The Potential Impacts of Increased Corn Production for Ethanol in the Great Lakes-St. Lawrence River Region

- A Research Paper -

Prepared by the Great Lakes Commission for the
U.S. Army Corps of Engineers Great Lakes & Ohio River Division

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Preface

This research paper was prepared by the Great Lakes Commission for the U.S. Army Corps of Engineers (USACE) Great Lakes & Ohio River Division, with funding provided under the Great Lakes Tributary Modeling Program. It provides an assessment of the current state and trends in U.S. corn-based ethanol production, a brief overview of current incentives to increase ethanol production, and a discussion of the potential impacts of increased corn production to supply ethanol facilities in the Great Lakes-St. Lawrence River region. The intent of the authors is to provide a balanced perspective on biofuel production in the region and assist Great Lakes states, provinces, local governments and other stakeholders in making informed policy and management decisions for land and water resources.

The Great Lakes Tributary Modeling Program, a joint initiative between the USACE and Great Lakes states, develops tools for watershed planning that can be used by stakeholders in making decisions about soil conservation and the prevention of nonpoint source pollution. By supporting state and local measures that will reduce sediment and associated pollutant loadings to tributaries, this joint initiative helps to reduce the need for – and the costs of – navigation dredging while promoting actions to delist identified Great Lakes Areas of Concern (AOCs). Increased corn production for ethanol fuel represents a potential cause of increased soil erosion, sedimentation, and nonpoint source pollution in the agricultural Great Lakes-St. Lawrence River region. The Program leadership believes it is important to begin an investigation and assessment of regional and national trends and quantify, where possible, the potential effects of projected future growth in corn production on corn-related markets and natural ecosystems.

The Great Lakes Commission provides technical and administrative support to the USACE in the implementation of the Great Lakes Tributary Modeling Program, as directed by Section 516(e) of the Water Resources Development Act of 1996. The Commission helps to facilitate USACE coordination with the Great Lakes states and the Great Lakes Basin Program for Soil Erosion and Sediment Control, a U.S. Department of Agriculture grant program for soil conservation that is managed by the Commission. The involvement of the Great Lakes Commission in this project is consistent with the purpose of the Commission, as described in the Great Lakes Basin Compact, in promoting "the orderly, integrated and comprehensive development, use and conservation of the water and related natural resources of the Great Lakes basin and St. Lawrence River."

The principle author of this paper is Laura E. Kaminski, Research Associate, Great Lakes Commission. Ongoing project consultation and oversight was provided by a research team from the Michigan State University Institute of Water Research and Purdue University's Department of Agricultural and Biological Engineering, led by Drs. Jon Bartholic and Bernard A. Engel, respectively (Appendix A). Additional review and comment was provided by Jan A. Miller (USACE, Great Lakes & Ohio River Division); Frederic Kuzel (Great Lakes Biomass State and Regional Partnership, Council of Great Lakes Governors); and Tim A. Eder, Thomas R. Crane, and Gary Overmier (Great Lakes Commission). The author thanks all of these individuals for their time and contributions.

Executive Summary

Rising energy costs and policies to reduce dependence on foreign energy supplies have dramatically increased the domestic production of bioethanol (ethanol produced from plants) as an alternative fuel. With available technology, virtually all bioethanol is derived from corn, though there is significant effort to expedite development of technologies that use cellulose-based materials. As a result of the demand for corn for ethanol production, prices of corn have risen sharply and farmers across the nation are making rapid changes to meet this demand. This paper provides an overview of the increased production of corn-based ethanol and resulting changes in agricultural practices, with emphasis on known and potential environmental and socio-economic impacts within the Great Lakes-St. Lawrence River region.

Ethanol production and use accounted for approximately 3.5 percent of the total U.S. fuel consumption in 2006 and is expected to reach 7 percent by the end of this decade. Ethanol is produced by fermenting and distilling starch feedstock crops (e.g., corn, barley and wheat) that have been converted to simple sugars or sugar-containing crops (e.g., sugar beets and sugar cane). Ethanol can also be produced from cellulosic biomass (e.g., fast-growing trees, corn stover, grain straw, switchgrass, forest products, waste and construction waste) that has been converted to sugar. However, technologies for ethanol production using cellulosic feedstocks are not yet economically viable for commercial production within the United States. At the present time, corn grain provides the most immediate and economic way to mass-produce raw materials for ethanol production. Roughly 98 percent of all U.S. ethanol is currently produced from corn grain.[1]

Manufacturing of ethanol fuel is now the second largest U.S. market for corn behind livestock feed/residual. As of December 2007, there were 134 operating ethanol production facilities in the U.S., with a total annual capacity of nearly 7.3 billion gallons of ethanol.[2] Another 66 facilities were under construction and 10 undergoing expansion, which will nearly double current U.S. ethanol production capacity. In the U.S. portion of the Great Lakes-St. Lawrence River region,[3] there are 39 ethanol production facilities with an annual capacity of 2.66 billion gallons and an additional 28 facilities and/or facility expansions underway. It is projected that the percentage of U.S. corn utilization for ethanol production will level out at around 30 percent of total U.S. corn yield by 2009-2010.

The increased demand associated with ethanol production has caused corn prices to rise from $2.00 per bushel in 2005 to $3.20-3.75 in 2007, with average prices projected to peak at $3.75 per bushel by 2010. The U.S. Department of Agriculture estimates 90.5 million acres of corn were planted in 2007, an increase of 12.3 million acres from 2006. Total U.S. corn production is estimated to rise 15.5 percent to an all-time record high of more than 12.2 billion bushels in 2007.[4]

The near-term increase in corn production has been largely accomplished by the conversion of existing croplands from soybeans to corn. The National Agriculture Statistics Services estimates a nationwide decrease of 11.1 percent in soybean acreage from 2006 levels. Within the Great Lakes states and provinces, corn acreage is projected to increase by 13.1 percent over 2006 figures with soybean acreage decreasing by 9.9 percent.

With a continued demand for ethanol as a fuel source and elevated price levels for corn, additional acres are expected to go into production. One source of this acreage is land that is currently fallow, in pasture or in conservation. Of the lands currently enrolled in the Conservation Reserve Program (CRP), the USDA has

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[1] Personal communication: M. Hartwig, Renewable Fuels Association, September 5, 2007.

[2] Production facilities include both corn and cellulose-based ethanol (Renewable Fuels Association, 2007).

[3] The Great Lakes-St. Lawrence River region includes the entire area of the eight U.S. states and two Canadian provinces. Alternatively, the Great Lakes-St. Lawrence River Basin contains the land area in those states and provinces that drains to the Great Lakes and St. Lawrence River, their tributaries, and connecting channels.

[4] USDA data reported on a marketing-year basis (September-August) and may vary depending on survey methods and estimating procedures.

projected that approximately 4.6 million acres, or roughly 12.5 percent, will be exiting the program without re-enrollment by 2010, as high crop prices encourage their return to production.

Potential economic issues and impacts that may result from increased corn and corn-based ethanol production include changes in fuel and food costs; decreased federal farm commodity payments due to higher corn and other crop prices; changes in waterborne, truck, and rail transportation; creation of jobs and increased farm income; rural economic development; and increasing real estate values. Some of the impacts are already evident to the consumer, such as higher grain and food costs resulting from corn price increases. Other impacts may take more time to realize, such as increased sediment accumulation in commercial and recreational harbors and channels which impacts navigation and contributes to an increased need for dredging.

Known and potential environmental impacts of increased ethanol production from corn and the resulting changes in the agricultural landscape include increased soil erosion and sedimentation occurring from tillage practices often used in corn production, increased water consumption for the production of both corn and ethanol, and increased loadings of nutrients and persistent contaminants from agricultural applications. These stressors may cause changes to the quality of surface and groundwater, aquatic habitat and fisheries, and recreational opportunities. The impacts on the Great Lakes ecosystem are likely to be most pronounced in regions where lands that are more highly erosive or environmentally sensitive – such as those currently in conservation – are brought into production. It is possible that increased loadings of sediments, nutrients and pesticides/herbicides may reverse some of the environmental gains made through previous nonpoint source control efforts.

While the increased use and production of ethanol has been a positive step toward decreasing North America's dependency on fossil fuel imports and a positive influence on rural economies, renewable energy production in the form of corn-based ethanol may have a variety of environmental and socio-economic impacts that deserve the attention and consideration of the region's leaders and stakeholders.

This paper does not present answers to these issues and potential problems but is intended to stimulate this discussion. Stakeholders around the Great Lakes-St. Lawrence River region and beyond are encouraged to use these data to inform additional studies and management strategies.

Introduction

Innovators and entrepreneurs in the United States and Canada have worked to develop new technologies and alternative fuels to reduce national dependency on foreign oil and petroleum. Bioethanol, an alcohol-based fuel made from plant materials, provides one alternative fuel that has received significant attention, capital investment, and media coverage.

As a result of rising fuel costs and increasing prices for corn, farmers across the nation have increased corn production to meet the growing demand for corn-based ethanol, the primary form of bioethanol. This has led to some of the biggest changes in corn production since 1944, when 95.5 million acres were planted during World War II (USDA-NASS, 2007c). Additionally, President George W. Bush in his 2007 State of the Union address called for an increased focus on renewable fuels – especially cellulosic ethanol – and higher mileage standards for cars and light trucks. The President predicted that such measures would help "reduce gasoline usage in the United States by 20 percent in the next 10 years" and dramatically reduce America's dependence on imported oil from the Middle East. The impacts of these recent changes are pervasive and affect growers, distributors and system processors, and consumers. As corn-based ethanol increasingly becomes an accepted mainstream fuel product, it is important to examine the rationale for increased ethanol production and potential big-picture effects through both national and regional lenses.

This research paper includes an overview of the current status and trends of corn-based ethanol production and the incentives stimulating increases in production, and an analysis of the potential environmental and economic impacts of ethanol production on the Great Lakes-St. Lawrence River region. The research paper authors note that other types of biofuel production are occurring within the Great Lakes-St. Lawrence River region and are important to consider; however, this paper is focusing on the issues specific to corn-based ethanol.

Most of the statistical data presented here were obtained from federal, state, and provincial agencies or organizations responsible for agricultural and industry-specific records. These data point to national trends within the United States and Canada, with a major focus on the upper Midwest "Corn Belt" states.[5] Trends specific to the Great Lakes-St. Lawrence River region, have also been identified, where possible.

Figure 1. Great Lakes-St. Lawrence River Region

Source: Great Lakes Commission
The Great Lakes-St. Lawrence River region includes the entire area of the eight U.S. states and two Canadian provinces. This differs from the Great Lakes-St. Lawrence River basin, which is shaded in gray (above).

[5] The Corn Belt is a region of the U.S. Midwest comprised of Iowa, Indiana, Illinois, and Ohio. Approximately 50 percent of all U.S. corn is grown within these four states. Additional Corn Belt states include parts of South Dakota, Nebraska, Kansas, Minnesota, Wisconsin, Michigan, Missouri, and Kentucky.

The Great Lakes-St. Lawrence River region, for purposes of this research paper, is defined as the entire area of the eight U.S. states (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin) and two Canadian provinces (Ontario and Québec) that border the Great Lakes and St. Lawrence River (Figure 1). This area differs from the Great Lakes-St. Lawrence River basin (or watershed) which contains the land area within those states and provinces that drains to the Great Lakes and St. Lawrence River, their tributaries, and connecting channels (Figure 1, shaded area). Even though the data reported for the Great Lakes-St. Lawrence River region represent an area larger than the Great Lakes-St. Lawrence River basin, the trends described in this paper are considered valid indicators of what is occurring or could potentially occur within the basin.

This research paper is intended to stimulate discussion among U.S. and Canadian Great Lakes-St. Lawrence River agencies and organizations with energy, environmental, economic development, and research responsibilities. Others are encouraged to build on these findings and use these data to inform additional studies or more significant efforts to mitigate any potential negative effects from increased corn production. Those adverse effects may include increased nonpoint source pollution, soil erosion and sedimentation, water consumption from agricultural irrigation, and others. To address the challenges identified in this paper, policymakers, practitioners, and decisionmakers should consider developing new partnerships and forging new integrated solutions to ensure and improve ecosystem health, economic prosperity, and the quality of life for all inhabitants in the Great Lakes-St. Lawrence River region.

What is Ethanol?

Ethanol – or ethyl alcohol – is another name for grain alcohol. For well over a century, ethanol has been valued as an industrial solvent. Ethanol was used as a fuel as early as 1908 when Henry Ford's Model T was designed to use ethanol, gasoline, or a combination of the two fuels (USDOE, 1997). During the 1930s, Midwestern service stations offered blended gasoline containing 6 to 12 percent corn-based ethanol. However, due to its cost, the blended formula disappeared from common use in the 1940s (USDOE, 1997). It was not until 1979, when ethanol-gasoline blends were reintroduced in response to disruptions in foreign oil supply, that ethanol fuel resurfaced as a potentially viable alternative to help offset imports of foreign petroleum (USDOE, 1997).

Ethanol production and use accounted for approximately 3.5 percent of the total U.S. fuel consumption in 2006 and is expected to reach 7 percent by the end of this decade (USDA-ERS, 2007a; USDOE-EIA, 2007a). Ethanol is commonly used to increase octane levels and emissions quality of gasoline by blending the two substances together: E10 (10 percent ethanol, 90 percent gasoline), E85 (85 percent ethanol, 15 percent gasoline), and E95 (95 percent ethanol, 5 percent gasoline)[6] (USDOE, 2006). Ethanol containing 35 percent oxygen provides more complete fuel combustion and thereby reduces harmful vehicle air emissions. Ethanol is also non-toxic, water soluble, and quickly biodegradable (Renewable Fuels Association, 2007). Blends with high levels of ethanol can be used by flexible fuel vehicles for transportation fuel. However, many foreign carmakers have not adopted this technology and have focused instead on the development of vehicles powered by other alternative sources of energy (OnPoint, 2007).

In 2006, ethanol accounted for roughly 3.5% of total U.S. fuel consumption, and is expected to reach 7% by 2010.

Researchers have worked to increase the efficiency of ethanol use and production as an alternative to gasoline. A recent RAND Corporation report shows that production of 25 percent of America's electric power and vehicle fuel from renewable sources is a feasible goal by 2025 with low costs to the U.S. economy. This research indicates that by 2025, America's farms, forests, and ranches can annually produce 86 billion gallons of ethanol, 1.1 billion gallons of biodiesel, and 932 billion KWH of electricity. Additionally, Midwestern states could be major sources of biomass energy in the future (RAND, 2006). Nevertheless, even as ethanol appears to be gaining wider acceptance, the high costs of producing ethanol remain an important constraint on ethanol as an alternative fuel (Asrar, 2007).

[6] E95 is not currently commercially available.

The Production of Ethanol

Ethanol is produced by fermenting and distilling starch feedstock crops (e.g., corn, barley and wheat) that have been converted to simple sugars or sugar-containing crops (e.g., sugar beets and sugar cane) (USDOE, 2006). During the fermentation process, yeast is used to break down the simple sugars, which creates both ethanol and substantial amounts of byproducts, such as nondegradable plant residues and cellulosic particles. These byproducts are often marketed as dried distiller's grains and used for livestock feed – mainly for dairy and beef cattle – and are thus referred to by some as "coproducts" (Asrar, 2007). According to the Renewable Fuels Association, approximately 17 pounds of byproduct are generated per bushel of corn. Another byproduct from the fermentation process of ethanol production is carbon dioxide (CO_2), which is either released into the atmosphere or captured and compressed for use as carbonation for beverages or frozen into dry ice (Mosier & Ileleji, 2007).

The two main types of commercial ethanol production are wet milling and dry grind. In wet milling, corn is first soaked in water to soften the kernels before separating the grain into starch, fiber, and germ for separate processing (Mosier & Ileleji, 2007). Byproducts from wet-mill ethanol production include two animal feed products – corn gluten meal and corn gluten feed – as well as corn germ, which can be further processed into corn oil (Mosier & Ileleji, 2007). Conversely, dry grind ethanol production utilizes the whole kernel, with residual components separated at the end of the process (Mosier & Ileleji, 2007; Renewable Fuels Association, 2007). According to the Renewable Fuels Association, dry mill facilities account for more than 80 percent of current corn ethanol production, producing approximately 2.8 gallons of ethanol from one bushel of corn.

Despite its name, dry grind processing as well as wet-milling methods both require the use of water to produce ethanol from corn grain. Many newer facilities have the capacity to recycle some of the water necessary for the processing of the corn grain; however, water is typically lost through evaporation during the cooling phase and through wastewater discharge (Keeney & Muller, 2006). Depending on the type of processing, the quality of water inputs, the efficiency of the facility, and seasonal variability, an estimated 3.5 to 6 gallons of water is required for the production of one gallon of ethanol (Keeney & Muller, 2006) (see "Water Use"). [7] Residual water and corn solids from these processes are called "stillage," and are separated into distiller's grains and liquid "thin stillage."

Cellulose-based ethanol is another form of bioethanol that is produced from cellulosic feedstocks (e.g., fast-growing trees, corn stover, grain straw, switchgrass, forest products, municipal waste and construction waste) and can be converted to sugar (USDOE, 2006). Cellulosic feedstocks may yield a higher energy balance than ethanol made from corn, but are less developed and not yet economically viable for commercial production.

Researchers and producers continue efforts to determine the best feedstocks and geographic regions for advancing energy production from renewable biomaterials. Different types of inputs and growing seasons are required to produce healthy and viable crops of each type of feedstock. However, corn provides an easy and immediate way to mass-produce raw materials for ethanol production. The U.S. Department of Agriculture's Agricultural Research Service (ARS) has worked to develop modified plant varieties, better agricultural practices, postharvest storing methods, and other strategies to increase corn yields and profitability (Asrar, 2007). Technology improvements have also been made to increase the efficiency of ethanol produced per unit of corn.

Most U.S. ethanol fuel production occurs in plants located in the Corn Belt or Midwest in close proximity to corn supplies (Figure 2) (USDOE, 1997; Renewable Fuels Association, 2007). Most ethanol distribution is by rail or truck since pipeline transportation is not feasible; phase separation from the absorption of moisture can occur in pipelines and render the ethanol unusable (USDOE, 1997).

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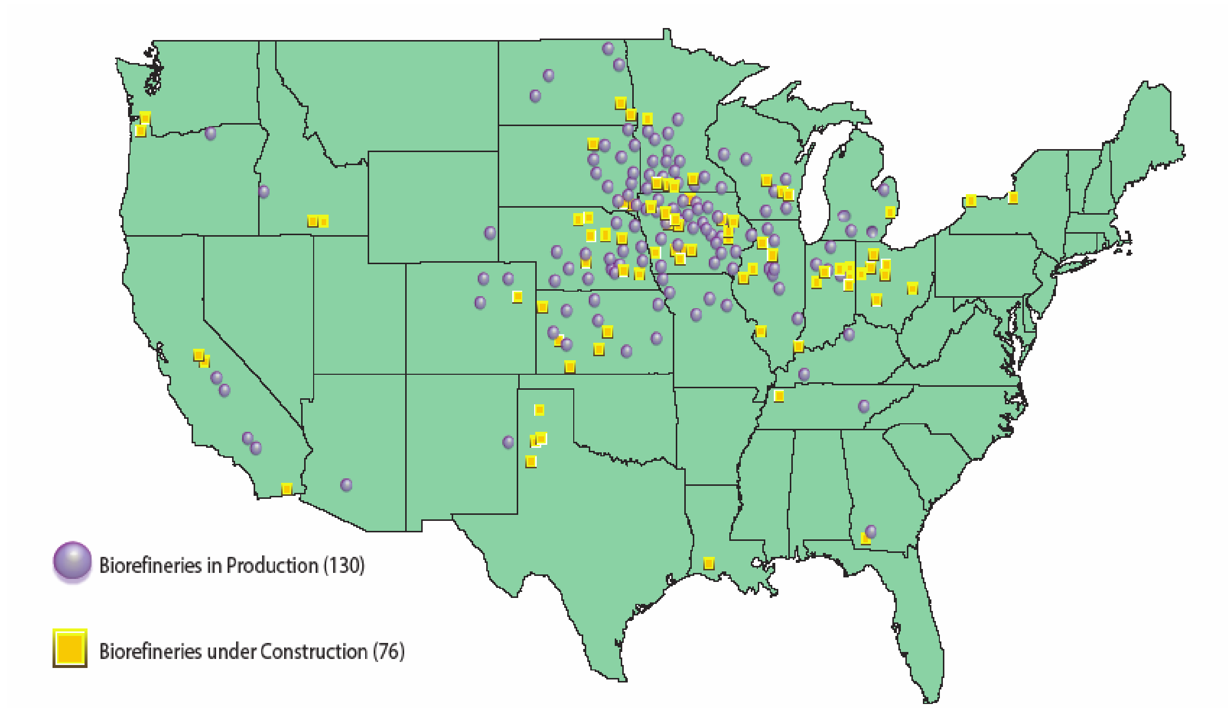
[7] Water use records for ethanol plants are not publicly available; however, these figures were obtained from records held by the Minnesota Department of Natural Resources for ethanol plants in that state. For a more detailed account, see Keeney and Muller, 2006.

Figure 2. U.S. Bioethanol Refinery Locations, October 2007



Source: Renewable Fuels Association, 2007
Production facilities include both corn and cellulose-based ethanol. Roughly 98 percent of current U.S. ethanol production is from corn grain.

U.S. Trends in Corn Production for Ethanol

Corn Production on the Rise

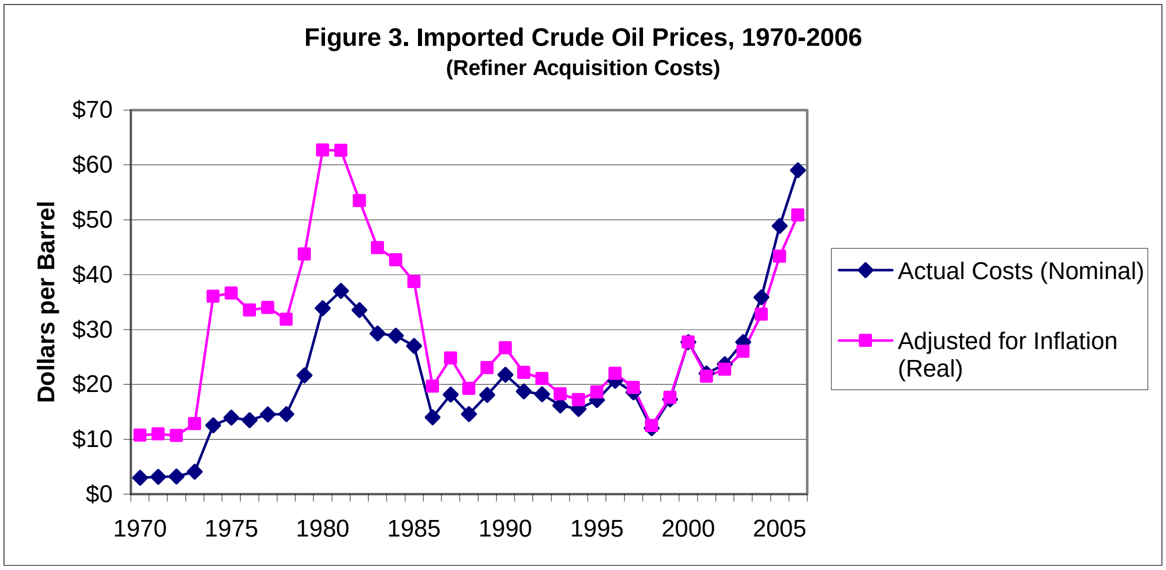
U.S. corn production is nearing an all-time record high with projected nationwide corn acreage of 90.5 million acres this year (2007).[8] According to data obtained from the U.S. Department of Agriculture's National Agricultural Statistics Service (USDA-NASS), these figures reflect a 15.5 percent increase over 2006 when 78.3 million acres of corn were planted and nearly 10.6 billion bushels were produced (USDA-NASS, 2007c).[9] Based on projected plantings and per acre yields, the United States is expected to produce more than 12.2 billion bushels of corn in 2007. This increase, as mentioned previously, results from a complex set of factors, including a rising demand for alternative fuels spurred by high fossil fuel energy prices; a significant increase in political support and policy decisions supporting ethanol production; high corn prices and increasing profit margins; and improvements in corn and ethanol production technology. The following sections review these factors in greater detail.

Rising Energy Prices

Rapid increases in fossil fuel energy costs are a primary driver of the increased demand for alternative fuels in the United States. Rising energy costs not only put pressure on economic growth, but result in higher costs for consumers as well (Centric Consulting Group, 2006). Worldwide oil demand has escalated in recent decades and fossil fuel markets have become more volatile. Global economic growth and the demands of expanding manufacturing sectors in China and India contribute to oil demand and market volatility (USDA-ERS, 2007a;

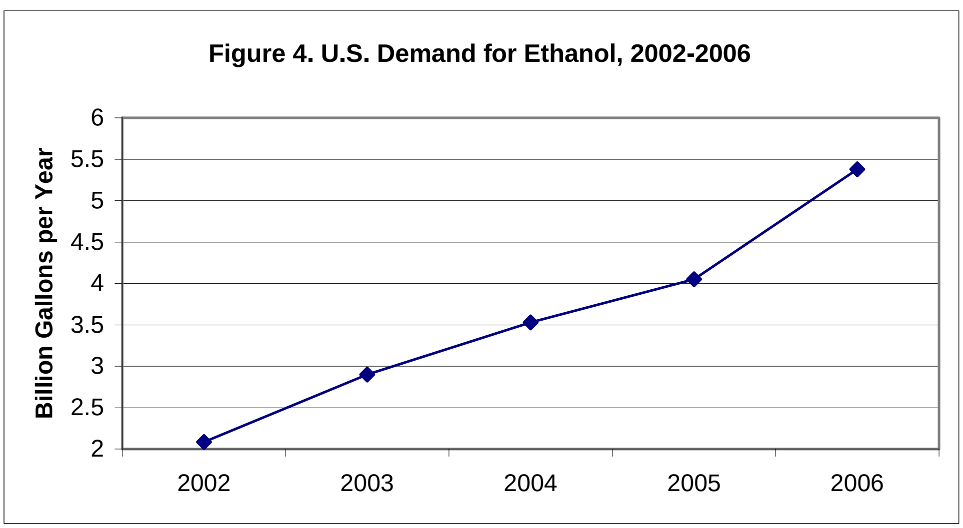
[8] The highest acreage of corn in the United States occurred in 1944 with 95.5 million acres planted during World War II (USDA-NASS, 2007c).
[9] USDA data reported on a marketing-year basis (September-August) and may vary depending on survey methods and estimating procedures. Latest data may be preliminary or projected.

Michigan Renewable Fuels Commission, 2007). This, paired with fluctuating supply and international trade factors, has resulted in a rapid increase in the cost of imported crude oil (Figure 3).



Source: USDOE-EIA, 2007a

To put this in perspective, refiners' costs for crude oil in the 1990s averaged around $17.50 per barrel (USDOE-EIA, 2007a).[10] In 2006, the price of crude reached nearly $68 per barrel and averaged $59 per barrel for the year (USDA-ERS, 2007a; USDOE-EIA, 2007a).[11] As of November 2007, the cost of crude had reached $87 per barrel (USDOE-EIA, 2007a). Likewise, average annual prices for U.S. unleaded regular grade gasoline at fuel pumps have stretched from $1.51 per gallon in 2000 to $2.59 per gallon in 2006 (USDOE-EIA, 2007b).[12] Average prices for unleaded gasoline nationwide reached a high of $3.13 per gallon in May 2007 (USDOE-EIA, 2007b). The United States has increasingly focused on the domestic production of alternative fuels to help offset the demand for and strain of imported oil (Figure 4).



Source: Renewable Fuels Association, 2007
Demand is defined as [U.S. Production] + [Imports] – [Exports] +/- [Stocks Change], and includes both corn and cellulose-based ethanol. Roughly 98 percent of current U.S. ethanol production is from corn grain.

[10] Adjusted for inflation: 1990s average = $19.5 per barrel (USDOE-EIA, 2007a)
[11] Adjusted for inflation: 2006 average = $50.85 per barrel (USDOE-EIA, 2007a)
[12] Adjusted for inflation: 2000 = $1.51 per gallon; 2006 = $2.23 per gallon (USDOE-EIA, 2007b)

Changes in Energy Policies

Political forces and important policy decisions have helped stimulate expansion of the ethanol industry in numerous ways. Several interrelated factors have recently come together contributing to a political desire that is refocused on energy security and independence. Among these, conflicts and instability in the Middle East and other oil-producing countries have caused energy security concerns to resurface with the highest profile since the global oil crises in 1973 and 1979. Increasingly widespread concerns about the impacts of greenhouse gas (GHG) emissions on global climate change has also spurred support for alternative sources of energy. These issues have refocused interest in developing viable alternatives to fossil fuels as well as more efficient conversion technologies for biofuels (Michigan Renewable Fuels Commission, 2007).

The U.S. Congress and state legislatures are also motivated by the desire to create new markets for agricultural products and are also influenced by lobbyists for corn and ethanol producers urging favorable policies for U.S. agriculture and domestic alternative energy production (Worldwatch Institute, 2007). Again, a confluence of factors has created a forceful new context. As debate continues over reauthorizing the 2007 U.S. Farm Bill, the role of USDA commodity payments and subsidies to farmers is being considered. Some projections indicate that pulling back support for ethanol may cause corn prices to tumble, resulting in lower prices for feedlot operators and new government commodity payments to corn growers under the new farm bill (Philpott, 2007). Federal tax laws, such as blender tax credits, and import tariffs also provide incentives for the domestic production of biofuels (USDA-ERS, 2007a).

In 2005, the United States adopted a Renewable Fuel Standard (RFS) requiring use of 7.5 billion gallons of biofuels for transportation by 2012 (or approximately 3 percent of projected gasoline demand in 2012). In addition, under new guidelines implementing the 1992 Energy Policy Act, many government fleet vehicles running on diesel fuel are required to use B20 blends (20 percent biodiesel) (Worldwatch Institute, 2007).

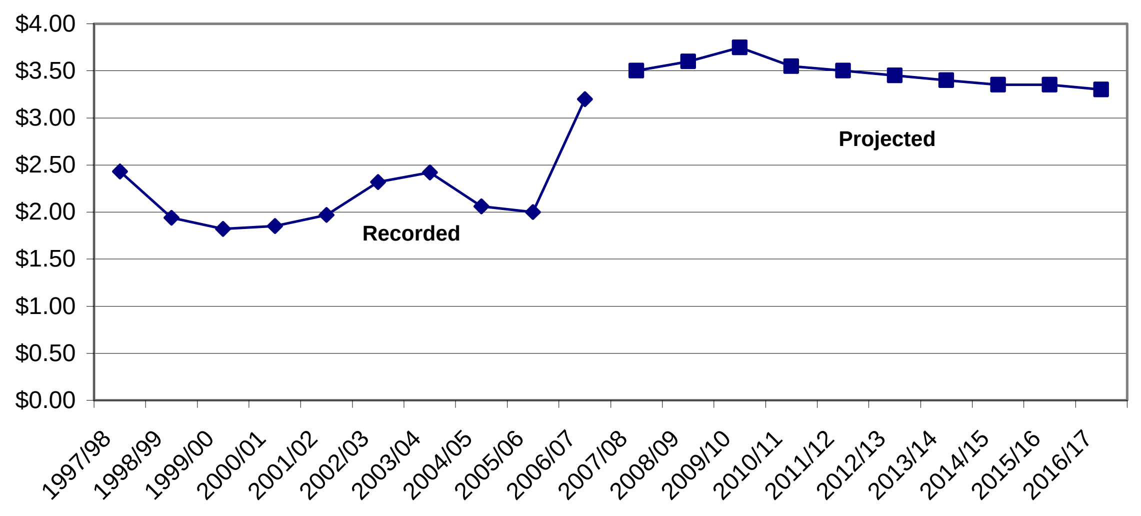
Several U.S. states legislatures have also weighed in. For example, Minnesota enacted a law in 1997 requiring all gasoline sold or offered for sale in the state to contain at least 10 percent ethanol by volume (E10), with some exceptions. In 2005, Minnesota also established by law a statewide E20 mandate to be enacted in 2013. This will go into effect unless at least 20 percent of the liquid fuel sold in the state is already derived from renewables by the end of 2010 or state officials have failed to obtain federal approval for the use of E20 as a motor fuel (Minnesota Statute 239.791). Further, all diesel fuel sold or offered for sale in the state for use in internal combustion engines must also contain at least 2 percent biodiesel fuel by volume (Minnesota Statutes 239.77 and 239.75).

In Canada, the federal government has mandated that 5 percent of all vehicle fuel consist of biofuels by 2010 (USDA, 2007b). To help meet the rapid increase in demand, the Canadian federal Ethanol Expansion Program (EEP) was established to support construction of new ethanol and biofuel facilities. Additionally, federal waivers for excise taxes on gasoline/ethanol blended fuels were enacted in the mid-1990s. Ethanol production capacity within Canada is expected to grow from 11 million gallons (42 million liters) in 2006 to about 211 million gallons (799 million liters) by 2010 (USDA, 2007b).

Escalating Corn Prices

The rapid expansion of ethanol and biodiesel production has influenced both U.S. corn and soybean prices in recent years. Average corn prices have increased from $2.00 per bushel in 2005 to $3.20-3.75 in 2007, a hefty 60 to 84 percent increase. Due to ethanol fuel demand, these prices will likely remain elevated for the near term, making corn production an enticing prospect for growers. Long-term USDA projections conducted in early 2007 show average corn prices peaking at $3.75 per bushel during the 2009-2010 marketing year (September 1-August 31 for U.S. corn supply) and then declining and stabilizing around $3.30 through 2016-2017 as ethanol expansion slows (Figure 5) (USDA-ERS, 2007a). As a result, prices for other crops such as soybeans, will also fluctuate due to acreage demands for corn and the decreased availability of substitute grains (Appendix B-1).

Figure 5. U.S. Corn Prices, 1997-2016

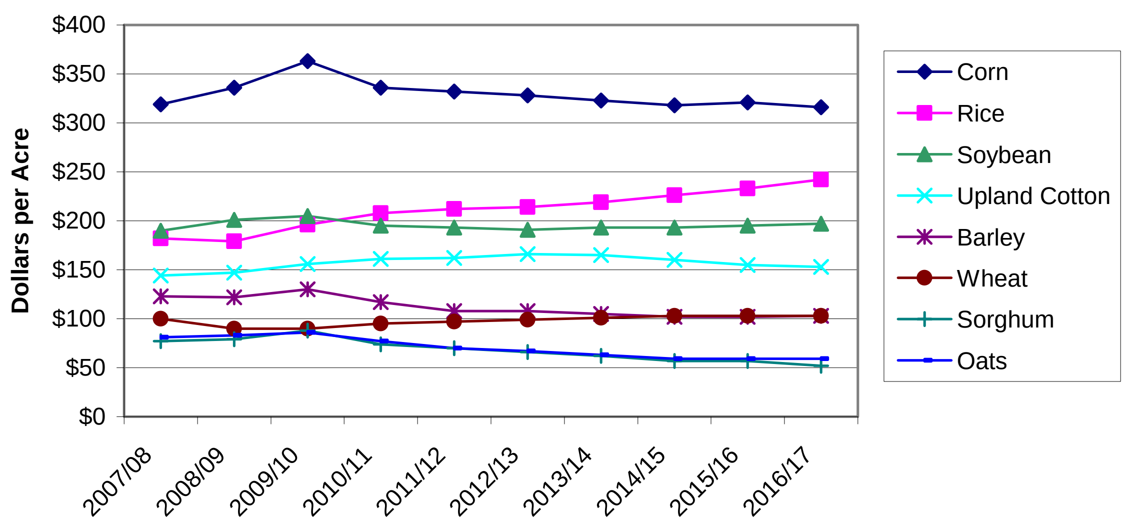


Source: USDA, 2007b (Prices not adjusted for inflation.)
Data reported on a marketing-year basis (September-August).

<u>Increasing Profit Margins</u>

A primary factor in commodity production is the profit margin. When compared to other field crops in recent years, corn unit prices and yields have resulted in net gains that far surpass those of comparable crops (Figure 6). The USDA projects this favorable trend in corn prices to continue through 2016 as soybean and other crop margins remain stable or decline slightly.

Figure 6. Projected U.S. Net Returns for Primary Crops, 2007-2016



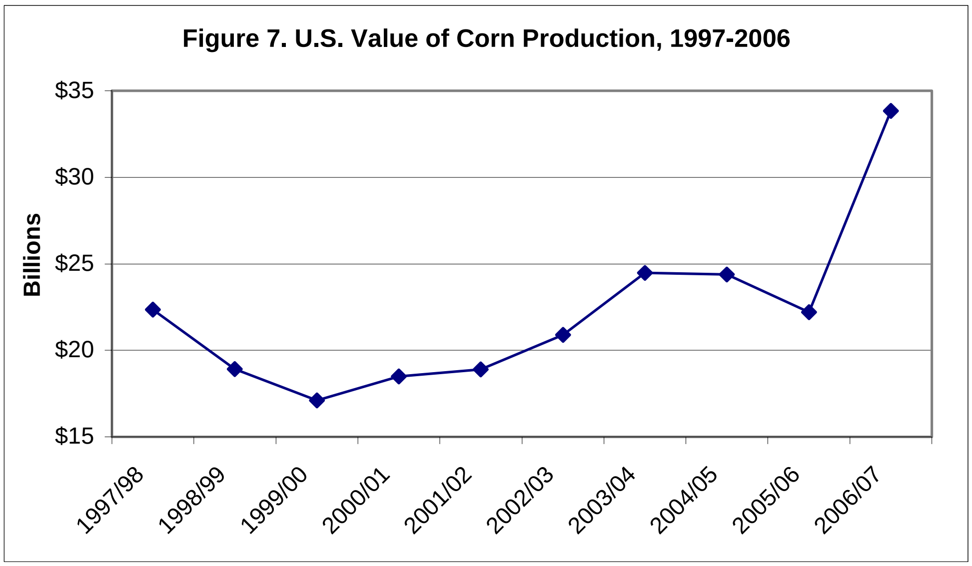
Source: USDA, 2007b
Data reported on a marketing-year basis (September-August).

The Role of Technology Improvements

Technology and process improvements can help make the production of corn and ethanol more efficient. As mentioned previously, USDA research has helped to develop modified plant varieties, improved agricultural practices, post-harvest storing methods, and other strategies for farmers to increase corn yields and profitability (Asrar, 2007). As the technology and processes for producing cellulose-based ethanol continue to be advanced and refined, the production of cellulosic ethanol may ultimately overcome the economic advantage currently held by corn. This may result in a decreased demand for corn. As a result, a shift of ethanol production away from the Corn Belt could potentially occur, depending on a number of economic constraints. Some of these factors include geographic and climate constraints for the production of desirable cellulosic feedstocks, transportation and storage of feedstocks and ethanol, and whether existing corn-based ethanol production facilities can be retrofitted to accommodate new cellulosic processes of ethanol production.

The Value of Corn Production

The value of domestic corn production climbed to nearly $33.8 billion in 2006 from $22.2 billion in 2005 (Figure 7). The value of corn production is expected to rise as the ethanol industry continues to expand.

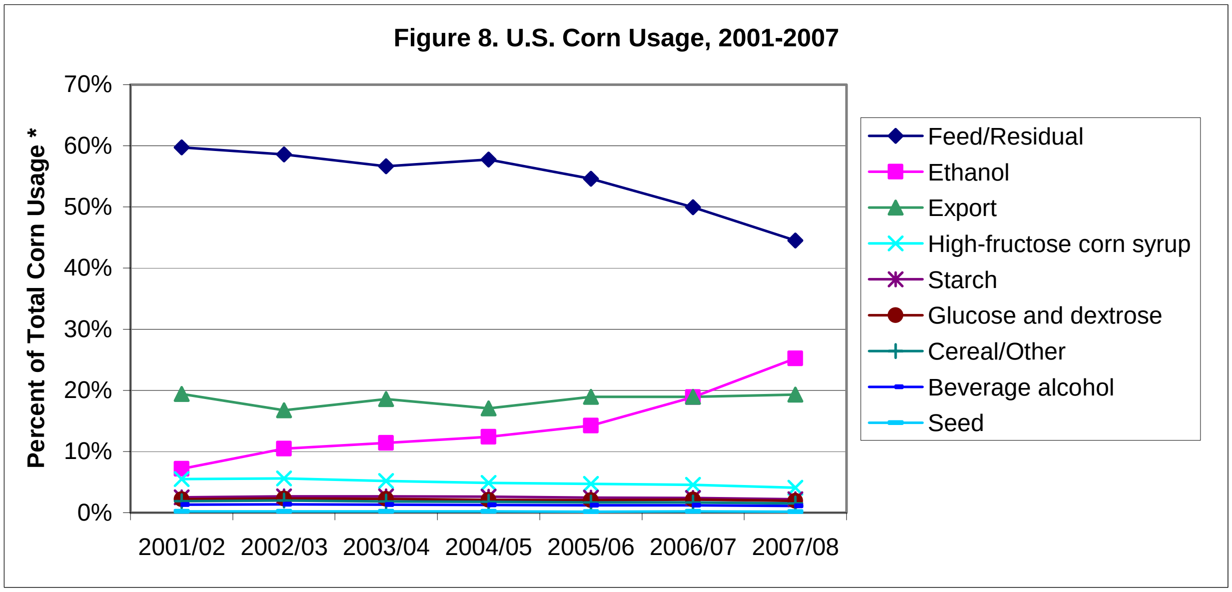


Source: USDA-NASS, 1997-2007
Values not adjusted for inflation. Data reported on a marketing-year basis (September-August) and may vary depending on survey methods and estimating procedures.
Latest data may be preliminary or projected.

The production of corn and corn-based ethanol generates revenue for other sectors as well. Examples include the sales and production of corn seed; fertilizers and pesticides; and farming equipment used for cultivating, planting, and harvesting corn. Storage facilities may experience significant shifts in demand and/or be supplemented by increased on-farm storage, and there will be increased needs for transportation of both corn and ethanol and ethanol production facilities.

Utilization of U.S. Corn Harvests

Within the United States, there are several main sectors for the use and consumption of corn. These include livestock feed/residual, export markets, and ethanol producers (Appendix B-2). Corn is also used for the domestic production of high-fructose corn syrup, starch, glucose and dextrose, cereal, beverage alcohol, and seed. As illustrated in Figure 8, in the last 3 to 4 years these percentages have begun to change as a result of the recent increase in demand for ethanol and increases in corn prices. Manufacturing of ethanol fuel is now estimated to be the second largest U.S. market for corn behind livestock feed/residual. Changes in the supply of and demand for corn have additional ripple effects throughout the agricultural and retail food sectors, including impacts on the costs of livestock feed, farm income, government payments, and consumer food prices (see "Economic Impacts," below).



Source: USDA-ERS, 2007b
* Total corn usage differs from total corn production or harvest.
Data reported on a marketing-year basis (September-August) and may vary depending on survey methods and estimating procedures. Latest data may be preliminary or projected.

Ethanol Production Capacity

According to the Renewable Fuels Association, as of December 2007 there were 134 operating ethanol production facilities with a total annual capacity of nearly 7.3 billion gallons of ethanol.[13] With 66 additional facilities under construction and 10 existing facilities undergoing expansions, U.S. ethanol production capacities will nearly double reaching a total of 13.5 billion gallons upon completion (Renewable Fuels Association, 2007). Production levels from January to September of 2007 were at approximately 517 million gallons per month, on average, with production at roughly 85 percent of the industry's current capacity. Of this, 98 percent or 507 million gallons per month are made from corn grain feedstock.[14] Projecting these figures for the entire year shows a total anticipated production of more than 6.01 billion gallons of corn-based ethanol for 2007 – a 26 percent increase over 2006 levels when 4.76 billion gallons (or 396 million gallons per month) of corn-based ethanol were produced (Figure 9) (Renewable Fuels Association, 2007). U.S. production is expected to exceed 10 billion gallons by 2009 (USDA-ERS, 2007a).

Ethanol represented about 3.5 percent of the total domestic vehicle fuel supplies in 2006 (USDA-ERS, 2007a). However, its production consumed approximately 16 percent of the country's 10.5 billion bushel 2006 corn production, and is projected to increase to nearly 18 percent in 2007 based on an anticipated yield of 12.2 billion bushels for the year. To meet the raw material needs for the total near-term projected ethanol production capacity (including those facilities currently under development or expansion, using only corn grain), approximately 4.8 billion bushels of corn, or about 39 percent of the projected 2007 U.S. corn production, would be required.[15,16] However, long-term USDA projections conducted earlier this year show that the percentage of U.S. corn utilization for ethanol production

Ethanol production is expected to consume 30% of the annual U.S. corn harvest by 2009.

[13] Total ethanol capacity, including both corn and cellulose-based ethanol.

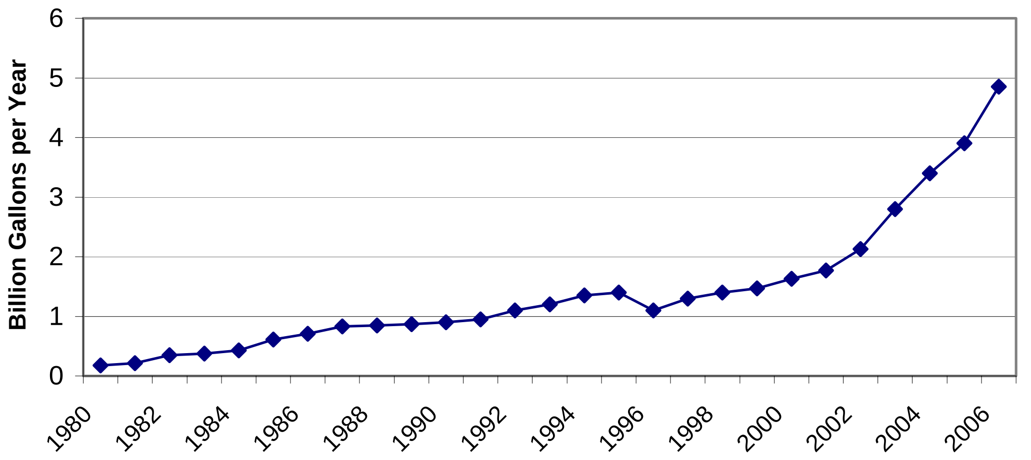
[14] Personal communication: M. Hartwig, Renewable Fuels Association, September 5, 2007.

[15] Based on projected 2007 yields recorded by USDA-NASS, 2007c.

[16] In reality, currently 98 percent of ethanol production uses corn grain as the feedstock. (Personal communication: M. Hartwig, Renewable Fuels Association, September 5, 2007)

will level out at around 30 percent of total U.S. corn yields by 2009-2010 (Appendix B-3) (USDA, 2007b). As demand for ethanol continues to increase, that which cannot be met by domestic production could be addressed by foreign ethanol imports (Appendix B-4). However, this too has additional policy implications. The top ethanol producers after the United States are Brazil, China, India, and France (Appendix B-5).

Figure 9. U.S. Ethanol Production, 1980-2006



Source: Renewable Fuels Association, 2007
Production figures include both corn and cellulose-based ethanol. Roughly 98 percent of current U.S. ethanol production is from corn grain.

On a parallel track, and as the technology for cellulosic ethanol becomes commercially viable, industry leaders see its production as an opportunity to increase the volume of ethanol fuel produced from biomass in the United States (Renewable Fuels Association, 2007) and Canada. Demonstration facilities, like the Iogen Corporation in Ottawa, Ontario, currently produce small quantities of cellulose-based ethanol from wheat, oat, and barley straw. In addition, waste products such as corn stover, forest thinnings, and municipal waste could become major feedstocks for the production of cellulosic ethanol within the next 10 years. Several existing U.S. ethanol facilities are engaged in research and demonstration projects supported by the U.S. Department of Energy (USDOE) (Renewable Fuels Association, 2007). These facilities could help make this type of ethanol production more marketable when they become operational in 2011.

Trends in the Great Lakes-St. Lawrence River Region

Corn Acreage, Yields, and Value of Production

Corn acreage for grain production has increased in the Great Lakes-St. Lawrence River region[17] (state- and province-wide) since 2006, similar to that which is occurring in the United States as a whole. Corn planting projections for the region show nearly 43 million acres for 2007, a 13 percent increase over 2006 figures for harvested acreage (Appendix B-6) (USDA-NASS, 2007c; OMAFRA, 2007a; and Institut de la Statistique Québec, 2007.)[18] Similarly, the two areas of highest corn production in the region, Illinois and Minnesota, will set new acreage records and are expected to experience record yields this year. These states are followed closely by Indiana, Wisconsin, and Ohio in total production. Percentage-wise, Ontario, Ohio, and Québec lead the region in the greatest increases in corn production from 2006-2007.

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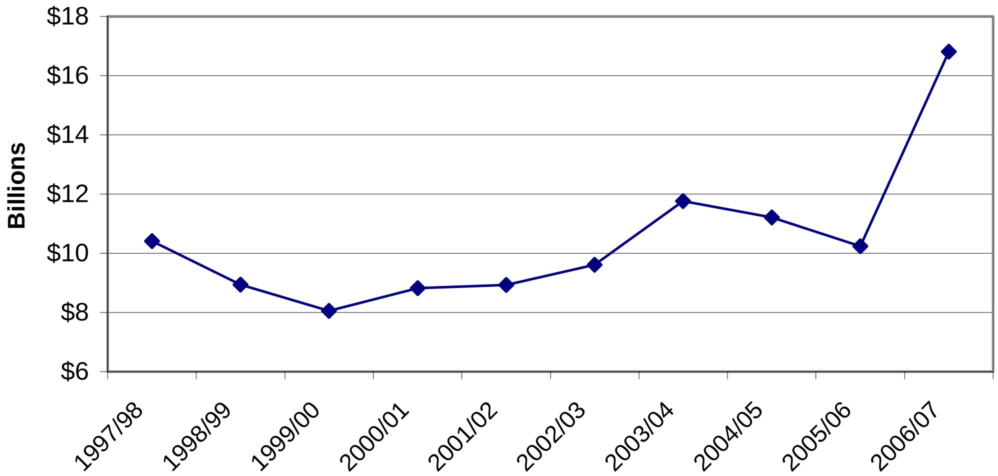
[17] The Great Lakes-St. Lawrence River region is defined as the entire area of the eight U.S. states and two Canadian provinces that border the Great Lakes and St. Lawrence River.
[18] USDA data reported on a marketing-year basis (September-August) and may vary depending on survey methods and estimating procedures. Latest data may be preliminary or projected.

The production of 5.1 billion bushels of corn in 2006 was nearly half of the total U.S. production (48 percent), yet this yield was produced from only 45 percent of the nation's total corn acreage (USDA-NASS, 1997-2007). In addition, average corn prices in the Great Lakes states have typically exceeded the national average. In 2006, the average price in the Great Lakes states was $3.31 per bushel – surpassing the national average by $0.11 per bushel. The 2006 value of corn production for the U.S. portion of the Great Lakes-St. Lawrence River region was $16.8 billion (Figure 10), roughly half the total U.S. value of corn production (USDA-NASS, 1997-2007).

Figure 10. Value of Corn Production in the U.S. Great Lakes States, 1997-2006



Source: USDA-NASS, 1997-2007
Data reported on a marketing-year basis (September-August) and may vary depending on Survey methods and estimating procedures. Latest data may be preliminary or projected.

In Ontario, approximately 231 million bushels of corn were produced in 2006 with projected 2007 yields of over 310 million bushels (OMAFRA, 2007a). Québec produced 141.3 million bushels of corn in 2006 and projects a 2007 yield of more than 163 million bushels (Institut de la Statistique Québec, 2007). Thus, as corn prices continue to rise, the Great Lakes-St. Lawrence River region anticipates record production and value levels from future corn harvests.

Ethanol Production Capacity in the Region

Within the U.S. portion of the Great Lakes-St. Lawrence River region, as of December 2007, 39 ethanol facilities have the capacity to produce up to 2.66 billion gallons of ethanol per year (Renewable Fuels Association, 2007). Assuming this capacity was dedicated in its entirety to corn-based ethanol production, approximately 950 million bushels of corn, or roughly 18 percent of current U.S. corn production in the region, would be required per year.[19,20] As of December 2007, the construction and/or expansion of 28 facilities was underway which, when completed, will nearly double the annual production capacity for the region's facilities to 4.8 billion gallons per year (Renewable Fuels Association, 2007). To meet this capacity using only corn grain, more than 1.7 billion bushels of corn per year would be required, or roughly 32 percent of the projected 2007 U.S. corn production in the region.[21]

In Ontario, two ethanol producers, Commercial Alcohols, Inc., (CAI) and Suncor, operate with a capacity of approximately 350 million litres (92 million gallons), using roughly 35 million bushels of corn per year or nearly

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[19] Based on 2006 yields recorded by USDA-NASS, 2007c; USDA-NASS, 1997-2007.
[20] In reality, currently 98 percent of ethanol production uses corn grain as the feedstock. (Personal communication: M. Hartwig, Renewable Fuels Association, September 5, 2007)
[21] Based on projected 2007 yields recorded by USDA-NASS, 2007c.

15 percent of corn grown within the province[22] to produce ethanol for fuel (OMAFRA, 2007a). In addition, the Ontario Ethanol Growth Fund (OEGF) has committed $520 million (CAN) over 12 years to support the construction and/or retrofitting of ethanol production facilities in the province (OMAFRA, 2007b). These activities are expected to add approximately 500 million litres to Ontario's annual ethanol production capacity (roughly 130 million gallons), which would require a proportionate increase in corn utilization per year.

In Québec, the Greenfield Ethanol Inc. plant in Varennes was constructed with funds provided by the federal Ethanol Expansion Program (EEP) and has been in operation since February 2007. The facility's current capacity of 120 million litres (approximately 32 million gallons) requires approximately 7 percent of annual provincial corn production.[23] The facility's production capacity could potentially be increased to 150 million litres (nearly 40 million gallons), requiring a proportionate increase in corn; however, no new grain corn-based ethanol facilities are currently planned for Québec. The Québec government's 2006-2015 energy strategy states that "the use of forest and agricultural biomass and urban waste will be given priority over corn grain" in the future production of renewable fuels (Government of Québec, 2006).

Known and Potential Impacts of Increased Corn Production

To ensure that renewable energy resources remain sustainable over time, management of these resources should rely on the use of sustainable agricultural practices and well-informed policy. Moreover, the energy costs associated with processing and transporting inputs, byproducts and end-products must be carefully considered to determine both the positive and negative impacts of renewable energy production. These considerations must be addressed in ways that minimize adverse environmental impacts while not causing unnecessary or unacceptable economic costs to end consumers.

In this manner, it is important to recognize the range of agricultural, environmental, and economic implications from increased corn and ethanol production to meet both new and existing needs. Several primary areas of consideration are detailed below. Potential secondary effects are also noted, where possible.

Agricultural Considerations

Conversion of Agricultural Lands

The agricultural landscape of the United States, and particularly that of the Midwest, has already been changed by the significant expansion of the area planted for corn (USDA-NASS, 2007b). Since approximately 300,000 to 550,000 acres, or roughly 0.2 to 0.4 percent of total farmland is lost per year, and principal crop plantings are increasing on the remaining farmland acreage, questions arise as to where the additional acres of corn to meet anticipated market demand will come from (Appendices B-7 and B-8).[24,25] Within the United States and Canada, wheat, coarse grains (including corn), and oilseeds (including soybeans) compete for limited temperate agricultural lands that support these crops. Therefore, with increased demand for corn for ethanol fuel leading to increased market prices and higher returns, other less profitable crops have experienced decreased production while corn acreage expands.

In the near-term, these additional acres of planted corn are coming primarily at the expense of soybean acres in the Midwest and Corn Belt regions. However, shifts from other crops such as hay, cotton, wheat, and rice are

[22] Based on 2006 yields recorded by USDA-NASS, 2007c; USDA-NASS, 1997-2007.

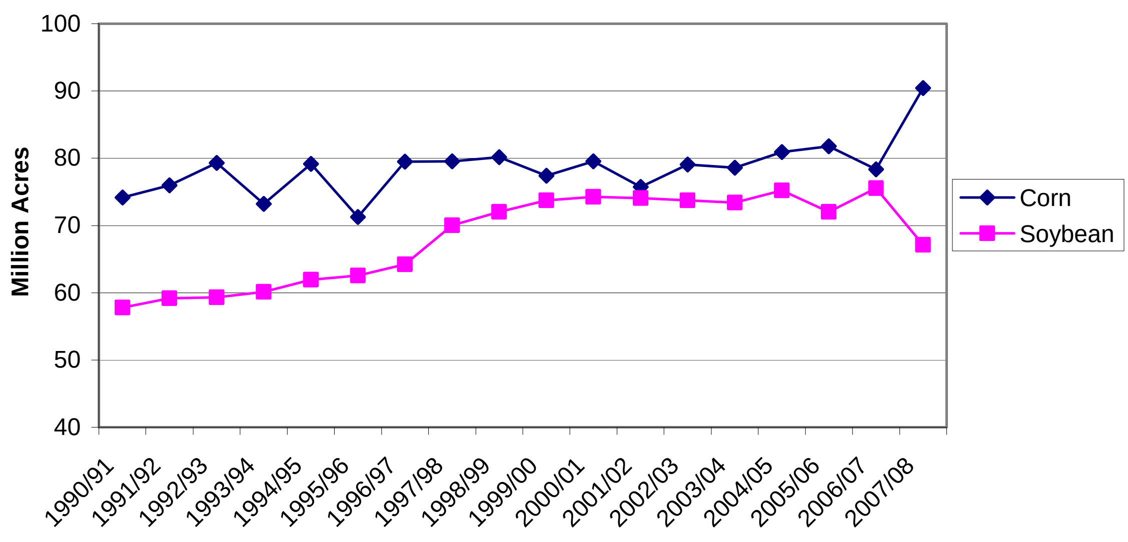
[23] Personal communication: C. Bernard, Québec Ministry of Agriculture, Fisheries and Food, December 13, 2007.

[24] Source: USDA-NASS, 2007a. For the purpose of the Census of Agriculture, the USDA defines a farm as any place from which $1,000 or more of agricultural products were produced and sold. The $1,000 value is not adjusted for inflation. Total land within a farm includes primarily agricultural land used for crops, pasture, or grazing. It also includes woodland and wasteland not actually under cultivation or used for pasture or grazing, provided it was part of the farm operator's total operation.

[25] Principal crops are defined by the USDA-NASS as corn, sorghum, oats, barley, winter wheat, rye, durum wheat, other spring wheat, rice, soybeans, peanuts, sunflower, cotton, dry edible beans, potatoes, sugarbeets, canola, and proso millet.

also occurring in other areas of the country (USDA-ERS, 2007a). Soybeans are commonly planted on the same land as corn during alternate planting seasons (i.e., crop rotations every other year) and require similar farm equipment. The National Agricultural Statistics Service (NASS) 2007 Planting Intentions Report projects a nationwide decrease of 11.1 percent in soybean acreage from 2006 levels, with 67.1 million acres of soybeans projected for 2007 (Figure 11, Appendix B-6).

Figure 11. U.S. Corn and Soybean Planted Acreage, 1990-2007



Source: USDA-NASS, 2007c
Data reported on a marketing-year basis (September-August) and may vary depending on survey methods and estimating procedures. Latest data may be preliminary or projected.

Similarly, the recent increase in corn acreage within the Great Lakes-St. Lawrence River region (state- and province-wide) mirrors a downward trend in soybean acreage with few exceptions (Appendix B-6). The region's soybean production is projected to decrease by roughly 10 percent in 2007, whereas corn production is shown to increase by more than 13 percent (USDA-NASS, 2007c; OMAFRA, 2007a; and Institut de la Statistique Québec, 2007.) The greatest decreases in production within the region are likely to occur in Wisconsin and Illinois, two of the highest corn-producing states. This shift from soybean to corn production has additional implications for farming practices and international trade (see "Environmental Considerations" and "Economic Considerations").

<u>Agricultural Monoculture</u>

Rising corn prices and the prospect of greater economic returns are driving many farmers to increase their corn acreage and expand corn production. In addition to converting conservation lands to production, farmers may choose to decrease cultivation of or abandon other crops as well as forego crop rotations. This leads to monocultural agriculture – the production of a single crop over a wide area over time.

A typical crop rotation alternates corn and soybeans every other year on the same land. In some portions of the Great Lakes-St. Lawrence River region, other rotations – such as corn-oats-hay – are used more frequently. Regardless of the rotation, rotating crops provides effective resource management and benefits. For example, growing legumes, such as soybeans, enhances soil fertility and reduces soil erosion through the incorporation of nitrogen-rich organic residue into the soil (Campbell et al., 1990). Nitrogen is naturally fixed by the soybean plants during growth and remains in the plant residue left behind after the harvest. This acts as a natural source of nitrogen for corn when planted in the next rotation after a soybean harvest.

However, in the drive to grow more corn, farmers are choosing to forego soybean crop rotation and instead plant corn in consecutive seasons. The likely result will be reduced soil productivity and lower yields paired with an increased use of nitrogen fertilizers to replace the loss of organic residue from the missing soybean rotation. Without a soybean rotation, an average loss of 9 percent in corn yields can be expected ranging from 2 to 23 percent overall (Erickson and Lowenberg-DeBoer, 2005). Data from experimental plots in northeast Iowa showed that corn grown after a soybean rotation results in a 51 pound-per-acre nitrogen savings compared to consecutive corn plantings (Hennessy, 2006).

This trend also increases the threat from pests, disease, and poor weather. A single crop type may become susceptible to pathogens or changes in weather patterns where diversified crops would tolerate threats more effectively. Diversification in agricultural production is an asset in much the same way as diversity is an asset in other sectors of the economy. Overreliance on one sector (or one crop) leads to greater vulnerability of that single sector (or crop) to changes adversely impacting that particular sector or crop. Efforts to offset the liabilities of a single crop may have their own liabilities. To protect against large-scale crop failure in a monocultural system, for example, farmers increasingly rely on pesticide use (see Chemical Usage, below) as well as genetically modified (GM) varieties of corn. Pesticides have both additional economic and potential environmental costs.

Loss of Conservation Acreage

To meet the demand for additional corn acreage, other lands that may be converted to agricultural production include pasture and fallow lands; forest lands; grasslands; wetlands; marginal lands not previously cultivated for farming (i.e., lands requiring larger agricultural chemical applications or containing highly erodible soils); and acreage from expiring Conservation Reserve Program (CRP) contracts, Conservation Reserve Enhancement Program (CREP) contracts, or other conservation initiatives (USDA-ERS, 2007a).[26] Alternatively, landowners considering setting aside lands for conservation purposes may be swayed by increasing crop prices to keep them in production. This conversion of land use/cover (or lack thereof) – while enabling farmers to plant new acreage and harvest additional yields – has potential environmental consequences, such as the removal of vegetative cover intended to reduce sediment loadings from agricultural lands to streams and lakes (see "Environmental Considerations").

A minimum of 4.6 million acres nationwide are expected to exit the CRP by 2010, as high crop prices encourage their return to production.

[26] The Conservation Reserve Program (CRP) provides technical and financial assistance to eligible farmers and ranchers to address soil, water, and related natural resource concerns on their lands in an environmentally beneficial and cost-effective manner. Farmers receive an annual rental payment for the term of the multi-year contract (10 or 15 years) to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover, such as tame or native grasses, wildlife plantings, trees, filter strips, or riparian buffers. There are substantial penalties for removing contracted CRP acres from the program before the end of the contract, and all payments received by the landowner must be returned with interest. The program is funded through the Commodity Credit Corporation as authorized under the 2002 U.S. Farm Bill, and is administered by the USDA-FSA. The Conservation Reserve Enhancement Program (CREP) is an offshoot of the CRP. Like CRP, CREP contracts require a 10- to 15-year commitment to keep lands out of agricultural production. CREP provides payments to participants who offer eligible land. Enrollment in a state is limited to specific geographic areas and practices. (USDA-FSA, 2007a; USDA-FSA, 2007b)

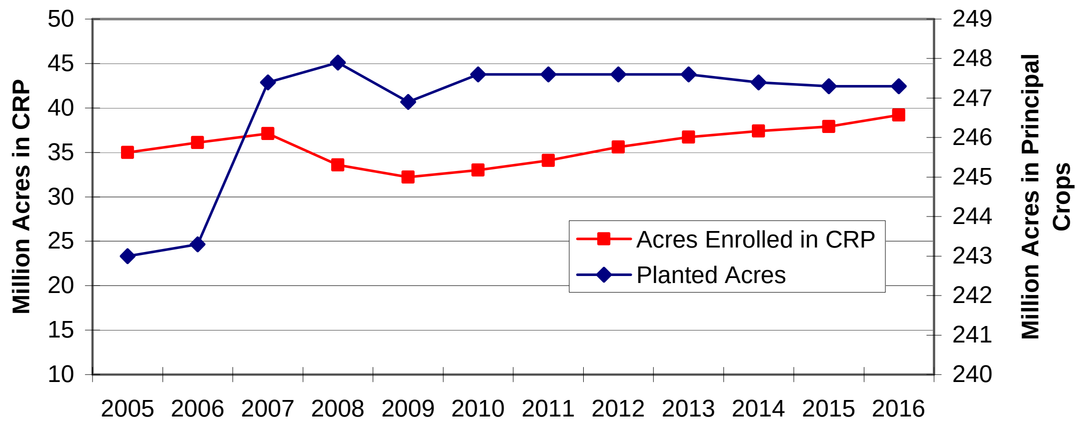
In-Depth Spotlight: Potential Impacts to Conservation Reserve Program (CRP) Acreage

The Conservation Reserve Program (CRP) provides technical and financial assistance to eligible farmers and ranchers to address soil, water and related natural resource concerns on their lands through the conversion of highly erodible cropland or other environmentally sensitive acreage to vegetative cover, wildlife plantings, trees, filter strips, or riparian buffers. Since the CRP's inception in 1986, nearly 36.8 million acres have been conserved nationwide at a total cost of $32.2 billion. In recent years, however, concerns that high crop prices may encourage the return of agricultural lands to production have grown considerably.

Since 2004, there has been a net gain in newly enrolled acreage under the CRP from year-to-year, both nationwide and within the Great Lakes states. Notably, however, Wisconsin has shown consistent losses in CRP acreage during this time period. In the last year (2006-2007), smaller increases in new acreage were reported than the year before (2005-2006) at both the national and Great Lakes regional scale. While one year of data cannot yield a conclusive assessment of the impacts of increased corn production on the enrollment of CRP acres, this does warrant further investigation in coming years.

Perhaps of greater concern, however, is that an estimated 4.6 million acres under expiring CRP contracts nationwide – or roughly 12.5 percent of total existing CRP acres – are expected to exit the program by 2010 instead of re-enrolling for another contract period (Figure 12) (USDA, 2007b and 2007c). Within the Great Lakes states, approximately one-third – or roughly 578,000 acres of expiring CRP lands – may or may not exit the program upon contract expiration (Appendix B-9).[A] These trends of fewer new CRP acreage enrollments and fewer contract renewals further support projections from the USDA which show a net loss of lands in conservation until 2010.

Figure 12. Projected U.S. Acreage in CRP Contracts vs. Planted Principal Crops, 2005-2016



Source: USDA, 2007b

The loss of CRP acres represents a reduction in the conservation benefits accrued by lands in the CRP program. This reversion of CRP and marginal lands to production could also mean a loss of critical and sensitive lands and habitats supporting species biodiversity (e.g., areas of high erodibility, wetlands, aquatic environments) in the region. To stem these potential losses of conservation acreage, the USDA is increasing the use of incentives for CRP contract holders, including the opportunity to continue CRP benefits without interruption through the CRP's Re-Enrollments and Extensions (REX) program (USDA-FSA, 2007b). After 2010, CRP acreage is projected to gradually rise to its legislated maximum of 39.2 million acres by 2016, as a result of assumed higher CRP rental rates (USDA, 2007b).

[A] Personal communication: D. Allen, Michigan State FSA Office, September 5, 2007.

Environmental Considerations

Soil Erosion and Sedimentation

Soil erosion not only damages farm productivity, resulting from the loss of fertile soils, but also has adverse impacts on nearby waterbodies and aquatic habitat. High sediment loadings to streams, rivers, lakes, and reservoirs from soil erosion is a well-documented, significant problem in the Great Lakes-St. Lawrence River system.

Sediment loadings cause a wide range of environmental damages influenced by complex hydrological, physical, chemical and biological factors (Figure 13). Some of these critical effects include changes in the size and configuration of river and stream channels; increased eutrophication[27] of lakes and reservoirs; ecosystem and habitat disturbances; and greater turbidity and degradation of water quality resulting in adverse impacts to aquatic habitat and populations. For example, many species of Great Lakes fish have experienced significant declines in their population due in part to increased sediment (Muncy, 1979).

Sediment is the largest contaminant of surface water in the nation and the leading pollution problem in rivers and streams.

(Koltum et al., 1997; U.S. EPA, 1998)

In addition, unintended secondary economic consequences of these environmental impacts include increased dredging of navigation channels and harbors; decreased enjoyment of recreational uses; additional maintenance to reservoirs and water storage systems, drinking water intake and treatment systems, and drainage and irrigation systems; diminished flood control; and diminished aesthetics and property values (see "Secondary Economic Impacts," below).

Figure 13.Types of Impacts from Soil Erosion and Sedimentation

Environmental Impacts	**Secondary Beneficial Use and Market Impacts**
• Sediment Loadings to Water Bodies	• Navigation and Dredging
• Channel Modification of Rivers and Streams	• Recreation
• Eutrophication of Lakes and Reservoirs	• Reservoirs and Water Storage
• Disturbances to Sensitive Habitats	• Drinking Water
• Increased Turbidity	• Drainage and Irrigation
• Degradation of Water Quality	• Flood Control
	• Aesthetics and Property Values

A majority of the corn production within the Midwest and Corn Belt regions relies on agricultural practices such as conventional tilling – the practice of turning or digging up soils – to prepare fields for planting new corn seed. This practice removes organic residue from the soil surface left by previous harvests or cover crops.[28] In disturbing the soil surface, soil is more susceptible to erosion from rain and wind. Conservation

[27] Eutrophication is the process by which lakes gradually age and become more biologically productive. Normally, this process takes hundreds or thousands of years to occur; however, humans have greatly accelerated this process through the addition of phosphorus, nitrogen and carbon to streams and lakes in various ways. Accelerated eutrophication results in rapid algae growth, which depletes the oxygen and sunlight in the water creating dead zones. The delivery of sediment can also cause lakes to slowly fill in and become shallower, which can lead to an increase in temperature and biologic productivity. This process accelerates the eutrophication process because of nutrients that bind to fine sediments.

[28] Cover crops are crops grown in to cover the soils of croplands in between the harvest of one crop and the planting of another crop in annual cropping systems. Cover crops help to maintain organic matter and soil structure, nitrogen production, soil microbial activity, nutrient enhancement, rooting action, weed suppression, and soil and water conservation. Soybeans are a common cover crop for corn production since legumes are known to fix nitrogen in the soils (National Sustainable Agriculture Information Service, 2003).

tillage or no-till farming, on the other hand, requires minimal or no cultivation, respectively. These practices can reduce costs, minimize land disturbances, and retain organic residues from past harvesting, but may require greater reliance on pesticides to control plant pests and weeds.

Although no-till would significantly reduce erosion, it is often not practiced with corn production since crop residues from past harvests paired with cool and wet soils typically encountered during the corn planting season make it more difficult to plant corn seed. Conventional tillage in the spring prior to planting corn helps to dry and warm the soil by clearing past crop residues, allowing corn to be planted at an optimal time. Improved tillage and cropping management systems could potentially greatly decrease soil erosion from corn intensive systems if the current limitations associated with no-till for corn production can be overcome.

Modeling analysis for the Great Lakes Tributary Modeling Program conducted by the Michigan State University (MSU) Institute of Water Research in 2002-2003 estimated sediment loadings in the Great Lakes tributary watersheds (Figure 14). The total potential soil loss from agricultural cropland under conventional tillage farming practices in the U.S. portion of the Great Lakes-St. Lawrence River basin is 68.0 million tons per year, 31.1 million tons under reduced tillage practices, and 11.3 million tons under no-till (Ouyang et al., 2003). The model results show that reduced tillage practices can cut soil loss by half and no-till practices can reduce soil loss by up to 80 percent. Correspondingly, sediment loads of 15.6 million tons per year from agricultural croplands under conventional tillage are cut to 7.1 million tons per year under reduced tillage and 2.6 millions under no-till practices (Ouyang et al., 2003).

Figure 14. Estimated Average Soil Erosion and Sediment Delivery Under Different Tillage Practices in the U.S. Portion of the Great Lakes-St. Lawrence River Basin

Tillage Practices	Average Erosion (tons/acre/yr)	Average Sediment Delivery (tons/acre/yr)
Conventional Tillage [A]	1.8	0.4
Reduced Tillage	0.8	0.2
No-Till	0.3	0.1

Source: Ouyang et al., 2003
[A] Conventional tillage is a common practice in the production of corn.

The expansion of corn production is likely to result in an increase in soil erosion, at least in the short term, unless soil conservation practices (e.g., conservation tillage) are used. In particular, the tilling of lands that were previously fallow or set aside for conservation purposes will contribute to this potential net increase in soil erosion. An analysis of potential sediment loadings to streams due to increased production of corn within a sample watershed – the Lower Maumee River in northwest Ohio – is available in Appendix B-10.

Water Use

The agriculture industry, in general, can be very water use-intensive by withdrawing water from ground and surface waters to irrigate and process crops. Nationwide, agriculture accounts for 80 percent of the country's consumptive water use, according to USDA estimates. Consumptive water use refers to that which is withdrawn or withheld that is lost through evaporation, plant transpiration, incorporation in the production of crops, or consumption by humans and livestock. Within the Great Lakes-St. Lawrence River basin, agricultural irrigation accounts for roughly 20 percent of all consumptive water use. Fortunately, the climate of the region typically requires little agricultural irrigation due to the amount of rainfall and temperatures during the region's growing season. However, these factors can vary throughout the season and from year-to-year, as is evident by weather extremes such as droughts and flood events. Agricultural irrigation may also be utilized in areas within the region that have crops planted on very permeable soils, which generally require larger volumes of water to support crop needs.[29]

[29] Personal communication: B.A. Engel, Purdue University, October 23, 2007.

Corn requires more water than other row crops since it is deep-rooted – growing to a depth of four feet or more – and produces greater biomass than other comparable crops. According to North Dakota State University researchers, corn requires between 18 and 22 inches of soil moisture during the growing season to achieve maximum yields. Average corn water use ranges from about 0.03 inches per day once the plant has emerged from the soil surface to over 0.27 inches per day during kernel formation (North Dakota State University, 1997). Hot and windy days may require over 0.35 inches of water to replace losses from evapotranspiration, the loss of water from the soil both by evaporation and by transpiration from plants (North Dakota State University, 1997). However, corn variety and maturity length as well as soil type and texture through the root zone will also impact seasonal water use for the production of corn. Irrigation may be required to supplement rainfall in drier areas and during dry periods to maintain this level of soil moisture.

Purdue University researchers have recently estimated potential changes in runoff and shallow groundwater recharge associated with various cropping systems and soil types in the Midwest to get a better sense of the impacts to water quantity associated with increased corn production (Appendix B-11). Based on their analyses, due to the water use rates of corn plants, runoff is estimated to decrease by approximately 1 percent while percolation of water below the rootzone is estimated to decrease by approximately 15 percent.[30] This decreased percolation could contribute to reduced baseflow in both streams and rivers.

Since an estimated 3.5 to 6 gallons of water per gallon of ethanol produced is required by ethanol facilities for the production of ethanol, water use by ethanol facilities must also be considered (Keeney & Muller, 2006).[31] This water-to-ethanol ratio varies seasonally and is largely dependent on the efficiency of the facility's cooling towers and the quality of the water coming into the facility.[32] Of this water, roughly 90 to 95 percent is lost through cooling towers, wet spent grain shipped locally, and exhaust from the spent grain dryers.[33] For a typical modern ethanol plant with a production capacity of 50 million gallons per year, this means that a minimum of 175 million gallons of water per year (nearly 480,000 gallons per day) is supplied for the production of ethanol. Many of the newer facilities under construction within the Great Lakes-St. Lawrence River region will have larger production capacities of 100 million gallons of ethanol per year or more, requiring 350 to 600 million gallons of water per year (nearly 0.96 to 1.65 million gallons per day), depending on their level of water efficiency and ability to recycle wastewater. Thus, even at the most water-efficient facilities, a significant volume of water is required for the production of ethanol.

An estimated 3.5 to 6 gallons of water is required to produce 1 gallon of ethanol.

Within the Great Lakes-St. Lawrence River region, the sustainable management of Great Lakes waters requires the balancing of many competing interests, such as agriculture, hydropower, navigation, recreation, potable and industrial water supply, as well as environmental and riparian interests. Protecting, conserving, restoring, and improving the Great Lakes-St. Lawrence River water resources is foundational to sound water resources management in the basin and essential to maintaining the integrity of the basin ecosystem. Therefore, the increased production of corn and corn-based ethanol will be germane to any discussion of expanding water needs in the basin, and will need to be evaluated in the context of the existing water use regulations.

The levels, flows, use, and diversions of Great Lakes waters are managed by the United States and Canada through a complex mixture of federal, state and provincial treaties and agreements, which include the Boundary Waters Treaty of 1909, International Niagara Treaty of 1950, and the Great Lakes-St. Lawrence River Basin

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30 It should be noted that a reduction in runoff does not necessary mean a decrease in soil erosion. With respect to the occurrence of soil erosion from cropland, this decrease in runoff is typically offset by tillage practices often used for the production of corn (Personal communication: B.A. Engel, Purdue University, September 14, 2007).

31 Water use records for ethanol plants are not publicly available; however, these figures were obtained from records held by the Minnesota Department of Natural Resources for ethanol plants in that state. For a more detailed account, see Keeney and Muller, 2006.

32 Personal communication: G. Mickelson, Minnesota Department of Natural Resources, November 29, 2007.

33 Personal communication: G. Mickelson, Minnesota Department of Natural Resources, November 29, 2007.

Sustainable Water Resources Agreement, signed by the Governors and Premiers in 2005. The Agreement – which has not yet been ratified into law by each Great Lakes state and province – requires new or increased uses to minimize impacts to basin waters and related natural resources, and to incorporate environmentally sound and economically feasible water conservation and efficiency measures.

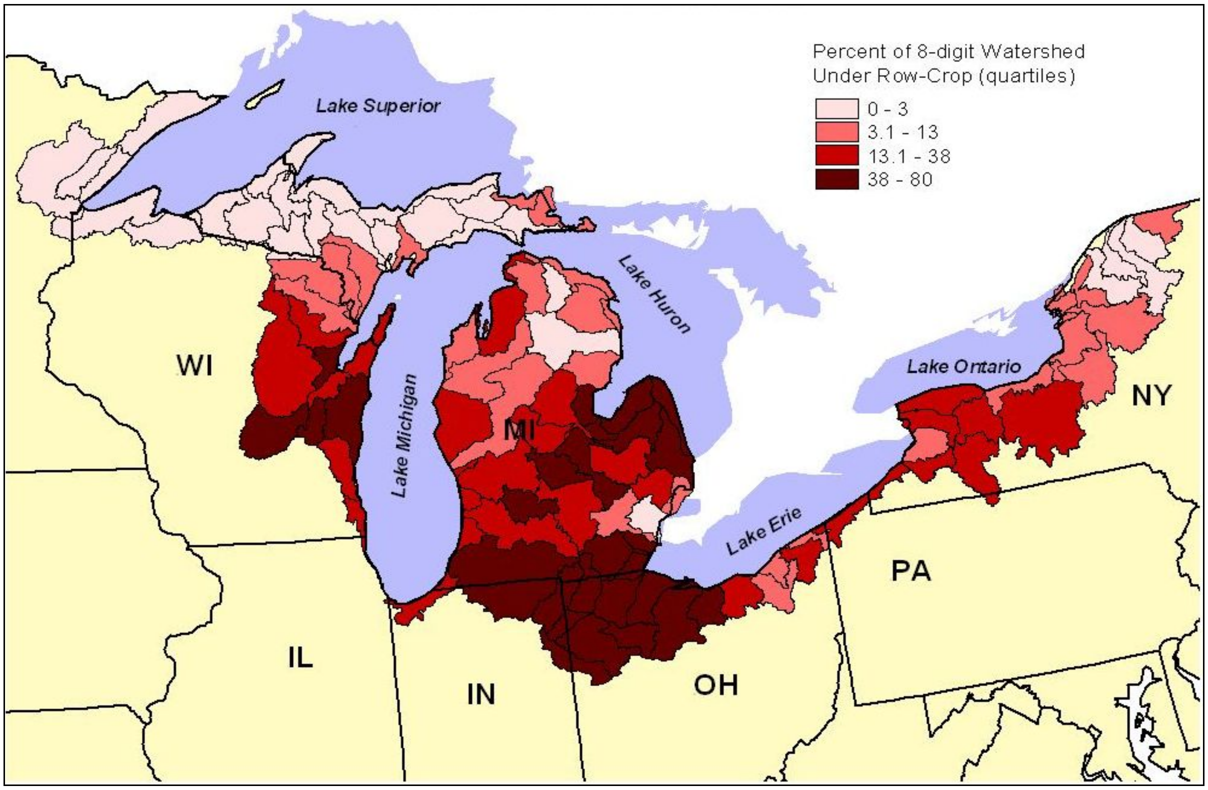
Continued sustainable, accessible, and adequate water supplies for the people and the economy of the Great Lake-St. Lawrence River basin are of vital importance as states and provinces balance economic development, societal goals, and environmental protection as interdependent and mutually reinforcing pillars of sustainable development.

<u>Loadings of Nutrients and Persistent Contaminants</u>
As market prices for corn increase, producers may also try to achieve greater yields on existing cropland. To increase yields per acre and maximize profitability, corn producers often increase nitrogen and other fertilizer applications.

Movement of agricultural chemicals from croplands is the leading cause of nonpoint source (NPS) pollution in the United States (Yu et al., 2004). As such, surface and ground water quality degradation resulting from runoff laden with fertilizers and pesticides from excessive or mismanaged applications to croplands poses a critical environmental challenge. Water quality is also a concern where agricultural practices such as tilling and a lack of buffers near streams may lead to increased runoff containing nutrients, pesticides, and soils from the land itself.

Figure 15 shows the concentration of row-crop agriculture in 2001 within the Great Lakes-St. Lawrence River basin, which can serve as an indicator for threats to water quality, and specifically nutrient loadings. Drainage tiles commonly used in Midwest agricultural fields may also carry water from rainfall and snowmelt to nearby streams and lakes without allowing excess water the opportunity to seep into the ground, filter out contaminants, and recharge groundwater aquifers.

Figure 15. Concentration of Row-Crop Agriculture in the U.S. Portion of the Great Lakes-St. Lawrence River Basin, 2001 [34]



Source: USEPA-MRLC, 2001

Corn is the greatest user of nitrogen and phosphate, accounting for roughly 40 percent and 38 percent of total U.S. consumption, respectively, according to USDA-ERS plant nutrient usage data (Appendix B-12). These figures vary from year to year, depending on the mix of crops planted, share of acreage treated, and application rates (Appendix B-13). Increased nitrogen applications are especially used when shifting from corn-soybean rotations to corn-only production because soybean residue – a source of nitrogen for corn – no longer remains on the fields. Some farmers have eliminated crop rotations in order to produce more corn, and fertilizer usage for corn acreage is projected to increase by approximately 9.5 percent in 2007 (USDA-ERS, 2007c). Corn also utilizes more soil phosphorus and less soil potassium per acre than soybeans (Vitosh et al., 1995).

In addition to nitrogen and other fertilizer applications, Kalkhoff et al. (2003) reported that more than 100,000 tons of pesticides are applied annually to cropland in the Corn Belt region of the Midwest, where nearly 80 percent of the country's corn and soybean production is concentrated. Total U.S. atrazine applications, a commonly used pesticide in corn production, exceeded 25,000 tons in 2003, most of which was applied in the Midwest (Kalkhoff et al., 2003). Agricultural runoff can carry atrazine along with other pesticides, sediment, and nutrients, and these loadings are ultimately delivered to the Great Lakes-St. Lawrence River system.

Movement of agricultural chemicals from croplands is the leading source of nonpoint-source pollution in the U.S.

[34] Each 8-digit hydrologic unit code (HUC) watershed was grouped according to their respective area percentage under row-crop agriculture. The 2001 NLCD served as the land cover data source, and EPA's ATtILA was the tool used to generate the data. ATtILA's estimates of nutrient loading from the Maumee River basin closely matched those recorded by Heidelberg College's National Center for Water Quality Research river gauges. Since ATtILA's only primary input is land cover, its rankings of watersheds by row-crop concentration should be a fairly reliable indicator of areas at risk for nutrient loading.

Nitrogen that does not bond with the soils, as well as that which has bonded with fine particles of eroded soil, can be easily transported from the fields to nearby creeks and rivers by runoff during rain events. Drain systems, including tiled fields, which are common in much of the Great Lakes-St. Lawrence River region, remove excess water from fields during and after rain events. However, as that nitrogen-rich water is emptied into nearby waterbodies along with nitrogen-containing sediments, undesirable adverse environmental impacts can result from increased nitrogen loads. For example, increased eutrophication or the creation of hypoxic 'dead zones' in lakes and reservoirs may result. As corn production continues to increase, scientists project record levels of hypoxia (depressed levels of oxygen similar to eutrophication) in the Gulf of Mexico from increased nutrient loadings to the Mississippi River as a direct result of increased corn production in the Corn Belt. Similarly, increased corn production in the Great Lakes-St. Lawrence River basin on lands which drain into the Great Lakes-St. Lawrence River system may contribute to the creation of dead zones in the region's lakes and reservoirs.

To get a better sense of the quantitative impacts associated with chemical usage and increased corn production in the Midwest, Purdue University researchers recently estimated the potential magnitude of nutrients and pesticide losses associated with various cropping systems and soil types (Appendix B-11). The loss of atrazine is expected to increase greatly – nearly double for continuous corn (i.e., corn grown without crop rotations). Nitrogen losses are expected to increase by 20 percent or more, especially if additional fertilizer is used in an attempt to maintain high corn yields. Phosphorus losses would nearly double, assuming current tillage practices, but could be much larger if corn stover (i.e., the plant stalks remaining after the corn ears have been harvested) were removed for production of cellulosic ethanol.

These changes in the landscape and crop systems could have consequences for public water supplies. Cities like Indianapolis and Ft. Wayne, Ind., in the heart of the corn production region, routinely experience excessive atrazine concentrations in public water supplies.[35] Increased corn production in watersheds that also provide drinking water from surface or groundwater sources could exacerbate this problem.

Economic Considerations

Fuel Costs

The United States currently imports 65 percent of its petroleum for domestic use, according to the U.S. Department of Energy. The production and use of nearly five billion gallons of ethanol in 2006 reduced oil imports by 170 million barrels, or about 5 percent of U.S. consumption for a savings of $11 billion (Urbanchuk, 2006; USDOE-EIA, 2007a). Thus, ethanol production can help the United States by reducing its dependence on imported oil while boosting the U.S. economy and keeping dollars spent on fuel in the United States.

Grain and Food Costs

The United States leads the world in trading coarse grains with 60 to 70 percent of global corn exports (USDA-ERS, 2007a).[36] U.S. corn exports are expected to drop to 55 to 60 percent as ethanol production continues to expand (USDA, 2007b). Increased demand for corn for ethanol has led to increased corn prices, resulting in decreased production of relatively less profitable crops like soybeans. At the same time, declining production of other crops coupled with the rising value of grain substitutes for livestock feed (e.g., soybeans) will increase the prices of those grain substitutes. As part of a typical market transition, it is expected that farmers will overproduce during times of higher prices. This will lead to market saturation and price declines until the market returns to equilibrium (OnPoint, 2007). U.S. exports, world trade, and foreign production of corn and other grains will all be impacted.

[35] Personal communication: B.A. Engel, Purdue University, October 23, 2007.
[36] Coarse grains include corn, barley, sorghum, rye, oats, millet, and mixed grains, as defined by the USDA.

One of the more controversial aspects of ethanol fuel development discussions is the question of using corn for fuel versus using corn for food. American and Canadian consumers are accustomed to inexpensive foods, like those made from corn and its derivatives, particularly high fructose corn syrups and other sweeteners. Corn is also used as a livestock feed for chickens, pigs, and cows with about 53 percent of the 2006 corn yield used for this purpose. However, as greater percentages of domestic corn yield are utilized for ethanol production, less corn will be available for these other uses.

Corn production for manufacturing ethanol fuel will peak at roughly 30 percent of the yield in 2009-2010 and then level out through 2016, according to USDA long-term projections conducted earlier this year (Appendix B-3). The use of corn for livestock feed will decrease to 44 percent and then drop to approximately 42 percent by 2016 (USDA, 2007b). These changes have significant market sector supply and demand implications.

Other livestock feeds may be substituted for corn as corn prices rise, but some substitute feeds are not sufficient or viable for all types of livestock. For example, ruminant animals (e.g., beef cattle and dairy cows) can more effectively consume distiller's grains – a high protein byproduct of ethanol production – whereas monogastric livestock (e.g., poultry and hogs) require corn for feed. However, soybean meal can help to offset some of these demands for livestock feed in the poultry and pork sectors (USDA, 2007b).

Federal Farm Commodity Payments

Higher corn and other crop prices will ultimately lead to reduced farm commodity payments under current programs, particularly those for price-sensitive market loan benefits and counter-cyclical payments (USDA-ERS, 2007a). At the same time however, as corn prices rise, so will agricultural land values, which impacts rental rates for federal cropland conservation programs like the CRP and CREP. These rental payments must remain competitive with increasing land values to provide sufficient incentive for landowners to enroll their land. Direct government payments to farmers are expected to decline from 8 percent of gross cash income in 2005 to less than 4 percent during the next decade as ethanol production expands (USDA-ERS, 2007a).

Transportation Impacts

In response to the increased production of corn and corn-based ethanol, stakeholders within the transportation sector must also adapt to related shifts in the transport of both grain and ethanol for domestic and export markets. Specifically, recent trends are expected to impact transport by rail, barge, and truck by varying degrees (USDA-AMS, 2007).

According to the USDA, trucks are currently the primary mode of transport of corn to domestic ethanol facilities, with rail supplementing this function for larger facilities. As ethanol production continues to expand, demand for corn grain transportation via all modes may rise proportionately (USDA-AMS, 2007). According to recent figures from the Lake Carriers' Association, grain has accounted for an average of 7 percent of domestic dry-bulk shipping cargo on the Great Lakes from 2002-2006. Yet, within that small percentage of transport, corn shipments are on the rise, increasing from 31 million bushels in 2005 to over 67 million bushels in 2006, a 116 percent increase (Lake Carriers' Association, 2007). However, many U.S. ships within the Great Lakes are not currently equipped to carry grain.

Once the ethanol leaves the production facility, it is then transported via rail, truck, or barge to locations where it is blended with gasoline at or near its final retail distribution point (USDA-AMS, 2007). According to the USDA, in 2005, the majority of ethanol was transported via rail (roughly 60 percent), with trucks and barges accounting for 30 percent and 10 percent, respectively (USDA-AMS, 2007). Data show that rail transportation of ethanol grew in 2006 along with the expanded domestic production of ethanol. Distiller's grains are also transported via rail, truck or barge. Within the United States, each of these three modes (rail, truck and barge) are either at or near current capacity for transporting cargo. Thus, as the demand for and production of ethanol continues to grow, experts project the need for infrastructure investments to ensure the safe and efficient transport of feedstocks, biofuels, and co-products from production to market.

Figure 16. Cargo Capacity Comparison

	Railcar	Barge	Truck
Grain (bushels)	3,500	52,500	910
Ethanol (gallons)	29,400	630,000	8,000
Dried Distiller's Grains with Solubles (tons)	100	1,500	25

Source: USDA-AMS, 2007

In 2006, the export of U.S. corn accounted for 19 percent of its total use, making it the second highest U.S. use for corn behind livestock feed/residual. In 2007, that figure is expected to remain stable (resulting in a slight volume increase in exports) while ethanol usage of corn climbs to 25 percent (Figure 8, Appendix B-2). Historically, ocean-going, foreign-owned and operated barges have carried large amounts of grain from Midwest ports down the Mississippi River for export to foreign markets, including much of the corn produced within the Great Lakes-St. Lawrence River region. Rail is also responsible for some transport of grain for export. Over time, the demand for exports may again increase as commodity markets adjust to the increased production of ethanol; however, this variability has related impacts to barge and rail traffic for export markets (USDA-AMS, 2007).

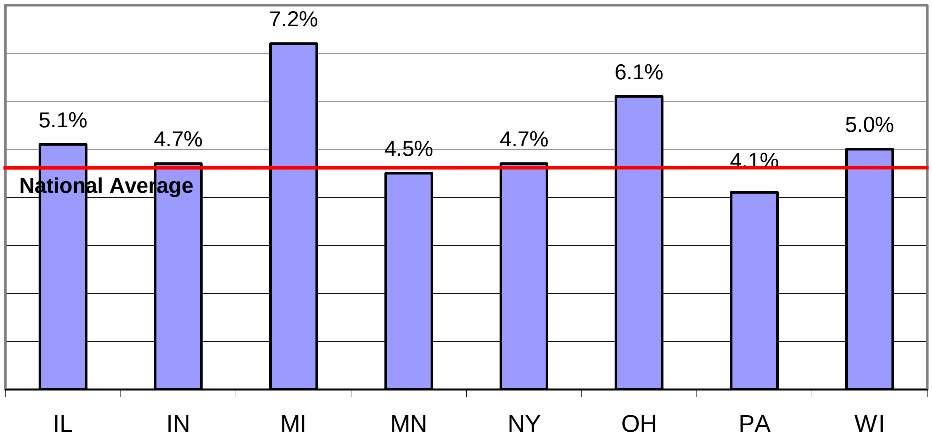
Other considerations with respect to shipping and transportation include the secondary impacts of soil erosion and sedimentation and the increased maintenance requirements for shipping channels and harbors. The U.S. Army Corps of Engineers (USACE) reports annual expenditures of $40-50 million to dredge 8.5 million tons of sediment from Great Lakes waters. According to the MSU Institute of Water Research High Impact Targeting (HIT) model estimates, agricultural erosion accounts for 7.1 of the 8.5 million tons.[37] In addition, according to Lake Carriers' Association figures, the largest vessels hauling limestone reported losing 500-700 tons per trip in 2006 due to inadequately dredged ports (Michigan Aggregates Association, 2006).

<u>Creating Jobs and Increasing Farm Income</u>

As the ethanol industry grows and new production facilities begin operating, new jobs will be created. This increase in jobs and associated economic development alleviates strain on local economies by creating additional household income (Renewable Fuels Association, 2007). This is particularly important to the Great Lakes-St. Lawrence River region, since six of the eight U.S. Great Lakes states currently have unemployment rates higher than the national average of 4.6 percent (seasonally adjusted). Minnesota and Pennsylvania are the exceptions, with unemployment rates just slightly below the national average (Figure 17). According to the Renewable Fuels Association – the primary industry association for the production of ethanol fuel – more than 160,000 jobs were created in all sectors of the U.S. economy in 2006 as a result of the U.S. ethanol industry, including more than 20,000 manufacturing jobs. This economic development resulted in a boost of $6.7 billion in U.S. household income in 2006, alone (Renewable Fuels Association, 2007).

[37] Model estimates potential sediment loading based on worst-case scenario of no acreage under conservation or no-till practices.

Figure 17. Unemployment Rates, Seasonally Adjusted
(as of June 2007)



Source: U.S. Department of Labor, 2007

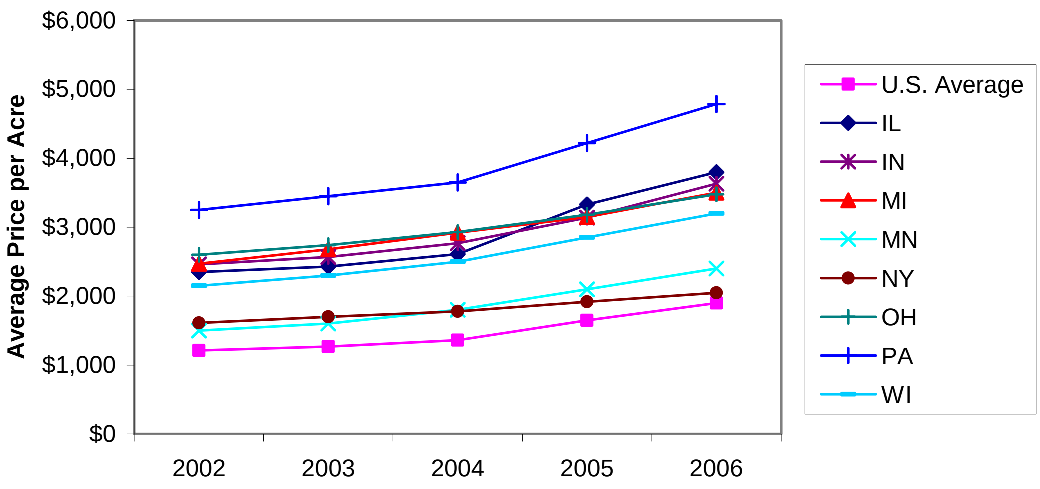
The demand for ethanol production has contributed to increased corn prices, and helped to create new opportunities for increasing income from farming and associated industries. The 2007 U.S. and Canadian corn harvests are expected to be the largest in more than 60 years. Short-term opportunities include increased employment in the agricultural sector for both producing and managing corn harvests. The Corn Belt and Midwest, comprised of many Great Lakes states, will benefit from these positive economic impacts.

Rural Economic Development and Real Estate

The creation of new ethanol industry jobs in rural areas will help strengthen rural communities while increasing capital investment and generating tax revenues for all levels of government (Renewable Fuels Association, 2007). Moreover, increasing numbers of farmers are creating cooperatives to build locally owned ethanol production facilities (Renewable Fuels Association, 2007), thereby keeping the profits in their local economy.

From 2005 to 2006, average U.S. agricultural land values rose more than 15 percent from $1,650 to a record high $1,900 per acre (USDA-NASS, 2006). All eight Great Lakes states recorded agricultural land values greater than the national average during the 2000-2006 time period with an average value of $3,356 per acre (USDA-NASS, 2006), as illustrated in Figure 18. This value reflects an increase of $370 per acre, or 12 percent, over 2005 values. The USDA estimates that this increase in agricultural real estate and farmland values is driven by increases in agricultural revenues (partially from increasing market prices and demand for crops such as corn), low interest rates, and a strong demand for nonagricultural land uses for development and recreation (USDA, 2007b).

Figure 18. U.S. Agricultural Land Values, 2002-2006



Source: USDA-NASS, 2006

<u>Secondary Economic Impacts</u>

The following impacts stem from some of the ecosystem changes noted above, including changes in water quality from increased soil erosion and sedimentation in streams, lakes, and rivers that are likely to be amplified by the expanded production of corn. As described below, these changes have potential economic impacts to the Great Lakes-St. Lawrence River region with respect to shipping, recreation, water-related infrastructure, the mitigation of natural hazards, property values, and the overall enjoyment of the region's natural resources and amenities.

Navigation and Dredging

Sediment deposited in harbors, bays, and navigation channels reduces channel depths for commercial and recreational watercraft, increasing incidents of ship groundings, creating safety hazards, and requiring commercial vessels to "light-load" which is less cost-efficient and necessitates additional trips. Increased soil erosion and the resulting sedimentation require increased dredging to keep these waterways open. The USACE has spent, on average, roughly $25.5 million annually to dredge more than 2.1 million cubic yards from Great Lakes harbors and channels in the past five years.[38] However, the USACE estimates that up to 3.35 million cubic yards need to be dredged on an annual basis to keep up with the deposition of materials, which would require $40.2 million per year.[39] These increased costs for dredging are compounded when the sediments are contaminated and their disposal is restricted. The costs for disposal in a landfill or confined disposal facility (CDF) may be 1 to 5 times the costs of the dredging itself (USACE & USEPA, 2003).

Recreation

Sediment has both direct and indirect impacts on the suitability of water for recreational use. For example, boating and fishing are affected by increased water turbidity and subsequent increased weed growth. Turbidity can reduce the pleasure of and opportunities for swimming and boating activities, and may lead to dangerous conditions by obscuring submerged hazards such as rock outcrops. It can diminish the quality of recreational fishing activities by reducing the populations of desirable fish species. Sediment can also impact other water-related recreational activities, such as canoeing and picnicking, by reducing the aesthetic appeal and attractiveness of the resource.

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[38] Personal communication: M. Strum, U.S. Army Corps of Engineers, November 16, 2007.

[39] Personal communication: M. Strum, U.S. Army Corps of Engineers, November 19, 2007.

Drinking Water
Sediment must be removed from water before it can be used for potable or industrial use. Sediment is also a source of chemical contamination as it often carries with it fertilizers, pesticides, and other chemicals. For this reason, operation and maintenance costs of water treatment facilities may increase as the amount of sediment increases.

Reservoirs and Water Storage
Reservoir sedimentation has been shown to reduce slightly more than 0.2 percent of the nation's reservoir capacity each year (Crowder, 1987). As water supplies become more critical within the Great Lakes-St. Lawrence River region, this could create potential concerns for the storage of water. Sediment and nutrients can also affect the rate of evaporation and transpiration from reservoirs. In this instance, suspended sediment may provide a benefit since it can reduce evaporation by reflecting some of the solar energy that would otherwise warm the water in reservoirs. However, sediment combined with nutrients can increase the rate of evapotranspiration by stimulating the growth of water-consuming vegetation on lake and reservoir borders.

Drainage and Irrigation
Sediment can impair the capacity of irrigation channels and other canals to carry water to its destined point of use, resulting in increased flooding along ditches and maintenance costs for the removal of sediment. Sediment may also increase the cost of pumping water from these channels as well as increase the wear on pumps.

Flood control
Sedimentation can increase the risk of flooding through aggradation, a process by which sediment deposition fills and raises the level of a streambed. This reduces the capacity of a stream to carry water, which can lead to an increase in the frequency and depth of flooding. When flooding does occur, sediment can exacerbate the damages by settling out of the water onto the floodplain. In agricultural areas, this sediment can smother crops or grasslands that support cattle and other livestock. In urban areas, sediment can settle in streets and between houses where it can be costly to remove. Figure 19 illustrates the average annual flooding costs for the eight Great Lakes states combined at nearly $1.6 billion per year (1999 dollars).

Figure 19. Average Annual Flooding Costs for the Eight U.S. Great Lakes States

State	National Rank	Av/Yr (millions 1999 US$)
Illinois	8	$218.7
Indiana	18	$113.4
Michigan	37	$35.6
Minnesota	15	$144.9
New York	9	$218.2
Ohio	22	$102.4
Pennsylvania	1	$682.3
Wisconsin	30	$60.9
Total		**$1,576.3**

Source: Extreme Weather Sourcebook (National Center for Atmospheric Research et al.,1999);
Information based on flood damage data from 1955-1999, and has been adjusted for inflation and wealth.

Aesthetics and Property Values
Property values can be lowered by polluted waters and sediment deposits. Preservation values represent the value that people place on clean water, even though they may never make direct use of the water body. Studies have shown preservation values to be higher than recreational and other user values.

Concluding Summary

This paper has described numerous benefits of increased ethanol production to the United States, Canada, and the Great Lakes-St. Lawrence River region, but has also identified various considerations that draw corn-based ethanol's long-term sustainability into question.

Within the United States and Canada, a rising demand for alternative fuels, including ethanol, has been spurred by high fossil fuel energy prices, changes in political support and policy decisions, high corn prices and increasing profit margins, and innovation and technology improvements. Advancements in research and engineering have made the production of ethanol more efficient – from increasing corn yields as a feedstock to producing more ethanol from a single bushel of corn. Ethanol production and use accounted for approximately 3.5 percent of the total U.S. fuel consumption in 2006 – a figure that is expected to reach 7 percent by the end of this decade. While the production of corn-based ethanol has been a positive step toward decreasing North America's dependency on fossil fuel imports and a positive influence on rural economies, renewable energy production in the form of corn-based ethanol is only part of the answer to achieving energy independence. Future alternative energy strategies must not only stress renewability but be sustainable as well.

Current trends have shown that the rapid expansion of biofuel production and the associated increased production of corn in the Midwest has had – and will continue to have – numerous and profound agricultural, environmental, and economic impacts. These impacts may be positive in some cases, neutral in others, and possibly negative in some instances if decisions and approaches lack foresight. Some impacts that are already occurring may have negative consequences depending on geographic, hydrologic, climatic, and temporal factors. These include the continued conversion of soybean acreage to corn, the loss or reduction of conservation lands, the possible pollution of ground and surface water supplies from increased agricultural chemical applications, and increased soil erosion from corn production using conventional tillage practices.

Looking ahead, the near term (i.e., 4 to 8 years) brings the possibility of trending toward the use of corn stover – the plant stalks remaining after the corn ears have been harvested – as a possible feedstock for ethanol as cellulose-based production becomes economically viable. Corn production for ethanol may also be displaced over the long-term by crops that produce large masses of cellulose such as fast growing trees and grasses such as switchgrass. These changes may have an entirely new set of impacts on land uses, as well as the hydrology, soils, and water quality of the landscape.

Addressing Future Challenges

The wealth of studies and research developed to evaluate and mitigate the impacts of urban and rural development in the Great Lakes-St. Lawrence River Region provides a solid foundation for considering many of the impacts associated with the ongoing increases in corn and ethanol production. However, this foundation of knowledge needs to be expanded, refocused, and applied to provide guidance for resource managers and other decisionmakers in a timely manner. To address the issues raised in this research paper, a joint effort is required involving private industry, academia, government, and conservation groups. Pertinent questions that this effort must address include:

- How long will the production of corn be favored for ethanol production within the region? Will other feedstocks be produced here, as well?
- What will happen to the corn market within the Midwest if corn is no longer the favored feedstock for ethanol production?
- Can corn-based ethanol facilities in the Midwest be retrofitted to accommodate cellulosic ethanol production?
- What economic and environmental advantages and disadvantages can be anticipated from biofuel feedstocks other than corn?

- How do we characterize those areas within the Great Lakes-St. Lawrence River region that are most vulnerable to land use changes?
- How quickly will we see the results of increased sedimentation and nonpoint source pollution in our region's waterbodies and drinking water sources?
- Can some of the impacts identified in this paper be minimized through improved efficiency in related water uses?

As we move forward, understanding the landscape-level environmental and economic impacts of biomass for biofuels production will help in the development of appropriate policy tools, as well as technology and management regimes to promote its positive impacts and mitigate its potential negative impacts.

Activities Underway Within the Great Lakes-St. Lawrence River Region

Several recent and ongoing initiatives within the Great Lakes-St. Lawrence River region are central to this discussion since the corn and ethanol industries play an important role in policy formulation at both the regional and national levels. Recent actions by the president, Great Lakes governors, members of Congress, public agencies, and interest groups have spurred a surge of attention to Great Lakes issues. Some of these initiatives include the Great Lakes Regional Collaboration of National Significance (GLRC) culminating in a strategic plan for the restoration and protection of the Great Lakes, and a recent report released by The Brookings Institution's Metropolitan Policy Program, which concludes that efforts to improve the health of the Great Lakes will produce economic benefits valued at almost twice the cost of the necessary investment (Austin et al., 2007). At the federal level, reauthorization of the 2002 U.S. Farm Bill[40] is currently being debated by the U.S. Congress, including possible changes to programs authorized under its conservation title.

Ultimately, the ability of corn-based ethanol to remain viable and sustainable over time requires that great thought and care be given to the agricultural and environmental impacts associated with its production and use. Of course, economic impacts (positive and negative) must be considered as well. As the biofuel industry continues to benefit from increasing levels of attention, capital investment, and media coverage, stakeholders within the Great Lakes-St. Lawrence River region should become more informed about the issues identified in this paper and begin a dialogue involving corn growers, land managers, researchers, economists, agency resource managers, and policy makers in order to address developing concerns over the increased production of corn-based ethanol. Policymakers, practitioners, and decisionmakers within the region must develop new partnerships and identify and forge new integrated solutions to ensure and improve ecosystem health, economic prosperity, and the quality of life for all inhabitants in the Great Lakes-St. Lawrence River region.

Without forethought and a careful, balanced approach to the production of biofuels such as corn-based ethanol, residents within the Great Lakes-St. Lawrence River region can expect to see profound impacts (both positive and negative) on the region's economy, environment, and ecosystems. Some of the anticipated less desirable impacts, such as the return to production of highly erodible lands or the introduction of marginal areas to row crop production, could be difficult to reverse. Thus, a continuing trend toward the increased production of corn – fueled by recent political support – could come at some expense to the region's ecosystem and natural resources. Optimism regarding the benefits of increased ethanol production should, therefore, be tempered with the need to learn more about the associated impacts in order to foster the region's shared ideals of environmental quality, economic growth, and stewardship for current and future generations.

[40] The Farm Security and Rural Investment Act of 2002 is commonly referred to as the U.S. Farm Bill.

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Appendix B – Additional Figures

Appendix B-1. U.S. Field Crops: Price per Unit, 1997-2006

	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07
Corn (Bu)	$2.43	$1.94	$1.82	$1.85	$1.97	$2.32	$2.42	$2.06	$2.00	$3.20
Soybean (Bu)	$6.47	$4.93	$4.63	$4.54	$4.38	$5.53	$7.34	$5.74	$5.66	$6.20
Barley (Bu)	$2.38	$1.98	$2.13	$2.11	$2.22	$2.72	$2.83	$2.48	$2.53	$2.85
Oats (Bu)	$1.60	$1.10	$1.12	$1.10	$1.59	$1.81	$1.48	$1.48	$1.63	$1.85
Sorghum (Cwt)	$2.21	$1.66	$1.57	$3.37	$3.46	$4.14	$4.26	$3.19	$3.33	$5.90
Wheat (Bu)	$3.38	$2.65	$2.48	$2.62	$2.78	$3.56	$3.40	$3.40	$3.42	$4.25
Canola (Cwt)	$11.30	$10.30	$7.82	$6.71	$8.77	$10.60	$10.60	$10.70	$9.62	$11.10
Cotton (Lb)	$0.66	$0.62	$0.47	$0.52	$0.32	$0.46	$0.63	$0.45	$0.50	$0.50
Hay (Ton)	$100.00	$84.60	$76.90	$84.60	$96.50	$92.40	$85.50	$92.00	$98.20	$109.00

Source: USDA-NASS, 1997-2007
Data reported on a marketing-year basis (September-August).
Data accessed August 2007. Latest data may be preliminary or projected.

Appendix B-2. U.S. Corn Usage, 2001-2007 (Million Bushels)

		2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08
Feed/Residual		5864.22	5562.85	5794.95	6,157.12	6,154.72	5,597.72	5,650.00
Export		1904.77	1587.89	1899.82	1,818.06	2,133.81	2,124.69	2,450.00
Food, Seed, Industrial								
	Ethanol	705.95	995.50	1,167.55	1,323.07	1,602.78	2,117.09	3,200.00
	High-fructose corn syrup	540.57	531.84	530.19	520.67	528.61	510.00	515.00
	Starch	245.70	255.73	271.49	278.64	275.38	271.68	280.00
	Glucose and dextrose	217.09	219.28	227.93	221.89	229.31	238.97	243.00
	Cereal/Other	186.00	186.90	187.40	189.00	190.20	190.42	192.80
	Beverage alcohol	131.00	131.00	132.00	132.80	135.00	136.00	136.50
	Seed	20.10	20.01	20.56	20.79	19.90	23.58	22.70
Total Use		9,815.40	9,491.00	10,231.89	10,662.04	11,269.71	11,210.15	12,690.00

Source: USDA-ERS, 2007b
Note: Totals may not add due to rounding. Data reported on a marketing-year basis (September-August) and may vary depending on survey methods and estimating procedures. Latest data may be preliminary or projected.

Appendix B-3. Projected Use of Future U.S. Corn Harvests for Ethanol, 2008-2016

	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Harvested acres (millions)	81.8	81.8	82.8	82.8	82.8	82.8	82.8	82.8	82.8
Yield/Acre	155	156.9	158.8	160.7	162.6	164.5	166.4	168.3	170.2
Projected harvest (million Bu)	12,679	12,834	13,149	13,306	13,463	13,621	13,778	13,935	14,093
Projected use for ethanol (million Bu)	3,700	3,900	4,000	4,075	4,150	4,200	4,250	4,300	4,350
% of harvest used for ethanol	29.2%	30.4%	30.4%	30.6%	30.8%	30.8%	30.8%	30.9%	30.9%

Source: USDA, 2007b
Data reported on a marketing-year basis (September-August) and may vary depending on survey methods and estimating procedures.

Appendix B-4. U.S. Ethanol Production and Demand, 2002-2006 (Million Gallons)

	2002	2003	2004	2005	2006
U.S. Production (all types of ethanol)	2,130	2,800	3,400	3,904	4,855
Imports	46	61	161	135	653
Exports	n/a	n/a	n/a	8	n/a
Total U.S. Demand	2,085	2,900	3,530	4,049	5,377

Source: Renewable Fuels Association, 2007
Production figures include both corn and cellulose-based ethanol. Roughly 98 percent of current U.S. ethanol production is from corn grain.

Appendix B-5. Top 5 Worldwide Producers of Ethanol (Million Gallons)

	2004	2005	2006
United States	3,535	4,264	4,855
Brazil	3,989	4,227	4,491
China	964	1,004	1,017
India	462	449	502
France	219	240	251

Source: Renewable Fuels Association, 2007

Appendix B-6. Corn and Soybean Production in the Great Lakes-St. Lawrence River Region

State/Province	Corn Production		Soybean Production	
	2007/08 Acres (projected)	% Change from 2006/07	2007/08 Acres (projected)	% Change from 2006/07
Illinois	12.9 million [A]	+ 14.2%	8.7 million	- 13.9%
Indiana	6.2 million	+ 12.7%	5.0 million	- 12.3%
Michigan	2.5 million	+ 13.6%	1.8 million	- 12.5%
Minnesota	7.9 million [B]	+ 8.2%	6.7 million	- 8.8%
New York	1.0 million	+ 7.4%	0.2 million	+ 5.0%
Ohio	3.7 million	+ 15.9%	4.4 million	- 5.4%
Pennsylvania	1.5 million	+ 7.4%	0.4 million	- 4.7%
Wisconsin	4.0 million	+ 9.6%	1.4 million	- 15.2%
Ontario (CAN)	2.1 million	+ 38.1%	2.2 million	+ 5.2 %
Québec (CAN)	1.1 million	+ 15.6%	0.4 million	- 10.7%
Great Lakes TOTAL	**42.9 million**	**+ 13.1%**	**31.2 million**	**- 9.9%**
United States TOTAL	**90.5 million**	**+ 15.5%**	**67.1 million**	**- 11.1%**

Sources: USDA-NASS, 2007c; OMAFRA, 2007a; and Institut de la Statistique Québec, 2007.
Data reported on a marketing-year basis (September-August) and may vary depending on survey methods and estimating procedures.
[A] Projected acreage is a record for Illinois.
[B] Projected acreage is a record for Minnesota.

Appendix B-7. U.S. Farm Acreage, 2000-2006 (Thousand Acres)

	2000	2001	2002	2003	2004	2005	2006
Number of Farms (U.S.)	2,166,780	2,148,630	2,135,360	2,126,860	2,112,970	2,098,690	2,089,790
Land in Farms (U.S)	945,080	942,070	940,300	938,650	936,295	933,210	932,430
IL	27,500	27,500	27,500	27,500	27,400	27,300	27,300
IN	15,200	15,100	15,100	15,040	15,000	15,000	15,000
MI	10,150	10,120	10,090	10,090	10,100	10,100	10,100
MN	27,900	27,800	27,800	27,700	27,600	27,500	27,400
NY	7,670	7,660	7,660	7,650	7,600	7,550	7,500
OH	14,770	14,680	14,610	14,600	14,500	14,300	14,300
PA	7,690	7,710	7,700	7,700	7,700	7,700	7,650
WI	16,000	15,800	15,700	15,600	15,500	15,400	15,300
Total Farmland in GL States	126,880	126,370	126,160	125,880	125,400	124,850	124,550

Source: USDA-NASS, 2007a

Appendix B-8. U.S. Planted Acreage in Principal Crops, 2000-2007 (Thousand Acres)

	2000	2001	2002	2003	2004	2005	2006	2007
Land in Principal Crops (U.S.)	328,325	324,830	327,881	325,693	322,329	317,754	315,835	320,052
IL	23,671	23,431	23,382	23,302	23,515	23,111	23,232	23,321
IN	12,547	12,442	12,177	12,193	12,393	12,330	12,345	12,310
MI	6,718	6,682	6,546	6,480	6,452	6,537	6,519	6,508
MN	20,398	19,379	20,256	20,006	19,711	19,377	19,682	19,673
NY	2,924	3,167	3,159	3,267	2,653	3,088	2,917	2,980
OH	10,657	10,587	10,388	10,109	9,991	10,103	10,082	10,085
PA	4,227	4,038	4,044	3,902	3,893	3,753	3,912	3,971
WI	7,859	7,677	8,022	8,306	7,960	8,197	8,193	8,176
Total Land in Principle Crops in GL States	89,001	87,403	87,974	87,565	86,568	86,496	86,882	87,024

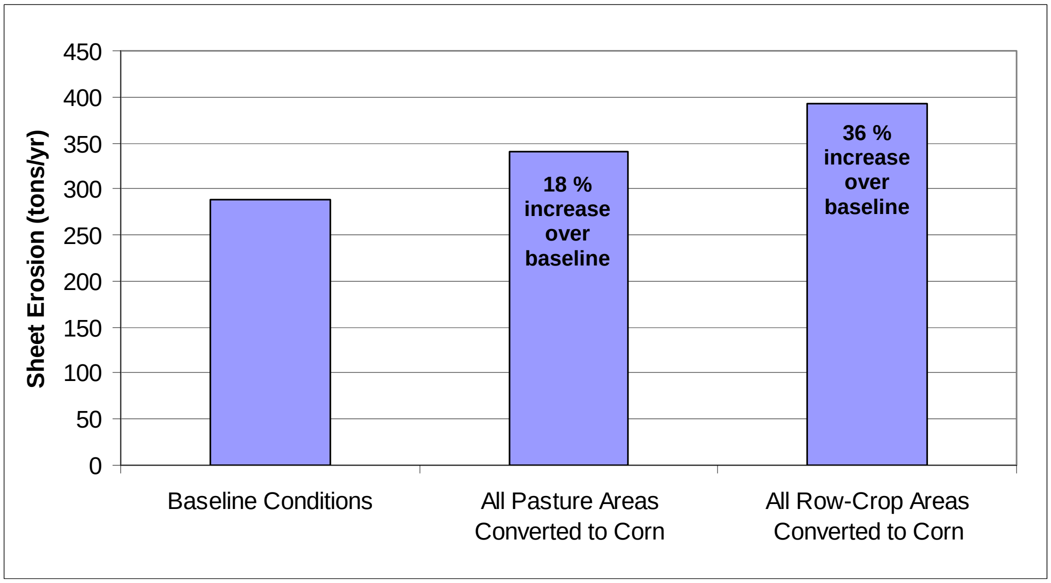
Source: USDA-NASS, 2000-2007
Crops included in area planted are corn, sorghum, oats, barley, winter wheat, rye, durum wheat, other spring wheat, rice, soybeans, peanuts, sunflower, cotton, dry edible beans, potatoes, sugarbeets, canola, and proso millet.

Appendix B-9. Expiring Conservation Reserve Program Acres, 2007-2010

	Active CRP Acres (July 2007)	**2007**	**2008**	**2009**	**2010**	**Total**	**Percent of Active Acres**
United States	36,790,942.8	5,131,585.9	2,251,704.7	4,564,309.2	4,759,591.5	**16,707,191.3**	45%
IL	1,087,272.3	122,798.6	78,059.8	67,341.3	77,432.3	**345,632.0**	32%
IN	315,491.4	53,921.9	26,601.3	19,003.0	19,916.7	**119,442.9**	38%
MI	276,013.2	29,993.6	32,373.0	17,995.8	18,308.8	**98,671.2**	36%
MN	1,831,788.7	139,561.4	273,347.5	174,123.9	80,927.5	**667,960.3**	36%
NY	66,897.6	19,786.3	9,160.6	3,416.7	3,010.0	**35,373.6**	53%
OH	362,525.2	60,659.8	22,804.6	17,691.3	20,137.1	**121,292.8**	33%
PA	230,422.2	28,919.3	11,493.8	5,355.1	2,018.4	**47,786.6**	21%
WI	607,851.5	110,378.8	83,693.4	44,320.0	58,308.1	**296,700.3**	49%
GL States Total	**4,778,262.1**	**566,019.7**	**537,534.0**	**349,247.1**	**280,058.9**	**1,732,859.7**	36%

Source: USDA-FSA, 2007b

Appendix B-10. Estimated Changes in Sheet Erosion Due to Increased Production of Corn in the Lower Maumee River Watershed



Source: Michigan State University, Institute of Water Research, 2007

To provide an in-depth perspective of potential erosion and sediment loading to streams within a sample watershed, researchers at Michigan State University's Institute of Water Research estimated the likely changes in erosion and sedimentation resulting from increased corn production in northwest Ohio's lower Maumee River watershed. As shown above, the result of a conversion of all pasture lands to corn would be an 18 percent increase in sheet erosion. Likewise, a 36 percent increase in sheet erosion is expected, should all row-crop areas be converted to corn. Similar relative increases are expected for sediment loadings to streams within the watershed; however, only 15 percent of total sheet erosion is shown to be introduced to streams through sediment loadings.

This analysis was completed using the Spatially Explicit Delivery Model (SEDMOD) and the Revised Universal Soil Loss Equation. Estimates are based on historical practices within the watershed and could change according to future management practices. Baseline conditions represent 30-year averages for precipitation data, land cover data from the 1992 NLCD (National Land Cover Dataset), and crop type and tillage data from the 1996-1998 Conservation Technology Information Center (CTIC) Crop Residue Management (CRM) surveys.

Appendix B-11. Annual Estimates of Nutrients, Pesticides, and Hydrology from Cropping Systems on Three Contrasting Soils in Northeast Indiana

Blount silt loam											
	NO_3-N in runoff		NO_3-N leached		P in sediment	Atrazine in runoff		Atrazine leached		Runoff	Percolation
Cropping Systems	kg/ha	ppm	kg/ha	ppm	kg/ha	g/ha	ppb	g/ha	ppb	Cm	cm
Corn-soybeans (probability of exceedence %)											
10	6.48	3.17	4.37	6.49	1.09	10.14	5.40	0.38	0.22	30.58	23.14
50	4.36	2.03	1.94	1.63	0.60	0.89	0.65	0.02	0.02	19.43	11.51
Corn-corn-soybeans (probability of exceedence %)											
10	7.68	3.31	3.05	3.78	1.27	18.63	7.81	0.64	0.65	30.30	20.57
50	3.89	2.00	1.05	0.72	0.65	0.45	0.20	0.00	0.00	19.46	12.17
Corn-corn-corn (probability of exceedence %)											
10	9.46	4.26	3.42	3.63	1.93	23.81	13.94	0.46	0.33	29.90	17.02
50	5.40	2.51	0.45	0.40	1.05	6.12	3.44	0.01	0.02	19.10	8.59

Hoytville clay											
	NO_3-N in runoff		NO_3-N leached		P in sediment	Atrazine in runoff		Atrazine leached		Runoff	Percolation
Cropping Systems	kg/ha	ppm	kg/ha	ppm	kg/ha	g/ha	ppb	g/ha	ppb	Cm	cm
Corn-soybeans (probability of exceedence %)											
10	5.59	2.31	14.97	7.61	0.22	8.68	5.56	0.52	0.17	27.05	35.41
50	3.48	1.99	5.70	2.32	0.04	0.59	0.75	0.03	0.01	17.42	23.62
Corn-corn-soybeans (probability of exceedence, %)											
10	5.71	2.75	15.31	7.57	0.25	8.98	5.35	0.80	0.24	26.87	32.84
50	3.48	1.97	3.87	2.18	0.05	0.43	0.21	0.01	0.01	17.32	24.18
Corn-corn-corn (probability of exceedence, %)											
10	6.69	3.04	9.38	5.06	0.41	14.70	9.63	0.47	0.19	26.77	29.69
50	3.89	2.11	3.21	1.74	0.08	4.16	3.01	0.06	0.04	17.20	21.21

Riddles sand loam											
	NO_3-N in runoff		NO_3-N leached		P in sediment	Atrazine in runoff		Atrazine leached		Runoff	Percolation
	kg/ha	ppm	kg/ha	ppm	kg/ha	g/ha	ppb	g/ha	ppb	Cm	cm
Corn-soybeans (probability of exceedence %)											
10	3.15	2.62	25.09	11.68	0.11	0.92	0.89	21.80	0.89	15.77	38.94
50	2.05	2.01	8.51	3.12	0.03	0.14	0.13	8.42	0.13	9.70	23.52
Corn-corn-soybeans (probability of exceedence %)											
10	3.36	2.85	14.35	8.37	0.17	0.55	0.90	53.01	31.04	15.77	34.95
50	2.07	2.01	5.57	2.57	0.04	0.07	0.06	4.69	3.00	9.70	22.12
Corn-corn-corn (probability of exceedence, %)											
10	3.79	3.84	9.47	6.48	0.39	1.64	2.14	38.26	26.41	15.67	31.04
50	2.51	2.55	3.85	1.81	0.08	0.37	0.42	8.14	5.81	9.55	18.64

Source: B.A. Engel and M. Thomas, Purdue University, personal communication, August 15, 2007
Estimates based on WWW GLEAMS-NAPRA simulation.

Appendix B-12. Estimated U.S. Plant Nutrient Use by Selected Crops, 1990-2005 (Thousand Tons)

Year ending June 30	Nitrogen					Phosphate					Potash				
	Corn	Cotton	Soybeans	Wheat	Other	Corn	Cotton	Soybeans	Wheat	Other	Corn	Cotton	Soybeans	Wheat	Other
1990	4,748	419	118	1,800	3,990	1,891	133	326	723	1,271	2,399	90	679	323	1,712
1991	4,715	477	118	1,734	4,243	1,868	151	312	679	1,189	2,245	98	568	301	1,789
1992	4,887	466	98	1,889	4,106	1,854	153	320	688	1,204	2,256	140	584	254	1,808
1993	4,369	508	84	1,986	4,445	1,681	171	304	736	1,543	2,054	140	641	215	2,091
1994	4,603	649	100	2,050	5,240	1,740	159	290	726	1,605	2,119	140	624	227	2,158
1995	4,158	700	154	1,955	4,752	1,496	204	372	719	1,635	1,800	173	665	236	2,254
1996	4,829	563	116	2,208	4,588	1,795	193	393	755	1,391	2,136	230	737	263	1,892
1997	4,792	525	175	2,043	4,816	1,783	219	490	719	1,402	2,172	286	1,016	257	1,694
1998	4,846	472	141	2,017	4,837	1,666	212	415	735	1,586	2,012	259	788	279	1,963
1999	4,650	544	139	1,907	5,212	1,580	215	441	669	1,349	1,936	309	805	246	1,657
2000	4,909	567	160	1,891	4,808	1,763	225	428	636	1,262	1,920	304	762	228	1,757
2001	4,249	569	148	1,764	4,805	1,552	236	448	617	1,404	1,888	314	793	221	1,710
2002	4,720	508	155	1,751	4,875	1,701	204	470	632	1,623	2,074	281	952	227	1,447
2003	4,710	508	154	1,804	4,815	1,682	210	448	651	1,281	1,963	280	827	234	1,707
2004	4,792	502	156	1,957	5,691	1,729	206	464	697	1,717	2,076	277	873	216	2,055
2005	4,959	521	151	1,625	5,080	1,758	215	448	581	1,636	1,823	290	860	198	2,002

Source: USDA-ERS, 2007c.

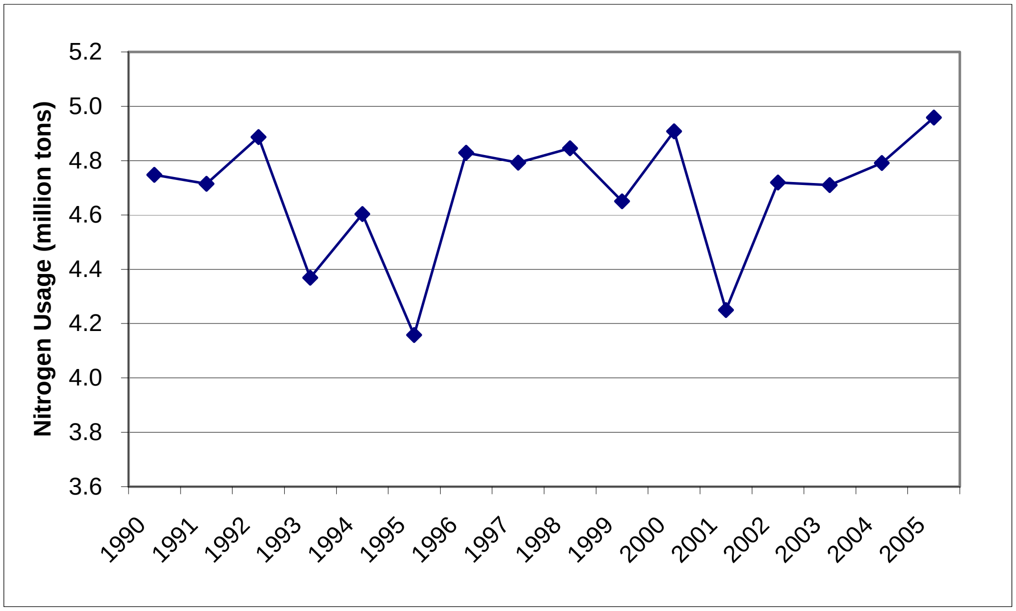
Estimates of plant nutrient use for other crops are determined by subtracting the plant use of the four selected crops from total use of each plant nutrient.

Shaded values are constructed by planted acres, and estimated application rates and percents of acres applied using three-year-moving average.

Plant nutrient use only for corn grains, excluding for corn silage.

Table revised October 23, 2006 to correct values for "other" category from 1994 through 2005.

Appendix B-13. Estimated U.S. Nitrogen Use for Corn Production, 1990-2005



Source: USDA-ERS, 2007d

Appendix C – Additional Resources

Pew Center on Global Climate Change – Agriculture & Global Climate Change
http://www.pewclimate.org/global-warming-in-depth/all_reports/agriculture

Purdue University Extension – BioEnergy
http://www.ces.purdue.edu/bioenergy

Renewable Fuels Association
http://www.ethanolrfa.org

U.S. Department of Energy – Alternative Fuels Data Center: Ethanol
http://www.eere.energy.gov/afdc/fuels/ethanol.html

U.S. Department of Energy – Energy Information Administration, Renewable and Alternative Fuels
http://www.eia.doe.gov/fuelrenewable.html