Impacts of Agriculture on Water Quantity in the Great Lakes-St. Lawrence River Basin

Outlining a Research Agenda for Agriculture, Trade and Water Quantity Management

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i. Preface

This paper was originally prepared for the Institute for Agriculture and Trade Policy (IATP) as background for a workshop entitled, "The Relationship of Agriculture, Trade, and the Environment to Surface and Groundwater Management in the Great Lakes-St. Lawrence River Basin" held in Sault Ste. Marie, Michigan (February 21-22, 2002). The goals of the workshop were: 1) to better understand the ecological, economic, and political relationships within the Great Lakes ecosystem; 2) to identify policy challenges in managing the system; and 3) to identify gaps in knowledge and outline research priorities regarding water quantity management.

Since the February meeting, the paper has been significantly revised to incorporate valuable comments from the workshop participants (listed in Section X) and other water quantity professionals. Jim Kleinschmit and Mark Muller of IATP's Environment and Agriculture Program were responsible for editorial oversight and some of the content. Any correspondence regarding this paper or its conclusions should be directed towards them.

This project received generous financial support from the Joyce Foundation.

ii. Executive Summary

The world's freshwater resources are becoming increasingly threatened. With an ever-growing population, water withdrawals from lakes, their tributaries and the groundwater feeding them have increased dramatically over the last century (World Water Council, 2001). At a November 2001 international conference on the conservation and management of lakes held in Shiga, Japan, a panel of experts found that more than half of the world's five million lakes and reservoirs – which hold nearly 90 percent of all fresh surface water – are facing massive ecological threats. In her book, *The Last Oasis: Facing Water Scarcity* (1997), Sandra Postel identifies one of the major consequences of impending water shortages: "…limited water supplies combined with population growth appear to be eliminating the option of food self-sufficiency in more and more countries… Many countries still do not have a clear picture of water-food linkages and thus are not taking the actions needed to secure their agricultural bases". The overuse of lake water, especially for irrigation, is one of the primary population-related phenomena causing declining water levels and degradation (World Water Council, 2001).

The freshwater resources of the Great Lakes-St. Lawrence River Basin are similarly at risk. Holding nearly 20 percent of the world's supply of fresh surface water, the Great Lakes-St. Lawrence River Basin is one of the most intensively used freshwater systems in the world, serving multiple interests including transportation and navigation, hydropower, irrigation and livestock production, municipal and industrial water supply, mining and recreation. Of these, the largest consumptive water use (water withdrawn and assumed lost from the system) is agriculture (Great Lakes Commission, 2000).

Despite critical connections between agriculture and ecosystem health, the relationship between agricultural water use and Great Lakes water levels has not been well researched. Current data does indicate, however, that the cumulative impacts of increasing freshwater use in most sectors will lead to decreasing water quantity in the Great Lakes-St. Lawrence River Basin (International Joint Commission (IJC), 2000; Canadian Environmental Law Association (CELA) and Great Lakes United (GLU), 1997; Quinn, 1999). It is estimated that if water is consumed at currently projected growth rates, and if projected impacts of climate change do occur, Great Lakes water levels will drop dramatically (CELU and GLU, 1997). In less than forty years, the flow from the Great Lakes system out of the St. Lawrence River could be reduced to less than three-quarters of its current flow, without accounting for the compounding impact that diversions out of the basin could have on lake levels (CELA and GLU, 1997). Growing water use in the Great Lakes-St.

Lawrence River Basin, combined with potential future impacts from population growth, climate change, land use and other changes, will lead to a combination of decreasing water availability and an ever-increasing value of freshwater due to competing interests.

At a workshop organized by the Institute for Agriculture and Trade Policy, entitled "The Relationship of Agriculture, Trade, and the Environment to Surface and Groundwater Management in the Great Lakes-St. Lawrence River Basin" held in Sault Ste. Marie, Michigan (February 21-22, 2002), water quantity experts identified numerous research and data needs regarding the role of agriculture and its relationship to water quantity in the Great Lakes-St. Lawrence River Basin. Such research needs include: 1) the need to define the current and future role of agriculture in the basin; 2) the need for multi-scale, geography-specific analyses which include both macro (watershed/region) and micro-levels (local); and 3) the need for improved data to develop alternative future agriculture, environment, trade and water quantity scenarios to better understand the implications of potential policy decisions and to improve overall management of the system.

This paper is written to provide background on these issues largely through literature review. It focuses on the relationship between agriculture and water quantity in the Great Lakes-St. Lawrence River Basin and analyzes historical trends in water balance and lake level fluctuations, ecological and ecosystem changes over time, current water uses, agricultural production and water use/efficiency in agriculture, water use policy, legislation, international trade implications, and cumulative impacts of reduced water levels resulting from potential future conditions. The paper explores perceived gaps in knowledge, outlines a research agenda for agriculture, trade, and water quantity management based on workshop recommendations, and finally makes recommendations for improved water quantity management that account for the role of agriculture to water availability and use.

I. Physical Characteristics and Geography of the Great Lakes-St. Lawrence River Basin

The Great Lakes-St. Lawrence River drainage basin is the largest body of freshwater in the world, containing nearly 20 percent of the world's available freshwater. The system extends from the Atlantic Ocean to nearly halfway across the North American continent (GLC, 1995). The basin is bordered by eight U.S. states (Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania and New York) and two Canadian provinces (Ontario and Québec), (Figure 1). More than one tenth of the U.S. population and one quarter of the population of Canada inhabit the basin (U.S. Army Corps of Engineers (USACE) and GLC, 1999).

Figure 1: The Great Lakes-St. Lawrence River Basin

Created by: Institute for Agriculture and Trade Policy
Data Source: Environmental Systems Research Institute (ESRI)

The five Great Lakes- Superior, Huron, Michigan, Erie and Ontario- with their connecting channels and Lake St. Clair (northwest of Lake Erie), have a total surface area of 94,900 square miles. The maximum dimensions of the basin are approximately 740 miles from north to south, and 940 miles from east to west. The total length of the shoreline, including islands, is 11,200 miles. Elevation ranges from 243 feet (Lake Ontario) to 600 feet (Lake Superior), the average depth ranges from 62 feet (Lake Erie) to 483 feet (Lake Superior), and total drainage area of each of the lakes (both land and water) ranges from 32,000 to 81,000 square miles. Lake Michigan is completely within the United States, while the lower St. Lawrence River is wholly within Canada. The Canadian shoreline of the Great Lakes and the international section of the St. Lawrence River are entirely within the Province of Ontario (U.S. Environmental Protection Agency (US EPA) and the Government of Canada, 1995). *See Box.*

Physical Features of the Great Lakes

	Superior	Michigan*	Huron*	Erie	Ontario
Elevation (feet)	600	577	577	569	243
Length (miles)	350	307	206	241	193
Width (miles)	160	118	183	57	53
Average Depth (feet)	483	279	195	62	283
Maximum Depth (feet)	1,332	925	750	210	802
Volume (cubic miles)	2,900	1,180	850	116	393
Land Drainage Area (sq. miles)	49,300	45,600	51,700	30,140	24,720
Water Drainage Area (sq. miles)	31,700	22,300	23,000	9,910	7,340
Total Drainage Area (sq. miles)	81,000	67,900	74,700	40,050	32,060
Shoreline Length (miles-includes islands)	2,726	1,638	3,827	871	712

*Lakes Michigan and Huron are hydraulically considered as one lake.

Sources: Great Lakes Seaway Website; U.S. Environmental Protection Agency and the Government of Canada, 1995.

Though vast, the Great Lakes have a relatively small drainage basin relative to surface area and an accordingly small renewal rate of only 1 percent (Sierra Club of Canada and GLU, 2000). This results in exceedingly long retention times, and thus an extremely long removal process of contaminants that have entered the system. It takes an average of 191 years for water to travel through Lake Superior (O'Connor et al, 1970). For more detailed information regarding Great Lakes physical characteristics, see Environment Canada (http://www.ec.gc.ca/water/index.htm), USACE and GLC, 1999 (http://www.glc.org/docs/lakelevels/lakelevels.pdf) and US EPA and the Government of Canada, 1995 (http://www.epa.gov/glnpo/atlas/).

II. Historical Perspective: Water Balance and Lake Level Fluctuations

Natural Variations in Lake Levels Due to Climate/Meteorology

Lake levels are determined by the combined influences of precipitation (the primary source of natural water supply to the Great Lakes), upstream inflows, groundwater recharge, surface water runoff, evaporation, diversions into and out of the system, dredging, and water level regulation. Climatic conditions control precipitation (and thus groundwater recharge), runoff, and direct supply to the lakes, as well as the rate of evaporation. These are the primary driving factors in determining water levels (IJC, 2000).

The total area of the Great Lakes-St. Lawrence River Basin, both land and water, is 298,500 square miles, about one-third of which is lake surface (Quinn, in: Adams, 1999). This natural feature absorbs the large variations in the precipitation falling directly on each lake and the runoff from land draining into each lake. Consequently, the outflow of each lake is modulated so as to maintain a remarkably steady discharge into the next lower lake (GLC, 1995). Because of the relatively small range in lake levels (about 6 feet, or 1.8 meters), significant human uses have become dependent upon reasonably constant water levels and outflows, resulting in system sensitivity to fairly small changes in climate variability and change (Quinn, in: Sellinger and Quinn, eds., 1999). This lack of variability in range of levels is exaggerated by water level controls, which further dampen lake level variations. *See Box*.

Fluctuations in Great Lakes Water Levels during the 20th Century

Lake Superior:	**1.2 meters (4 feet)**
***Lakes Michigan and Huron*:**	**1.9 meters (6.3 feet)**
***Lake Erie*:**	**1.9 meters (6.3 feet)**
***Lake Ontario*:**	**2.0 meters (6.7 feet)**

The full extent of these ranges is not seen during any one year. However, in 1998, Lake Ontario saw a drop of 1.2 meters from April to December. Rising Spring lake levels due to heavy precipitation and snowmelt runoff can also be dramatic, and when combined with severe spring windstorms, are a concern for many shoreline property owners.

Source: Environment Canada Website (1).

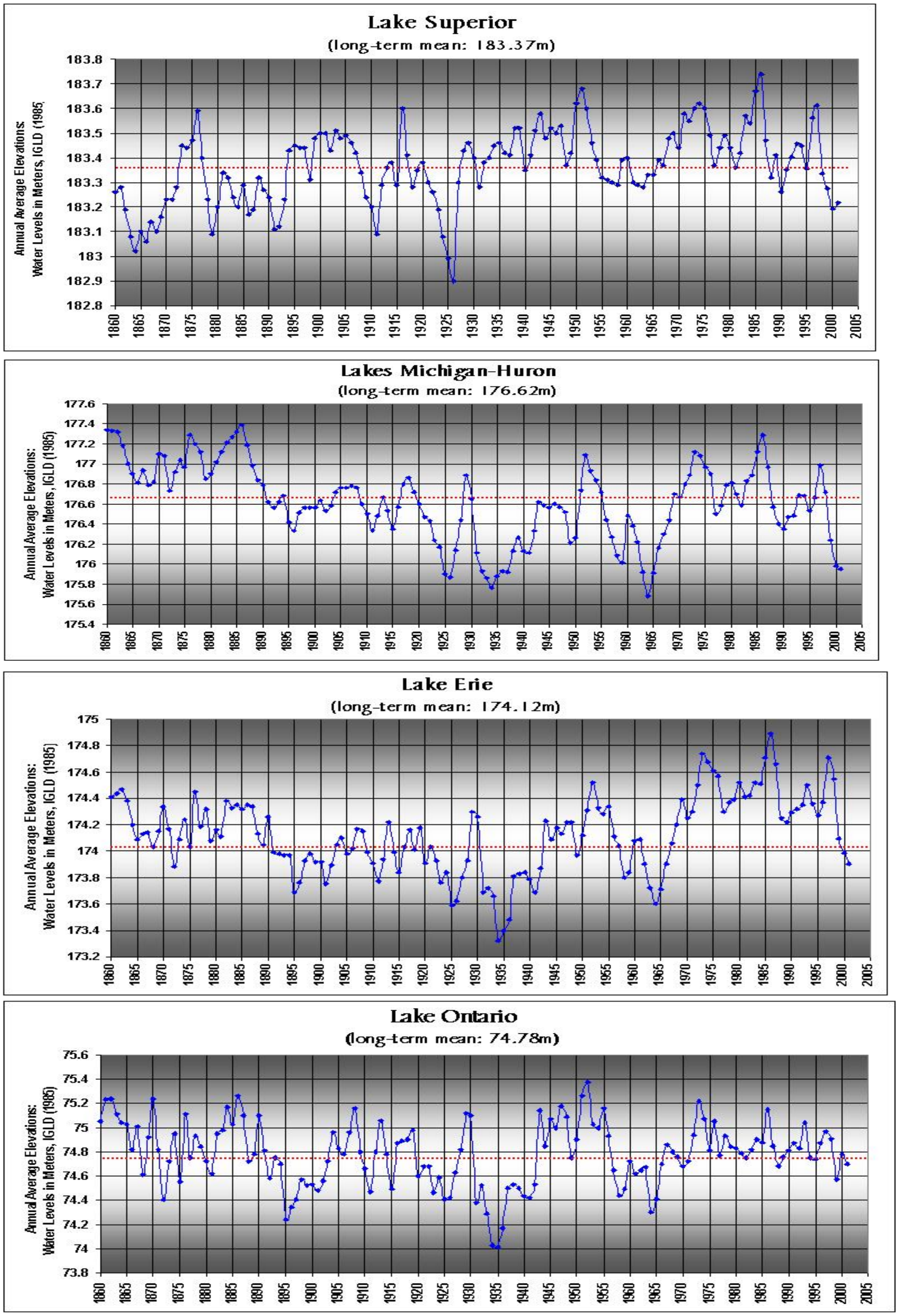
As illustrated in Figure 2, between 1860 and 2001, there were several periods of extremely high and extremely low water levels. Some of the Great Lakes fell to their lowest recorded levels in the late 1920s, the mid-1930s and the mid-1960s. Extremely high levels occurred in some lakes in the mid-1870s and 1880s, the early 1950s, the early 1970s and the mid-1980s. High lake levels occurred between 1985 and 1987, when many of the lakes reached their highest levels recorded in the 20th century. Much of the 1990s were characterized by persistently high water levels [Environment Canada Website (3)]. Extremely low water levels were experienced in the late 1990s through early 2002 [Great Lakes Water Levels Homepage (1)].

According to Frank Quinn, (retired) Senior Research Hydrologist from the National Oceanic Atmospheric Administration's (NOAA) Physical Sciences Division, precipitation in the Great Lakes-St. Lawrence River Basin showed a consistent upward trend over the 30 years prior to the 1990s (through 1997), which is essentially the result of a changed precipitation regime (Quinn, 1999). This increase in precipitation, more than any other cause, contributed to the higher lake levels. According to Doug Cuthbert, manager of Environment Canada's Water Issues Division, although significantly higher than a half century ago, water levels on the lakes for most of the 1990s were still within the range of normal variability (GLC, Advisor, 1997).

The recent declines in Great Lakes water levels are due mostly to evaporation during the above-average temperatures of the past several years, a series of mild winters, and below-average snowpack in the Lake Superior Basin (GLERL Website). In August 2002, Great Lakes water levels were generally consistent with their long-term averages and slightly above the previous year's levels [Great Lakes Water Levels Home Page (1)]. Precipitation over most of the upper Great Lakes in February 2002 helped to improve conditions of lake levels through August 2002 [Great Lakes Water Levels Home Page (2)].

Studies of water level fluctuations have shown that the Great Lakes can respond relatively quickly to changes in precipitation, water supply, and temperature conditions (IJC, 2000). However, the factors that influence lake levels are still poorly understood (GLERL/NOAA Website).

Figure 2: Historic Annual Mean Lake Levels, 1860-2001



Created by: Institute for Agriculture and Trade Policy
Data Source: Dr. Frank Quinn of GLERL/NOAA, March 2002 (Personal Comm.)

Hydrologic Cycles

Water level fluctuations affect most of the 40 million people who live within the Great Lakes watershed. High water levels are of serious concern to those who own and live on Great Lakes shoreline property as serious flood and erosion damages can occur during storm conditions. Low water levels, on the other hand, can have a huge economic impact on shipping, recreational boating and hydroelectric power generation [Environment Canada Website (1)].

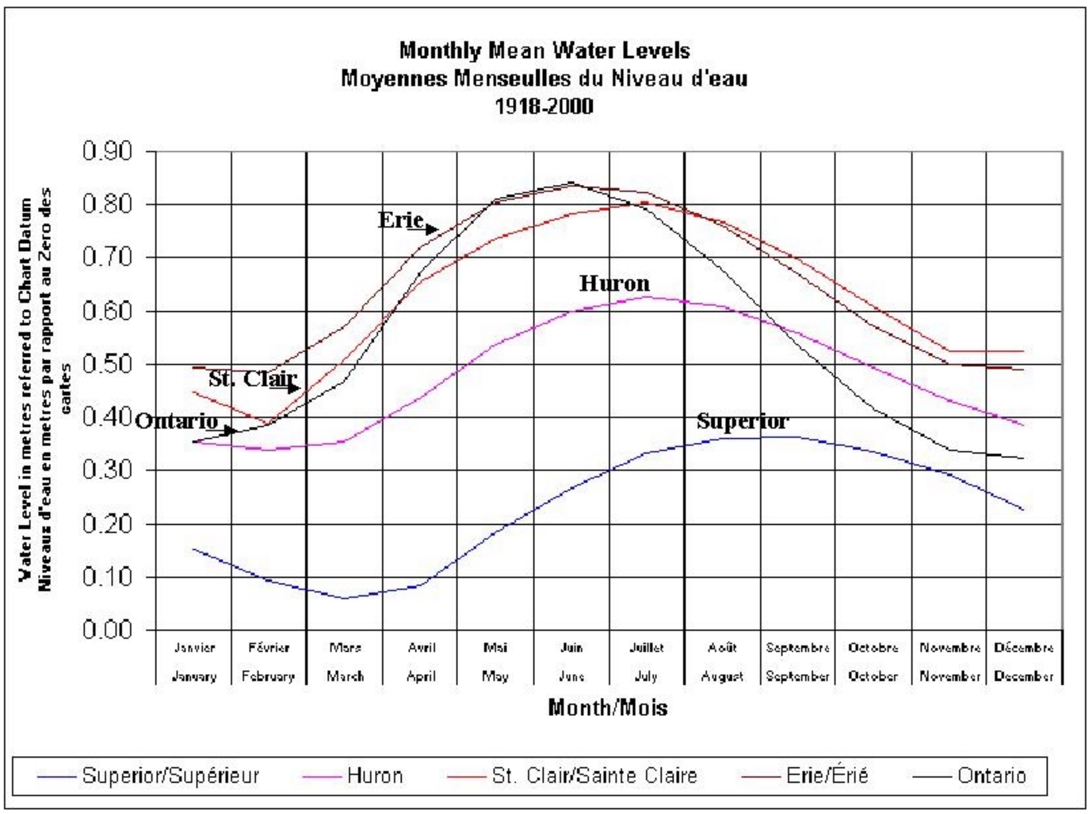
Fluctuating water levels on the Great Lakes are natural, however, and essential to the well being of the ecosystem. Lake levels normally vary from year to year, with size and capacity being the fundamental characteristics governing the balance of water (US EPA and the Government of Canada, 1995). Water levels on the Great Lakes change seasonally and can vary dramatically over longer periods. There are three types of water level fluctuations on the Great Lakes: long-term (multi-year), seasonal (one-year) and short-term (from less than an hour to several days). Short-term changes are generally of greater magnitude than seasonal or longer-term averages [Environment Canada Website (1)].

Long-term fluctuations: Long-term fluctuations occur over periods of consecutive years. More than a century of records in the Great Lakes-St. Lawrence River Basin indicate no regular, predictable cycle. The intervals between periods of high and low levels and the length of such periods can vary widely and erratically over a number of years, and only some of the lakes may be affected (Canadian Hydrographic Service, 2000).

Seasonal fluctuations: These fluctuations reflect the annual hydrologic cycle, characterized by higher net basin supplies during the spring and early summer and lower net basin supplies during the remainder of the year. Water levels rise to their peak in the summer, when evaporation from the lakes is least and more water is entering the system than leaving. Seasonal rises begin earlier on the more southern lakes that experience a slightly warmer climate, while Lake Superior, the northernmost lake, is generally the last to peak, usually in August or September (Figure 3), (Canadian Hydrographic Service, 2000; USACE and the GLC, 1999).

Short-term fluctuations: Some water level fluctuations are not a function of changes in the amount of water in the lakes, but are due to winds or changes in barometric pressure. These short-term fluctuations can last from less than an hour to several days. One such phenomenon, known as wind set-up or storm surge, ("seiche"), occurs when sustained high winds from one direction push the water level up at one end of a lake, which reduces the volume by a corresponding amount at the opposite end. In deep lakes such as Lake Ontario, the surge of water level rarely exceeds 1.5 feet (0.5 meters), but in shallow Lake Erie, water-level differences of more than 16.5 feet (5 meters) have been observed from one end of the lake to the other. Although the range in fluctuations may be large, there are only minor changes in the overall volume of water in the lake (Canadian Hydrographic Service, 2000). For a more detailed discussion regarding hydrologic cycles, see the Canadian Hydrographic Service (2000) and Quinn (2000).

Figure 3: Historic Monthly Mean Lake Levels, by Lake, 1918-2000



Source: Canadian Hydrographic Service, 2000

The fluctuations of Great Lakes water levels reflect the annual hydrologic cycle, characterized by higher net basin supplies during the spring and early summer and lower net basin supplies during the remainder of the year.

Ecological and Ecosystem Changes from Human Activities

Despite the predominant role played by climatic influences on Great Lakes water levels, in 1975, the International Joint Commission (IJC), a bi-national body established to approve use, conduct studies, and address and resolve disputes regarding the management of boundary waters, predicted that water consumption in the Great Lakes would increase three to seven times by 2035 (CELA and GLU, 1997). In a more recent report, (IJC, 2000), the IJC points out that although it is impossible to say with confidence exactly how much the increase in water consumption will be, there is agreement that *water withdrawals will increase in the future* [IJC projections currently extend to 2025]. Anthropogenic changes imposed due to irrigation, diversions, hydropower, and water level regulations must be considered in the overall water balance of the Great Lakes. The ecological impacts of such activities are extensive. According to a recent report by the World Wildlife Fund, the world's freshwater ecosystems have declined significantly over the last 30 years as a result of over-exploitation [Great Lakes Environmental Library, Current Articles, 2002 (2)].

The glacial history of the Great Lakes region and the vastness of the lakes create unique conditions that support a wealth of biological diversity including ecosystems with vast forests and wilderness areas, rich agricultural land, hundreds of tributaries, thousands of smaller lakes, and extensive mineral deposits as well as more than 130 rare species (World Water Council, 2001). Each river basin contains many natural ecosystems including not only the aquatic habitats associated with water in the river channel, but all of the elements of the river catchment that contribute water, nutrients and other inputs to the river (GLC, 2001). These ecosystems include: the headwaters and the catchment landscapes; the channel from the headwaters to the sea; riparian areas; associated groundwater in the channel/banks and floodplains; wetlands; the estuary and any near shore environment that is dependent upon freshwater inputs (GLC, 2001). These ecosystems perform functions such as flood control and storm protection, yield products such as wildlife, fisheries and forest resources, and are of aesthetic and cultural importance to millions of people (GLC, 2001).

Habitat within the basin has changed dramatically, both in terms of area and quality, since settlers arrived in the late 17th century (Maynard, in: GLC, 1996). Worldwide, fully 36 percent of the species extinctions that have occurred since 1600 resulting from known causes are attributed to habitat destruction (U.S. Congress, Office of Technology Assessment, 1995). The Nature Conservancy has identified 100 species and 31 ecological communities at risk within the Great Lakes system, and notes that half of these do not exist anywhere else (Barlow, 1999). Since the early 20th century, significant changes in land use in the Great Lakes-St. Lawrence River Basin have resulted from deforestation, urban development and encroachment, land clearing and drainage, and the management of water levels (Maynard, in: GLC, 1996). One result of such activities is a staggering loss of two-thirds of the once extensive wetlands of the basin

(Barlow, 1999), at a rate of 20,000 acres per year (CELA and GLU, 1997). Land use changes have altered the runoff characteristics of the drainage basin as well. Although the extent to which these land use changes impact lake levels is difficult to define, research suggests that some of these changes have increased water flows into the Great Lakes from some tributary streams [Environment Canada Website (3)].

Another impact of human activities is the depletion of groundwater aquifers. Groundwater is important to the Great Lakes ecosystem because it provides a reservoir for storing water and for slowly replenishing the Great Lakes through base flow into the lakes and tributaries. Groundwater also serves as a source of water for many human communities, plants and other biota (IJC, 2000). However, groundwater supplies, like surface waters, are becoming increasingly depleted. According to Sandra Postel of the Worldwatch Institute (1999), groundwater overpumping may be the single biggest threat to food production worldwide, due to accessibility and lower cost of groundwater extraction as compared to river/surface water use. In the Great Lakes-St. Lawrence River Basin, while most withdrawals for overall use are from surface water, about half of the water used for irrigation and livestock operations comes from groundwater sources (USGS, 1995).

Human activities have also resulted in the introduction of non-indigenous, invasive species into the basin. According to Mills et al. (in: Great Lakes Research Review, 1998), since the early 1800s, the Great Lakes have been exposed to 141 non-indigenous species, at considerable cost for monitoring and control. Nearly two-thirds of these species arrived in the Great Lakes via two methods: unintentional releases (34 percent) and shipping activities (31 percent). Mills et al. assert that almost one-third of these species have been introduced to Great Lakes waters in the last thirty years, corresponding to the opening of the St. Lawrence Seaway. Two hundred years ago, the five Great Lakes each had a flourishing aquatic community. However, over time, the native species in each of these aquatic communities have been overwhelmed by exotic species, with devastating results to the native species (Barlow, 1999).

Pollution resulting from human activities has also had a profound impact on the Great Lakes-St. Lawrence ecosystem. For decades, dilution was seen as a manageable offsetting measure, thus enormous amounts of pollution were released directly into Great Lakes waters. One result of a reduction in Great Lakes water levels will be greater concentrations of harmful contaminants, as well as the increased possibility that contaminated sediments will be disturbed, leading to the release of these dangerous substances into the food chain.

III. Current Conditions: Trends in Water Use

Global, U.S. and Canadian Water Use

Although lakes are among the most vulnerable and difficult to restore of all natural ecological systems, they have been widely ignored even as they have deteriorated, according to Masahisa Nakamura, Director of the Lake Biwa Research Institute in Biwa, Japan (World Water Council, 2001).

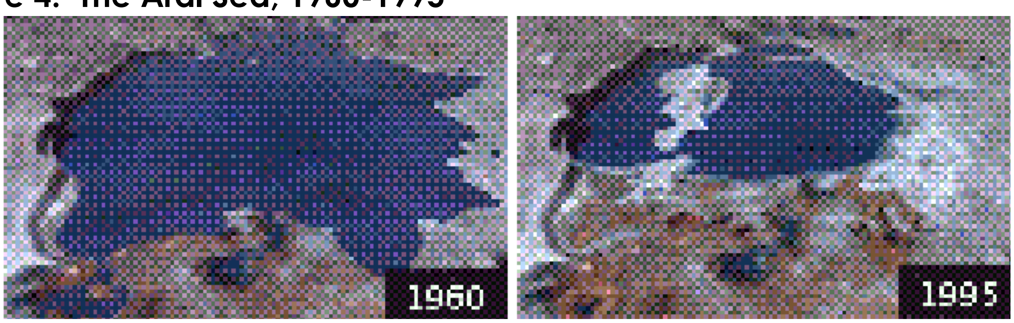
Lakes Deteriorating from Overuse

- Between 1950 and 1980, 543 large and medium-sized lakes in China disappeared when their water was diverted for irrigation;
- The Arre Lake in Denmark has suffered severe water loss because of the rising use of water for growing populations;
- Many lakes and reservoirs in the Amazon Basin of Brazil have been drained for agriculture and other economic activities;
- Lake Okeechobee in Florida, the second largest lake entirely within the U.S., has been severely depleted because of its use as a water source for growing populations, with the loss of the natural flow adversely affecting the Everglades;
- The most dramatic example is that of the Aral Sea, located between Kazakhstan and Uzbekistan, which has lost more than 60% of its area and 80% of its volume since 1960 (Figure 4). The Aral Sea has dropped in size from the world's 4th largest lake to the 8th largest, predominantly from heavy withdrawals for irrigation.

Source: World Water Council, 2001.

The cumulative climatic, ecological and economic consequences of these worldwide water losses are immeasurable.

Figure 4: The Aral Sea, 1960-1995

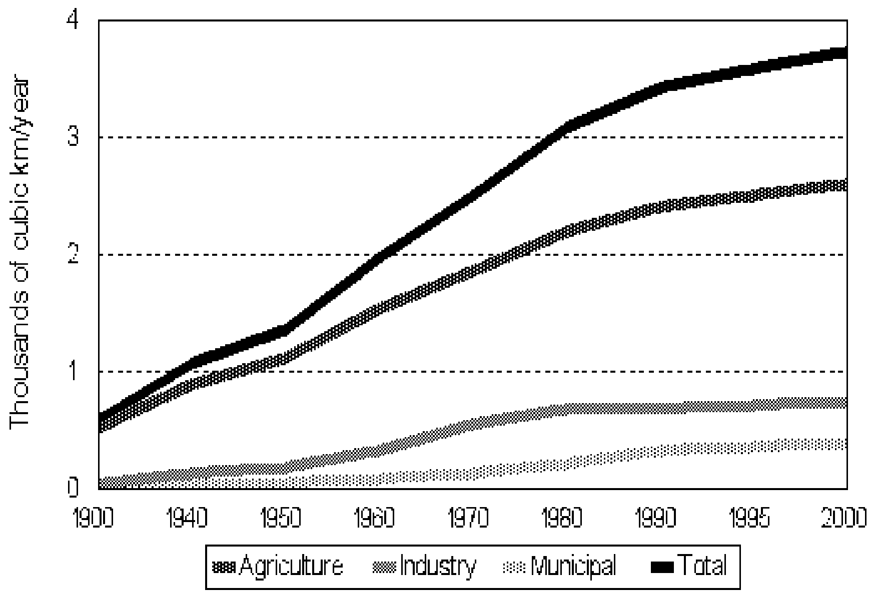


Climatic consequences	Ecological/economic consequences
Mesoclimatic changes (increase of continentality)	Degeneration of the delta ecosystems
Increase of salt and dust storms	Total collapse of the fishing industry
Shortening of the vegetation period	Decrease of productivity of agricultural fields

Source: The Aral Sea Homepage

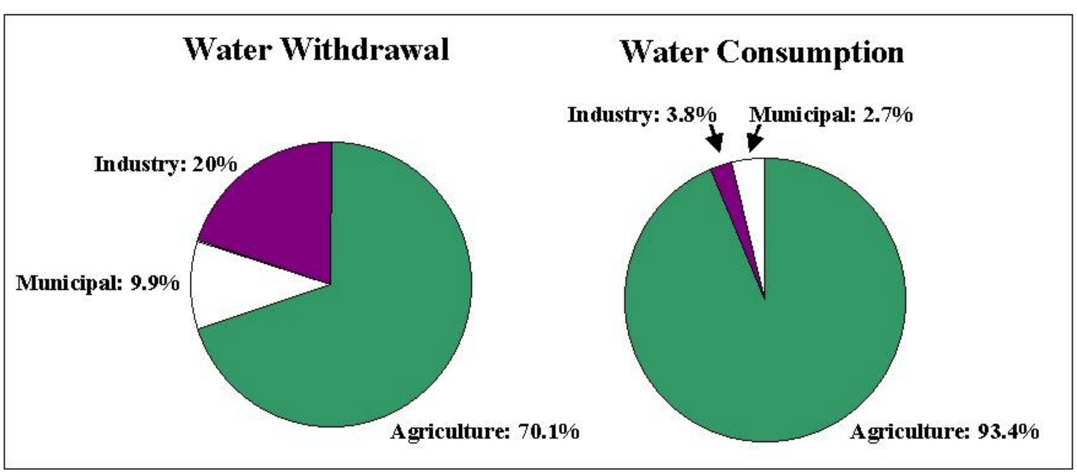
Global water usage has increased dramatically over the last century, with consumption of freshwater doubling every twenty years (500 percent), since 1900 (The Western Producer, 2001). One study estimates a six-fold increase in water withdrawals from lakes and rivers between 1990 and 1995, a rate that is twice as fast as population growth (World Water Council, 2001). Most of the increase in water withdrawals (Figure 5) and water currently consumed (Figure 6), is devoted to agriculture (World Meteorological Organization, 1997). Irrigation accounts for 70 percent of all the water taken from lakes, rivers, and underground sources worldwide (World Meteorological Organization, 1997).

Figure 5: Global Water Withdrawals by Sector, 1900-2000



Source: World Meteorological Organization, 1997

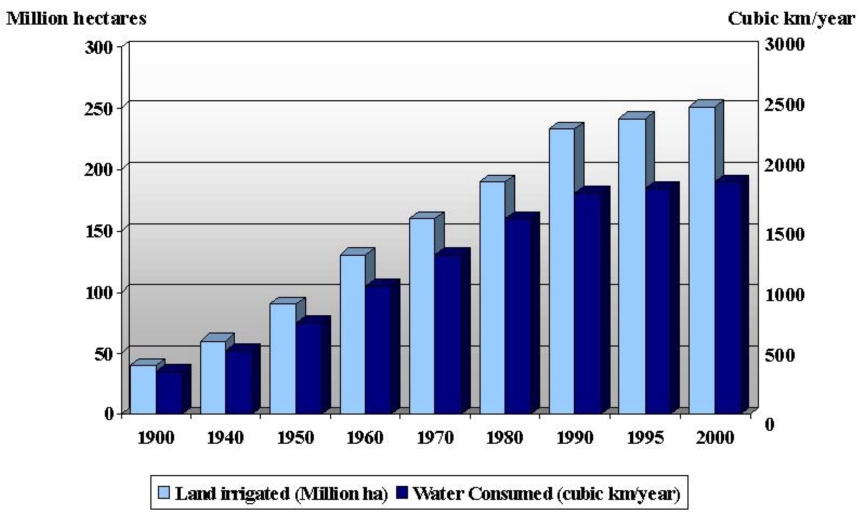
Figure 6: Current Water Withdrawal and Consumption by Sector, 1997



Source: World Meteorological Organization, 1997; Recreated by: Institute for Agriculture and Trade Policy

Worldwide, the total amount of irrigated land and water consumed for irrigation has been increasing dramatically over the last century (Figure 7). Global water withdrawals for irrigation have increased over 60 percent since 1960 (World Meteorological Organization, 1997). Until the late 1970s, the increase in the amount of land being irrigated exceeded the rate of population growth. Since then, the amount of irrigated land has increased more slowly than population, due to limited available land suitable for irrigation, increasing water scarcity and the loss of some irrigated areas from soil degradation (World Meteorological Organization, 1997).

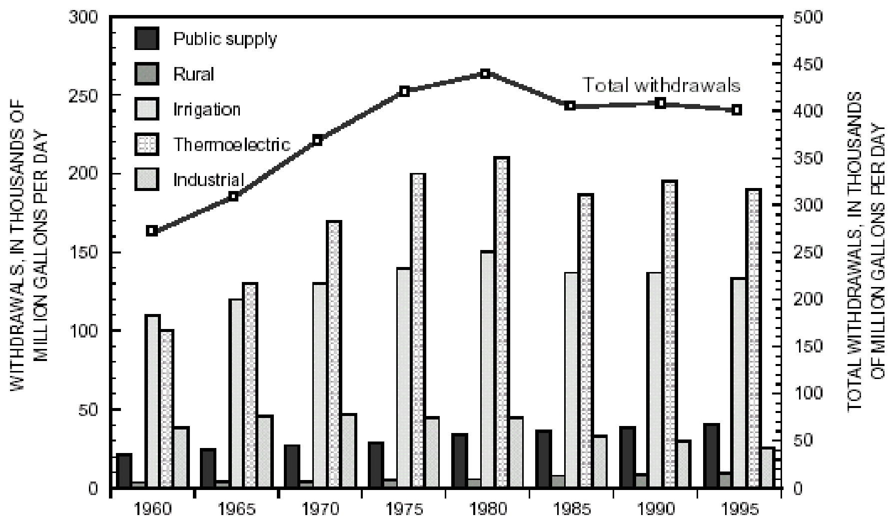
Figure 7: Amount of Irrigated Land in the World and Water Consumed for Irrigation, 1900-2000



Source: World Meteorological Organization, 1997
Recreated by: Institute for Agriculture and Trade Policy

In the U.S., total national water withdrawals increased from 1965 to 1980, and gradually declined from 1980 to 1995, the most recent year for which data are available (Figure 8), [USGS, 1995; USGS Website (1)]. Public supply and rural domestic and livestock categories are the only two categories that show continual increases from 1960 to 1995, with the increase in public supply largely due to population increases. The increase in rural domestic and livestock categories is attributable to an increase in livestock withdrawals, especially animal specialties withdrawals. More water continues to be withdrawn for thermoelectric power generation than for any other category, peaking in 1980. Industrial withdrawals declined from 1980 to 1995 as a result of new industries and technologies that require less water, improved plant efficiencies, increased water recycling and conservation measures. Total irrigation withdrawals steadily increased from 1965 to 1980, and gradually decreased from 1980 to 1995. Irrigation application rates vary from year to year and depend on many factors, including annual rainfall, surface water availability, energy costs, farm commodity prices, application technologies and conservation practices. In the 1980s, improved application techniques increased competition for water, and a downturn in the farm economy temporarily reduced overall U.S. demand for irrigation water [USGS, 1995; USGS Website (1)].

Figure 8: National Trends in U.S. Water Withdrawals, by Sector, 1960-1995



Source: USGS, 1995

The two largest U.S. water use categories continue to be thermoelectric power and irrigation. In 1995, the most water withdrawn (fresh and saline) was for thermoelectric power cooling, whereas the most freshwater withdrawn was for irrigation (USGS, 1995).

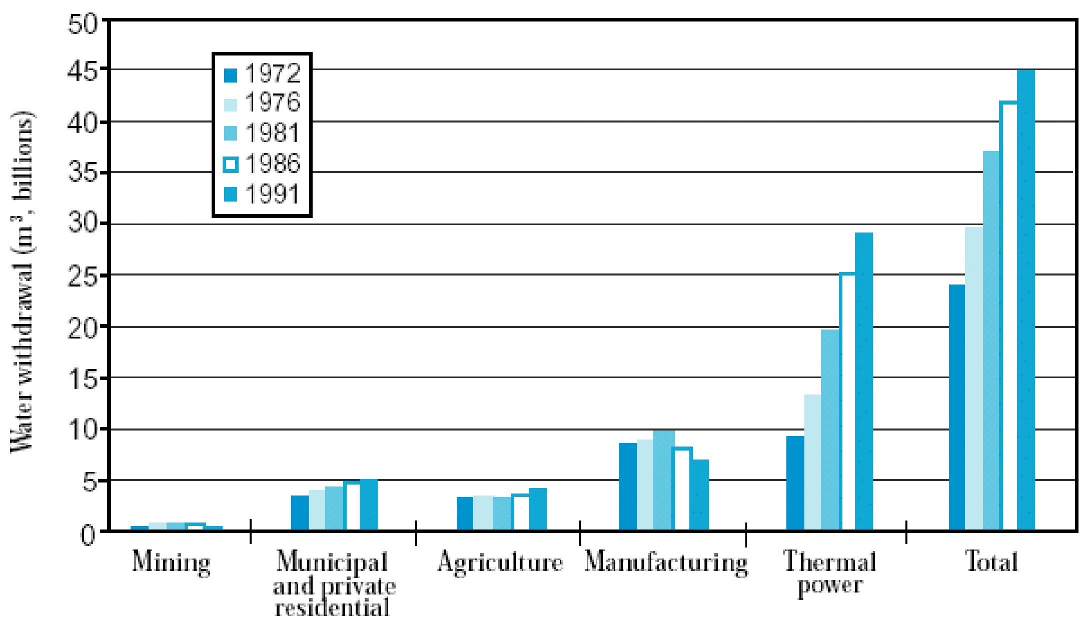
In Canada, the trend in overall water usage is increasing (Figure 9, Agriculture and Agri-Food Canada, 2000). At a national level, agriculture withdraws a relatively small amount of water (9%) compared with thermal power generation (63%) and manufacturing (16%), however, unlike these industries, agriculture does not return a large portion of what it uses to the system (Agriculture and Agri-Food Canada, 2000).

Estimates regarding the amount of water lost or not directly returned to the system from irrigation vary. The World Meteorological Organization (1997) estimates about 40 percent of the water used for irrigation is lost to the system; the IJC (2000) and Agriculture and Agri-Food Canada (2000) estimate more than 70 percent loss; and USGS estimates 100 percent consumption from irrigation (Crane, in: GLC, 1996). Most states and provinces agree that consumption from irrigation is not 100 percent, however little research has been done to determine better estimates

(Crane, in: GLC, 1996). The efficiency of irrigation systems also varies considerably depending on the type and timing of irrigation, as well as the crop grown.

In Canada, the demand for water is growing in most sectors, increasing the potential for competition and conflict among water users. Irrigation, the largest agricultural consumer of water, is often at the centre of such competition (Agriculture and Agri-Food Canada, 2000).

Figure 9: Total Water Withdrawals in Canada, by Sector, 1972-1991



Water Uses in the Great Lakes-St. Lawrence River Basin

Water uses in the Great Lakes-St. Lawrence River Basin consist of non-consumptive and consumptive uses. Non-consumptive use refers to any water withdrawal or in-stream use in which virtually all of the water is returned to the system (USACE and GLC, 1999). Non-consumptive uses include hydropower/thermoelectric power, transportation, navigation and recreation.

Consumptive use is defined as that portion of water withdrawn or withheld from the Great Lakes and their connecting channels and assumed to be lost, or otherwise not returned to the system due to evaporation, incorporation into products or other processes (GLC, 2000). Consumptive uses include diversions, dredging, domestic, industrial and municipal water uses, agricultural exports, irrigation and livestock production. Consumptive uses of Great Lakes waters are generally not directly measured but are reported by water users under state or provincial water use permit programs, and are usually estimated from water withdrawals using consumptive use coefficients (GLC, 2000).

Water Uses in the Great Lakes Basin

- ***Thermoelectric Power Use***. At thermoelectric power plants, water is used principally for condenser and reactor cooling. In the United States, thermoelectric withdrawals have remained relatively constant since 1985 and are expected to remain near their current levels for the next few decades. In Canada, modest increases are expected to continue along with population and economic growth.

- ***Industrial and Commercial Use***. In the United States, industrial and commercial water use has declined in response to environmental pollution legislation, technological advances, and a change in the industrial mix from heavy metal production to more service-oriented sectors. A similar trend is evident in Ontario, so combined use is expected to gradually decline through 2020.

- ***Domestic and Public Use***. In the United States, water use for domestic and public purposes in the Great Lakes Basin generally increased from 1960 to 1995 and is expected to climb gradually through 2020. In Ontario, however, the modest downward trend established in recent years because of water conservation efforts is expected to continue.

- ***Agriculture***. In the United States, water use for agriculture in the Great Lakes region increased from 1960 to 1995 and is expected to continue to grow. In Canada, the rate of increase was somewhat greater, so that combined projections indicate a significant increase by 2020. Climate change could increase even further the competitive advantage the basin has in agriculture as a result of its relative abundance of water.

Source: International Joint Commission, 2000

Non-Consumptive Water Uses: Hydropower, Transportation, Navigation and Recreation

Hydropower: Ninety-four percent of the water withdrawn from the Great Lakes for human use is taken by hydroelectric power plants. It does not figure in consumptive use estimates since almost all of it is returned to the lakes. However, the use of water for hydropower seriously disrupts the natural flows and levels of the rivers and lakes and thus affects downstream users- both people and wildlife (CELA and GLU, 1997). Hydropower water use and its structures can also negatively affect the environment through increased shore erosion and disruption or elimination of fish migration patterns (GLC, 1995). As discussed by Linton (in: Barlow, 1999), "existing water diversions and hydroelectric projects in Canada are causing local climate change, reduced biodiversity, mercury poisoning, loss of forest, and the destruction of fisheries habitat and wetlands."

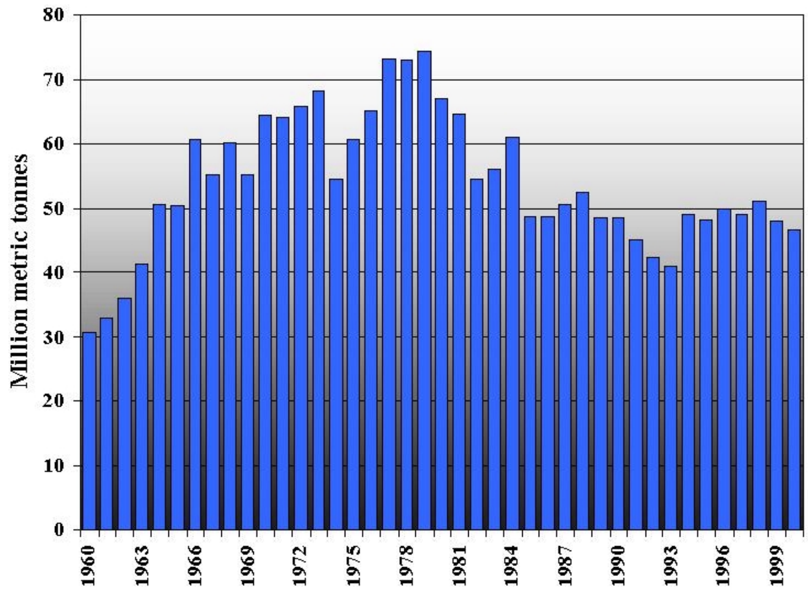
Transportation/Navigation: The Great Lakes-St. Lawrence transportation system stretches over 2,000 miles (3,700 kilometers). Transportation was a pivotal factor in the development of the Great Lakes region. The combination of a natural water transport infrastructure and a strong resource base promoted settlement, agricultural development and a manufacturing economy (GLC, 1995). The St. Lawrence Seaway provides the mid-continent with an important trade link to world markets. Opened to navigation in 1959, annual commerce exceeds 200 million net tons (180 million metric tons). The St. Lawrence Seaway part of the system has moved more than 2.1 billion metric tons of cargo in 40 years, with an estimated value of $173 billion U.S. ($258 billion Canadian). Almost 50 percent of this cargo travels to and from overseas ports [Great Lakes-St. Lawrence Seaway System Website (1)].

In recent years, however, the Great Lakes-St. Lawrence Seaway has endured a dramatic decline in total tonnage (Figure 10). While there have been year-to-year fluctuations since the late 1970s, there has been a substantial negative trend in average tonnage (GLC, 1995). Since the peak in Seaway tonnage in 1979 (74.3 million metric tons), total tonnage moving through the system has declined by 37 percent (1979-2001), [Great Lakes-St. Lawrence Seaway Website (3), (4); St. Lawrence Seaway Management Corporation and the St. Lawrence Seaway Development Corporation].

Similarly, the Montreal/Lake Ontario section of the Seaway peaked in 1977, transporting 57.4 million metric tons (GLC, 1995). In 2001, the section transported 30.3 million metric tons, a 47 percent decline in traffic [Great Lakes-St. Lawrence Seaway System Website (2)]. These declines are a result of a number of factors:

- agricultural products are increasingly transported by rail to the west coast rather than using the Seaway;
- demand for Midwest coal and other mined products has declined;
- Canada has revised its national transportation laws, making transport more expensive;
- the transportation industry's reliance on large *panamax*-sized ships (the largest ships that can pass through the Panama Canal) and year-round access to ports has diminished the attractiveness of the Seaway.

Figure 10: Total Tonnage Transported on the St. Lawrence Seaway, 1960-2000



Created by: Institute for Agriculture and Trade Policy
Data Sources: Great Lakes-St. Lawrence Seaway Website (3), (4);
St. Lawrence Seaway Management Corporation and the St. Lawrence Seaway Development Corporation

The Great Lakes-St. Lawrence Seaway has endured a dramatic decline in total tonnage in recent years.

Recent analyses of the navigation system's economic impact indicate that more than 60,000 U.S. and Canadian jobs are dependent on the cargo movements that generate more than $3 billion in business revenue and personal income. However, maintaining levels of flow for shipping, maintenance dredging, and ice management, among other aspects of the transportation use of the Great Lakes, poses potential conflicts with other uses (GLC, 1995), such as ecosystem protection and maintenance. For example, despite the substantial decline in Seaway tonnage, there has been ongoing pressure from the shipping industry for longer shipping seasons, as well as a push for major deepening and widening of the locks and channels of the Seaway to accommodate much larger *Panamax*-sized vessels into the basin. If such an expansion of Seaway channels were to occur, the impacts on the Great Lakes ecosystem and water levels would likely be quite dramatic.

The U.S. Army Corps of Engineers is currently reviewing the feasibility and costs of such an expansion to improve commercial navigation and has acknowledged that "dredging, blasting, constructing wider and deeper locks and channels, and all the other proposed works will seriously impact the lakes through introduction of additional aquatic nuisance species, aquatic habitat disruptions, loss of habitat, areas of dead water, alterations in flow patterns and dredging of hundreds of millions of cubic yards of material requiring placement" (GLU, Action Alert, August, 2002). Great Lakes United points out that despite these environmental concerns, "the draft report predicts that 'improvements' to the Great Lakes navigation system will provide annual benefits of $1.4 billion dollars, however, it fails to add up the potential costs to hydropower, riparian owners, sustenance communities, commercial and recreational fishing and the tourist industry that depend on a healthy, diverse, fully functioning ecosystem" (GLU, Action Alert, August, 2002).

Recreation: The Great Lakes support a wealth of recreational opportunities. The Great Lakes States are home to 4.2 million recreational boats, or about one-third of all registered recreational vessels in the United States (Great Lakes-St. Lawrence Seaway System Website). Additionally, an estimated 1.2 million recreational boats are registered in the Canadian Province of Ontario. Recreational boating provides over 125,000 jobs and contributes approximately $9 billion (U.S.) annually to the regional economy [Great Lakes-St. Lawrence Seaway System Website (1)]. Although recreational activities do not impact water levels, decreasing water levels would have negative consequences on this sector of the economy.

Consumptive Water Uses:
Diversions, Dredging, Domestic and Public Use, Industrial and Commercial Use, Agricultural Exports and Freshwater Use for Agriculture

Diversions: Anthropogenic, or man-made changes, have resulted in either permanent alteration of water levels or a decreased range in levels (Quinn, 1999), resulting in significant environmental, social and economic harm (CELA and GLU, 1997). Permanent alterations in levels result from diversions into, out of, or between the lakes, navigational dredging, and infrastructure placed in the connecting channels. A decreased range in levels results from the regulation of levels in Lakes Superior and Ontario. At present, more water is diverted into the system than is taken out (IJC, 2000).

In l982, the International Joint Commission reported on a study of the effects of existing diversions into and out of the Great Lakes system and on consumptive uses. Until this study, consumptive use had not been considered significant for the Great Lakes because the volume of water in the system is so large. Although the study concluded that climate and weather changes affect the levels of the lakes far more than existing human-made diversions, the report also concluded that if consumptive water uses continue to increase at historical rates, outflows through the St. Lawrence River could be reduced by as much as 8 percent by around the year 2030 (US EPA and the Government of Canada, 1995). Major diversion proposals in recent years have resulted in the Council of Governors and Premiers adopting a posture of opposition to any further out of basin diversions (GLC, 1995).

"While individual impacts may or may not seem significant, cumulative impacts of even small changes may be important" (Quinn, 1999).

Dredging: Unlike other consumptive uses, dredging in the connecting channels has had a noticeable impact on lake levels, even in the context of natural fluctuations. Connecting channels and canals that have been dredged to facilitate deep-draft shipping have permanently lowered Lakes Michigan and Huron by approximately 16 inches (40 cm), [IJC, 2000, CELA and GLU, 1997, Environment Canada Website (3)]. Channel and shoreline modifications in connecting channels of the Great Lakes have affected lake levels and flows as well. For example, in the Niagara River, construction of bridges and in-filling of shoreline areas have slightly reduced the flow carrying capacity of the river [Environment Canada Website (3)].

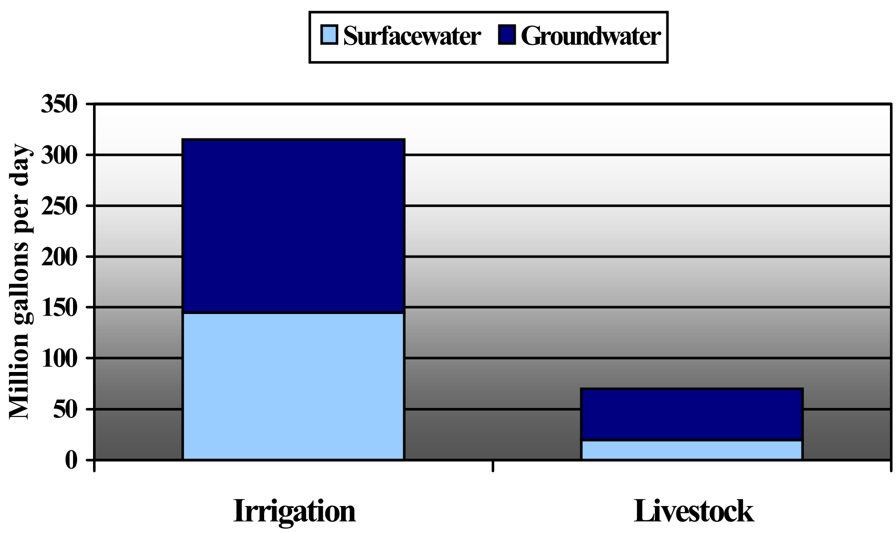
Domestic and Public Use: In terms of intensity of freshwater usage per area, Great Lakes States withdraw more freshwater nationally than other regions primarily due to the larger populations in the Eastern states (USGS, 1995). In the United States, water use for domestic and public purposes in the Great Lakes-St. Lawrence River Basin generally increased from 1960 to 1995 and is expected to climb gradually through 2020. In Ontario, however, the modest downward trend established in recent years because of water conservation efforts is expected to continue (IJC, 2000).

Industrial and Commercial Use: In the United States, industrial and commercial water use has declined in response to environmental pollution legislation, technological advances, and a change in the industrial mix from heavy metal production to more service-oriented sectors. A similar trend is evident in Ontario, so combined use is expected to gradually decline through 2020 (IJC, 2000).

Agricultural Exports: Agricultural exports are also considered a consumptive use in that much of the water used for food production is not returned, but exported in the form of food and fiber products, bottled beer/processed beverages and bottled water. Overall agricultural exports from Great Lakes Provinces have been increasing in recent years, while exports from Great Lakes States have been declining.

Freshwater Use for Agriculture: At a national scale, freshwater consumptive use (surface and groundwater) for agriculture in the Great Lakes region is minimal compared to other parts of the country (USGS, 1995). Less freshwater used for irrigation results largely from natural climatic conditions such as modest rainfall and humidity. Less freshwater used for livestock results from a comparatively smaller proportion of livestock production in the region. However, according to the IJC (2000), irrigation use in the Great Lakes region increased from 1960 to 1995, and is expected to continue to grow. As irrigation in the basin increases, reservoirs and groundwater levels may be reduced, potentially causing conflicts with other water uses (Crane, in: GLC, 1996). Of the freshwater used for irrigation and livestock, more than half of that used in Great Lakes States comes from groundwater sources (USGS, 1995), (Figure 11).

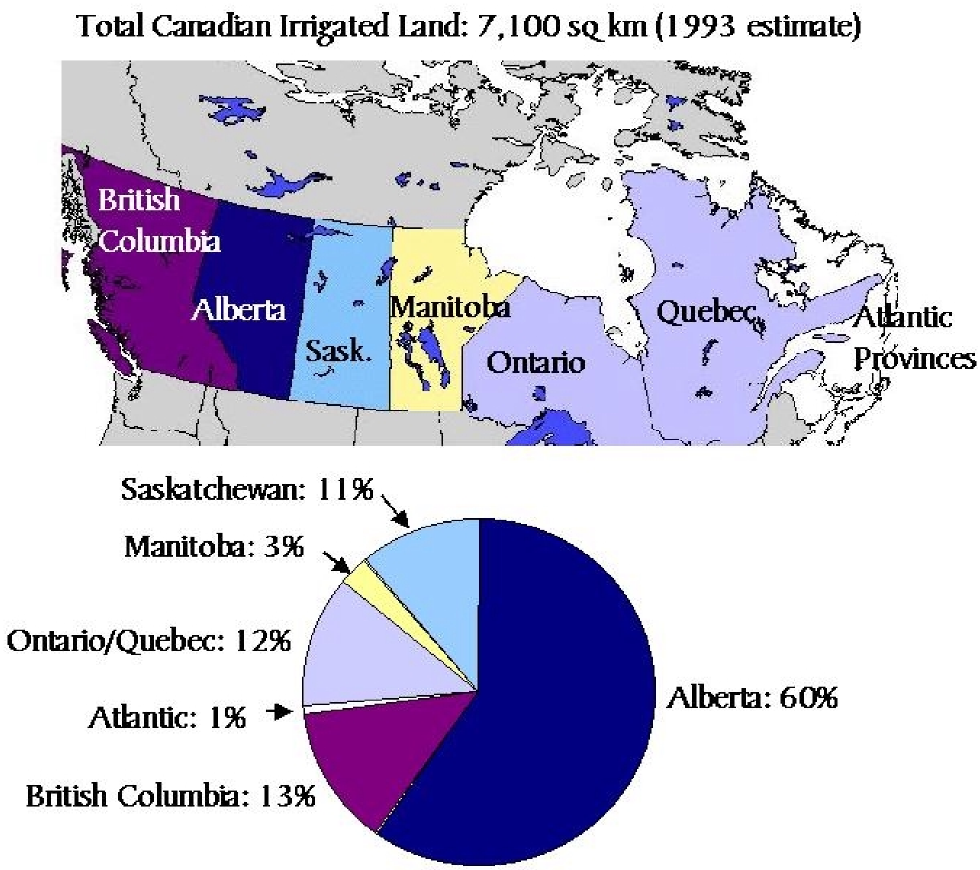
Figure 11: Surface and Groundwater Withdrawals for Irrigation and Livestock by Great Lakes States, 1995



Created by: Institute for Agriculture and Trade Policy; Data Source: USGS, 1995

In Canada, the Province of Alberta has the highest percentage of irrigated land nationally (60%), whereas the Great Lakes Provinces of Ontario and Québec represent a combined total of just 12 percent of Canada's irrigated land (Figure 12). Although water shortages do arise where there is conflict between urban and rural water needs (such as in the Kitchener-Waterloo area in Ontario), according to Harker (1999), water supply issues apply most often to the semi-arid West. There, water quantity issues often revolve around considerations of whether there is enough water, how it will be apportioned, and security of supply. As discussed by Harker (1999), when it comes to irrigation, demand/pricing for irrigation water can significantly reduce the amount of water available for wildlife, recreation and other uses. He argues that irrigation development itself may be restricted due to a shortage of water, and that there simply may not be enough water available to irrigate substantially more lands. Over time, this may mean increasing pressure to divert Great Lakes water to more arid parts of the country.

Figure 12: Distribution of Irrigated Land in Canada



Created by: Institute for Agriculture and Trade Policy
Sources: Agriculture & Agri-Food Canada, 2000; International Commission on Irrigation & Drainage Website; ESRI

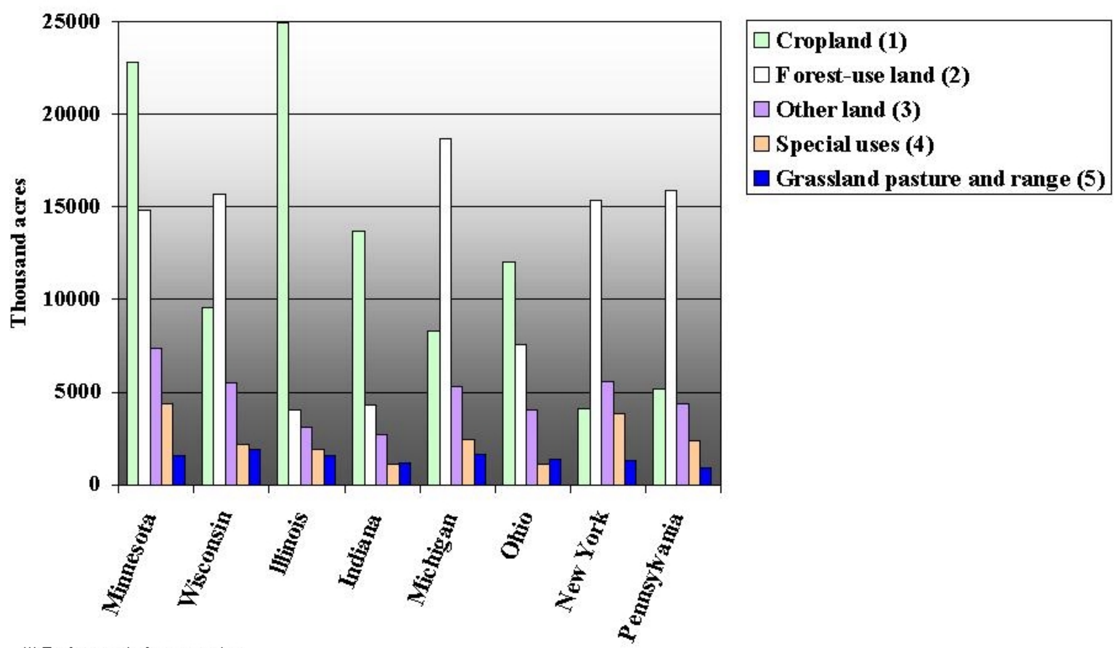
IV. Status of Great Lakes Agriculture*

As noted, agriculture is the major consumptive user of water in the Great Lakes Basin. At the same time, however, agriculture provides much of the open space that allows for rainwater infiltration and groundwater recharge. The agricultural sector contributes not only essential food and fiber, but also has the potential to provide such public benefits as wildlife habitat, biodiversity conservation, flood prevention and erosion control. Economically, agriculture is not only significant in the Great Lakes regional economy, but nationally as well, contributing almost 20 percent of all U.S. agricultural production and almost 40 percent of all Canadian production (in dollars), [USDA, National Agricultural Statistics Service (NASS) (8)], [Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001, (3)].

Land Use

Land use in the Great Lakes region is dominated by agriculture. Cropland/cultivated land represents the largest percentage of land use in Great Lakes States, followed closely by forest-use land (Figure 13).

Figure 13: Major Land Uses in Great Lakes States, 1997 Snapshot



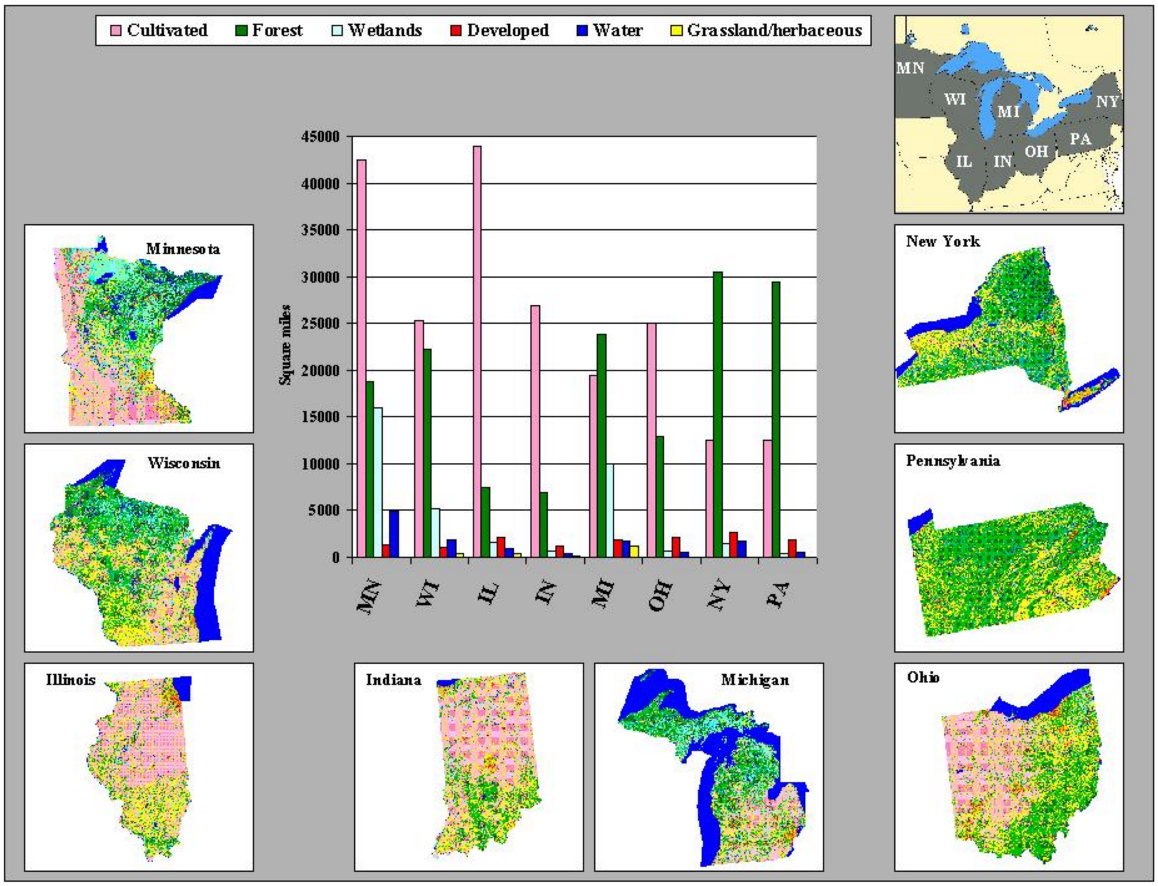
(1) Total acreage in the crop rotation.
(2) Excludes an estimated 105 million acres in parks and other special uses of land.
(3) Misc. areas such as marshes, open swamps, bare rock areas, deserts, urban and other special uses not inventoried.
(4) Transportation, recreation, and other special uses.
(5) Grasslands and other non-forested pasture and range in farms excluding cropland used only for pasture, plus estimates of open or nonforested grazing land not in farms.

Created by: Institute for Agriculture and Trade Policy; Data Source: USDA, 1997

*For data purposes, Great Lakes regional trends include data from all U.S. States and Canadian Provinces that border the Great Lakes. **Data *are not* presented at the basin/watershed level.**

As illustrated in Figure 14, the states with the greatest proportion of cultivated land in the Great Lakes region are Illinois, Minnesota, Indiana, Wisconsin and Ohio. Forests are the dominant landcover in New York, Pennsylvania and Michigan, followed by cultivated land.

Figure 14: Landcover Statistics for Great Lakes States, 1992

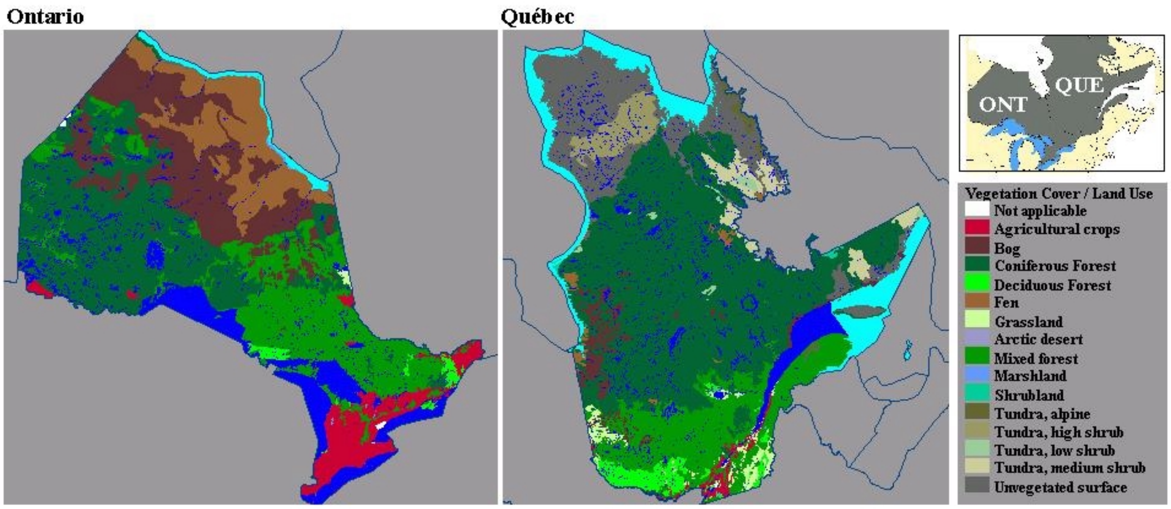


Created by: Institute for Agriculture and Trade Policy
Data Source: USGS, National Land Cover Statistics Database, 1992

Cultivated land and forest land dominate land use in the Great Lakes States.

Land use/landcover in the provinces of Ontario and Québec consists predominantly of coniferous and deciduous forest, as well as a large proportion of fen and bog in northern Ontario (Figure 15). Unlike the Great Lakes States, agricultural land use represents a much smaller proportion of overall land use, located almost entirely in the extreme southern regions of both provinces.

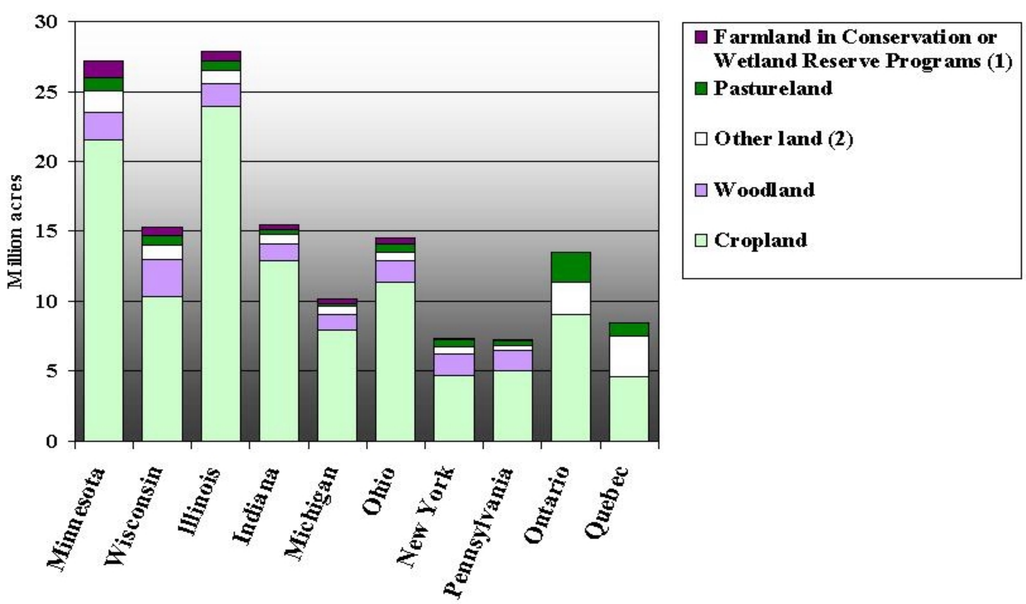
Figure 15: Landcover in Great Lakes Provinces, 2001



Data Sources: Agriculture and Agri-Food Canada, 2001; ESRI

Farmland characteristics in the basin consist predominantly of cropland, with comparatively smaller areas of woodland, pastureland, and farmland in the conservation or wetland reserve programs (Figure 16). (Provincial data do not include woodland or farmland in the conservation or wetland reserve programs).

Figure 16: Farmland Characteristics in Great Lakes States (1997 Snapshot) and Provinces (2001 Snapshot)

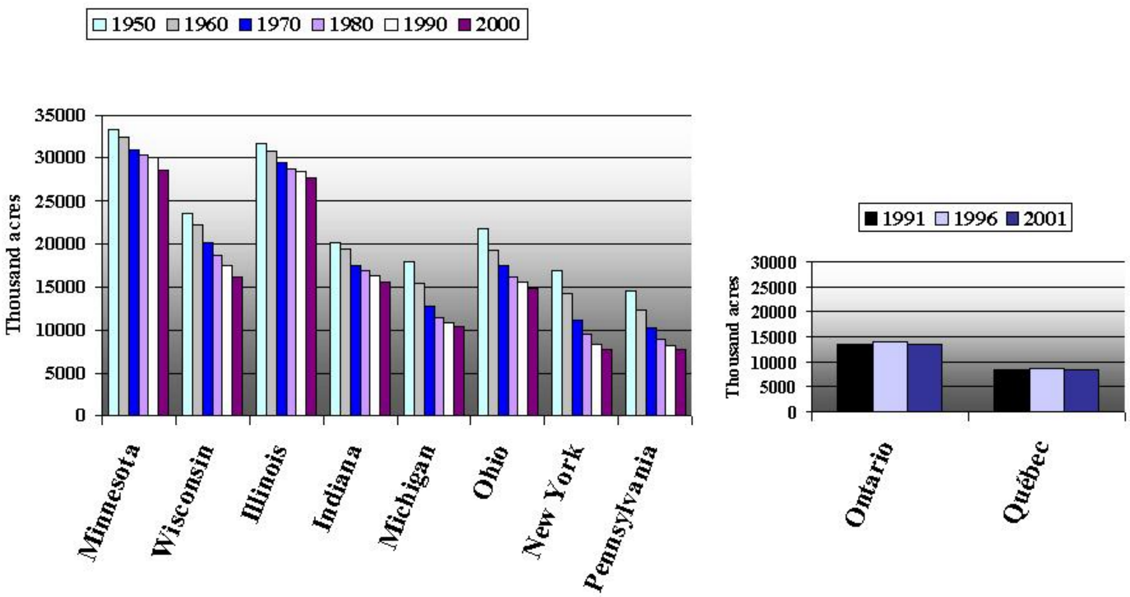


Created by: Institute for Agriculture and Trade Policy
Data Sources: USDA, Economic Research Service (ERS) (3);USDA, NASS (3); Statistics Canada, 2001 (1)

According to two different U.S. land use inventories, Major Land Uses (MLU) and the National Resources Inventory (NRI), there has been a significant drop in total U.S. cropland from 1982 to 1997 (USDA, 1997). The inventories differ somewhat, however, in their estimations of where this land is estimated to have "gone." According to the MLU, much of this land was converted to "special-uses," mostly due to increases in parks, fish and wildlife areas, and wilderness areas, while the NRI estimates that much of this land has gone to "miscellaneous uses," which include urban areas and roads (the NRI does not include Federal lands, or Alaska). For more detailed information, see U.S. Department of Agriculture (USDA), 1997, Statistical Bulletin Number 973: *Major Land Uses in the United States*.

In either case, there is agreement that there has been a reduction in total farmland. Figure 17 illustrates that in Great Lakes States, total land in farms has declined by almost 30 percent over the last fifty years. In Great Lakes Provinces, land in farms has remained stable over the last decade.

Figure 17: Total Land in Farms:
Great Lakes States (1950-2000) and Provinces (1991-2001)



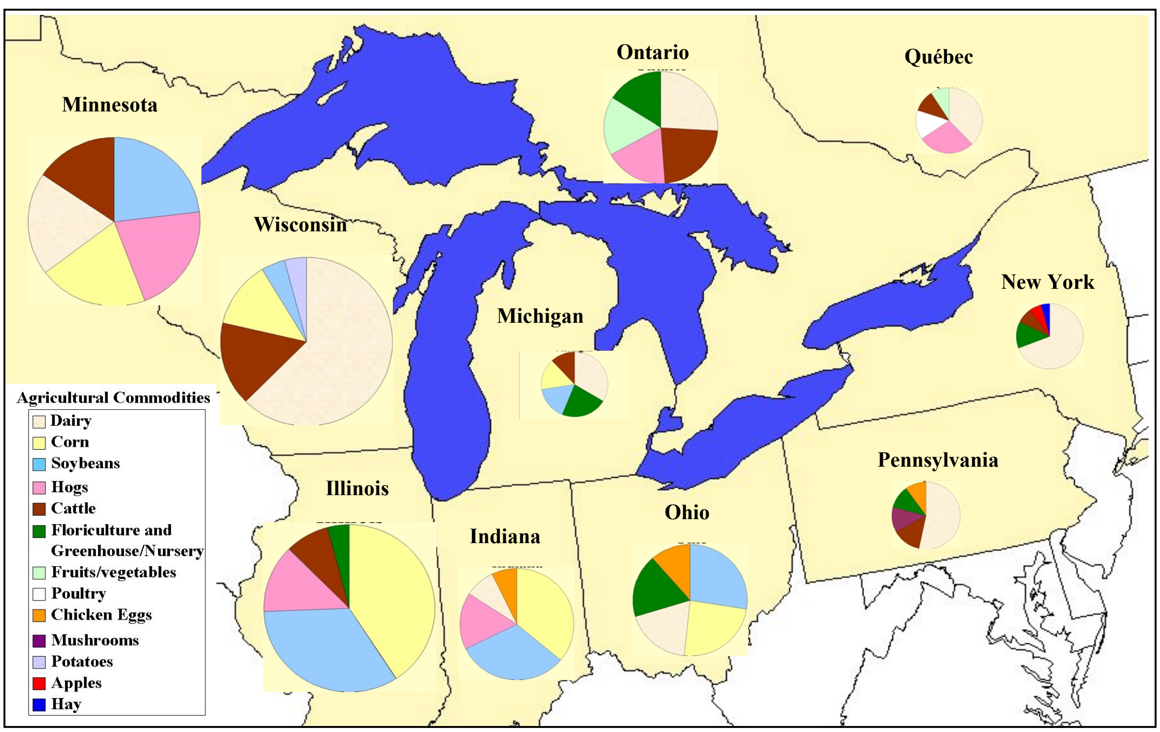
Created by: Institute for Agriculture and Trade Policy
Data Sources: USDA, NASS (5); Ministry of Agriculture and Food, Statistics Canada, Census of Agriculture (1)

Agricultural Production

The leading agricultural commodities produced in the Great Lakes region are dairy products, corn, soybeans, hogs and cattle (Figure 18). The states of Illinois, Minnesota and Wisconsin lead regional production in terms of U.S. dollars, followed by Indiana, Ontario and Ohio. Dairy is the leading agricultural commodity produced in Wisconsin, New York, Pennsylvania, Québec, Ontario and Michigan; soybeans lead production in Minnesota and Ohio; corn leads production in Illinois and Indiana, followed closely by soybeans [USDA, ERS (3); Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001 (3); Institut de la Statistique du Québec, Statistique Canada (1)].

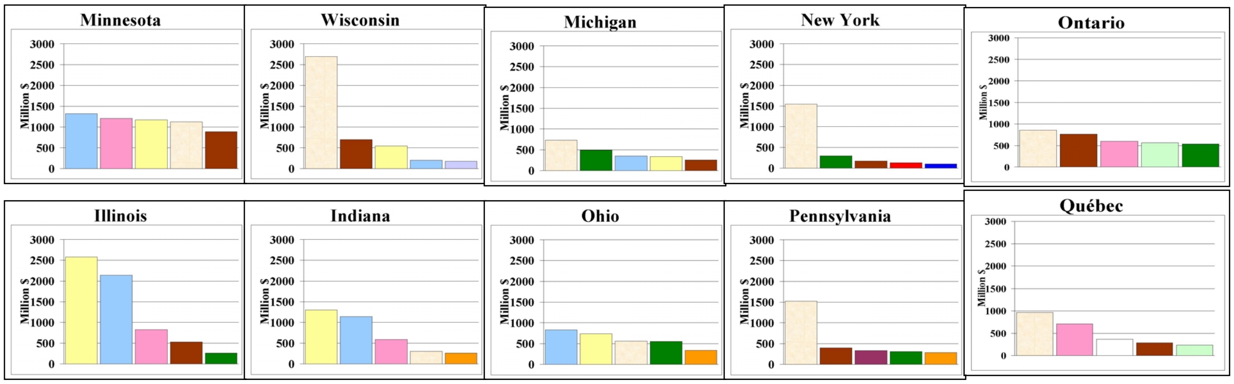
Ontario and Québec together produce about one-third of total crops and almost half of total livestock and products in Canada. These provinces also produce the greatest proportion of dairy products (70 percent), corn (97 percent), soybeans (99 percent), and hogs (54 percent) in the country, as compared to other provinces [Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001 (2)]. Cattle/calf production in Ontario and Québec represents more than half of Canada's total production [Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001(2)].

Figure 18: Leading Agricultural Commodities Produced in Great Lakes States (2000 Snapshot) and Provinces (2001 Snapshot).
Dairy, Corn, Soybeans, Hogs, Cattle



Notes:

- Legend illustrates leading agricultural commodities in all Great Lakes States and Provinces.
- Size of pie chart reflects relative regional contribution to agricultural production in million U.S. dollars (large: $4,000-$6,400; medium: $3,000-$3,600; small: $2,000-$3,000).
  Canadian dollar conversion: Cdn $ divided by 1.6.
- "Top 5" commodities only are shown for each state/province; combinations of leading commodities differ.

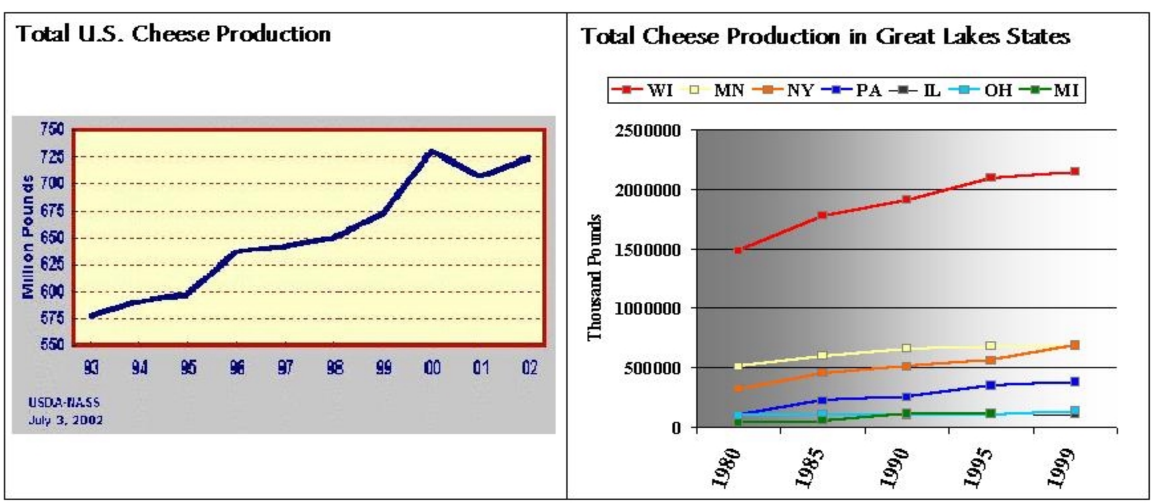


Created by: Institute for Agriculture and Trade Policy
Data Sources: USDA, ERS (3);
Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001 (3);
Institut de la Statistique du Québec, Statistique Canada (1)

Dairy

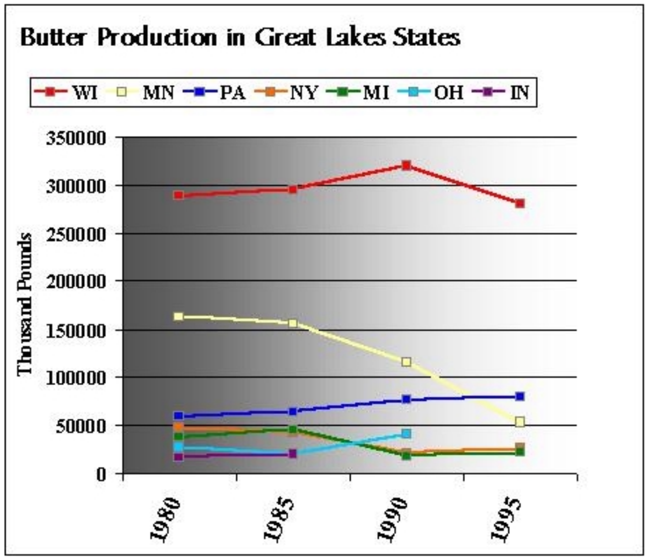
Since 1980, dairy production in Great Lakes States has remained relatively constant, while the number of producers has declined sharply. As in the rest of the U.S., total cheese production has greatly increased in the region (Figure 19), averaging a total increase of more than 50 percent. The largest increases occurred in the top dairy producing states: Wisconsin (+45 percent), New York (+113 percent) and Pennsylvania (+270 percent). Butter production, on the other hand, decreased by almost 30 percent from 1980-1995 (Figure 20), while milk production remained relatively constant (Figure 21).

Figure 19: Total U.S. Cheese Production, 1993-2002;
Production in Great Lakes States, 1980-1999



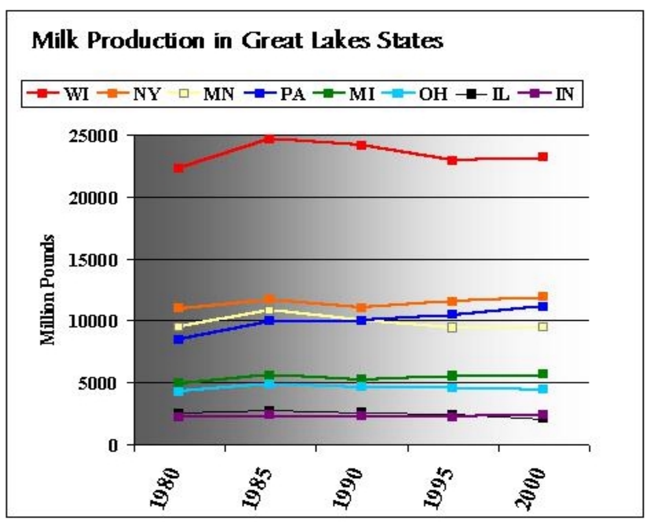
Note: Indiana's production is not illustrated due to incomplete data.
Created by: Institute for Agriculture and Trade Policy; Data Sources: USDA, NASS (1); USDA, NASS (5);

Figure 20: Butter Production in Great Lakes States, 1980-1995



Notes: Indiana data through 1985; Ohio data through 1990.
Created by: Institute for Agriculture and Trade Policy; Data Source: USDA, NASS (5)

Figure 21: Milk Production in Great Lakes States, 1980-2000



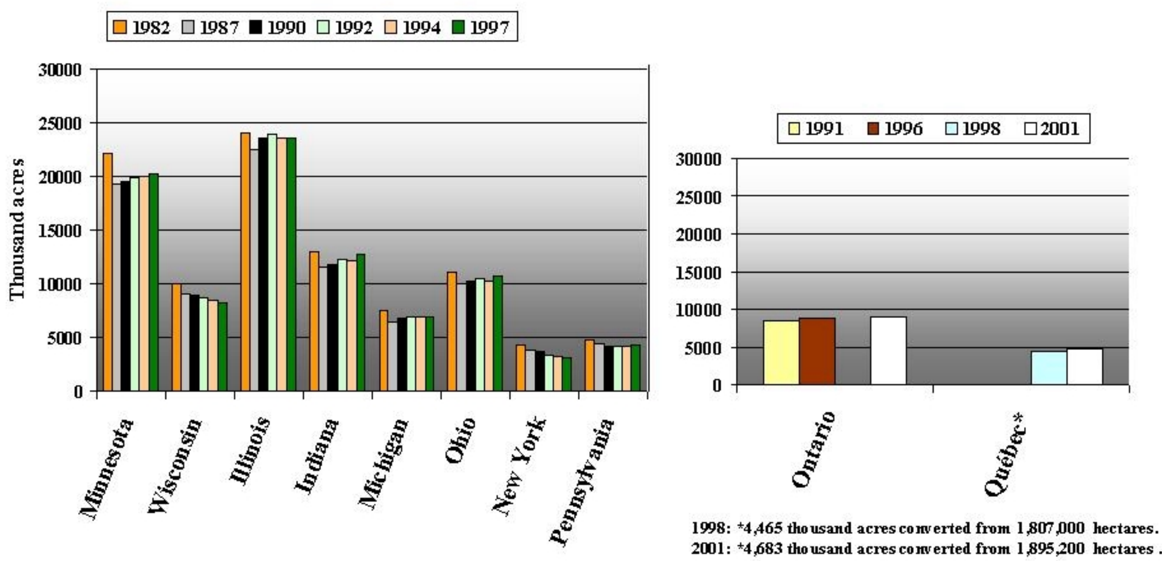
Created by: Institute for Agriculture and Trade Policy; Data Source: USDA, NASS (5)

In Canada, Ontario and Québec account for 70 percent (33 and 37 percent, respectively) of Canada's dairy industry [Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001 (2)]. Production of dairy products in both provinces increased an average 12 percent between 1996 and 2001 [Ministry of Agriculture and Food, Statistics Canada, Census of Agriculture (2)].

Principal Crops

Although total acres planted for all principal crops have remained relatively constant in Great Lakes States and Provinces in recent years (Figure 22), the amount planted per crop has changed over time. Over the last twenty years, acres of corn have decreased slightly, while soybean acres have increased. For both crops however, overall production is growing, with soybeans showing the most significant gains in production.

Figure 22: Acres Planted for All Principal Crops in Great Lakes States (1992-1997) and Provinces (1991-2001)

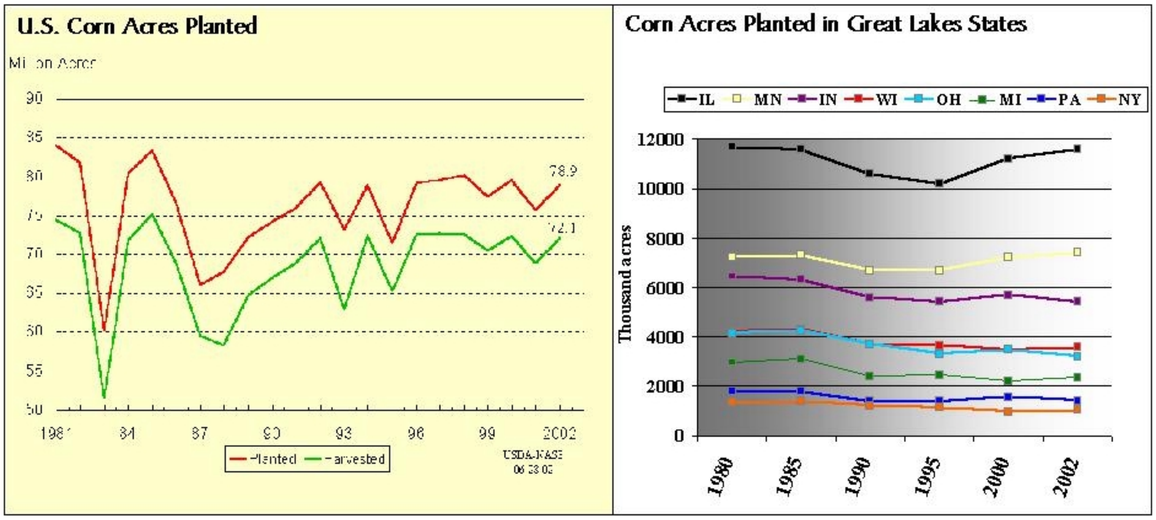


Notes: Ontario data available for 1991, 1996, 2001; Québec data available for 1998, 2001.
Created by: Institute for Agriculture and Trade Policy; Data Sources: USDA, NASS (6); USDA, NASS (7); Ministry of Agriculture & Food, Statistics Canada, Census of Agriculture (3); Institut de la Statistique du Québec, Statistique Canada (5)

Corn

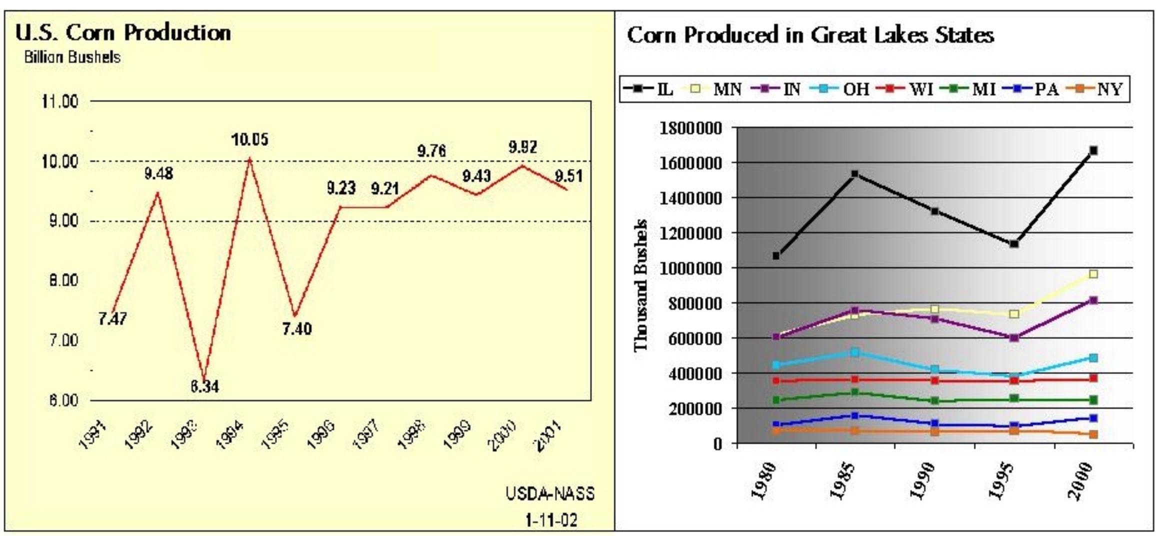
Trends in U.S. corn production show a slight decline in total acres planted since 1981. Corn acres planted in Great Lakes States show a similar trend, averaging a 10 percent decrease since 1980 (Figure 23). However, despite this decrease, production of corn has increased both nationally (+27 percent since 1991) and in Great Lakes States (+35 percent since 1980), (Figure 24). The most significant increases in corn production have occurred in Illinois (+57 percent), Minnesota (+58 percent), Indiana (+34 percent) and Pennsylvania (+42 percent). Corn production is one of the top agricultural commodities produced in Illinois, Minnesota and Indiana.

Figure 23: Corn Acres Planted and Harvested in U.S., 1981-2002; Corn Acres Planted in Great Lakes States, 1980-2002



Data Sources: USDA, NASS (1); USDA, NASS (5)*.
*Created by: Institute for Agriculture and Trade Policy

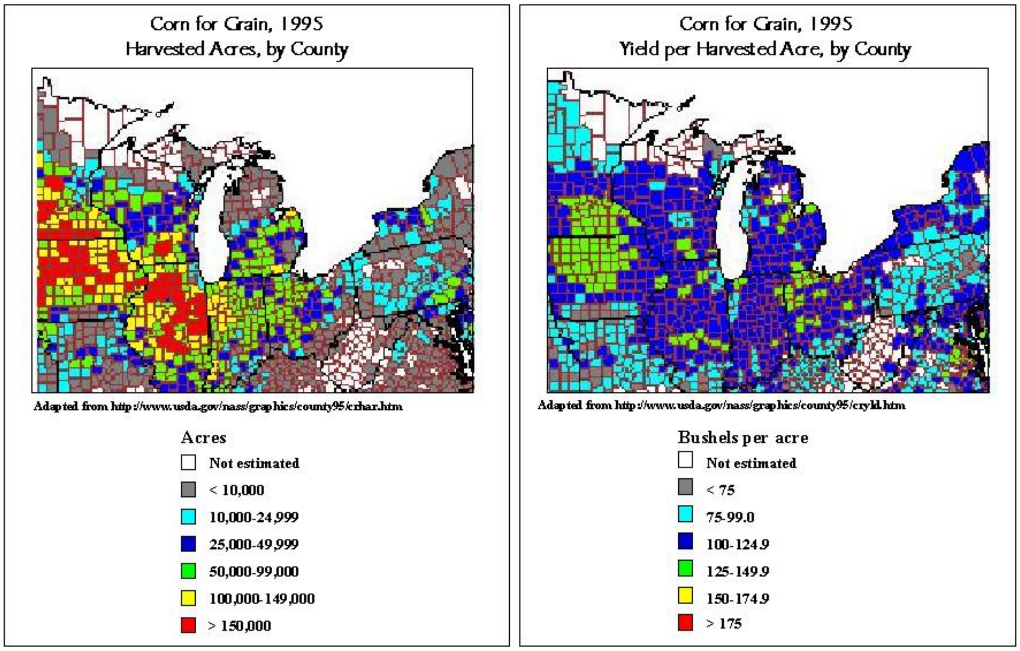
Figure 24: Corn Production in U.S., 1991-2001; Corn Production in Great Lakes States, 1980-2002



Data Sources: USDA, NASS (1); USDA, NASS (5)*.
*Created by: Institute for Agriculture and Trade Policy

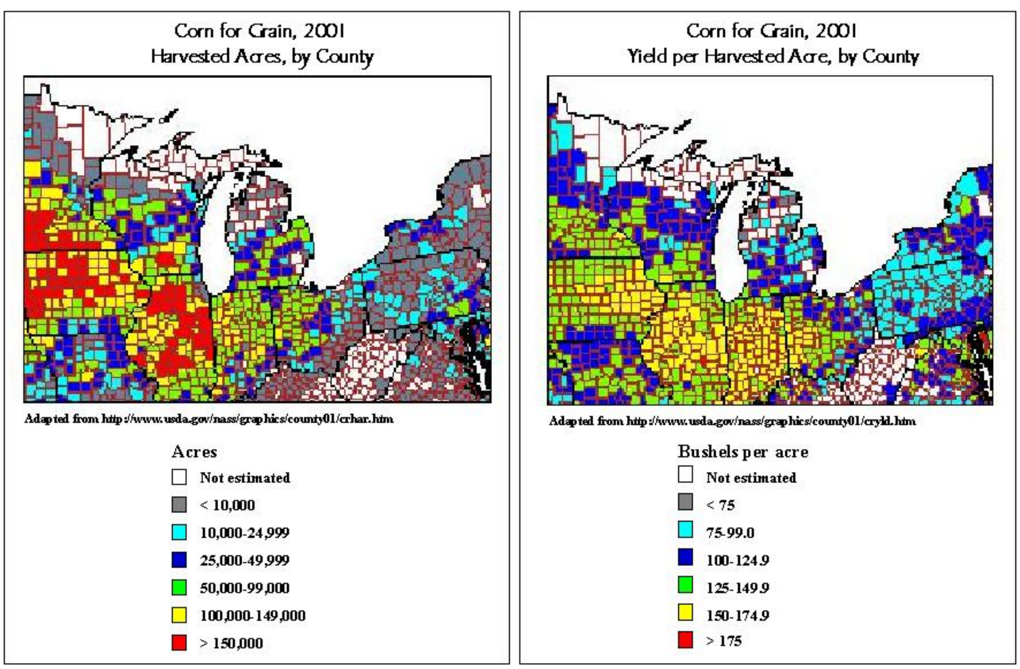
Figures 25 and 26 provide geographic snapshots of county level corn production and yield per harvested acre in Great Lakes States in 1995 and 2001. Although harvested acres remain relatively constant in 1995 vs. 2001, significant increases in yield are occurring in many counties in Illinois, Indiana, Ohio and Wisconsin in 2001, as compared to 1995.

Figure 25: Corn Production and Yield by County, Great Lakes States (1995 Snapshot)



Source: USDA, NASS (2)

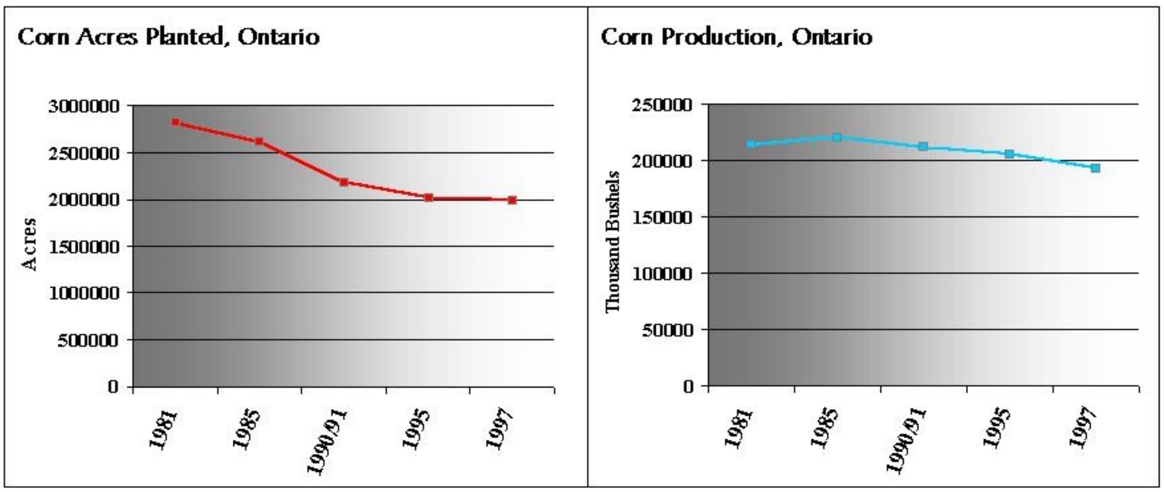
Figure 26: Corn Production and Yield by County, Great Lakes States (2001 Snapshot)



Source: USDA, NASS (2)

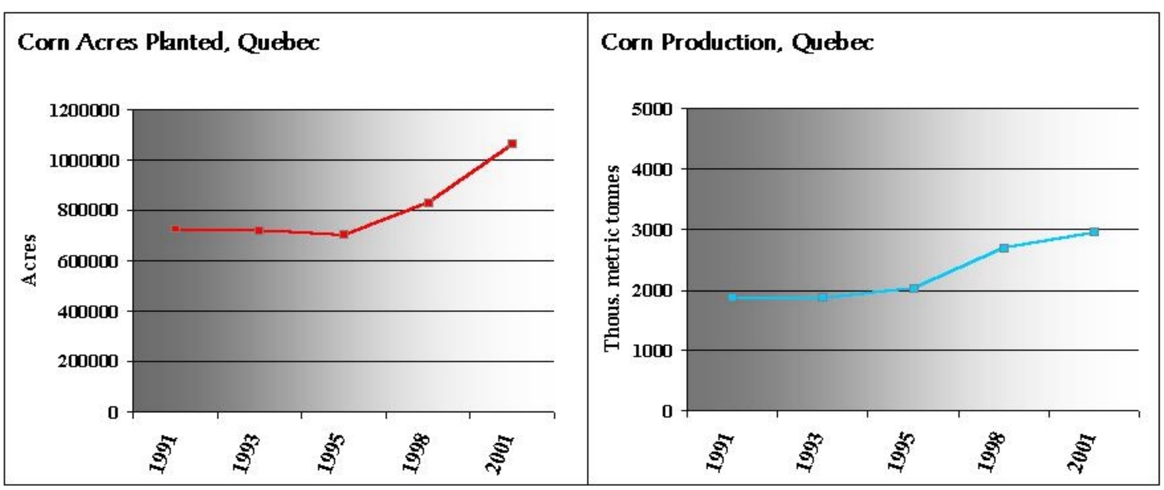
Ontario and Québec account for almost all of the corn produced in Canada (60 and 36 percent, respectively), [Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001 (2)]. As illustrated in Figure 27, the number of corn acres planted has decreased significantly in Ontario since 1981 (-30 percent). Corn production, however, has declined only slightly (less than 10 percent), over the same time period. In Québec, however, the number of corn acres planted (for grain) increased 46 percent between 1991 and 2001, with an almost 60 percent increase in production over the same time period (Figure 28), [Institut de la Statistique du Québec, Statistique Canada (6), (7), (8)].

Figure 27: Corn Acres Planted and Produced in Ontario, 1981-1997



Created by: Institute for Agriculture and Trade Policy
Data Source: Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001 (6)

Figure 28: Corn Acres Planted and Produced in Québec, 1991-2001

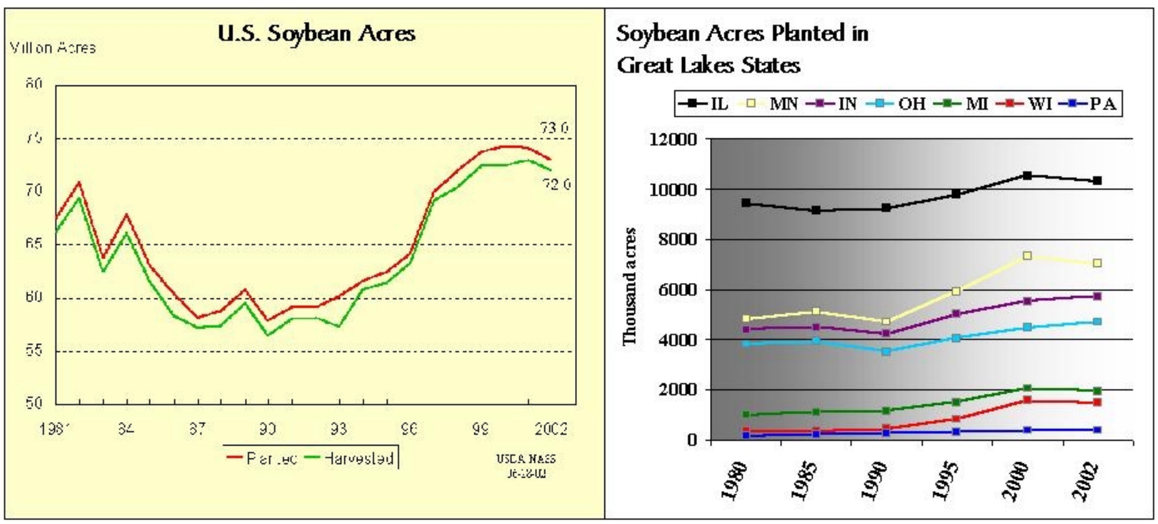


Created by: Institute for Agriculture and Trade Policy;
Data Source: Institut de la Statistique du Québec, Statistique Canada (6), (7), (8)

Soybean

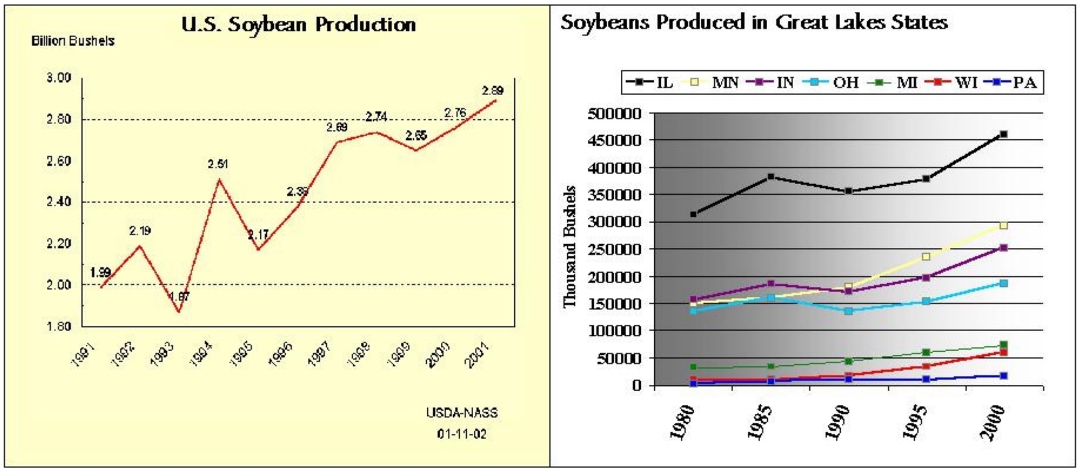
Although the total amount of U.S. soybean acres planted has not changed significantly since 1980 (about +8 percent), there has been a considerable increase in acres planted since 1990 both nationally (+25 percent), and in Great Lakes States (+34 percent), (Figure 29). Overall soybean production during the same time period (1990-2000) has increased even more dramatically in the US generally (+45 percent), and in Great Lakes States (+47 percent), as shown in Figure 30. The most significant gains occurred in Minnesota (+63 percent), Indiana (+47 percent), Michigan (+69 percent), and Wisconsin (240 percent), since 1990. Soybeans are one of the leading agricultural commodities produced in all of these states.

Figure 29: Soybean Acres Planted and Harvested in U.S., 1981-2002; Soybean Acres Planted in Great Lakes States, 1980-2002



Data Sources: USDA, NASS (1); USDA, NASS (5); Created by: Institute for Agriculture and Trade Policy

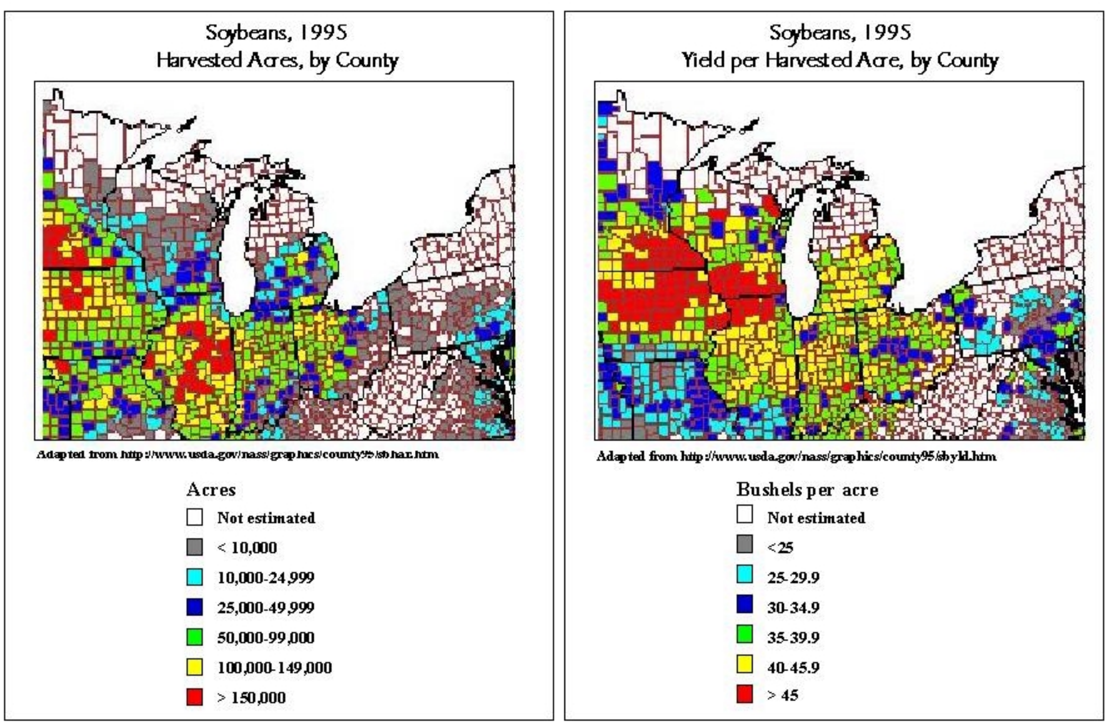
Figure 30: Soybean Production in U.S., 1991-2001;
Soybean Production in Great Lakes States, 1980-2000



Data Sources: USDA, NASS (1); USDA, NASS (5)*. *Created by: Institute for Agriculture and Trade Policy

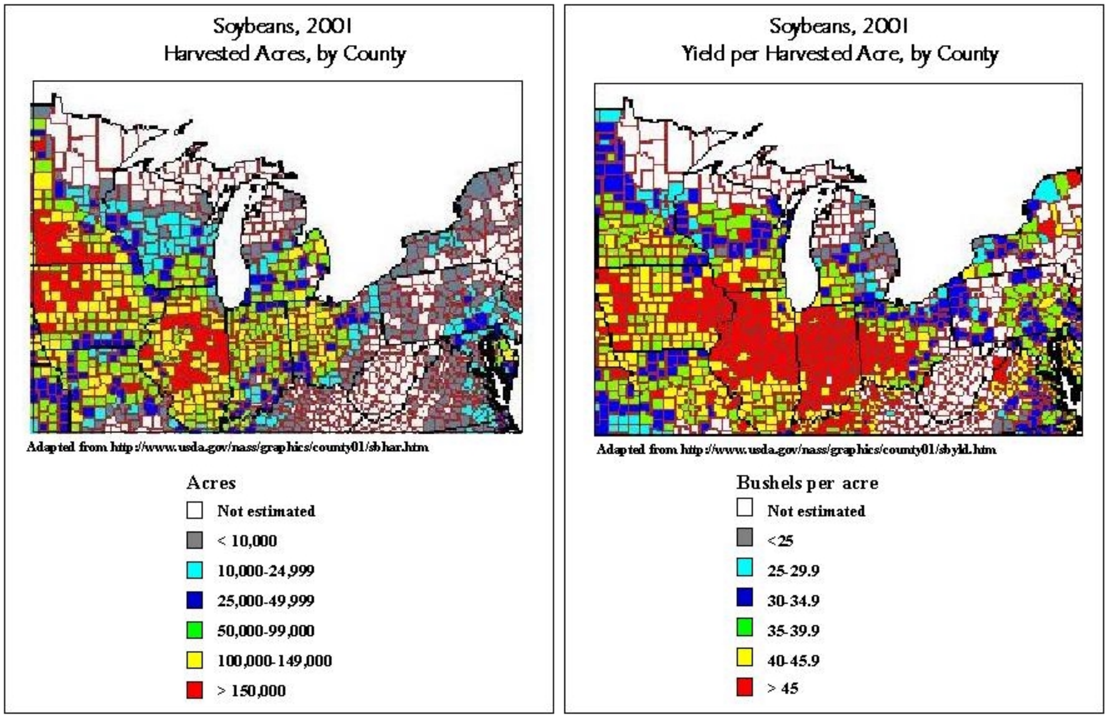
Figures 31 and 32 provide geographic snapshots of county level soybean production and yield per harvested acre in Great Lakes States in 1995 and 2001. Regionally, the number of harvested acres remains relatively constant in both time periods. However, in terms of yield per harvested acre, significant increases are occurring in much of Indiana, Illinois and Ohio.

Figure 31: Soybean Production and Yield by County, Great Lakes States (1995 Snapshot)



Source: USDA, NASS (2)

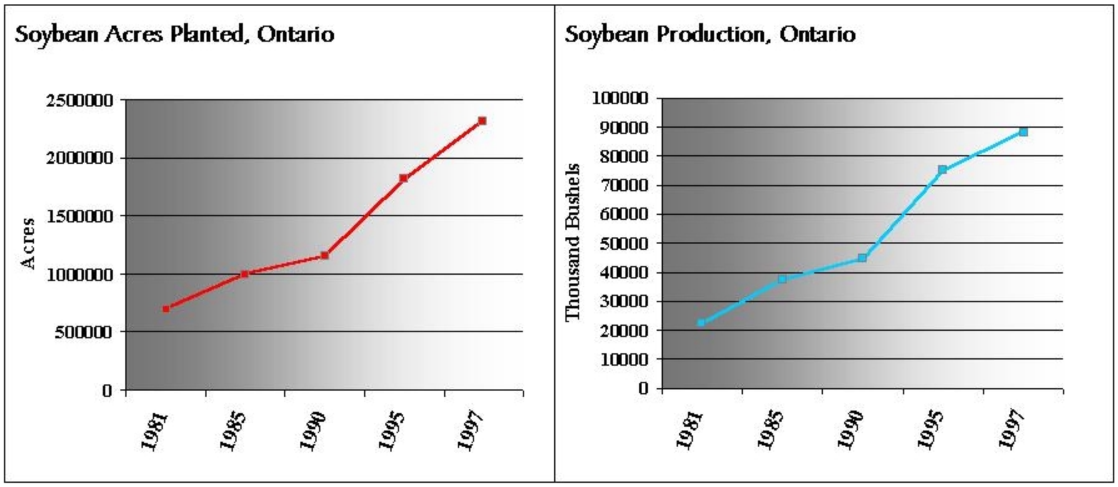
Figure 32: Soybean Production and Yield by County, Great Lakes States (2001 Snapshot)



Source: USDA, NASS (2)

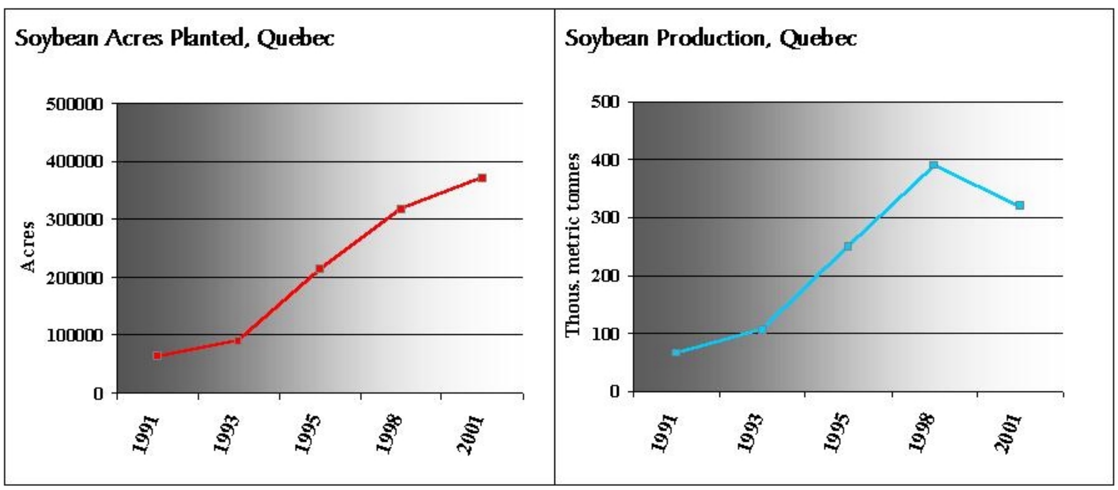
Soybean production in Ontario and Québec, even more so than corn, represents virtually all of Canada's production (84.2 and 15.6 percent, respectively), [Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001 (2)]. As illustrated in Figure 33, the number of soybean acres planted in Ontario jumped more than 200 percent since 1981, with soybean production increasing almost 300 percent over the same time period. In Québec, the number of soybean acres planted increased four times between 1991 and 2001, with production increasing five times over the same time period (Figure 34), [Institut de la Statistique du Québec, Statistique Canada (7), (8), (9)].

Figure 33: Soybean Acres Planted and Produced in Ontario, 1981-1997



Created by: Institute for Agriculture and Trade Policy
Data Source: Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001 (6)

Figure 34: Soybean Acres Planted and Produced in Québec, 1991-2001



Created by: Institute for Agriculture and Trade Policy
Data Source: Institut de la Statistique du Québec, Statistique Canada (7), (8), (9).

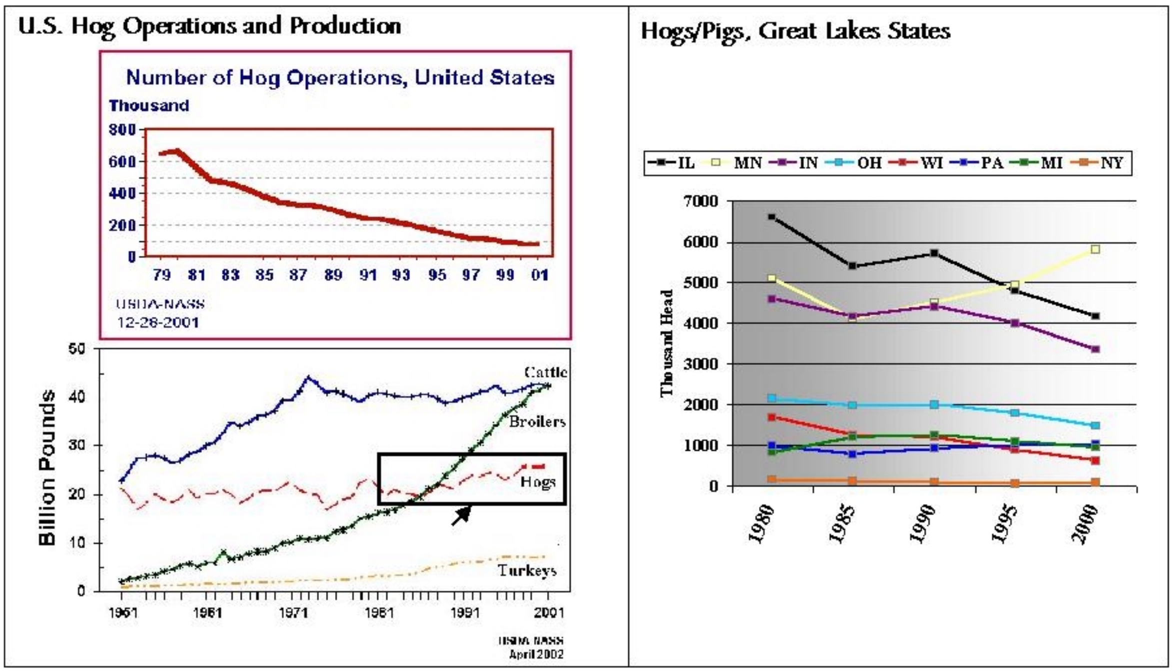
Swine Production

While overall US hog production has increased by around 15 percent over the last 22 years, the number of farmers raising hogs has decreased dramatically, as illustrated in figure 35. The increase in production has mostly bypassed the Great Lakes States, with total hog production in the region declining by an average of 20 percent over the same time period.

In the Great Lakes States in which hogs are a leading agricultural commodity, production declined significantly in Illinois (-37 percent) and

Indiana (-27 percent), whereas in Minnesota, production increased (+14 percent). However, in all of the states the reduction in hog farms mirrored the national trend, with even Minnesota losing over 60 percent of its hog operations since 1987 [USDA NASS (9); USDA NASS (10)].

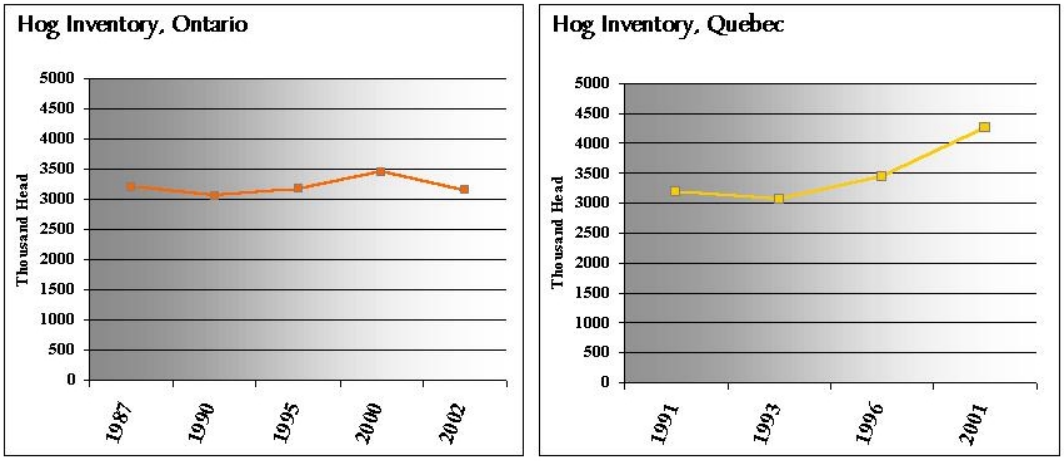
Figure 35: U.S. Hog Operations (1979-2001) and Production (1951-2001); Hogs/Pigs Produced in Great Lakes States, 1980-2000



Data Sources: USDA, NASS (1); USDA, NASS (5); Created by: Institute for Agriculture and Trade Policy

The Great Lakes Provinces produce over half of all Canadian hogs, with 25 and 29 percent of the national hog inventory in Ontario and Québec respectively [Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001 (2)]. In Ontario, hog production has remained relatively stable over the last fifteen years (1987-2002), (Figure 36). In Québec, the number of animals increased 34 percent between 1991 and 2001, [Institut de la Statistique du Québec, Statistique Canada (11); Statistics Canada, 2001 (3)].

Figure 36: Hog Inventories in Ontario (1987-2002) and Quebec (1991-2001)

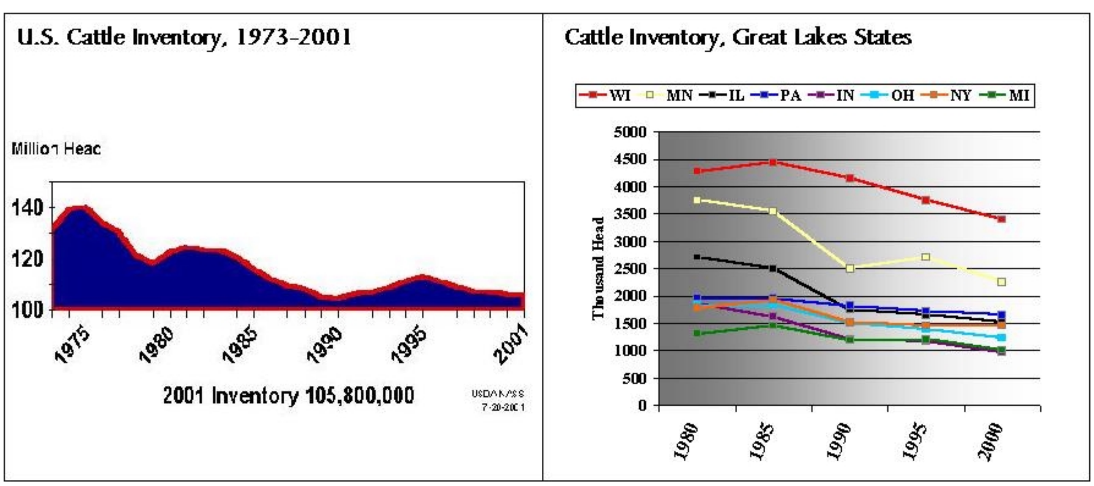


Created by: Institute for Agriculture and Trade Policy
Data Sources: Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001 (4); Institut de la Statistique du Québec, Statistique Canada (11); Statistics Canada, 2001 (3)]

Cattle Production

As illustrated in Figure 37, U.S. cattle production has been on the decline since the mid-1970s. In the same time period (1980-2000), cattle production in Great Lakes States declined at about twice the rate (-31 percent) as the national average (less than +15 percent). The most significant decreases in cattle inventories in the region have occurred in Minnesota (-40 percent), Illinois (-44 percent) and Indiana (-48 percent). However, cattle production still represents one of the top agricultural commodities for both Minnesota and Illinois.

Figure 37: U.S. Cattle Inventory, 1975-2001; Cattle Inventory in Great Lakes States, 1980-2001

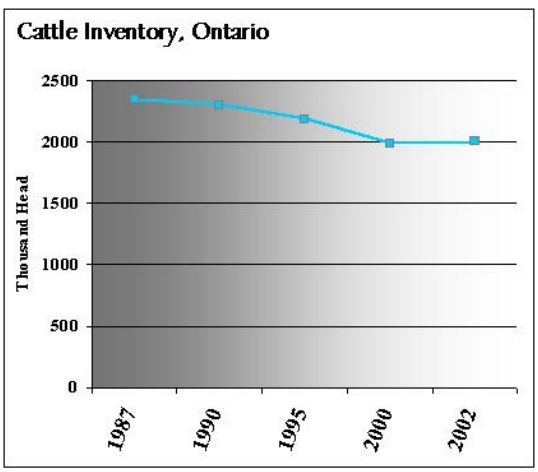


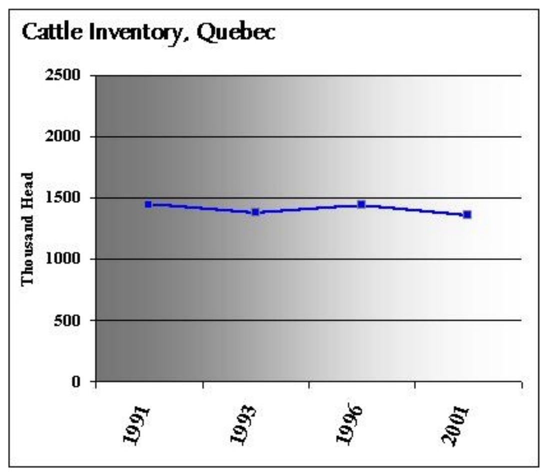
Data Sources: USDA, NASS (1); USDA, NASS (5); Created by: Institute for Agriculture and Trade Policy

In Canada, although the number of cattle operations is decreasing overall, existing farms are increasing in size and yearly production of livestock products is increasing nationwide. Between the 1991 and 1996 census, national cattle numbers increased by 15 percent (USDA, Briefing Room, 2002).

Ontario and Québec together produce 55 percent of Canada's cattle. In Ontario, the number of cattle on farms declined at a rate of 15 percent between 1987 and 2002, as opposed to national trends (Figure 38), [Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001 (5)]. In Québec, the number of cattle has remained relatively stable since 1991 [Institut de la Statistique du Québec, Statistique Canada (10); Statistics Canada, 2001(4)].

Figure 38: Cattle Inventories in Ontario (1987-2002) and Québec (1991-2001)





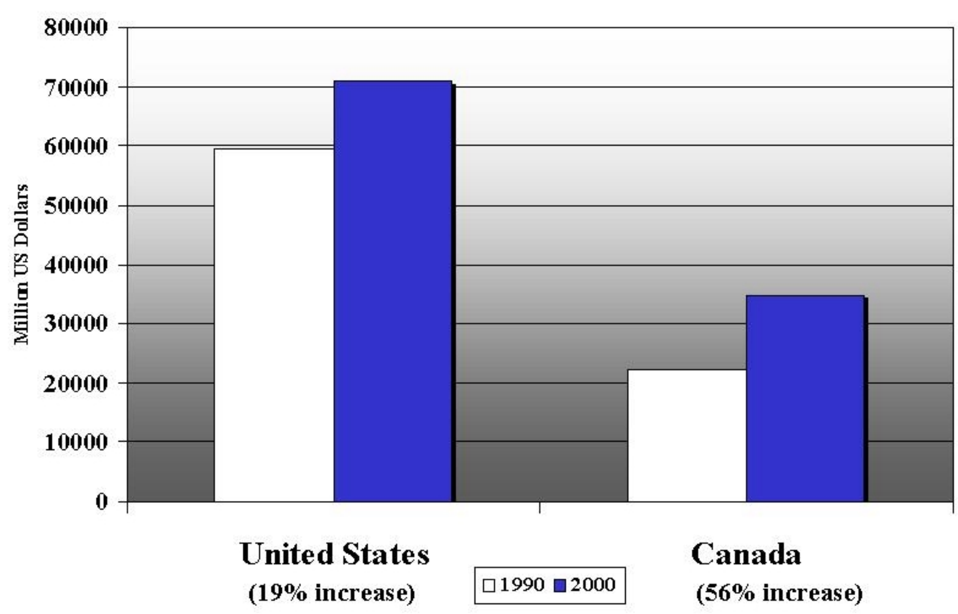
Created by: Institute for Agriculture and Trade Policy
Data Sources: Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001 (5); Institut de la Statistique du Québec, Statistique Canada (10); Statistics Canada, 2001(4)

Agricultural Exports

Although national agricultural exports by the U.S and Canada have increased in total over the last decade [World Trade Organization (WTO) Website, 2001 (2)], (Figure 39), in the Great Lakes region, the value of agricultural exports have been decreasing overall since 1996. As illustrated in Figure 40, exports from all Great Lakes States are on the decline, whereas exports from Ontario and Québec are increasing. The states with the largest overall dollar contribution from agricultural exports (Illinois, Minnesota, Indiana, Ohio) show some of the greatest decreases.

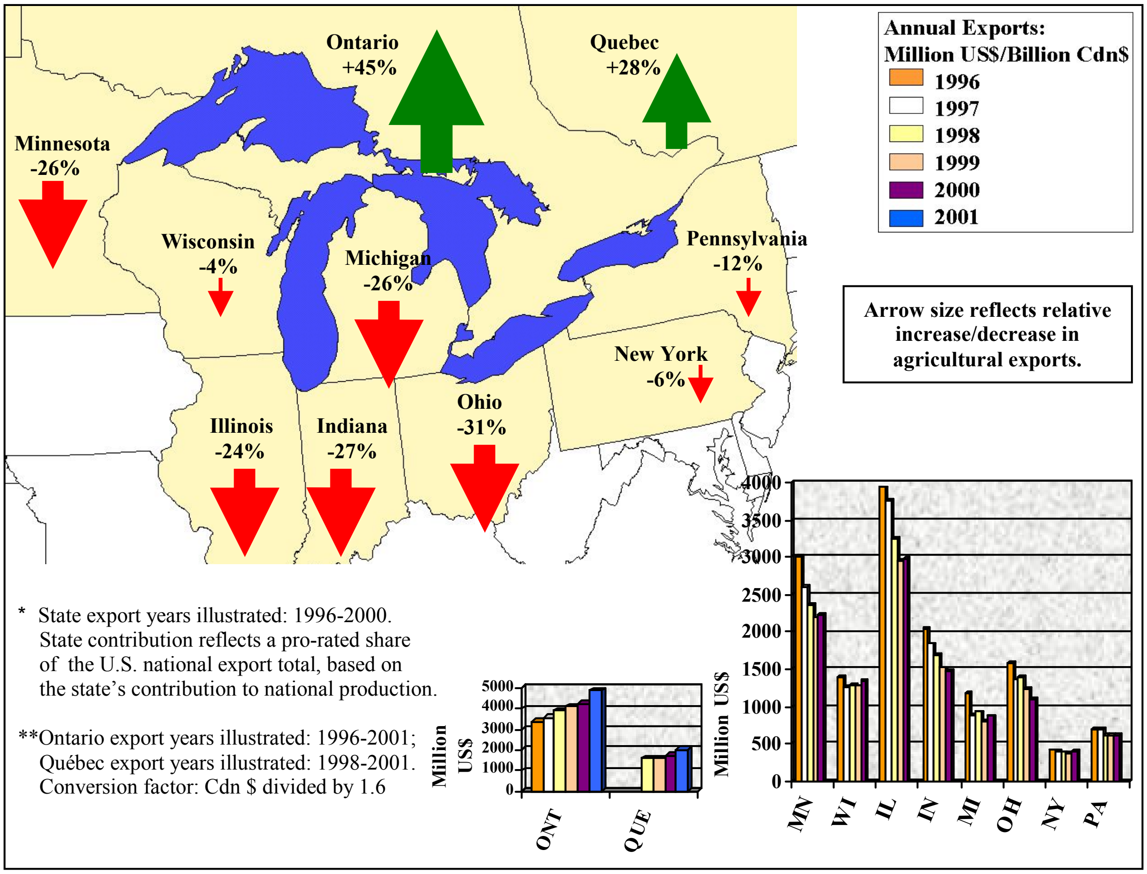
The leading agricultural exports from Great Lakes States are soybeans, feed grains, live animals/meat and vegetables (Figure 41). Dairy production, which is the primary agricultural industry in the region, is not one of the leading agricultural exports from Great Lakes States, indicating that most dairy products produced in the region are not exported. In terms of comparative agricultural production trends, only two of the leading agricultural commodities in the region show an increasing trend: corn and soybeans. Paired with the considerable growth in soybean production in recent years, soybeans and soybean products lead agricultural exports from the region, representing the top export from five of the eight Great Lakes States (Illinois, Minnesota, Indiana, Ohio and Michigan). Coincidentally or not, these are also the same states that have had the greatest decline in agricultural exports value since 1996. Although soybeans lead each state's agricultural exports, production of the other leading agricultural commodities in these states has not been sufficient to maintain overall export growth (corn for feed grains exports, hogs and cattle for live animals/meat exports).

Figure 39: Agricultural Exports by the United States and Canada, 1990-2000



Created by: Institute for Agriculture and Trade Policy
Data Source: World Trade Organization Website (2)

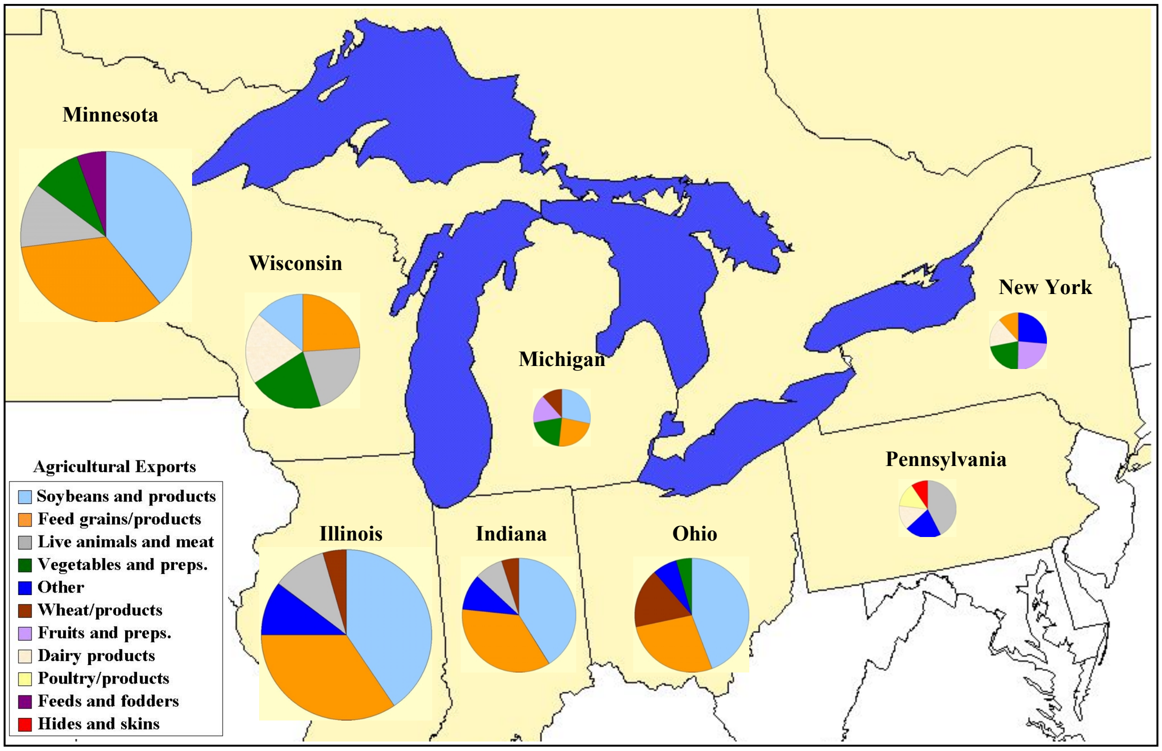
Figure 40: Agricultural Exports from Great Lakes States* and Provinces** 1996-2001



Created by: Institute for Agriculture and Trade Policy
Data Sources: USDA, Economic Research System (ERS) (4); Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001 (7); Institut de la Statistique du Québec, Statistique Canada (3), (4)

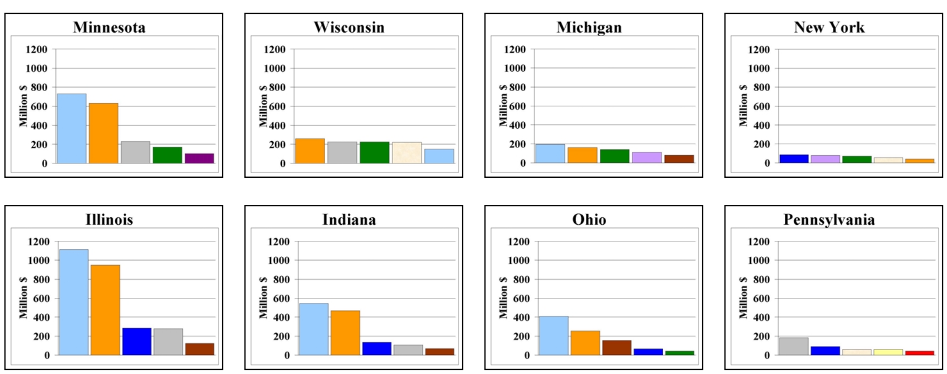
Agricultural exports have been decreasing overall in the Great Lakes region since 1996. As illustrated in the map above, exports from all Great Lake States are on the decline, whereas exports from Ontario and Québec are increasing (size of arrow reflects relative increase/decrease in exports).

Figure 41: Leading Agricultural Exports from each of the Great Lakes States, 2000 Snapshot



Notes:

- Legend illustrates leading agricultural exports from all Great Lakes States;
- Size of pie chart reflects relative regional contribution to agricultural exports in million U.S. dollars (large: $1,800-$2,800; medium: $900-$1,400; small: $300-$700);
- "Top 5" agricultural exports only are shown for each state; combinations of leading exports differ.

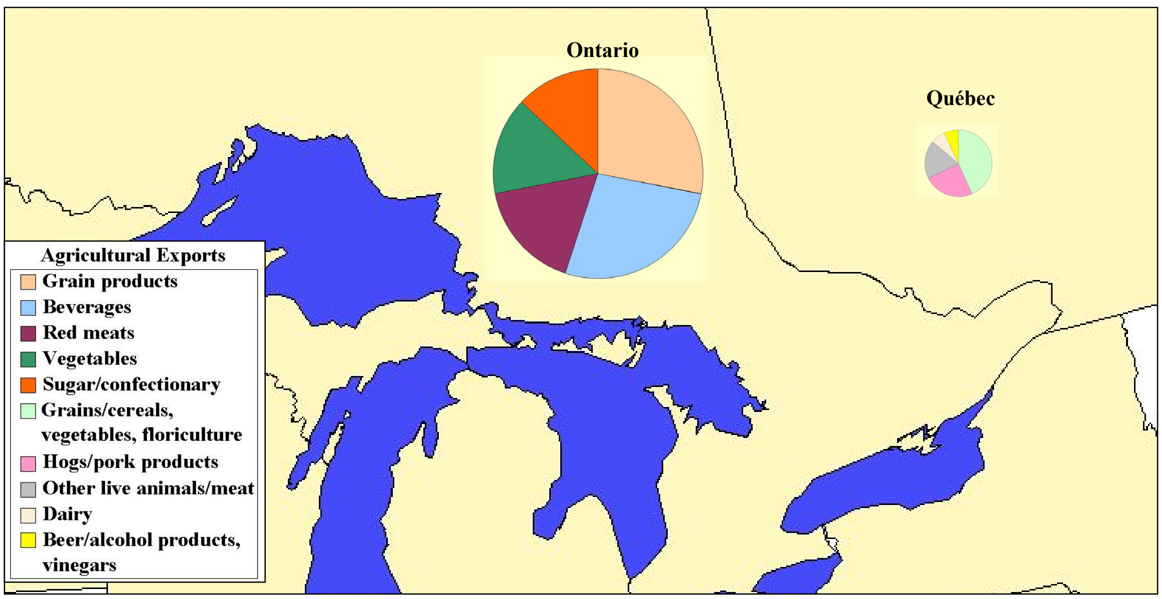


Created by: Institute for Agriculture and Trade Policy
Data Source: USDA, ERS (3)

The "Top 5"agricultural exports are shown for each state.

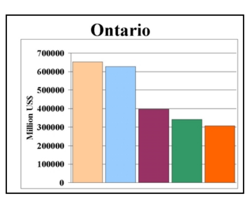
As illustrated in Figure 42, the leading agricultural commodities exported from Ontario are grain and grain products, beverages, red meats, vegetables, and sugar/confectionary; Québec's leading agricultural exports include grains/cereals, floriculture and vegetable products, hogs/pork products, other live animals/meat (cattle, sheep, poultry, etc.), dairy, and beer/alcohol products and vinegars [Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001 (8); Institut de la Statistique du Québec, Statistique Canada (4)]. Ontario exports significantly more agricultural products than does Québec.

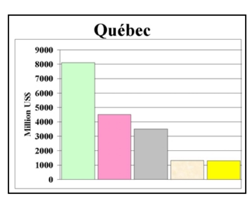
Figure 42: Leading Agricultural Exports from Ontario and Québec, 2000 Snapshot



Notes:

- Legend illustrates all leading agricultural exports from Great Lakes Provinces;
- Scales differ for Ontario vs. Québec;
- Size of pie chart reflects relative regional contribution to agricultural exports in million U.S. $ (Conversion: Canadian $ divided by 1.6);
- "Top 5" agricultural exports only are shown for each province; combinations of leading exports differ.





Created by: Institute for Agriculture and Trade Policy
Data Sources: Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001 (8); Institut de la Statistique du Québec, Statistique Canada (4)

The "Top 5"agricultural exports are shown for each Province.

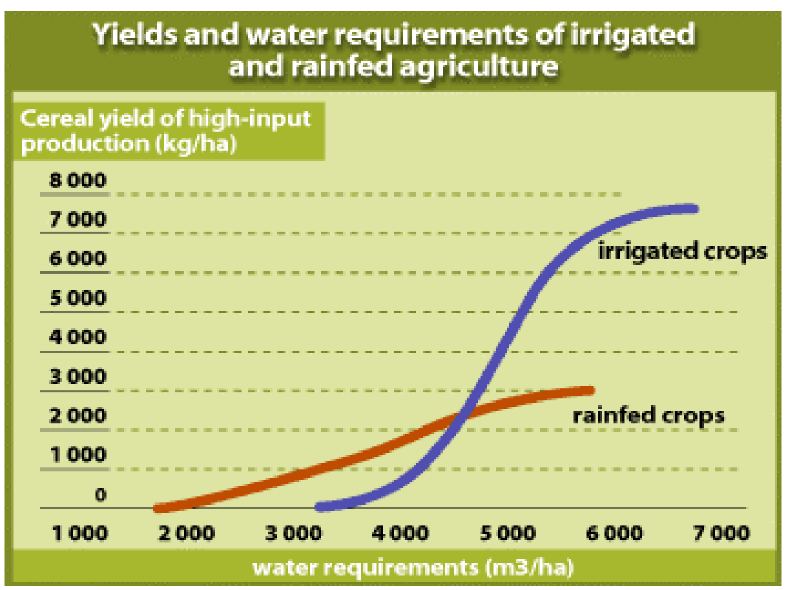
Water Use and Efficiency in Great Lakes Agriculture

Agriculture uses more water than any other consumptive use sector. However, despite the important connections between agriculture and ecosystem health, little is known regarding agriculture's impacts on water resources in the basin. Irrigation methods, cropping systems, individual crop and livestock water needs, and associated crop production trends all influence agricultural water use and conservation.

Irrigation Water Use

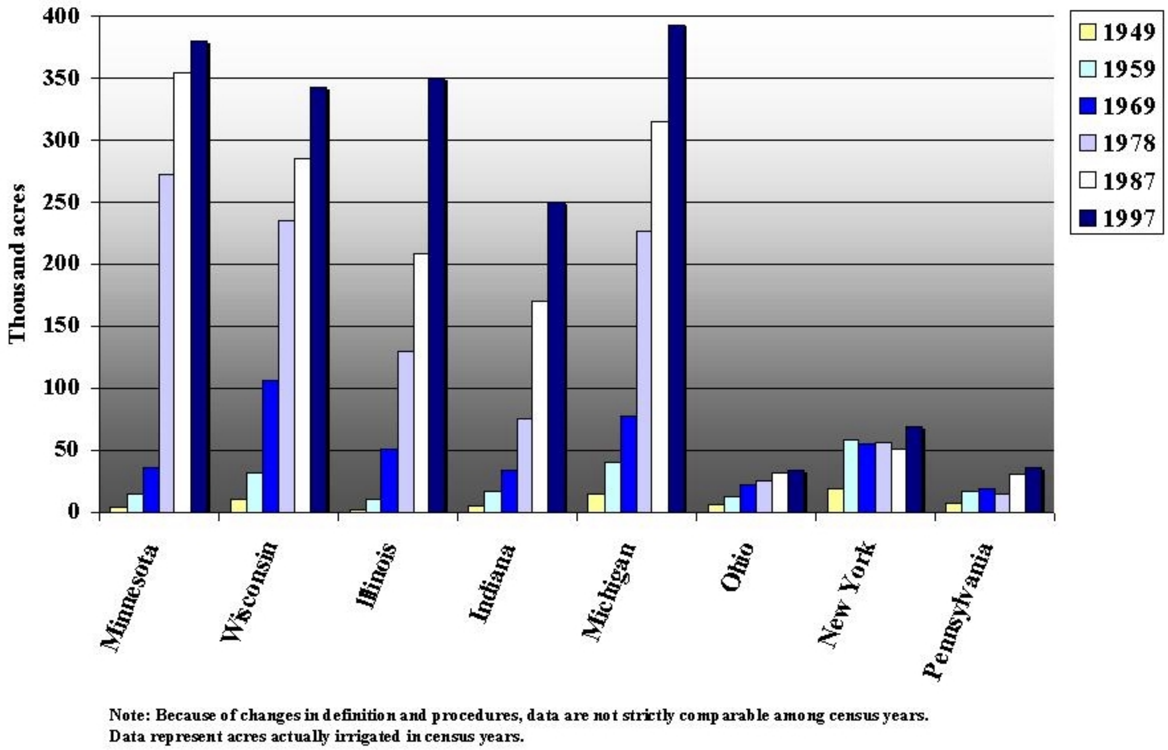
As shown in Figure 43, irrigated land produces between two and three times greater yield than rain-fed land, however it also requires proportionately more water (FAO Website). In the Great Lakes States, total irrigated land in farms has increased a staggering 25 times over the last fifty years and by almost 30 percent, on average, in the last decade alone (Figure 44), despite the decline in farmland in the region. This dramatic increase and its timing are explained in part by the introduction of the center-pivot sprinkler system in the late 1960s - early 1970s. This new technology made irrigation more water efficient, cost-effective and practical as a "risk-aversion" tool compared to earlier irrigation systems, especially in states with soil types incompatible with flood irrigation (i.e. sandy soils).

Figure 43: Yields and Water Requirements of Irrigated and Rain-fed Agriculture



Source: FAO Website

Figure 44: Irrigated Land in Farms in Great Lakes States, 1949-1997

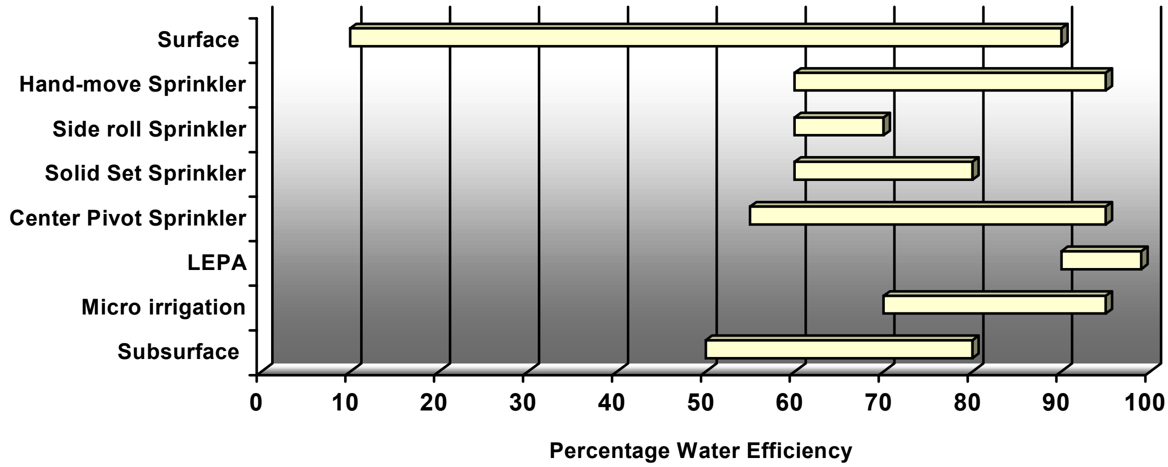


Created by: Institute for Agriculture and Trade Policy Data Source: USDA, 1997

Of the water used for irrigation worldwide, half or more is lost to evaporation or runoff (National Geographic, 2002). The more efficient an irrigation system, the less water is lost, and thus less needs to be applied. Water efficiencies of different irrigation systems vary significantly (Figure 45). Sprinkler systems, the most common type of irrigation for row crop production in the U.S., (with center-pivot used most extensively), average between 55 and 95 percent water efficiency (Environmental Central Website (2), (3)]. Surface irrigation systems, which use gravity to flood fields with water, have the widest range in efficiency. Micro-irrigation systems on the other hand, which apply water droplets to small areas near or below the surface, are one of the most water efficient systems, but are also among the expensive to install and maintain [Environmental Central Website (1), (2)].

Irrigation efficiency depends on various factors such as the type of irrigation system used, soil type and conditions, regional climate patterns, as well as the weather on the day of irrigation. For example, the same irrigation system in the same location will be less efficient on hot, dry or windy days, because more water is lost to evaporation [Environmental Central Website (3)].

Figure 45: Water Efficiencies of Various Irrigation Systems



Created by: Institute for Agriculture and Trade Policy
Source: Environmental Central Website (2)

Types of Irrigation Systems

Surface irrigation systems use gravity to flood fields with water. Some systems flood the entire field, while others use rows of ditches. This is the oldest method of watering crops.

Sprinkler systems spray water from above, and can be found on golf courses as well as farms. Types include: *hand-move sprinklers, side roll sprinklers, solid set sprinklers, center pivot sprinklers*, and *low energy precision application* (LEPA).

Micro-irrigation systems apply water droplets to small areas, near or below the surface.

Sub-surface flood irrigation systems use pumps or ditches to raise the water table, forcing groundwater to move toward crops.

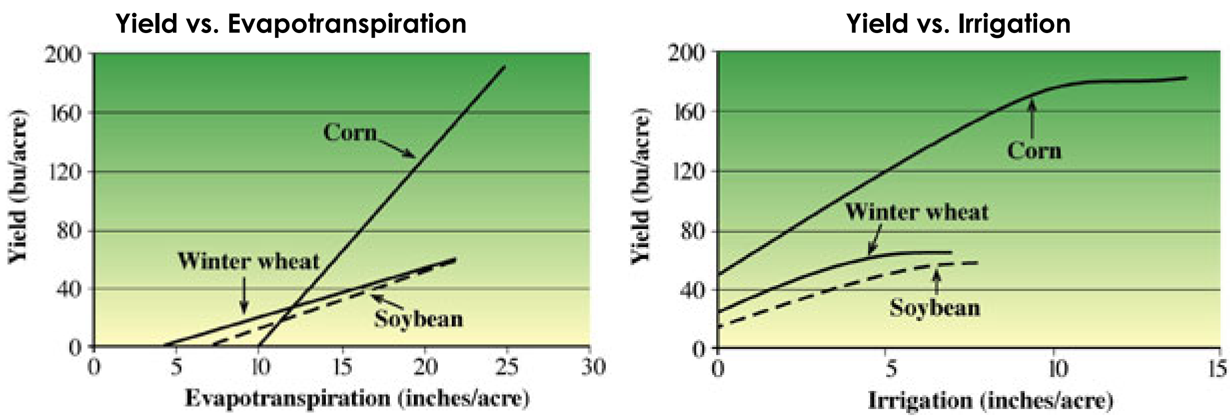
Source: Environmental Central Website (1)

Crop Water Use

Crop water use (and the need for irrigation) depends on many factors including: type of crop, stage of growth, climatic conditions, type of soil and moisture levels. Climatic influences on a crop's daily water use include maximum and minimum temperatures, solar radiation, humidity, and wind (Wright, 2002). Water used by the plant (and then transferred into the atmosphere) and the water that evaporates from the soil is referred to as *evapotranspiration*. Figure 46 illustrates the relationship between crop water use/evapotranspiration (from irrigation and precipitation) and yield for corn, soybeans and winter wheat (at left). As shown, the amount of evapotranspiration is directly related to both crop type and yields. Crop type also determines how much water it takes to produce the first bushel of grain (shown here as the intersection of the crop line with the horizontal axis, where grain yield is zero), [University of Nebraska Cooperative Extension (1)].

Figure 46 also illustrates the relationship between crop yields and irrigation (shown right). Corn yields show the strongest response to increasing water, but corn also requires the most water to achieve maximum yield. The curving (or flattening) of each crop's yield line indicates that there is a diminishing return in yields from irrigation, as both irrigation systems and soils eventually become less efficient in supplying water to crops. When the soil becomes saturated and more water is applied (either through irrigation or rainfall), some of the water will move deeper into the soil, beyond where plant root structures can make use of it (termed *deep percolation*).

Figure 46: Yield vs. Evapotranspiration for Corn, Soybeans and Winter Wheat; Yield vs. Irrigation for Corn, Soybeans and Winter Wheat



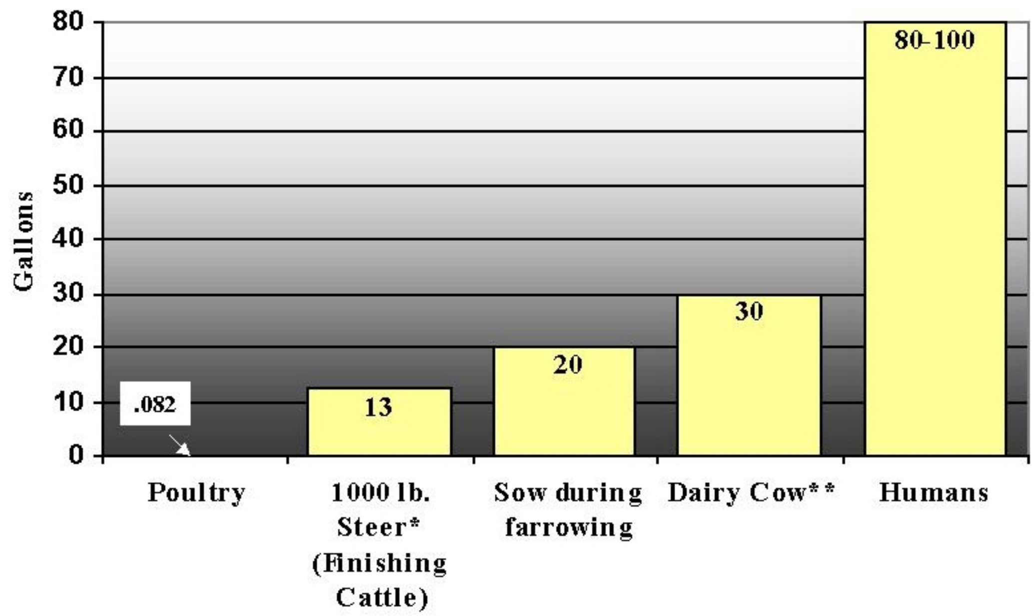
Source: University of Nebraska Cooperative Extension (1)

Livestock Water Use

Livestock operations, including dairies, are the other significant agricultural water use. Livestock water use consists of water used to produce cattle, sheep, goats, hogs and poultry, and includes water needed for washing and sanitation (for dairies and swine operations). About 60 percent of livestock water is used for drinking [U.S. Soil Conservation Service, 1975 in: USGS Website (2)]. Livestock and poultry water consumption depend on a number of physiological and environmental conditions such as: type and size of animal; physiological state (lactating, pregnant or growing); activity level; type of diet (grain, dry hay, silage or pasture); temperature (hot summer days above 25°C can sometimes double the water consumption of animals raised outside); and water quality (palatability and mineral content).

As illustrated in Figure 47, while animal needs appear high (30 gallons/day for a producing dairy cow), water use for livestock operations pales in comparison to daily human water use, with USGS estimates ranging from 80 – 100 gallons/day, or about three times that of livestock water needs (USGS Website (3), Alberta Agriculture, Food and Rural Development Website).

Figure 47: Daily Livestock Water Use vs. Human Use



Notes: Numbers are based on conventional livestock practices.
* Averaged over the entire year for a 1000 lb. steer (higher consumption in hot summer months; less in winter).
** Numbers include water used for washing.

Created by: Institute for Agriculture and Trade Policy
Sources: Alberta Agriculture, Food and Rural Development Website; University of Nebraska Cooperative Extension (2); USGS Website (3)

Although direct consumption of water by livestock is relatively low compared to crop requirements, these numbers do not take into account the water used to produce animal feed, which for most conventional operations, is primarily grain. Thus, if the water needed for animal feed production and waste management processes would be included in calculations, it would quickly become apparent that conventional, concentrated livestock production is much more water intensive than these numbers would suggest.

Influences on U.S. and Canadian Agriculture in the Great Lakes Basin

The type, scale and character of agriculture in the Great Lakes region is determined not only by the area's natural characteristics and resources, but also by such factors as US and Canadian federal farm and economic policies, land use pressures and technological advances. This section provides a brief look at each of these factors and how they have or may influence the face of agriculture in the basin.

U.S. and Canadian Farm Policy

From the introduction of the groundbreaking agricultural legislation in the 1930s, the price of grain in the U.S. had been moderated by price supports, grain reserves and controls on production. The US farm support system, which provided a basic level of support for farmers, was altered over time, but remained basically intact until the 1996 U.S. Farm Bill. Convinced that U.S. agriculture could be more competitive in global markets if free market philosophies were implemented, in 1996 policymakers opted to remove most of these "price-distorting" tools. The belief was that farmers could more readily respond to price signals and change their plantings accordingly.

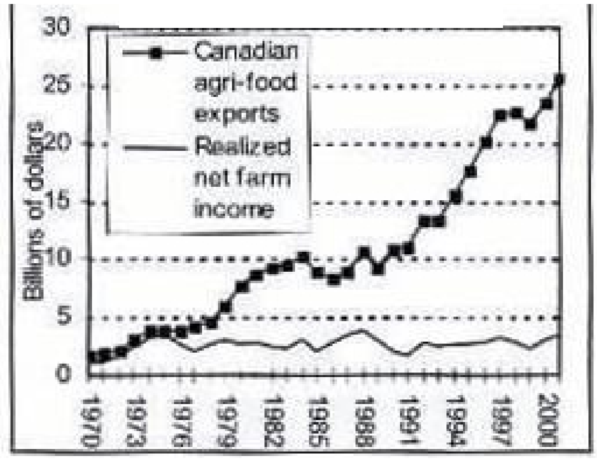
Grain markets, however, have proven to respond poorly to price signals. The reasons for this are varied and complex, but include the limited ability of farmers to adjust agricultural production in the short run, the inelasticity of grain demand, and the fact that farmland is rarely idled (Ray, 1999). Farmers' planting options are also constrained by the policies of buyers, who often attempt to gain economies of scale by buying a large volume of a few crops in a particular region. Similar arrangements have affected the livestock and dairy sectors as well. The result has been some of the lowest grain prices in decades. These low grain prices – coupled with uncompetitive markets due to industry consolidation – have also contributed to very low prices for milk, hogs and poultry. As a result, agriculture in the U.S. and the Great Lakes States has been in crisis in recent years, as is evident from the continued reduction in both the number of farm operations and the amount of land in farms throughout the region and country.

The recently signed 2002 U.S. Farm Bill will continue most of the policies implemented in 1996, although it also includes increased conservation spending and incentives, depending on the Bill's final form and funding. From the main focus of the policy, however, it can be expected that the corn-soybean rotation will continue to dominate much of the Great Lakes Basin (especially in the south and west); there will likely be a continued trend towards fewer, larger and less diverse crop farms and animal feeding operations for hogs, poultry and dairy; and there will be increased pressure on Great Lakes dairy farmers, Michigan and New York apple growers and Great Lakes horticultural producers from their competitors both in the U.S. and abroad.

Historically, Canadian agriculture has been characterized by co-operation among farmers and between farmers and governments. Such co-operation served to develop agriculture in the hinterland and to give farmers some power in and influence over the marketplace. Some of the primary aspects of this approach to federal policy include: the *Canadian Wheat Board*, supply management, a marketing board for hogs, etc. In addition, farmers and government contributed to income stabilization programs such as the *Net Income Stabilization Account* and *Crop Insurance* programs. The final historic "leg" of Canadian agricultural policy was the transportation subsidy program, which provided generous assistance to the rail industry in return for reduced rates for the transport of grain produced in the Western provinces (Ash in *Agri-food Policy in Canada*, 1998).

Over the last two decades, however, these programs have undergone significant changes. Canadian agricultural policy, like its US counterpart, has been heavily influenced by global trade accords and pressures (i.e. NAFTA/GATT), resulting in a shift in its focus towards promoting exports, reducing governmental involvement in and subsidization of transportation, and re-shaping existing safety net systems. The shift has succeeded in dramatically increasing Canadian agri-food exports (from $4 billion in 1975 to approximately $25 billion in 2001), but net Canadian farm incomes have actually *fallen* in real dollar terms during the same period, as shown in Figure 48, and the number of farmers has also dropped significantly (National Farmers Union, in *Canadian Policy and the Farm Crisis*, 2001).

Figure 48: Canadian Agri-food Exports and Realized Net Farm Income, 1970 - 2000



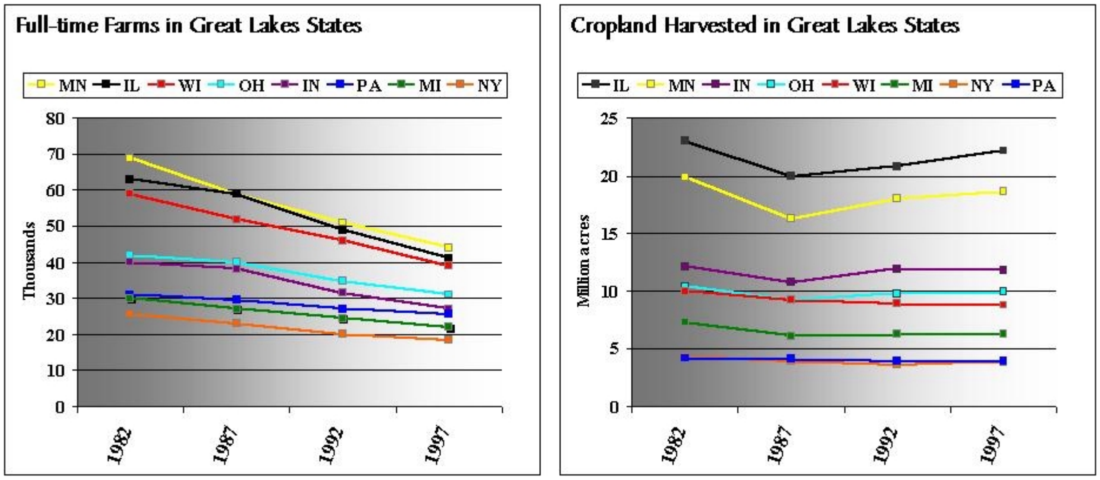
Source: National Farmers Union, Canada

The change in Canadian agricultural policy is continuing. The stated intention of the new "Agricultural Policy Framework" is to promote Canada as a world leader in food safety and food quality, environmentally responsible production and the creation of innovative agri-based products and services. (Agri-Canada website, 2002) This policy, which is still being formulated, has the potential to integrate environmental protection, agricultural policy and food safety regulation, which could benefit farmers, consumers and the environment. However, some Canadian farmers and farm groups fear it may be merely a different name for a continuation of the current trends towards decreased regulation and government support and increased corporate ownership.

Consolidation of Farmland

The consolidation of farmland in the Great Lakes region is both the result of other influences, such as policy, markets and land use pressures, and an influence itself on the future face of farming in the region. From 1982 –1997, the number of full-time farms in Great Lakes States dropped considerably. During the same period, however, the amount of land harvested in the Great Lakes region remained relatively constant, despite the overall decrease in land in farms and the number of full-time farms (Figure 49). This combined data indicates that not only are fewer farmers farming more land area, but also that a significant part of the land area being farmed was not previously cultivated. This consolidation has an impact on both land use and land prices, which can limit entry into the sector by new or smaller farmers.

Figure 49: Number of Full-time Farms in Great Lakes States, 1982-1997; Total Cropland Harvested in Great Lakes States, 1982-1997



Created by: Institute for Agriculture and Trade Policy; Source: USDA, NASS (3)

Agriculture in Ontario and Québec has been undergoing a similar transformation. While the overall number of farms in Ontario and Québec has declined significantly over the last two decades (by 27.6% and 33.2% respectively), total cropland in both provinces has increased, as has average farm size (by 35.6% and 24.9% respectively), [Statistics Canada, 2001 (5)].

Technology

The introduction of center-pivot and other moderately priced sprinkler irrigation systems over the last 40 years has significantly increased the ability of small and medium-sized farms with access to ground or surface water to irrigate. The wider availability and use of these systems, which include *side roll*, *traveling big gun, linear move,* as well as the ubiquitous *center-pivot*, has contributed greatly to the increase in both irrigation and production in the Great Lakes Basin.

The relatively recent introduction of surface and subsurface drip irrigation and other more efficient systems (detailed earlier) has the potential to significantly decrease water loss and increase irrigation efficiency in agriculture. However, the perceived disadvantages of such systems, which include high initial equipment cost and more complex management and repair needs, have so far helped to limit the general introduction of such systems.

Other technological innovations that have the potential to impact agricultural water use and productivity in the region is the increased use of Global Information Systems (GIS) with farm machinery. The integration of these technologies has allowed farmers to map variations in soil type, nutrient levels, water retention and crop yields within farm fields. This information could be used to help farmers to manage water, nutrients and cropping systems more efficiently, which could lead to reduced water use and loss. However, the high cost of such equipment is likely to limit its use on smaller farms.

Summary: Agriculture in the Great Lakes Basin

The face of agriculture in the Great Lakes Basin (and throughout North America) has changed significantly over the last fifty years. Under the influences of farm policy, market pressures, consolidation, technological innovations, development pressures and changing rural demographics, the management, labor needs, landscape, production and water use of agriculture in the Great Lakes region has undergone a major transformation. In the Great Lakes States, there has been a considerable increase in farm size, production and water use. At the same time, there has been a noticeable decrease in the number of operations, the diversity of these farms and the products they produce, and the overall export value of agricultural products from the region. For the Great Lakes Provinces, the trends have been quite similar, with the notable exception of the increase for both provinces in the value of their agricultural exports.

V. Water Use Policy

Water Policy Framework

Over the last century, there have been numerous policy initiatives regarding water quantity management in the Great Lakes-St. Lawrence River Basin- each stemming from the inability or limitations of the previous initiative to achieve its intended goal of protecting Great Lakes water resources and controlling diversions: the 1909 Boundary Waters Treaty; the 1985 Great Lakes Charter; the 1986 Water Resources Development Act; and Annex 2001 to the Great Lakes Charter. *See Box*.

The 1909 Boundary Waters Treaty: The Boundary Waters Treaty was designed to address and resolve disputes and issues regarding the Great Lakes and other boundary waters. It created the International Joint Commission and gave it the power and responsibility to regulate the flow of waters along the boundary between Canada and the United States. Article III of the treaty provides that any diversion or obstruction that would "affect . . . the natural level or flow of boundary waters on the other side of the line" needs the approval of not only the Canadian and U.S. governments, but also of the IJC. However, what appears to provide the IJC with significant authority over levels, flows and diversions in the Great Lakes has not occurred. In 1985, the IJC expressed its frustration with the situation, concluding that: "the international requirements under the Boundary Waters Treaty with respect to both large and small diversions of boundary waters are not explicit, nor is any consistent practice followed" (CELA and GLU, 1997). Throughout its history, the IJC has never denied a request for approval for a control works or diversion in the Great Lakes Basin (see: CELA and GLU, 1997 for more detailed information). Article VIII establishes a hierarchy of water uses: 1) domestic and sanitary; 2) navigation; 3) electric power and irrigation. Of importance today is the fact that the needs of the ecosystem are not included. Current societal values such as the ecological integrity of the Great Lakes and recreational uses are not reflected, which could be a barrier to egalitarian action on water quantity issues.

The 1985 Great Lakes Charter: Recognizing the value and limited supply of water in the Great Lakes, the growing potential for new proposals to obtain water supplies from the region, and limitations of the existing legal framework for managing the Great Lakes waters, the Governors and Premiers from the states and provinces bordering the Great Lakes developed a non-binding agreement known as the Great Lakes Charter of 1985 (New York State Department of Environmental Conservation Website). The stated purpose of the charter is to conserve the levels and flows of the Great Lakes and their tributary and connecting waters; to protect and conserve the environmental balance of the Great Lakes Basin ecosystem; to provide for cooperative programs and management of the water resources of the Great Lakes Basin by the signatory states and provinces; to make secure and protect present developments within the region; and to provide a secure foundation for future investment and development within the region (Council of Great Lakes Governors Website). The Charter establishes a protocol for each State or Province to consult with the others in the region before approving any diversion of water greater than 5 million gallons per day/average in any 30-day period. The charter had the potential to be a framework for sustainability by gathering data on use of the waters of the Great Lakes, by gauging future demands, by promoting cooperation, and by preventing

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diversions (CELA and GLU, 1997). However, the Charter stopped short of establishing a comprehensive and enforceable standard by which a State or Province should deny certain projects. Therefore, each Great Lakes State and Province has no real enforcement authority or regionally consistent evaluation process under the Charter to prevent the removal of Great Lakes water from another State or Province (New York State Department of Environmental Conservation Website).

The Water Resources Development Act of 1986: The U.S. Water Resources Development Act of 1986 (WRDA) requires approval by the governor of each of the Great Lakes States for diversions out of the Great Lakes Basin. This legislation is more powerful than the Great Lakes Charter because it requires unanimous consent by the governors and because it has no minimum trigger level, meaning that the legislation applies to even the smallest diversion out of the basin. Unlike the Great Lakes Charter, WRDA does not apply to major consumptive uses within the basin. As discussed by Farid et al. (in: CELU and GLU, 1997), this legislation has numerous weaknesses: it applies only to diversions that were established after 1986; it applies only to inter-basin diversions; there is ambiguity as to whether the terms of the legislation provide that each governor must actually consent to a diversion proposal, or whether it simply means that they have the right to veto a proposal for a diversion; the legislation applies only to the United States: Ontario and Québec are excluded from the provisions of the law despite the fact that water resources in both these jurisdictions would be detrimentally affected by a diversion out of the Great Lakes; confusion has arisen around whether the WRDA applies to groundwater diversions.

Annex 2001 to the Great Lakes Charter: The purpose of Annex 2001, a new provision of the 1985 Great Lakes Charter, is to forge a binding agreement to manage Great Lakes waters, to develop a new standard for new or increased water withdrawals, and to make further commitments to improve the Great Lakes water management system (New York State Department of Environmental Conservation Website). Since the signing of the Great Lakes Charter, there have been great improvements to the state of scientific knowledge of how the ecosystem can be affected by changes in hydrology. The legal and policy context regarding water quantity management has also changed. For example, the states and provinces have adopted various regulations governing the use of Great Lakes waters, as well as the U.S. and Canada entering into two significant international trade agreements [the North American Free Trade Agreement (NAFTA) and the General Agreement on Tariffs and Trade (GATT), supplemented by agreements concerning the World Trade Organization (WTO)], that affect decisions about the use and transfer of water (Great Lakes Protection Fund Website). In December 2000, the Council of Great Lakes Governors, acting on behalf of the Great Lakes Governors and Premiers, released a draft amendment to the Great Lakes Charter called Annex 2001, for public review and comment. On June 18, 2001, the Annex document was signed by all of the Great Lakes Governors and Premiers to protect the Great Lakes against bulk water exports and large-scale diversions. In the Annex, the Governors and Premiers reaffirm their commitment to the Charter principles and also "commit to develop and implement a new common, resource-based conservation standard and apply it to proposed new or added increased capacity withdrawals of Great Lakes water"
(Great Lakes Protection Fund Website).

These water policy initiatives represent repeated attempts by Great Lakes leaders to create a reliable legal framework to conserve, protect and effectively manage Great Lakes water resources. However, most of these attempts have been insufficient in protecting the Great Lakes ecosystem due to such issues as the non-binding legal nature of the policies, the inability to implement regionally consistent decision-making standards regarding diversions, inconsistent methods of monitoring, permitting and understanding of state/provincial surface water and groundwater uses, and the lack of a basin-wide conservation strategy. The issue of diversions remains a constant threat to the long-term viability of the Great Lakes ecosystem and the people who live there. The recent decision to update the 1985 Great Lakes Charter, termed "Annex 2001," represents the most current and comprehensive proposal to address these issues and to achieve what earlier water policy initiatives could not: complete protection of Great Lakes water resources from bulk water exports and diversions, improvement of the Great Lakes ecosystem, and establishment of a precautionary principle regarding Great Lakes water use and management.

Annex 2001: Challenges and Next Steps

In signing Annex 2001, Great Lakes leaders have agreed to regional collaboration to strengthen the protection of Great Lakes water resources by reforming state and provincial water use law to protect the environment, rather than only the interests of human water users (GLU, Sustainable Waters Watch #9, February, 2002). Under the agreement, Great Lakes leaders have accepted a standard set of principles to guide state and provincial decision-making regarding water diversions, whether intended for use inside or outside of the Great Lakes Basin. This new standard would be created through a separate binding agreement among states and provinces. The goal is to make future rejections of damaging bulk water export and diversion proposals immune from challenge under U.S. trade laws or international trade agreements (GLU, Sustainable Waters Watch #9, 2002). The principles of the Annex state that any Great Lakes water withdrawal proposal:

- must implement reasonable water conservation measures;
- will not cause significant adverse impacts to the water and water-dependent natural resources;
- will result, either individually or cumulatively, in an overall improvement to the resource.

Once authorized by state and federal legislation, this new standard will apply to all new and expanded withdrawals within or originating within the Great Lakes-St. Lawrence River Basin [Northeast-Midwest Institute Website (1)]. (Although there was to be an exception for withdrawals with *de minimus* impact, this clause will likely be dropped).

For the process to move forward, the basin's governments now need to incorporate the conservation principles of Annex 2001 into state and provincial law. The Annex calls on the states and provinces to develop coordinated laws that guide individual water use decisions toward the common goal of protecting and enhancing the Great Lakes ecosystem:

- Great Lakes governors and premiers must develop binding standards from Annex 2001 principles to create an intrastate and provincial compact. Once developed, the U.S. Congress and Canadian Parliament must ratify the compact, then enact and implement related legislation;
- Great Lakes States and Provinces must enact legislation that promotes water efficiency within each state and province, improves the ecosystem, and recognizes the integral relationship between the basin's surface and groundwater resources;
- Great Lakes leaders and citizens must work at the community level to build awareness and improve understanding of the need to conserve and safeguard their water sources (National Wildlife Federation and Michigan Land Use Institute, September, 2002).

The Annex 2001 initiative was initiated to strengthen regional water policy. However, until Great Lakes governments transform the Annex's principles into law, the Great Lakes ecosystem and the communities that depend on it will lack regulatory protection. States such as New York, Ohio, Illinois and Wisconsin are particularly at risk since unplanned growth and the absence of consistent water supply and water use oversight has led to shortages and high management costs (National Wildlife Federation and Michigan Land Use Institute, September, 2002). In addition, issues such as considerable budget shortfalls and an extremely ambitious timeline make successful completion of the Annex process even more challenging. For more detailed information regarding Annex 2001 see: Great Lakes United Website (www.glu.org).

Water Use Legislation in the Great Lakes – St. Lawrence River Basin

There is a substantial mixture of water management regimes within the Great Lakes-St. Lawrence River Basin. According to Farid et al. (in: CELA and GLU, 1997), while all jurisdictions measure water use, the categorizations of water use are different within each jurisdiction. In addition, not all states and provinces are in a position to regulate water, either because the legislation does not exist, or because the needed funds have not been allocated to this purpose. Finally, although most jurisdictions have attempted to conform to the provisions of the Great Lakes Charter, each state or province takes a different approach to doing so. In the Annex 2001 negotiations now underway, the states and provinces are endeavoring to put in place a more uniform system of protections in order to remedy these disparities.

Water Use Legislation in Great Lakes States

The current system for approving withdrawals, [as legislated in the Water Resources Development Acts (WRDA) of 1986 and 2000], prohibits any diversion or export of Great Lakes water outside of the basin without the consent of all eight Great Lakes Governors [Northeast-Midwest Institute, (1)]. However, there is no standard regarding how the various states legislate and monitor water withdrawals. Several states (and provinces) have programs that require large water users to obtain water withdrawal permits. Others require large water users to register with the state (or provincial) regulatory agency but do not have to apply for a permit. Only Minnesota has a formal system that clearly defines water use priorities under the riparian system (Crane, in: Great Lakes Commission, 1996). *See Box*.

Water Use Regulations in Great Lakes States

Illinois is legally limited in the amount of water that it can divert from the Great Lakes. Therefore, the state has developed a permitting process to allocate its share of Lake Michigan water, giving first priority to maintaining minimum flows in the Sanitary and Ship Canal and to certain residential, commercial or industrial users. The state considers the conservation practices of applicants when issuing permits.

Indiana does not require a permit for any water withdrawals, either groundwater or surface water. State law does not allow water to be diverted from within the Great Lakes Basin for use outside of the basin, unless the diversion is approved by the Governors of each Great Lakes state; however, because the state does not require permits, it has difficulty identifying withdrawals that might be diverted out of the basin.

Michigan does not regulate water withdrawals. However, the state requires community public water supply systems and certain large water users such as thermoelectric power plants and irrigated golf courses to submit water withdrawal reports.

Minnesota requires a water use permit from all users withdrawing more than 10,000 gallons per day (gpd) or 1 million gallons per year. Also, any inter-basin water diversion of more than 2 million gpd requires permission of the legislature and an environmental assessment. Furthermore, a diversion or consumptive use of more than 5 million gpd (average) from the Great Lakes Basin also requires approval from additional state agencies and the other Great Lakes States and Provinces.

New York requires registration of all withdrawals from the Great Lakes Basin that exceed 100,000 gpd averaged over a 30-day period. New York will consult with other Great Lakes States on any new withdrawal that will result in a 5 million gpd loss (30 day average) to the basin. Any inter-basin diversions from the Great Lakes require the approval of the governor and the legislature.

Ohio requires the owner of any facility with the capacity to withdraw more than 100,000 gpd to register that facility with the Ohio Department of Natural Resources. Also, the state may designate an area as a groundwater stress area, establish a threshold withdrawal capacity for that area, and require registration for any withdrawals above this threshold.

Pennsylvania does not have any system for permitting or notification of water withdrawals.

Wisconsin requires reporting of any water withdrawal over 100,000 gpd (30 day average). A permit is required if the total water lost from the basin is greater than 2 million gpd (30 day average). A diversion or consumptive use of 5 million gpd or greater requires consultation with the other Great Lakes States.

Source: Northeast-Midwest Institute Website (1).

The issue of consistent, basin-wide water withdrawal/water use tracking systems is particularly important in the context of Annex 2001. The states of Pennsylvania, Ohio and Michigan currently have no tracking systems in place to monitor water withdrawals, nor any comprehensive law addressing water use management. Without consistent, standardized water use tracking systems in all of the Great Lakes States and Provinces, available data will be inadequate to accurately monitor current and future trends in basin water withdrawals and use. The states lacking such water use tracking systems are the same states in which the most significant changes are expected to occur as a result of the Annex 2001 process.

Provincial Water Use Regulations

In response to growing demands for limited water supplies, most Canadian provinces have developed water use legislation to regulate the withdrawal of surface and groundwater for beneficial uses. A difficulty in Canada regarding regulation is the issue of water "ownership," which arises from the split in authority and control over water between federal and provincial governments. There is a basic division between western and northern Canada, where the "Crown" (now federal government) has declared that it owns the water, and most of central and eastern Canada, where, under the same European principles applied at the time of settlement, no one owns the water. Prior appropriation, which is the basis for western water management, states that the first to gain water rights has first privileges to sell those rights, independent of the land. In practice, however, most aspects of water management are within provincial authority. Despite this fact, the federal government could still intervene in this management through legislation [Agriculture and Agri-Food Canada, 2000 (2)]. *See Box*.

The Québec government has enacted a moratorium on bulk water exports while establishing new water regulations. The Water Resources Preservation Act and the Québec Public Hearings Bureau (BAPE) released its final report on water management in Québec, where it recommended that all water projects (including commercial bottlers involving the daily removal of more than 75 cm of groundwater and water sold in containers greater than 25 liters) be subject to impact assessment and review by the Environment Minister (Sierra Club of Canada and GLU, 2000). Ontario has added to its basic riparian rights a permitting system that allows the provincial government to monitor and control all major consumptive uses of water [Agriculture and Agri-Food Canada, 2000 (2)].

Provincial water use regulations generally list water uses in order of importance, with domestic and municipal needs in first and second place. Domestic uses are generally exempted from legislation and from licensing. Use of water for other purposes without a license or outside of license conditions carries penalties.

Besides meeting the requirements of water rights legislation, major water projects, such as irrigation and hydroelectric dams, must also comply with other federal and provincial statutory requirements. Among the major pieces of federal legislation that govern water development and use are the Fisheries Act, Navigable Waters Protection Act, Canadian Environmental Protection Act, and Canadian Environmental Assessment Act [Agriculture and Agri-Food Canada, 2000 (3)].

Who Owns the Water?

The question of who owns the water in Canada does not have a simple answer. At the time of European settlement… the prevailing doctrines of English and French law emphatically suggested that running water could not be owned by any individual. A person owned water only when it was captured, and then only in the actual quantity captured. English common law recognized that only riparian owners (the limited class of people whose land adjoined a watercourse) had rights to use water for domestic purposes and a restricted right to use water for other purposes, provided these uses did not perceptibly alter the quality or quantity of its natural flow.

This fundamental legal assumption started to change in western Canada when settlers were faced with the realities of farming in an arid region. In 1894–1895, the federal government perceived a need to provide secure water rights to settlers to encourage irrigated agriculture. In 1895 it enacted the North-West Irrigation Act, declaring that "the property in and the right to the use" of all water was vested in the Crown. Having thus

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brought water firmly under its control, the federal government granted rights to others, in the form of licenses, to divert and use water in quantities and at locations that the common law of riparian rights did not allow.

In 1930, as part of the general transfer of natural resources, the provinces of Alberta, Saskatchewan, and Manitoba assumed ownership of water inside their boundaries. British Columbia had placed itself in a similar position in 1925 by declaring that it too owned and had the right to use all water. In the Northwest and Yukon territories and Nunavut, the property in and right to the use and flow of all water now vests in the Crown.

Thus, today there is a basic division between western and northern Canada, where the Crown has declared that it owns the water, and most of central and eastern Canada, including Québec, where, under the same European principles applied at the time of settlement, no one owns water. In Nova Scotia, however, by a provision broadly similar to that found in the West, all watercourses are vested in the province along with the right to use and divert the water they contain.

This division between regions on the question of who owns the water emphasizes that this question is not of fundamental importance. No matter who officially "owns" the water, provincial governments can control water so as to regulate all significant issues of quality and quantity. Thus, for example, in western and northern Canada, the Crown allocates the right to divert and consume water by granting licenses to those who apply for them. In central and eastern Canada, where water shortages are less common, the rights to divert and use water still belong to riparian owners. But there is no doubt that the governments of provinces in these regions control water within their boundaries enough that they could enact licensing or permit systems similar to those in western and northern Canada. For example, Ontario has added to its basic riparian rights a permit system allowing the provincial government to monitor and control all major consumptive uses of water. Nova Scotia can grant authorizations to use water, which are somewhat similar to the licenses issued in the West and North, in a system that retains some vestiges of riparian rights. The ability to control all waters within their boundaries has also allowed the provinces to make provisions controlling water pollution, an issue of water quality.

Today the main difficulty arises from the extent to which authority and control over water are divided between federal and provincial governments. In simple terms, most aspects of water management are within provincial authority. The federal government has the right to regulate water as it affects fisheries and navigation, based on provisions to that effect in the Constitution Act. A cloud of doubt surrounds jurisdiction over inter-provincial bodies of water, for which the division of powers is quite uncertain. In practice, the provinces can effectively regulate both quality and quantity of these waters day to day, but the federal government could intervene in this management at any time by legislation.

D.R. Percy, University of Alberta

Source: Agriculture and Agri-Food Canada, 2000 (2)

Outflow Regulations for Lakes Superior and Ontario

In 1914, the International Joint Commission approved a diversion for hydropower generation. The order specified that certain conditions be met in the construction and operation of the facilities, which led to the regulation of outflows of Lake Superior (IJC, 2001). Although some control can be exerted over the levels and flows in the upper lakes, like the impacts of other human activities, outflow regulation is limited, and has a minimum effect on levels and flows as compared to natural variability (IJC, 2001).

Only limited controls of levels and flows are possible and currently, only for Lake Superior and Lake Ontario (IJC, 2001). The flows are controlled by locks and dams on the St. Marys and St. Lawrence Rivers, respectively. The current regulation attempts to balance the levels of Lake Superior and Michigan-Huron about their mean levels, with considerations for their natural fluctuations. Minimum allowable outflows designed to maintain minimum water levels in the lower St. Marys River are incorporated into the regulation. The plan also includes maximum winter allowable outflows to reduce risk of flooding from ice jams in the lower St. Marys (IJC, 2001).

Since the Upper Great Lakes-St. Lawrence River Basin has been experiencing episodes of very high and very low water levels in recent years, concerns have been expressed about the ability of the current regulation plan to cope with these situations, as well as changes in future water supplies due to climate change and variability. In October 2001, the IJC developed a draft Plan of Study for review of the regulation of outflows from Lake Superior. The study's objective is to review the current regulation criteria and regulation plan, identify the needs of interest groups affected by water levels, consider potential impacts from climate change that could affect water levels and flows of the Great Lakes system and determine possible improvements to Lake Superior outflow regulation. This document describes the necessary tasks, schedules and costs. It is expected that the first phase of the study will be completed in 2004 (IJC, 2001).

The IJC has also established a bi-national group to develop a Plan of Study to review the criteria by which Lake Ontario levels are regulated. The mission of the study is to consider, develop, evaluate and recommend updates and changes to the 1956 criteria for Lake Ontario-St. Lawrence River water levels and flow regulation. This study is also supposed to take into account how water level fluctuations and changing conditions in the system (including climate change) affect all interests – all within the terms of the Boundary Waters Treaty (IJC Website).

VI. Issues of Concern for Great Lakes Water Quantity

Nationally and internationally, the possibility of large-scale diversions of water from the Great Lakes-St. Lawrence River Basin has become a high profile issue over the last few years. The most notable example was the 1998 proposal by the Canadian company *the Nova Group* to export Lake Superior water to Asian markets. Throughout the basin, concerns were voiced over the lack of consultation, the environmental implications of the withdrawal, and the legal precedent that such a withdrawal would set. While the request was subsequently withdrawn, this situation brought diversion issues to the top of the Great Lakes agenda (USACE et al, 2001).

In their final report to the governments of Canada and the United States, the International Joint Commission recommended that the Canadian and United States federal, provincial, and state governments not permit the bulk removal of water from the Great Lakes Basin, citing the need to protect its ecological integrity (IJC, 2000). The only exception to this recommendation would be if the permit applicant could show that the removal would not have any adverse environmental effects. In addition, the applicant would need "to demonstrate that there are no practical alternatives to the removal, sound planning has been applied in the proposal, the cumulative impacts of the removal have been considered, and that conservation practices are in place in the region importing the water" (IJC, 2000). The eight Great Lakes States, acting through the Great Lakes Commission, have formed a united front to oppose the withdrawal of Great Lakes water for overseas export (Great Lakes Commission, 1998), and in December 2001, Canada reintroduced legislation to prohibit bulk water removals from the Great Lakes. Most recently, on June 18, 2001, the Annex 2001 document was signed by all of the Great Lakes Governors and Premiers to protect the Great Lakes against bulk water exports and large-scale diversions.

In looking at influences on Great Lakes Basin water quantity beyond specific regional and federal water policies, international trade accords, population growth, land use changes, climate change and conservation practices all play – or have the potential to play – a role in determining current and future water availability.

International Trade Accords

One of the many reasons for the work on Annex 2001 is that water resources are not protected, and may, in fact, be endangered by current international trade agreements. The primary guiding principle for both the NAFTA (North American Free Trade Agreement between the U.S., Canada and Mexico) and GATT/WTO (General Agreements on Tariffs and Trade/World Trade Organization) is that governments cannot act in ways that give economic advantage to their own people over people in other countries who wish to trade with them (CELA and GLU, 1997).

As discussed by Farid et al, "Free trade has serious implications for attempts to prevent diversions from the Great Lakes. The ability of governments to act through the Great Lakes Charter, the imposition of special taxes on water use, the use of subsidies to help water users convert to conservation methods—all these are placed into serious doubt by free trade…The threat of a challenge under trade agreements may well be enough to discourage governments from even trying to proceed with such programs." Farid et al. conclude that it is essential to prevent the export of water from the Great Lakes-St. Lawrence River Basin because, "under free trade, once we turn the tap on, we cannot turn it off." (CELA and GLU, 1997)

There are three key provisions of NAFTA that could place water at risk according to Barlow (1999). One is "National Treatment," whereby no country can "discriminate" in favor of its own private sector in the commercial use of water resources (Barlow, 1999). The second provision is "Investor State" (Chapter 11), whereby a corporation of a NAFTA country can sue the government of another NAFTA country for compensation if the company is refused national treatment rights or if that country implements legislation that "expropriates" the company's future profit. Thus, if any NAFTA country, state or province tries to allow only domestic companies to export water, corporations in the other countries may demand compensation for "discrimination" (Barlow, 1999). Finally, there is the provision of "proportionality," under which the government of a NAFTA country cannot reduce or restrict the export of a resource to another NAFTA country once the export flow is established (Barlow, 1999).

According to the Sierra Club of Canada and Great Lakes United (September 2000), the key GATT/WTO provision with implications for water exports is the prohibition of quantitative restrictions (Article XI). WTO rules, however, create a number of exceptions relevant to trade in water (Article XX), including the "health exception," which relates to measures "necessary to protect human, animal, or plant life or health," and the "conservation exception," which relates to "the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption." The IJC concedes that there may be some dispute as to whether water is an exhaustible natural resource, although this raises less of a problem in the case of a discrete ecosystem such as the Great Lakes Basin, where only a small part of the resource is replenished annually. Both exceptions are qualified by a requirement that they "not be applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail, or a disguised restriction on international trade" (Sierra Club of Canada and GLU, 2000).

The continued analysis of these organizations determined that "although dispute-settlement panels considering these GATT exceptions have affirmed, in principle, that trade interests may have to give way to legitimate environmental concerns, it is also true that the same panels have questioned very closely whether measures nominally taken for environmental reasons have underlying protectionist elements. Many public submissions to the IJC in this reference noted that to date, in all the cases before the World Trade Organization involving issues of protecting environmental or natural resource interests, the WTO had ruled against those interests." The only exception is the recent WTO ruling "that the French ban on Canadian asbestos could be upheld on public health grounds under Article XX(b). This is the first time any public health measure has survived the GATT and should be acknowledged as such. But if this result represents what is required before a general exception to trade obligations can succeed, there remains serious doubt that Article XX has developed adequately to ensure the observance of legitimate domestic objectives, including Great Lakes water protection" (Sierra Club of Canada and GLU, 2000).

The IJC concluded, based upon WTO general exceptions, that "…the achievement of a coherent and consistent approach to water conservation and management in the Great Lakes Basin - an approach clearly grounded in environmental policy - would be an important step in addressing any trade-related concerns with respect to the use of basin waters" (IJC, 2000). This recommendation has been acknowledged and supported by Great Lakes leaders and environmental groups in the development of a common standard on water use and removals that is focused on the environmental aspects of water conservation, in the hope of falling within the WTO/NAFTA general exceptions (Sierra Club of Canada and GLU, 2000).

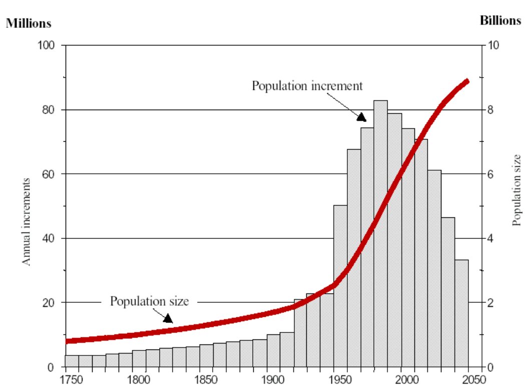
For example, the Canadian government, in lieu of pursuing an outright ban on water exports – which would likely evoke trade agreements – has acted to exercise its constitutional right to protect its water as natural ecosystems (not export commodities) through law. Recognizing that Canada's water is a precious resource, the Government of Canada proposed new regulations to implement amendments to the International Boundary Waters Treaty Act to prohibit the bulk removal and diversion of boundary waters out of Canadian drainage basins and to grant veto power to the

Canadian Minister of Foreign Affairs and International Trade over water export proposals. The prohibition applies to the Canadian portion of the Great Lakes and other boundary waters in Canada. The proposed regulations, published in the Canada Gazette on June 28, 2002, will implement this prohibition [Great Lakes Environmental Library, Current Articles, 2002 (1)]. The promulgation of such water protection regimes, like the binding regulations recommended by Annex 2001, are the most profound water protection that can be exercised in the Great Lakes. Changing NAFTA or WTO clauses alone would not accomplish this (personal communication, Sarah Miller, CELA, 2002).

Population Growth

Many of the risks to the world's lakes derive from a growing global demand for water, which will be increased as the world population rises by nearly 2 billion people by the year 2030 (Figure 50), (World Water Council, 2001). Despite potential reductions in consumption and agricultural water use through increased efficiency and conservation, there is still expected to be a significant increase in demand for finite water resources. Postel (in: Worldwatch Institute, 1999) discusses the disparity between increasing population and water availability. Regarding the increasing use of groundwater aquifers for irrigation, she raises a vital question: "if so much of irrigated agriculture is operating under water deficits now, where are farmers going to find the additional water that will be needed to feed the more than 2 billion people projected to join humanity's ranks by 2030?"

Figure 50: Long-term World Population Growth, 1750-2050

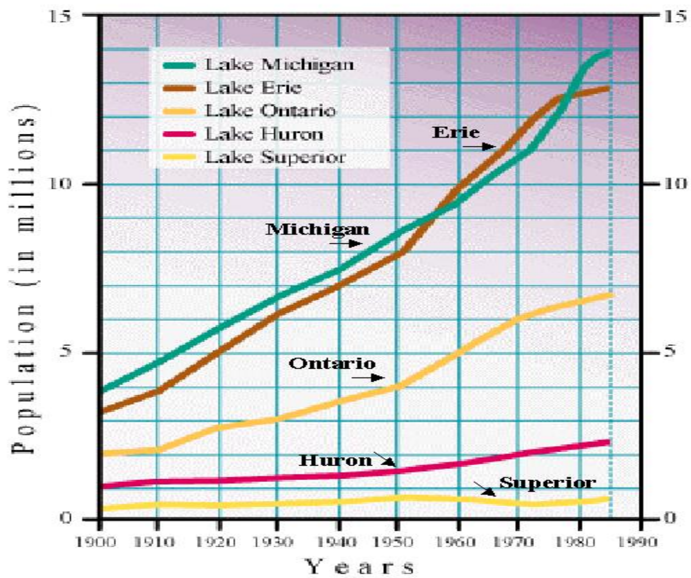


Source: United Nations Population Division, 1999

"Many of the risks to the world's lakes derive from a growing global demand for water, which will be increased as the world population rises by nearly 2 billion people by the year 2030" (World Water Council, 2001).

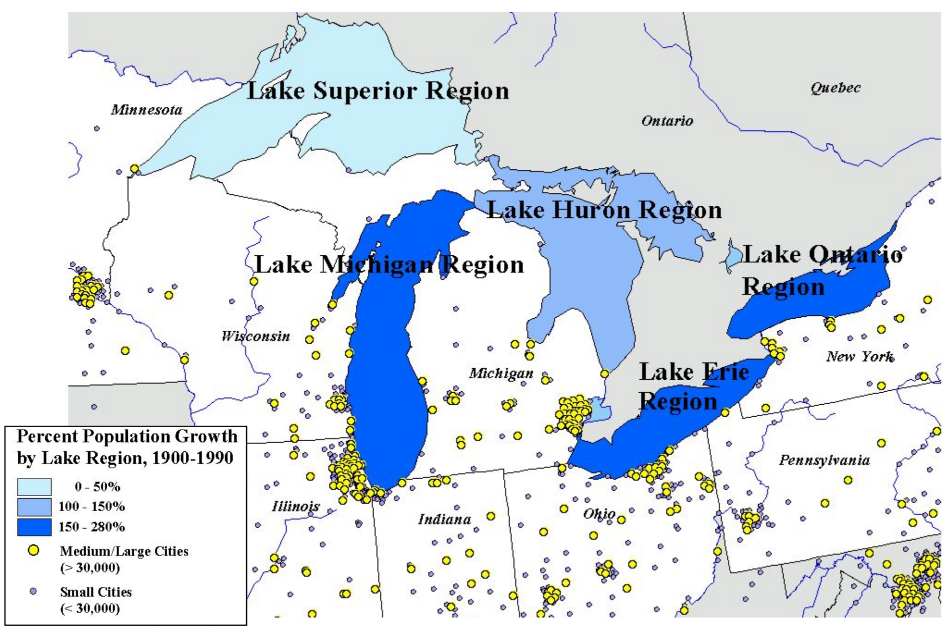
As shown in Figures 51 and 52, the population in the Great Lakes-St. Lawrence River Basin has also been growing over the last century, most significantly near Lakes Erie, Michigan, and Ontario.

Figure 51: Population Growth in the Great Lakes-St. Lawrence River Basin, 1900-1990



Source: US EPA and the Government of Canada, 1995

Figure 52: Percent Population Growth by Lake Region, 1900-1990; U.S. Population Distribution, 2000



Created by: Institute for Agriculture and Trade Policy
Data Sources: US EPA and the Government of Canada, 1995 (population growth); ESRI (population distribution).

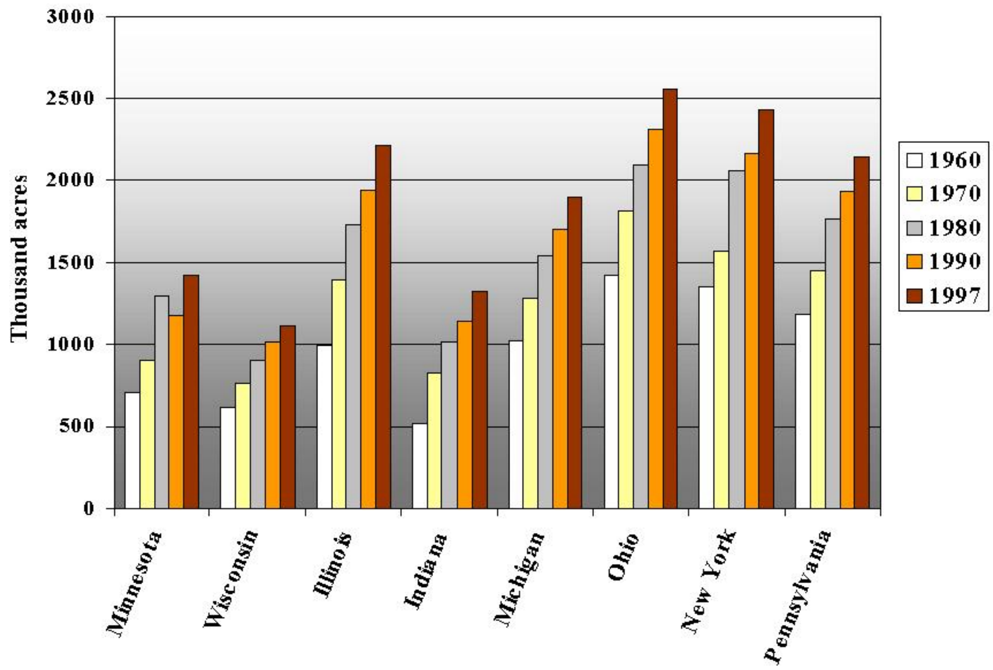
In-migration for both the U.S. and Canada has also been increasing considerably since 1970. In 1995, the U.S. and Canada were ranked first and fifth by the United Nations Population Division (1999) of the ten countries or areas with the greatest in-migration. Between 1999 and 2050, population growth in the U.S. and Canada is estimated to increase 26 and 37 percent, respectively (United Nations Population Division, 1999). One major factor potentially impacting this trend would be the in-migration of environmental refugees to the Great Lakes-St. Lawrence River Basin. In this scenario, immigrants to the region would be fleeing from water-short countries and regions and the political, economic and social instability that often accompanies such conditions. According to estimates from the United Nations and the United States government, by 2015, at least 40 percent of the world's population, or about three billion people, will live in countries where it is difficult or impossible to get enough water to satisfy basic needs (New York Times, 2002). As the world's supply of freshwater becomes more limited, population growth is likely to become even greater in those regions of greatest supply.

Although populations outside of the Great Lakes Basin may indeed put political or other pressure on Great Lakes water resources in future, the primary threat to the Great Lakes today is most likely to come from overuse and misuse of water by users within the basin. Further, the major push for water removals is not expected to come as much from foreign countries as from more local sources, such as drier regions of the U.S. or Canada, and from communities just outside of the basin. It is therefore vital to establish a regional conservation strategy to lessen water use within the basin and to mitigate the environmental impacts of increasing water use.

Land-use Changes

There are very few areas in the Great Lakes-St. Lawrence River Basin which have been unaffected by human activity. As stated earlier, some of the farmland that has been lost in the Great Lakes region is certainly a result of the dramatic increase in urban areas over the last 40 years (Figure 53). On average, land in urban areas has almost doubled in Great Lakes States (+93 percent), as population continues to grow. According to the USDA, (1997), unlike other land uses, such urban area increases are essentially permanent: "Urban area increases are unique because, contrary to the other major land use changes, which are dynamic and shift between uses over time, urbanization tends to be a one-way, irreversible shift. Once urbanized, very little land ever reverts to another major land use."

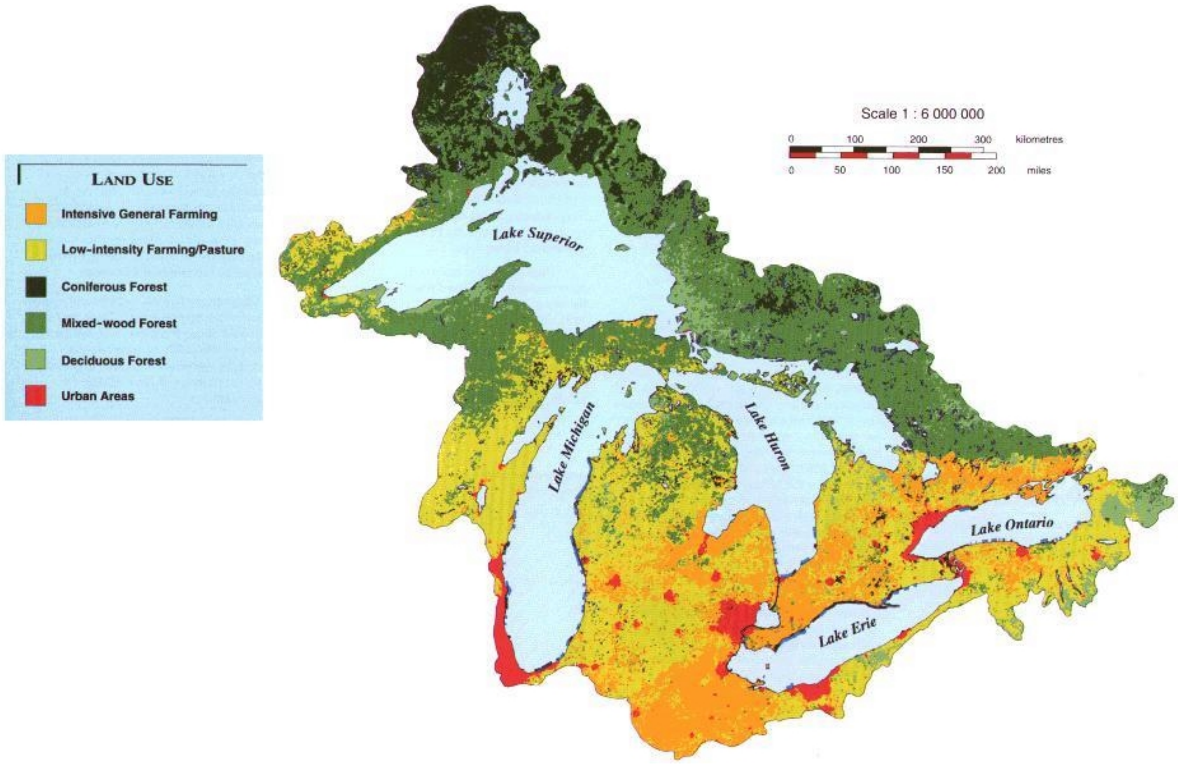
Figure 53: Land in Urban Areas in Great Lakes States, 1960-1997



Created by: Institute for Agriculture and Trade Policy; Data Source: USDA, 1997

Conversion of farmland to non-farm uses has been one of the most significant land use changes in the region over the last century. According to Thorp (in: Great Lakes Commission, 1996), the increasing conversion of farmland to non-farm use, particularly around metropolitan areas (Figure 54), is resulting in dramatic impacts on the natural resources that sustain the regional economy. Land classified as farmland in the basin has declined by more than 4.5 million acres between 1981-82 and 1991-92. Thorp argues that efforts should be directed toward reversing this trend to improve long-term sustainability: "If significant conversion of farmland continues in the basin, the agricultural production base will decline and with it future farming opportunities… because of the connection between farmland conversion and proximity to metropolitan areas, efforts to preserve farmland may also help to contain sprawling development patterns and improve community sustainability" (Thorp, in: Great Lakes Commission, 1996).

Figure 54: Land Use in the Great Lakes Basin, 1991



Source: U.S. EPA and the Government of Canada, 1995

Conversion of farmland to non-farm uses, particularly near metropolitan areas, has been one of the most significant land use changes in the region over the last century.

Climate Change

Research is showing that the impacts of potential climate change to Great Lakes water levels could be dramatic [IJC, 2000; Quinn et al, 2000; Quinn, in: Adams, 1999; CELA and GLU, 1997]. Experts from NOAA and Environment Canada believe that climate change could result in a lowering of lake level regimes by up to three feet (one meter) or more by the middle of the 21st century, a development that would cause severe economic, environmental, and social impacts throughout the Great Lakes region. Experts associated with the U.S. National Assessment on the Potential Consequences of Climate Variability and Change indicate the possibility of both slightly increased and decreased lake levels as a result of their analysis of climate models. Given the large discrepancies in some model results, there continues to be a high degree of uncertainty associated with the magnitude of potential changes (IJC, 2000).

Despite the uncertainties, many experts agree that factors such as future consumptive use, cumulative small-scale water removals and climate change are likely to place downward pressures on water levels. Although there are insufficient data and inadequate scientific understanding to place precise estimates on the extent and timing of such impacts, the impacts could be significant. The IJC (2000) concludes that this, plus the prospect of adverse cumulative impacts of new human interventions, suggests a need for great caution in dealing with those water use factors that are within the control of basin managers. Because population will increase, there is a greater probability of increasing water use in the future than there is of decreasing use (IJC, 2000).

As discussed by Farid et al, (in: CELA and GLU, 1997), scientists forecast that if CO_2 concentrations double by the year 2100 as is predicted, climate change will have the following impacts on the Great Lakes-St. Lawrence River Basin:

- Average temperature increases of 15 degrees Fahrenheit (9.1 degrees centigrade);
- Lake level decreases basin-wide by over three feet (one meter), and in Lake Michigan by 8 feet (2.5 meters);
- Loss of wetlands and the concomitant loss of essential habitat;
- Loss of forests, especially the boreal forests north of Lake Superior;
- Loss of cold water fish;
- Decreased water quality due to the resurfacing of buried contaminated sediments;
- Increased crop damage;
- Decreased shipping because of low lake levels;
- Losses to industries such as breweries, the chemical industry and hydropower generators which are highly dependent on water;
- Increased human health problems, including diseases now unknown in the Great Lakes region such as malaria.

According to a recent study published in the journal *Science*, climate change is increasing global environmental disease as a result in changes in temperature, rainfall and humidity (Great Lakes Environmental Library, Current Articles, 2002 (3)]. Climate change is expected to result in an increased survival rate of pathogens over a greater geographic range, and is expected to stress plants and animals, making them more susceptible to infection. Over time, such impacts, combined with decreasing water availability, will result in further environmental strain on the Great Lakes ecosystem.

Water Conservation

A widespread outlook that there is an almost limitless supply of water in the Great Lakes has helped to limit water conservation efforts in the region. The predominant research and environmental focus has targeted water quality as opposed to water quantity issues. Low water pricing in both the U.S. and Canada has also contributed to the lack of effective water conservation measures. Developing a coordinated conservation strategy at the basin/watershed level will be fundamental to improving water resource management and protection in the Great Lakes region.

The differing systems of water laws and policies in western/northern and central/eastern Canada pose differing barriers to water conservation. Prior appropriation, the basis for western water management, provides water rights that may date back to claims when the region was settled and may not reflect societal use or current water needs. The eastern riparian approach, on the other hand, binds water rights to those owning property adjacent to the resource, or over the resource, in the case of groundwater. Riparian rights can only be transferred with the sale of the land (personal communication, Sarah Miller, CELA, 2002).

In those areas of Canada where water supply is limited, there is a growing emphasis on demand management rather than supply management, creating a climate favorable to research on technologies that use water more efficiently, such as improved irrigation systems. At the same time, public support of water metering and user-pay programs is increasing. In agricultural terms, demand management involves finding ways of using existing water more efficiently, learning to farm with less water, and facing the prospect of paying for water that traditionally has been a free or low-cost resource [Agriculture and Agri-Food Canada, 2000 (1)]. In Ontario, there has been a modest downward trend in domestic, industrial and municipal water use in recent years because of improved water conservation practices (IJC, 2000).

In the U.S., the degree of future water conservation will depend on numerous factors, including overall water availability, water use policies and the introduction of incentives for conservation (World Meteorological Organization, 1997). There is a critical need to understand how water conservation targets in the basin could work to reduce current consumption as well as preventing future in-basin needs for increased withdrawals.

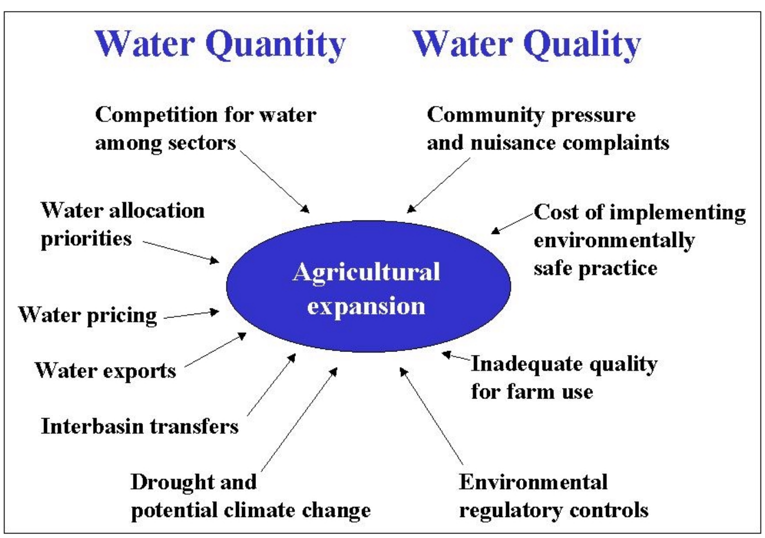
VII. Cumulative Impacts of Reduced Water Levels

Human interventions (withdrawals, consumptive uses, regulation, diversions, dredging, land use, etc.) are inherently cumulative. Although the impact of localized, small-scale activities may be difficult to quantify on an individual basis, collectively, they can significantly alter the level and flow regime and associated ecological conditions. Even modest changes induced by individual, discrete actions have incremental and other cumulative impacts on both a localized and system-wide basis (IJC, 2000).

Long-term agricultural expansion in the Great Lakes-St. Lawrence River Basin will likely be limited by water quantity issues such as increasing competition for water among sectors, water exports, water allocation priorities and climate change, as well as water quality issues (Figure 55), [Agriculture and Agri-Food Canada, 2000 (1)]. Increasing water usage and the potential for permanently lowered water levels will have significant ecological and economic impacts, not only to agricultural production. The synergy of such impacts will likely result in new water policies not previously considered.

As discussed by Farid et al, (in: CELA and GLU, 1997): "As water sources throughout the North American continent are depleted, the grand schemes that have thus far been set aside may well become more viable and the need ever more compelling".

Figure 55: Constraints on Agricultural Expansion Related to Water



Source: Agriculture and Agri-Food Canada, 2000
Recreated by: Institute for Agriculture and Trade Policy

Available data regarding cumulative impacts of reduced water levels are extremely limited. Establishing a consistent, basin-wide data collection system regarding the cumulative ecological and economic impacts of increasing water withdrawals/use is therefore vital to best inform policy and practice. Specifically, more extensive data sets and better models are needed that link hydrologic regimes with ecosystem processes and ecological interactions (Great Lakes Commission, 2002). The Great Lakes Commission's work to develop a framework for a water resources decision support system for the Great Lakes-St. Lawrence River Basin is an important step in providing data, information and the processes required to ensure timely and well-informed public policy decisions concerning the use and management of surface water and groundwater in the Great Lakes Basin (Great Lakes Commission, 2002).

Ecological Impacts

Although changes to lake levels and outflows are relatively easy to determine, the impacts of these changes are subject to interpretation. The impacts of the changes on the ecosystem as a whole, and especially on its lake and river subsystems, are not well understood. Research shows that decreasing water levels have many impacts to Great Lakes habitat, including changes to the hydroperiod (length of one wet and dry cycle), reductions to water flow variability and ecological niches, reduced biodiversity in coastal wetlands, and potential disruptions in fish breeding cycles. However, experts participating in a workshop on cumulative impacts concluded that it is difficult to quantify with any degree of precision the ecological impacts of most water withdrawals, consumptive uses, and removals (IJC, 2000).

Nestler & Long (1997), (in: Great Lakes Commission, 2001), present a hydrological analysis of historic stream data collected on the Cache River at Patterson, Arkansas, as the basis for cumulative impact analysis of riverine wetlands. Subtle, long-term changes in hydroperiod, which could collectively have major effects on wetland function, are quantified. Various types of analyses show a steady decline in the magnitude and predictability of the baseflow during low flow periods. Complementary information suggests that hydroperiod alterations are associated with increased groundwater pumping. The changes in hydroperiod identified using these methods may have the potential to explain changes in biotic communities or wetlands structure as part of comprehensive wetlands studies.

Adamus & Stockwell (1983), (in: Great Lakes Commission, 2001), review wetland functions. Cumulative impacts and social factors affecting wetland significance are discussed, and effects of various factors on wetland function are documented, including: surface area, area of watershed and drainage area, land cover, soils, climate, wetland system, vegetation form, hydroperiod, water level fluctuations, tidal range, depth, vegetation density, flow pattern, human disturbance, temperature, and biotic diversity.

Naiman & Turner (2000), (in: Great Lakes Commission, 2001), explore trends in alterations to freshwater ecosystems, discuss the ecological consequences of biophysical alterations expected to occur in the next 20-30 years, and identify some of the major scientific challenges and opportunities to effectively address the changes. Topics discussed include altered hydrological regimes, altered biogeochemical cycles, altered land use, riparian management, and relations between climate change and water resource management. The researchers focus their discussion on processes at the watershed and landscape scales that require better understanding. They conclude a basic need is the incorporation of ecological principles into aquatic resource use and management decisions.

Regarding bulk water removal, another study concluded that in conjunction with other variables such as climate change and industrial, municipal and agricultural uses, bulk water removal projects could have direct or cumulative impacts on watersheds. Impacts could include the inter-basin transfer of non-native micro-organisms and exotic species, the alteration of natural ecosystems and changes in water flows, levels and groundwater tables [Environment Canada Website (2)].

Economic Impacts

Should lower water levels continue in the future, there are numerous economic impacts that could be significant to the regional economy including losses in hydroelectric power generation, higher shipping/transportation costs, commercial navigational impacts, and losses in tourism/recreation (IJC, 2000). *See Box on next page*.

Economic Impacts from Lower Lake Levels

- ***Hydroelectric Power Generation.*** Although not nearly as severe as those projected in climate change scenarios, record low levels and flows in the 1960s caused hydropower losses of between 19 percent and 26 percent on the Niagara and St. Lawrence Rivers. A small proportion of such losses would be offset by lower heating costs, but this in turn would be offset by increases in air conditioning costs.

- ***Transportation/Navigation*.** For a typical 1,000-foot iron ore carrier, the loss of one foot of water means 3,240 tons less cargo per trip. The ship would have to make 2.5 extra trips to make up the difference over a season, costing the shipping company an estimated $121,000 per ship over the course of a season. Adaptation measures could include significant channel dredging.

- ***Tourism, Recreational Boating and Sport Fishing*.** There would likely be detrimental effects to tourism as a result of less attractive scenic views and the need to modify water intakes and waste disposal outlets. Certain boat launches would no longer be viable and some boat slips that had been deep enough for docking may no longer be accessible.

- ***Fish Populations*.** Reductions in freshwater discharges into the St. Lawrence Estuary, Gulf, and beyond, would affect fish populations and other components of the St. Lawrence and Atlantic ecosystems, resulting in both ecological and economic impacts.

Sources: IJC, 2000; Michigan Environmental Council Website

According to one study, large-scale diversions of Great Lakes water could result in significantly increased costs for shipping and hydroelectric power production (David et al, 1988). This same study, however, did not attempt to quantify the economic impact of diversions on environmental attributes (such as wetlands, wildlife, and recreation) that would be affected by changes in lake levels. Neither did the study consider the cost of physically moving large amounts of water from the Great Lakes, considered to far exceed the estimated costs to shipping and hydroelectric power production. The authors thus believe that their findings significantly understate total potential costs of diverting water from the lakes (David et al, 1988).

Synergy of Effects: As freshwater becomes less plentiful and more valuable, how might our thinking change regarding water quantity management in the Great Lakes?

As freshwater becomes more and more scarce, there may be an increased need to revise certain aspects of water policy and management in the

Great Lakes Basin. In a future environment of increasing population and decreasing water availability, policy options that may have seemed too costly or politically difficult to implement in the past may need to be reconsidered. At this critical juncture for Great Lakes water protection, difficult choices regarding domestic water policy, ecosystem protection and international trade issues are imminent.

This section will discuss some of the water management policies that are being considered or proposed for Great Lakes water resources. Issues such as integrated watershed management, water markets, water transfers, water banking, green reporting, irrigation water conservation policies and other voluntary and non-voluntary initiatives are introduced. Inclusion in this list does not necessarily imply support for these initiatives, but recognition that these alternatives are being discussed in the context of water management in the Great Lakes and elsewhere and need to be better understood in order to inform future policy decisions.

Integrated Watershed Management

Economic development is inherently linked to environmental health. The watershed is the fundamental ecological unit in protecting and conserving water resources. A consolidated, broad-based approach to watershed management that recognizes the linkages of water systems and the need to manage water within drainage basins rather than on a river-by-river or lake-by-lake basis is needed to support a sustainable economy over the long-term [Environment Canada Website (2); Kerr at al, 1998]. In Canada, provinces, territories and the federal government are adopting a watershed approach as a key principle in water policy and legislation [Environment Canada Website (2)]. In the U.S., considerable research also discusses the need for a broad-based watershed management approach (CELA and GLU, 1997; IJC, 2000; Regier and Baskerville in: Clark and Munn, Editors, 1986; U.S. Environmental Protection Agency and the Government of Canada, 1995).

Although both countries are focusing more broadly on management of the Great Lakes Basin than they have in the past, no government agency currently has the ability both to legislate and manage Great Lakes water resources according to an integrated watershed approach. Current management efforts could be greatly improved through better coordination between stakeholders, specifically governments, as has begun with Annex 2001. As discussed by Farid et al. (in: CELA and GLU, 1997), sustainable watershed planning requires a basin-wide management plan, making it necessary that the political system of each of the jurisdictions adapts to the demands of the Great Lakes ecosystem.

However, each government jurisdiction in the Great Lakes-St. Lawrence River Basin has a different management system in place to address water quantity issues. Even more significantly, some jurisdictions have very few controls over the consumption and diversion of water. Annex 2001 is attempting to resolve such issues.

Water Markets

It has been argued that, if properly implemented, water markets and water trading could theoretically lead to improved conservation through the creation of economic incentives. However, there are many serious concerns regarding the equity, feasibility and sustainability of water trading policies. Implementation issues dealing with riparian doctrine, trade implications and ecological impacts are of particular concern, as are trading boundaries. For example, trading schemes, as well as conservation schemes, are often discussed in the context of political boundaries, as opposed to the more applicable watershed boundaries. However, it is at the watershed level, not at the political/state level, that a sound water trading system functions. In order for water transfers or trade requests to be properly evaluated regarding ecological impacts, they would need to be scrutinized and implemented only at the watershed or sub-watershed level (personal communication, Sarah Miller, CELA, 2002).

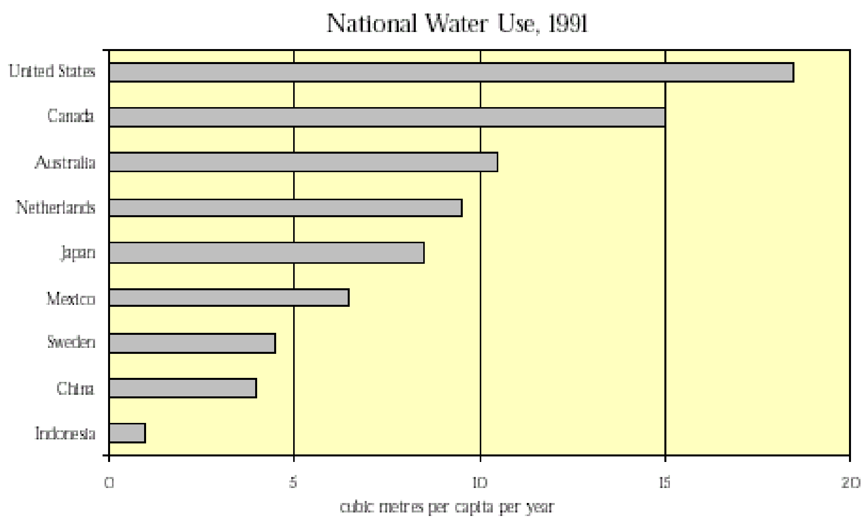
Water Transfers

Allowing the sale of water rights or temporary "leasing" of water has also been pointed to as way to potentially encourage the conservation of agricultural water by providing farmers and other water users compensation for unused water entitlements. However, such developments have so far been limited due to various factors. For most federal water projects, changes in water deliveries are subject to administrative review, and water is generally not transferred beyond the project service area. Further, laws governing water use and transfer are vested with the individual state. Since in most states, irrigators do not retain rights to water conserved through improved irrigation efficiency, there is no significant economic incentive to "save" water. Meanwhile, political concerns have focused on downstream impacts and secondary effects of reduced agricultural activity on local communities [U.S. Department of Agriculture, Economic Research Service, (2)].

In recent years, there have been some changes in water-related legislation. Statutory changes at the state level have increasingly recognized both the need to transfer water to meet new demands, and the idea of rights to water "salvaged" through conservation. Recent changes in water transfer policies may suggest a potential change in policy on transfers involving federal water supplies [U. S. Department of Agriculture, Economic Research Service (2)].

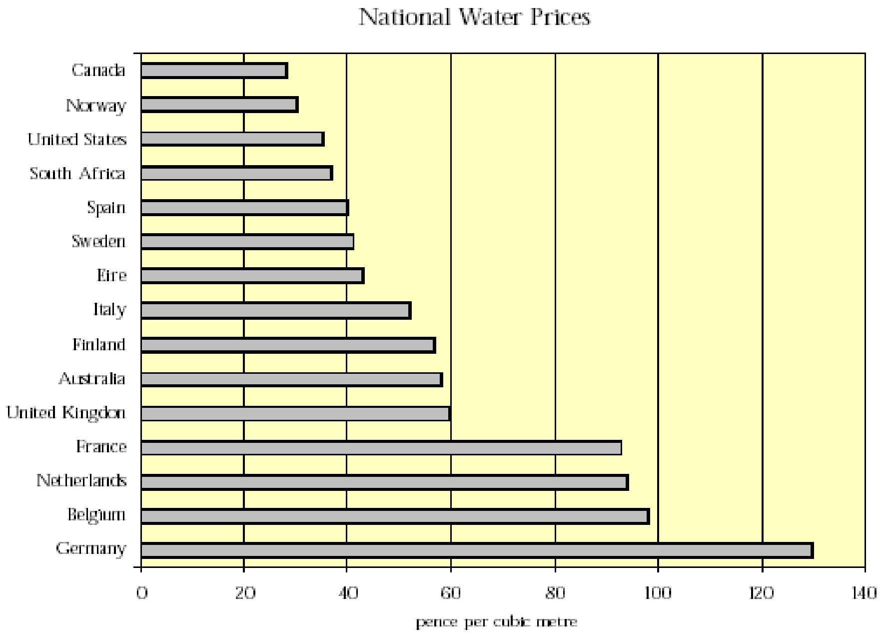
Another factor to be considered while discussing water transfers is low water pricing and costs. National water use and pricing statistics show that the U.S. and Canada lead the world in per capita water usage while at the same time maintaining some of the lowest water prices worldwide (Figures 55 and 56). With relatively low water prices, there is little conservation incentive, whereas when water users pay more of the full cost of water, improved water conservation may result, although this will also increase water scarcity issues for disadvantaged and low-income populations.

Figure 55: National Water Use, 1991



Source: CELA and GLU, 1997

Figure 56: National Water Prices, 1995



Source: CELA and GLU, 1997

Water Banking

Water banking systems are another management option sometimes considered regarding Great Lakes water resources. In this type of system, water is "borrowed" in times of need and is owed as a "loan" to be paid back in times of plenty to its place of origin. Such a system would be complex in that allowance for water borrowing would be accepted only for sustainable purposes. In addition, for a banking system to be effective, it would need to be among geographic neighbors, ideally within the same sub-watershed. Strong attention would also need to be paid regarding reversibility of such arrangements if conditions at the source were to diminish water availability or ecosystem health (personal communication, Sarah Miller, CELA, 2002).

Green Reporting

Green reporting refers to practices that increase consumer awareness of the environmental benefits of a particular product. Environmental labels, the most widely used form of green reporting, benefit both the producer and consumer, and have already been successfully used in North America and Europe. "Green" companies may maintain or enhance their market share in environmentally conscious markets (Kerr et al, 1998), and consumers are given relevant information to make purchasing decisions accordingly. For Great Lakes water conservation purposes, green reporting could provide the interested public with such environmental information as producer water usage and conservation activities to use in comparing products produced in the basin. Again, there are numerous implementation issues associated with such measures, including monitoring, reporting standardization, comparability of alternative conservation initiatives, and in terms of trade, international recognition and acceptance of such standards (Kerr et al, 1998).

There are currently several companies that have demonstrated that superior environmental performance can be consistent with strong financial performance (Kerr et al, 1998). Although debatable within the context of international trade rules, Kerr et al. (1998) argue that environmental concerns can be the basis for excluding a good or service from a country. They argue that this can happen via government mandate or regulation, including those adopted under multilateral environmental agreements, regulations aimed at protecting consumer health and safety, as well as consumer actions and boycotts on issues of environmental or social concerns. Environmental concerns can also be the basis for a company expanding its share in foreign markets through improved products, eco-labels, or environmental improvements that yield economic benefits, depending on customer awareness, interest and ability to pay. However, in discussing all such trade distinctions and options, one has to be aware of and sensitive to the concerns of citizens in the "global South" countries, who are in a disadvantaged position in these discussions.

Irrigation Water Conservation Policies

Various research has examined the effects of irrigation water policy on water use and conservation. It was found that while limited water savings can often be achieved through lower-cost efficiency gains, more significant water savings generally require reductions in consumptive use, with potential implications for producer profit [U. S. Department of Agriculture, Economic Research Service (2)]. Significant water savings are more likely to be observed through changes in irrigated land base and acreage by crop, rather than through adjustments in per-acre water applications. In addition, substitutions among crops and inputs can result in significant regional water savings. One study found that improvements in on-farm water use efficiency increased the level of regional water savings attributable to crop substitution (the production of one crop in favor of another due to environmental or economic concerns). A mix of conservation policies may help to distribute the costs of water conservation across water users and regions [U. S. Department of Agriculture, Economic Research Service(2)]. Methods to improve irrigation water conservation include drip irrigation, timed irrigation to minimize water loss through evapotranspiration, low or no till cultivation systems and cover cropping systems to preserve soil loss and enhance water retention, and crop substitution of more drought tolerant or less water intensive crops and/or varieties.

Other Voluntary and Non-Voluntary Initiatives

Water law reform may also result from a change in attitudes. For example, the issue of water quality in Canada was brought to the forefront of the public's attention when an outbreak of *E-Coli* bacteria in the municipal water supply of a small agricultural community in southwestern Ontario caused illness in thousands of people and an estimated seven deaths in the community (Sierra Club of Canada and GLU, 2000). Reforms are now underway in Ontario due to the public outcry and the exhaustive inquiry following this tragedy. Other non-voluntary initiatives may also improve conservation through creation of economic incentives, such as in the case of Ontario, where certain grants for infrastructure are given only to those municipalities with conservation programs in place (personal communication, Sarah Miller, CELA, 2002).

VIII. Perceived Gaps in Knowledge: Outlining a Research Agenda for Agriculture, Trade and Water Quantity Management in the Great Lakes Basin

Although it is projected that future cumulative impacts of increasing water usage in the Great Lakes-St. Lawrence River Basin could result in dramatic reductions of Great Lakes water levels, research regarding the relationship between agriculture and decreasing water availability has been quite limited. In the current literature, various information gaps exist regarding water quantity management, including: the need for research that differentiates between natural climatic variability, anthropogenic influences and the impacts of water management strategies to water levels; research that quantifies the cumulative impacts of increasing water use; research that bridges water quantity changes with specific ecosystem effects; improved methods to accurately measure consumptive uses; and research that better quantifies the ecological and economic impacts of water withdrawals, diversions and consumptive uses.

At a workshop organized by the Institute for Agriculture and Trade Policy entitled, "The Relationship of Agriculture, Trade, and the Environment to Surface and Groundwater Management in the Great Lakes-St. Lawrence River Basin," held in Sault Ste. Marie, Michigan (February 21-22, 2002), water quantity experts identified numerous research and data needs regarding the role of agriculture and its relationship to water quantity in the Great Lakes-St. Lawrence River Basin. Identified research needs include: 1) the need to define the current and future role of agriculture in the basin; 2) the need for multi-scale, geography-specific analyses which include both macro (watershed/region) and micro-levels (local); and 3) the need for improved data to develop alternative future agriculture, environment, trade and water quantity scenarios to better understand the implications of potential policy decisions and to improve overall management of the system.

1) The Current and Future Role of Agriculture

Understanding the current role of agriculture and its relationship to water availability is fundamental to the future of water quantity management in the Great Lakes Basin. There are various factors which may affect future agricultural production in the region (and throughout the world) that are not well understood, such as the relationship between agriculture and water availability, the environmental impacts of land use changes, specifically regarding groundwater and surface water recharge, and trade in agricultural products. Improved understanding of these issues will help us to better determine the current role of agriculture, how agriculture may change in future, and in turn, the potential impacts to water availability in the Great Lakes-St. Lawrence River Basin.

Agriculture/Water Relationship

What is the impact of agriculture to water quantity in the Great Lakes-St. Lawrence River Basin, and how may it change in future?

How do changes in agricultural systems, farm size, production and management affect water use, recharge and availability?

What types of agricultural production and management systems conserve water most efficiently and at least cost, in terms of production, ecological considerations and economic return?

How can total consumptive water use for agriculture be minimized, while maintaining (or even increasing) agricultural output?

What is the relationship between soil conservation and water conservation?

What are the limitations of current agriculture and water use data, and how can it be improved?

In order to understand the role agriculture plays in terms of impacts to water availability, the environment and economic output, additional research that quantifies various aspects of agricultural practices and water usage is necessary, specifically in regard to site-specific analysis that takes into account soil types, irrigation methods, crop selection and economic return.

Only some of these data are currently collected, and there are significant limitations associated with their accuracy and usefulness. For example, a major challenge associated with annual state-level water consumption data (collected by the Great Lakes Commission for the Great Lakes Regional Water Use Database Repository), is each jurisdiction's ability to provide complete water use data in a timely manner (Great Lakes Commission, 2000). This water use database has been operational since 1988. However, the most recent annual report available, revised in February 2000, represents 1993 water use data. The state of Michigan is still unable to submit complete water use data despite such obligations set forth in the Great Lakes Charter (Great Lakes Commission, 2000). Data collection methods are inconsistent and non-standardized, thus limiting the accuracy of both total regional estimates and state by state comparisons.

Since most data are collected at a state/macro-level, there are also limitations on the ability to answer farm-specific/micro-level questions, except on an aggregate. To improve the usefulness of the data necessary for understanding the role of agriculture and water availability in the basin, both a data needs assessment as well as a broad data utility analysis should be performed in order to understand the limitations of the current data and to determine what additional data may be needed for more informed decision-making.

Land Use Changes

Considering the dramatic changes in land use that have occurred over the last century, how has this impacted current water availability and how might further changes in land use in the Great Lakes Basin likely impact future water availability and use?

In addition to changes in the character of the landscape and water cycle of the basin, land use changes have also influenced agricultural development, practices, water availability and use. Research is needed to provide a better understanding of how such land use changes as increasing and encroaching urban areas, reductions in forest and pasture land and further concentration of livestock in the basin may impact water availability and use.

International Trade

What are the impacts of international trade agreements on our ability to control water use and exports?

The future role of agriculture in the basin is also highly influenced by trade regimes. Research that evaluates potential impacts of international trade agreements on water use and agricultural exports, evaluation of current trade agreements and their effect on agricultural production, farm vitality and consumption patterns would benefit our understanding of how the role of agriculture will likely change in the future, and how water quantity may be affected.

2) Multi-scale, Geographic Analyses (by watershed/ region; state/province; sub-watershed/local/county)

Multi-scale analyses are needed to determine the differences in agriculture and water consumption patterns geographically, to begin to understand the reasons behind the differences, and, if applicable, to apply site-specific policies to better manage water resources. For example, in some cases macro-level policy may not be as effective at the micro-level, if local conditions differ significantly from the basin-wide average (i.e. variations in land use, irrigation, conservation initiatives, soil characteristics, flow conditions, legislation, etc.)

Geographic data and mapping techniques are valuable tools in that the exact locations of certain practices, patterns and effects can be illustrated visually, at multiple scales. By overlaying various geographic datasets in map format, one can better understand the spatial relationships between the data layers, such as the relationships between agriculture, water consumption patterns and availability, land use, demographic trends, climate change and ecological trends, at the watershed, state/province, or local level. Further analysis can then be performed to understand the likely reasons behind the patterns, and to consider whether alternative management strategies can successfully be applied.

Macro-level/Basin-wide

Where are the predominant geographic differences in agriculture, water consumption patterns and ecological impacts at the watershed/regional level vs. state/province vs. the sub-watershed/local level?

In comparing those regions of greatest and least water use, what can be learned about the policies, legislation, agricultural practices and conservation strategies of each location regarding total water consumption? Can successful policies used in some regions successfully be modeled in other regions?

Water Consumption/Costs by Sector

What are the geographic trends in water consumption and costs by sector? (i.e. agriculture vs. municipal vs. industrial water use).

Do the trends differ at differing scales? If so, why (i.e. differences in land use, irrigation, conservation initiatives, soil characteristics, flow conditions, legislation)?

How may high consumption patterns in certain areas be improved?

Land Use vs. Water Quantity

Agricultural land conversion: What has been the impact of the conversion of agricultural land to other uses on water levels basin-wide and in nearby communities?

Borderline/outlying communities: What are the impacts of growing borderline urban centers on the region's agriculture and water use trends?

Rural/municipal conversion: Are water supplies for rural or borderline communities coming from rural sources, or are there increasing cases where water is being supplied from more distant urban centers? Has there been any movement away from groundwater sources to surface water sources?

Environmental status: To what extent has agricultural land conversion impacted environmental/ecosystem health? How can these geographic differences be explained?

Demographic Trends

To what extent has a growing population in the basin impacted land use and agricultural areas (in terms of settlement patterns and agricultural land conversion)? Where are these changes occurring?

Climate Change Impacts

What is the geographic differentiation of climate change impacts in the basin?

How will agriculture in the region be altered by the predicted increase in temperatures and climatic variability? (Long-term trends in average temperatures vs. location and specific crops grown).

How and where will the predicted reduced water availability in soil, rivers, and lakes impact future irrigation needs?

Ecological Impacts

<u>Habitat loss</u>*: What is the geographic relationship between land use and habitat loss to changes in inflows to lakes? Where is most habitat loss occurring and why? What are the species that are endangered, threatened, or completely lost to the system? How sensitive are they to changes in hydroperiod?*

Can habitat loss be explained in terms of water consumption by sector, and if so, which sector has the most influence?

<u>Groundwater/tributary impacts</u>*: What is the geographic relationship between total basin and sub-basin withdrawals and consumptive use patterns to recharge rates, tributary dynamics and related ecology?*

3) Scenario Building

Finally, research that attempts to answer broad, policy-relevant questions regarding the future of agriculture, trade, the environment and water availability in the Great Lakes Basin is necessary. In order to build future scenarios, accurate, comprehensive data on the key drivers for change is critical. By identifying the drivers for change, recognizing data limitations, considering geographic differences, and modifying the drivers based on future expectations, conservation and management goals, we can develop prospective agriculture/trade/environment/water scenarios that will help us to determine the best options for improving water quantity management in the Great Lakes Basin.

Determining the Drivers for Future Change: Water Use/Water Policy, Population Growth, Land Use, Climate Change Science

Water Use/Water Policy

As discussed earlier, data concerning water use by sector, groundwater vs. surface water use, a viable comprehensive water budget, water valuation and the role of economic incentives in conservation strategies are all necessary in understanding how meaningful reductions in water consumption and increased water efficiency may be achieved. For example, what types of conservation strategies (regulatory vs. market-based/economic incentives) could result in the most meaningful improvements in efficiency and reductions in agricultural water use? How could pricing schemes impact water consumption (positively and negatively)? How much water is currently exported in non-bulk form (food products, beer/processed beverages, and bottled water)? Could water exports ever be deemed sustainable? Further research is needed to provide answers to these and other questions about future water use.

Population Growth

Data regarding projected population growth for the Great Lakes-St. Lawrence River Basin in the coming century are necessary to estimate future water needs at the local and regional level, as well as basin-wide. For example, how important a role will in-migration play in terms of the increasing growth of "environmental refugees" relocating from regions suffering from water-scarcity or other environmental crises? Such issues are critical in terms of projected total water consumption, impacts to food production and future water availability.

Land Use

Data regarding potential land use changes, specifically as related to population growth, are necessary to interpret how the conversion of additional agricultural or undeveloped land to urban or other uses could impact water availability and the environment.

Climate Change Science

Data regarding the direct and indirect impacts of climate change to agriculture are needed to increase our understanding of the potential long-term impacts to food production and water availability. More information is needed about projected direct impacts to agriculture such as the likely combination of increased storm events with increasing drought conditions, increasing temperatures, increasing pathogens and decreasing recharge of water in soil, lakes and rivers. More information is also needed regarding projected indirect impacts to agriculture such as extended growing seasons (likely resulting in different crops grown), changing water requirements, and the exacerbation of existing water quantity issues from decreasing supply/lower flow conditions and increasing water/irrigation needs. Improved understanding is also needed regarding identifying what steps may still be taken to mitigate the degree of climate change by altering present agricultural and other anthropogenic practices.

IX. Recommendations

Agriculture dominates land use and uses more water than any other consumptive use in the Great Lakes Basin. The use of considerable amounts of freshwater for irrigation and livestock production, more than half of which comes from groundwater sources, is weakening nature's ability to replenish the lakes, placing both ecological and human communities at risk. Population growth, land use changes, climate change, the threat of water exports and diversions, and the potential impacts of international trade agreements together pose enormous threats to Great Lakes water resources and ecological integrity. However, as discussed earlier, despite the integral relationship between agriculture and ecosystem health, not enough is currently known regarding the impacts of agriculture on water availability in the Great Lakes Basin. Considerable research is necessary, and until key questions regarding the relationship between food production and water quantity can be answered, strong conservation strategies and a precautionary approach to water quantity management are vital to protecting and improving the Great Lakes for years to come. Recommendations for improved overall management of the Great Lakes ecosystem include:

1) Developing an integrated basin-wide water quantity management strategy based on sound conservation principles (such as those outlined in Annex 2001), that accounts for the role of agriculture to water availability and use, and is coordinated by an effective and equitable trans-national body;
2) Making water quantity issues a priority for agricultural policy and research;
3) Implementing a targeted research agenda for agriculture, trade and water quantity management in the basin;
4) Increasing Basin-wide stakeholder dialogues on water availability, needs and conservation and equity in governance issues;
5) Improving the quality, monitoring, availability and presentation of accumulated data;
6) Improving public outreach, communication and education regarding the environmental integrity of the Great Lakes, water use, availability and management.

1) Integrated Basin-wide Water Quantity Management

A consolidated, basin-wide approach to water quantity management is vital to achieving water conservation goals and maintaining a sustainable ecosystem over the long-term. Although both the U.S. and Canada are focusing more broadly on management of the Great Lakes Basin than they have in the past, no government agency currently has the ability both to legislate and manage Great Lakes water resources according to an integrated watershed approach (CELA and GLU, 1997).

Implementing an integrated basin-wide approach to management is necessary not only for water quantity, but for the good of the entire Great Lakes ecosystem. Sustainable watershed planning requires a basin-wide management plan in order to understand current conditions, to coordinate and develop necessary procedures and governance institutions for successful implementation and to measure progress. For this to occur, it is necessary that the political system of each of the jurisdictions adapts to the demands of the Great Lakes ecosystem (CELA and GLU, 1997). Considerable efforts should be directed toward identifying specific management and conservation goals and, to the extent possible, coordinating policy options and management systems in both the U.S. and Canada regarding water quantity issues.

Identifying Specific Management and Conservation Goals

Total water consumption/agricultural water consumption goals, ecosystem needs, conservation strategies (types, measurement, monitoring), standardization of consumptive use measurement methods, stakeholder participation and timeframe must all be clearly defined before can we look toward establishing the applicable institutions and legislation necessary to achieve these goals.

Coordinating Water Policy Options and Management Systems

Legislation, regulatory controls, water use monitoring, improved conservation initiatives and research must all be coordinated such that the implications of potential water policy options will ensure an environmentally sound water policy as part of a basin-wide management strategy. In this context, further work needs to be done to determine what type of entity could be given the powers to effectively provide this coordination. More focus should also be given to evaluating current international trade agreements and their potential water quantity. Great Lakes water managers will increasingly need to analyze data from outside the region in order to fully understand water trends, continentally and globally, that might, for example, bring requests for Great Lakes water exports.

2) Water Quantity as an Agricultural Policy and Research Priority

Water quantity issues also need to be made a policy and research priority for agriculture in general. In recent years, policymakers have recognized some of the adverse agricultural environmental impacts, such as nutrient leaching and sediment runoff. As a result of this increased awareness and changes in agricultural policy, some reductions in nutrient loss and runoff have occurred. Water quantity issues have to be prioritized in a similar manner. Research needs to be conducted that investigates agriculture's overall contribution to water availability, use and management. The results of this research should inform potential policy changes in the region in order to promote increased agricultural water efficiency. In considering policy, voluntary, market-based and regulatory approaches to managing overall water use, irrigation and drainage need to be evaluated for effectiveness, ease of introduction and implementation and other such factors.

3) Increased and Improved Research

Beyond the priorities outlined above in section VIII, additional research is also needed to bridge water quantity issues with both ecosystem effects and policy, specifically as related to cumulative impacts of reduced water availability. In the literature, the primary concerns of reduced water levels are economic (shipping/navigation, reduced hydropower, recreation, etc). Research examining the relationship between water levels and measurable ecosystem impacts should be expanded, specifically, more extensive datasets and better models are needed that link hydrologic regimes with ecosystem processes and ecological interactions (For more information regarding ecological impacts of water use, see Great Lakes Commission, 2002: *Ecological Impacts of Water Use and Changes in Levels and Flows: a Literature Review*).

4) Improving Stakeholder Involvement and Equity in Dialogues and Governance

There is a need to improve equity between the varied and sometimes competing interests in the region (i.e. international interests vs. state/tribal interests vs. urban/rural interests vs. upstream/downstream interests). Questions of equity in terms of gender and race also need to be addressed, as well as corresponding legislation among stakeholder groups. Case studies of participatory processes and institutions should be examined as potential governance models (Hemmati, 2001), such as the European Union's Water Framework Directive, which focuses on sustainable use and stakeholder participation (Europa: The European Union Online, 2002). Such participatory governance models represent an opportunity for improvement in Great Lakes water management efforts. One principal example is the need for modification of Annex 2001, which currently excludes such key stakeholders as the IJC, U.S. and Canadian federal governments and Tribal Nations in its governance objectives. Considering the importance of stakeholder buy-in and involvement, such integral players in water quantity management in the basin need to be better engaged in the decision-making process regarding regional water conservation and management.

Representation of agricultural interests has also been limited in the discussions about the future of the basin. It is imperative not only that agricultural concerns and contributions are included in the ongoing dialogue about Great Lakes water quantity management, but also that the full spectrum of farm interests and organizations are involved, in order to provide a more genuine picture of agriculture in the basin and to increase overall agricultural stakeholder acceptance of the process. Considering the importance of stakeholder buy-in and involvement, such integral players in the basin need to be better engaged in the decision-making process regarding water conservation and management.

5) Improved Data Quality, Monitoring, Availability and Presentation

Data Quality

Considerable effort should be dedicated to improving the quality of Great Lakes water and environmental data. Great Lakes States and Provinces have made some progress in developing a uniform and consistent methodology for collecting and reporting water use data; however, additional work is needed. A uniform methodology is lacking, which some provisions of Annex 2001 are intended to address. Better estimation techniques are also necessary to improve the quality of consumptive water use data and improve current coefficient estimates.

Monitoring

Consideration should be given to integrating U.S. and Canadian water level monitoring efforts in terms of standardization of measurement and collection methods, equipment, data format (GIS), timescale, availability, etc. Such coordination would be beneficial both in terms of cost savings as well as reducing potentially duplicative efforts. Ecosystem monitoring efforts should also be greatly expanded.

Availability

Great Lakes water quantity data and information also needs to be more accessible, preferably from one bi-national, centralized website. Currently, all Great Lakes environmental data are housed by multiple agencies and organizations in the U.S. and Canada. Instead, one bi-national coordinating body should act as a data clearinghouse/data repository for both U.S. and Canadian Great Lakes data and information. Technical management of databases could be assigned to a university, which could fuel additional research and interest in Great Lakes environmental issues. It would greatly benefit policy makers, researchers and the public if all or most of the ongoing studies and analyses, data, map products, and current future management scenarios could be found in one location.

Presentation

Expanded utilization of geographic information systems (GIS) would be useful both for improved decision-making as well as a persuasive communication tool. GIS could be used to improve not only the capacity to analyze current and future water policy alternatives, water consumption patterns, land use changes, agricultural trends, conservation strategies and cumulative impacts at multiple scales, but could also be used to improve public understanding of the geography of Great Lakes environmental issues.

In addition, based on current and future research, the creation of a geographically-based Great Lakes Water Atlas would greatly assist efforts to better understand, communicate, and balance water needs and use. Modeled on the *Water Resources Atlas of Florida* (Florida State University, 1984), such a product could be an invaluable tool for providing a comprehensive assessment of the threats to Great Lakes water quantity, surface and groundwater use, water laws and policy, water management, human impacts to the system, conservation initiatives, future scenarios, current research objectives and options for improved management. Most of this information could be illustrated using maps, images and graphics, in addition to tables and written information.

6) Increased Public Outreach, Communication and Education

Efforts to increase public understanding of Great Lakes water quantity issues and environmental concerns through improved outreach and communication are desperately needed. Raising general awareness of the Great Lakes and highlighting the importance of this enormous ecosystem as an invaluable natural resource - regionally, nationally and worldwide - would improve our ability to protect and manage it effectively. The threat to the Great Lakes needs to be given national attention in order to raise public awareness, perhaps in a similar manner as the campaign for the threatened Florida Everglades. Educational materials should emphasize the ecological and economic importance of the ecosystem as well as explain policy issues and legislation, ongoing strategies for improved water quantity management, conservation initiatives and options for public involvement. Such materials should be directed not only to the general public, but also to the various stakeholders such as farmers/food producers, power producers, industry, Native American Tribes, policy makers, researchers and students.

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XI. Glossary of Terms

Agricultural water use: can be divided between irrigation and livestock. Irrigation includes all water applied to farm or horticultural crops; livestock incorporates water used for livestock, dairies, feedlots, fish farms, and other farm needs.

Boundary waters: shared waters with the U.S. - Canada border running through them. The principal boundary waters are the Great Lakes.

Bulk water removal: the removal and transfer of water out of its basin of origin by man-made diversions (e.g., canals), tanker ships or trucks, and pipelines. Such removals have the potential, directly or cumulatively, to harm the health of a drainage basin.

Consumptive use: that portion of water withdrawn or withheld from the Great Lakes-St. Lawrence River Basin and assumed to be lost or otherwise not returned to the basin due to evaporation, incorporation into products, or other processes.

Commercial water uses: those which take place in office buildings, hotels, restaurants, civilian and military institutions, public and private golf courses, and other non-industrial commercial facilities.

Diversion: a transfer of water from the Great Lakes-St. Lawrence River Basin into another watershed, or from the watershed of one of the Great Lakes into that of another.

Domestic water use: includes everyday uses that take place in residential homes.

Dredging: the process of deepening a harbor, canal, river, etc. often to maintain or improve navigation.

Great Lakes region: the geographic region comprised of the Great Lakes States and Provinces.

Great Lakes States and Provinces: the states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, and Wisconsin, the Commonwealth of Pennsylvania, and the provinces of Ontario and Québec.

Great Lakes-St. Lawrence River Basin: the watershed of the Great Lakes and the St. Lawrence River, upstream from Trois Rivières, Québec.

Great Lakes-St. Lawrence River Basin ecosystem: the interacting components of air, land, water and living organisms, including humankind, within the basin.

Great Lakes-St. Lawrence River Basin water resources: the Great Lakes and all streams, rivers, lakes, connecting channels, and other bodies of water, including tributary groundwater, within the basin.

Hydrologic cycle: the natural cycle of water on earth, including precipitation as rain and snow, runoff from land, storage in lakes, streams, and oceans, and evaporation and transpiration (from plants) in the atmosphere.

Industrial water uses: include cooling in factories and washing and rinsing in manufacturing processes, estimated to be 8 percent of total freshwater use for all offstream categories. (Some of the major water-use industries include mining, steel, paper and associated products, and chemicals and associated products).

Instream water uses: uses which do not require a diversion or withdrawal from the surface or ground water sources, such as:

- Water quality and habitat improvement
- Recreation
- Navigation
- Fish propagation
- Hydroelectric power production

Inter-basin diversion: a transfer of water from the Great Lakes-St. Lawrence River Basin into another watershed.

Non-consumptive use: refers to any water withdrawal or instream use in which virtually all of the water is returned to the system.

Offstream water use: involves the withdrawal or diversion of water from a surface or ground water source for:

- Domestic and residential uses
- Industrial uses
- Agricultural uses
- Energy development uses

Removals: waters that are conveyed outside their basin of origin by any means, for example, diversion, other types of removals such as removal by marine tanker, bottled water, or ballast water.

Return Flow: the difference between the volume of water withdrawn and that consumed.

Riparian states/provinces: those states or provinces bordering a river.

Seiche: an oscillation in water level from one end of a lake to another due to rapid changes in winds and atmospheric pressure.

Watershed: a land area draining into a common watercourse or waterbody. Often called a catchment area, a drainage basin or a river basin. Examples of major watersheds in Canada include Atlantic (including the Great Lakes and St. Lawrence River), Hudson Bay, Pacific and Arctic. For example, the Great Lakes Drainage Basin is not restricted to the lakes themselves, but includes the many rivers and their tributaries that ultimately flow into the lakes.

Wind set-up: a local rise in water levels caused by winds pushing water to one side of a lake.

Withdrawal: water extracted from surface or groundwater sources.

XII. Bibliography

See: *URL Source References* for source links for all figures, where available.

Adams, D. B., Editor, 1999. Quinn, F. H. *The Potential Impacts of Climate Change on Great Lakes Water Resources, a Review.* Specialty Conference on Potential Consequences of Climate Variability and Change to Water Resources on the United States, Atlanta, GA, May 10-12, 1999. American Water Resources Association, pp. 311-315.

Agriculture and Agri-Food Canada, 2001. *Soil Landscapes of Canada*. http://sis.agr.gc.ca/cansis/nsdb/slc/intro.html

Agriculture and Agri-Food Canada, 2000.
The Health of Our Water: Toward Sustainable Agriculture in Canada
Publication 2020/E.
1) *Complete Report*: http://res2.agr.gc.ca/research-recherche/science/Healthy_Water/epdf.html
2) *Surface water:*
http://res2.agr.ca/research-recherche/science/Healthy_Water/e02b2.html
3) *Legislation and Regulation of Water Use:*
http://res2.agr.ca/research-recherche/science/Healthy_Water/e03d.html

Agriculture and Agri-Food Canada, 1998.
Agri-food Policy in Canada, K. Ash
http://www.agr.gc.ca/policy/epad/english/pubs/adhoc/98040/report.pdf

Agri-Food Trade Service, Statistics Canada, 2001. *Trade Statistics: Canadian Export Trade Highlights, 1998-2000*.
http://canadaonline.about.com/gi/dynamic/offsite.htm?site=http%3A%2F%2Fats.agr.ca%2Fpublic%2Fhome-e.htm

Alberta Agriculture, Food and Rural Development Website.
Farm Water Supply Requirements:
http://www.agric.gov.ab.ca/agdex/700/716c01.html

Aral Sea Homepage: http://www.dfd.dlr.de/app/land/aralsee/

Barlow, M., 1999. *Blue Gold: The Global Water Crisis and the Commodification of the World's Water Supply*. A Special Report Issued by the International Forum on Globalization (IFG).

Bennett, L. L., Issue Editor, January 2001. Universities Council on Water Resources (UCOWR). Issue No. 118: Complexities with Trans-boundary

Water Resource Management- Progress and Stumbling Blocks. Anderson, T.L. and C. J. Landry. "*Exporting Water to the World*". http://www.uwin.siu.edu/ucowr/updates/pdf/V118_A8.pdf

Bowman, L., 2001. "Study: Half of Lakes in Peril", Scripps Howard News Service. Detroit News, November 12, 2001. http://www.detnews.com/2001/nation/0111/12/a05-341695.htm

Canadian Environmental Law Association and Great Lakes United (CELA and GLU), 1997. Farid, C., J. Jackson and K. Clark. *The Fate of the Great Lakes: Sustaining or Draining the Sweetwater Seas*? http://www.glu.org/publications/fate%20report/swtfrpt.pdf

Canadian Hydrographic Service, (Central Arctic Region), 2000. "*Fluctuations in Lake Levels*". http://chswww.bur.dfo.ca/danp/fluctuations_e.html

Clark, W.C. and R.E. Munn, Editors, 1986. *Sustainable Development of the Biosphere*. Regier, H.A. and G.L. Baskerville, Chapter 3: "*Sustainable Redevelopment of Regional Ecosystems Degraded by Exploitive Development*". Cambridge University Press.

Commissioner of the Environment and Sustainable Development of the Auditor General of Canada, 2001. *2001 Report*. http://www.oag-bvg.gc.ca/domino/cesd_cedd.nsf/html/menu3_e.html

Council of Great Lakes Governors Website. http://www.cglg.org/pub/charter/

Cuthbert, D., 1999. Great Lakes Issue Paper: "*Water Quantity*". Environment Canada, Great Lakes 2000 Program. http://www.on.ec.gc.ca/glimr/glrenewal/pdf/water_quantity.pdf

David, M., S. Rosenthal, E. Loucks, E. Joeres and K. Potter, June, 1988. (Tom Sinclair, Editor). *Diversion of Great Lakes Water Part 2: Economic Impacts*. IES Report 131, UW Sea Grant Publication No. WIS-SG-87-247. Institute for Environmental Studies, University of Wisconsin, in cooperation with the University of Wisconsin Sea Grant Institute.

Environment Canada Website: http://www.ec.gc.ca/water/index.htm
1) *Weather, Climate and Water Levels*:
http://www.on.ec.gc.ca/glimr/water-e.html
2) *Background information on Bulk Water Removals and Water Export*:

http://www.ec.gc.ca/press/bulk_water_b_e.htm
3) *Water: the Great Lakes*
http://www.ec.gc.ca/water/en/info/pubs/primer/e_prim09.htm
4) *Water Use*: http://www.ec.gc.ca/water/en/manage/use/e_use.htm

Environmental Central Website.
1) *Types of Irrigation Systems*:
http://ec.chias.org/ref/item.page?entry_id=459&time=1031931886
http://ec.chias.org/ref/item.page?entry_id=460&time=1032297013
2) *Water Efficiency of Different Irrigation Systems*:
http://ec.chias.org/ref/item.page?entry_id=439
3) *Why Does the Efficiency of an Irrigation System Vary So Much?*
http://ec.chias.org/ref/item.page?entry_id=465&time=1031931339)
Environmental Systems Research Institute (ESRI). Data and maps included with ArcView 3.2 GIS software on CD-ROM (1998).

Europa: The European Union Online, 2002. "Introduction into the New EU Water Framework Directive".
http://europa.eu.int/comm/environment/water/water-framework/overview.html

Florida State University, 1984. Fernald, E. and D. Patton, Editors. *Water Resources Atlas of Florida*.

Food and Agriculture (FAO) Website. *Water to Feed the World: Perspectives for the Future*
http://www.fao.org/news/2000/000306-e.htm

Governments of Canada and the United States, 2001. *State of the Great Lakes: 2001, Fourth Biennial Report*.
http://www.binational.net/sogl2001/download.html

Great Lakes Commission (GLC), June 13, 2002. Limno-Tech, Inc. and M. Slivitzky.
Ecological Impacts of Water Use and Changes in Levels and Flows: A Literature Review.
http://www.glc.org/waterquantity/wrmdss/Final_Review.pdf

Great Lakes Commission (GLC), October, 2001. M. Slivitzky. *A Literature Review on Cumulative Ecological Impacts of Water Use and Changes in Levels and Flows*.

Great Lakes Commission (GLC), 2000. *Annual Report of the Great Lakes Regional Water Use Data Base Repository* (representing 1993 water use data). Prepared by the Great Lakes Commission for the Water Resources Management Committee, Council of Great Lakes Governors, July 1998. Revised, February, 2000.

Great Lakes Commission (GLC), 1998. "*Great Lakes Commission Says "No" to Water Export*." GLC Announce, October 28, 1998. http://www.glc.org/announce/98/export.htm

Great Lakes Commission (GLC), 1996. *An Agricultural Profile of the Great Lakes Basin: Characteristics and Trends in Production, Land-Use and Environmental Impacts*. Prepared by the Agricultural Profile Project Team (Ann Arbor, MI). Crane, T. R. "*Irrigation and Great Lakes Basin Agriculture*"; Maynard, L.A. "*Habitat and Biodiversity Issues and Agriculture in the Great Lakes Basin*"; Thorpe, S. "*Economic and Production Dimensions of Great Lakes Agriculture*".

Great Lakes Commission (GLC), June 1995. *Annual Report of the Great Lakes Regional Water Use Data Repository*, Ann Arbor MI.

Great Lakes Commission (GLC), Advisor, March/April 1997. *Rising Lake Levels, Rising Concern*: http://www.glc.org/docs/advisor/97/v10n2cov.html

Great Lakes Environmental Library, Current Articles, 2002.
1) *Proposed Regulations Would Protect Canadian Side of Great Lakes from Bulk Water Removals.* July 26, 2002.
http://www.greatlakesdirectory.org/on/072602_water_export.htm
2) *Earth will Expire by 2050*. July 7, 2002. Townsend, M. and J. Burke.
http://www.greatlakesdirectory.org/zarticles/070702_freshwater.htm
3) *New Study Says Climate Change Is Increasing Environmental Disease*. June 26, 2002. BBC.
http://www.greatlakesdirectory.org/zarticles/0626_climate_change_great_lakes.htm

Great Lakes Environmental Research Lab (GLERL)/National Oceanic and Atmospheric Administration (NOAA) Website. *Great Lakes Water Levels*: http://www.glerl.noaa.gov/pubs/brochures/wlevels/wlevels.pdf

Great Lakes Information Network (GLIN) Website: http://www.great-lakes.net

Great Lakes Net Website: http://www.great-lakes.net/teach/envt/levels/lev_1.html

Great Lakes Protection Fund Website:
http://www.glpf.org/Annex%20rfp.htm

Great Lakes Research Review, February, 1998. Mills, E., S. Hall, and N. Pauliukonis. *Exotic Species in the Laurentian Great Lakes: From Science to Policy*. Great Lakes Exotic Species II, Volume 3, No. 2.

Great Lakes-St. Lawrence Seaway System Website. Great Lakes Waterways Management Forum, Ninth Coast Guard District.
1) *The Great Lakes: A Waterways Management Challenge*:
http://www.greatlakes-seaway.com/en/pdf/waterwaymanagement.pdf
2) *2001 Tonnage Information: Montreal/Lake Ontario Section*:
http://www.greatlakes-seaway.com/en/news/tonnage2001.html
3) *The St. Lawrence Seaway Traffic Report: 2000 Navigation Season*
http://www.greatlakes-seaway.org/en/pdf/traffic_report_2000.pdf
4) *2001 and 2002 Tonnage Information*:
http://www.greatlakes-seaway.com/en/news/tonnage_info.html

Great Lakes 2000 Program, February 15-19, 1999. Workshop Summary: Planning the Next Phase. Issue Workshops.
1) "*Land Use*". Environment Canada.
http://www.on.ec.gc.ca/glimr/glrenewal/pdf/wksp_landuse.pdf
2) "*Water Quantity*". Environment Canada.
http://www.on.ec.gc.ca/glimr/glrenewal/pdf/wksp_wquantity.pdf

Great Lakes United (GLU), Action Alert, August 15, 2002. *Stop the Great Lakes Navigation Study*: http://www.glu.org

Great Lakes United (GLU), Sustainable Waters Watch #9, February 8, 2002. *Governors/Premiers Pledge Diversion Protection This Year*.
http://www.greatlakesdirectory./org//zarticles/28waterdiversion.htm

Great Lakes United (GLU) Website: http://www.glu.org

Great Lakes Water Levels Home Page (U.S. Army Corps of Engineers).
1) *Current Month's Levels in Meters* (August, 2002):
http://huron.lre.usace.army.mil/levels/lev85sm.html
2) *Great Lakes Water Levels Improving Due to Near Average Snow Water Equivalent*:
http://huron.lre.usace.army.mil/levels/swe-news-2002.pdf

Gunderson, L., C.S. Holling and S.S. Light, Editors, 1995. *Barriers and Bridges to the Renewal of Ecosystems and Institutions.* Francis, G.R. and H. A. Regier, Chapter 6: "*Barriers and Bridges to the Restoration of the Great*

Lakes Basin Ecosystem". Columbia University Press. New York.

Harker, D. B., 1999. *Water Quantity and Quality Issues in Canada: Agriculture and the Nation's Private Lands.* Presented at: "The State of North America's Private Land", Soil and Water Conservation Society (SWCS), Chicago, Illinois, January 19-21, 1999. A Prairie Farm Rehabilitation Administration Publication.
http://www.agr.ca/pfra/pub/swcsfnl.htm

Hemmati, M. 2001. *Multi-Stakeholder Processes for Governance and Sustainability - Beyond Deadlock and Conflict*. Chapter 6: "The Practice: Examples of Multi-stakeholder Processes". Earthscan, London.
http://www.earthsummit2002.org/msp/book/chap6.pdf

Institut de la Statistique du Québec, Statistique Canada (July, 2002).
1) www.stat.gouv.qc.ca/donstat/agricult/general/bf9be100.htm
2) www.stat.gouv.qc.ca/donstat/agricult/culture/culture/am110001.htm
3) www.stat.gouv.qc.ca/donstat/agricult/general/aa500120.htm
4) www.stat.gouv.qc.ca/donstat/agricult/general/aa500121.htm
5) Field Crops: acreage planted, yield per hectare and production, by administrative region
www.stat.gouv.qc.ca/donstat/econm_finnc/filr_bioal/culture/culture/index_an.htm
6) Revised estimate of corn (grain) acreages and production, by agricultural region, 1991-1997:
www.stat.gouv.qc.ca/donstat/econm_finnc/filr_bioal/culture/culture/am116re2.htm
7) Field Crops: acreage planted, yield per hectare and production, 1998
www.stat.gouv.qc.ca/donstat/econm_finnc/filr_bioal/culture/culture/am110008.htm
8) Field Crops: acreage planted, yield per hectare and production, 2001
www.stat.gouv.qc.ca/donstat/econm_finnc/filr_bioal/culture/culture/am110001.htm
9) Revised estimate of soybean acreages and production, by agricultural region, 1991-1997:
www.stat.gouv.qc.ca/donstat/econm_finnc/filr_bioal/culture/culture/am119re2.htm
10) Cattle inventory by administrative region, 1991-1996
http://www.stat.gouv.qc.ca/donstat/econm_finnc/filr_bioal/elevage/boeuf/ab110re6.htm
11) Hogs/Pigs inventory by administrative region, 1991-1996
www.stat.gouv.qc.ca/donstat/econm_finnc/filr_bioal/elevage/porc/ac110re6.htm

Institute for Agriculture and Trade Policy (IATP), December 1999. Muller, M. and R. Levins. *Feeding the World? The Upper Mississippi River Navigation Project*.

International Commission on Irrigation and Drainage Website: http://www.icid.org/cp_canada.html

International Joint Commission (IJC), 2001. *Draft Plan of Study for Review of the Regulation of Outflows from Lake Superior*. Prepared for the International Joint Commission by the Upper Great Lakes Plan of Study Team.
http://huron.lre.usace.army.mil/ijc/uglpos/pos_draft.pdf

International Joint Commission (IJC), 2000. *Protection of the Waters of the Great Lakes:*
Final Report to the Governments of Canada and the United States.
http://www.ijc.org/boards/cde/finalreport/finalreport.html

International Joint Commission (IJC), 1993. *Report on Methods of Alleviating the Adverse Consequences of Fluctuating Water Levels in the Great Lakes-St. Lawrence River Basin. A Report to the Governments of Canada and the United States*.

International Joint Commission (IJC) Website: http://www.ijc.org/ijcweb-e.html

Kerr, R., A. Cosbey, and R. Yachnin, 1998. *Beyond Regulation: Exporters and Voluntary Environmental Measures*. International Institute for Sustainable Development (Winnipeg, Manitoba).

Lee, D. H., 1999. *Institutional and Technical Barriers to Risk-Based Water Resources Management: A Case Study*. Journal of Water Resources Planning and Management. July/August, 1999: 186-193.

Michigan Environmental Council Website. *Water Diversion Fact Sheet*.
http://www.mecprotects.org/Protect_Water/diversion.htm

Miller, Sarah. Coordinator, Canadian Environmental Law Association. June 17, 2002. Personal communication.

Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001.
1) *Information and Resources*:
http://www.gov.on.ca/OMAFRA/english/infores.html
2) *Provincial Share of Canadian Total Farm Cash Receipts by Commodity,*

2001: http://www.gov.on.ca/OMAFRA/english/stats/finance/provshare.html
3) *Farm Cash Receipts, 2001:*
http://www.gov.on.ca/OMAFRA/english/stats/finance/farmcashreceipts.html
4) *Number of Pigs on Farms, July, 1986 to July, 2002*:
http://www.gov.on.ca/OMAFRA/english/stats/livestock/pigs.html
5) *Number of Cattle on Farms, July 1986 to July 2002:*
http://www.gov.on.ca/OMAFRA/english/stats/livestock/cattle.html
6) *Field Crop Statistics*:
http://www.gov.on.ca/OMAFRA/english/stats/crops/
7) *Ontario Agri-food Trade*:
http://www.gov.on.ca/OMAFRA/english/stats/trade/agrifoodtrade.html
8) *Ontario Agri-food Trade by Commodity Group, 2000*
http://www.gov.on.ca/OMAFRA/english/stats/trade/commod00.html

Ministry of Agriculture and Food, Statistics Canada, Census of Agriculture
1) *Number and Area of Census Farms, Canada and the Provinces, 1991, 1996 and 2001*:
http://www.gov.on.ca/OMAFRA/english/stats/census/number.html
2) *Farm Cash Receipts*:
http://www.statcan.ca/english/Pgdb/Economy/Primary/prim06.htm
3) *Ontario Farm Data, 1991, 1996 and 2001 Census of Agriculture:*
http://www.gov.on.ca/OMAFRA/english/stats/census/summary.html

Moulton, R. J. and D. R. Cuthbert, 2000. *Cumulative Impacts/Risk Assessment of Water Removal or Loss from the Great Lakes-St. Lawrence River System.* Canadian Water Resources Journal, v.25, no. 2, Summer, 2000.

National Farmers Union Website. http://www.nfu.ca

National Farmers Union, 2001. *Canadian Policy and the Farm Crisis*

National Geographic, 2002. F. Montaigne. *Water Pressure*. Volume 202, No. 3, September, 2002. Washington, D.C.

National Wildlife Federation (NWF) and Michigan Land Use Institute (MLUI), September, 2002. *Annex 2001 Fact Sheet* (Draft Release).

New York State Department of Environmental Conservation Website.
http://www.dec.state.ny.us/website/greatlakes/annexbackground.html

New York Times, August, 2002. Special Series: *Running Dry*. Part One: *In Race to Tap the Euphrates, the Upper Hand Is Upstream*. Jehl, D., August 25, 2002.
http://www.nytimes.com

Northeast-Midwest Institute Website.
1) *Great Lakes Water Diversions*. http://www.nemw.org/glwater_divert.htm
2) *Sustainable Use of Great Lakes Water: The Diversion Threat's Silver-Lining*? Cangelosi, A. http://www.nemw.org/ERGLwaterdivert.htm

O'Connor, D.J. and J. A. Mueller, 1970. *Water Quality Model of Chlorides in the Great Lakes*, J. Sanit Eng. Div., Proc. Am. Soc. Civ. Eng. 96(SA4):955-975.

Postel, S., 1997. *Last Oasis: Facing Water Scarcity*. The Worldwatch Environmental Alert Series. L. Starke, Series Editor. W.W. Norton & Company, New York/London.

Quinn, F. H. Senior Research Hydrologist (Retired), Great Lakes Environmental Research Lab/ National Oceanic and Atmospheric Administration. March, 2002. Personal communication.

Quinn, F. H., 2000. *Low Water: Should We Get Used to It?* Great Lakes SeaWay Review, Volume 29, Number 1, Harbor House, Boyne City, MI, pp. 33-35.

Quinn, F. H., July, 1999. *Anthropogenic Changes to Great Lakes Water Levels*. U.S. Army Corps of Engineers (Detroit District), *Great Lakes Update* (136:1-4).

Quinn, F. H., and B. M. Lofgren, 2000. *The Influence of Potential Greenhouse Warming on Great Lakes Hydrology, Water Levels, and Water Management*. Preprints, 15th Conference on Hydrology, Long Beach, CA, January 9-14, 2000. American Meteorological Society, Boston, MA, pp. 271-274.

Ray, Daryll E., August 4, 1999 . "*Why Grain Markets Don't Self-Correct Under Current Policies*". Testimony before the U.S. Senate Committee on Agriculture, Nutrition and Forestry.

Rivers, R., 1999. Great Lakes Issue Paper: "*Land Use*" (Draft Deliberative Copy). Environment Canada, Great Lakes 2000 Program.
http://www.on.ec.gc.ca/glimr/glrenewal/pdf/land_use.pdf

Sellinger, C.E. and F. H. Quinn, Editors, 1999. *Proceedings of the Great Lakes Paleo Levels Workshop: The Last 4000 Years*. NOAA Technical Memorandum ERL GLERL-113. Great Lakes Environmental Research Laboratory, Ann Arbor, MI.
http://www.glerl.noaa.gov/pubs/techrept/techrept.html

Sierra Club of Canada and Great Lakes United (GLU), September 19, 2000. *NAFTA Effects on Water: Testing for NAFTA Effects in the Great Lakes Basin.* Presented by C. Elwell.
http://res2.agr.gc.ca/initiatives/manurenet/download/sierra_pap4_nafta.pdf.

Statistics Canada, 2001.
1) *Land use, by Province, Census Agricultural Region and Census Division*:
http://www.statcan.ca/english/freepub/95F0301XIE/tables/html/Table5Can.htm#35)
2) *Top Five Field Crops by Area, Provinces:*
http://www.statcan.ca/english/Pgdb/Economy/Census/econ100f.htm
3) *Pigs, Provinces*:
http://www.statcan.ca/english/Pgdb/Economy/Census/econ106f.htm
4) *Cattle and Calves, Provinces*:
http://www.statcan.ca/english/Pgdb/Economy/Census/econ105f.htm
5) *2001 Census of Agriculture: Farm Data, Initial Release:*
http://www.statcan.ca/english/freepub/95F0301XIE/index.htm

St. Lawrence Seaway Management Corporation and the St. Lawrence Seaway Development Corporation. *The St. Lawrence Seaway Report: Historical Tables,*
1959 – 1992.

United Nations Commission on Sustainable Development, 2002. *Multi-Stakeholder Participation in Sustainable Development Efforts Discussed as Johannesburg Preparatory Committee Holds Dialogue*.
http://www.un.org/News/Press/docs/2002/ENVDEV611.doc.htm

United Nations Population Division, October, 1999. *The World at Six Billion*. Department of Economic and Social Affairs, United Nations Secretariat.
http://www.un.org/esa/population/publications/sixbillion/sixbillion.htm

University of Nebraska Cooperative Extension.
1) "*Irrigating for Maximum Economic Return with Limited Water*", no. G01-1422. Schneekloth, J. P., N. A. Norton, R. T. Clark, N. L. Klocke, 2001.
http://www.ianr.unl.edu/pubs/water/g1422.htm
2) "*Water Requirements for Beef Cattle*", Guyer, P. Q., 1977.

http://www.ianr.unl.edu/pubs/beef/g372.htm#top

U.S. Army Corps of Engineers (Detroit District) and the Great Lakes Commission (USACE and GLC), 1999. *Living With the Lakes: Understanding and Adapting to Great Lakes Water Level Changes*. http://www.glc.org/docs/lakelevels/lakelevels.pdf

U.S. Army Corps of Engineers (Jacksonville District) (USACE), 1999. *Central and Southern Florida Comprehensive Review Study: Final Integrated Feasibility Report and Programmatic Environmental Impact Statement*, April 1999.
http://www.evergladesplan.org/pub/restudy_eis.shtml

U.S. Army Corps of Engineers (USACE), U.S. Environmental Protection Agency (US EPA), U.S. Coast Guard, U.S. Department of Agriculture (USDA), National Oceanographic and Atmospheric Administration (NOAA), U.S. Fish and Wildlife Service (USFWS), U. S. Geological Survey (USGS), Agency for Toxic Substances and Disease Registry, U.S. Forest Service (USFS), Great Lakes Fishery Commission, Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin, Great Lakes Tribal Governments (Partners), Spring, 2001. *"Great Lakes 2001- A Plan for the New Millennium: A Strategic Plan for the Great Lakes- Our Environmental Goals and How We Plan to Achieve Them"*. (Draft 8.1). http://www.epa.gov/grtlakes/gls/glsv81.pdf

U.S. Congress, Office of Technology Assessment, 1995. *Agriculture, Trade, and Environment: Achieving Complementary Policies* (OTA-ENV-617). Washington, D.C., U.S. Government Printing Office, May 1995.

U.S. Congress, Office of Technology Assessment, 1995. *Targeting Environmental Priorities in Agriculture: Reforming Program Strategies* (OTA-ENV-640). Washington, D.C., U.S. Government Printing Office, September, 1995.

U.S. Department of Agriculture (USDA), 1997.
Statistical Bulletin Number 973: *Major Land Uses in the United States*:
http://usda.mannlib.cornell.edu/usda/reports/general/sb/sb973.pdf

U.S. Department of Agriculture (USDA), Briefing Room, 2002.
Canada, Basic Information:
http://www.ers.usda.gov/briefing/Canada/basicinformation.htm

U.S. Department of Agriculture, Economic Research Service (USDA, ERS).
1) *Agricultural Baseline Projection Tables, February, 2002:*

http://www.ers.usda.gov/data/sdp/view.asp?f=baseline
2) *Agricultural Resources and Environmental Indicators, 1996-97*. Agricultural Handbook No. 712, July, 1997. Anderson, M. and R. Magleby. Chapter 4.6: "Irrigation Water Management".
http://www.ers.usda.gov/publications/ah712/
3) *State Facts, 2000*: http://www.ers.usda.gov/StateFacts
4) *U.S. Agricultural Exports, 1996-2000:*
http://www.ers.usda.gov/data/FATUS/DATA/16010.xls

U.S. Department of Agriculture, National Agricultural Statistics Service (USDA, NASS).
1) *Agricultural Graphics:*
http://www.usda.gov/nass/aggraphs/graphics.htm
2) *Crop Acreage and Yield Maps, 2001*:
http://www.usda.gov/nass/aggraphs/cropmap.htm
3) *1997 Census of Agriculture, State Volumes, Appendix A*:
http://www.nass.usda.gov/census/census97/volume1/us-51/usgexp.pdf
4) *1998 Farm and Ranch Irrigation Survey, 1997 Census of Agriculture*. *Table 1: Irrigated Farms in the Censuses of Agriculture: 1997 and Earlier Censuses*.
http://www.nass.usda.gov/census/census97/fris/fris.htm
5) *Published Estimates Database*: http://www.nass.usda.gov:81/ipedb/
6) *Statistical Bulletin Number 896*. *Field Crops, Final Estimates by States, 1987-92*:
http://usda.mannlib.cornell.edu/data-sets/crops/94896/sb896.txt
7) *Statistical Bulletin Number 947*. *Field Crops, Final Estimates by States, 1992-97*:
http://usda.mannlib.cornell.edu/usda/reports/general/sb/B9471298.txt
8) *Statistical Highlights of U.S. Agriculture, 2000 and 2001. Cash Receipts: State Rankings, 1999:*
http://www.usda.gov/nass/pubs/stathigh/2001/stathigh2001.pdf
9) *1992 Census of Agriculture, Highlights of Agriculture: 1992 and 1987, Minnesota:*
http://www.nass.usda.gov/census/census92/atlas92/datafile/mnst.txt
10) NASS Quarterly Hog and Pigs Report, December 2001:
http://jan.mannlib.cornell.edu/reports/nassr/livestock/php-bb/2001/hgpg1201.txt

U. S. Department of Commerce, Office of Trade and Economic Analysis, International Trade Commission, 2000. *State Merchandise Exports to the World, 1997-2000, By Product Sector*. (Source: Exporter Location Series, Census Bureau).
http://www.ita.doc.gov/td/industry/otea/state/preformat.html

U.S. Environmental Protection Agency (US EPA), Global Warming Website:

Impacts to Water Resources.
http://www.epa.gov/globalwarming/impacts/water/

U.S. Environmental Protection Agency (US EPA), Office of Water Website: *Cleaner Water through Conservation: How we use water in the United States.*
http://www.epa.gov/OW/you/chap1.html

U.S. Environmental Protection Agency (US EPA) and the Government of Canada, 1995. *The Great Lakes: An Environmental Atlas and Resource Book*. Jointly produced by the Government of Canada, Toronto, Ontario and the U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL. Third Edition.
http://www.epa.gov/glnpo/atlas/

U. S. Geological Survey (USGS), 1992. National Landcover Statistics Database.
http://edcw2ks15.cr.usgs.gov/lccp/states_regions.asp

U. S. Geological Survey (USGS), 1995. W. B. Solley, R. R. Pierce, and H. A. Perlman. *Estimated Use of Water in the United States in 1995.* U.S.G.S. Circular 1200. http://water.usgs.gov/watuse/pdf1995/html/

U. S. Geological Survey (USGS) Website.
1) Estimated Use of Water in the United States in 1990:
Trends in Water Use, 1950-1990:
http://water.usgs.gov/watuse/wutrends.html
Total Water Use: http://water.usgs.gov/watuse/wuto.html
State Level Irrigation Water Use, 1995:
http://water.usgs.gov/watuse/pdf1995/pdf/irrigation.pdf
State Level Livestock Water Use, 1995:
http://water.usgs.gov/watuse/pdf1995/pdf/livestock.pdf
2) National Handbook of Recommended Methods for Water Data Acquisition. *Chapter 11, Water Use:*
http://water.usgs.gov/pubs/chapter11/index.html
Livestock and Animal Specialties:
http://water.usgs.gov/pubs/chapter11/chapter11I.html#HEADING03
3) *Water Q&A - Water Use at Home:*
http://ga.water.usgs.gov/edu/qahome.html

Western Producer, September 12, 2001. *The Future of Canada's Water*. B. Cross. Special Report: http://www.producer.com/

World Meteorological Organization, 1997. *Comprehensive Assessment of the Freshwater Resources of the World.* The Stockholm Environment Institute Library, Stockholm, Sweden.
http://www.un.org/esa/sustdev/freshwat.htm

World Resources Institute (WRI), October, 2001. *Pilot Analysis of Global Ecosystems: Freshwater Systems*. Revenga, C., J. Brunner, N. Henninger, K. Kassem, and R. Payne.
http://www.igc.org/wri/wr2000/freshwater_page.html

World Trade Organization (WTO) Website, 2001.
1) *International Trade Statistics, 2001*:
http://www.wto.org/english/res_e/statis_e/its2001_e/its01_toc_e.htm
2) *Exports of Agricultural Products of Selected Economies, 1990-00*:
http://www.wto.org/english/res_e/statis_e/its2001_e/section4/iv08.xls

Worldwatch Institute, September/October 1999. Postel, S. *When the World's Wells Run Dry*.

World Water Council, 2001. Press Release: Ninth International Conference on the Conservation and Management of Lakes. "*Partnerships for Sustainable Life in Lake Environments: Making Global Freshwater Mandates Work*." Shiga, Japan, November 11-16, 2001.
http://www.worldwatercouncil.org/download/LakesPR-Final.PDF

Wright, J. 2002. University of Minnesota Extension Service: "*Irrigation Scheduling Checkbook Method*." Publication no. FO-01322.
http://www3.extension.umn.edu/distribution/cropsystems/DC1322.html

URL Source References for Figures

Figure 1: **The Great Lakes-St. Lawrence River Basin**
Environmental Systems Research Institute (data included with ArcView 3.2 GIS software on CD-ROM, 1998). See: http://www.esri.com

Figure 2: **Historic Annual Mean Lake Levels, 1860-2001**
Great Lakes Environmental Research Lab/NOAA:
Frank Quinn (personal communication).
Based on 1918-2000 data presented by the Canadian Hydrographic Service, (Central Arctic Region), 2000. *Fluctuations in Lake Levels*.
See: http://chswww.bur.dfo.ca/danp/fluctuations_e.html

Figure 3: **Historic Monthly Mean Lake Levels, 1918-2000**
Canadian Hydrographic Service:
http://chswww.bur.dfo.ca/danp/fluctuations_e.html

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The Aral Sea Homepage: http://www.dfd.dlr.de/app/land/aralsee/

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World Meteorological Organization, 1997:
http://www.un.org/esa/sustdev/freshwat.htm

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World Meteorological Organization, 1997:
http://www.un.org/esa/sustdev/freshwat.htm

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World Meteorological Organization, 1997:
http://www.un.org/esa/sustdev/freshwat.htm

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USGS, 1995: http://water.usgs.gov/watuse/pdf1995/pdf/trends.pdf

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Agriculture and Agri-Food Canada, 2000: http://res2.agr.gc.ca/research-recherche/science/Healthy_Water/PDF/e3-6.pdf

Figure 10: **Total Tonnage Transported on the St. Lawrence Seaway, 1960-2000**
Great Lakes-St. Lawrence Seaway Website:
http://www.greatlakes-seaway.org/en/pdf/traffic_report_2000.pdf;
http://www.greatlakes-seaway.com/en/news/tonnage_info.html;
St. Lawrence Seaway Management Corporation and the St. Lawrence Seaway Development Corporation, *The St. Lawrence Seaway Report: Historical Tables*, 1959-1992 (in print only).

Figure 11: **Surface and Groundwater Withdrawals for Irrigation and Livestock by Great Lakes States, 1995**
USGS, 1995: http://water.usgs.gov/watuse/pdf1995/pdf/irrigation.pdf;
http://water.usgs.gov/watuse/pdf1995/pdf/livestock.pdf

Figure 12: **Distribution of Irrigated Land in Canada**
Agriculture and Agri-Food Canada, 2000: http://res2.agr.gc.ca/research-recherche/science/Healthy_Water/PDF/e3-6.pdf;
Environmental Systems Research Institute (data included with ArcView 3.2 GIS software on CD-ROM, 1998). See: http://www.esri.com

Figure 13: **Major Land Uses in Great Lakes States, 1997 Snapshot**
USDA, Statistical Bulletin 973, Major Land Uses in the United States, 1997: http://usda.mannlib.cornell.edu/usda/reports/general/sb/sb973.pdf

Figure 14: **Landcover Statistics for Great Lakes States, 1992**
USGS, National Land Cover Statistics Database, 1992: http://edcw2ks15.cr.usgs.gov/lccp/states_regions.asp

Figure 15: **Landcover in Great Lakes Provinces, 2001**
Agriculture and Agri-Food Canada, 2001. Soil Landscapes of Canada: *Ontario:*http://map1.agr.ca/scripts/esrimap.dll?name=Slc&Left=239227.563&Bottom=5818148.000&Right=1381834.125&Top=7467731.000&Lang=En&uniq=138152431&Pr=5&P=5&Var=9&V=9&Func=Dom&U=Retrieve+classes&Cls=0&Mapsize=0&Cmd=ZoomIn).

Quebec: http://map1.agr.ca/scripts/esrimap.dll?name=Slc&Left=-239227.563&Bottom=5818148.000&Right=1381834.125&Top=7467731.000&Lang=En&uniq=591138&Pr=4&P=5&Var=9&V=9&Func=Dom&U=Retrieve+classes&Cls=0&Mapsize=0&Cmd=ZoomIn.
Mini-map: Environmental Systems Research Institute (data included with ArcView 3.2 GIS software on CD-ROM, 1998). See: http://www.esri.com

Figure 16: **Farmland Characteristics in Great Lakes States (1997 Snapshot) and Provinces (2001 Snapshot)**
USDA, ERS, State Facts, 2000: http://www.ers.usda.gov/StateFacts;
1997 Census of Agriculture, State Volumes, Appendix A: http://www.nass.usda.gov/census/census97/volume1/us-51/usgexp.pdf;
Statistics Canada, 2001. Land use, by Province, Census Agricultural Region and Census Division: http://www.statcan.ca/english/freepub/95F0301XIE/tables/html/Table5Can.htm#35

Figure 17: **Total Land in Farms: Great Lakes States (1950-2000) & Provinces (1991-2001)**
USDA, NASS, Published Estimates Database: http://www.nass.usda.gov:81/ipedb/;
Ministry of Agriculture and Food, Statistics Canada, Census of Agriculture. Number and Area of Census Farms, Canada and the Provinces, 1991, 1996 and 2001: http://www.gov.on.ca/OMAFRA/english/stats/census/number.html

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USDA, ERS, State Facts, 2000: http://www.ers.usda.gov/StateFacts;
Ministry of Agriculture and Food, Agricultural Statistics for Ontario, 2001. Farm Cash Receipts, 2001: http://www.gov.on.ca/OMAFRA/english/stats/finance/farmcashreceipts.html;

Institut de la Statistique du Québec, Statistique Canada:
http://www.stat.gouv.qc.ca/donstat/agricult/general/bf9be100.htm

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USDA, NASS, Agricultural Graphics:
http://www.usda.gov/nass/aggraphs/cheese_e.htm;
USDA, NASS, Published Estimates Database:
http://www.nass.usda.gov:81/ipedb/

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USDA, NASS, Published Estimates Database:
http://www.nass.usda.gov:81/ipedb/

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USDA, NASS, Published Estimates Database:
http://www.nass.usda.gov:81/ipedb/

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USDA, NASS. Statistical Bulletins 896 and 947: Field Crops, Final Estimates by States, 1987-1992 and 1992-1997:
http://usda.mannlib.cornell.edu/data-sets/crops/94896/sb896.txt;
http://usda.mannlib.cornell.edu/usda/reports/general/sb/B9471298.txt;
Ministry of Agriculture and Food, Statistics Canada, Census of Agriculture. Ontario Farm Data, 1991, 1996 and 2001 Census of Agriculture:
http://www.gov.on.ca/OMAFRA/english/stats/census/summary.html;
Institut de la Statistique du Québec, Statistique Canada:
http://www.stat.gouv.qc.ca/donstat/agricult/culture/culture/am110001.htm

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USDA, NASS, Agricultural Graphics:
http://www.usda.gov/nass/aggraphs/cornac.htm;
USDA, NASS, Published Estimates Database:
http://www.nass.usda.gov:81/ipedb/

Figure 24: **Corn Production in U.S., 1991-2001; Corn Production in Great Lakes States, 1980-2002**
USDA, NASS, Agricultural Graphics:
http://www.usda.gov/nass/aggraphs/cornprod.htm;
USDA, NASS, Published Estimates Database:
http://www.nass.usda.gov:81/ipedb/

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USDA,NASS: http://www.usda.gov/nass/aggraphs/cropmap.htm

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USDA, NASS: http://www.usda.gov/nass/aggraphs/cropmap.htm

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Ministry of Agriculture and Food, Agricultural Statistics for Ontario.
Field Crop Statistics: http://www.gov.on.ca/OMAFRA/english/stats/crops

Figure 28: **Corn Acres Planted and Produced in Québec, 1991-2001**
Institut de la Statistique du Québec, Statistique Canada (July, 2002).
http://www.stat.gouv.qc.ca/donstat/econm_finnc/filr_bioal/culture/culture/am116re2.htm
http://www.stat.gouv.qc.ca/donstat/econm_finnc/filr_bioal/culture/culture/am110008.htm
http://www.stat.gouv.qc.ca/donstat/econm_finnc/filr_bioal/culture/culture/am110001.htm

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USDA, NASS, Agricultural Graphics:
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USDA, NASS, Published Estimates Database:
http://www.nass.usda.gov:81/ipedb/

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http://www.usda.gov/nass/aggraphs/soyprod.htm;
USDA, NASS, Published Estimates Database:
http://www.nass.usda.gov:81/ipedb/

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USDA, NASS: http://www.usda.gov/nass/aggraphs/cropmap.htm

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USDA, NASS: http://www.usda.gov/nass/aggraphs/cropmap.htm

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Ministry of Agriculture and Food, Agricultural Statistics for Ontario.
Field Crop Statistics: http://www.gov.on.ca/OMAFRA/english/stats/crops

Figure 34: **Soybean Acres Planted and Produced in Québec, 1991-2001**
Institut de la Statistique du Québec, Statistique Canada (July, 2002).
http://www.stat.gouv.qc.ca/donstat/econm_finnc/filr_bioal/culture/culture/am110008.htm
http://www.stat.gouv.qc.ca/donstat/econm_finnc/filr_bioal/culture/culture/am110001.htm
http://www.stat.gouv.qc.ca/donstat/econm_finnc/filr_bioal/culture/culture/am119re2.htm

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USDA, NASS, Agricultural Graphics:
http://www.usda.gov/nass/aggraphs/hgoper_e.htm;
USDA, NASS, Agricultural Graphics:
http://www.usda.gov/nass/aggraphs/lbspr.htm;
USDA, NASS, Published Estimates Database:
http://www.nass.usda.gov:81/ipedb/

Figure 36: **Hog Inventories in Ontario (1987-2002) and Quebec (1991-2001)**
Ministry of Agriculture and Food, Agricultural Statistics for Ontario.
Number of Pigs on Farms, July 1986 to July 2002:
http://www.gov.on.ca/OMAFRA/english/stats/livestock/pigs.html
Institut de la Statistique du Québec, Statistique Canada:
http://www.stat.gouv.qc.ca/donstat/econm_finnc/filr_bioal/elevage/porc/ac110re6.htm
Statistics Canada, 2001:
http://www.statcan.ca/english/Pgdb/Economy/Census/econ106f.htm

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USDA, NASS, Agricultural Graphics:
http://www.usda.gov/nass/aggraphs/jul_inv.htm;
USDA, NASS, Published Estimates Database:
http://www.nass.usda.gov:81/ipedb/

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Ministry of Agriculture and Food, Agricultural Statistics for Ontario.
Number of Cattle on Farms, July 1986 to July 2002:
http://www.gov.on.ca/OMAFRA/english/stats/livestock/cattle.html
Institut de la Statistique du Québec, Statistique Canada:
http://www.stat.gouv.qc.ca/donstat/econm_finnc/filr_bioal/elevage/boeuf/ab110re6.htm;
Statistics Canada, 2001:
http://www.statcan.ca/english/Pgdb/Economy/Census/econ105f.htm

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World Trade Organization Website, International Trade Statistics, 2001:
http://www.wto.org/english/res_e/statis_e/its2001_e/section4/iv08.xls

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USDA, ERS, U.S. Agricultural Exports, 1996-2000:
http://www.ers.usda.gov/data/FATUS/DATA/16010.xls;
Ministry of Agriculture and Food, Agricultural Statistics for Ontario.
Ontario Agri-Food Trade, 1988-2001:
http://www.gov.on.ca/OMAFRA/english/stats/trade/agrifoodtrade.html;
Institut de la Statistique du Québec, Statistique Canada:
http://www.stat.gouv.qc.ca/donstat/agricult/general/aa500120.htm;
http://www.stat.gouv.qc.ca/donstat/agricult/general/aa500121.htm

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USDA, ERS, State Facts, 2000:
http://www.ers.usda.gov/StateFacts

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Ministry of Agriculture and Food, Agricultural Statistics for Ontario.
Ontario Agri-food Trade by Commodity Group, 2000:
http://www.gov.on.ca/OMAFRA/english/stats/trade/commod00.html;
Institut de la Statistique du Québec, Statistique Canada:
http://www.stat.gouv.qc.ca/donstat/agricult/general/aa500121.htm

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FAO Website:
http://www.fao.org/news/2000/000306-e.htm

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USDA, Statistical Bulletin 973, Major Land Uses in the United States, 1997:
http://usda.mannlib.cornell.edu/usda/reports/general/sb/sb973.pdf

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Environmental Central Website. Water Efficiency of Different Irrigation Systems: http://ec.chias.org/ref/item.page?entry_id=439

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University of Nebraska Cooperative Extension.
http://www.ianr.unl.edu/pubs/water/g1422.htm

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Alberta Agriculture, Food and Rural Development Website. Farm Water Supply Requirements: http://www.agric.gov.ab.ca/agdex/700/716c01.html;
University of Nebraska Cooperative Extension. Water Requirements for Beef Cattle: http://www.ianr.unl.edu/pubs/beef/g372.htm#top;
USGS Website. Water Q&A - Water Use at Home:
http://ga.water.usgs.gov/edu/qahome.html

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National Farmers Union, 2002, *"Free Trade": Is it Working for Farmers?*
http://www.agr.gc.ca/policy/epad/english/pubs/adhoc/98040/report.pdf

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USDA, NASS, *1997 Census of Agriculture, State Volumes, Appendix A*:
http://www.nass.usda.gov/census/census97/volume1/us-51/usgexp.pdf

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United Nations Population Division, 1999:
http://www.un.org/esa/population/publications/sixbillion/sixbilpart1.pdf

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U.S. EPA and the Government of Canada, 1995:
http://www.epa.gov/glnpo/atlas/images/chart301.gif

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U.S. EPA and the Government of Canada, 1995:
Adapted from: http://www.epa.gov/glnpo/atlas/images/chart301.gif;
Environmental Systems Research Institute (data included with ArcView 3.2 GIS software on CD-ROM, 1998). See: http://www.esri.com

Figure 53: **Land in Urban Areas in Great Lakes States, 1960-1997**
USDA, Statistical Bulletin 973, Major Land Uses in the United States, 1997:
http://usda.mannlib.cornell.edu/usda/reports/general/sb/sb973.pdf

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U.S. EPA and the Government of Canada, 1995:
Adapted from: http://www.epa.gov/glnpo/atlas/images/big07.gif

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Agriculture and Agri-Food Canada, 2000: http://res2.agr.gc.ca/research-recherche/science/Healthy_Water/PDF/e11-14.pdf

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Canadian Environmental Law Association and Great Lakes United, 1997:
http://www.glu.org/publications/fate%20report/swtfrpt.pdf

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Canadian Environmental Law Association and Great Lakes United, 1997:
http://www.glu.org/publications/fate%20report/swtfrpt.pdf