Future Patterns of U.S. Grains, Biofuels, and Livestock and Poultry Feeding

By Robert Wisner, David Anderson, Ronald Plain, Don Hofstrand, and Daniel O'Brien

A project financed by the Institute for Feed Education & Research (IFEEDER) on behalf of the American Feed Industry Association (AFIA) and The Council on Food, Agricultural and Resource Economics (C-FARE)

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Abstract

Corn and soybeans are key inputs in animal agriculture's processing of grain into human food. For most of the 1990s and early 2000s, supplies of both crops were ample and low-priced as the markets reacted to policies that were intended to increase use and prevent a build-up of carryover stocks. Extremely rapid growth in the use of corn for biofuels transformed corn from primarily a food and feed crop to a food, feed and fuel crop. Soybeans also became an energy crop through rapid growth in biodiesel production. This report outlines recent and probable future changes in the biofuels and crops sectors of U.S. and global agriculture. Developments in the biofuels and crops sectors are linked to recent changes in patterns of livestock and poultry production, and potential future directions for the animal agriculture and feed industries. Key requirements for future expansion and competitiveness are identified.

Key words: Biofuels, ethanol, distillers' grain, pork, beef, broilers, dairy products, livestock product exports

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Executive Summary

The future of the nation's livestock and poultry industries depends heavily on feed availability and costs. In the first decade of the 21st century, the U.S. livestock, dairy, and poultry sectors and the feed industry faced major challenges brought on by sharply higher and more volatile feed costs. This new feed cost environment has negatively affected the entire feed, livestock, poultry and dairy industries. Availability and cost of grain and protein meal in the next several years will, to a large extent, determine the future patterns and direction of these industries.

Biofuels: A Major Driver of the Changing Feed Cost Environment

A very rapid increase in corn use for ethanol, and fats and oil use for biodiesel production shifted the traditional role of corn and soybeans from food and feed crops to a combined role as food, feed and fuel crops. In the 2000-01 to 2010-11 corn marketing years (MY), total use of U.S. corn for feed and other non-ethanol uses plus exports fell by 1.5 billion bushels.

Domestic livestock feeding was the largest source of the decrease, although U.S. corn exports also declined. Part of the lower feed use was offset by increased feeding of DGS, the major co-product of the ethanol industry. Domestic food processing and non-ethanol industrial uses are a very small part of the demand for corn and have increased only marginally since 2000-01. Over the same period, corn processing at ethanol plants increased by 4.42 billion bushels or 623%.

A number of developments contributed to the explosive growth in biofuels demand, including the September 11, 2001 crisis and the shift toward policy emphasis on increased U.S. energy independence. Government programs supporting that goal include mandated volumes of ethanol and biodiesel blending with motor fuels, phasing out Methyl Tertiary Butyl Ether (MTBE) as an oxygen-enhancing agent for gasoline, a blenders' tax credit that expired in 2011, efforts to reduce greenhouse gas emissions, and financial assistance for smaller ethanol plants.

Before corn became a major energy crop, supplies frequently exceeded market demand, pushing prices down in response to government programs that encouraged corn use and discouraged stocks buildups. Those conditions and policies resulted in low-cost feed for the nation's livestock producers. As ethanol processing capacity expanded rapidly, demand for corn steadily increased and grain supplies tightened substantially. Corn prices rose to reflect the crop's value as a motor fuel. At the same time, fuel prices rose, thus further increasing the motor-fuel equivalent value of corn.

Prices of other crops responded as higher corn prices led to increased U.S. and foreign corn plantings and competition for crop acreage. Chinese imports of soybeans for feed increased rapidly at the same time, from 19% in 2001-02 to about 60% of global soybean imports in 2011-12. China's expanded feedstuffs demand required additional South American cropland for soybeans at the same time that more acres were needed to produce corn-starch ethanol. U.S. Government biofuel mandates affect both the level and potential volatility of feed costs. When U.S. corn yields are below the long-run trend, such as in 2010 and 2011, mandated blending requirements can give the ethanol industry a purchasing-power advantage over the livestock industry. The mandates require a specific amount of ethanol to be used in the U.S. motor fuel supply, regardless of the cost of producing it. That allows the ethanol industry to pay whatever price is needed for corn to

fill the mandates, unless government officials would decide emergency conditions call for a partial waiver of the mandated ethanol volumes.

Saturation of Domestic Ethanol Market May Slow Growth in Corn Demand

In the next three to seven years, provided U.S. corn yields return to their longer-term upward trend, corn supplies for the feed and livestock industries appear likely to be more adequate than in the past few years.

Government ethanol blending mandates will increase annually to 2015, but at a much slower rate than in the last few years, capping at 15 billion gallons. That prospect along with near-saturation of the domestic ethanol market likely will slow the growth in corn demand in the next three to five years. After two consecutive low-yield years in 2010 and 2011, resumption of the long-term upward trend in yields would mean more readily available corn supplies for the feed industry in the three to eight year horizon. However, a number of key longer-term questions remain.

China appears to be an emerging major corn importer in response to rapid growth of consumer incomes and dietary shifts away from grain consumption to more animal-based protein. In February 2012, USDA's 10-year global model projected that China will import 9 million tons (355 million bushels) of corn in 2016-17, up from an estimated 5 million tons in 2011-12. The USDA model projects that China's corn imports will double between 2016-17 and 2021-22.[1]

With much slower expected growth in U.S. corn-starch ethanol production through 2022, the long-term upward trend in U.S. corn yields would be expected to result in adequate supplies to meet expanding Chinese demand and increased supplies for the U.S. feed industry. If U.S. and/or major foreign grain yields are below normal; however, the inelastic demand for biofuel likely will lead to sharply higher feed costs and reduced non-ethanol utilization. The U.S. livestock industry likely would bear the brunt of much of the required cuts in use in the event of short-crop conditions.

Livestock Sector Adjustments Vary by Species

When feed costs rise to unprofitable levels, the broiler industry is able to adjust more rapidly than producers of other species. A short biological production cycle allows the poultry industry to quickly curtail production until the profit potential improves. This flexibility, along with greater grain-to-meat conversion efficiency, will help the poultry industry grow more rapidly than the red meat industry in times of tight grain supplies.

The relatively steady decades-long growth in the pork industry is expected to continue with more adequate grain supplies. Pork producers will continue to increase production. Only minor on-going structural changes in the pork industry are expected in the next three to eight years. Expanding global demand for pork is strengthening hog prices and has helped the pork industry cope with higher feed costs.

The dairy industry experienced severe losses in 2009 – 2010, triggered by rising feed costs and reduced exports, but is recovering and beginning to expand although returns were still depressed in early 2012. In the next several years, if current expectations of much slower growth in ethanol demand and increasing U.S. corn yields materialize, the dairy industry will continue its long-term expansion and increased efficiency and productivity.

The beef sector has the advantage of being able to use grass and other roughages to produce meat. It also is able to use DGS more effectively than monogastric species and may benefit as more ethanol plants remove corn oil from DGS to provide a feedstock for reaching government biodiesel and advanced biofuels mandates.

A large and expanding DGS supply has reduced corn use in the beef industry as well as other livestock sectors and has helped control costs. However, DGS and corn prices are closely related and DGS prices have risen in response to higher corn prices. Thus, the beef industry also has been stressed by higher feed costs and the need for adjustments in rations and production levels. Beef cattle numbers are cyclical, and as beef profitability declined in the past few years, producers reduced their herds. The severe southern Plains drought of 2010-12 accelerated the process and set the stage for fewer cattle being grain fed and reduced beef production in the next few years.

If adequate feed supplies are available at reasonable cost as currently anticipated, a cyclical upturn in beef cow numbers and beef production could occur. However, the cattle industry has a longer biological production cycle and greater grain requirements per pound of meat produced than other species. These aspects of beef production, especially high feed costs, will put additional pressure on the beef industry to increase production efficiency and feed conversion efficiency.

Biofuels Industry Facing Longer-term Challenges

Several ethanol firms are beginning to either transition their plants to biobutanol production or expand by adding biobutanol facilities. Biobutanol can be made from corn and offers a potential for expanding the biofuels market beyond ethanol's current 10% blend wall or a possible 12-15% blend wall if retail sales of E-15 become widespread. If biobutanol production becomes economical, it could create a second-stage biofuels expansion and growth in corn demand that could be significantly greater than projected Chinese imports and could tighten U.S. feed supplies. It will be important for the livestock and feed industries to monitor developments in biobutanol in the next few years. Current indications are that major growth in that industry, if it occurs, may be several years away.

The feed-livestock sector will face a number of other important questions and from potential challenges during the next eight years and beyond. These challenges stem from global population and income growth, constraints on global cropland acreage, the need to increase grain yields, foreign biofuels mandates, possible large-scale cellulosic ethanol production and environmental concerns.

Organization of Report

Feed represents the largest single cost item in producing meat, milk and eggs. Recent developments in feed markets have caused severe economic stresses in all categories of U.S. livestock and poultry production, and have raised questions of whether inadequate feed supplies will halt future growth of these U.S. industries.

This report begins with a review of trends in non-feed uses of corn, drivers of the dramatic expansion in processing of corn into fuel ethanol, impacts on the total demand for corn domestically and internationally, accompanying price changes, and domestic and international acreage responses to higher grain prices. This discussion is followed by a perspective on the likely short-, intermediate-, and long-term directions for corn use for ethanol as well as possible second and third-stage expansions of the biofuels market. The report outlines the impacts on the livestock sector of the possible increases in the China's demand for corn.

These sections of the report are followed by an examination of major trends in the livestock and poultry industries, likely future short and intermediate-term directions for the different species, and challenges ahead. The report then shifts to longer-term (12- to 38-year) challenges for the grain and livestock sectors that will be involved in meeting an expanding world population and increasing per capita consumption of meat, poultry, and dairy products in developing countries.

Future Patterns of U.S. Grains, Biofuels, and Livestock and Poultry Feeding

Rapid increases in the amount of corn processed into ethanol triggered sharp increases in feed costs starting in the mid-2000s, which at times were amplified by adverse U.S. or foreign growing conditions as well as exchange-rate fluctuations. Other uses of U.S. corn declined substantially while processing for ethanol increased very dramatically, creating a new block of demand nearly equal to global feed grain exports. U.S. and global feed grain supplies tightened with the conversion of corn to an energy crop along with its traditional uses as a source of food and feed. In response, corn prices increased substantially and became more volatile. Higher corn and soybean prices triggered increases in South American crop acreage, expanded wheat feeding and reduced U.S. corn exports.

The livestock and poultry sectors have wrestled with major shocks from feed costs in the past six years and have experienced severe financial pressures. Their future, as well as that of the feed industry that supplies them, will depend heavily on feed costs and availability in the years ahead. For that reason, the starting point in looking at the future of livestock feeding is an analysis of biofuels, feed supplies, related global responses to large-scale biofuels production, and future prospects for non-feed uses of grain.

Changes in Grain and Feed Markets Present Challenges for U.S. Livestock and Poultry Industries

In the first decade of the 21st century, the grain and feed industry experienced dramatic changes as use of corn and soybeans expanded to include energy production. The rapid increase in corn use for fuel ethanol resulted in tighter corn supplies and substantially higher feed costs. The price and feed availability effects on the livestock sector were amplified by below-normal U.S. corn yields in 2010 and 2011 and a drought in the southern U.S. Great Plains. A severe South American drought in late 2011 and early 2012 also reduced that region's corn and soybean supplies. In late June 2012, there was concern that adverse weather might again reduce U.S. crop yields for a third consecutive year, and that also increased feed cost volatility.

China's rapid increase in soybean imports also contributed to higher corn prices. This trend occurred simultaneously with a global need for more corn acres for biofuel, resulting in competition among corn, soybeans, and other major crops for cropland that contributed to higher prices for alternative feed crops.[2]

Corn's transition to a major energy crop was accompanied by sharply increased supplies of distillers' grain and solubles (DGS) for both domestic and foreign livestock feeders and adjustments in rations to use this ingredient effectively. Explosive growth in biofuels was accompanied by more than a seven-fold increase in corn prices at times and sharp increases in the cost of DGS as other users of corn were forced to compete with ethanol producers for supplies. As a result, feed costs have risen substantially, become more volatile, and increasingly sensitive to fluctuations in crude petroleum prices. Feed markets also have become potentially more responsive to exchange rate fluctuations, due to the sensitivity of crude petroleum prices to the value of the U.S. dollar.

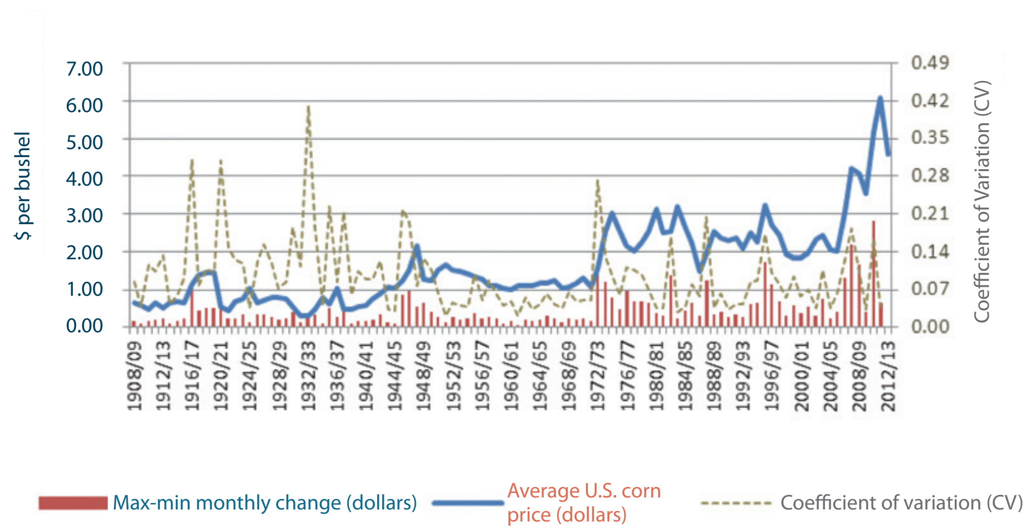
Putting Price Volatility in Perspective

There are several ways to look at feed cost volatility. The most relevant approach from a feed and livestock industry perspective is to measure volatility as a percentage of net profit margins. However, time constraints did not allow that type of analysis for this report.

A traditional volatility measure focuses on a mathematically calculated coefficient of price variation (CV, the standard deviation of prices divided by the mean) for relatively long time periods. This measure reflects percentage variations in prices. U.S. corn prices have trended upward irregularly since the early 1900s, as has the absolute size of monthly price changes (figure 1). Although absolute corn price variation has been higher in the past few years, this comparison indicates recent relative or percentage price variations are similar to those of three, four and seven decades ago. However, long-term views of corn price volatility somewhat mask the recent shocks to the livestock sector resulting from abrupt changes in feed markets after a decade and a half with only short-term spikes in grain prices.

These long-term measures of relative or percentage monthly price variation indicate that U.S. corn price variations were at times higher pre-World War II than in post 1973/74. However, an average over this later period can be misleading because it reflects wide diversity in market conditions, including fifteen years of large Soviet grain imports combined with weather shocks that increased price volatility and triggered livestock sector adjustments similar to those of the past few years. The post 1973/74 period was followed by rather benign price and weather situations from the late 1980s through the early 2000s, except for a brief period of lower U.S. corn production and temporary Chinese corn imports in the mid-1990s that led to a temporary price spike. At that time and in the next several years, China normally was the world's second or third largest corn exporter.

Figure 1. **U.S. corn prices and monthly price variation have trended upward irregularly since the early 1900s**



Source: U.S. Department of Agriculture, Economic Research Service, 1908-09 to projected 2012-13

Recent increases in corn price volatility, while not unusual from an historical perspective, substantially increased feed and livestock industries' risk-management challenges and costs compared with previous periods. When viewed in conjunction with government biofuel mandates, potential future volatility could be greater if U.S. corn and soybean yields drop sharply below long-run trend yields, as occurred during the 1930s, mid-1940s, 1970s, and 1980s.

Biofuel Mandates Affect Corn Price Volatility

Biofuel mandates require specific quantities of ethanol and biodiesel to be blended with domestic motor fuels. In a short-crop environment where grain supplies are inadequate to maintain recent rates of consumption, the biofuel mandates allow ethanol and biodiesel producers to pay whatever price is necessary for feedstocks in order to comply. A policy mechanism exists for dealing with this potential problem, but its parameters are not very precise. If the Secretaries of the U.S. Department of Agriculture and U.S. Department of Energy determine that adverse economic impacts would result from enforcing the mandates, EPA may apply a waiver or partial waiver of the mandates[3] EPA is the agency that enforces the mandates.

In reality, in a situation where a partial waiver might be needed, the political decision to apply a waiver likely would not be made until a crisis had emerged in the livestock industry.

Foreign biofuels mandates also could contribute to future corn price volatility, although U.S. mandates likely will be a more significant factor. More than 50 other countries are following the U.S. lead on biofuels mandates, including Canada, European Union (EU), Brazil, Australia, China, India, and Argentina.[4] The list may grow in the next few years. Rising foreign mandates may affect feed market price levels and volatility, especially when U.S. or major foreign grain producer crop yields are low.

Corn is Used for Feed, Food and Fuel

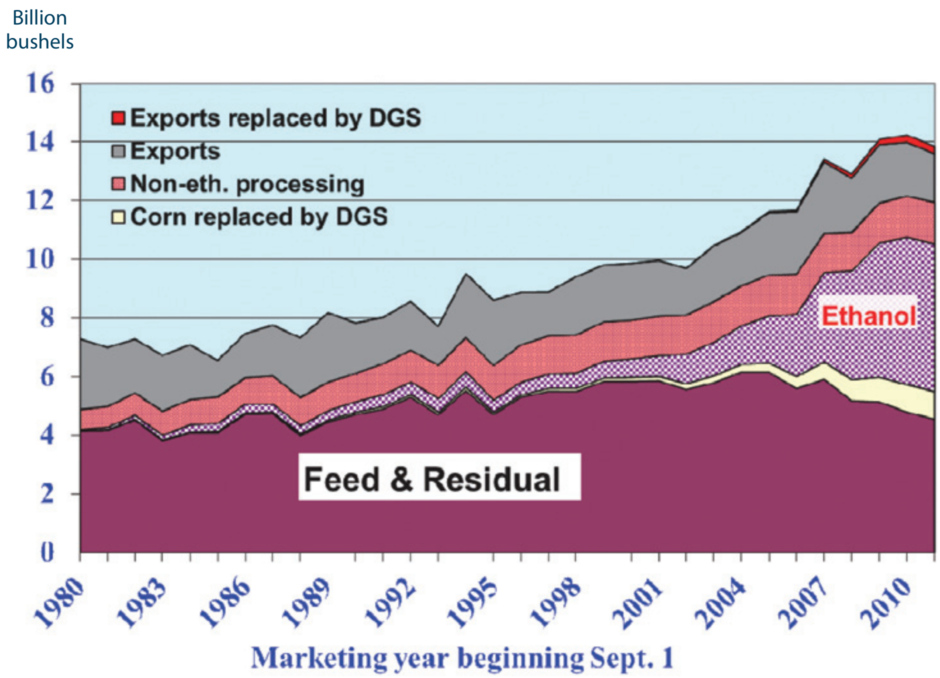
Corn accounts for 95% to 97% of total U.S. feed grain production. Combined domestic corn use for feed and the corn equivalent of DGS fed domestically peaked in 2004-05 (based on residual use calculations from data developed by the National Agriculture Statistics Service, USDA, and official corn export and Census processing data). Corn feed and residual (handling losses and statistical errors) use of corn in 2011-12 is projected to be 1.27 billion bushels below 2000-01 (figure 2). Domestic feeding of DGS offset an estimated 56% of the decline.

U.S. corn exports peaked in 1980-81 and again in 2005-06. From 2000-01 to 2010-11, U.S. corn exports fell by 106 million bushels. A further decline is projected for the marketing year ending August 31, 2012. These trends indicate total non-ethanol use of U.S. corn has declined by 1.5 billion bushels since 2000.

High fructose corn sweetener (HFCS) use increased gradually from the early 1980s until peaking in 1999-2000 (figure 3). HFCS use grew as it increasingly replaced sugar in soft drinks, processed foods and other applications.

Domestic corn use for sucrose, dextrose and starch has trended slowly upward since 1980-81. However, these products accounted for only 4% of total U.S. corn use in the marketing year that ended on August 31, 2011.

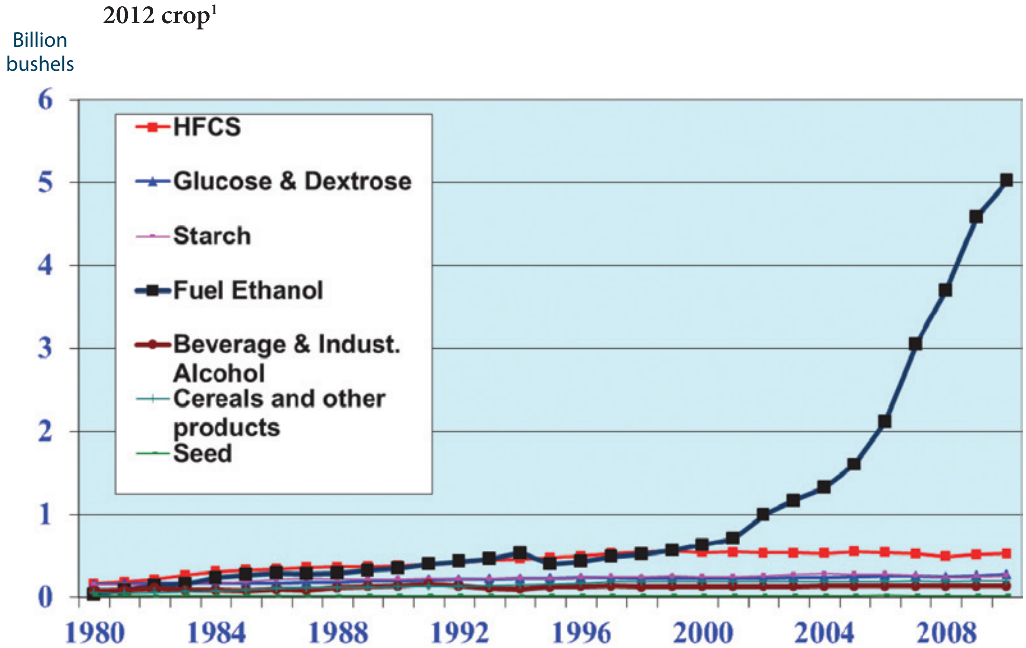
Figure 2. **Ethanol production increased total corn use by 45% since 2001-02**



Note: DGS = Distillers' grain and solubles.

Sources U.S. Department of Agriculture, Economic Research Service, Feedgrains data base, Tables 4 and 34, http://www.ers.usda.gov/data-products/feed-grains-database/feed-grains-yearbook-tables.aspx, compiled by Wisner, R., Ag Marketing Resource Center, Iowa State University.

Figure 3. **Domestic non-feed & non-fuel use of U.S. corn equals 9.5% of potential 2012 crop[1]**



Data Source: U.S. Department of Agriculture, Economic Research Service, Feed Grain Yearbook, Table 31, http://www.ers.usda.gov/data-products/feed-grains-database/feed-grains-yearbook-tables.aspx.

HFCS = High Fructose Corn Sweetners [1]With USDA projected 166 bu/acre yield

Corn use for beverage and industrial alcohol has been stable at approximately 1%. Use in cereals and other products increased only 13 million bushels in the past 13 years, accounting for about 1.5% of total U.S. corn use.

The five non-fuel and non-feed uses plus corn use for seed increased by only 59 million bushels in the 11-year period ending August 31, 2011 and accounted for 9.5% of the potential 2012 U.S. corn crop (assuming normal corn yields). These categories accounted for only 0.18% of the growth in total corn use in the 11-year period.

Rapid Growth in Ethanol Production Increased Corn Use and Prices

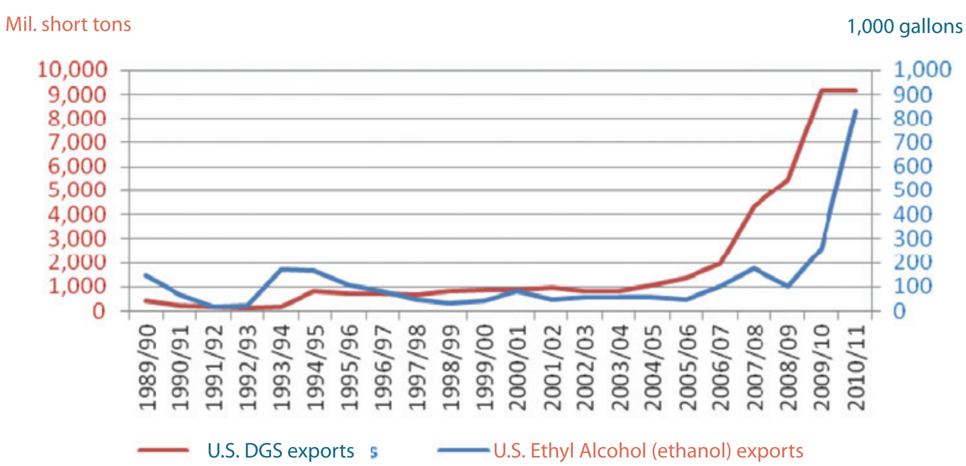
Corn processing for ethanol grew 4.42 billion bushes or 623% since 2000, while other non-food uses of corn were relatively stable (figure 3). In contrast, non-fuel industrial corn use of corn increased 1.3% over the same time period.

Biofuel-related demand is tied to world crude oil prices and government biofuel blending mandates, and has been insensitive to changes in corn prices. For example, during 2004-2011, Western Corn Belt cash corn prices at elevators varied from $1.50 to over $8.00 per bushel, while corn use for ethanol trended steadily upward**.**

Exports of U.S. ethanol and distillers' grains have increased sharply since the 2005/06MY, spurred by increased U.S. ethanol production (figure 4) and rising foreign incomes. U.S. ethanol exports of 834 million gallons accounted for roughly 6% of total U.S. ethanol production from September 1, 2010 through August 31, 2011 corn MYs.[5] In addition, U.S. DGS exports of 9.15 million short tons in MY 2010/11 accounted for approximately 21% of U.S. DGS production.[6]

Future U.S. ethanol exports will depend partly on foreign sugar production, especially in Brazil. Brazilian sugar cane ethanol is the major potential competitor with U.S. ethanol exports. Brazilian ethanol production has been constrained in the past 2-3 years by lower production and high prices that made sugar production more profitable than ethanol. May 2012 USDA reports indicate that smaller sugar crops are likely to restrain Brazilian ethanol production until at least early 2013.[7] An EU action that placed an increased tariff on imports of U.S. ethanol sharply curtailed U.S. ethanol exports beginning in early 2012.[8]

Figure 4. Exports of U.S. ethanol distillers' grain and solubles have increased sharply since 2005/06



Note: DGS=Distillers' grain and solubles

Source: U. S. Department of Agriculture, Economic Research Service, Data Products, Feed grain data base, tables 32 and 34, 1989-90 to 2010-11 marketing years; http://www.ers.usda.gov/data-products/feed-grains-database.aspx

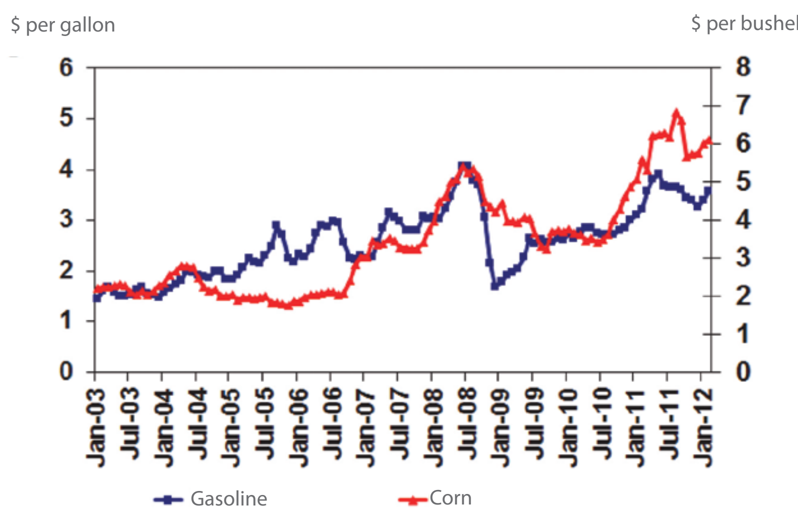
China became a large market for U.S. DGS exports, starting in 2010. However, in response to domestic ethanol industry concerns, China placed an anti-dumping tariff on imports of U.S. DGS imports in 2011. With China's halting of its dumping investigation in late June 2012, it appears that the tariff will be removed.[9] If so, the Chinese demand for U.S. DGS could expand considerably in the future.

Ethanol Links Corn Prices to Gasoline Market

In early October 2006, the value of corn processed into fuel ethanol at plants in western Iowa, after deducting processing costs and including DGS value, was approximately $4.05 per bushel.[9] The cash or spot ethanol plant prices for corn in western Iowa in 2006 were about $2.33 per bushel because of plentiful corn supply relative to market demand. However, as ethanol production expanded rapidly in the next five years and corn supplies tightened, prices moved up sharply to reflect corn's energy value when converted to motor fuel. At the same time, gasoline prices increased and raised the energy value of corn. As this transformation took place, the corn market shifted from a long period of prices in the $1.50- to $2.25-per bushel range at western Corn Belt elevators, to prices $6.00 to $8.00 per bushel and for short times even higher.

Figure 5 shows the relationship between gasoline prices and corn prices over the past several years using USDA and Department of Energy (DOE) price data. The relationship does not have perfect correlation and is influenced by variables such as U.S. and foreign weather and crop yields. However, there is a clear pattern of relationship between the two price series beginning in 2007.

Figure 5. **As ethanol production increased, corn prices rose sharply to reflect the energy value of corn**

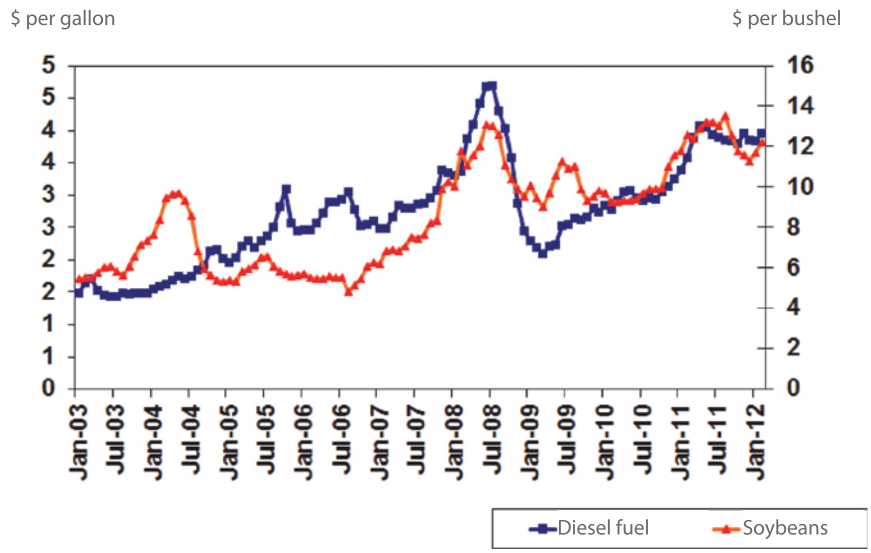


Sources: Energy Info. Admin., May 2012 Monthly Energy Review & NASS, USDA, Ag Prices, various issues

In the mid-2004-late 2006 period, corn supplies were very plentiful compared with market demand. For that reason, corn prices reacted independently from gasoline prices. During mid-2008 to early 2009, U.S. and foreign weather concerns and anticipated tighter corn supplies meant that corn prices were relatively stronger than gasoline prices. That pattern occurred again in 2011 in response to below normal U.S. corn yields.

For soybeans, the market connection with fuel prices comes from the use of soybean oil for biodiesel, and competition with corn for U.S. and foreign cropland. Figure 6 shows a clear relationship between diesel fuel and soybean prices, although the soybean market also is influenced by weather, biological factors, and foreign demand growth.

Figure 6. Iowa average use of soybean oil for biodiesel results in clear relationship in prices



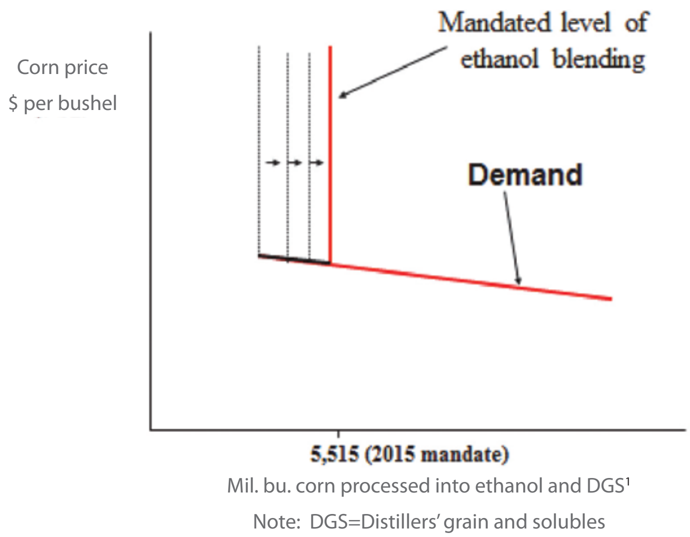
Source: Energy Info. Admin., May 2012 Monthly Energy Review & NASS, USDA Ag Prices, selected issues

Energy Information Administration, Monthly Energy Review, "Petroleum and other liquids" http://www.eia.gov/petroleum/ and U.S. Department of Agriculture, National Agricultural Statistics Service, Ag Prices, 2003-2012 and http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1002d.

Policies Influence the Growth of Biofuels[10]

Modest volumes of U.S. corn had been processed into fuel ethanol from the late 1970s to the early 2000s in response to government incentives, including a tax credit for blending with gasoline. By the first decade of the 21st century, use of corn for fuel ethanol accelerated for several reasons. The September 11, 2001 crisis spawned interest in more aggressively pursuing biofuel policies to reduce dependence on imported oil such as mandated volumes of blending from the Renewable Fuel Standards (RFS1 and RFS2[11]) and government incentives to increase bioenergy production. Efforts to reduce greenhouse gas emissions have been an additional contributing factor, along with banning the use of methanol as an oxygenate in gasoline to meet clean air standards.

Figure 7. **Mandated renewable fuel standards could increase the sensitivity of corn prices to reduced corn production**



Source: R. Wisner, Iowa State University

Developed by Wisner, R., Iowa State University, based on conventional ethanol blending mandates from the U.S. Congress, Energy Independence and Security Act, December 2007; http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf

Biofuels mandates increase potential sensitivity of corn prices to reduced production (figure 7). When supplies are extremely tight, the mandates cause ethanol processors' demand for corn to become perfectly inelastic (price insensitive). Thus, with tight supplies, most or all of the adjustment to limited supplies would probably occur in the feed and livestock industries. Use of corn for domestic human food is relatively price insensitive since the cost of corn in these products is a very small part of the end-product retail price.

U.S. Cropland Adjustments Occurred in Response to Increased Ethanol Demand

Rapid growth in corn processing for ethanol and the accompanying corn price increases have required major U.S. and global agricultural adjustments, including shifting acreage from idle land to crops and from other crops to corn. Other adjustments included changes in livestock and poultry rations.

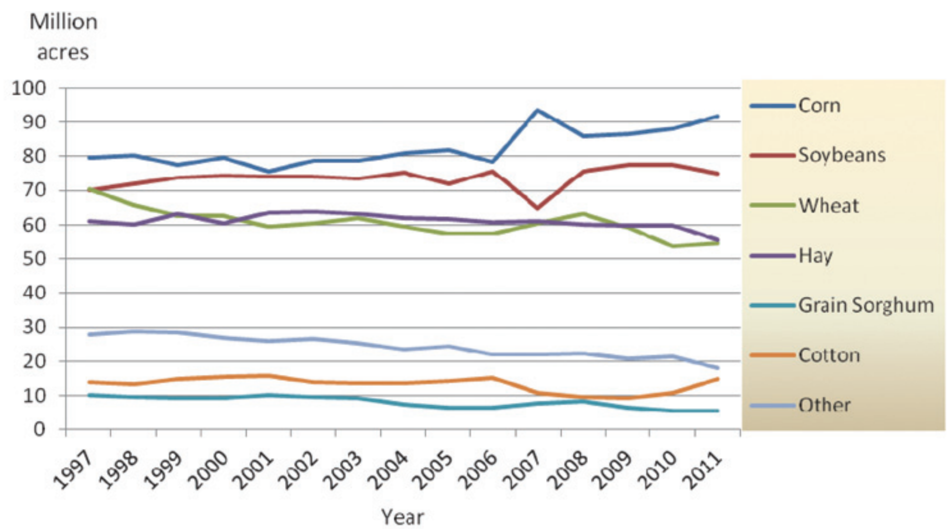
U.S. corn planted area increased 17% from 78.9 million acres in 2002 to 91.92 million acres in 2011 (figure 8). USDA's March 2012 prospective plantings survey[12] indicates that corn plantings will reach an estimated 95.9 million acres in 2012.

Approximately 67% of the increase in corn acreage since 2002 was matched by reduced sorghum, barley, and oats plantings (included with cotton in the "other crops" in figure 8). Wheat planted area declined by 5.9 million acres during the same period. U.S. hay acreage dropped from 61.1 million acres in 1987 to 55.6 million in 2011. Alfalfa fell from 23.6 to 19.2 million acres over the same period.

From 1997 to 2011, western U.S. hay acreage increased in some states (Arizona, 24%; Colorado, 2%; and Montana, 4%) but declined markedly in others (Texas, 17%; California, 8%; Kansas, 11%; and Oklahoma, 2%). Extreme drought conditions in Texas and Oklahoma caused large reductions in hay acreage in 2011[13] . Declines in wheat and the three non-corn feed grains provided enough additional acreage to slightly more than offset the increase in corn acres. With reduced plantings, less oats, barley, and sorghum production were available to use as livestock feeds.

U.S. soybean area planted increased by approximately one million acres from 1987 to 2011. However, USDA's March 2012 Prospective Plantings survey indicates that soybean acreage may decline in 2012 to marginally less than in 2002. Combined U.S. acreage of minor oilseeds also has fallen since 2002. Cotton area increased by about 750,000 acres from 1997 to 2011, but in 2012 is expected to be slightly below the 1997 level.

Figure 8. U.S. corn planted area increased from 17% from 2002 to 2011



Source: U.S. Department Agriculture, National Agricultural Statistics Service, Quickstats 2.0 http://www.nass.usda.gov/Quick_Stats/ and Crop Production

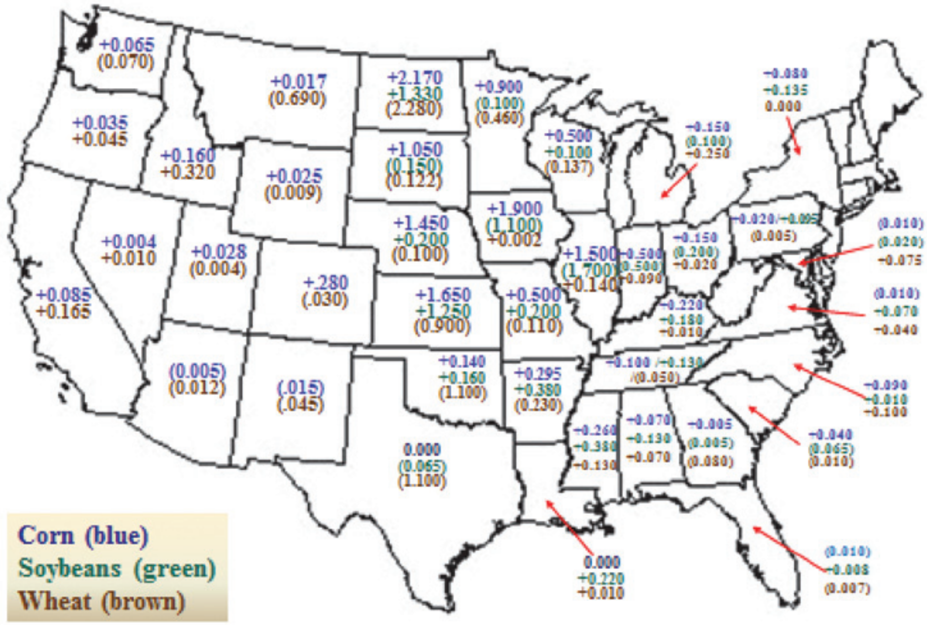
2011 Summary, and Crop Production Annual Summary, January 2012, ISSN: 1057-7823; HYPERLINK "http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1047%20" http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1047

Regional Shifts in Production Accompanied Acreage Changes

The Soybean Belt (historically from eastern Nebraska to Ohio & Missouri to Minnesota) expanded westward, especially in the Northern Plains. Corn production intensified in the heart of the Corn Belt but also expanded south and west (figure 9). Despite these changes, total planted acreage of U.S. principal crops declined from 327.3 million acres in 2002 to an estimated 315 million acres in 2011 (figure 10). Early indicators point to slightly over 322 million acres of U.S. principal crops in 2012, bringing the total back near the 2003 level. Reduced acreage occurred in the Midwest, Great Plains, Far West and intermediate western states. The Southeast and South Central states had small increases in principal crops acreage. Further large gains in U.S. corn acreage, however, likely will be much more difficult to attain than the estimated 22% or 17.5 million-acre gain from 2006 to 2012.

In addition to considering shifts in crop acreage, it also is important to factor in possible trends in crop yields. The expansion of U.S. corn since 2002 was partly achieved by bringing into production lower-quality, previously fallow cropland on the fringes of the U.S. Corn Belt that was in the Conservation Reserve Program or devoted to forage or other more drought-resistant crops. Corn yield potential on these more marginal croplands is lower than in the traditional areas of the Corn Belt. Also, agronomic research indicates yields typically are 10% to 15% lower for land shifted from soybeans to multiple-year corn production than with a corn-soybean rotation.

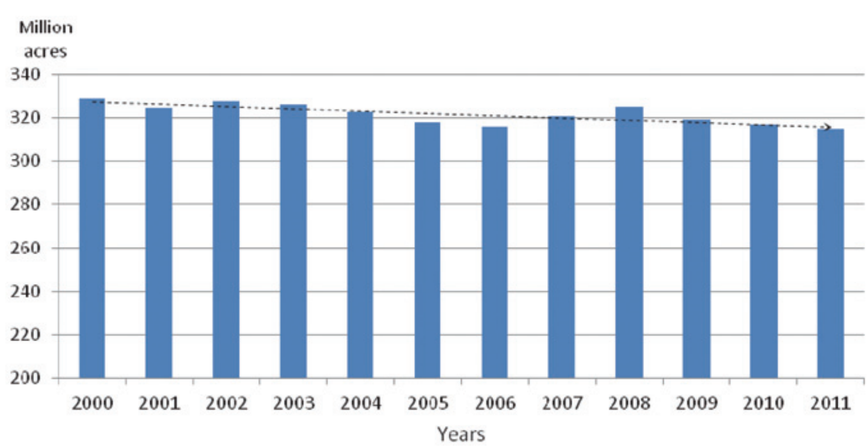
Figure 9. Corn production intensified in the heart of the Corn Belt and expanded south and west



Note: State-by-state changes in million acre units planted from 2002 to 2011

Source: U.S. Department of Agriculture, National Agriculture Statistics Service, Historic data, field crops; 1909-2011, http://www.nass.usda.gov/Statistics_by_State/Washington/Historic_Data/fieldcrops/corngrn.pdf and World Agricultural Outlook Board, U.S. Department of Agriculture, World Agriculture Supply Demand Estimates, WASDE – 506, May 10, 2012.

Figure 10. Despite increases in corn and soybean acreage, total planted acreage of U.S. principal crops declined from 2002 to 2011



Source: U.S. Department of Agriculture, National Agricultural Statistics Service, Crop Production Annual Summary, January 2001-2012,ISSN: 1057-7823, http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1047

A Global Perspective on Shift of Corn to an Energy Crop

Explosive growth in U.S. corn demand has created shock waves across U.S. and foreign grain, feed, and livestock sectors. Substantial changes in price relationships of corn to other crops are changing crop acreage patterns in U.S. regional and major foreign crop producing areas.

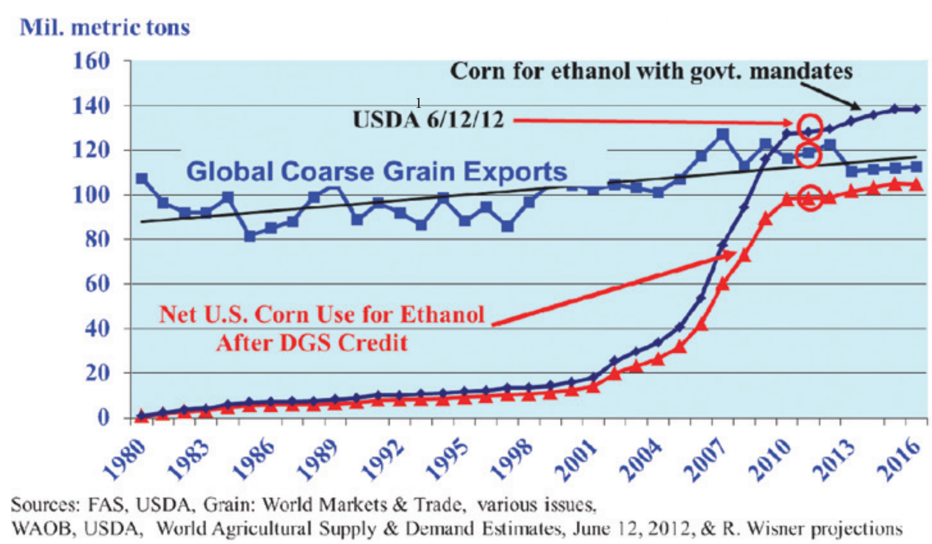
The approximate 4.4 billion-bushel increase in U.S. corn processing for ethanol since 2000-01 is equivalent to 10% of 2010-11 global feed grain production and 13% of world corn production. After adjusting for replacement of corn by ethanol's major co-product, DGS, the numbers are approximately 7% and 10%, respectively. U.S. corn processing for ethanol from 2002 to 2010 created a new block of demand that, after adjusting for replacement of corn by DGS, is nearly as large as global coarse grain (feed grain) exports (figure 11).

Over this same period, U.S. corn exports as a share of global exports trended downward (figure 12). Before the mid-2000s, U.S. corn exports accounted for 60% to 75% percent of global exports. Higher world corn prices in response to corn becoming a major energy crop stimulated foreign production of feed grains and feed wheat, thus reducing the U.S. share of the global corn export market.

Biofuels Bring Global Agricultural Adjustments

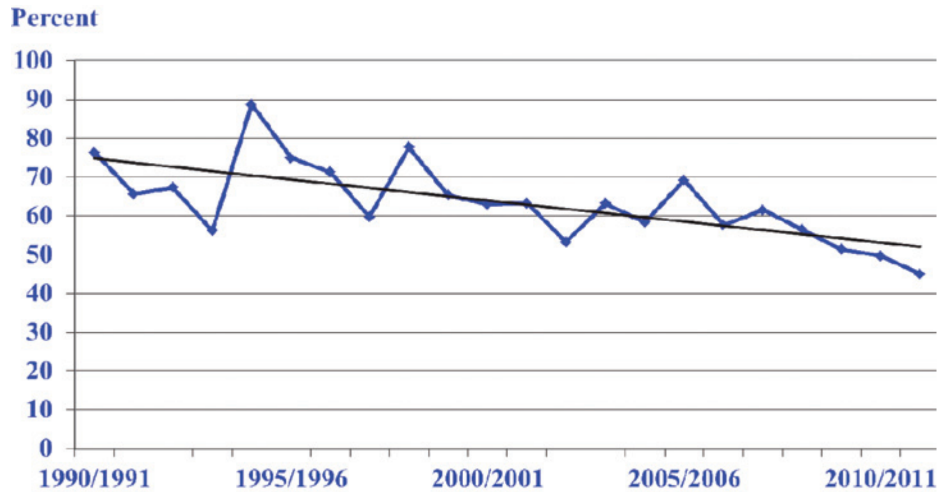
Higher grain prices associated with the rapid growth in U.S. ethanol production triggered increases in foreign grain and oilseed production. South America has seen major growth in land devoted to feed grain and oilseed production (figure 13). From 2002 through 2011, South American farmers increased their harvested crop area by 19 million hectares (46.9 million acres). Most of the growth was in Brazil and Argentina. These countries still have a significant amount of land that can be converted to grain and oilseed crops, although environmental controls will likely be more of a restraint than in the past.

Figure 11. U.S. corn processing for ethanol increased 697% from 2000 to 2011, creating new demand nearly equalling global coarse grain exports



Footnote: [1] Projections from USDA Long-term Projections (U.S. corn processing for ethanol increased 697%from 2000 to 2011, creating new demand nearly equalling global coarse grain exports), March 9, 2012.

Figure 12. **U.S. share of world corn exports has declined since the mid-2000s**



Scource: Foreign Agricultural Service, U.S. Department of Agriculture, Grains: World Markets and Trade, May 2012, http://www.fas.usda.gov/grain_arc

Figure 13. **Harvested acres of farmland devoted to South American feed grain and oilseed production grew 47% between 1998-99 and 2011-12**

Source: USDA Foreign Agricultural Service psdonline, http://www.fas.usda.gov/psdonline/

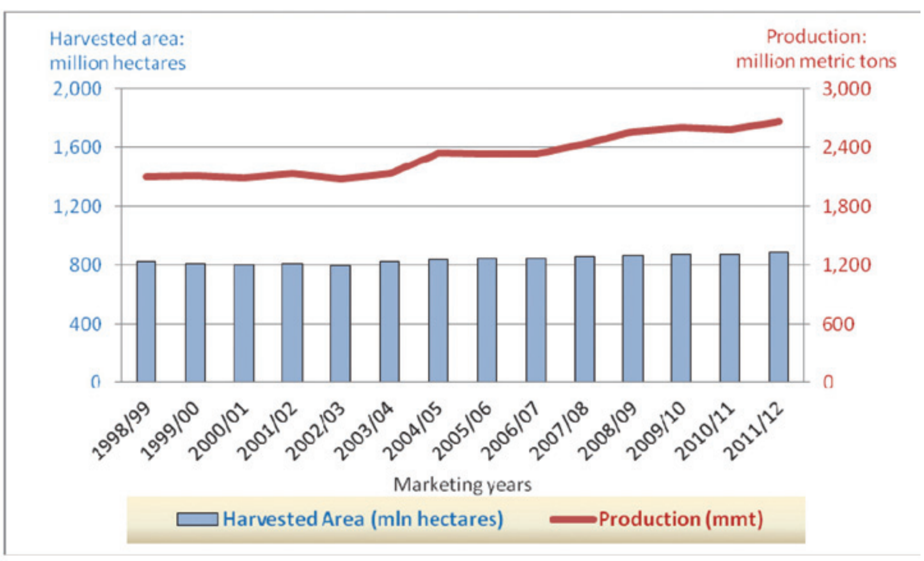
Global harvested area of 11 major crops increased by 89 million hectares or 219.8 million acres from 2002 to 2011 (figure 14). Harvested area increased 11% and tonnage of harvested crops, 28%. The increased acreage and production brought greater demand for crop inputs and contributed to higher prices for seed, fertilizer, and chemicals, boosting the cost of crop production.

Figure 15 shows global corn and soybean area harvested from 1998-2011. South America accounted for approximately 94% of the increase in global soybean area harvested in 2002-2011 period and 62% growth in world corn harvested area. Growth in U.S. corn area harvested contributed 19% so that 4/5 of the growth in global corn area was in the Western Hemisphere. The Ukraine contributed another 7% along with 11% reported for China (the accuracy of China's grain data is uncertain because huge revisions were made in the early 2000s and many would question where China would have obtained the large increase in total crop hectares – See Figure 16). Decreases in harvested acres in Canada, EU, South Africa and other smaller producing countries partially offset the global gains.

China Will Be Key Influence on U.S. and Global Agriculture

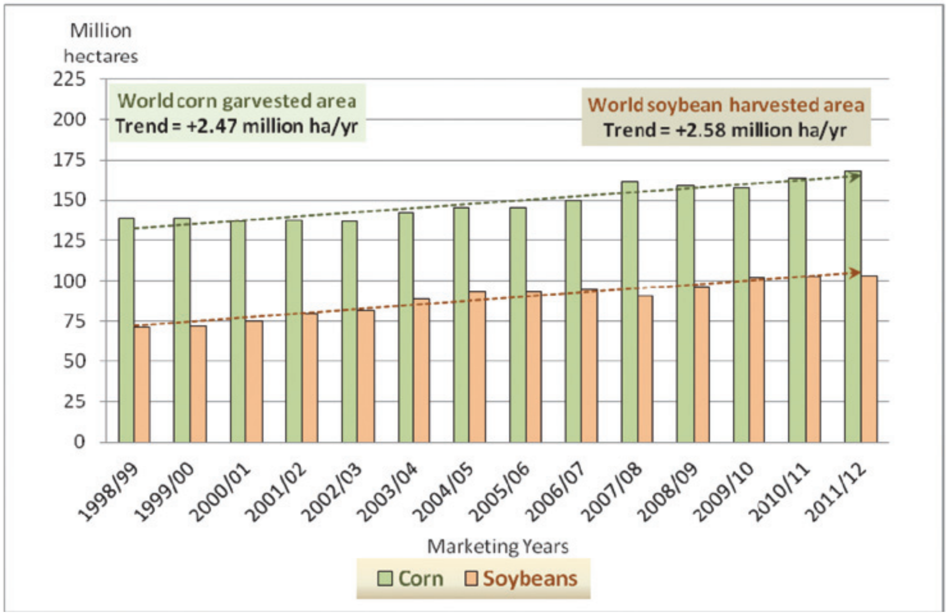
Rapid growth in economic output, increased consumer incomes, expanding middle class population, and dietary shifts away from grains to increased consumption of meat, poultry, seafoods, and dairy products have made China an important player in global agricultural markets. In the past decade, China has become the world's leading importer of soybeans. China's share has grown to over 60% of world soybean imports in an effort to meet increased demand for feedstuffs and vegetable oil. Dietary changes also are rapidly increasing China's demand for corn, raising questions of whether China might soon become a large consistent importer of corn. Through mid-June of the 2011-12 MY, China had purchased 198 million bushels of U.S. corn--an 804% increase from the previous year, even though official Chinese and USDA data indicate that Chinese farmers had record 2011 yields and corn crops.

Figure 14. Global harvested area of eleven major crops increased 11% and volume rose 28%



Source: U.S. Department of Agriculture, Economic Research Service, Livestock, dairy, and poultry, "Livestock & meat domestic data", http://www.ers.usda.gov/data-products/livestock-meat-domestic-data.aspx and "Meat Statistics", HYPERLINK "http://www.ers.usda.gov/data-products/livestock-meat-domestic-data.aspx" \l "26055" http://www.ers.usda.gov/data-products/livestock-meat-domestic-data.aspx#26055

Figure 15. South America accounted for about 94% of increased global soybean area harvested in 2002-2011

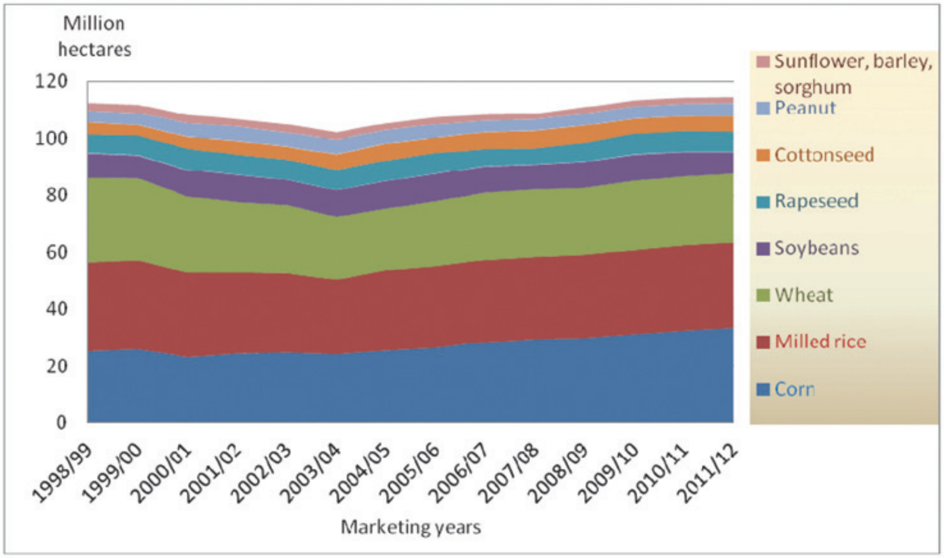


Source: U.S. Department of Agriculture, Economic Research Service, Livestock, dairy, and poultry, "Livestock & meat domestic data", http://www.ers.usda.gov/data-products/livestock-meat-domestic-data.aspx and "Meat Statistics", HYPERLINK "http://www.ers.usda.gov/data-products/livestock-meat-domestic-data.aspx" \l "26055" http://www.ers.usda.gov/data-products/livestock-meat-domestic-data.aspx#26055

Chinese total crop acreage trended downward from the early 1998-99 until 2003-04 when area harvested began to increase (figure 16). Total major-crops area harvested jumped from 102.1 million hectares in 2002-03 to 114.7 million hectares or 283.3 million acres in 2011-12. To put this increased area in perspective, it is equivalent to finding new cropland in a 10-year period equal to 126% of the principal crop in Iowa, the U.S. leader in harvested acreage. China's agricultural data are viewed by many analysts as being of uncertain accuracy due to complexities in surveying several hundred million farmers and small firms that handle their crops, so the size of the reported increase in cropland should be viewed with a certain amount of skepticism. If the numbers are accurate, it is doubtful that China can continue its recent rate of increase in cropland for the next several years.

In addition to land availability, corn yield per acre is the other key variable in determining whether China will become a continually large corn importer. China's corn yield in recent years has trended upward at approximately 1.7 bushels per acre or 1.8% per year, a considerably slower rate than its annual increase in pork, poultry, and dairy production. Chinese swine slaughter rose an average of 2.2% annually from 2002 to 2011-12, broiler production increased an average of 3.8% annually, and milk production, 13.6%. With a population of 1.347 billion[14], China represents a potentially large import market for feed grains along with further expansion potential soybean imports.

Figure 16. **Total harvested acreage in China began increasing in 2003-04**



Source: U.S. Department of Agriculture, National Agricultural Statistics Service, Crop Production: Annual summary, 2000-20011, HYPERLINK "http://usda01.library.cornell.edu/usda/current/CropProdSu/CropProdSu-01-12-2012.txt%20%20%20" http://usda01.library.cornell.edu/usda/current/CropProdSu/CropProdSu-01-12-2012.txt

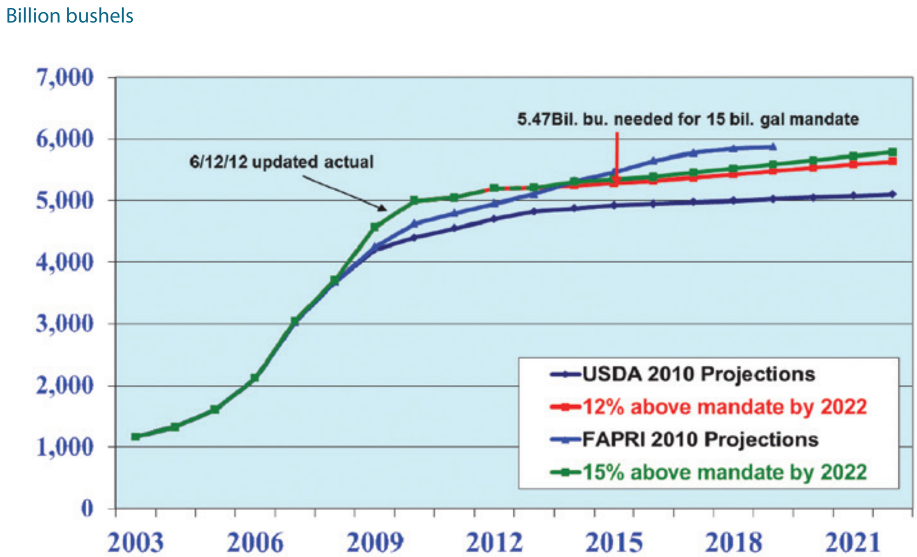
Corn Use for Ethanol is Expected to Increase More Slowly in Next Decade

Three factors will largely be responsible for slower growth in corn use for ethanol: (1) much slower increases in U.S. government ethanol mandates and a corn-starch ethanol cap in 2015; (2) approaching the "blend wall" with the average U.S. ethanol-gasoline blend percentage now at or slightly above 10%; and (3) wholesale and retail petroleum industry impediments that may slow the transition to a higher U.S. average ethanol-gasoline blend.

Figure 17 shows several alternative projections of U.S. corn use for ethanol to 2022. The lower projection is from USDA's 10-year projections model in 2010[15]. The 2022 projected level of corn use for ethanol looks unrealistically low since corn processed through ethanol plants in the 2010-11 MY almost reached the level projected for 2022. The upper projections are from the Food and Agricultural Policy Research Institute (FAPRI), a joint effort of Iowa State University and the University of Missouri, in 2010[16]. Actual corn use for ethanol, as indicated by Figure 11, has exceeded both of these sets of projections for the past two years and is expected to do so again in the current marketing year. Figure 17 includes two other sets of ethanol projections in which U.S. corn processed into corn-starch ethanol exceeds: (1) the 2022 EISA mandate by 10% and (2) the 2022 mandate by 15%.[17] Recent corn use for ethanol has exceeded the mandates by percentages within these ranges.

The U.S. corn-starch ethanol mandates reach a maximum of 15 billion gallons in 2015 and remain constant through 2022. However, the mandates are a required minimum level of corn-starch ethanol blending in the nation's gasoline supply, not a maximum. Also, it should be noted that ethanol exports have been large in the past two years and are another way corn use for ethanol could exceed the mandates. All of the projections indicate that corn use for ethanol in the next several years is expected to increase much more slowly.

Figure 17. **Growth in corn use for starch ethanol is expected to slow, as indicated by several alternative projections to 2022**



Source: ERS, USDA, Agricultural Baseline Projection Tables (94005), 2010, Table 18, FAPRI, Missouri, US Biofuel Baseline Briefing Book, Projections for agricultural and biofuel markets, FAPRI-MU Report #04-10, May 2010, ERS, USDA, Feed Grains Yearbook Tables, Table 31, June 12, 2012, & R. Wisner, "Net Corn Acres Needed for U. S. Biofuels from 2010 through 2022", forthcomin Iowa State University Dept. of Economics white paper.

If corn use for corn-starch fuel ethanol is 10 to 15 percent above the mandated level by 2022, 600 to 800 million more bushels of corn would need to be processed into ethanol and distillers grain then expected for 2011-2012 marketing year. The additional ethanol would require the corn produced on 2.5 to 4 million acres, using a normal U.S. average yield and adjusting for corn replaced by DGS feeding. That is slightly less than the increase in corn acreage that was planted in 2012. In the next few years, with slowing growth in corn use for ethanol, U.S. corn yields recovering from recent below-normal levels and following the 1990-2007 historical trend, and Chinese corn purchases remaining near current levels, corn and DGS availability for the U.S. feed, livestock, and poultry industries could increase modestly from the 2011-12 marketing year.

Looking Beyond 2012-15, a Number of Issues Could Affect Feed Availability

Key feed-crop related issues for the future include:

- How much additional growth in ethanol demand can be anticipated in the next 5 to 10 years?
- What impact will reduced DGS oil content have on its feed value and acceptability in non-ruminant domestic and foreign livestock and poultry industries?
- Will some ethanol plants be considered producers of advanced biofuels for RFS-2 mandate purposes?

- Will next-generation technology such as biobutanol create a second stage of growth in corn use for biofuels? Several ethanol plants are in the initial stages of either converting their facilities to biobutanol production or adding a biobutanol production unit, with DGS as a co-product.
- Where can additional U.S. cropland be obtained now that minor feed grain and oilseed plantings are low and wheat acreage has declined to the lowest levels in 40 years?
- What will be the future trend in U.S. corn yields?
- Will foreign growth in demand for DGS reduce the availability for domestic livestock and poultry feeding?
- What additional crop adjustments are likely in foreign countries that might increase global grain supplies, thus reducing U.S. corn export demand?
- What is likely to be the trend in foreign use of feed grains in the next several years?
- Is China on the verge of becoming a consistent major corn importer?
- Will next-generation (cellulosic) biofuels reduce the amount of land available for pasture and forage?
- Will sustained increases in feedstuff price volatility raise risk-management costs for the feed and livestock industries?

Complete answers to these questions would require a much more extensive project than the current one.

Livestock and Dairy Industries in Transition Since Feed Costs Began to Rise

The livestock market's reaction to increasing costs is complicated by the biological nature of livestock production. It takes time to adjust to rising costs and the speed at which adjustments are made varies with each livestock type. For example, the adjustment period for poultry is shorter than for cattle because the average time from planning to birth to final weight is a few weeks for chickens versus about three years for beef cattle. Many of the events in livestock agriculture over the past few years reflect its continuing transition to new economic realities and provide insights on the challenges ahead. Future patterns of U.S. livestock and dairy feeding and production also will depend heavily on alternative domestic and foreign demands for feed grains and protein meal, available domestic supplies, and feed prices.

Feed Costs are Largest Single Cost for Most Livestock Producers

Corn prices increased sharply beginning in 2006 (figure 18). Average prices for fall 2010 through early summer 2012 were around $6.00 per bushel, up from a long period of $2.00 per-bushel prices. The livestock and feed industries also faced greater feed cost volatility and increased risk management challenges.

Range livestock producers in the West and cow-calf producers in the eastern U.S. may be a partial exception, since the bulk of their livestock feed is grown on the range or pastures that are rented, leased or owned. Even so, the sale value of range and pasture-produced livestock is affected by feed costs so that this part of the livestock sector is not completely immune to impacts of feed grain and protein costs and availability.

Rising gasoline prices, the ethanol mandates, and other government incentives increased demand for corn for ethanol production which has been a prime factor in sharply higher feed costs. Combined with China's growing demand for soybean imports, the result was strong competition between corn, soybeans and other crops for cropland and higher prices for all feedstuffs.

Figure 18. Higher corn prices accompanied by feed cost variability and greater risk management challenges

Data source: ERS, USDA, Feed Grains: Yearbook Tables, table 9, June 12, 2012

Economic Research Service, U.S. Department of , Agriculture, Feedgrains database, Table 9, June 12, 2012, http://www.ers.usda.gov/data-products/feed-grains-database/feed-grains-yearbook-tables.aspx

Note: U.S. weighted monthly average farm corn prices include a combination of earlier forward contracts and average sales in that month's spot market. Daily spot market prices would show more volatility.

A sharp increase in U.S. and foreign planted crop acres accelerated demand for fertilizer, crop-related chemicals, farm machinery. Input prices and cropland rental rates rose in a demand-pull response, increasing feed production costs.

While higher fuel prices contributed to higher livestock production costs, increased feed costs are responsible for the bulk of the increase. Feed typically accounts for about 60% of the total cost of raising hogs, with corn and soybean meal accounting for a large majority of these costs. Higher costs contributed to large financial losses across all livestock industries as they transitioned to the new feed cost dynamics. Sharply higher costs triggered reduced production for all livestock industries, although pork and poultry producers began expanding slightly again in 2012.

Increased Feed Costs Have Triggered Changes in Economics of Dairy and Hog Production

Over the past three decades, production has shifted from small dairies that grew their own feed to an increased number of large operations that rely on purchased feeds, control little land, and focus on milk production ("western model"). For more than thirty years, it was cheaper to buy feed than grow it which encouraged the expansion of dairy operations, particularly in the West. Inexpensive feed also led to more specialized hog farms that relied on purchased feeds.

With the large increase in feed costs, the milk production economic advantage has shifted to producers that grow their own feed, leaving them better able to weather high and volatile feed costs. Livestock producers that have land to apply manure to also benefit from the less expensive fertilizer nutrients compared to purchased fertilizer.

Dairy and hog producers relying on purchased feed continue to struggle with the transition to higher input costs, although pressures may moderate some in the next several years. Much slower projected growth in corn use for biofuels in the next three to five years, a recovery of U.S. corn yields per acre after two years of adverse weather, continued long-term increases in corn yields, and potential livestock and dairy export market growth may ease pressures facing large U.S. dairy producers. If these developments materialize, the trends toward larger farms, improved animal genetics, greater feed conversion efficiency and increased production per cow are likely to continue.

Beyond the three- to seven-year horizon, feed-related developments become more uncertain and larger challenges could potentially emerge. For example, rapid growth in the economies of eastern Asia, especially China, may accelerate the demand for corn and soybeans. At the same time, depending on production costs and government policies, biobutanol could potentially trigger a second stage of growth in corn-starch biofuel production and another surge in demand for corn.

Several U.S. corn-starch ethanol plants are in the initial stages of moving toward biobutanol production[18]. One plant announced its start-up of commercial biobutanol production in late May 2012[19]. Biobutanol does not require engine modifications, has higher fuel mileage per gallon than ethanol, and can be shipped in petroleum product pipelines, thus lowering transport costs. If economically competitive, expansion in biobutanol production might be a way of avoiding the current ethanol blend wall–the point at which the domestic ethanol market becomes saturated.

Reasons for Expecting Less Feed Cost Pressure Ahead

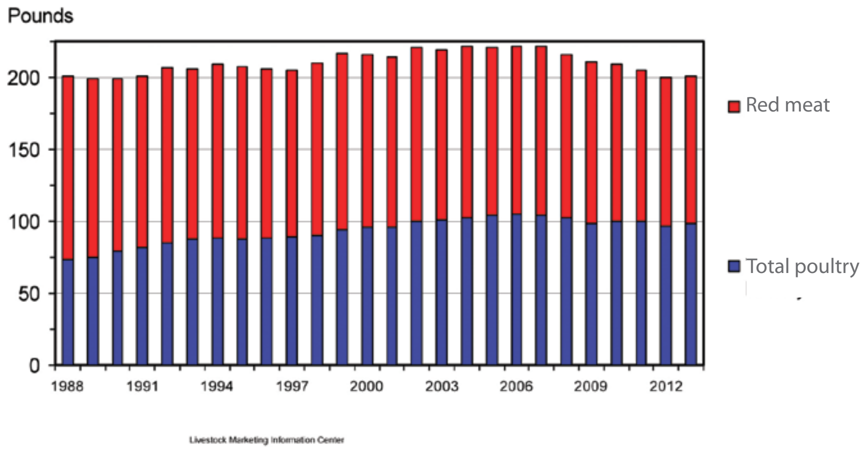
The U.S. ethanol industry has entered a period of much slower growth with near-saturation of the domestic ethanol market and with much slower increases in ethanol blending mandates in the next three years than in the recent past. From 2015 onward, mandated blending of corn-starch ethanol will level off and remain constant. These conditions and a return to improved U.S. and South American weather should generate increased availability of corn and soybean meal for U.S. livestock and poultry producers in the three to eight year period ahead. If these conditions materialize as anticipated, the stage will be set for further expansions in the U.S. feed and livestock industries. However, relatively inelastic demand for ethanol as a motor fuel can be expected to contribute periodically to spikes in feed costs when adverse weather seriously impacts crops in the U.S. and/or major foreign producing regions.

If the anticipated much slower growth in biofuel-related demand for corn and improved U.S. corn yields materialize, the pork industry will likely experience some easing of financial pressures. The industry will likely continue its long-term growth pattern, with increased production and feed conversion efficiencies and ability to respond to potentially increased export demand. Livestock and dairy exports continue to be a growth area for the livestock and dairy industries in response to foreign economic growth and rising foreign consumer incomes that have increased the demand for animal-based protein. An expanding export market is expected to continue for the foreseeable future, although it will vary from year to year.

Meat Consumption Shifted in Response to Feed Prices, Exports, and Consumer Preferences

U.S. per capita red meat and poultry consumption increased from 200 pounds in the early 1990s to about 221 pounds by 2007, before starting to decline as feed costs rose and food price increases accelerated (figure 19). Per capita consumption fell about 10 percent to a projected 200 pounds in 2012 due to decreased domestic production and increased exports.

Figure 19. **U.S. per capita red meat and poultry consumption grew to 221 pounds in 2007 before starting to decline**



Source: USDA-NASS, Compiled & Analysis by LMIC
U.S. Department of Agriculture, National Agricultural Statistics Service, Livestock slaughter annual summary. Also U.S. Department of Agriculture, Economic Research Service, Livestock, dairy, and poultry, "Livestock & meat domestic data", http://www.ers.usda.gov/data-products/livestock-meat-domestic-data.aspx and "Meat Statistics"

Note: Annual per capita consumption, retail weight

Price of Competing Meats Influences Demand for Individual Types

Efficiency gains have allowed poultry production cost and prices to decline relative to beef and pork. Efficiency gains in the pork industry have meant lower prices than beef for consumers. In addition, beef requires more grain per pound of meat than the other species, placing it at a cost disadvantage when grain prices increase. Future efficiency gains in beef production, especially in feeding efficiency through reduced pounds of feed per pound of beef produced, will be necessary to offset higher feed costs and allow the U.S. beef industry to compete more effectively with pork and poultry.

While all meat prices have increased since the mid-2000s, beef prices have risen much more than broilers and slightly more than pork and turkey (figure 20). If a slowdown in growth of corn use for biofuels emerges in three-to-five-years as anticipated and U.S. corn yields recover from below-normal yields and resume a long-term upward trend, lower and less volatile feed costs would tend to slow the increases in retail meat prices. That, in turn, would set the stage for increased production,

"Concentrate feed per pound of meat" Vs. "Concentrate feed per pound of gain."

This report reviews "**concentrate feed per pound of meat**," in analyzing how beef compares with meat production by other species when grain supplies are tight. The purpose in reviewing "concentrate feed per pound of meat" is that the beef animal can be left on pasture for a longer or shorter part of its life, depending on other factors. This way of focusing on the beef industry will be very important in the future in a limited-grain-supply agriculture sector.

Typically, "**concentrate feed per pound of gain**" relates to feedlot economics since that is important in determining whether it will be profitable to put the animal in a feedlot and finish it to market weight. "concentrate feed per pound of gain" analysis only looks at a limited part of the animal's life. Using only "concentrate feed per pound of gain" in the big-picture analysis would exclude the part of beef production originating from pasture and forage, and would greatly over-state the amount of grain needed to supply a pound of beef at the retail counter.

While this report focuses on "concentrate feed per pound of meat," the "concentrate feed per pound of gain" concept will still be important in feedlot economics and there will be a need for continued research to increase that type of feeding efficiency as well as the efficiency of converting pasture and forage to meat production.

with pork and poultry likely retaining the longer term competitive advantage relative to beef. Due to beef's longer biological production cycle, increased production will occur later than for pork and poultry.

The U.S. will continue to produce meat and dairy products but at higher costs and resulting higher prices for consumers. The higher U.S. consumer prices mean people will likely consume fewer pounds of some types of meat and dairy products, unless rising incomes boost demand. Incomes have been rising faster in some foreign countries than in the U.S., especially in East Asia. Strong economies in these and other regions have generated increased export demand for products of the U.S. livestock industry. The pattern is expected to continue in the three- to seven-year horizon and very likely longer, although export growth rates will fluctuate from year to year.

Beef Consumption Trending Downward Since 1975

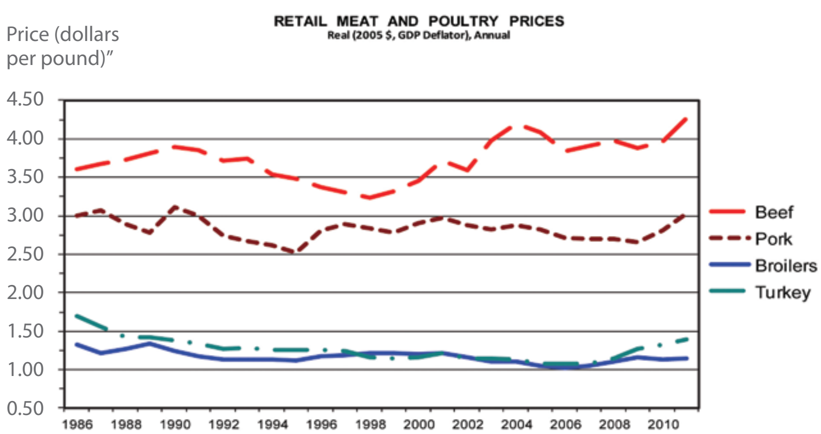
Over the past five years, beef accounted for slightly less than half of the reduction in per capita meat consumption, though the decline was slower than in some prior years. For instance, beef consumption per capita declined rapidly during the 15-year period beginning in the mid-1970s. Corn prices rose in the early part of the period, triggered by sharply higher corn and wheat exports and volatile weather that caused corn yield fluctuations and increased grain price volatility. The beef industry responded to negative returns and reduced demand by decreasing production. Relatively lower prices for poultry products, changes in consumer tastes and preferences, and health concerns also reduced beef demand and negatively affected beef prices. With lower feed costs in the early 2000s, per capita consumption stabilized until sharply higher feed costs emerged again in the last half of the decade.

Future trends in U.S. per capita beef consumption will be influenced by export demand, consumer attitudes toward beef, and the ability of the beef industry to compete with lower-priced pork and poultry.

Pork Consumption Relatively Steady for Past Three Decades

Several factors are responsible for the pork industry's steady increases in production. First, U.S. per capita pork consumption in recent decades has been stable at roughly 50 pounds of retail weight per person annually. Since the U.S. population grows each year, steady per capita consumption means domestic pork consumption expanded in most years.

Figure 20. Meat prices have increased since the mid-2000s, but beef prices rose more than broilers, pork and turkey



Note: U.S. weighted monthly average farm corn prices
Annual real prices, 2005 dollars, Gross Domestic Price deflator

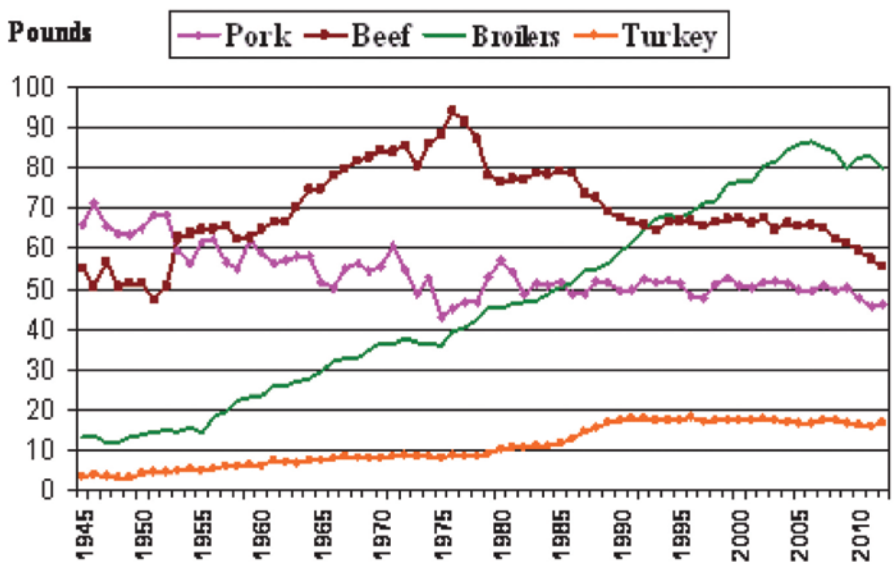
Source: Economic Research Service, U.S. Department of Agriculture, Livestock, dairy, and poultry, "Livestock & meat domestic data", http://www.ers.usda.gov/data-products/livestock-meat-domestic-data.aspx and "Meat Statistics", HYPERLINK "http://www.ers.usda.gov/data-products/livestock-meat-domestic-data.aspx" \l "26055" http://www.ers.usda.gov/data-products/livestock-meat-domestic-data.aspx#26055

Over the past 30 years, per capita pork consumption declined by 2.9 pounds, compared with 19.6 pounds for beef. In contrast, broiler consumption increased by 36.4 pounds per person, and turkey consumption was up 5.5 pounds per person. Why is per capita pork consumption so stable? A common explanation is pork's near monopoly on breakfast meats. When Americans eat meat for breakfast, it is likely to be bacon, ham, or sausage. Due to its price competitiveness, pork has been able to avoid much of the beef-for-chicken swap occurring at other meals. Also, bacon has become a common addition to sandwiches at fast-food places and other restaurants.

Poultry Consumption Increased Rapidly, Largely at Expense of Beef

Production technology innovations helped lower the broiler industry's production costs until the past six years. Reduced production costs led to relatively lower retail broiler prices than for other meats, increased per capita consumption, and higher broiler production. Broiler consumption declined slightly in the last few years as the industry adjusted to higher feed costs and consumer responses to a weak national economy (figure 21).

Figure 21. Broiler consumption began declining in 2005 in response to the higher feed costs and a weak national economy



Note: Annual per capital consumption, retail weight

Source: U.S. Department of Agriculture, Economic Research Service, http://www.ers.usda.gov/data-products/food-availability-(per-capita)-data-system.aspx

Like broilers, the shorter biological cycle allows the turkey industry to adjust more quickly to changing production economics. The relatively flat U.S. turkey consumption pattern suggests that without further consumer product innovations, a period of lower and less volatile feed costs could lead to continued slow growth of the U.S. turkey industry as the U.S. population expands.

International Trade – Pluses and Minuses for the Livestock Industry

The U.S. livestock and dairy sectors have benefitted from expanding exports. In 2011, U.S. exports of pork, beef, chicken and turkey were each record high. Recent expansions in beef and dairy exports to record levels, along with strong pork and poultry exports have contributed to higher domestic prices for producers and helped to partially offset higher feed costs.

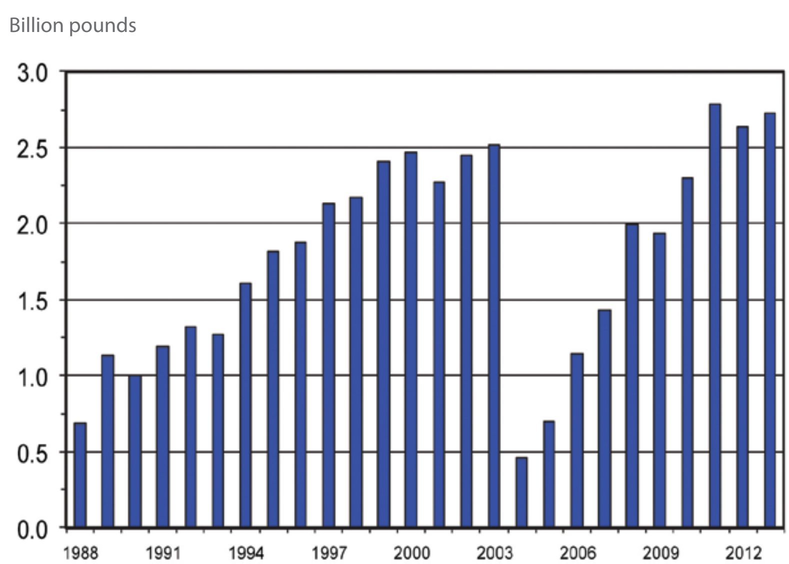
Exports remove supplies from the domestic market and allow the industry to expand without accumulating supplies and depressing prices, provided feed costs remain manageable. However, they do involve risks. International markets are vulnerable to consumer boycotts and trade restrictions. An outbreak of certain diseases can bring an immediate halt to meat exports, with the potential for major impacts on U.S. producers.

If not for the effect of strong livestock, poultry, and dairy product exports on prices, financial losses to the livestock sector would have been even more severe than has occurred. In spite of, or perhaps at least partly because of, the financial pressures placed on U.S. livestock producers from rising feed prices, the drive toward increasingly efficient cost– reducing livestock production has continued unabated. This has been and will continue to be a primary means of livestock-poultry-dairy sector adjusting to the biofuels expansion as well as international competition.

U.S. Beef Export Markets Expanding

Beef exports totaled a record 2.7 billion pounds in 2011, finally recovering to exceed exports prior to the discovery of Bovine spongiform encephalopathy in December 2003 (figure 22). While the value of beef exports has long exceeded the value of imports, export volume surpassed imports in 2010 and 2011. The U.S.'s big four beef export markets continue to be Mexico, Canada, Japan, and South Korea. However, with global economic growth, other countries such as Vietnam, Hong Kong and Russia also are becoming significant export markets for U.S. beef. The trend of increasing U.S. beef exports is expected to continue in the next several years, unless interrupted by disease or feed additive issues.

Figure 22. Record beef exports helped partially offset higher feed costs

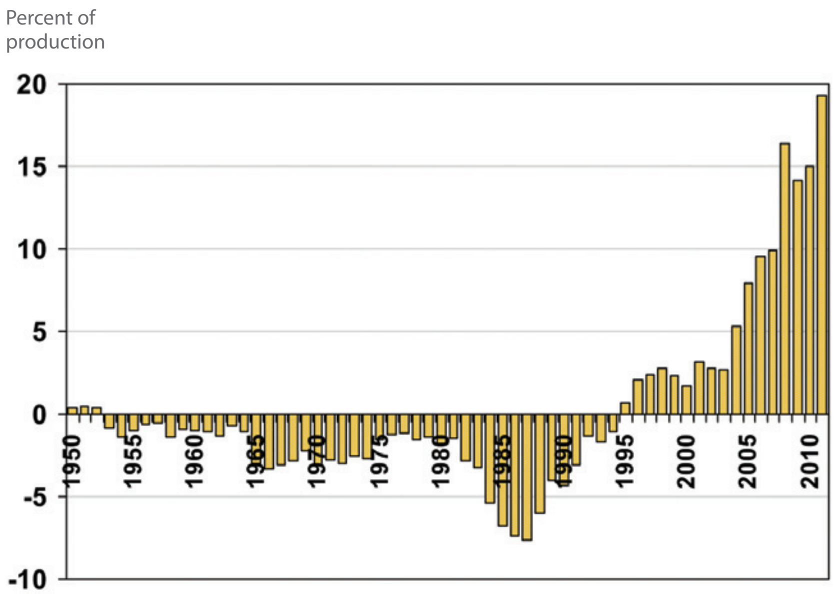


Note: Annual per capital consumption, retail weight
Source: U.S. Department of Agriculture, Economic Research Service, Livestock and Meat Trade Data, http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354

Pork Exports Expected to Continue Growing

The volume of pork imports exceeded exports from 1953 through 1994. However, a shift in U.S. pork net trade occurred in the mid-1990s, with exports exceeding imports every year from 1995 to date. In 2011, the U.S. imported 803.4 million pounds of pork and exported 5.2 billion pounds (figure 23). Fast growing exports have made up for a slowdown U.S. population growth and a slight decline in domestic per capita pork consumption. All longer-term indicators point to continued U.S. pork export growth for the next several years. In 2011, net pork exports accounted for nearly 1/5 of the nation's pork production (Figure 23).

Figure 23. Pork imports equaled 3.5% of U.S. production in 2011 and exports totaled 22.8%

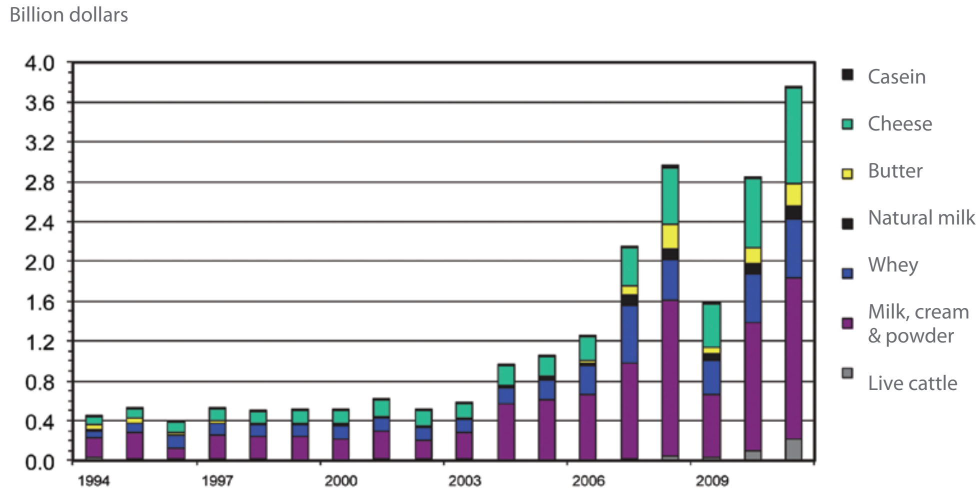


Note: U.S. pork exports minus imports as a percent of production
Source: U.S. Department of Agriculture, Economic Research Service, Livestock and Meat Trade Data, http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354

U.S. Dairy Industry Benefitted From Increased Exports

U.S. dairy exports increased to an equivalent of about 13 percent of milk solids produced in 2011 (figure 24). In the past, the U.S. often had not been price competitive in world markets. However, that has changed due to increasing incomes in the rest of the world that boosted milk product demand, along with limited ability to expand milk production in other major exporting countries, reduced production in some foreign regions and a few years of low U.S. prices and/or declining U.S. dollar exchange rates.

Figure 24. **Dairy exports increased to an equivalent of about 13% of milk solids produced in 2011**



Note: Annual export values.
Source: U.S. Department of Agriculture, Economic Research Service, Livestock, dairy, and poultry, "Dairy Yearbook 89032", http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1207 , Charts and data compiled by Livestock Marketing Information Service, HYPERLINK "http://www.lmic.info/%20%20" http://www.lmic.info/

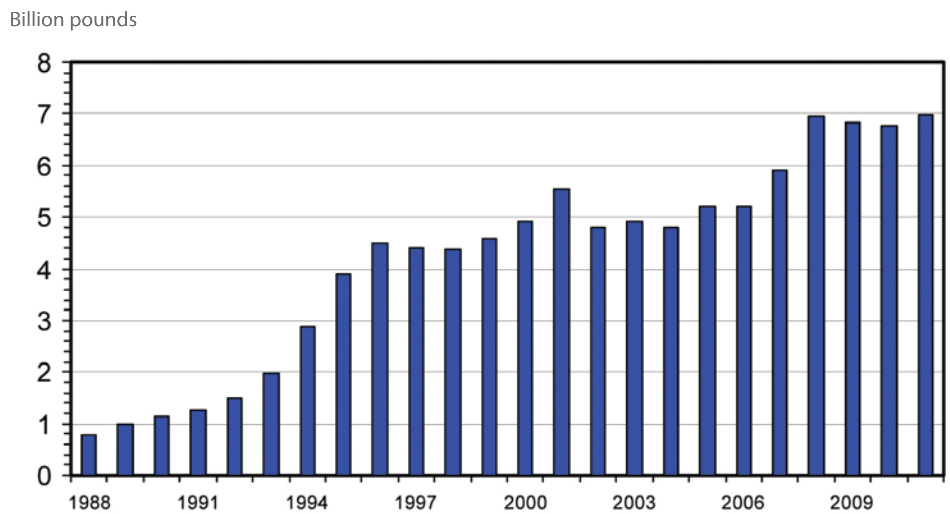
The export market partially cushioned the blow of higher feed costs in 2007 and 2008. Even so, a global economic slowdown brought reduced exports and sharply lower milk prices at the same time that feed costs were rising, leading to the dairy industry's worst financial year in 2009. Dairy profits have recovered somewhat but the industry is still struggling with high feed costs.

Looking ahead, if the anticipated easing of tight U.S. feed supplies does occur, additional expansion of U.S. milk production is likely in the three-to-seven-year horizon. The trend of higher exports is expected to continue, also helping to support expanding demand for U.S. dairy products.

Expanding Export Markets Allowed U.S. Broiler Production to Increase without Depressing Prices

Broiler exports have increased to about 7 billion pounds per year since 2008 (figure 25). Russia is a large export market for broiler meat but a number of trade disruptions have caused increased price volatility. Mexico also is a growing market for broiler meat and was the largest single U.S. export destination in 2011.

Figure 25. Broiler exports have increased to about 7 billion pounds per year since 2008



Note: Ready to cook, annual
Source: U.S. Department of Agriculture, Economic Research Service, Livestock and Meat Trade Data, http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354

Competition in the export markets comes from a number of sources. One of the industry's most important competitors is Brazil. Brazil is the world's largest exporter of broiler meat, with slightly larger exports than those of the U.S.[20] It accounts for about 1/3 of the total global broiler meat exports. Current indications are that Brazil's broiler exports will temporarily level off because of high feed costs and an unfavorable currency exchange rate, but will continue a longer-term upward trend, thus tempering growth in U.S. exports to some extent. Future competition from Brazil will be affected by trends in the exchange rate of the U.S. dollar relative to the Brazilian real. Also, the outcome of EU debt problems and its impacts of global economic growth as well as exchange rates will influence future U.S. broiler meat exports as well as exports of other products of animal agriculture. In an environment of sluggish global economic growth, broiler meat exports may fare somewhat better than those for beef and pork.

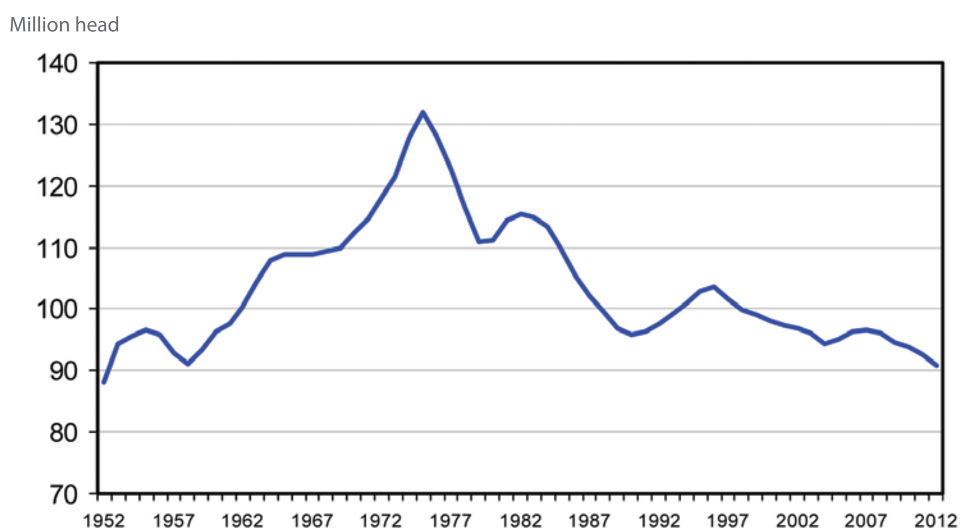
Future Livestock Sector Developments Will Vary by Species

The livestock industry is transitioning to a new economic environment of higher and more volatile feed costs. This transition is occurring at varying speeds for different species, with poultry being the quickest and cattle the slowest. Markets function through price signals. Recent sharply higher feed costs resulted in financial losses. The lack of profits forced market participants to reduce numbers and production. Less production leads to higher prices, offsetting increased costs. The hog and poultry sectors are now positioned for slight to modest future expansion, and their future direction will depend on feed availability and costs. History indicates that pork is likely to hold its market share much better than beef. Beef production is likely to rebound but with a time lag, as profits are again realized and herd expansion occurs.

Beef Biological Cycle Means Longer Adjustments to Higher Costs

U.S. cattle inventories began increasing in the 1950s and peaked at slightly over 130 million head in the mid-1970s. Inventories declined when feed costs rose significantly in 1973 (figure 26). The number of cattle decreased cyclically over the next 25 years as beef demand declined due to higher prices relative to competing meats, health concerns about red meat, and changes in consumer's tastes and preferences. Since the mid-1970s, cattle inventories have had three relatively small cyclical uptrends. Cattle numbers declined to just over 90 million head in 2012, the smallest cow herd in 50 years.

Figure 26. Since the mid-1970s, beef cattle inventory has declined due to higher relative prices, health concerns, and changes in consumer preferences

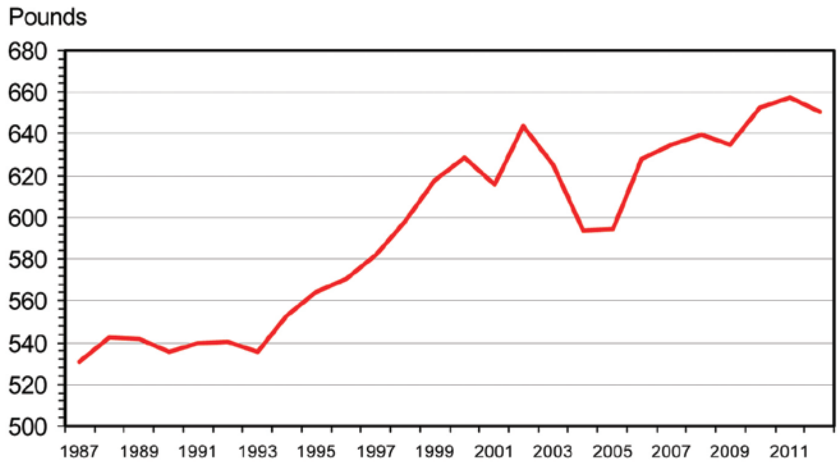


Note: January 1 U.S. total annual cattle inventory
Charts and data compiled by Livestock Marketing Information Center, http://www.lmic.info/ , C-N-01, 01/29/12, Data Source: U.S. Department of Agriculture, National Agricultural Statistics Service,
Data Source: USDA-FAS

Although total cattle numbers have fallen, the industry has become more productive (figure 27). Beef production per cow increased from about 530 pounds to about 650 pounds over the past 25 years. Beef production rose 70 percent from 14.9 billion pounds in 1962 to a projected 25.4 billion pounds in 2012. Several factors contributed to the increase in beef per cow, including feeding steers and heifers to heavier weights, reduced calf slaughter, which results in more pounds of beef produced, and increasing cattle imports from Canada and Mexico to take advantage of the U.S. comparative advantage in cattle feeding and meatpacking.

Figure 27. **Beef production per cow increased from about 530 pounds to about 650 pounds over the past 25 years**

1987-2012[1] (Est.), Annual



Note: January 1 U.S. total annual cattle inventory
Source: USDA-NASS, Compiled & Analysis by LMIC
M-S-08A 04/20/12
[1]*2012 Estimated*

The U.S. cattle feeding industry is clustered in the Great Plains, Corn Belt and Western states like California, Arizona, and the Pacific Northwest. Corn and DGS are the predominant feeds. The growth in ethanol production in the Corn Belt has changed the economics of feeding. It gives cattle feeders close to ethanol plants an advantage in purchasing DGS in its wet or partially dried form. Feeding efficiency tends to be somewhat better for wet or partially dried DGS than for the dry product that is available to more distant cattle feeders. Also, feeding locally produced DGS allows Corn Belt cattle feeders to avoid transportation costs.

Access to more economical ethanol co-products has created a shift in advantage away from Plains feedlots to western Corn Belt feedlots near ethanol plants. However, that does not mean that all cattle feeding will be done close to ethanol plants. Southern Plains feedlots have some offsetting advantages including climate's impact on feed conversion efficiency, greater ease of environmental permitting due to climate and less population, and the current location of packing plants.

The cattle feeding industry has achieved increased feed conversion efficiencies and a continuation of this trend will be important for future competitiveness. Pounds of feed to produce a pound of gain have declined. However, these gains have been slow relative to the feeding efficiency gains in pork and poultry. If expectations of some easing of tight feed supplies and high feed costs materialize, the U.S. beef industry could begin to expand, but with a longer lag time than for other species. The beef industry will face competitive pressures to accelerate gains in feeding efficiency to maintain competitiveness with pork and poultry.

Cattle producers have some flexibility in the production process to reduce high feed costs and the amount of grain needed per pound of beef. Beef can be produced from cull cows that often receive little grain or other concentrates. In 2011, cull cows contributed about 17 percent of total beef production. Calves can be held on grass longer, putting feeders in the feedlot at heavier weights. The amount of concentrate feed (grain and protein meal) to produce beef is affected by the in-weight of the feeder cattle, the out-weight of the fed cattle, and the gain per day. Heavier placement weight, however, does mean reduced efficiency in that it takes more feed to produce the pound of gain, but the total amount of feed is reduced (table 1).

Table 1. **Heavier feeder cattle placed in feedlots give the beef industry flexibility in concentrate feed needed per pound of meat**

Species	Concentrate[1] feed fed per pound of meat.[2]
Broilers	1.8
Hogs	2.9
Beef	
@ 550-pound feeder cattle	3.50
@ 750-pound feeder cattle	3.02
@ 1,000-pound feeder cattle	2.39

[1]Primarily grain and protein meal. [2]Carcass weights for pork and beef; ready to cook weight for poultry.

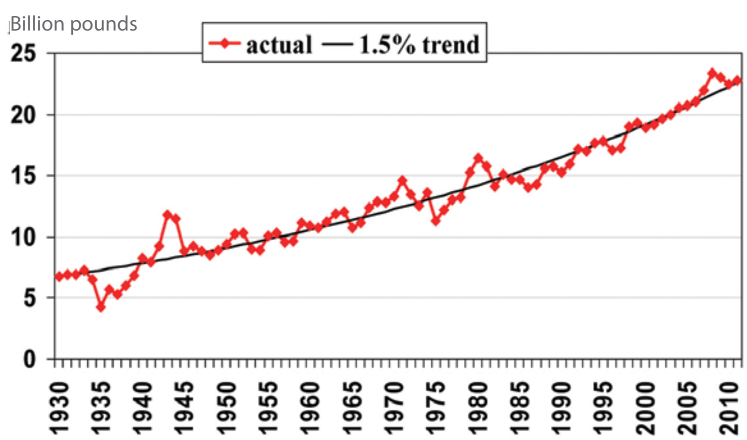
Source: Dr. David Anderson, Texas A & M University

The advantages of increasing in-weights suggest that continued transition in cattle feeding would be expected to include more emphasis on stocker cattle gains resulting in heavier calves placed on feed. Increased interest in other byproduct feeds or crop residual feeds also might be expected.

U.S. Hog Industry is Expanding

U.S. pork production increased 237% from 1930 to 22.8 billion pounds in 2011 (figure 28). The hog industry has grown at a remarkably consistent pace for the past 80 years. Although there is some cyclical variation, the long-term trend in pork production has been 1.5% growth per year. The industry fell short of trend production during the Great Depression, but overproduced during World War II. As a general rule, pork production slows when reduced corn production results in high corn prices. Industry growth is faster when corn is plentiful and relatively cheap. The long-term trend in industry growth is likely to continue.

Figure 28. **For eight decades, the long-term growth trend in pork production has been 1.5% per year**

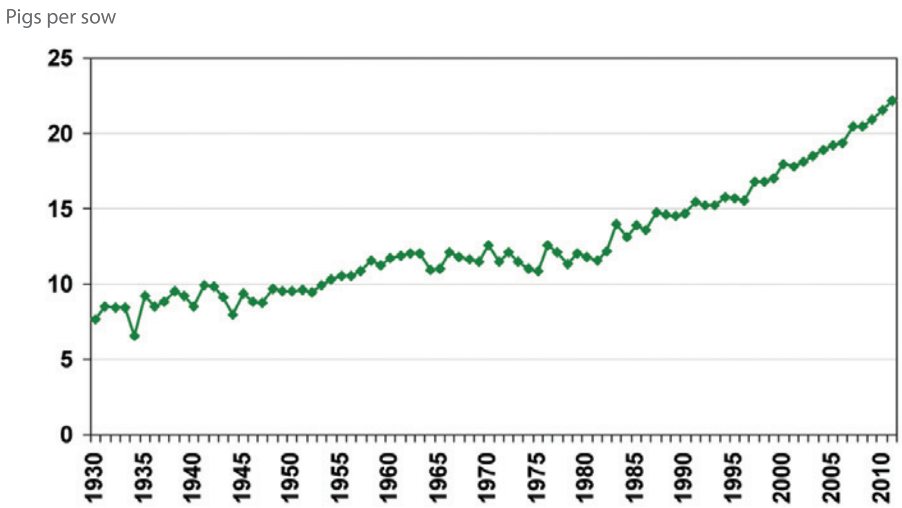


Note: Annual U.S. pork production

Source: U.S. Department of Agriculture, National Agricultural Statistics Service, Livestock slaughter annual summary. Also U.S. Department of Agriculture, Economic Research Service, Livestock, dairy, and poultry, "Livestock & meat domestic data", http://www.ers.usda.gov/data-products/livestock-meat-domestic-data.aspx and "Meat Statistics", HYPERLINK "http://www.ers.usda.gov/data-products/livestock-meat-domestic-data.aspx" \l "26055" http://www.ers.usda.gov/data-products/livestock-meat-domestic-data.aspx#26055

Productivity growth is another key factor behind the expansion of the hog industry (figure 29). Productivity increased 188.2% since 1930 as a result a 66.2% increase in pigs per litter (to 9.97 head in 2011) and a 73.4% gain in litters per sow per year to 2.22 litters in 2011.

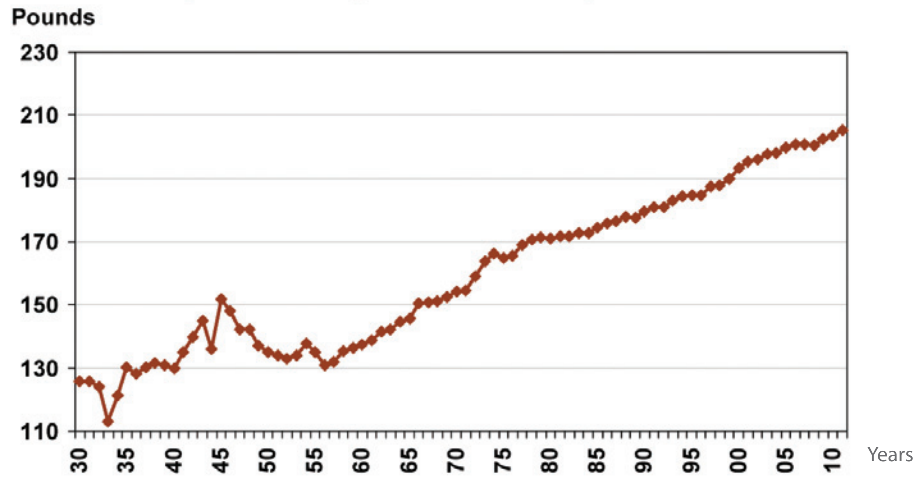
Figure 29. Pigs per sow per year increased 188% percent since 1930 to 22.16 head in 2011



Source: Calculations by R. Plain, University of Missouri, using data from U.S. Department of Agriculture, National Agricultural Statistics Service, Quarterly Hogs and Pigs, ISSN:1949-1921, 1950-2012, http://usda01.library.cornell.edu/usda/current/HogsPigs/HogsPigs-06-29-2012.txt

Slaughter weights also have increased steadily. The average carcass weight of hogs slaughtered increased 63.3% from 125.8 pounds in 1930 to 205.3 pounds per head (figure 30) in 2011. More pigs per litter, more litters per sow per year, and heavier slaughter weights have combined to increase pork produced per sow per year 2.3% per year from 701 pounds in 1930 to 4,367 pounds in 2011. The growth in the number of litters per sow per year appears to be slowing, but pigs per litter and slaughter weights likely will continue to grow rapidly.

Figure 30. Average carcass weight of hogs increased about a pound per year since 1930 to over 205 pounds

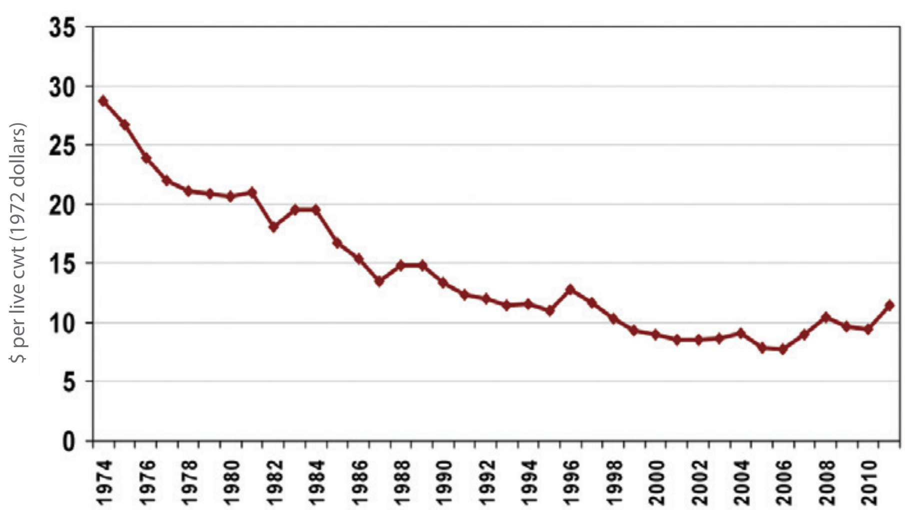


Source: U.S. Department of Agriculture, National Agricultural Statistics Service, Livestock Slaughter Annual Summary, various years. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1097

Also Red Meat Yearbook from U.S. Department of Agriculture / Economic Research Service, http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354

Increased pork production per sow has allowed the cost of raising hogs and producing pork to increase more slowly than the overall rate of inflation. Adjusted by the Consumer Price Index, the per-pound cost of producing a market hog currently is less than half of what it was in the mid-1970s (figure 31).

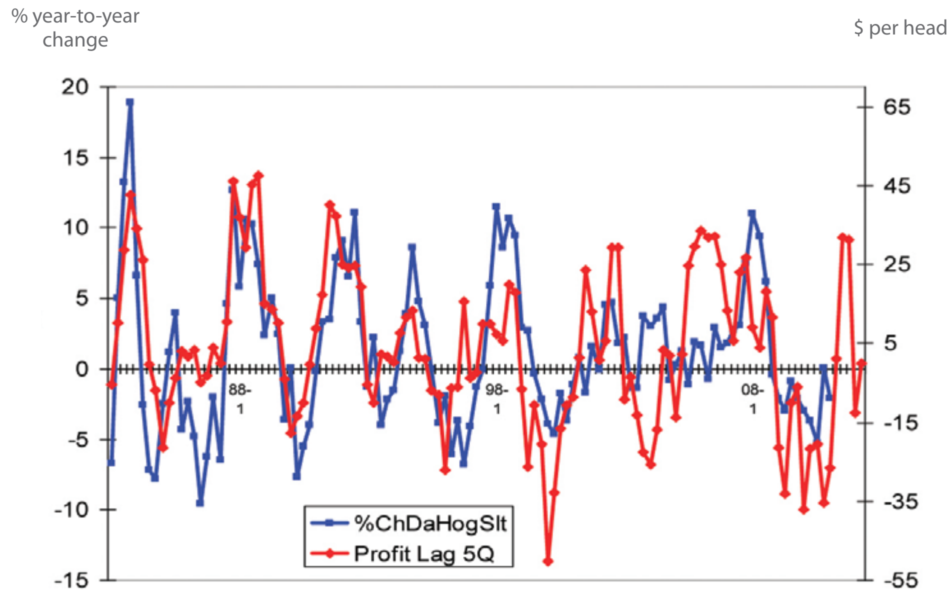
Figure 31. Per-pound cost of producing hogs is less than half of mid-1970s



Source: Ellis, Shane, and Lawrence, John D. Iowa State University, Ag Decision Maker, Livestock, Monthly Swine Farrow to Finish Returns, B1-B31, HYPERLINK "http://www.extension.iastate.edu/agdm/livestock/html/b1-31.htmlandU.S"http://www.extension.iastate.edu/agdm/livestock/html/b1-31.html and U.S. Department of Agriculture, National Agricultural Statistics Service, Quarterly Hogs and Pigs,ISSN:1949-1921, 1950-2012, http://usda01.library.cornell.edu/usda/current/HogsPigs/HogsPigs-06-29-2012.txt

Because of the biological nature of production (it is roughly 10 months from breeding until the resulting litter is ready for slaughter), there is a natural lag between profits and changes in slaughter. Periods of high profits or financial losses are typically followed 15 months later by increased pork production or reduced slaughter (figure 32). The fluctuations in production caused by the hog cycles have dampened over time with structural changes in the industry. Thus, these cycles have less impact on price and production.

Figure 32. Hog industry characterized by natural lag between profits and changes in slaughter



Source: Ellis, Shane, and Lawrence, John D. Iowa State University, Ag Decision Maker, Livestock, Monthly Swine Farrow to Finish Returns, B1-B31, http://www.extension.iastate.edu/agdm/livestock/html/b1-31.html

Two Decades of Change in the Dairy Industry

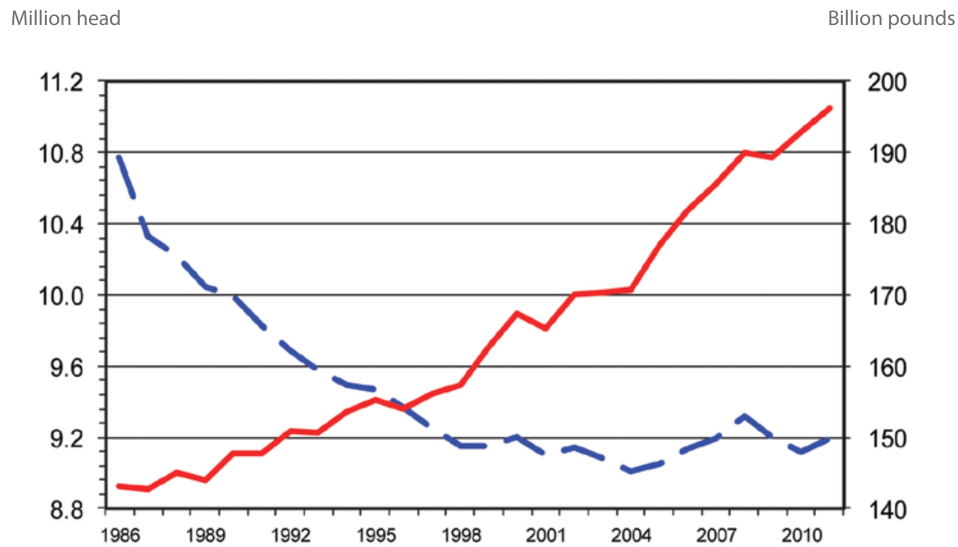
The dairy industry has undergone many regional, structural, and technological changes over the past two decades, along with major efficiency gains. U.S. dairy cow numbers have declined but milk production has continued to trend upward (figures 33 and 34). Better nutrition, higher feeding rates per cow, improved genetics, industry migration to drier, more favorable production climates, increased size of dairy farms and resulting scale economies have increased milk production per cow. Improved management technology and expertise also have contributed to increased dairy farm productivity.

As with other livestock species, feed availability and costs will be key factors in the future of the U.S. dairy industry. If feed costs moderate as expected in the next several years, increases in efficiency of the nation's dairy farms and expanded milk production will continue. Long-term gains in milk output per cow and feed conversion efficiency would be expected to continue well into the next decade, although dairy cow numbers will likely continue their long-term downward trend. The average size of dairy farms likely will continue to increase.

U.S. Poultry Industry Hit Hard by Rising Corn and Soybean Prices

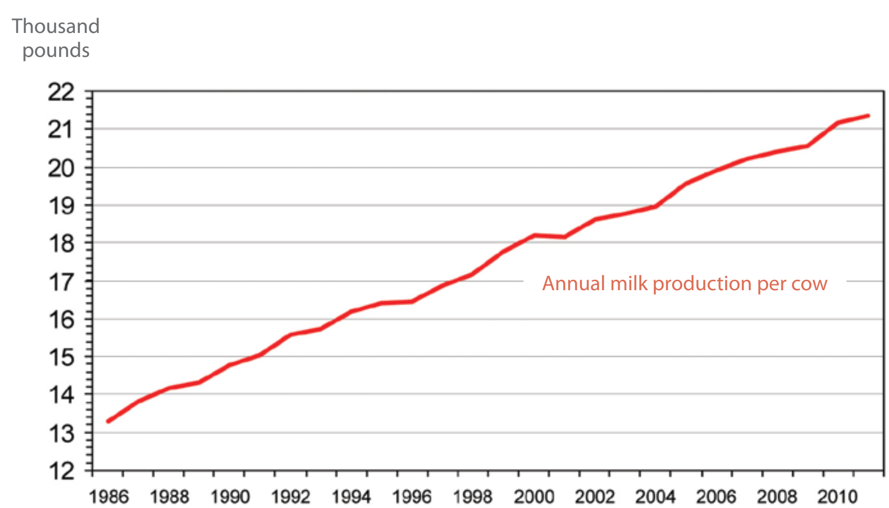
Severe financial losses due to rising feed costs led to a number of bankruptcies of major poultry producers. Over the past 5 years, the broiler industry has been through two periods of reduced production in response to the financial losses. These have been followed by recoveries in production, declining profitability, and another round of reduced production.

Figure 33. **Despite fewer cows, milk production has continued to trend upward**



Note: U.S. average annual milk cow inventory
Source: USDA/NASS
D-S-10 04/01/12

Figure 34. **Many factors have increased milk production per cow, including better nutrition, increased feeding rates per cow and improved genetics**



Source: Charts and data compiled by Livestock Marketing Information Center, http://www.lmic.info/ , 04/01/12,
Data Source: U.S. Department of Agriculture, National Agricultural Statistics Service,

Projected moderating feed costs will allow the U.S. poultry industry to enhance domestic and global competitiveness and continue its long-term trend of increased production efficiency. A large U.S. biofuels industry, along with occasional periods of temporarily reduced U.S. or foreign grain yields and production will create sharp spikes in feed costs. That in turn will bring temporary reductions in U.S. poultry production.

The ability of broiler producers to produce a pound of meat with less concentrate feed than other species and a short production cycle will give the poultry industry a long-term competitive advantage over other meats. The turkey industry has been able to adjust production more effectively than the broiler industry to prevent further financial losses from excess production and subsequent lower prices.

Issues Point to Need for More Research

Many emerging key issues that will affect the future of livestock feeding in the U.S. are beyond the scope of this report. U.S. animal agriculture will continue to be under competitive pressures to increase efficiency and expand production to meet rising global demand while adjusting to environmental policies, animal welfare concerns, possible climate changes and other issues. An assessment of these and other issues will require much additional research. Developments relating to these issues will be important for both the feed and the livestock industries to monitor in the next few years.

- Research is needed on the value of low-fat DGS and the most effective ways to use it.
- Cattle have a distinct advantage as ruminants over monogastric species because they have the ability to use grass and other roughages from crop residues, lower-quality land, and land that would otherwise be unharvestable. The feedlot finishing period is the phase that today's beef production depends on and is where it competes for grain supplies. Cattle, as ruminants, also are able to utilize DGS more effectively than other species and will likely be able to use the rapidly emerging supplies of low-fat DGS more effectively than poultry and hogs. How this will affect cost variations across species is uncertain.
- The ability to increase selection of beef animals to improve feed conversion efficiency, as the hog and poultry sectors have done, will be important for future competitiveness of the cattle and beef industry.
- The potential for growth and technological breakthroughs in cellulosic ethanol production will be important for the livestock sector to monitor. If economically efficient and commercially viable technologies emerge, aggressive RFS2 cellulosic ethanol mandates will raise questions of whether conversion of grazing or hay land to feedstock production for cellulosic ethanol may pose a risk for ruminant species. If so, what beef cattle adjustments might be needed?
- The world's population is projected to rise by 2 billion to reach 9 billion in 2050. Average incomes are expected to increase and foreign consumers will consume more meat. A key question is what will be required to feed 9 billion people? It appears that the world can and will be able to feed a population of 9 billion, but at what cost and what changes will be needed in crop and livestock production? Also, what will be the combination of beef, pork, poultry, dairy products, and seafood as we move ahead?
- Over the longer term, limited cropland and increasing feed costs will put pressure on the livestock sector to increase feed conversion efficiency.
- What role will biofuels plan in this longer-term environment?
- The U.S. policy environment will play a key role in the production efficiency and cost of food in the future. Policies and regulations, whether government or market enforced that result in less efficient, higher cost grain supplies will limit the livestock industry from both supply and demand standpoints. Movements that roll back scientific progress

on productivity and efficiency of crop and livestock production will hamper the ability to produce enough feed for meat production and food consumption and will impact consumer food costs.

Long-term Issues: Will There be Enough Feed to Support a Viable World Livestock Industry in 2050?

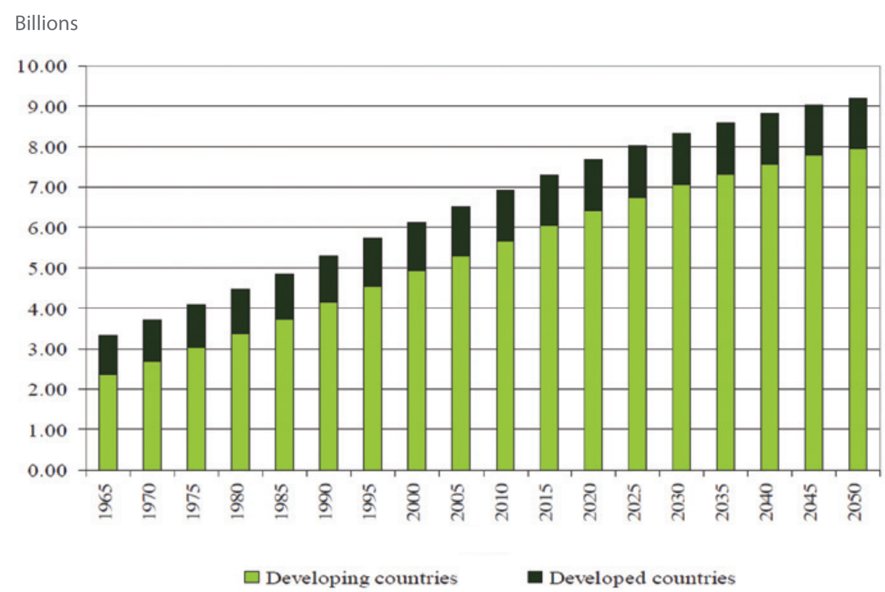
World agriculture has successfully kept up with world population growth. But will it be able to continue this pace in the next forty years as the demand for food from a growing world population places additional requirements on the sector? An important aspect of this question is the ability of the livestock sector to provide the meat and dairy products for an additional 2 billion people by 2050. It will depend in part on the ability of the feed industry to supply an expanding livestock industry.

Expanding World Population Will Increase Demand for Meat and Dairy

The rate of population growth increased significantly from the 19th to the 20th century. When Lewis and Clark embarked on their historic journey in 1804, one billion people lived in the world. Population continued to increase but didn't reach two billion until 1927, 123 years later. At that point, population started to grow more rapidly reaching three billion people in 1960, only 33 years later (figure 35). By 1974 (14 years later) world population was four billion, climbing to five billion in 1987 (13 years later) and six billion in 1999 (12 years later).

The rate of increase peaked at the turn of the century and then began a slow decline. It is projected that it will take 15 years to reach eight billion and an additional 19 years (2046) to reach nine billion (figure 35).

Figure 35. **The rate of population increase began a slow decline after peaking in 2000**



Source: Department of Economic and Social Affairs of the United Nations Secretariat, Population Division(2007) (1). How to Feed the World in 2050, Food and Agriculture Organization of the United Nations. Available online: http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf.

Population changes are due to the relationship between births and deaths known as the "fertility rate." The world's fertility rate-- the number of children the average woman will give birth to in her lifetime--declined from almost 5 births per woman in 1950 to a projected 1.6 births by 2050[22]. The current fertility rate is approaching the replacement rate (if a woman has two children, she will have replaced herself and her husband, for example). India and the Philippines are well above replacement (table 2). The fertility rate of many European countries is below the developed country replacement rate of 2.1 so population in these countries is expected to decline over the next 40 years.

Although the world's fertility rate is approaching replacement, population will continue to grow well into the future. It may take several generations for this fertility rate to be fully reflected in the rate of population growth. If the world has been in a period of high population growth, the number of young people of child bearing age will comprise a disproportionately large portion of the population. So population will continue to grow even though the fertility rate drops because the fertility rate will be applied to a disproportionately large share of the population. Population will not stabilize until the age distributions within the population reach equilibrium. This is called the "population lag effect" or "population momentum".

Table 2. World's fertility rate declined from almost 5 births per woman in 1950 to a projected 1.6 births by 2050[1/]

	Fertility Rate	Population	
	2009	2010	2050
	(Births per woman)	*(Millions)*	
World average	2.47	6,909	9,150
United States	2.1	314	399
China	1.6	1,369	1,434
India	2.7	1,189	1,580
Philippines	3.2	91	142
Russia	1.5	140	116
United Kingdom	2.0	66	78
Nigeria	5.6	149	272

[1/] Fertility rate is the number of children the average woman will give birth to in her lifetime.

Source: U.N. Food and Agriculture Organization, FAOSTAT, http://faostat.fao.org/site/339/default.aspx The World Bank and International Food Policy Research Institute

Food Needs Will Increase as Incomes in Developing Countries Rise

As incomes rise, people tend to eat fewer grains and increase consumption of meat and high-value foods. This transition requires higher levels of resource use and increased demand for feed grains as meat consumption rises. Although projections of future economic growth are more tenuous than those for population, there is general consensus that the world economy will expand in the long-term despite the current financial problems in developed countries.

While per capita consumption of meat and milk has increased in both developing and developed countries, the gains in developing countries have been more rapid. Additional large increases in per capita animal product consumption in developing countries are likely as consumers catch up to developed countries.

Currently, about half of the world's population lives in urban areas. By 2050, the share is expected to rise to 70%. Urbanization and rising incomes will encourage further diversification of diets resulting in less consumption of grains and other staples and more consumption of meat, dairy products, vegetables, fruits and fish. Demand for semi-processed and ready to eat foods also will increase.

Increased Production Will Require Additional Gains in Yields

World production of the three major crop commodities, wheat, corn and soybeans, increased substantially over the past fifty years, with most of the gains from higher yields (table 3). Cropland area expanded only modestly.

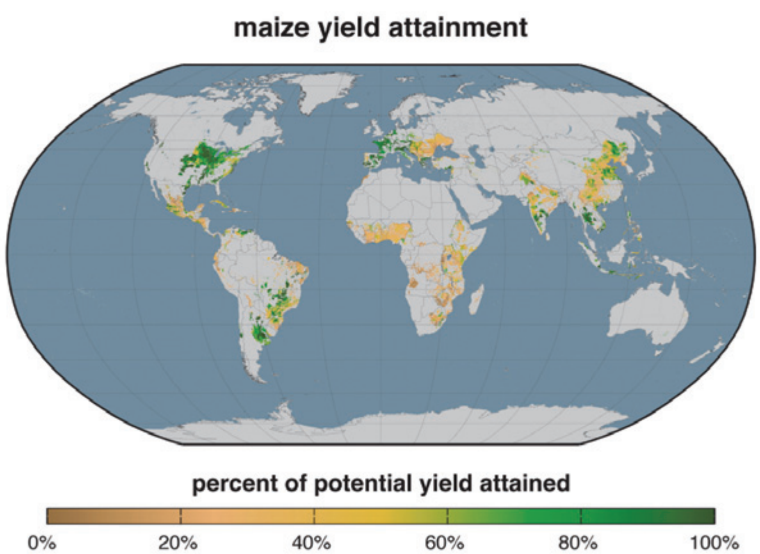
With growing focus on environmental concerns and greenhouse gas emissions, the ability to significantly increase production area is limited. Expanded production over the next forty years must come primarily from higher yields. However, there are concerns among the scientific community about the ability of the U.S. and other parts of the world to continue increasing yields as more countries expand the use of fertilizer and other key inputs.

Table 3. **Yield increases responsible for much of growth in world crop production**

Crop	1969	2009	Percent Increase
		(metric tons)	
Maize	270	819	203
Wheat	309	686	122
Rice, paddy	296	685	131
Soybeans	42	223	431

Source: U.N. Food and Agriculture Organization, FAOSTAT, http://faostat.fao.org/site/339/default.aspx

Figure 36. **Maize yields in Eastern Europe, Africa and Eastern Asia are below levels possible given the current state of technology**



Source; Jonathan A. Foley, et al., "Solutions for a Cultivated Planet – Supplementary Information -- Figure S4a", Nature 478, 337-342 (20 October, 2011). http://www.nature.com/nature/journal/v478/n7369/extref/nature10452-s1.pdf

Closing Yield Gaps Offers Greatest Potential to Increase Crop Production

Yields in many countries are not at the level they should be considering the current state of technology, resulting in "yield gaps." The most noticeable with significant yield gaps are Eastern Europe, Africa and Eastern Asia (figure 36).

A recent study estimated that increasing the yields of 16 important worldwide crops up to 95% of their potential could boost global production by 58%. Bringing yields of these crops up to only 75% of their potential could increase global production by 28%[23]. A key requirement for shrinking yield gaps will be adequate global supplies of fertilizer and other inputs.

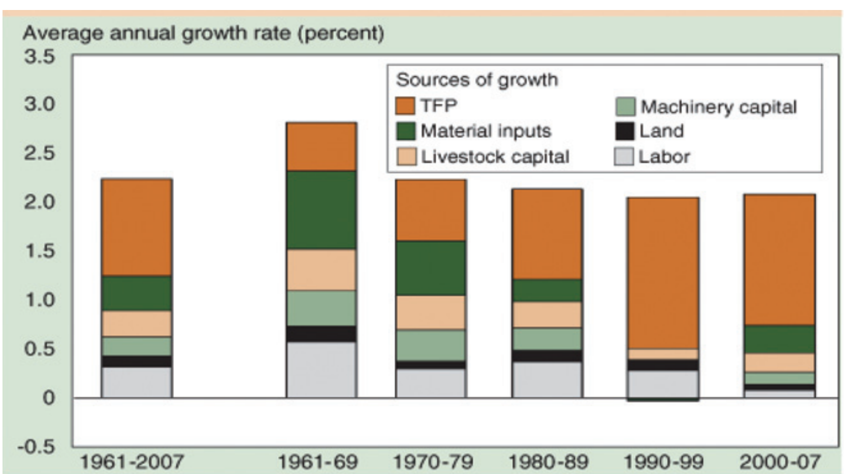
Improving Agricultural Productivity Requires Investments in Research

Agricultural productivity can be improved by developing new technologies that increase agricultural output per unit of input, or decrease the amount of inputs needed to produce a unit of output.

Total Factor Productivity (TFP) is defined as the amount of output per unit of total factors (production inputs) used to produce the output. Five factors or inputs were included in an analysis of agricultural productivity by USDA's Economic Research Service (ERS): amount of land, hours of labor, number of tractors, number of head of livestock and amount of inorganic fertilizer applied. The ERS analysis showed that global agricultural output grew by about 2.2 percent per year from 1961 to 2007 (figure 37). Almost half of the growth was due to greater use of production inputs, such as fertilizer and pesticides, and the remainder to increased efficiency of production inputs. From 1961 to 2007, the rate of increase in agricultural input use declined but output growth stayed at or above 2% as TFP increased.

Maintaining or increasing the rate of agricultural productivity will be important in meeting the world's food demand in 2050, while minimizing the impact on the world's resources.. High levels of productivity require significant investments in agricultural application of new technologies. These investments need to be made soon for the impact on productivity to fully emerge by 2050.

Figure 37. Total factor productivity (TFP) accounts for a rising share of agricultural growth over time



Agricultural total factor productivity (TFP) measures the average productivity of all land, labor, capital, and materials used to produce crops and livestock. One percent growth in TFP means 1 percent fewer resources are needed to produce the same amount of output.

Source: USDA, Economic Research Service using Evenson and Fuglie (2010), *Journal of Productivity Analysis*, Vol. 33, No. 3, pp. 173-190.

Less Food Waste Could Reduce the Pressure on Feed Production

Food waste is a widespread problem in developed and developing countries. Estimates of the amount of food wasted vary, but 30 percent appears to be a reasonable estimate. Food waste in high-income countries primarily occurs at the point of consumption. Waste is prevalent at restaurants, buffets and other foodservice establishments as well as in homes. In low-income countries, waste occurs along the entire food chain but primarily in the storage after harvest due to poor post-harvest infrastructure and technology. Examples include losses from spillage, drying, contamination and consumption by pests. Reducing non-meat and non-dairy waste could potentially free-up grains and oilseeds for livestock production. The magnitude of the problem should not be underestimated. If agricultural production must increase 70% by 2050 to meet the food needs of nine billion people, cutting food waste in half, for example, would reduce the necessary increase in agricultural productivity to 55%. Reducing non-meat and non-dairy waste could potentially free-up grains and oilseeds for livestock production.

Many Countries with Growing Populations, Rising Incomes Will Rely on Imports

Food security generally is highest in countries with large areas of arable land relative to the size of their population. Arable land per person is highest in Oceania, North America and Europe (table 4). However, North Americas' population is expected to grow by only 4% and Europe's population is expected to decrease by 1%[24]. Half of the population growth is expected to occur in Sub-Saharan Africa where arable land per person is currently only three-quarters of an acre. Without additional arable land, Sub-Saharan Africa's land area per capita will drop to half of an acre by 2050.

Asia's population is expected to grow 41 percent with arable land currently only one-third of an acre per capita. Projected population growth will decrease per capita land area to less than a quarter of an acre by 2050. Countries in these regions will need to substantially increase agricultural production or import a larger portion of their food. Many of the developing countries with rapidly growing populations and rising incomes will need to import feed supplies for a growing livestock industry or import meat and dairy products directly.

Table 4 **Highest rates of population growth will occur in areas with less arable land per person**

	Arable land
	(Acres per person)
Oceania	3.85
North America	1.68
Europe	0.96
South America	0.77
Sub-Saharan Africa	0.77
Middle East and North Africa	0.62
Central America and Caribbean	0.49
Asia	0.32

Source: 2011 GAP Report, Global Harvest Initiative

Fuel Demand Will Depend on Crude Oil Prices and Policy Decisions

Although ethanol has had a significant impact on U.S. corn use, competition from expanded biofuel demand for grain and oilseeds is relatively small in the rest of the world. However, high-priced crude oil and an uncertain oil supply could quickly increase biofuel production, resulting in increased competition for the world's grain and oilseeds.

Fuel demand will depend on crude oil prices and policy decisions focused on reducing greenhouse gases. If future biofuel production comes from grasses and other non-food crops as specified in current U.S. energy legislation, it will still impact food and feed crop production due to the competition for limited world cropland and possible reduced forage for beef and dairy animals.

Climate Change Will Have Uncertain Impacts on Agriculture

Science has established an uptrend in the earth's average temperature which creates uncertainty about the impact on global climates. A changing world climate will certainly have a significant impact on world agriculture.

Because land areas warm faster than oceans, average temperature increases are likely to be greater in farming areas than for the world as a whole. Although warmer temperatures can increase agricultural productivity, there is a threshold temperature over which productivity declines. Higher temperatures may improve productivity in many industrial countries, but they will negatively impact productivity in most developing countries since many of them are located in arid areas or have poor soils that dry out easily. As warming continues, fewer regions are expected to experience positive productivity impacts and more regions will see negative effects.

Possible sluggishness of crop enterprises in adjusting to climate changes could negatively impact crop yields in some regions, thus negatively impacting the livestock-feed sector. Some researchers postulate an increased frequency of extreme weather events caused by climate-change. If so, this would increase volatility and risk in crop yields, feed supplies and prices.

Although increased atmospheric concentration of carbon dioxide leads to more warming, there is a positive influence called "carbon fertilization." During photosynthesis, carbon dioxide is taken in by plants and the carbon is used to fuel plant growth. With more atmospheric carbon dioxide, plants can convert carbon dioxide more readily, resulting in more plant growth and higher yields. This is true for most crops except corn which does not respond to carbon fertilization.

The potential for "carbon fertilization" to improve the yields of most crops may place corn at a competitive disadvantage to other crops. It may result in a longer-term decline in corn acreage and production that would have a significant impact on the livestock feed sector.

Report Summary: Future Patterns of U.S. Livestock and Poultry Feeding

In this report, we have reviewed recent trends in the U.S. and the global bioenergy, grain, feed, and livestock industries. The report focuses on the impact of development of the U.S. bioenergy industry on grain and feed availability for the livestock sector as well as industry profitability, production, efficiency, demand, and the future of the feed-livestock sector. Bioenergy likely will continue to be a driving force influencing the future direction of the feed and livestock industries.

We focused on the feed-livestock industry's adjustments to the new dynamics of the feed and grain sectors, how the industry has and will be affected, and some key challenges to monitor. Our focal points include: 1) grain and livestock production efficiency; 2) future bioenergy production; 3) rapid foreign economic growth, especially in East Asia, with its implications for dietary change, demand for feedstuffs, and feed availability; and 4) long-term challenges, including global population growth, increased foreign consumption of livestock products, cropland constraints, climate change, and related issues.

Bioenergy Development Drivers

It is beyond the scope of this report to evaluate the costs and benefits of biofuels, except to acknowledge that some recently highlighted benefits will influence policy decisions. An objective analysis of long term costs and benefits of U.S. ethanol production would require comparing the direct positive impact of ethanol on U.S. consumers' fuel expenditures with the negative impacts on the feed, livestock, and food sectors and food costs.

On the benefit side, a recent study by the Center for Agricultural and Rural Development (CARD) at Iowa State University[i] indicates the growth in U.S. ethanol production reduced wholesale gasoline prices by an average of $0.29 per gallon from January 2000 to December 2011. In 2011, increasing ethanol production and higher crude oil prices pushed the price reduction to $1.09 per gallon, indicating that consumers benefit more from ethanol as gasoline prices rise.

The large 2011 price effect comes partly from reducing stress on the nation's limited petroleum refinery capacity, which is expected to decrease further in late 2012. In 2011, the U.S. Energy Information Administration (EIA) reported that the U.S. consumed 134 billion gallons of gasoline domestically[ii]. Applying the CARD estimates, the direct public benefit of ethanol production in 2011 was about $146 billion dollars. Over 2000-11, estimated benefits averaged $35-$40 billion annually.

U.S. government expenditures for U.S. ethanol production subsidies of approximately $5.1 billion dollars in 2009[iii] partially offset the average benefits from lower gasoline prices. In addition, ethanol policies that contributed to higher corn prices reduced farm program expenditures. Higher corn prices, however, have increased costs to the feed-livestock sector and have contributed to higher food costs.

The estimated benefits from ethanol production will be a major factor in developing and debating future biofuel policy options. We expect current U.S. ethanol and biodiesel policies and mandates prescribed through 2022 by the 2007 Energy Independence and Security Act[iv] will remain in effect.

U.S. corn use for ethanol production increased by 4.42 billion bushels or 623% from the 2000-01 to 2010-11 corn marketing years. At the same time, total use of U.S. corn for feed declined by about 1.27 billion bushels. We estimate that approximately 55% of this decline was offset by increased feeding of distillers' grain and solubles (DGS), the major by-product or co-product of the ethanol industry. Other non-ethanol and non-feed uses plus exports declined by 182 million bushels.

U.S. corn going into domestic food processing and non-ethanol industrial uses accounts for about 8 to 10 percent of the total demand for corn and has increased by only 55 million bushels since 2000-01. Therefore, the largest adjustment to increased use of corn for ethanol and tightening supplies was in domestic livestock feeding. A number of developments contributed to the explosive biofuels demand growth, including higher fuel costs that increased the energy value of corn and soybeans, the September 11, 2001 crisis and government programs that support U.S. energy independence, such as mandated volumes of ethanol and biodiesel blending with motor fuels, a blenders' tax credit that expired at the end of 2011, and efforts to reduce greenhouse gas emissions.

Easing of Tight Feed Supplies Anticipated

In the next three to seven years, provided U.S. corn yields return to their longer-term upward trend, corn supplies appear likely to be more adequate than in the past few years. Ethanol blending mandates will increase more slowly from the current 13.2 billion gallons to a maximum of 15 billion gallons in 2015. To meet these mandates, about 380 to 400 million bushels more corn will be needed in 2015 than are projected to be processed into ethanol in the 2011-12 corn marketing year. From 2015 onward, the ethanol mandates remain constant.

Corn processing for ethanol will increase more slowly in the next few years. At the same time, increased U.S. corn yields should provide more adequate corn supplies for the livestock sector. However, when U.S. or major foreign producer crop yields are low, the biofuel mandates and highly inelastic demand for biofuel will set the stage for additional sharp feed price spikes. Feed costs also will be influenced by the price of crude petroleum and gasoline.

Beyond the Seven-year Horizon

At least two major uncertainties will need to be monitored by the feed-livestock sector beyond 2020. The first is China's demand for corn and the second is the possibility of a second-stage growth in corn processing for biofuel.

China appears to be on the verge of becoming a major corn importer, as it is for soybeans. Rapid growth in China's economy, rising consumer incomes, and urbanization are bringing rapid shifts in diets from grain to increased consumption of animal products. Because China's cropland base is limited, U.S. exports increased to an estimated 200 million bushels of corn in the 2011-12 marketing year – despite record Chinese corn yields and production.

USDA's 10-year global economic model projects Chinese corn imports of 9 million tons or about 350 million bushels in 2016-17, with a doubling of its imports by 2021-22. Chinese soybean imports accounted for about 60% of the world total and about 60% of U.S. soybean exports in 2011-12. China's corn imports also will be affected by how rapidly its farmers can adopt new corn genetics, increase crop fertility, improve weed control, enhance water management, and adopt other technology to increase corn yields. Reported Chinese average corn yield was about 56% of a normal U.S. corn yield in 2011-12.

It also will be important for the feed and livestock industries to monitor the development of biobutanol. Several U.S. ethanol plants have announced that they are in the initial stages of either converting plants to biobutanol production or adding a biobutanol production unit to the plant. Biobutanol can be produced by a corn fermentation process, with DGS as a co-product. Biobutanol may offer opportunities for the biofuels industry to move beyond the blend wall since it does not require engine modifications and can be shipped in petroleum pipelines. As this report was being written, no economic analysis of biobutanol was available.

Bioenergy Impacts in the Livestock Sector

The rapid increase in corn-starch ethanol production since 2005, along with increasing Chinese soybean import demand[v] have had a significant impact on U.S. grain and livestock enterprise profitability as feed costs have increased and become more volatile.

High feed prices, while not the sole cause of the intermittent periods of financial losses, down-sizing, and restructuring that have recently occurred in the U.S. livestock industry, have been the primary contributor in the poultry and beef industry. Species with shorter production cycles (poultry, followed by pork) have been able to manage and adapt to changing feed conditions more quickly than those with longer response times (beef and dairy). Looking to the future, these input market cost dynamics are expected to continue to favor species that are more flexible and quick-responding.

If not for the positive impact of strong exports on prices in the last few years, financial losses to the livestock sector would have been even more severe. In spite of, or perhaps at least partly because of, the financial pressures placed on U.S. livestock producers from rising feed prices, the drive toward increasingly efficient cost–reducing livestock production will continue to be a primary means of the poultry and livestock sectors adjusting to the biofuels expansion and international competition.

Adjustments by Species

Adjustments of the livestock sector to dramatically higher and more volatile feed costs, the severe 2010-12 Great Plains drought and other developments vary by species.

Pork — Pork producers have enjoyed relatively steady decades-long growth. If U.S. corn yields are near normal in the next three to seven years, that trend will likely continue and will allow further increases in production and may give pork a slightly larger share of the domestic meat market. Pork producers have a long history of increasing production efficiency which will continue in the years ahead. Any structural changes in the pork industry are expected to be minor in the next three to eight years. Global demand for U.S. pork has created an important and expanding export market. Current export markets absorb about one pound of U.S. pork out of every five produced. Strong export demand has helped to strengthen hog prices and assist the pork industry in coping with higher feed costs. The pork export market is expected to continue expanding.

Dairy — Dairy farmers recently experienced a period of severe losses stemming from rising feed costs and reduced exports. However, after a year of some financial recovery in 2011, the industry is again facing stress from low milk prices and high feed costs. In the next several years, if current expectations of much slower ethanol demand growth and increasing U.S. corn yields materialize, the dairy industry will again continue long-term expansion and increases in efficiency and productivity.

Beef — Cattle have the advantage of being able to use grass and other roughages produced on range and pasture lands unsuitable for cropping. Cattle producers also are able to use crop residues such as corn stover and ethanol co-products, to lower production costs. Cattle's ability as ruminants to use forages provides flexibility in that only the finishing period in beef production is grain-based, not the entire production cycle as with other species.

Cattle are able to use DGS more effectively than monogastric species which may give beef producers with an advantage over pork and poultry as more ethanol plants remove corn oil from DGS. Corn oil is being removed to provide a feedstock for reaching government biodiesel and advanced biofuels mandates. Oil in the DGS provides energy for livestock and poultry rations. Removing some or all of it requires changes in ration formulations to adjust for the lower energy content of de-oiled DGS. Ruminants, unlike poultry and hogs, are able to convert fiber in DGS into energy.

Beef cow inventories and production have declined for several years due to the economic transition to higher costs. The downturn was accelerated by the severe southern Plains drought of 2010-12, which will almost certainly result in reduced numbers of cattle being grain fed and lower beef production in the next few years. If adequate feed supplies are available at reasonable cost in the future as currently anticipated, a cyclical upturn in beef cow numbers and beef production can be anticipated. However, the cattle industry's longer biological production cycle and greater grain requirements per pound of meat produced than other species create some disadvantages for the industry. These aspects of production, especially with high feed costs, will increase pressure on the industry to increase its production efficiency and feed conversion efficiency.

Poultry — If feed costs move up to unprofitable levels, the poultry industry is capable of adjusting more rapidly than producers of other species. That is because a short biological production cycle allows the poultry industry to quickly reduce production and wait for improved profit margins. The poultry industry also has greater grain-to-meat conversion efficiency than either pork or beef. These features likely will allow the poultry industry to grow more rapidly in the years ahead than the red meat industry, as well as to adjust more quickly to changing feed market conditions. Domestic per capita consumption of broilers has increased almost steadily for several decades and that trend is expected to continue for the intermediate future.

De-oiled DGS and Research Needs

De-oiled DGS is a relatively new development stemming largely from government blending mandates for biodiesel and advanced biofuels. Biodiesel currently is the only U.S.-produced advanced biofuel produced in large volumes for commercial sales. As advanced biofuel mandates increase in the next ten years, greater production of de-oiled or partially de-oiled DGS is almost certain. For the feed and livestock industries, additional research on how to most effectively feed this product will be important.

A large and expanding DGS supply has partially reduced corn use in the beef industry as well as other livestock sectors and has helped control costs. However, DGS prices are closely related to corn prices and have risen in response to higher prices for corn. Even with extensive DGS feeding, the beef industry has been stressed by higher feed costs and the need for adjustments in rations and production levels. Beef cattle numbers are cyclical, and as beef profitability declined in the past few years, cow owners reduced their herds. With a time lag, easing of feed cost pressures may set the stage for a future increase in beef production.

Longer Term Challenges

Looking ahead two to three decades, the feed-livestock sector will face a number of other important issues and potential challenges, including global population and income growth, constraints on global crop acreage, the need to increase grain yields, foreign biofuels mandates, possible large-scale cellulosic ethanol production, environmental concerns, and climate change issues.

Food-Population Issues

By 2050, two billion more people are expected in the world, for a total of nine billion. Most of the growth will occur in developing countries, while some industrialized countries will lose population. Much of the population growth will occur in countries with limited arable land so that more food or feed will need to be imported.

- If recent strong economic growth in developing countries continues, much of the world's population will move from poverty into the middle class, resulting in less direct human grain consumption per person and more grain consumed in the form of animal products.
- Higher feed grain production to meet dietary changes will occur from increased yields and modestly expanded acreage. Most of the increased output will need to come from higher yields. Maintaining or increasing agricultural research investments will be critically important in generating the required productivity growth.
- Expanding crop production will place additional stresses on water, fertilizer, agricultural chemicals, fuel, and other global resources.
- In this environment, the long-term role of biofuels is uncertain.

Possible Climate Change Issues

- The potential for "carbon fertilization" due to higher levels of atmospheric carbon dioxide to improve the yields of most crops except corn may place corn at a competitive disadvantage to other crops. It may result in a longer-term decline in corn acreage and production that would have a significant impact on the livestock feed sector.
- Possible sluggishness of crop enterprises in adjusting to climate changes could negatively impact yields in some regions, and in turn, the livestock-feed sector.
- Some researchers postulate more frequent extreme weather events caused by climate-change. If so, this would increase volatility and risk in crop yields, feed supplies and prices.

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