Chapter 2

OVERVIEW OF THE FOOD AND AGRICULTURAL SITUATION IN THE UNITED STATES

This chapter outlines the main challenges and opportunities for the US food and agriculture sector, and the drivers of its performance, including innovation. It outlines the contribution of the sector to the economy, and the natural resource base upon which it relies. It identifies the main structural characteristics of primary agricultural and upstream and downstream industries; describes the main food and agriculture outputs and markets; reviews trends in farm and household income performance; and analyses developments in agricultural productivity and sustainability, and their main drivers: innovation, natural resources, climate change, and structural change – which in turn are influenced by a range of policies.

Challenges and opportunities: The need for innovation in food and agriculture

The demand for agricultural products is growing and changing. Rising incomes in the developing world are creating a growing global middle class, which in turn is creating increased global demand for meat and dairy products along with the animal feeds used to produce them. At the same time, a substantial volume of US crop production is going to produce fuel. Each development increases the demand for US agricultural products.

US consumers are turning toward a diet differentiated along several dimensions. They eat more fresh fruits and vegetables, year round, and rely on a sophisticated transportation and marketing network to deliver those products in a timely fashion, even while some households also want more foods produced locally, near their homes. Consumers are increasingly interested in how agricultural products are produced, and attach increasing value to animal welfare, fair trade, environmental stewardship, and nutritional attributes of food products. These developments, which are also occurring in other high income countries, have led to adjustments in global supply chains in which private procurement standards play a major role.

Farmers face a growing set of climate-related challenges in meeting those demands. Climate change is expected to raise growing season temperatures; alter the amount and variability of rainfall; reduce soil moisture; and ease the wider spread of animal and plant pests and diseases. These developments threaten crop yields and pose significant risks for animal production.

Farmers also face the challenge of meeting growing and changing demands for agricultural products while still conserving soil, air, and water resources. While soil losses, aquifer depletion, and nutrient over-applications have been slowed through the application of technologies and the financial support and incentives provided by public policy, increasing commodity demands and climate stresses pose new threats.

Innovation has driven the growth of agricultural productivity in the United States over the last seven decades. The sector's capacity to meet these new demands, while maintaining and improving its record of sustaining natural resources, depends critically on the further development and diffusion of innovations in farm inputs, farm production, food marketing, and public policy.

Past productivity growth has benefited from mechanical innovations in agricultural equipment, and from innovations in how farms and agri-business are organised and how they interact with one another. Further developments along these lines will be crucial. However, investments in science, which have played a primary role in supporting past productivity growth, continue to provide the largest opportunities, and challenges, for meeting future demands for agricultural products.

Developments in science — particularly the integration of the life sciences with physics, engineering, and computational sciences represented as the "New Biology" — provide enormous opportunities for developing the innovations needed to spur continuing productivity growth in agriculture while sustaining resources. However, effective application of scientific developments to the food economy will depend on continuing innovations in public policy, in the form of transparent and well-designed regulations on the testing and commercial introduction of products; communication and statistical reporting that provides comprehensive and trusted information; and programmes to provide financial support for research and conservation.

The place of food and agriculture in the US economy

Production and land use

US agriculture produces a diverse array of commodities from a wide range of soils and climates. It is a market-oriented sector, in which prices respond to market shifts, and producer decisions are responsive to price signals. The farm sector accounts for about half of all land, about 1.5% of total employment, and about 1% of Gross Domestic Product (GDP).

The United States is a large, high-income country with a substantial endowment of agricultural land (Table 2.1). With a total GDP comparable to the European Union, the United States has higher per capita levels of GDP, water resources, and arable land. As in other high-income countries, primary agriculture is a small part of the economy: value added in agriculture amounted to 1% of GDP in 2014, compared to 8% in 1950 (Figure 2.1). The long-term decline in agriculture's share reflects slow growth in domestic food consumption, combined with high growth in agricultural productivity, which reduces the amount of land, capital, and labour required per unit of agricultural production. However, because of the country's large endowment of arable land, agriculture remains a large industry that accounts for a significant share of US exports.

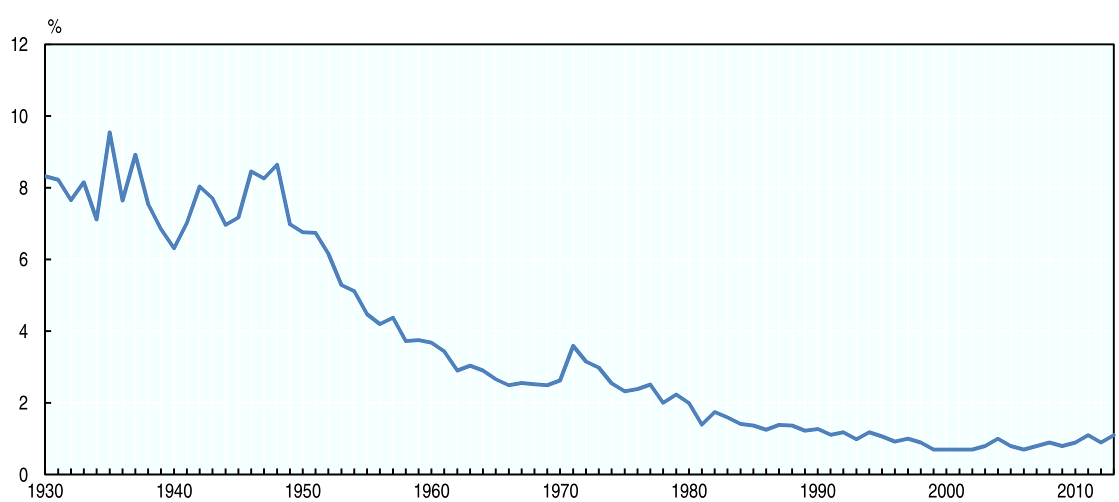
Table 2.1. Contextual indicators, 2014*

	GDP	GDP per capita	Population	Total land area	Agricultural land	Arable land per capita[1]	Freshwater resources[1]	Freshwater resources per capita[1]
Unit	PPP USD billion	PPP USD	Million	'000 km2	'000 ha	Hectares	Billion m³	m³
Year	2014	2014	2014	2013	2013	2012	2013	2013
United States	**17 348**	**54 353**	**319**	**9 147**	**405 437**	**0.49**	**2 818**	**8 914**
(ranking)	*(1)*	*(10)*	*(3)*	*(3)*	*(2)*	*(15)*	*(4)*	*(51)*
Australia	1 095	46 281	23	7 682	396 615	2.07	492	21 272
Brazil	2 974	15 065	199	8 358	278 808	0.37	5 661	28 254
Canada	1 600	45 025	36	9 094	65 251	1.32	2 850	81 071
China	18 015	13 171	1 394	9 425	515 358	0.08	2 813	2 072
EU28	18 758	36 920	508	4 238	186 356	0.26	1 505	4 740
Russian Federation	3 359	22 629	144	16 377	216 840	0.84	4 313	30 056
South Africa	705	13 032	53	1 213	96 841	0.23	45	843
OECD	49 688	39 217	1 264	34 341	1 211 805	0.30	10 466	28 117

* Or latest available year.
PPP: Purchasing Power Parity.
1. World Bank, *World Development Indicators, 2015*. http://data.worldbank.org.

Source: OECD (2015), *Agricultural Policy Monitoring and Evaluation 2015*, http://dx.doi.org/10.1787/agr_pol-2015-en.

Figure 2.1. Agriculture's share of US GDP, 1930-2014



Source: US Department of Commerce (2015), Bureau of Economic Analysis, www.bea.gov/industry.

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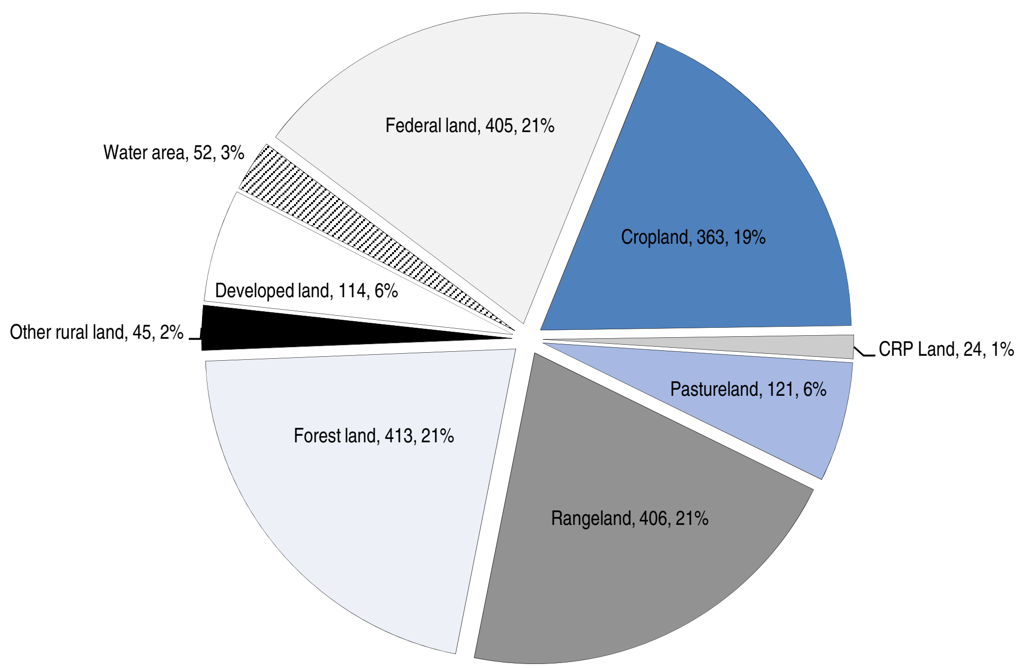
The food system includes agriculture, food processing, wholesaling, retailing, food service, and input suppliers to the farm sector, and the food system combined accounts for about 6% of GDP. Because food retailing and food services are labour intensive industries, the food system accounts for a substantial share of total employment. In 2014, 10.7 million people were employed in food services, including restaurants, many on a part-time basis. Another 6.2 million people were employed in food processing, retail food stores, and farming (including those self-employed in farming). The total, 16.9 million, amounted to 11% of total US employment.

Agriculture uses nearly half of the land area in the United States (Figure 2.2). Twenty-seven per cent of the country's surface area is devoted to pasture and range land (in addition, some federal land is also used for grazing). Cropland accounts for about 19%. The amount of land used for crops has remained remarkably stable in spite of a growing population and spreading suburban development. In 2012, 340 million acres of cropland were used for crops, compared to 331 million acres in 1987 and 383 million in 1982 — the extreme values in a series that extends back to 1945.

Figure 2.2. US surface area by land cover and use, 2012

Millions of acres and percentage of total surface area



CRP: Conservation Reserve Program.

Source: USDA (2015j), Natural Resource Conservation Service, Natural Resource Inventory. www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri/.

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California, on the Pacific Coast, is the leading agricultural state, with about 12% of the value of US production, focused on intensive fruit, nut, vegetable, and dairy operations. Eight Midwestern States, with an emphasis on field crops, cattle, dairy, and pigs, together account for 30% of the value of US agricultural production, while five adjoining Great Plains States, with a major focus on field crops and cattle, add another 16%. Six Atlantic Coast states (Florida, Georgia, North Carolina, Virginia, Delaware, and Maryland) specialise in poultry, pigs, and specialty crops, and jointly account for nearly 10% of the value of production.

US agriculture is highly diversified. Total sector cash receipts are split almost evenly between crops and animals/animal products (Table 2.2). In turn, three aggregations — meat animals and their products (cattle and pigs); dairy products and poultry and eggs; and feed and oil crops — each account for about one quarter of cash receipts, while vegetables, melons, fruits, and nuts together account for another one-eighth.

Table 2.2. Cash receipts in the US farm sector, by commodity class, 1955, 1985 and 2014

Percentage of all cash receipts

	1955	1985	2014
Animals and products	54.1	48.6	50.4
Meat animals	28.0	26.9	25.6
Dairy products	14.2	12.5	11.7
Poultry and eggs	10.8	7.8	11.5
Miscellaneous animals, products	0.9	1.4	1.6
Crops	45.9	51.4	49.6
Food grains	6.7	6.2	3.7
Feed crops	8.7	15.5	15.5
Cotton	8.7	2.6	1.8
Oil crops	3.8	8.6	10.3
Tobacco	4.2	1.9	0.4
Vegetables and melons	5.7	6.0	4.5
Fruits and nuts	4.3	4.8	7.1
All other crops	3.7	5.8	6.3

Source: USDA (2015c), Economic Research Service, Farm Income and Wealth Statistics. www.ers.usda.gov/data-products/farm-income-and-wealth-statistics/us-and-state-level-farm-income-and-wealth-statistics.aspx.

Recent years have seen shifts in area planted to different crops in response to changes in commodity prices, particularly as growing ethanol production increased the demand for maize. Some of the increased demand was met through yield increases, but planted maize area rose from 80 million acres (1 acre = 0.404686 ha) in 2000 to 97 million in 2013, before falling back to 88 million acres in 2015. Soybean area also expanded in recent years, to 83 million acres in 2015, and maize and soybeans together accounted for 53% of all area planted to principal field crops in 2015, up from 47% in 2000, according to the annual *Acreage* report produced by the National Agricultural Statistics Service of the US Department of Agriculture (USDA) (USDA/NASS, 2015). Acreage planted to wheat, cotton, and hay — the third, fourth, and fifth largest crops by planted area — fell by nearly 17 million acres over 2000-15.

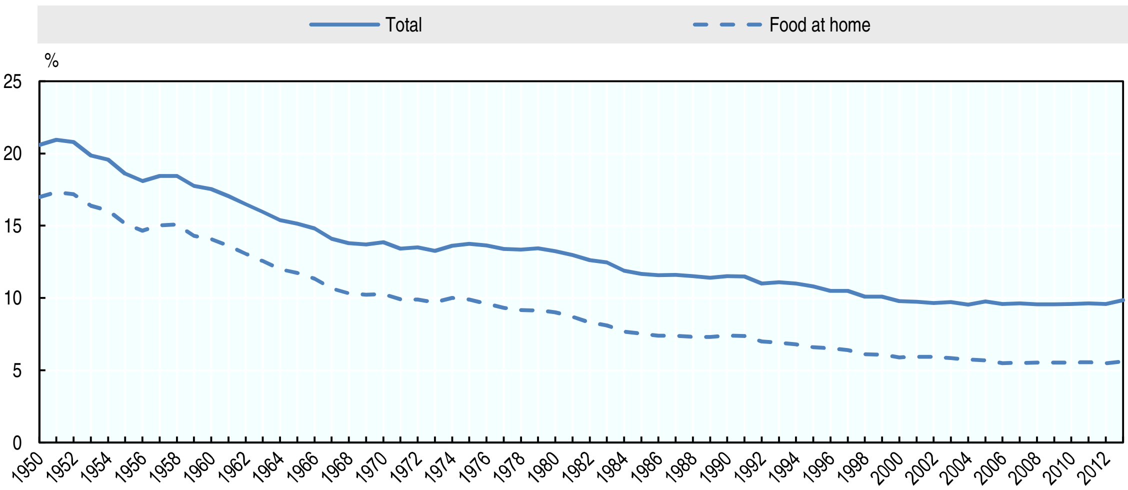
Domestic food consumption

Consumer decisions — about what to eat, whether to eat at or away home, and how to prepare food — play a driving role in retailer and processor strategies and ultimately in agricultural production.

As in other higher-income countries, food spending in the United States accounts for small shares of aggregate income, and changes in income have small effects on per-capita food spending. Recent Economic Research Service (ERS) research finds that food spending by US households is not very responsive to changes in household income and total spending. Specifically, 1.0% increases in total household expenditures are associated with increases of just 0.01 to 0.21%, on average, in expenditures for different major food groups (Okrent and Alston, 2012).

As a result, domestic food consumption is rather insensitive to business cycles, falling little during recessions, but rising little in response to expansions. However, this finding also implies that the share of consumption devoted to food will decline over time as incomes grow. Expenditures on food accounted for over 20% of personal household disposable income in the United States in 1950, but fell to 9.8% by 2013 (Figure 2.3). Over the same period, the share of income devoted to food consumed at home fell even more rapidly, as the share devoted to food consumed away from home rose slightly.

Figure 2.3. US food expenditures as a share of personal disposable income, 1950-2013



Source: USDA (2015d), Economic Research Service, Food expenditures series. www.ers.usda.gov/data-products/food-expenditures.aspx.

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In turn, expenditures on farm commodities account for a small share (17.4% in 2013) of consumer expenditures on domestically produced food. Current estimates are produced with methods that cannot be extended before 1993, but it appears that farm shares were substantially higher in the 1960s and 1970s. The long-term declining share of the farm sector in domestic food expenditures follows from three main factors: relatively rapid productivity growth in agriculture, which reduces the agricultural inputs required for any given volume of consumer food products; increased processing of food products, which adds inputs in the processing and retailing sectors; and a shift of consumption to food consumed away from home (food service and restaurants) which adds service inputs to food retailing.

Changes in American diets have led to several important changes in agricultural production. While total per capita meat consumption changed little between 1970 and 2013, the mix changed sharply, toward more poultry, less pork, and substantially less beef. Americans also consumed more fresh fruit and less processed fruit; more processed potatoes; and more fresh green vegetables (USDA/ERS, 2016a).

Food consumption has become more diversified in several important ways. Consumers now spend nearly half of their food dollars on food away from home (Figure 2.3). When they eat at home, they can chose from a wider variety of foods provided through their supermarkets, including products that require very little home preparation time, such as pre-cut fresh fruits and vegetables or pre-cooked meat items (Martinez, 2007). There is widespread and growing interest in food with specific product attributes, such as distinct varieties of fruits, meat from specific pork breeds, or coffee from specific locations.

There is also growing interest among food consumers and retailers in how farm products are produced, and not just in the sensory attributes of the products themselves. The most well-known package of alternative practices, organic agriculture, eschews the use of synthetic chemicals, genetically engineered seeds, and certain animal drugs in production. While the organic sector is still a small part of US agriculture, it has grown rapidly. Three million acres of US cropland and about 255 000 milk cows were certified organic in 2011, up from 1.3 million cropland acres and 49 000 milk cows in 2001 (USDA/ERS, 2016b).

Other examples of differentiation by production practices include eggs that are produced by layers who are not confined in small cages ("cage-free"); pork production using sows that are not confined to gestation crates; grass-fed beef; meat from animals that are raised without antibiotics; products derived from crops that have not been genetically modified ("GMO-free"); and coffee that is produced under "fair trade" standards.

According to USDA's Agricultural Marketing Service, consumers purchased meats and produce directly from farmers at over 8 000 farmer markets in 2014, more than double the number ten years before. Sellers in farmers markets often base their marketing efforts on the practices used to produce products. To choose another example, the Consumers Union conducted a recent survey of 35 grocery store chains, and found that 31 of them offered meat and poultry products that were labelled as raised without antibiotics (Consumer Reports, 2012). Various kinds of animal welfare standards are also being introduced in product marketing.

These are a few examples of a much broader shift to a more diverse array of products. Because most consumers are unable to observe how animals and crops are raised, issues of labelling, certification, and information provision are crucial for marketing these products. The growth in organic production has in part been spurred by an organic certification programme performed by 3rd party certifiers under USDA administration. The Department offers verification services for other claims about production practices, and various private certification services have emerged to provide verification as well.

Food labelling has become a political issue in several states and in the US Congress. Voters in California rejected a ballot initiative that would have required labelling of some foods made from genetically modified plants in 2012, and in 2013 voters in the state of Washington rejected a similar initiative. In 2014, the legislature in the state of Vermont passed an Act requiring such labelling as of 1 July 2016. In late July 2016, a federal law was enacted requiring mandatory labelling of food products made from genetically modified plants, and which will pre-empt the Vermont law. This law will require food manufacturers to provide an on-package disclosure in the form of text, a symbol, or an electronic link, such as a scannable code, that would inform consumers whether a product contained ingredients from genetically modified plants. Restaurants are exempted from labelling requirements, as are products derived from animals whose feeds contained genetically modified crops.

Farm structure

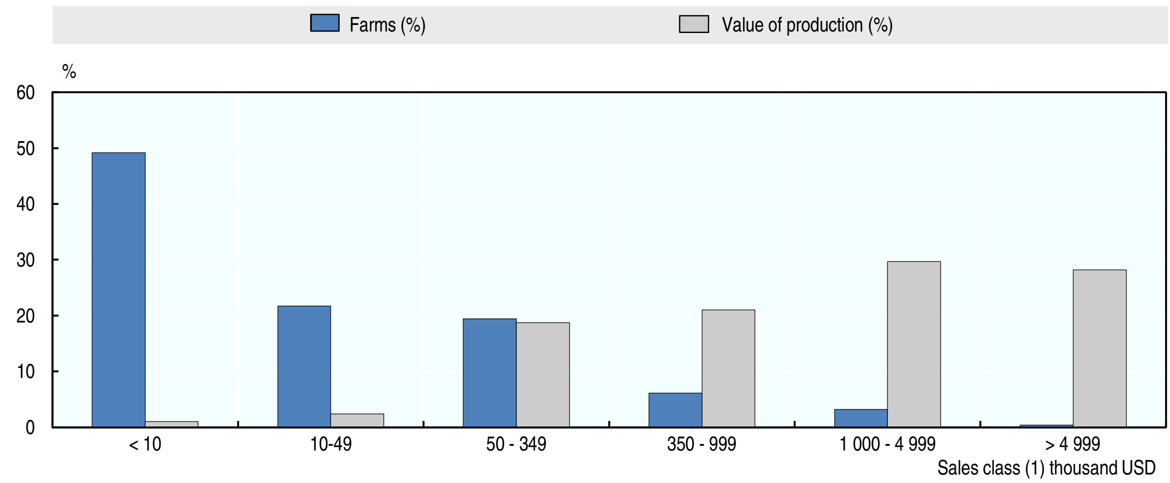
The US farm sector includes an extraordinary range of farms of different sizes. While farms are less diversified, on average, than they were a century ago, most still produce a range of different commodities. Production is shifting to larger farms in most commodities and most states, but even so family farms still dominate the sector.

In US farm statistics, a farm is any place that produces, or normally could produce, at least USD 1 000 of agricultural commodities in a year. The definition, in place since 1974, is not adjusted for inflation. With rising prices for farm commodities, more very small units will be counted as farms, and the statistics do show a growing number of very small farms. The US Department of Agriculture (USDA) reports that there were 2.08 million farms in 2014. Half had sales of less than USD 10 000, and collectively those farms accounted for 1% of agricultural production (Figure 2.4).

The consolidation of farm production in larger operations has been rapid. About 75 000 farms — 3.6% of the total — had sales of USD 1 million or more in 2014, and those farms accounted for 57.9% of the value of US farm production, up from 33% of production in 1996 (Figure 2.5). This comparison adjusts for inflation in farm commodity prices using the Producer Price Index for Farm Products (US Bureau of Labor Statistics), and compares 1996 and 2014 sales using 2014 prices. Most of the shift in production to larger size classes has come at the expense of small commercial farms with USD 50 000-USD 350 000 in sales. Those farms accounted for over one third of total production in 1996, but less than 20% by 2014.

Figure 2.4. The size distribution of US farms, 2014

Percentage of farms or production



1. Sales are measured by gross cash farm income.

Source: USDA, (2015a), *Agricultural Resource Management Survey (ARMS),* www.ers.usda.gov/data-products/farm-household-income-and-characteristics.aspx.

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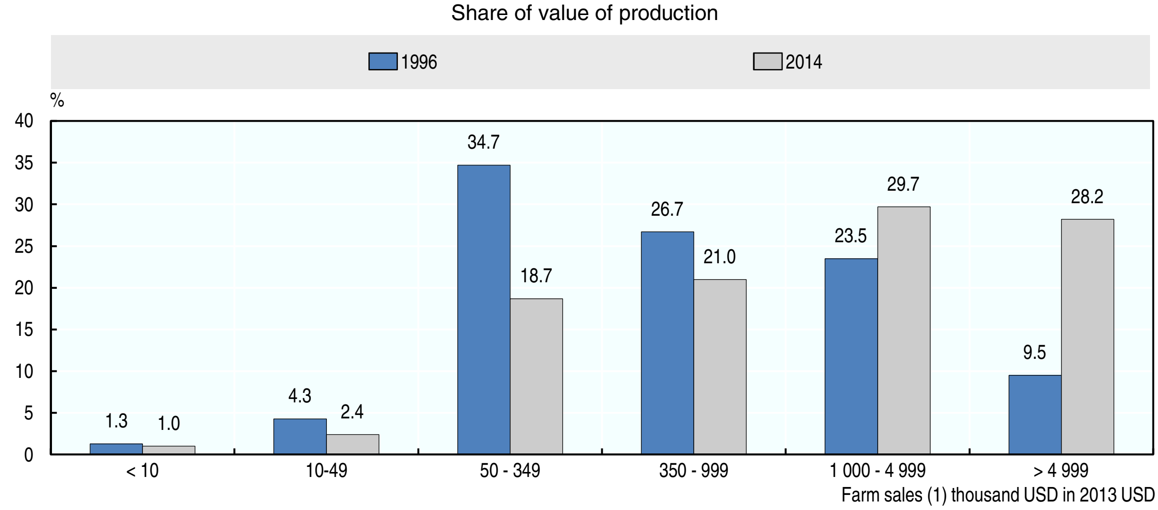
Figure 2.5. Agricultural production is shifting to larger farms, 1996 and 2014

Share of value of production



1. Sales measured as gross cash farm income.

Source: USDA (2015a), *Agricultural Resource Management Survey (ARMS),* www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices/arms-data.aspx.

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With a highly skewed farm size distribution, simple measures of mean size may not be effective for tracking consolidation of land or production. In this case, a midpoint measure can be useful. The midpoint is a type of median, the size of farm at which half of acres (or production) are on larger farms and half are on smaller. Among US crop farms, the midpoint size, measured in acres of cropland, was 600 acres in 1987 — half of all US cropland was on farms with no more than 600 acres of cropland, and half was on farms with no less (MacDonald, Korb, and Hoppe, 2013). By 2012, the midpoint had increased to 1 201 acres.

Production shifted to larger farms in most commodities and in most regions (Table 2.3). For crops, midpoints were calculated based on harvested acres of the crop. For dairy farms, the midpoint is calculated for milk cow inventory (herd size), while for other livestock the midpoint is calculated for annual number of head sold or removed.

In 1987, half of harvested maize area came from farms with at least 200 harvested acres of maize, and half came from farms no more than 200 (Table 2.3). By 2012, the midpoint for maize had grown to 633 acres, as acreage and production shifted to larger farms. Midpoint sizes increased by more than 100% for other major field crops, and also increased, by 100% on average, for most fruit, vegetable, melon and tree nut crops.

Table 2.3. Changes in midpoint enterprise size, selected commodities, 1987 and 2012

Commodity	1987	2012
Field crops	Acres harvested	
Maize	200	633
Soybeans	243	567
Wheat	404	1,005
Cotton	450	970
Vegetables		
Asparagus	160	200
Lettuce	949	1 275
Potatoes	350	1 054
Sweet maize	100	300
Tomatoes	400	930
Tree crops		
Apples	83	179
Almonds	203	547
Oranges	450	1 335
Poultry/livestock	Annual head removed/sold	
Broilers	300 000	680 000
Pigs	1 200	40 000
Fattened cattle	17 532	38 369
	Milk cow herd	
Dairy cows	80	900

For crops, the midpoint size is that at which half of all harvested acres are on larger farms and half are on smaller farms. For dairy cows, half of all cows are in herds larger than the midpoint, and half in smaller. For other livestock, half of all animals sold, or removed under contract, are from farms with more sales, and half with less. The midpoint is the median of the distribution of harvested acres, or livestock, by farm size.

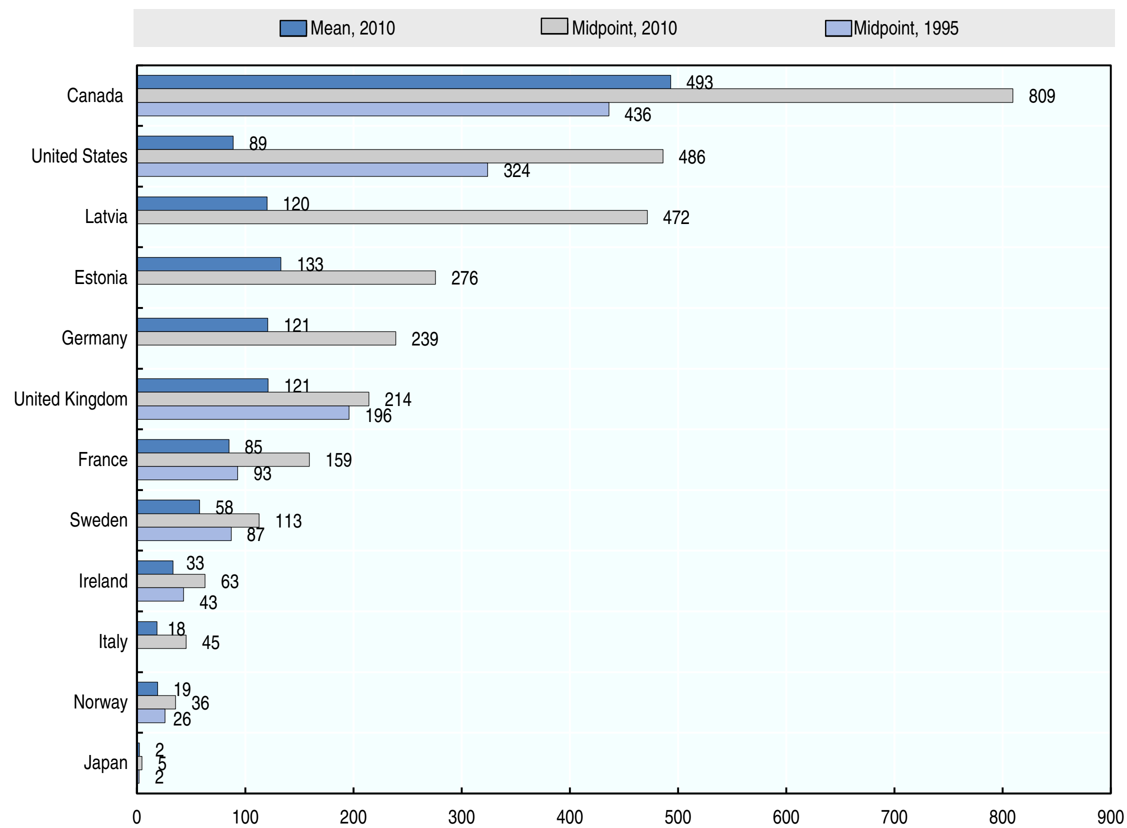
Source: USDA Economic Research Service calculations, from Agriculture Census.

Changes in some livestock sectors were spectacular. In 1987, half of all milk cows were on farms with no more than 80 cows. Twenty-five years later, that midpoint was at 900 cows. The change in pigs was even more dramatic as each industry underwent wide-ranging and comprehensive set of structural changes. Midpoint enterprise sizes for broilers and for fed cattle more than doubled.

Cropland is also consolidating into larger farms in other OECD countries, but the pace of consolidation varies widely. In a comparison of 12 selected OECD countries, the midpoint size of a crop farm was at least 60% greater than the mean size in each, indicating that farm sizes tend to be skewed in all (Figure 2.6). The midpoint crop farm size ranges widely across countries, from 5 hectares of cropland in Japan and 36 in Norway (the small end) to 486 in the United States and 809 in Canada. Temporal comparisons could be provided for eight countries (Canada, the United States, Japan, France, Norway, the United Kingdom, Ireland, and Sweden) for 1995-2010 (Figure 2.6). Midpoint farm sizes increased in each country, and midpoints increased more rapidly than means in each.

Figure 2.6. Farm size in selected OECD countries, 1995 and 2010

Crop farms, ha of cropland



Source: Bokusheva and Kimura (2016). http://dx.doi.org/10.1787/5jlv81sclr35-en.

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There is strong evidence of a link between structural change and productivity growth in the US dairy and pig sectors. In dairy, Mosheim and Lovell (2009) identified substantial scale economies, with unit costs falling sharply through herd sizes of 500 head, and then falling steadily, at a more modest rate throughout the range of herd sizes in their dataset in 2000. Since then, US dairy production has continued to shift to farms with 2 000 or more head, and MacDonald, Cessna, and Mosheim (2016) estimate that the industry's structural change toward larger operations reduced industry-average costs by 19% between 1998 and 2012. In the pig sector, McBride and Key (2013) show that there were significant unexploited economies of scale in 1992, and that in subsequent years industry-average costs fell as farms expanded to realise scale economies, and as continuing innovations in breeding, housing, and feeding reduced costs for all farms. By 2009, the economies of scale in the industry had largely been fully exploited, so that further increases in farm size are not expected to reduce costs. In broilers, there was a more gradual shift to larger operations (Table 2.3), and MacDonald and Wang (2011) identify a small advantage to larger farms from scale economies, consistent with the observed gradual shifts.

The estimation of scale economies and associated size advantages is more technically challenging in crops, because farms usually produce multiple outputs, output decisions are interrelated (via rotation decisions), and generally unobservable weather and soil features play important roles in outcomes. Furthermore, since most farms in the United States remain family-run businesses of relatively small size compared to other businesses, production scale economies are unlikely to be nearly as extensive as they are in some nonfarm industries. Nevertheless, crop production has been shifting to larger farms, and larger field crop, fruit, and vegetable farms appear to realise lower per-acre capital and labour costs than smaller farms over the range of observed farm sizes in the United States (MacDonald, Korb, and Hoppe, 2013).

Technological changes, which allow farmers and farm families to manage more acres, are an important force driving farm consolidation in crop production (MacDonald, Korb, and Hoppe, 2013). Specifically, larger and faster pieces of equipment allow farmers to complete field tasks in less time. Developments in seeds, in chemicals, and in information technology also appear to reduce the hours required for certain tasks. In agriculture, which is still dominated by family farms, reductions in the family hours required for specific field operations can be used to manage larger operations. The value of these labour-saving innovations is conditional on land features. They are most effective in regions with large, flat, contiguous fields. Hence the pace of consolidation differs across States and regions in the United States.

US farms have become much more specialised, although most still combine several agricultural commodities. In the early 20th century, most of them kept a variety of livestock, and they raised feed crops for their animals as well as cash crops for sale. As late as 1960, more than half of US farms grew maize, largely in support of pig, cattle, chicken, or dairy production. By 2012, only one in six farms grew maize. Sixty per cent of those farms raised no livestock, and those that did raise livestock often purchased most of their feed.

The separation of crop production and livestock feeding led to geographic shifts in each sector, as feed grain production concentrated in the Midwest while livestock production shifted toward the South and West (MacDonald, Korb, and Hoppe, 2013). In turn, the geographic movement of commodity production to the regions that were most appropriate contributed to increasing crop yields (Beddow and Pardey, 2015).

Despite the shifts to larger operations, most US agricultural production is carried out on family farms, and most large farms are family farms. ERS defines a family farm as one on which the principal operator, and people related to the principal operator by blood or marriage, own more than half of the farm business. Under this definition, family farms accounted for 99% of all US farms and 90% of farm production (Hoppe and MacDonald, 2015).

Nonfamily farms include farms whose principal operator is a manager hired by the owners to operate the farm; partnerships of unrelated people who jointly operate the farm; and farms operated by large publically-held corporations. Most nonfamily farm production does not come from large corporations, but instead comes from partnerships among unrelated people, who sometimes organise themselves into small tightly-held corporations (Hoppe, Korb, and Banker, 2008).

Agribusiness structure

US farms operate in a food system of processors, retailers, and input providers. Most are large corporations, and few directly operate farms — there is little vertical integration between agriculture and other parts of the food system. However, farms are often tightly linked with other firms in the food system through various types of contractual relationships. Some agri-food firms have been sources of innovation in coordinating production, developing new products, and facilitating the spread of production technologies and practices.

The tightest and most extensive system of contractual control is in broiler chicken production, where firms own processing plants, feed mills, and hatcheries, and contract with farmers to raise broilers for them. Almost all broilers are raised under production contracts; the firms provide farmers with chicks and feed, and provide specific guidelines for equipment and housing requirements and production practices. The pig and turkey sectors are not quite as tightly controlled, but are still dominated by contract production. In other commodities, farmers may use contracts with buyers that tie prices to commodity attributes, and they may have longstanding but less formal ties to specific buyers.

Large retailers affect agricultural production by setting procurement standards. The retailers usually work through processors or other intermediaries, rather than contract directly with farmers, but the requirements that they set — for attributes of products and production processes — are conveyed back to farms through the intermediaries, with third-party certification organisations involved as well.

US farmers also use contracts and leases for many input requirements. Over 60% of US cropland is rented, usually from owners who are not farmers. Farmers also often contract with custom providers of agricultural services, and they often lease equipment. Some crop production arrangements cover seed and chemical purchases, and outlets for the resulting crop, in one package.

Although farms are getting larger, almost all agricultural commodities still feature many producers: agricultural production is not concentrated. The same cannot be said for sellers of farm inputs such as seed, chemicals, and equipment. Nor does it hold for the buying side — the elevators, processors, packers, and retailers who purchase agricultural commodities. The number of highly concentrated agricultural markets has increased greatly. In particular, monopsony (buyer) power matters in some markets.

Processing industries that buy farm commodities directly from farmers often have just a few major producers, and concentration in those industries has risen over time as firms have become larger and fewer (Table 2.4). Similarly, concentration in input industries — like seeds and agricultural chemicals, and in some agricultural transportation services — is high and rising. The issue of concentration and competition in meatpacking has attracted considerable attention, fuelled by the dramatic increase in concentration in beef in the 1980s and 1990s. However, concentration is not increasing in all of agribusiness — concentration has fallen quite sharply in ethanol as many new firms entered the industry.

Food retailing has also undergone significant change in the last 25 years. The four largest grocery retail chains accounted for 36% of grocery store sales in 2013, up from 17% in 1992. Supermarkets have grown much larger, and provide a much wider range of products. Non-traditional retailers, including mass merchandisers, supercentres, club warehouse stores and dollar stores, have increased their food offerings since the mid-1990s, and now account for a significant share of all retail food sales in the United States (Leibtag, Barker, and Dutko, 2010). Technology and scale are at the heart of the growth of these stores (Basker, 2007). They have developed innovations in logistics, distribution, and inventory control that allow them to realise lower costs than traditional single-store and chain retailers; the firms combined these technological innovations with a location strategy of placing stores in high-volume sites near highways, allowing the firms to realise economies of scale in distribution and retailing. The entry of these stores, and their replacement of traditional retail stores, accounted for almost all growth in labour productivity in the US retail sector during their expansion in the 1990s (Foster, Haltiwanger, and Krizan, 2006). Between 1994 and 2014, labour productivity in retail trade rose by 3% per year, according to the US Bureau of Labor Statistics, compared to growth of 0.6% per year in traditional supermarkets.

Non-traditional retailers offer lower prices to consumers, and their presence places downward pressure on other retailers' prices. Basker (2007) reports that prices at Walmart, the largest non-traditional retailer, ranged from 8 to 27% lower than those at traditional supermarkets, depending on the market and products evaluated. Some of those differences may reflect differences in package sizes, but Leibtag, Barker, and Dutko (2010) reported that prices at non-traditional retailers were 7.5% lower, on average, than prices at traditional supermarkets, when comparing identical products. Lower income households are more likely to shop at Walmart and other non-traditional retailers than higher income households, so the price differences offer a larger boost in real incomes to lower-income households.

Sales growth at non-traditional formats have slowed in recent years, as non-food retail sales have shifted to internet outlets, as traditional supermarket chains have adapted, and as non-traditional format food sales have reached maturity. Labour productivity growth in retail trade slowed, to 1.8% annually in 2004-2014 from 4.2% annually in 1994-2004. It remains to be seen whether food retailers will find a new productivity-enhancing set of innovations, or whether the expansion of non-traditional formats represented a one-time improvement to retail productivity concentrated in the 1990s and early 2000s.

Table 2.4. Selected four-firm concentration ratios in US agribusiness

Largest four firms' share of	Beginning year	Ending year
Seed shipments	Year=2000	Year=2007
Maize seed	60	72
Cotton seed	95	95
Soybean seed	51	55
	Year=1980	Year=2007
Railroad grain shipments	53	84
Grain exports	Year=1998	Year=2009
Maize exports	70	80
Wheat exports	47	65
Soybean exports	62	66
Manufacturing shipments	Year=1977	Year=2012
Fluid milk processing	18	46
Flour milling	33	50
Wet maize milling	63	86
Soybean processing	54	79
Rice milling	51	47
Cane sugar refining	63	95
Beet sugar	67	78
Nitrogenous fertiliser manufacturing	34	69
Phosphate fertiliser manufacturing	35	88
Pesticide manufacturing	44	57
Farm machinery	46	61
Livestock procurement	Year=1980	Year=2011
Steer and heifer slaughter	36	84
Pig slaughter	34	64
	Year=1995	Year=2011
Broiler processing	50	52
Turkey processing	41	55

Table reports share of the four largest firms in each activity.

Sources: Seed shipments: Professor Kyle Steigert, University of Wisconsin; Railroad grain: USDA, Agricultural Marketing Service. *Study of Rural Transportation Issues*. April, 2010; Grain exports and livestock procurement: USDA Grain Inspection, Packers and Stockyards Administration; Manufacturing shipments: US Census Bureau.

Farmer-owned cooperatives play a major role in the marketing of farm commodities and the purchase of farm inputs. Cooperatives market farm products on behalf of members, and sometimes process products as well; in each function, cooperatives can help offset the market power held by private processors in some markets. Farm supply cooperatives acquire farm inputs — primarily crop protectants, feed, fertiliser, petroleum, and seed, but also building materials, hardware, and machinery. Service cooperatives provide services such as drying, shipping, storage, or grinding. Cooperatives may also diversify into non-farm businesses, like grocery or gasoline retailing.

In 2014, there were 2 106 farm cooperatives, which in the aggregate recorded USD 147.7 billion in product sales (net of sales between cooperatives), with dairy and grain and oilseed sales accounting for 75% of the total (Table 2.5). Cooperatives also purchased USD 92.6 billion in farm inputs, with petroleum accounting for 42% and fertiliser and feed for another 32%.

Table 2.5. US farm cooperatives by activity, 2000-14

	2000	2005	2010	2014
Marketing cooperatives (number)	1 888	1 586	1 238	1 114
Volume of sales (billion USD)	80.5	80.0	103.9	147.7
Dairy	25.8	31.7	34.3	52.4
Grain/oilseed	22.8	24.0	41.0	58.8
Fruit/vegetable	10.2	7.2	7.7	8.4
Sugar & sugar products	2.7	4.2	5.0	7.8
Farm supply cooperatives (number)	1 293	1 166	916	875
Volume of sales (billion USD)	34.7	38.1	63.8	92.6
Petroleum	11.2	14.4	24.5	39.2
Fertiliser	7.3	6.7	11.1	16.3
Crop protectants	4.0	3.8	8.1	11.5
Feed	6.6	7.0	10.8	13.7
Seed	1.4	2.1	4.3	5.8

Source: USDA (2016a), Rural Development, Cooperative Programs. www.rd.usda.gov/programs-services/all-programs/cooperative-programs.

Some cooperatives have grown quite large. Thirty had more than USD 1 billion in volume in 2014, and they accounted for more than half of total cooperative sales and purchase volume. However, while size can generate scale economies in some functions, large cooperatives frequently contain highly diverse memberships, and goal conflicts among members can hamper performance. Some cooperatives provide specialised services to small numbers of like members — such as veterinary services or feed purchasing services shared across a few relatively large dairy farms.

Farm sector and farm household financial performance

Policymakers, input providers, and farm groups use farm sector income measures to track changes in the financial performance of the farm sector. Net farm income — the most closely tracked indicator — grew to reach record levels in 2013, but has declined sharply since then as commodity prices have declined. Because farm operator households are a highly diverse group, often with multiple sources of income, USDA farm accounts also measure and track changes in the income accruing to farm households.

Net farm income — the return to farm operators for their land, labour, and management after payment of expenses — can fluctuate sharply from year to year, depending on movements in input and commodity prices and on the support provided through government policies (Figure 2.7).

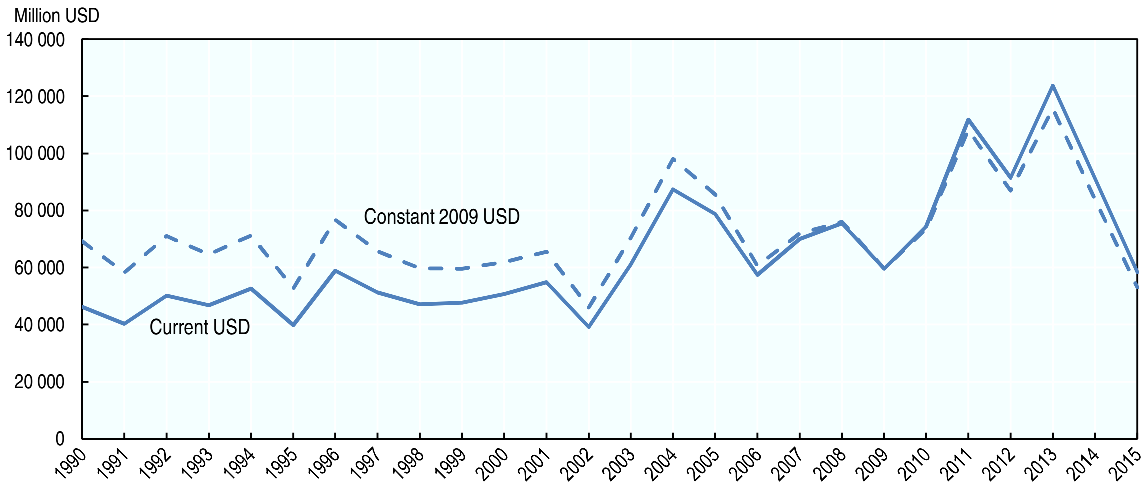
Net farm income averaged USD 81.1 billion per year in 2004-2015, 27% higher than its 1990-2003 average (in inflation-adjusted terms). Net farm income fell by 20% during the global recession in 2009, compared to 2008, but recovered quickly in 2010. It reached a record level of USD 123.7 billion in 2013, but ERS forecasts that it will fall to USD 54.8 billion in 2016, after declining to USD 56.4 billion in 2015.

Commodity price movements drive recent changes in net farm income (Figure 2.8). Grain prices rose by 150% between 2005 and 2008, fell quite sharply in 2009, and have fluctuated widely since then. Prices for slaughter livestock have risen considerably since 2009, but remained at or below their 1990 values until then. The decline in 2015 follows from commodity price declines in all sectors, starting with crops early in the year and spreading through the year to poultry, swine, dairy, and cattle. The volatility in commodity prices has influenced changes in farm policy, toward greater reliance on risk management.

Purchases of new farm equipment move in line with increases in net farm income, increasing during income expansions and falling off during declines. Since new technology is often embodied in new equipment, the diffusion of innovations is affected by changes in income.

ERS tracks household income for the principal operators of family farms (farms may have multiple operators, and ERS asks survey respondents to select a principal operator). Household income provides a more direct measure of the well-being of farm families.

Figure 2.7. Net farm income, 1990-2015

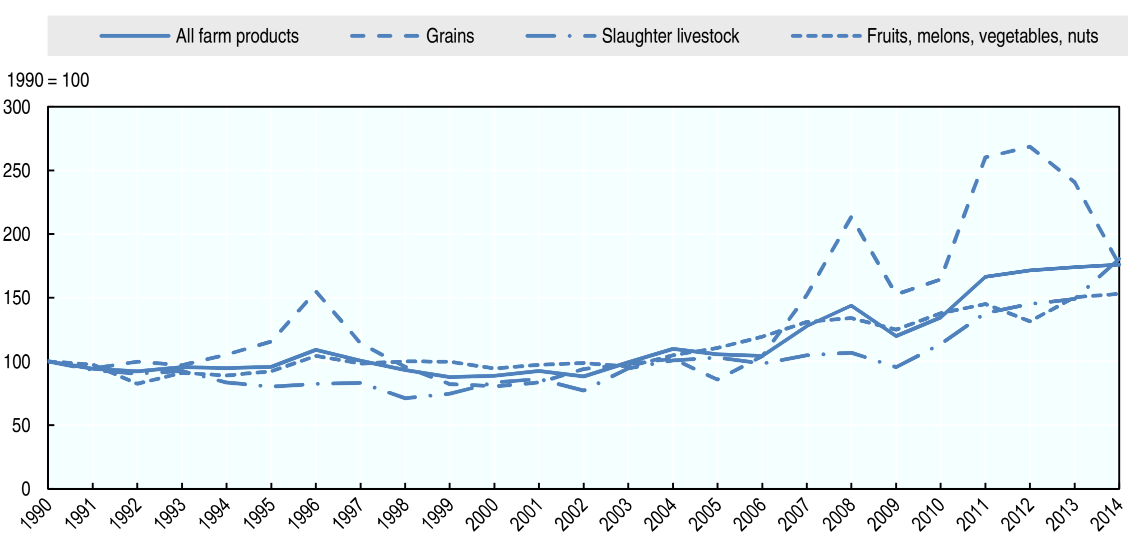


2015 is ERS forecast as of August 2015. Constant USD estimates use GDP chain-type deflator.

Source: USDA (2015c), Economic Research Service, Farm Income and Wealth Statistics. www.ers.usda.gov/data-products/farm-income-and-wealth-statistics/us-and-state-level-farm-income-and-wealth-statistics.aspx.

StatLink http://dx.doi.org/10.1787/888933408144

Figure 2.8. Price trends for farm products, 1990-2014



Source: US Bureau of Labour Statistics (2015), Producer Price Indexes annual. www.bls.gov/ppi/data.htm.

StatLink http://dx.doi.org/10.1787/888933408151

Table 2.6. Farm operator household income, by farm type, 2014

	Share of all		Median household income		Median household wealth
	Farms	Output	From all sources	From farming	
	Percentage		USD		
Small farms (Sales<USD 350 000)					
Operator is retired from farming	13.6	1.2	64 273	4 222	807 000
Primary occupation is non-farming	45.4	5.4	95 120	-4 000	782 000
Primary occupation is farming					
Sales<USD 150 000	25.3	5.8	60 059	-2 250	779 561
Sales of USD 150 000-USD 349 999	5.3	9.4	108 173	51 014	1 570 755
Midsize farms (USD 350 000-USD 999 000)	6.0	20.6	185 306	115 339	2 185 542
Large-scale farms					
USD 1 000 000-USD 4 999 999 in sales	3.0	27.2	368 304	271 522	3 472 740
USD 5 000 000 of more in sales	0.3	19.9	1 183 148	957 301	6 493 950
All family farms	98.9	89.6	80 620	-1 765	872 637

Source: USDA (2015a), Agricultural Resource Management Survey (ARMS) Phase II. www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices/arms-data.aspx.

The median household income for principal operators of family farms was USD 80 620 in 2014 (Table 2.6), well above that for all US households (USD 53 657). Because US farms and farm households are highly diverse, ERS has created a farm typology based on farm sales, the primary occupation of the farm principal operators, and whether the operation is a family or non-family operation. ERS reports median household income for primary operators in each class of family farm.

Three small-farm categories (operators who are retired from farming; those with a non-farm primary occupation; and operators for whom farming is a primary occupation and with farm sales of less than USD 150 000) account for 84% of farms but 12.4% of production (Table 2.6). Most of those households, because they do relatively little farming, realise negative net income from farming, and support themselves with off-farm income. Nonetheless, median household incomes in those classes match or exceed median income for the all US households.

Households in the other four classes, which represent just over 300 000 farms (14.6% of all farms), earn larger household incomes on average, with much or most deriving from farm activities (Table 2.6). Their household incomes are much more sensitive to developments in the agricultural economy, although note that most also derive substantial income from off-farm activities, and therefore have some cushion against adverse farm developments.

Average household incomes in the broader US economy exceeded average farm sector household incomes until the 1970s, and in the 1930s and 1940s the farm sector included a significant share of the population living in poverty (Gardner, 2002). But average farm sector household incomes grew more rapidly than those in the overall economy, and now considerably exceed the average for the United States. Operators of commercial farms earn household incomes that are in line with owners of other small-to-midsize businesses in the US economy, which is an important factor in attracting talented people to the industry, and in retaining them.

Agricultural trade

Agricultural exports have been important to the United States since the country's beginning, and global grain markets played a significant role in agriculture's westward expansion in the 19^{th} century. In recent decades, the composition of US agricultural exports have shifted away from bulk grain and oilseed commodities and toward fruits, vegetables, and meat and dairy products.

International trade does not play as important a role in the US economy as it does for some countries, such as Canada, China, or Russia (Figure 2.9). However, imports and exports account for growing shares of US GDP, and the country is far more exposed to trade than it was 30 years ago, when trade exposure (exports plus imports as a share of GDP) was less than 40% of what it is today.

Agriculture has historically accounted for an outsize portion of all US trade. Agricultural exports — including semi-processed and processed food products as well as raw commodities — accounted for nearly 11% of all US exports in 2014 (Figure 2.10). Agricultural exports accounted for 19% of all US exports in 1980; the share later declined as other US industries became more trade-oriented, and reached 7% of US exports in 2000, but has risen since then. The value of agricultural exports has risen quite sharply since 2005, and reached USD 150.5 billion in 2014; with agricultural imports at USD 111.7 billion in 2014, the agricultural trade balance stood at USD 38.8 billion.

The steady improvements in agricultural productivity since the 1940s have been a major reason for the positive trade balance in agricultural products. High agricultural productivity means lower unit costs of production, which improves competitiveness in international markets.

The composition of US agricultural trade has changed sharply since the 1980s (Figure 2.11). In 1980, most US agricultural exports were bulk commodities, with a heavy concentration in maize, wheat, soybeans, and cotton. But, especially over the last two decades, exports of tree nuts and fresh and processed fruits and vegetables have grown rapidly.

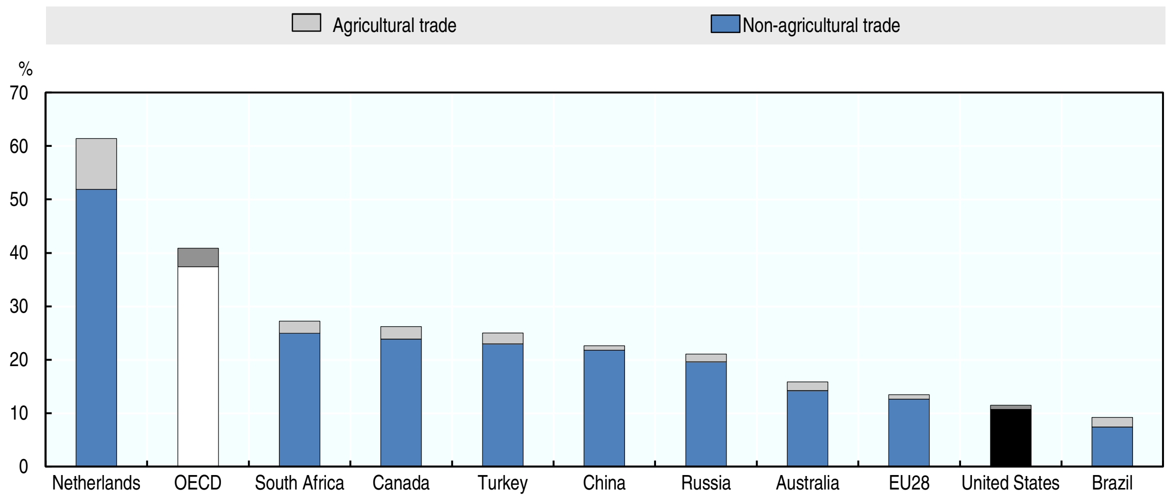
Animal product exports have also become important elements of US trade: dairy product exports increased more than five-fold, pork and pork product exports rose by more than fourfold, while exports of beef and poultry products also grew markedly over the last two decades. At the same time, export values for maize, cotton and wheat declined, and among major field crops only soybeans saw large increases in exports. Of course, maize and soybeans were exported indirectly as feed for animal products that saw large increases in exports.

The geographic focus of US exports has also changed (Figure 2.12). In 1990, Japan and the European Union (EU) were the two largest destinations, and together accounted for nearly 40% of US agricultural exports. By 2014, just over 17% of agricultural exports went to those destinations, while exports to China and North America (Canada and Mexico) accounted for 43% of exports, up from 19% in 1990.

Canada, Mexico, and the European Union accounted for about half of US agricultural imports in 1990 and 2014, but import shares were reallocated among them during the period, with Canada and Mexico accounting for sharply growing import shares. US agricultural imports include cattle and beef products, wines and malt beverages, and tropical products like coffee, cocoa, and bananas.

Figure 2.9. Exposure to trade, 2014

Trade (average of imports and exports) as a percentage of GDP



Source: OECD (2015), System of National Accounts, http://stats.oecd.org and UN COMTRADE (2015), UN http://comtrade.un.org.

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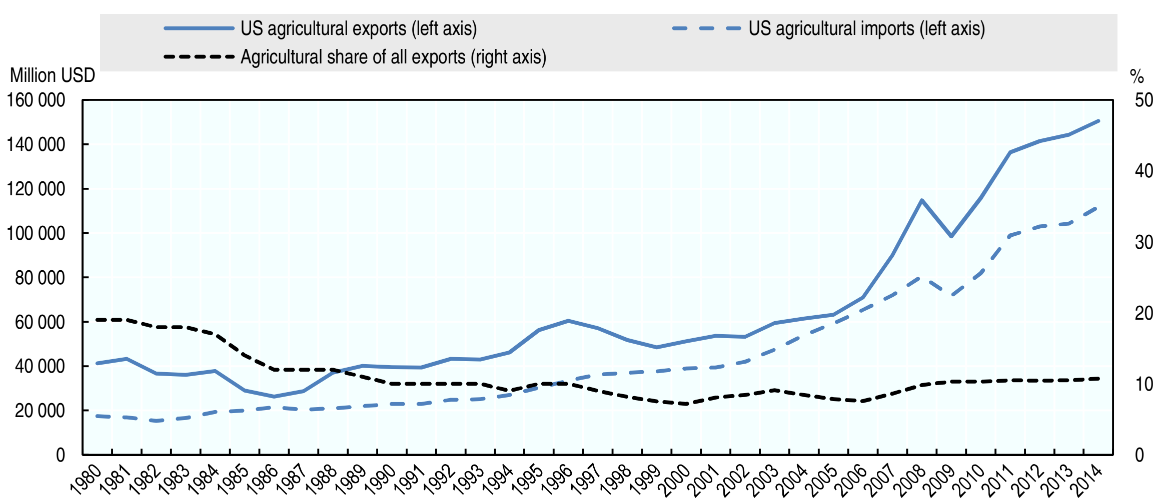
Figure 2.10. US agricultural trade, 1980-2014



Source: US Department of Commerce (2015), Bureau of Economic Analysis. www.bea.gov/international/index.htm#trade.

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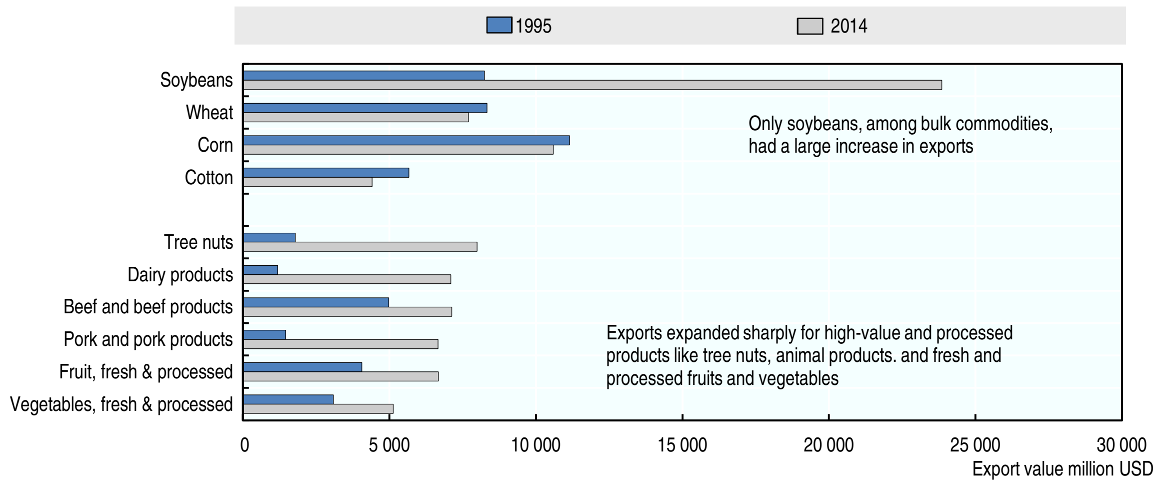
Figure 2.11. Changes in the composition of US agricultural exports, 1995 and 2014



Source: US Department of Commerce (2015), Bureau of Economic Analysis. www.bea.gov/international/index.htm#trade.

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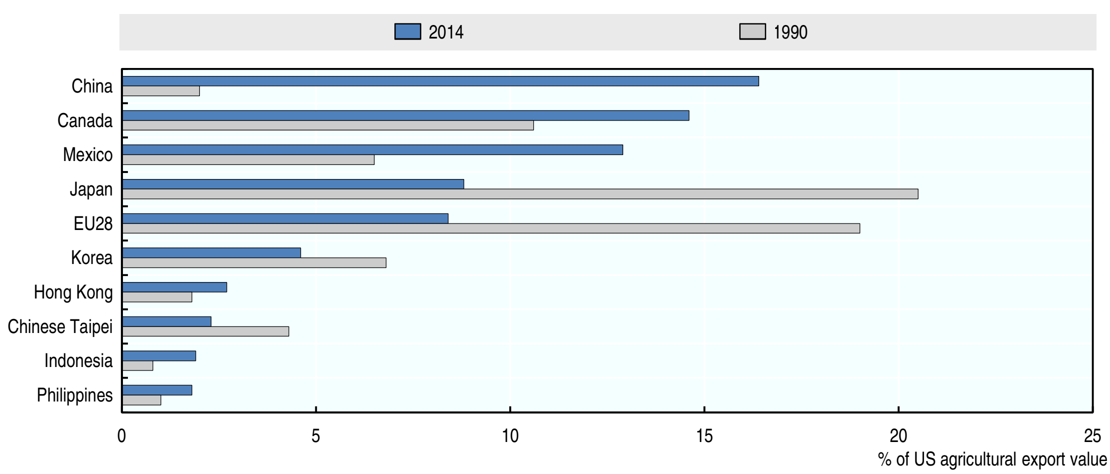
Figure 2.12. The ten primary destinations for US agricultural exports, 1990 and 2014



Source: USDA (2015f), Foreign Agricultural Trade of the United States. www.fas.usda.gov/regions.

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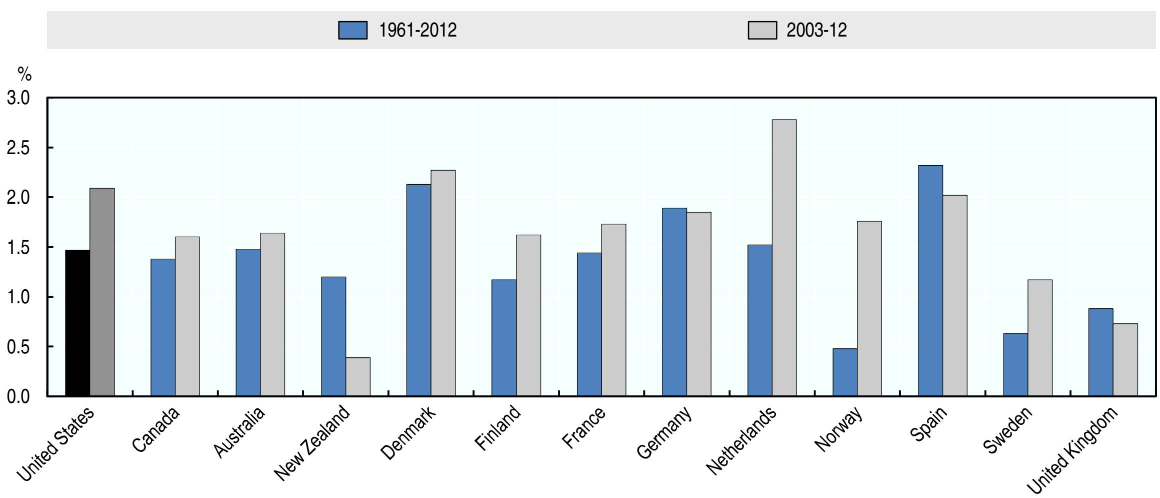
Agricultural productivity

Trends in productivity growth

Agricultural productivity has grown steadily since at least the 1940s. The country has been able to increase total agricultural output by 169% between 1948 and 2013, while reducing the amount of land and labour devoted to agriculture. That growth has come largely through the application of a series of innovations in crop and livestock breeding, nutrient use and pest management, farm practices, and farm equipment and structures, most of them developed from investments in scientific research.[1]

US agricultural productivity has experienced sustained high rates of growth for decades. Using estimates from the ERS International Agricultural Productivity accounts, total factor productivity (TFP) growth in the United States averaged 2.10% per year over 2003-12, and 1.47% per year over the longer period, 1961-2012 (Figure 2.13). The US performance places it among the OECD leaders.

Figure 2.13. Annual agricultural TFP growth rates for selected OECD countries, 1961-2012 and 2003-12



Source: USDA (2015e), Economic Research Service, International Agricultural Productivity: www.ers.usda.gov/data-products/international-agricultural-productivity.aspx.

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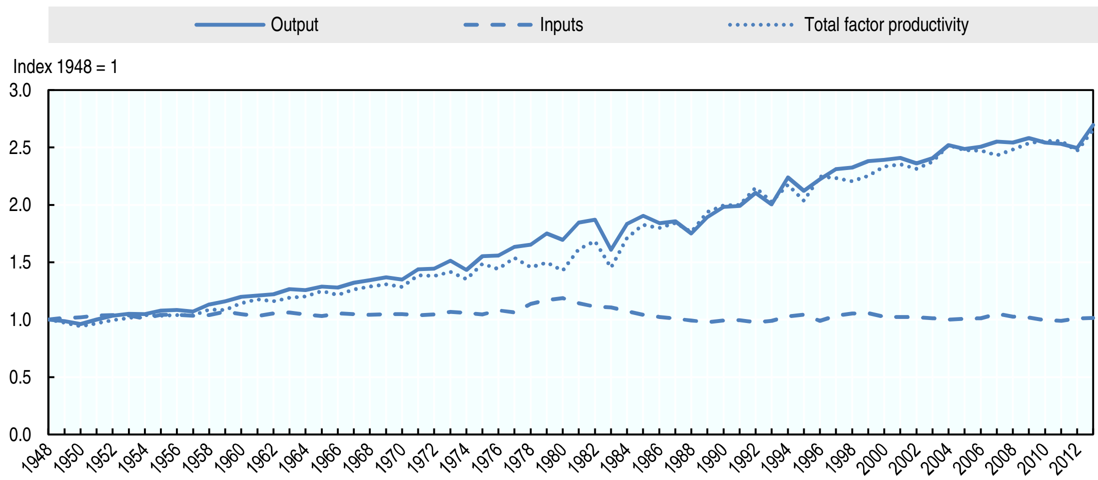
The international TFP comparisons are hampered by data limitations. In particular, they only crudely account for certain important inputs, like pesticides and contract services. ERS produces a more comprehensive set of domestic productivity accounts for US agriculture, covering 1948-2013. This series explicitly accounts for pesticides and contract services, and also quality-adjusts land, chemical, and labour input indexes for changes in factor attributes, while the capital stock index is adjusted for changes in composition over time.

Using the domestic productivity accounts, agricultural TFP grew at an average annual rate of 1.48% per year between 1948 and 2013 (Figure 2.14), and at a rate of 1.45% per year over 1961-2012 (the years reported for the international accounts above). There was essentially no growth in total inputs over the longer period, (although the composition of inputs changed), so TFP growth accounted for all of the growth in agricultural output. This is a distinctive feature of agriculture, because output growth in most other industries in the US economy is driven largely by expanded use of capital, labour, energy, and materials inputs.

Figure 2.14. US agricultural productivity growth, 1948-2013



Source: USDA (2015i), Economic Research Service, Agricultural Productivity Accounts. www.ers.usda.gov/data-products/agricultural-productivity-in-the-us.aspx.

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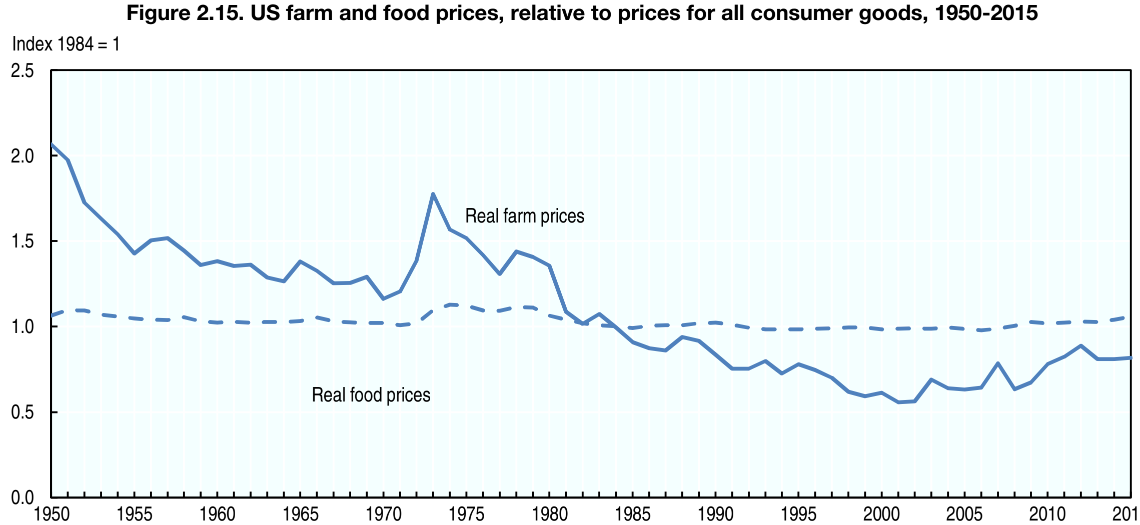
Figure 2.15. US farm and food prices, relative to prices for all consumer goods, 1950-2015



Source: US Bureau of Labor Statistics (2016), Producer Price Index for farm products deflated by Consumer Price Index for food products, each deflated Consumer Price Index for all items. www.bls.gov/ppi/data.htm.

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Productivity growth rates in agriculture are high when compared to the rest of the US economy. For example, Jorgenson, Ho, and Stiroh (2005) calculated TFP measures for 44 industry sectors over 1977-2000. Agriculture had the fourth highest TFP growth rate over that period, and retains its high ranking in a separate comparison of 1947-2012 (Jorgenson, Ho, and Samuels, 2015).

High agricultural productivity growth contributed to generally falling prices for agricultural commodities, relative to prices for consumer products (Figure 2.15); the relative decline was interrupted twice, in the 1970s and in 2001-11, by sharp increases in commodity demand. However, food prices did not fall during the long decline in real farm prices, compared to other consumer products: instead, rapid productivity growth in agriculture just offset slow productivity growth and added services in the rest of the food system to keep food prices rising at the same pace as consumer prices.

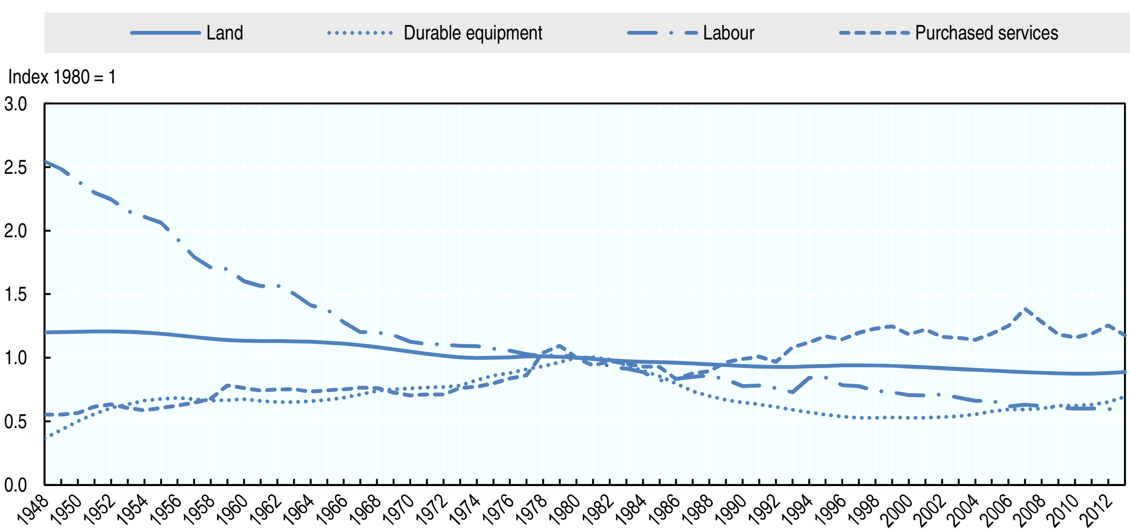
Productivity growth in agriculture constrains food prices, but that effect is modest because farm commodities account for a small share of retail food costs. A major effect of agricultural productivity growth has been to free resources — of labour, land, and capital that would have been needed to produce food — for use elsewhere in the economy.

Productivity growth and input use

There were significant changes in the composition of agricultural inputs over 1948-2013. The amount of labour used in agriculture dropped by about 75% over 1948-2013, even in an index that is adjusted for improvements in education (Figure 2.16). Similarly, the aggregate land input to US agriculture declined steadily, largely because of declines in pasture and rangeland. Between 1948 and 1980, the sector added durable equipment, but that input also declined sharply over 1980-1998, and by 2013 the stock of durable equipment capital still had not returned to its 1980 value.

One reason for the post-1980 decline in durable equipment stocks is a change in farm operator practices, toward growing reliance on purchased services, often in the form of leased capital equipment and the use of custom service providers. These shifts represent organisation innovations that allowed farmers to limit the risks associated with large investments in fixed capital, while in many cases allowing for more intensive use of the equipment.

Figure 2.16. Trends in selected agricultural inputs, 1948-2013



Source: USDA (2015h), National Agricultural Statistics Service, Economic Research Service. www.usda.gov/wps/portal/usda/usdahome?navid=DATA_STATISTICS.

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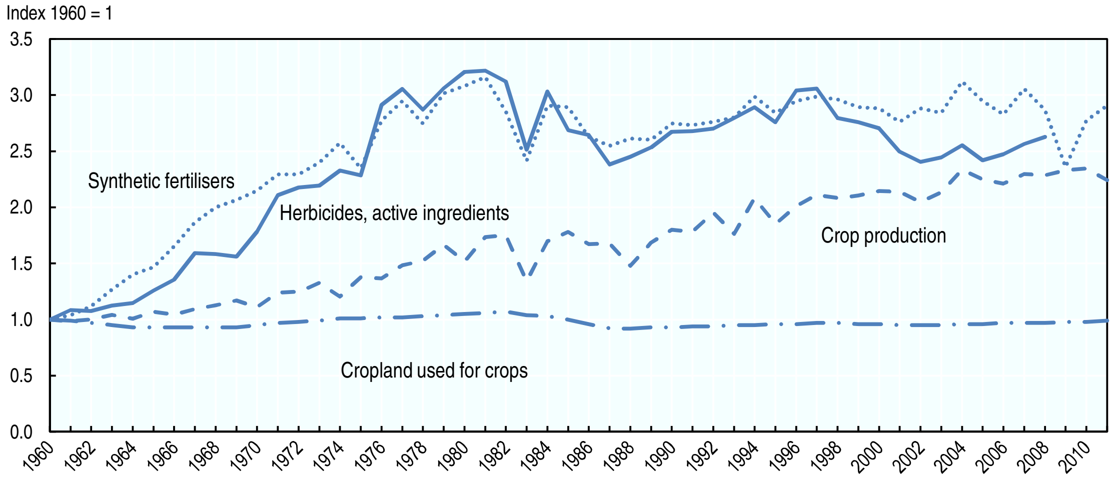
Total applications of synthetic fertilisers and chemical herbicides in US agriculture, when measured by the weight of active ingredients, increased by about 200% between 1960 and 1980 (Figure 2.17). Expanded use of those chemicals was associated with increased crop yields, and crop production grew by 50% between 1960 and 1980, even as the amount of cropland used for crops remained unchanged. However, total application of herbicides and synthetic fertilisers, as measured by pounds of active ingredients, shows no trend since 1980, although there have been substantial year-to-year fluctuations.

Figure 2.17. US crop land, crop production, and chemical use, 1960-2011



Source: USDA (2015h), National Agricultural Statistics Service, USDA (2015b), Economic Research Service. www.usda.gov/wps/portal/usda/usdahome?navid=DATA_STATISTICS.

StatLink http://dx.doi.org/10.1787/888933408241

Agricultural chemicals — primarily, synthetic fertilisers and pesticides — can boost productivity growth, by providing plant nutrients and limiting pest damage, but excessive applications can also generate externalities. Runoff of fertilisers and pesticides from fields can degrade drinking water quality in groundwater and rivers and streams, while volatilisation of chemicals can degrade air quality. Degraded air and water quality can harm human health, and can create further economic costs for other resource users.

The attributes of pesticides and synthetic fertilisers have changed, with some delivering greater effectiveness for lower volumes of active ingredients. The ERS productivity accounts adjust chemical inputs for changes in attributes; that series shows steady continuing growth in the effective pesticide input, amounting to 3.8% per year from 1980-2013. Almost all of that growth is due to changes in pesticide attributes, rather than growth in physical quantities applied.

Increased crop yields are often associated with improved take-up of agricultural nutrients, and reduced run-off and volatilisation of nutrients and pesticides. Research leading to improved crop yields, as well as research leading to more effective pesticides and synthetic fertilisers, or improved pest management practices, can also contribute to reducing the environmental pressures linked to the use of these inputs. Developments in biotechnology have contributed to those goals.

Biotechnology and input use

Biotechnology became important to US agricultural production when advances in molecular and cellular biology allowed scientists to introduce desirable traits from other species into crop plants (Phillips, 2013). The most commonly introduced genetically engineered (GE) traits augmented traditional strategies of pest management. They either allowed plants to produce their own insecticide, thus reducing yield losses to insects, or to tolerate herbicides, so that broad spectrum herbicides could be used to control weeds without harming crops.

There are several different insect resistant (IR) GE traits, aimed at different insects, as well as several herbicide tolerant (HT) traits for different herbicides. Other commercially available traits allow for virus resistance and drought tolerance. Seeds increasingly feature “stacked traits” — that is, multiple GE traits introduced into one seed.

GE HT and IR seeds were commercially introduced in 1996, and were planted on over 90% of US maize, cotton, and soybeans acres by 2015 (USDA/NASS, 2015). HT traits have been introduced for all three crops, and were used on 94% of soybean acres and 89% of maize and cotton acres in 2015; IR traits have not been introduced for soybeans, but were used on 84% of cotton acres and 81% of maize acres in 2015 (Figure 2.18). These three crops account for most acreage planted with GE seeds, but the seeds are also widely used in alfalfa, canola, papaya, and sugar beets.

Adoption of GE crops in the United States has been associated with substantial declines in insecticide use, and a substitution of the herbicide glyphosate for other herbicides (Fernandez-Cornejo et al., 2014). GE crops were developed to be tolerant of glyphosate, so it could be sprayed after plants emerged; it also displayed lower persistence in soils, superior performance in controlling a wide range of weeds, and declining retail prices after going off-patent. Glyphosate is thought to be less environmentally damaging than other herbicides (Phillips, 2013). Moreover, producers of HT crops are more likely to use conservation tillage techniques, which convey additional environmental and soil health benefits (Perry, Moschini, and Hennessy, 2016).

Farmers who adopt IR traits realise higher yields and increased net cash income. The effects of HT adoption on net cash income are ambiguous, but adopters realise reduced labour hours, which could then be reallocated to other farm, off-farm, or family activities (Fernandez-Cornejo et al., 2014; MacDonald, Korb, and Hoppe, 2013).

Intensive use has led to increased weed resistance to glyphosate, particularly in soybeans (Livingston et al., 2015). Glyphosate is far more effective than other herbicides in soybean production and by 2004 it accounted for over 80% of herbicide applications in soybeans (Figure 2.19). In contrast, glyphosate is only one of several herbicides used in maize production (Figure 2.20).

Resistance develops more rapidly where a single herbicide is used to control weeds, and where it is used over consecutive years. As glyphosate resistance spread widely in soybeans, farmers responded by increasing applications of glyphosate and other herbicides as well (Figure 2.19). In maize, where glyphosate resistance has spread more slowly, application rates of glyphosate and other herbicides continued to fall between 2008 and 2014 (Figure 2.20).

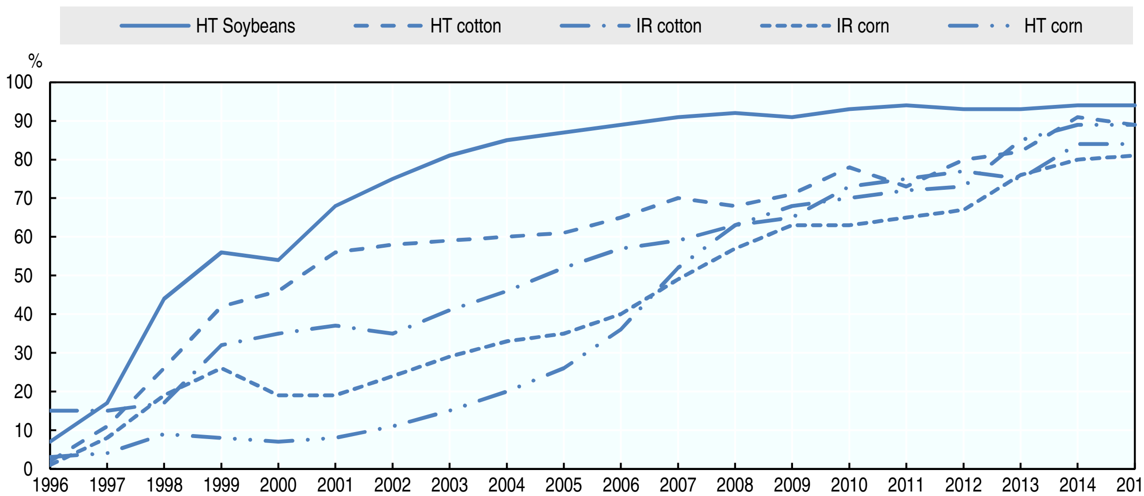
Active management of resistance, by varying the mode of action of herbicides, rotating crops and herbicides, and working jointly with neighbouring farms, yields positive net benefits for farmers at time horizons that exceed a year (Livingston et al., 2015).

GE crops have increased agricultural productivity by reducing the amount of labour required per unit of output (Fernandez-Cornejo et al., 2014). To the extent that GE crops require fewer field passes for spraying and tillage, they also reduce the amount of capital and energy required per unit of output. GE crops can also increase crop yields to the extent that they suppress pests that would not have suppressed by conventional means. Each of these impacts, as well as related reduction in environmental pressure, are attenuated as resistance develops among weeds or insects.

Diagnostic tools developed in association with genetic engineering have found application in conventional plant and livestock breeding. Tools such as marker-assisted selection allow for more rapid identification of desirable traits, and therefore speedier application of conventional breeding procedures.

Some ongoing research in agricultural biotech continues the focus on gene transfer. For example, some work aims to improve plant growth in grasses and field crops by increasing the efficiency of light capture during photosynthesis. The most successful approaches, not yet commercialised, involve introducing genes from photosynthetic bacteria into plants, without affecting the activity of other genes.

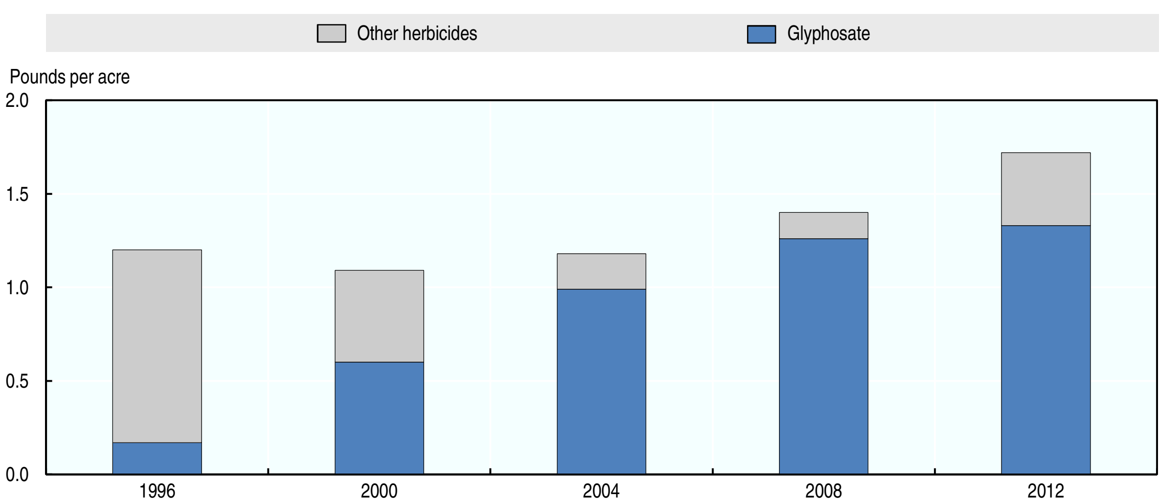
Figure 2.18. Adoption of genetically engineered seeds in the United States, 1996-2015



Source: 1996-99 are from Fernandez-Cornejo and McBride (2002), www.ers.usda.gov/publications/aer-agricultural-economic-report/aer810.aspx; 2000-2015 are from USDA (2015g), National Agricultural Statistics Service, Acreage Report http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1000.USDA).

StatLink http://dx.doi.org/10.1787/888933408255

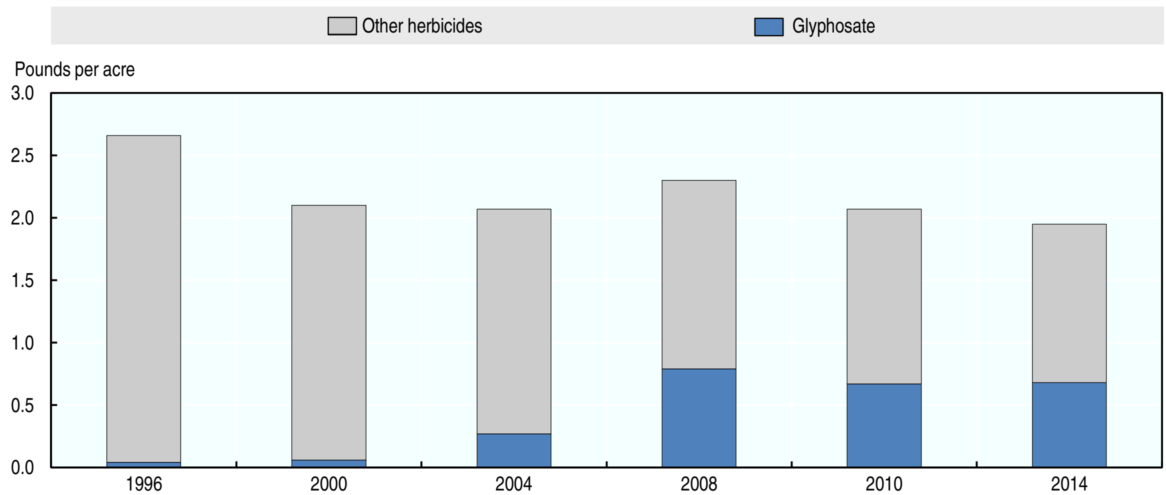
Figure 2.19. Herbicide application rates for soybeans, 1996-2012



Source: USDA (2015h), National Agricultural Statistics Service.
www.usda.gov/wps/portal/usda/usdahome?navid=DATA_STATISTICS.

StatLink http://dx.doi.org/10.1787/888933408265

Figure 2.20. Herbicide application rates for maize, 1996-2014



Source: USDA (2015h), National Agricultural Statistics Service. www.usda.gov/wps/portal/usda/usdahome?navid=DATA_STATISTICS.

StatLink http://dx.doi.org/10.1787/888933408271

More recent developments in biotechnology are focusing on gene editing — the ability to cut and alter the DNA of a species at almost any genomic site (Mayaguez, 2016). Gene editing techniques forego the introduction of genes from one species into another, thus avoiding one of the major objections to prior GE products. Related techniques allow scientists to make precise mutations, to disable genes by snipping them out of DNA sequences, or to enhance or suppress gene expression. In labs and field experiments, the technologies have been used to edit crop strains for drought resistance and herbicide tolerance; to extend the growth phase of plants by reducing seed dormancy or by preventing or delaying flowering; to create virus resistance in certain swine varieties; and to alter musculature in cattle. These developments will create new types of biotechnology products, but may also create new types of market, environmental and safety risks, and may require adjustments in biotechnology regulatory processes.

Sustainability performance

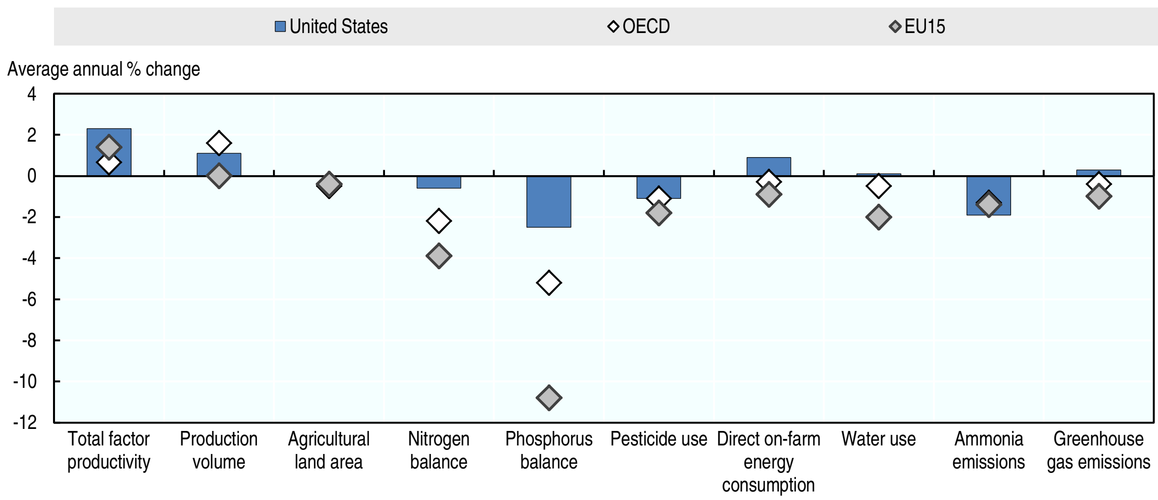
Overall sustainability performance

Agricultural production, depending on how it is performed, can degrade or conserve soil, water, and air resources. Sustainability outcomes can arise as the result of the intended or unintended consequences of innovations, policies, or production decisions. Measures of US sustainability performance show improvements, which can be traced to important policy initiatives.

Most environmental pressures from agriculture trended downward in the United States during the last decade including: nitrogen and phosphorus surplus per hectare of agricultural land, pesticide use, and ammonia emissions from agriculture (Figure 2.21). Other indicators are relatively stable in time, such as water abstraction, greenhouse gas emissions, and direct on-farm energy consumption (slightly increasing). These improvements follow those observed in the OECD and EU15 areas, although of a lower magnitude –partly due to the fact that initial levels of environmental pressures were lower in the United States for some indicators (e.g. nutrient surplus).

Decreases in environmental pressures have been accompanied by a significant increase of agricultural production, essentially arising from growth in total factor productivity. As explained above, such productivity gains allowed farmers to produce more with less land and inputs (fertilisers, chemicals and water), leading to environmental decoupling of agricultural production nationwide.

Figure 2.21. Development of environmental indicators for agriculture, United States, OECD and European Union, 1998-2000 to 2008-10



Recent data show a significant increase in pesticide use since between 2008 and 2013, mainly due to increasing herbicide sales.

Source: OECD (2013), OECD Compendium of Agri-environmental Indicators, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264181151-en.; USDA (2015e), Economic Research Service, International Agricultural Productivity Database. www.ers.usda.gov/data-products/international-agricultural-productivity.aspx.

StatLink http://dx.doi.org/10.1787/888933408289

This reduction of environmental pressures from agriculture has resulted in improvement or maintenance of the state of the environment in many places. For example, pesticide concentration in groundwater has been relatively stable or decreasing over the last two decades; at worst slightly increasing in some cases (Toccalino et al., 2014). Although pesticides are frequently detected in samples (53%), the proportion of samples with pesticide concentrations posing a problem for human health has been estimated at 1.8% per year by (Toccalino et al., 2014).

Despite this general improvement, there still exist areas with significant environmental problems linked to agriculture, such as: water shortages in California due to a series of serious drought events in recent years; hypoxic zones in the Gulf of Mexico due to excessive nutrient pollution of the Mississippi River (mainly from agricultural sources); local pollution of microbial pathogens and pharmaceuticals in areas with concentrated animal feeding operations (CAFOs); or excessive soil erosion in some geographical areas. More generally, agriculture remains a primary threat to habitats and associated biodiversity in the United States. Recent trends in herbicide sales indicate that pesticide use is significantly trending upward since the late 2000s. The higher total pesticide use in the last decade is in response to declining effectiveness of some herbicides and expanded maize and soybean acreage.

Land conservation

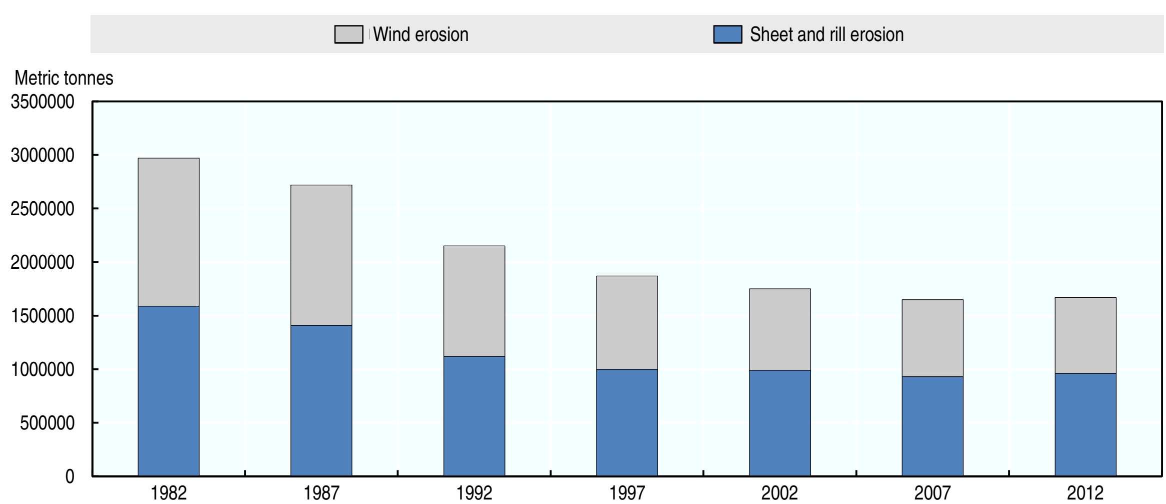
In 2012, just over 913 million acres (369 million ha) were used for agricultural production, excluding federal land leased for grazing, which is not separately identified (Figure 2.2). More than half of agricultural land is in grazing use as rangeland and pasture, with the rest in cropland and conserving uses –primarily land in the Conservation Reserve Program (CRP). Between 1982 and 2012, the total area of land used for agriculture declined by 58 million acres or roughly 6%. While some of the land leaving agriculture shifted to forest uses, most went to metropolitan development.

In recent years, a significant share of environmentally sensitive agricultural land has been withdrawn from production and placed in the CRP. Most CRP land is cropland that producers and landowners have agreed to place in conserving use (usually grass or trees) for 10 years or more. In exchange, producers receive cost-sharing for establishment of cover and annual payments that are roughly equal to the income forgone. At the programme's peak in 2007, 36 million acres (14.5 million ha; 9% of cropland) was enrolled, compared to 24 million acres at the end of 2015. After 2007, high prices for crop commodities drew more acreage into crop production, with much of that coming from the CRP.

CRP average per-acre rental rates were increased by 16% over 2007-13, but this was substantially less than the 74% increase in average cropland rental rates over the same period; without programme adjustment, rising commodity prices are likely to draw land out of CRP (Hellerstein and Malcolm, 2011). Since 2007, CRP has also focused spending on high-priority practices like riparian buffers, field-edge filter strips, and wetland restoration, as well as State-Federal Partnerships through the Conservation Reserve Enhancement Program. These types of enrolments are thought to provide higher levels of environmental benefits per acre than the whole-farm or whole-field enrolments that still account for 75% of CRP area. Thus, declines in CRP enrolled area reflect both market forces and policy choices (Claassen, 2014).

Soil erosion on US cropland declined substantially between 1982 and 2012 (Figure 2.22). In 1982, total soil erosion on cropland was estimated at 2.69 billion metric tonnes) per year. By 2012, total cropland erosion had dropped to 1.51 billion metric tonnes per year, a 43% decline. Most of the reduction in cropland erosion occurred by 1997, when erosion was reduced to 1.70 billion metric tonnes per year. Large reductions in both rainfall (sheet and rill) and wind erosions were recorded. Contributing to the decline in soil erosion was the placement of sensitive cropland in the CRP and the adoption of soil and crop management technologies like conservation tillage.

Figure 2.22. Soil erosion on cropland, 1982-2012



Source: USDA (2015j), Natural Resource Conservation Service, Natural Resources Inventory. www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri/.

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Nutrient use efficiency

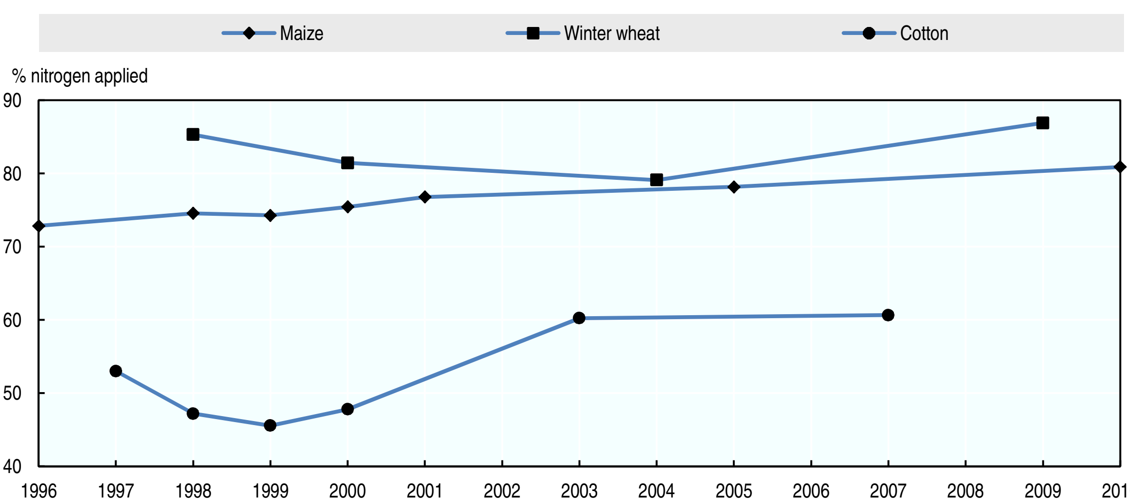
A large majority of major crops grown on US farms receive some type of fertiliser or manure. Commercial nitrogen, for example, was applied to 96% of maize in 2010, 83% of winter wheat in 2009, and 92% of cotton in 2007 (USDA-ERS). Manure was applied to 15% of maize in 2010, 2.4% of wheat in 2009, and 3.2% of cotton in 2007. Some portion of applied nutrient, which is not used by the crop, can be lost to the environment through runoff, leaching, or volatilisation.

The nutrient recovery rate is the ratio of the amount of nutrient in the harvested crop to the amount of nutrient applied. Partial recovery occurs when the amount applied exceeds the amount removed. For maize, nitrogen recovery efficiency increased from 73% in 1987 to 81% 2010, while phosphate recovery hovered near 100% (Figures 2.23 and 2.24). For soybeans, phosphate recovery is above 100%, suggesting that phosphates are actually mined from the soil.

US cropland area where excess nutrients are applied is declining. For maize, the share of planted acres with excess nitrogen applied (above 25% of the crop's needs) declined from 59% in 1996 to 47% in 2010, while the share of acres with excess phosphate declined from 43% in 1996 to 31% in 2010 (Figures 2.25 and 2.26). Other crops also exhibit either declining or unchanged shares of planted acres with excess use of nitrogen or phosphate.

Nutrient use efficiency has been increased largely through higher yields and improved nutrient management practices. Higher yields result in more nutrients being removed from the soil, thus reducing nutrient losses. Yields (and efficiency) have benefited from increased crop rotation (maize planted after soybeans), soil testing for nitrogen, use of GE seeds to reduce pest damage, increase in seeding rate, and adoption of precision technology (such as yield monitors and soil map).

Figure 2.23. Crop nitrogen recovery rates, 1996-2010



Source: ERS calculation from USDA (2015a) *Agricultural Resource Management Survey* (ARMS), Phase II. www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices/arms-data.aspx.

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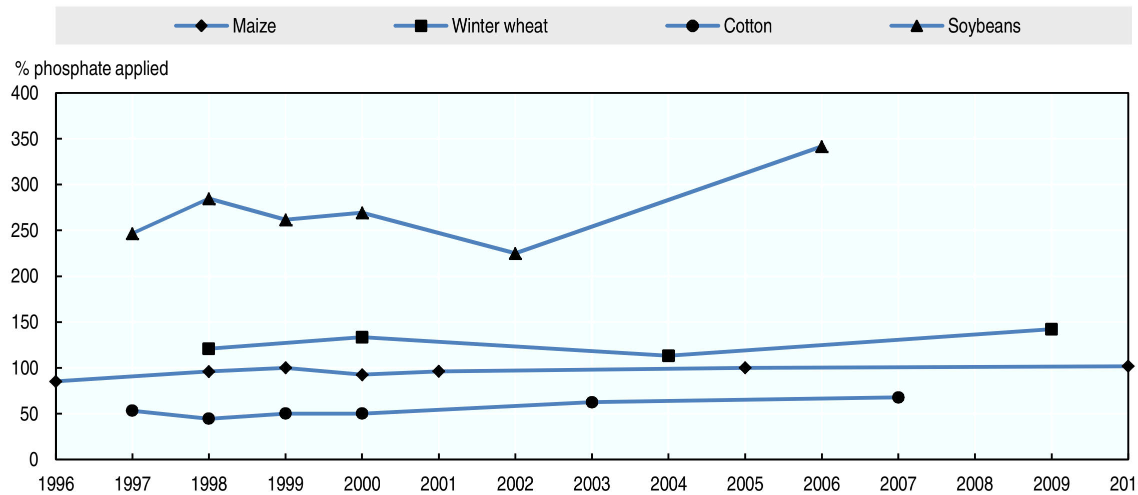
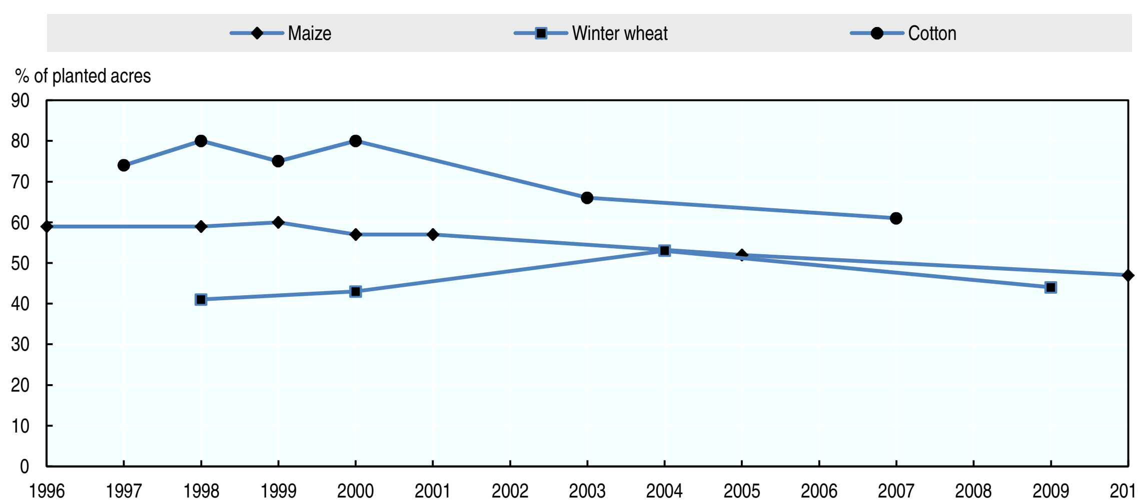
Figure 2.24 Crop phosphorous recovery rates, 1996-2010



Source: ERS calculation from USDA (2015a), *Agricultural Resource Management Survey* (ARMS), Phase II. www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices/arms-data.aspx.

StatLink http://dx.doi.org/10.1787/10.1787/888933408314

Figure 2.25. Planted areas receiving excess nitrogen, 1996-2010

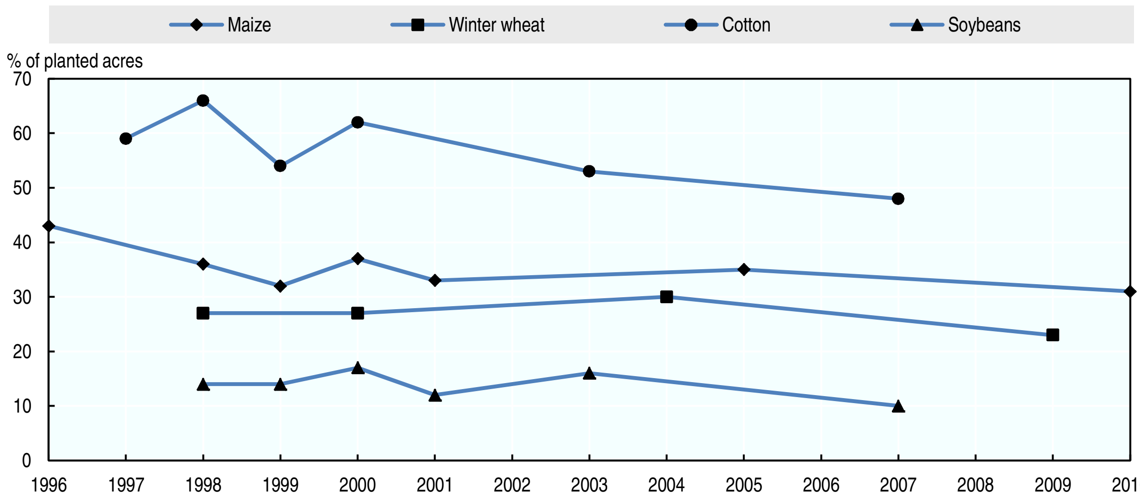


Nutrients application that exceeds crop need by 25% are considered excess.

Source: ERS calculation from USDA (2015a), *Agricultural Resource Management Survey* (ARMS), Phase II. www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices/arms-data.aspx.

StatLink http://dx.doi.org/10.1787/888933408326

Figure 2.26. Planted areas receiving excess phosphorous, 1996-2010



Nutrients application that exceeds crop need by 25% are considered excess.

Source: ERS calculation from USDA (2015a), *Agricultural Resource Management Survey*(ARMS), Phase II. www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices/arms-data.aspx.

StatLink http://dx.doi.org/10.1787/888933408338

Research suggests, however, that additional improvement in nutrient use efficiency could be obtained by increasing adoption of nutrient management best management practices (BMPs). Wade et al. (2015) show that only 24% of cotton acres and 6% of maize acres combined four nutrient management practices for nitrogen: 1) no application in the fall, 2) some application after planting, 3) application at rates below a nutrient management “benchmark” rate, and 4) fertilisers incorporated or injected below the soil surface. Nonetheless, many farmers now use one or more nutrient BMPs, contributing to the overall increase in nutrient use efficiency.

Production has concentrated into larger farms and fewer locations, which in some places led to stocks of manure nutrients that exceeded local crop needs. Consolidation in US livestock production has had complex effects on nutrient use and disposal: concentration can increase local pollution; but at the same time this can be partially offset by higher feed efficiency on larger farms. Improvements in feed conversion reduce the amount of manure created and the amount of feed required for any given volume of meat production. For example, ERS analyses indicate that feed conversion in pig finishing operations fell from 3.83 pounds of feed per pound of weight gain in 1992 to 2.07 by 2009 (McBride and Key, 2013). Feed conversion improvements have also occurred, more slowly, for broilers: from 2.08 pounds in 1980 to 1.74 in 2011, for the same 4 pound size of bird (MacDonald, 2014).

However, concentration has led to several major events associated with failures of manure storage structures, and to concerns with excessive applications of manure, resulting in expanded regulation as well as litigation. For example, a pig waste lagoon in North Carolina overflowed in 1995, dumping over 20 million gallons of pig waste in the New River, and a hurricane in 1999 led to further flooding of North Carolina pig waste lagoons and contaminated water supplies. The state, the second largest pig producer, imposed moratoriums on pig farm construction in 1995 and on farms with lagoons in 1999. Elsewhere, the attorney general of the state of Oklahoma initiated a lawsuit against 14 poultry companies in the adjoining (and upstream) state of Arkansas, concerning run-off of phosphorus from poultry litter into the Illinois River watershed. In Texas, the City of Waco initiated a lawsuit against 14 large dairy farms near the city, concerning the effects of dairy manure on phosphorus levels in the North Bosque River and Lake Waco, the source of the city’s drinking water. The suit was settled with an agreement on waste management practices between the farms and the city.

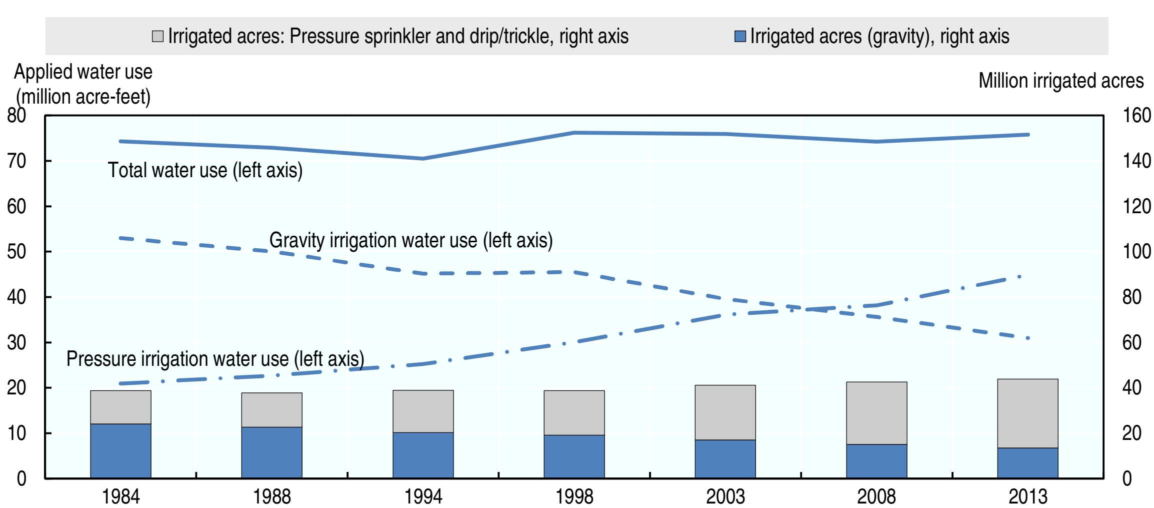
Agricultural water use

Roughly 56 million acres (22.7 million ha) — or 7.6% of all US cropland and pastureland — were irrigated in 2012. Nearly three-quarters of irrigated acres are in the 17 western-most contiguous States (Western States). USDA's Farm and Ranch Irrigation Survey (FRIS) reports that in 2013, farmers and ranchers applied 91.2 million acre-feet of water (an acre-foot of water is equivalent to 325 851 gallons, or 1 233 cubic metres). The US Geological Survey (USGS) estimates that irrigated agriculture accounted for 38% of the Nation's freshwater withdrawals from sources like rivers, lakes or aquifers in 2010. Some water withdrawals are eventually returned to sources. Agriculture accounts for approximately 80 to 90% of consumptive water use in the United States. Water that is consumed — e.g. for crop growth and transpiration in agriculture — is not returned to the source.

In recent decades, on-farm irrigation efficiency — the share of applied water that is beneficially used by the crop — has increased (Figure 2.27). In 1984, gravity systems — where roughly 54% more water per acre is applied compared with pressurised systems, on average — accounted for more than 70% of all water applied for crop agriculture in the 17 Western States. By 2013, gravity systems applied less than half of all irrigation water, while water used with pressure systems accounted for 59% of water applied.

Irrigation is widely viewed as an important adaptation to shifting production conditions under climate change. However, Marshall et al. (2015) project that irrigated field crop acreage in the United States will decline over 2020 to 2080 due to competition over water supplies, which are anticipated to decline in certain areas. Before mid-century, the decline in irrigated acreage is largely driven by regional constraints on surface-water availability for irrigation. Beyond mid-century, the decline reflects a combination of increasing surface-water shortages and declining relative profitability of irrigated production. Crop production is expected to shift toward rain-fed growing conditions. There are water stress hotspots in some regions, which could be exacerbated by climate change.

Figure 2.27. Irrigated acres and water use, 1984-2013



Source: USDA (2014), *Economic Research Service Farm and Ranch Irrigation Survey* (FRIS) data. www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use/background.aspx.

StatLink http://dx.doi.org/10.1787/888933408348

Climate change mitigation and adaptation

Climate change is expected to result in higher and more variable average temperatures during growing seasons, to alter the seasonality of rainfall, and to increase the incidence of extreme weather events and pest and disease pressures. These developments could have significant effects on crop yields and prices (Malcolm et al., 2012; Schlenker and Roberts, 2009).

Nationwide, the impact of climate change on income from the crop sector is uncertain: it could be negative, with aggregate losses of up to USD 1.5 billion; or positive, with gains of up to USD 3.6 billion. Much of this uncertainty is related to the difficulty in estimating hydrological impacts of climate change, particularly at local level (Malcolm et al., 2012).

The impacts of climate change on yields and incomes of American agriculture are likely to vary widely between regions. It is estimated that the southern regions will suffer more significant yield reductions. Malcolm et al. (2012) estimate current losses related to climate change in the Corn Belt crops sector between USD 1.1 and 4.1 billion. This is in addition to losses related to plant disease estimated between USD 400 and 600 million (Malcolm et al., 2012).

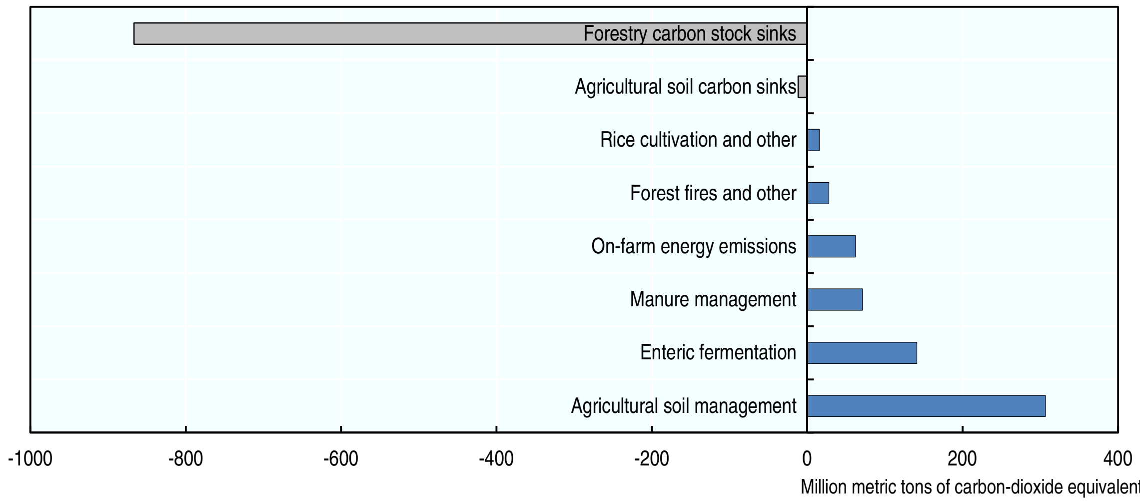
Other studies show more concerning climate change impacts on agriculture (OECD, 2014; Schlenker and Roberts, 2009). In that regard, the assumptions made about the possibilities of adaptation by farmers (rotation changes, inputs, production relocations) are crucial to estimate the net impact — that is to say, after adaptation of climate change on agriculture. These options depend on institutional, economic and social conditions, in addition to natural conditions (soil, climate). A recent study tends to show that flexibility needed for adaptation may be relatively satisfactory in the crop sector, but less in the livestock sector (Yang and Shumway, 2015).

The adaptation response to climate change — changes in crop acreage and input use —is likely to increase environmental pressures from agriculture in certain regions. For example, Malcolm et al. (2012) estimate that cropland area could increase by up to 1% and nitrogen fertiliser losses by up to 5% due to adaptation responses. This may increase pollution problems in some areas, and suggests that policy responses to pollution problems may need to take account of negative, unintended effects of adaptation responses.

In terms of Greenhouse Gas (GHG) emission, agriculture is an emissions intensive sector. The agriculture and forestry sectors together accounted for 10.4% of US greenhouse gas emissions in 2012, while accounting for less than 1% of GDP. Crop and pasture soil management are the activities that generate the most emissions, due largely to the use of nitrogen-based fertilisers and other nutrients (Figure 2.28). The next largest sources are enteric fermentation (digestion in ruminant livestock) and manure management. Agriculture and forestry are unique in providing opportunities for withdrawing carbon from the atmosphere through biological sequestration in soil and biomass carbon sinks.

Land-based activities with the highest potential for sequestering carbon are conversion of cropland and pasture land to forest uses (afforestation), and management of forest land. In addition, changes in agricultural practices and land uses can reduce GHG emissions. For land remaining in crop and pasture uses, activities with the highest potential include improved grazing management on rangeland and pasture, retirement of cropland (through the CRP, for example), adoption of no till on cropland, and land use change from cropland to less intensive farmland uses. Improved fertiliser management (e.g. reducing application rates and using slow-release fertiliser or nitrification inhibitors) can reduce GHG emissions from soils. Changes in livestock management that focus on the reduction of methane emissions and the capture of biogas (e.g. improved diet and installation of anaerobic digesters) also offer mitigation potential; however, some manure management approaches (such as handling manure in solid form, via composting) could increase GHG emissions.

Figure 2.28 Agriculture and forestry greenhouse gas emissions and sequestration, 2012



Negative values indicate carbon sequestration. Forestry sink includes afforestation and forest management.

Source: ERS calculation using US Environmental Protection Agency (2015), *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2012*. www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html.

StatLink http://dx.doi.org/10.1787/888933408352

Summary

- The United States has a large competitive agricultural sector, which accounts for a small share of GDP and employment. With abundant land and water resources, and diverse climatic conditions, it produces a wide range of commodities, split evenly between crop and livestock products. The country is a net exporter of agri-food products, which account for a significant share of total exports.

- Changes in food consumption include an increased preference for poultry over red meats, for fresh fruit over processed fruit; more processed potatoes; and more fresh green vegetables. There is also an increase in food consumption away from home, and food purchased outside supermarkets. There is widespread and growing interest in food with specific product attributes, such as distinct varieties of fruits, meat from specific pork breeds, or coffee from specific locations, as well as organic products.

- These developments have led to several important changes in agricultural production and food processing and distribution, as well as the composition of US agri-food exports. For example, the share of fruits and vegetables, in particular nuts, in production and exports has increased. Higher exports of animal products also respond to global growth in demand for those products from a wealthier population.

- There is also growing interest among US food consumers and retailers in how farm products are produced, and not just in the sensory attributes of the products themselves. Organic agriculture for example is growing rapidly, as well as direct sales at farmers' markets. These shifts create a growing demand for public and private certification services.

- Agricultural production has consolidated into larger farms. Consolidation has occurred in all commodity sectors and regions, but even so family farms still dominate the sector. Moreover, a high diversity of farm operations remains, in terms of farm size and activities. Developments in both farm size and off-farm activities by farm household operators have been permitted by the adoption of labour-saving technologies.

- Farm income can vary sharply from one year to the other, although agricultural policies contribute to reducing the variability of farm receipts. In addition, farm income is only part of total farm household income, which on average grew more rapidly than those in the overall economy. The average for the US operators of commercial farms now earn household incomes that are in line with owners of other small-to-midsize businesses in the US economy, which is an important factor in attracting talented people to the industry, and in retaining them. High farm incomes are associated with increased in farm equipment purchases, and thus contribute to the diffusion of innovation.

- Most processors, retailers, and input providers are large corporations. There is little vertical integration between agriculture and other parts of the food system, but farms are often tightly linked with other firms in the food system through various types of contractual relationships. For example, US farmers use contracts and leases for many inputs; and large retailers set procurement standards. Food processing industry concentration has increased over time, raising issues regarding concentration in some sectors. Farmer-owned cooperatives play a major role in the marketing of farm commodities and the purchase of farm inputs. Some have grown quite large and have diversified services.

- US agriculture achieves high levels of productivity and productivity growth. Agricultural productivity has grown steadily since at least the 1940s. The country has been able to increase total agricultural output by 169% between 1948 and 2013, while reducing the amount of land and labour devoted to agriculture. That growth has come largely through the application of a series of innovations in crop and livestock breeding, nutrient use and pest management, farm practices, and farm equipment and structures, most of them developed from public investments in scientific research. Productivity growth is linked to adoption of new technology, including genetically engineered (GE) seeds, and practices, as well as changes in the composition of inputs. Moreover, geographical shift in production to take opportunity of better conditions contributed to increased yields.

- Productivity growth rates in agriculture are high when compared to the rest of the US economy, and just offset slow productivity growth and added services in the rest of the food system to keep food prices rising at the same pace as consumer prices. Productivity growth in agriculture constrains food prices, but that effect is modest because farm commodities account for a small share of retail food costs. A major effect of agricultural productivity growth has been to free resources — of labour, land, and capital that would have been needed to produce food — for use elsewhere in the economy.

- High productivity performance in the 2000s has been achieved with an overall reduction in environmental pressures from agriculture, as illustrated by trends in agri-environmental indicators. This has resulted in improvement or maintenance of the state of the environment in many places. Despite this general improvement, there are still areas with significant environmental problems linked to agriculture, such as water shortages and excessive nutrient pollution at regional or local levels; pesticide sales are significantly trending upward since 2008; and agriculture remains a major threat for ecosystems in several regions.

- Climate change is likely to have deep implications for agricultural production and incomes in the coming decades, especially in some regions that combine higher sensitivity and exposure to climate changes, and fewer opportunities to adapt. Aggregate impacts of climate change may be limited, but regional impacts much more significant. Indirect effects through pests and diseases remain largely unknown. Finally, adaptation responses could also have negative impacts on the environment through changes in crop acreages; increases in input use.

- Changes in demand at global and US levels provide opportunities for US agri-food products, but the rise in concerns about the way food is produce imposes new constraints. Climate- and resource-related constraints create new challenges in meeting those demands, while maintaining past high productivity performance and improving sustainability. Enormous opportunities arise from new science but they will materialise only if stakeholders and society accept those innovations.

Note

1. See Huffman and Evenson (1993, 2006), Alston et al. (2010, 2011), Wang et al. (2012), and Jin and Huffman (2016) for evidence on the long-term link between public investment in agricultural R&D and TFP growth in US agriculture. Table 7.5 provides estimates of the internal rate of return to public investments in agricultural research from various studies.

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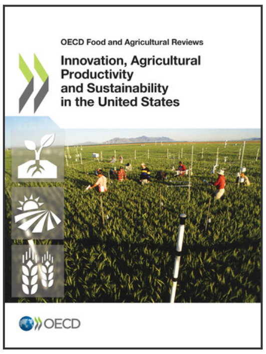

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