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U.S. Rice Production in the New Millennium: Changes in Structure, Practices, and Costs

William D. McBride
Sharon Raszap Skorbiansky
Nathan Childs

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Abstract

Farms growing rice changed significantly over the past two decades in terms of operation size and the ways in which rice is produced. As the total number of farms growing rice declined (from 9,627 in 1997 to 5,591 in 2012), total U.S. planted rice acres also dropped at an annual average rate of about 0.75 percent between 1995 and 2017. U.S. farms growing rice expanded that acreage more than 50 percent between 2000 and 2013 to an average of 600 acres per farm. Farm size increased most in the South where larger farms were able to take advantage of size economies. The most significant change in rice production technologies from 2000 to 2013 was the introduction and adoption of new rice seed varieties. Southern rice producers increasingly planted hybrid and non-genetically modified herbicide-tolerant seed. Precision farming technologies also proliferated, especially the use of yield monitors and guidance systems for tractors and other self-propelled machines. The adoption of new technologies in rice farming pushed per-acre production costs higher, but rice yields also increased, offsetting much of the higher costs. U.S. rice production saw an estimated productivity gain of 29 percent from 2000 to 2013, about 2.2 percent annually. Structural and productivity changes on U.S. farms growing rice benefited U.S. domestic rice consumers by helping to keep prices low and enhanced the competitiveness of U.S. rice producers in global markets.

Keywords: rice, farm productivity, hybrid seed, precision farming, cost-of-production, economies of size, Agricultural Resource Management Survey

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A report summary from the Economic Research Service December 2018

U.S. Rice Production in the New Millennium: Changes in Structure, Practices, and Costs

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What Is the Issue?

Over the past two decades, the size of U.S. farms growing rice and methods of rice production have changed substantially. As the total number of farms growing rice declined (from 9,627 in 1997 to 5,591 in 2012), total U.S. planted rice acres also dropped at an annual average rate of about 0.75 percent between 1995 and 2017. During this time, rice producers adopted several new technologies that improved the economic efficiency of rice production. This report shows the changing structural characteristics and production practices in U.S. rice production and examines how these changes have affected farm productivity, yields, and production costs. It also discusses how rice producers, consumers, and the global competitiveness of U.S. rice production have fared in the midst of these changes.

What Did the Study Find?

Structural and technological changes in U.S. rice production, 2000-2013:

Acres per farm expanded. Total acres operated on farms growing rice increased more than 40 percent to average nearly 1,850 acres per farm. During the same time, acreage planted to rice on those same farms increased more than 50 percent to an average of 600 acres per farm in 2013. Rice producers in the Gulf Coast region expanded farm acreage the most to achieve economies of size and remain competitive with other Southern regions. By 2013, about 33 percent of farms growing rice in the Gulf Coast planted 750 or more rice acres, whereas only 17 percent of farms growing rice were that large in California.

Producers adopted hybrid and non-genetically modified herbicide-tolerant rice seed varieties. Rarely planted in 2000, hybrid seed encompassed 29 percent of U.S. rice acreage, and herbicide-tolerant rice was planted on 43 percent of U.S. rice acres by 2013. All of the new seed varieties were for long-grain rice, adopted only in the South where long-grain rice predominates.

Precision farming technologies proliferated. Yield monitor use increased from 18 percent of rice acreage in 2000 to 58 percent in 2013. Most notable was the adoption of guidance systems for tractors and other self-propelled machines. Rarely used on farms growing rice in 2000, guidance systems were used on more than 50 percent of rice acreage in 2013.

Effects of structural and technological changes in U.S. rice production from 2000 to 2013:

- **U.S. rice productivity grew.** U.S. rice productivity rose an estimated 29 percent, about 2.2 percent annually—second only to peanuts (at 3.5 percent annually) among major U.S. field crops. These gains were facilitated by expanding acreage, exploiting economies of size (lowering production costs by increasing size), and by adopting new technologies—mainly improved seed stock and precision farming techniques.

- **Productivity growth varied by region.** Productivity growth for rice was greatest in the Gulf Coast at 43 percent (3.3 percent annually)—followed by California, 25 percent (1.9 percent annually); Mississippi River Delta, 24 percent (1.8 percent annually); and Arkansas Non-Delta, 18 percent (1.4 percent annually). Greater productivity growth in the Gulf Coast can be attributed in part to growth in farm size that far exceeded growth in other regions.

- **Per-acre production costs rose.** While improving rice yields, new technologies in rice farming also increased per-acre production costs more than 100 percent—led by seed and fertilizer costs that increased 200 percent and chemical costs that increased 108 percent. Production costs grew most where the new technologies were most readily adopted, in the Arkansas Non-Delta and Mississippi River Delta, and much less in California. As a result, regional cost differences narrowed.

- **Yield increases centered in the South.** U.S. rice yields increased by 22 percent, mostly in Southern regions. Compared with increases in planted acre yields of only 10 percent in California, yields in the Southern regions increased as follows: Arkansas Non-Delta (18 percent), Mississippi River Delta (24 percent), and Gulf Coast (31 percent). Consequently, yield differences diminished among the major rice-producing regions.

- **Domestic consumers and U.S. rice exporters benefited.** By holding long-grain rice prices lower than would otherwise be expected, productivity growth on U.S. farms growing rice benefited U.S. rice consumers. Productivity growth can also make U.S. producers more competitive in global rice markets and may have helped to increase U.S. medium-grain rice exports during this period.

- **Further capacity for productivity growth exists in the South.** Further gains from exploiting economies of size are widely available among Southern rice producers. There also remains a significant capacity for the adoption of technologies and practices that contribute to productivity growth in Southern rice production. The capacity for further productivity growth appears more limited in California.

How Was the Study Conducted?

This report used data from USDA surveys of U.S. rice producers conducted for 2000, 2006, and 2013 as part of USDA's annual Agricultural Resource Management Survey (ARMS). Data summaries for each year were used to describe farm and operator characteristics, production technologies, input use, production costs, and yields of U.S. rice producers and those in major rice-producing regions. This information was used to describe structural change in rice production from 2000 to 2013. Productivity change was identified by the change in price adjusted (deflated) unit production costs. Other data on rice input and output prices and rice exports were used to explore the implications of structural and productivity change in U.S. rice production.

U.S. Rice Production in the New Millennium: Changes in Structure, Practices, and Costs

Introduction

In this report, we examine trends and developments in U.S. rice production over the last two decades, analyzing changes in the characteristics, practices, technologies, input use, and production costs of rice producers and evaluating structural and productivity trends. (See box “A Primer on Rice Production.”) Our objective is to convey how the farm-level economics of U.S. rice production has evolved over the last two decades and to explore implications of these changes for U.S. rice producers and consumers.

The report’s analyses are based on data from detailed surveys of U.S. rice producers collected in the 2000, 2006, and 2013 USDA, National Agricultural Statistics Service and Economic Research Service, Agricultural Resource Management Survey (ARMS). Information from the USDA Commodity Costs and Returns data product (USDA, ERS, 2017a) supplements the farm data. Data and information from the USDA Rice Yearbook (USDA, ERS, 2017b); annual reports on rice acreage and production (USDA, NASS, 2017b); annual reports on prices (USDA, NASS, 2017a), and Census of Agriculture (USDA, NASS, 1997, 2002, 2007, 2012) summary tables are used to provide context about the rice industry and give indicators of rice production and market conditions in the new millennium.

A Primer on Rice Production

Rice production occurs over vast areas of the world, particularly in Asia where it is a staple crop and has significant cultural and historical roots. Economically sound rice production requires particular agronomic requirements, such as a plentiful supply of water applied in a timely fashion (via rain or irrigation from groundwater or surface water sources), high average temperatures during the growing season, a smooth land surface to facilitate uniform flooding and drainage, and a subsoil hardpan that inhibits the percolation of water. Therefore, rice production in the United States is limited to certain areas.

Four regions, which span portions of six States, meet the required characteristics and produce almost the entire U.S. rice crop (USDA, ERS, 2017b.)

- Arkansas Grand Prairie (Non-Delta);
- Mississippi Delta, (parts of Arkansas, Mississippi, Missouri, and Louisiana);
- Gulf Coast (Texas and Southwest Louisiana); and
- Sacramento Valley (California).

Different regions grow different types of rice—i.e., long-, medium-, or short-grain—as determined by regional soil conditions. Long-grain rice is grown almost exclusively in the South and has accounted for approximately 70 percent of U.S. production since the mid-1980s. Medium-grain rice is grown both in California and the South and accounts for more than 25 percent of U.S. production. The majority of U.S. medium-grain rice is grown in California, while the majority of the Southern medium-grain rice production occurs in Arkansas. California grows almost exclusively medium-grain, accounting for over 90 percent of production, with the remaining production being mostly short-grain rice. Short-grain rice accounts for only 1-2 percent of total U.S. rice production and is grown almost exclusively in California. Unlike other parts of the world where production is divided between irrigated and non-irrigated fields, all U.S. rice is produced in irrigated fields, achieving some of the highest yields in the world.

The U.S. rice-growing season varies by region. Planting typically begins in early or mid-March in Texas and southwest Louisiana. Producers in the Delta States plant the bulk of their crop in April, and California's crop is planted from late April through May. Harvest begins by mid-July in Texas and southwest Louisiana. Peak harvest in the South is in September and early October when the Delta harvests the bulk of its crop. Some producers in Texas and southwest Louisiana are able to re-flood rice fields after harvest and achieve a partial second or "ratoon" crop from the stubble of the first. California typically begins harvest at the end of September and finishes by early or mid-November.

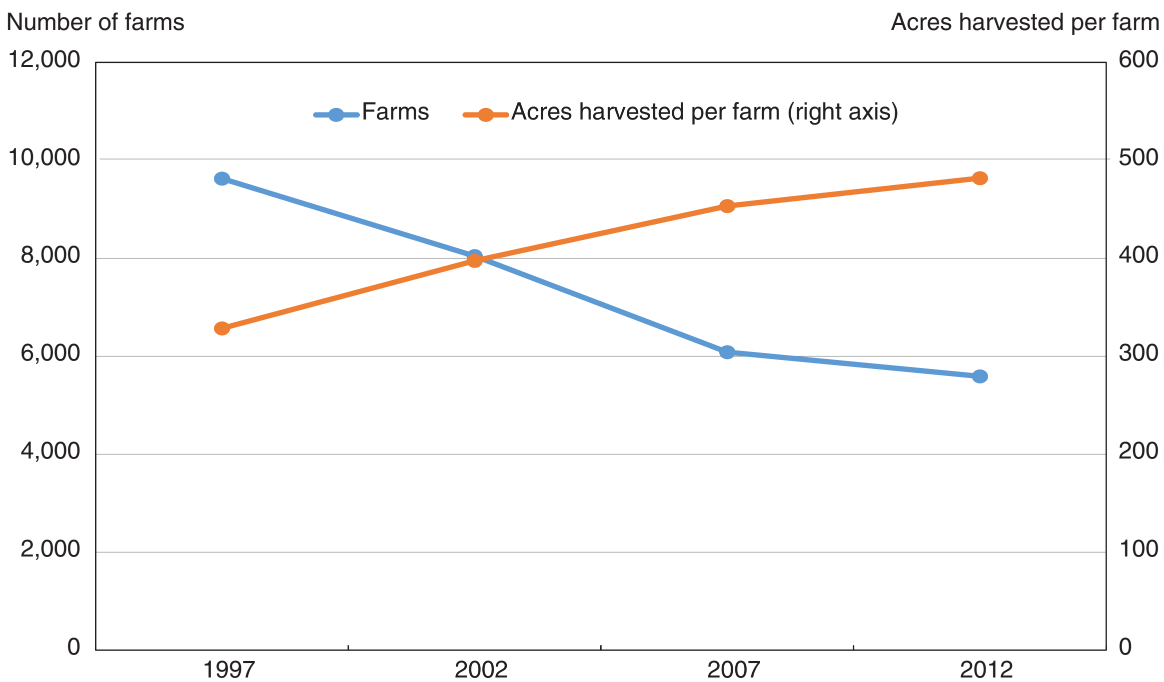
U.S. Rice Farming

The background information about U.S. rice farming in this chapter uses historical data about rice acreage, production, yields, and number of rice farms from the past two decades.[1] We also examine rice producer profitability using data about the returns to rice production since 2000.

Rice Farms and Acreage

The number of U.S. farms producing rice has declined continually over the past 20 years, as rice farms have trended toward consolidation into larger operations (Baldwin et al., 2011). In 1997, 9,627 farms harvested rice. By 2012, this number had fallen to 5,591 (fig. 1), a 42-percent decline. While the number of rice farms has decreased, harvested rice acres per farm increased. In 1997, U.S. rice farms harvested an average of 328 rice acres per farm. By 2012, rice acres harvested per farm were up to 482, a 47-percent increase, and half of rice farms harvested 800 or more acres (MacDonald et al., 2018). The number of rice farms with 1,000 acres or more doubled between 1997 and 2012, while the number with less than 1,000 acres fell nearly 50 percent. Larger rice farms (1,000 acres or more) accounted for 41 percent of harvested rice acreage in 2012, up from 20 percent in 1997 (USDA, NASS, 1997 and 2012).

Figure 1
Number of U.S. farms harvesting rice and average acres harvested per farm, 1997, 2002, 2007, and 2012



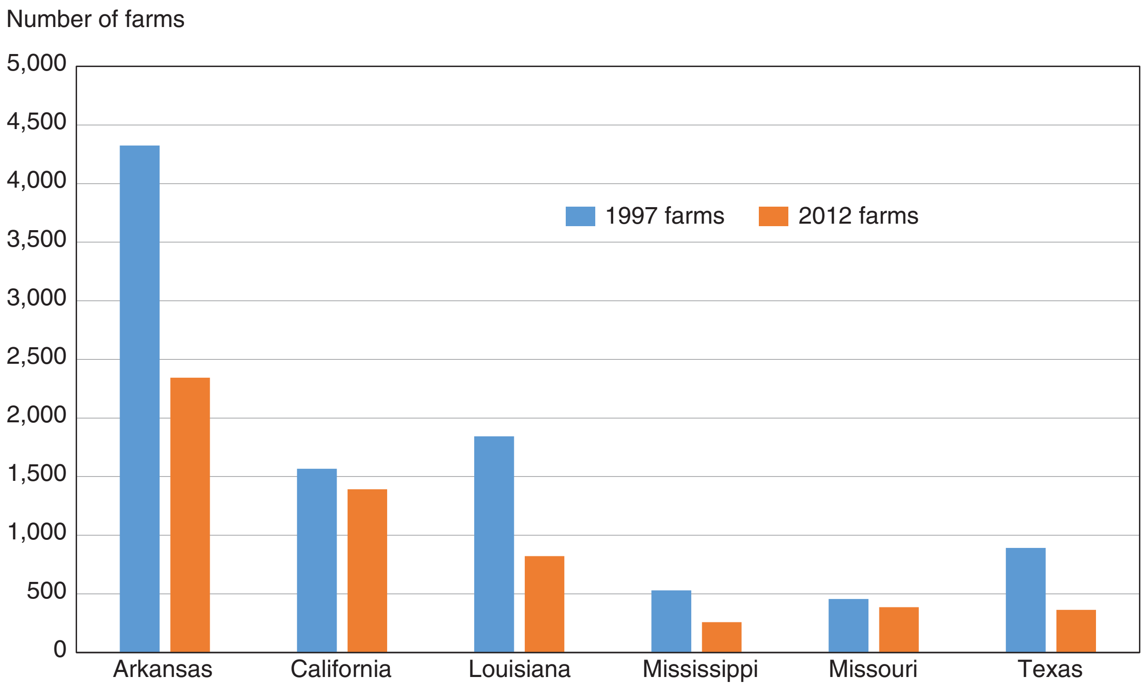
Source: USDA, National Agricultural Statistics Service, Agriculture Census, 1997, 2002, 2007, and 2012.

[1]For the purposes of this report, a "rice farm" is any farm that grows rice. The farm may also grow other crops, and rice does not necessarily comprise the majority of acres.

Among major rice-producing States, Arkansas had the largest number of rice farms, accounting for more than 40 percent of the U.S. total in both 1997 and 2012. However, the number of rice farms in Arkansas fell 46 percent over this period (fig. 2). Louisiana had the second highest number of rice farms in 1997, but by 2012, had about 500 fewer farms than California. Rice farm numbers were most stable in California, falling only 11 percent from 1997 to 2012. The largest percentage declines in number of rice farms were in Texas and Louisiana, down 59 and 55 percent, respectively.

As the total number of rice farms declined, total U.S. rice acreage also dropped. Between 1995 and 2017, annual rice acres planted ranged from a high of over 3.6 million acres in 2010 to a low of about 2.5 million in 2013 and 2017 (fig. 3). U.S. planted rice acres trended down at a statistically significant annual average rate of about 0.75 percent between 1995 and 2017.[2] However, acreage trends varied significantly among major producing States (fig. 4). Planted rice acres declined the fastest in Texas, with an annual average drop of 3.2 percent, followed by Mississippi (2.6 percent) and Louisiana (1.7 percent). Rice acreage trended higher in Missouri (1.6 percent). Although California rice acreage dropped considerably in 2014 and 2015 because of ongoing drought conditions, the trend in California rice acreage over the 1995-2017 period was not statistically significant. (See box "Drought Impacts California Rice Acreage.")

Figure 2
Number of farms harvesting rice in major producing States, 1997 and 2012

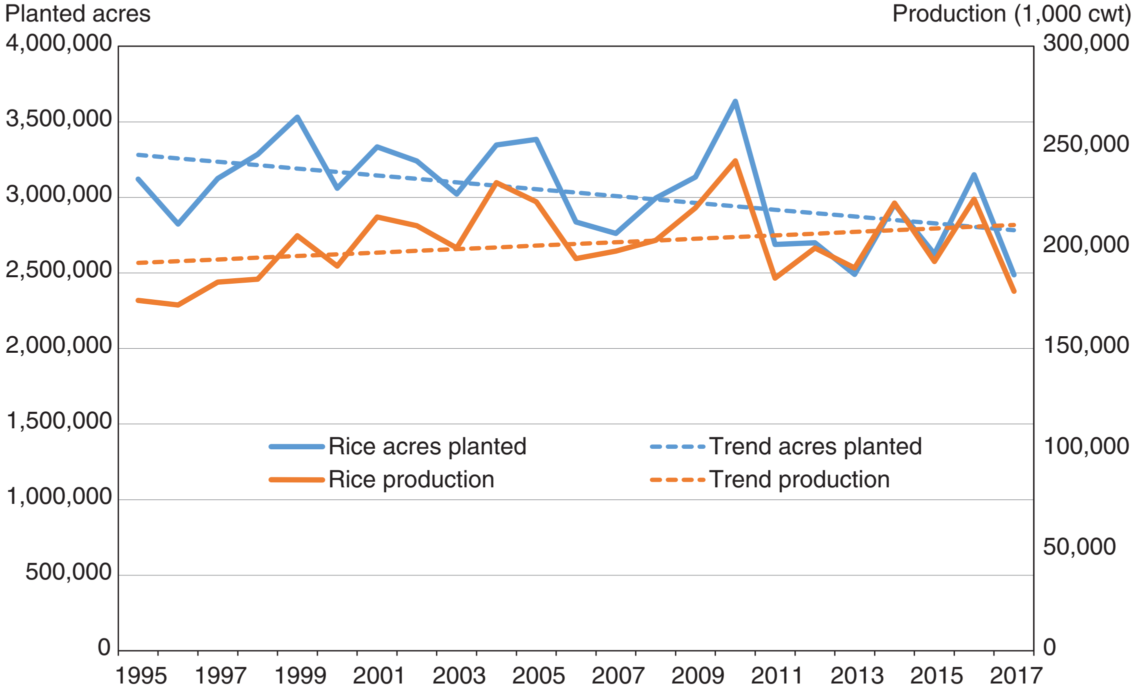


Source: USDA, National Agricultural Statistics Service, Agriculture Census, 1997 and 2012.

[2]Trends are measured as the average annual change expressed as a percent of the series mean and are indicated as statistically significant only if the annual change was significantly different from zero at the 5-percent level.

Figure 3

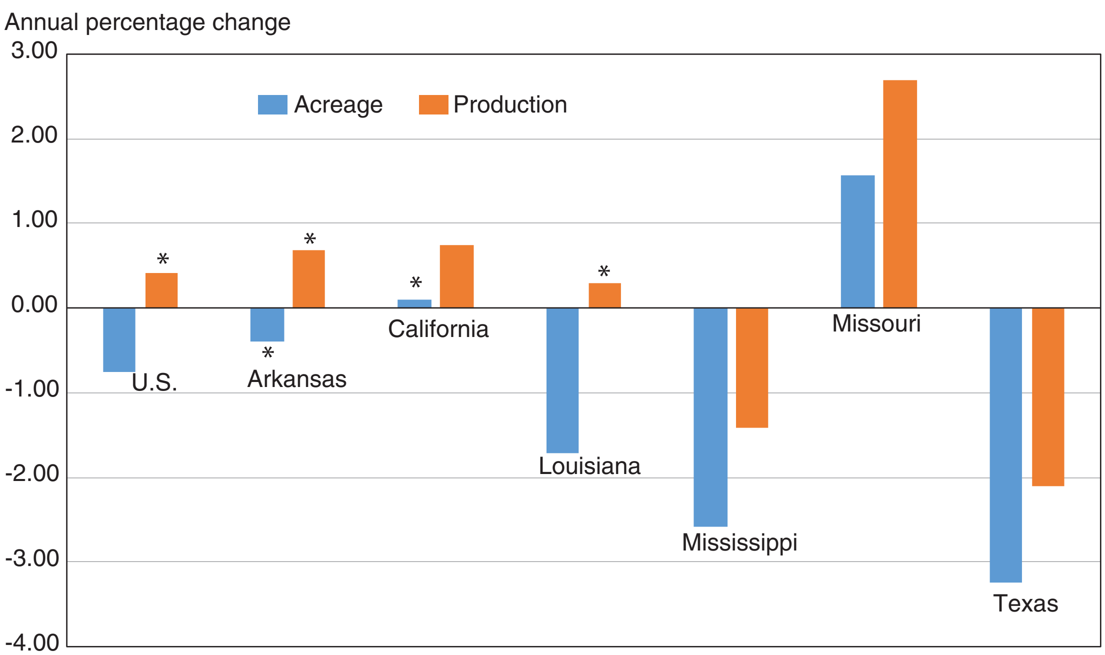
U.S. planted rice acres and production, 1995-2017



Source: USDA, National Agricultural Statistics Service, Crop Production, various years.

Figure 4

Average annual change in rice acres planted and production, U.S. and major producing States, 1995-2017



*Not statistically different from zero at the 5-percent level.
Source: USDA, National Agricultural Statistics Service, Crop Production, various years.

Drought Affects California Rice Acreage

California has experienced several periods of severe dryness and drought. The most recent drought for the State was particularly intense, lasting from 2012 to 2017.

California farmers receive water from a complex and changing water system. The Federal Bureau of Reclamation (USBR) and the California State Water Project (SWP) allocate water, taking into account historical rights, known as senior or "pre-1914" water rights. These authorities approve contractors for a requested quantity of water, affected by water availability. All agricultural contractors north of the Sacramento-San Joaquin River Delta, which includes rice growers, received 100 percent of requested allocations in 14 of the past 21 years. When growers receive smaller allocations under severe drought conditions, uncertainty about the future of water availability affects their planting decisions. California rice producers received reduced water allocations from both the USBR and SWP during the most recent drought period.

As a result of a lower water allocation and lower prices of rice compared with more lucrative crops (e.g., almonds), planted rice acreage in 2014 decreased 22 percent compared with the previous year. Acreage fell an additional 4 percent in 2015. Planted rice acreage fluctuated thereafter, increasing 21 percent in 2016 before falling 8 percent in 2017. As such, planted rice acreage has yet to return to levels observed before the most recent drought. Declining rice acreage and water availability in California have also decreased the habitat for wetland-dependent birds (Petrie et al., 2014).

Production and Yields

Despite declining U.S. rice acreage, U.S. rice production did not exhibit a statistically significant trend. Rice production closely tracked acreage, ranging from a low of about 172 million hundredweight (cwt) in 1996 to a high of 243 million cwt in 2010 (fig. 3). Production trended lower only in the two States where planted acres declined the most, Texas and Mississippi, down annual average rates of 2.1 and 1.4 percent, respectively (fig. 4). Production trended higher in California by less than 1 percent per year, but was up 2.7 percent per year in Missouri.[3]

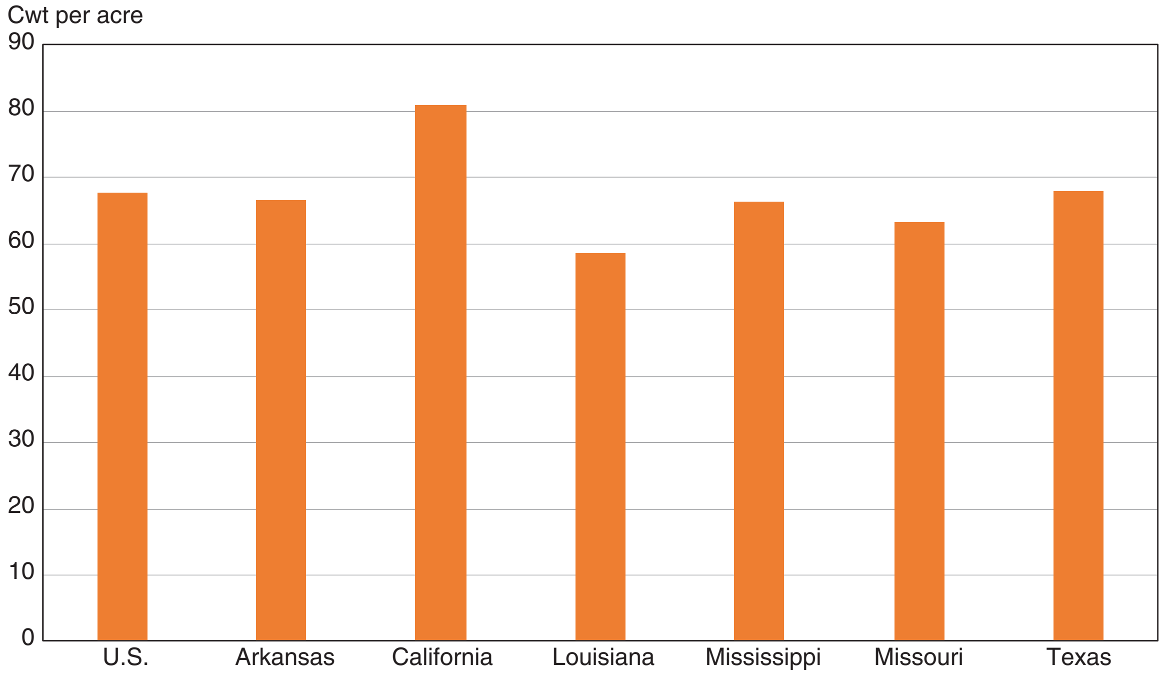
U.S. rice yields averaged 68 cwt per acre between 1995 and 2017, ranging from 56 cwt to 77 cwt per acre.[4] Yields were highest in California, mostly medium-grain rice, at an average of 81 cwt per acre (fig. 5). In the South, average rice yields were similar in most States ranging between 63 cwt and 71 cwt, except in Louisiana where rice yields averaged only 59 cwt per acre. Annual yield variation was also the greatest in Louisiana with a coefficient variation (CV) of 14 percent, followed by Texas with a CV of 11 percent.[5] Yield variation was least in California with a CV of about 7 percent.

[3]Production trends were statistically significant in California, Mississippi, Missouri, and Texas, but not in Arkansas and Louisiana.

[4]Farm yields of rough rice including a composite average of long-, medium-, and short-grain rice. Yields are per harvested acre.

[5]The coefficient of variation expresses the standard error of estimate as a percent of the mean. Yield variation may be higher in Louisiana and Texas in part because Gulf Coast producers are able to harvest a ratoon, or second crop, in some years but not others. (See box "A Primer on Rice Production.")

Figure 5
Average rice yields, United States and major producing States, 1995-2017



Note: cwt = hundredweight.
Source: USDA, National Agricultural Statistics Service, Crop Production, various years.

Total U.S. rice production in 1995-2017 did not trend lower because increasing yields offset declining acreage. U.S. rice yields trended higher at an annual average rate of 1.25 percent. Rice yield trends varied significantly among the major-producing States. Rice yields increased the fastest in Louisiana (2.0 percent per year), much more quickly than in other States, and slowest in California (0.7 percent per year) where the average yield was highest. Other State yield trends fell between these extremes with annual growth rates of 1.4 percent in Missouri, 1.2 percent in Arkansas and Mississippi, and 1.1 percent in Texas.

Producer Profitability

Rice producer profitability was measured by returns above operating costs and returns above total (economic) costs (USDA, ERS, 2017a). Operating costs include variable cost items such as seed, fertilizer, chemicals, and fuel. Total (economic) costs include operating costs plus the opportunity cost of resources used in production, including land, labor, and capital. Producers must be able to cover operating costs in the short run to remain in business, but as the length of the planning period increases, opportunity costs[6] need to be considered. The influence of opportunity costs on farm enterprise decisions can vary significantly among producers for many reasons, including lifestyle preferences, agronomic conditions, and the willingness of some producers to accept resource returns that are less than the assumed opportunity cost.[7]

[6]In economics, "opportunity cost" is the loss of potential gain from other alternatives when one alternative is chosen.

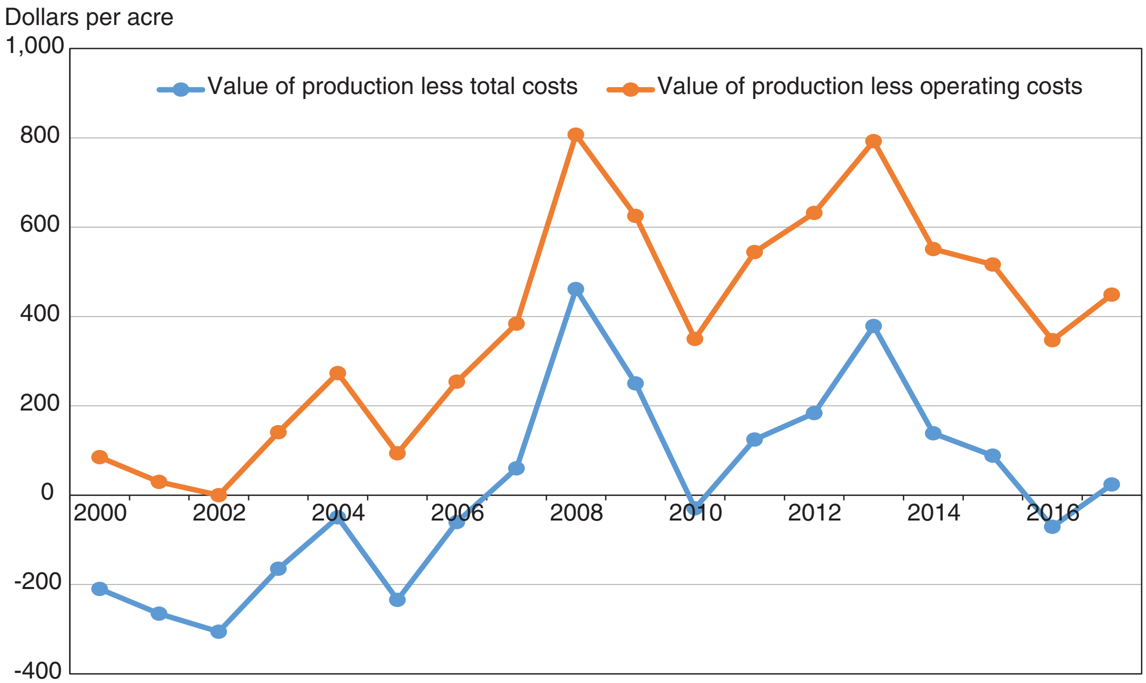
[7]For example, unpaid labor used in rice production is charged at an estimate of what rice producers could have earned had they worked off-farm. Some producers may be willing to accept a return less than this assumed opportunity cost in order to be farming instead of working off-farm.

Average returns above operating costs among U.S. rice producers were positive in 17 of the 18 years from 2000 to 2017, ranging from -$0.11 per acre in 2002 to more than $800 per acre in 2008 (fig. 6). Average returns above total (economic) costs of U.S. rice production were negative in 2000-06, falling to a low of about -$300 per acre in 2002. Low returns in this period can be attributed to low prices for long-grain rice.[8] Farm prices for rice improved starting in about 2006 as global rice supplies tightened.[9]

After turning positive in 2007, returns to rice production moved to more than $460 per acre in 2008 as rice prices increased. Average returns to rice production were strong in 2007-17, positive each year except 2010 and 2016. Higher returns to rice since 2007 can be partially attributed to a global rice crisis in 2008 that significantly increased prices, particularly of medium- and short-grain rice (USDA, ERS, 2017b).

Returns from rice production relative to those of other crops are shown as the average dollars per planted acre for each crop over the entire 2000-17 period and during 2007-17 (fig. 7). Over the entire period, average returns are positive for only two of the seven crops, rice, and soybeans. In 2007-17, average returns to corn were also positive, but average returns to rice production far exceeded the other crops at nearly $150 per acre.

Figure 6
U.S. average returns to rice production, 2000-17

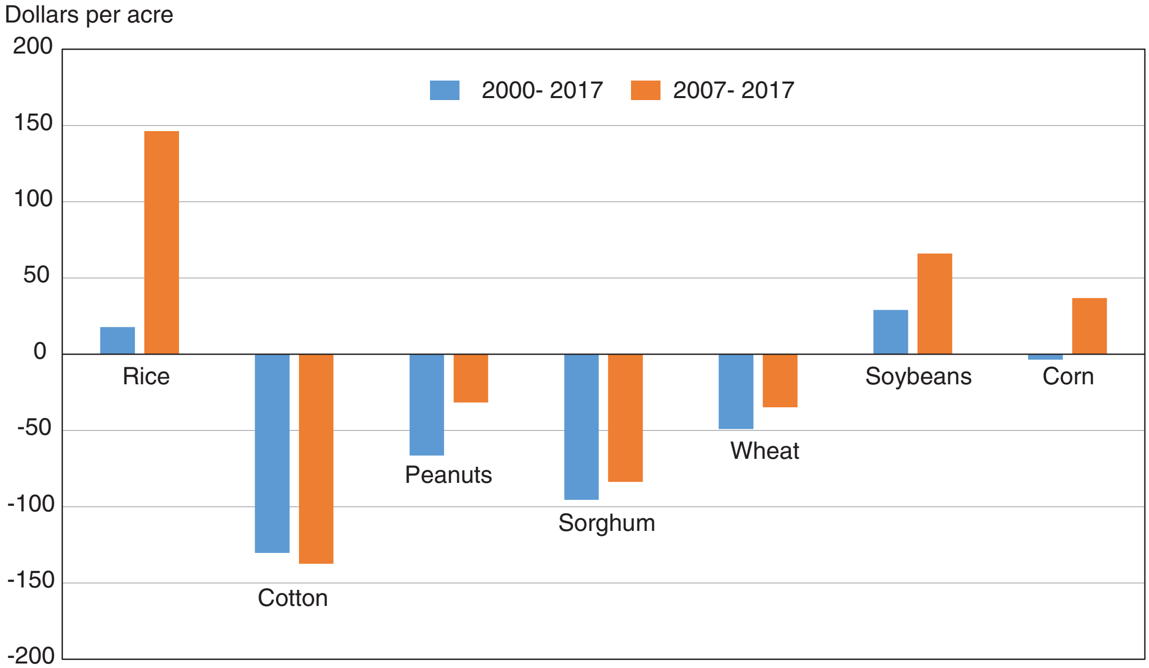


Source: USDA, Economic Research Service, Commodity Costs and Returns.

[8]The price of medium-grain rice rebounded quicker than for long-grain rice, but the average is dominated by the larger volume of long-grain rice produced by U.S. growers.

[9]A disruption in the U.S. rice market took place in 2006 when trace amounts of genetically modified rice were identified from rice samples for commercial shipment. The protein Liberty Link, or LLRICE601, had been approved for other food and feed products and was deemed to be not harmful for human consumption and the environment. The European Union closed its market to U.S. rice imports, although the rice industry quickly approved an elimination of the strain. The industry's action, combined with a bullish global situation as the stocks-to-use ratio was the lowest it had been since 1981, eased the effect on the U.S. export market.

Figure 7
U.S. average returns to major field crop production, 2000-17 and 2007-17



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

Positive returns above total costs suggest that profits are possible for these crops, and one would expect their acreage to expand. Corn acreage increased from about 76 million acres in 2001 to more than 97 million acres in 2012 (USDA, NASS, 2017b). Likewise, soybean acres were at or below about 75 million through 2007 before climbing steadily to reach over 90 million acres in 2017. Most of the expanded corn and soybean acreage replaced less profitable wheat, grain sorghum, and cotton acres. Despite the profitability of rice, the unique agronomic requirements of rice production limit the potential for acreage expansion. (See box "A Primer on Rice Production.")

Structural Change

ARMS data in 2000, 2006, and 2013 are summarized and compared to examine structural change in U.S. rice production. (See box "The Agricultural Resource Management Survey.") Farm characteristics, technologies, and input use are compared at each point in time. Change in rice production is also examined for each major U.S. rice-producing region (fig. 8).

The Agricultural Resource Management Survey

The Agricultural Resource Management Survey (ARMS), conducted annually, is USDA's primary source of economic data about the U.S. farm sector.[10] In 2000, 2006, and 2013, ARMS included a version that specifically targeted rice producers, with a sample that covered States that constituted more than 90 percent of U.S. rice acreage in each of those survey years. States surveyed included the major rice-producing States of Arkansas, California, Louisiana, Mississippi, Missouri, and Texas. The data included 607 rice farms in 2000, 698 in 2006, and 643 in 2013.

Each farm surveyed in ARMS represented a number of similar farms in the population, as indicated by the surveyed farm's expansion factor. The expansion factor, or survey weight, was determined from the farm's selection probability and thereby expanded the sample to represent the target population. In the rice surveys, the target population was farms that planted an acre or more of rice during each survey year.

The ARMS data came from cross-sectional samples selected each year rice was surveyed. Operators were chosen randomly each year, rather than in a panel where the same operators were surveyed repeatedly. For this reason, some of the differences across time resulted from the fact that different operators were selected for each survey. However, many rice farms have exited and entered rice production during the past two decades, and these farms differ substantially from continuing farms. The trend in farm numbers by farm size suggests that most exiting rice farms were smaller and entering rice farms were larger than continuing rice farms. Therefore, a panel survey that samples only continuing rice farms would not provide an accurate perspective of rice production, making repeated cross-sectional surveys preferable for the purpose of this study.

[10]For more information about ARMS, see USDA, ERS (2017d).

Figure 8
Major U.S. rice-producing regions

Source: USDA, National Agricultural Statistics Service.

Farm and Operator Characteristics

Average acres operated by U.S. rice farmers grew more than 40 percent between 2000 and 2013, from about 1,300 to nearly 1,850 acres (table 1). Growth in rice farm size was accomplished mainly by renting more acres as land ownership per farm remained at 350-400 acres, while rented acres grew more than 50 percent and accounted for more than 80 percent of operated farm acreage in 2013.[11] The increase in rented acreage could be due to the accessibility of land for rent, as well as lower financial risks associated with leasing versus owning land. Land may become more accessible for rent if retiring rice farmers choose to rent out instead of selling their land. (See MacDonald et al. (2018) for more information about crop farm consolidation.)

Rice farms in 2013 were largest in the Mississippi River Delta, at nearly 3,200 acres, compared with around 2,000 acres in the Arkansas Non-Delta, 2,100 acres in the Gulf Coast, and 660 acres in California (see appendix tables 1-4). Farm size growth during 2000-13 was greatest by far in the Gulf Coast (87 percent), followed by the Arkansas Non-Delta (57 percent). Average rice acreage on U.S. rice farms increased about 50 percent (395 to 600 acres) during this period.

Rice farms in the Southern regions (Arkansas Non-Delta, Mississippi River Delta, and Gulf Coast) were large operations as rice covered more than 600 acres per farm by 2013 (fig. 9). Growth in rice acreage per farm over 2000-13 was above 50 percent in all regions except the Mississippi River Delta. Per-farm rice acreage in the Gulf Coast was similar to that in California in 2006, ranking behind the other regions, but Gulf Coast acres per farm grew the fastest during 2006-13 (42 percent),

[11]Operated farm acreage equals owned acres plus rented acres, minus acres rented to others.

far exceeding the other regions.[12] By 2013, the Gulf Coast had the highest share of farms (more than 33 percent) with 750 or more acres of rice. In 2006-13, rice acreage per farm grew least in California (8 percent), as only 17 percent of California rice farms had 750 or more acres in 2013.

Table 1

Characteristics of U.S. rice farms and farm operators, 2000, 2006, and 2013

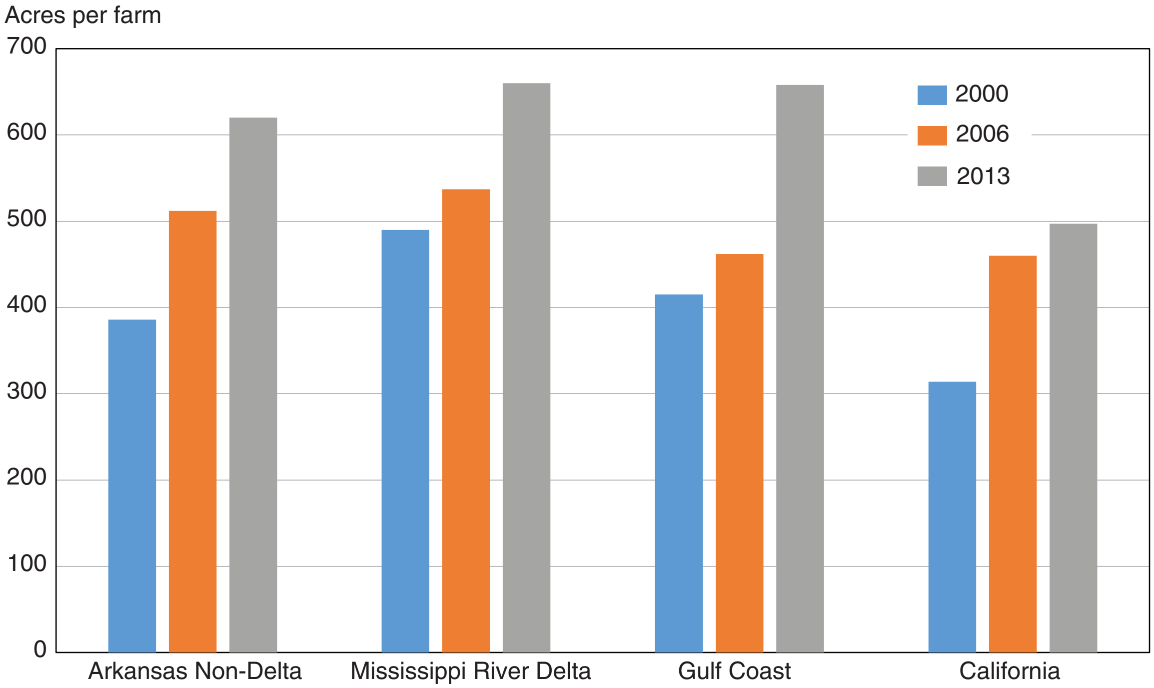
Item	2000	2006	2013
Farm size			
Operated acres	1,299	1,580	1,848
Owned acres	355	405	389
Land value ($/acre)	1,120	1,733	3,705
Percent of acres owned	27.14	25.64	25.18
Rented acres	994	1,220	1,524
Planted rice acres	395	496	600
Planted rice acres-% of farms			
Fewer than 250 acres	46.03	33.91	29.72
250-499 acres	27.81	31.96	20.42
500-749 acres	14.50	13.58	24.07
750 or more acres	11.66	20.54	25.79
Value of production (dollars)			
Rice	148,445	291,178	768,445
Farm	292,073	559,295	1,476,055
Percent from rice	50.82	52.06	52.06
Region-% of farms			
Arkansas Non-Delta	39.10	44.87	35.48
Mississippi River Delta	23.94	20.38	16.86
Gulf Coast	15.65	16.62	19.99
California	19.93	18.13	27.67
Farm commodity-% of farms			
Corn	8.36	10.24	31.65
Soybeans	57.40	63.26	60.61
Small grain crops	29.87	19.96	17.55
Operator age-years	50	53	55
Less than 50 years-percent	48.47	38.26	26.05
Operator education-% of farms			
Less than high school	7.24	2.15	1.38
Completed college	29.48	32.39	35.90

Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.

[12]In 2000, rice production costs were highest in Southern regions on Gulf Coast farms, creating an incentive for producers in the Gulf Coast to expand rice production in order to achieve size economies.

Figure 9

Average rice acres per rice farm by region, 2000, 2006, and 2013



Source: USDA, National Agricultural Statistical Service and Economic Research Service, Agricultural Resource Management Survey.

Although rice acres per farm grew significantly during this period, the average farm value derived from rice production remained close to 50 percent. Farms continued to alternate and/or divide acreage between rice and other crops. Rice's proportion of farm production value varied among regions, accounting for about 30 percent in the Mississippi River Delta, 50 percent in the Arkansas Non-Delta, 65 percent in the Gulf Coast, and 80 percent in California. The composition of commodities on rice farms changed as more farms planted corn in response to higher corn prices, mainly in the Arkansas Non-Delta and Mississippi River Delta. Cotton, planted on about 35 percent of Mississippi River Delta rice farms in 2000, fell by more than half to 16 percent of farms in 2013. In the Gulf Coast, soybeans were planted more often on rice farms, moving from 20-25 percent in earlier years to 50 percent of farms in 2013. California rice producers became more specialized in rice as fewer rice farms planted other crops like fruits and vegetables.[13]

The average rice farm operator age increased between 2000 and 2013, rising from 50 to 55 years, while the percent of farm operators less than 50 years of age declined from 48 to 26 percent.[14] This pattern was consistent across regions as the average age increase ranged from 4 years in the Arkansas Non-Delta to 7 years in the Mississippi River Delta and California. The aging population of rice producers may be due in part to constraints that limit new entrants to rice production—namely, the high cost of rice farm assets and the lack of land suitable to grow rice (Baldwin et al., 2011). Rice farmers must make significant investments in land and equipment to achieve a size of

[13]As the drought became dire in California, some rice producers concentrated acreage in more lucrative crops like almonds or pistachios, while in other cases, they sold their water rights (Medellin-Azuara et al., 2016).

[14]Rice farm operator age ranged from just over 20 to nearly 90 years old.

operation that is profitable. Land suitable for growing rice is limited by the unique conditions needed for rice production. (See box "A Primer on Rice Production.")

Education levels of rice farm operators also increased over time. By 2013, less than 2 percent had not completed high school in any region. The percent of rice farm operators who had completed college rose from 29 to 36 nationally, and increased in all regions except the Gulf Coast. In the Mississippi River Delta, the percent of rice farmers who had completed college increased 13 percentage points in 2000-13 (from 23 percent to 36 percent), and by 2013 more than half of California rice farmers had completed college.

Technologies

Rice is classified by the length of grain. U.S. long-grain rice, with characteristics very similar to the global classification of indica rice, is the subspecies that encompasses nonsticky and long-grain rice.[15] Medium- and short-grain rice belong to the japonica classification, which is stickier and typically shorter grained than indica. Calrose is the major variety of japonica grown in California, adapted for California's temperate weather. Most rice varieties grown in the South are long-grain, but several medium-grain varieties are also grown. Popular medium-grain varieties include Diamond, for its field and milling yield quality, and Jupiter, for its field and yield quality and moderate resistance to bacterial panicle blight (Hardke et al., 2016). Medium-grain varieties in the South are engineered to withstand growing conditions in the South.

About 75 percent of U.S. rice production is of the long-grain variety, and nearly all the rest is medium-grain (table 2). More than 90 percent of rice acreage in the Southern regions is the long-grain variety. In contrast, about 90 percent of California rice acreage is medium-grain, and most of the rest is short-grain. [16] The percent of rice grown by type, nationally and by region, was stable throughout 2000-13.[17]

Among the various methods for seeding rice, farmers can plant via air drop from a plane into a wet or flooded seedbed or drill or broadcast seed onto a dry seedbed. A majority of rice acres—60 percent in 2000 and 2006 and 65 percent 2013—were drilled into a dry seedbed, but seeding practices varied by region (see appendix tables 5-8). In the Arkansas Non-Delta and Mississippi River Delta, 90 percent or more of acreage was drilled, with little variation over time. In contrast, nearly all California rice acreage was seeded by airplane. California growers flooded fields at planting to aid in weed suppression. In the Gulf Coast, 60 percent of rice acres were seeded via air on a wet seedbed in 2000. By 2013, over 60 percent of the Gulf Coast rice acres had shifted to a conventional method of ground seeding, particularly seeding via dry drilling.[18] Once the seed has been drilled, the field is flooded after the rice plant develops four leaves, usually 3 to 4 weeks after emergence.

[15]Long-grain rice is actually a japonica variety, but has the appearance of an indica variety.

[16]Southern long-grain and medium-grain prices are much lower than the California medium-grain price. However, Southern medium-grain rice usually receives a small price premium over Southern long-grain rice.

[17]Because of the limited ARMS sample size in each year and the concentration of rice varieties in each region, it was not possible to break out data on long- and medium-grain varieties by year in each region.

[18]This shift was facilitated by the adoption of the herbicide-tolerant technology and happened primarily in the Gulf Coast.

Table 2

Technologies used on U.S. rice acreage, 2000, 2006, and 2013

Item	2000	2006	2013
Type of rice grown-% of acres			
Long grain	72.23	79.39	72.68
Medium grain	26.45	18.95	25.64
Short grain	1.32	1.67	1.69
Seeding method-% of acres			
Air (water)	26.22	22.61	24.81
Drilled (dry)	60.21	60.10	65.33
Air (dry)	8.45	10.18	7.43
Broadcast (dry)	5.11	7.11	2.42
Hybrid rice seed-% of acres[1]	5.24	11.45	28.57
HT rice seed-% of acres[2]	0.00	22.71	43.38
Previous crop-% of acres			
Rice	38.42	37.58	44.95
Corn	0.38	0.72	0.96
Soybeans	43.25	46.08	39.65
Small grain	0.00	0.00	0.00
Other crop	4.29	3.12	3.26
Hay and fallow	13.65	12.50	11.18
Crop rotation-%of acres			
Monoculture	25.25	28.44	33.58
Continuous row crop	53.80	51.97	48.88
Idle year	12.75	12.50	11.18
Precision ag tech-% of acres			
Yield monitor	18.49	29.00	57.88
Yield map	5.94	9.44	18.08
GPS soil map[3]	10.05	7.59	11.91
Guidance system	0.00	25.57	53.40
Variable rate-fertilizer	2.11	5.41	16.42
Variable rate-seeding	1.58	1.66	7.14
Variable rate-chemicals	2.72	2.60	9.21
Irrigation system-% of acres			
Portal	16.13	16.99	19.15
Poly pipe	3.58	6.57	6.60
Gated pipe	0.51	1.93	3.02
Open discharge	77.86	71.35	61.88

[1]Hybrid rice was first released in 2000. Reported use in the 2000 ARMS appears considerably higher than in other sources (see Nalley et al., 2016).

[2]HT = herbicide-tolerant.

[3]GPS = global positioning system.

Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.

The most significant change in rice seeding in 2000-13 was the increase in planting hybrid and herbicide-tolerant rice varieties for long-grain rice production. Nationally, hybrid rice seed was reported in the ARMS to be planted on 5 percent of acreage in 2000. This increased to 29 percent by 2013.[19] Hybrid rice gained favor primarily because it is higher yielding than conventional rice, although sometimes of a lower quality. (See box "Hybrid Rice.") From 2000 to 2013, hybrid rice acreage increased from 2 percent to 42 percent in the Arkansas Non-Delta, 11 percent to 37 percent in the Mississippi River Delta, and 10 percent to 28 percent in the Gulf Coast (fig. 10). A few medium-grain hybrid varieties are planted in the South (Hardke et al., 2016), although they are a very small percentage of rice acreage. There is no hybrid rice planted in California.

Herbicide-tolerant rice has been bred to withstand applications of specific herbicides that kill targeted weeds. This feature allows producers to broadcast herbicides after both the rice and weeds have emerged, killing targeted weeds without harming the rice. Unlike most herbicide-tolerant corn, soybeans, and cotton, herbicide-tolerant rice varieties have been developed through traditional plant-breeding methods rather than genetic modification (Sudianto et al., 2013).

The Clearfield (CL) variety was the first herbicide-tolerant rice developed to help Southern producers manage "red rice." Red rice is a weed unique to rice production, being the same genus and species as rice, but having an off-color seed coat that is undesirable to consumers (International Rice Research Institute). Herbicide-tolerant CL rice was not available until 2001, but by 2013, was planted on 43 percent of U.S. rice acreage.[20] As with hybrid rice, adoption was extensive in Southern rice regions, reaching nearly 50 percent of acreage in the Gulf Coast and about 60 percent of acreage in the other Southern regions by 2013 (fig. 11). Red rice is absent in California where herbicide-tolerant rice has not been planted, and flooding is used as the main method of weed control.

U.S. rice producers often plant rice in rotation with other crops for various reasons.[21] However, over time, rice farmers have increasingly planted rice in consecutive years. The percent of acreage on which rice followed rice increased from 38 percent in 2000 to 45 percent in 2013. In addition, crop rotation, a measurement of the practices used over a 3-year cycle, shows a trend toward greater monoculture rice (25 to 34 percent of acres).[22] Rotational practices vary among regions. In the Arkansas Non-Delta, the practice of rice after rice doubled from 17 percent to 35 percent of acreage between 2000 and 2013, while the acreage under monoculture rice increased from 6 percent to 22 percent. In the Mississippi River Delta, rice was planted after rice on about 40 percent of acreage each year. High returns to rice production relative to other crops created incentives to plant rice more frequently, reducing rotations. Also, the advent of herbicide-tolerant rice made this practice more practical in the South because red rice is better managed.

[19]The 5-percent hybrid rice adoption measured in the 2000 ARMS is considerably higher than that reported elsewhere. Nalley et al. (2016) reported hybrid rice adoption in Arkansas at only 0.8 percent of acreage in 2000 (the first year of release), 1.3 percent in 2003, and 40.8 percent in 2013. In ARMS responses, producers who are unaware or unfamiliar with a new technology have tended to misunderstand questions about its use. As the technology becomes more well-known over time, as in the case of hybrid rice adoption, this issue diminishes.

[20]A new herbicide-tolerant rice, Provisia, was released in 2017 and is expected to be planted on 75,000 to 100,000 rice acres in 2018, mainly in northeast Arkansas and Louisiana (Bennett, 2017).

[21]For example, soybeans are often planted in Southern regions as a pest control practice.

[22]Monoculture rice is defined as planting rice on the same acres for at least 3 consecutive years.

Hybrid Rice

Hybrid rice is a cross between two distantly related parents whose offspring benefit from hybrid vigor: hybrid rice has consistently higher yields than conventional rice varieties. The first hybrid rice variety for commercial cultivation was released by China in 1976 (Guo-hui and Long-ping, 2015). The first hybrid rice variety to be sold in the United States was XL6 by RiceTec in 2000. The first herbicide-tolerant (Clearfield) varieties, CL121 and CL141, were released in 2002, and the first hybrid with herbicide-tolerant traits was sold in 2003. Both public and private institutions have been involved with the development and improvement of hybrid rice (Andrews, 2017).

Although hybrid rice varieties produce higher yields, their milling quality is sometimes lower than that of conventional varieties (Lyman and Nalley, 2013). The revenue of rice producers is based on field (paddy) yield and, unlike other row crops, the outcome of postharvest processing or milling. More specifically, rice prices received by producers at the mill are directly affected by the milling quality of the (rough) rice delivered. The first hybrid variety released in the United States, XL6, had a high yield potential, but produced poor milling results that prevented it from being widely adopted (Nalley et al., 2016). Improvements in the milling quality of subsequent hybrid rice varieties have led to more widespread adoption of the technology.

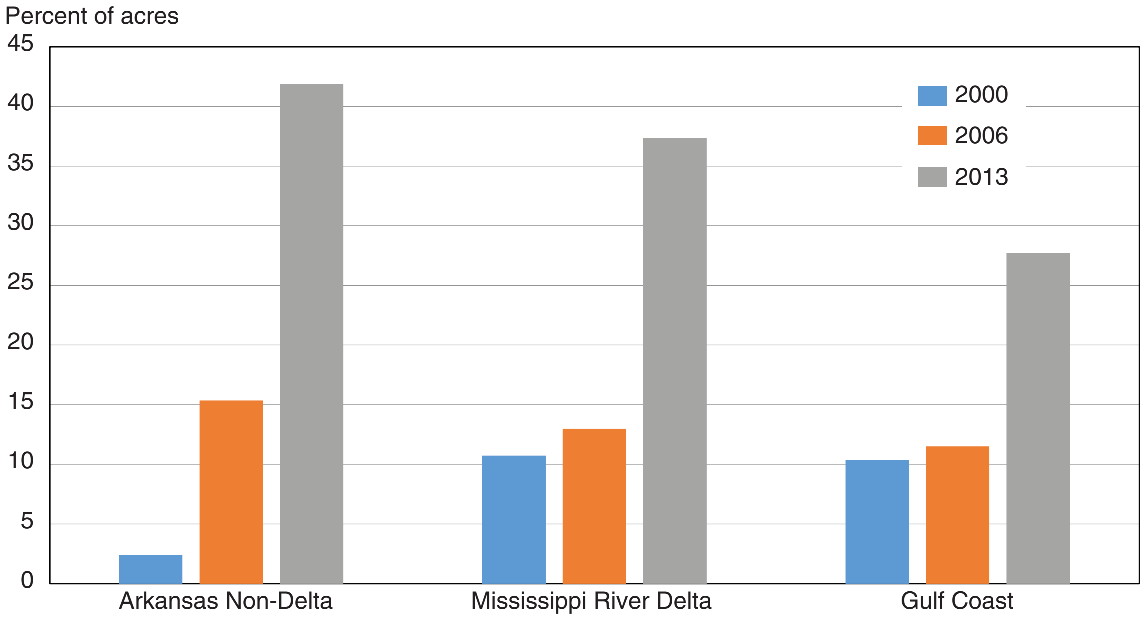
Although seed costs are higher, the adoption of hybrid seed varieties has significantly lowered seeding rates (seed planted per acre) on rice acreage, made possible by the extensive spreading, known as tillering, of hybrid rice. Research by Nalley et al. (2016) using data from Arkansas and Mississippi in 2003-13 found hybrid rice to be more profitable than conventional varieties. Greater (paddy) yields more than offset the lower milling rate and greater seed costs of hybrid rice. Given adoption rates and adjusted prices for milling differences, Nalley et al. (2016) estimated that hybrid rice adoption contributed over $839 million to the economies of Arkansas and Mississippi between 2003 and 2013.

In 2000-13, about 90 percent of California producers planted rice continuously, following rice with rice, and 90 percent planted monoculture rice. California rice fields are particularly well suited to rice production, but not necessarily to other crops because of poor drainage. Only in the Gulf Coast did the use of crop rotations increase. The percent of producers planting rice following rice fell from 30 percent to 13 percent of acres, and monoculture rice fell from 18 percent to 7 percent. Gulf Coast rice producers increased rotations with soybeans, another relatively profitable crop during this period.[23]

[23]In some areas of the South, mainly Louisiana, crawfish are grown on rice fields during the autumn and winter between crops of rice. This practice can reduce costs by spreading annual fixed costs, such as land costs, over two commodities.

Figure 10

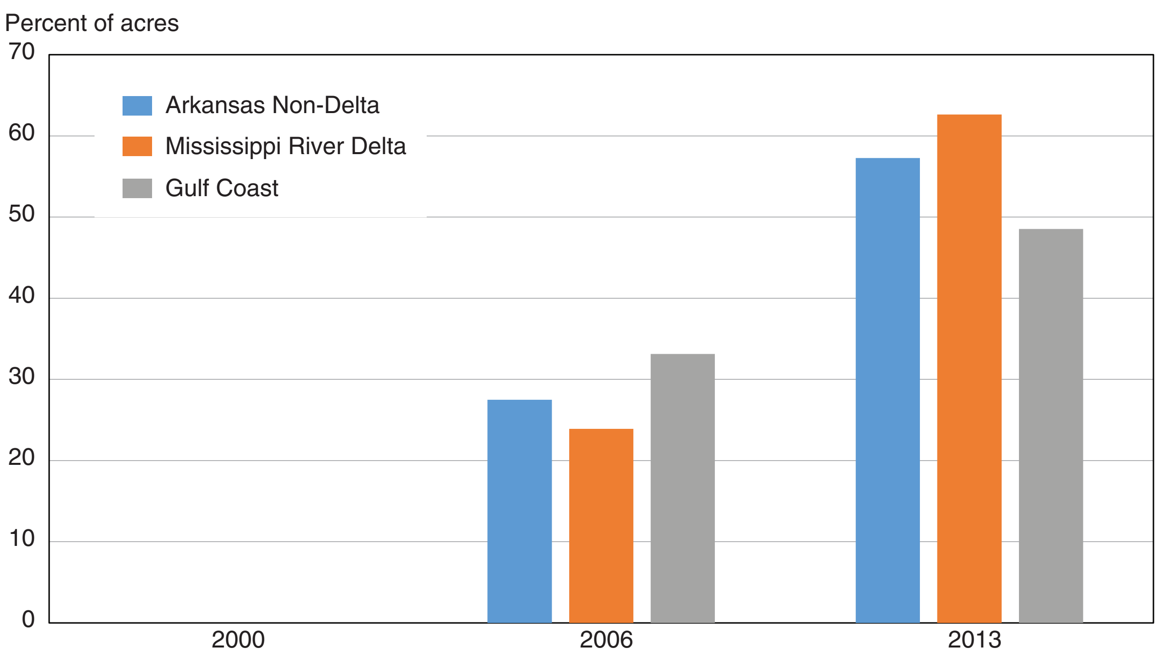
Rice acres planted with hybrid seed by region, 2000, 2006, and 2013



Note: Hybrid rice seed was first released in 2000. Reported use in the 2000 Agricultural Resource Management Survey appears considerably higher than in other sources (see Nalley et al., 2016). Hybrid rice was not available for California producers.
Source: USDA, National Agricultural Statistical Service and Economic Research Service, Agricultural Resource Management Survey.

Figure 11

Rice acres planted with herbicide-tolerant seed, 2000, 2006, and 2013, by region

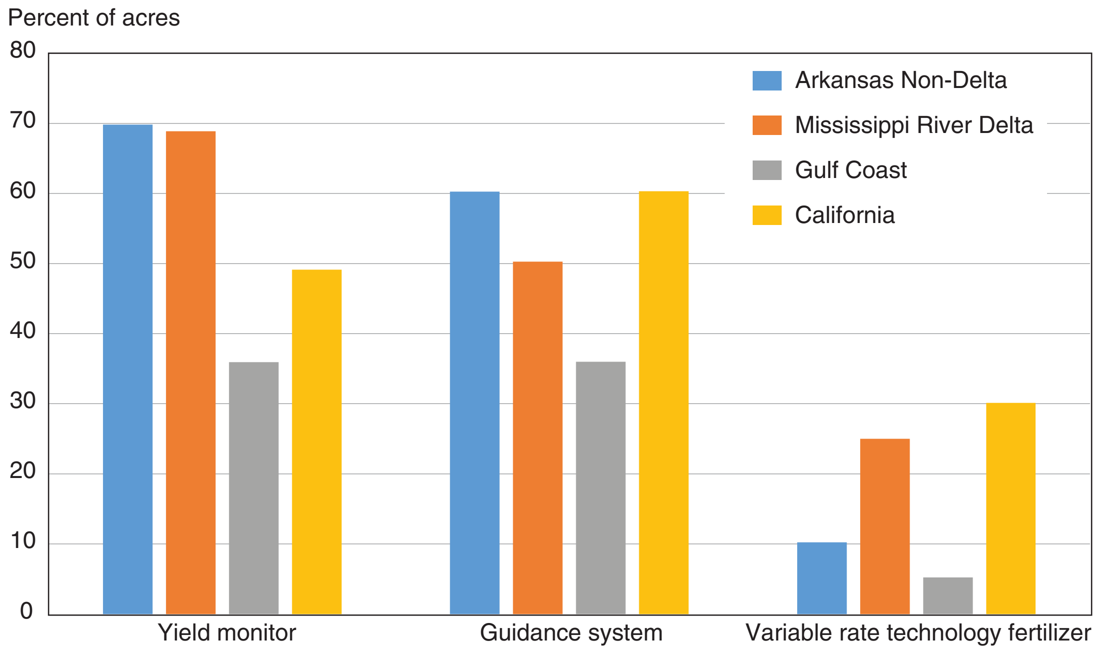


Note: Herbicide-tolerant seed was not available for California producers.
Source: USDA, National Agricultural Statistical Service and Economic Research Service, Agricultural Resource Management Survey.

The adoption of precision farming techniques among rice producers was particularly rapid during the 2000-13 period.[24] Yield monitors, used to measure variation across a field, were used on 58 percent of U.S. rice acres in 2013 (up from 18 percent in 2000) and on about 70 percent of rice acres in the Arkansas Non-Delta and Mississippi River Delta (fig. 12). Despite an increase in monitoring, the collected information was used to create a yield map for only 18 percent of rice acreage in 2013. Yield maps are a necessary step to fully utilize the spatial yield information in production decisions. Consequently, variable rate input applications have been slow to be adopted, with variable rate fertilizer applications in 2013 covering only 16 percent of U.S. rice acreage and covering the highest share in California at 30 percent. Despite the slow pace of change, adoption of these technologies in rice production has exceeded that for peanuts and cotton, the other major field crops grown in the South (Schimmelpfennig, 2016).

The most notable increase in precision farming technology adoption was in guidance systems. These systems guide/steer tractors and other self-propelled machines across fields, reducing operator fatigue. The systems also potentially reduce input use and increase yield by decreasing coverage gaps and overlaps and placing fertilizer for greater crop utilization. Rice producers rarely used guidance systems in 2000, but by 2013, this technology was employed on more than 50 percent of acreage. Adoption of guidance systems occurred across all rice regions, ranging in 2013 from 36 percent of rice acreage in the Gulf Coast to 60 percent in the Arkansas Non-Delta and in California (fig. 12). Rapid growth in the adoption of guidance systems for rice has mirrored that for other major U.S. field crops and is closely associated with farm size (Schimmelpfennig, 2016). The increasing size of rice farms may have contributed to growing guidance system adoption.

Figure 12
Rice acres using selected precision farming technologies by region, 2013



Source: USDA, National Agricultural Statistical Service and Economic Research Service, Agricultural Resource Management Survey.

[24]Precision farming includes a suite of information technologies, such as soil and yield maps using a global positioning system (GPS), GPS tractor or self-propelled machine guidance systems, and variable-rate input applicators that allow farm operators to fine-tune their production practices in an effort to reduce input costs and/or increase yields (Schimmelpfennig, 2016).

Two types of irrigation systems were predominant on rice fields in 2000, 2006, and 2013. The open discharge system was used on most rice acres, mainly in Southern regions, covering 78 percent of acres in 2000. Though still the key irrigation system, open discharge declined to 62 percent of acres in 2013. An open discharge system has only one point of discharge, typically from a well head or pump. This method is often used in conjunction with levees or dikes and land-forming (leveling or grading of land) to maintain an even water depth throughout the field. Portal-type rice irrigation systems use a ditch, gated pipe, or polyethylene (poly) pipe to direct water from a ditch to the field. These systems are used to direct water from irrigation district canals or farm ditches onto rice fields (Henry et al., 2013).

In California, portal irrigation increased from 57 percent of rice acreage in 2000 to 69 percent in 2013 as open discharge systems declined. In the Arkansas Non-Delta and Mississippi River Delta, the use of poly pipe, a relatively new system, increased to cover 10 percent or more of the 2013 rice acreage. A poly pipe system uses flexible, collapsible, plastic (polyethylene) tubes up to 18 inches in diameter, unrolled across each paddy (areas between the levees), along the side or through the field with holes punched or closeable gates installed to match furrow, border, or levee width. The tubing may be reused for more than 1 year, but it is inexpensive and single-season use is common.

Input Use

Changes in rice varietal and seeding technologies significantly reduced rice seeding rates.[25] From 2000 to 2013, the U.S. average rice seeding rate declined from 123 pounds to 84 pounds per acre. Seeding rates declined significantly in all regions except California, where no hybrid rice was planted. In the Southern regions, the adoption of hybrid seed varieties significantly lowered seeding rates on rice acreage. The absence of hybrid rice and aerial broadcasting of rice seed in California kept seeding rates much higher than in other regions. Average 2013 seeding rates in Southern regions were around 60 pounds per acre, compared with 166 pounds in California. (See appendix tables 9-12.)

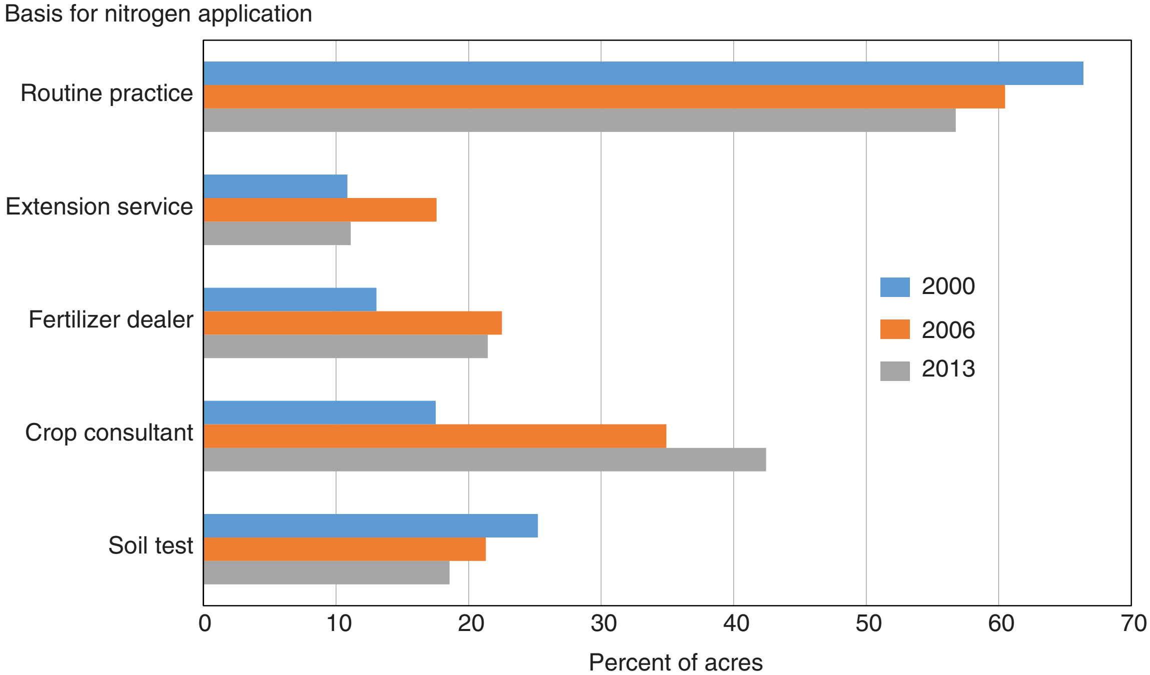
Nitrogen is the nutrient required by rice in the largest quantity and is typically a substantial input cost for rice producers. Profitable rice grain yields are very dependent on proper and effective nitrogen fertilizer management (Roberts et al., 2013). Nitrogen was applied to nearly all (95 percent or more) rice acres in each of 2000, 2006, and 2013. The share of rice acres receiving phosphorus increased over time from 58 percent in 2000 to 75 percent in 2013, while potassium was applied on about 50 percent of U.S. rice acreage each year. Phosphorus and potassium are usually applied according to soil test results. Nitrogen is often applied according to a desired or potential yield goal that is normal, or routine for the field.

The average rate of nitrogen applied on U.S. rice acres increased from 142 pounds per acre in 2000 to 184 pounds in 2006 (28 percent), while the average yield goal rose 13 percent.[26] Between 2006 and 2013, average nitrogen use on rice acres dropped 12 pounds per acre (6 percent), but the average yield goal increased 3 percent. More efficient use of nitrogen over time may have been affected by changes in factors that influence producer application decisions. In 2000-13, the use of crop consultants in making nitrogen application decisions increased from 18 to more than 40 percent of rice acres (fig. 13).

[25]Seeding rate refers to the units of rice seeded per unit of land.

[26]Yield goal is the rice yield that producers expected at planting, considering the inputs applied, cropping practices used, and typical yield achieved from the field.

Figure 13
Basis on which nitrogen applications were made to U.S. rice acreage 2000, 2006, and 2013



Source: USDA, National Agricultural Statistical Service and Economic Research Service, Agricultural Resource Management Survey.

In contrast, use of most other factors in making nitrogen application decisions declined over the period, including the most often reported basis for application decisions, routine practice.

Weed control is another major input cost to rice producers. In 2000, 2006, and 2013, herbicides were applied to about 95 percent of rice acreage. Increasingly, herbicide-tolerant varieties are planted to enable the broadcast spraying of specific herbicides to kill weeds such as red rice and other dry and aquatic weeds without harming the rice. Herbicide use per acre, measured by the number of treatments per treated acre, trended higher throughout 2000-13, from an average of 2.83 to 3.72 (table 3), with little variation across regions. Insecticides were used on about 30 percent of U.S. rice acres, with more variation across regions and years than for herbicides. The use of fungicides on U.S. rice acres grew significantly over the 2000-13 period, from about 22 percent to 50 percent of acreage. Rice sheath blight and blast are among the major diseases for which fungicides are applied to rice (Wamishe et al., 2013).

Table 3

Input use on U.S. rice acreage, 2000, 2006, and 2013

Item	2000	2006	2013
Seeding rate-pounds/acre	123	107	84
Fertilizer use-% of acres			
Nitrogen	99.43	95.41	96.83
Phosphorus	58.40	65.19	75.24
Potassium	46.74	53.09	53.68
Manure or compost	0.00	2.52	2.09
Fertilizer-pounds/treated acre			
Nitrogen	141.91	183.56	171.81
Phosphorus	52.07	52.65	53.62
Potassium	56.52	65.09	68.09
Nitrogen application basis-% of acres			
Soil or tissue test	25.23	21.31	18.56
Crop consultant	17.52	34.92	42.44
Fertilizer dealer	13.06	22.52	21.45
Extension service	10.86	17.59	11.10
Nitrogen or crop prices	6.70	8.38	5.48
Routine practice	66.38	60.48	56.75
Rice yield goal-cwt/planted acre	70.98	80.16	82.93
Chemical use-% of acres			
Herbicide	96.55	94.62	96.96
Insecticide	23.18	22.31	29.38
Fungicide	22.11	40.49	49.70
Biological	0.28	1.33	0.89
Chemicals-treatments/treated acre			
Herbicide	2.83	3.34	3.72
Insecticide	1.54	1.24	1.03
Fungicide	1.20	1.20	1.77
Number of tillage operations	2.94	2.76	2.71
Field operations-% of acres			
No-till[1]	2.57	6.51	2.10
Moldboard plow	9.52	5.83	6.17
Purchased water-% of acres	21.42	20.18	25.49
Water applied-inches/acre	43	34	34

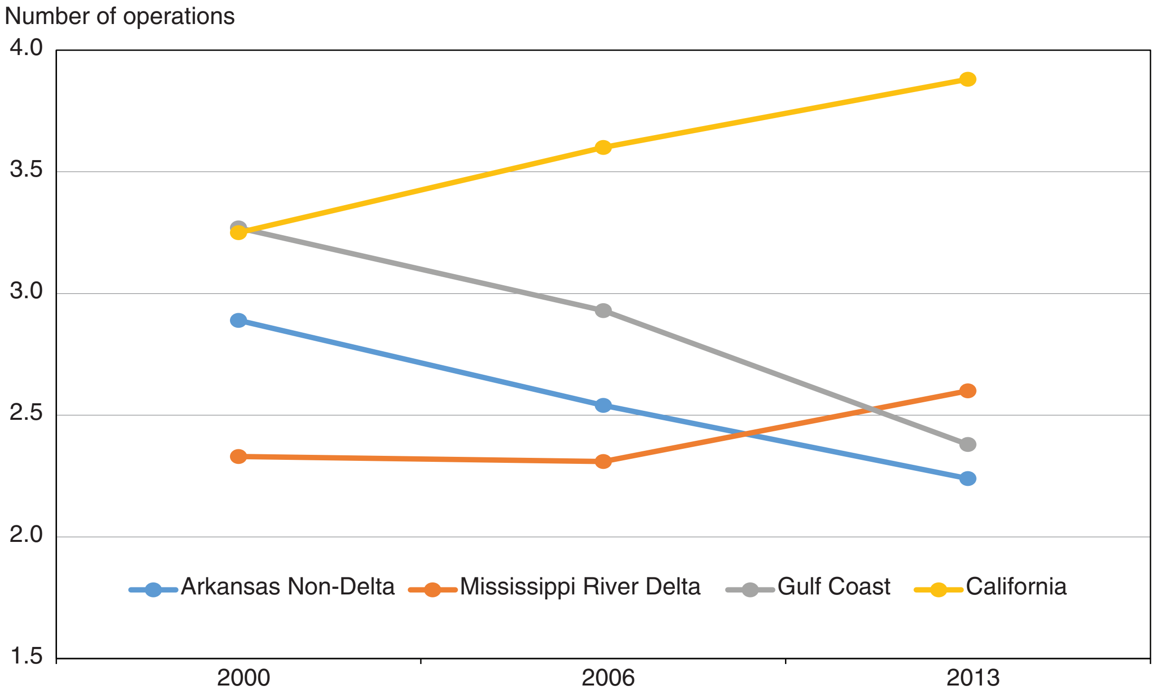
[1]A farm was defined as using no-till if no tillage operations were done and a no-till planter was used.

Source: Estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey.

Tillage operations contribute to the fuel cost incurred on rice farms, and reducing tillage is one strategy for lowering fuel costs. The average number of annual tillage operations conducted on U.S. rice acreage declined about 8 percent from 2000 to 2013, but changes in tillage practices varied significantly by region (fig. 14). The average number of tillage operations declined the most on Gulf Coast rice acreage, from 3.27 to 2.38 passes, about 27 percent. Likewise, tillage operations on Arkansas Non-Delta rice acreage fell from 2.89 to 2.24—22 percent. In the Mississippi River Delta, the number of tillage operations was flat between 2000 and 2006 at just over 2.30, but increased to 2.60 in 2013. California rice producers used the most tillage, averaging 3.88 passes in 2013, up from 3.25 in 2000. However, use of a moldboard plow[27] in California rice production fell from 42 percent of acres in 2000 to 15 percent in 2013, suggesting a decline in the intensity of tillage operations performed on California rice acreage.

No-till refers to planting into unplowed soil. It can reduce labor and machinery costs, reduce soil erosion, and improve the organic structure of the soil. No-till was done on 3 percent of U.S. rice acres in 2000, increased to about 7 percent in 2006, but declined to 2 percent by 2013.[28] No-till was most often used in the Arkansas Non-Delta and Mississippi River Delta during 2006, reaching close to 10 percent of acres in each region. However, by 2013, the use of no-till had fallen to around just 2 percent of rice acres in these regions. Only in the Gulf Coast did no-till increase over 2000-13 and, even there, had reached only 4 percent by 2013.[29]

Figure 14
Number of tillage operations conducted on rice acreage by region, 2000, 2006, and 2013



Source: USDA, National Agricultural Statistical Service and Economic Research Service, Agricultural Resource Management Survey.

Average water application on U.S. rice acreage declined from 43 inches per acre in 2000 to 34 inches in 2006 and 2013. Water use declined on rice acres in all regions in 2000-13 except California (fig. 15). The largest decline occurred in the Arkansas Non-Delta and Mississippi River Delta regions

[27]A moldboard plow has a curved metal plate that turns over the soil, burying the soil surface including residue from the previous crop.

[28]No-till was indicated when no tillage passes were done and a no-till planter was used.

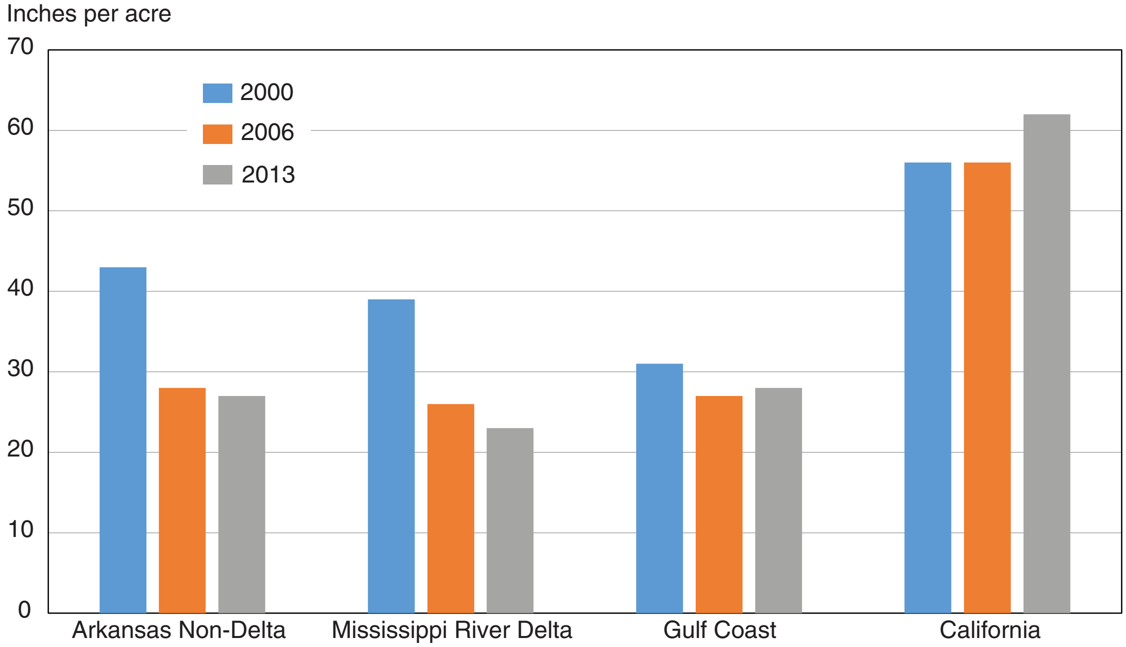
[29]With such limited use of no-till on rice acreage, the changes observed in 2000-13 may not be significant.

where inches applied fell around 40 percent. Some of this efficiency gain may be due to changes in irrigation technologies and other practices (such as seeding) used in these regions.

California rice producers have the highest water use among rice-producing regions, about double that in other regions. California is characterized by higher water use for rice production because most of the water used is purchased from irrigation districts and flows via gravity over rice fields until being drained for use on other down-slope farms. Most water use in Southern regions is pumped from farm wells or surface sources and remains on rice fields through a system of levees.

Figure 15

Annual water usage on rice acreage by region, 2000, 2006, and 2013



Source: USDA, National Agricultural Statistical Service and Economic Research Service, Agricultural Resource Management Survey.

Production Costs

Average U.S. rice costs of production per planted acre, in nominal dollars, are displayed in table 4. Most operating and allocated overhead costs increase with successive survey years. (See box "Measuring Production Costs.") Operating costs per acre for U.S. rice producers rose from $284 in 2000 to $603 in 2013, more than 110 percent. Much of this increase was from higher fertilizer and chemical costs, up 200 and 108 percent, respectively. The adoption of hybrid and herbicide-tolerant seed varieties was reflected in higher seed costs, which were up more than 200 percent between 2000 and 2013.

Although not to the same extent as operating costs, allocated overhead costs per planted acre also increased in 2000-13. Total allocated overhead costs were up 40 percent, led mainly by capital and unpaid labor costs that were over 50 percent higher in 2013 than in 2000. Average land costs for rice production rose about 47 percent during this time. Total costs per acre for U.S. rice production from 2000 to 2013 increased from $579 to $1,016, about 76 percent.

Table 4

U.S. rice production costs per planted acre, 2000, 2006, and 2013

Item	2000	2006	2013
	Dollars per planted acre		
Operating costs:			
Seed	23.31	36.75	84.39
Fertilizer	46.66	60.49	138.82
Chemicals	49.25	65.96	102.41
Custom operations[1]	68.69	63.51	109.74
Fuel, lube, and electricity[2]	57.84	95.90	106.07
Repairs	19.16	26.40	45.25
Purchased irrigation water[3]	11.12	10.36	15.57
Interest on operating capital	7.77	8.11	0.27
Total, operating costs	283.80	366.48	602.52
Allocated overhead:			
Hired labor	26.28	18.42	26.83
Opportunity cost of unpaid labor	43.55	41.23	66.62
Capital recovery of machinery and equipment	79.42	96.80	119.65
Opportunity cost of land (rental rate)	108.04	118.31	158.54
Taxes and insurance	15.69	15.49	16.01
General farm overhead	22.11	24.24	26.21
Total, allocated overhead	295.09	314.49	413.86
Total costs listed	578.89	680.97	1,016.38

[1]Includes commercial drying cost.
[2]Irrigating and farm drying costs of rice are part of the fuel, repairs, capital, and labor costs.
[3]Water purchased from off-farm sources, such as an irrigation district.
Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.

Measuring Production Costs

Rice production costs are measured using the methods adopted by USDA in the annual reporting of commodity costs and returns (USDA, ERS, 2017a). Production costs are "economic costs" measured as the sum of operating and allocated overhead costs. Operating costs include those for seed, fertilizer, chemicals, custom operations, fuel, repairs, purchased irrigation water, and operating capital. Fuel cost includes the cost of electricity and other fuels used for tillage and other field operations, to irrigate rice fields, and to dry rice. Commercial drying costs for rice are included among the custom operations. Other costs of field operations, irrigation, and drying rice are part of repairs, capital, and labor costs. Purchased irrigation water is that purchased from off-farm sources, such as an irrigation district.

Allocated overhead costs are for hired and unpaid labor, capital, land, general farm overhead, and taxes and insurance. Opportunity costs are charged for unpaid labor, capital, and land. The amount of unpaid labor used in rice production is charged at a wage rate that reflects what farm operators earn in off-farm employment. Land is charged at the rate at which rice acres are cash rented. The capital recovery approach is used to estimate capital costs, comprising a replacement cost of the capital assets consumed during the production process, along with the opportunity cost of the unconsumed capital charged at an estimate of the longrun rate of return to farm assets.

Total production costs per planted acre increased over time in each region, although the rate of growth varied among regions (fig. 16). Per acre costs increased the fastest in the Arkansas Non-Delta and Mississippi River Delta, 89 and 95 percent respectively, between 2000 and 2013.[30] Total costs were highest in California during all years, but costs grew by only 56 percent during this period. In 2000, the Gulf Coast region had the highest production costs of all Southern rice regions, but average total costs in the Gulf Coast increased only 50 percent from 2000 to 2013. By 2013, average total production costs in the Gulf Coast approximated those of the Arkansas Non-Delta and the Mississippi River Delta (fig. 16).[31]

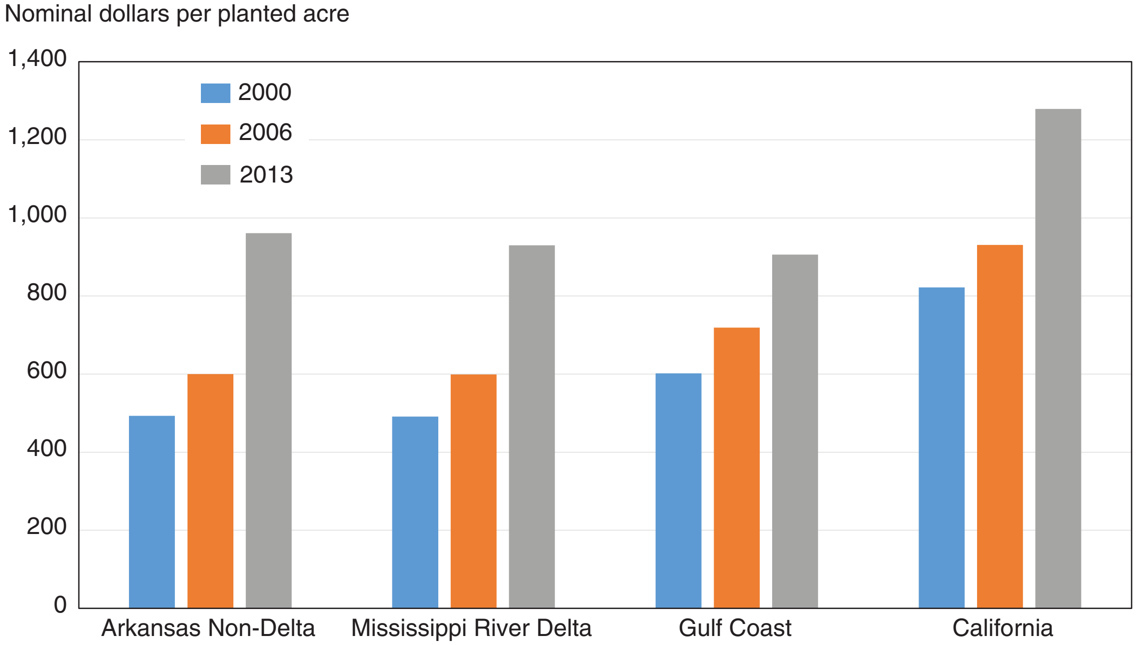
Much higher production costs in 2000-13 among Southern rice growers were due primarily to the rapid growth in costs for operating inputs. Total operating input costs per acre grew more than 150 percent in the Arkansas Non-Delta, 130 percent in the Mississippi River Delta, and nearly 90 percent in the Gulf Coast. The increasing adoption of hybrid and herbicide-tolerant seed varieties was instrumental in boosting the cost of rice production in the South. Seed costs per acre in the Arkansas Non-Delta and Mississippi River Delta moved higher by more than 370 percent, while fertilizer costs increased more than 200 percent. In contrast, operating costs per acre in California, where these new seed varieties were not available, increased only 71 percent, and seed costs merely doubled. High costs in California, relative to other regions, were primarily due to land costs that averaged more than $300 per acre in 2013, compared with $83 per acre in the Gulf Coast.[32]

[30]Insufficient data about medium-grain rice production in Southern regions meant that cost differences by type of rice in each region could not be examined.

[31]Detailed production costs for each region are found online. (See USDA, ERS (2017a).)

[32]Cash rental rates for land in rice production are used to determine the opportunity cost of land. This method assumes that if the grower did not produce rice, the landowner would have rented the land to another rice producer.

Figure 16
Rice production costs per acre by region, 2000, 2006, and 2013



Source: USDA, National Agricultural Statistical Service and Economic Research Service, Agricultural Resource Management Survey.

Yields and Unit Costs

Technological advancement in rice production had a significant effect on rice yields in 2000-13. To normalize rice yields, U.S. yields per planted acre and yields in each region were measured as 5-year averages around each survey year, including the 2 preceding and 2 following years, along with the survey yield in each year, 2000, 2006, and 2013.[33] This measure counters the effect that annual yield variation has on the characterization of yield changes over time. After normalization, the U.S. average planted acre yield increased 22 percent in 2000-13, from 65 to 79 cwt,[34] amounting to an average annual increase of 1.6 percent.

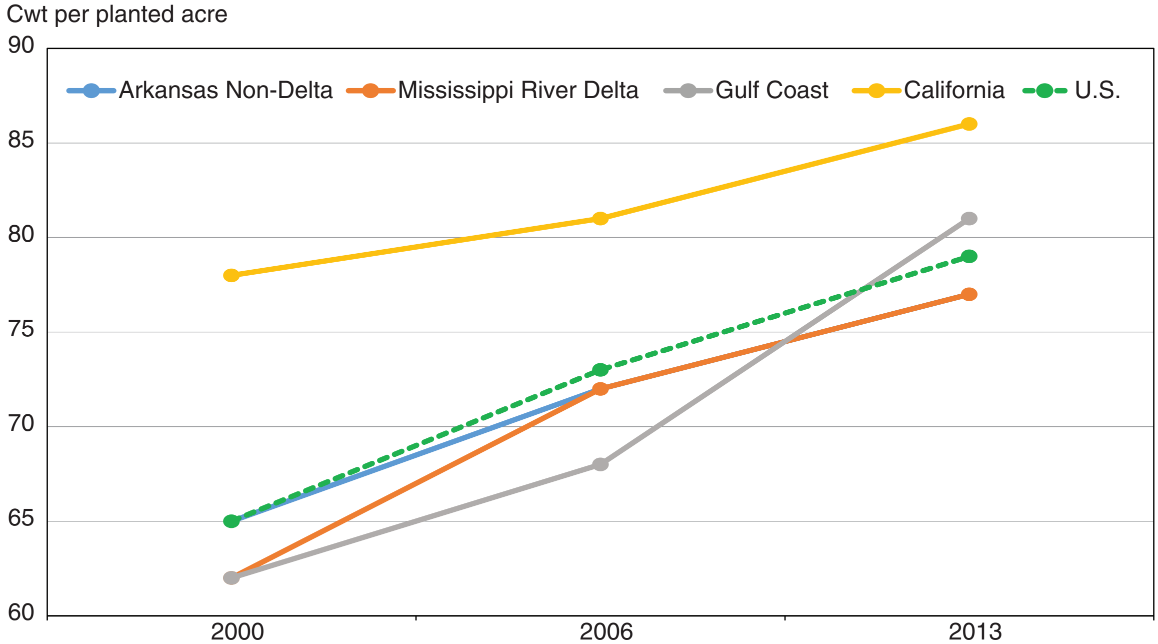
The largest increase in rice yields was in the Southern regions where hybrid and herbicide-tolerant rice were adopted. In the Arkansas Non-Delta, average rice yield per planted acre increased from 65 to 77 cwt per acre, 18 percent (fig. 17). Mississippi River Delta and Gulf Coast rice yields increased 24 and 31 percent, respectively. Hybrid and herbicide-tolerant rice varieties were not available in California, where average yields rose only 10 percent. Average rice yields in California significantly exceeded those in the other regions during each year, but the yield advantage diminished over time, particularly compared with the Gulf Coast. The average Gulf Coast rice yield was 62 cwt per acre in

[33]U.S. and regional yields are taken from the Commodity Costs and Returns data product (USDA, ERS, 2017a). Yields from this source are per planted acre. Planted acre yields are used in order to match the costs per planted acre.

[34]Official USDA data (USDA, NASS, 2017b) on U.S. rice yields also indicate an average yield per planted acre increase of 22 percent from 2000 to 2013.

2000, 79 percent of the California yield. By 2013, the average Gulf Coast yield was 81 cwt per acre, 94 percent of the average yield in California.[35]

Figure 17
Rice yield per planted acre, 2000, 2006, and 2013, United States and by region



Notes: cwt = hundredweight. Average rice yields are identical in the Arkansas Non-Delta and Mississippi River Delta during 2006 and 2013, so the lines overlap.
Source: Estimated as 5-year moving averages around each year using data from the USDA, ERS Commodity Costs and Returns data product.

U.S. rice total costs per cwt in nominal dollars, computed using the normalized yields in each year, increased 43 percent (about 3 percent per year) from 2000 to 2013 (table 5). Among the regions, nominal production costs increased the least in the Gulf Coast, 15 percent from 2000 to 2013 (about 1.1 percent per year). Unit cost growth in the Gulf Coast was kept down by a combination of relatively slow growth in per-acre production costs, and relatively fast growth in rice yields (figs. 16 and 17). The other regions saw unit production costs rise by at least 50 percent during 2000-13, with an average annual growth rate of 3.5 percent or more. (See box "Rice Yield Trends by State in 2000-13.")

[35]U.S. rice yields and yields in each region are weighted by the acreage of each type of rice—long-, medium-, and short-grain. Of the most widespread types, long- and medium-grain rice, medium-grain rice has higher yields, all else being equal. However, between 2000 and 2013 the yield differential between medium- and long-grain rice narrowed because of the new technologies for long-grain rice. Over this period, the U.S. average long-grain rice yield per planted acre increased 27 percent, while the average yield of medium-grain rice rose only 14 percent (USDA, NASS, 2017b).

Table 5

U.S. and regional rice costs per cwt, nominal and 2013 dollars, by region, 2000, 2006, and 2013

Item	2000	2006	2013
Total costs (nominal $)	*Dollars per cwt*		
U.S.	8.97	9.32	12.82
Arkansas Non-Delta	7.60	8.32	12.52
Mississippi River Delta	7.97	8.30	12.08
Gulf Coast	9.79	10.51	11.24
California	10.53	13.61	15.87
Total costs (2013 $)[1]			
U.S.	17.95	14.52	12.82
Arkansas Non-Delta	15.20	12.97	12.52
Mississippi River Delta	15.94	12.93	12.08
Gulf Coast	19.58	16.38	11.24
California	21.07	17.86	15.87

[1]Nominal costs were deflated to 2013 dollars using the National Agricultural Statistics Service prices paid index for production items.

Note: cwt = hundredweight.

Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.

Rice Yield Trends by State in 2000-13

Rice yields used to compute the unit costs are based on those collected with the cost-of-production data each year rice was surveyed in ARMS (2000, 2006, and 2013). Yields between surveys are estimated by indexing the survey yields by State crop yields (USDA, NASS, 2017b). Therefore, State yield trends are an important component of unit cost estimates and the measure of productivity change over time.

Annual yield trends by State during 2000 to 2013 show that average yields increased at the greatest rate in States of the Gulf Coast region, Louisiana and Texas, particularly in 2006-13. During 2000 to 2013, rice yields trended higher at a rate of 1.94 percent per year in Louisiana and 1.23 percent per year in Texas. During 2006 to 2013, Louisiana and Texas were the only States with rice yield trends significantly different from zero, with yields trending higher at an annual average rate of 2.40 and 2.16 percent, respectively.

	Annual percentage change in rice yield during time period		
State	2000 to 2013	2000 to 2006	2006 to 2013
Arkansas	1.06*	1.91*	1.00
California	0.39	-0.88	0.72
Louisiana	1.94*	1.97*	2.40*
Mississippi	1.01*	1.85*	0.37
Missouri	1.17*	2.32*	0.75
Texas	1.23*	0.34	2.16*

*Average yield trend is statistically different from zero at the 5-percent level.

Source: USDA, Economic Research Service estimated using data from U.S. Department of Agriculture, National Agricultural Statistics Service, Crop Production data product.

Productivity Change

Productivity change can be described as the change in inputs needed to produce a given level of output. This was measured for rice farming using the difference in the growth of input prices and production costs over time (McBride and Key, 2013; Fuglie et al., 2007). [36] Nominal production costs were adjusted by changes in farm input price levels to reflect costs each year in real terms, expressed as 2013 dollars. The NASS prices-paid index for farm production items, a broad indicator of price-level changes for farm inputs, was used to adjust, or deflate, the costs. A comparison of nominal rice production costs per cwt and the prices-paid index for farm production items, along with the trend of each, is shown in figure 18. Both data series increased over time, but input prices increased faster than production costs. The price index increased by an average annual rate of 4.7 percent, compared with 2.6 percent for production costs. This difference implies that productivity growth occurred in rice production.

Deflated, or real, production costs were normalized using 5-year average yields[37] around each survey year to develop measures of productivity change between each survey year, 2000, 2006, and 2013 expressed in 2013 dollars.[38] Total production costs among U.S. rice producers expressed in 2013 dollars declined from $17.95 per cwt in 2000 to $14.52 in 2006 and then to $12.82 in 2013 (table 5). This change amounts to a total productivity gain of 29 percent, or just above 2 percent per year over the period.[39] Productivity growth was nearly the same over the two periods, 2000-06 and 2006-13, but the change in productivity varied by region (fig. 19).

Productivity growth in rice production in 2000 to 2013 was greatest in the Gulf Coast region at 43 percent, or about 3 percent per year, much higher than the other regions. Most of this growth occurred in 2006 to 2013, with 31 percent total growth averaging about 6.2 percent per year. Total productivity growth was 25 percent in California, 2.1 percent per year. Productivity growth in the Arkansas Non-Delta was 18 percent (about 1.3 percent per year) and in the Mississippi River Delta was 24 percent (about 1.7 percent per year). With the exception of the Gulf Coast, productivity growth was greatest during 2000 to 2006, slowing somewhat between 2006 and 2013.

[36]McBride and Key (2013) used this technique to show productivity change over time in U.S. hog production. Fuglie et al. (2007) show that the growing divergence between farm input and farm product prices closely parallels growth in total factor productivity. Productivity growth allowed more output to be produced from the same amount of inputs, reducing the average unit cost of production.

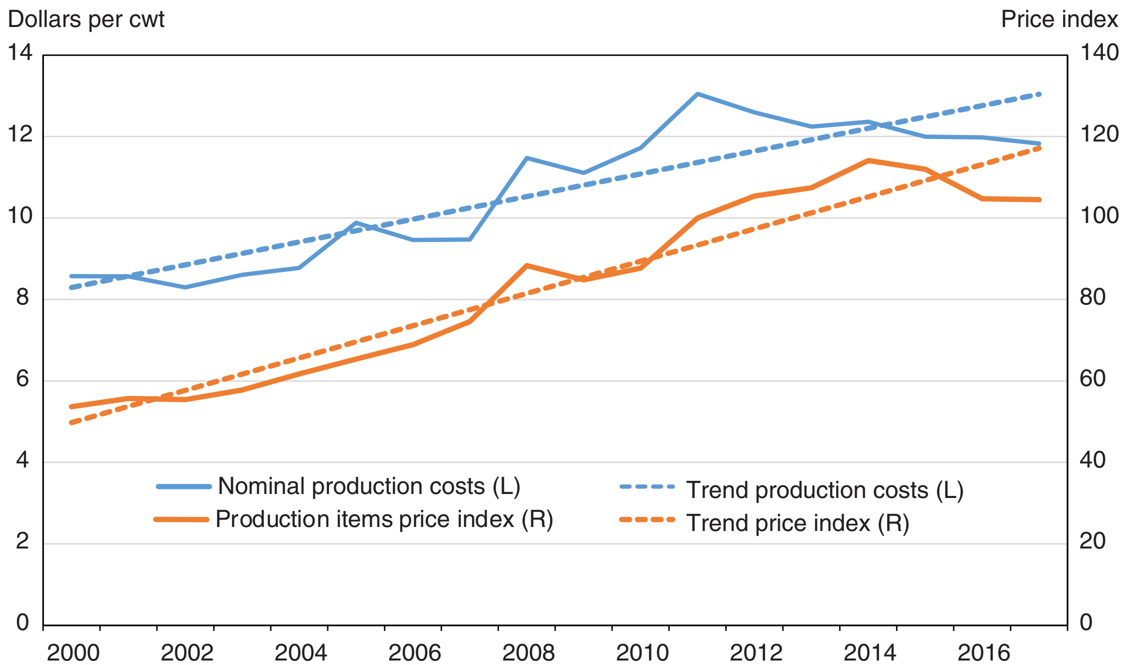
[37]Yields and production costs are per planted acre.

[38]Productivity is commonly defined as the ratio of a volume measure of output to a volume measure of input use. While there is no disagreement on this general notion, the productivity literature and its various applications reveal that there is neither a unique purpose for, nor a single measure of, productivity. Among the various measures, the choice often depends on the purpose of productivity measurement and the availability of data. Real cost savings is regarded as a pragmatic way to measure productivity change (OECD, 2001).

[39]The annual average rate of productivity change was measured as the total rate of productivity change over the period divided by the number of years in the period.

Figure 18

Rice production costs and farm input price index, 2000-17

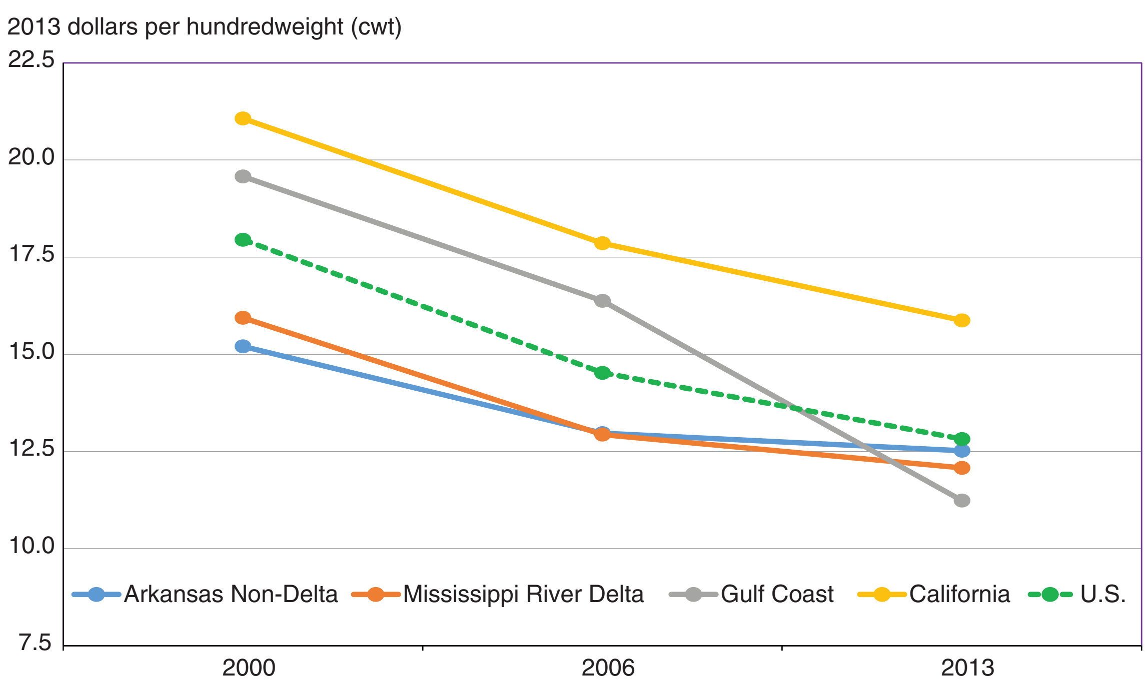


Note: L = left axis. R = right axis.

Source: Estimated from USDA, Economic Research Service, Commodity Costs and Returns data product and National Agricultural Statistics Service Agricultural Prices.

Figure 19

Deflated average production costs of rice, 2000, 2006, 2013, United States and by region



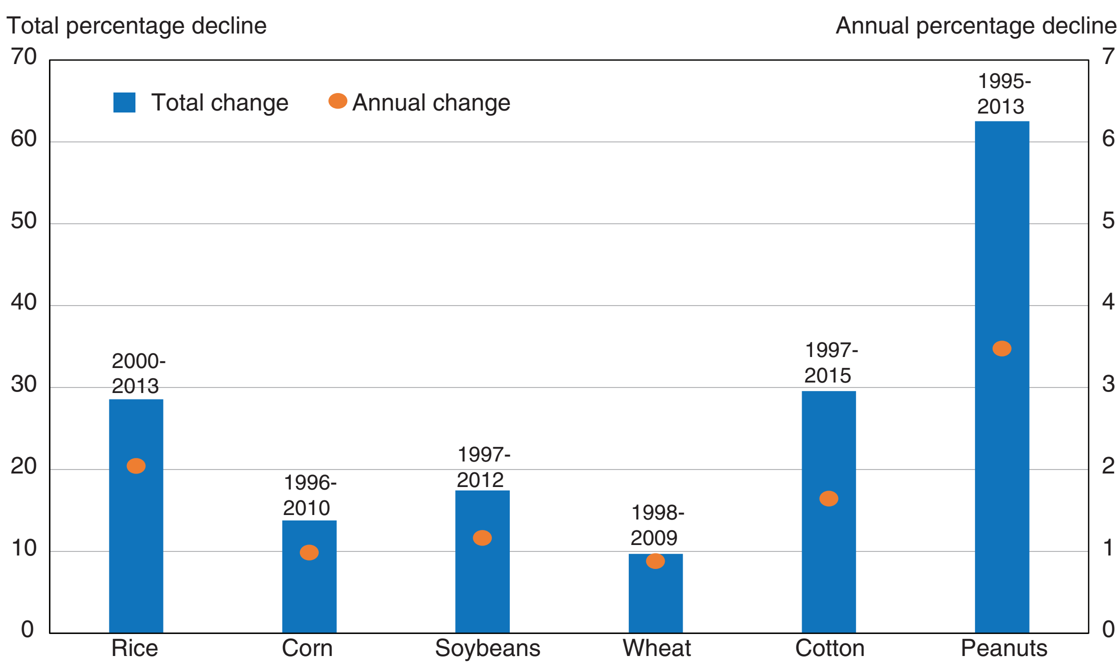
Source: USDA, National Agricultural Statistics Service and USDA, Economic Research Service, estimated from the Agricultural Resource Management Survey.

To put into context the productivity growth for rice, we compared it with that of other major field crops over roughly the same timeframe. Using the most recent ARMS data for each crop in comparison with earlier data, we compared productivity growth for rice with that for five other field crops (fig. 20). Productivity growth, measured as the change in deflated unit production costs[40] between surveys (ARMS), is presented for the total period and computed on an annual basis over the period measured for each crop. Peanut farming saw the greatest productivity growth with real production costs declining more than 60 percent between 1995 and 2013 (an annual average of 3.5 percent).[41] Among other crops, the annual rate of productivity growth for rice of 2.1 percent was highest, followed by cotton (1.6 percent), soybeans (1.2 percent), corn (1.0 percent), and wheat (0.9 percent).

Economies of Size

Economies of size exist if unit costs decline as the size of operation increases. The existence of economies of size has been shown to be a driving force behind changes in operation size and productivity over time (McBride and Key, 2013). To evaluate economies of size in rice production, unit costs from the 2000 and 2013 ARMS data were summarized for selected size groups, measured by the number of rice acres per farm. Because of the different cost structures in Southern rice-producing regions and California, we analyzed economies of size separately for these distinct areas.

Figure 20
Percentage decline in deflated unit production costs of major field crops, 1990s-2010s, various years



Source: USDA, National Agricultural Statistics Service and Economic Research Service, estimated from the Agricultural Resource Management Survey, years indicated for each crop.

[40]Unit production costs refers to the unit of output measurement for each commodity; bushels, cwt, or pounds.

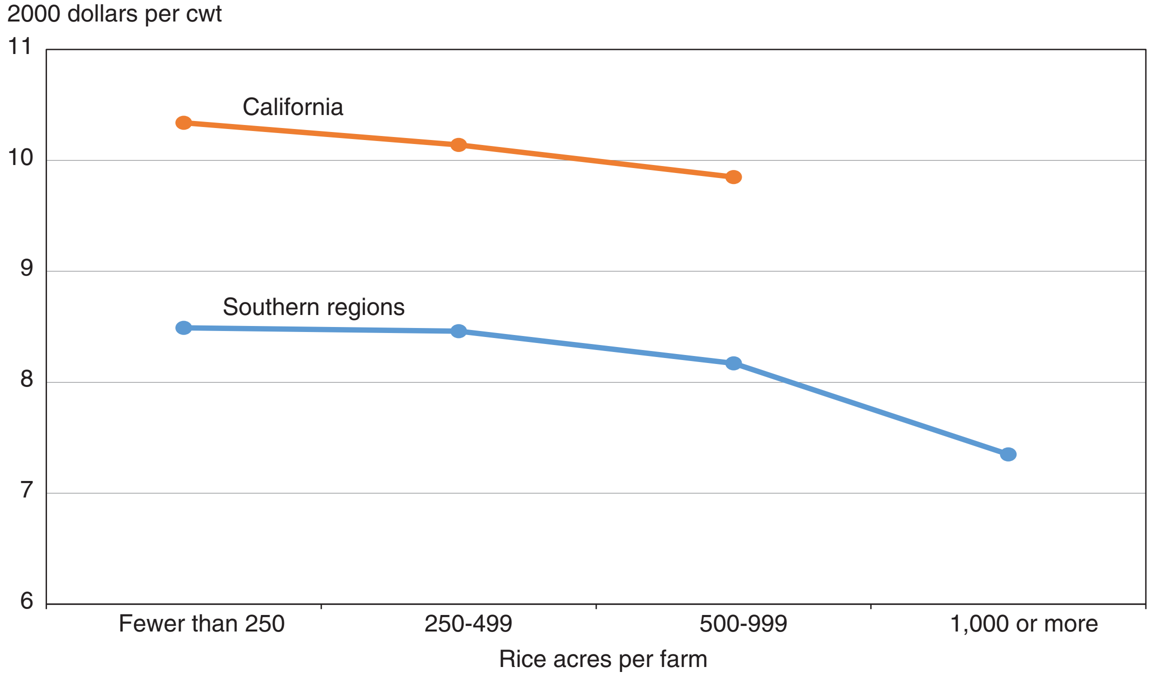
[41]During this timeframe, the Federal Government overhauled its farm program for peanuts as peanut producer quotas were bought out by the Government. A more market-oriented system, similar to that for other major field crops, was instituted for peanuts (Dohlman et al., 2009).

In Southern rice regions, the Arkansas Non-Delta, Mississippi River Delta, and Gulf Coast, unit production costs declined at an increasing rate with successive size groups in 2000 (fig. 21). Farms in the two smallest size groups had virtually identical average costs, but average costs declined by 3 percent for farms with 500-999 acres and an additional 10 percent for farms with 1,000 or more acres. Similarly in 2013, unit production costs were much the same for operations in size groups with less than 750 rice acres. Not until operation sizes reached 750 rice acres were economies of size evident in 2013 (fig. 22). Costs declined continuously with successive size groups beyond the size group of farms with 500-750 rice acres, declining at a decreasing rate. Compared with operations in the preceding size group, average unit costs in 2013 fell 5.2 percent for the 750-999 acre group, 2.6 percent for the 1,000-1,249 acre group, and 0.7 percent for the 1,250 or more acre group.

California rice producers have higher costs for medium-grain rice production than the primarily long-grain rice produced in the South, but the value of California medium-grain rice is much higher. The average size of California rice farms is also much smaller than in the South. Average California rice production costs in 2000 declined modestly for successive size groups, about 2 percent from the smallest to the mid-size group and nearly 3 percent from the mid-size to the largest (500 acres or more) size group (fig. 21). In 2013, nearly all economies of size were achieved on California farms with 250-499 rice acres (fig. 22). Farms with 250-499 acres had production costs that were 4.2 percent less than those of farms with fewer than 250 acres. However, in size groups larger than 250-499 acres, average unit costs for rice production on California farms did not decline much more.

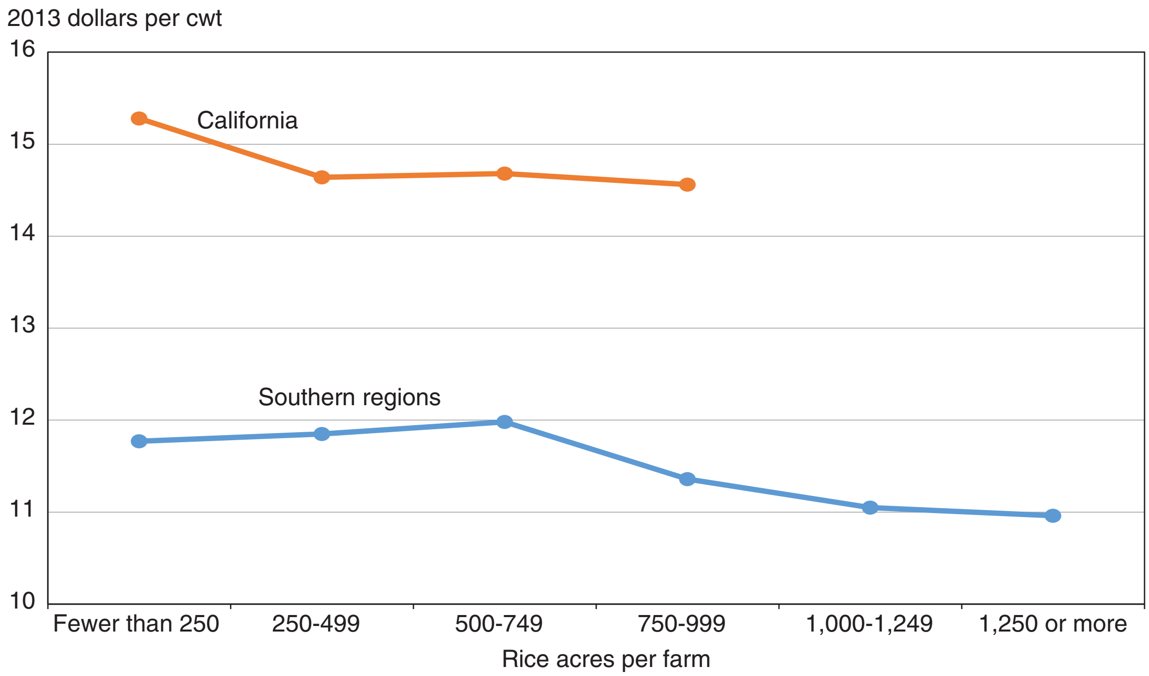
The distribution of farms and acreage by size of operation provides an indicator of the potential for rice farms in each area to further exploit economies of size. For example, in 2013, only 13 percent of California rice farms (accounting for only 2 percent of rice acres) had fewer than 250 rice acres. Since most size-economies in California rice production were achieved at 250-499 acres, the ability to exploit additional economies of size in California rice production appears to be severely limited. In contrast, costs in Southern rice-producing regions trended downward after the 500-749 acreage size group. Of rice producers in the South, 48 percent (with 20 percent of rice acreage) have 500-749 or fewer rice acres. In total, 71 percent of Southern rice farms (with 41 percent of rice acreage) are smaller than those in the largest group (1,250 or more rice acres). The high share of smaller farms suggests that Southern rice producers have the potential to further exploit size economies, and the higher cost savings on larger farms in the South (compared with California) suggest this potential is much greater than that among California producers.

Figure 21
Production costs by size of operation and region, 2000



Note: Southern regions include the Arkansas Non-Delta, Mississippi River Delta, and Gulf Coast.
Source: USDA, National Agricultural Statistics Service and Economic Research Service, 2000 Agricultural Resource Management Survey.

Figure 22
Production costs by size of operation and region, 2013



Note: Southern regions include the Arkansas Non-Delta, Mississippi River Delta, and Gulf Coast.
Source: USDA, National Agricultural Statistics Service and Economic Research Service, 2013 Agricultural Resource Management Survey.

Implications of Structural and Productivity Change

Structural and productivity change on U.S. rice farms has enhanced national economic efficiency by freeing up land, labor, capital, and other resources for the production of other goods and services. These changes help keep U.S. rice competitive in comparison with other domestic crops, as well as in some global rice markets. (See box "A Primer on Rice Marketing and Use.")

Prices

A main benefit of productivity gain is its effect on prices. Productivity gains that lower farm production costs will generally lower farm prices. In turn, lower farm prices could lead to lower consumer prices if processors and retailers pass cost savings on to consumers. The question is *have productivity gains in rice production been reflected in prices?*

One way to address this question is to estimate how much rice prices would have increased had there been no change in farm productivity, which is possible by examining input prices. In a competitive market, the price received by farmers for rice equals the total cost of inputs, including a "normal" rate of return on resource owners' equity. If the normal rate of return is constant over time and farm productivity does not change, rice prices can be expected to parallel input prices.

Because rice prices and costs differ significantly for Southern long- and medium-grain and California medium-grain varieties, input and output price comparisons are made separately for each type of rice. Input price levels between 1990 and 2016 are measured by an aggregate input price index that reflects inputs used in rice production. The price index is a weighted sum of input prices used in rice production, using the average, inflation-adjusted costs of rice inputs from each survey year (2000, 2006, 2013) as the weights.[42] Input prices are indicated by the NASS price index for each production item (USDA, NASS, 2017a).

For long-grain rice, the weighted input price index increased steadily over 1990-2016, with an average annual growth rate of about 4 percent (fig. 23). Because rice prices should reflect farm production costs, farm prices for long-grain rice would be expected to increase about 4 percent per year in the absence of productivity gains.[43] Figure 23 also shows farm prices for long-grain rice during the same 1990-2016 period. Although much more variable than input prices, the trend in long-grain rice prices parallels that of input prices, but at slightly lower rate. Long-grain rice prices trended higher at an annual rate of 2.7 percent, compared with 4 percent for input prices. All other factors being equal, slower growth in farm rice prices compared with input prices can be attributed to farm productivity gains.[44]

[42]Weights are the average cost share for inputs used in rice production in the 2000, 2006, and 2013 surveys, and are estimated separately for long- and medium-grain rice. Input cost weights are greatest for land, capital, fuel, and fertilizer, although their relative shares varied for each type of rice.

[43]The determination of farm prices received for rice is discussed in the box "A Primer on Rice Marketing and Use."

[44]Other factors that could affect the growth rate of rice prices are the increased adoption of hybrid rice and rice exports. Lower prices are received for hybrid rice if the milling quality is less. Thus, the growing adoption of hybrid rice could affect the growth rate of long-grain rice prices. Changes in the export demand for rice may also affect the growth rate of rice prices.

A Primer on Rice Marketing and Use

Five different byproducts can be derived from the rough rice produced on farms: hulls, bran, brown rice, whole-kernel (head) milled rice, and brokens (broken-kernel milled rice). Broken kernels are further categorized into secondheads, used in flour production, and brewers, used in beer and pet food production. The first stage of milling removes the hull, producing brown rice that can be cooked and consumed. The next stage of milling removes the bran layer, leaving milled white rice. Prior to milling, rough rice may be parboiled, a process of soaking rice in water and steaming it under intense pressure. Parboiling makes the rice less likely to break during milling and pushes nutrients from the bran layer into the kernel. Parboiled rice typically sells at a premium.

On average, every 100 pounds of rough rice yields about 70 pounds of whole-kernel milled rice, 10 pounds of bran, and 20 pounds of hull (Hardke, 2012). Milled rice is composed of head rice (those kernels retaining three-fourths or more of their original length) and broken kernels (brokens). Head rice yield (HRY) is the mass of head rice expressed as a percentage of the original rough rice mass and can vary from 0 (all brokens) to a maximum of 70 (no brokens). Milling quality is often expressed as the ratio of HRY to MRY (milled rice yield). Several factors affect grain quality, including type of rice planted, disease, insects, harvest moisture content, nighttime air temperature, and postharvest handling and storage (Hardke, 2012). The price that rice producers are quoted is based on an industry standard rate of 55 percent HRY and 70 percent MRY, or 55/70. When a producer's rice is milled at a higher or lower rate than the industry standard, an adjustment is made to the producer price received (Nalley et al., 2016).

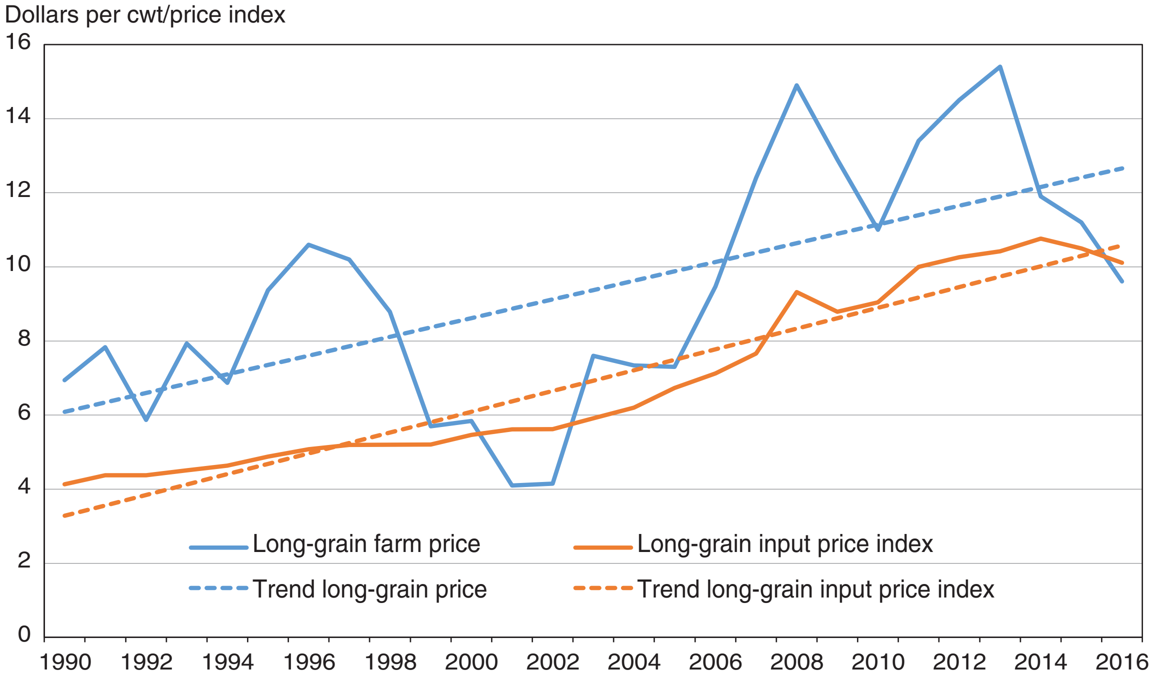
Domestic uses of rice include food for human consumption (direct food use and in processed foods), beer, and pet food. Direct food use accounts for about two-thirds of total domestic rice disappearance (including imports). Use in processed foods—primarily flavored rice mixes, cereal, and rice cakes—accounts for around 13 percent of domestic use. Use of rice in beer production is at less than 10 percent of domestic disappearance. Rice use for pet food, which almost exclusively involves broken grains, accounts for nearly 10 percent of total domestic disappearance (USDA, ERS, 2017b).

Much of U.S. rice is marketed as a whole-kernel milled product. Yet the United States is one of the few countries that allows exports of the un-milled product, with over 35 percent of U.S. exports sold as rough rice. Milled rice production requires care during the drying, storage, milling, and marketing phases to minimize the number of broken kernels. Rice exporting countries prefer to export the milled product to capture added-value benefits. However, there is a global market for rough rice, and several nations import U.S. rough rice to support their milling industry, including Mexico, Venezuela, Columbia, much of Central America, and Libya.

Although the U.S. produces less than 2 percent of the world's rice, it currently accounts for around 7 percent of the annual volume of global rice trade. The United States is regarded as a consistent and timely supplier of high-quality rice in both the long- and combined medium-/short-grain global markets. The U.S. rice industry relies heavily on the export market, as the global market accounts for half of annual sales. Major consumers of U.S. long-grain exports are countries in South, Central, and North America, along with the Caribbean and Middle East. Mexico is the largest importer of U.S. long-grain rice, purchasing mostly rough rice. Haiti is the largest market for long-grain milled rice. Smaller volumes are also shipped to the European Union (EU 27) and Sub-Saharan Africa. Major consumers of medium-grain rice include Japan, Taiwan, South Korea, Turkey, Jordan, and Libya (USDA, ERS, 2017b). Medium- and short-grain rice account for all U.S. rice shipments to Northeast Asia—Japan, South Korea, and Taiwan. U.S. shipments to these three Asian countries are all purchased as part of each importer's World Trade Organization (WTO) commitments, with total annual WTO commitments currently stable for each importer.

Figure 23

U.S. long-grain rice prices and input price index, 1990-2016



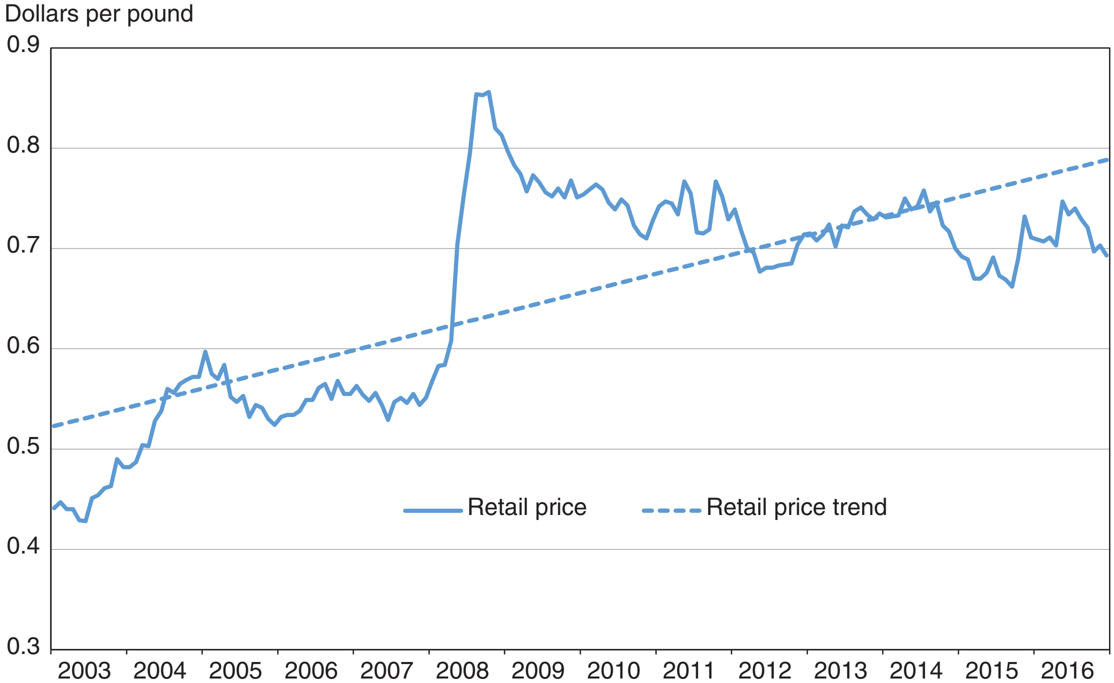
Note: cwt = hundredweight. The input price index is scaled down by a factor of 10 to facilitate the comparison with output prices.
Source: USDA, National Agricultural Statistics Service, Agricultural Prices.

Farm productivity gains have a limited impact on retail prices for consumers. Over 1993-2015, farmers received (from sale of the raw commodity) an average of about 17 cents of a dollar spent on food, while the remaining 83 cents went for processing and marketing (USDA, ERS, 2017c). These data suggest that, by itself, a 10-percent reduction in rice production costs will reduce retail prices only by 1.7 percent if the cost reduction is fully passed on to retail prices. Retail prices are also affected by productivity growth (or the lack of it) in processing, distribution, transportation, and retailing, which account for most of retail costs. In other words, the relatively small share of the commodity in retail costs matters, as well as different (usually slower) productivity trends in other sectors of the supply chain.[45]

Retail prices tend to be more stable than farm prices, as processing and marketing costs are affected by factors less volatile than commodity prices, such as fixed machinery expenses, multi-year contracts, and wages (Kuhns and Volpe, 2014). Data on retail prices for U.S. long-grain rice from 2003-16 show an average annual growth rate of 2.9 percent, slightly higher than farm price growth but below that of farm input prices (fig. 24).

[45]While productivity growth in rice may modestly affect retail prices and consumption, another important effect is to free land, capital, and labor resources for use elsewhere in the economy, including environmental improvements.

Figure 24
Retail long-grain rice prices, 2003-16



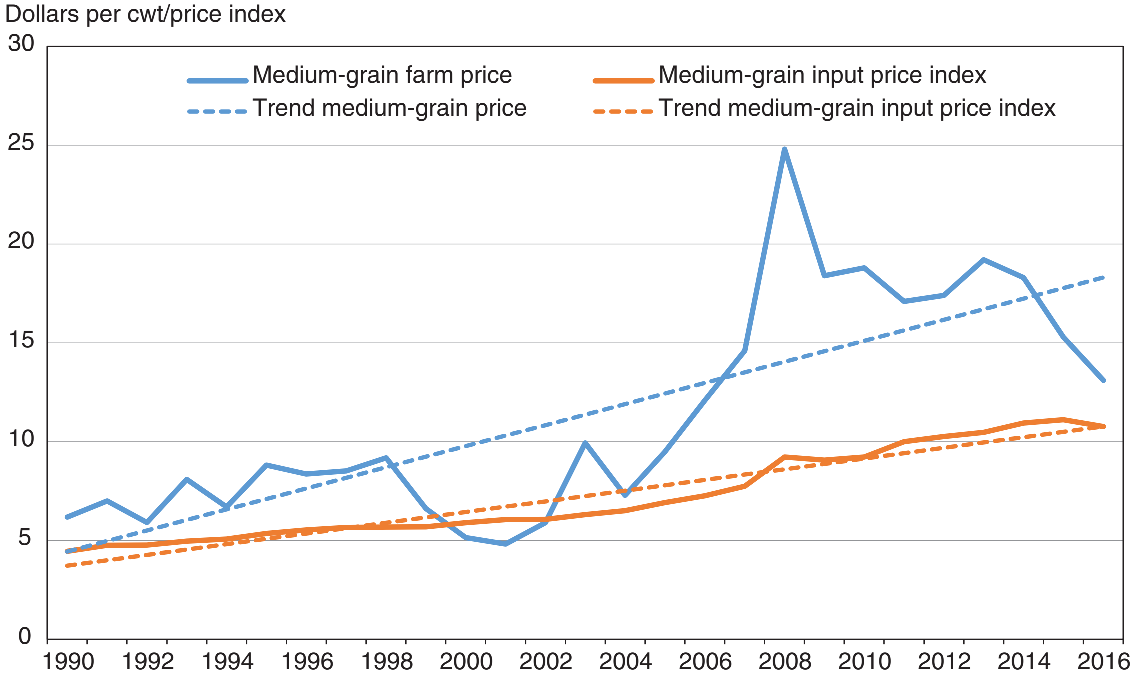
Source: U.S. Department of Labor, Bureau of Labor Statistics.

The weighted input price index for medium-grain rice grew at an annual average rate of 3.7 percent over 1990-2016 (fig. 25). Again, since rice prices should reflect farm production costs, farm prices for medium-grain rice would be expected to increase about 3.7 percent per year in the absence of productivity gains. However, farm prices for medium grain rice grew at an annual average rate of 4.7 percent—faster than production costs. Consequently, other factors must have influenced the farm price of medium-grain rice during this period. Among possible factors are prolonged drought conditions in California (see box “Drought Affects California Rice Acreage”) and exports of medium-grain rice.

Exports

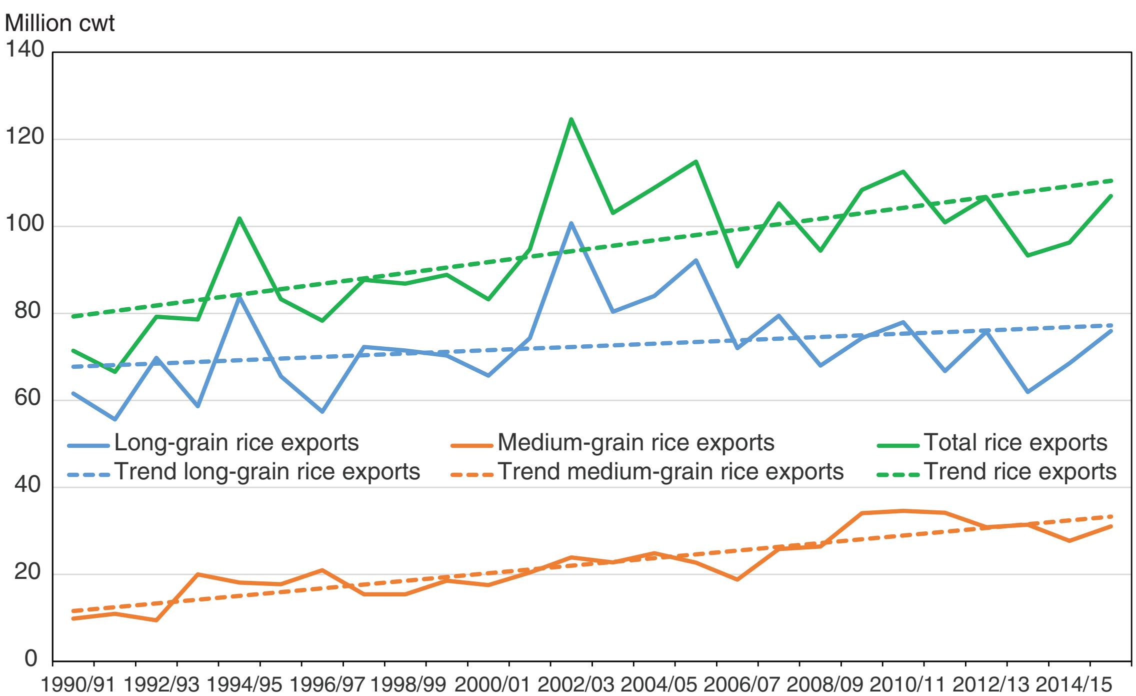
U.S. rice producers face considerable challenges selling in global markets. Although U.S. rice has a reputation for high quality globally, both in long- and medium-grain markets, the high quality comes at prices that often make U.S. rice uncompetitive, particularly in price-sensitive markets (U.S. International Trade Commission, 2015). Despite these limitations, U.S. rice exports trended higher during 1990-2016 at an annual average rate of 1.3 percent, but annual variations were significant (fig. 26). Export growth also varied by type of rice.

Figure 25
U.S. medium-grain rice prices and input price index, 1990-2016



Notes: cwt = hundredweight, The input price index is scaled down by a factor of 10 to facilitate the comparison with output prices.
Source: USDA, National Agricultural Statistics Service, Agricultural Prices.

Figure 26
U.S. rice exports by type, 1990/91-2015/16



Note: cwt = hundredweight.
Source: USDA, Economic Research Service, U.S. Rice Yearbook.

Long-grain rice has made up the majority of U.S. rice exports, accounting for 70 to 85 percent of annual exports since 1990 and about 70 percent since 2006. U.S. long-grain exports are predominantly to countries in the Western Hemisphere of which Mexico and Central American countries constitute the largest (and growing) markets. Mexico and Central America are also advantageously located near the United States and offer favorable tariff treatment under free trade agreements. Moreover, these markets have a preference for paddy (or rough) rice, which the United States, unlike most other exporters, is willing to supply. However, the United States faces increasing competition in these markets. The competition is from both lower priced Asian suppliers with improving rice quality (e.g., Thailand and Vietnam) and, more importantly, high-quality South American suppliers (e.g., Brazil and Uruguay) that have recently taken U.S. market share in many Mexican/Central American markets (U.S. International Trade Commission, 2015). Haiti remains the largest market for U.S. long-grain milled rice, with the United States still supplying the bulk of Haiti's imports.

Annual variation in U.S. long-grain rice exports has been substantial, but no trend, either up or down, was statistically significant during 1990-2016 (fig. 26). U.S. farm productivity growth enhanced the competitive position of U.S. long-grain rice on world markets. Productivity growth has likely helped the U.S. maintain its position in the highly competitive global market for long-grain rice.

Annual U.S. exports of medium-grain rice have been fairly stable from 2006 to 2016, while trending higher over 1990-2016, with an annual average growth rate of nearly 4 percent. U.S. medium-and short-grain exports have been mainly to Japan, Taiwan, and South Korea, where all annual rice purchases by these three importers are part of their World Trade Organization (WTO) commitments. The U.S. share of these purchases has been fairly consistent (U.S. International Trade Commission, 2015). Both Japan and South Korea's imports initially expanded as a result of their WTO import commitments, which were a factor behind rising U.S. medium- and short-grain exports. Annual purchase commitments are now stable for all three importers. Export growth of U.S. medium-grain rice—coupled with a prolonged drought in California where most U.S. medium-grain rice is produced—likely contributed to faster growth in medium-grain rice prices than input price growth would suggest (fig. 25).[46]

[46]During 2000-16, total U.S. rice export growth and that of long-grain rice were not statistically significant. However, exports of medium-grain rice trended higher at an average annual rate of 3.4 percent.

Conclusions

Changes in farm size, technologies, and practices used to produce rice have been dramatic over the past two decades. Farm size and rice acreage per farm increased, affording rice producers the advantages of size economies. New technologies, including hybrid and herbicide-tolerant seed varieties and precision farming techniques, altered rice cropping patterns and improved rice yields. Technology adoption increased the costs of rice production, but higher yields raised the economic efficiency. Productivity gains during 2000-13 in rice production were significant. These gains were most notable for Southern rice producers, particularly those in the Gulf Coast region who improved their competitive position relative to producers in other regions.

Structural and productivity change on U.S. rice farms during 2000-13 benefited the U.S. domestic market by keeping rice prices lower than would be expected in the absence of productivity gains. These changes benefited rice consumers and enhanced the position of U.S. rice producers in competitive international markets. U.S. rice producers can take further advantage of these changes to realize yet more efficiencies. Gains from exploiting size-economies are still available to many rice producers in the South, and more potential remains for adopting technologies and practices that enhance farm productivity.

References

Andrews, R. 2017. *Hybrid Rice – The Journey: From China to the U.S.A. across Four Decades.* Charleston, SC: Art Services of Charleston. First edition. September 24.

Baldwin, K., E. Dohlman, N. Childs, and L. Foreman. 2011. *Consolidation and Structural Change in the U.S. Rice Sector*, RCS-11d-01, U.S. Department of Agriculture, Economic Research Service, April.

Childs, N., and K. Baldwin. 2010. “Price Spikes in Global Rice Markets Benefit U.S. Growers, at Least in the Short Term,” *Amber Waves,* U.S. Department of Agriculture, Economic Research Service, December.

Bennett, D. 2017. “Provisia Rice Set To Make Jump in Mid-South Acres,” Delta Farm Press, December 26.

Dohlman, E., L. Foreman, and M. Da Pra. 2009. *The Post-Buyout Experience: Peanut and Tobacco Sectors Adapt to Policy Reform,* EIB-60*,* U.S. Department of Agriculture, Economic Research Service, November.

Foreman, L., and J. Livesey. 2004. *Characteristics and Production Costs of U.S. Rice Farms,* SB-974-7, U.S. Department of Agriculture, Economic Research Service, March.

Guo-hui, M., and Y. Long-ping. 2015. “Hybrid Rice Achievements, Development and Prospect in China,” *Journal of Integrative Agriculture* 14(2):197-205.

Fuglie, K., J. MacDonald, and E. Ball. 2007. *Productivity Growth in U.S. Agriculture*, Economic Brief No. 9, U.S. Department of Agriculture, Economic Research Service, September.

Hardke, J., K. Moldenhauer, X. Sha, Y. Wamishe, R. Norman, D. Frizzell, E. Casteneda, G. Lee, D. Wisdom, M. Blocker, J. Bulloch, T. Beaty, R. Mazzanti, R. Baker, S. Runsick, M. Duren, Y. Liyew, and J. Chlapecka. 2016. *Arkansas Rice Cultivar Testing, 2014-2016*. Rice Information No. 176, University of Arkansas, Division of Agriculture, Research and Extension, December.

Hardke, J. 2012. *Factors Affecting Rice Milling Quality*, Arkansas Row Crops. University of Arkansas, Division of Agriculture, Research and Extension, December.

Henry C., M. Daniels, and J. Hardke. 2013. “Chapter 10: Water Management,” in *Arkansas Rice Production Handbook*, J. Hardke, ed., July 24.

International Rice Research Institute. 2012. “Herbicide-Resistant Rice.” Available online.

Kuhns, A., and R. Volpe. 2014. “Food Price Transmission From Farm to Retail,” *Amber Waves*, U.S. Department of Agriculture, Economic Research Service, May 5.

Lyman, N., and L. Nalley. 2013. “Economic Analysis of Hybrid Rice Performance in Arkansas,” *Agronomy Journal* 105:1-12.

MacDonald, J., R. Hoppe, and D. Newton. 2018. *Three Decades of Consolidation in U.S. Agriculture*, EIB-189, U.S. Department of Agriculture, Economic Research Service, March.

McBride, W., and N. Key. 2013. *U.S. Hog Production From 1992 to 2009: Technology, Restructuring, and Productivity Growth*, ERR-158, U.S. Department of Agriculture, Economic Research Service, October.

Medellin-Azuara, J., D. MacEwan, R. Howitt, D. Sumner, and J. Lund. 2016. *Economic Analysis of the 2016 California Drought on Agriculture*, Center for Watershed Sciences, University of California, Davis.

Nalley, L., J. Tack, A. Barkley, K. Jagadish, and K. Brye. 2016. "Quantifying the Agronomic and Economic Performance of Hybrid and Conventional Rice Varieties," *Agronomy Journal* 108:1514-23.

Organisation for Economic Co-operation and Development (OECD). 2001. "Measuring Productivity: Measurement of Aggregate and Industry-Level Productivity Growth," *OECD Manual,* Paris, France. Available online.

Petrie, M., M. Brasher, and D. James. 2014. *Estimating the Biological and Economic Contributions that Rice Habitats Make in Support of North American Waterfowl Populations*, The Rice Foundation, Stuttgart, AR.

Roberts, T., N. Slaton, and R. Norman. 2013. "Chapter 9: Soil Fertility," in *Arkansas Rice Production Handbook*, J. Hardke, ed., July 24.

Schimmelpfennig, D. 2016. *Farm Profits and Adoption of Precision Agriculture*, ERR-217, U.S. Department of Agriculture, Economic Research Service, October.

Sudianto, E., S. Beng-Kah, N. Ting-Xiang, N. Saldain, R. Scott, and N. Burgos. 2013. "Clearfield@ Rice: Its Development, Success, and Key Challenges on a Global Perspective," *Crop Protection* 49:40-51.

Swegal, H. 2017. *The Rise and Fall of Almond Prices: Asia, Drought, and Consumer Preference,* U.S. Department of Commerce, Bureau of Labor Statistics: Beyond the Numbers, Vol. 6, No. 12.

U.S. Bureau of Reclamation. 2017. Summary of Water Allocations.

U.S. Department of Agriculture, Economic Research Service. 2017a. "Commodity Costs and Returns" data product. Available online.

U.S. Department of Agriculture, Economic Research Service. 2017b. "Rice Yearbook" data product. Available online.

U.S. Department of Agriculture, Economic Research Service. 2017c. "Food Dollar Series" data product. Available online.

U.S. Department of Agriculture, Economic Research Service. 2017d. "ARMS Farm Financial and Crop Production Practices" data product. Available online.

U.S. Department of Agriculture, National Agricultural Statistics Service. 1997, 2002, 2007, 2012. "Census of Agriculture" data product. Available online.

U.S. Department of Agriculture, National Agricultural Statistics Service. 2017a. "Agricultural Prices" data product. Available online.

U.S. Department of Agriculture, National Agricultural Statistics Service. 2017b. "Crop Production" data product. Available online.

U.S. International Trade Commission. 2015. *Rice: Global Competitiveness of the U.S. Industry*, Publication Number: 4530, Investigation Number: 332-549, April.

Vekshin, A. 2014. "California Water Prices Soar for Farmers as Drought Grows," Bloomberg, July 24.

Wamishe, Y., R. Cartwright, and F. Lee. 2013. "Chapter 11: Management of Rice Diseases," in *Arkansas Rice Production Handbook*, J. Hardke, ed., July 24.

Appendix Tables

Appendix table 1

Characteristics of Arkansas Non-Delta rice farms and operators, 2000, 2006, and 2013

Item	2000	2006	2013
Farm size			
Operated acres	1,266	1,696	1,988
Owned acres	297	514	369
Land value ($/acre)	1,127	1,483	3,739
Percent of acres owned	25.06	28.62	20.31
Rented acres	981	1,250	1,630
Planted rice acres	386	512	620
Planted rice acres-% of farms			
Fewer than 250 acres	40.12	31.46	33.78
250-499 acres	33.10	32.38	16.17
500-749 acres	17.73	11.77	23.98
750 or more acres	9.05	24.39	26.07
Value of production (dollars)			
Rice	146,390	293,546	806,214
Farm	295,118	566,417	1,598,461
Percent from rice	49.60	51.83	50.44
Farm commodity-% of farms			
Corn	9.76	14.23	46.31
Cotton	5.61	4.68	4.85
Peanuts	0.00	0.00	2.72
Sorghum	12.01	2.38	6.32
Soybeans	99.64	96.43	96.19
Hay	2.47	7.57	2.32
Small grain crops	56.60	35.47	27.58
Fruit and vegetables	0.00	6.08	0.00
Livestock	4.40	9.92	3.89
Operator age-years	50	52	54
Less than 50 years-percent	42.84	36.20	30.53
Operator education-% of farms			
Less than high school	12.33	1.31	1.52
Completed college	20.26	28.75	29.02

Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.

Appendix table 2

Characteristics of Mississippi River Delta rice farms and operators, 2000, 2006, and 2013

Item	2000	2006	2013
Farm size			
Operated acres	2,463	2,452	3,181
Owned acres	869	464	644
Land value ($/acre)	1,034	1,379	3,044
Percent of acres owned	29.74	21.66	22.07
Rented acres	1,682	2,004	2,575
Planted rice acres	490	537	660
Planted rice acres-% of farms			
Fewer than 250 acres	44.02	38.50	39.33
250-499 acres	19.55	29.49	16.25
500-749 acres	16.58	9.67	14.07
750 or more acres	19.86	22.34	30.34
Value of production (dollars)			
Rice	170,757	328,068	783,829
Farm	506,269	822,043	2,527,083
Percent from rice	33.73	39.91	31.02
Farm commodity-% of farms			
Corn	13.47	19.47	75.24
Cotton	34.80	23.75	16.17
Peanuts	0.00	0.38	0.00
Sorghum	14.69	6.62	7.21
Soybeans	80.42	98.24	96.79
Hay	1.92	0.00	1.20
Small grain crops	37.67	12.73	32.91
Fruit and vegetables	0.25	0.00	0.42
Livestock	7.02	8.54	1.20
Operator age-years	48	48	55
Less than 50 years-percent	58.61	50.49	25.75
Operator education-% of farms			
Less than high school	2.45	3.68	1.85
Completed college	23.20	26.37	36.13

Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.

Appendix table 3

Characteristics of Gulf Coast rice farms and operators, 2000, 2006, and 2013

Item	2000	2006	2013
Farm size			
Operated acres	1,135	1,480	2,118
Owned acres	184	294	293
Land value ($/acre)	990	1,268	2,007
Percent of acres owned	17.31	16.75	17.58
Rented acres	1,006	1,221	1,878
Planted rice acres	415	462	658
Planted rice acres-% of farms			
Fewer than 250 acres	38.76	36.62	18.09
250-499 acres	33.85	34.16	21.47
500-749 acres	10.85	16.78	26.85
750 or more acres	16.54	12.43	33.58
Value of production (dollars)			
Rice	142,357	259,226	786,417
Farm	186,182	339,813	1,211,035
Percent from rice	76.46	76.28	64.94
Farm commodity-% of farms			
Corn	5.10	2.34	7.44
Cotton	2.93	4.24	3.48
Peanuts	0.00	0.00	0.00
Sorghum	5.73	8.09	14.63
Soybeans	25.56	20.25	50.82
Hay	8.36	4.99	11.10
Small grain crops	3.00	1.21	2.79
Fruit and vegetables	0.00	0.00	0.00
Livestock	35.33	37.44	17.78
Operator age-years	50	53	56
Less than 50 years-percent	50.98	34.89	22.59
Operator education-% of farms			
Less than high school	5.27	5.24	1.10
Completed college	31.96	27.11	26.51

Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.

Appendix table 4

Characteristics of California rice farms and operators, 2000, 2006, and 2013

Item	2000	2006	2013
Farm size			
Operated acres	500	699	660
Owned acres	105	215	328
Land value ($/acre)	2,541	4,246	5,544
Percent of acres owned	35.23	30.25	38.83
Rented acres	414	514	491
Planted rice acres	314	460	497
Planted rice acres-% of farms			
Fewer than 250 acres	62.46	33.17	27.07
250-499 acres	21.15	31.10	27.65
500-749 acres	11.72	17.92	28.26
750 or more acres	4.68	17.81	17.02
Value of production (dollars)			
Rice	138,360	284,318	697,647
Farm	206,739	524,676	870,099
Percent from rice	66.93	54.19	80.18
Farm commodity-% of farms			
Corn	4.52	0.97	3.78
Cotton	0.00	0.00	0.00
Peanuts	0.00	0.00	0.00
Sorghum	0.00	0.00	1.96
Soybeans	0.00	0.00	0.00
Hay	5.40	7.15	6.87
Small grain crops	3.42	8.38	6.00
Fruit and vegetables	20.45	24.80	14.46
Livestock	8.04	0.00	3.29
Operator age-years	50	57	57
Less than 50 years-percent	49.66	35.80	22.97
Operator education-% of farms			
Less than high school	4.10	0.00	1.10
Completed college	42.53	49.98	51.38

Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.

Appendix table 5

Technologies used on Arkansas Non-Delta rice acreage, 2000, 2006, and 2013

Item	2000	2006	2013
Type of rice-% of acres			
Long grain	81.35	94.60	90.48
Medium grain	18.64	5.40	9.52
Short grain	0.01	0.00	0.00
Seeding method-% of acres			
Air (water)	2.45	7.38	3.50
Drilled (dry)	85.50	79.73	89.36
Air (dry)	0.16	0.96	3.26
Broadcast (dry)	11.90	11.93	3.87
Hybrid rice seed-% of acres[1]	2.39	15.35	41.88
HT rice seed-% of acres[2]	0.00	27.48	57.26
Previous crop-% of acres			
Rice	17.44	24.85	35.11
Corn	0.00	1.32	2.35
Soybeans	80.30	71.39	57.71
Small grain	0.00	0.00	0.00
Other crop	0.67	1.91	3.31
Hay and fallow	1.60	0.53	1.52
Crop rotation-% of acres			
Monoculture	5.88	15.10	21.84
Continuous row crop	91.24	80.26	71.13
Idle year	1.60	0.53	1.52
Precision ag tech-% of acres			
Yield monitor	14.97	30.15	69.82
Yield map	2.53	7.67	18.69
GPS soil map[3]	10.71	9.97	13.56
Guidance system	0.00	29.85	60.26
Variable rate-fertilizer	2.71	3.90	10.24
Variable rate-seeding	0.55	2.11	5.99
Variable rate-chemicals	1.39	0.00	3.40
Irrigation system-% of acres			
Portal	2.88	1.04	0.00
Poly pipe	3.11	8.88	12.43
Gated pipe	0.00	0.39	0.00
Open discharge	92.88	86.97	80.82

[1]Hybrid rice seed was first released in 2000. Reported use in the 2000 ARMS appears considerably higher than in other sources (see Nalley et al., 2016).

[2]HT = herbicide-tolerant.

[3]GPS = global positioning system.

Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.

Appendix table 6

Technologies used on Mississippi River Delta rice acreage, 2000, 2006, and 2013

Item	2000	2006	2013
Type of rice-% of acres			
Long grain	99.66	100.00	97.77
Medium grain	0.06	0.00	2.23
Short grain	0.28	0.00	0.00
Seeding method-% of acres			
Air (water)	3.23	1.44	2.45
Drilled (dry)	95.10	86.99	95.42
Air (dry)	0.56	4.67	0.59
Broadcast (dry)	1.10	6.90	1.54
Hybrid rice seed-% of acres[1]	10.73	12.99	37.37
HT rice seed-% of acres[2]	0.00	23.89	62.63
Previous crop-% of acres			
Rice	43.33	34.62	41.34
Corn	0.00	0.61	0.13
Soybeans	52.47	58.36	55.63
Small grain	0.00	0.00	0.00
Other crop	1.68	5.32	2.15
Hay and fallow	2.51	1.10	0.74
Crop rotation-% of acres			
Monoculture	22.28	23.44	17.97
Continuous row crop	71.57	61.53	75.02
Idle year	2.48	1.10	0.74
Precision ag tech-% of acres			
Yield monitor	26.36	31.49	68.90
Yield map	13.20	6.17	23.16
GPS soil map[3]	11.95	4.95	22.57
Guidance system	0.00	22.58	50.29
Variable rate-fertilizer	4.01	5.60	24.99
Variable rate-seeding	2.28	2.08	24.42
Variable rate-chemicals	5.99	5.89	19.52
Irrigation system-% of acres			
Portal	2.77	0.36	0.26
Poly pipe	5.67	8.74	10.20
Gated pipe	0.07	0.00	1.04
Open discharge	87.86	89.64	77.26

[1]Hybrid rice seed was first released in 2000. Reported use in the 2000 ARMS appears considerably higher than in other sources (see Nalley et al., 2016).

[2]HT = herbicide-tolerant.

[3]GPS = global positioning system.

Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.

Appendix table 7.
Technologies used on Gulf Coast rice acreage, 2000, 2006, and 2013

Item	2000	2006	2013
Type of rice-% of acres			
Long grain	93.34	98.13	95.65
Medium grain	6.35	1.87	4.35
Short grain	0.31	0.00	0.00
Seeding method-% of acres			
Air (water)	60.10	36.52	27.27
Drilled (dry)	29.83	39.28	61.29
Air (dry)	8.81	22.69	8.25
Broadcast (dry)	1.26	1.51	3.20
Hybrid rice seed-% of acres[1]	10.35	11.51	27.73
HT rice seed-% of acres[2]	0.00	33.12	48.54
Previous crop-% of acres			
Rice	30.48	17.76	13.46
Corn	1.79	0.00	0.18
Soybeans	11.57	13.00	35.92
Small grain	0.00	0.00	0.00
Other crop	2.94	3.22	5.16
Hay and fallow	53.22	66.02	45.28
Crop rotation-% of acres			
Monoculture	18.29	9.42	7.09
Continuous row crop	19.55	14.33	36.76
Idle year	53.22	66.02	45.28
Precision ag tech-% of acres			
Yield monitor	6.67	8.55	35.93
Yield map	3.09	2.03	7.26
GPS soil map[3]	6.32	2.74	4.73
Guidance system	0.00	8.66	36.00
Variable rate-fertilizer	0.90	0.62	5.23
Variable rate-seeding	0.75	0.38	1.89
Variable rate-chemicals	0.00	0.38	2.51
Irrigation system-% of acres			
Portal	16.64	23.74	16.74
Poly pipe	1.73	4.94	0.00
Gated pipe	0.23	1.88	6.87
Open discharge	79.01	67.49	59.61

[1]Hybrid rice seed was first released in 2000. Reported use in the 2000 ARMS appears considerably higher than in other sources (see Nalley et. al., 2016).
[2]HT = herbicide-tolerant.
[3]GPS = global positioning system.

Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.

Appendix table 8

Technologies used on California rice acreage, 2000, 2006, and 2013

Item	2000	2006	2013
Type of rice-% of acres			
Long grain	0.99	2.15	1.74
Medium grain	92.72	88.71	90.86
Short grain	6.29	9.14	7.40
Seeding method-% of acres			
Air (water)	62.11	70.59	76.17
Drilled (dry)	5.16	1.33	4.68
Air (dry)	32.72	27.67	19.15
Broadcast (dry)	0.00	0.41	0.00
Previous crop-% of acres			
Rice	90.87	90.71	93.15
Corn	0.00	0.00	0.00
Soybeans	0.00	0.00	0.00
Small grain	0.00	0.00	0.00
Other crop	4.29	3.69	2.32
Hay and fallow	4.84	5.60	4.53
Crop rotation-% of acres			
Monoculture	78.91	84.50	90.00
Continuous row crop	5.34	5.54	1.78
Idle year	0.16	5.60	4.53
Precision ag tech-% of acres			
Yield monitor	21.48	42.22	49.14
Yield map	10.09	24.16	22.88
GPS soil map[1]	12.44	8.90	7.15
Guidance system	0.00	33.58	60.32
Variable rate-fertilizer	0.74	13.39	30.13
Variable rate-seeding	4.16	1.26	0.00
Variable rate-chemicals	4.90	7.61	16.81
Irrigation system-% of acres			
Portal	57.46	68.44	68.59
Poly pipe	5.15	0.00	0.00
Gated pipe	1.67	7.87	6.14
Open discharge	34.26	16.30	19.89

[1]GPS = global positioning system.

Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.

Appendix table 9

Input use on Arkansas Non-Delta rice acreage, 2000, 2006, and 2013

Item	2000	2006	2013
Seeding rate-pounds/acre	115	92	58
Fertilizer use-% of acres			
Nitrogen	99.68	97.93	94.93
Phosphorus	48.29	69.49	74.18
Potassium	47.38	63.40	67.75
Manure or compost	0.00	1.86	2.77
Fertilizer-pounds/treated acres			
Nitrogen	148.96	199.45	174.55
Phosphorus	47.52	55.95	67.47
Potassium	61.78	74.73	82.20
Nitrogen application basis-% of acres			
Soil or tissue test	27.12	27.53	24.03
Crop consultant	22.58	38.50	44.75
Fertilizer dealer	11.52	17.83	12.08
Extension service	17.10	20.21	15.04
Nitrogen or crop prices	3.40	6.04	4.68
Routine practice	56.53	49.25	35.93
Rice yield goal-cwt/planted acre[1]	68.34	73.48	83.43
Chemical use-% of acres			
Herbicide	98.82	93.04	97.15
Insecticide	3.14	7.57	23.76
Fungicide	5.16	36.66	42.13
Biological	0.54	1.37	0.77
Chemicals-treatments/treated acre			
Herbicide	2.71	3.42	3.93
Insecticide	0.81	1.01	1.11
Fungicide	1.78	1.18	1.97
Number of tillage operations	2.89	2.54	2.24
Field operations-% of acres			
No-till[2]	4.37	10.06	2.45
Moldboard plow	2.61	1.86	5.40
Purchased water-% of acres	0.00	0.37	0.97
Water applied-inches/acre	43	28	27

[1]cwt = hundredweight.

[2]A farm was defined as using no-till if no tillage operations were done and a no-till planter was used.

Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.

Appendix table 10

Input use on Mississippi River Delta rice acreage, 2000, 2006, and 2013

Item	2000	2006	2013
Seeding rate-pounds/acre	108	98	59
Fertilizer use-% of acres			
Nitrogen	99.01	92.52	100.00
Phosphorus	21.03	35.08	51.44
Potassium	14.04	18.18	7.07
Manure or compost	0.00	0.82	2.67
Fertilizer-pounds/treated acre			
Nitrogen	168.27	217.46	219.15
Phosphorus	91.79	58.14	47.75
Potassium	62.20	81.95	87.55
Nitrogen application basis-% of acres			
Soil or tissue test	21.83	15.64	26.48
Crop consultant	16.01	33.83	61.71
Fertilizer dealer	6.63	15.58	11.51
Extension service	14.55	13.58	12.24
Nitrogen or crop prices	4.05	6.66	2.45
Routine practice	60.97	58.23	52.58
Rice yield goal-cwt/planted acre[1]	67.15	76.82	80.63
Chemical use-% of acres			
Herbicide	98.85	98.76	99.51
Insecticide	30.93	31.28	48.11
Fungicide	27.63	35.75	55.97
Biological	0.37	2.64	0.00
Chemicals-treatments/treated acre			
Herbicide	3.32	3.70	4.01
Insecticide	1.66	1.11	1.00
Fungicide	1.28	1.21	1.82
Number of tillage operations	2.33	2.31	2.60
Field operations-% of acres			
No-till[2]	4.83	8.82	1.52
Moldboard plow	1.68	0.32	4.36
Purchased water-% of acres	0.00	0.00	0.51
Water applied-inches/acre	39	26	23

[1]cwt = hundredweight.

[2]A farm was defined as using no-till if no tillage operations were done and a no-till planter was used.

Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.

Appendix table 11

Input use on Gulf Coast rice acreage, 2000, 2006, and 2013

Item	2000	2006	2013
Seeding rate-pounds/acre	118	99	63
Fertilizer use-% of acres			
Nitrogen	99.71	98.76	96.65
Phosphorus	90.64	84.46	89.62
Potassium	90.03	82.90	85.27
Manure or compost	0.00	0.41	1.30
Fertilizer-pounds/treated acre			
Nitrogen	156.94	163.60	159.19
Phosphorus	49.29	48.69	44.12
Potassium	53.86	56.06	63.90
Nitrogen application basis-% of acres			
Soil or tissue test	31.41	14.21	10.41
Crop consultant	8.54	30.55	31.32
Fertilizer dealer	10.89	32.50	27.12
Extension service	2.65	21.15	10.87
Nitrogen or crop prices	6.92	14.22	5.92
Routine practice	65.69	70.64	69.18
Rice yield goal-cwt/planted acre[1]	69.61	69.71	79.06
Chemical use-% of acres			
Herbicide	94.26	96.18	95.43
Insecticide	38.33	51.93	18.82
Fungicide	46.52	46.66	62.76
Biological	0.00	1.11	0.94
Chemicals-treatments/treated acre			
Herbicide	2.89	3.28	3.62
Insecticide	2.08	1.71	1.10
Fungicide	1.01	1.15	2.04
Number of tillage operations	3.27	2.93	2.38
Field operations-% of acres			
No-till[2]	0.00	1.26	4.25
Moldboard plow	0.82	1.63	0.00
Purchased water-% of acres	19.60	21.29	19.25
Water applied-inches/acre	31	27	28

[1]cwt = hundredweight.

[2]A farm was defined as using no-till if no tillage operations were done and a no-till planter was used.

Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.

Appendix table 12

Input use on California rice acreage, 2000, 2006, and 2013

Item	2000	2006	2013
Seeding rate-pounds/acre	167	163	166
Fertilizer use-% of acres			
Nitrogen	98.92	89.13	97.61
Phosphorus	85.46	69.04	82.95
Potassium	33.47	37.41	38.61
Manure or compost	0.00	7.90	1.20
Fertilizer-pounds/treated acre			
Nitrogen	95.67	122.53	139.88
Phosphorus	51.69	45.80	45.20
Potassium	47.87	33.82	32.26
Nitrogen application basis-% of acres			
Soil or tissue test	20.31	18.31	10.50
Crop consultant	21.05	31.14	33.29
Fertilizer dealer	26.48	32.54	39.91
Extension service	4.03	12.05	3.80
Nitrogen or crop prices	5.33	10.73	8.83
Routine practice	89.54	81.68	83.58
Rice yield goal-cwt/planted acre[1]	83.52	109.98	87.47
Chemical use-% of acres			
Herbicide	91.83	92.73	96.00
Insecticide	43.06	22.41	33.44
Fungicide	27.22	49.51	45.42
Biological	0.00	0.00	1.76
Chemicals-treatments/treated acre			
Herbicide	2.76	2.77	3.19
Insecticide	1.03	0.65	0.93
Fungicide	1.25	1.28	1.09
Number of tillage operations	3.25	3.60	3.88
Field operations-% of acres			
No-till[2]	0.00	0.00	0.00
Moldboard plow	42.09	25.52	14.57
Purchased water-% of acres	90.35	90.27	92.29
Water applied-inches/acre	56	56	62

[1]cwt = hundredweight.

[2]A farm was defined as using no-till if no tillage operations were done and a no-till planter was used.

Source: USDA, Economic Research Service (ERS) estimated from the 2000, 2006, and 2013 Agricultural Resource Management Survey, jointly administered by ERS and USDA, National Agricultural Statistics Service.