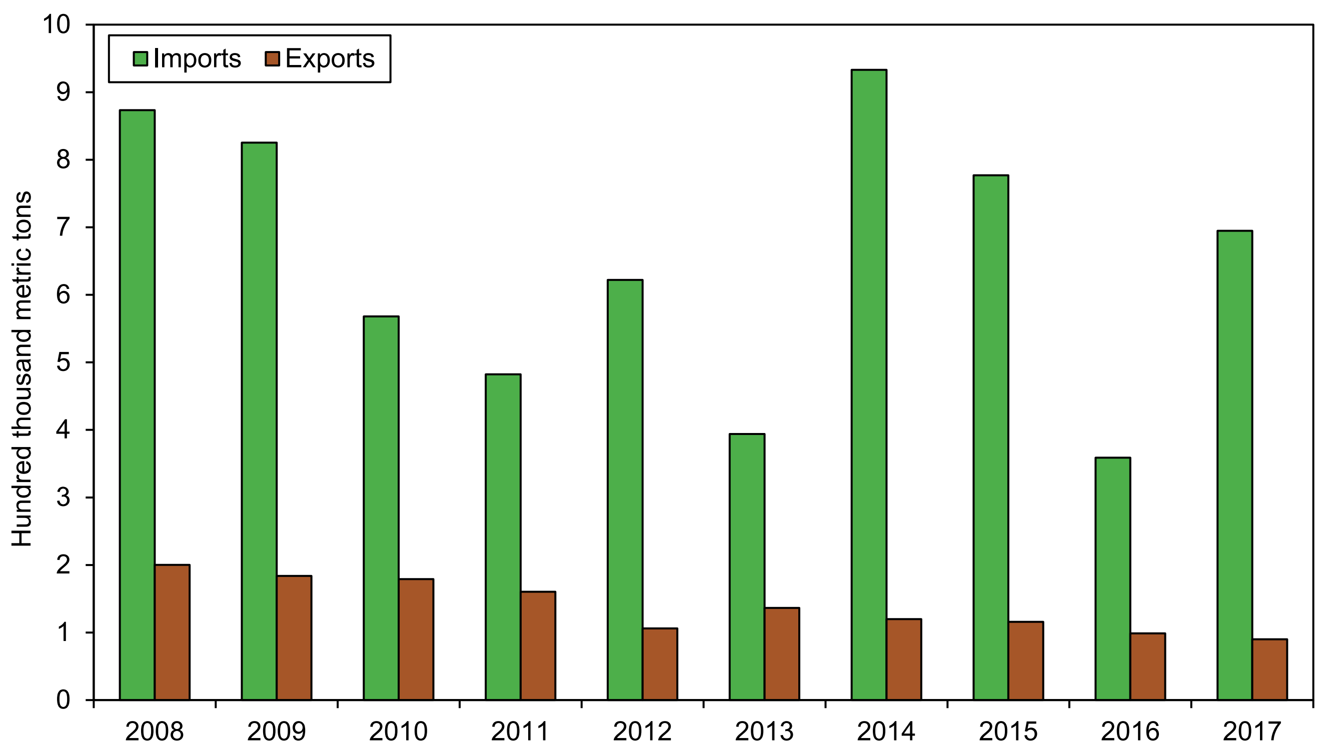

Figure 1.10.7. Total canola exports versus total canola imports in the United States from 2008 to 2017 (in hundred thousand metric tons) (2).

Economics

The price of canola has fluctuated over the years, and it does not correlate well to production. Since canola imports are a significant portion of consumption, factors in other producing nations likely influence the price. The price of canola oil in 2017, at 327 dollars per metric ton, was slightly below the price in 2008, which was 360 dollars per metric ton (Figure 1.10.8).

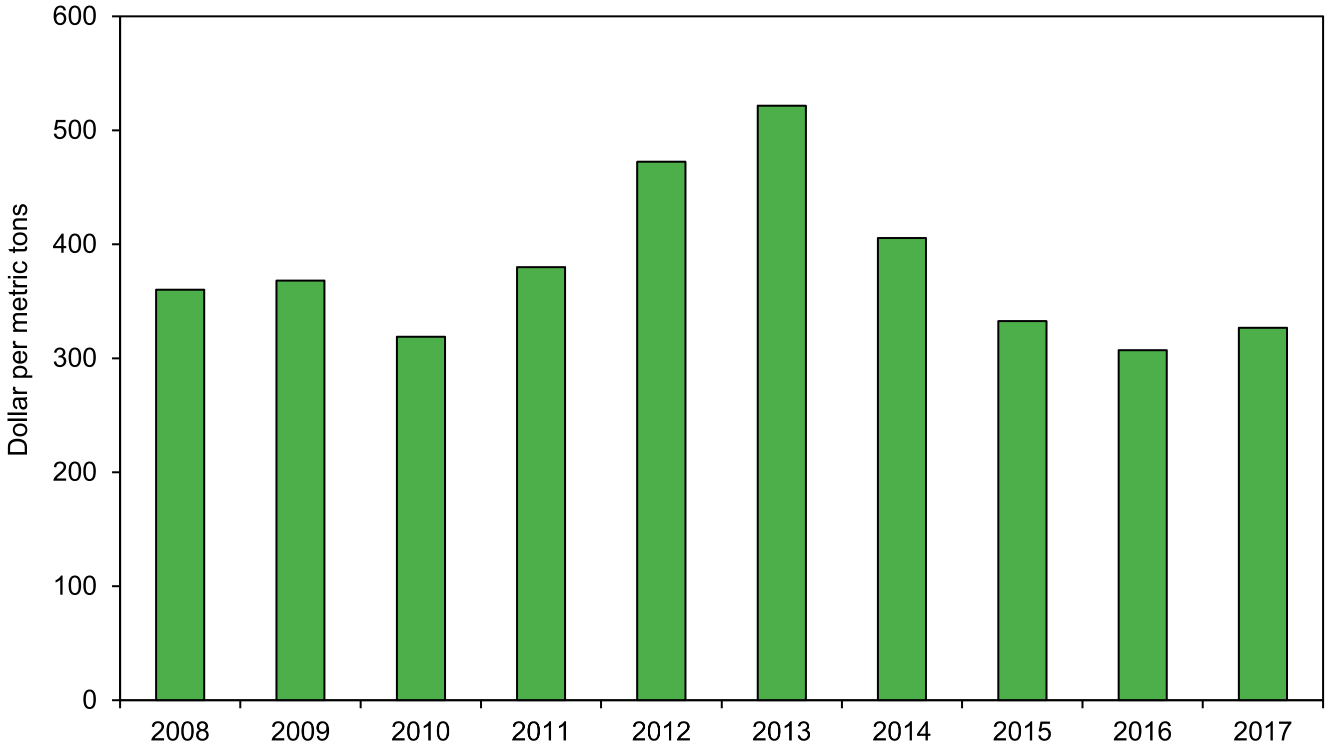

Figure 1.10.8. Farm price of canola from 2008 to 2017 (in dollars per metric ton) (9).

Sales of canola by county are not available.

The value of canola oil used for biodiesel jumped in 2011, from 100 million dollars in the prior year to 500 million dollars. From 2012 through 2016, the value of canola oil for biodiesel was below the 2011 level. In 2017 however, the value of canola oil for biodiesel was 560 million dollars (Figure 1.10.9)

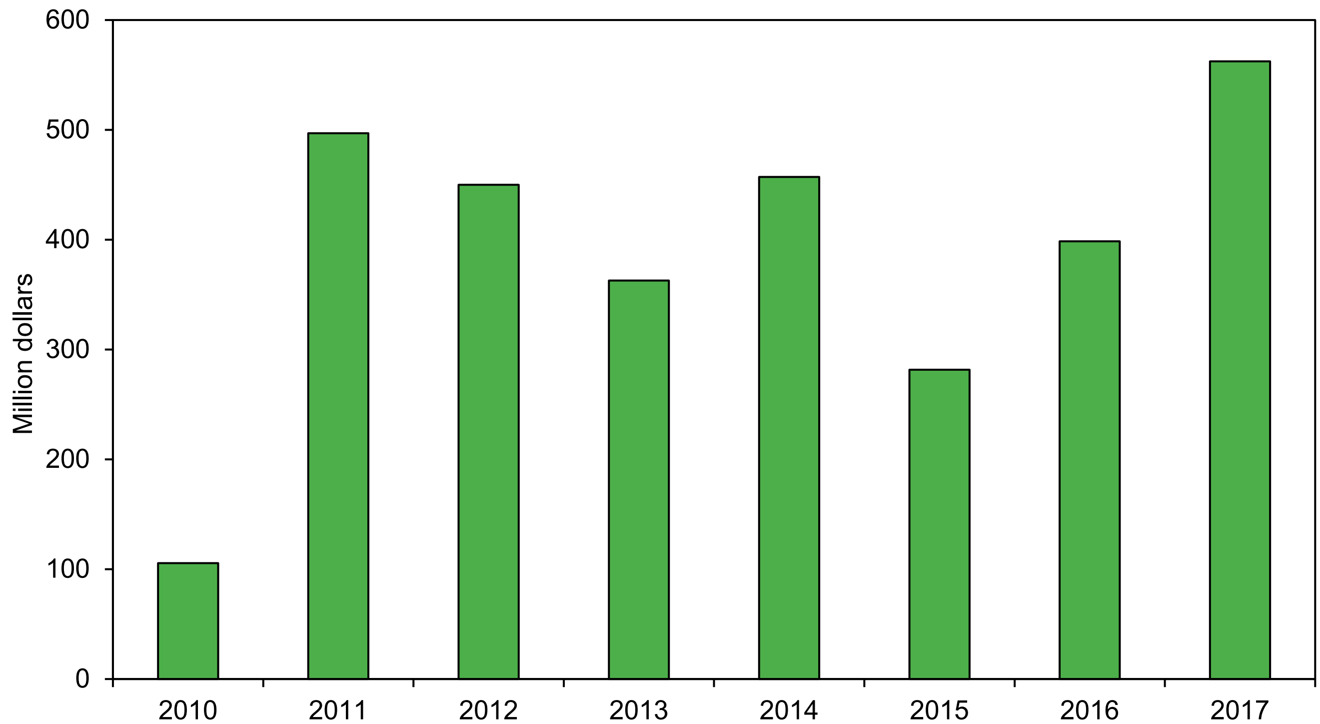

Figure 1.10.9. Economic value of canola oil used for biodiesel from 2010 to 2017 (in million dollars) (8, 9).

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2. BIOENERGY INDICATORS

2.1. Summary

Number of bioenergy facilities in the U.S. ↑ 2.1%

TOP 5 TYPES OF BIOENERGY PLANTS

2014 2,829 Plants	2017 2,889 plants
Biogas [2,306]	Biogas [2,367]
Ethanol [214]	Ethanol [209]
Wood Pellets [137]	Wood Pellets [148]
Biodiesel [94]	Biodiesel [95]
Waste to energy [78]	Waste to energy [70]

Total energy consumed in the U.S. from bioenergy sources in 2017 ↓ 0.2%

TOP 5 BIOENERGY SOURCES

2016 4,257 Trillion BTUs	2017 4,249 Trillion BTUs
Wood Pellets [2,131]	Biogas [2,367]
Ethanol [1,216]	Ethanol [209]
Waste to energy [503]	Wood Pellets [148]
Biodiesel [266]	Biodiesel [95]
Biogas [141]	Waste to energy [70]

ETHANOL

	Exports	Imports	Direct Jobs
Change	↑ 17.8%	↑ 111.6%	↑ 5.4%
2016	1.2 B GALLONS	36 M GALLONS	339,176
2017	1.4 B GALLONS	76 M GALLONS	357,493

BIODIESEL

Exports ↑ 5.7%

2016: 88 M GALLONS VS 2017: 93 M GALLONS

Imports ↑ 44.5%

2016: 709 B GALLONS VS 2017: 394 B GALLONS

Direct Jobs ↑ 4.2%

2015: 49,486 VS 2016: 47,400

WOOD PELLETS

Exports ↑ 28.2%

2016: 4.1 MMT VS 2017: 5.2 MMT

Imports ↑ 3.3%

2016: 0.20 MMT VS 2017: 0.21 MMT

Direct Jobs ↑ 0.8%

2015: 23,416 VS 2016: 23,596

2.2. Ethanol

Photo 20. (20).

Ethanol is a renewable fuel derived from various plant materials, collectively known as biomass (e.g., sugar, starches, cellulosic materials). Figure 2.2.1 shows that nearly all ethanol (98 percent) in the United States is derived from starchy feedstocks (1-8). Corn is the leading crop used as a feedstock for domestic ethanol production (9).

Although cellulosic ethanol represents 2 percent of the total ethanol produced in the United States, it presents several advantages over starch-based ethanol (1-8). It takes advantage of materials that otherwise would be discarded as a waste in other industries and utilizes those materials as an energy feedstock. (9).

Ethanol is a biofuel used for transportation. It can be used in several blends with gasoline. The usual blend is 10 percent ethanol and 90 percent gasoline, which is known as E10. The number after the "E" indicates the percentage of ethanol, by volume. E10 fuel does not require any special fueling equipment as all automakers approve blends up to E10 in their gasoline vehicles. Ethanol is also available as E85, also referred to as "flex fuel". E85 fuel contains between 51-to-83 percent ethanol, depending on geography and season. Flex fuel vehicles are specially designed to run on gasoline, E85, or any mixture of the two (9).

The number of ethanol plants in the United States increased during the period between 2010 and 2015, when it reached a peak of 214 plants. After that, there was a slight decrease to 209 plants in 2017 (1-7). This accounts for over 350,000 American jobs according to the Renewable Fuel Association (1-7). Most of these facilities are in the Midwest (Figures 2.2.2 and 2.2.4) (8).

Although the number of plants has been reduced, ethanol production and consumption are rising, achieving 16 billion gallons of ethanol produced and 14.4 billion gallons of ethanol consumed in the United States in 2017 (10).

In 2017 the United States was the world's leading ethanol producer, accounting for 58 percent of world production (7) and exported 1.4 billion gallons of ethanol, primarily to Brazil and Canada (11, 12). The United States imported a total of 76.6 million gallons of ethanol in 2017, most of which came from Brazil (13,14).

Infrastructure

Photo 21. (21).

The number of ethanol production facilities increased from 2010 to 2015, reaching a peak of 214 plants. In 2017, 209 ethanol production facilities existed in the United States (1-7). Nearly all ethanol plants in the United States use starch as a feedstock (Figure 2.2.1) (8).

Despite the number of facilities decreasing in recent years, there were seven ethanol facilities under construction in 2017, with an additional 11 proposed facilities (Table 2.2.1) (8).

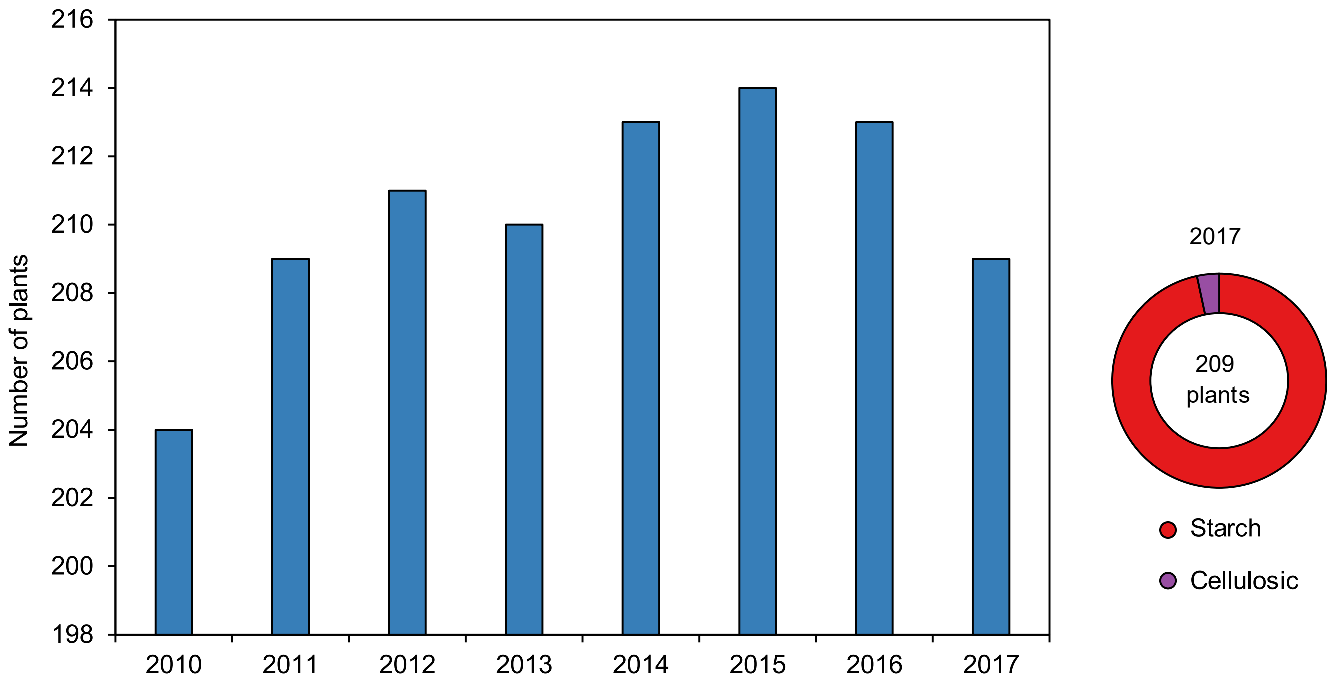

Figure 2.2.1. Total number of ethanol plants in the United States from 2010 to 2017 and the type of ethanol plant (1–8).

ETHANOL PHYSICAL INFRASTRUCTURE	2010	2011	2012	2013	2014	2015	2016	2017
# of ethanol plants in the United States	204	209	211	210	213	214	213	209
# of ethanol plants operational	-	193	194	192	198	199	200	201
# of existing plants under construction	-	-	-	7	3	3	3	7
# of proposed ethanol plants	-	-	-	-	-	-	-	11
# of states that have an ethanol production facility	29	29	29	28	29	29	28	28

Table 2.2.1. The physical infrastructure of first-generation ethanol industry facilities in the United States from 2010 to 2017 (1–7, 15).

Figure 2.2.2 shows existing ethanol production facilities in 2017. Most of the facilities are concentrated in the Midwest. Specifically, 21 percent of all existing ethanol production facilities are in Iowa, 13 percent in Nebraska, and 10 percent in Minnesota (see Table 2.2.2 for additional details) (8). Ethanol production facilities tend to be located in the states where more corn is grown (see Figure 1.2.2).

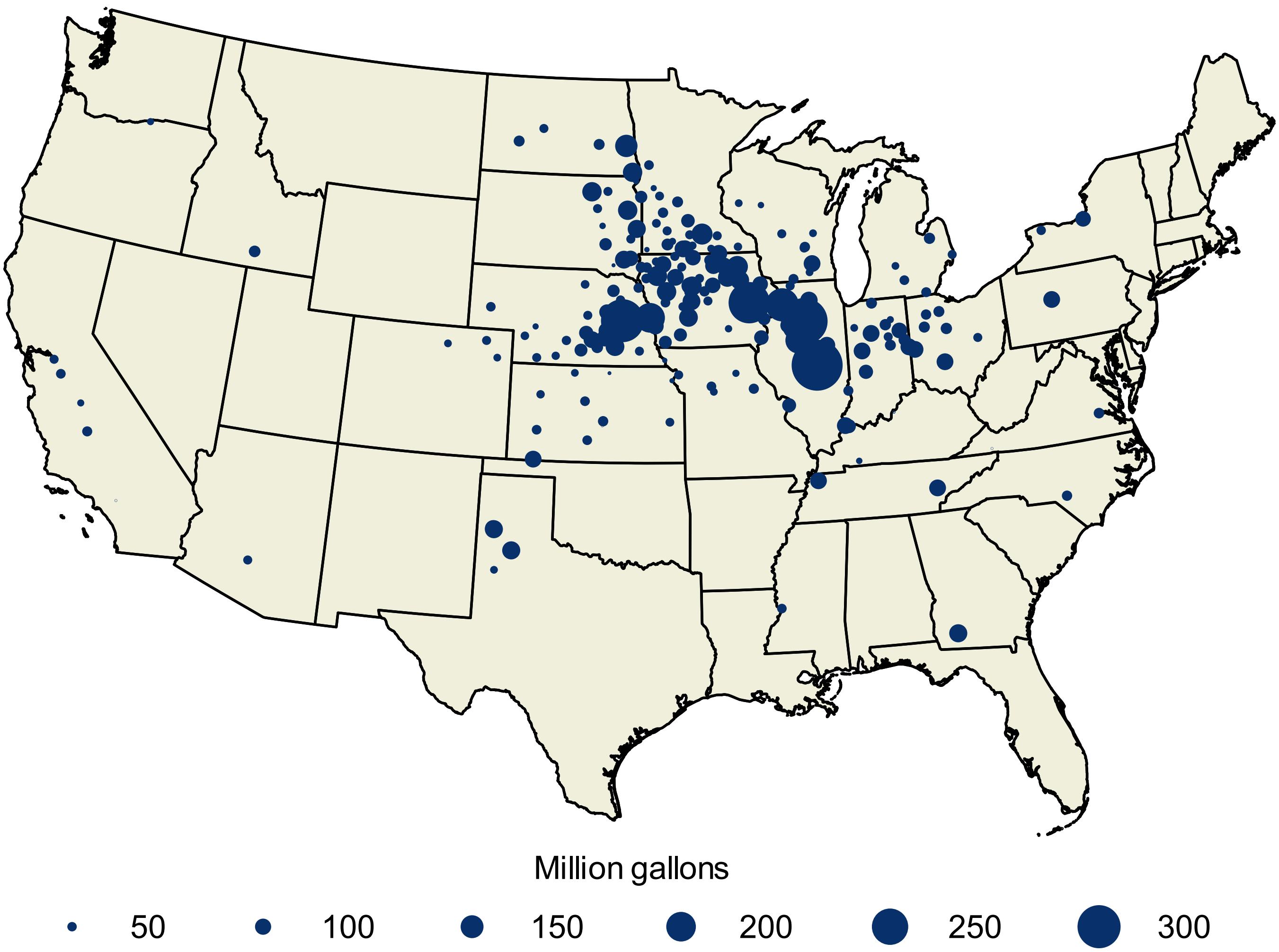

Figure 2.2.2. Ethanol production facilities in 2017 by location and capacity in the United States (in million gallons) (8).

State	Number of ethanol facilities	Percentage of total facilities
Iowa	41	20.7
Nebraska	25	12.6
Minnesota	19	9.6
South Dakota	15	7.6
Indiana	14	7.1

Table 2.2.2. Top 5 states for ethanol production facilities in the United States in 2017 (8).

Production

The United States is the world's leading ethanol producer, accounting for 58 percent of global ethanol production in 2017 (7).

Consumption and production of ethanol have grown since 2010, with 16 billion gallons of ethanol produced, and 14.4 billion gallons consumed in 2017 (10). Since 2010, the production of ethanol has been greater than the consumption, which results in the United States being a net exporter of ethanol (Figure 2.2.3).

The majority of the ethanol consumed in the United States is used within the transportation sector, as indicated in Figure 2.2.3 (10).

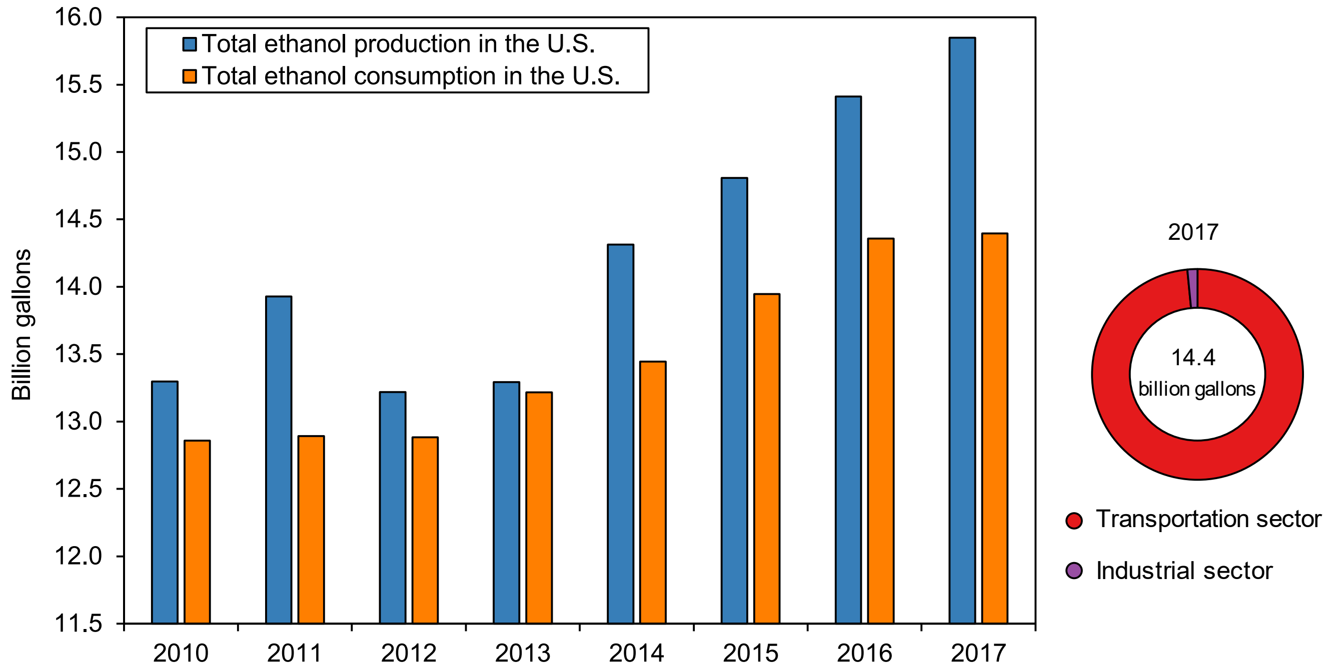

Figure 2.2.3. Total ethanol production versus total ethanol consumption in the United States from 2010 to 2017 (in billion gallons) and consumption of ethanol by sector in the United States in 2017 (10).

Almost 90 percent of total ethanol is produced in the Midwest; the top five producing states are Iowa, Nebraska, Illinois, Minnesota and Indiana (Figure 2.2.4 and Table 2.2.3) (8).

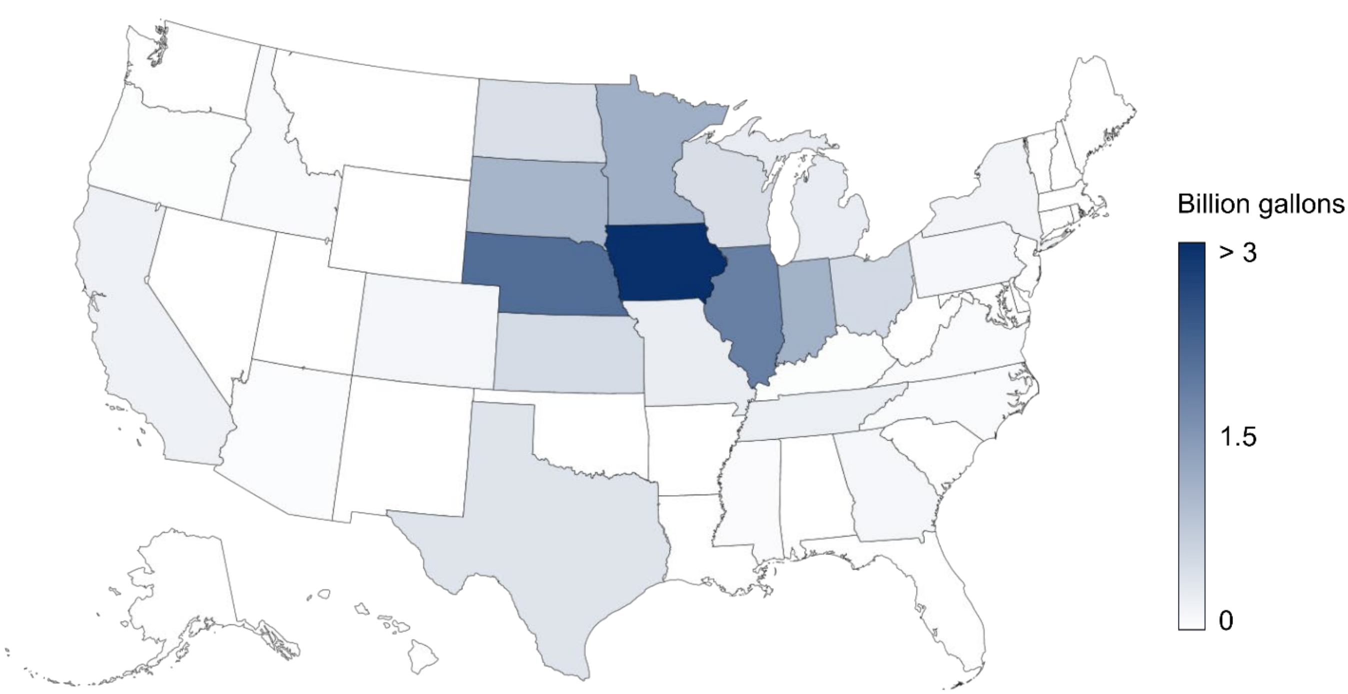

Figure 2.2.4. Total production capacity of ethanol in the United States by state in 2017 (in billion gallons) (8).

State	Billion gallons	Percentage of total U.S capacity
Iowa	4.0	25.8
Nebraska	2.1	13.6
Illinois	1.8	11.9
Minnesota	1.2	7.5
Indiana	1.1	7.2

Table 2.2.3. 5 states with the highest production capacity for ethanol in the United States in 2017 (in billion gallons) (8).

Ethanol exports correlate to domestic ethanol production (Figure 2.2.3); that is, those years with the largest domestic ethanol production are also the same years with the largest ethanol exports. In 2017, the United States exported 1.4 billion gallons, compared to 0.4 billion gallons in 2010 (11).

In 2017, Canada and Brazil were the top markets for United States ethanol exports, accounting for 56 percent of total exports.

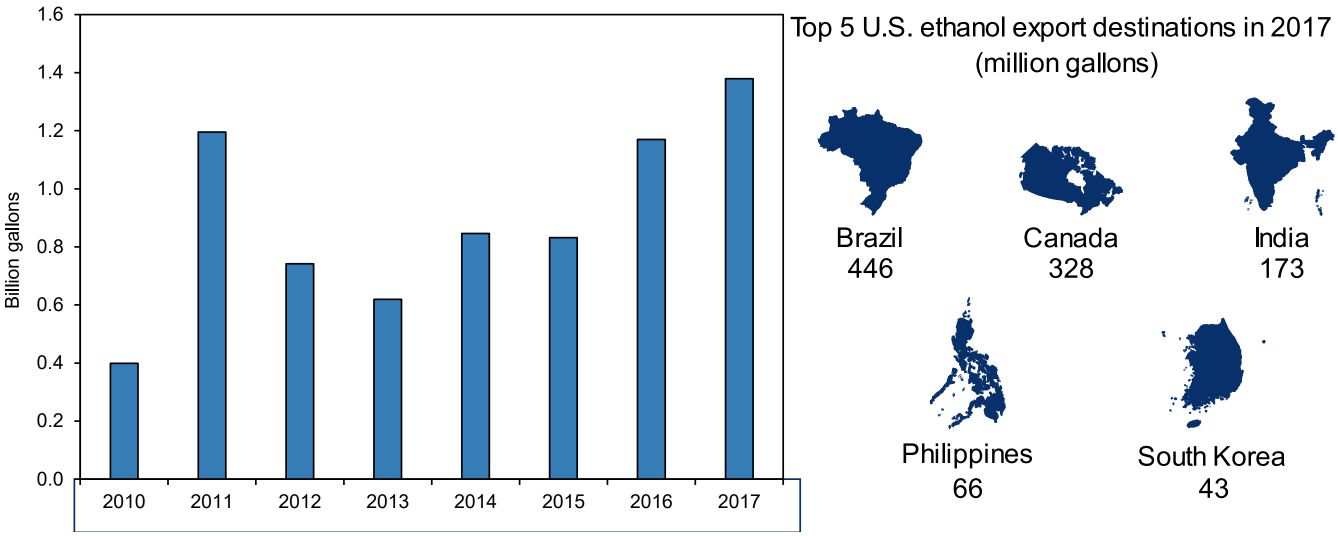

Figure 2.2.5. Exports of ethanol in the United States from 2010 to 2017 (in billion gallons) (11) and top 5 United States exports destinations in 2017 (in million gallons) (12).

Imports of ethanol are considerably lower than exports; most imports came from Brazil (13, 14). The highest volume of imports took place in 2012, with 500 million gallons of ethanol imported. The year 2012 also marked the lowest U.S ethanol production in the past eight years, attributable to a drought that reduced the corn crop (Figure 2.2.2) (13).

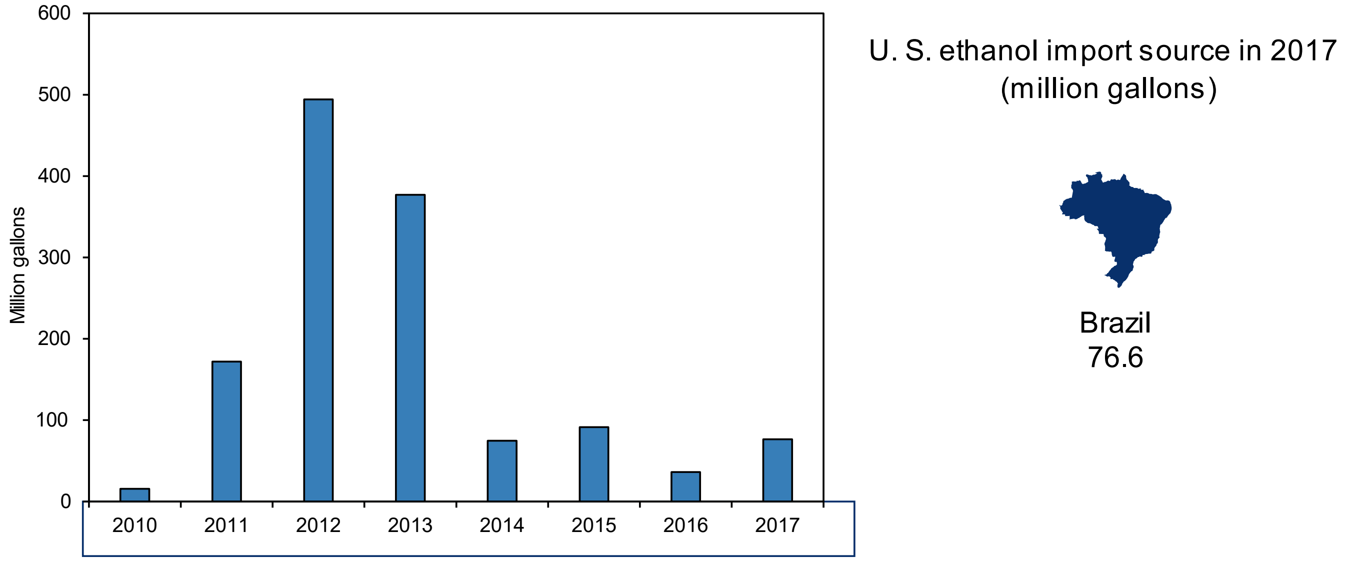

Figure 2.2.6. Imports of ethanol in the United States from 2010 to 2017 (in million gallons) (13) and United States import source in 2017 (in million gallons) (14).

Economics

The price of ethanol, E85 and E10 has significantly decreased since 2012, which matches the decrease in crude oil prices (16-19). In 2017 ethanol prices matched E10 prices (Figure 2.2.7) (16-17).

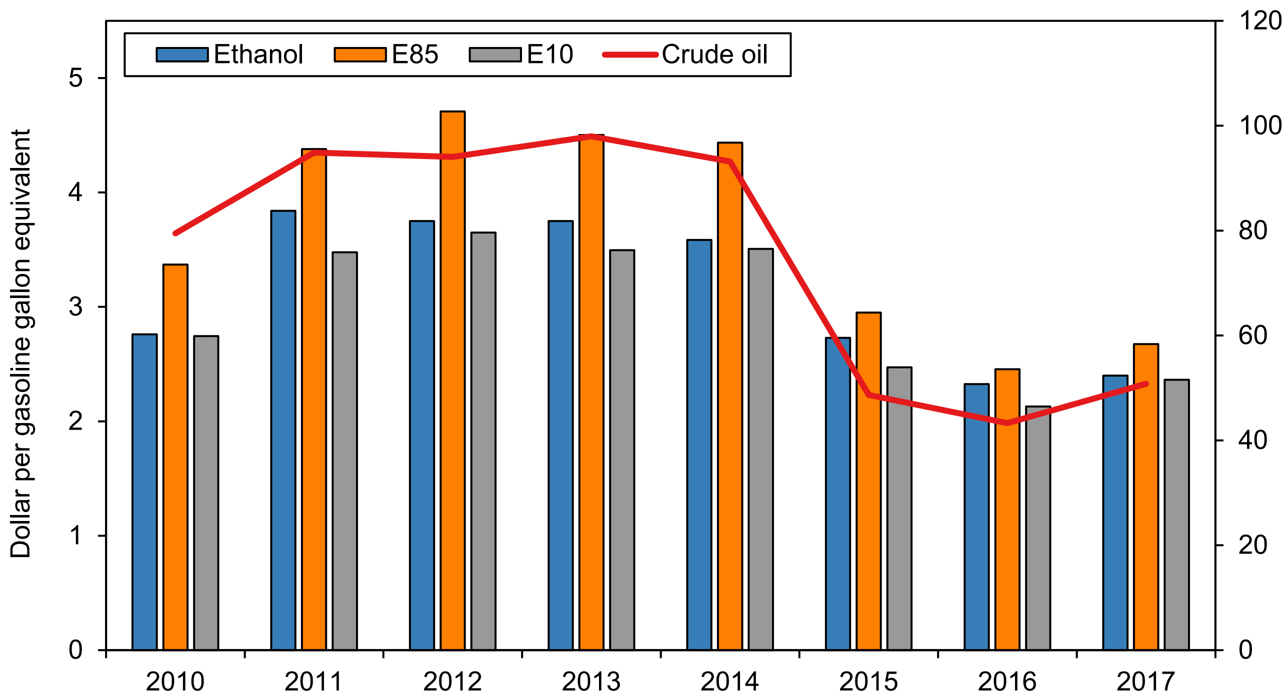

Figure 2.2.7. The bar chart represents the relative price of ethanol, E85 and E10 from 2010 to 2017 (in dollar per gasoline gallon equivalent) (left axis) (16, 17), while the line chart denotes the price of crude oil for the same time period (in dollars per barrel) (right axis) (18,19).

The number of American jobs related to the ethanol industry has remained relatively constant between 2010 and 2017, with a slight decrease in total jobs from 400,000 in 2010 to 357,493 in 2017 (Figure 2.2.8) (1-7).

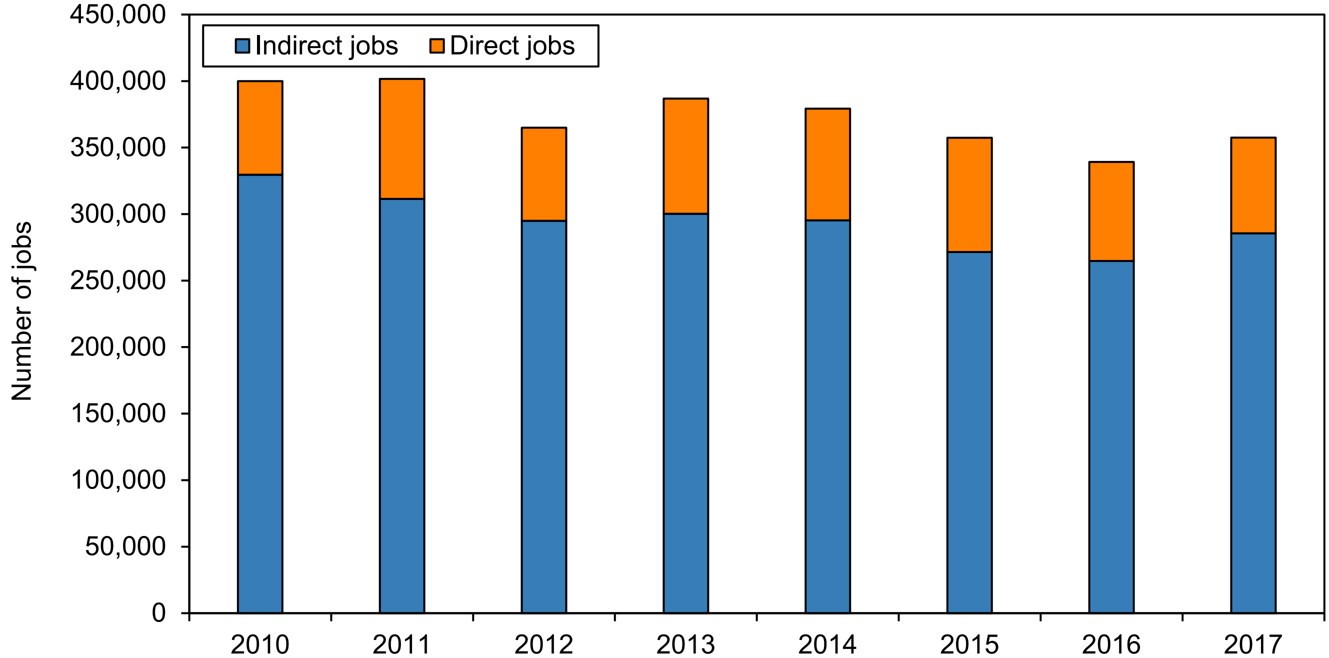

Figure 2.2.8. Number of total jobs generated from the biobased ethanol industry from 2010 to 2017 (1–7).

The ethanol industry created 45 billion dollars in gross domestic product, which is the value of all ethanol produced in the United States in 2017 (Figure 2.2.9) (1-7). In addition, the ethanol industry generated 24 billion dollars in household income and 10 billion dollars in tax revenue in 2017 (1-7). These values are slightly lower than 2010 values, likely due to the decrease in ethanol prices exhibited in Figure 2.2.7.

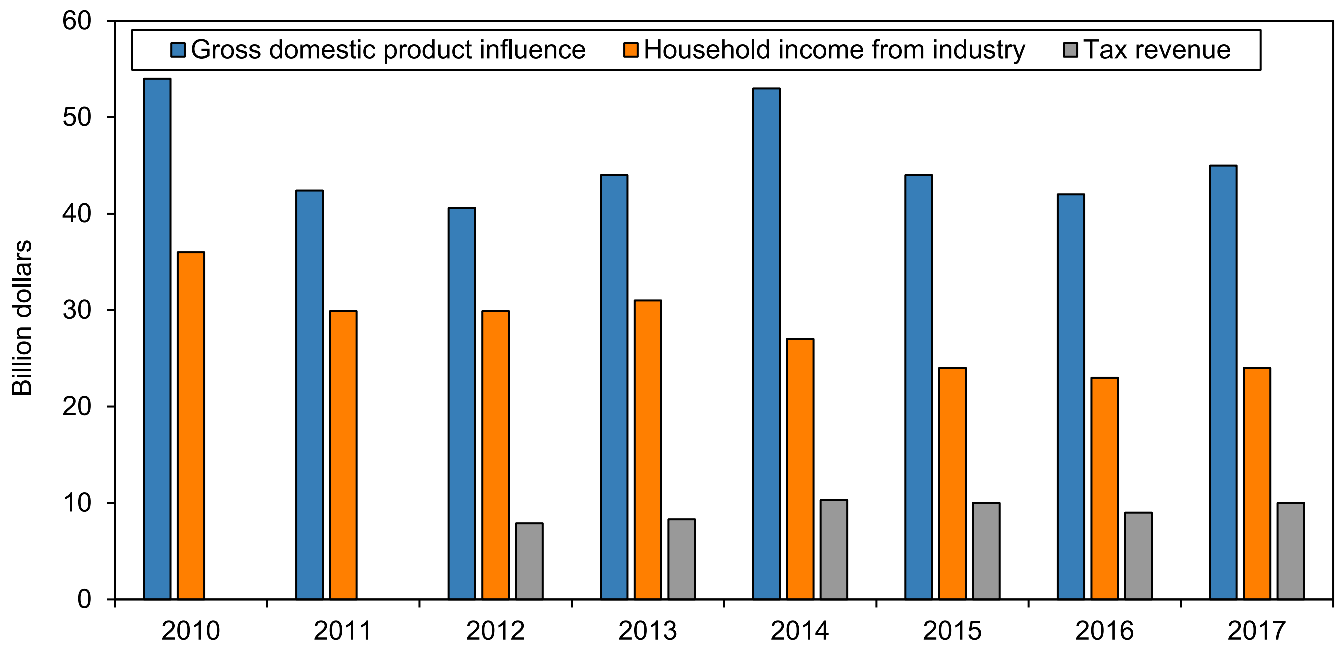

Figure 2.2.9. The ethanol industry's influence on the United States economy from 2010 to 2017 (in billion dollars) (1–7).

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2.3. Biodiesel

Photo 22. (18).

Biodiesel is a biofuel derived from vegetable oils, animal fats, or recycled grease (1). In the United States, soybean oil is the leading oil used as a feedstock for domestic biodiesel production (2).

Biodiesel is mainly used for transportation. It can be found unblended or blended with petroleum diesel. The high-level biodiesel blends are known as B100 (pure biodiesel) or B99 (99 percent biodiesel, 1 percent petroleum diesel). Although biodiesel can be used at any blend without upgrading the vehicle, low-level blends like B20 (20 percent biodiesel, 80 percent petroleum diesel) are more common than B99/100 due to the lack of regulatory incentives and pricing (1).

The number of biodiesel plants in the United States slightly decreased to 95 plants in 2017, compared with 103 plants in 2011 (2). This accounts for almost 50,000 direct jobs (3). Most of these facilities are in the Midwest (4).

Biodiesel production reached 1.6 billion gallons in 2017 as compared to 0.3 billion gallons in 2010 (2). Since 2013, the consumption of biodiesel is larger than the production, which means that the United States is a net importer of biodiesel (2,5). In 2017, imports of biodiesel were four times larger than exports, reaching 394 million gallons of biodiesel (5). The United States imports come from just four countries, with Argentina as the main import source (6).

Exports of biodiesel increased until 2013 when they reached a peak of 196 million gallons. After that, exports decreased significantly to 93 million gallons in 2017 (5). The decrease in exports matches the decrease of production between 2013 and 2014. The United States exported 87 percent of total biodiesel to Canada (7).

Photo 23. (19).

The number of biodiesel production facilities has decreased slightly from 103 plants in 2011 to 95 plants in 2017, similar to the ethanol industry (2). Soy oil plays an important role in the production of domestically produced biodiesel (4), which is consistent with the soy consumption patterns analyzed in section 1.6 (Figure 2.3.1).

While the total number of biodiesel plants in the U.S. has decreased since 2011, new plants are being built. In 2017, there were plans for 10 new plants to be constructed with a total additional capacity of 250.5 million gallons (Table 2.3.1) (4).

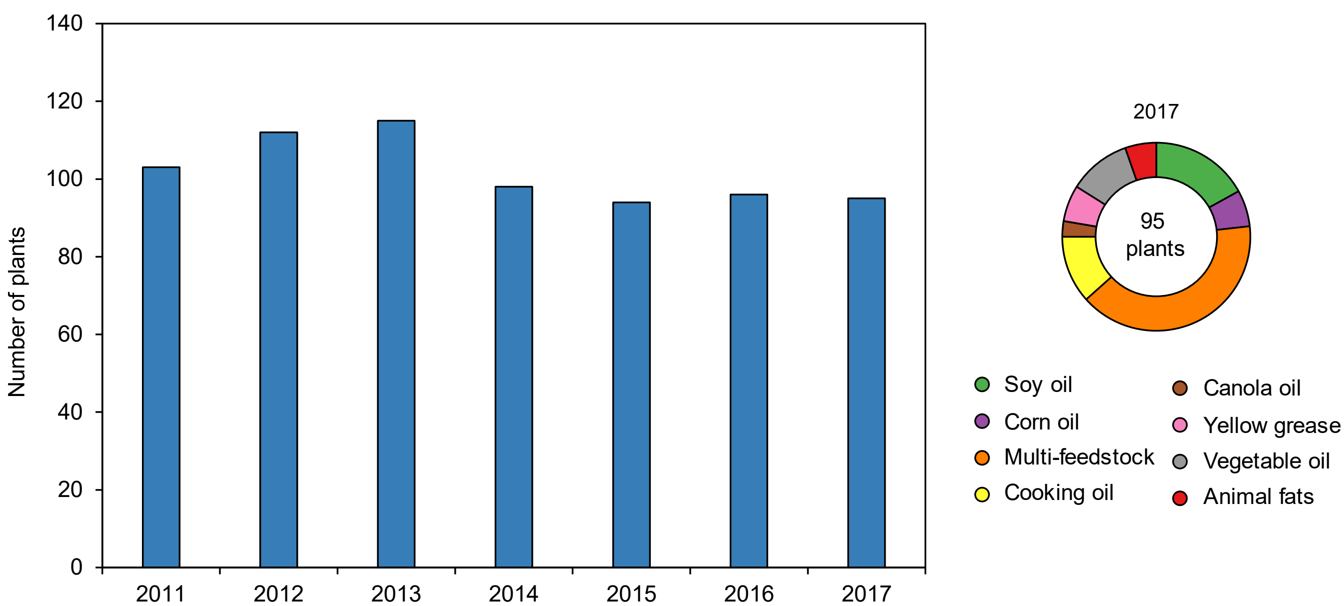

Figure 2.3.1. Total number of biodiesel plants in the United States from 2011 to 2017 and biodiesel plants by feedstock (2, 4).

PHYSICAL INFRASTRUCTURE	2011	2012	2013	2014	2015	2016	2017
# of biodiesel plants in the United States	103	112	115	99	94	96	95
# of proposed biodiesel plants	-	-	-	-	-	6	0
# of existing plants under construction	-	-	-	-	-	15	10
# of states which have a biodiesel production facility	35	37	38	35	36	37	36

Table 2.3.1. The physical infrastructure of the biodiesel industry in the United States from 2011 to 2017 (2, 4).

Texas is home to 10 percent of the total biodiesel plants in the country. Missouri with 8 percent, and California, Iowa and Illinois with 7 percent each complete the top 5. Note that although California is in the top 5, the production capacity of the California biodiesel plants is very small in comparison with other states (Figure 2.3.2 and Table 2.3.2) (4).

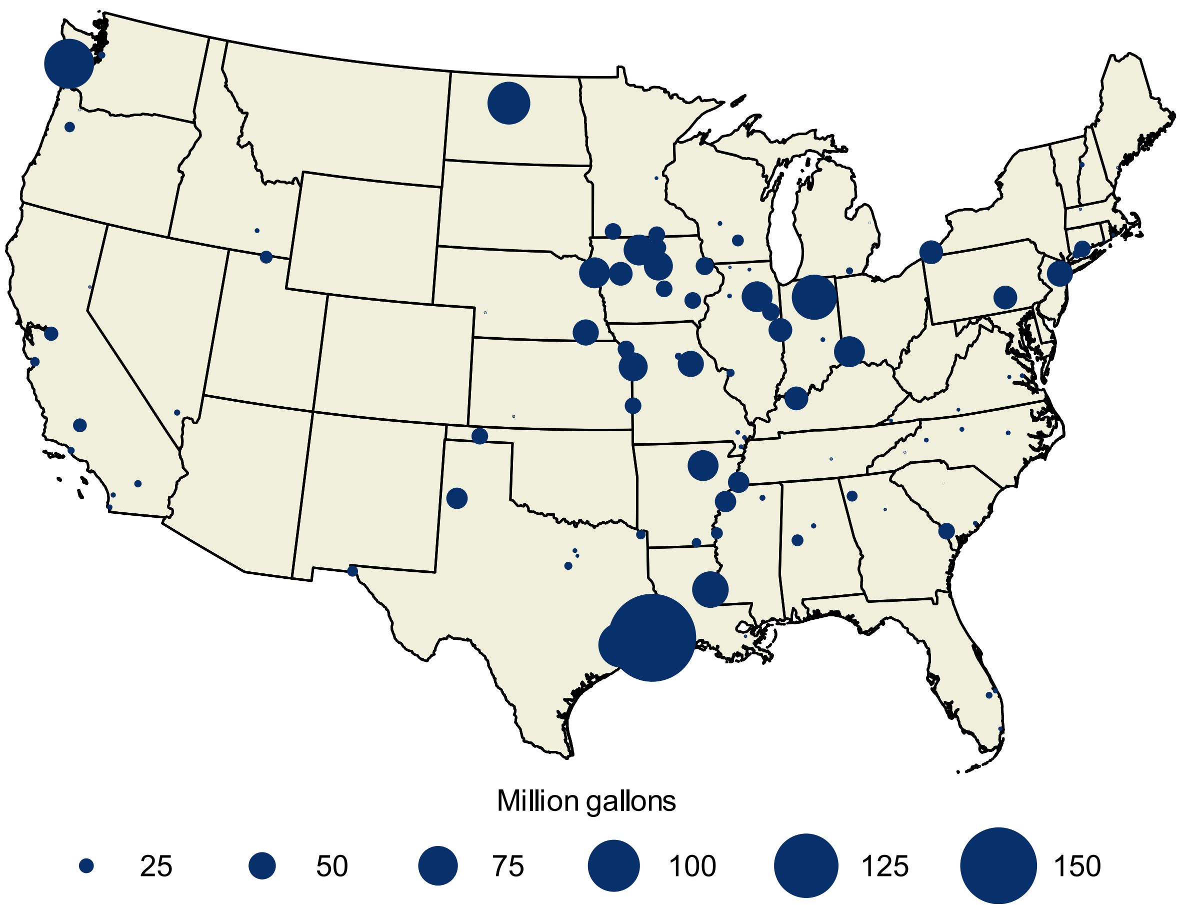

Figure 2.3.2. Biodiesel production facilities location by capacity (in million gallons) in the United States in 2017 (4).

State	Number of plants	Percentage of total plants
Texas	11	10.2
Missouri	9	8.3
California	8	7.4
Iowa	8	7.4
Illinois	8	7.4

Table 2.3.2. Top 5 states for biodiesel production facilities in the United States in 2017 (4).

The number of B20 and B100 fueling stations has remained nearly constant over the years; there were 697 biodiesel stations in 2016 (Figure 2.3.3) (8).

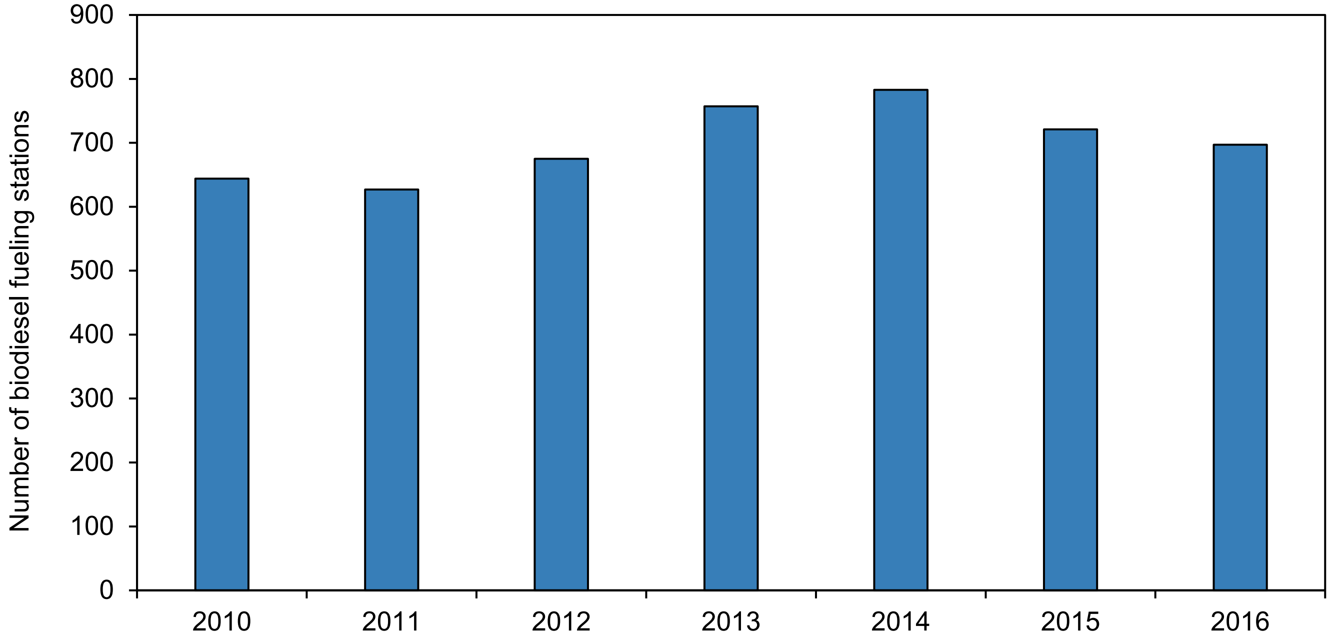

Figure 2.3.3. Number of biodiesel fueling stations in the United States from 2010 to 2016 (8).

Production

Biodiesel production reached 1.6 billion gallons in 2017 as compared to 0.3 billion gallons in 2010. The consumption of biodiesel also increased from 0.3 billion gallons in 2010 to 2 billion gallons in 2017 (2). Given that the total number of biodiesel plants has decreased (Table 2.3.1), the average size/production capacity of newly constructed facilities must be increasing, given the increase in total production of biodiesel. Since 2013 the consumption of biodiesel is larger than the production, which means that the United States is a net importer of biodiesel (Figure 2.3.4) (2, 5).

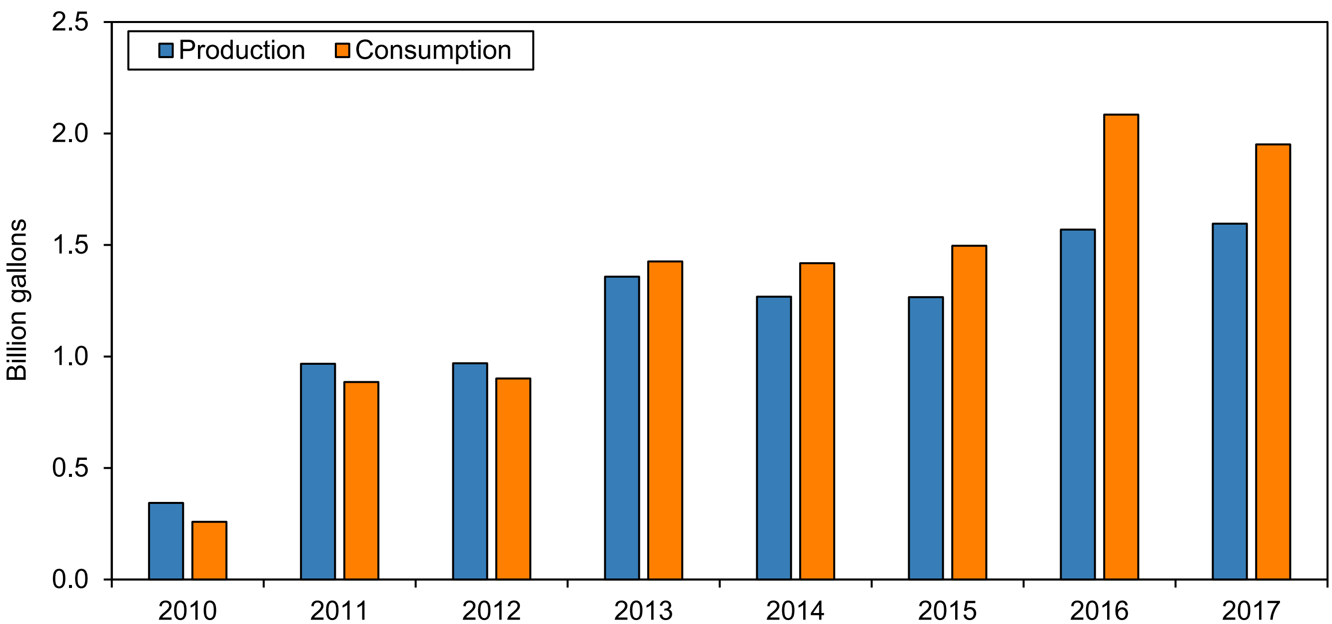

Figure 2.3.4. Biodiesel production and consumption in the United States from 2010 to 2017 (in billion gallons) (2, 5).

Texas has 10 percent of biodiesel plants but 17 percent of total biodiesel production capacity. However, almost 50 percent of biodiesel production capacity is located in the Midwest (Figure 2.3.5 and Table 2.3.3) (4).

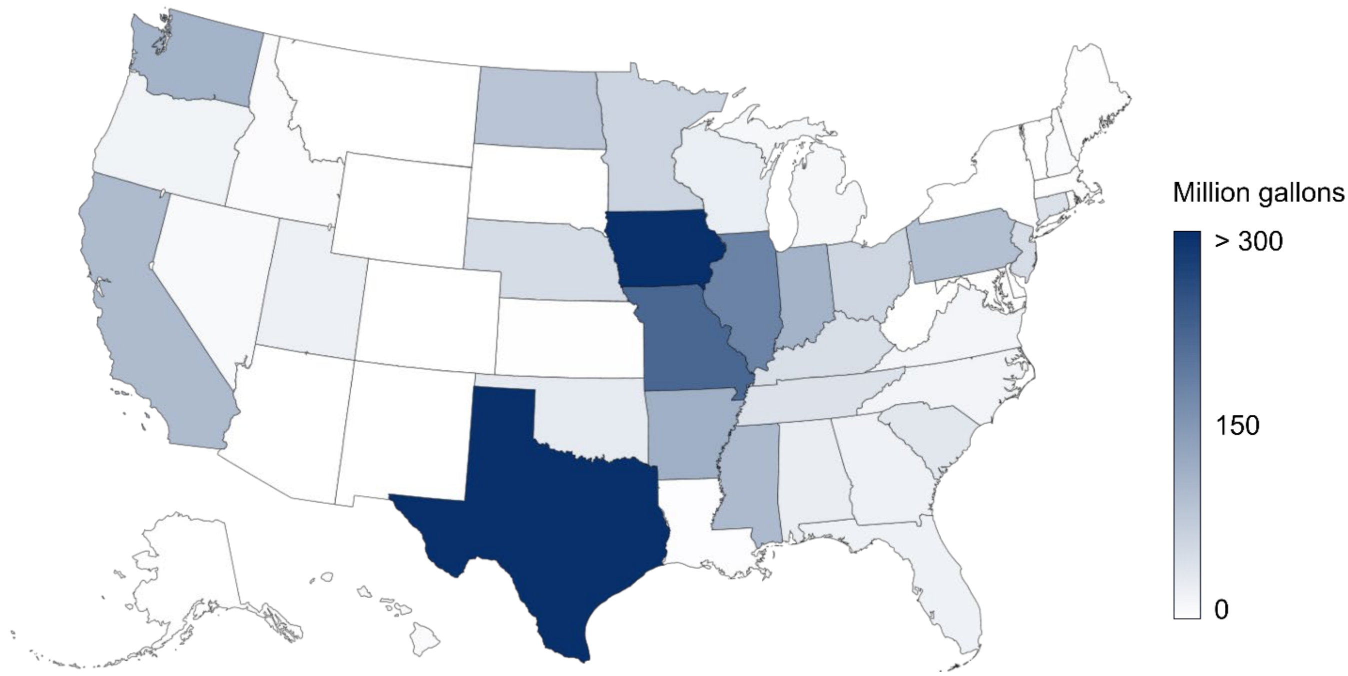

Figure 2.3.5. Total production capacity of biodiesel in the United States by state in 2017 (in million gallons) (4).

State	Million gallons	Percentage of total capacity
Texas	412	16.5
Iowa	344	13.8
Missouri	221	8.9
Illinois	180	7.2
Arkansas	115	4.6

Table 2.3.3. 5 states with highest production capacity of biodiesel (in million gallons) in the United States in 2017 (4).

Exports of biodiesel from 2010 to 2017 and export destinations in 2017 are presented in Figure 2.3.6. Exports of biodiesel increased until 2013 when they reached a peak of 196 million gallons. After that, exports decreased significantly to 93 million gallons in 2017 (5). The decrease in exports matches the decrease in production between 2013 and 2014. In 2017, Canada imported 87 percent of total biodiesel exported by the United States (Figure 2.3.6) (7).

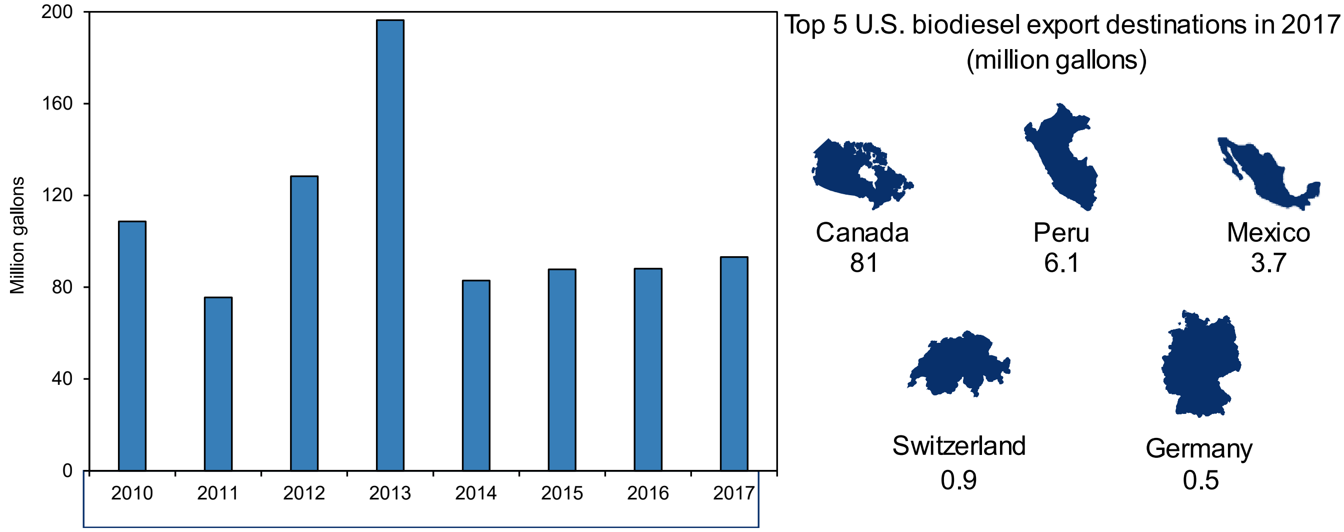

Figure 2.3.6. Exports of biodiesel in the United States from 2010 to 2017 (in million gallons) (5) and top 5 United States exports destinations in 2017 (in million gallons) (7).

In 2017, imports of biodiesel were four times larger than exports and the United States imported biodiesel from just four countries: Argentina, Canada, Germany and South Korea (Figure 2.3.7) (5, 6).

In 2013 the United States not only became a net importer of biodiesel, but also increased the domestic demand (see Figure 2.3.4). This is driven by two main factors: (1) the need to satisfy he Renewable Fuel Standards targets, (2) the increase in biodiesel tax credits to incentivize biodiesel production. However, the amount of biodiesel imported decreased during 2014 due to uncertainty about both the Renewable Fuel Standards targets and the elimination of the tax credits. At the end of 2015, the United States Environmental Protection Agency finalized Renewable Fuel Standards targets for 2014, 2015, and 2016. Around the same time, Congress extended the biodiesel tax credit through 2016, which resulted in a significant increase in biodiesel imports and consumption. The tax credit was again allowed to expire on Dec. 31, 2016, which explains the drop of biodiesel imports in 2017 (6-9).

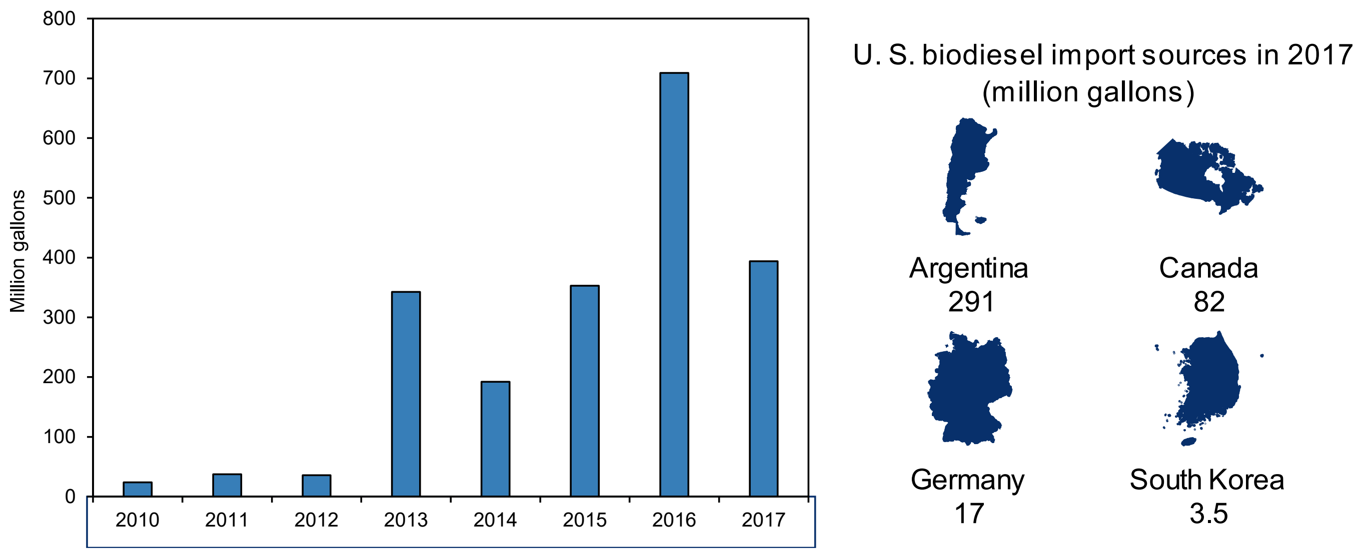

Figure 2.3.7. Imports of biodiesel in the United States from 2010 to 2017 (in million gallons) (5) and the United States import sources in 2017 (in million gallons) (6).

Economics

The price of B99/100, B20 and diesel has significantly decreased after 2014, which matches the decrease in soy prices (10-12). In 2017, the price of B20 matched the price of diesel fuel. Price parity is an important consideration for the consumption of renewable fuels (Figure 2.3.8) (10,11).

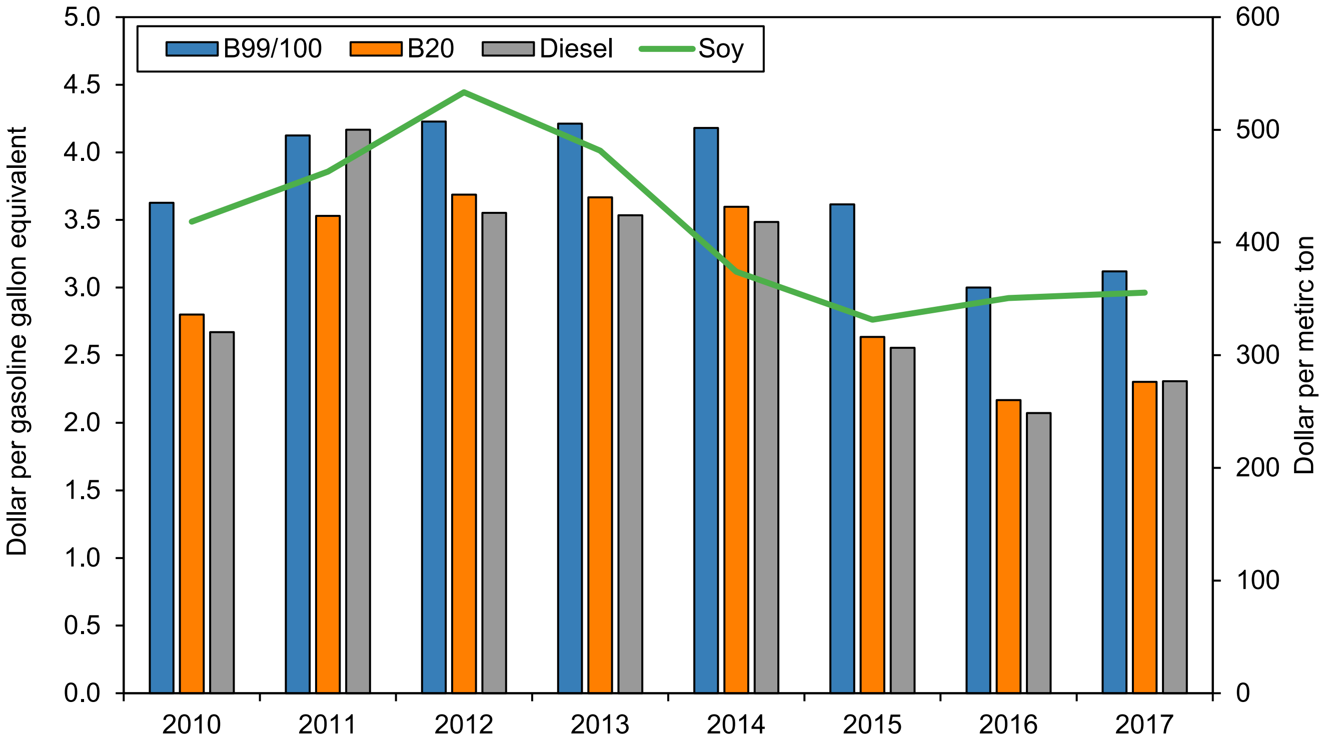

Figure 2.3.8. The bars represent the relative price of B99/100, B20, and diesel and from 2010 to 2017 (in dollar per gasoline gallon equivalent) (left axis) (10,11) and the line the relative price of soy from 2010 to 2017 (in dollars per metric ton) (right axis) (12).

The number of direct jobs generated by the biodiesel industry has decreased from 64,000 jobs in 2012 to 47,000 jobs in 2016 (Figure 2.3.9) (3, 12, 13). This is consistent with the decrease in production facilities (Figure 2.3.1 and Table 2.3.1).

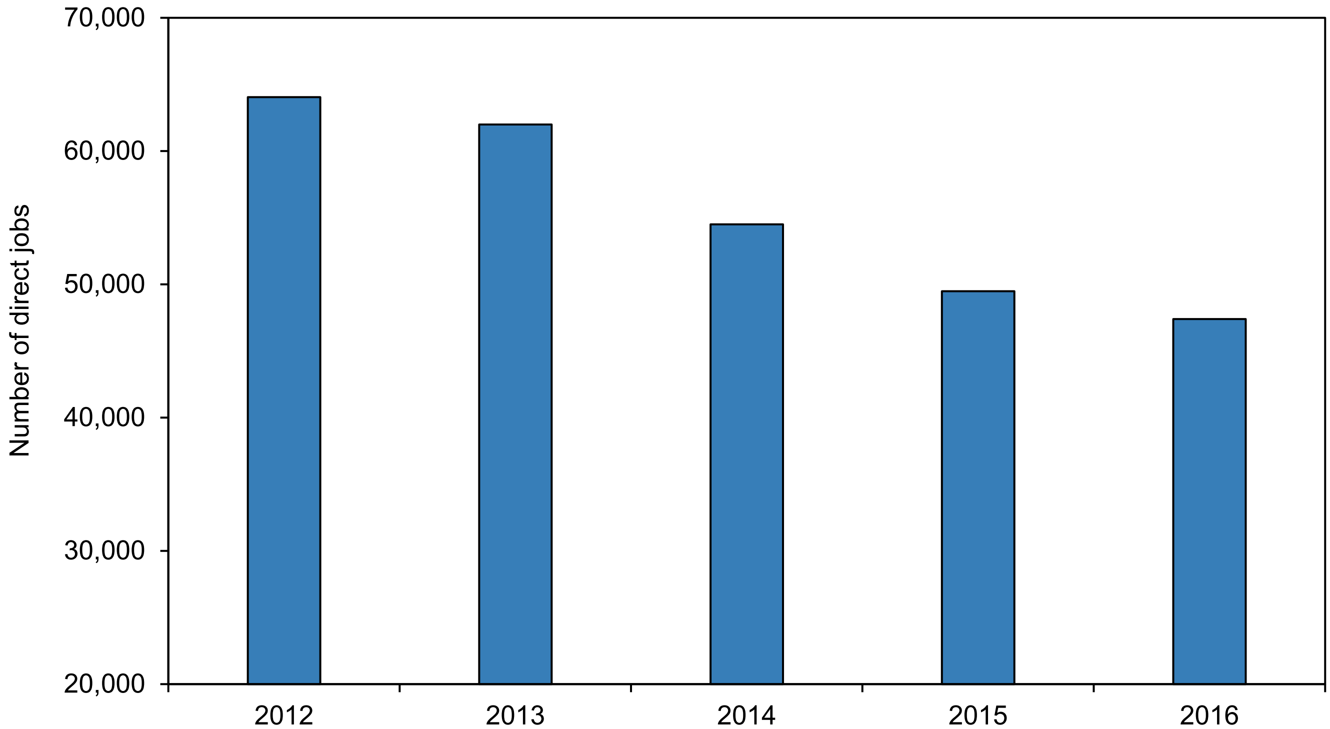

Figure 2.3.9. Number of direct jobs generated from the biodiesel industry from 2012 to 2016 (3, 13, 14).

The biodiesel industry created 15 billion dollars in gross domestic product in 2016 as compared to 6 billion dollars in 2012 (13-17) while household income slightly decreased from 2.6 billion dollars in 2013 to 1.9 billion dollars in 2015 (Figure 2.3.10) (14,16).

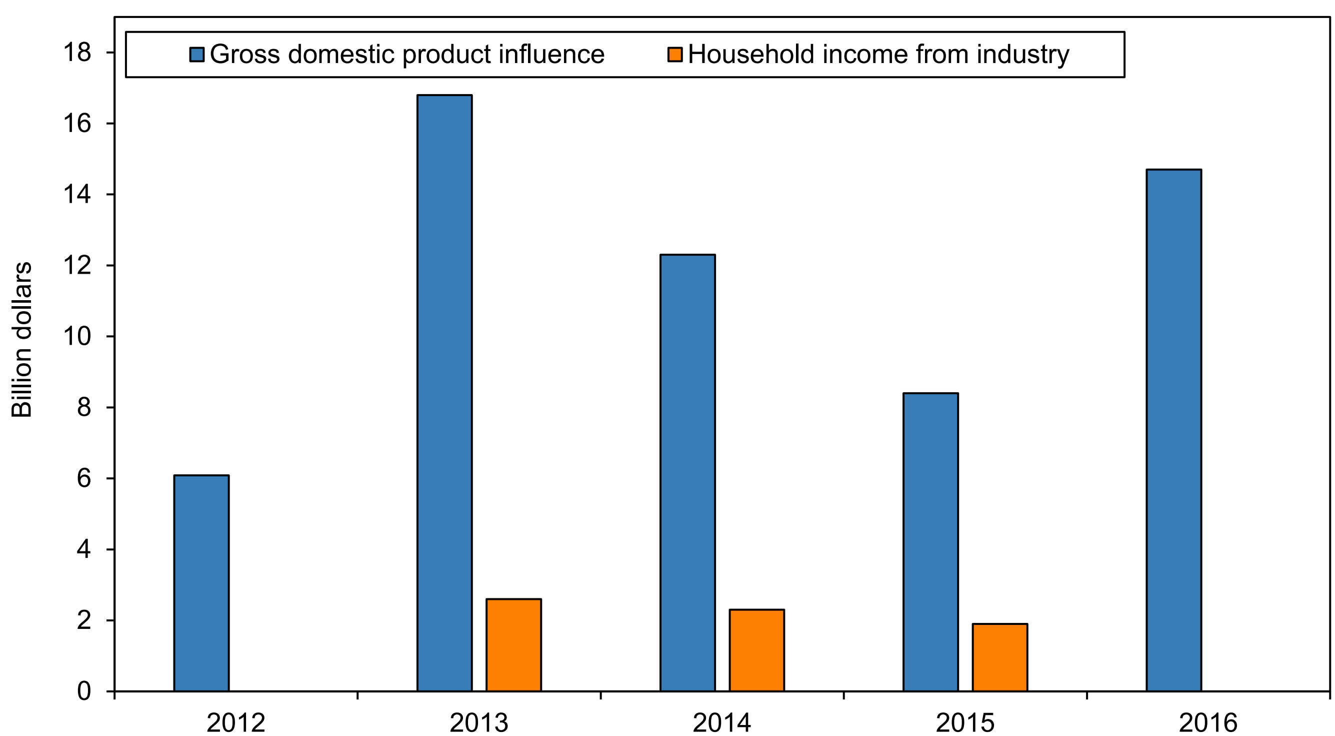

Figure 2.3.10. Biodiesel industry's influence on the United States economy from 2013 to 2016 (in billion dollars) (14–17).

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2.4. Wood Pellets

Photo 24. (17).

Wood pellets are a biofuel derived from various wood feedstocks, including tops and limbs, commercial thinning, and sawmill residues. Wood pellets can be utilized for both electricity generation and heating, with the latter occurring in the northern portion of the United States (1).

In 2017, the total number of wood pellet plants in the United States increased slightly to 148 production plants (2-6). These facilities account for almost 24,000 direct jobs (7), with a majority located in the southeastern United States (8).

The United States is the world's leading wood pellets producer, accounting for 22 percent of total global production (9). The production of wood pellets increased from 3.2 million metric tons in 2012 to 6.3 million metric tons in 2017 (9).

Just 20 percent of total U.S production of wood pellets is consumed domestically, and it is used primarily for heating. In particular, wood pellet domestic consumption accounted for 148 trillion BTUs for electricity generation and 1,997 trillion BTUs for heating in 2017 (10). Note that the domestically consumed ratio varies with winter temperatures and the growth in exports.

From 2012 to 2017 exports of wood pellets increased from 1.9 million metric tons to 5.2 million metric tons (11). In 2017, the United States exported 70 percent of total domestic wood pellet production to the European Union (9, 11).

While wood pellets are used domestically for heating, exports of wood pellets are primarily used for electricity generation (12). In order to achieve the European Union's target of 20 percent renewable energy use by 2020, these wood pellets were primarily used in coal-fired power plants, such as the Drax power station in the United Kingdom, for electricity generation (12).

Photo 25. (18).

The number of wood pellet production facilities is presented in Figure 2.4.1. The number of facilities increased slightly from 2013 to 2017, when it reached a peak of 148 plants (2-6). In 2017, four new plants were under construction and seven proposed to be constructed, which would have a total additional capacity of 702,500 metric tons of wood pellets per year (Figure 2.4.1 and Table 2.4.1) (2-6).

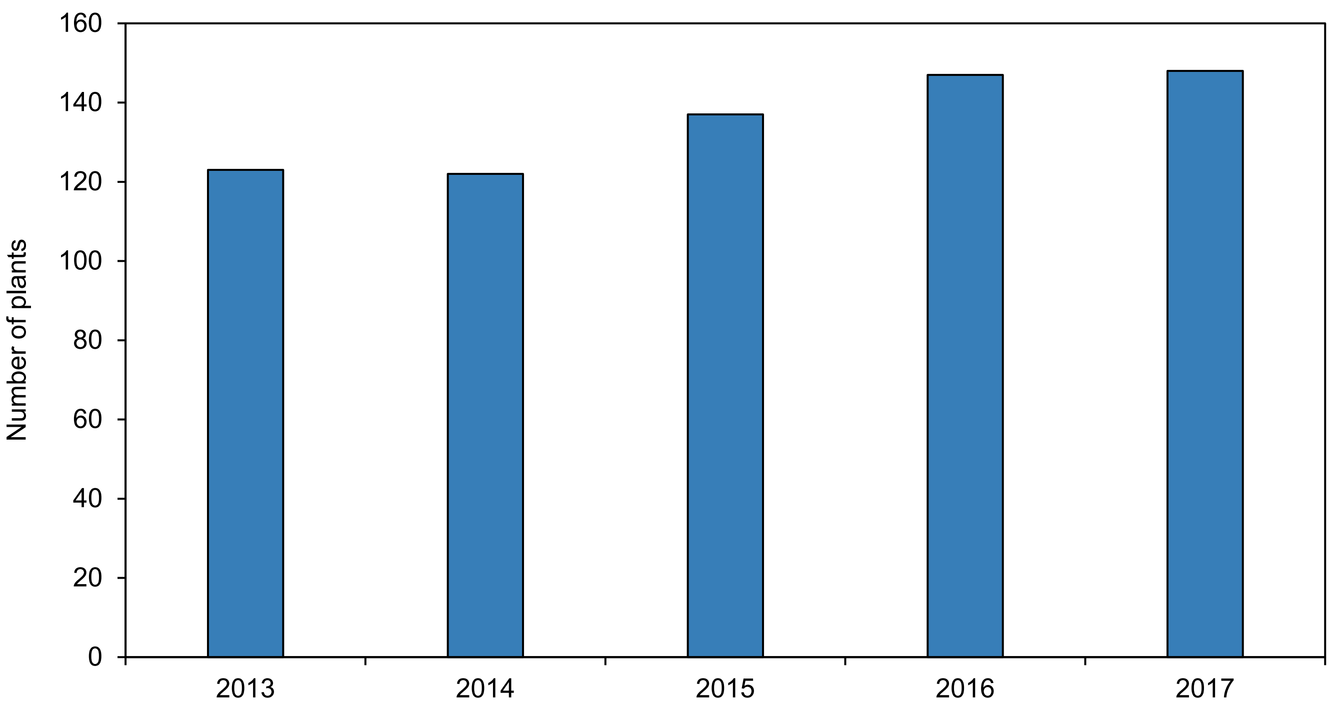


Figure 2.4.1. Total number of wood pellet production plants in the United States from 2013 to 2017 (2-6).

PHYSICAL	2013	2014	2015	2016	2017
# of wood pellets plants in the United States	123	122	137	147	148
# of existing plants under construction	7	9	9	11	4
# of proposed wood pellet plants	11	15	22	18	7
# of existing plants that were put on standby	-	-	-	13	11
# of states that have a wood pellets production facility	36	36	36	38	37

Table 2.4.1. Physical infrastructure of the wood pellet industry in the United States from 2013 to 2017 (2-6, 13).

Wood pellet production plants are distributed across the country, with the largest concentration in the southeastern United States (Figure 2.4.2 and Table 2.4.2) (8).

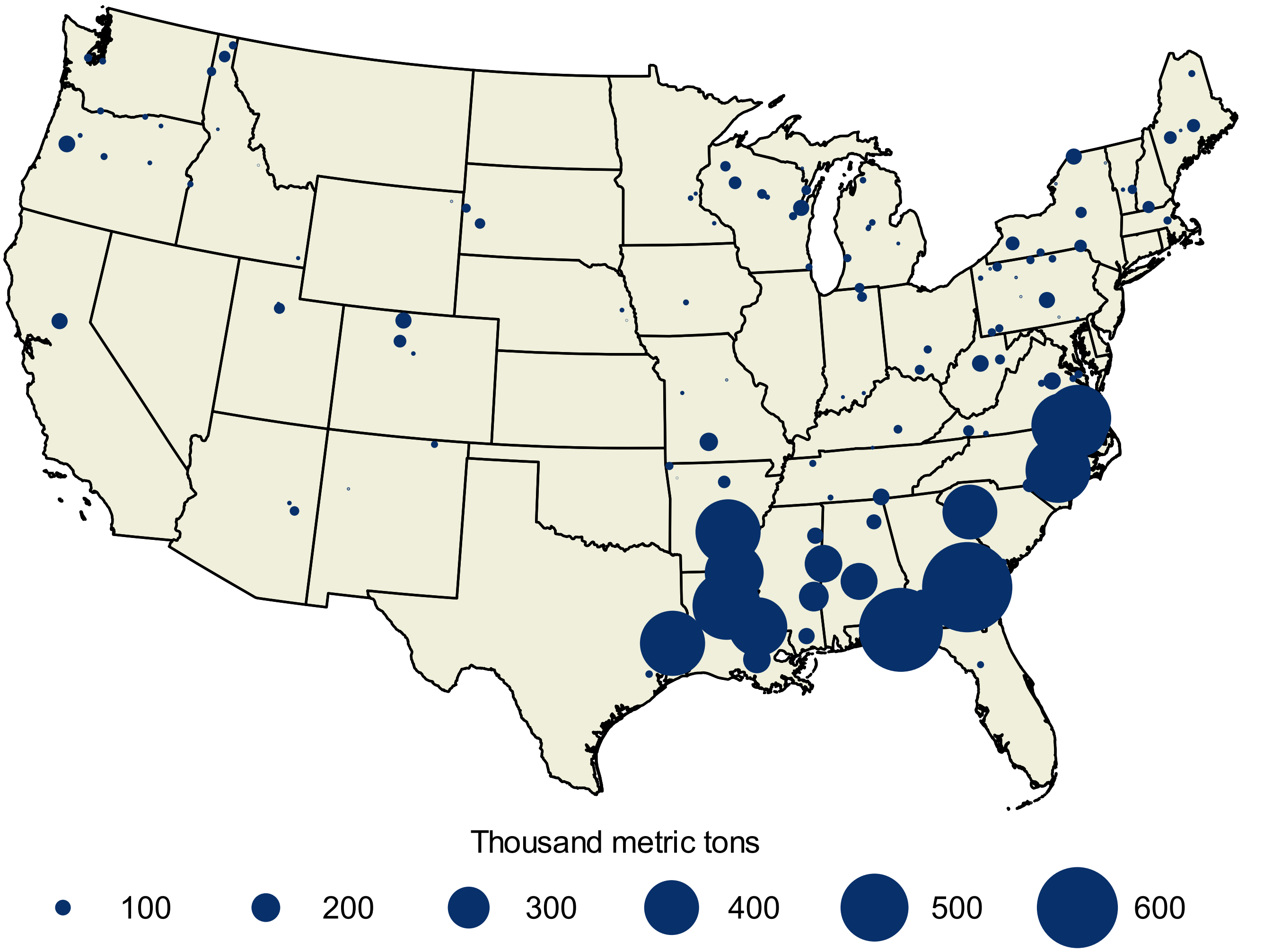


Figure 2.4.2. Wood pellet production facilities in the United States in 2017, sorted by capacity (in thousand metric tons) (8).

State	Number of plants	Percentage of total capacity
Pennsylvania	12	8.6
Virginia	10	7.2
Michigan	9	6.5
Wisconsin	8	5.8
Georgia	7	5.0

Table 2.4.2. Top 5 states for wood pellets production facilities in the United States in 2017 (8).

Production

In 2017, the United States was the world's leading wood pellets producer, accounting for 22 percent of total worldwide production (see Figure 2.4.3 and Table 2.4.3) (9).

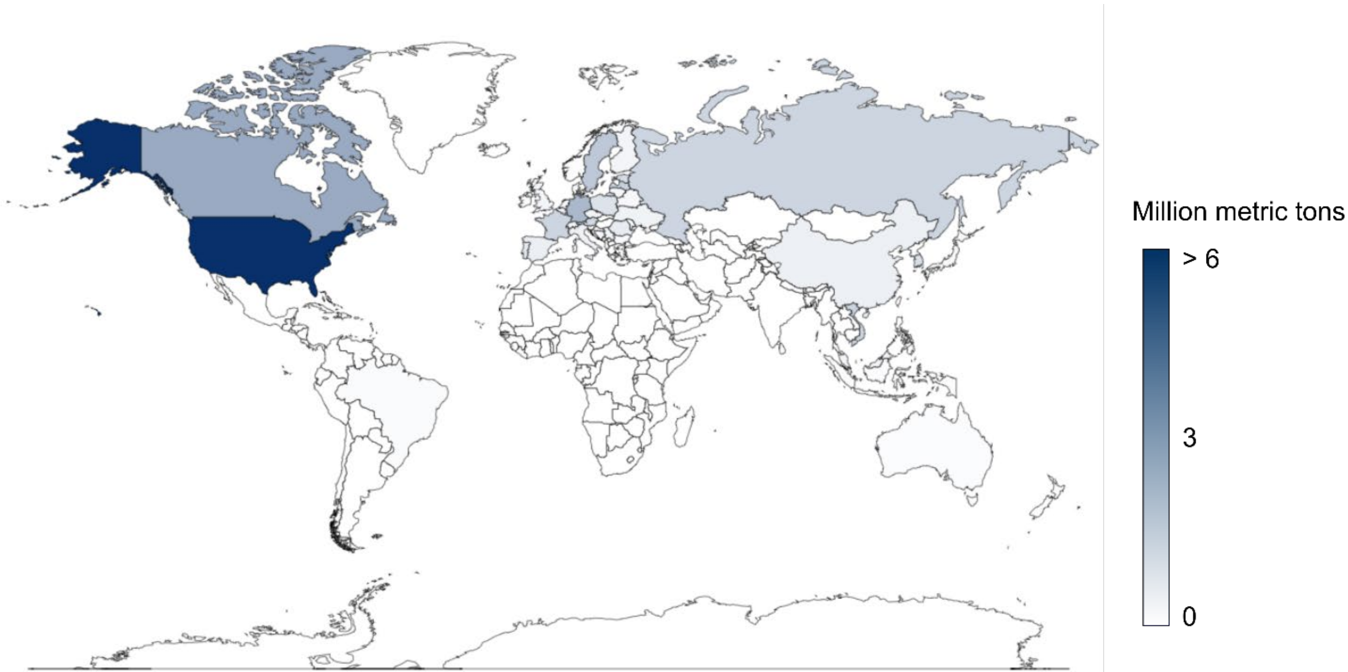
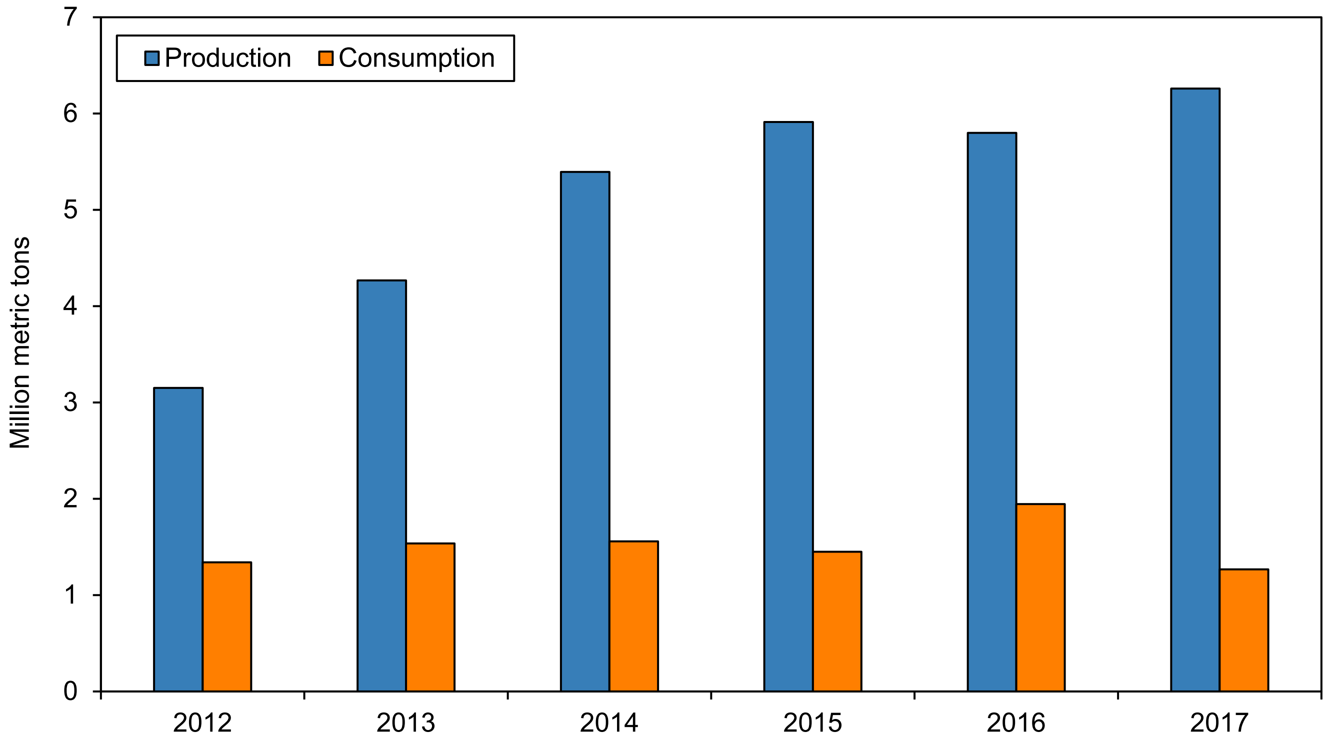


Figure 2.4.3. Wood pellet production worldwide in 2017 (in million metric tons) (9).

Country	Million metric tons	Percentage of total production
United States	6.3	22
Canada	2.4	9
Germany	2.0	7
Sweden	1.6	6
Latvia	1.4	5

Table 2.4.3. 5 countries with largest wood pellet production in 2017 (in million metric tons) (9).

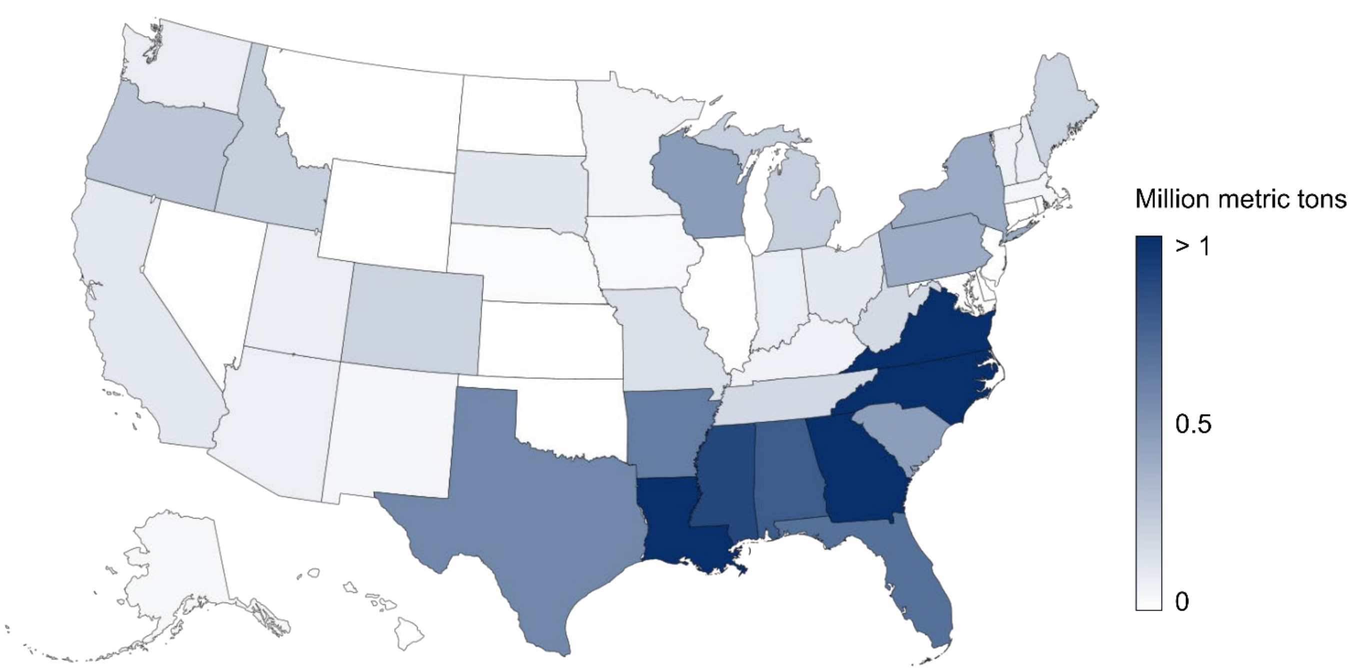
The production of wood pellets in the United States increased from 3.2 million metric tons in 2012 to 6.3 million metric tons in 2017 (9). In addition, consumption of wood pellets is, in average, a third of production, which indicates that the United States is a significant net exporter of wood pellets (Figure 2.4.4) (9).



*Note: Wood pellets consumption is not available, and it has been approximated via the following formula: Consumption = Production + Imports – Exports.

Figure 2.4.4. Total wood pellet production versus total wood pellet consumption in the United States from 2012 to 2017 (in million metric tons) (9).

The southeastern United States are home to 69 percent of U.S. wood pellet production capacity. Specifically, North Carolina and Georgia have the largest wood pellet production capacity (Figure 2.4.5 and Table 2.4.4) (8).



*Note: Wood pellets production is expressed in terms of fuel capacity because 2017 production data is not available.

Figure 2.4.5. Wood pellets fuel capacity by state (in million metric tons) in 2017 (8).

State	Million metric tons	Percentage of total capacity
North Carolina	1.50	11.3
Georgia	1.50	11.2
Louisiana	1.17	8.8
Virginia	1.09	8.2
Mississippi	0.89	6.7

Table 2.4.4. 5 states with largest wood pellet production capacity in the United States in 2017 (in million metric tons) (8).

Wood can be used for electricity generation and for heating. The amount of wood energy generated has remained almost constant between 2010 and 2017, reaching 148 trillion BTUs for electricity generation and 1,997 trillion BTUs for heating in 2017 (10). In the U.S., wood energy is primarily consumed for heating. The industrial sector consumes more energy from wood, followed by the residential sector, the electric power sector, and finally the commercial sector (Figure 2.4.6) (10).

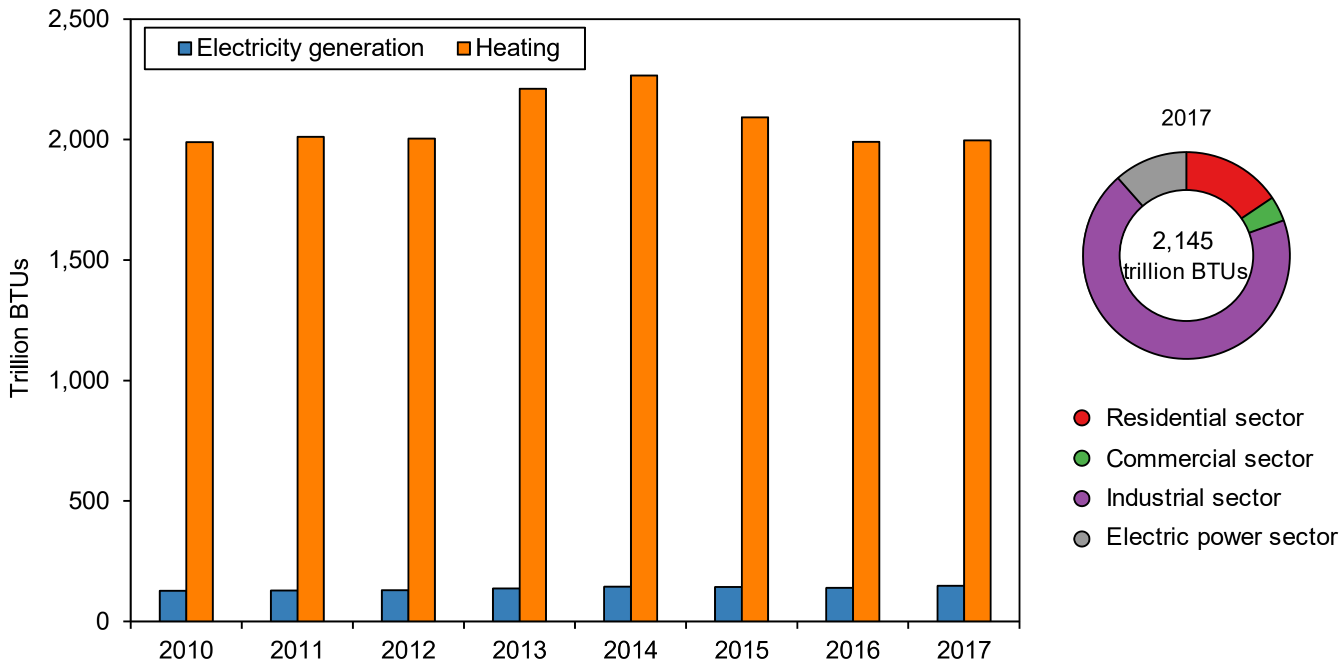


Figure 2.4.6. Energy consumption from wood in the United States by final use and sector from 2010 to 2017 (in trillion British Thermal Units (BTU)) (10).

The United States is the world's leading exporter of wood pellets. In 2017, 70 percent of total United States production was exported, primarily to the European Union (11).

From 2012 to 2017 exports of wood pellets increased by 174 percent, going from 1.9 million metric tons to 5.2 million metric tons. In 2017, wood pellet exports were valued at more than 660 million dollars (11).

Since 2013, the United Kingdom and Belgium have been the two largest importers of the United States wood pellets (11). In 2017, the United Kingdom (80 percent of total) and Belgium (10 percent of total) combined to import 90 percent of all United States wood pellet exports, as shown in Figure 2.4.6 (11).

Domestically, wood pellets are primarily used for heating. In the European Union (e.g., United Kingdom) wood pellets are used for electricity generation (12).

The main driver for the increase of wood pellet consumption in Europe is the European Commission's 2020 climate and energy plan, which sets three key targets: 20 percent cut in greenhouse gas emissions (from 1990 levels); 20 percent of European Union energy from renewables; and 20 percent improvement in energy efficiency (14). In particular, the United Kingdom plans to achieve the target by using wood pellets in cofiring (combustion of two different fuels) or dedicated biomass power plants (12).

The Drax power station, located east of Leeds (England), is one of the largest facilities to switch their feedstocks from coal to wood pellets. In fact, 65 percent of the plant's output is through burning biomass. The power station, which is one of Britain's larger power station, has a capacity of 3,906 Megawatts and supplies 7 percent of the country's electricity needs (15).

In 2017, nearly 60 percent of Drax's biomass feedstock mix came from the United States, which corresponds to 97 percent of total United States wood pellet exports to the United Kingdom and to 79 percent of total U.S wood pellet exports (16).

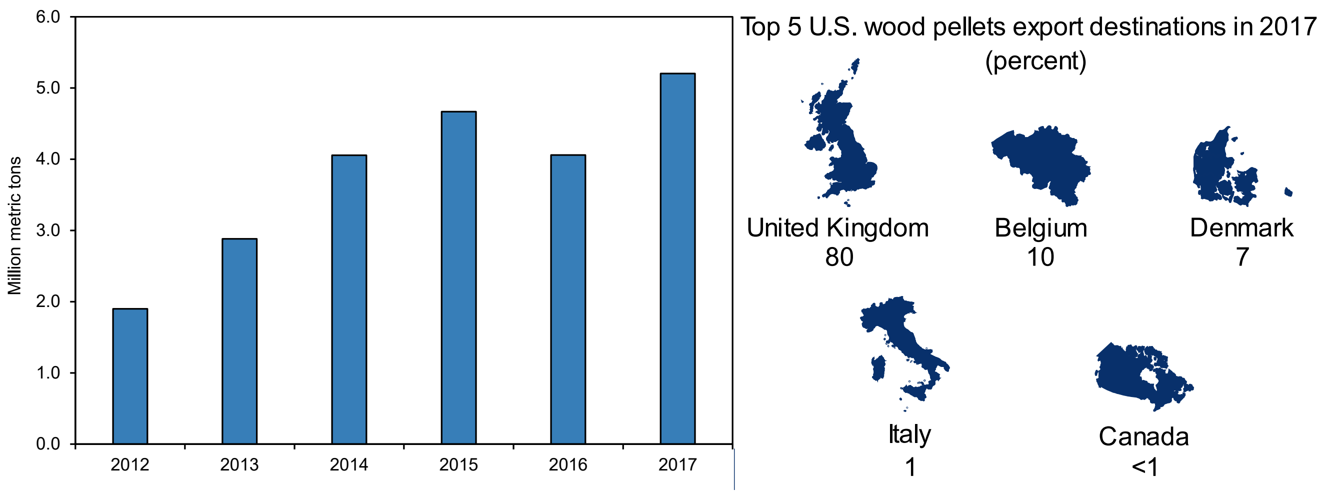


Figure 2.4.7. Exports of wood pellets in the United States from 2012 to 2017 (in million metric tons) and top 5 United States exports destination in 2017 (in percent) (11).

Imports of wood pellets are small in comparison with exports; exports are in millions of metric tons, but imports are only a few hundred thousand metric tons. In 2014, U.S wood pellet imports peaked at 220 thousand metric tons. Since then, pellet imports have remained constant around 200 thousand metric tons (11). Almost all wood pellet imports are received from Canada (Figure 2.4.8) (11).

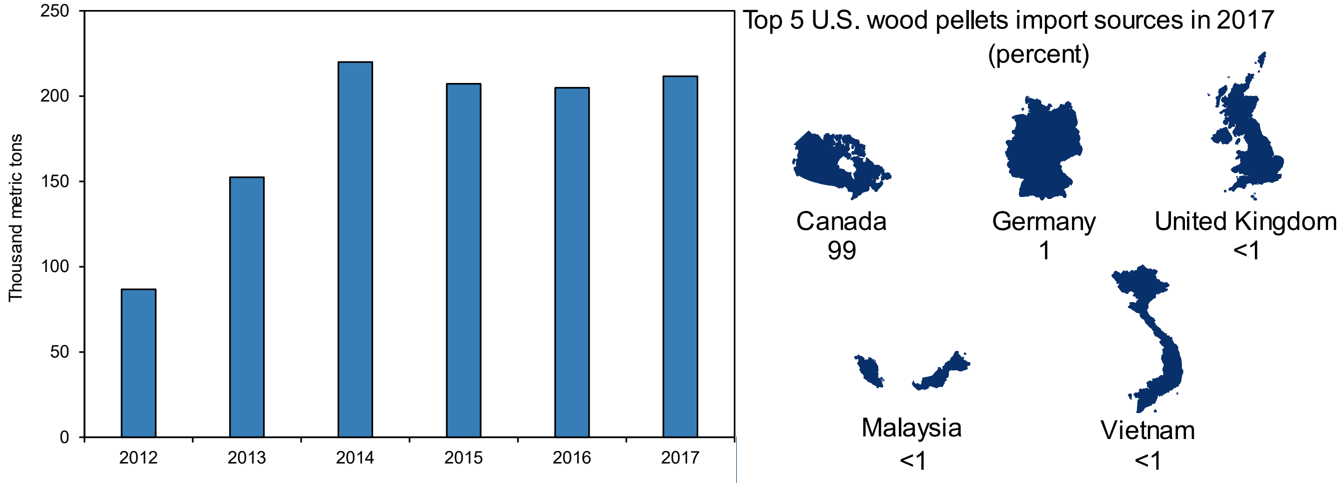


Figure 2.4.8. Imports of wood pellets in the United States from 2012 to 2017 (in thousand metric tons) and top 5 United States import sources in 2017 (in percent) (11).

Economics

The number of direct jobs in the wood pellet industry has slightly decreased from 26,500 jobs in 2010 to 23,600 jobs in 2016, which is consistent with the production reduction in 2016 (Figure 2.4.9) (7,9).

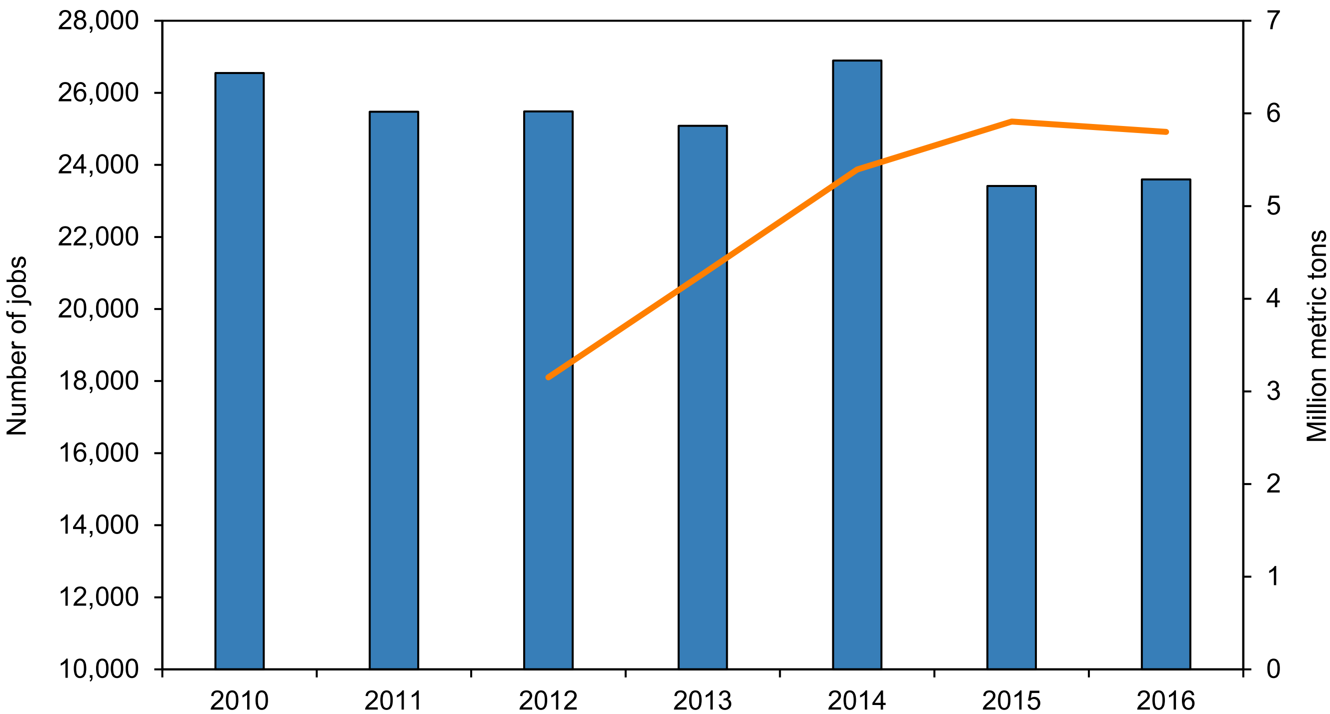


Figure 2.4.9. The bars represent the number of direct jobs generated in the United States from the wood biomass industry from 2010 to 2016 (left axis) and the line is the wood pellets production in the United States from 2012 to 2016 (in million metric tons) (right axis) (7,9).

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2.5. Waste-to-Energy

Photo 26. (13).

Waste-to-energy is the production of energy or heat from waste. There are different types of waste-to-energy plants depending on the technology used to generate energy (1).

In the United States, the most common type burns municipal solid waste to generate electricity or heat (1). However, there are other technologies that can generate energy from waste, such as liquid fuel synthesis or biogas recovery from landfills (1).

Municipal solid waste, which includes commercial and household wastes, can be classified into: (1) biogenic materials (i.e., plants or animal based); (2) non-biomass materials (i.e., petroleum based); or (3) noncombustible materials (i.e., glass and metals). Before being burned in a waste-to-energy plant, hazardous and recyclable materials are separated from municipal solid waste (1).

In the United States, the generation of municipal solid waste increased by 3 percent between 2010 (228 million metric tons) and 2014 (235 million metric tons), with 12.8 percent combusted for energy recovery (2).

The number of waste-to-energy plants that incinerate municipal solid waste for energy recovery in the United States slightly decreased to 70 plants in 2017, compared with 86 plants in 2010 (3). Most waste-to-energy facilities are located in the northeastern United States, which is a densely populated region with little land availability for landfills (4).

The consumption of biogenic municipal solid waste for energy generation has remained constant over the years, accounting for 19 million metric tons of biogenic municipal solid waste burned in 2016. This generated 154 BTUs of energy, which was primarily used for electricity generation (5).

Photo 27. (14).

The number of waste-to-energy facilities (i.e., incinerators) is shown in Figure 2.5.1. The total number of facilities decreased from 86 plants in 2010 to 70 plants in 2017 (3).

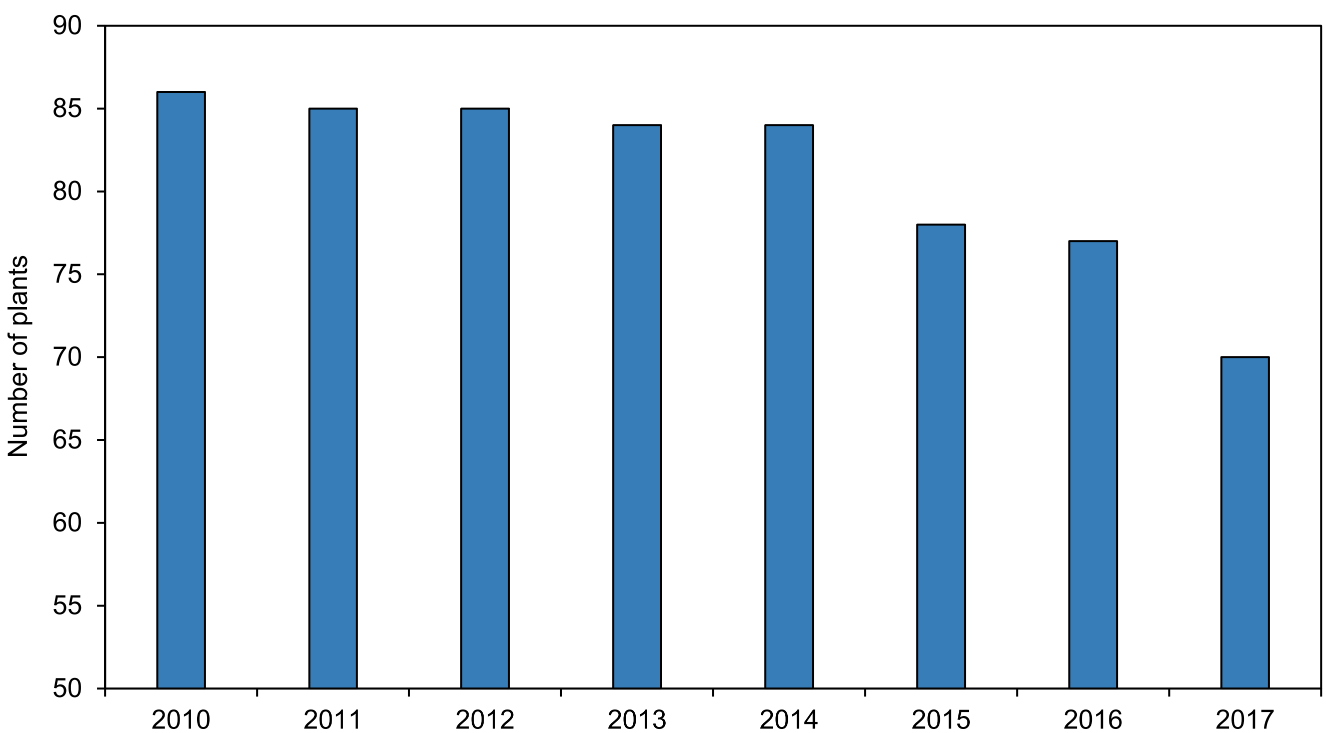

Figure 2.5.1. Total number of waste-to-energy plants in the United States from 2010 to 2017 (3).

In 2017, 11 plants were closed while there were no proposals to construct new plants (Table 2.5.1) (3). One factor in the decrease of waste-to-energy plants is that cities are embracing zero waste policies and renewable energy targets, shifting away from incineration plants (6).

Another factor might be the public opposition to the facilities. Communities are concerned about toxic emissions associated with these facilities and their contribution to climate change. Consequently, companies are using municipal solid waste in co-incineration plants (i.e., plants whose primary purpose is the production of material products or generation of energy) rather than building new waste-to-energy plants (6).

PHYSICAL INFRASTRUCTURE	2010	2011	2012	2013	2014	2015	2016	2017
# of waste-to-energy plants in the United States	86	85	85	84	84	78	77	70
# of waste-to-energy plants proposed in the United States	2	0	2	2	1	0	0	0
# of waste-to-energy existing plants that were put on standby	2	2	2	2	2	2	1	1
# of waste-to-energy existing plants that were closed/shut down	11	10	11	13	8	9	11	11
# of waste-to-energy fuel switching plants in the United States	20	20	16	13	15	15	15	10
# of states which have a waste-to-energy fuel switching production facility	9	9	7	5	7	7	7	8

Table 2.5.1. Physical infrastructure of the waste-to-energy industry in the United State from 2010 to 2017 (2, 3).

There were two geographic clusters of waste-to-energy facilities that burned municipal solid waste for energy recovery in 2017. Most of the facilities are either in the northeastern United States or within Florida. Specifically, 16 percent of existing waste-to-energy plants are in Florida, 15 percent in New York and 9 percent each are in Massachusetts, Minnesota and Pennsylvania (Figure 2.5.2 and Table 2.5.2) (3).

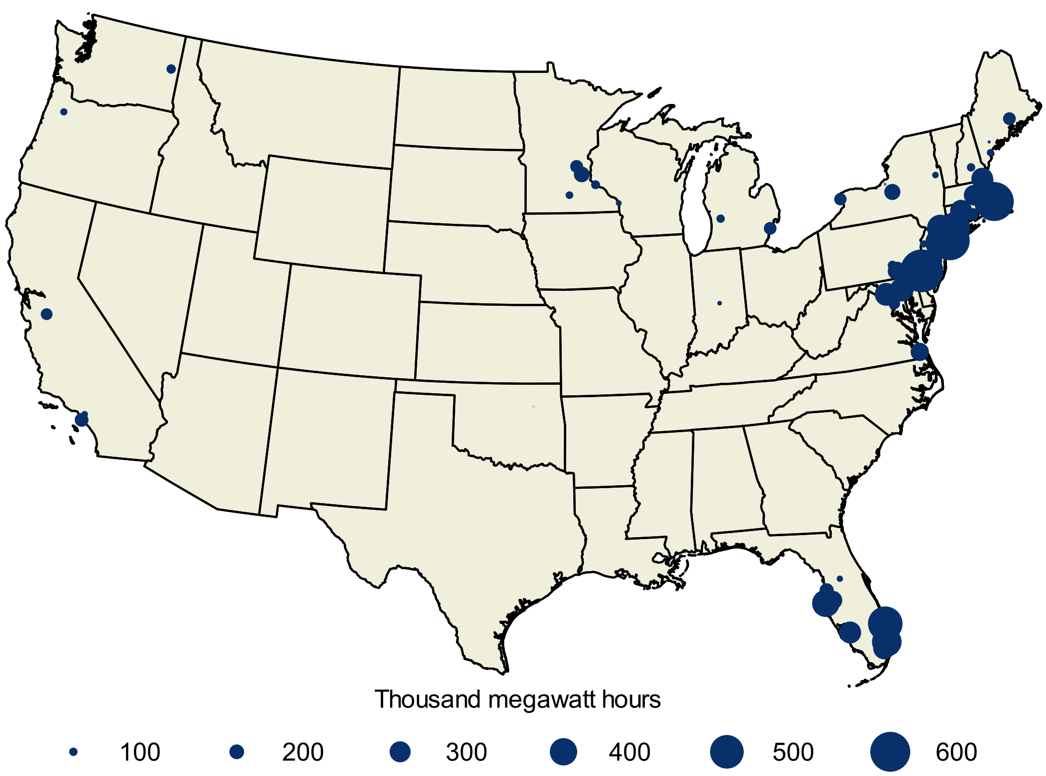

Figure 2.5.2. Waste-to-energy facilities located within the United States in 2017, sorted by net generation (in thousand megawatt hours) (3).

State	Number of plants	Percentage of total generation
Florida	11	15.9
New York	10	14.5
Massachusetts	6	8.7
Minnesota	6	8.7
Pennsylvania	6	8.7

Table 2.5.2. Top 5 states for waste-to-energy facilities in the United States in 2017 (3).

Generating energy is not the only reason to burn municipal solid waste; it is also a waste management option (1). In fact, the majority of waste-to-energy plants are located in the northeastern United States given that the region is highly urbanized and densely populated, leaving little room for landfills (4). In addition, Florida and the northeastern United States are also geographic areas where shallow water Tables may prevent landfills (7,8).

Production

The generation of municipal solid waste increased by 3 percent in the period between 2010 and 2014 (2). In 2014, the United States generated 235 million metric tons of municipal solid waste, of which 34.6 percent was recycled, 12.8 percent combusted for energy recovery and 52.6 percent landfilled (Figure 2.5.3) (2). The municipal solid waste can be classified into (1), biogenic materials (i.e., plant or animal based), (2) non-biogenic materials (i.e., petroleum based), or (3) noncombustible materials.

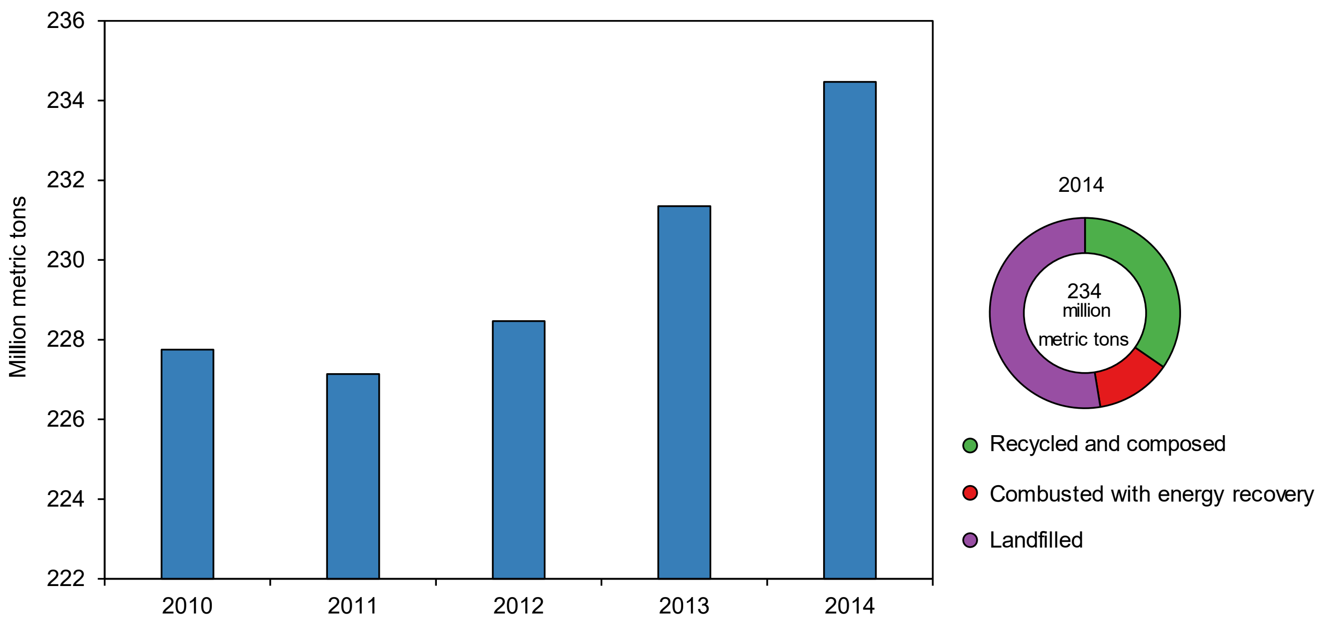

Figure 2.5.3. Total municipal solid waste generation in the United States from 2010 to 2014 (in million metric tons) and end disposal method in 2014 (2).

The consumption of biogenic municipal solid waste for energy generation by final use and sector, in million metric tons and British Thermal Units (BTUs), is shown in Figures 2.5.4 and 2.5.5. Consumption has remained roughly constant over the years, accounting for 19 million metric tons of biogenic municipal solid waste burned in 2016, which generated 154 BTUs of energy (5). In 2017, 88 percent of energy generated by biogenic municipal solid waste was used for electricity generation and was consumed mostly by independent power producers (5).

Note that non-biogenic municipal solid waste is not included in the analysis since in 2001 it was reclassified as non-renewable energy source, and the EIA does not collect this data separately (1).

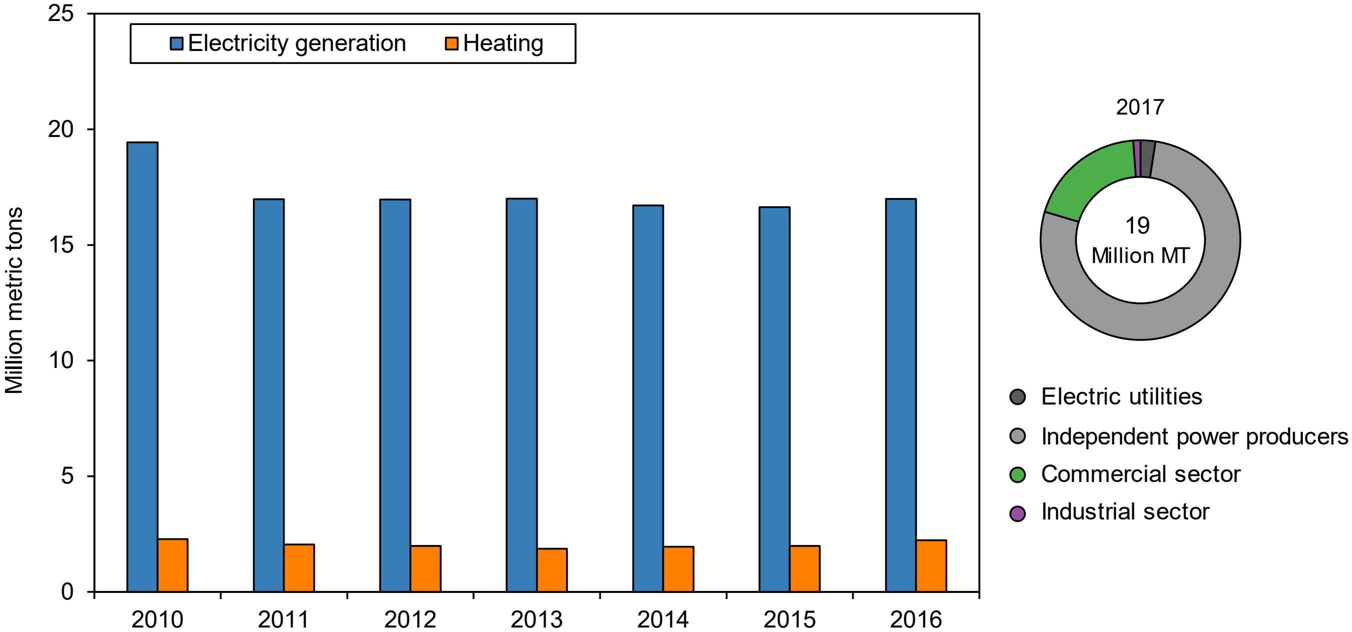

Figure 2.5.4. Biogenic municipal solid waste consumption for energy generation in the United States by final use and sector from 2010 to 2016 (in million metric tons) (5).

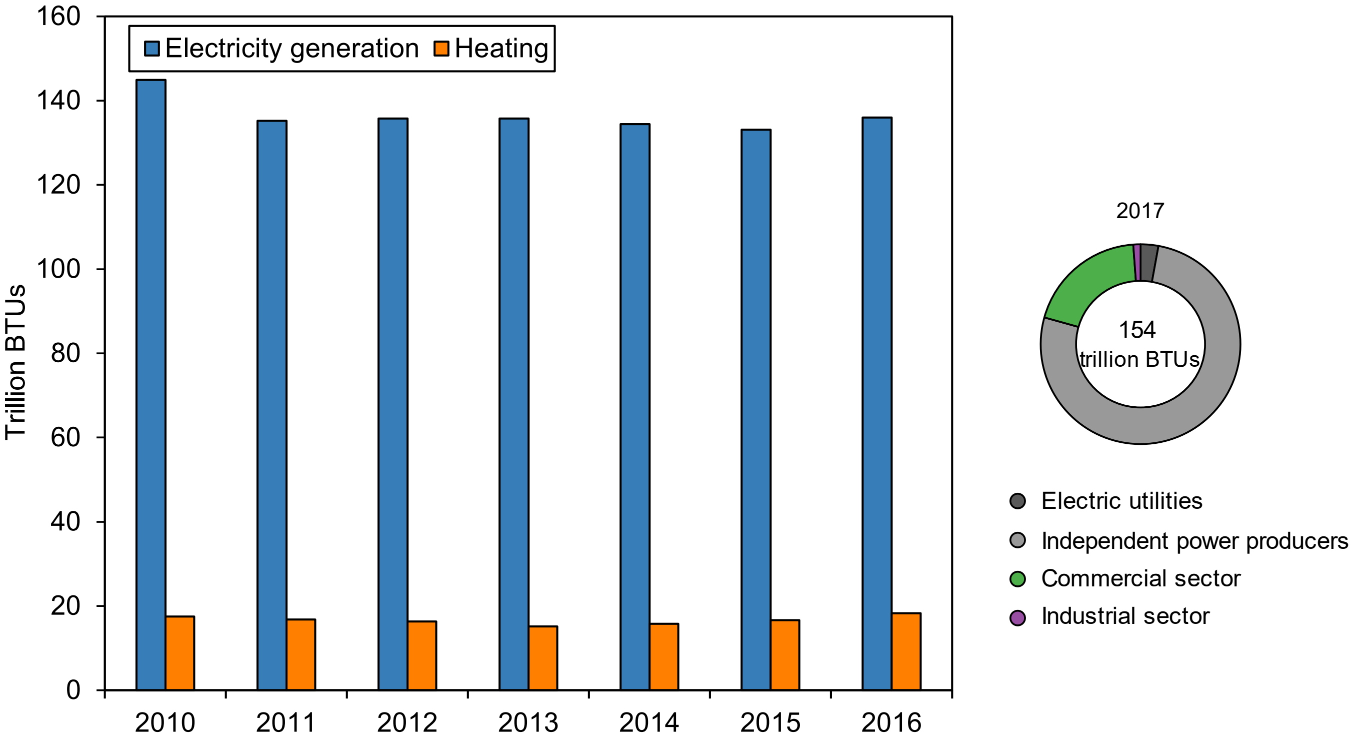

Figure 2.5.5. Energy consumption from biogenic municipal solid waste in the United States by final use and sector from 2010 to 2016 (in trillion British thermal units) (5).

Electricity generation from waste is concentrated in the northeastern United States (3). Although Florida has the largest total, about 45 percent of waste-fired electricity generation takes place in New York, Pennsylvania, Massachusetts, and Connecticut (Figure 2.5.6 ant Table 2.5.6).

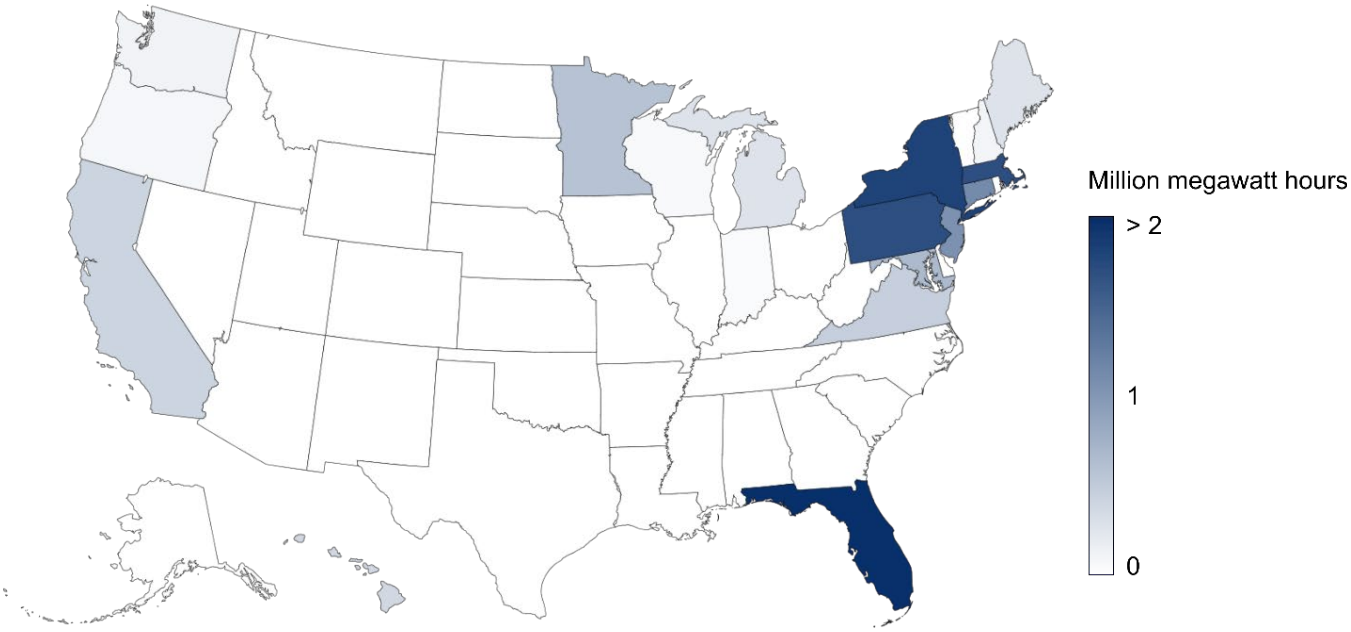

Figure 2.5.6. Electricity net generation from waste-to-energy plants by state (in million megawatt hours) in 2017 (3).

State	Million megawatt hours	Percentage of total generation
Florida	2.9	21.2
New York	1.8	13.2
Pennsylvania	1.7	12.4
Massachusetts	1.7	12.4
Connecticut	1.1	8.2

Table 2.5.3. 5 states with highest net generation of electricity from waste-to-energy plants in the United States in 2017 (3).

Economics

The impact of the waste-to-energy sector on the economy of the United States is presented as revenue from waste-to-energy electricity generation and the number of direct jobs created.

The revenue from the electricity generated from waste decreased from 640 million dollars in 2010 to 227 million dollars in 2017 (Figure 2.5.7) (9). This is due to the decrease of waste-to-energy plants (see Table 2.5.1).

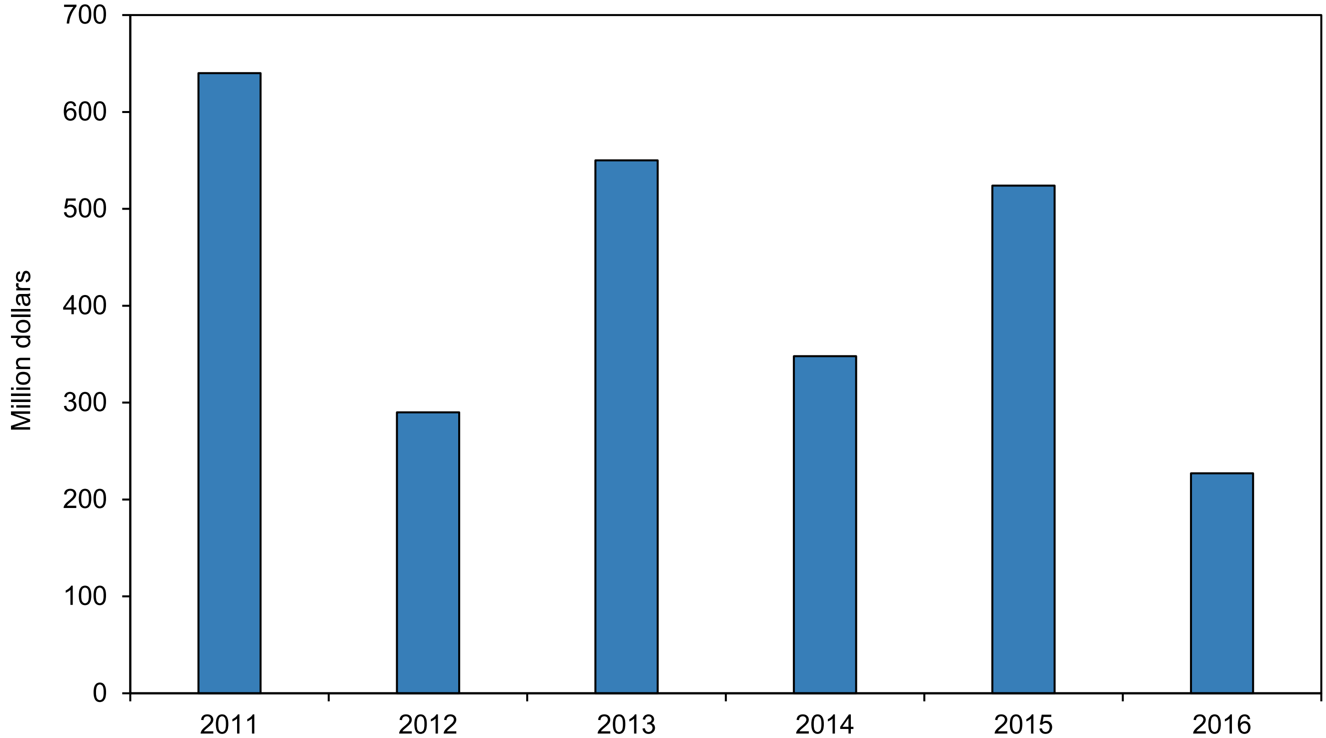

Figure 2.5.7. Revenue from waste-to-energy electricity generation in the United States from 2011 to 2016 (in million dollars) (9).

The number of direct jobs generated by the waste-to-energy sector decreased from 7,000 jobs in 2012 to 5,350 jobs in 2014 (Figure 2.5.8) (10-12). This decrease is also consistent with the decrease in waste-to-energy industries analyzed in Table 2.5.1.

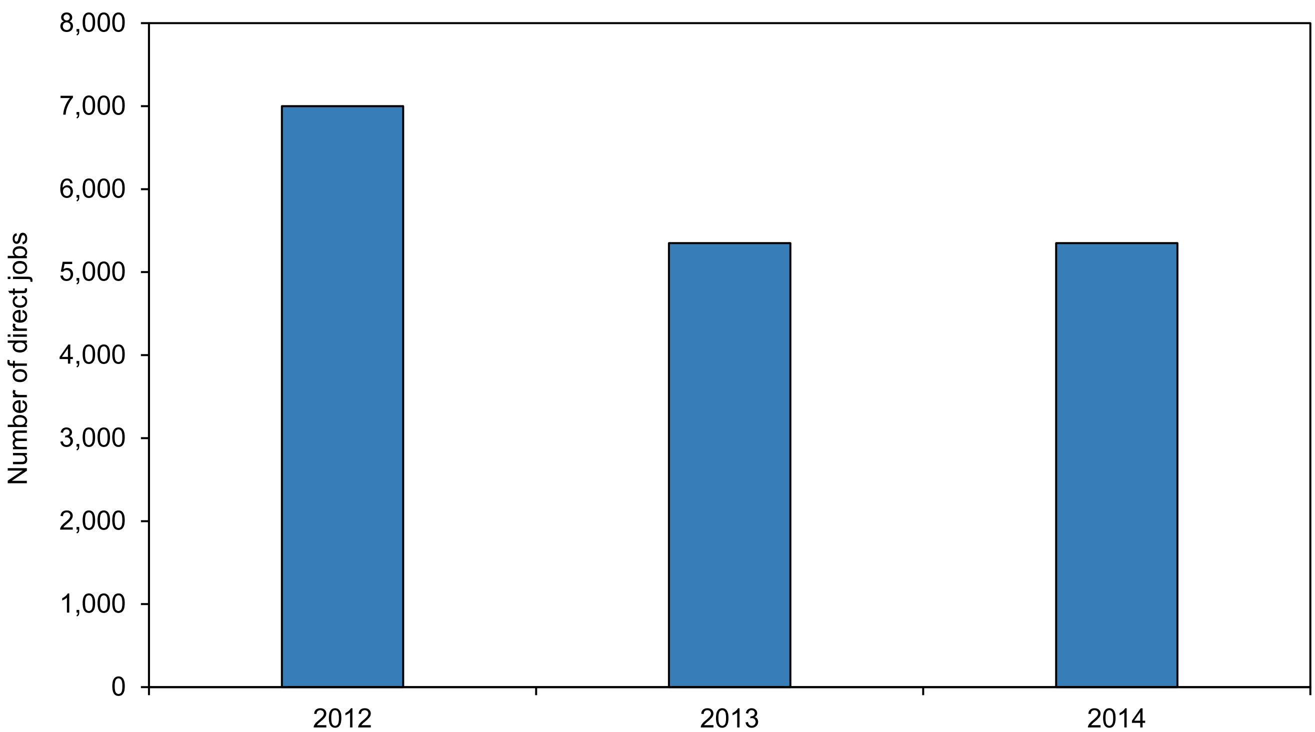

Figure 2.5.8. Number of direct jobs generated from the waste-to-energy industry from 2012 to 2014 (10-12).

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2.6. Biogas

Photo 28. (11).

Biogas is a renewable energy source produced by anaerobic digestion when organic material is broken down by bacteria in the absence of oxygen (1).

Biogas can be produced from different waste sources like landfills, wastewater treatment plants, animal manure and organic waste. Biogas is primarily methane and carbon dioxide (2). The share of methane in the mixture depends on the biogas source: landfill biogas contains between 40 and 60 percent methane, and farm and wastewater treatment biogas contain between 55 and 70 percent methane (2).

Biogas systems capture methane that otherwise would escape into the atmosphere and use it to generate energy in the form of electricity generation, heating or transportation fuel. Anaerobic digestion can occur naturally in landfills, or it can be optimized using anaerobic digesters (i.e., farms, wastewater) (1).

In 2017, there were over 2,300 sites producing biogas in the United States: 250 anaerobic digesters on farms that produced 1.9 million metric tons of methane; 849 landfills gas projects that produced 2.6 million metric tons of methane; and 1,268 wastewater treatment facilities that produced 2.3 million metric tons of methane (2-5). Most of the facilities are in the Midwest and northeastern United States (3-5).

The overall production of biogas increased from 225 billion cubic feet of biogas in 2010 to 286 billion cubic feet of biogas in 2017 (3, 6) (Note that further processing entailing some yield loss would be required to produce renewable natural gas suitable for pipeline distribution). The collection and use of biogas has direct benefits for the environment. In fact, in 2017 landfill biogas capture reduced greenhouse gas emissions by 123 million metric tons of carbon dioxide equivalent, and biogas capture form anaerobic digesters in farms reduced greenhouse emissions by 3.2 million metric tons of carbon dioxide equivalent (3, 4).

Photo 29. (12).

Between anaerobic digesters at farms, landfills and wastewater treatment facilities, there are over 2,300 sites producing biogas in the United States (3-5). This section analyzes the trends of biogas facilities in farms and landfills, but not in wastewater treatment facilities due to a lack of reliable information.

The number of biogas recovery systems has increased by 60 percent in farms and by 46 percent in landfills between 2010 and 2017 (Figure 2.6.1 and Table 2.6.1) (3, 4).

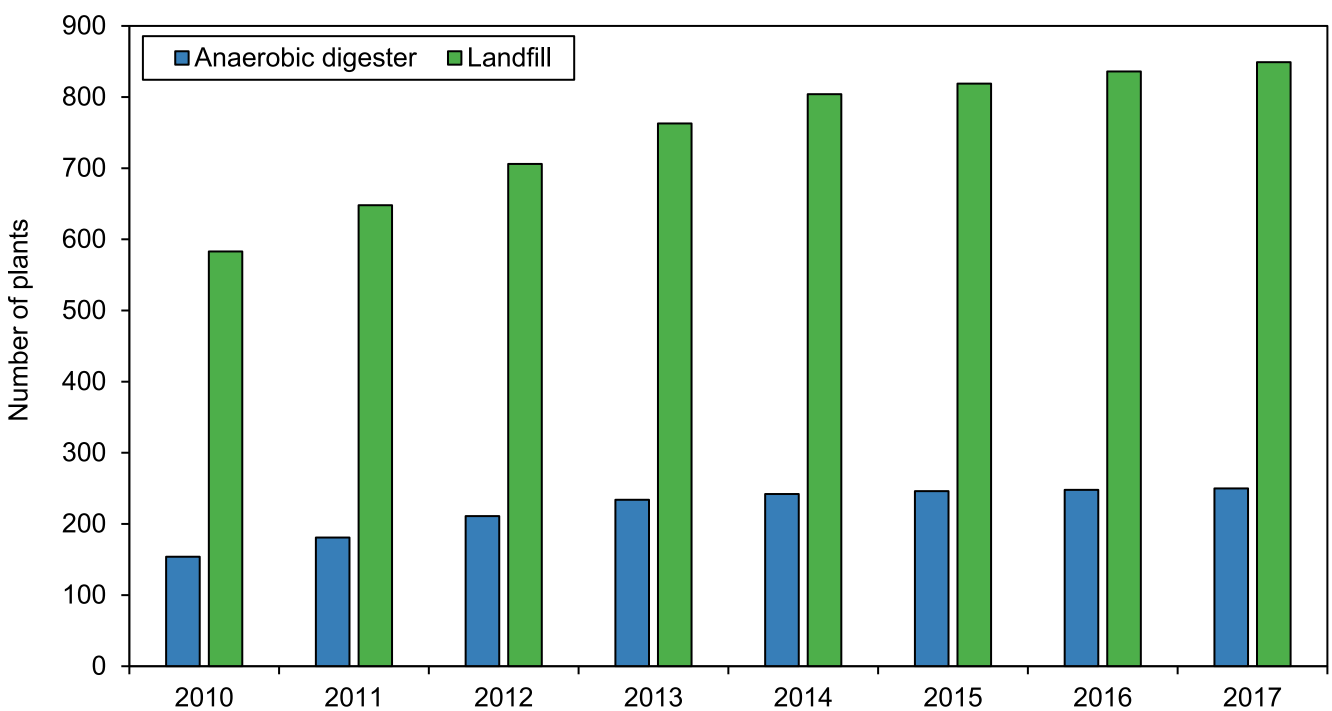

Figure 2.6.1. Total number of biogas plants in the United States by type from 2010 to 2017 (3, 4).

PHYSICAL INFRASTRUCTURE	2010	2011	2012	2013	2014	2015	2016	2017
# of anaerobic digestion plants	154	181	211	234	242	246	248	250
# of anaerobic digesters in livestock farms used for electricity	45	58	76	90	95	97	99	101
# of anaerobic digesters in livestock farms used for boiler/furnace	25	25	27	27	28	28	28	28
# of anaerobic digesters in livestock farms used for "flare full time"	13	14	14	14	15	14	14	14
# of anaerobic digesters in livestock farms used for cogeneration	84	96	109	121	124	126	125	125
# of new anaerobic digestion plants that went on line from livestock	19	27	30	23	8	4	2	2
# of existing anaerobic digestion plants under construction	0	1	4	1	0	2	2	3
# of anaerobic digestion plants that shut down	3	6	1	2	3	8	2	0
# of states which have an anaerobic digestion production facility	30	35	36	37	38	38	38	38
# of landfill biogas plants	583	648	706	763	804	819	836	849

Table 2.6.1. Physical infrastructure of the biogas industry in the United States from 2010 to 2017 (3, 4).

More than half of total facilities are in the Midwest and northeastern United States. California, which has 17 anaerobic digester locations, 86 biogas landfill facilities, and 156 wastewater treatment facilities, has the most biogas recovery systems in the country (Figure 2.6.2; Tables 2.6.2 – 2.6.4) (3-5).

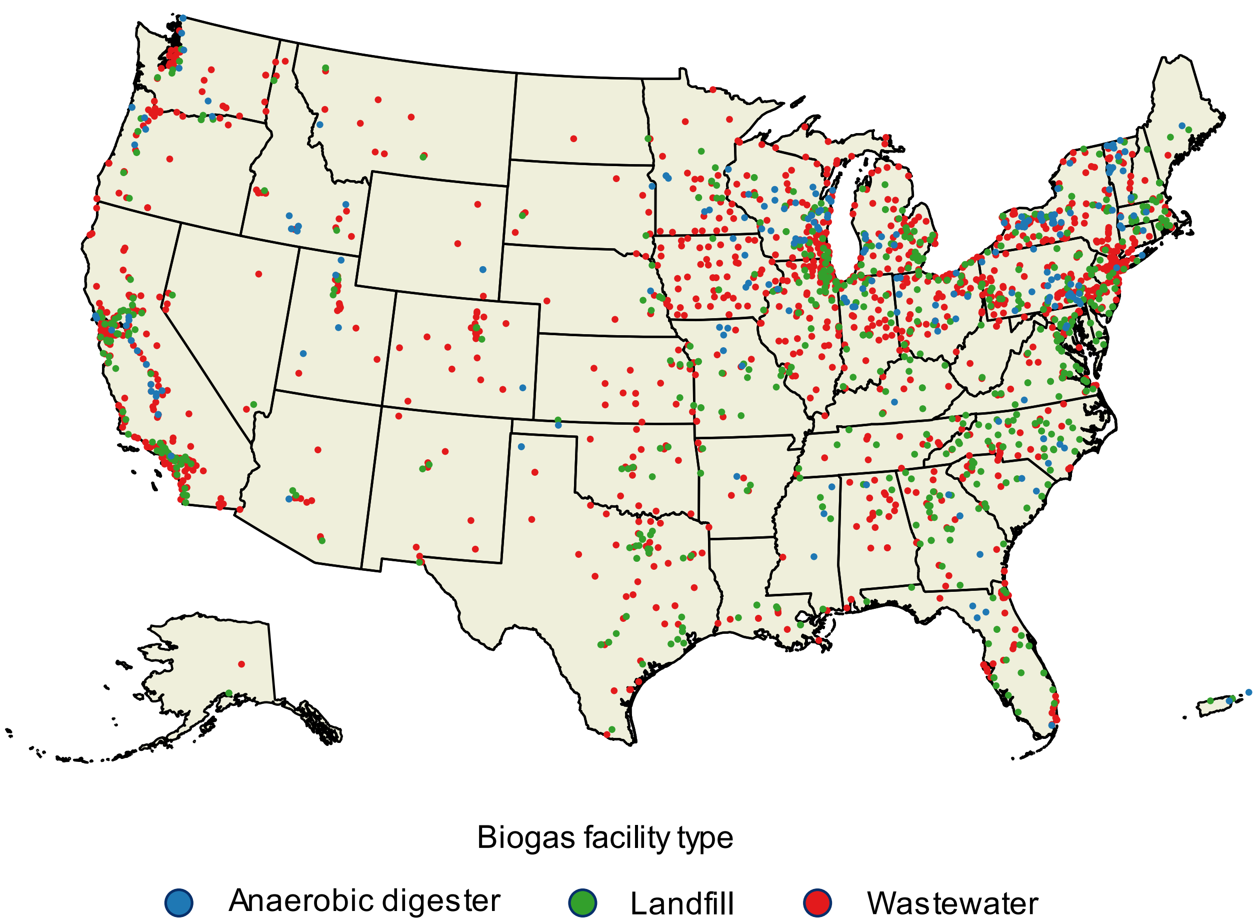

Figure 2.6.2. Biogas facilities location by type in the United States in 2017 (3-5).

State	Number of plants	Percentage of total facilities
Wisconsin	37	14.9
New York	33	13.3
Pennsylvania	28	11.3
Vermont	18	7.3
California	17	6.9

Table 2.6.2. Top 5 states for anaerobic digester on farms in the United States in 2017 (3).

State	Number of plants	Percentage of total facilities
California	86	10.2
Michigan	68	8.0
Pennsylvania	60	7.1
New York	52	6.1
Wisconsin	45	5.3

Table 2.6.3. Top 5 states for biogas recovery systems on landfills in the United States in 2017 (4).

State	Number of plants	Percentage of total facilities
California	156	12.3
New York	118	9.3
Illinois	87	6.9
Pennsylvania	81	6.4
Michigan	65	5.1

Table 2.6.4. Top 5 states for biogas recovery systems in wastewater treatment facilities in the United States in 2017 (5).

Production

U.S. biogas resources are characterized in terms of methane potential, which is the amount of methane in the biogas, from landfills, wastewater, animal manure, and organic waste. Landfill biogas has the largest methane potential, accounting for 2.6 million metric tons per year, followed by wastewater treatment facilities, which have a methane potential of 2.3 million metric tons per year (Figure 2.6.3 and Table 2.6.5) (2).

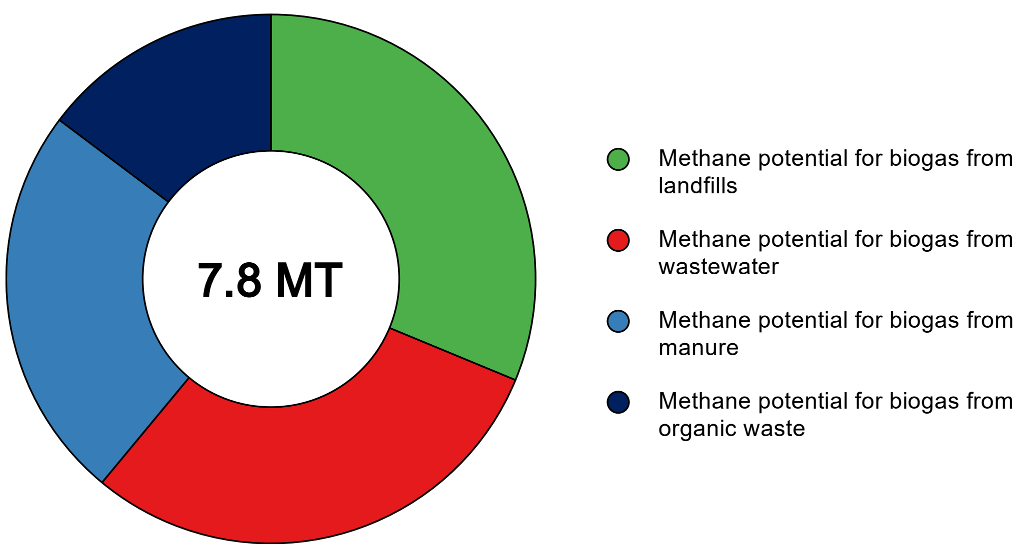

Figure 2.6.3. Methane potential of biogas from different biogas sources in 2014 (in million metric tons) (2).

Source	Methane Potential (million metric tons/year)
Landfills	2.6
Wastewater	2.3
Animal manure	1.9
Organic waste	1.2

Table 2.6.5. Methane potential of biogas from different biogas sources in 2014 (in million metric tons) (2).

The volume of biogas captured in landfills is 35 times larger than the biogas captured from farms (3, 6).

The capture of landfill biogas increased until 2014 when it reached a peak of 288 billion cubic feet. Since then, the total has slightly decreased to 282 billion cubic feet in 2017 (6). On the other hand, biogas from farms increased from 4.7 billion cubic feet in 2010 to 7.9 billion cubic feet in 2017 (Figure 2.6.4) (3).

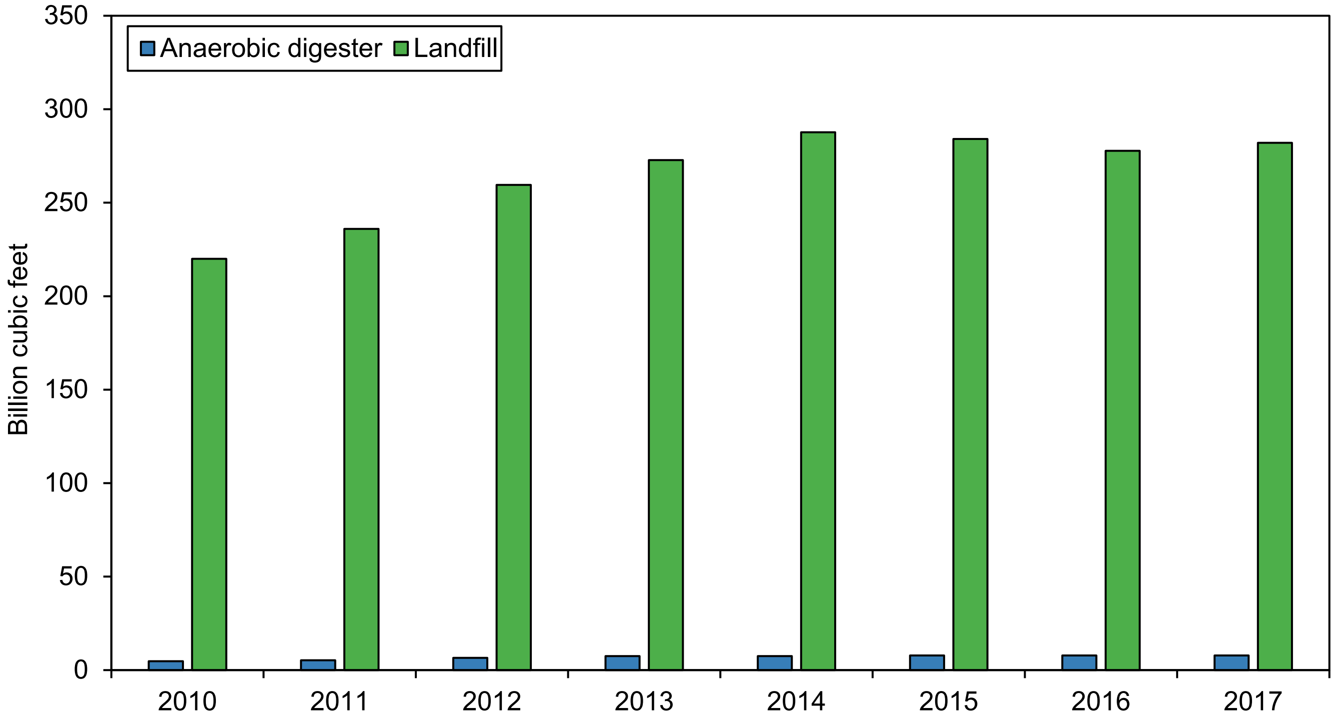

Figure 2.6.4. Estimate of total biogas captured by source from 2010 to 2017 (in billion cubic feet) (3, 6).

As of 2013, more than 30 percent of potential methane was available in just two states: California had 322 thousand metric tons available, and North Carolina had 309 thousand metric tons available (Figure 2.6.5 and Table 2.6.6) (7).

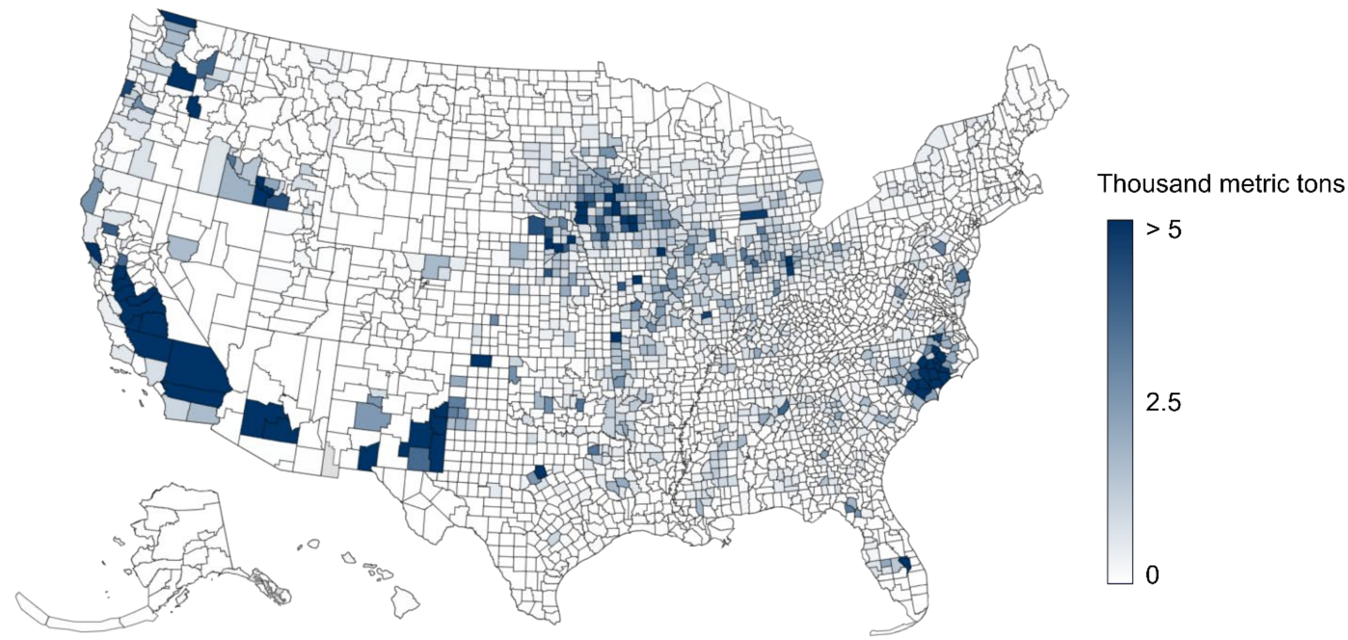

Figure 2.6.5. Methane capturing potential for anaerobic digesters on farms in the United States by county in 2013 (in thousand metric tons) (7).

State	Thousand metric tons	Percentage of total	Primary feedstocks
California	322	16.9	Dairy manure [32 million gallons/day] Beef manure [6.6 million gallons/day]
North Carolina	309	16.2	Broiler manure [119.2 million gallons/day] Swine manure [13.2 million gallons/day]
Iowa	170	8.9	Swine manure [31.3 million gallons/day] Beef manure [10.1 million gallons/day]
Missouri	95	5.0	Broiler manure [43.2 million gallons/day] Beef manure [20.6 million gallons/day]
New Mexico	90	4.7	Dairy manure [5.8 million gallons/day] Beef manure [4.7 million gallons/day]

Table 2.6.6. 5 states with highest capturing methane potential for anaerobic digester on farms in the United States in 2013 (in thousand metric tons) and primary feedstocks (7,8).

California also exhibits the most potential for methane capture from landfills, with 423 thousand metric tons, representing 17 percent of total methane potential from landfills (Figure 2.6.6 and Table 2.6.7) (7).

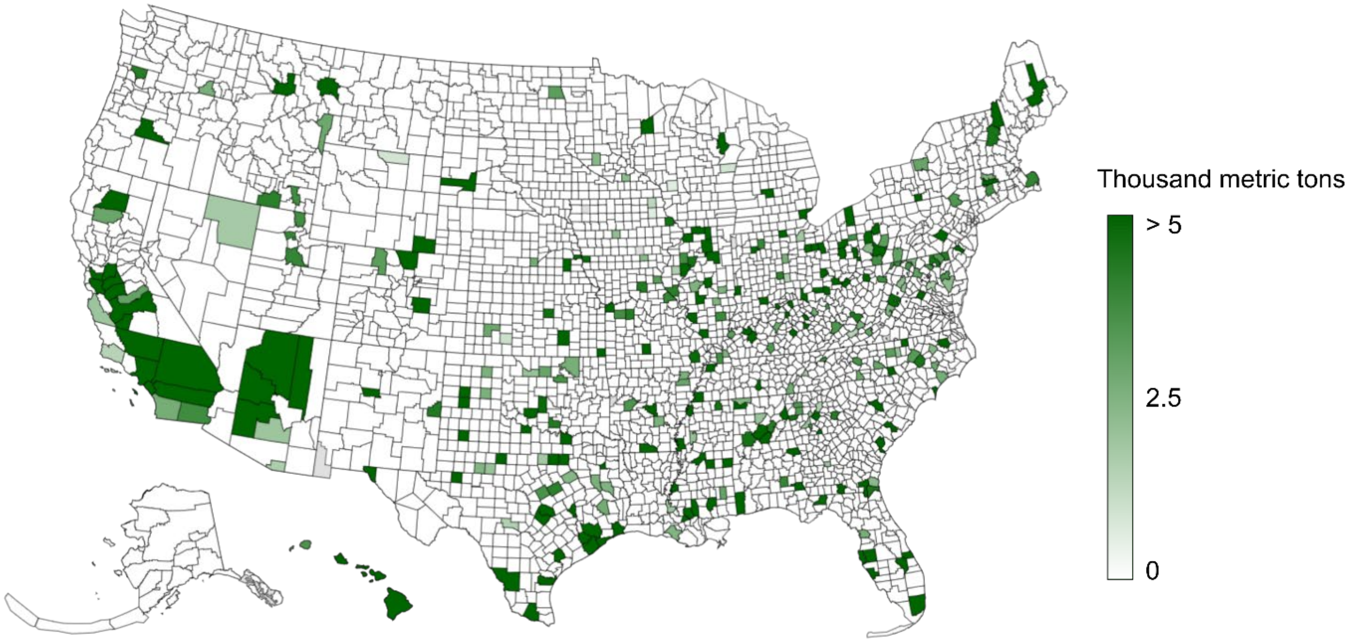

Figure 2.6.6. Methane capturing potential for landfills in the United States by county in 2013 (in thousand metric tons) (7).

State	Thousand metric tons	Percentage of total
California	423	17.2
Texas	310	12.6
Illinois	188	7.7
Ohio	151	6.1
Florida	140	5.7

Table 2.6.7. 5 states with highest capturing methane potential for landfills in the United States in 2013 (in thousand metric tons) (7).

The methane potential from wastewater facilities is more evenly distributed than methane potential from manure or landfills. Similar to other sources of biogas, California is the state with largest methane potential from wastewater, with 222 thousand metric tons, followed by Texas with 181 thousand metric tons (Figure 2.6.7 and Table 2.6.8).

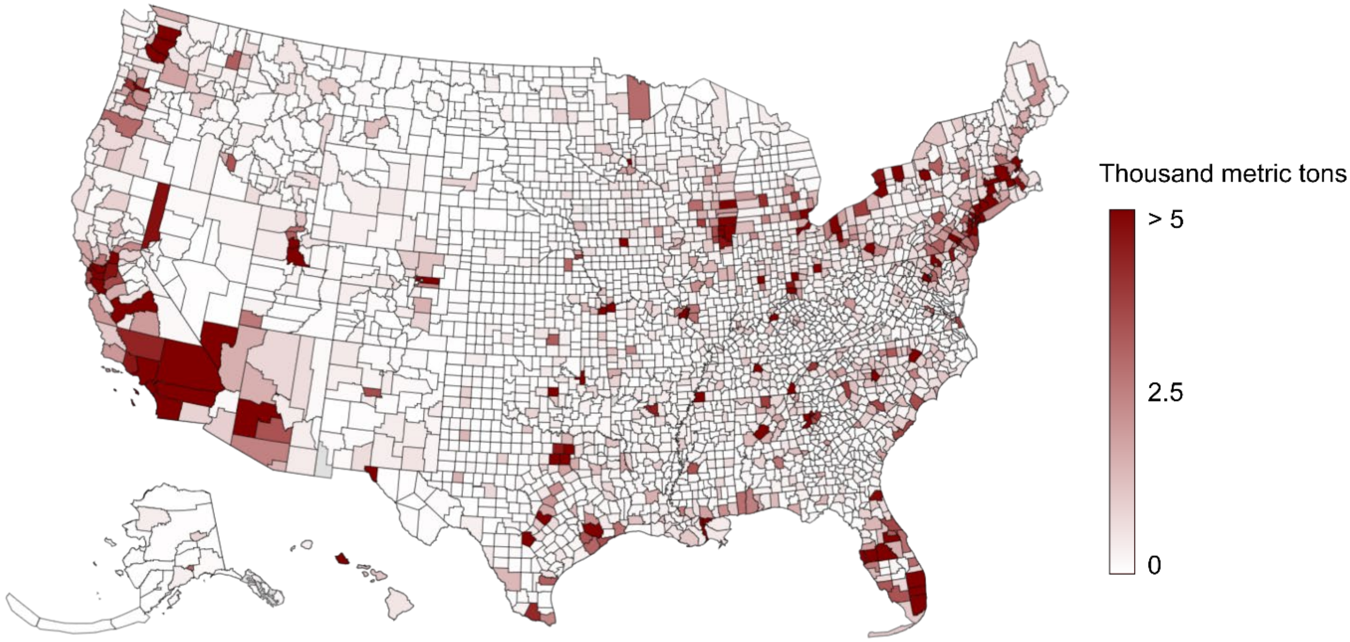

Figure 2.6.7. Methane capturing potential from wastewater treatment in the United States by county in 2013 (in thousand metric tons) (7).

State	Thousand metric tons	Percentage of total
California	222	9.5
Texas	181	7.8
New York	171	7.4
Illinois	155	6.7
Florida	117	5.0

Table 2.6.8. 5 states with highest capturing methane potential for wastewater treatment in the United States in 2013 (in thousand metric tons) (7).

Biogas can be used for electricity generation, for heating and as a transportation fuel. Landfills supply much more biogas than anaerobic digesters (3, 6). From 2010 to 2017, the generation of biogas energy from landfills increased from 107 trillion BTUs to 140 trillion BTUs. The energy generated from anaerobic digester also increased from 1.5 trillion BTUs in 2010 to 3.3 trillion BTUs in 2017 (Figure 2.6.8) (3, 6).

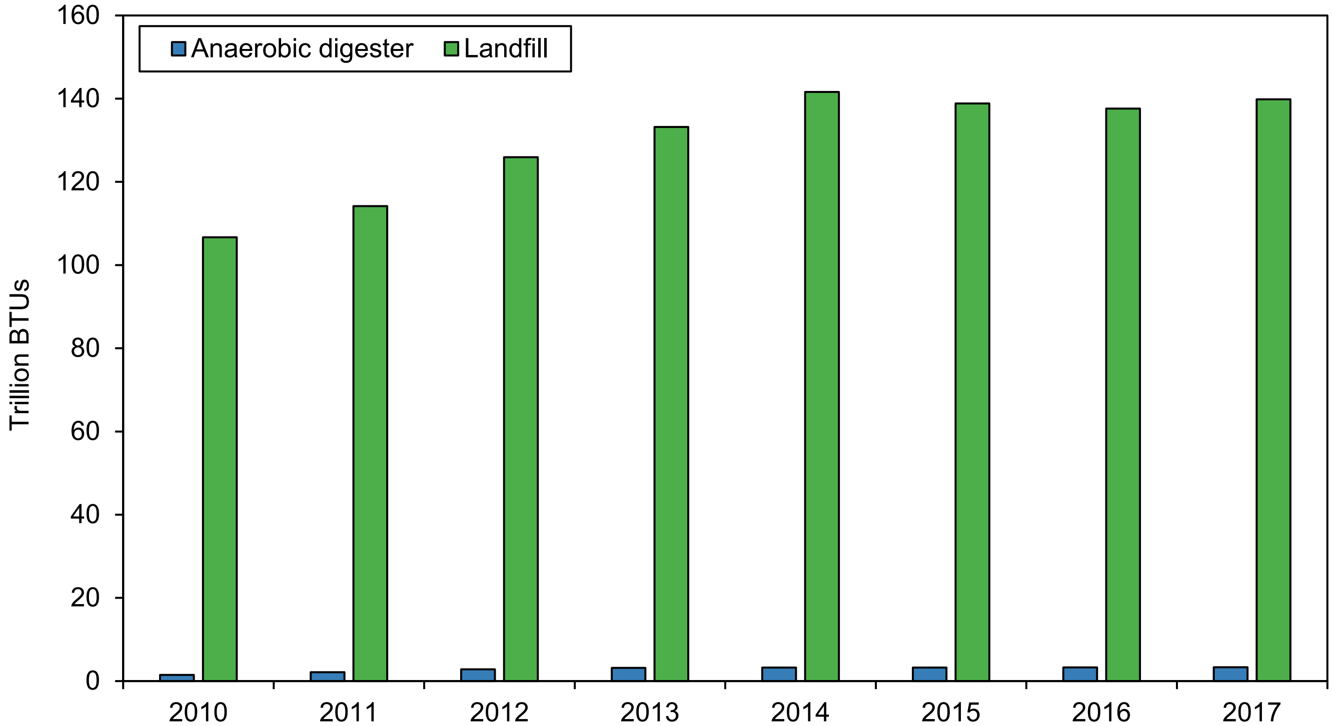

Figure 2.6.8. Total energy generated from biogas by source from 2010 to 2017 (in trillion British Thermal Units (BTU)) (3, 6).

Methane is a valuable source of energy, but it is also a deleterious greenhouse gas. In fact, methane's global warming potential, which is a measure of the amount of heat a greenhouse gas traps in the atmosphere, is 25 times more potent than carbon dioxide (9). Therefore, the collection and use of biogas has direct benefits for the environment (1). Methane capture increased steadily from 2010 through 2017. In 2017, 123 million metric tons of carbon dioxide equivalent were captured from landfills, and 3.2 million metric tons of carbon dioxide equivalent were captured from anaerobic digesters (Figure 2.6.9) (3, 4).

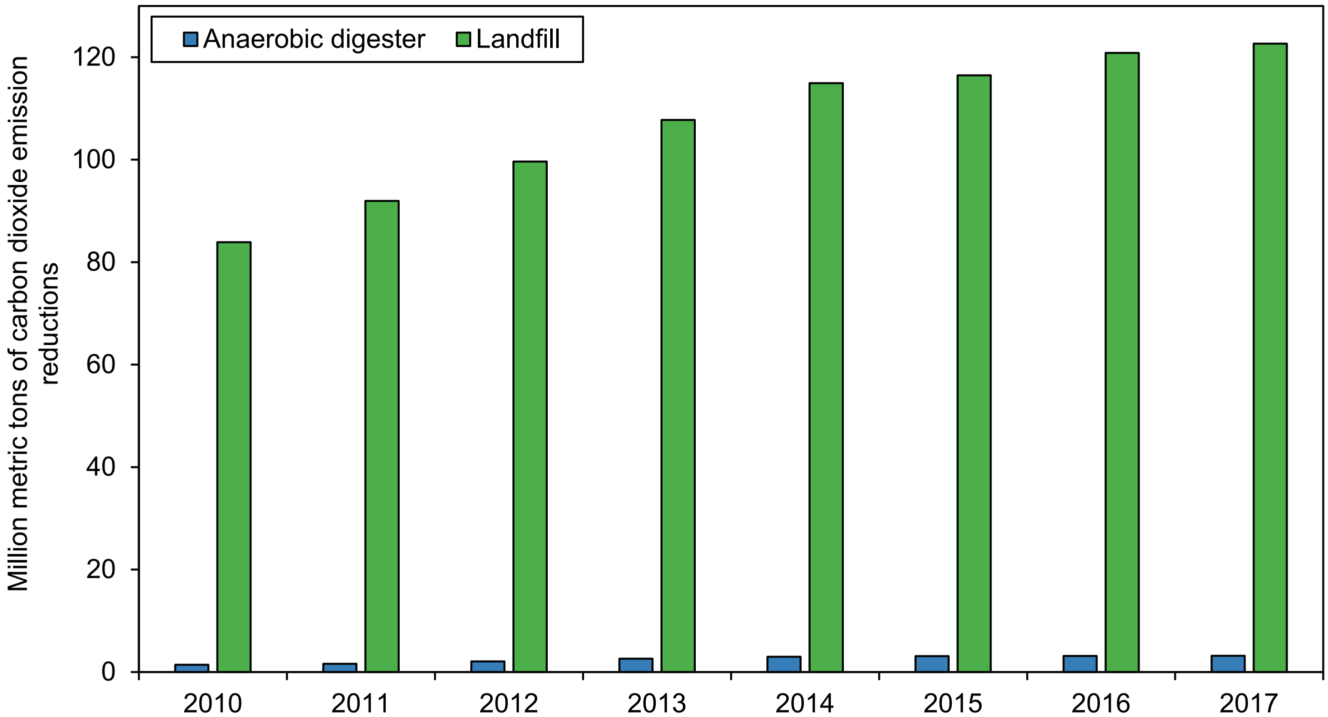

Figure 2.6.9. Total methane emission reductions by source from 2010 to 2017 (direct methane emission reductions, in million metric tons of carbon dioxide equivalent) (3, 4).

One way to assess the biogas potential is by comparing the amount of methane emitted into the atmosphere by sector (i.e., agriculture and waste) with methane emissions reduction attributed to biogas capture systems.

Methane emissions from waste decreased by 17 million metric tons from 2010 to 2017, which is consistent with the increase in methane capture from landfills (10). In 2016 the methane emissions reduction from biogas recovery systems on landfills were approximately equal the total methane emission from waste, which indicates that the biogas recovery systems on landfills can double their volume in order to capture all the methane emitted by waste (Figure 2.6.10) (3,10).

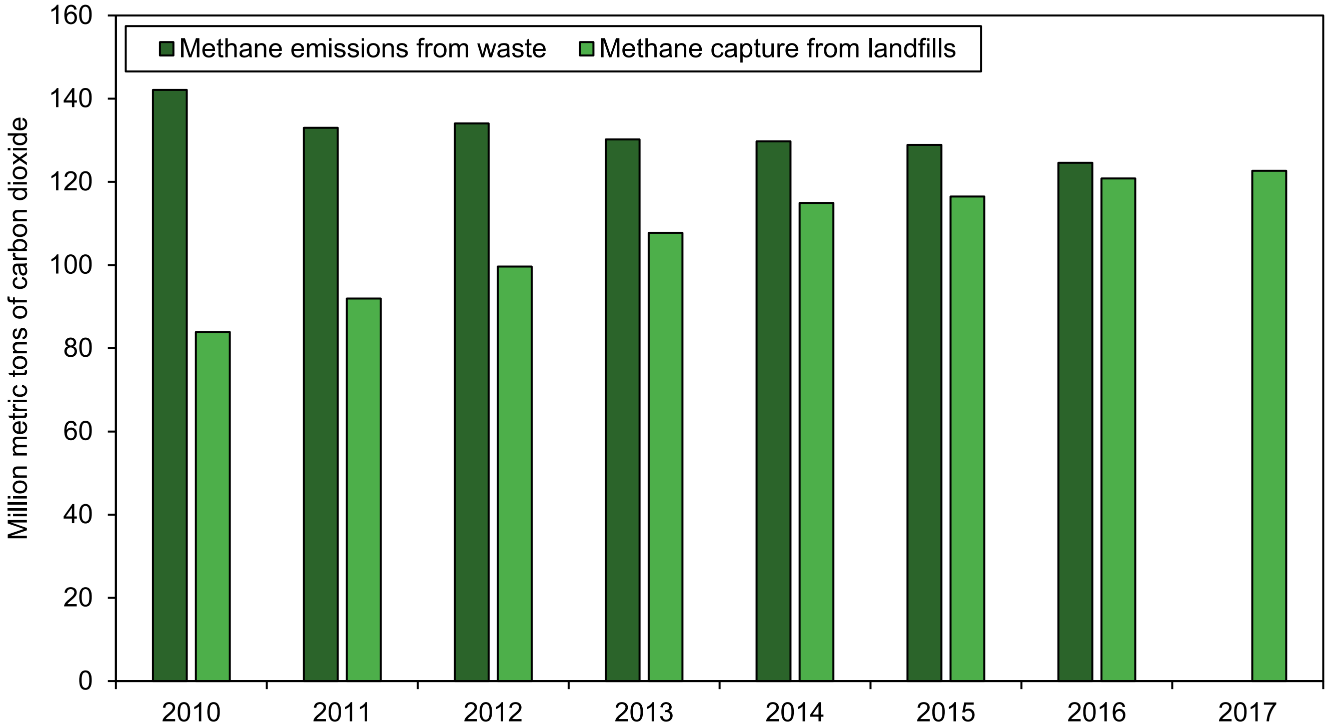

Figure 2.6.10. Total methane emission from waste in the United States from 2010 to 2016 (10) and total methane reductions from biogas recovery systems on landfills from 2010 to 2017 (in million metric tons of carbon dioxide equivalent) (3,10).

The methane emissions reduction from anaerobic digesters on farms is very small. As a consequence, there is not a significant reduction of total methane emissions; the amount of methane emitted from agriculture was constant from 2010 to 2016 (10). Methane emissions from agriculture are 250 times larger than the amount of methane recovery from farms, which indicates that the number and size of the biogas recovery systems on farms can be considerably increased in the coming years (Figure 2.6.11) (4,10).

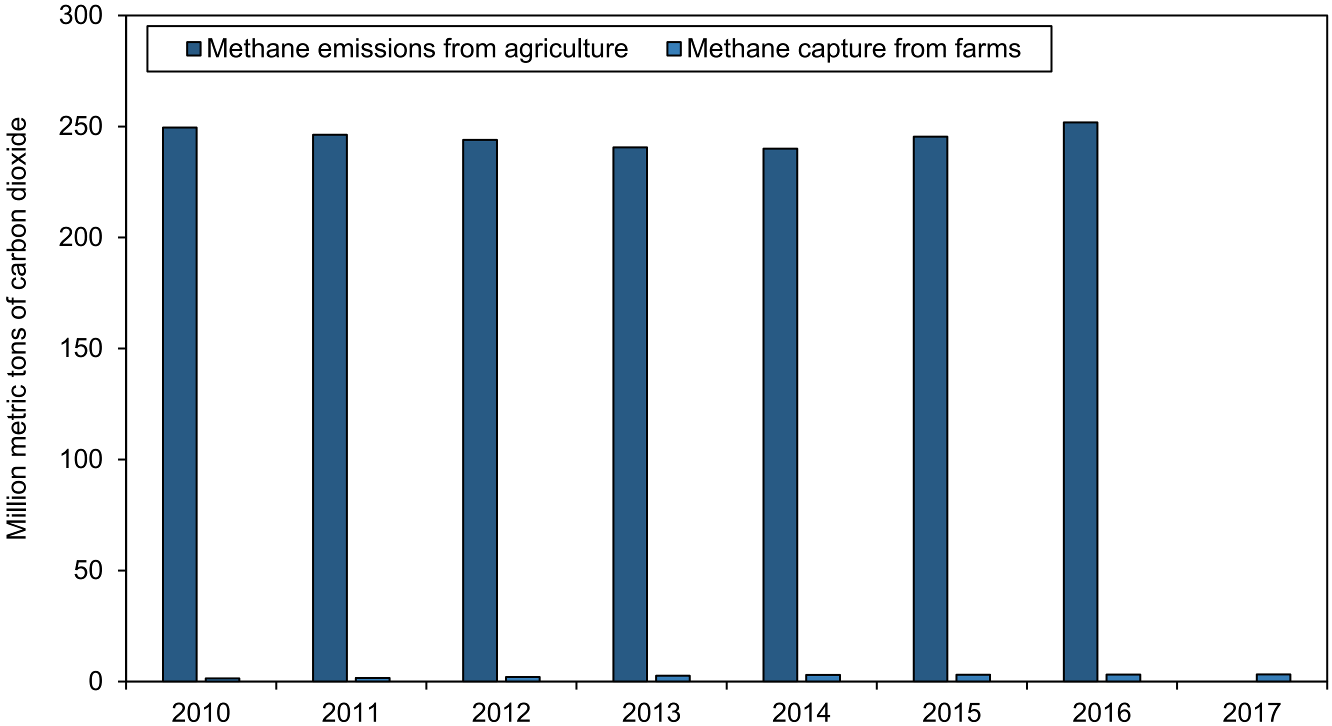

Figure 2.6.11. Total methane emission from agriculture in the United States from 2010 to 2016 (10) and total methane reductions from anaerobic digesters on farms from 2010 to 2017 (in million metric tons of carbon dioxide equivalent) (4,10).

Economics

Due to the lack of tracking and consolidation of financial and technical data from the biogas industry, current analysis of the economic state of the industry is limited.

In 2014, the United States Environmental Protection Agency conducted an industry survey and concluded that building 11,000 biogas recovery systems would result in 275,000 short-term construction jobs and 18,000 permanent jobs. The study also concluded that the market potential from installing digesters on 2,647 dairy operations would be 2.9 billion dollars (1).

In 2015, the American Biogas Council studied the biogas potential and the economic implications by state. California, Texas and North Carolina are the states with the largest methane production potential from farms, landfills and wastewater treatment plants (Figure 2.6.12 and Table 2.6.9).

California's biogas industry can grow by 330 percent, from 276 biogas operational projects to 1,187 potential biogas projects. Texas has potential for 534 new biogas projects, which is an increase of 487 percent. Finally, North Carolina can increase its biogas industry by 1,099 percent, which is equivalent to creating 899 new biogas recovery systems (8). In both California and North Carolina between 80 and 85 percent of total biogas potential is from anaerobic digesters in farms (8).

Constructing the aforementioned projects would generate 3.5 billion dollars in capital investment in California, 1.6 billion dollars in Texas and 2.7 billion dollars in North Carolina. In addition, that would create 29,675 short-term jobs and 2,374 long-term jobs in California, 13,350 short-term jobs and 1,068 long-term jobs in Texas, and 22,475 short-term jobs and 1,798 long-term jobs in North Carolina (see Table 2.6.9) (8).

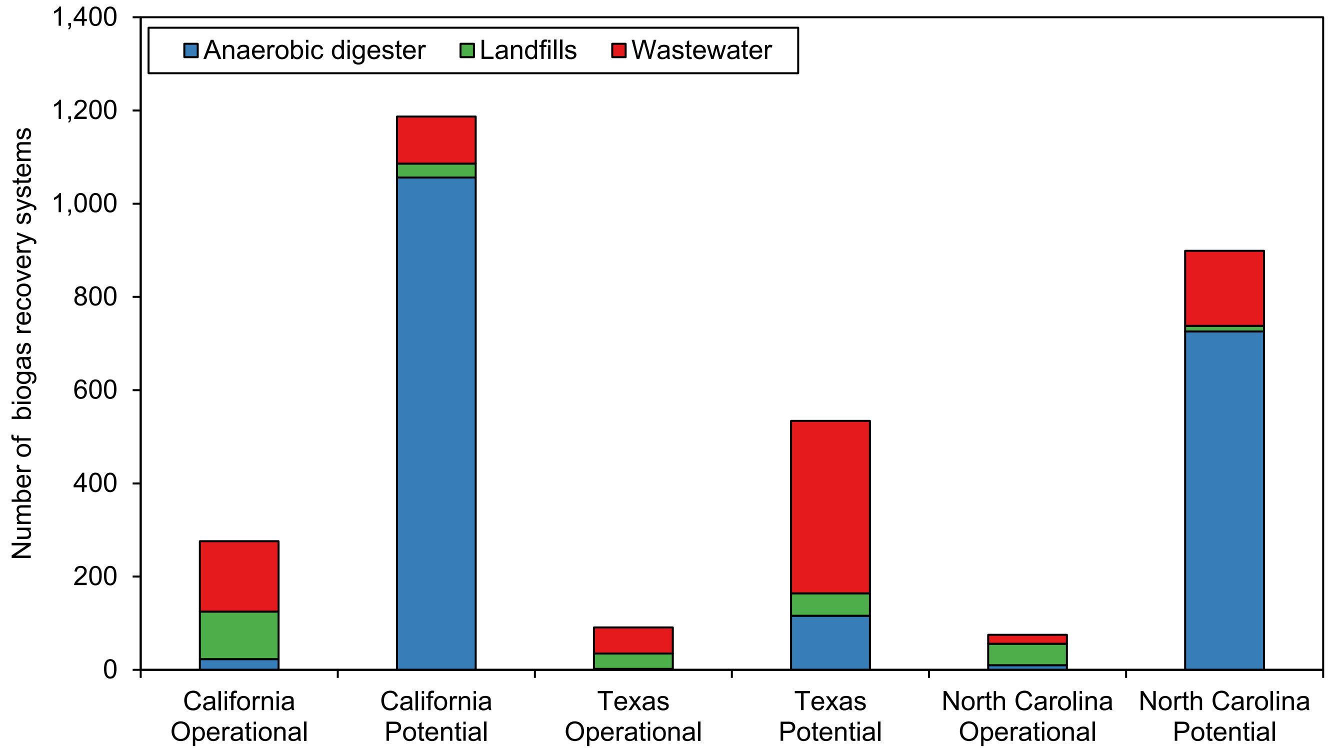

Figure 2.6.12. Operational and potential biogas recovery systems – by type – in California, Texas and North Carolina in 2015 (8).

	California	Texas	North Carolina
Potential anaerobic digesters in farms	1,056	116	726
Potential biogas systems at landfills	30	48	12
Potential biogas systems at wastewater treatment plants	101	370	161
Capital investment in billion dollars	3.5	1.6	2.7
Short-term jobs	29,675	13,350	22,475
Long-term jobs	2,374	1,068	1,798

Table 2.6.9. Potential biogas recovery systems – by type – in California, Texas, and North Carolina. Economic impact statistics (e.g., jobs, investment) are for the year 2015 (8).

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3. BIOBASED PRODUCTS

3.1. Summary

Number of companies participating in the BioPreferred Program: **>2,200 Companies**

TOP 5 TYPES OF BIOENERGY PLANTS

California [262]
Washington [175]
Texas [136]
Illinois [123]
Florida [118]

The number of products in the BioPreferred catalog is **>3,500 Products**

bioplastics represents **66%** of total products.

Global production of bioplastics in 2017 ↑ **0.7%**

TOP 5 TYPES OF BIOPLASTICS

2016
2.0 million metric tons

Packaging [1.43]
Textiles [0.20]
Consumer goods [0.14]
Automotive and transport [0.12]
Agriculture [0.11]

2017
2.1 million metric tons

Packaging [1.20]
Textiles [0.22]
Automotive and transport [0.15]
Consumer goods [0.14]
Agriculture [0.11]

Renewable chemical production in the U.S.

⬆ 354%

2012
0.17
MMT

VS

2017
0.75
MMT

Value of global market for industrial enzymes

⬆ 2.0%

2015
4.9 B
DOLLARS

VS

2016
5.0 B
DOLLARS

Forest products represent the largest contribution of renewable source for the biobased products industry .

TOP 5 CATEGORIES

2016

Paper [237 Million tons]
Wood-based panels [201 Million m3]
Wood pulp [92 Million tons]
Sawnwood [78 Million m3]
Wood residues [64 Million m3]

2017

Paper [239 Million tons]
Wood-based panels [207 Million m3]
Wood pulp [92 Million tons]
Sawnwood [80 Million m3]
Wood residues [64 Million m3]

3.2. Bioproducts

Photo 30. (3).

Biobased products, or bioproducts, are both commercial and industrial products that are derived in whole, or in significant part, of biological or renewable materials. Such products generally provide an alternative to conventional, petroleum-derived products, including offerings such as lubricants, detergents, inks and plastics. The U.S. Department of Agriculture manages the BioPreferred Program, which is intended to increase the purchase and use of biobased products (1). The BioPreferred Program has two major parts: (1) mandatory purchasing requirements for federal agencies and their contractors, and (2) voluntary labeling initiative for biobased products (1).

Federal law, the Federal Acquisition Regulations, and Presidential Executive Orders direct that federal agencies purchase biobased products in categories defined by the BioPreferred Program. Each category specifies the minimum biobased contact for products within the category (1).

In addition, the BioPreferred Program also created a voluntary labeling initiative through which companies can apply for certification to display the USDA certified biobased product (see Figure 3.2.1). This label was created to inform the consumer on whether or not a given product is indeed biobased (1).

USDA
CERTIFIED
BIOBASED
PRODUCT
PRODUCT 100%

Figure 3.2.1. A sample United States Department of Agriculture Certified Biobased Product label (1).

In this context, the United States Department of Agriculture BioPreferred Program assists companies in identifying products that might qualify for mandatory federal purchasing and/or might be certified through the voluntary labelling initiative (1).

More than 2,200 companies participate in the BioPreferred Program. California (262 companies) has the largest number of companies participating in the program, followed by Washington (175 companies) and Texas (136 companies) (see Figure 3.2.2 and Table 3.2.1 for further details) (2).

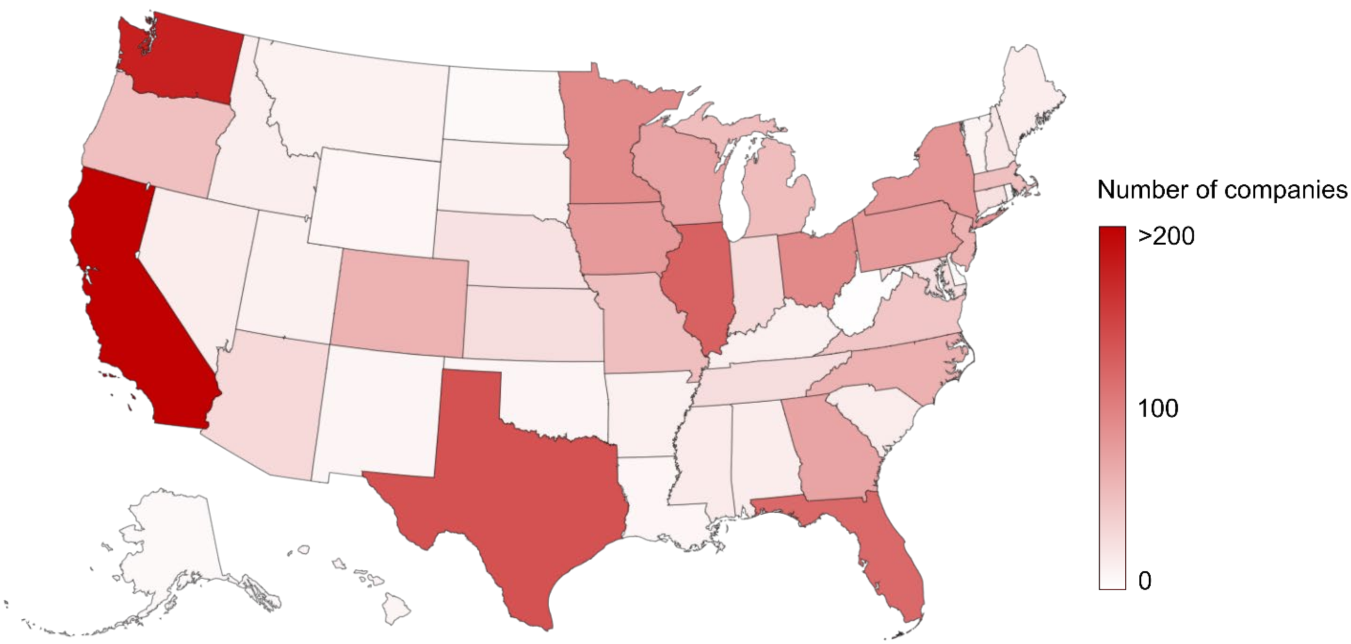

Figure 3.2.2. Number of companies participating in the BioPreferred Program in 2016 (2).

State	Number of companies	Percentage of total companies
California	262	11.8
Washington	175	7.9
Texas	136	6.1
Illinois	123	5.5
Florida	118	5.3

Table 3.2.1. Top 5 states ranked by number of companies participating in the BioPreferred Program in 2016 (2).

Tracking the BioPreferred Program through the years shows the evolution of the biobased economy, given the increase in the number of product offerings within the program (e.g., lubricants, cleaning products, bioplastics). The number of mandatory federal purchasing offerings increased from just 32 categories in 2008 to 109 categories in 2017. Voluntary labeling offerings increased from 50 categories in 2011 to 100 categories in 2016 (Figure 3.2.3) (1, 2).

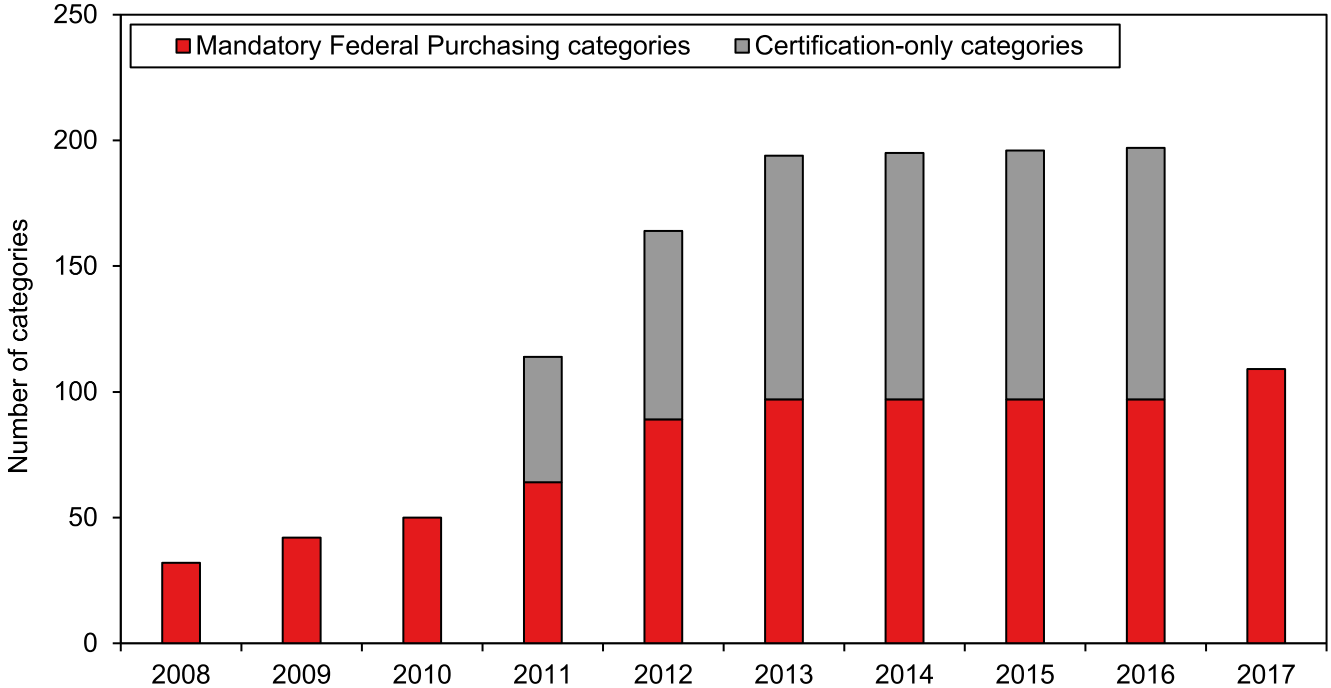

Figure 3.2.3. Number of categories of biobased products for mandatory Federal Purchasing from 2008 to 2017 and certification-only categories from 2011 to 2016 (1).

The BioPreferred Program estimates that the total number of biobased products in the United States increased 135 percent from 17,000 products in 2008 to more than 40,000 products in 2014 (1). Within these estimated 40,000 products, about 15,000 are included in the BioPreferred Program, around 12,400 products for mandatory federal purchasing initiative, 900 certified-only products, and 1,700 products that qualify for the both initiatives (Figure 3.2.4) (1).

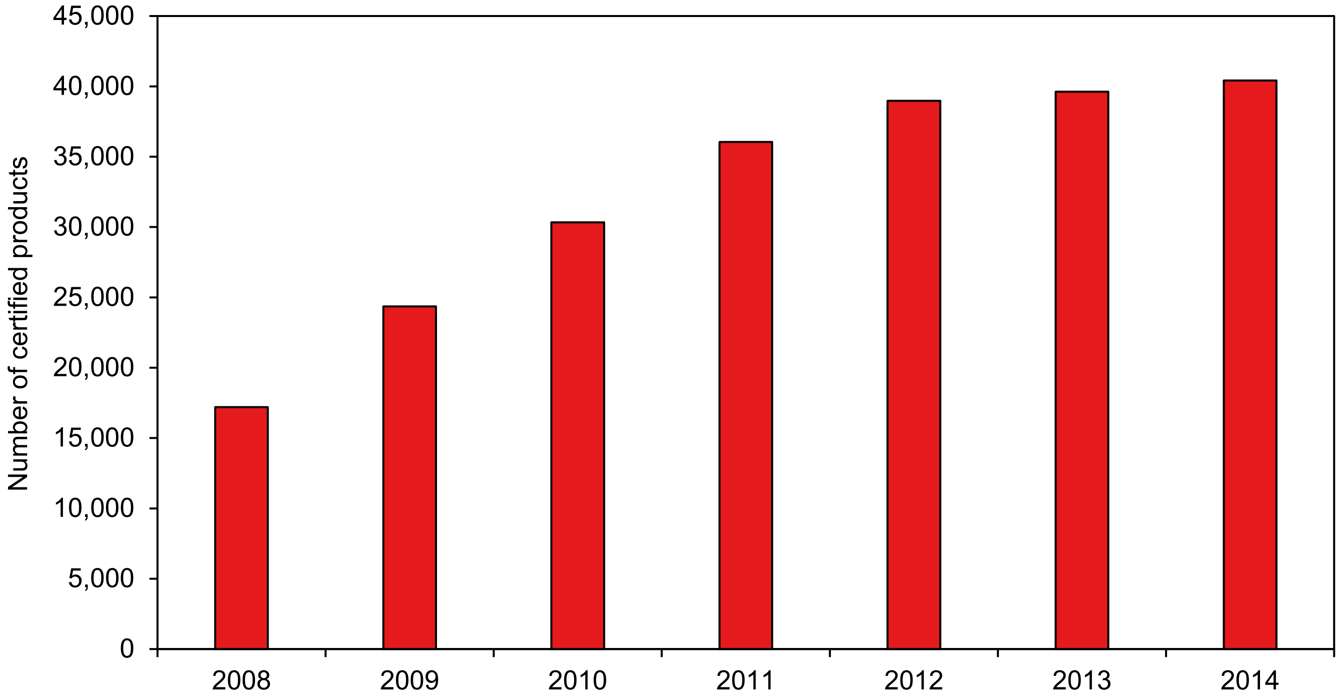

Figure 3.2.4. United States Department of Agriculture's BioPreferred Program estimate of the total number of biobased products in the United States from 2008 to 2014 (1).

Figure 3.2.5 presents the products in the BioPreferred catalog by category in 2016. Bioplastics represent 66 percent of total products in the catalog, followed by enzymes (15 percent of total products) (1).

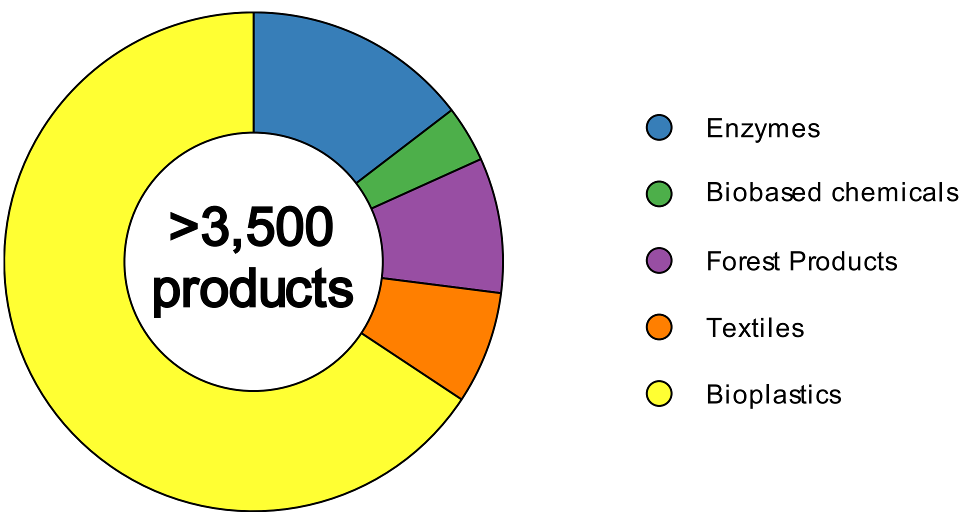

Figure 3.2.5. Federal purchasing products and certified-only products in the catalog by category in 2016 (1).

A key performance indicator of the United States bioproducts economy is job creation. The number of jobs contributed to the United States economy by the bioproducts industry in 2014 is 4.5 million. As seen, California has the most direct (145,080) and total (265,530) jobs. North Carolina (179,380) and Texas (178,480) are ranked second and third, respectively, in total jobs contributed from the bioeconomy (Figures 3.2.6-3.2.7 and Tables 3.2.2-3.2.3) (2).

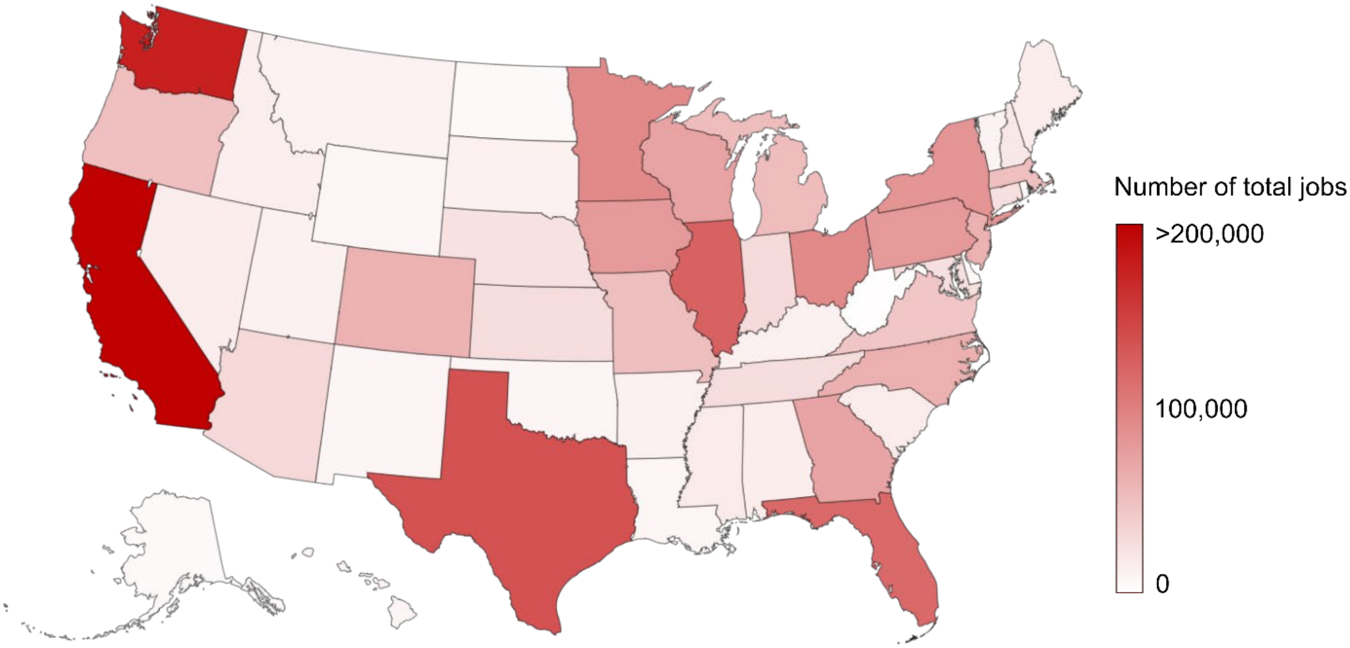

Figure 3.2.6. Total number of jobs contributed to the United States economy through the biobased products industry in 2014 (2).

State	Number of jobs	Percentage of total jobs
California	265,530	8.7
North Carolina	179,380	5.9
Texas	178,480	5.8
Georgia	178,110	5.8
Wisconsin	160,010	5.2

Table 3.2.2. Top 5 states with the most American jobs – direct and indirect – from the biobased products industry in 2014 (2).

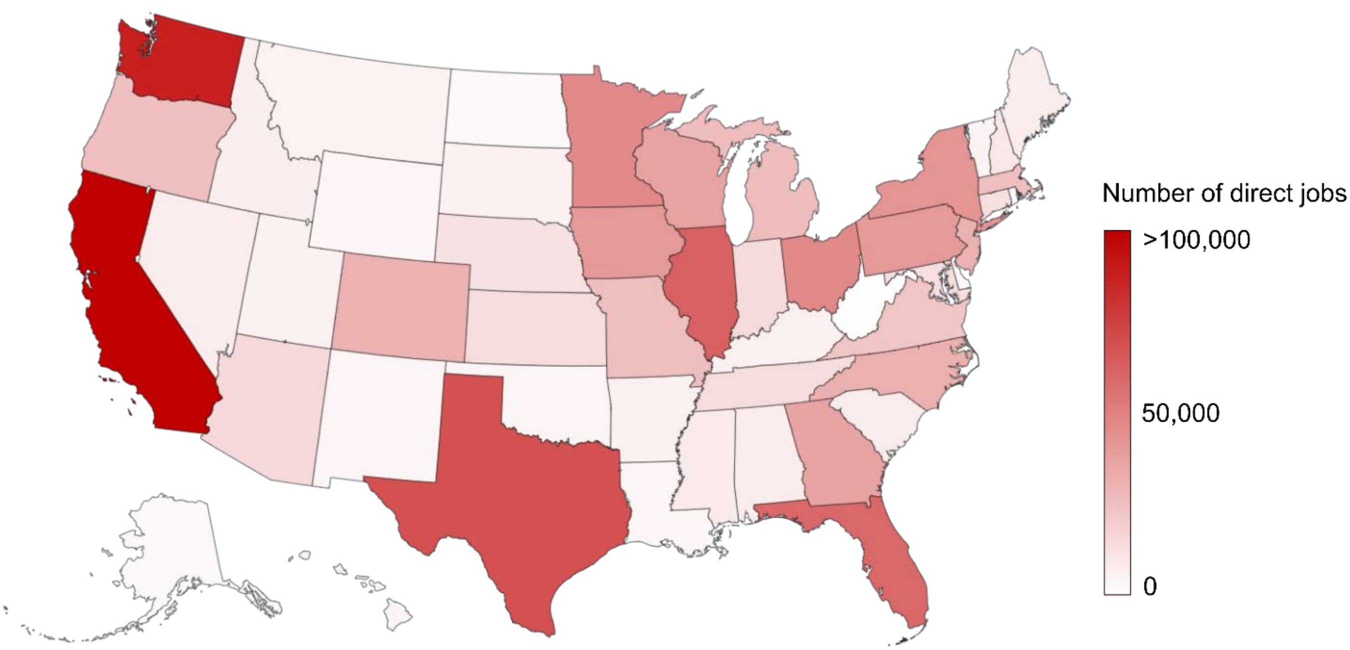

Figure 3.2.7. Number of direct jobs contributed to the United States economy through the biobased products industry in 2014 (2).

State	Number direct of jobs	Percentage of total direct jobs
California	145,080	9.7
North Carolina	90,040	6.0
Texas	88,680	5.9
Georgia	80,520	5.4
Pennsylvania	71,360	4.8

Table 3.2.3. Top 5 states with the most direct American jobs from the biobased products industry in 2014 (2).

In 2014, the bioproducts industry contributed 393 billion dollars in value added to the United States economy. California, which has the largest number of companies participating in the BioPreferred Program (see Table 3.2.1), contributes the most value added to the economy, with 21.6 billion dollars of total value added and 9.9 billion dollars of direct value added (Figures 3.2.8-3.2.9 and Tables 3.2.4-3.2.5) (2).

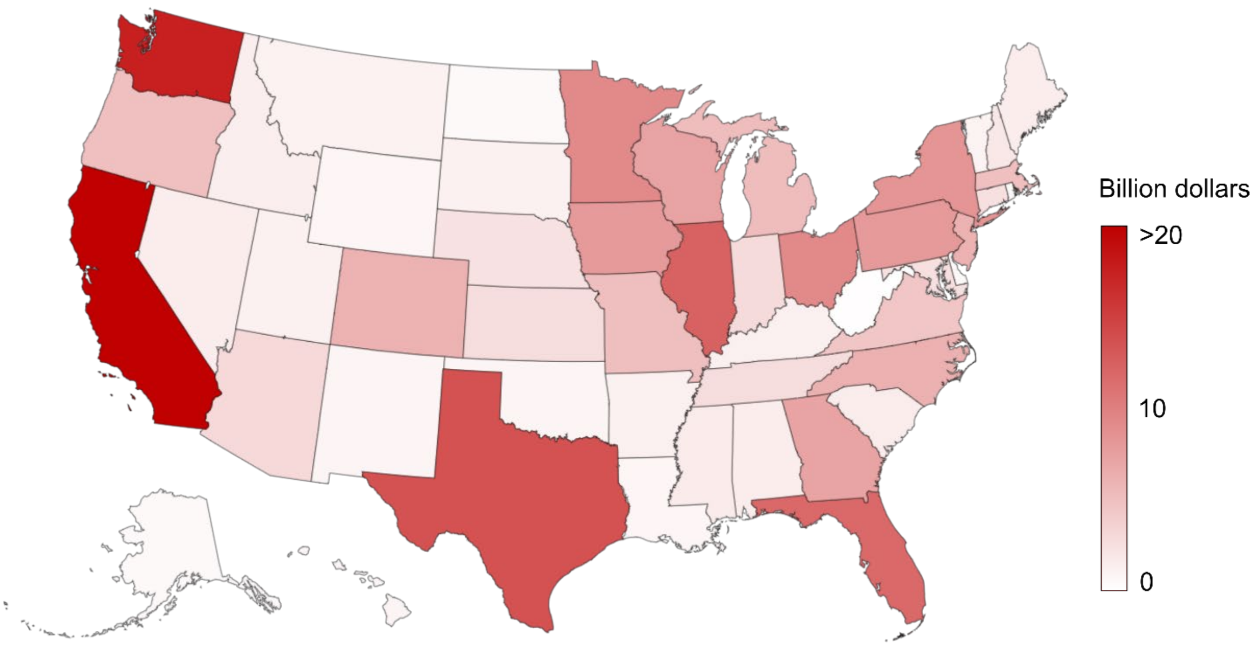

Figure 3.2.8. Total value added contribution to the United States economy through the biobased products industry in 2014 (in billion dollars) (2).

State	Billion dollars	Percentage of total value added
California	21.6	8.6
Georgia	16.4	6.5
Texas	15.2	6.1
Pennsylvania	13.7	5.4
North Carolina	13.6	5.4

Table 3.2.4. Top 5 states ranked by total value added to the United States economy through the biobased industry in 2014 (2).

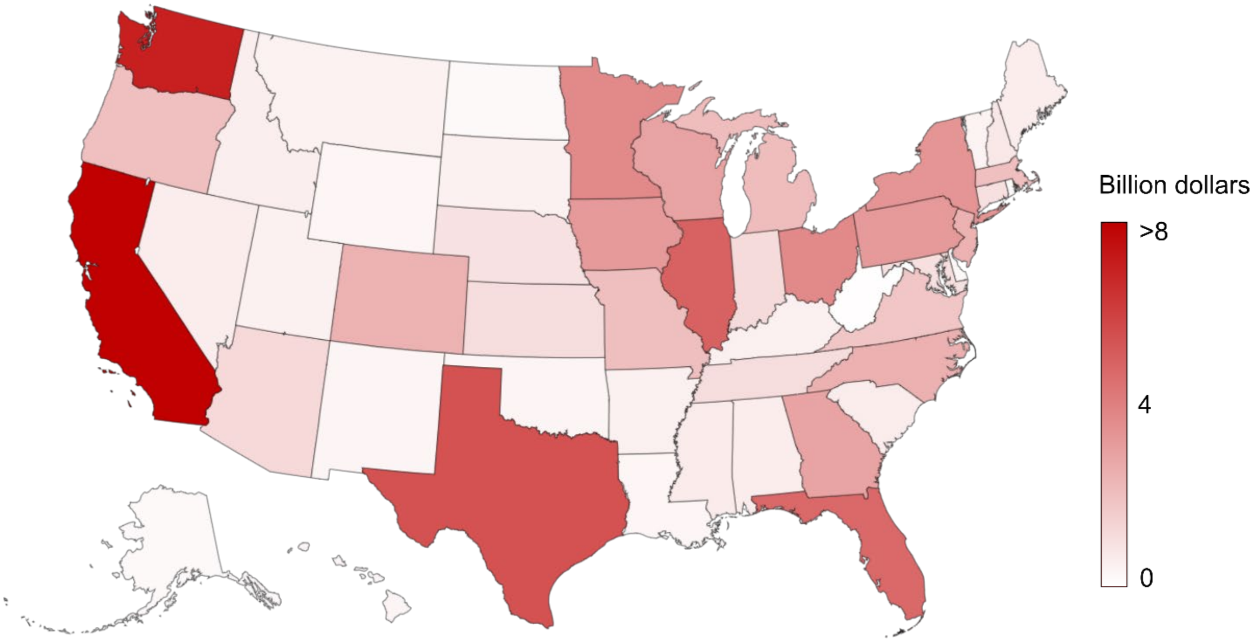

Figure 3.2.9. Direct value added contribution to the United States economy through the biobased products industry in 2014 (in billion dollars) (2).

State	Billion dollars	Percentage of total direct value added
California	9.9	8.7
Georgia	8.2	7.3
Texas	6.8	6.0
Pennsylvania	6.5	5.8
North Carolina	6.4	5.7

Table 3.2.5. Top 5 states ranked by direct value added contribution to the United States economy through the biobased industry in 2014 (2).

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1. United States Department of Agriculture - USDA - BioPreferred|Site Map. Available at: https://www.biopreferred.gov/BioPreferred/faces/pages/AboutBioPreferred.xhtml [Accessed August 8, 2018].
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3.3. Bioplastics

Photo 31. (6).

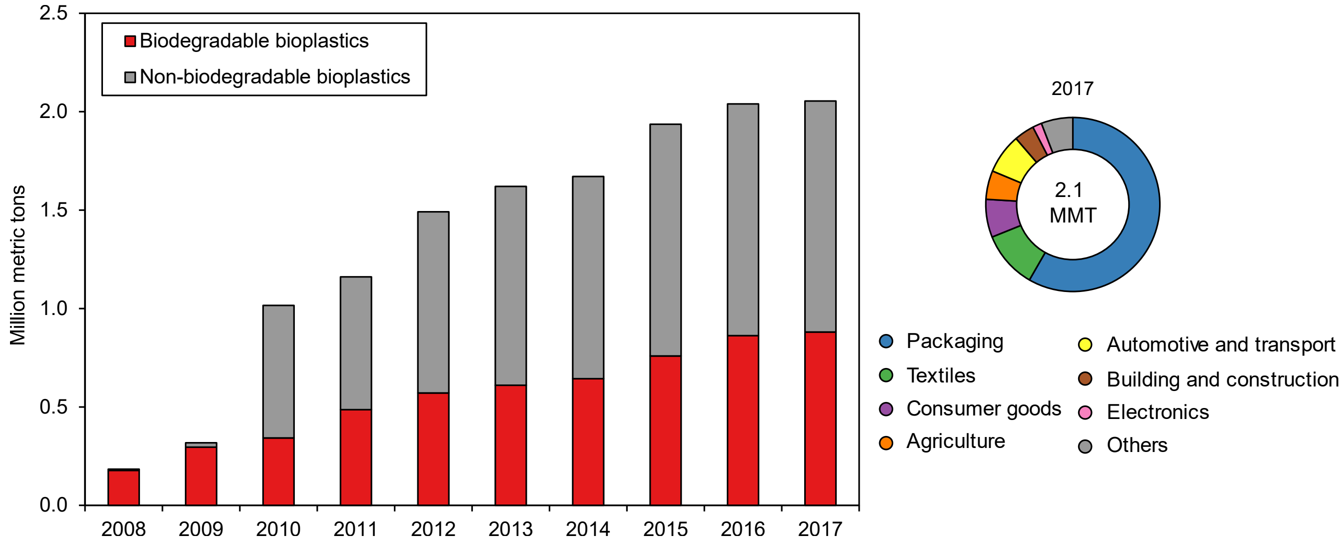
Bioplastics are a type of plastic that is partially or fully biobased and/or biodegradable. A biobased plastic is produced from renewable resources (e.g., corn, sugarcane, potatoes) as opposed to fossil fuels. Biodegradable plastic can degrade by naturally occurring microorganisms (e.g., bacteria, fungi) in a defined environment and timescale (1).

Under such a definition, a plastic is considered a bioplastic even if it is made from non-renewable sources (i.e., fossil fuel) and it is biodegradable, and if it is biobased but not biodegradable (1).

Benefits of using bioplastics instead of conventional plastics include the reduction of fossil fuel usage, reduction of carbon footprint, and reduction of global warming potential (1).

Global production of bioplastics from 2008 to 2017 and the final sector end use are shown in Figure 3.3.1. World production of bioplastics grew over 1,000 percent from 0.18 million metric tons in 2008 to 2.05 million metric tons in 2017. While in 2008 and 2009 total global production was almost 100 percent biodegradable bioplastics, since 2010 the production of non-biodegradable bioplastics has increased to represent 57 percent of total production in 2017 (2–4).

In 2017, 58 percent of global bioplastics were used for packaging, 11 percent were used in the textile industry, 7 percent in consumer goods and 24 percent in various other uses (5).



*Note: Data after 2014 is predicted.

Figure 3.3.1. Global production of bioplastics by type from 2008 to 2017 (in million metric tons) (2–4) and final use in 2017 (5).

More than half the total of global production of bioplastics is in Asia, while just 16 percent is produced in North America (Figure 3.3.2) (5).

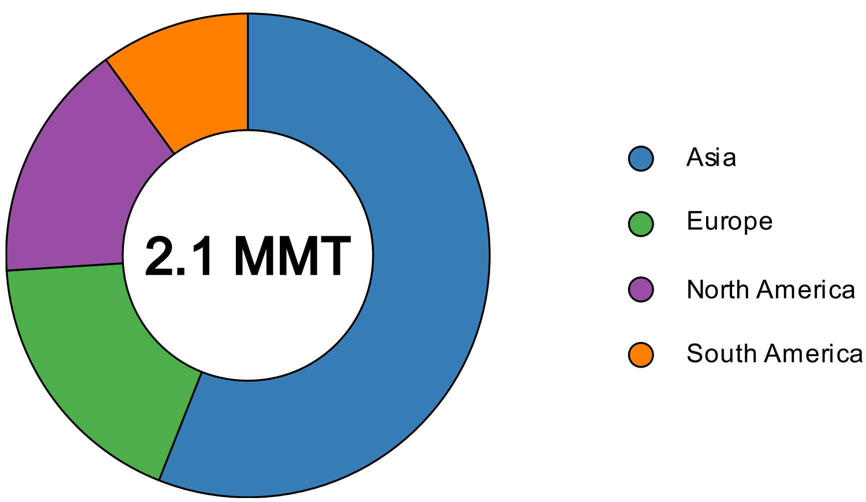


Figure 3.3.2. Global production of bioplastics by region in 2017 (in million metric tons) (5).

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3.4. Biobased Chemicals

Photo 32. (4).

Biobased chemicals are chemicals totally or partially produced from plants or renewable sources (1).

In 2012, the United States renewable chemical production was estimated at 165 thousand metric tons. By 2017, this number was projected to grow by 354 percent, with total production estimated to be 750 thousand metric tons. By 2022, total U.S. renewable chemical production is estimated to reach 3,200 thousand metric tons (2).

The United States job creation potential stemming from the projected renewable chemical production is estimated to be 19,400 jobs in 2022 (2). This estimate includes both direct and indirect jobs stemming from the production of the renewable chemicals.

The forecasted value added by renewable chemicals in the United States is projected to be 3,045 million dollars per year in 2022 (2).

The biobased chemical industry created 18,000 American jobs in 2014. Texas had the most direct jobs (1,680), followed by Ohio (1,310) and California (1,250) (Figure 3.4.1 and Table 3.4.1) (2).

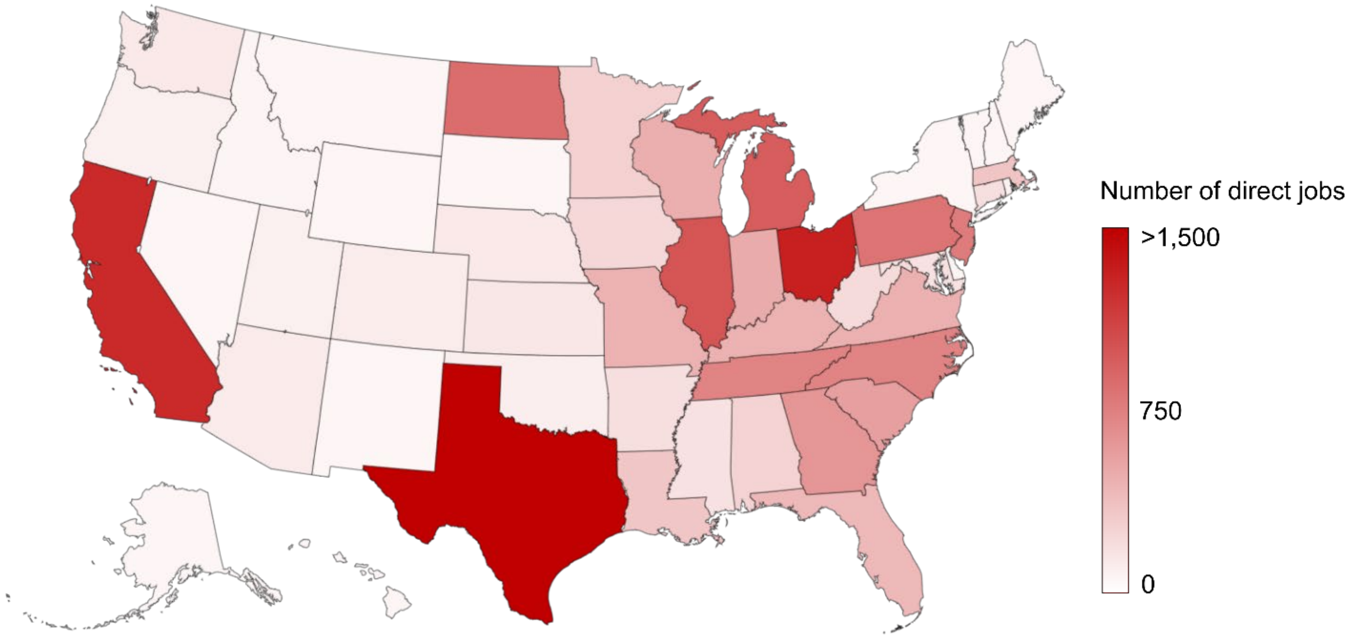

Figure 3.4.1. Number of direct jobs contributed to the United States economy through the biobased chemicals industry in 2014 (3).

State	Number of jobs	Percentage of total direct jobs
Texas	1,680	9.3
Ohio	1,310	7.3
California	1,250	6.9
Illinois	1,000	5.6
Michigan	950	5.3

Table 3.4.1. Top 5 states ranked by direct American jobs from the biobased chemicals industry in 2014 (3).

In 2014, the biobased chemical industry contributed 5 billion dollars to the United States economy. The states with larger creation of American jobs were the states with larger direct value added to the United States economy. Texas was the state with the largest value added, at 471 million dollars, closely followed by Ohio, at 444 million dollars and California, at 350 million dollars (Figure 3.4.2 and Table 3.4.2) (2).

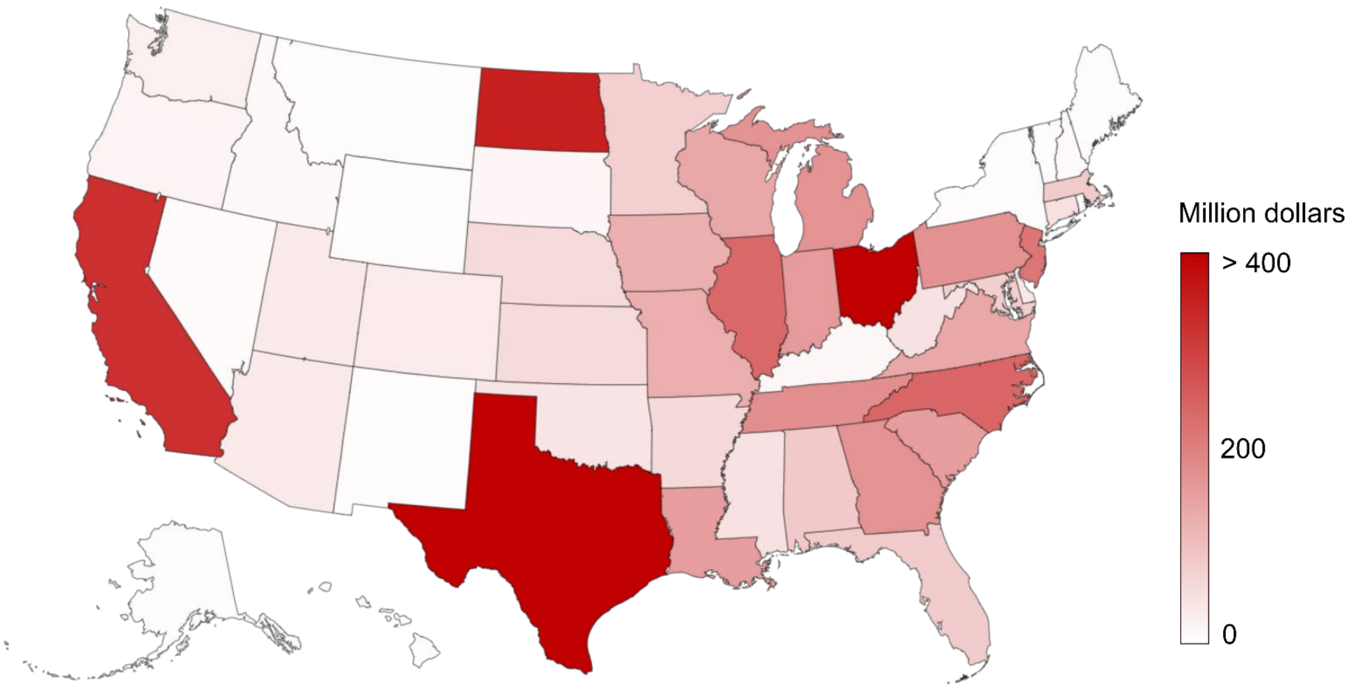

Figure 3.4.2. Total value added to the United States economy through the biobased chemicals industry in 2014 (in million dollars) (3).

State	Million dollars	Percentage of total direct value added
Texas	471	9.5
Ohio	444	9.0
North Dakota	350	7.1
California	324	6.6
North Carolina	238	4.8

Table 3.4.2. Top 5 states ranked by total value added to the United States economy through the biobased chemicals industry in 2014 (3).

References

1. International Energy Agency - IEA - Bio-based Chemicals. Value added products from biorefineries Available at: www.iea-bioenergy.task42-biorefineries.comwww.ieabioenergy.com [Accessed August 21, 2018].
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4. Shutterstock. Available at: https://www.shutterstock.com/image-photo/biochemical-analysis-protein-content-using-spectrophotometry-1173830437?src=VSwnvw8a4Yg-hVQp1UiejA-1-20 [Accessed September 19, 2018].

3.5. Enzymes

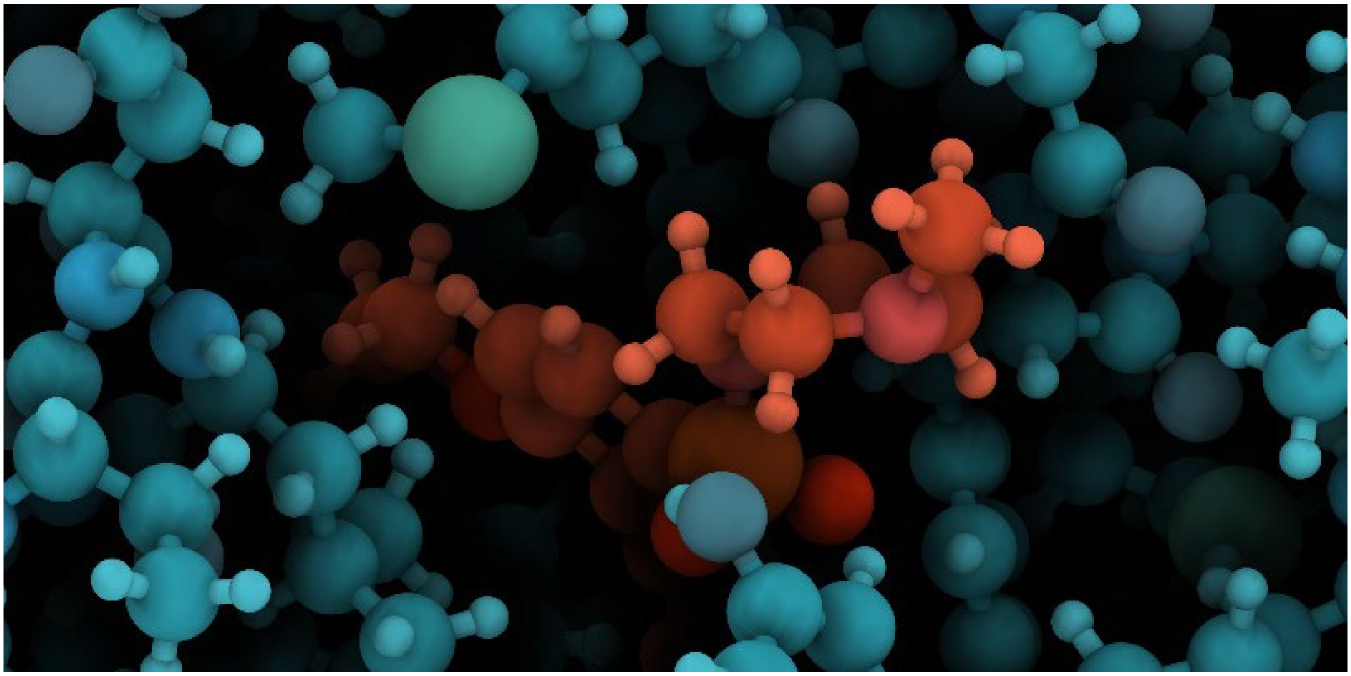

Photo 33. (4)

Enzymes are substances produced by living organisms that act on a specific biochemical reaction. Enzymes serve two purposes: (1) act as a catalyst to facilitate the reaction in industrial processing of food ingredients, feed additives or other chemicals; (2) as a component in end products such as detergents, laboratory reagents, or digestive aids (1).

The global market for industrial enzymes has increased from 2.9 billion dollars in 2008 to 5 billion dollars in 2016 (2). There is not a predominant type of enzyme since each type (i.e., food, animal feed, detergent and technical) represented approximately 25 percent of total enzymes (Figure 3.5.1) (2).

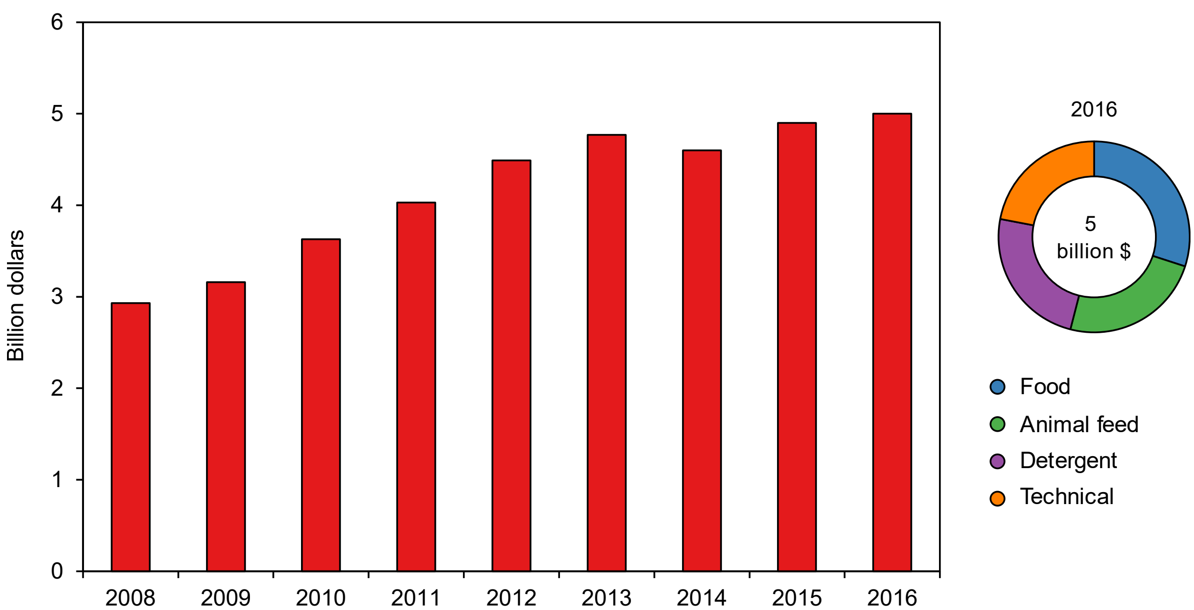

Figure 3.5.1. Global market for industrial enzymes from 2008 to 2016 by type (in billion dollars) (2).

The enzyme industry created 3,970 direct jobs in the United States in 2014. Texas with 350 jobs, North Dakota with 210 jobs and Ohio with 180 direct jobs, were the top 3 states (Figure 3.5.2 and Table 3.5.1) (3).

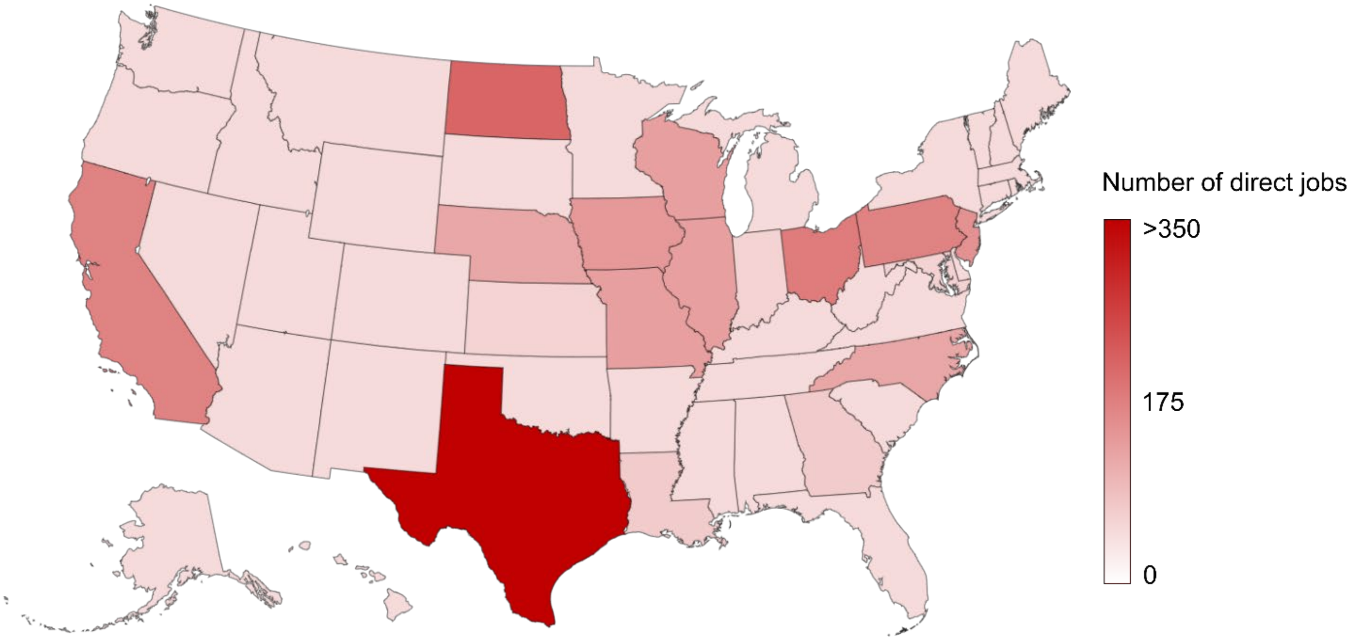

Figure 3.5.2. Number of direct jobs contributed to the United States economy through the enzyme industry in 2014 (3).

State	Number of jobs	Percentage of total direct jobs
Texas	350	8.8
North Dakota	210	5.3
Ohio	180	4.5
California	170	4.3
Pennsylvania	170	4.3

Table 3.5.1. Top 5 states ranked by direct American jobs from the enzyme industry in 2014 (3).

The enzyme industry contributed 1 billion dollars in direct value to the United States economy. The top three contributing states in value from industrial enzymes included: Illinois, with 20 percent of the total; North Dakota, with 9.4 percent; and Texas, with 9.2 percent (Figure 3.5.3 and Table 3.5.2) (3).

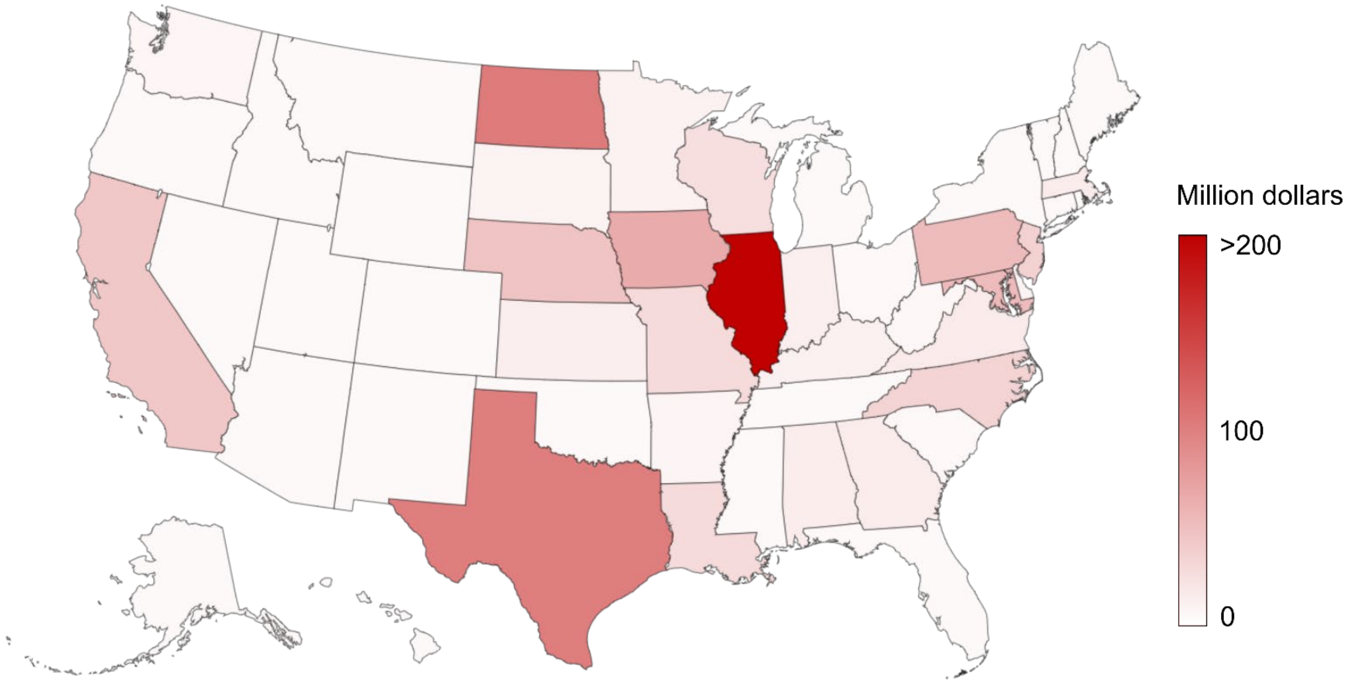

Figure 3.5.3. Total value added to the United States economy through the enzyme industry in 2014 (in million dollars) (3).

State	Million dollars	Percentage of total direct value added
Illinois	222	20.1
North Dakota	104	9.4
Texas	101	9.2
Iowa	65	5.9
Maryland	53	4.8

Table 3.5.2. Top 5 states ranked by total value added to the United States economy through the enzyme industry in 2014 (3).

References

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3.6. Forest Products

Photo 34. (4).

Forest products represent the largest share of renewable sources for the biobased products industry (1).

From 2008 to 2017, the production of forest products remained nearly constant in the United States. Paper products and wood-based panels, which include veneer, plywood, particleboard and fiberboard, are the largest categories forest products, with a production of 239 million tons and 207 million cubic meters in 2017, respectively. These two product categories were followed by wood pulp, at 92 million tons; sawnwood, at 80 million cubic meters; and wood residues, at 64 million cubic meters (Figures 3.6.1 and 3.6.2) (2).

The production of wood pellets, wood fuel, other fiber pulp, and roundwood is very small in comparison with other forest products (2).

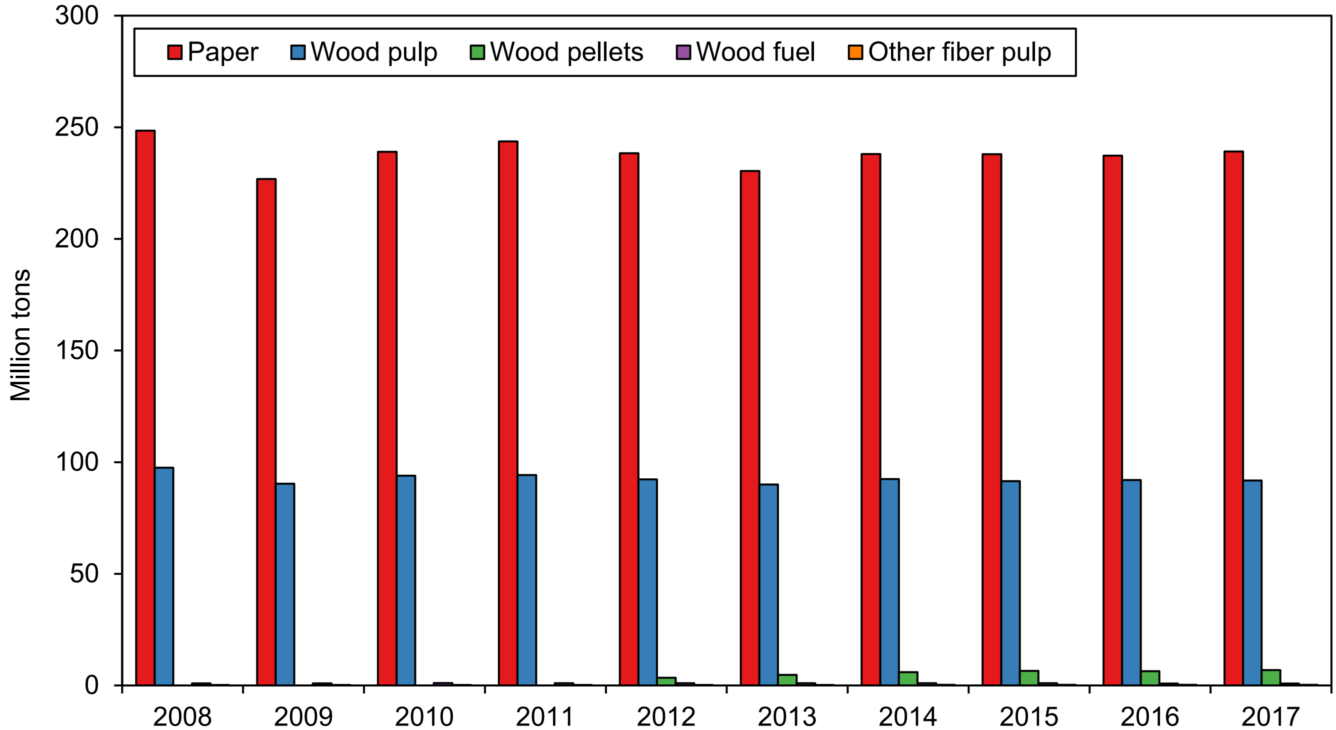

Figure 3.6.1. Production of paper, wood pulp, wood pellets, wood fuel and other fiber pulp in the United States from 2008 to 2017 (in million tons) (2).

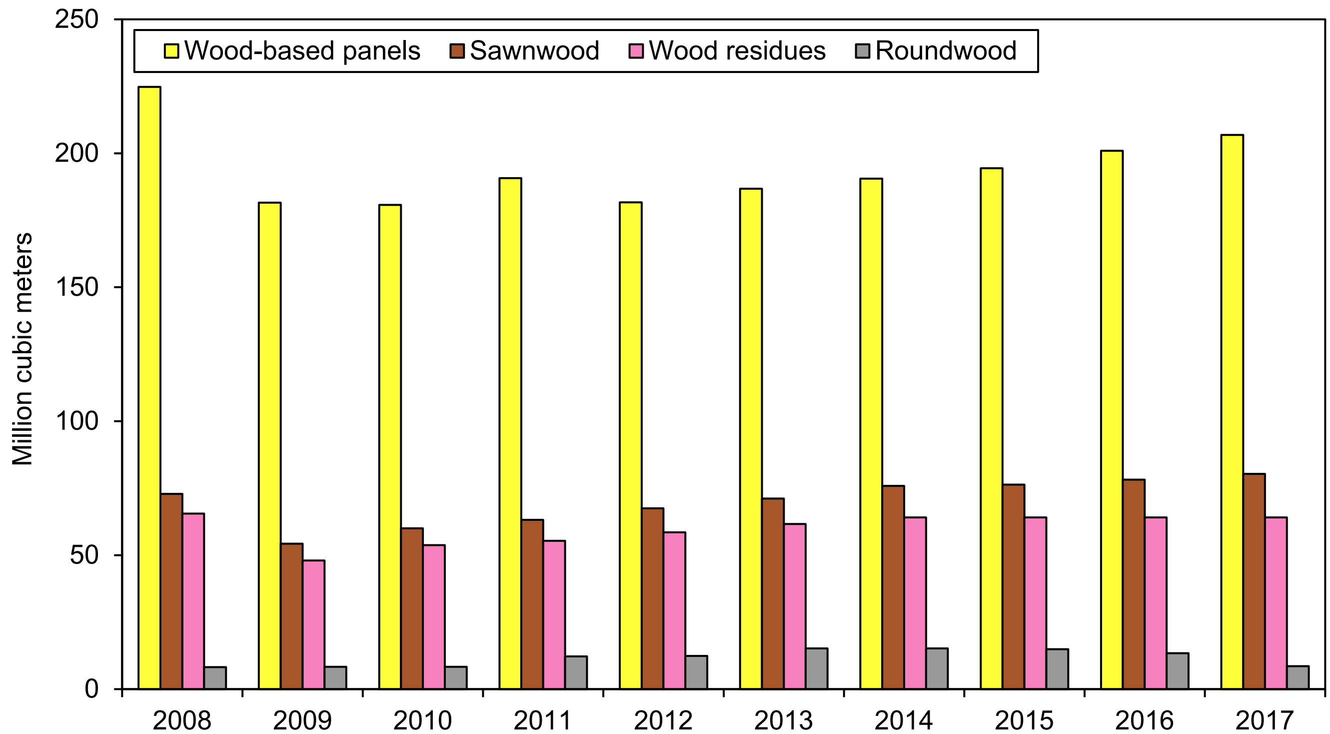

Figure 3.6.2. Production of wood-based panels, sawn wood, wood residues and round wood in the United States from 2008 to 2017 (in million cubic meters) (2).

Imports and exports of forest products are presented in Figure 3.6.3. In 2008, the United States was a net importer of forest products. However, from 2009 to 2017 exports increased and the United Sates became a net exporter (2).

From 2008 to 2017, imports of forest products slightly increased from 24 billion dollars to 25 billion dollars, and exports from 21 billion dollars to 27 billion dollars (2).

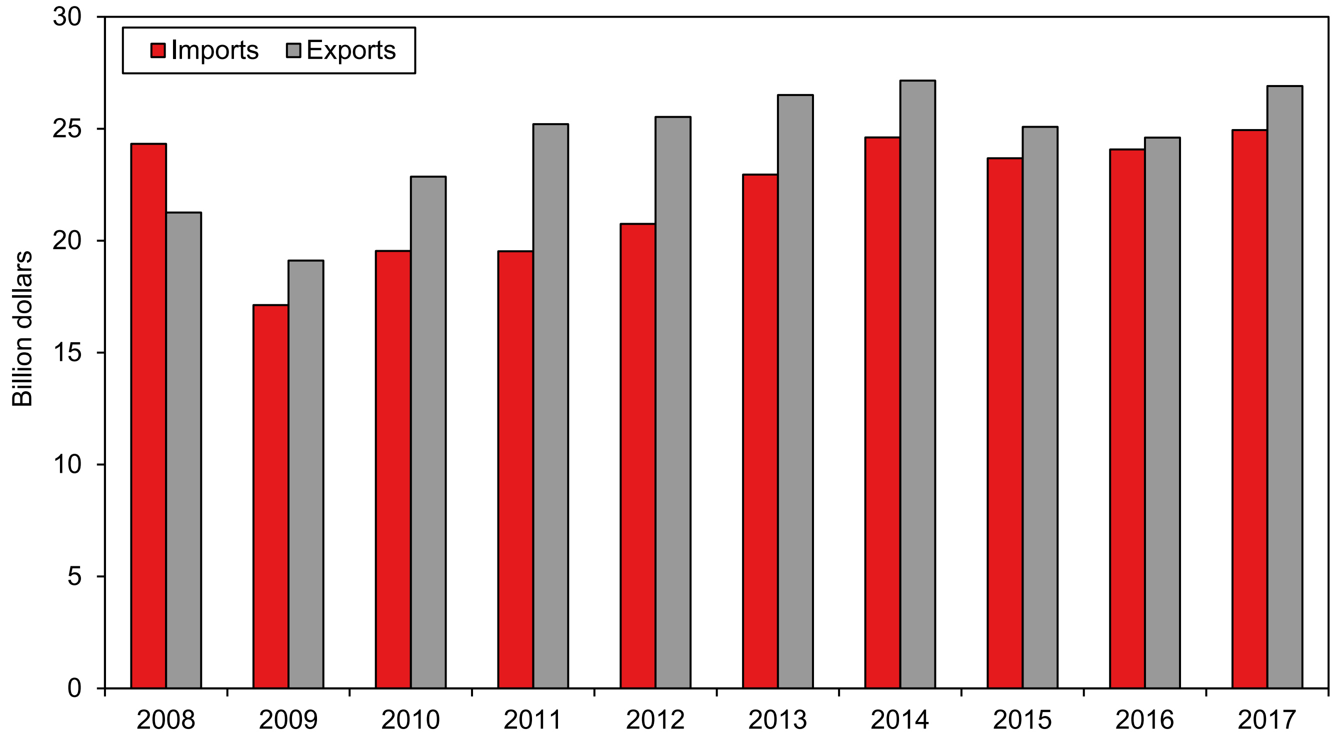

Figure 3.6.3. Imports and exports (in billion dollars) of forest products to and from the United States, 2008 to 2017 (2).

The number of jobs contributed to the United States economy by the forest products industry in 2014 is 1.1 million. California, with 71,340 direct jobs, contributed the most jobs to the United States economy. North Dakota and Wisconsin complete the top 3 contributing states (Figure 3.6.4 and Table 3.6.1) (3).

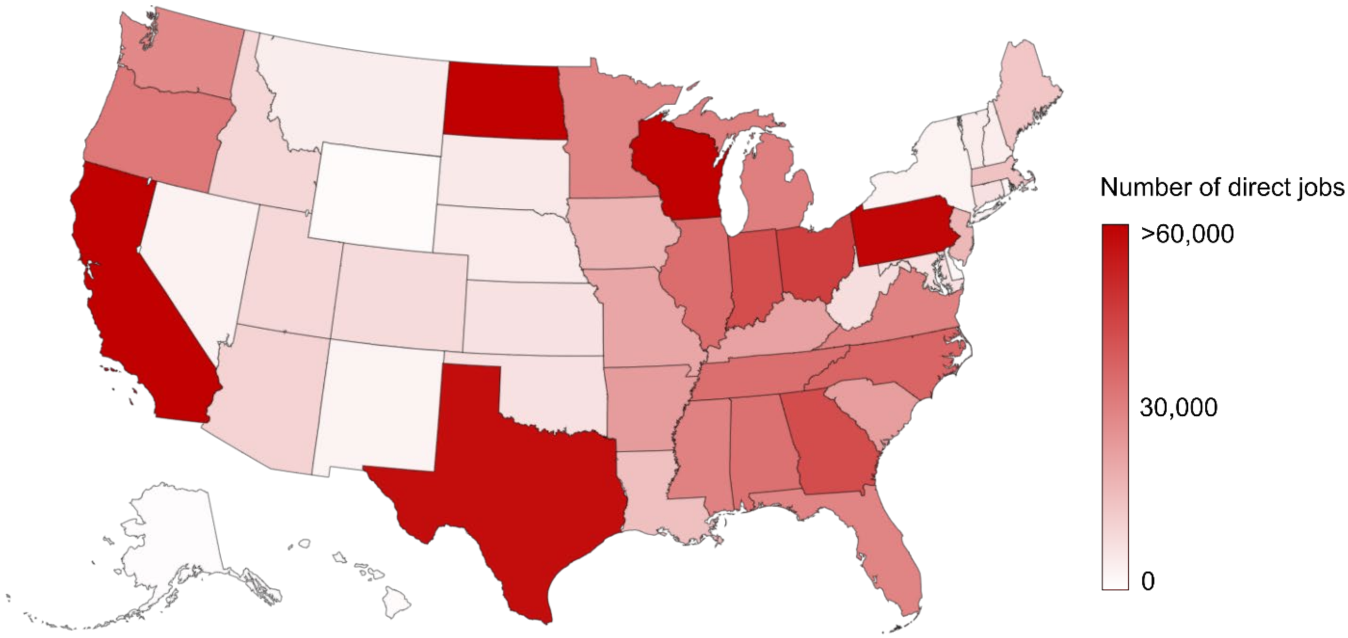

Figure 3.6.4. Number of direct jobs contributed to the United States economy through the forest products industry in 2014 (3).

State	Number of jobs	Percentage of total direct jobs
California	71,340	6.7
North Dakota	61,930	5.8
Wisconsin	60,760	5.7
Pennsylvania	58,790	5.5
Texas	57,020	5.4

Table 3.6.1. Top 5 states ranked by direct American jobs from the forest products industry in 2014 (3).

In 2014, the forest products industry contributed 93 billion dollars in value added to the United States economy. Wisconsin and Pennsylvania are the states with the largest value added contribution, each with 5.8 billion dollars of direct value added, followed closely by California with 5.7 billion dollars (Figure 3.6.5 and Table 3.6.2) (3).

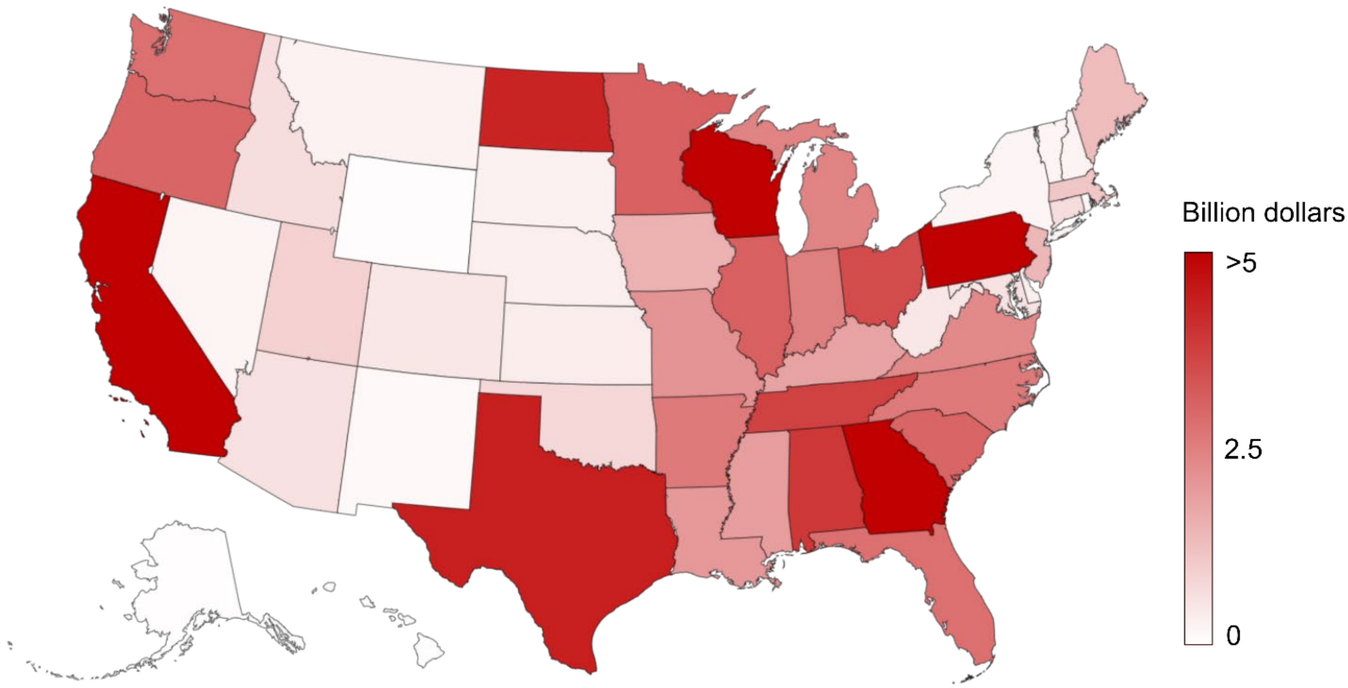

Figure 3.6.5. Total value added to the United States economy through the forest products industry in 2014 (in billion dollars) (3).

State	Billion dollars	Percentage of total direct value added
Wisconsin	5.8	6.2
Pennsylvania	5.8	6.2
California	5.7	6.1
Georgia	5.1	5.5
Texas	4.4	4.7

Table 3.6.2. Top 5 states ranked by total value added to the United States economy through the forest products industry in 2014 (3).

References

1. National Research Council (US) Committee on Biobased Industrial Products. (2000) Biobased Industrial Products: Priorities for Research and Commercialization. Available at: https://iwaponline.com/wst/article/59/5/927/15563/Defining-the-biomethane-potential-BMP-of-solid [Accessed August 21, 2018].
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3.7. Textiles

Photo 35. (2).

The production, consumption and trade of biobased textiles are not directly tracked. The estimated impact that the biobased textile industry has on the United States economy is presented below.

The biobased textile industry created 164,040 American jobs in 2014. California contributed 31,090 direct jobs; followed by Georgia, at 21,020 direct jobs; and North Dakota, at 17,870 direct jobs (Figure 3.7.1 and Table 3.7.1) (1).

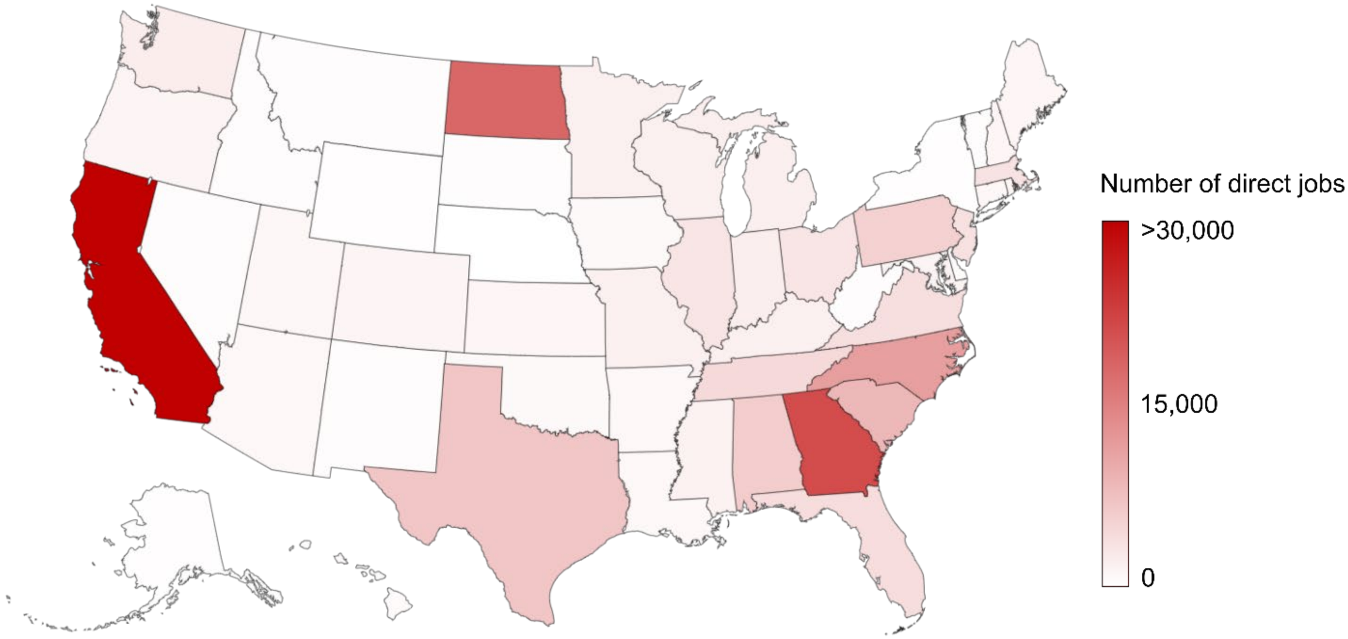

Figure 3.7.1. Number of direct jobs contributed to the United States economy through the biobased textile industry in 2014 (1).

State	Number of jobs	Percentage of total direct jobs
California	31,090	19.9
Georgia	21,020	12.8
North Dakota	17,870	10.9
North Carolina	11,260	6.9
South Carolina	8,370	5.1

Table 3.7.1. Top 5 states ranked by direct American jobs from the biobased textile industry in 2014 (1).

In 2014, the biobased textile industry contributed 10 billion dollars in value to the United States economy. The states with largest creation of American jobs were also the states with the largest direct value added to the United States economy. Georgia was the state with the largest value added with 1.6 billion dollars, closely followed by California with 1.5 billion dollars and North Dakota with 1.1 billion dollars (Figure 3.7.2 and Table 3.7.2) (1).

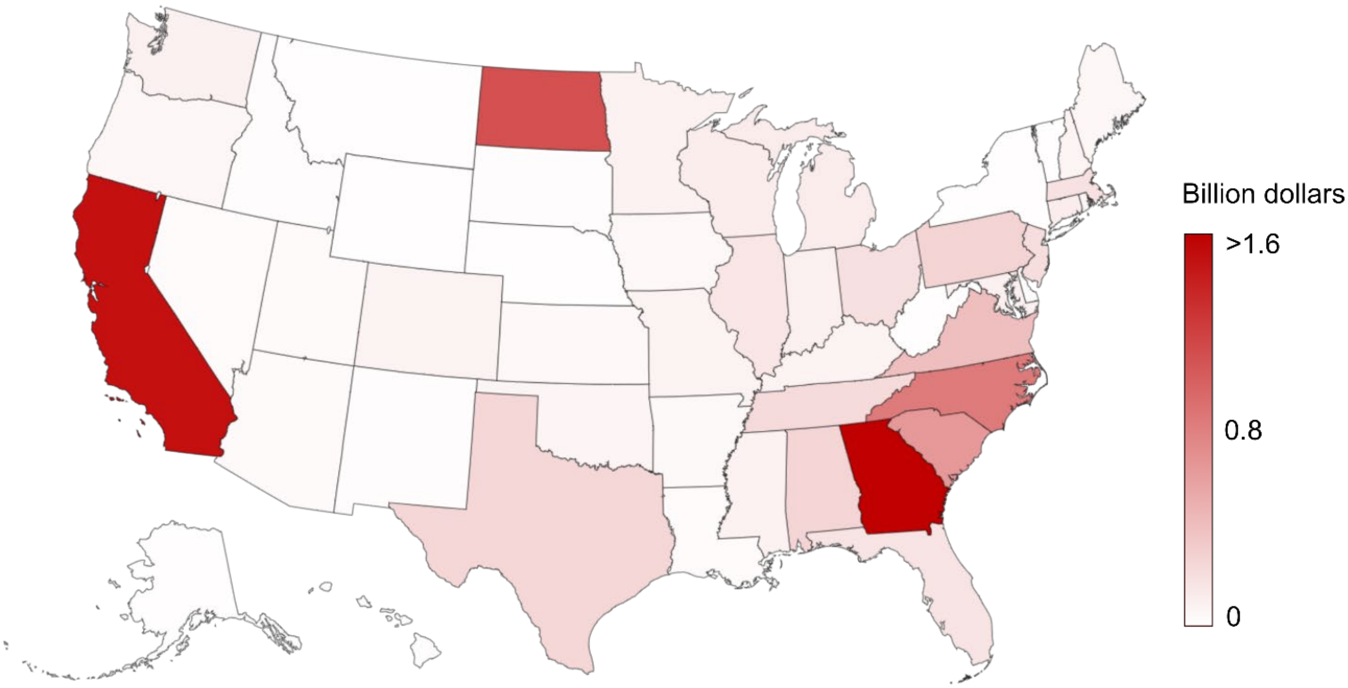

Figure 3.7.2. Total value added contribution to the United States economy through the biobased textile industry in 2014 (in billion dollars) (1).

State	Billion dollars	Percentage of total direct value added
Georgia	1.6	16.6
California	1.5	15.6
North Dakota	1.1	11.4
North Carolina	0.8	8.6
South Carolina	0.6	6.7

Table 3.7.2. Top 5 states ranked by total value added contribution to the United States economy through the biobased textile industry in 2014 (1).

References

1. Golden JS, Handfield R, Daystar J, McConnell E (2016) An Economic Impact Analysis of the U.S. Biobased Products Industry Available at: https://www.biopreferred.gov/BPResources/files/BiobasedProductsEconomicAnalysis2016.pdf [Accessed April 1, 2018].
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4. POLICY

4.1. Federal

The biobased economy has been impacted by key Federal legislation related to alternative fuels and biobased products. This section will analyze the policies that have contributed to the growth of production and consumption of biofuel, renewable chemicals, and biobased products.

Biofuel

Federal policies dating back to 1975 relating to biofuels include the following: fuel economy standards, tax incentives, alternative fuels, biomass and bioenergy, and energy conservation (see Figure 4.1.1).

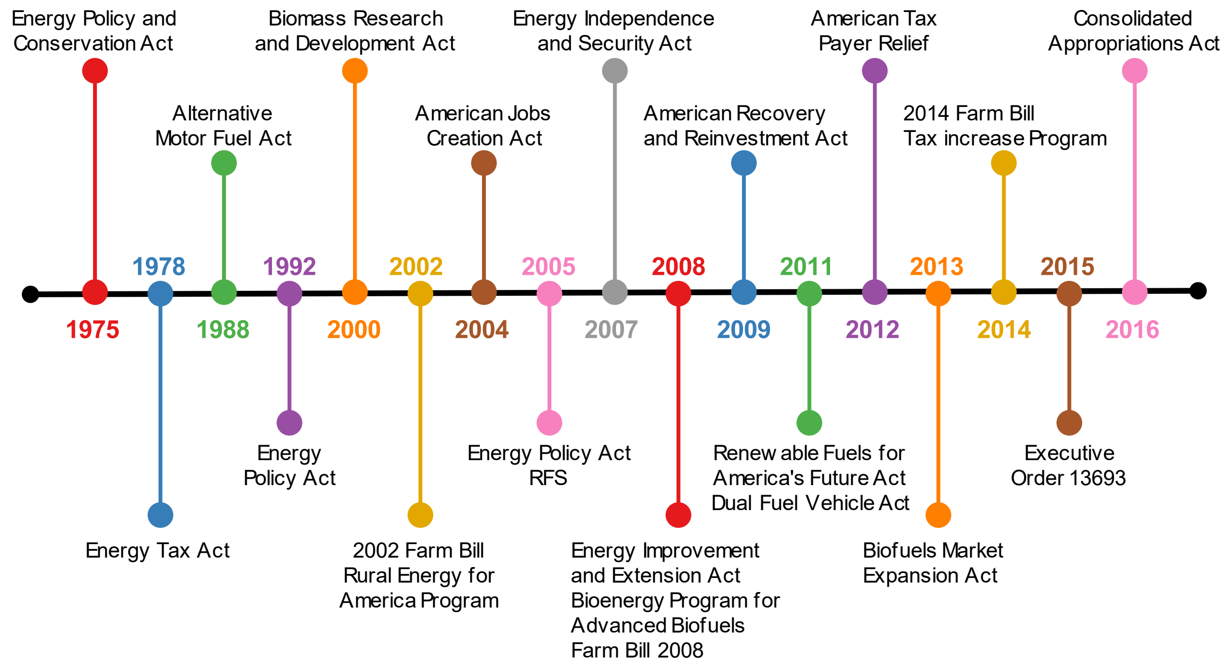

Figure 4.1.1. Timeline of Federal policies related to biofuels.

The Energy Policy and Conservation Act of 1975 established the Corporate Average Fuel Economy (CAFE) standards. The CAFE standards regulate how far vehicles must travel on a gallon of fuel. The regulation also requires consumers be given fuel economy information (1).

Three years later, the Energy Tax Act of 1978 was created as part of the National Energy Act. It provides tax incentives, such as the tax credit of 15 percent of the energy conservation expenditures up to a maximum of 2,000 dollars, to those who conserve energy or substitute alternative sources of energy for oil and gas (2).

A decade later, the Alternative Motor Fuel Act of 1988 was enacted to establish vehicle manufacturer incentives through CAFE credits (1).

The Energy Policy Act of 1992 sets regulation requirements for Federal, State, and alternative fuel provider fleets to increase the amount of alternative fuel vehicles (1).

In 2000, the Biomass Research and Development Act authorized 49 million dollars in funding to: develop crops and systems that improve production and processing; use cellulosic biomass to produce biobased fuels and products; improve production technologies of biofuels and bioproducts; and analyze the impact of biomass technologies (3).

The Biomass Research and Development Act of 2000 was amended by the Food, Conservation and Energy Act of 2008, and created the Biomass Research and Development initiative to further develop the biomass industry in the United States for energy-related projects. The program provided grant funding (35 million dollars each fiscal year, 2009 to 2012) for projects addressing research, development, and demonstration of biofuels and bio-based products and the methods, practices, and technologies for their production (3-5).

The 2002 Farm Bill directed 115 million dollars of funding toward agricultural subsidies. The purpose was to encourage the production of energy on farms, as well as to promote the use of renewable energy sources and an increase in energy efficiency (6).

The Rural Energy for America Program (REAP) provides grants and loan guarantees to agricultural producers and rural small businesses to purchase renewable energy systems or make energy efficiency improvements (7). The maximum loan guarantee is 25 million dollars, and the maximum grant funding is 500,000 dollars for renewable energy and 250,000 dollars for energy efficiency. At least a fifth of the grant funds awarded must be for grants of 20,000 dollars or less (7). REAP is funded through fiscal year 2019, and it is essential for those making energy efficiency improvements for renewables, feasibility studies, and energy audits (8).

The goal of the American Jobs Creation Act of 2004 was to help the agricultural and energy sectors, in addition to supporting domestic and multinational manufacturers. The act offers tax cuts while also aiming to increase revenue for the United States economy in the following years (9).

The Energy Policy Act of 2005 provides tax incentives and loan guarantees for energy production of various types (10). Entities using innovative technologies avoiding the by-production of greenhouse gases can receive loan guarantees (10). The act also increased the amount of biofuel required to be blended with gasoline sold in the United States.

The Energy Policy Act of 2005 introduced the Renewable Fuels Standards (RFS) to increase the production of alternative fuels. The program, which was amended by the Energy Independence and Security Act of 2007, ensures that transportation fuel sold in the United State contains a minimum volume of renewable fuel. The standards set requirements for cellulosic biofuel, biodiesel, advanced biofuel, and total renewable fuel (11,12). These standards apply to all gasoline and diesel produced or imported (13).

Energy conservation is a main goal for legislation and funding pertaining to biofuels. Legislation has been passed and grants used for incentivizing and promoting greater energy independence and security for the United States, in addition to improving energy performance and reducing energy-related greenhouse gas emissions. The Energy Independence and Security Act of 2007 was established with the goals of: increasing the production of clean renewable fuels; reducing the dependence on fossil fuels; reducing greenhouse gas emissions; and increasing energy security (14).

The Energy Improvement and Extension Act of 2008 provides incentives for energy production and conservation. The act made revenue enhancements as well. Those who invest in new clean renewable energy bonds can get a tax credit for the operation of renewable energy facilities (15).

The Repowering Assistance program and the Bioenergy Program for Advanced Biofuels both promote advanced biofuel production. Repowering Assistance provides payments to existing biorefineries to replace fossil fuels, used for heating or electricity, with renewable biomass (8). On the other hand, the Bioenergy Program for Advanced Biofuels provides payments to eligible agricultural producers to support and ensure an expanding production of advanced biofuels. Nearly every other type of biofuel besides corn starch ethanol is eligible for the program. This includes ethanol, biogas, butanol, or biodiesel derived from cellulose, sugar or starches, waste materials, sugarcane, or woody biomass (16). The Repowering Assistance program was eliminated in the 2018 Farm Bill.

The Food, Conservation, and Energy Act of 2008 was enacted to provide increased support for the production of cellulosic ethanol and also funding for the research of pests, diseases and other agricultural problems (3, 17). The Biomass Crop Assistance Program was authorized by the bill to support the establishment and production of crops for conversion to bioenergy and assist with the collection, harvest, storage and transportation of materials for biomass conversion (8,18,19). Qualified feedstock producers are eligible for a reimbursement of 50 percent of the cost of establishing a biomass feedstock crop, as well as annual payments for up to five years for herbaceous feedstocks and up to 15 years for woody feedstocks. This program was funded through fiscal year 2018 (20).

The American Recovery and Reinvestment Act of 2009 was enacted to appropriate nearly 800 billion dollars towards job creation, economic growth, tax relief, improvements in education and healthcare, infrastructure modernization, and investments in energy independence and renewable energy technologies. The act supports a variety of alternative fuel and advanced vehicle technologies through grant programs, tax credits, research and development, fleet funding, and other measures (1).

The Renewable Fuels for America's Future Act of 2011 extended, through 2016, and modified credits for alcohol used as a fuel and other purposes. It required a reduction in the income and excise tax credits for alcohol used for fuel by the amount of alcohol used to meet the taxpayer's renewable fuel obligation under the Clean Air Act (17). The Dual Fuel Vehicle Act of 2011 increased demand of ethanol to ensure the availability of dual fueled automobiles and light duty trucks. Under this act, automobile manufacturers are required to ensure that at least 50 percent of 2014 and 2015 model year automobiles and light duty trucks manufactured for sale in the United States are dual fueled, capable of operating on alternative fuel and on gasoline or diesel fuel or a mixture of biodiesel and diesel fuel (21,22). In 2013, the Biofuels Market Expansion Act revised ethanol content requirements for renewable fuel and increased manufacturing of dual fueled vehicles. The act requires automobile manufacturers to ensure that at least 50 percent of 2015 and 2016 model year automobiles and light duty trucks manufactured for sale in the United States are dual fueled. It increased the minimum to 90 percent for 2017 and subsequent model years and excluded automobiles and light duty trucks that operate only on electricity (23).

H.R. 1149 of 2011 proposed to include algae as a biofuel. It would have amended the Clean Air Act to include algae biofuel in the RFS program and would have amended the Internal Revenue Code of 1986 to include algae biofuel in the cellulosic biofuel producer credit (24). This bill did not pass the House, however.

The American Tax Payer Relief of 2012 was effective through December 31, 2013 and increased the demand of biofuels by extending discretionary funding for the United States Department of Agriculture's Advanced Biofuel Production Grants and Loan Guarantees, Advanced Biofuel Production Payments, Biodiesel Education Grants, Biomass Research and Development Initiative, and Ethanol Infrastructure Grants and Loan Guarantees (1,19). In addition to the American Tax Payer Relief of 2012, both the Tax Increase Prevention Act of 2014 and the Consolidated Appropriations Act of 2016 reinstated alternative fuel tax incentives. The bill reinstated the alternative fuel infrastructure tax credit, the excise tax credit for alternative fuels, the tax credit for second generation biofuel production, the income and excise tax credits for biodiesel and renewable diesel fuel mixtures, the special depreciation allowance for second generation biofuel plant property, the tax credit for second generation biofuel production, and the fuel cell motor vehicle tax credit (25,26). The Consolidated Appropriations Act of 2016 also reinstated many alternative fuel tax incentives (1).

The Agricultural Act of 2014 was a continuation of critical programs such as Supplemental Nutrition Assistance Program (SNAP), specialty crops, organic farmers, and bioenergy. With the 2014 Farm Bill, the USDA is allowed to continue to record accomplishments and expand the agricultural product market.

The benefits include the following: makes major changes in commodity programs; adds new crop insurance options; streamlines conservation programs; modifies some provisions of SNAP; and expands programs for specialty crops, organic farmers, bioenergy, rural development, and beginning farmers and ranchers (27).

Executive Order 13693 of 2015 looks to reduce the governmental footprint with national greenhouse gas emissions reduction. Planning for Federal sustainability in the next decade includes cutting the government's greenhouse gas emissions by 40% in next decade (2008 levels) and increasing the share of electricity the government consumes from renewable energy to at least 30 percent by fiscal year 2025 (28).

In addition to the policies analyzed above, there are other programs and initiatives such as taxes, tax credits, grants and bonds to promote the production and use of biofuels.

Tax credits and grants are given to businesses for their fuels and blends. A value-added producer grant is a competitive grant program administered by the Rural Business-Cooperative Service of USDA that will help to generate new products, create and expand marketing opportunities, and increase producer income. The grant is available to help independent agricultural producers enter or expand value added activities, including innovative uses of agricultural projects, such as biofuels production (29).

The alternative fuel infrastructure tax credit allowed for fueling equipment for natural gas, propane, liquefied hydrogen, electricity, E85 (an ethanol fuel blend consisting of 15 percent gasoline and 85 percent ethanol), or diesel fuel blends containing a minimum of 20 percent biodiesel installed through December 31, 2017, to be eligible for a tax credit of 30 percent of the cost, not to exceed 30,000 dollars. Fueling station owners who install qualified equipment at multiple sites are allowed to use the credit towards each location. Consumers who purchased qualified residential fueling equipment prior to December 31, 2017 may receive a tax credit of up to 1,000 dollars (30).

The alternative fuel mixture credit allows fuel blenders to claim a tax incentive on the sale or use of the alternative fuel blend. The credit may be taken against the blender’s Federal motor fuel excise tax or Federal income tax liability. The credit is in the amount of 50 cents per gallon of alternative fuel used to produce a mixture containing at least 0.1 percent gasoline, diesel, or kerosene. Compressed natural gas, liquefied natural gas, liquefied hydrogen, propane, P-Series fuel, liquid fuel derived from coal through the Fischer-Tropsch process, and compressed or liquefied gas derived from biomass are qualified alternative fuels (31). The biodiesel mixture credit allows $1.00 per gallon for biodiesel and renewable diesel blends. Both the alternative fuel mixture credit and the biodiesel mixture credit applied to fuels blended through December 31, 2017.

The second generation biofuel producer tax credit allows for a second generation biofuel producer, registered with the Internal Revenue Service, to be eligible for a tax incentive in the amount of up to 1.01 dollar per gallon of second generation biofuel that is: sold and used by the purchaser in the purchaser's trade or business to produce a second generation biofuel mixture, sold and used by the purchaser as a fuel in a trade or business, sold at retail for use as a motor vehicle fuel, used by the producer in a trade or business to produce a second generation biofuel mixture, used by the producer as a fuel in a trade or business (31). This credit was also available for production through December 31, 2017.

The alternative fuel and advanced vehicle technology research and demonstration bonds promote qualified energy conservation projects by offering competitive rates on bonds to fund capital expenditures. Qualified state, tribal, and local governments may issue Qualified Energy Conservation Bonds subsidized by the United States Department of Treasury at competitive rates to fund capital expenditures on qualified energy conservation projects (32).

Advanced biofuel production grants and loan guarantees promote the increase of biorefineries that produce advanced biofuels. The Biorefinery Assistance Program provides loan guarantees for the development, construction, and retrofitting of commercial-scale biorefineries that produce advanced biofuels (26). Eligible applicants include individuals, state or local governments, farm cooperatives, national laboratories, institutions of higher education, and rural electric cooperatives. The maximum loan guarantee is 250 million dollars (33). The loan guarantees are available through the end of fiscal year 2019.

To support and ensure an expanding production of advanced biofuels, advanced biofuel production payments are given to biofuel producers for their finished advanced biofuel products. Any entity that produces and sells advanced biofuel is eligible to apply (34). These payments are available through fiscal year 2019.

Biodiesel education grants educate people on the benefits of biodiesel use. Competitive grants are available through the Biodiesel Fuel Education Program to educate governmental and private entities that operate vehicle fleets, the public, and other interested entities about the benefits of biodiesel use. Eligible applicants are non-profit organizations and institutes of higher education that have demonstrated knowledge of biodiesel fuel production, use, or distribution (35). The biodiesel education program was available through fiscal year 2018.

Diesel emissions reduction is a priority for those looking to reduce pollution. There are more than two million agricultural diesel engines in operation within the United States. The agricultural sector contributes nearly one-quarter of the nitrogen oxides and one third particulate matter of all land-based, non-road diesel emissions (36). Two innovative programs – the Clean Construction USA and Clean Agriculture USA – are part of the National Clean Diesel Campaign, working at reducing pollution emitted from diesel engines from construction and agricultural equipment (36,37).

Several programs have been created to promote better air quality via cleaner fuels. These programs include the Voluntary Airport Low Emission Program, the Air Pollution Control Program, the Clean Cities, and the Clean Ports USA/ Ports Initiative:

- The Voluntary Airport Low Emission Program of 2004 improves airport air quality and provides air quality credits for future airport development. Through this program, airport sponsors can use Airport Improvement Program funds and Passenger Facility Charges to finance low emission vehicles, refueling and recharging stations, gate electrification, and other airport air quality improvements (30,37).

- The Air Pollution Control Program aims to prevent and control air pollution by assisting state, tribal, municipal, intermunicipal, and interstate agencies in planning, developing, establishing, improving, and maintaining adequate programs for the continuing prevention and control of air pollution and/or in the implementation of national primary and secondary air quality standards (38).

- Clean Cities advances the energy, economic, and environmental security of the United States by supporting local initiatives to adopt practices that reduce the use of petroleum in the transportation sector (37,39).

- Clean Ports USA/Ports Initiative was created to promote the replacement of old diesel engines with new technologies and use cleaner fuels (40). Port authorities and terminal operators can retrofit and replace older diesel engines with new technologies and use cleaner fuels (37,41).

Grants are used to incentivize developing new, advanced technology that will increase fuel efficiency and reduce dependence on foreign energy imports. Advanced energy research project grants are developing new advanced energy technologies for reducing dependence on foreign energy imports and reducing the United States energy-related emissions. Grants ensure that the United States maintains its leadership in developing and deploying advanced energy technologies (42).

Both the Air Force and the Navy have tested biojet fuel in their aircraft. Together with the Departments of Energy and Agriculture, the Navy has launched a project to invest up to half a billion dollars in biofuel refineries. The Great Green Fleet, which began in 2009, is an internal program beginning to use biofuel options for energy innovation. The Department of the Navy initiative demonstrates the sea service's efforts to transform its energy use. Maritime vessels also utilized alternative fuel sources, including nuclear power for aircraft carriers and a blend of advanced biofuel and traditional petroleum for escort ships (43).

Biobased products

A focus on the bioproduct industry has led to an increase of policies supporting the production of biobased products. Many programs and executive orders have stressed the development of biobased products within the United States economy (see Figure 4.1.2).

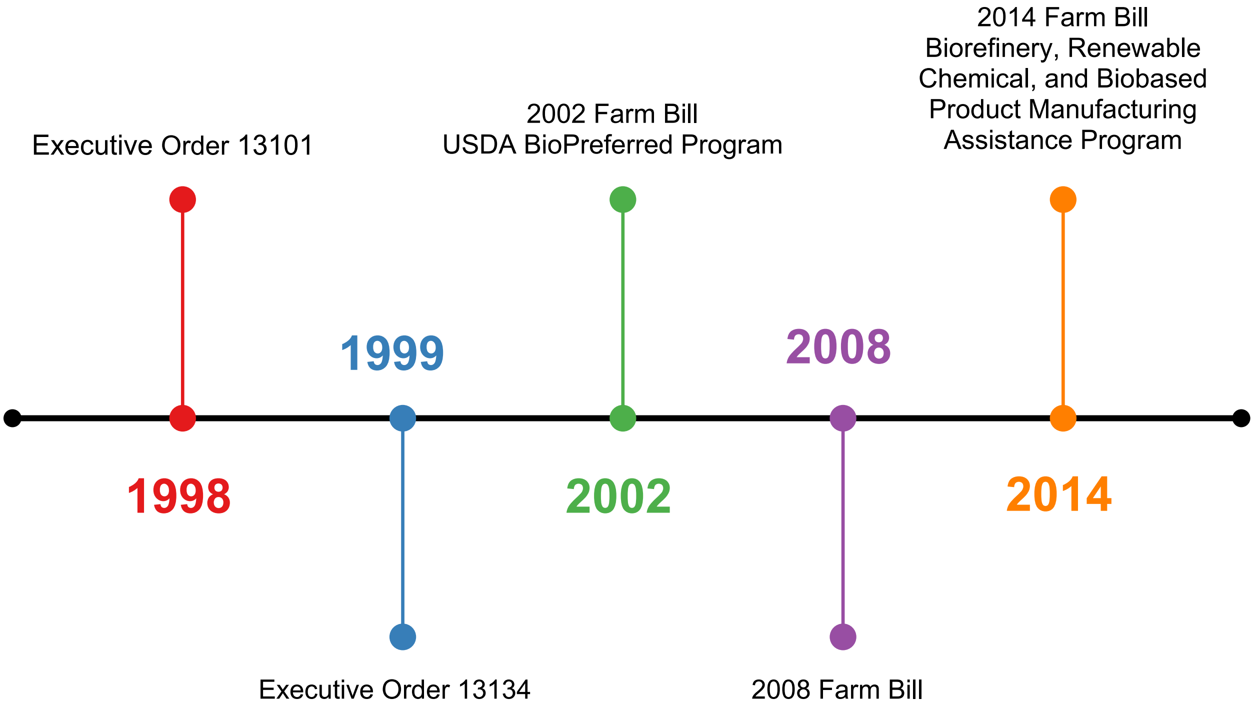

Figure 4.1.2. Timeline of Federal policies related to bioproducts.

Under Executive Order 13101 (1998), federal agencies must comply with executive branch policies for the acquisition and use of environmentally preferable products and services. The agencies implement cost-effective procurement preference programs that favor the purchase of these products and services (44). In order to achieve "Greening the Government," pollution prevention must be activated whenever feasible. This includes the actions of waste prevention and recycling. Use of environmentally preferable products and services is recommended and the pollution that cannot be prevented or recycled should be treated in an environmentally safe manner (29).

Executive Order 13134 (1999) was created to develop and promote biobased products and bioenergy with research, development, and private sector incentives used to stimulate the creation and early adoption of technologies needed to make biobased products and bioenergy cost-competitive in large national and international markets (45).

In 2002, the USDA BioPreferred Program was created by the 2002 Farm Bill to focus on new and emerging markets, further supported by the 2008 Farm Bill, and then reauthorized and revised by the 2014 Farm Bill (46). The goal of the 2014 Farm Bill was to increase the purchase and use of biobased products, such as biobased chemicals, enzymes, bioplastics, forest products and textiles. The USDA BioPreferred Program uses the mandatory federal purchasing initiative and voluntary "USDA Certified Biobased Product" label. Federal agencies are required to purchase biobased products designated for mandatory federal purchasing under the BioPreferred program (47).

Projects eligible for the Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program of 2014 include biorefineries and biobased manufacturing facilities. A project loan guarantees up to 250 million dollars for the development, construction and retrofitting of new and emerging technologies for advanced biofuels, renewable chemicals and biobased products (23,25).

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4.2. State

Biofuel

Several biofuel policies exist at the state level. While many states have similar policies, several states are distinguished by their differences in terminology and standards, such as a further breakdown of how a state defines the term 'biodiesel'. States have alternative fuel incentives, tax credits, or exemptions that are either similar or varying in nature. Figure 4.2.1 lists how many state biofuel policies each state has.

As depicted, California has the most biofuel policies of any state; followed by Virginia, Illinois, and Indiana. Such policies include alternative fuel school bus regulations and incentives, alternative fuel labeling and ethanol labeling requirements, and biofuels blend use requirements. States with the fewest biofuel policies include Alaska, Michigan, Delaware, and the District of Columbia.

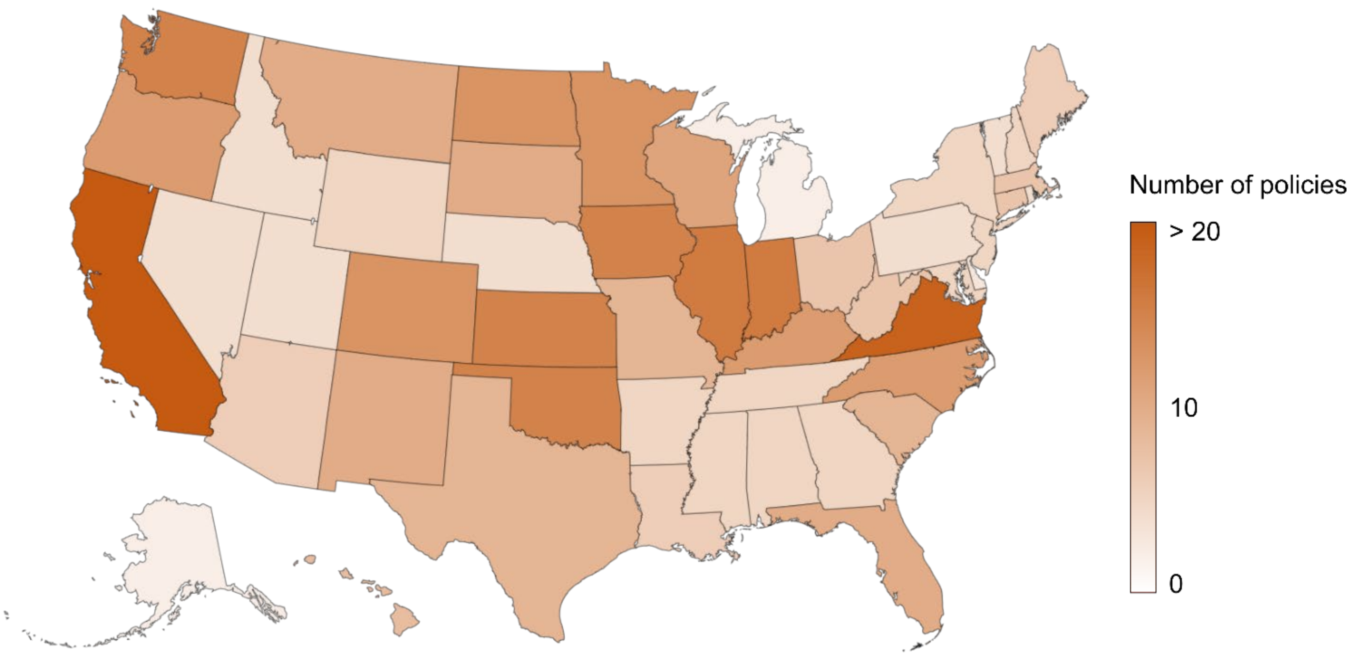

Figure 4.2.1. Number of biofuel policies, by State in 2017.

California Low Carbon Fuel Standard (LCFS) is currently one of the most impactful state biofuels policies. This policy was enacted by the Governor's Executive Order S-01-07 in 2007 and was implemented in 2010. The goal of the LCFS is to reduce by 10 percent the greenhouse gas emissions from transportation fuels by 2020. The reduction of greenhouse gas emissions is expected to come from increasing the use renewable energy (1).

Modeled after California's LCFS, the Oregon Clean Fuels Program seeks to reduce the average carbon intensity of Oregon's transportation fuels by 10 percent in 10 years, from 2016 to 2025. This policy establishes annual targets for gasoline and gasoline substitutes (i.e., ethanol) and for diesel and diesel substitutes (i.e., biodiesel) and calculates emissions of transportation fuels using life cycle analysis (2).

State biofuel policies set alternative fuel school bus regulations and incentives. Virginia and West Virginia have alternative fuel school bus regulations and incentives based on their Boards of Education. The Virginia Board of Education may not limit any local school division to purchase and use school buses powered by compressed natural gas or other alternative fuels or convert its school buses to use compressed natural gas or other alternative fuels. In West Virginia, any county that uses compressed natural gas or propane for its school bus fleet is eligible for a 10 percent reimbursement from the West Virginia Department of Education. That helps offset the cost of maintenance, operation, and other costs incurred from using those compressed natural gas or propane (3,4).

Texas has a Clean School Bus Program. The Texas Commission on Environmental Quality gives grants to any school district or charter school to pay for the incremental costs to replace school buses or install diesel oxidation catalysts, diesel particulate filters, emission-reducing add-on equipment, and other emissions reduction technologies in qualified school buses (5). Like Texas, California also has a Lower-Emission School Bus Program that grants funds for the replacement of older school buses and for the purchase of air pollution control equipment for in-use buses (6).

Connecticut seeks to reduce emissions by requiring school buses with engines 1994 model and newer to be equipped with specific emissions control systems (7). Ohio has a School Bus Replacement Grant Program (8). Other states with bioenergy policies pertaining to school buses include: Kentucky, North Carolina, New Jersey, Illinois, South Carolina, and Oregon.

North Carolina and Alabama offer alternative fuel and idle reduction grants. Alabama divides low interest energy efficiency loan programs for private and public entities (9,10). On the other hand, North Carolina has grants for the incremental cost of original equipment manufacturer alternative fuel vehicles, vehicle conversions, and implementing idle reduction programs (11). Similarly, Maryland and Virginia have alternative fuel infrastructure grants for planning, installation, and operating public access alternative fueling and charging infrastructure (12,13).

The following states have alternative fuel use and vehicle acquisition requirements: Nevada, Texas, Vermont Utah, Missouri, North Carolina, Oklahoma, Maryland, Ohio, West Virginia, Kansas, and Washington.

In Utah, by August 30, 2018, at least 50 percent of new or replacement light-duty state agency vehicles must meet Bin 2 emissions standards, which apply to all vehicle weight categories, including cars, minivans, light-duty trucks, and SUVs (14).

In Kansas, state agencies must purchase flexible fuel vehicles capable of operating on E85 fuel if available (15).

North Carolina's alternative fuel vehicle acquisition goal is that at least 75 percent of new or replacement state government light-duty cars and trucks with a gross vehicle weight rating of 8,500 pounds or less must be alternative fuel vehicles or low emission vehicles (16).

New Mexico and Minnesota have biodiesel blend mandates. In New Mexico, all diesel fuel sold for use in on-road motor vehicles to state agencies, political subdivisions of the state, and public schools must contain at least 5 percent of biodiesel (17). In Minnesota, diesel fuel sold in the state must be at least 10 percent biodiesel, increasing to 20 percent biodiesel on May 1, 2018 (18). Iowa and South Dakota also offer biodiesel blend tax credits (19,20).

Biodiesel production and blending tax credits are provided to aid qualified producers or blenders. Kentucky and North Dakota are examples of states that have biodiesel production and blending tax credits. In Kentucky, qualified biodiesel producers or blenders are eligible for an income tax credit of 1.00 dollar per gallon of pure biodiesel or renewable diesel produced or used in the blending process (21). In North Dakota, a corporate income tax credit of 10 percent of the direct costs incurred to add equipment to retrofit an existing facility or construct a new facility in the state for the purpose of producing or blending diesel fuel containing at least two percent of biodiesel or green diesel is given to qualified producers or blenders (22).

Texas and Oklahoma have natural gas vehicle and fueling infrastructure rebates. The Texas Gas Service Conservation Program offers a 2,000 dollars rebate for the purchase of a qualified natural gas vehicle or 3,000 dollars for the conversion of a gasoline powered vehicle to operate on natural gas (5). Oklahoma Natural Gas offers rebates for natural gas vehicles purchased or converted after June 20, 2016, in the amount of 2,000 dollars for a dedicated of bi-fuel natural gas vehicle. Also, 3,000 dollars can go toward the cost of a compressed natural gas home fueling station (23).

Virginia and Wisconsin have alternative fuel license policies. In Virginia, people with alternative fuel vehicles from a private source that do not pay the alternative fuels tax must obtain an alternative fuel license from the Virginia Department of Motor Vehicles (24). In Wisconsin, anyone acting as an alternative fuels dealer must hold a valid alternative fuel license and certificate from the Wisconsin Department of Administration (25). To conduct business in Wyoming, an annual 25 dollar license from the Wyoming Department of Transportation must be obtained by an alternative fuel supplier, refiner, distributor, terminal operator, importer or exporter of alternative fuel used in motor vehicles (26).

Virginia has clean transportation technology investment funding. In Virginia, the Commonwealth Energy Fund provides early-stage investment funds for Virginia-based technology, life science, and clean technology companies (27).

Alternative fuel labeling and ethanol labeling requirements vary by state. Illinois requires that 15 percent of all vehicles purchased with state funds must be fueled by electricity, natural gas, or liquefied petroleum gas (i.e., propane) (28). In North Dakota, alternative fuel retailers must label retail dispensing units with the price, name, and main components of the alternative fuel or alternative fuel blend being sold (29). Every alternative fuel automobile, truck, motorcycle, motor home, or off-road vehicle in Washington must bear a reflective placard from the National Fire Protection Association indicating that the vehicle is powered by an alternative fuel (30). In North Carolina, pumps dispensing and selling ethanol-blended gasoline must be labeled with the registered brand name and the volume percentage, or blend level, of the ethanol (10 percent or less, 10 to 15 percent, 15 to 85 percent or 85 percent) (31). Connecticut requires any motor vehicle fuel sold at retail containing more than one percent ethanol or methanol to be labeled according to Connecticut Department of Consumer Protection (32). All gasoline in Mississippi and Oklahoma containing one percent or more ethanol by volume offered for sale must be conspicuously identified as "with ethanol" or "containing ethanol" (33,34).

Many states have biofuel production facility tax credits or exemptions. For example, in South Carolina, a taxpayer constructing a commercial facility for the production of biofuel is eligible for a tax credit of up to 25 percent of the cost of constructing or renovating a building and equipping the facility (35). In Montana, a tax credit of up to 15 percent of the cost of constructing and equipping a facility to be used for biodiesel or bio-lubricant production is available to businesses (36). Any newly constructed or expanded biomass-to-energy facility in Kansas is exempt from state property taxes for up to 10 taxable years after construction (37).

Alternative fuel tax rates can vary by state. In Maine, blended fuels that contain at least 10 percent of gasoline or diesel are taxed at the full tax rate of gasoline (0.30 dollars per gallon) or diesel (0.312 dollars per gallon) (38). Wyoming has a license tax of 0.24 dollars per gasoline gallon equivalent or a diesel gallon equivalent is collected on all alternative fuel used, sold, or distributed for sale or use (39). In Hawaii, any alternative fuel used to operate an internal combustion engine distributor must pay a license tax of 0.0025 dollars for each gallon of alternative fuel the distributor sells or uses and pay a license tax for each gallon of fuel sold or used by the distributor for operating a motor vehicle on state public highways (40).

North Dakota has a special excise tax rate of two percent that is imposed on the sale of propane and an excise tax of 0.23 dollars per gallon is imposed on all special fuels sales and deliveries (41).

Iowa and Kentucky have alternative fuel production tax credits. Iowa's High Quality Jobs Program offers state tax incentives to business projects for the production of biomass or alternative fuels. Kentucky companies engaged in energy-efficient alternative fuel production, alternative fuel production, and gasification may be eligible for an incentive through the Kentucky Enterprise Initiative Act (effective July 14, 2018) (42,43). Kentucky also has the Kentucky Economic Development Finance Authority, which provides tax incentives to construct, retrofit, or upgrade an alternative fuel production or gasification facility that uses coal or biomass as a feedstock (44).

Each state has a different biodiesel tax exemption, deduction, and refund. Oregon's exemption is on biodiesel blends containing at least 20 percent biodiesel derived from used cooking oil. The blends are exempt from the 0.34 dollars per gallon state fuel excise tax (45). In Rhode Island, biodiesel is exempt from the 0.30 dollars per gallon state motor fuel tax (46). In North Carolina, biodiesel for use in a private passenger vehicle is exempt from the state motor fuel excise tax (47). Similarly in Montana, biodiesel producers that produce biodiesel from waste vegetable oil feedstock are exempt from the state special fuel tax (48). Montana's biodiesel tax refund allows a licensed distributor paying the special fuel tax on biodiesel to claim a refund equal to 0.02 dollars per gallon of biodiesel sold during the previous quarter if the biodiesel is made entirely from components produced in Montana (49).

As part of the Hawaii Clean Energy Initiative, Hawaii will produce 70 percent of the state's energy needs from energy-efficient and renewable sources by 2030 and 100 percent of the state's energy needs from energy-efficient and renewable sources by 2045 (50).

Biobased products

Since 2008, states have been adding more initiatives, programs, plans, and strategies that increase the use of renewable chemicals and other biobased products. State goals include increases in biobased products and environmentally preferable products, increases in organic farms, reduction of solid waste, and giving tax credits for biorenewable chemicals.

Massachusetts created the Environmentally Preferable Products Procurement Program of 2009, which has the following functions: gives specifications for sustainable products on statewide contracts; fosters cost effective responsible purchasing choices that help reduce impacts on public health and the environment; works with agencies, departments and others to encourage their use in public operations (51,52).

In 2010, Ohio became the first state to establish a Bio-based Products Preference Program. In this program, state agencies and institutions of higher learning (state-supported colleges) are obligated to purchase products with the highest percentage of biobased content as determined via ASTM D6866 (53).

California's 75 Percent Initiative went into effect in 2013. The initiative increases demand for bioproducts. It has a goal of 75 percent recycling, composting or source reduction of solid waste by 2020. This will tremendously decrease California's future reliance on landfills. The highest and best use of all materials in California can be achieved when the current landfill diversion programs are equal partners with the materials management program (54).

The Iowa Nutrient Reduction Strategy of 2013 is a science and technology-based approach to assess and reduce nutrients delivered to Iowa waterways and the Gulf of Mexico. It promotes voluntary efforts to reduce nutrients in surface water from both point sources (wastewater treatment plants and industrial facilities) and nonpoint sources (farm fields and urban areas), in a cost-effective manner (55).

Iowa's 2016 Biorenewable Chemical Tax Credit created an income tax credit equal to five cents per pound of qualified chemicals produced. New businesses can get up to one million dollars, while existing businesses can receive 500,000 dollars. The credit is limited to 10 million dollars per fiscal year in total awards (56). The Biorenewable Chemical Tax Credit Program is a revenue-neutral tax incentive and economic development package designed to attract national biochemical companies and pioneering new businesses to the state. The Biorenewable Chemical Tax Credit Program is the strongest incentive package in the world for biochemicals, and Iowa contains by far the nation's strongest biorenewables infrastructure (57).

North Dakota's Foundation for Agricultural and Rural Resources Management and Sustainability works to ensure the sustainability, health, and diversity of small farms and communities across the state. The foundation includes educational programs and opportunities and aims to cultivate the next generation of organic farmers. It gives farmers the tools necessary to build and sustain thriving organic farms, promotes the purchase of locally grown produce, and expands agricultural education in schools. Low interest loans and grants for sustainable farm improvements or enterprise startups are available with the Grants to Grow program (58).

Reinvigorating Louisiana's sugar and chemical industries is being promoted by the State's Sustainable Bioproducts Initiative. The initiative entails a regional program for production of multiple agricultural feedstocks and processing to biofuels and biobased chemicals. It is led by Louisiana State University's AgCenter (59,60).

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4.3. International

International policies work toward connecting multiple countries with agreements over topics such as trade, biofuels and accessibility to resources. The United States' biobased economy is supported by international agreements or other country actions. Many countries beyond the United States have agreements and actions in place. Some examples are presented below.

World Trade Organization Agreements (WTO Agreements) cover goods, services and intellectual property. Individual countries commit to lower customs tariffs and trade barriers. The agreements help keep services markets open, with a focus on the imports and exports of biomaterials between countries. Developing countries are prescribed special treatment. Governments are required to make their trade policies transparent by notifying the WTO about laws in force and measures adopted. Also, the secretariat must give regular reports on countries' trade policies (1).

United States' economic relations with neighboring countries in Central America and the Caribbean are essential to accessing goods. The Caribbean Basin Initiative of 1983 facilitated the development and export diversification of stable Caribbean Basin economies. It provides countries with duty-free access to the United States market for goods such as biofuels and bioproducts. This initiative plays a vital role in the United States' economic relations with Central America countries and the Caribbean. Issues with imports and exports are minimalized with this initiative (2).

International trade can be negatively affected by barriers such as tariffs, quotas, and embargos. The General Agreement on Tariffs and Trade (GATT) of 1994 is used to promote international trade by reducing or eliminating trade barriers such as tariffs or quotas. The core principles of GATT involve biofuels sustainability. Under GATT, there are many provisions including balance-of-payments, waivers, and non-application to name a few. There is an increase in surveillance of activities, which is done with stronger notification and review procedures (4).

Created in 2001, Everything But Arms (EBA) grants full duty-free and quota-free access to the European Union Single Market for all products, including biofuels and bioproducts, with the exception of arms and armaments. A country is granted EBA status if it is listed as a Least Developed Country (LDC) by the United Nations Committee for Development Policy. A country will not lose EBA status by entering into a Free Trade Agreement with the European Union (5).

The European Union has established more than 130 environmental targets and objectives to meet between 2010 and 2050 through the implementation of environmental policies. The environmental targets stablished cover a wide range of topics such as energy, greenhouse gas emissions and ozone-depleting substances, air quality, transport emissions, waste, water, sustainable consumption and production, chemicals and biodiversity. As an example, in March 2007 the European Council established the 20-20-20 energy targets. These targets, set with a 2020 deadline, include: a 20 percent reduction in total European Union greenhouse gas emissions; a 20 percent increase in energy efficiency; and an increase in the share of energy consumption from renewable resources by 20 percent (6). These targets were translated into legislations through the Climate and Energy Package in 2009, the Energy Efficiency Plan in 2011, and the Directive 2009/28/EC (6). Many of the policies established in the European Union influence the biofuel and bioproducts imports and exports of the United States.

In 2017, the Nigerian government was planning to spend 50 billion dollars to fund and stimulate the investment in local biofuels production in Nigeria. Funds would be provided by the Biofuels Equity Investment Fund. This was set in place with the proposed Nigerian Bio-Fuel Policy and Incentives document (7). Now in 2018, the Nigerian governments, Raw Materials Research and Development Council would like to use jatropha, a flowering Euphorbiaceous plant that is native to the American tropics, as a potential feedstock for biodiesel. The council has been promoting the crop since 1991 and states that are planting the crop and distributing the seeds to farmers will be beneficial. As much as 200,000 hectares of jatropha should be planted for biodiesel feedstock (8).

The national policy on biofuels for India (2018) expands the scope of raw material for ethanol production. With the approval of National Biofuel Coordination Committee, the policy allows the use of surplus food grains for ethanol production for blending with petrol. Conversion of surplus grains and agricultural biomass can help in price stabilization. India's policy supports the setting up of supply chain mechanisms for biodiesel production, which can come from non-edible oilseeds, used cooking oil, and short gestation crops. India's biofuel policy will help to reduce import dependency year-over-year with better ethanol supply (9).

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4.4. Business to Business

Many corporations are creating their own internal and external policies that increase the demand for renewable chemicals and other biobased products. Business to business policies are designed and implemented to grow the economy and provide jobs in an environmentally sustainable and energy efficient manner. To advance the nation's industrial ability, many of these policies are set in place to represent the nation's leading manufacturing sectors. Select examples of business to business policies are included below.

The Sustainable Apparel Coalition created the Higg Index, which is a standardized supply chain measurement tool that describes a company's environmental, social, and labor impacts of making and selling their products and services (1,2). By measuring sustainability performance, the industry can address inefficiencies (1). It can also help to resolve damaging practices and achieve the environmental and social transparency demanded by consumers. By joining forces in a coalition, addressing urgent, systemic challenges is possible (1).

Fair Trade makes sure companies' products become certified by following social, environmental and economic standards. The companies must promote safe working conditions, aim to protect the environment, be transparent in their efforts, and empower the community to succeed. Products originating in more than 45 countries that are Fair Trade Certified™ are being sold in the United States (3).

B Lab is a nonprofit organization that allows companies to become Certified B Corporations. When a company is a certified B corporation, it meets the standards of verified, social and environmental performance, public transparency, and legal accountability. B Lab promotes Mission Alignment using innovative corporate structures. These include the benefit of a corporation to align the interests of business with those of society (4).

The Outdoor Industry Association is a premier trade association in Boulder, Colorado, consisting of a collaboration of hundreds of outdoor organizations to implement better practices in the supply chain. Goals of the Outdoor Industry Association include driving change in the recreation industry and trade policy, sustainability in business innovation, and increased outdoor participation. The association offers the following tools and resources: networking events, education opportunities, research reports, case studies, business savings and brand recognition opportunities (5).

Modern biotechnology offers breakthrough products and technologies that are advantageous. Current day biotechnology not only combats debilitating and rare diseases, but also reduces the environmental footprint, feeds the hungry, uses less and cleaner energy, and makes having safer, cleaner and more efficient industrial manufacturing processes possible. The Biotechnology Innovation Organization (BIO) represents more than 1,100 biotechnology companies, academic institutions, and state biotechnology centers across the United States plus 30 other countries. All members of BIO are involved in the research and development of healthcare, agricultural, industrial, and environmental biotechnology products. The organization hopes to educate the media and public about the biotechnology industry's progress. It also provides member companies with business development services (6).

Patagonia, a designer of outdoor clothing, currently uses fossil fuels to produce the shell of their coats. Alternative energy sources are being sought out to develop a more environmentally-friendly process. Patagonia is being transparent about the fact that they are contributing to climate change. The brand supports a variety of initiatives to reduce their carbon footprint and discover more sustainable ways to produce these high-quality products (7). To give back, the company donates one percent of sales to an Earth Tax. That money in turn supports environmental organizations around the world that take down dams, restore forests, protect endangered species, and promote sustainable agriculture practices.

Patagonia has donated 70 million dollars to these initiatives so far. The company is also looking for ways to make their facilities more eco-friendly. Through the Employee Drive Less Program, Patagonia provides a monetary incentive to employees that car pool, take public transportation, walk, or use any mode of transportation besides driving alone (7).

IKEA utilizes renewable energy sources and waste management tactics to become environmentally friendly. IKEA has a sustainability strategy called People & Planet Positive. Because consumers shouldn't have to choose between design, functionality, price, or sustainability when purchasing a product, their product lines are manufactured through eco-friendly practices. IKEA only uses LED bulbs in their facilities and was the first major retailer to sell exclusively LED bulbs and lighting fixtures in their stores. Solar panels have been installed on 90 percent of their United States buildings. To power their buildings in Texas and Illinois, IKEA has two wind farms generating renewable energy. IKEA has planted 2.4 million trees in American forests and only sends about 15 percent of waste to landfills to offset carbon dioxide emissions. IKEA's goal is to use 100 percent renewable energy through wind farms and solar panels. IKEA also plans to source wood from more sustainable locations. All these initiatives have cost IKEA over one billion dollars (7).

Johnson & Johnson is another business looking forward to offsetting carbon dioxide emissions. The company's sustainability plan is called Citizenship & Sustainability 2020 Goals. It focuses on making individual consumers and their homes healthier by increasing the recyclability of products and reducing carbon dioxide emissions by 20 percent. Johnson & Johnson includes their vehicle fleet and facility emissions when calculating their carbon dioxide emissions (7).

The Hershey Company, consisting of manufacturing and distribution centers, hotels, and an amusement park, wants to do more with their sustainability efforts. In the next seven years, the company would like to reduce greenhouse gas emissions by 50 percent. Also by 2025, all 11 Hershey facilities would like to achieve zero waste-to-landfill status. Another goal for the company is to reach a 95 percent company-wide recycling rate (7). By 2020, the company would like to transition to 100 percent certified cocoa. The cocoa will need to be verified by independent auditors to ensure that it meets labor, environmental, and farming standards. Other company incentives include the expanded use of electric vehicles to reduce emissions (7).

TMD Technologies Group Company- Go Green Bioproducts, LLC, which has its headquarters in the United Kingdom, breaks down and recycles packaged Go Green Bioproducts from a wide variety of beverage and food products to completely eliminate waste discharge, not leaving any materials that must be disposed of or discharged as a liquid. The Go Green Concentrate (sugar) is converted into biofuels or value added bioproducts for future use (8).

Olleco, established in 2014, is a renewable energy business. It provides the United Kingdom's food sector with the opportunity of fleets to be run on the same oil in which they fry their chips. This makes carbon dioxide savings of more than 95 percent when compared to fossil fuels. Olleco collects used cooking oils, fats and food waste from 50,000 catering and hospitality businesses to produce biofuels such as biodiesel. Olleco recycles more than 100,000 tons of organic waste each year. It generates 1MWh of renewable heat and power and produces 16 million liters of biodiesel, which meets the strict European Union specifications (9).

GENeco, located in the United Kingdom, extracts energy in the form of biogas from a mix of food waste, commercial liquid waste and domestic sewage. It is then refined to the same composition as natural gas. The company is diverting 100 percent of waste from landfills and providing renewable energy for nearly 150,000 homes. In 2013, the company was awarded zero-waste-to-landfill status and is carbon neutral. GENeco's plant turns the biogas to biomethane. GENeco helped create the Bio-Bug, the United Kingdom's first VW Beetle powered by human waste. The Bio-Bug can be powered for a whole year with the biogas from the waste of just 70 homes (10).

Wyke Farms is working on redefining the dairy business. It has become the first national cheddar brand to be 100 percent self-sufficient in solar and biogas energy. Wyke Farms is one of the first United Kingdom grocery brands and it saves over 22 million kilos of carbon dioxide per year. Over the next few years, the company aspires to be one of the most sustainable grocery suppliers in the sector. The company's latest investment project is to generate more upgraded biogas to fuel HGV vehicles like milk tankers and increase solar energy by using other roofs and recovering heat from the rear of solar panels (11).

The National Biodiesel Board (NBB), founded in 1992 as the National Soy Diesel Development Board, is a nonprofit trade association dedicated to coordinating the biodiesel industry and educating the public about the fuel. The board has been advancing the biodiesel industry for 25 years. NBB members include the following: state, national, and international feedstock and processor organizations; biodiesel suppliers; fuel marketers and distributors; and technology providers. Today, the NBB has over 150 companies as members, representing nearly all 50 states. In 2011, the board launched the Advanced Biofuel Initiative. Last year, antidumping and countervailing duties on biodiesel imports from Indonesia and Argentina were filed. The goal of the duties is to level the playing field for domestic producers (12).

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