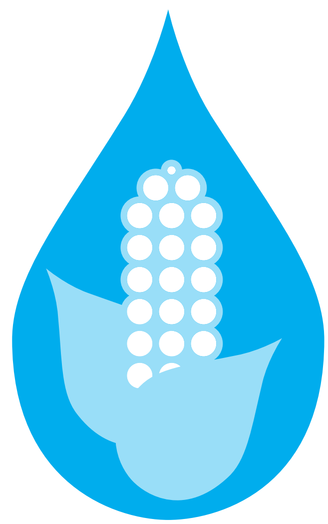
Water & Climate Risks Facing U.S. Corn Production



How Companies & Investors Can Cultivate Sustainability

A Ceres Report

June 2014

Authored by
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About Ceres

Ceres is a nonprofit organization mobilizing business and investor leadership on climate change, water scarcity and other sustainability challenges. Ceres directs the Investor Network on Climate Risk, a network of over 100 institutional investors with collective assets totaling more than $13 trillion. For more information, visit www.ceres.org or follow Ceres on Twitter: @CeresNews

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To access the interactive maps associated with this report, visit www.ceres.org/cornmaps

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Water & Climate Risks Facing U.S. Corn Production

U.S. corn farmers are among the most productive and technologically advanced in the world, generating a record harvest of nearly 14 billion bushels in 2013—enough corn to fill a freight train longer than the circumference of the Earth. This production supports a mammoth agricultural sector comprised not just of farmers, but also major food, feed and energy companies that have an enormous stake in the long-term productivity and resilience of American agriculture. However, in the face of this bounty, three major threats to U.S. corn production loom: climate change, unsustainable water use and inefficient and damaging fertilizer practices.

Recent extreme weather events such as the devastating Midwest drought of 2012 helped drive record corn prices ($8/bushel). This provided a taste of what is predicted to become the new normal in many parts of the Corn Belt thanks to climate change—a point powerfully reinforced by the latest National Climate Assessment.

Growing irrigation demand for corn production, alongside unchecked withdrawals of groundwater from stressed water sources—in particular, the High Plains aquifer that spans eight Great Plains states and California's over-extended Central Valley aquifer—create additional risks for the $65 billion a year corn industry, which has nearly doubled in size over the past two decades. Economically wasteful and unregulated pollution from fertilizers running off cornfields into waterways—a key contributor to a Connecticut-sized hypoxic "dead zone" in the Gulf of Mexico—is still another area of risk.

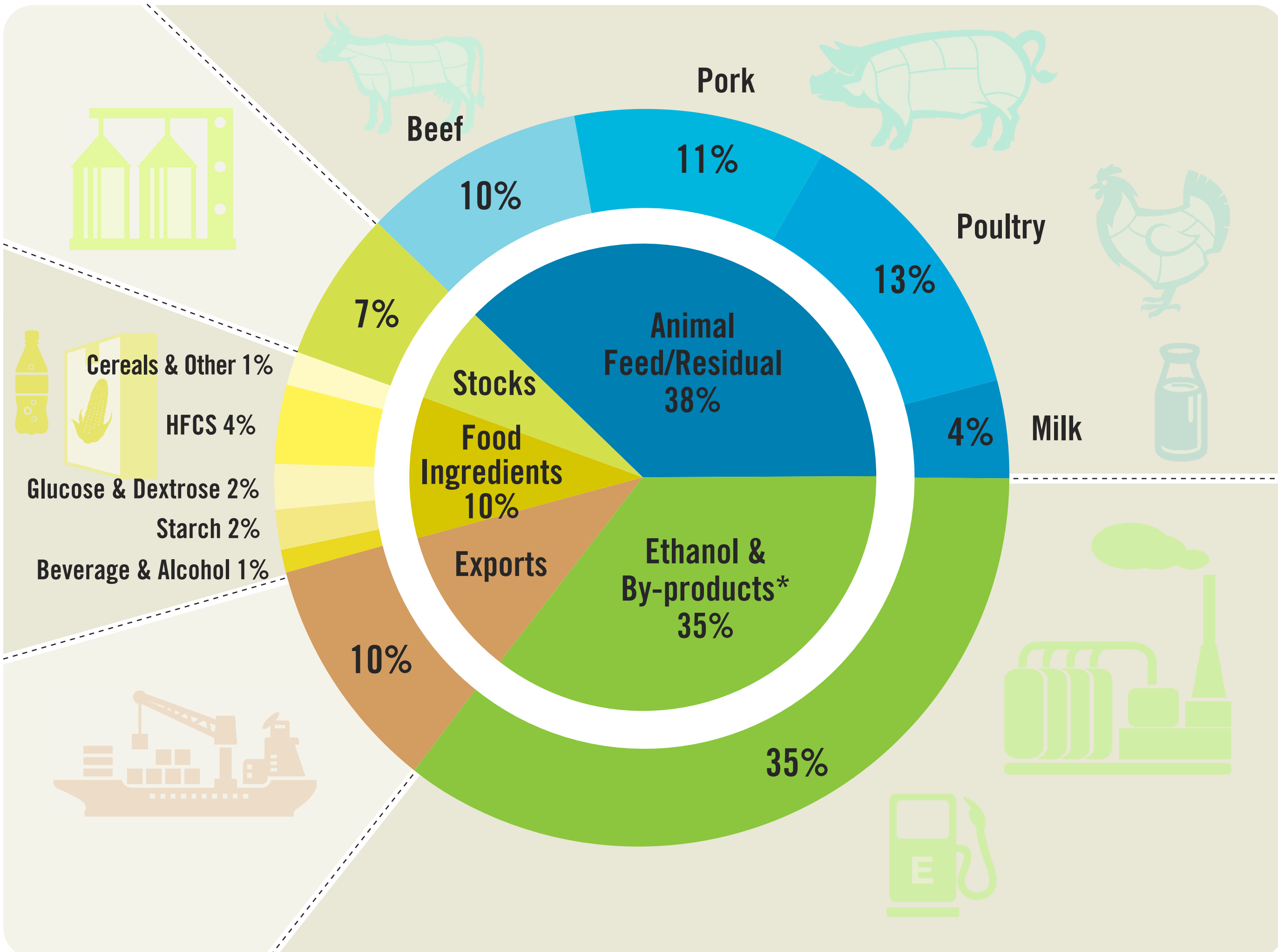
Given the scale of the challenges facing U.S. corn production and the key industries that depend on it, investors need to understand how companies in the grain processing, food, beverage, livestock, ethanol, grocery and restaurant sectors are addressing these risks in their supply chains. Already, there is growing demand from food retailers and manufacturers for more sustainable products and new supply chain initiatives that encourage more resilient and sustainable agricultural production. But these efforts have not been moving at the pace and scale necessary to address the risks at hand.

This report provides new data and interactive maps on the risks facing U.S. corn production, as well as detailed recommendations for how corn-buying companies and their investors can catalyze more sustainable agricultural practices that will reduce these risks, preserve and enhance yields, and protect precious water resources.

The U.S. Corn Value Chain

Corn is the nation's biggest crop economically, outpacing both soy and wheat in production value, number of acres planted and overall water use. The United States is the world's largest producer and exporter of corn grain, dedicating nearly one-third of its cropland to corn—an area equivalent to two Floridas. In 2013, nearly three-quarters of the U.S. corn crop went either to feed animals or to fuel cars, and just 10 percent was used for direct human consumption **(Exhibit ES1)**.

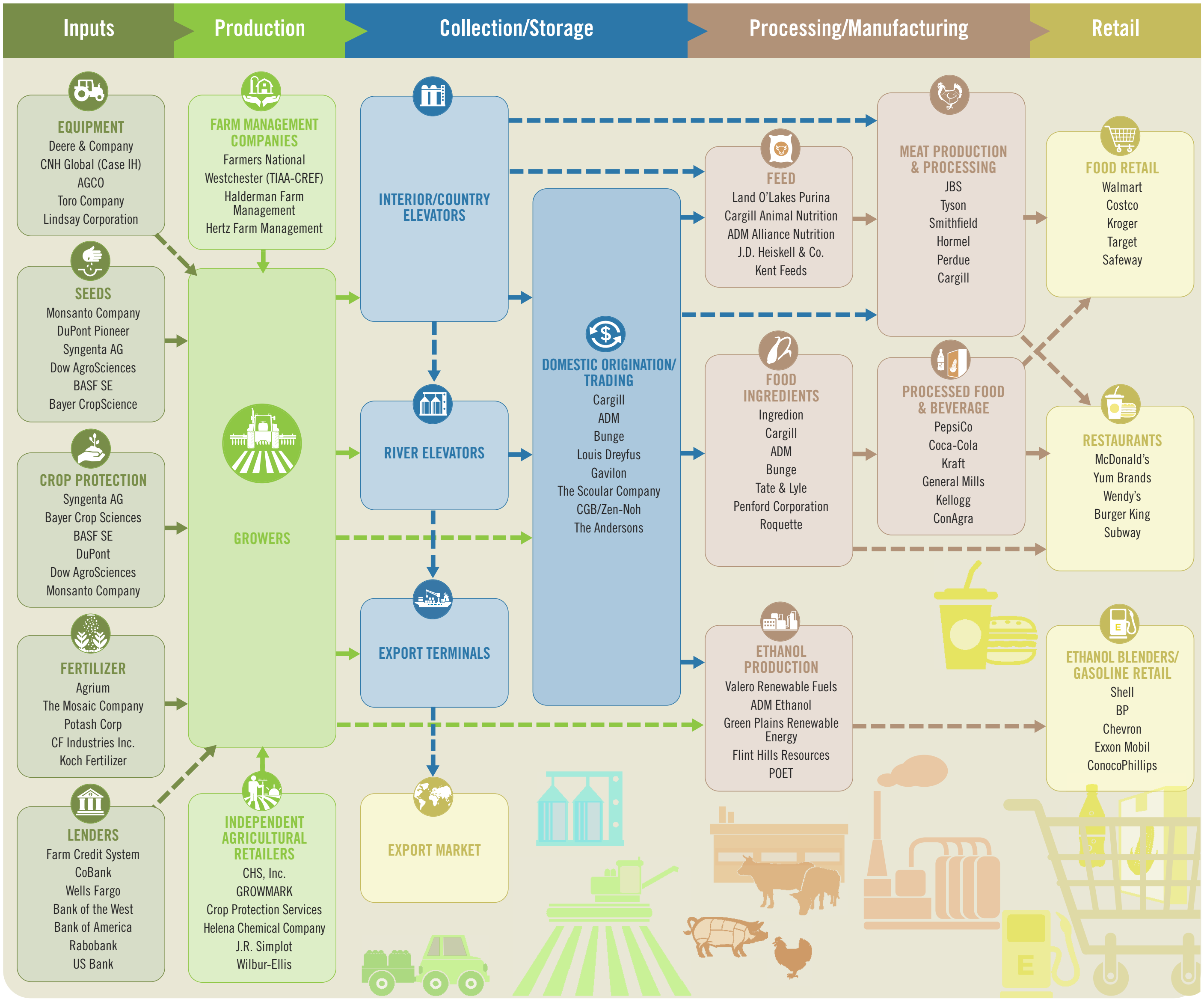
Exhibit ES1: U.S. Corn Use by Segment (2013)



* Corn dry-mill ethanol production also generates a co-product sold as livestock feed.

Source: USDA, ERS, Feed Grains Database

Exhibit ES2: Key Industries & Companies in the U.S. Corn Value Chain



The U.S. corn value chain consists of 16 major industries. This exhibit shows the largest companies in each segment, from inputs to origination and trading to processing, manufacturing and retail.

Source: Ceres, adapted from HighQuest Partners, April 2013

Corn is a key commodity for major industries across the U.S. economy. In assessing the U.S. corn value chain, this report finds that 16 separate sectors—from fast food companies to fertilizer manufacturers to grocery retailers—depend on U.S. corn as a key ingredient of their products or as a market for their inputs and services **(Exhibit ES2)**. In 2013, the top 45 companies in the corn value chain earned $1.7 trillion in revenue, more than the value of Australia's annual GDP.

Increasingly severe weather events and higher domestic demand for corn by the ethanol industry have contributed to a steady uptick and unprecedented volatility in corn prices, which ranged from $2 a bushel 10 years ago to a record $8 a bushel during the devastating 2012 drought. This volatility, extreme even within a broader context of commodity price volatility, has vast implications for the many industries that rely on corn. High corn prices in the wake of extreme flooding in spring 2011 and the prolonged drought in 2012 shuttered ethanol plants, contributed to the culling of beef herds, and reduced margins for many processed food and beverage companies.

Rising corn prices have also triggered unsustainable farming practices, including the expansion of corn production into highly erodible and ecologically sensitive land.[1] There has also been a dramatic shift away from the traditional annual rotation of corn and soybeans in favor of "continuous corn"(i.e. no rotation), which increases vulnerability to pests, and diminishes soil quality and long-term yields.[2]

Extreme Weather & Climate Change

Despite a bumper U.S. harvest in 2013 and lower corn prices in early 2014, many of the drivers of high corn prices, price volatility and overall risk are likely to worsen. Severe droughts, floods and heat waves at key moments in the growing season are becoming increasingly common, causing dramatic year-to-year supply shocks. The Federal Crop Insurance Program, which subsidizes approximately 60 percent of farmer premiums, is paying out unprecedented losses to corn farmers as a result of this extreme weather, including a record payment of $10.8 billion in 2012.[3]

Corn is uniquely sensitive to hotter temperatures and water stress. According to the latest National Climate Assessment, farmers can expect a higher incidence and intensity of floods, droughts and extreme heat, which can reduce corn's ability to pollinate.[4, 5] Given limited water availability in parts of the Great Plains region, a northward shift in corn acreage is predicted, increasing the risk of stranded agricultural assets such as processing, storage and transportation infrastructure.[6]

Irrigation Demand & Groundwater Depletion

Corn is a thirsty plant, and receives the most irrigation water overall of any American crop: 15.4 million acre-feet annually,[7] or the equivalent of more than 7 million Olympic-sized swimming pools. While per bushel water use has improved over time, total irrigated water demand for corn has grown due to geographic expansion of the crop, especially in areas with high water stress and groundwater depletion. Our analysis of corn production and water stress data developed by the World Resources Institute shows that 87 percent of irrigated corn is grown in regions with high or extremely high water stress **(Exhibit ES3)**, meaning that a large portion of existing water supplies are already spoken for. Many of these same regions can also expect worsening water shortages due to climate change. The most vulnerable regions are Nebraska, Kansas, California, Colorado and Texas.

Over half of the country's irrigated corn production—worth nearly $9 billion annually—depends on groundwater from the over-exploited High Plains aquifer. In western Kansas, for example, more than 30 percent of the aquifer's total volume has already been withdrawn, with another 39 percent projected to be pumped over the next 50 years.[8]

This report finds that $2.5 billion-worth of corn grain is grown in 20 counties over portions of the High Plains aquifer where groundwater levels are rapidly declining. Of these, five counties have over $150 million each in annual corn grain production at risk from groundwater depletion: Yuma County in Colorado and York, Hamilton, Adams and Filmore counties in Nebraska.

California's agricultural economy is also highly reliant on groundwater-irrigated corn production, most of which goes to feeding the state's 1.8 million dairy cows. As of spring 2014, California's record drought had forced a reduction in deliveries of surface water to irrigation districts in the state's Central Valley, leading many farmers to either fallow corn acres or redouble their use of already depleted local groundwater supplies.[9]

1 Christopher K. Wright and Michael C. Wimberly, "Recent land use change in the Western Corn Belt threatens grasslands and wetlands," Proceedings of the National Academy of Sciences of the United States of America, Jan. 2013, http://www.pnas.org/content/early/2013/02/13/1215404110.full.pdf+html.

2 James D. Plourde, Bryan C. Pijanowski, Burak K. Pekin, "Evidence for increased monoculture cropping in the Central United States," *Agriculture, Ecosystems and Environment* 165 (2013), 50–59.

3 Calculated from data sourced from: USDA, Risk Management Agency, Summary of Business Reports and Data: National Summary by Crop, (1989-2013).

4 U.S. Global Change Research Program, *Climate Change Impacts in the United States: The Third National Climate Assessment*, Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014:, 841 pp. doi:10.7930/J0Z31WJ2, http://nca2014.globalchange.gov.

5 Sharon M. Gourdji et al., "Global crop exposure to critical high temperatures in the reproductive period: historical trends and future projections," *IOP Science*, (30 May 2013).

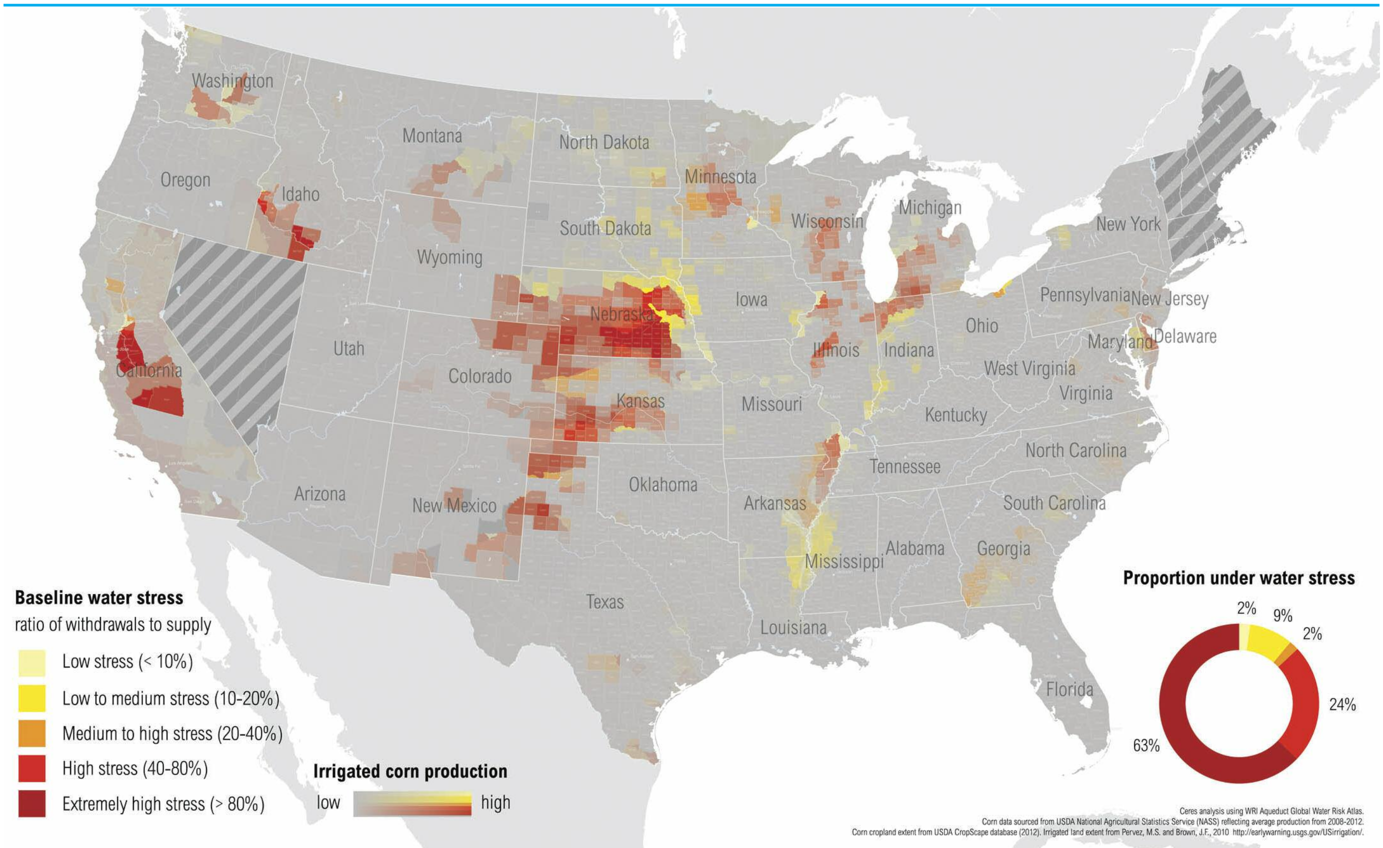
6 Michael J. Roberts and Wolfram Schlenker, "The Evolution of Heat Tolerance of Corn: Implications for Climate Change," *The Economics of Climate Change: Adaptations Past and Present*, Ch. 8 (May 2011), 225-251.

7 Corn grain production required 11,991,515 acre-feet of water, and corn silage production required 3,430,434 acre-feet. Source: USDA 2008 Farm and Ranch Irrigation Survey.

8 David Steward et al., "Tapping unsustainable groundwater stores for agricultural production in the High Plains Aquifer of Kansas, projections to 2110," *Proceedings of the National Academy of Sciences of the United States of America*, vol. 110 no. 37, (2013), http://www.pnas.org/content/110/37/E3477.full.

9 Ching Lee, "Drought influences dairy farmers' feed plans,"AgAlert, February 19, 2014, http://agalert.com/story/?id=6399.

Exhibit ES3: Competition for Water in Areas of Irrigated Corn Production



Red areas are regions where a large portion of existing water supply is already being used.

For an interactive version of this map, see www.ceres.org/cornmaps

Source: WRI Aqueduct Water Risk Atlas in combination with data from the USDA's National Agricultural Statistics Service (NASS) including the NASS CropScape database

In the face of these trends, there are significant opportunities to reduce irrigation demand. Roughly one-fifth of irrigated corn acres still use inefficient flood or furrow irrigation, and only a handful of irrigated corn farms (0.1 percent) utilize highly efficient drip irrigation.[10] What's more, many farming practices that help retain soil moisture and reduce irrigation demand—such as no till, extended crop rotations, and cover-cropping—are not yet widely adopted.

The ethanol industry, which uses 35 percent of all U.S. corn, adds further stress to regions experiencing declining water tables. This report finds that 36 ethanol refineries are located in and source corn irrigated with water from the High Plains aquifer **(Exhibit ES4)**. Of these, 12 refineries with an ethanol production capacity worth nearly $1.7 billion a year are in areas where the aquifer is experiencing water-level declines.

Inefficient Fertilizer Use

Compounding these environmental challenges, corn uses the most fertilizer of all major U.S. crops.[11] In 2010, U.S. corn production required 9.5 million tons of nitrogen, phosphorus and potash[12]—the equivalent of 380 million 50-pound bags of household lawn fertilizer. Nitrogen run-off from cornfields is the single largest source of nutrient pollution to the Gulf of Mexico's "dead zone," an area the size of Connecticut that is essentially devoid of life due to agricultural run-off **(Exhibit ES5)**.[13] According to the USDA, only 34 percent of U.S. corn acres are farmed using best practices for nitrogen fertilizer management, such as not over-applying fertilizer and applying fertilizer at the right

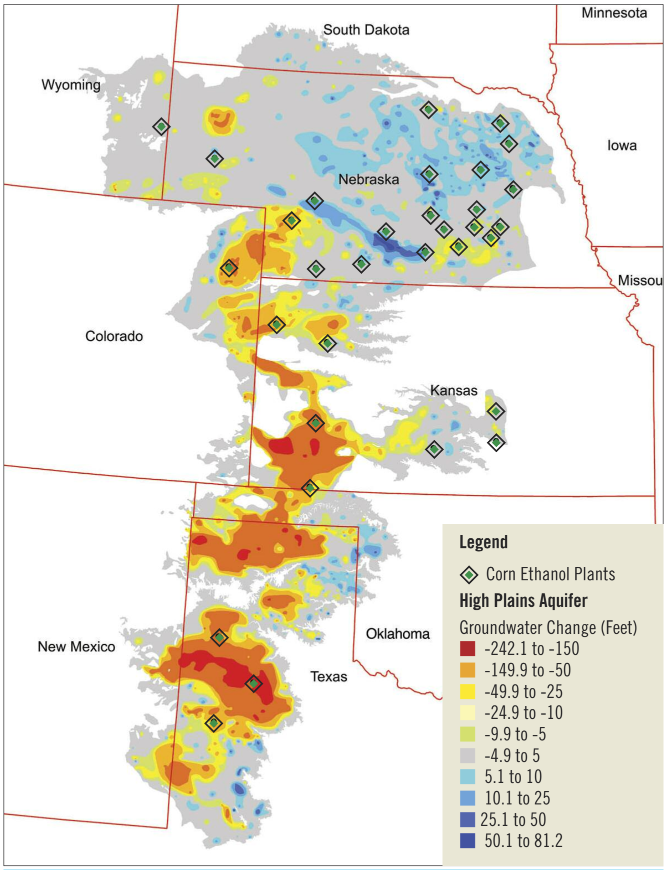
10 USDA Census of Agriculture, *2003 and 2008: Farm and Ranch Irrigation Survey*.

11 USDA, Economic Research Service, *Fertilizer Use and Price*, 2013 http://www.ers.usda.gov/data-products/fertilizer-use-and-price.aspx#26730.

12 Ibid.

13 Richard Alexander et al., "Differences in Phosphorus and Nitrogen Delivery to The Gulf of Mexico from the Mississippi River Basin," *Environmental Science Technology* 42, no. 3 (2008), 822–830, http://pubs.acs.org/doi/pdf/10.1021/es0716103.

Exhibit ES4: Corn-based Ethanol Refineries Over Areas of the High Plains Aquifer Experiencing Water-Level Declines



Map of corn-based ethanol refineries against declines/increases in water levels in the High Plains aquifer from pre-development to 2011. Twelve corn-based ethanol refineries are in areas of the aquifer experiencing water-level declines.

For an interactive version of this map, see www.ceres.org/cornmaps

Source: Ceres, using data from USGS, "Water-Level and Storage Changes in the High Plains Aquifer, Predevelopment to 2011 and 2009–11," by V.L. McGuire, 2013; and "Biorefinery Locations," Renewable Fuels Association website. GIS mapping by Agricultural Conservation Economics.

time during the growing season.[14] Fertilizer run-off can be further addressed by practices such as extended crop rotations, cover-cropping, and the development of buffer strips and artificial wetlands that naturally filter excess nitrogen and phosphorus.

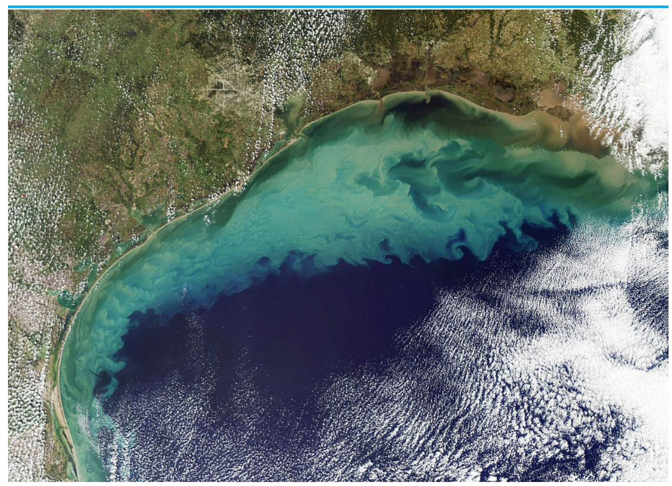
Because water pollution from agricultural run-off is largely unregulated, drinking water utilities, and the commercial fishing and outdoor recreation industries currently bear the financial burden of nutrient pollution. The USDA estimates that the cost of removing nitrate alone from U.S. drinking water supplies by large water utilities is more than $4.8 billion per year.[15]

Nutrient pollution also represents a direct loss to corn farmers: this report finds that in 2013, $420 million in fertilizer washed off corn acres into the Mississippi River and eventually the Gulf of Mexico.

The ethanol sector also makes a significant contribution to water pollution through its corn purchases. This report identifies 60 corn ethanol refineries with $8.8 billion in annual production capacity that are sourcing corn from watersheds with high local nitrogen pollution from agriculture **(Exhibit ES6)**. Several large ethanol producers including POET Biorefining, Valero Renewable Fuels and Flint Hill Resources have more than 50 percent of their production capacity in high pollution watersheds.

State-level strategies to reduce agricultural run-off as well as growing pressures from some food retailers and processed food companies are creating new drivers for more efficient fertilizer use in the Corn Belt. Walmart recently announced a goal for U.S. farmers in its supply chain to increase efficiency of their fertilizer use by 30 percent on 10 million acres of corn, wheat and soybeans by 2020.

Exhibit ES5: The Gulf of Mexico's "Dead Zone"



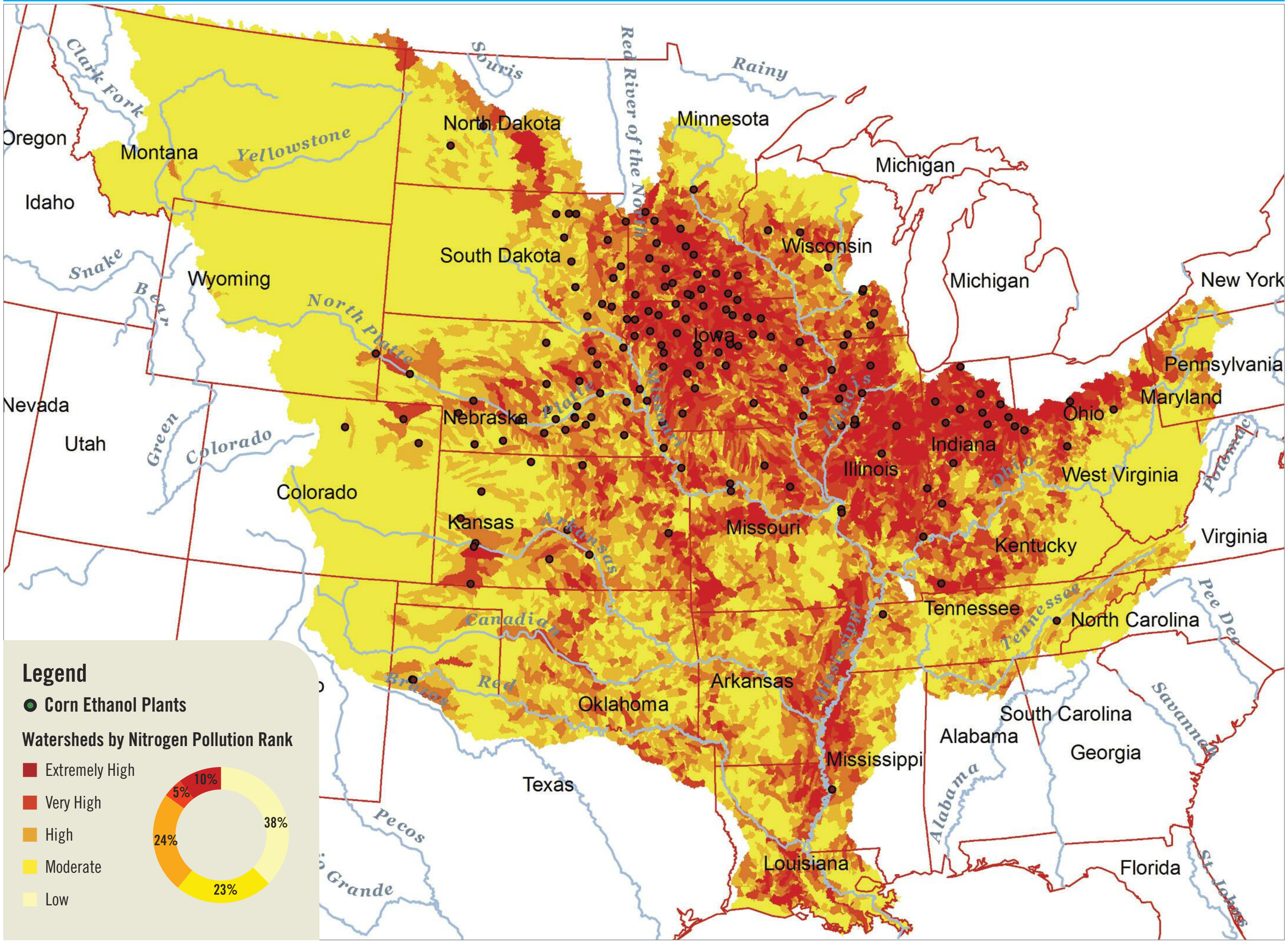
Fertilizer contamination in the Mississippi River Basin promotes the growth of algal blooms that deplete oxygen in the water when they decompose. As a result, every summer a large hypoxic area or "dead zone" forms in the Gulf of Mexico. In 2013, the dead zone covered an area of about 5,800 square miles, roughly the size of Connecticut.

Source: NASA Earth Observatory, acquired with the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite, September 2010

14 USDA, Economic Research Service, *Nitrogen Management on U.S. Corn Acres, 2001-10*, by Marc Ribaudo, Michael Livingston, and James Williamson, EB-20 November 2012 http://www.ers.usda.gov/publications/eb-economic-brief/eb20.aspx#.U0K6fK1dXd0

15 USDA, Economic Research Service, *Nitrogen in Agricultural Systems: Implications for Conservation Policy*, by Marc Ribaudo et al., Economic Research Report No. 127, September 2011, http://www.ers.usda.gov/publications/err-economic-research-report/err127.aspx#.UzmK9a1dXd0.

Exhibit ES6: **Ethanol Refineries in Watersheds with High Local Nitrogen Pollution from Agriculture**



Corn ethanol refineries locations are overlaid against watersheds in the Mississippi River Basin ranked by their relative contribution of agriculture-related nitrogen pollution to local waterways. Ethanol plants located in red or dark red watersheds are likely sourcing corn feedstock from regions where agricultural-related nitrogen pollution is a major contributor to the impairment of local water quality. Sixty corn ethanol refineries with approximately 33 percent of the country's corn ethanol production capacity are located in watersheds with "high" or above delivery of nitrogen pollution to local waterways.

For an interactive version of this map, see www.ceres.org/cornmaps

Source: Ceres, using data from the Renewable Fuels Association and USGS SPARROW. GIS mapping by Agricultural Conservation Economics.

Recommendations for Companies

This report highlights many of the farming practices that can help reduce the risks facing America's corn growers, while also improving yields and saving on input costs. It also provides recommendations for companies that source U.S. corn—and their investors—on how to be key partners in mitigating impacts to water resources. The recommendations for companies include:

1. **Setting meaningful policies and goals.** Companies that buy corn should develop a corporate policy that commits them to sourcing agricultural inputs that are grown in ways that reduce impacts to freshwater and the environment. These policies should be tied to measureable, time-bound goals.
2. **Communicating clear expectations to suppliers.** For companies not dealing directly with farmers (i.e. those buying grain from intermediary suppliers), priorities for reducing environmental risks in farming practices should be well communicated to suppliers and integrated into supplier codes and procurement contracts. Where possible, policies, metrics and data requests should be aligned with others in the industry.
3. **Incentivizing the procurement function.** To enable improved sourcing practices, supply chain managers will need additional expertise on environmental risks in agriculture, and should be compensated against performance objectives that include reducing these risks.
4. **Prioritizing action based on risk.** Companies should develop sourcing strategies that prioritize action in sourcing regions of higher risk, such as those associated with water stress, groundwater depletion and/or nutrient pollution, using the maps in this report.
5. **Joining multi-stakeholder efforts to develop shared metrics and approaches.** Companies should consider constructive participation in initiatives such as Field to Market that are providing U.S. corn growers with the tools, information and other resources to improve farming practices.
6. **Providing value to farmers.** Farmers should not be expected to change their practices without incentives and support from others in the value chain. Companies can help growers by providing direct agronomic assistance, performance guarantees and credit, as well as financial support to local and regional organizations that assist farmers.
7. **When possible, buying less corn.** Corn has an inherently higher fertilizer and water use profile than many other crops. For sectors with a heavy reliance on corn such as meat and ethanol, substitute grains with a preferable environmental risk profile may already be available or their production can be encouraged by working with growers to select profitable alternatives.
8. **Taking public policy positions that support sustainable agriculture.** Government policies that mitigate climate change and encourage risk-reducing, environmentally beneficial farming practices and long-term land and water stewardship will lead to more stable commodity prices and resilient agricultural markets. Companies should ensure that their own policy positions, lobbying activities, and industry groups support legislation and regulation that advances those ends.
9. **Being transparent.** Disclose to investors and stakeholders the company's exposure to climate and water-related risks in its agricultural supply chain, as well strategies and progress toward mitigating these risks.

Introduction to the U.S. Corn Value Chain

Chapter Summary:

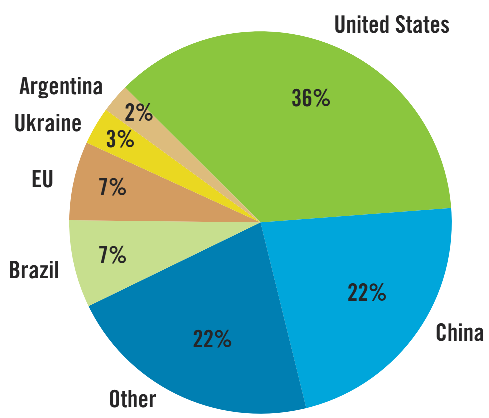
- Corn is an enormously important crop due to its high productivity, generating more biomass per acre than other major crops such as wheat and soybeans. Nearly one-third of America's cropland is dedicated to corn production—an area more than double the size of Florida. The United States is the world's largest producer and exporter of corn with a $67 billion corn harvest in 2013, three-quarters of which went either to animal feed for livestock production, or to ethanol as automotive fuel.
- Corn farming is concentrated in a small number of Midwestern states by an ever-shrinking number of large-scale farms: just five percent of corn farms produce over one-third of the national harvest. The industries that buy corn are far more concentrated, with small numbers of grain traders, livestock, ethanol and processed food companies dominating their respective sectors. In 2013, the 45 largest companies in the corn value chain collectively earned $1.7 trillion in revenue, more than the annual gross domestic product of Australia.
- Corn has experienced significant overall price increases in recent years (2014 notwithstanding), accompanied by high levels of daily price volatility. Higher corn prices and short-term price volatility have adversely affected the competitiveness of meat and dairy producers due to high feed costs, while also reducing margins for ethanol and food and beverage companies. High prices have also driven expansion of corn acreage, including into native grasslands and low quality, erosion-prone land. Additionally, an increase in continuous corn cropping (i.e. reduced crop rotation) threatens soil and water quality.
- Despite a near-term reduction in the corn price, many of the underlying market drivers for high and volatile corn prices remain in place. These include demand side drivers such as U.S. ethanol policy and growing meat consumption in emerging markets, as well as supply side drivers like generous government crop insurance and increasingly severe droughts, heat waves and floods.

U.S. Corn Production Overview

The U.S. is the world's largest corn producer and exporter.

The U.S. leads the world in the production of field or "dent" corn,[1] with 36 percent of global output **(Exhibit 1.1)** and a long-term trend of steady production growth **(Exhibit 1.2)**. In the 2013/14 crop year,[2] the country's farmers grew 13.9 billion bushels of corn grain, up 29 percent from 2012/13 when a prolonged drought ravaged the Corn Belt.[3]

Exhibit 1.1: World Corn Production by Country (2013-2014)

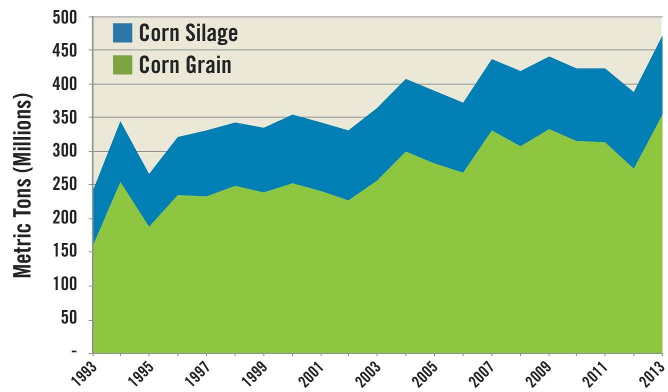


Source: USDA, Foreign Agricultural Service, Production, Supply, and Distribution (PSD) Database

U.S. field corn is used as either grain or silage. Corn grain goes primarily to livestock feed, ethanol production, or as a food ingredient in the form of cereal, starch, oil and syrup.

Corn silage consists of the entire plant which is harvested, chopped, packed tightly and stored, typically for use as livestock feed. In any given year, between 25-30 percent of total corn production is used for silage **(Exhibit 1.2)**.

Exhibit 1.2: U.S. Corn Production (1993-2013)



Source: USDA, National Agricultural Statistics Service (NASS)

The U.S. will export only about 13 percent of the corn grain it produces in the 2013/14 crop year,[4] yet this volume represents 39 percent of total global corn grain exports.[5] Other major exporters include Brazil, Ukraine and Argentina. The volume of corn exported by the United States has remained relatively stable in recent years, while the value of U.S. corn exports has risen significantly, reflecting rising corn prices.[6]

Corn: The King of Grains

From its humble origins as the ancient Central American grass *teosintle*, modern corn has become the most harvested grain in the world because of its high productivity and versatility. The corn plant has responded well to breeding and genetic modification, and not only efficiently converts solar energy into biomass, but is also a large source of energy and nutrients for animal and human consumption. Corn has higher yields in terms of mass produced per acre than other major crops like wheat and soybeans, and can also be grown across relatively diverse soil types and climates. Lastly, corn can be transformed into a diverse range of food and industrial products, including cereals, starches, sweeteners, beverage and industrial alcohol, animal feed, ethanol and bio-based plastics.

1 Field or "dent" corn represents the vast majority (more than 99 percent or 93 million acres) of corn grown in the country. Sweet corn, familiar to most Americans as corn-on-the-cob, was planted on 623,000 acres in 2007. The focus of this report is field corn, and unless otherwise noted, the term "corn" in this report and accompanying figures is used to refer to field corn used for both grain and silage.

2 The crop year (or marketing year) is the 12-month period beginning with the month in which the bulk of the crop harvest begins. Crop years are always expressed as a split year (e.g. 2013/14). Corn crops around the world are planted and harvested at different times, but within the U.S., corn is usually planted in April-June and harvested in October-November.

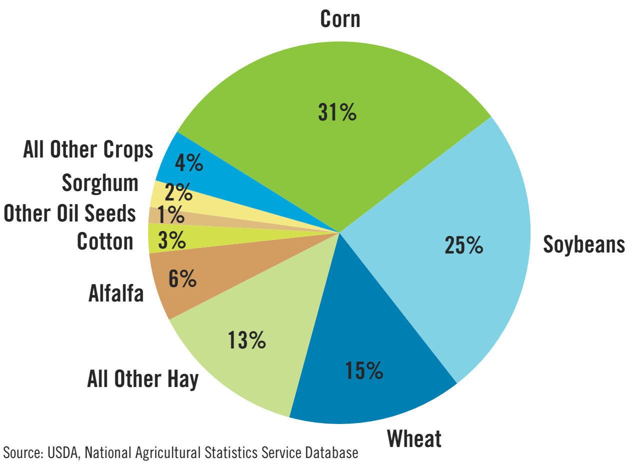
3 USDA, Office of the Chief Economist, Agricultural Marketing Service, Farm Service Agency, Economic Research Service, Foreign Research Service, *World Agricultural Supply and Demand Estimates*, WASDE—527 ISSN: 1554-9089, March 10, 2014, http://www.usda.gov/oce/commodity/wasde/latest.pdf.

4 Ibid.

5 USDA, Foreign Agricultural Service, Production, Supply, and Distribution (PSD) Database.

6 USDA, Foreign Agriculture Service, Global Agricultural Trading System (GATS) Database.

Exhibit 1.3: **U.S. Crops by Harvested Acreage (2013)**



Source: USDA, National Agricultural Statistics Service Database

Corn has the most harvested acres of any U.S. crop.

Corn, which is typically planted in rotation with soy, dominates the U.S. agricultural landscape. Almost one-third of U.S. cropland, or 93.9 million acres, was devoted to corn production in 2013 **(Exhibit 1.3)**. Other major crops include soybeans and wheat.

Corn is the most valuable U.S. crop.

Despite typically commanding a lower market price per bushel than other row crops,[7] corn's total production value in recent years has surpassed that of both wheat and soybeans combined **(Exhibit 1.4)**. Its estimated total value was approximately $67 billion in 2013/14.

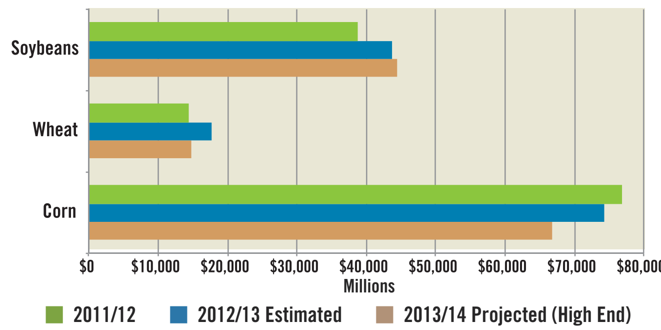
Ninety percent of U.S. corn relies on biotech seeds.

Most of the corn planted in the United States has been genetically modified to be tolerant of herbicides (e.g. Roundup Ready corn), resistant to insects (e.g. Bt corn), or to contain "stacked traits" in which the corn is both herbicide-tolerant and insect-resistant. Stacked traits are becoming increasingly popular, and currently 71 percent of all corn planted in the U.S. contains stacked traits **(Exhibit 1.5)**.

The number of corn acres harvested—as well as yield per acre—has risen over time.

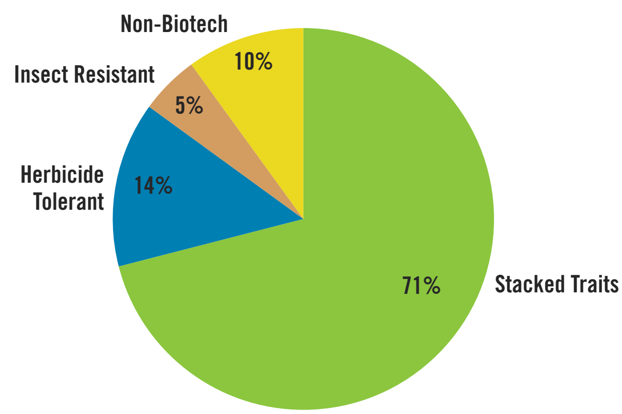
Over the last 20 years, there has been steady growth in the number of acres used to grow corn as well as in bushels produced per acre **(Exhibit 1.6)**. Higher corn yields have resulted from changes in technology (e.g. improved seed varieties, and the use of fertilizers, pesticides, and farm machinery) as well as changes in production practices (e.g. irrigation, reduced tillage, crop rotations, and pest management approaches).[8]

Exhibit 1.4: **Total Production Value by U.S. Crop (2011-2013)**



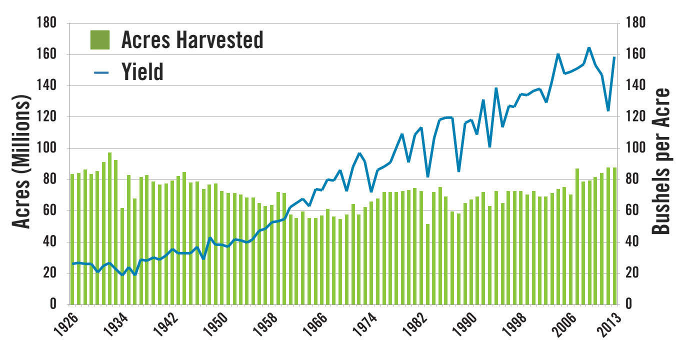
Source: USDA, World Agricultural Supply and Demand Estimates

Exhibit 1.5: **Biotech Share of U.S. Corn Acres Planted (2013)**



Source: USDA, National Agricultural Statistics Service Database

Exhibit 1.6: **U.S. Corn Productivity, Acres Harvested vs. Yield (1926-2013)**



Source: USDA, National Agricultural Statistics Service Database

7 According to the 2013/14 WASDE projections (April 9, 2014 release), corn is expected to have a value of between $4.40-$4.80 per bushel, while wheat is projected to have a value of $6.75-$6.95/bushel and soybeans, $12.50-$13.50/bushel.

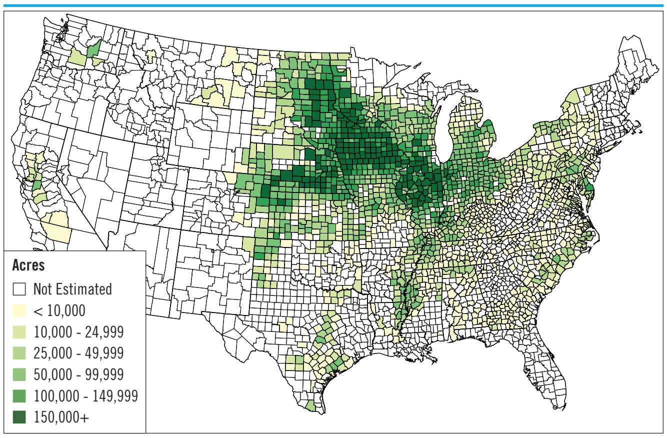
8 "Corn: Background," USDA, Economic Research Service, http://www.ers.usda.gov/topics/crops/corn/background.aspx#.UtyzvJF6joA.

The U.S. Corn Value Chain

More than 50 percent of U.S. corn is harvested in just four states.

Most corn is farmed in the Midwestern Corn Belt **(Exhibit 1.7)**, and four states account for 52 percent of corn grain production: Iowa, Illinois, Nebraska and Minnesota **(Exhibit 1.8)**. Corn production has been centered in this region due to a historically favorable combination of weather conditions, soil quality and groundwater availability.

Exhibit 1.7: Corn Grain Acres Harvested by County (2012)



Source: USDA, National Agricultural Statistics Service, *Corn for Grain 2012 Harvested Acres by County for Selected States*

Exhibit 1.8: Corn Acres Harvested & Corn Grain Production by State (2013)

State	Corn Acres Harvested	Percent of Total U.S. Acres Harvested	Corn Grain Production (Bushels)	Percent of Total U.S. Production
Iowa	13,490,000	14%	2,161,500,000	16%
Illinois	11,890,000	13%	2,100,400,000	15%
Nebraska	9,810,000	10%	1,623,500,000	12%
Minnesota	8,530,000	9%	1,304,000,000	9%
Indiana	5,990,000	6%	1,035,450,000	7%
South Dakota	6,140,000	7%	808,680,000	6%
Rest of the U.S.	38,074,000	41%	4,891,617,000	35%
U.S. TOTAL	**93,924,000**		**13,925,147,000**	

Source: USDA, National Agricultural Statistics Service Database

Corn is produced on increasingly larger farms by non-owner/operators.

While 97 percent of U.S. farms (across all crop types) remain family farms,[9] U.S. farmland ownership is consolidating into the hands of fewer landowners with ever-larger farms. In 2009, large-scale family farms and non-family farms accounted for only 12 percent of farms but 83 percent of the value of production.[10]

Corn grain production mirrors this broader trend. The number of corn farms greater than 500 acres has increased over time, while the number of corn farms with fewer than 500 acres has declined.[11] In 2012, five percent of corn farms accounted for 36 percent of production **(Exhibit 1.9)**.

Beyond consolidation, another trend affecting corn production is an increase in corn acres leased versus those farmed by the landowners themselves, Across the Corn Belt, at least 38 percent of agricultural acres are farmed by non-landowners in 2012.[12] Iowa in particular stands out for high rates of rented farmland. Excluding land in government programs (e.g. Conservation Reserve Program[13] acres), 60 percent of Iowa farmland was rented in 2012, up from 45 percent in 1982.[14]

"Non-operating landlords" are less likely to live on the farm, tend to be older, and are also less likely to participate in conservation programs.[15] The average age of farmers has been rising nationwide and the retirement of many owner/operators is expected to accelerate the trend of rented acres. Again, to take Iowa as an example: in 2012, 56 percent of Iowa farmland was owned by people over the age of 65; in 1982, 29 percent was owned by people over the age of 65.[16]

Exhibit 1.9: Farm Size & Concentration, Corn Grain (2012)

All U.S. Corn Grain Farms		Large-Scale Corn Grain Farms (>1,000 acres)	
Number of Farms	348,530	17,514	5%
Acres Harvested	87,413,045	30,028,386	34%
Bushels	10,333,410,157	3,670,111,522	36%
Value of Production	$67,250,120,000	$23,892,426,008	36%

Source: USDA 2012 Census of Agriculture: Table 37, Specified Crops by Acres Harvested, and Table 2, Market Value of Agricultural Products Sold

9 The USDA defines family farms as farms in which "the majority of the business is owned by the operator and individuals related to the operator by blood, marriage, or adoption, including relatives that do not live in the operator household." Family farms do not include those organized as cooperatives, organized as corporations with the majority of shareholders not related (by blood, marriage, or adoption), nor farms operated by a hired manager. "Glossary," last modified February 11, 2014, http://www.ers.usda.gov/topics/farm-economy/farm-household-well-being/glossary.aspx#familyfarm.

10 USDA, Economic Research Service, *Agricultural Resources and Environmental Indicators*, 2012 Edition, by Osteen Craig, Jessica Gottlieb, and Uptal Vasavada, eds., EIB-98, (Washington D.C., August 2012)

11 "Corn: Background," USDA, Economic Research Service.

12 USDA, Economic Research Service, *Trends in U.S. Farmland Values and Ownership*, Cynthia Nickerson et al, 2012, http://www.ers.usda.gov/media/377487/eib92_2_.pdf.

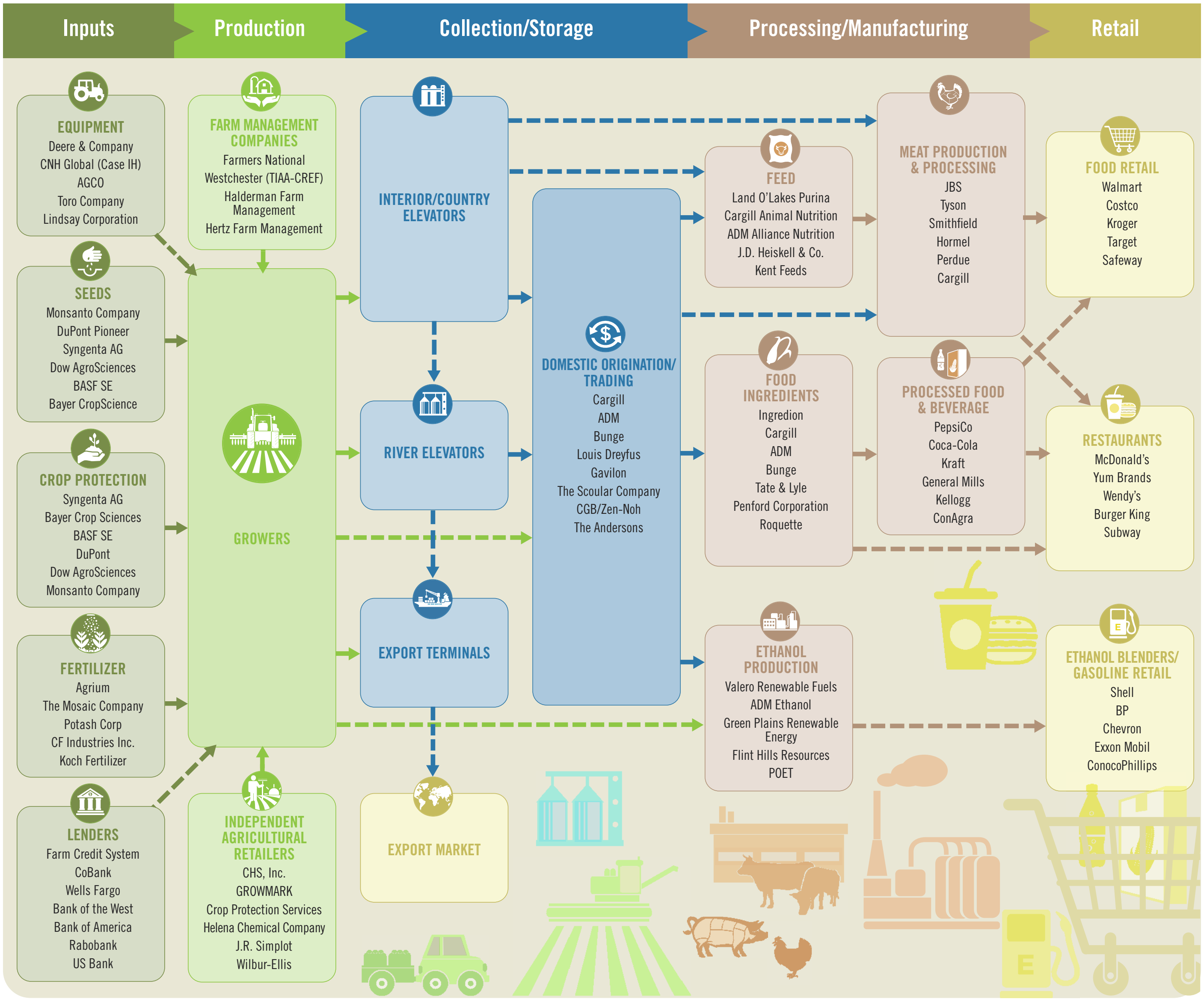
13 The Conservation Reserve Program is a cost-share and rental payment program under the USDA that encourages farmers to convert highly erodible cropland or other environmentally sensitive acreage to non-farmed, vegetative cover.

14 Michael Duffy and Ann Johanns, "Farmland Ownership and Tenure in Iowa 2012," *Iowa State University Extension and Outreach*, Jan. 2014, http://econ2.econ.iastate.edu/faculty/duffy/documents/pm1983_2012.pdf.

15 USDA, *Trends in U.S. Farmland Values and Ownership*

16 Duffy and Johanns, "Farmland Ownership and Tenure in Iowa 2012." http://econ2.econ.iastate.edu/faculty/duffy/documents/pm1983_2012.pdf.

Exhibit 1.10: Top Industries and Companies in the U.S. Corn Value Chain



The U.S. corn value chain consists of 16 major industries. This exhibit shows the largest companies in each segment, from inputs to origination and trading to processing, manufacturing and retail.

Source: Ceres, adapted from HighQuest Partners, April 2013

Forty-five large companies with collective revenues of over $1.7 trillion depend on U.S. corn production.

The U.S. corn value chain is made up businesses that sell inputs and services to farmers and landowners, as well as those that buy, transport and process corn, and sell corn-based products to consumers. In total, there are at least 16 distinct industries along the U.S. corn value chain **(Exhibit 1.10)**.

In many sectors within the corn value chain, a very small number of companies control significant market share. The highest levels of industrial concentration fall in 10 sectors: fertilizer, origination/trading, seeds and crop protection, meat production and processing, equipment, food retail, restaurants, processed food and beverage, and ethanol production **(Exhibit 1.11)**. The 45 largest companies in these sectors together brought in over $1.7 trillion in revenue in 2013. Those that were publicly-traded had a total market capitalization of $1.5 trillion as of December 31, 2013.

Exhibit 1.11: Highly Concentrated Sectors & Top Companies in the U.S. Corn Value Chain

Industry	Estimated 5-Firm Concentration Ratio	Top Companies in Segment	2013 Revenue (in $M) * = FY 2012	Market Capitalization (as of 12/31/13 in $M)
Fertilizer	80%	Agrium (AGU)	$16,686*	$13,256
		Mosaic (MOS)	$9,027	$20,136
		Potash Corp. (POT)	$7,305	$28,428
		CF Industries (CF)	$6,104*	$13,356
		Koch Fertilizer	NA	NA
Grain Origination/ Trading	80%	Cargill Inc.	$136,654	NA
		Archer Daniels Midland (ADM)	$89,804	$28,556
		Bunge (BG)	$60,991*	$12,120
		Louis Dreyfus Commodities BV	$57,140*	NA
Seeds & Crop Protection	70%	BASF SE (BASFY)	$72,129*	$99,003
		Dow Chemical Co. (DOW)	$57,080	$53,851
		EI du Pont de Nemours & Co. (DD)	$35,734	$60,169
		Monsanto (MON)	$14,861	$61,286
		Syngenta AG (SYT)	$14,688	$37,223
		Bayer CropScience (BYILF)	$7,360*	$56,781
Meat Production & Processing	70%	JBS SA (JBSS3: Sao Paulo Stock Exchange)	$38,902*	NA
		Tyson (TSN)	$34,374	$11,504
		Smithfield (SFD)	$13,221	$4,729
		Hormel (HRL)	$8,752	$11,910
		Purdue	NA	NA
Equipment	65%	Deere & Co. (DE)	$37,278	$34,019
		CNH Industrial NV (CNHI)	$25,778	$15,310
		AGCO (AGCO)	$10,787	$5,763
		Toro (TTC)	$2,041	$3,613
		Lindsay Corp. (LNN)	$691	$1,065
Food Retail	50%	Walmart (WMT)	$469,162	$254,623
		Costco (COST)	$105,156	$52,336
		Kroger (KR)	$96,751	$20,418
		Target (TGT)	$73,301	$39,992
		Safeway (SWY)	$44,207*	$7,859
Restaurants	50%	McDonald's (MCD)	$28,106	$96,548
		Yum Brands (YUM)	$13,084	$33,671
		Wendy's (WEN)	$2,505*	$3,415
		Burger King Worldwide (BKW)	$1,966*	$8,029
		Subway	NA	NA
Processed Food & Beverage	40%	PepsiCo (PEP)	$65,492*	$127,197
		Coca-Cola (KO)	$48,017*	$182,422
		Kraft (KRFT)	$18,339*	$32,123
		General Mills (GIS)	$17,774	$31,171
		Kellogg (K)	$14,792	$22,119
Ethanol Production	40%	Valero Energy Corp. (VLO)	$138,074	$27,194
		Archer Daniels Midland (ADM)	$89,804	$28,556
		Green Plains Renewable Energy (GPRE)	$3,041	$591
		Flint Hill Resources	NA	NA
		Poet LLC	NA	NA

* Revenues and market capitalization not available for most privately held companies.

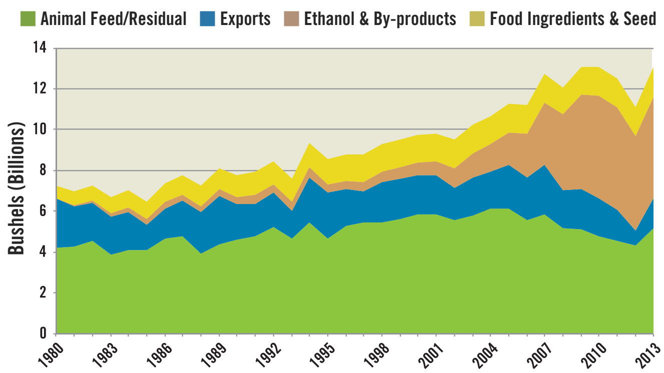
Sources: Five-firm concentration ratios adapted from HighQuest Partners and Ceres (April 2013); 2013 Revenue and Market Capitalization. FY 2013, via Bloomberg LP, accessed January 30, 2014.

U.S. corn primarily feeds animals and fuels cars.

Corn grown in the United States is used primarily as an input to animal feed (38 percent) and as a feedstock for ethanol (35 percent),[17] with a much smaller proportion used for food ingredients (10 percent) **(Exhibit 1.12)**. Corn may be processed into a multitude of food and industrial products such as cereals, starches and sweeteners (including high fructose corn syrup (HFCS), glucose and dextrose), as well as beverage and industrial alcohol.

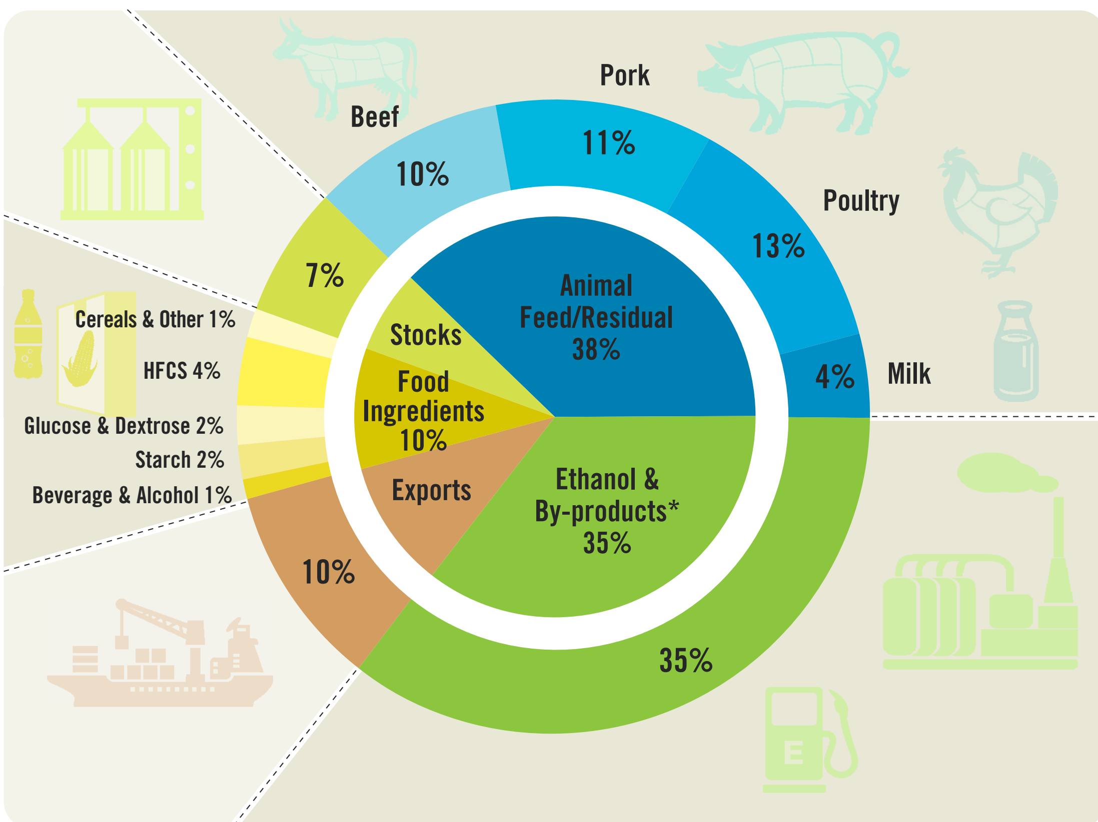
While the other uses of corn have remained relatively stable over time, the share of corn used for ethanol production has increased substantially since 2005 to meet requirements under the U.S. Renewable Fuel Standard **(Exhibit 1.13)**. The legislation mandates that domestically produced ethanol replace a portion of imported petroleum used for gasoline, creating an essentially inelastic demand for corn used as ethanol. In order to meet rising annual blending obligations, the production of corn-based ethanol has doubled since 2007, making the United States the largest producer of corn ethanol in the world.

Exhibit 1.13: Historic U.S. Corn Use by Segment (1980-2013)



Source: USDA, National Agricultural Statistics Service Database

Exhibit 1.12: U.S. Corn Use by Segment (2013)



* Corn dry-mill ethanol production also generates a co-product sold as livestock feed.

Source: USDA, National Agricultural Statistics Service Database

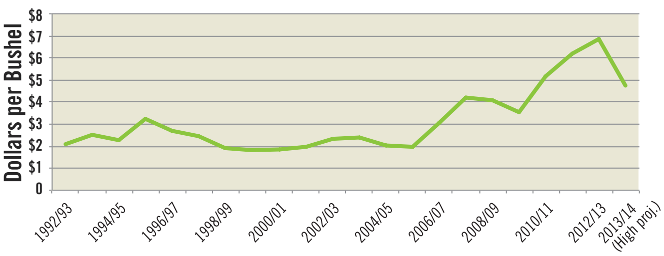
17 Corn dry-mill ethanol production also produces a co-product that is often sold as livestock feed known as distillers' dried grains with solubles (DDGS). The use of DDGS as livestock feed has been rising, following the trend in rising ethanol production. Source: USDA, *Market Issues and Prospects for U.S. Distillers' Grains Supply, Use, and Price Relationships*, by Linwood Hoffman and Allen Baker, FDS-10k-01 (2010), http://www.ers.usda.gov/publications/fds-feed-outlook/fds10k-01.aspx#.U1llo-ZdWwg.

Corn Price Volatility

The price of corn has been rising over time.

Over the last 20 years the price of corn has been steadily rising, with a notable increase since 2005 that coincides with the creation of the Renewable Fuel Standard **(Exhibit 1.14)**. In August 2012, stemming in large part from low supply brought on by severe drought, corn prices hit an all-time high of over $8 per bushel.[18] However, the 2013 record harvest (13.9 billion bushels) has pushed the price of corn down to $4-$5 per bushel.

Exhibit 1.14: Historic U.S. Corn Grain Prices (1992-2014) Weighted-Average Annual Farm Price[19]

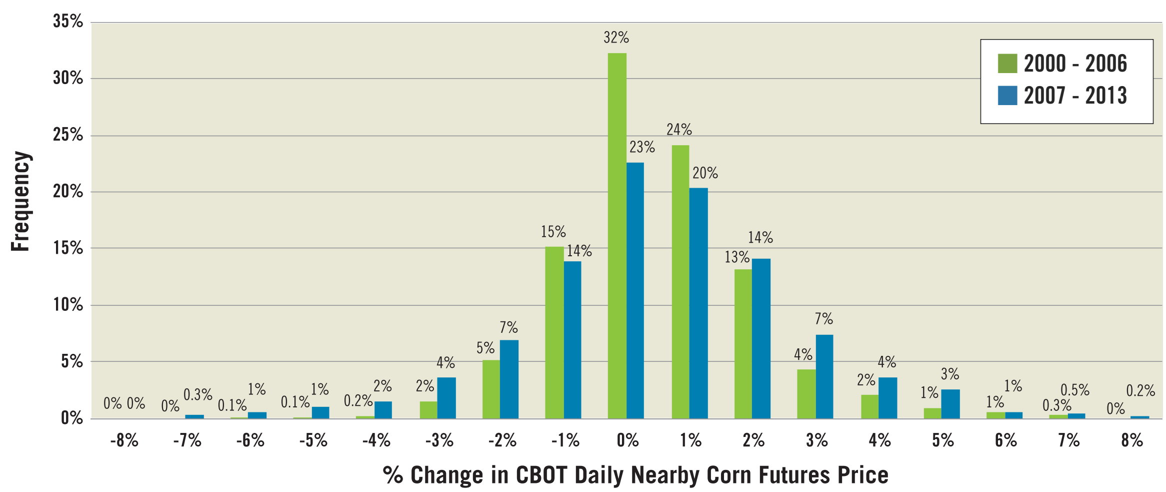


Source: USDA, Economic Research Service, *Feed Grains Yearbook Tables*

The volatility of daily corn prices has also been rising.

Beneath recent year-on-year increases in corn price, the industry is also seeing more pronounced short-term price volatility, adding complexity and risk for participants in the corn markets. Farmers and grain buyers alike have had to contend with much larger daily swings in corn prices, necessitating more sophisticated use of hedging instruments than has been typical in the past. **Exhibit 1.15** illustrates the significant shifts in corn price volatility (as measured by changes in the daily price of the Chicago Board of Trade nearby corn futures contract) between the 2000-2006 period and the 2007-2013 period. During 2000-2006, nearly one-third of trading days (32 percent) saw no shift in the nearby contract price for corn, versus only 23 percent of trading days during the more volatile 2007-2013 period.

Exhibit 1.15: Daily Corn Price Volatility (2000-2013)



Between 2007-2013, daily corn prices were significantly more volatile than between 2000-2006, as measured by changes in the daily price of the Chicago Board of Trade (CBOT) nearby corn futures contract.

Source: Ceres analysis. Data retrieved from Last Price of Nearby Daily Price of Corn, January 1, 2000—December 31, 2013, via Bloomberg LP

18 "Corn prices - Will Their Rout Extend into 2014?" *Agrimoney.com*, 6 Jan 2014. http://www.agrimoney.com/feature/corn-prices—-will-their-rout-extend-into-2014—255.html.

19 In August 2012, corn hit a record price of over $8 per bushel. However, this exhibit reflects data for corn prices averaged over the entire crop year and a maximum of $6.89 per bushel is displayed for the 2012/13 crop year.

High corn prices have had repercussions along the entire corn value chain.

The 2012 drought, which contributed to higher average corn prices and short-term price volatility, had direct impacts on livestock producers because of high feed costs, and also reduced margins for ethanol and food and beverage companies **(Exhibit 1.16)**. Players across the corn value chain—from grain traders to ethanol refiners, meat companies to food retailers—have different levels of exposure to this price volatility, and typically employ a range of strategies such as hedging or diversification of suppliers to manage exposure to price risk. However for many companies in the corn value chain, this price risk has become significantly harder for procurement managers to mitigate, with impacts manifested in terms of missed earnings, higher consumer pricing, and investment in product reformulations.[20]

Exhibit 1.16: The Financial Impacts of High Corn Prices

"Corn prices club meat producer shares"

Marketwatch, July 2012

"Investors are lightening up on their protein diets, unloading shares of Sanderson Farms Inc., Pilgrim's Pride Corp. and Tyson Foods Inc. over the past month amid a swift rise in futures prices for feed grains."[21]

"Drought increases price of corn, reduces profits to ethanol producers"

U.S. Energy Information Administration, August 2012

"Drought conditions in Midwestern states have reduced expectations for the amount of corn that may be harvested in 2012, and contributed to a 35 percent rise in the price of corn from June 18 to August 29. During the same time period, the spread between ethanol and corn prices (known as the 'crush spread') declined by $0.22 dollars per gallon. The corn crush spread indicates the relative profitability of producing ethanol from corn."[23]

"Coca-Cola can't shuck rising corn costs"

MSN Money, July 2012

"Coca-Cola, one of the most ubiquitous brands in the world and one of Warren Buffett's favorite stocks, is a powerhouse in the business world. But there are some forces even more powerful than Coke. Namely, a force of nature. Drought has caused rising corn prices and taken a bite out of Coke's bottom line. Rising costs held back the soft drink maker in its second quarter—though higher sales volume meant impressive revenue numbers—in a sign that higher costs are taking a bigger chunk out profits for major corporations."[22]

20 "Managing Supply in Volatile Agriculture Markets," AT Kearney, 2012, http://www.atkearney.com/documents/10192/666796/Managing+Supply+in+Volatile+Agriculture+Markets.pdf/60bef455-4e54-487a-811c-a3b55d264ac6

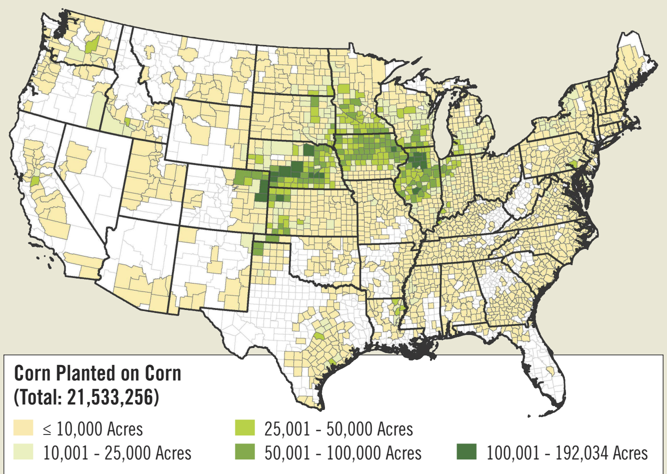
21 Matt Andrejczak, "Corn prices club meat producer shares," *MarketWatch*, 10 July 2012, http://www.marketwatch.com/story/corn-prices-club-meat-producer-shares-2012-07-10.

22 Jeff Reeves, "Coca-Cola can't shuck rising corn costs," *MSN Money*, 17 July 2012, http://money.msn.com/top-stocks/post.aspx?post=1bd0d68f-513e-4106-9dbf-da977147868d.

23 "Drought increases price of corn, reduces profits to ethanol producers," *U.S. Energy Information Administration*, 31 Aug 2012, http://www.eia.gov/todayinenergy/detail.cfm?id=7790.

High Corn Prices Have Contributed to Riskier Growing Practices

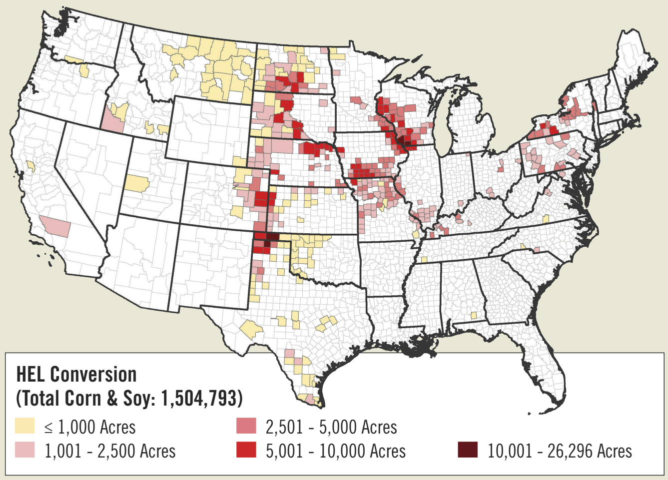
Exhibit 1A: Corn Planted in Continuous Rotation (2011 & 2012)



Corn planted on corn between the 2011 and 2012 crop years on fields that were greater than 10 acres.

Source: EWG using data from USDA's CropScape Cropland Data Layer and adapted methods used by Wright and Wimberly in "Recent land use change in the Western Corn Belt threatens grasslands and wetlands," *PNAS*, February 2013. Copyright © Environmental Working Group, www.ewg.org. Reprinted with permission.

Exhibit 1B: Highly Erodible Land Converted to Corn (2008-2012)



Highly erodible land (HEL) converted to corn production on fields greater than 10 acres within counties with wetland conversion of at least 2.5 percent and equal to or greater than 2,500 acres.

Source: EWG using data from USDA's CropScape Cropland Data Layer and adapted methods used by Wright and Wimberly in "Recent land use change in the Western Corn Belt threatens grasslands and wetlands," *PNAS*, February 2013. Copyright © Environmental Working Group, www.ewg.org. Reprinted with permission.

Crop rotation has been practiced for centuries, and corn-soybean rotation is common practice in the Midwest. There are a number of significant benefits to crop rotation, including improved soil quality, fewer pests, and consequently higher yields.[24] This practice has been in decline in recent years, however. In order to produce more corn and capitalize on higher prices, more farmers have employed "continuous cropping" (i.e. reduced crop rotation),[25] while also expanding corn acreage into erosion-prone and ecologically sensitive land.

In the United States, studies published over the last few years found that about a quarter of all corn acreage has been planted to corn for at least two consecutive years,[26] and that some farmers in the Corn Belt have been planting corn on the same parcel of land for as many as four consecutive years.[27, 28] In 2011 and 2012, 22 percent of total corn acres (approximately 21 million acres) were planted in continuous rotation[29] **(Exhibit 1A)**.

Participation in the federal Conservation Reserve Program (CRP), which pays farmers to remove environmentally sensitive land from production, has also declined as farmers capitalized on attractive crop prices. Between 2011 and 2013, the amount of land in the CRP fell from 31.2 million acres to 27 million acres nationwide.[30] In parallel, the acreage planted to corn has also expanded into highly erodible, ecologically sensitive land such as grassland and wetlands. Between 2008 and 2012, 5.3 million acres of highly erodible land[31] were converted to grow row crops, an estimated 26 percent of which was planted to corn and 13 percent to soybeans[32] **(Exhibit 1B)**. Comparable grassland conversion rates have not been seen in the Corn Belt since the Dust Bowl of the 1920s and '30s.[33]

24 Trenton Stanger and Joseph Lauer, "Corn Grain Yield Response to Crop Rotation and Nitrogen over 35 Years," *Agronomy Journal,* 100, issue 3 (2008), 643-650, http://corn.agronomy.wisc.edu/pubs/JL_JournalArticles/643.pdf.

25 James D. Plourde, Bryan C. Pijanowski, Burak K. Pekin, "Evidence for increased monoculture cropping in the Central United States," *Agriculture, Ecosystems and Environment,* 165 (2013), 50–59.

26 Stan Daberkow, James Payne, and James Schepers, "Comparing Continuous Corn and Corn-Soybean Cropping Systems," *Western Economic Forum*, Spring 2008.

27 Ibid.

28 Plourde et al, "Evidence for increased monoculture cropping in the Central United States."

29 A total 97.155 million acres were planted to corn in 2012. Source: USDA, National Agricultural Statistics Service Database (2012), http://quickstats.nass.usda.gov/.

30 Jonathan Knutson, "CRP Faces Challenges,"*AgWeek*, 29 Apr. 2014 http://www.agweek.com/event/article/id/20823/#sthash.vrA61H7g.dpuf.

31 Highly erodible land (HEL) is cropland, hayland or pasture that can erode at excessive rates; specifically, it contains soils that have an erodibility index of eight or more. See: USDA, Farm Service Agency and Natural Resources Conservation Service, *Fact Sheet: Highly Erodible Land Conservation and Wetland Conservation Compliance*, Apr. 2012.

32 Craig Cox and Soren Rundquist, "Going, Going, Gone! Millions of Acres of Wetlands and Fragile Land Go Under the Plow," *Environmental Working Group*, 23 Jul. 2013, http://static.ewg.org/pdf/going_gone_cropland_hotspots_final.pdf.

33 Christopher K. Wright and Michael C. Wimberly, "Recent land use change in the Western Corn Belt threatens grasslands and wetlands," Proceedings of the National Academy of Sciences of the United States of America, Jan. 2013, http://www.pnas.org/content/early/2013/02/13/1215404110.full.pdf+html.

Underlying Drivers of High and Volatile Corn Prices

Despite recent drops in corn prices, many of the underlying drivers for high and volatile corn prices remain in place. Demand-side factors such as rising global demand for corn, the influence of biofuels policy and commodity market speculation may increase prices and price volatility. Supply-side drivers include growth in agricultural productivity, generous crop insurance and other federal programs that promote corn production, and extreme weather events that impact yields. This latter point is of particular concern as extreme weather events linked to climate change such as droughts, heat waves, and floods increasingly influence commodity prices.[35] Other new factors shaping medium and long-term U.S. corn production capacity include growing levels of groundwater depletion and nutrient pollution.

The following tables explore demand and supply-side drivers of high and volatile corn prices in greater detail **(Exhibit 1.17)**.

Exhibit 1.17: Demand-Side & Supply-Side Drivers of Corn Prices & Price Volatility

Demand-Side Drivers of Corn Prices & Price Volatility	
Rising Global Population & Changing Consumption Patterns	The two largest drivers of rising demand for corn worldwide are population growth and changing consumption patterns as a result of economic growth and rising per capita incomes. As incomes rise, consumers in emerging markets increasingly move away from traditional staple foods, such as wheat and rice, and increase their consumption of vegetable oils, meat and dairy products (the latter of which require more corn in the form of livestock feed). As a result, the growth rates in average annual global consumption are projected to be higher for meats (2.2%) and coarse grains such as corn (1.5%) than for wheat (0.9%) and rice (1%) over the next decade.[36]
Rising Export Demand	In order to meet rising consumer demand, certain countries will increasingly rely on foreign imports over domestic production of corn. Major importers of corn over the next 10 years are projected to include China, Mexico and Japan, as well as South Korea, Egypt and the European Union.[37] The U.S. will likely continue to play an important role in meeting the rising global demand for corn. According to projections made by the USDA, the U.S. is expected to remain the largest corn exporter, representing between 35-40% of total global exports over the next 10 years.[38]
Ethanol Policy (the U.S. Renewable Fuel Standard)	The Renewable Fuel Standard (RFS) was signed into law under the Energy Policy Act of 2005 and was later expanded by the Energy Independence and Security Act of 2007. The law's original intent was to enhance U.S. energy security by replacing a portion of imported petroleum with domestically produced ethanol. In order to meet rising annual blending obligations (ethanol must be blended into motor-vehicle and other fuels), the production of corn ethanol has doubled since 2007, making the U.S. the largest producer of corn ethanol in the world.[39] As increasing amounts of corn are shifted away from food and feed production and toward ethanol production, the RFS may be driving up corn prices. There is growing pressure to modify or eliminate the RFS from diverse stakeholder groups concerned about corn prices and the environmental impacts of ethanol. In November 2013, the EPA proposed to reduce the total annual target for blending volumes by 16% to 15.2 billion gallons (this is the first time the EPA has adjusted the yearly target to a lower level).[40] Another response to the RFS is the recently proposed Feinstein/Coburn bill, *The Corn Ethanol Mandate Elimination Act of 2013*, which would remove corn ethanol as a part of the RFS.[41]

35 Noah Diffenbaugh, "Response of corn markets to climate volatility under alternative energy futures," *Nature Climate Change 2*, (2012), 514-518.

36 USDA, Economic Research Service, *Long-Term Prospects for Agriculture Reflect Growing Demand for Food, Fiber, and Fuel*, by Paul Westcott and Ronald Trostle, September 2012, http://www.ers.usda.gov/amber-waves/2012-september/long-term-prospects-for-agriculture.aspx#.Uyxn_a1dXd0.

37 USDA, Economic Research Service, *USDA Agricultural Projections to 2023*, by Paul Westcott and Ronald Trostle, OCE-141 (2014), http://www.usda.gov/oce/commodity/projections/USDA_Agricultural_Projections_to_2023.pdf.

38 Ibid.

39 Mari Hernandez and Matt Kasper, "An Overview of the Renewable Fuel Standard and Why It is Good for the Climate," *Center for American Progress*, 11 Dec. 2013, http://www.americanprogress.org/wp-content/uploads/2013/12/RenewabeFuelStandard.pdf.

40 Ibid.

41 "Feinstein, Coburn Intro Bipartisan Bill to Eliminate Corn Ethanol Mandate" Dianne Feinstein, United States Senator for California, 12 Dec. 2013, http://www.feinstein.senate.gov/public/index.cfm/press-releases?ID=82d3db11-efc7-421a-8c5d-0636b31ca9cd.

Demand-Side Drivers of Corn Prices & Price Volatility	
Commodities Speculation	The increased flow of speculative money into commodity markets has been cited as a potential contributor to higher corn prices and price volatility.[42] The amount of capital that has entered commodity markets in recent years is staggering: increasing from $13 billion in 2003 to a peak of $317 billion in 2008. Viewed another way, financial speculators accounted for 30% of commodities markets in 2002, and 70% in 2008.[43] The role of Wall Street speculation in driving up commodity prices is widely debated, with mixed academic evidence.[44]

Supply-Side Drivers of Corn Prices & Price Volatility	
Agricultural Productivity	The USDA projects that the long-term trends in crop yields due to improvements in technologies such as new seed hybrids and biotechnology, as well as improved growing practices (e.g. better pest and nutrient management and precision planting) will continue to support greater yields per acre.[45] While continued investment in agricultural R&D may potentially increase corn yields even with the added effects of climate change,[46] some have questioned the additional yield potential of biotech hybrids.[47]
Federal Crop Insurance	The Federal Crop Insurance Program (FCIP) protects farmers when they experience weather-related disasters by providing "catastrophic coverage" which indemnifies losses of 50% or more of a farm's productive value at no cost to farmers.[48] Farmers can expand their coverage, indemnifying up to 85% of their production value, by purchasing additional insurance through crop insurance companies.[49] In 2012, the FCIP covered 70% of the nation's total cropland and subsidized approximately 60% of each farmer's insurance premium.[50]
Federal Income Support Programs	While the latest Farm Bill removed the direct subsidy program, payouts from two income support programs—Price Loss Coverage (PLC) and Agricultural Risk Coverage (ARC)—may meet or surpass cost savings from the elimination of the direct subsidy program. Farmers may be more likely to plant crops that qualify for federal programs such as these, supporting increased corn production over time. The PLC program pays farmers when crop prices fall below floor (or reference) prices, which were set at historically high levels in the new Farm Bill. Based upon the "USDA Agricultural Projections to 2023," it has been estimated that there is a 40% chance that price loss payouts to corn farmers will be more than 150% higher than the direct payments.[51] The ARC program pays farmers if their revenue from crop sales drops below a benchmark level based upon average revenue of the previous 5 years. Similarly, based upon the USDA's projections, low prices may trigger large payouts as farm revenue falls from the record highs of 2008-2013.
Extreme Weather Events & Declining Water Availability	According to the US Global Climate Research Program (USGCRP), the increasing frequency of extreme weather events such as droughts, heat waves and floods due to climate change will continue to have a negative impact on U.S. agricultural production.[52] In addition to losses in crop and livestock productivity and the degradation of agricultural soil and water assets, extreme weather also increases stress from weeds, diseases and insect pests, affecting both production and post-harvest processing and storage.[53] Continued depletion of key groundwater sources like the High Plains aquifer will also impede long-term agricultural productivity if pumping is maintained at current rates.[54]

42 Luciano Gutierrez, "Speculative bubbles in agricultural commodity markets," *European Review of Agriculture*, 2013, 40 (2): 217-238 http://erae.oxfordjournals.org/content/40/2/217.short.

43 David Kocieniewski, "Academics Who Defend Wall St. Reap Reward," New York Times, 27 Dec. 2013, http://www.nytimes.com/2013/12/28/business/academics-who-defend-wall-st-reap-reward.html?_r=0.

44 Dwight R. Sanders and Scott H. Irwin, "A Speculative Bubble in Commodity Futures Prices? Cross-Sectional Evidence," *Agricultural Economics*, 41 (2010): 25-32, accessed May 6, 2014, doi: 10.1111/j.1574-0862.2009.00422.x.

45 USDA, Economic Research Service, *USDA Agricultural Projections to 2023*.

46 USDA, Economic Research Service, "Science, Technology, and Prospects for Growth in U.S. Corn Yields," by Paul Heisey, December 1, 2009, http://www.ers.usda.gov/amber-waves/2009-december/science,-technology,-and-prospects-for-growth-in-us-corn-yields.aspx#.UscutPZRaPs.

47 Doug Gurian-Sherman, "Failure to Yield, Evaluating the Performance of Genetically Engineered Crops," *Union of Concerned Scientists*, Apr. 2009, http://www.ucsusa.org/food_and_agriculture/our-failing-food-system/genetic-engineering/failure-to-yield.html.

48 Claire O'Connor, "Soil Matters: How the Federal Crop Insurance Program should be reformed to encourage low-risk farming methods with high-reward environmental outcomes" (blog), *Natural Resources Defense Council*, http://www.nrdc.org/water/soil-matters/.

49 Ibid.

50 USDA, Risk Management Agency Federal Crop Insurance Corp, *Summary of Business Report*, www3.rma.usda.gov/ apps/sob/current_week/sobrpt2010-2013.pdf.

51 Environmental Working Group (EWG), "Falling Crop Prices Mean Big Payouts," February 25, 2014, http://www.ewg.org/agmag/2014/02/falling-crop-prices-mean-big-payouts.

52 U.S. Global Change Research Program, *Climate Change Impacts in the United States: The Third National Climate Assessment*, Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014:, 841 pp. doi:10.7930/J0Z31WJ2, http://nca2014.globalchange.gov.

53 Ibid.

54 David Steward et al., "Tapping unsustainable groundwater stores for agricultural production in the High Plains Aquifer of Kansas, projections to 2110," *Proceedings of the National Academy of Sciences of the United States of America*, vol. 110 no. 37, (2013) http://www.pnas.org/content/110/37/E3477.full.

Extreme Weather & Climate Change

Chapter Summary:

- Weather risk is nothing new to agriculture, but the frequency and intensity of severe weather events have been increasing in the United States and around the world. As a result, companies dependent on U.S. corn production must contend with growing volatility of corn prices linked to extreme weather and climate change.
- Record-breaking weather events—including prolonged drought, intense precipitation and high temperatures—are increasingly common in the Corn Belt and are negatively impacting corn yields and corporate profits. The 2012-2013 drought exemplified the vulnerability of the U.S. corn supply chain to extreme weather. The record drought decreased corn supply in a year of high demand, reducing the profitability of many companies, driving up costs for meat and dairy production, as well as for ethanol refining.
- According to the latest National Climate Assessment, the negative effects of climate change on agricultural productivity in the Midwest and Great Plains will outweigh any positive effects. Corn plants are particularly sensitive to high temperatures (which can reduce pollination and grain count) as well to drought. Also, recent evidence suggests that corn hybrids have become more sensitive to drought over the past two decades. Higher temperatures and increased water stress mean that increased irrigation for corn will be required. Given limited water availability in parts of the Great Plains region, a northward shift in corn acreage is predicted, increasing the risk of stranded agricultural assets such as processing, storage and transportation infrastructure.
- According to the "slow-warming scenario" of a recent study, climate change could cause corn and soybean yields in the United States to decline between 18-23 percent from 2020-2049, and an additional 38-40 percent from 2070 to 2099. Under the "fast-warming scenario," corn and soybean yields are projected to decline 22-30 percent from 2020 to 2049, and 75-85 percent from 2070 to 2099.
- Farmers, who can reduce their vulnerability to extreme weather through practical, well-documented farm practices like conservation tillage and cover-cropping, face limited incentives to do so from the government's Federal Crop Insurance Program (FCIP), which paid out a record $10.8 billion to corn growers for claims largely linked to severe drought in 2012. The FCIP, although providing an essential safety net for farmers, sets premium formulas that encourage riskier decisions such as expanding production onto marginal land and planting corn on the same plot year after year.

The frequency and intensity of extreme weather events are increasing.

Farmers have always grappled with adverse weather conditions. However, weather patterns are becoming less predictable due to climate change. In addition to an overall trend toward warmer average temperatures, extreme weather events such as heat waves, droughts, heavy precipitation and floods have become more frequent and intense.[1]

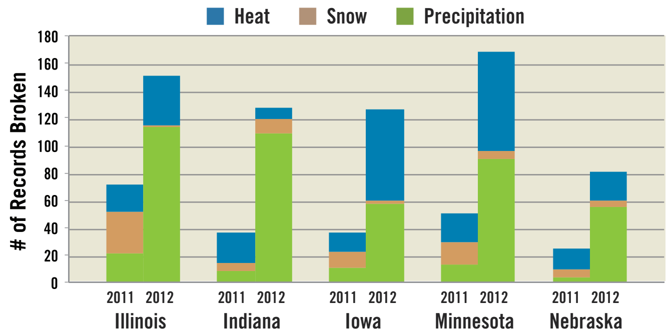
A significant number of record-breaking weather events have been observed in the Corn Belt.

Data from the National Climatic Data Center illustrates the large number of weather records broken[2] in 2011 and 2012 in top corn-growing states, including new records for maximum temperature, drought, and precipitation **(Exhibit 2.1)**. In 2012, 168 record-breaking events were recorded in Minnesota, the nation's fourth largest corn-producing state. Some of the newly broken records previously stood for 30 years or more.

Insured losses for U.S. corn production due to extreme weather have grown in recent years.

Since the late 1980s, U.S. farmers have claimed approximately $97 billion in losses associated with crop failure insured under the Federal Crop Insurance Program (FCIP). While the formula for covering losses has varied over time, the average value going to corn farmers relative to farmers of other federally-insured crops has steadily increased from the 1990s to present day **(Exhibit 2.2)**.

Exhibit 2.1: Weather Records Broken in Top 5 Corn-Producing States (2011 & 2012)



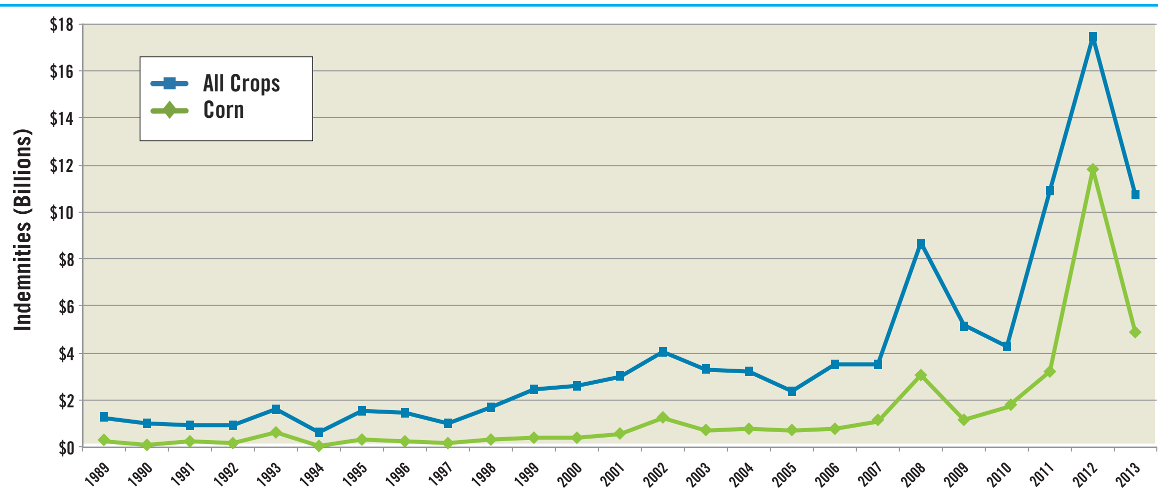
Source: Data from "Extreme Weather Map 2012," Natural Resources Defense Council.

At its peak in 2012, indemnities for corn due solely to weather-related losses totaled about $10.8 billion, or 68 percent of total indemnified crop losses.[3]

Recent drought disrupted corn supply and negatively affected operations of many companies in the corn value chain.

The 2012-2013 drought had unusually severe financial impacts for many companies in the U.S. corn value chain, hitting the meat and grain trading sectors particularly hard. Impacts ranged from interruption in corn supply, which affected meat processing and ethanol refining activities, to operational challenges linked to insufficient water for manufacturing facilities to low Mississippi River levels that restrict transport of agricultural goods **(Exhibit 2.3)**.

Exhibit 2.2: Insured Losses for Corn vs. Insured Losses for All Crops, 1989-2013 Federal Crop Insurance Program (All Causes)



Source: USDA, Risk Management Agency, Summary of Business Reports and Data Database: National Summary by Crop, (1989-2013).

1 Jerry M. Melillo, Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2, http://nca2014.globalchange.gov.

2 "Record-breaking" was defined as exceeding the monthly maximum for each of 3 major event types (heat, rain, snow) over the past 30 years; or for events that broke other standing records related to fire, drought, and flooding over the course of 2012. "Extreme Weather Map 2012," *Natural Resources Defense Council*, http://www.nrdc.org/health/extremeweather/.

3 Calculated with data sourced from: USDA, Risk Management Agency, Summary of Business Reports and Data: National Summary by Crop, (1989-2013).

Exhibit 2.3: Impacts of 2012-2013 Drought on Companies in the Corn Value Chain

January 2013

"Cargill to idle Plainview, Texas, beef processing plant; dwindling cattle supply cited"

Cargill shuts down a beef processing facility with 2,000 employees because prolonged drought conditions reduced feed supply, leading to a large reduction of the local beef herd.[4]

January 2013

"Poet blames drought for Missouri ethanol plant shutdown"

Biofuels producer Poet forced to shutdown 3,000 barrels per day ethanol facility in Macon, Missouri because of a lack of corn supply due to drought.[5]

March 2013

"Decatur OKs deal with ADM to lessen strain on water supply"

To avoid a repeat of nearly losing access to water for its processing plants during a recent drought, ADM reached an agreement with the city of Decatur to construct two large wells as back-up supplies. The company also agreed to pay the city $2.5 million for developing alternate water supplies.[6]

October 2012

"Mosaic profits drop amid drought, weak phosphate sales"

Fertilizer producer Mosaic saw profits drop 18% due to dry weather. The drought caused a poor corn harvest, lowering demand for fertilizer. It also reduced water levels on the Mississippi River, which delayed shipment and increased transportation costs.[7]

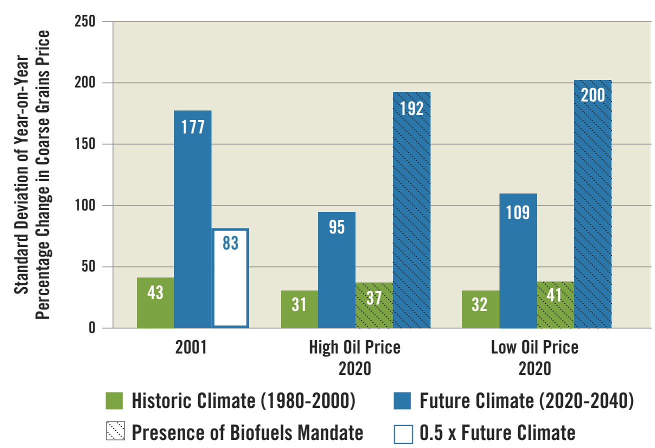
The growing frequency of extreme weather events is projected to increase corn price volatility.

The increasing frequency of extreme weather events can decrease yield and also increase yield volatility, which in turn spur higher corn prices and daily corn price volatility. One recent study projects that due to climate change, U.S. corn price volatility may be significantly higher in the 2020-2040 period compared to the 1980-2000 period.[8] This effect is magnified by the U.S. Renewable Fuels Standard, which creates an inelastic demand in the market and enhances the sensitivity of corn price volatility to climate change by more than 50 percent **(Exhibit 2.4)**.

Climate change will negatively impact agricultural productivity in the Midwest and Great Plains.

Most U.S. corn production is centered in the agricultural heartland of the Midwest and Great Plains regions. Under most climate models, rising greenhouse gas emissions are predicted to have overall negative effects on agricultural productivity in these regions.[9] **Exhibit 2.5** summarizes the current and projected impacts of climate change across all crop types in these regions, according to the most recent National Climate Assessment.

Exhibit 2.4: Corn Price Volatility Under Alternative Climate Change, Policy & Economic Scenarios



Standard deviation of year-on-year percentage change in U.S. corn prices under alternative climate, policy and economic scenarios. Each bar shows the standard deviation of U.S. corn prices in the historic (green) and future (blue) climate, in the presence (hashed) or absence (solid) of the biofuels mandate and high (US$169 per barrel) or low (US$53 per barrel) oil price.

Source: Adapted from Diffenbaugh et al, "Response of corn markets to climate volatility under alternative energy futures," *Nature Climate Change*, 2012.

4 "Cargill to idle Plainview, Texas, beef processing plant; dwindling cattle supply cited," Cargill Inc., press release, on the Cargill Inc. website, January 17, 2013, http://www.cargill.com/news/releases/2013/NA3070552.jsp.

5 "Poet blames drought for Missouri ethanol plant shutdown," Argus News, January 25, 2013, http://www.argusmedia.com/News/Article?id=832051.

6 Allison Petty, "Decatur OKs deal with ADM to lessen strain on water supply," Herald-Review.com, 5 March 2013, http://herald-review.com/news/local/decatur-oks-deal-with-adm-to-lessen-strain-on-water/article_0ae928a4-854e-11e2-8c9f-0019bb2963f4.html.

7 Paul Waldie, "Mosaic profits drop amid drought, weak phosphate sales," The Globe and Mail, 2 Oct. 2012, http://www.theglobeandmail.com/globe-investor/mosaic-profits-drop-amid-drought-weak-phosphate-sales/article4581766/.

8 Noah Diffenbaugh, "Response of corn markets to climate volatility under alternative energy futures," Nature Climate Change 2, (2012), 514-518.

9 Hatfield et al, *Climate Change Impacts in the United States: The Third National Climate Assessment*, Ch. 6: Agriculture.

Exhibit 2.5: Climate Change Impacts in the Great Plains and Midwest

Great Plains Region: Kansas, Montana, Nebraska, North Dakota, Oklahoma, South Dakota, Texas, Wyoming

Agriculture in the Region	Past/Current Climate in the Region	Projected Climate Changes Level of Confidence: ● (red) Very High ● (orange) High	Projected Impacts on Agriculture ▲ Positive ▼ Negative
• More than 80% of the land is used for agriculture, including cropland, pastureland, and rangeland • 26% of U.S. corn is produced in the region[14] • U.S. corn grain production in the region is valued at $16.3 billion[15] • Nebraska and South Dakota are the 3rd and 5th largest producers of biofuels • The High Plains aquifer (which includes the Ogallala) is the primary source of irrigation	• Highly diverse climate due to large North-South range as well as large changes in elevation • The Northern Plains tend to be cooler and wetter than the Southern Plains • The region experiences a wide range of weather events including floods, droughts, severe storms, tornados, hurricanes, and winter storms • Between 2011-2013, 21 billion-dollar weather events affected the Great Plains region[16]	**Temperature Effects:** ● (red) Increased frequency and intensity of heat waves ● (orange) More frequent higher maximum temperatures in N. and S. Plains ● (orange) More frequent higher minimum temperatures in N. and S. Plains ● (orange) Warmer and longer winters **Precipitation Effects:** ● (red) Increased frequency and intensity of drought ● (orange) Increased precipitation in the N. Plains (and days with little or no precipitation will be less common in the N. Plains) ● (orange) Decreased precipitation in the S. Plains (and days with no precipitation will be more common in the S. Plains) ● (orange) Increased number of days with heavy precipitation, especially in the N. Plains	**Overall:** • The negative impacts are expected to outweigh the positive effects of climate change • Combined temperature and precipitation impacts of increased snowfall and more rapid spring warming and intense rainfall will increase devastating flooding • An overall northward shift in crop and livestock production **Temperature Impacts:** ▼ Increase in evaporation/surface water loss ▼ Increase in heat stress days ▲ Rising temperatures lengthens the growing season,[17] enabling a second annual crop in some areas ▼ Decreased surface and groundwater supplies (and increased vulnerability to water shortages) ▼ Increase in "overwintering" insect populations; some pests and weeds able to survive warmer winters ▼ Increased drought frequency and intensity transforms marginal lands into deserts **Precipitation Impacts:** ▲ In the N. Plains, increased water availability and reduced dependence on irrigation ▼ Increased run-off and flooding will increase nutrient run-off, decrease water quality, and erode soils ▼ In the S. Plains, increased irrigation demand will increase withdrawals from High Plains aquifer and accelerate its depletion[18] ▼ Decreased water resources leads to greater competition for water between agricultural, municipal, and industrial uses

Sources: All data from *Climate Change Impacts in the United States: The Third National Climate Assessment*, Chapters 18 and 19, May 2014, unless otherwise noted.

14 USDA, National Agricultural Statistics Service Database (2013), http://quickstats.nass.usda.gov/.

15 Ibid.

16 "Billion-Dollar Weather/Climate Disasters: Billion Dollar Events," *National Climatic Data Center.*

17 The growing season is projected to extend by an average of 24 days by mid-century, relative to the 1971-2000 average (p.444). Shafer, M., D. Ojima, J. M. Antle, D. Kluck, R. A. McPherson, S. Petersen, B. Scanlon, and K. Sherman, 2014: Ch. 19: Great Plains. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 441-461. doi:10.7930/J0D798BC, http://nca2014.globalchange.gov/report/regions/great-plains.

18 "Holding other aspects of production constant, the climate impacts of shifting from irrigated to dryland agriculture would reduce crop yields by about a factor of two." Ibid. (p.447)

Midwest Region: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, Wisconsin

Agriculture in the Region	Past/Current Climate in the Region	Projected Climate Changes Level of Confidence: ● Very High ● High	Projected Impacts on Agriculture ▲ Positive ▼ Negative
• More than two-thirds of the land is used for agriculture • 61% of U.S. corn is produced in the region[10] • U.S. corn production in the region is valued at $37.9 billion[11] • Most agricultural production is rainfed, although the Great Lakes are also a major source of water in the region	• Average annual temperatures have risen by 1.5ºF from 1895-2012 • The growing season has been lengthened by almost 2 weeks since 1950 due to earlier occurrence of the last spring freeze • Precipitation is greatest in the east, declining toward the west.[12] Annual precipitation has increased over the past century, mostly driven by intensification of the heaviest precipitation events • Between 2011-2013, 20 billion-dollar weather events affected the Midwest[13]	**Temperature Effects:** ● (Very High) Increased occurrence of higher temperatures during early spring ● (Very High) Increased occurrence of cold air outbreaks during the spring ● (High) Warmer and longer winters ● (High) Increased frequency and intensity of heat waves **Precipitation Effects:** ● (High) Increase in total annual amount of precipitation from rainfall and snowfall ● (High) Increasing intensity and frequency of extreme precipitation events ● (High) Increase in average number of days without precipitation ● (High) Increased frequency and intensity of drought	**Overall:** • The negative impacts are expected to outweigh the positive effects of climate change • Extreme weather events will have greater (negative) influence on future crop yields than changes in average temperature or annual precipitation • Combined temperature and precipitation impacts of increased snowfall and more rapid spring warming and intense rainfall will increase devastating flooding **Temperature Impacts:** ▼ Increase in heat stress days ▲ Rising temperatures lengthens the growing season and increases yields ▼ Small but long-term increases in average temperature shortens the reproductive development period of corn, contributing to yield declines (even when offset by increased CO_2 fertilization) ▼ Heat waves during pollination of corn and soybeans decrease yields ▼ Increase in "overwintering" insect populations; some pests and weeds able to survive warmer winters **Precipitation Impacts:** ▼ Wetter springs reduce yields if farmers switch to late-planted, shorter season varieties ▼ Increased run-off and flooding will increase nutrient run-off, decrease water quality, and erode soils

Sources: All data from *Climate Change Impacts in the United States: The Third National Climate Assessment*, Chapters 18 and 19, May 2014, unless otherwise noted.

10 2013 corn production statistics: Source: USDA, National Agricultural Statistics Service Database (2013), http://quickstats.nass.usda.gov/.

11 2013 value of production (for corn grain) statistics: Source: USDA, National Agricultural Statistics Service Database (2013), http://quickstats.nass.usda.gov/.

12 "Precipitation occurs about once every seven days in the western part of the region and once every three days in the southeastern part. The 10 rainiest days can contribute as much as 40% of total precipitation in a given year." (p. 424) Pryor, S. C., D. Scavia, C. Downer, M. Gaden, L. Iverson, R. Nordstrom, J. Patz, and G. P. Robertson, 2014: Ch. 18: Mid- west. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 418-440. doi:10.7930/J0J1012N, http://nca2014.globalchange.gov/report/regions/midwest.

13 "Billion-Dollar Weather/Climate Disasters: Billion Dollar Events," National Climatic Data Center, http://www.ncdc.noaa.gov/billions/events.

Drought and extreme heat negatively impact corn production by increasing plant stress and reducing yield.

Sustained heat waves and drought adversely affect corn production in several ways. High temperatures increase the stress on a plant, preventing it from absorbing water and nutrients effectively. Heat and drought events can be particularly damaging if they strike during vulnerable periods in the crop's lifecycle, such as corn's pollination period.[19]

While corn is particularly sensitive to high temperatures, the predominant effect of heat on corn is driven by increased water stress. With more hot days (above 86°F/30°C), the corn plant simultaneously increases its demand for soil water and also loses more water via transpiration. This reduces the future supply of soil water and creates the risk of even more drought stress later in the season.[20] Recent evidence also suggests that corn hybrids grown in rainfed regions, which tend to be densely planted, have become more sensitive to drought over the past two decades.[21]

Furthermore, exposure to extreme heat during key growth phases such as the reproductive period can severely damage corn production by reducing grain number and ultimately final yields, or in extreme cases, leading to crop failure.[22] From 1980 to 2011, corn had the greatest percentage (15 percent) of harvested acreage globally exposed to above-optimal temperatures for at least five reproductive days compared to other major crops. This number is projected to increase to 31 percent by the 2030s and 44 percent by the 2050s, worldwide.[23]

According to the "slow-warming scenario" of a recent study, climate change could cause corn and soybean yields in the United States to decline between 18-23 percent from 2020-2049, and an additional 38-40 percent from 2070 to 2099.[24] However, under the "fast-warming scenario," corn and soybean yields were projected to decline 22-30 percent from 2020 to 2049, and 75-85 percent from 2070 to 2099. The largest driver behind these reductions in yield was the projected increase in temperatures.[25]

Increased drought and extreme heat are linked to projected increases in irrigation demand for corn.

When assessing the impact of climate change on corn ethanol production specifically, one study found that by the 2050s, higher average temperatures may reduce the yield of corn grown for ethanol by an average of seven percent while increasing the amount of irrigation necessary by nine percent.[28] And in the Midwest, where corn production is primarily fed by rainfall, corn will be subjected to more intense but less frequent precipitation, especially during the summer.[29] According to researchers, maintaining crop production in the Corn Belt will therefore require a 5-25 percent increase in irrigation. The transition from rainfed to irrigated corn production would be expensive due to the need for additional infrastructure, and would also contribute to existing stress on surface and groundwater sources.[30]

Drought-Resistant Corn Hybrids

Water shortages and high temperatures trigger different physiological responses in corn plants, and can also compound each other's effects.[26] Certain characteristics or traits that increase a corn plant's tolerance to drought have been developed using both traditional breeding and biotechnologies. In general, drought-tolerant breeds are designed to help the plant retain moisture longer before it perishes, and therefore withstand longer dry spells. Drought-tolerant corn is not engineered to require less water to grow than non-drought-tolerant corn; it can simply wait longer to receive the water it needs.

Specifically, drought-tolerant hybrids may have smaller stomata on their leaves to reduce the amount of water lost to evapotranspiration, deeper root systems, leaves that better shade the soil, and the ability to promote kernel development or combat pests despite lack of water.[27] Drought-tolerant corn hybrids may also be targeted toward drought that occurs in the early versus late stage of corn growth, or designed for droughts of different severities.

Currently, there are three leading drought-tolerant corn hybrids in the U.S., created by Syngenta (the first to release drought-tolerant corn), DuPont Pioneer, and Monsanto, but all currently have limited levels of uptake by farmers.

19 Hatfield et al, *Climate Change Impacts in the United States: The Third National Climate Assessment*, Ch. 6: Agriculture.

20 Lobell et al. also note, "effects of elevated CO2 on transpiration efficiency should reduce yield sensitivity to extreme degree days (EDD) [greater than 86°F/30°C] in the coming decades, but at most by 25%." David B. Lobell et al., "The critical role of extreme heat for maize production in the United States," *Nature Climate Change 3*, (3 Mar 2013) 497–501.

21 Lobell et al., "Greater Sensitivity to Drought Accompanies Maize Yield Increase in the U.S. Midwest," Science 344, no. 6183 (2 May 2014), 516-519.

22 Sharon M. Gourdji et al., "Global crop exposure to critical high temperatures in the reproductive period: historical trends and future projections," *IOP Science*, (30 May 2013).

23 Ibid.

24 These projections hold growing areas constant and do not account for CO2 fertilization, which may increase yields.

25 Michael J. Roberts and Wolfram Schlenker, "Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change," *Proceedings of the National Academy of Sciences*, August 2009

26 Terry Stecker and ClimateWire, "Drought-Tolerant Corn Efforts Show Positive Early Results" *Scientific American*, 27 Jul 2012 http://www.scientificamerican.com/article/drought-tolerant-corn-trials-show-positive-early-results/.

27 Ibid.

28 Rosa Dominguez-Faus et al., "Climate Change Would Increase the Water Intensity of Irrigated Corn Ethanol," *Environmental Science & Technology*, (23 May 2013).

29 Ibid.

30 Ibid.

Extreme precipitation and flooding negatively impact corn production by degrading soil quality and increasing erosion.

The Midwest has seen a 37 percent increase in the heaviest precipitation events between 1958 and 2012, increasing the risk of dangerous flooding.[31] The rising frequency of flooding degrades agricultural soil and water assets, directly affecting immediate yields as well as degrading long-term agricultural productivity. Flooding during the growing season causes crop losses due to low oxygen levels in the soil, increased susceptibility to root diseases, and higher soil compaction from the use of heavy farming equipment on wet soils.[32] Increased precipitation and heavy rainfall also contribute to soil erosion, heightening the potential for run-off of sediments, nutrients and pesticides into waterways.[33]

Farmland is particularly susceptible to erosion during the spring when there is the least groundcover, and climate models suggest that the Midwest will receive more precipitation during future spring seasons.[34] Increased precipitation during the spring also makes farmers less likely to implement soil protection measures. Wetter springs limit the number of days a farmer can work in the fields and influences them to plant/seed when soils are more vulnerable to compaction.[35]

Extreme precipitation and flooding events are very costly. The severe flooding events that took place in both the upper and lower Mississippi River Basin in spring 2011 were among the largest and most damaging recorded along this waterway in the past century, imposing $5 billion in

Federal Crop Insurance Program Leaves Growers Unprepared for Climate Change

The Federal Crop Insurance Program (FCIP) provides an essential safeguard to farmers, protecting them when weather events reduce farm productivity. In 2012, this federal government program covered 70 percent of the nation's total cropland and subsidized approximately 60 percent of each farmer's insurance premium.[36] The FCIP fully subsidizes "catastrophic coverage," which indemnifies losses of 50 percent or more of a farm's productive value, and farmers may "buy up" beyond catastrophic coverage, indemnifying a maximum of 85 percent of their production value.[37]

In 2011, the FCIP paid out a record-breaking $10.9 billion in crop insurance claims to farmers, largely as a result of floods in the Upper Mississippi River Basin. In 2012 it broke that record again by paying out $17.4 billion in claims, 75 percent of which were linked to severe drought. The FCIP premium formulas have been criticized for not doing more to reward growers that use farming practices that improve their resilience to climate change, which could also reduce taxpayer burden.[38] Experts have suggested that the FCIP should be adjusted by charging lower premiums to farmers that implement well-established practices that help protect crops against drought and floods such as conservation tillage and cover-cropping.[39]

The new 2014 Farm Bill replaced direct subsidies with an expanded FCIP as the key component of the federal safety net for farmers. The new FCIP program requires all farmers that purchase crop insurance to be in compliance with conservation provisions for highly erodible lands and wetlands beginning in 2015 (requirements that had previously been associated with the direct payments program that has been ended).[40, 41] However, premium structures and payouts remain unlinked to other farming practices that reduce grower exposure to weather-related losses.

31 Melillo et al, *Climate Change Impacts in the United States: The Third National Climate Assessment*.

32 U.S. Global Change Research Program, *Global Climate Change Impacts in the United States*, by Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.), Cambridge University Press, (June 2009) 71-78.

33 J. Hatfield, 2012, "Agriculture in the Midwest, In U.S. National Climate Assessment Midwest Technical Input Report," J. Winkler, J. Andresen, J. Hatfield, D. Bidwell, and D. Brown, coordinators. Available from the Great Lakes Integrated Sciences and Assessments Center, http://glisa.umich.edu/media/files/NCA/MTIT_Agriculture.pdf.

34 J. Hatfield, R. Cruse, M. Tomer, "Convergence of Agricultural Intensification and Climate Change in the Midwestern United States: Implications for Soil and Water Conservation," *Marine and Freshwater Research,* 64 (2013), 423-435 http://www.publish.csiro.au/paper/MF12164.htm.

35 Ibid.

46 USDA, Risk Management Agency Federal Crop Insurance Corp., *Summary of Business Report*, www3.rma.usda.gov/ apps/sob/current_week/sobrpt2010-2013.pdf.

37 Claire O'Connor, "Soil Matters: How the Federal Crop Insurance Program should be reformed to encourage low-risk farming methods with high-reward environmental outcomes," August 2013, *Natural Resources Defense Council*, http://www.nrdc.org/water/soil-matters/files/soil-matters-IP.pdf.

38 Ibid.

39 Ibid.

40 Gary Schnitkey, "2014 Crop Insurance Decisions: The 2014 Farm Bill and 2014 Product Recommendations," *FarmDoc Daily*, http://farmdocdaily.illinois.edu/2014/02/2014-crop-insurance-decisions-2014-farm-bill-product-recommendations.html.

41 Jen McPhillips, "Five-Year Farm Bill Heads to the President's Desk," *IA Magazine*, 6 Feb. 2014, http://www.iamagazine.com/news/read/2014/02/06/five-year-farm-bill-heads-to-the-president-s-desk.

damages on affected areas.[42] Over 50 percent of corn is grown in the upper Mississippi River Basin, most of which functions as an important flood plain. Agriculture has been encroaching on the wetlands and flood plains that surround the Mississippi River, and the eight states of the Upper Basin have lost an estimated 35 million acres of wetlands, an area the size of Illinois.[43] This wetland loss exacerbates the region's vulnerability to destructive floods caused by intense precipitation events and fast snowmelt.

The presence of weeds, diseases and insect pests affecting corn production may increase.

Increased stress from weeds, diseases and insect pests will cause declines in both crop and livestock production, and will also have consequences for post-harvest processing and storage. Rising CO_2 levels and warmer climates create an environment in which weeds thrive, and the use or herbicides (as well as herbicide costs) are expected to rise,[44] increasing the risk for the development of herbicide-resistant weeds. Warmer temperatures and higher humidity also help diseases and insects flourish, negatively impacting both production yield as well as post-harvest stores. Finally, earlier spring and warmer winter conditions can increase the survival and proliferation of disease-causing agents and insect pests.[45]

U.S. corn production will likely shift northward, potentially stranding agricultural assets.

The combined effects of the changing climate patterns will shift corn and soybean production northward into traditionally wheat-producing areas.[46] As cropping patterns shift, some agricultural processing, storage, and transportation assets will likely become stranded, meaning that they may be pre-maturely written-off or converted to liabilities. Although a detailed analysis of potential stranded assets in the Corn Belt has not been conducted, an analysis of climate change and other environmental factors facing agriculture globally by Oxford University identified a potential value at risk as high as $11.2 trillion.[47]

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42 "Billion-Dollar Weather/Climate Disasters: Billion Dollar Events," *National Climatic Data Center*.

43 Sandra Postel, "Mississippi floods can be restrained with natural defenses" (blog) *National Geographic: Water Currents,* 3 May 2011 http://newswatch.nationalgeographic.com/2011/05/03/mississippi-floods-can-be-restrained-with-natural-defenses/#comments.

44 Hatfield et al, *Climate Change Impacts in the United States: The Third National Climate Assessment*, Ch. 6: Agriculture.

45 Ibid.

46 Roberts and Schlenker, "The Evolution of Heat Tolerance of Corn: Implications for Climate Change."

47 Ben Caldecott, Nicholas Howarth, and Patrick McSharry, "Sustainable Assets in Agriculture: Protecting Value from Environment-Related Risks," *Smith School of Enterprise and the Environment* http://www.smithschool.ox.ac.uk/research/stranded-assets/Stranded%20Assets%20Agriculture%20Report%20Final.pdf.

Irrigation Demand & Water Stress

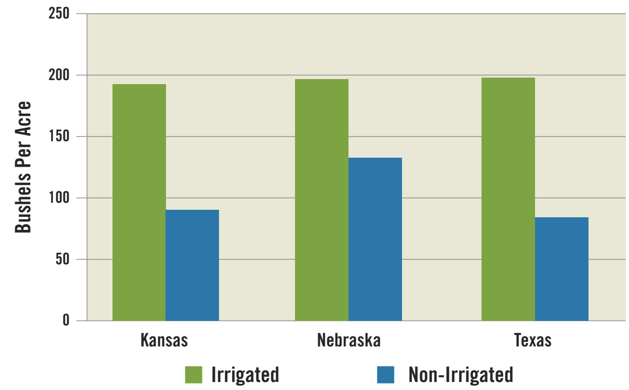
Chapter Summary

- There is a fundamental mismatch between irrigation demand for corn production and long-term sustainable supply of water in many of the crop's key growing regions. This imbalance has been driven by expansion of corn acreage in areas of traditional dryland farming coupled with chronic over-extraction of groundwater, particularly in the High Plains aquifer.
- Corn is a thirsty plant, and receives the most irrigation water of any American crop: 15.4 million acre-feet annually, or the equivalent of 7.6 million Olympic-sized swimming pools. While the amount of water needed to produce one bushel of corn has decreased in recent years, total water demand for corn has grown, largely in areas of high water stress and groundwater depletion.
- There are significant opportunities to further improve water efficiency in corn production. Twenty-two percent of irrigated corn acres still employ inefficient flood or furrow irrigation methods, and only a handful of irrigated corn farms (0.1 percent) use highly efficient sub-surface drip technologies. What's more, many farming practices that help retain soil moisture and reduce irrigation demand—such as no-till, extended crop rotations, and cover-cropping—are not yet widely adopted.
- Over half of the country's irrigated corn production—worth nearly $9 billion annually—depends on groundwater from the over-exploited High Plains aquifer. In western Kansas, more than 30 percent of the aquifer's total volume has already been withdrawn, with another 39 percent projected to be pumped over the next 50 years.
- This report finds that $2.5 billion-worth of corn grain is grown in 20 counties over parts of the High Plains aquifer where water levels are rapidly declining. Of these, five counties have over $150 million each in annual corn grain production at risk from groundwater depletion: Yuma County in Colorado and York, Hamilton, Adams and Filmore counties in Nebraska.
- The ethanol sector purchases over one-third of all U.S. corn. Ceres' analysis identifies 12 ethanol refineries with nearly $1.7 billion in annual ethanol production capacity that are located in and sourcing corn from regions of the High Plains aquifer where water levels are declining.

Although only 15 percent of U.S. corn acres are irrigated, these acres are highly productive.

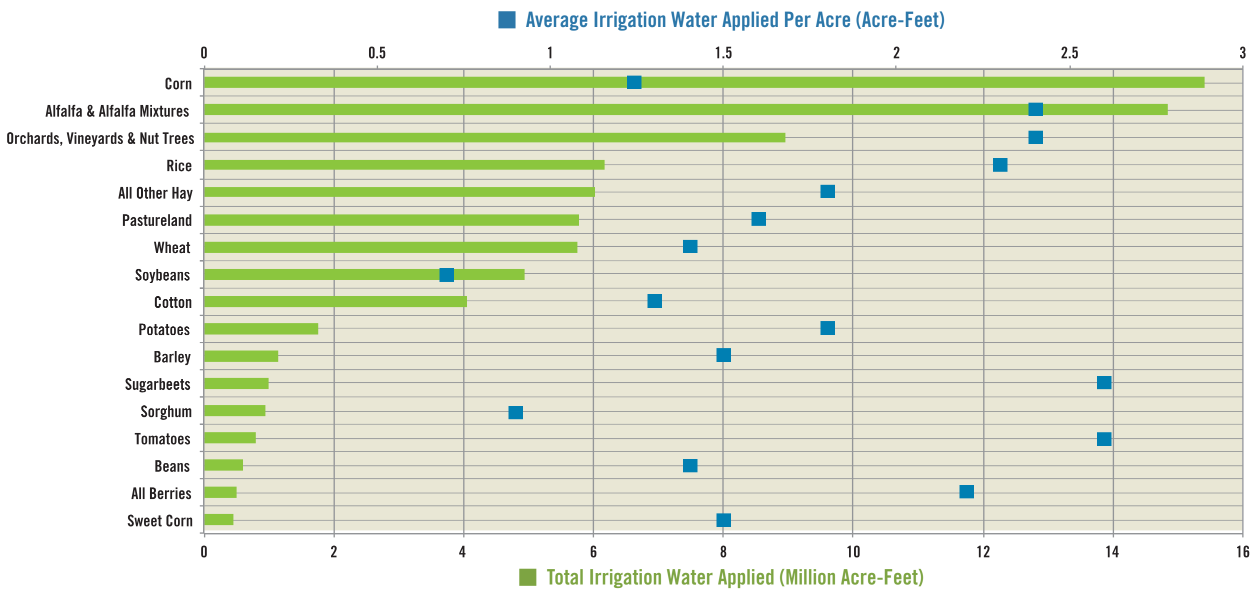
Irrigated production accounts for about 21 percent[1] of all corn bushels harvested. Yields for irrigated corn are higher than rainfed corn, with irrigated acres producing on average 25 percent more bushels than rainfed acres across the U.S.[2, 3] While rainfed corn production is centered in the Midwest, the majority of irrigated corn production takes place in the relatively arid Great Plains states of Nebraska, Kansas, and Texas.[4, 5] Within these states, irrigated grain corn acres are on average of 93 percent more productive than their dryland counterparts **(Exhibit 3.1)**.

Exhibit 3.1: Yields for Irrigated vs. Rainfed Corn Grain Acres, Select States (2013)



Source: USDA, National Agricultural Statistics Service Database

Exhibit 3.2: Total Irrigation Water Applied & Per Acre Water Use, Multiple Crops Among Harvested Acres (2008)



Source: USDA *Census of Agriculture, 2008: Farm and Ranch Irrigation Survey*

Corn uses more water for irrigation than any other U.S. crop.

Despite the relatively small fraction of corn production that is irrigated, corn uses the most irrigation water of all U.S. crops, consuming a total of 15.4 million acre-feet in 2008,[6] or 17 percent of all water used in the country for agricultural irrigation **(Exhibit 3.2)**. On a per acre basis, however, corn production is relatively water-efficient compared to crops such as rice and alfalfa, with corn farmers applying on average 1.2 acre-feet of water per acre in 2008 for corn grain and silage production combined.[7]

1 Calculated from USDA 2012 Census data. Total irrigated corn production was estimated by the product of irrigated yields for corn (grain and silage) and the total irrigated acres harvested for corn (grain and silage).

2 Irrigated corn for grain and corn for silage yield 25 percent and 64 percent more bushels on average respectively. Source: USDA, National Agricultural Statistics Service Database (2012), http://quickstats.nass.usda.gov/.

3 Calculated from USDA, 2007 Census data, http://quickstats.nass.usda.gov/.

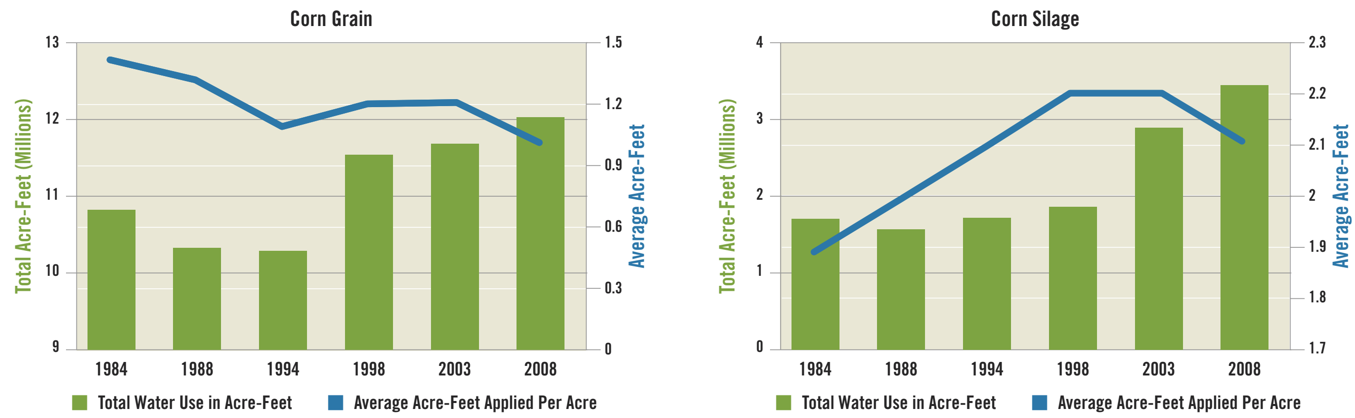
4 Ibid.

5 The top 10 states producing irrigated corn are Nebraska, Kansas, Texas, Colorado, California, Arkansas, Missouri, Mississippi, Illinois and Louisiana. Source: USDA, National Agricultural Statistics Service Database (2013), http://quickstats.nass.usda.gov/.

6 Corn grain production required 11,991,515 acre-feet of water, and corn silage production required 3,430,434 acre-feet. Source: USDA, 2008 Farm and Ranch Irrigation Survey.

7 On average, corn grain production received one acre-feet of water per acre, versus 2.1 acre-feet per acre for silage. Although corn silage is typically harvested earlier in the growing season than corn grain, and thus tends to receive less irrigation compared to corn grain grown in the same region, a significant proportion of corn silage is grown in extremely arid regions that require additional irrigation such as California, typically in association with significant dairy production. Source: USDA, 2008 Farm and Ranch Irrigation Survey.

Exhibit 3.3: Total & Average Irrigated Water Use for Corn Grain and Silage (1984-2008)



Source: *USDA Census of Agriculture*, 2008: *Farm and Ranch Irrigation Survey*

The total volume of water used for irrigating corn has increased over time.

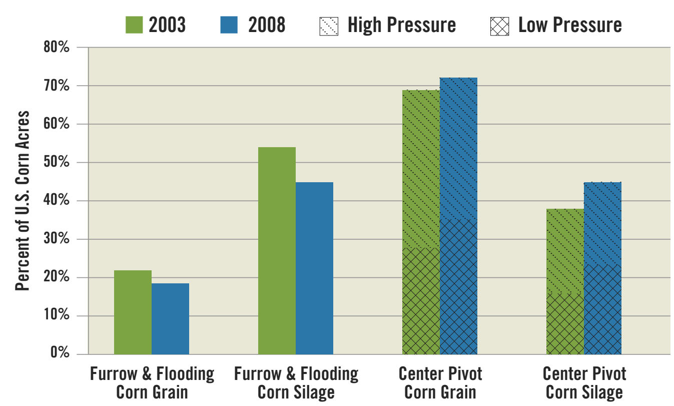
The absolute volume of irrigation water applied to corn has been rising over the past 20 years, in line with overall expansion of corn acres.[8] Between 1984 and 2008, the volume of irrigation water applied to corn grain increased by 11 percent to 11.9 million acre-feet, and the volume applied to silage increased by 97 percent to 3.4 million acre-feet **(Exhibit 3.3)**.

While corn's per acre water efficiency has improved, many farms still use inefficient irrigation practices.

Irrigated corn production has become more water-efficient in recent decades. Corn grain production became 29 percent more water-efficient on a *per acre basis* between 1984-2008, meaning that less water was applied per acre to obtain the same level of production. Efficiency increased by an even greater amount when assessed on a *per bushel basis*: increasing by 46 percent between 1984-2008, meaning that farmers were able to get more "crop per drop."[9]

The increased adoption of higher efficiency irrigation technologies (relatively efficient center pivot sprinkler irrigation versus traditional flood or furrow irrigation) has played a role in this improvement. Between 2003 and 2008, the number of corn acres irrigated with center pivot sprinkler systems increased by three percent for corn grain and by seven percent for silage **(Exhibit 3.4)**. Among center pivot-irrigated acres, there was an increase in the use of lower pressure, higher efficiency sprinklers (by four percent

Exhibit 3.4: Irrigated U.S. Corn Acres by Method



Source: *USDA Census of Agriculture, 2003 and 2008: Farm and Ranch Irrigation Survey*

for corn grain and 18 percent for silage). Nevertheless, 22 percent of total irrigated corn acres still used inefficient flood or furrow irrigation. Only a tiny fraction of corn farmers use subsurface drip or micro irrigation technologies (0.1 percent of total corn grain acres).[10]

Irrigation management practices are also an important determinant of water efficiency. For example, new technology allows farmers to match irrigation quantities to crop demands by scheduling irrigation to address unique plant, soil, and climate characteristics.[11, 12] However, the most recent USDA survey of farmers with irrigated cropland shows that many farmers in corn-growing states are still not using modern practices when deciding when and with how much water to

8 Total irrigated acres harvested for corn has increased 54.8 percent from 1984-2008, but total water used increased only 10.5 percent from 1984-2008. Source: USDA, 2007 Census of Agriculture, Irrigation Survey, http://www.agcensus.usda.gov/Publications/Irrigation_Survey/.

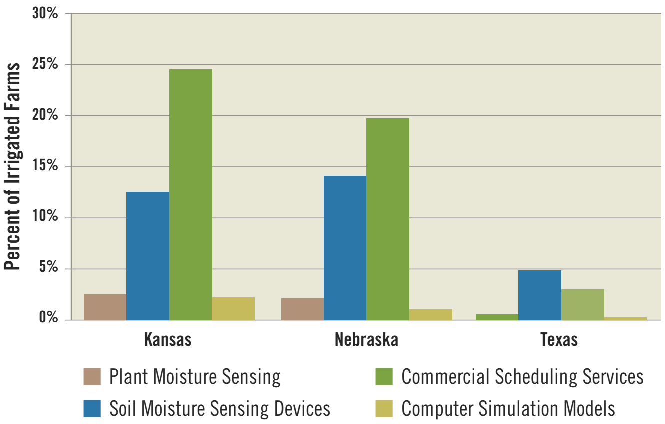
9 USDA, Census of Agriculture, 2008 Farm and Ranch Irrigation Survey, Last Modified: 7 Nov 2013, http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Farm_and_Ranch_Irrigation_Survey/index.php.

10 USDA, Census of Agriculture, 2008 and 2003 Farm and Ranch Irrigation Surveys.

11 R. Huang, C. J. Birch and D. L. George, "Water Use Efficiency in Maize Production" (paper presented at 6th Triennial Conference of the Maize Association of Australia, Griffith New South Wales Australia, February 21-23 2006), http://www.researchgate.net/publication/43468291_Water_use_efficiency_in_maize_production_-_the_challenge_and_improvement_strategies/file/9fcfd50caa42c95d36.pdf.

12 William Kranz et al., "Irrigation Management for Corn," *University of Nebraska-Lincoln Extension NebGuide*, G1850 (2008), http://www.ianrpubs.unl.edu/live/g1850/build/g1850.pdf.

Exhibit 3.5: Percent of Irrigated Corn Farms Using Modern Technology to Guide Irrigation Decisions (2008)



Source: USDA, Economic Research Service, *Western Irrigated Agriculture*, June 2013

irrigate their fields. Less than 13 percent of irrigated farms in Kansas, Nebraska and Texas used modern approaches for determining irrigation needs such as soil and plant-moisture sensing devices **(Exhibit 3.5)**.

Irrigation demand is associated with higher energy costs.

Although in most regions irrigation water itself is free, farmers can incur significant costs related to the energy used for pumping and moving water. In western Kansas, for example, these energy costs can be high, representing 10 percent of the total costs for growing corn, which is slightly higher than the cost of land rent.[21] More efficient irrigation technologies could therefore reduce energy and pumping costs for farmers, which is critical given rising energy prices.[22]

Soil Management Practices to Reduce Irrigation Demand

Efficient irrigation technologies are a double-edged sword. While gains in irrigation efficiency reduce the amount of water needed and may increase productivity, they also enable expansion of irrigated production into dryland acres and a switch to more water-intensive crops (for e.g., from wheat to corn).[13] A recent study of irrigation efficiency improvements in western Kansas, for example, found that the adoption of more efficient irrigation technology has actually increased unsustainable groundwater extraction in the region, in part due to shifting crop patterns.[14] More efficient irrigation can also lead to increased salinity levels in soil, which harms productivity.[15]

Given these challenges, it is important to note that irrigation needs can also be reduced in many regions through agricultural practices that promote the health and water retention of the soil.

Conservation tillage (i.e. "no-till" or "low-till" systems), extended crop rotations, cover-cropping, and conservation structures and vegetative measures such as terraces and riparian buffers reduce irrigation demand through three primary mechanisms: increasing water retention (improving water infiltration in the soil), decreasing run-off and decreasing evaporation.[16, 17, 18, 19, 20] These soil management practices may be used in conjunction with efficient irrigation technologies, or in some cases may eliminate the need for irrigation entirely.

For more on these farming practices, see **Appendix D**.

Corn production is centered in regions where there is growing competition for water.

In some corn-growing regions of the Midwest and Great Plains, nearly all available water is already allocated to existing agricultural, municipal and industrial users. A high level of competition for water or "water stress" indicates that any new water demands are likely to be constrained or limited by existing uses. In collaboration with the World

13 Lisa Pfeiffer and C.Y. Cynthia Lin, "Does efficient irrigation technology lead to reduced groundwater extraction? Empirical evidence," *Journal of Environmental Economics and Management*, 67, no 2 (March 2014), 189-208, http://www.sciencedirect.com/science/article/pii/S0095069613001095.

14 Ibid.

15 Alain Ayong Le Kama, Agnes Tomini, "Water Conservation Versus Soil Salinity Control," *Environmental Modeling & Assessment*, December 2013, Volume 18, Issue 6, http://link.springer.com/article/10.1007%2Fs10666-013-9368-0.

16 USDA, Economic Research Service, *Agricultural Resources and Environmental Indicators, 2012 edition*, by Craig Osteen et al., Economic Information Bulletin No. 98, August 2012, http://www.ers.usda.gov/publications/eib-economic-information-bulletin/eib98.aspx#.U0WlJuZdXd0.

17 Claire O'Connor, "Soil Matters: How the Federal Crop Insurance Program should be reformed to encourage low-risk farming methods with high-reward environmental outcomes," *Natural Resources Defense Council*, http://www.nrdc.org/water/soil-matters/.

18 Humberto Blanco-Canqui, "Addition of Cover Crops Enhances No-till Potential for Improving Soil Physical Properties," *Soil Science Society of America Journal*, 75 no. 4 (2011), 1471; Stacey M. Williams and Ray R. Weil, "Crop Cover Root Channels May Alleviate Soil Compaction Effects on Soybean Crops," *Soil Science Society of America Journal*, 68, no. 4 (2004), 1403; Kipling Balkcom et al., *Managing Cover Crops Profitably, 3rd Edition: Managing Cover Crops in Conservation Tillage Systems Chapter* (College Park, MD: Sustainable Agriculture Research and Education and United Book Press, 2012), http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Managing-Cover-Crops-in-Conservation-Tillage-Systems.

19 USDA, Economic Research Service, *Nitrogen in Agricultural Systems: Implications for Conservation Policy*, by Marc Ribaudo et al., Economic Research Report No. 127, September 2011, http://www.ers.usda.gov/publications/err-economic-research-report/err127.aspx#.UzmK9a1dXd0.

20 J. Schneekloth, T. Bauder, N. and Hansen, "Limited Irrigation Management: Principles and Practices," *Colorado State University Extension*, Jan. 2014, http://www.ext.colostate.edu/pubs/crops/04720.html.

21 Dumler, T. J., D. M. O'Brien, B. L. Olson, and K. L. Martin, 2009, "Center-pivot-irrigated corn cost-return budget in Western Kansas," *Farm Management Guide MF- 585*, Kansas State University, http://www.ksre.ksu.edu/library/agec2/mf585.pdf.

22 Lisa Pfeiffer and C. Y. Lin "The Effects of Energy Prices on Groundwater Extraction in Agriculture in the High Plains Aquifer," paper presented at 2014 Allied Social Sciences Association (ASSA) Annual Meeting, Philadelphia, PA, January 3-5, 2014, http://ageconsearch.umn.edu/bitstream/161890/2/Pfeiffer%20and%20Lin.pdf.

Resources Institute (WRI), the level of water stress facing both irrigated and rainfed corn production was analyzed using the water stress indicator from WRI's Aqueduct tool, as well as data on corn production derived from USDA estimates and remote sensing data (see **Appendix A** for detailed methodology).

The analysis found that 35 percent of total U.S. corn production is taking place in regions with high to extremely high water stress, meaning in regions where the ratio of water withdrawals to renewable supplies exceeds 40 percent on an average annual basis. Breaking this down further, 87 percent and 27 percent of irrigated and rainfed corn production, respectively, were in regions with high or extremely high water stress **(Exhibits 3.6** & **3.7)**. The most vulnerable regions are Nebraska, Kansas, California, Colorado and Texas.

For irrigated corn production regions, high water stress levels mean there is very little additional surface water available to augment irrigation. For rainfed corn production regions, high water stress indicates limited irrigation potential should a changing climate increase the corn crop's demand for water.

California's Drought Hurts Corn Silage Production

California, while not typically thought of as a major corn-growing state, is the country's second largest producer of corn silage.[23] This is due to the state's position as the nation's largest dairy producer. California's approximately 1.8 million dairy cows consume significant quantities of locally-grown corn silage, the vast majority of which is irrigated using highly stressed surface and groundwater resources. As of spring 2014, California's record drought had forced a reduction in deliveries of surface water to irrigation districts in the state's Central Valley, leading many farmers to either fallow corn silage acres or to increase their use of already depleted local groundwater supplies.[24]

Most irrigated corn grain is grown in counties that rely on the High Plains aquifer.

The High Plains aquifer supplies about 30 percent of the country's irrigated groundwater, and is the lifeblood of the nation's agricultural "bread basket." The aquifer lies beneath eight states in the Great Plains region and is one of the most over-exploited groundwater basins in the world.[25]

Together, 170 corn-producing counties in this region supply a significant portion of overall U.S. corn grain production (13 percent in 2013). More than 90 percent of corn production in these counties is irrigated using groundwater. Groundwater-dependent corn grain production in the region is equivalent to nearly $9 billion in market value **(Exhibit 3.8)**.

Exhibit 3.8: Annual Corn Grain Production of Counties Overlying the High Plains Aquifer (By State)

State	Groundwater-Irrigated Corn Grain Production in Counties Overlying the High Plains Aquifer (Bushels)	Production Value
NE	1,132,689,572	$5,980,600,942
KS	314,737,797	$1,661,815,568
CO	63,302,267	$334,235,970
TX	152,484,883	$805,120,180
OK	18,966,197	$100,141,521
SD	12,338,990	$65,149,866
WY	2,425,286	$12,805,508
NM	4,120,333	$21,755,360
TOTAL	**1,701,065,325**	**$8,981,624,915**

USDA corn production data from counties overlying the High Plains aquifer was used for this analysis. Counties over the aquifer were identified based on USDA/NRCS, *Groundwater Irrigation and Water Withdrawals: The Ogallala Aquifer Initiative*, August 2013. A 5-year average of corn production data (grain only) was used for each county, where available. Corn production data was modified based on the percentage of total irrigation water use derived from groundwater, data for which was sourced from USGS, *Estimated Use of Water in the United States in 2005*. Production value was calculated using 5-year average of U.S. corn price for 2009-2013, or $5.28/bushel.

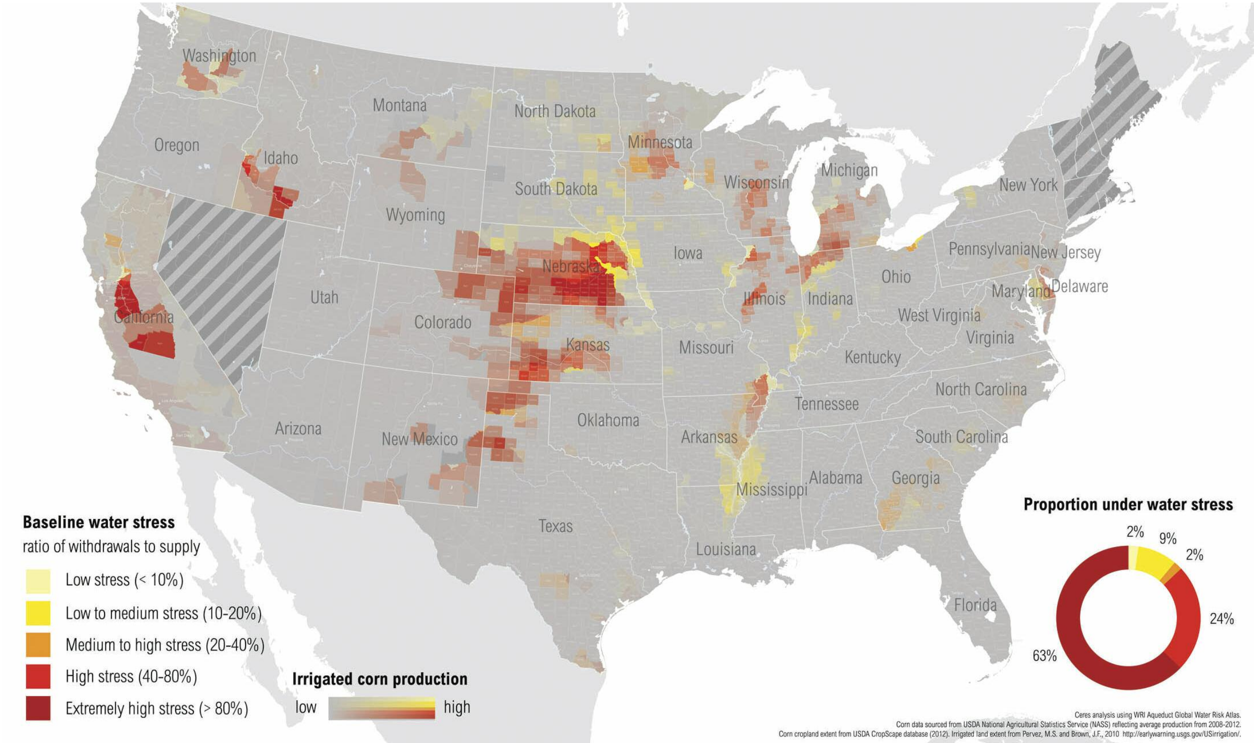
Sources: USDA, National Agricultural Statistics Service Database and USGS, *Estimated Use of Water in the United States in 2005*, by Joan F. Kerry et al., Circular 1344, Reston, Virginia, 2009.

23 USDA, Quickstats database.

24 Ching Lee, "Drought influences dairy farmers' feed plans," *AgAlert*, February 19, 2014, http://agalert.com/story/?id=6399.

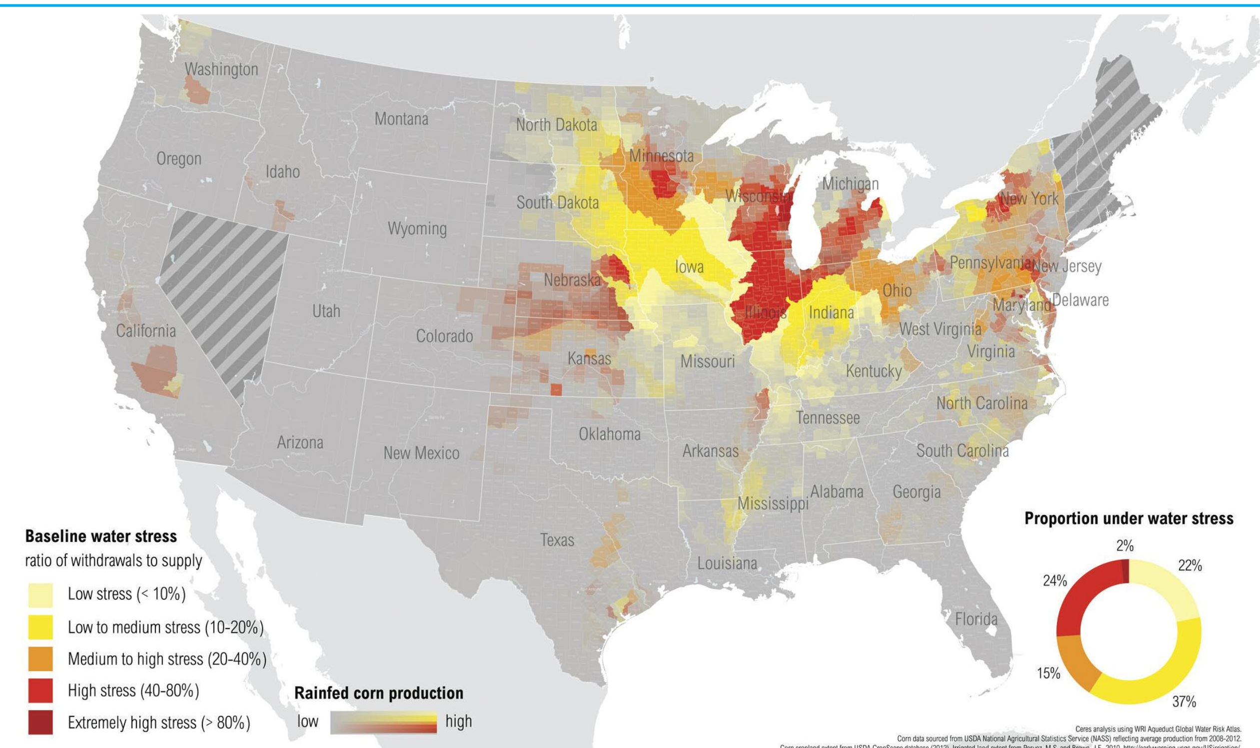
25 Tom Gleeson and Yoshihide Wada, "Assessing Regional Groundwater Stress for Nations Using Multiple Data Sources with the Groundwater Footprint," *Environmental Research Letters*, 8 (2013) 044010, http://iopscience.iop.org/1748-9326/8/4/044010/pdf/1748-9326_8_4_044010.pdf.

Exhibit 3.6: Competition for Water in Areas of Irrigated Corn Production



Red areas are regions where a large portion of existing water supply is already being used. Regions with high groundwater-irrigated corn production that face high water stress have limited access to alternative surface water irrigation resources.

Exhibit 3.7: Competition for Water in Areas of Rainfed Corn Production



Red areas are regions where a large portion of existing water supply is already being used. Regions of rainfed corn production that face high water stress have less ability to switch to irrigated production should changes in climate lead to increases in irrigation demand.

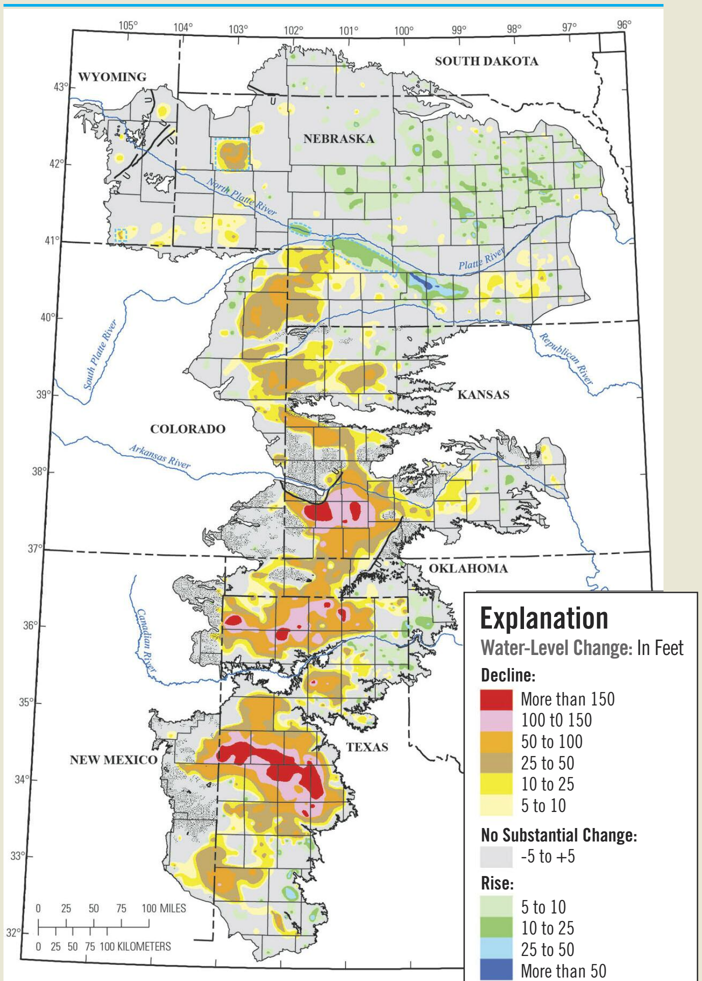
For an interactive version of these maps, see www.ceres.org/cornmaps

Source: WRI Aqueduct Water Risk Atlas in combination with data from the USDA's National Agricultural Statistics Service (NASS) including the NASS CropScape database.

The High Plains Aquifer

The High Plains aquifer—also referred to as the Ogallala aquifer—lies beneath approximately 225,000 square miles in the central United States.[26] Thirty percent of all groundwater withdrawn for irrigation in the country comes from this aquifer, which also provides drinking water to 82 percent of the people living within its boundaries.[27] Agriculture is the major user of the High Plains aquifer, accounting for 97 percent of all water withdrawn on an annual basis.[28]

Exhibit 3A: Water-Level Changes in the High Plains Aquifer, Pre-Development to 2011

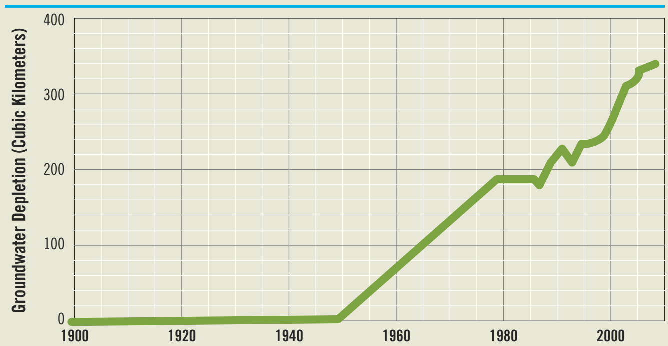


Source: USGS, *Water-Level Changes and Changes in Water in Storage in the High Plains Aquifer, Pre-development to 2011, and 2009-11, U.S. Geological Survey Scientific Investigations Report 2012–5291*, by V.L. McGuire, 2013

The characteristics of the aquifer vary widely across the region. The groundwater basin is more than 1,000 feet thick in parts of Nebraska, where it is more regularly recharged due to relatively higher levels of precipitation in the state. However, farther south and west, the aquifer is much thinner, and due to arid conditions and high evaporation rates, there is little water available to replenish it. In some parts of the aquifer, the water table has declined by more than 150 feet over the past century and groundwater is essentially being mined **(Exhibit 3A)**.

Substantial pumping of the aquifer began in the 1940s. The aquifer's overall rate of depletion[29] spiked during the last eight years (2001-2008) representing about 32 percent of the total amount of water removed during the 20th century **(Exhibit 3B)**.[30] In parts of the aquifer, groundwater has been extracted well beyond renewable levels. For instance, in western Kansas, it has been estimated that more than 30 percent of the aquifer's total volume has already been withdrawn, with another 39 percent projected to be pumped over the next 50 years.[31] In the southern portion of the High Plains, based on current depletion rates, it is projected that 35 percent of the region will be unable to support irrigation within the next 30 years.[32]

Exhibit 3B: Cumulative Groundwater Depletion in the High Plains Aquifer (1900-2008)



Source: USGS, *Groundwater depletion in the United States (1900–2008): U.S. Geological Survey Scientific Investigations Report 2013–5079*, by L.F. Konikow, 2013

As a result of this depletion, long-term sustainability of agriculture in some regions over the aquifer is threatened. When excessive withdrawals reduce the overall saturated thickness of the aquifer to 30 feet or less, high volume irrigation is effectively no longer feasible.[33] Currently, several regions have a saturated thickness of 30 feet or less **(Exhibit 3C)**. Looking ahead, 36 counties with irrigated agriculture in the region are projected to reach the 30-foot threshold by 2050.[34]

26 "Ogallala Water Initiative," USDA, Natural Resources Conservation Service, http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/?cid=stelprdb1048809.

27 Weiwei Wang, Seong C. Park, Bruce A. McCarl and Steve Amosson, "Economic and Groundwater Use Implications of Climate Change and Bioenergy Feedstock Production in the Ogallala Aquifer Region," (paper presented at Agricultural & Applied Economics Association's 2011 AAEA&NAREA Joint Annual Meeting, Pittsburgh Pennsylvania, July 24-26, 2011), http://ageconsearch.umn.edu/bitstream/103642/1/AAEA-OAP.pdf.

28 USGS, National Water Quality Assessment Program, *Water Quality in the High Plains Aquifer, Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming, 1999–2004*, by Jason J. Gurdak, Peter B. McMahon, Kevin Dennehy, and Sharon L. Qi, Reston, Virginia, Circular 1337, 2009, http://pubs.usgs.gov/circ/1337/pdf/C1337.pdf.

29 Groundwater depletion occurs when water demand through pumping exceeds water supply through recharge.

30 The rate of depletion during this 8-year period averaged about 2.4 cubic miles/year, and the total amount of depletion by 2008 was approximately 82 cubic miles. USGS, *Groundwater Depletion in the United States (1900–2008): U.S. Geological Survey Scientific Investigations Report 2013–5079*, 63 p., by L.F. Konikow, 2013, http://pubs.usgs.gov/sir/2013/5079.

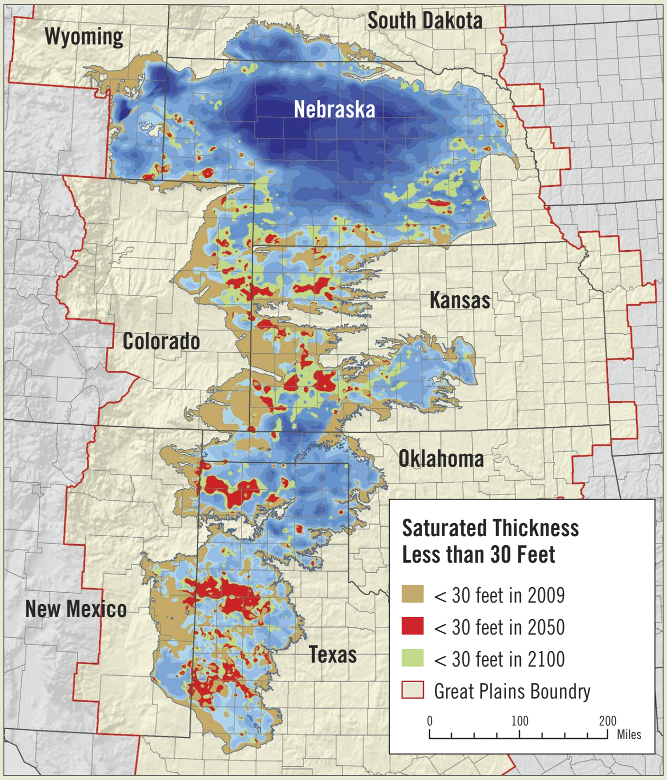
31 David Steward et al., "Tapping unsustainable groundwater stores for agricultural production in the High Plains Aquifer of Kansas, projections to 2110," *Proceedings of the National Academy of Sciences of the United States of America*, vol. 110 no. 37, (2013), http://www.pnas.org/content/110/37/E3477.full.

32 Bridget Scanlon et al., "Groundwater Depletion and Sustainability of Irrigation in the US High Plains and Central Valley," *Proceedings of the National Academy of Sciences of the United States of America,* 109, no. 24 (2012), 9320–9325, http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1506&context=usgsstaffpub.

33 R. W. Buddemeier, "Water Table Drawdown and Well Pumping," *An Atlas of the Kansas High Plains Aquifer*, last revised 11 Dec 2000, http://www.kgs.ku.edu/HighPlains/atlas/apdrdwn.htm.

34 Joel Kotkin, "Rise of the Great Plains: Regional Opportunity in the 21st Century," *Texas Tech University* (2012), 27, http://gis.ttu.edu/center/greatplains/document/KotkinGreatPlains.pdf.

Exhibit 3C: Saturated Thickness of the High Plains Aquifer

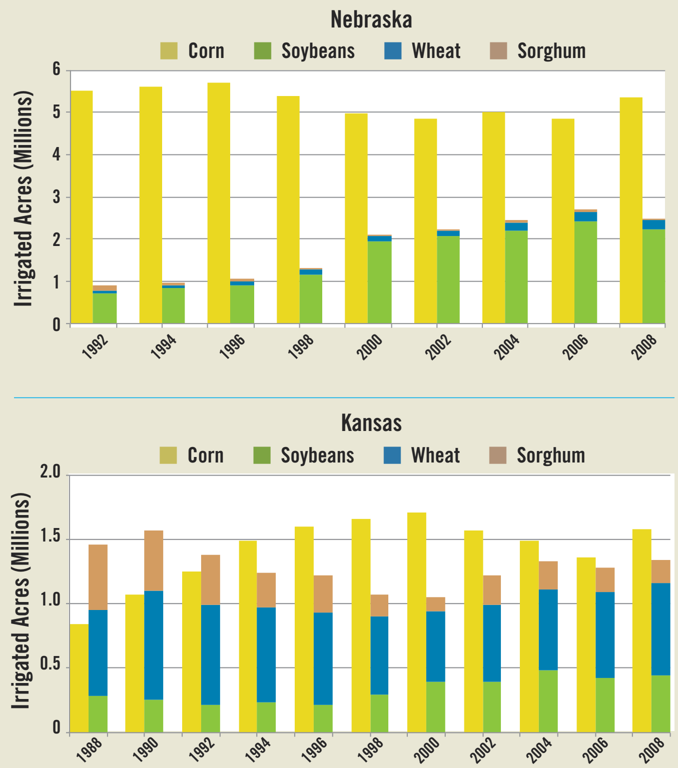


When excessive withdrawals reduce the overall saturated thickness of the aquifer to 30 feet or less, high volume irrigation is effectively no longer feasible. Several portions of the aquifer (in red) already have a saturated thickness of 30 feet or less.

Source: Joel Kotkin, "Rise of the Great Plains: Regional Opportunity in the 21st Century," *Texas Tech University* (2012), using 2009 USGS data.

The corn-growing states of Nebraska, Kansas and Texas are among the largest users of water from the High Plains aquifer. In 2005, Nebraska, Kansas and Texas accounted for 78 percent of all the groundwater withdrawn for irrigation from the eight states overlying the High Plains aquifer. These three states withdraw over 16 billion gallons of groundwater per day.[35] Kansas and Nebraska are major producers of corn, and combined accounted for 15 percent of total U.S. corn production in 2013.[36] In both states, corn accounts for more irrigated acres than any other crop **(Exhibit 3D)**.

Exhibit 3D: Irrigated Acres Planted to Major Crops in Nebraska and Kansas



Source: USDA, National Agricultural Statistics Service Database

$2.5 billion worth of corn is grown over parts of the aquifer experiencing water level declines.

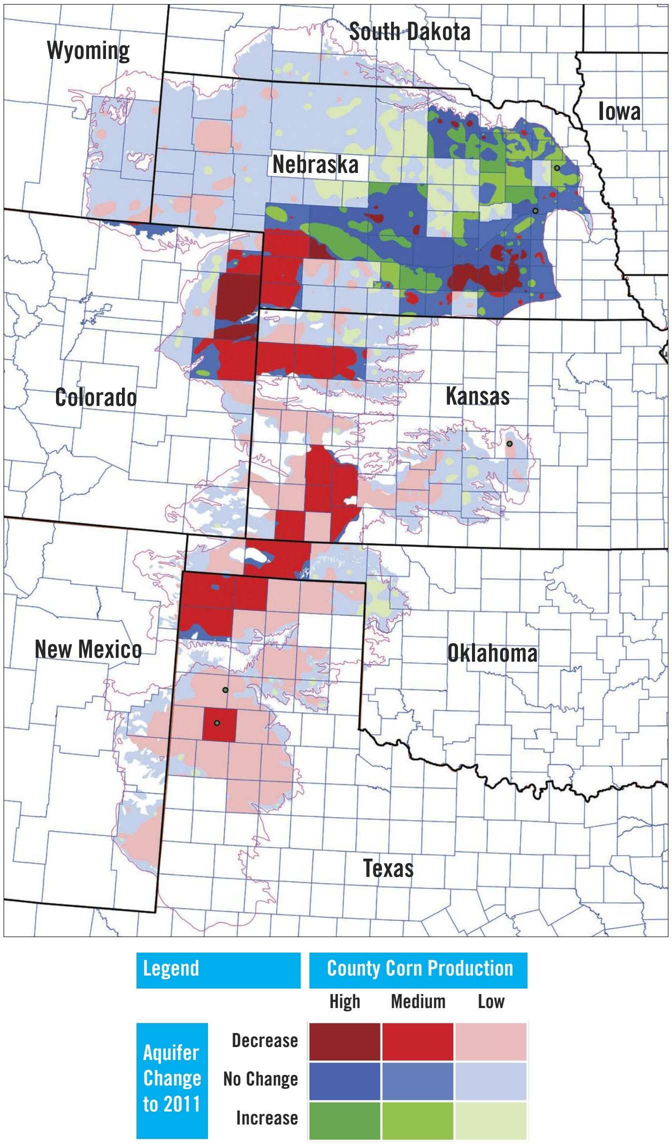
To analyze the potential risk of water table declines to corn production in the region, data from the USGS measuring cumulative declines in water levels in the High Plains aquifer[37] was overlaid against USDA data on irrigated, groundwater-dependent corn production **(Exhibit 3.9)**. Ceres' analysis identified at least 20 counties in Colorado, Kansas, Nebraska and Texas with high rates of irrigated corn production that are also in areas experiencing water-level declines. Among these, five counties had over $150 million each in corn grain production: Yuma County in Colorado and York, Hamilton, Adams and Filmore counties in Nebraska. Together, corn grain production in the top 20 counties was equivalent to nearly $2.5 billion in annual market value **(Exhibit 3.10)**.

35 USGS, *Estimated Use of Water in the United States in 2005*, by Joan Kenny et al, 2009, http://pubs.usgs.gov/circ/1344/.

36 Nebraska produced 1,623,500,000 bushels of corn in 2013 (or 11.7% of the U.S. total), and Kansas produced 508,000,000 bushels of corn (3.7% of the U.S. total). USDA, National Agricultural Statistics Service Database (2013), http://quickstats.nass.usda.gov/.

37 USGS, *Water-Level and Storage Changes in the High Plains Aquifer, Predevelopment to 2011 and 2009–11, U.S. Geological Survey Scientific Investigations Report 2012–5291*, by V.L. McGuire, 2013, http://pubs.usgs.gov/sir/2012/5291/.

Exhibit 3.9: Counties over the High Plains Aquifer with Irrigated Corn Production in Regions with Water-Level Declines



Data on county-level corn production in bushels, based on a 5-year average yield (2007-2012) of irrigated, groundwater-dependent corn production, overlaid against data on declines/increases in water-levels from pre-development to 2011. For counties where corn production is ranked as "low," an average of less than 13,595,444 bushels are produced annually. "Medium" counties fall between 13,595,445- 27,1159,889 bushels of average annual production, and "high counties" between 27,159,890 - 40,724,333 bushels.

Source: Ceres, using data from USGS, *Estimated Use of Water in the United States in 2005*, by Joan Kenny et al., 2009, and USGS, *Water-Level and Storage Changes in the High Plains Aquifer, Predevelopment to 2011 and 2009–11*, by V.L. McGuire, 2013. GIS by Agricultural Conservation Economics

Exhibit 3.10: Value at Risk: Top 20 Counties with High Corn Grain Production in Regions with Water-Level Decline in the High Plains Aquifer

County	Groundwater-Irrigated Corn Grain Production (Bushels)	Production Value
Yuma (CO)	39,681,306	$209,517,295
York (NE)	38,312,287	$202,288,877
Hamilton (NE)	37,081,422	$195,789,906
Adams (NE)	33,179,293	$175,186,665
Fillmore (NE)	30,957,064	$163,453,297
Clay (NE)	28,152,579	$148,645,617
Chase (NE)	25,702,960	$135,711,629
Perkins (NE)	24,270,040	$128,145,811
Hartley (TX)	23,863,875	$126,001,260
Castro (TX)	20,261,500	$106,980,720
Thomas (KS)	19,642,000	$103,709,760
Kit Carson (CO)	19,585,932	$103,413,720
Dallam (TX)	19,173,660	$101,236,923
Stevens (KS)	18,959,200	$100,104,576
Sherman (KS)	17,238,400	$91,018,752
Meade (KS)	16,017,000	$84,569,760
Sherman (TX)	15,975,960	$84,353,069
Haskell (KS)	15,475,000	$81,708,000
Phillips (CO)	14,785,750	$78,068,760
Gray (KS)	14,742,400	$77,839,872
Totals	**473,057,627**	**$2,497,744,270**

A 5-year average of corn grain production data was used for each county, where available, using USDA NASS Quick Stats. Corn production data was modified based on the percentage of total irrigation water use derived from groundwater, data for which was sourced from *USGS, Estimated Use of Water in the United States in 2005* by Joan Kenny et al., 2009 and USDA, National Agricultural Statistics Service Database.

Twelve ethanol refineries in the High Plains region are in areas experiencing significant water-level declines.

Most corn ethanol refineries are located in close proximity to cornfields and typically source corn within a 50-mile radius.[38] There are 36 corn-based ethanol refineries[39] located in or within 1,000 meters of the High Plains aquifer. To analyze the risk of water-level declines to irrigated corn sourced by ethanol producers, refinery locations and estimated sourcing radiuses were overlaid against USGS data on water-level declines in the aquifer[40] **(Exhibit 3.11)**.

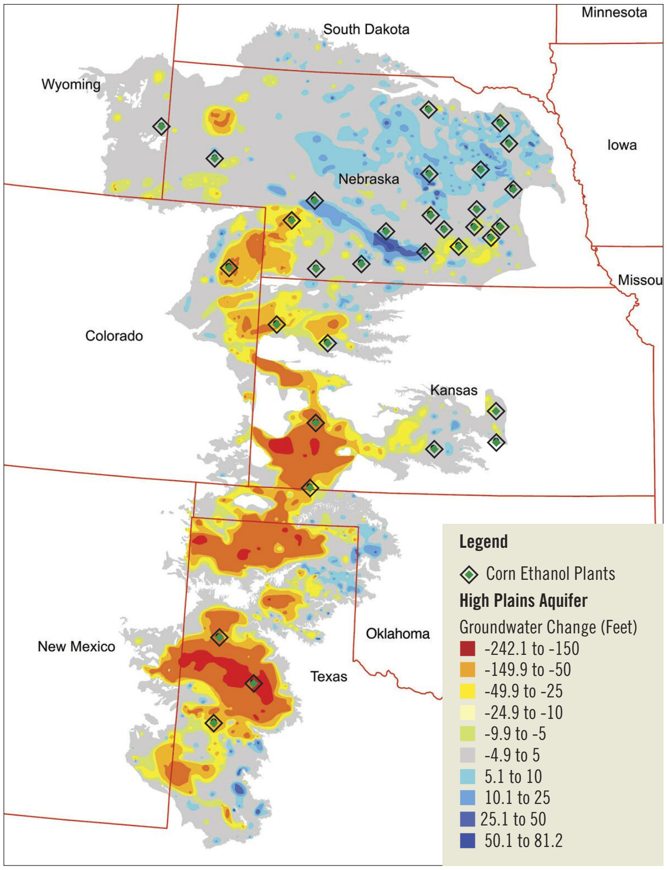
Twelve refineries above the High Plains aquifer, representing nearly $1.7 billion in annual ethanol production capacity, are in areas experiencing cumulative declines in groundwater levels **(Exhibit 3.12)**. Six of these refineries are in regions of extreme water-level decline (between 50-150 feet of cumulative decline).

38 USDA, *Ethanol Transportation Backgrounder: Expansion of U.S. Corn-based Ethanol from the Agricultural Transportation Perspective*, September 2007, http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5063605.

39 Thirty-one of the corn ethanol plants over the aquifer reported using corn only as feedstock, five reported using a mix of corn and sorghum. Source: "Biorefinery Locations," Renewable Fuels Association, last updated: 21 Mar. 2014, http://www.ethanolrfa.org/bio-refinery-locations/.

40 USGS, *Water-Level and Storage Changes in the High Plains Aquifer, Pre-development to 2011 and 2009–11, U.S. Geological Survey Scientific Investigations Report 2012–5291*, by V.L. McGuire, 2013, http://pubs.usgs.gov/sir/2012/5291/.

Exhibit 3.11: Corn-Based Ethanol Refineries in Regions of the High Plains Aquifer Experiencing Water-Level Declines



Map of corn-based ethanol refineries against declines/increases in water-levels in the High Plains aquifer from pre-development to 2011. Twelve corn-based ethanol refineries, are in areas of the aquifer experiencing water level declines.

For an interactive version of this map, see www.ceres.org/cornmaps

Source: Ceres, using data from USGS, "Water-Level and Storage Changes in the High Plains Aquifer, Predevelopment to 2011 and 2009–11," by V.L. McGuire, 2013; and "Biorefinery Locations," Renewable Fuels Association website. GIS mapping by Agricultural Conservation Economics.

Wide-ranging financial risks of groundwater depletion in the High Plains region are increasingly recognized by government.

In addition to its importance to corn production, the High Plains aquifer supports nearly one-fifth of the wheat, cotton and cattle produced in the United States.[41] The economic value of the agricultural production in the region is substantial. For instance, according to the Kansas Water Office, irrigation from the High Plains aquifer in western Kansas produces $5 billion in value each year.[42] In Texas, the High Plains region accounts for $1.3 billion in agriculture annually, including $421 million in corn.[43]

As a result, calls for better management of groundwater resources in the region have grown in recent years, and federal and state governments have responded in various ways. At the federal level, the USDA's Natural Resources

Exhibit 3.12: Corn-Based Ethanol Refineries Located in Regions of the High Plains Aquifer Experiencing Water-Level Declines

Company	Corn Ethanol Refineries Located in Areas of Aquifer Level Decline	Groundwater Level Declines, Pre-Development—2011 (Feet)	Refinery Production Capacity (Millions of Gallons/Year)	Share of Total Ethanol Production Capacity in Regions of Groundwater Level Decline	Annual Value of Ethanol Production at Risk
Arkalon Energy, LLC	Liberal, KS	-44	110	100%	$206,800,000
Bonanza Energy, LLC	Garden City, KS	-70	55	100%	$103,400,000
Chief Ethanol	Hastings, NE	-10	62	100%	$116,560,000
Diamond Ethanol	Levelland, TX	-46	40	100%	$75,200,000
Flint Hills Resources LP	Fairmont, NE	-8	110	17%	$206,800,000
Green Plains Renewable Energy (GPRE)	Wood River, NE	-5	115	11%	$216,200,000
Mid America Agri Products/Wheatland	Madrid, NE	-35	44	100%	$82,720,000
Murphy Oil (MUR)	Hereford, TX	-59	105	100%	$197,400,000
Reeve Agri-Energy	Garden City, KS	-70	12	100%	$22,560,000
White Energy	Plainview, TX	-148	110	100%	$206,800,000
White Energy	Hereford, TX	-66	100		$188,000,000
Yuma Ethanol	Yuma, CO	-50	40	100%	$75,200,000
Total					**$1,697,640,000**

Source: Ceres analysis using data from USGS, "Water-Level and Storage Changes in the High Plains Aquifer, Predevelopment to 2011 and 2009-11," by V.L. McGuire, 2013; and "Biorefinery Locations," Renewable Fuels Association website. GIS analysis by Agricultural Conservation Economics. Using Chicago Platts average ethanol price between 4/30/13-4/30/14, $1.88/gallon.

41 USDA, Ogallala Aquifer Initiative," National Resources Conservation Service, http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/?cid=stelprdb1048809.

42 Kansas Water Office, "Vision for the Future Water of Kansas," http://www.kwo.org/50_Year_Vision/Brochure_50_Yr_Vision.pdf.

43 Steve Amosson et al., "The Impact of Agribusiness on the High Plains Trade Area," http://amarillo.tamu.edu/files/2010/11/ImpactofAgribusinessintheHighPlains.pdf.

Conservation Service (NRCS) has partnered with local conservation districts, state environmental agencies and land grant universities to create the Ogallala Aquifer Initiative (OAI). The program focuses on reducing aquifer use, improving quality of groundwater and enhancing economic viability of croplands and rangelands in the eight states overlying the aquifer.[44] The OAI provides technical and financial assistance to farmers, and contributed to reducing water withdrawals from the aquifer by at least 1.5 million acre-feet between 2009-2012.[45]

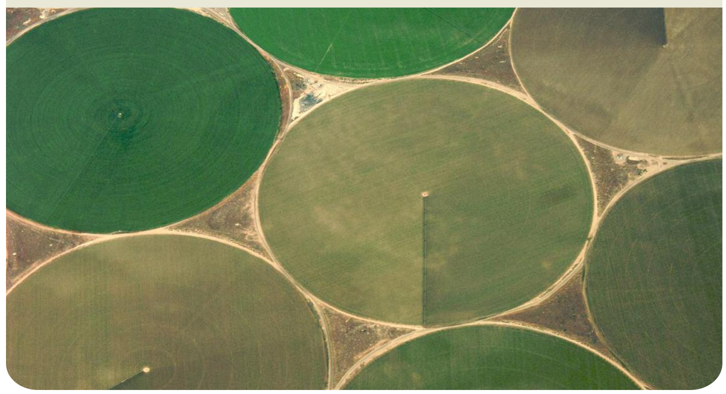
State lawmakers are also focusing more attention on groundwater protection, although most policy initiatives have focused on managing depletion rather than ending it. Kansas' Governor Brownback has made extending the useful life of the High Plains aquifer a central policy priority and in 2012 helped pass legislation that removed a "use it or lose it" provision for water rights holders. This legislation means that groundwater rights holders can now choose to reduce their water withdrawals in wetter years in order to access more water in dryer years, without running the risk of losing their water rights and thus creating incentives for conservation.[46] One of the state's water districts also recently enacted a self-imposed 20 percent withdrawal reduction plan over the next five years with the goal of preserving finite water supplies into the future.[47]

In Nebraska, where recharge rates for the High Plains aquifer are typically much higher than in neighboring states, a major driver restricting groundwater use is the state's legal obligation to share flows of the Republican River with Kansas.[50] A Supreme Court ruling has forced some groundwater management districts in Nebraska to introduce a variety of agricultural water use restrictions to ensure adequate river flows (to which groundwater contributes), including moratoria on new wells, annual volumetric restrictions on existing wells and well metering.[51]

In many High Plains states, groundwater is the property of the state and is allocated like surface water under the rule of prior appropriation (first in time, first in right). As a result, the state has direct authority to reduce groundwater pumping. In Texas, however, groundwater is private property although collectively managed by groundwater rights owners through groundwater conservation districts.

Planned Depletion? Water as a Non-Renewable Resource

Most local and state initiatives to conserve groundwater have been framed around the goal of slowing the rate of depletion or extending the "useable life" of the aquifer. While this is an understandable objective, other goals focused on ending depletion (which is not necessarily the same as ending extraction) deserve consideration. In Texas, most local groundwater conservation districts manage their groundwater permits to achieve depletion of their portion of the High Plains aquifer at a given future date. However, a few Texas conservation districts have set groundwater management targets to maintain sufficient water levels to provide springflow to sustain local rivers.[48] In Oklahoma in 2003, a law was passed ordering the water board to determine how much water could safely be removed from the Arbuckle-Simpson aquifer without disturbing springs and streams. This law has recently resulted in a capping of aquifer withdrawals.[49]



The objectives of each groundwater conservation district (called "Desired Future Conditions") are determined locally, and groundwater permits are allocated using modeling provided by the Texas Water Development Board. However, two recent Texas court cases have made it more difficult to determine how groundwater conservation districts can regulate groundwater production—first, by confirming that groundwater is a vested property right of the landowner, and second, that groundwater districts may be required to compensate landowners for restricting their right to the use of their groundwater.[52]

44 USDA, "Ogallala Aquifer Initiative," National Resources Conservation Services, http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/?cid=stelprdb1048809.

45 USDA, National Resources Conservation Services, *Ogallala Aquifer Initiative Conservation Beyond Boundaries*, June 21, 2013, http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1142809.pdf.

46 "Governor Brownback completes 2012 water agenda," Kansas Water Office press release, May 25, 2012, http://www.kwo.org/Ogallala/Governor%20Signs%20Bills%2005.25.12%20final%20water.pdf

47 Brett Walton, "With Locals at the Helm, Kansas Charts New Course for Groundwater Management," *Circle of Blue*, 10 Apr 2013, http://www.circleofblue.org/waternews/2013/world/with-locals-at-the-helm-kansas-charts-new-course-for-groundwater-management/.

48 "Groundwater Management Area Process," Texas Living Waters Project, http://texaslivingwaters.org/groundwater/groundwater-management-area-process/

49 Logan Layden, "After Decade of Consideration, State Caps Withdrawals from Oklahoma's Most Sensitive Aquifer," NPR, October 24, 2013, https://stateimpact.npr.org/oklahoma/2013/10/24/after-decade-of-consideration-state-caps-withdrawals-from-oklahomas-most-sensitive-aquifer/.

50 Russ Quinn, "Ogallala Aquifer: Nebraska Not Immune to Sustainability Issues," *AgFax.com*, 26 Aug 2013, http://agfax.com/2013/08/26/ogallala-aquifer-nebraska-not-immune-to-sustainability-issues/.

51 Jeffrey Savage and Jennifer Ifft, "Does Pumping Pay: Groundwater Management Institutions and Cropland Values in Nebraska," (paper presented at Agricultural & Applied Economics Association's 2013 AAEA & CAES Joint Annual Meeting, Washington, DC August 4-6, 2013), http://ageconsearch.umn.edu/bitstream/150581/2/SavageIfft.pdf.

52 Amy Hardberger, "World's Worst Game of Telephone: Attempting to Understand the Conversation between Texas's Legislature and Courts on Groundwater," June 20, 2013, *University of Texas Environmental Law Journal*, http://ssrn.com/abstract=2282543.

Fertilizer Use & Nutrient Pollution

Chapter Summary

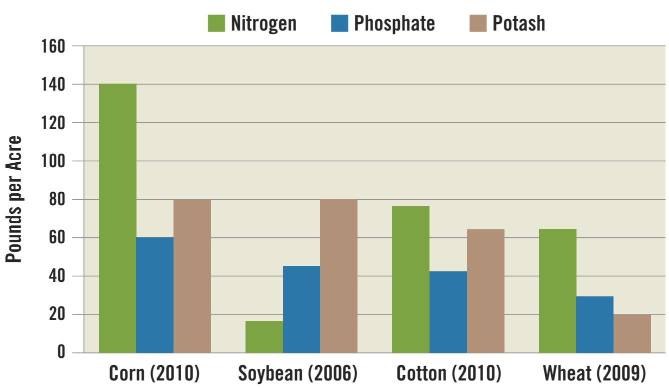
- Corn is extremely fertilizer intensive, using more than half of all commercial fertilizer applied to U.S. cropland. While corn's fertilizer use per bushel is low relative to many other crops, per acre use is high and corn plants typically do not fully absorb this fertilizer. As a result, every year, millions of tons of nitrogen and phosphate fertilizer leach into groundwater and run off fields into waterways (also known as nutrient pollution).
- Nutrient pollution is the most significant water quality challenge facing the nation's rivers and streams, according to the EPA. Agricultural run-off from U.S. corn acres damages lakes, streams and groundwater and is the single largest source of pollution to the Gulf of Mexico's "dead zone"—an area the size of Connecticut that is essentially devoid of life.
- For corn farmers, inefficient fertilizer use represents a direct economic loss. This report finds that in 2012, nearly half a billion dollars worth of commercial fertilizer ran off corn acres into the Mississippi River Basin and eventually into the Gulf of Mexico.
- There are opportunities to significantly reduce nutrient pollution from corn: only 34 percent of U.S. corn acres are currently farmed according to best practices for nitrogen fertilizer management. These practices include avoiding over-applying fertilizer and applying fertilizer at the right time in the growing season. Fertilizer run-off can be further addressed by practices such as cover-cropping, and the development of buffer strips and artificial wetlands that naturally filter excess nitrogen and phosphorus.
- Since water pollution from agricultural run-off is largely unregulated, drinking water utilities and the commercial fishing and outdoor recreation industries currently bear the financial burden of nutrient pollution. The cost of removing nitrate (a chemical form of nitrogen) from U.S. drinking water is estimated at more than $4.8 billion per year. At least one-third of this cost, or an estimated $1.7 billion per year, can be attributed to fertilizer run-off from agriculture.
- The ethanol sector purchases 35 percent of all U.S. corn. This report identifies 60 corn ethanol refineries with $8.8 billion in annual ethanol production capacity that are sourcing corn from watersheds with high local nitrogen pollution from agriculture. Several large ethanol producers including POET Biorefining, Valero Renewable Fuels and Flint Hill Resources have more than 50 percent of their production capacity in watersheds with high local nitrogen pollution.
- State-level strategies to reduce agricultural run-off as well as growing pressures from food retailers and processed food companies are creating new drivers for more efficient fertilizer use in the Corn Belt. For instance, Walmart recently announced a goal for U.S. farmers in its supply chain to increase efficiency of their fertilizer use by 30 percent on 10 million acres of corn, wheat and soybeans by 2020.

Corn is a fertilizer-intensive crop.

Chemical fertilizers composed of nitrogen, phosphate and potash are the major source of applied nutrients in U.S. corn production.[1] Ninety-seven percent of U.S. corn acres receive nitrogen fertilizers annually, 78 percent receive phosphate and 61 percent receive potash.[2, 3]

The quantity of nitrogen and phosphate-based fertilizers applied to corn on a per acre basis is higher than for other major crops, with corn receiving an average of 140 lbs/acre of nitrogen fertilizer, compared to 65 lbs/acre for wheat, and 16 lbs/acre for soy[4] **(Exhibit 4.1)**. It should be noted that these rates are for those crop acres that received nitrogen fertilizer (only 18 percent of soybean acres received nitrogen fertilizer in 2006).

Exhibit 4.1: Average Fertilizer Application Rates for Select U.S. Crops

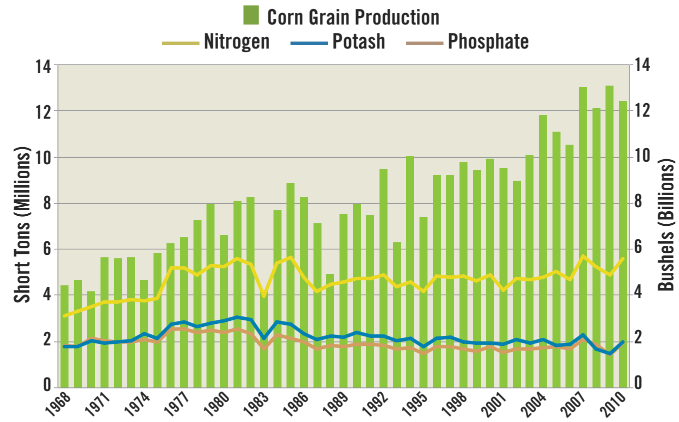


Source: USDA, Economic Research Service, Fertilizer Use and Price Data Summary

The amount of fertilizer applied to corn has risen steadily since the 1960s, while total corn production has more than tripled.

The overall quantity of fertilizer applied to U.S. corn has steadily risen since the 1960s. Total nitrogen use grew by 80 percent from 1968-2010, while the consumption of phosphate and potash has remained relatively stable since the mid-1980s **(Exhibit 4.2)**. In 2010, U.S. corn production received a total of 19.1 billion pounds of commercial fertilizer.[5] The efficiency of fertilizer use has improved overall, with the amount of corn produced per ton of nitrogen increasing by more than 50 percent, and corn produced per ton of phosphate increasing by 168 percent between 1968 and 2010.

Exhibit 4.2: Historical U.S. Corn Production vs. Fertilizer Use (1968-2010)

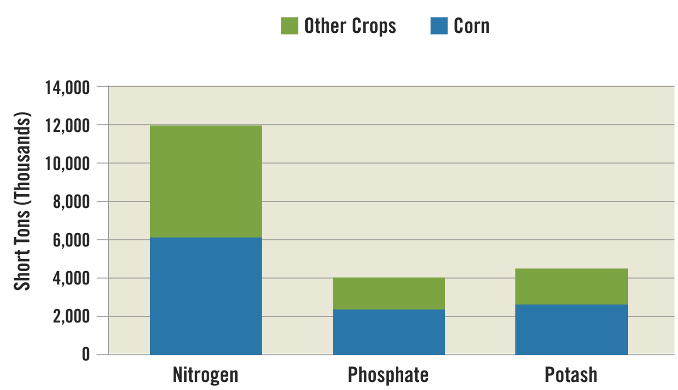


Source: USDA, Economic Research Service, Fertilizer Use and Price Data Summary

Corn production consumes more than half of all fertilizer applied to U.S. crops.

Total fertilizer use for corn represented 54 percent of all fertilizer applied (nitrogen, phosphate, and potash) to U.S. crops in 2010. Specifically, corn production consumed 54 percent, 53 percent, and 55 percent of all nitrogen, phosphate and potash used in U.S. crop production, respectively **(Exhibit 4.3)**.

Exhibit 4.3: Fertilizer Applied to Corn vs. All Other Crops (2010)



Source: USDA, Economic Research Service, Fertilizer Use and Price Data Summary

1 While chemical fertilizers represent the majority of nutrients applied to corn, manure is applied to about 15% of fertilized corn acres. Only 0.3% of planted corn was grown under certified organic farming systems in 2011. Source: USDA, *Agricultural Resource Management Survey,* 2010; and USDA, Economic Research Service, "Growth Patterns in the U.S. Organic Industry," by Catherine Greene, October 24, 2013 http://www.ers.usda.gov/amber-waves/2013-october/growth-patterns-in-the-us-organic-industry.aspx#.UvuSMo3ePCV.

2 USDA, Economic Research Service, *Nitrogen Management on U.S. Corn Acres, 2001-10*, by Marc Ribaudo, Michael Livingston, and James Williamson, EB-20 November 2012, http://www.ers.usda.gov/publications/eb-economic-brief/eb20.aspx#.U0K6fK1dXd0.

3 USDA, Economic Research Service, *Fertilizer Use and Price*, 2013, http://www.ers.usda.gov/data-products/fertilizer-use-and-price.aspx#.Uyiztl3ePCU.

4 The latest data available for wheat is from 2009, and for soy from 2006. Source: USDA, Economic Research Service, *Fertilizer Use and Price*, 2013.

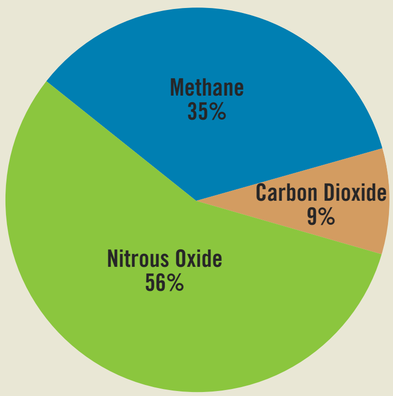
5 USDA, Economic Research Service, *Fertilizer Use and Price*, 2013.

Contribution of Corn Production to U.S. Greenhouse Gas Emissions

In 2012, agriculture contributed to eight percent of total U.S. greenhouse gas (GHG) emissions.[7] Nitrous oxide, an extremely potent greenhouse gas with 300 times more warming potential than carbon dioxide, makes up the largest portion of agriculture's contribution (56 percent)[8] **(Exhibit 4A)**.

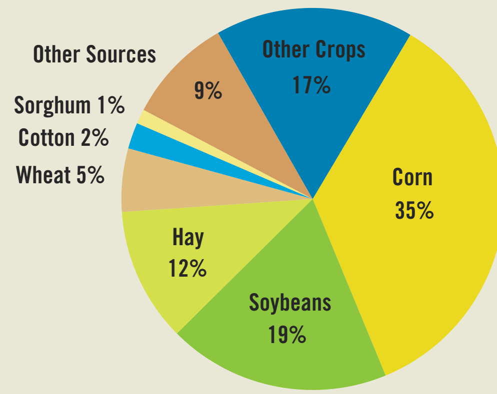
Corn production was the largest contributor to U.S. nitrous oxide emissions from crops in 2008, accounting for 35 percent of the total **(Exhibit 4B)**. Nitrogen can be converted to nitrous oxide directly from fertilizer applied to cornfields (direct emissions account for the majority of nitrous oxide released), or through indirect mechanisms such as leaching, run-off, and volatilization.[9]

Exhibit 4A: Greenhouse Gas Emissions from U.S. Agriculture (2012)



Source: EPA, *Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2012*, February 2014

Exhibit 4B: Nitrous Oxide Emissions by Type of U.S. Crop (2008)



Source: Global Change Program Office, Office of the Chief Economist, USDA, *U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2008*, 2011

Corn grain and silage production require different levels of fertilizer. For silage, the whole corn plant is harvested and shredded for use as livestock feed or in ethanol production. Harvesting silage leaves behind little crop residue on the field, contributing to a greater risk of soil erosion and ultimately requiring more fertilizer because the nutrient removal rate from the soil is greater. For example, corn silage needs on average an extra 20 pounds of nitrogen fertilizer/acre, 30 pounds of phosphate and 115 pounds of potassium than corn grain with comparable yields.[6]

Inefficient fertilizer use increases the risk of pollution to surface and groundwater from leaching and run-off.

When improperly applied, excess fertilizer can pollute groundwater through leaching, or pollute surface water through run-off. Although nitrogen and phosphorus are critical to plant growth, elevated levels of these nutrients in surface water causes excessive algae growth, reducing dissolved oxygen and essentially suffocating aquatic life. According to the EPA, fertilizer that is not absorbed by crops is the leading source of water quality impacts to the country's rivers and lakes and the second largest source of impairments to wetlands.[10]

The leaching of nitrogen fertilizers from soils into groundwater used for domestic water supply also poses risks to human health. Ingesting water with nitrogen in the form of nitrate can be especially harmful to infants, for whom elevated levels of nitrate restricts oxygen transport in the bloodstream leading to a form of suffocation known as "blue baby syndrome." High nitrate levels in water have also been shown to affect thyroid function in adults and have been linked to thyroid

6 G.W. Roth and A.J. Heinrichs, "Corn Silage Production and Management," *Penn State College of Agricultural Sciences Agricultural Research and Cooperative Extension Agronomy Facts* 18 (2001), http://pubs.cas.psu.edu/freepubs/pdfs/uc079.pdf.

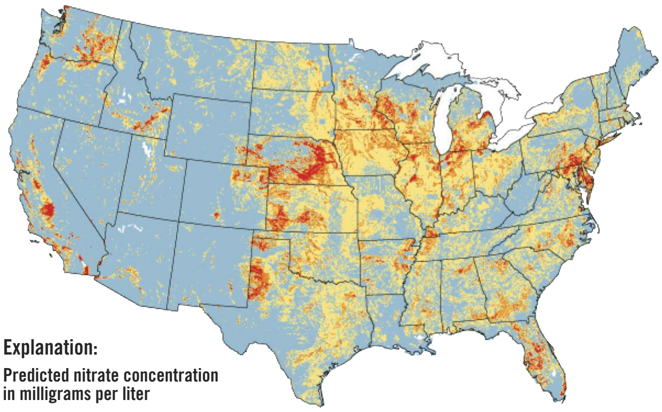
7 US EPA, *Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2012, Chapter 6: Agriculture*, February 21, 2014, http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Chapter-6-Agriculture.pdf.

8 Ibid.

9 Indirect emissions include the conversion of nitrous oxide from nitrate that leaches into the groundwater or runs off the soil surface, or nitrogen that is volatilized to the atmosphere and then deposited back onto soils before being converted to nitrous oxide. Source: Global Change Program Office, Office of the Chief Economist, USDA, *U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2005*, Technical Bulletin No. 1921, August, 2008, http://www.usda.gov/oce/climate_change/AFGG_Inventory/USDA_GHG_Inventory.pdf.

10 US EPA, *Agricultural Nonpoint Source Fact Sheet*, EPA 841-F-05-001, March 2005, http://water.epa.gov/polwaste/nps/agriculture_facts.cfm.

Exhibit 4.4: Areas with Groundwater at Risk from Nitrate Contamination



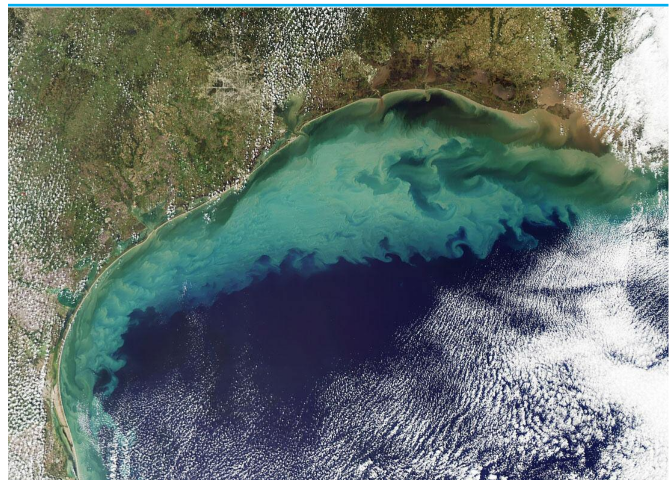
Explanation:
Predicted nitrate concentration in milligrams per liter

≤ 1 | > 1 - 5 | > 5 - 10 | > 10 | Missing Data

A U.S. Geological Survey model for shallow groundwater predicts moderate (yellow and orange) to severe (red) nitrate contamination in areas with large nitrogen sources and where the geologic features allow the nitrate to reach the groundwater. Nitrate concentrations above 10 milligrams per liter exceed the federal drinking water standard.

Source: USGS, U.S. Department of the Interior, *Nutrients in the Nation's Streams and Groundwater, 1992–2004*, by Neil M. Dubrovsky et al., 2010, redrawn from B. Nolan and K. Hitt, "Vulnerability of Shallow Groundwater and Drinking-Water Wells to Nitrate in the United States," *Environmental Science Technology*, vol. 40 (2006), 7834-7840.

Exhibit 4.5: The Gulf of Mexico's "Dead Zone"



The contamination of the Mississippi River Basin by fertilizer promotes the growth of algal blooms that deplete oxygen in the water when they decompose. As a result, every summer a large hypoxic area or "dead zone" forms in the Gulf of Mexico. In 2013, the dead zone covered an area of about 5,800 square miles, roughly the size of Connecticut.

Source: NASA Earth Observatory, acquired with the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite, September 2010

cancer.[11, 12] Many regions in the country with the highest risk for groundwater contamination from nitrates are centered in the Corn Belt **(Exhibit 4.4)**. The U.S. Geological Survey has found high levels of nitrate in the shallow groundwater of more than half of the country's rural watersheds.[13] In 20 percent of these watersheds, the groundwater was unsafe to drink per the EPA's standards for nitrates.[14]

Nutrient pollution from U.S. corn farming is the largest contributor to the Gulf of Mexico's "dead zone."

The Mississippi River Basin drains 40 percent of the contiguous United States into the Gulf of Mexico and is the third-largest watershed in the world.[15] Eighty percent of the country's corn and soybean production is centered in this region[16] and each year, about seven million metric tons of nitrogen from commercial fertilizers are applied to cropland in the watershed.[17]

Nutrient contamination in the Mississippi River and its tributaries promotes the growth of algal blooms, which in turn consume oxygen as they decompose, leading to reduced oxygen levels in water.[18] Such conditions kill fish and other aquatic life or force them to leave in search of more suitable habitats. Every summer a large hypoxic zone or "dead zone" forms in the Gulf of Mexico, covering an area of about 5,800 square miles, roughly the size of Connecticut[19] **(Exhibit 4.5)**.

Run-off from corn and soybean fields into the Mississippi River Basin accounts for more than half of the nitrogen pollution entering the Gulf of Mexico, and one-quarter of the phosphorus pollution[20] **(Exhibit 4.6)**.

11 BA Kilfoy et al., "Dietary nitrate and nitrite and the risk of thyroid cancer in the NIH-AARP Diet and Health Study," *International Journal of Cancer* 129, no. 1 (2011), 160-72, http://www.ncbi.nlm.nih.gov/pubmed/20824705.

12 MH Ward et al., "Nitrate Intake and the Risk of Thyroid Cancer and Thyroid Disease," *Epidemiology* 21, no. 3 (2010), 389-95, http://www.ncbi.nlm.nih.gov/pubmed/20335813.

13 USGS, U.S. Department of the Interior, *Nutrients in the Nation's Streams and Groundwater*, 1992–2004, by Neil M. Dubrovsky et al., Circular 1350, September 23, 2010, http://pubs.usgs.gov/circ/1350/.

14 US EPA, *EPA's Report on the Environment (ROE) (2008 Final Report)*, Washington, DC: National Center for Environmental Assessment, EPA/600/R-07/045F (NTIS PB2008-112484), 2008, http://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=190806.

15 US EPA, *The Mississippi-Atchafalaya River Basin (MARB)*, by Mississippi River Gulf of Mexico Watershed Nutrient Task Force, http://water.epa.gov/type/watersheds/named/msbasin/marb.cfm.

16 Simon Donner and Christopher Kucharik, "Corn-based ethanol production compromises goal of reducing nitrogen export by the Mississippi River," *Proceedings of the National Academy of Sciences of the United States of America* 105, no. 11 (18 Mar. 2008) 4513-4518, http://www.pnas.org/content/105/11/4513.full.

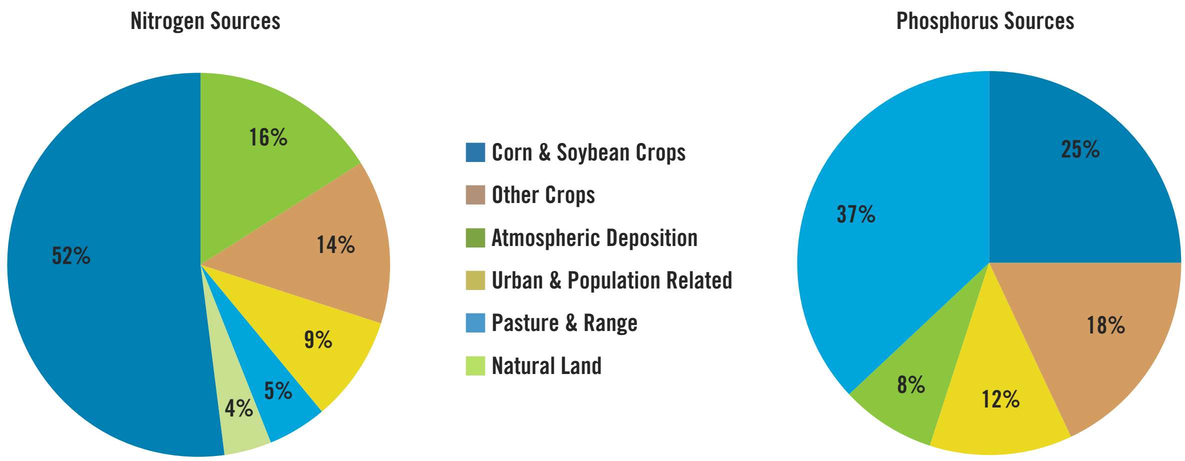
17 USGS, *Changes in Streamflow and the Flux of Nutrients in the Mississippi-Atchafalaya River Basin*, USA, 1980–2007, by William A. Battaglin et al., Scientific Investigations Report 2009–5164, 2010, http://pubs.usgs.gov/sir/2009/5164/pdf/SIR09-5164.pdf.

18 US EPA, *Hypoxia 101*, by Mississippi River Gulf of Mexico Watershed Nutrient Task Force, http://water.epa.gov/type/watersheds/named/msbasin/hypoxia101.cfm.

19 National Oceanic and Atmospheric Administration NCCOS, *2013 Gulf of Mexico Dead Zone Size Above Average But Not Largest*, August 9 2013, http://coastalscience.noaa.gov/news/coastal-pollution/2013-gulf-of-mexico-dead-zone-size-above-average-but-not-largest/.

20 Richard Alexander et al., "Differences in Phosphorus and Nitrogen Delivery to The Gulf of Mexico from the Mississippi River Basin," *Environmental Science Technology* 42, no. 3 (2008), 822–830, http://pubs.acs.org/doi/pdf/10.1021/es0716103.

Exhibit 4.6: Sources of Nitrogen & Phosphorus Entering the Gulf of Mexico



Agricultural run-off from land dedicated to corn and soybeans is responsible for an estimated 52% of the nitrogen and 25% of the phosphorus entering the Gulf of Mexico annually.

Source: Richard Alexander et al., "Differences in Phosphorus and Nitrogen Delivery to The Gulf of Mexico from the Mississippi River Basin," *Environmental Science Technology* 42, no. 3 (2008)

Only one-third of U.S. corn acres are farmed using best practices for nitrogen fertilizer management.

Typically, a relatively small percentage of fertilizer applied to corn is absorbed by the plant, increasing the risk that nutients will leach out of the soil.[21] However, farmers can reduce pollution risk by ensuring they are applying the right amount of fertilizer needed by the crop and by timing fertilizer application to correspond with crop planting. Farmers can also use better methods of applying fertilizer such as through injection or incorporation rather than spraying or "broadcasting" the fertilizer on the soil surface.[22] A USDA study found that in 2010, only 34 percent of corn acres achieved these nitrogen best management practices.[23]

The problem of fertilizer run-off is magnified by changes that have been made to the landscape in many regions of the Corn Belt to support intensive crop production. These include loss of perennial cover of certain grasses and limited cover-cropping (i.e. the use of crops like rye, wheat, oats, or various legumes), as well as agricultural encroachment on wetlands and alterations to the original hydrology of the land through the use of tile drainage (pipes installed below the soil) to remove excess water from fields.[24] These changes have reduced or eliminated natural filtering mechanisms in the environment that would otherwise absorb excess nitrogen and phosphorus and slow down their transport into waterways.

About $420 million-worth of fertilizer from U.S. corn acres was washed into the Gulf of Mexico in 2013.

Studies of corn production practices have shown that as much as 35-45 percent of the nitrogen that farmers apply is not absorbed by the plant.[25] A portion of this excess nitrogen runs off into surface or groundwater, or is converted to nitrous oxide. In any case, this wasted fertilizer represents a significant economic loss to the farmer. In 2012, an estimated 984 million metric tons of nitrogen and phosphorus entered the Gulf of Mexico via the Mississippi River,[26] nearly one-half of which was associated with corn production.[27] Based on 2013 fertilizer costs and typical corn application rates, Ceres calculates that this loss of nutrients from corn acres is equivalent to over $420 million a year in fertilizer sales.[28]

21 Sawyer et al, "Concepts and Rationale for Regional Nitrogen Rate Guidelines for Corn," 2006, Iowa State University Extension.

22 USDA, Natural Resources Conservation Service, *Natural Resources Conservation Service Conservation Practice Standard: Nutrient Management, National Handbook of Conservation Practice*, 2006, http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_022228.pdf.

23 USDA, Economic Research Service, *Nitrogen Management on U.S. Corn Acres, 2001-10*, by Marc Ribaudo, Michael Livingston, and James Williamson, EB-20 November 2012, http://www.ers.usda.gov/publications/eb-economic-brief/eb20.aspx#.U0K6fK1dXd0.

24 McLellan et al, "Reducing Nitrogen Losses from Rowcrop Landscapes in the U.S. Corn Belt: Insights and Implications from a Spatially Explicit Watershed Model," In review, *Journal American Water Resources Association.*

25 Sawyer et al, "Concepts and Rationale for Regional Nitrogen Rate Guidelines for Corn."

26 USGS, *Changes in Streamflow and the Flux of Nutrients in the Mississippi-Atchafalaya River Basin, USA, 1980–2007*, by William A. Battaglin et al., Scientific Investigations Report 2009–5164, 2010, http://pubs.usgs.gov/sir/2009/5164/pdf/SIR09-5164.pdf.

27 Richard Alexander et al., "Differences in Phosphorus and Nitrogen Delivery to The Gulf of Mexico from the Mississippi River Basin," *Environmental Science Technology* 42, no. 3 (2008), 822–830 http://pubs.acs.org/doi/pdf/10.1021/es0716103.

28 Calculated using USDA reported 2008-12 average costs for commonly used fertilizer types. Data sources: USDA, Economic Research Service and USGS, Streamflow and Nutrient Delivery to the Gulf of Mexico.

Drinking water utilities and the commercial fishing and outdoor recreation industries bear the financial burden of nutrient pollution.

Polluted agricultural run-off has significant financial impacts to downstream drinking water utilities. To clean polluted water to safe drinking standards, utilities must remove nitrogen and phosphorus from drinking water, as well as the toxins resulting from algal blooms—typically at significant cost. In addition, chemicals such as chlorine that are often used to disinfect drinking water can also form carcinogenic compounds when they react with algal organic matter.[29]

In 2011, the USDA estimated that the cost of removing nitrates alone from U.S. drinking water supplies by large utilities was more than $4.8 billion per year.[30] Over one-third of this cost, or an estimated $1.7 billion per year, is due to U.S. agriculture's contribution of fertilizers to nitrate loading in surface and groundwater.[31] The water utility that serves the city of Des Moines, Iowa, for instance, sources its drinking water from rivers running through major corn-growing areas, and has been forced to invest in the world's largest nitrate-removal system, costing $7,000/day to operate.[32] Beyond nitrates, the costs of addressing algal blooms and removing toxins created by the blooms are estimated to range between $12 million and $56 million for a town of 100,000 people.[33] According to the USDA, reducing nitrate concentrations by just one percent would have significant savings for water utilities, reducing water treatment costs by over $120 million per year.[34]

Algal blooms and resulting hypoxia caused by excess nutrients in surface water also harm commercial and recreational fishing, recreational beach use and tourism on both fresh and saltwater bodies. The National Oceanic and Atmospheric Administration estimates that harmful algal blooms (not all of which are due to nutrient pollution) cause economic losses of about $38 million per year to U.S. commercial fisheries and $37 million per year in public health costs of associated illness.[35]

States have primary responsibility for addressing nutrient pollution from agriculture.

Nutrient pollution from *point sources* (known pollution discharge locations) are regulated by the federal Clean Water Act (CWA) and are subject to water quality standards, permit requirements and enforcement measures that are promulgated by the EPA and states. Nutrients that enter groundwater and surface water from some agricultural *nonpoint sources* such as farm fields however, are not directly subject to the CWA. In the absence of CWA permitting requirements, state agencies and the USDA sometimes implement voluntary programs aimed at controlling nutrients from nonpoint agricultural sources.[36]

The effectiveness of these voluntary programs to control nutrient pollution associated with agricultural run-off has been criticized for decades while the growing dead zone in the Gulf of Mexico has garnered increased national attention. In 1997, the U.S. government responded by creating the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force made up of federal and state agencies with the goal of addressing hypoxia in the Gulf of Mexico and reducing the dead zone's size to 1,930 square miles by a variety of actions including the development of state-level nutrient reduction strategies.[37] As of September 2013, only five[38] of the 12 states participating in the Task Force had finalized or released drafts of their nutrient reduction strategies, with the rest expected to have draft strategies completed by 2014.[39]

Although state-level actions appear less tepid now than in the past, the slow pace of progress prompted environmental groups in 2012 to sue the EPA. As a result of this lawsuit in the fall of 2013, a federal district court ruled that the EPA must take action to assess whether state water quality standards are sufficiently addressing nutrient loading in the Mississippi River and at its mouth in the Gulf of Mexico.[40] If the EPA deems state standards to be insufficient, the agency will be required to propose new standards to fulfill the requirements of the Clean Water Act. This could pave the way for federal action to address the phosphorus and nitrogen pollution with numeric limits and stricter pollution controls.

29 Olga Naidenko, Craig Cox, and Nils Bruzelius, "Troubled Waters, Farm Pollution threatens Drinking Water," *Environmental Working Group*, April 2012, http://static.ewg.org/reports/2012/troubled_waters/troubled_waters.pdf.

30 USDA, Economic Research Service, *Nitrogen in Agricultural Systems: Implications for Conservation Policy*, 2011.

31 Ibid.

32 "Historic Nitrate Levels in Des Moines Water Works' Source Water," *Des Moines Water Works*, May 2013, http://www.dmww.com/about-us/news-releases/historic-nitrate-levels-in-des-moines-water-works-source-water.aspx.

33 Naidenko et al, "Troubled Waters, Farm Pollution Threatens Drinking Water."

34 USDA, Economic Research Service, *Nitrogen in Agricultural Systems: Implications for Conservation Policy*, 2011.

35 National Oceanic and Atmospheric Administration, *Nutrient Pollution Impacts Coastal Residents and Economies,* NOAA's State of the Coast, http://stateofthecoast.noaa.gov/hypoxia/impacts.html.

36 "Controlling Nutrient Loadings to U.S. Waterways: An Urban Perspective," *National Association of Clean Water Agencies*, Oct. 2011, http://www.nacwa.org/images/stories/public/2012-03-06wp.pdf.

37 US EPA, *Hypoxia Task Force Annual Report 2011, Moving Forward on Gulf Hypoxia*, by Mississippi River Gulf of Mexico Watershed Nutrient Task Force, 3, http://water.epa.gov/type/watersheds/named/msbasin/upload/Hypoxia_Task_Force_Annual_Report_2011.pdf.

38 Indiana, Iowa, Mississippi, Ohio and Wisconsin.

39 US EPA, *Reassessment 2013: Assessing Progress Made Since 2008*, by Mississippi River Gulf of Mexico Watershed Nutrient Task Force, http://water.epa.gov/type/watersheds/named/msbasin/upload/hypoxia_reassessment_508.pdf.

40 Gavin Broady, "EPA Must Make A Call On Algae-Choked Dead Zones Petition," *Law360*, 23 Sept. 2013, http://www.law360.com/articles/474651/epa-must-make-a-call-on-algae-choked-dead-zones-petition.

Companies sourcing corn from watersheds with high levels of nutrient pollution may be exposed to regulatory and market risks.

Growing regulatory and supply chain focus on improvements in fertilizer management and reductions in nitrogen and phosphorus pollution highlight potential risks for both farmers and companies sourcing U.S. corn. The estimated costs of implementing state nutrient management strategies that contribute to the EPA's goal of reducing the size of the dead zone are significant. For example, Iowa's draft strategy for reducing both nitrogen and phosphorus loads from agriculture by 45 percent has been estimated to require an initial capital investment between $1.2-4 billion, and annual operating costs between $77 million-$1.2 billon.[41] The degree to which farmers will bear this cost (versus state and federal coffers) is unclear.

At the same time, food retailers like Walmart and processed food and beverage companies including General Mills, Coca-Cola and Kellogg are putting growing expectations on farmers in their supply chains to reduce inefficient fertilizer use and associated water pollution and greenhouse gases. Walmart in particular recently set a goal to improve the fertilizer application efficiency of U.S. row crop farmers in its food supply chain by 30 percent by 2020 **(Exhibit 4.7)**.

Exhibit 4.7: Walmart's Fertilizer Reduction Initiative

Walmart, the country's largest food retailer, announced in September 2013 a goal for its top food suppliers to work with U.S. farmers to optimize their fertilizer use and reduce greenhouse gas emissions on 10 million acres of corn, wheat and soybeans by 2020. The company wants farmers in its supply chain to profitably reduce loss of fertilizer nutrients to the environment, and in areas where fertilizer use is too high, to increase efficiency of fertilizer use by 30 percent. ***Walmart "…expect[s its] top food supplier partners to recognize, support, and grow these programs by developing plans with clear milestones and timelines. Our merchant and supplier teams will be measured by their level of integration of sustainability into standard business processes."***

The company projects that achieving its 2020 goal will lead to reductions in nutrient pollution to the water supply, improved soil health, and a reduction of over seven million metric tons of greenhouse gases.

Source: "How to Make A Difference: Fertilizer Optimization," Walmart Sustainability Hub, http://www.walmartsustainabilityhub.com/app/answers/detail/a_id/219/session/L3RpbWUvMTM4MDEzMjYwNS9zaWQvanNuKkRkQmw%3D

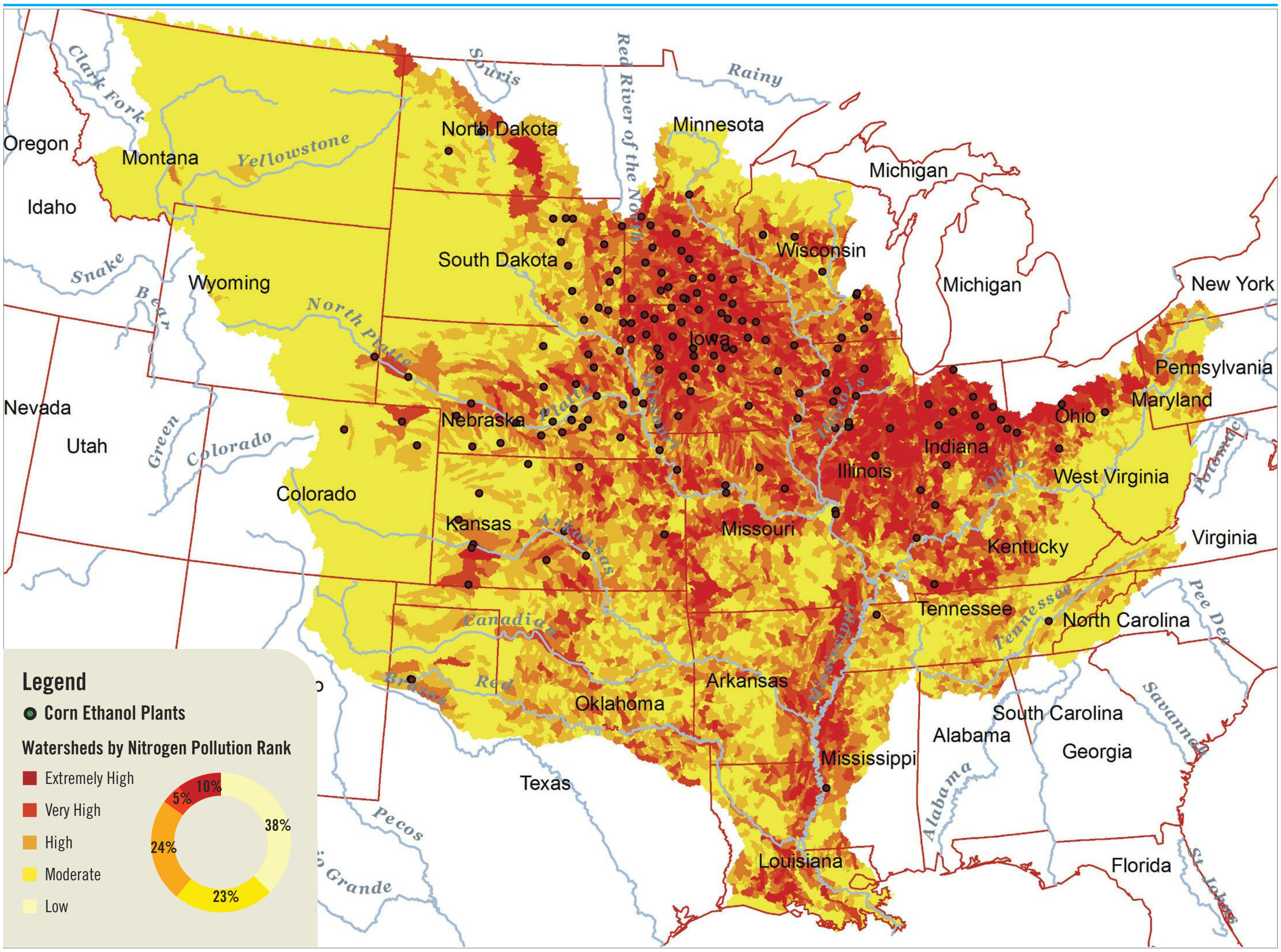
41 "Iowa Nutrient Reduction Strategy," Section 2.1 Executive Summary: Iowa Science Assessment of Nonpoint Source Practices to Reduce Nitrogen and Phosphorus Transport in the Mississippi River Basin, prepared by Iowa State University Science Team, July 2012, http://www.nutrientstrategy.iastate.edu/sites/default/files/documents/NRS2.pdf.

Sixty U.S. ethanol refineries are sourcing corn from watersheds in the Mississippi River Basin with high nitrogen pollution levels.

Ethanol companies currently purchase about 35 percent of the annual U.S. corn crop for use at approximately 200 corn-based refineries, the majority of which (85 percent) are located in the Mississippi River Basin.[42] Most corn ethanol refineries are located near cornfields and typically source the majority of their feedstock from farms within a 50-mile radius.[43] The locations of these refineries and their sourcing radiuses were analyzed against regional water quality maps for nitrogen pollution using the U.S. Geological Survey's SPARROW tool (see **Appendix C** for a detailed methodology).

Exhibit 4.8 shows ethanol refinery locations in the Mississippi River Basin against watersheds ranked by the level of local nitrogen pollution coming from agricultural sources such as commercial fertilizers or manure. Sixty

Exhibit 4.8: Ethanol Refineries in Watersheds with High Local Nitrogen Pollution from Agriculture



Corn ethanol refineries locations are overlaid against watersheds in the Mississippi River Basin ranked by their relative contribution of agriculture-related nitrogen pollution to local waterways. Ethanol plants located in red or dark red watersheds are likely sourcing corn feedstock from regions where agricultural-related nitrogen pollution is a major contributor to the impairment of local water quality. Sixty corn ethanol refineries with $8.8 billion in annual corn ethanol production capacity are located in watersheds with "high" or above delivery of nitrogen pollution to local waterways.

For an interactive version of this map, see www.ceres.org/cornmaps

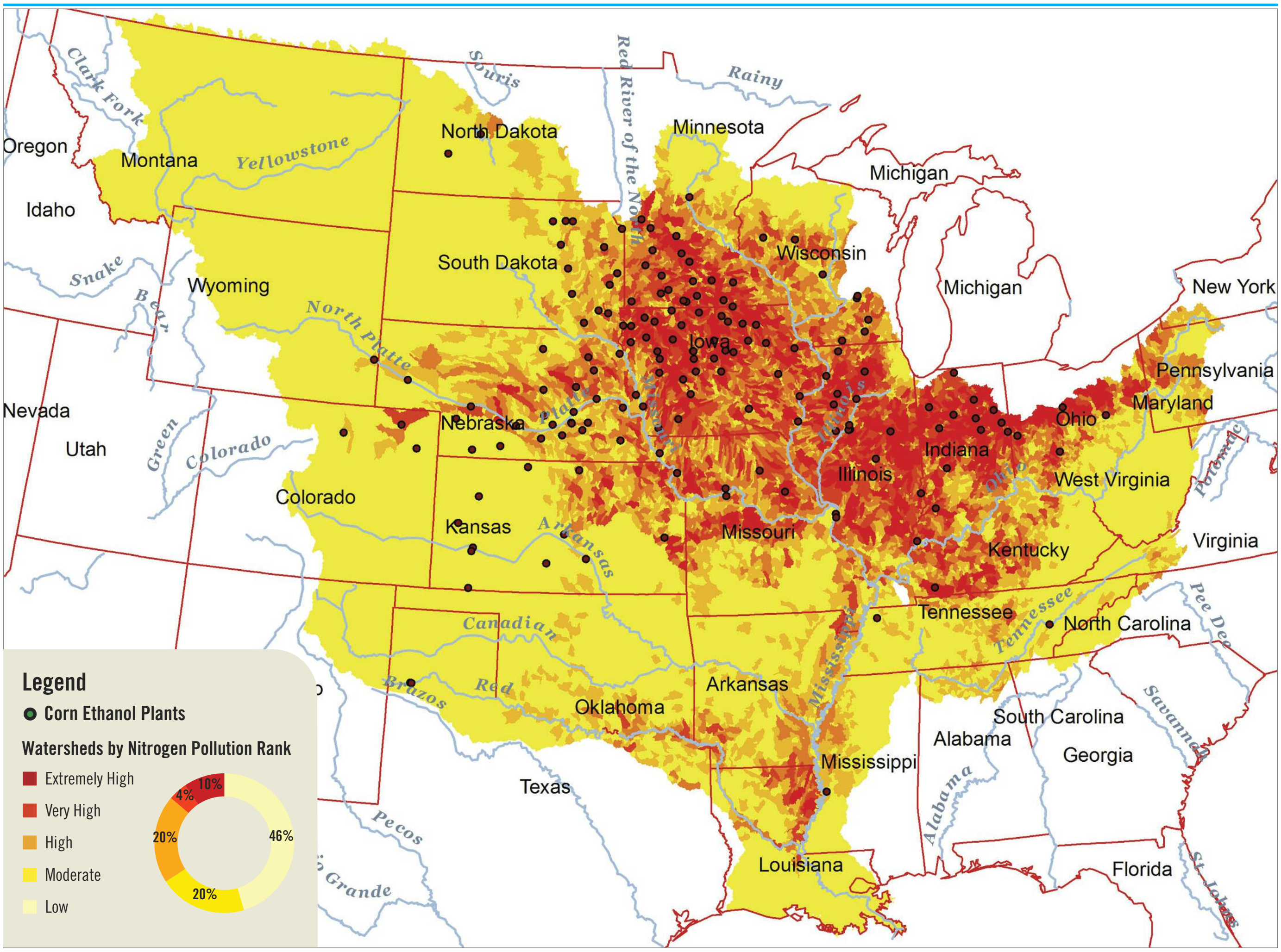
Source: Ceres, using data from the Renewable Fuels Association and USGS SPARROW. GIS mapping by Agricultural Conservation Economics.

42 Ceres analysis based on data from the Renewable Biofuels Association.

43 USDA, Agricultural Marketing Service, *Ethanol Transportation Backgrounder*, September 2007, http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5063605.

corn ethanol refineries with $8.8 billion in annual corn ethanol production capacity are located in watersheds with "high," "very high" or "extremely high" delivery of nitrogen pollution to local waterways. When analyzing the nitrogen delivery levels of specific watersheds to Gulf of Mexico pollution (i.e. the amount of nitrogen loading that is ultimately transported from a watershed into the main stem of the Mississippi River and into the Gulf), it was found that 51 refineries with $7.7 billion in annual corn ethanol production are in watersheds with "high," "very high" or "extremely high" delivery of nitrogen pollution to the Gulf of Mexico **(Exhibit 4.9)**.

Exhibit 4.9: Ethanol Refineries in Watersheds with High Delivery of Nitrogen Pollution to the Gulf of Mexico



Corn ethanol refineries locations are overlaid against watersheds in the Mississippi River Basin ranked by their relative contribution of agriculture-related nitrogen pollution to the Gulf of Mexico. Ethanol plants located in red or dark red watersheds are likely sourcing corn feedstock from regions where a high level of local agricultural-related nitrogen pollution leaves the watershed, and is transported onto the Mississippi River and ultimately to the Gulf of Mexico. Fifty-one refineries with $7.7 billion in annual corn ethanol production are in watersheds with "high" or above delivery of nitrogen pollution to the Gulf of Mexico.

For an interactive version of this map, see www.ceres.org/cornmaps

Source: Ceres, using data from the Renewable Fuels Association and USGS SPARROW. GIS mapping by Agricultural Conservation Economics.

Exhibit 4.10: **Ethanol Companies Ranked by Exposure to High Nitrogen Pollution Watersheds in the Mississippi River Basin**

Exposure to High Local Nitrogen Pollution Watersheds in the Mississippi River Basin			
Company	Ethanol Design Capacity in Watersheds Where Agricultural Production Contributes to High Local Nitrogen Pollution (Millions of Gallons/Year)	Annual Value of Ethanol Production from High Pollution Watersheds	Percent of Corn Ethanol Production Capacity in Watersheds Where Agricultural Production Contributes to High Local Nitrogen Pollution
POET Biorefining	883	$1,660,040,000	54%
Valero Renewable Fuels (VLO)	660	$1,240,800,000	58%
Flint Hills Resources LP	440	$827,200,000	67%
Green Plains Renewable Energy (GPRE)	220	$413,600,000	22%
Big River Resources, LLC	200	$376,000,000	57%
Cargill	115	$216,200,000	33%
The Andersons Ethanol LLC	110	$206,800,000	33%
Louis Dreyfus Commodities	100	$188,000,000	69%
Archer Daniels Midland (ADM)	40	$75,200,000	3%

Data sources: Ethanol refinery data from the Renewable Fuels Association. Nitrogen loading data from USGS SPARROW. GIS by Agricultural Conservation Economics. Using average Chicago ethanol (Platts) price between 4/30/13-4/30/14, $1.88/gallon.

Several large ethanol producers have more than 50 percent of their production capacity in watersheds with high local nitrogen pollution. POET Biorefining has the most capacity in high pollution watersheds (883 million gallons/year), followed by Valero Renewable Fuels (660 million gallons/year), and Flint Hill Resources (440 million gallons/year) **(Exhibit 4.10)**.

Recommendations for Reducing Risk in U.S. Corn Production

America's corn growers are among the most productive and technologically advanced in the world. Resilient and innovative, they have a strong track record of adopting stewardship practices that support long-term productivity and enhance the value of their land. For example, corn growers as a whole have embraced the lessons of the Dust Bowl, and dramatically improved tilling practices in recent years, leading to an overall reduction in soil erosion of 67 percent between 1980 and 2011.[1]

Today, U.S. corn growers—and the companies that depend on their output—must tackle a new set of challenges related to water resources and climate change. These include increasingly severe droughts, floods and heat waves, as well as inefficient irrigation practices and high collective demands on strained groundwater resources that threaten the long-term sustainability of corn-growing in many regions. Additionally, fertilizer practices that accelerate the flow of nutrient pollution into surface and groundwater continue to degrade water resources and necessitate costly water treatment.

These challenges interact and reinforce each other, creating mounting risks for farmers and the companies that buy their products. Fortunately, there are a number of proven farming practices that can be implemented to reduce many water-related risks, while also creating value for corn growers. Supply chain efforts that provide farmers with the agronomic expertise, incentives and assurances to experiment with new practices will also be critical to accelerate adoption.

This chapter highlights some of the farming practices that can help reduce the risks facing America's corn farmers (while in many cases improving productivity) and provides recommendations for companies that source U.S. corn—and their investors—on how to be key partners in ensuring the long-term sustainability of agricultural production.

1 Field to Market, "Corn Environmental Results," 2012, http://www.fieldtomarket.org/report/national-2/FINAL_Fact_Sheet-Env_Results_Corn_081913.pdf.

Farming Practices That Reduce Risk

Given the vast differences in farm size, soil types, local climates, water resources, and farming systems among U.S. corn growers, there can be no one-size-fits-all prescription for reducing farmers' exposure to climate change and water supply and quality risks. Nevertheless, there are many proven practices and relatively low-cost technologies that can be used to improve soil health and thus strengthen resilience to drought and floods; reduce dependency on imperiled groundwater; and significantly improve fertilizer use efficiency while reducing field run-off and greenhouse gas emissions. Some of these farming practices, such as conservation tillage, are already in widespread use, while many others have lower adoption levels but significant potential to improve yields and protect crops from the impacts of extreme weather **(Exhibit 5.1)** (see **Appendix D** for further details).

Exhibit 5.1: Farming Practices that Reduce Environmental Risks

Practice	Description	Risks Addressed	Level of Adoption	Economic Benefits
Conservation Tillage	Traditional tillage involves plowing soil to prepare for seeding and control pests and weeds. "Conservation" or low/no-tillage practices involve seeding directly into crop residues rather than disturbing the soil.	✓ Drought ✓ Irrigation Demand ✓ Soil Erosion ✓ Nutrient Pollution	Low-till was practiced on 51% of corn acres in 2005.[2] No-till was practiced on 24% of corn acres in 2005 (projected at 30% in 2009).[3]	No-till corn yielded 24% more bushels/acre and used 32% fewer gallons of water/year in 2010.[4] In 2010, no-till corn farmers were 30% less likely than conventional till farmers to receive a Federal Crop Insurance indemnity payment.[5] It has been estimated that if all U.S. farmers implemented no-till systems, $224 million in indemnities could have been avoided in 2010.[6]
Crop Rotation	Planting of corn and soybeans (or corn and a forage crop) on the same plot in alternating years in order to improve soil health and reduce fertilizer needs. Extending rotation to a third crop further improves soil health and reduces input requirements.[7]	✓ Drought ✓ GHG Emissions ✓ Irrigation Demand ✓ Soil Erosion ✓ Nutrient Pollution	In 2011 and 2012, 78% of total corn acres were planted in rotation with soybeans and/or other crops.[8]	Input costs are lower because less fertilizer and pesticide is required and corn yields are typically between 13-19% higher after soybean plantings.[9] While recently high corn prices have drawn some farmers toward planting corn year-on-year, one recent study demonstrates that always rotating, regardless of prices, has optimal economic returns.[10]
Cover Crops	Cover crops are non-commodity crops planted to protect and improve the soil.	✓ Drought ✓ Irrigation Demand ✓ Soil Erosion ✓ Nutrient Pollution	Only about 7% of U.S. row crop farmers planted cover crops in 2012.[11, 12] In the Mississippi River Basin, less than 2% of cropland had cover crops in 2011.[13]	Cover crops require additional upfront time and investment, but have been shown to increase yields in the short term[14] and increase yield potential and stability over time.[15] In 2012, corn planted after cover crops had 9.6% yield advantage over fields with none. Yield gains were even higher for areas hardest hit by the drought, with an 11% yield advantage for corn planted after cover crops.[16]

2 USDA, *"No-Till" Farming Is a Growing Practice*, by John Horowitz, Robert Ebel, and Kohei Ueda, Economic Information Bulletin No. (EIB-70), November 2010, http://www.ers.usda.gov/publications/eib-economic-information-bulletin/eib70.aspx#.U0WicuZdXd0.

3 Ibid.

4 Claire O'Connor, "Soil Matters: How the Federal Crop Insurance Program should be reformed to encourage low-risk farming methods with high-reward environmental outcomes," *Natural Resources Defense Council*, Issue Paper: 13-04-A, August 2013, http://www.nrdc.org/water/soil-matters/files/soil-matters-IP.pdf

5 Ibid.

6 Ibid.

7 Adam Davis et al, "Increasing cropping system diversity balances productivity, profitability and environmental health," PLoS ONE 7(10): e47149. doi:10.1371/journal.pone.0047149, http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0047149

8 A total 97.2 million acres were planted to corn in 2012. Source: USDA, National Agricultural Statistics Service Database (2012), http://quickstats.nass.usda.gov/.

9 Liz Morrison, "Including soybeans in crop rotation provides advantages," *Corn and Soybean Digest*, September 25, 2013, http://cornandsoybeandigest.com/soybeans/including-soybeans-crop-rotation-provides-advantages.

10 USDA, University of Hawaii, *Optimal Sequential Plantings of Corn and Soybeans Under Price Uncertainty*, by Michael Livingston, Michael Roberts and Yue Zhang, 2012, http://www2.hawaii.edu/~mjrobert/main/Working_Papers_files/AJAE_revise.pdf.

11 Conservation Technology Information Center and USDA North Central Sustainable Agriculture Research & Education, *2012–2013 Cover Crop Survey: June 2013 Survey Analysis*, http://www.northcentralsare.org/educational-resources/From-the-Field/Cover-Crops-survey-analysis.

12 According to a March 2013 Amber Waves article, "Only about 3 to 7 percent of farms use cover crops in rotations, and, since these operations do not put all of their land into cover crops, only 1 percent of cropland acreage uses cover crops." USDA, Economic Research Service, "While Crop Rotations Are Common, Cover Crops Remain Rare," by Steven Wallander, March 04, 2013, http://www.ers.usda.gov/amber-waves/2013-march/while-crop-rotations-are-common,-cover-crops-remain-rare.aspx#.U0Wr3-ZdXd1.

13 Lara Bryant, Ryan Stockwell and Trisha White, "Counting Cover Crops," *National Wildlife Federation*, 2013, http://www.nwf.org/~/media/PDFs/Media%20Center%20-%20Press%20Releases/10-1-13_CountingCoverCrops-FINALlowres.ashx.

14 Humberto Blanco-Canqui et al., "Summer Cover Crops Fix Nitrogen, Increase Crop Yield, and Improve Soil-Crop relationships," *Agronomy Journal*, 104 no. 1 (2012), 137-147.

15 S. Snapp et al., "Evaluating Cover Crops for Benefits, Costs and Performance Within Cropping System Niches," Agronomy Journal, 97 no. 1 (2005), 322-332.

16 *2012-2013 Cover Crop Survey*, Sustainable Agriculture Research and Education.

Practice	Description	Risks Addressed	Level of Adoption	Economic Benefits
Efficient Irrigation	More efficient irrigation systems include low-pressure center pivot systems and drip/trickle systems, as well as the use of efficient irrigation technologies such as soil moisture monitors to schedule irrigation given unique plant, soil, and climate characteristics.[17, 18]	✔ Drought ✔ Irrigation Demand ✔ Soil Erosion ✔ Nutrient Pollution	As of 2008, 22% of irrigated corn acres still used inefficient flood or furrow irrigation.[19] Very few corn grain acres (0.1%) used subsurface drip or micro irrigation.[20] As of 2008, less than 15% of farms in the corn-growing states of Kansas, Nebraska and Texas used modern approaches for determining irrigation needs such as soil and plant-moisture sensing devices.[21]	The upfront installation costs for more efficient irrigation technologies can be relatively high.[22] However, depending upon the type of irrigation technology as well as the specific farming system, the cost of installing or upgrading the irrigation system can be earned back in a few years time.[23] Increases in revenue stemming from higher yields, reduced fertilizer requirements, reductions in pumping costs[24] and improvements in logistics may also offset the cost of adopting drip irrigation systems, as well as enable production of crops in areas with severely limited water resources.[25]
Nutrient Management	Best nutrient management practices match the type and amount of fertilizer to crop needs, minimize the loss of fertilizer, and enhance plants' capability to absorb nutrients.[26] Best practices for improving nitrogen use efficiency relate to the proper nutrient application rate, the timing of the application, and the application method.[27]	✔ GHG Emissions ✔ Nutrient Pollution	Only 34% of U.S. corn acres met all three management criteria (rate, timing, and method) in 2010.[28]	Reducing fertilizer use and/or increasing efficiency also assists farmers in managing high fertilizer costs.[29] Yields may also benefit.[30] There are also significant cost-savings for the public from reducing the amount of treatment required to remove nitrate from drinking water supplies.[31] According to the USDA, reducing nitrate concentrations by 1% would reduce water treatment costs in the U.S. by over $120 million per year.[32]
Precision Agriculture	Precision technologies increase production efficiency and save on fuel use by gathering information during field operations and calibrating application of inputs and water. Four key information technologies support precision agriculture: yield monitors, variable-rate application technologies (VRTs), guidance systems and GPS maps.	✔ GHG Emissions ✔ Irrigation Demand ✔ Soil Erosion ✔ Nutrient Pollution	Yield monitoring was used on 40-45% of U.S. corn and soybean acres as of 2005-6, but very few growers have adopted VRTs or GPS maps. Nationally, VRTs were used on only 12% of corn acres in 2005.[33] The adoption rate is slightly higher in the Corn Belt, where VRTs and GPS maps were used on 16% and 24% of corn acres in 2005.[34]	Corn yields are higher for farmers using yield monitors, variable rate fertilizer equipment, and GPS mapping technologies, than for farmer not using these precision technologies.[35] Corn farmers that use yield monitors and VRTs also had lower per-acre fuel expenses.

17 R. Huang, C. J. Birch and D. L. George, "Water Use Efficiency in Maize Production," (paper presented at 6th Triennial Conference of the Maize Association of Australia, Griffith New South Wales Australia, February 21-23 2006), http://www.researchgate.net/publication/43468291_Water_use_efficiency_in_maize_production_-_the_challenge_and_improvement_strategies/file/9fcfd50caa42c95d36.pdf.

18 William Kranz et al., "Irrigation Management for Corn," *University of Nebraska-Lincoln Extension NebGuide*, G1850 (2008), http://www.ianrpubs.unl.edu/live/g1850/build/g1850.pdf.

19 USDA, National Agricultural Statistics Service, Farm & Ranch Irrigation Surveys (1994-2008).

20 Ibid.

21 USDA, National Agricultural Statistics Service, Farm & Ranch Irrigation Surveys (1994-2008).

22 USDA, Economic Research Service, *Agricultural Resources and Environmental Indicators*, 2012 edition, by Craig Osteen et al., Economic Information Bulletin No. 98 August 2012, http://www.ers.usda.gov/publications/eib-economic-information-bulletin/eib98.aspx#.U0WlJuZdXd0.

23 "Financial Benefits of Drip Irrigation," *DripIrrigation.org*, http://www.dripirrigation.org/financial_benefits.html.

24 Lisa Pfeiffer and C.Y. Lin "The Effects of Energy Prices on Groundwater Extraction in Agriculture in the High Plains Aquifer," paper presented at 2014 Allied Social Sciences Association (ASSA) Annual Meeting, Philadelphia, PA, January 3-5, 2014, http://ageconsearch.umn.edu/bitstream/161890/2/Pfeiffer%20and%20Lin.pdf

25 ASABE Annual International Meeting Sponsored by ASABE, Pittsburgh, Pennsylvania June 20—June 23, 2010), http://www.dripirrigation.org/images/Toro_Drip_on_Field_Crops_May_2010.pdf.

26 USDA, Economic Research Service, *Agricultural Resources and Environmental Indicators*.

27 USDA, Natural Resources Conservation Service (USDA, NRCS), 2006. "Natural Resources Conservation Service Conservation Practice Standard: Nutrient Management," *National Handbook of Conservation Practice.*

28 Ribaudo, Marc, Michael Livingston, and James Williamson. *Nitrogen Management on U.S. Corn Acres, 2001-10*, EB-20. USDA, Economic Research Service, November 2012.

29 Ibid.

30 USDA ERS, *Agricultural Resources and Environmental Indicators 2012*.

31 The cost of removing nitrate from U.S. drinking water is over $4.8 billion per year, and agriculture's contribution to the nitrate concentrations accounts for $1.7 billion per year. Marc Ribaudo et al, *Nitrogen in Agricultural Systems: Implications for Conservation Policy*.

32 Ribaudo et al, *Nitrogen in Agricultural Systems: Implications for Conservation Policy*.

33 USDA, Economic Research Service, "On the Doorstep of the Information Age: Recent Adoption of Precision Agriculture," by David Schimmelpfennig and Robert Ebel, EIB-80, August 2011, http://www.ers.usda.gov/publications/eib-economic-information-bulletin/eib80.aspx#.U1-8Fq1dWwg.

34 Ibid.

35 Ibid.

Practice	Description	Risks Addressed	Level of Adoption	Economic Benefits
Conservation Structures & Vegetative Measures	Structures and vegetation such as grassed waterways, grade stabilization structures, filter strips, riparian buffers and wetlands reduce soil erosion and nutrient run-off.	✓ Soil Erosion ✓ Nutrient Pollution ✓ Irrigation Demand	In 2010, erosion control structures were used on about 55% of highly erodible land (HEL) planted to corn, about 12% of all non-HEL planted to corn, and about 18% of all land planted to corn.[36] In 2010, conservation buffers were used on about 20% of HEL planted to corn, about 10% of all non-HEL planted to corn, and about 11% of all land planted to corn.[37]	While the installation can be expensive, the USDA NRCS supports farmers through the Conservation Reserve Program (CRP) and the Environmental Quality Incentives Program (EQIP). There are also long-term cost savings in terms of improving retention and management of water resources, reduced soil erosion and reduced nutrient run-off (reducing water treatment costs).[38]

Beyond-the-Field Measures that Protect Water Quality

Reducing water quality impacts associated with agriculture doesn't stop at the field's edge. Watershed-level approaches are important for coordinating individual farmers' installation of measures that protect water quality both at the field-level as well as within their region as a whole. There are numerous measures that can restore nutrient processing capacity to farmland and the surrounding areas, including terraces, grassed waterways, grade stabilization structures, filter strips, and riparian buffers. In many cases, these practices can provide significant water quality benefits despite occupying only two percent of the landscape, often in areas where cropland is less productive.[39]

In Iowa, for instance, a recent assessment determined that installing wetlands to treat 45 percent of all row crop acres in the state could reduce nitrogen run-off by 22 percent, and the installation of bioreactors on all tile-drained acres could reduce nitrogen run-off by 18 percent.[40, 41]

Current Barriers to Implementation

While the USDA and the Farm Bill provide incentives for farmers to take on some of these agricultural management practices, growers may choose not to implement them for a number of reasons. Some obstacles to adoption include farmer knowledge of the on-farm and off-farm consequences of their practices, concern that resource conservation practices may reduce yields, landlord-tenant or lease issues that discourage installation and maintenance of conservation systems and practices,[42] and a Federal Crop Insurance Program that does not reward farmers for adopting risk-reducing practices.[43] With respect to water efficiency in particular, cheap or free irrigation water, and "use it or lose it" water rights can also pose challenges. The voluntary adoption of conservation-oriented practices is often self-funded, or when USDA agencies provide partial financial support, farmers may simply lack the cash or credit to fund their share of the implementation.[44] In some cases, long wait-lists or limited funding for farmers interested in participating in USDA programs further limits implementation.

The Role of Companies that Buy Corn

For companies dependent on U.S. corn production, there are compelling reasons to examine the risks facing their corn purchases and the opportunities available to them to encourage more resilient agricultural practices. Today, the majority of U.S. corn goes to market through a relatively complex supply chain starting with initial sorting and

36 USDA, ERS, Agricultural Resources and Environmental Indicators 2012.

37 Ibid.

38 Ribaudo et al, *Nitrogen in Agricultural Systems: Implications for Conservation Policy.*

39 "Reducing Nitrogen Export from the Corn Belt to the Gulf of Mexico: Agricultural Strategies for Remediating Hypoxia," E. McLellan, D. Robertson, K. Schilling, M. Tomer, J. Kostel and K. King (2014), Journal of the American Water Resources Association, in press.

40 Iowa State University Science Team, "Summary—Iowa Science Assessment of Nonpoint Source Practices to Reduce Nitrogen and Transport in the Mississippi River Basin," Iowa State University, pp. 33-41, http://www.nutrientstrategy.iastate.edu/sites/default/files/documents/NRS2.pdf.

41 AGree, "Collaborative Management of Agricultural Landscapes: Achieving Measurable Conservation Improvements," (workshop report for June 2013), http://www.foodandagpolicy.org/sites/default/files/AGree%20PEO%20report_June%2027.pdf.

42 USDA, National Resources Conservation Services, *People, Partnerships and Communities: The Adoption and Diffusion of Conservation Technologies*, Issue 7, June 2005, http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1045558.pdf

43 Claire O'Connor, "Soil Matters: How the Federal Crop Insurance Program should be reformed to encourage low-risk farming methods with high-reward environmental outcomes."

44 USDA, National Resources Conservation Services, *People, Partnerships and Communities: The Adoption and Diffusion of Conservation Technologies.*

grading at grain elevators, followed by processing and refining at separately-owned corn mills, which is subsequently purchased and sometimes processed further by food, beverage, and meat companies. This complexity and the comingling of grain that occurs at the elevator level poses challenges to companies seeking to identify the ultimate geographic origins of their corn inputs, or to set higher sustainability standards for corn producers in their supply chain.

"Today, the majority of U.S. corn goes to market through a relatively complex supply chain starting with initial sorting and grading at grain elevators, followed by processing and refining at separately-owned corn mills."

Fortunately, there are various initiatives underway that are seeking to help companies overcome these obstacles by providing more visibility down their supply chain, as well as by supporting growers in reducing their exposure to water and climate risks.

The Sustainability Consortium

One relevant initiative is the Sustainability Consortium, a network of retailers, consumer product companies, universities and NGOs that is developing ways to identify and measure the environmental impacts of consumer products across a product's lifecycle, from raw materials to consumer use. Launched and initially funded by Walmart to support the company's goal of assessing the environmental impacts of its suppliers' goods, the environmental data generated by the Sustainability Consortium is now being used as part of Walmart's supplier evaluation process, known as the Sustainability Index.[45]

The Sustainability Consortium has a Food, Beverage and Agriculture working group comprised of nearly 100 companies, academics and NGOs that is developing environmental data and key performance indicators relevant to various agricultural commodity supply chains. The working group is also beginning to undertake research to help food and beverage companies better understand the origins and trade flows of the various agricultural commodities they source. This process, and its tie to the Walmart supplier evaluation process, is creating new incentives for commodity supply chains participants to enhance transparency in these systems and identify ways to support farmer adoption of more resilient agricultural practices.

Field to Market: The Alliance for Sustainable Agriculture

Field to Market is a multi-stakeholder initiative involving major growers associations, agribusinesses, food companies, retailers, conservation organizations, universities and agency partners working to define, measure, and develop a supply chain system for agricultural sustainability for U.S. row crops. Field to Market was initially launched with the goal to produce a set of environmental indicators for major U.S. row crops including corn that could be used to substantiate environmental performance progress made by growers.

This work has evolved to leverage these environmental performance indicators for self-assessment and benchmarking by farmers in the form of an online resource called the Fieldprint Calculator.[46] Developed with the assistance of the USDA's Natural Resources Conservation Service, the tool enables growers to compare their environmental performance against county, state and national averages, as well as model how a change in agricultural practices may affect overall environmental and financial outcomes. Indicators measured by the tool include energy use and greenhouse gas emissions, irrigated water use, soil carbon, soil erosion, and water quality.

Thirteen pilot projects using the Fieldprint Calculator that involve a variety of crops are currently underway across the country.[47] These pilot projects are sponsored by buyers and other supply chain players, and enlist growers in using the tool to better understand their environmental impacts and to identify areas for potential improvement. For example, Kellogg and Bunge are partnering with The Nature Conservancy in the Corn Belt to help corn growers implement practices that minimize nutrient run-off and greenhouse gas emissions, while also tracking the environmental impacts of these changes using the Fieldprint Calculator. Coca-Cola is conducting a similar pilot with corn growers in Michigan in partnership with the World Wildlife Fund **(Exhibit 5.2)**. Results are giving farmers an opportunity to compare their inputs, outputs, practices and environmental impacts in a confidential format.

Field to Market now seeks to build on these pilot projects to develop a protocol for enabling buying companies to track the environmental performance improvements of farmers in their supply chain over time. As part of this, it is developing a process for third-party verification to enable public reporting of these improvements.

45 Walmart, "Sustainability Index," http://corporate.walmart.com/global-responsibility/environment-sustainability/sustainability-index.

46 See "Fieldprint Calculator," Field to Market, http://www.fieldtomarket.org/fieldprint-calculator/.

47 Lynn Grooms, "Big food companies make moves to source sustainably," *Farm Industry News*, December 10, 2013, http://farmindustrynews.com/business/big-food-companies-make-moves-source-sustainably?page=1.

Recommendations for Companies and Investors

Given the significant new challenges facing U.S. corn production and the industries that depend on it, investors need to understand how their portfolio companies in the grain processing, food, beverage, livestock, ethanol and grocery sectors are managing these risks. Due to the level of climate change and water stress projected in key growing regions, traditional approaches to managing commodity supply and price volatility risks—such as hedging or diversification of sourcing locations—are likely to be less effective than in the past.[48, 49] What's more, growing pressures from retailers and food manufacturers for more sustainable products, coupled with emerging tools and initiatives to support supply chain transparency, mean that companies in the corn value chain face a new set of opportunities to contribute to more sustainable agricultural production.

"Due to the level of climate change and water stress projected in key growing regions, traditional approaches to managing commodity supply and price volatility risks—such as hedging or diversification of sourcing locations—are likely to be less effective than in the past."

The following recommendations are steps that companies should take—and investors should encourage—to lower risks and impacts in their corn and broader agricultural supply chains.

RECOMMENDATION #1:

Establish a corporate policy for sourcing agricultural inputs that are grown more sustainably, along with time-bound goals.

A growing number of companies are developing corporate-wide policies and time-bound goals aimed at reducing environmental and social risks associated with their agricultural supply base. For example, PepsiCo's *Global Sustainable Agriculture Policy & Guiding Principles* sets out the company's priorities for reducing the impacts of agriculture in six key areas: water, soil conservation, agrochemical use, energy use, farm economics and community improvement.[50] Policies and priorities should be paired with time-bound goals and

Exhibit 5.2: Coca-Cola: Sourcing More Sustainable Corn Syrup

The Coca-Cola Company announced in July 2013 a goal to sustainably source all of its key agricultural ingredients by 2020—including the corn that goes into its high fructose syrup. Driving this commitment was a growing understanding of the significant risks and environmental impacts associated with agricultural water use. Even before setting this goal, Coke had sponsored a number of sustainable agriculture projects across the U.S. Corn Belt, including an initiative in lower Michigan's Paw Paw River watershed. Over five years, the Paw Paw project has supported farmers in adopting conservation tillage on 2,000 acres of cropland, reducing run-off and recharging groundwater on participating farms.

Building on this experience and with an eye to bring these efforts to scale, Coke is now partnering with its major corn syrup suppliers to gain greater transparency and understanding of on-farm management practices for corn production. Coke's suppliers are encouraging their corn farmer supply base to use the Fieldprint Calculator, a tool developed by Field to Market, to analyze and assess how the management decisions of farmers affect land use, energy use, water use, greenhouse gas emissions, and soil loss. The Calculator helps explore differing scenarios and combinations of on-farm management decisions, which may help improve natural resource management and an operation's efficiency and financial return. As more farmers utilize this tool and adopt improved practices, data tracked at the regional level will reflect the overall impact that these changes are having on water and other natural resources. Coke's suppliers will begin baseline data collection with growers in 2014. Using this data, Coke's aims to then develop goals and programs to support continuous improvement by farmers.

48 "Rethinking the F&A Supply Chain: Impact of Agricultural Price Volatility on Sourcing Strategies," Rabobank, http://www.saiplatform.org/uploads/Modules/Library/rethinking-fanda-supply-chain.pdf.

49 "Managing Supply in Volatile Agriculture Markets," AT Kearney, http://www.atkearney.com/consumer-products-retail/ideas-insights/featured-article/-/asset_publisher/KQNW4F0xInID/content/managing-supply-in-volatile-agriculture-markets/10192.

50 "Sustainable Agriculture," PepsiCo, http://www.pepsico.com/Download/PepsiCo_agri_0531_final.pdf.

strategies for advancing improvements. General Mills' agricultural sourcing plan includes a goal to sustainably source 100 percent of its 10 priority ingredients by 2020, including dry milled corn.[51]

RECOMMENDATION #2:

Integrate requirements for more sustainable agricultural production into supplier codes and procurement contracts.

For companies not dealing directly with farmers (i.e. those buying grain from processors or other intermediary suppliers), it is important that priorities for reducing environmental risks in farming practices be well communicated to suppliers through codes of conduct and integrated into requests for proposals (RFPs) and procurement contracts. Ongoing communication and data exchange between suppliers and buyers about the sustainability of inputs purchased is also essential. For example, Unilever has set a goal to source all of its agricultural raw materials sustainably by 2020 and communicates this expectation to suppliers through its *Sustainable Agriculture Code*, which provides a detailed protocol for evaluating grower practices and is referenced in procurement contracts.[52] Suppliers are required to regularly report to Unilever their progress against the code, which is spot-audited by a third party and reported annually to shareholders and stakeholders.

"Aligning policies, metrics and data requests with others in the industry reduces complexity and costs for grain suppliers and farmers, and helps send clearer signals about the sustainability performance improvements that are most important to customers."

In developing new policies and requirements for suppliers, buying companies should consider if requirements are aligned with those being used by others in their industry or in shared supply chains. Where possible, aligning policies, metrics and data requests with others in the industry reduces complexity and costs for grain suppliers and farmers, and helps send clearer signals about the sustainability performance improvements that are most important to customers.

RECOMMENDATION #3:

Empower the procurement function to address environmental risks in agricultural sourcing.

Enhancing focus on environmental risks in the supply chain also requires internal communication and education. Procurement managers in many companies have limited knowledge of agricultural production practices and environmental sustainability issues. Companies can bolster the capacity of their procurement function by providing training for appropriate decision-makers and departments and by hiring procurement experts with relevant knowledge. Procurement managers also benefit from performance criteria that value sustainability objectives alongside more traditional procurement fundamentals of price, quality and on-time delivery. For instance, Walmart, to align sustainability commitments with the procurement function, began requiring in 2013 that all of its U.S. and global buyers have performance objectives dedicated to sustainability.[53]

RECOMMENDATION #4:

Prioritize action by identifying geographic sourcing regions of higher risk, such as those associated with high water stress, groundwater depletion or nutrient pollution.

Attaining field-level improvements in agricultural run-off, water use and erosion—while generally beneficial—will have a more transformative impact to the environment if targeted in regions or watersheds where water availability and water and soil quality are most impaired. Achieving field-level traceability of corn and other commodity crops is difficult to achieve in many supply chains, but grain suppliers can often trace crops to a general sourcing region in proximity to their elevators or mills. Armed with this information, buying companies can use the interactive maps in this report **(www.ceres.org/cornmaps)** as a starting place to identify if corn production is happening in regions of high nitrogen pollution, water stress or groundwater depletion. Other resources such as the Sustainability Consortium's commodity maps, Environmental Working Group's maps of corn production acreage in ecologically sensitive regions,[54] and WWF's Water Risk Filter[55] can also provide high-level insights about potential risks and hotspots.

51 "General Mills Commits to Sustainably Source 10 Priority Ingredients by 2020," General Mills, September 25, 2013, http://content.generalmills.com/ChannelG/NewsReleases/Library/2013/September/sourcing_10.aspx.

52 "Unilever Sustainable Agriculture Code," Unilever, 2010, http://www.unilever.com/images/sd_Unilever_Sustainable_Agriculture_Code_2010_tcm13-216557.pdf.

53 "The Walmart Sustainability Index, Frequently Asked Questions," Walmart, http://customers.icix.com/?wpfb_dl=28.

54 "Going, Going, Gone," EWG, Craig Cox et al, 2013, http://www.ewg.org/research/going-going-gone.

55 "The Water Risk Filter," *WWF International*, http://waterriskfilter.panda.org/

Third-party data can never substitute for the insights provided through local agricultural and environmental experts, suppliers and growers themselves. Companies should complement high-level assessments with on-the-ground fact-finding activities to more fully assess the nature of existing risks facing agricultural production in key sourcing regions.

RECOMMENDATION #5:

Join and play a constructive role in multi-stakeholder initiatives that support farmer adoption of environmental measurement systems and best management practices.

Companies should consider constructive participation in initiatives that are focused on working with growers to provide tools, information and other resources that can help improve farming practices. Field to Market is one such initiative, although it currently has limited representation from companies in the livestock and ethanol sectors, which together represent more than two-thirds of the nation's corn procurement. There are also opportunities to get involved in more targeted initiatives such as the Adapt Network, a collaboration of land grant university experts, farm advisors and NGOs working with farmers to help them fine-tune fertilizer application and use nutrients more efficiently.[56]

RECOMMENDATION #6:

Incentivize continuous improvement with growers by working in concert with others in the value chain, NGOs and public agencies to provide resources, performance guarantees, and agronomic advising.

While many farming practices that reduce water and climate-related risks provide both short and long-term productivity benefits to growers, the potential economic risks of experimenting with new approaches is understandably a deterrent for many farmers. Contributing to this hesitancy are long-standing regulatory and public policy incentives facing growers—from a Federal Crop Insurance Program that does not preference risk-reducing environmental practices, to weak regulation of nutrient pollution, and cheap or free irrigation water. Companies that seek to catalyze durable improvements in the sustainability of agricultural production will need to find ways to provide real value and incentives for growers to make changes.

Providing value does not necessarily mean providing a premium, however. There are a variety of ways that buying companies can deliver value in the supply chain down to farmers. For example, companies can provide financial support to on-the-ground nonprofit organizations or resource conservation districts that provide agronomic and environmental training and assistance to growers in target regions. Companies can support efforts that reduce the financial risks that farmers face when implementing new practices, such as the American Farm Land Trust's "BMP Challenge," which provides financial guarantees that allow farmers to experiment with conservation practices, observe performance over time in side-by-side comparisons, and evaluate economic impact, without risk to their incomes.[57] Companies can also play a role in helping support low-interest credit programs that enable farmers to purchase equipment or technologies that help reduce their environmental risks and impacts.

Finally, companies may consider hiring staff with agronomic and environmental expertise that can play a direct role in advising and supporting growers. Miller Coors, for example, has hired agronomists that consult with its U.S. barley growers on issues including irrigation, crop rotation and other sustainable farming practices.[58]

RECOMMENDATION #7:

Participate in new market-based efforts to support farmer investments in better on-farm practices, including nutrient trading programs.

There are various market-based initiatives currently being developed to reward enhanced agricultural practices by U.S. growers that are relevant to the corn supply chain. For instance, there is a nascent nutrient trading market in the Ohio River Basin that aims to achieve water quality goals for eight states in the region. Developed as a collaboration between the Electric Power Research Institute (the U.S. utility industry's research arm) and farmers, wastewater utilities, state and federal agencies, the project seeks to create a market-based mechanism for supporting farmers' implementation of practices that reduce nutrient pollution. Farmers who implement conservation practices that mitigate or prevent nonpoint source nutrient pollution generate water quality credits (or offsets), which they then sell to point sources such as sewage treatment and industrial plants, as well as to companies interested in permanently retiring the credits. A series of pilot trades will be executed through 2015, and are expected to keep about 66,000

56 See http://adaptnetwork.org/.

57 See "AFT's BMP Challenge," http://www.farmland.org/programs/environment/solutions/bmp-challenge.asp.

58 "Sustainable Agriculture," Miller Coors, http://www.millercoors.com/GBGR/Supply-Chain/Sustainable-Agriculture.aspx.

pounds of nitrogen and 30,000 pounds of phosphorus out of the Ohio River. Although current participants in the trading system are largely from the electric power sector, companies with agricultural supply chains seeking to support improved farmer practices can also participate.[59]

Another new, market-based effort that offers incentives to certain types of grain farmers for improving their environmental practices is the Responsible Crop Certificate initiative. A collaboration between a Minnesota-based nonprofit organization, the Environmental Initiative, and GNP Company, a large Midwestern chicken producer, it allows food companies that are interested in marketing environmentally-friendly products to purchase a Responsible Crop Certificate from participating corn and soybean growers. These growers, in turn, will receive a premium for verification against specific environmental requirements.[60]

RECOMMENDATION #8:

Substitute other grains for corn where environmental benefits are well demonstrated.

Corn has an inherently higher fertilizer and water use profile than many other crops. For companies with a heavy reliance on corn, substitute grains with a preferable environmental risk profile may already be available or their production can be encouraged by working with growers to select profitable alternatives. For instance, ethanol plants are increasingly looking to incorporate new feedstock such as sorghum, which has a lower irrigation and fertilizer demand than corn.[61] Livestock companies should also evaluate opportunities to reduce corn's share in animal feed, and boost the percentage of alternative grains such as sorghum, wheat and barley.[62]

RECOMMENDATION #9:

Align the company's public policy positions and lobbying activities to support the goal of reducing environmental risks in corn production.

Farmers do not make decisions in a vacuum. They are incentivized to optimize returns and invest in their land in the context of market signals, government programs, and regulatory requirements. Government policies that mitigate climate change, encourage risk-reducing, environmentally beneficial practices and long-term land and water stewardship will lead to more stable commodity prices and resilient agricultural markets. Companies that rely on corn and other agricultural inputs should ensure that their own policy positions, lobbying activities, and industry groups support legislation and regulation that advances those ends. For instance, companies can join with other companies to advocate for meaningful climate change policies through the Ceres' BICEP coalition.[63] They can also support policies at the state and federal levels that incentivize farmers to reduce their impacts on water quality, improve their resilience to climate change, and limit excessive withdrawals from stressed aquifers.

The ethanol sector, whose existence is due in large part to federal government mandates, has a particular responsibility to support efforts to ensure that corn production has a lower environmental footprint. Ethanol companies should align their own goals and policy positions in support of efforts to reduce the impact of corn production on freshwater, such as supporting and contributing to the government's Gulf Hypoxia Action Plan goal of significantly reducing nitrogen and phosphorus pollution run-off to the Gulf of Mexico.

RECOMMENDATION #10:

Disclose to investors and stakeholders the company's exposure to climate and water-related risks in its agricultural supply chain, as well strategies and progress made toward mitigating these risks.

Companies publicly-listed in the United States are required by the Securities and Exchange Commission (SEC) to disclose to shareholders any financially material risks related to climate change and water that face their operations and supply chain.[64] Beyond disclosing these risks in a company's annual 10-K, investors are also looking for more detailed disclosure of risks and mitigation strategies in corporate sustainability reports and in responses to the CDP's investor surveys. Specifically, companies should disclose existing sustainable agricultural policies and goals, progress made against those goals, strategies for linking these goals to procurement and supplier contracts, and participation in relevant initiatives.

59 See "Ohio River Basin Trading Project," Electric Power Research Institute, http://wqt.epri.com/index.html.

60 See: "Responsible Crop Certificate," Environmental Initiative, http://www.environmental-initiative.org/projects/responsible-crop-certificate.

61 Art Hovey, "Ethanol plants turning toward grain sorghum," *The Lincoln Journal Star*, May 4, 2013, http://journalstar.com/news/local/ethanol-plants-turning-toward-grain-sorghum/article_24c89ce9-f999-570e-bbcc-43e46d99884d.html.

62 Whitney McFerron, "Livestock Eat More Wheat as Cheapest Corn Alternative Since 1996," Bloomberg, June 14, 2011, http://www.bloomberg.com/news/2011-06-14/livestock-eat-more-wheat-as-cheapest-corn-alternative-since-1996.html.

63 See www.ceres.org/bicep.

64 For an in-depth discussion of the SEC Climate Guidance, see: Berkley Adrio, "Clearing the Waters: A Review of Corporate Water Disclosure in SEC Filings," Ceres, June 2012, https://www.ceres.org/resources/reports/clearing-the-waters-a-review-of-corporate-water-risk-disclosure-in-sec-filings/view.

Methodology: U.S. Corn Production in Areas of Water Stress

To understand the level of water competition facing both irrigated and rainfed U.S. corn production, Ceres worked with the World Resources Institute (WRI) to overlay the water stress indicator from WRI's Aqueduct Water Risk Atlas against data on corn production derived from USDA's National Agricultural Statistics Service (NASS)[1] and the USDA's NASS CropScape database.

Three measures of corn production were needed for this analysis: total, irrigated, and rainfed. The primary data source for corn production was the USDA National Agricultural Statistics Service (NASS) database. Average production values from 2008-2012 were used since not all counties reported statistics for all years. Total corn production in tons was calculated by adding corn grain production (measured in bushels) to corn silage production (measured in tons) using a conversion factor of 0.245 tons per bushel.

Data from USDA's NASS CropScape[2] database was used for irrigated corn production where available. Since the sum of irrigated and rainfed production for some counties did not match total production, irrigated production was bias-corrected to total corn production, preserving the ratio of irrigated-to-rainfed production in each county. For the remaining counties that did not differentiate between irrigated and rainfed production, the proportion of total production which was irrigated was estimated based on the proportion of corn acres which were irrigated in each county.

Modeling Irrigated Corn Production

To estimate irrigated production in counties that did not report irrigation data, total corn acres and irrigated corn acres were first estimated. Total corn acres were calculated from 30x30m cornfield extent data from the NASS CropScape database for the year 2012. Irrigated acres were then calculated from the overlap between cornfields and 250x250m satellite-based measurements of cropland irrigation.[3]

The percentage of corn production that was irrigated was estimated using a maximum likelihood beta regression[4] fit to the counties that reported irrigated production **(Exhibit A1)**. Final tonnage estimates were calculated by multiplying modeled percent irrigated with reported total production. All regression variables were highly significant ($p \ll 0.01$), with a positive coefficient on irrigated area and negative coefficients on total area and climate humidity, as expected.[5] Overall model performance was high with a pseudo R^2 of 0.80 between modeled and reported percentages of irrigated production, and an R^2 of 0.96 between modeled and reported tons of irrigated production **(Exhibits A2 & A3)**.

Exhibit A1: Model Variables to Predict Percent of Corn Production that was Irrigated

Variable		Coefficient (Significance)
ln(irrarea)	Log of irrigated corn area	1.077 (p<0.01)
ln(allarea)	Log of all corn area	-1.419 (p<0.01)
ln(ai)	Log of aridity index (higher values more humid)[a]	-1.837 (p<0.01)
intercept	Model intercept	19.75 (p<0.01)

Data from: R.J. Hijmans, S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, "Very high Resolution Interpolated Climate Surfaces for Global Land Areas," *International Journal of Climatology* 25 (2005), 1965-1978. http://www.worldclim.org/current.

1 USDA, National Agricultural Statistics Service Database, http://quickstats.nass.usda.gov/.

2 USDA, National Agricultural Statistics Service, CropScape - Cropland Data Layer, http://nassgeodata.gmu.edu/CropScape/.

3 M.S. Pervez and J.F. Brown, "Mapping irrigated lands at 250-m scale by merging MODIS data and national agricultural statistics," Remote Sensing, 2 no. 10 (2010), 2388-2412; doi:10.3390/rs2102388, http://www.mdpi.com/2072-4292/2/10/2388/. Data available at U.S. Geological Survey, "Moderate Resolution Imaging Spectroradiometer (MODIS) Irrigated Agriculture Dataset for the United States (MIrAD-US)," http://earlywarning.usgs.gov/USirrigation/.

4 Beta regression is a specific form of generalized linear model that constrains the response variable to a beta distribution. This form of regression is most appropriate in situations where the value one is trying to predict is known to be between zero and one. See: F. Cribari-Neto and A Zeileis, "Beta Regression in R," Journal of Statistical Software, 34 no. 2 (2010), 1–24, http://www.jstatsoft.org/v34/i02/.

5 Irrigated land should have less productivity advantage over rainfed land in more humid areas.

Exhibit A2: Reported vs. Modeled Irrigated Corn Production

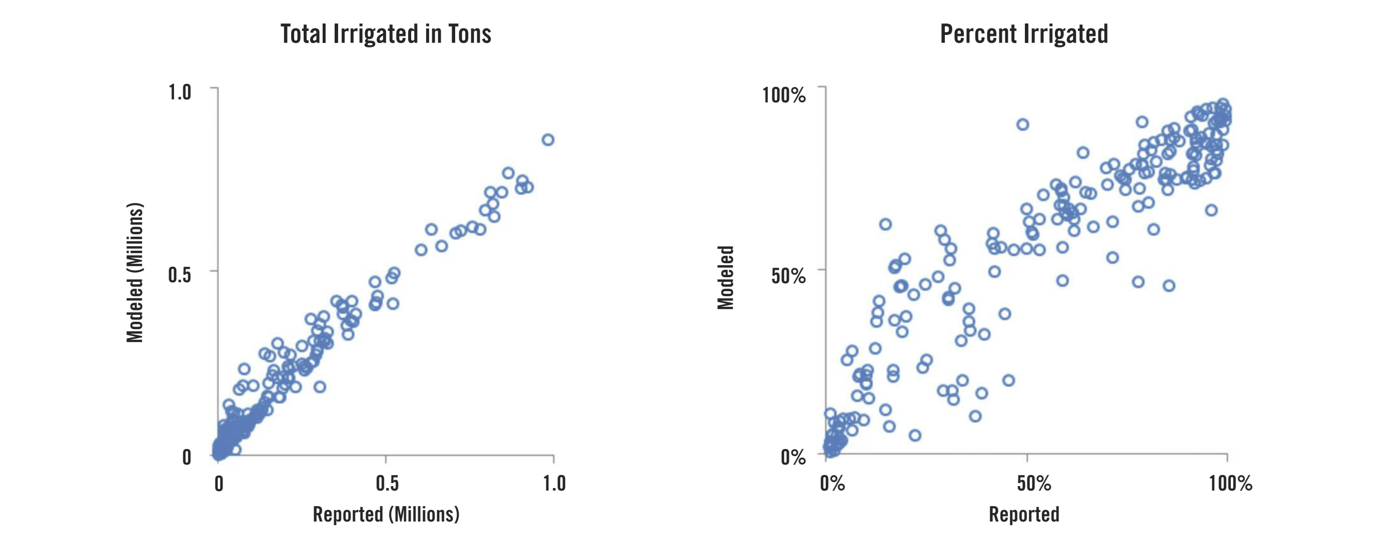
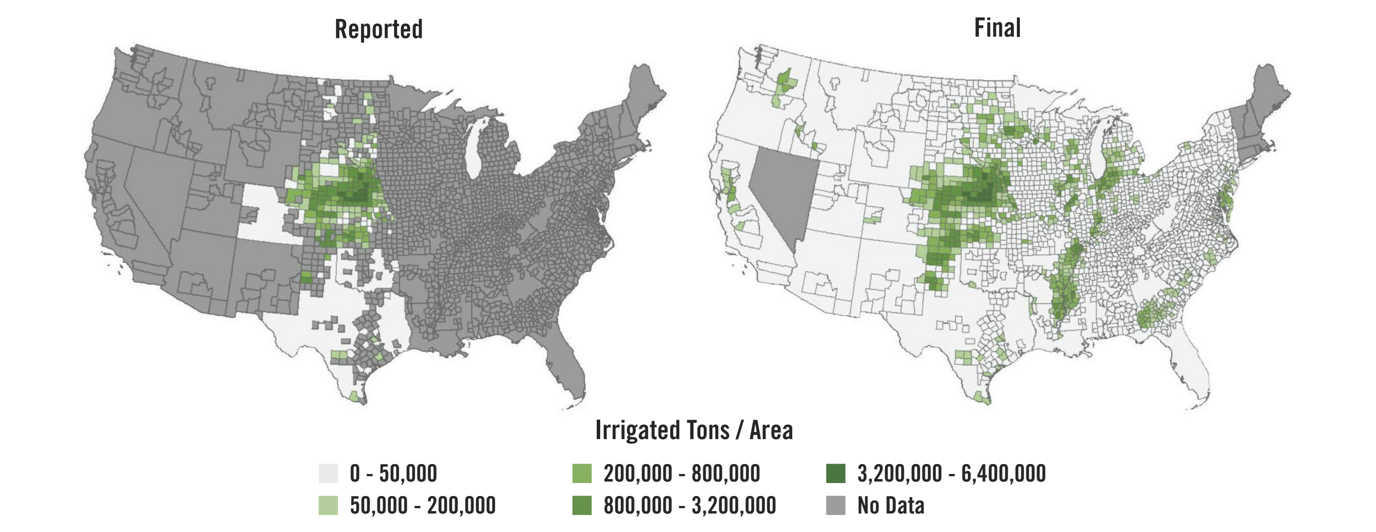


Exhibit A3: Reported vs. Final (Modeled in Areas Without Reported Data) Irrigated Corn Production



Note: Data reported for "all other counties" are mapped as single regions covering the area of all counties within the state that did not report data.

Methodology: Corn Ethanol Plants over the High Plains Aquifer

To understand the relationship between ethanol refinery locations, the surrounding regions from which they source corn feedstock, and areas of water table decline in the High Plains (or Ogallala) aquifer, Ceres worked with Agricultural Conservation Economics to overlay data on ethanol refinery locations against a map of cumulative water-level increases/decreases in the aquifer.

Data related to the ethanol refineries was sourced from the Renewable Fuels Association website,[1] which provides data on plant locations and ownership, the feedstock used, and the design capacity of the plant in million gallons of ethanol per year. Data gaps were supplemented with information from company websites and the Nebraska Energy Office website.[2]

Forty ethanol refineries were identified as located in or close to (within 1,000 meters of) the High Plains aquifer, 36 of which use corn or a mix of corn and other grains for feedstock. The spatial data set of water-level changes in the High Plains aquifer was sourced from the U.S. Geological Survey.[3] The data set is drawn from well measurements from federal, state and local agencies and shows water level changes (both decreases and increases) that have occurred in the aquifer from pre-development (roughly the early 1950s) up until 2011.

Because the changes in water table declines vary considerably over small areas, the location of the refinery itself is not a robust indicator of agriculture-related groundwater depletion. Ethanol refineries typically source corn from within a 50-mile radius,[4] so in many cases depending on their production capacity and the corn production density in the surrounding region, corn feedstock is coming from neighboring regions with different levels of water table declines as well as differing levels of irrigation.

To address this, the radius of the area required to supply the amount of corn needed to meet the plant's full ethanol design capacity was calculated using data on from the USDA on irrigated and non-irrigated corn grain production and acreage by county, the average acre-feet of water applied to corn in the region, and county level data from USGS on use of groundwater versus surface for irrigation.

Again, it should also be noted that these are the assumed areas from which the corn is sourced. Some plants may be operating with corn feedstock drawn from sources farther than indicated by this method.

1 Renewable Fuels Association website, http://www.ethanolrfa.org/bio-refinery-locations/. Data downloaded 1/28/2014.

2 Nebraska Energy Office, "Ethanol Facilities Capacity by State and Plant," http://www.neo.ne.gov/statshtml/122.htm.

3 USGS, *Water-Level and Storage Changes in the High Plains Aquifer, Predevelopment to 2011 and 2009–11*, V.L. McGuire, February 2013, http://pubs.usgs.gov/sir/2012/5291/.

4 USDA, "Ethanol Transportation Backgrounder," 2007, http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5063605.

Methodology: Corn Ethanol Plants in Watersheds with High Levels of Nitrogen Pollution

To understand the relationship between areas of high nitrogen pollution from agriculture and the corn sourced by ethanol refineries, Ceres worked with Agricultural Conservation Economics to overlay data on ethanol refinery locations, the surrounding regions from which they source corn feedstock, and refinery production capacity against watersheds in the Mississippi River Basin with high local nitrogen loading from agricultural sources, as well as against watersheds with high nitrogen delivery to the Gulf of Mexico.

Data on the ethanol plants was sourced from the Renewable Fuels Association website,[1] which includes data on plant locations and ownership, the feedstock used, and the design capacity of the plant in million gallons of ethanol per year. Data gaps were supplemented with information from company websites and the Nebraska Energy Office website.[2]

Data on nitrogen loading from agriculture was sourced from the U.S. Geological Survey's SPARROW model online decision support system.[3] Data on nitrogen delivered from fertilizer, manure, and agricultural area loadings to their local stream segments (incremental load) and to the mouth of the Mississippi River Basin was calculated using the total nitrogen models for the Upper Mississippi, Lower Mississippi and Arkansas-Red-White, the Missouri, and the Tennessee portion of the South Atlantic-Gulf-Tennessee Region models.

Because the watersheds delineated in the SPARROW model are small relative to the area from which each ethanol refinery receives corn, the location of the specific watershed in which the refinery is located is not a robust indicator of agricultural nitrogen loading. Ethanol refineries typically source corn from within a 50-mile radius,[4] so in many cases depending on their production capacity and the corn production density in the surrounding region, corn feedstock is coming from neighboring watersheds with different levels of agricultural nitrogen loading.

To address this, the radius of the area required to supply the amount of corn needed to meet the plant's full ethanol design capacity was calculated using the average corn yield in the county in which the plant is located. The data for all the watersheds within this radius of the plant was then accumulated, weighting the data by the area of the watershed within the buffer defined by that radius. Again, It should also be noted that these are the assumed areas from which the corn is sourced. Some plants may be operating with corn feedstock drawn from sources farther than indicated by this method.

Because the calculated delivered nitrogen loads in the SPARROW models include both the incremental delivery of that watershed to the local stream segment (local nitrogen pollution) and loads passing down through the segment (nitrogen pollution to the Gulf of Mexico), delivered nitrogen load from the watershed was recalculated as the product of incremental delivery and the delivery fraction from that watershed.

To rank watersheds by the delivery of agricultural nitrogen to the Gulf of Mexico, the calculated delivered loads from agricultural sources within each watershed were ranked from largest to smallest, accumulated, and the sum was divided by the total delivered load at the mouth of the Mississippi River Basin and converted to a percentage ranking **(Exhibit C1)**. Thus, a watershed ranked as 5 percent (or "extremely high") is one in which only 5 percent of the watersheds in the basin have larger delivered loads, while a watershed ranked as 95 percent (or "low") has a delivered load smaller than 95 percent of all watersheds in the basin. The same process was used to rank watersheds with high local agricultural nitrogen pollution. Incremental loadings from each watershed (that is, delivered to the local stream segment, but not down the river system to the mouth) were ranked.

Exhibit C1: Definitions for Watersheds Ranked by Incremental (Local) or Delivered (to Gulf) Nitrogen Load

Watershed Rank	Incremental or Delivered Nitrogen Load
Extremely High	Less than 10 percent rank
Very High	10-20 percent rank
High	20-50 percent rank
Moderate	50-75 percent rank
Low	More than 75 percent rank

1 Renewable Fuels Association website, http://www.ethanolrfa.org/bio-refinery-locations/. Data downloaded 1/28/2014.

2 Nebraska Energy Office, "Ethanol Facilities Capacity by State and Plant," http://www.neo.ne.gov/statshtml/122.htm.

3 USGS, SPARROW Decision Support System, http://cida.usgs.gov/sparrow.

4 USDA, "Ethanol Transportation Backgrounder," 2007, http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5063605.

Agricultural Management Practices that Lower Risks for Farmers

Given the vast differences in farm size, soil types, local climates, water resources, and farming systems among U.S. corn growers, there can be no one-size-fits-all prescription for reducing farmers' exposure to climate, water supply and nutrient pollution risks. Nevertheless, there are many proven practices and relatively low-cost technologies that can be used by farmers to increase their resilience to drought and floods, reduce their dependency on imperiled groundwater, and significantly improve their fertilizer use efficiency while reducing field run-off and greenhouse gas emissions. Many of these practices have economic benefits in terms of improved yields and risk reduction in both the immediate and longer-term. The tables below describe these practices, their level of adoption and economic and environmental benefits.

Agricultural Management Practice		
CONSERVATION TILLAGE	**Level of Adoption**	**Risks Addressed**
Tillage is the process of plowing farmland to prepare for seeding, as well as control pests and weeds. In low-intensity or conservation tillage, at least 30% of the soil is covered by crop residues (i.e. not tilled) just after planting the current crop.[1] Conservation tillage practices include mulch till, ridge till, strip till, and no-till.[2] In no-till production systems, farmers plant their seeds directly into last year's residue, which acts like mulch by protecting the soil and preventing weeds.	• No-till was practiced on 24% of corn acres in 2005 (projected at 30% in 2009).[3] • Low-till was practiced on 51% of corn acres in 2005.[4]	✓ Drought ✓ Irrigation Demand ✓ Soil Erosion ✓ Nutrient Pollution
Environmental Benefits: Conservation tillage practices improve the long-term health of soil and water resources by reducing erosion and nutrient run-off.[5] Conservation tillage also retains moisture within the soil and mitigates the effects of erratic rainfall or declining irrigation resources by decreasing evaporation from the soil surface and improving water infiltration to plant root systems.[6] These practices may also reduce the release of greenhouse gas emissions from the soil.[7]		
Economic Benefits: Compared to conventional tillage systems, no-till systems typically require less water and have higher yields. Specifically, no-till corn yielded 24% more bushels/acre and used 32% fewer gallons of water/year in 2010.[8] No-till systems also use less labor and fuel, and require fewer inputs overall. One study found that no-till corn farmers invested $795/acre in their annual production, while conventional till farmers invested $859/acre.[9] With the higher yields achieved from no-till systems, no-till farmers were 52% more profitable than conventional till farmers (with net revenues of $190/acre versus $91/acre).[10] Conservation till systems also have cost savings for the Federal Crop Insurance Program (FCIP). In 2010, no-till corn farmers were 30% less likely than conventional till farmers to receive a FCIP indemnity payment.[11] It has been estimated that if all U.S. farmers implemented no-till systems, about $224 million in indemnities could have been avoided in 2010.[12]		

1 USDA, *"No-Till" Farming Is a Growing Practice*, by John Horowitz, Robert Ebel, and Kohei Ueda, Economic Information Bulletin No. (EIB-70), November 2010, http://www.ers.usda.gov/publications/eib-economic-information-bulletin/eib70.aspx#.U0WicuZdXd0.

2 USDA, National Resources Conservation Service, *Energy Estimator*, http://ecat.sc.egov.usda.gov/Help.aspx/.

3 USDA, *"No-Till" Farming Is a Growing Practice*, by John Horowitz, Robert Ebel, and Kohei Ueda, Economic Information Bulletin No. (EIB-70), November 2010, http://www.ers.usda.gov/publications/eib-economic-information-bulletin/eib70.aspx#.U0WicuZdXd0.

4 Ibid.

5 Martin Shipitalo et al., "Effect of No-till and Extended Rotation on Nutrient Losses in Surface Runoff," *Soil Science Society of America Journal 77*, no. 4 (11 Jun. 2013) 1329-1337, http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=290884.

6 USDA, Economic Research Service, *Agricultural Resources and Environmental Indicators*, 2012 edition, by Craig Osteen et al., EIB-98 August 2012, http://www.ers.usda.gov/publications/eib-economic-information-bulletin/eib98.aspx#.U0WlJuZdXd0.

7 One study found that farmers in the Corn Belt that switch from conventional tillage to reduced tillage would sequester 0.33 more metric tons of carbon dioxide per acre per year of a 20-year period, and a switch to no-till would sequester 0.64 more metric tons. USDA, *"No-Till" Farming Is a Growing Practice*, by John Horowitz, Robert Ebel, and Kohei Ueda, Economic Information Bulletin No. (EIB-70), November 2010, http://www.ers.usda.gov/publications/eib-economic-information-bulletin/eib70.aspx#.U0WicuZdXd0.

8 Claire O'Connor, "Soil Matters: How the Federal Crop Insurance Program should be reformed to encourage low-risk farming methods with high-reward environmental outcomes," *Natural Resources Defense Council*, Issue Paper: 13-04-A, August 2013, http://www.nrdc.org/water/soil-matters/files/soil-matters-IP.pdf.

9 Claire O'Connor, "Farmers Reap Benefits as No-Till Adoption Rises," *Switchboard (blog), Natural Resources Defense Council Staff Blog*, November 14, 2013, http://switchboard.nrdc.org/blogs/coconnor/farmers_reap_benefits_as_no-ti.html.

10 Ibid.

11 Claire O'Connor, "Soil Matters: How the Federal Crop Insurance Program should be reformed to encourage low-risk farming methods with high-reward environmental outcomes," *Natural Resources Defense Council*, Issue Paper: 13-04-A, August 2013, http://www.nrdc.org/water/soil-matters/files/soil-matters-IP.pdf.

12 Ibid.

CROP ROTATION	Level of Adoption	Risks Addressed
Crop rotation involves the planting of corn and typically soybeans on the same plot in alternating years. It is a common practice that has been popularly implemented in the U.S. Corn Belt since the mid-twentieth century. Corn and soybeans may also be rotated with other forage crops like alfalfa or oats.	• In 2011 and 2012, 78% of total corn acres were planted in rotation with soybean and/or other crops.[13]	✔ Drought ✔ GHG Emissions ✔ Irrigation Demand ✔ Soil Erosion ✔ Nutrient Pollution
Environmental Benefits: Corn planted in rotation with soybeans or other forage crops improves the health and structure of the soil by conserving soil moisture and reducing soil erosion, and reduces fertilizer needs (soybeans and other forage crops are nitrogen-fixing). Crop rotation also controls pests and reduces pesticide inputs; for example, crop rotation is an effective method of controlling corn rootworms in most of the U.S. Corn Belt.[14] During periods of drought or other forms of weather stress, corn that has been rotated with soybeans is more resilient than continuous corn.[15] Rotating corn and soybeans with other forage crops for extended periods of time (at least 3 years) also further reduces nitrogen inputs, improves soil quality and increases corn grain yields.[16, 17]		
Economic Benefits: In addition to lowering input costs because less fertilizer and pesticides are required, crop rotation leads to corn yields that are on average between 13-19% higher after soybean plantings.[18] While recently high prices of corn have drawn some farmers toward planting corn year-on-year and away from corn-soybean rotations, one recent study has demonstrated that always rotating, regardless of prices, has optimal economic returns.[19]		

COVER CROPS	Level of Adoption	Risks Addressed
Cover crops are non-commodity crops that are planted in order to protect and improve the soil. Farmers use different cover crops depending upon the region, and may plant grass cover crops (rye, wheat, oats, or ryegrass), legume cover crops (hairy vetch, crimson clover, or Australian winter pea), as well as other crops like buckwheat or forage radish.[20]	• Only about 7% of U.S. row crop farmers planted cover crops in 2012.[21, 22] • In the Mississippi River Basin, less than 2% of cropland planted cover crops in 2011, equivalent to between 1.8-4.3 million acres.[23]	✔ Drought ✔ Irrigation Demand ✔ Soil Erosion ✔ Nutrient Pollution
Environmental Benefits: Cover-cropping increases water infiltration and storage and reduces surface evaporation,[24, 25] reduces soil erosion,[26] and decreases chemical fertilizer and pesticide inputs by increasing the soil organic matter and also controlling weeds.[27]		
Economic Benefits: Using cover crops usually requires more time and money than not using cover crops,[28] but cover crops have been shown to increase yields in the short term[29] and increase yield potential and stability over time.[30] According to a survey of 759 farmers in the Corn Belt, corn planted after cover crops had a 9.6% increase in yield compared to fields with no cover crops in 2012.[31] Yield gains were even higher for areas hardest hit by the drought, with an 11% yield increase for corn planted after cover crops.		

13 A total 97.2 million acres were planted to corn in 2012. USDA, National Agricultural Statistics Service Database, http://quickstats.nass.usda.gov/.

14 Liz Morrison, "Including soybeans in crop rotation provides advantages," *Corn and Soybean Digest*, September 25, 2013, http://cornandsoybeandigest.com/soybeans/including-soybeans-crop-rotation-provides-advantages.

15 Ibid.

16 Trenton Stanger and Joseph Lauer, "Corn Grain Yield Response to Crop Rotation and Nitrogen over 35 Years," *Agronomy Journal* 100, issue 3 (2008), 643-650, http://corn.agronomy.wisc.edu/pubs/JL_JournalArticles/643.pdf.

17 Douglas Karlen et al., "Crop Rotation Effects on Soil Quality at Three Northern Corn/Soybean Belt Locations," *Agronomy Journal* 98, (2006), 484-495, http://naldc.nal.usda.gov/download/3824/PDF.

18 Liz Morrison, "Including soybeans in crop rotation provides advantages," *Corn and Soybean Digest*, September 25, 2013, http://cornandsoybeandigest.com/soybeans/including-soybeans-crop-rotation-provides-advantages.

19 USDA, University of Hawaii, *Optimal Sequential Plantings of Corn and Soybeans Under Price Uncertainty*, by Michael Livingston, Michael Roberts and Yue Zhang, 2012, http://www2.hawaii.edu/~mjrobert/main/Working_Papers_files/AJAE_revise.pdf.

20 Kipling Balkcom et al., *Managing Cover Crops Profitably, 3rd Edition: Managing Cover Crops in Conservation Tillage Systems Chapter* (College Park, MD: Sustainable Agriculture Research and Education and United Book Press, 2012), http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Managing-Cover-Crops-in-Conservation-Tillage-Systems.

21 Conservation Technology Information Center and USDA North Central Sustainable Agriculture Research & Education, *2012–2013 Cover Crop Survey: June 2013 Survey Analysis*, available at http://www.northcentralsare.org/educational-resources/From-the-Field/Cover-Crops-survey-analysis.

22 According to a March 2013 Amber Waves article, "Only about 3 to 7 percent of farms use cover crops in rotations, and, since these operations do not put all of their land into cover crops, only 1 percent of cropland acreage uses cover crops." USDA, Economic Research Service, "While Crop Rotations Are Common, Cover Crops Remain Rare," by Steven Wallander, March 04, 2013, http://www.ers.usda.gov/amber-waves/2013-march/while-crop-rotations-are-common,-cover-crops-remain-rare.aspx#.U0Wr3-ZdXd1.

23 Lara Bryant, Ryan Stockwell and Trisha White, "Counting Cover Crops," *National Wildlife Federation*, 2013, http://www.nwf.org/~/media/PDFs/Media%20Center%20-%20Press%20Releases/10-1-13_CountingCoverCrops-FINALlowres.ashx.

24 Humberto Blanco-Canqui, "Addition of Cover Crops Enhances No-till Potential for Improving Soil Physical Properties," *Soil Science Society of America Journal*, 75 no. 4 (2011), 1471; Stacey M. Williams and Ray R. Weil, "Crop Cover Root Channels May Alleviate Soil Compaction Effects on Soybean Crops," Soil Science Society of America Journal, 68 no. 4 (2004), 1403.

25 Kipling Balkcom et al., *Managing Cover Crops Profitably, 3rd Edition: Managing Cover Crops in Conservation Tillage Systems Chapter* (College Park, MD: Sustainable Agriculture Research and Education and United Book Press, 2012).

26 Ibid.

27 Ibid.

28 Kipling Balkcom et al., *Managing Cover Crops Profitably, 3rd Edition: Managing Cover Crops in Conservation Tillage Systems Chapter* (College Park, MD: Sustainable Agriculture Research and Education and United Book Press, 2012).

29 Humberto Blanco-Canqui et al., "Summer Cover Crops Fix Nitrogen, Increase Crop Yield, and Improve Soil-Crop relationships," *Agronomy Journal*, 104 no. 1 (2012), 137-147.

30 S. Snapp et al., "Evaluating Cover Crops for Benefits, Costs and Performance Within Cropping System Niches," *Agronomy Journal*, 97 no. 1 (2005), 322-332.

31 Kipling Balkcom et al., *2012-2013 Cover Crop Survey*, (College Park, MD: Sustainable Agriculture Research and Education and United Book Press, 2012), http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Managing-Cover-Crops-in-Conservation-Tillage-Systems.

EFFICIENT IRRIGATION	Level of Adoption	Risks Addressed
Traditional irrigation systems include high-pressure sprinkler systems as well as unlined furrow and flood systems without field borders. More efficient pressure-sprinkler systems include subsurface drip/trickle systems or low-pressure sprinkler systems (the pressure per square inch < 30). More efficient gravity irrigation systems include furrow systems with above- or below-ground pipes, lined open ditches, and flood irrigation systems (between borders or within basins) that use laser-leveling and pipe or lined open ditch systems.[32] Other efficient irrigation technologies include using soil moisture monitors to schedule irrigation appropriately given unique plant, soil, and climate characteristics,[33, 34] alternate furrow irrigation, alternate root-zone application, and subsurface drip irrigation (SDI).	• As of 2008, 22% of irrigated corn acres still used inefficient flood or furrow irrigation. Very few corn grain acres (0.1%) used subsurface drip or micro irrigation.[35] • As of 2008, less than 15% of farms in the corn-growing states of Kansas, Nebraska and Texas used modern approaches for determining irrigation needs such as soil and plant-moisture sensing devices.[36]	✓ Drought ✓ Irrigation Demand ✓ Soil Erosion ✓ Nutrient Pollution
Environmental Benefits: More efficient irrigation technologies reduce the amount of water needed to irrigate the crop and therefore reduce total groundwater withdrawals, as well as soil erosion and nutrient run-off caused by excess water application. Additional benefits include reduction in the incidence of disease because the plants are not kept excessively wet.[37] According to a 2009 University of Nebraska study, corn farmers who used soil moisture monitors to schedule irrigation reduced the amount of water they applied to their corn by 15% without impacting yields.[38] With the application of subsurface drip irrigation (SDI), studies have found that water use for corn could be reduced between 25-55% without impacting yields.[39, 40]		
Economic Benefits: The installation of efficient irrigation technologies can be costly, and the majority of U.S. irrigation investment is financed privately (fewer than 10% of farms reporting irrigation improvements in 2008 received public cost-share assistance such as those provided through EQIP).[41] However, depending upon the type of irrigation technology as well as the specific farming system, the cost of installing or upgrading the irrigation system can be earned back in a few years time.[42] Increases in revenue stemming from higher yields, reductions in cost and improvements in logistics may offset the cost of adopting drip irrigation systems, as well as enable production of crops in areas with severely limited water resources.[43] The energy costs associated with irrigation are also high, representing for example 10% of the costs for growing corn in western Kansas, which is slightly higher than the cost of land rent.[44] More efficient irrigation technologies could therefore reduce energy/pumping costs for farmers, which is all the more important given rising energy prices.[45]		

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<table>
<tr><th>NUTRIENT MANAGEMENT</th><th>Level of Adoption</th><th>Risks Addressed</th></tr>
<tr><td>Best nutrient management practices match the amount of nutrients to the needs of the crop, minimize the loss of nutrients, and enhance plants' capability to absorb nutrients.[46] Specifically, the best practices for improving nitrogen use efficiency are the nutrient application rate, the timing of the application, and the proper application method.[47] The best rate of application is defined as not applying more than 40% more than what is removed with the crop at harvest based on the yield goal. Best timing is defined as applying fertilizer just before the crop needs it, i.e., not applying nitrogen in the fall for a crop planted in the spring.[48] The best application methods involve injecting (placing fertilizer directly into the soil) or incorporating (applying fertilizer to the surface and then "discing" the fertilizer into the soil) rather than simply broadcasting the fertilizer on the soil surface.[49] Regular soil tests are also important for determining site-specific nutrient needs (which often vary within farmland) and applying only the accurate amount of nutrients needed.[50]</td><td>• Only 34% of U.S. corn acres met all three management criteria (rate, timing, and method) in 2010.[51]</td><td>✓ GHG emissions
✓ Nutrient Pollution</td></tr>
<tr><td colspan="3">Environmental Benefits: Best nutrient management practices increase nitrogen use efficiency (NUE), reduce nutrient run-off, and reduce GHG emissions.[52] Some studies have shown that NUE can be doubled by incorporating fertilizer into the soil instead of broadcasting it on the surface.[53] Injection and incorporation of fertilizer also reduce losses of nitrogen stemming from ammonia volatization,[54] while the impact of fertilizer placement on nitrous oxide emissions is less clear. One study found that injection of liquid urea ammonium nitrate at deeper levels resulted in 40-70% lower nitrous oxide emissions than the rate associated with shallow injection or surface application,[55] however other studies have found that incorporation actually increases nitrous oxide emissions.[56] Injection or incorporation could also increase nitrate leaching, especially where soils are coarse.[57]</td></tr>
<tr><td colspan="3">Economic Benefits: In addition to nutrient use efficiency (NUE), yields may also benefit from the implementation of best nutrient management practices.[58] Reducing fertilizer use and/or increasing efficiency also assists farmers in managing high fertilizer costs.[59] There are also significant cost-savings from reducing the amount of treatment required to remove nitrate from drinking water supplies.[60] According to the USDA ERS, reducing nitrate concentrations by 1% would reduce water treatment costs in the U.S. by over $120 million per year.[61]</td></tr>
</table>

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PRECISION AGRICULTURE	Level of Adoption	Risks Addressed
Precision technologies increase production efficiency and also economize on fuel use by gathering information during field operations (from planting to harvest) and calibrating the application of inputs. There are four key information technologies that support precision agriculture: yield monitors, variable-rate application technologies (VRTs), guidance systems, and global positioning system (GPS) maps. VRTs are seeders, sprayers, and other fertilizer and pesticide application equipment that can be continually adjusted to optimize application depending upon field conditions. Guidance technologies and GPS maps improve the accuracy of VRTs and also help farmers avoid overlapping their application or missing sections.[62]	• Yield monitoring is being used on 40-45% of U.S. corn and soybean acres as of 2005-6, but very few producers have adopted VRTs or GPS maps. Nationally, VRTs were used on only 12% of corn acres in 2005.[63] • The adoption rate is slightly higher in the Corn Belt, where VRTs and GPS maps were used on 16 and 24% of corn acres in 2005.[64]	✓ Irrigation Demand ✓ GHG Emissions ✓ Soil Erosion ✓ Nutrient Pollution
Environmental Benefits: A recent extensive literature review of precision agriculture studies worldwide found that precision agriculture contributes in many ways to the long-term agricultural sustainability by reducing losses from excess application of fertilizers and pesticides, reducing environmental loading and conserving water quality, reducing soil erosion, and also reducing pesticide resistance development.[65] For example, studies included in the review found that nitrogen leaching was reduced by an average of 13-50% in U.S. and Canadian corn farms using VRTs, and that herbicide use was reduced by 42-80% in grain and cereal farms that use VRTs.[66]		
Economic Benefits: Corn yields are higher for farmers using yield monitors, VRT fertilizer equipment, and GPS mapping technologies, than for farmers not using these precision technologies. Corn farmers that use yield monitors and VRTs also had lower per-acre fuel expenses.[67]		

CONSERVATION STRUCTURES AND VEGETATIVE MEASURES	Level of Adoption	Risks Addressed
Structures and vegetation such as terraces, grassed waterways, grade stabilizati on structures, filter strips, wetlands and riparian buffers reduce soil erosion and nutrient run-off. Terraces are earthen structures that transform long sloping fields into a series of moderately sloped fields that slow the movement of sediment. Grassed waterways are areas of permanent vegetation planted directly into areas with high amounts of surface water flow in order slow and or trap run-off. Filter strips and riparian buffers are rows of vegetation that are planted next to waterways in order to trap run-off.[68] Other practices, such as drainage water management involve the installation of a riser within the field drainage outlets that can be adjusted when drainage occurs in order to manage the depth of the water table and reduce the amount of water drained from the fields as well as the amount of nutrient run-off.[69]	• In 2010, erosion control structures were used on about 55% of highly erodible land (HEL) planted to corn, about 12% of all non-HEL land planted to corn, and about 18% of all land planted to corn.[70] • In 2010, conservation buffers were used on about 20% of highly erodible land (HEL) planted to corn, about 10% of all non-HEL land planted to corn, and about 11% of all land planted to corn.[71]	✓ Irrigation Demand ✓ Soil Erosion ✓ Nutrient Pollution
Environmental Benefits: The effectiveness of vegetative buffers depends on the size of the buffer, the density of vegetation, and hydrologic conditions within the buffer zone,[72] however a review of a wide range of studies found that buffers can remove about 74% of the nitrogen passing through the buffer root zone.[73] Drainage water management reduces the amount of water discharged from fields, thereby reducing the loss of agricultural chemicals by 30-50%.[74]		
Economic Benefits: While the installation of such conservation structures and vegetative measures can be expensive, the USDA NRCS supports U.S. farmers through the Conservation Reserve Program (CRP) and the Environmental Quality Incentives Program (EQIP). There are also long-term cost savings in terms of improving retention and management of water resources, reduced soil erosion and reduced nutrient run-off (reducing water treatment costs).[75]		

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