The Great Lakes basin holds the world's largest supply of surface freshwater and is home to over 35 million people. Climate change is predicted to have major impacts on the natural resources of this system, which will exacerbate existing problems and create new challenges. This series of policy briefs explores several impacts of climate change and emphasizes the need for responsible stewardship of our vital water resources.

Climate Change Impacts on Agriculture in the Great Lakes Basin

Agriculture is a vital component of the Great Lakes basin economy, generating more than $15 billion annually through crop and livestock production (GLCR 2013). Agriculture uses approximately one-third of the basin's 201,000 square miles to produce grain, corn, soybeans, dairy, and livestock (GLCR 2013, EPA 2012). Overall, the Great Lakes basin accounts for nearly 7 percent of total agricultural production in the United States and 25 percent of total production in Canada (GLCR 2013).

These high production rates require tremendous amounts of water (Figure 1). On average, more than 620 million gallons per day (MGD) of basin water is withdrawn for crop irrigation (GLC 2012). Of that, over 540 MGD are consumed and are not returned to the system. Livestock production accounts for another 120 MGD of water withdrawals, of which more than 14 MGD are consumed (GLC 2012).

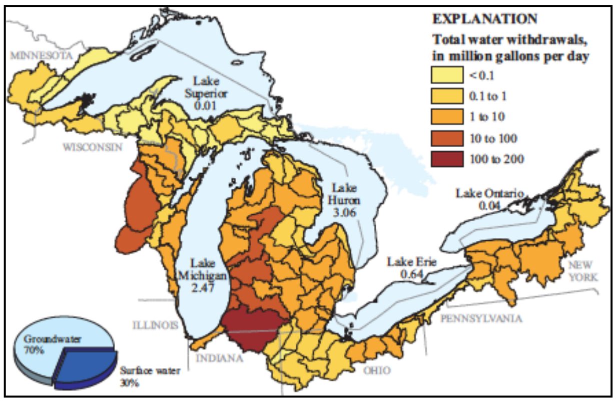

Figure 1. Total daily irrigation withdrawals from U.S. Great Lakes states. Source: Mills & Sharpe 2010.

Impacts of Climate Change

Climate change will have multiple effects on the Great Lakes basin (Figure 2). A majority of general circulation models (GCMs) predict an increase in air temperature that could range from 1-7°C by 2090 (Lofgren *et al.* 2002, Gregg *et al.* 2012). Subsequently, evaporation rates are also predicted to increase by 16-39 percent over the same time period (Lofgren *et al.* 2002). While model estimates range from a 20 percent increase to a 9 percent decrease by 2090, predictions about future precipitation trend toward an overall increase (Lofgren *et al.* 2002).

These warmer temperatures and altered weather patterns will likely increase the number of extreme weather events throughout the Great Lakes basin. More intense summer heat will lead to increased humidity and prolonged periods of drought (Gregg *et al.* 2012). A higher frequency of multiday downpours will increase instances of flooding, which can lead to elevated rates of riverbank erosion and nutrient-rich runoff from agricultural fields (IJC 2003). Heavy downpours, which are classified as the largest 10 percent of rainfall within a 24-hour period, are already occurring twice as frequently as they did a century ago (Gregg *et al.* 2012).

Climate change will have numerous impacts on agriculture in the Great Lakes basin. Higher temperatures will lead to an overall increase in the length of the growing season (IJC 2003). Already, growing seasons have increased by 1.5 days per decade over the last 50 years (Gregg *et al.* 2012). By the end of the century, the average growing season is predicted to be 4-9 weeks longer than it was during the period 1961-1990 (Kling *et al.* 2003). Due to this longer growing season, overall corn yields are predicted to increase by up to 5 percent (Southworth 2000).

Changes in crop production, however, will vary throughout the basin, with optimal farming conditions moving northward and eastward (Kling *et al.* 2003). Northern parts of the basin, once hampered by short growing seasons, will experience an increase in crop production, with corn yields in some areas predicted to increase by as much as 45 percent (Gregg *et al.* 2012, Southworth 2000). On the other hand, warmer temperatures in southern areas may lead to reduced soil moisture and a subsequent decrease in crop production (Bootsma 2002).

Changes in rain distribution may also impact agriculture throughout the basin. Periods of intensely wet weather in transitional seasons could flood fields and delay planting and harvesting (Kling *et al.* 2003). Prolonged periods of drought may decrease summer soil moisture by up 30 percent, requiring an increase in groundwater withdrawals and diversions for irrigation (Kling *et al.* 2003).

There is also the potential for increased use of pesticides and herbicides to combat the proliferation of weeds, insects, and diseases that result from higher temperatures (Bootsma 2002). Warmer and shorter winters will allow more southerly pests, such as corn earworms and fall armyworms, to expand their range (National Assessment Synthesis Team 2000). Furthermore, pests that are normally killed during intense cold will now have a greater chance of surviving milder winter temperatures (Gregg *et al.* 2012). The growing use of pesticides and herbicides will threaten the health of the Great Lakes ecosystem through increased chemical runoff into prairie wetlands, groundwater, rivers, and lakes (IJC 2003).

Policies Moving Forward

Future policies should focus on promoting the transition from traditional to climate-adapted farming practices. For example, planting a cover crop during the dormant season would reduce erosion and nutrient-rich runoff during intense rain events, and switching to drought-tolerant varieties of crops would buffer against lower soil moisture (IJC 2003). Overall, policymakers should foster programs that educate farmers on climate-adapted practices such as these and provide incentives to adopt them.

Lake	Air temperature increase	Change in precipitation	Change in evaporation
Superior	2.9-5.4°C	14-16%	19-39%
Michigan-Huron	2.7-5.6°C	14-20%	16-34%
Erie	2.6-5.9°C	5-21%	17-29%
Ontario	2.7-5.4°C	7-17%	16-31%

Figure 2. Predicted Great Lakes climate change effects by 2090. Source: Lofgren *et al.* 2012.

Policymakers should also promote water-efficient irrigation practices. Using less water to maintain the same level of productivity is an effective way to "reduce the possibilities for water conflicts and enhance the possibilities for economic growth with the region" (IJC 2003). Water-efficient methods such as deficit, drip, and micro-spray irrigation are all potential alternatives to traditional flooding and spray irrigation. Implementing these water-efficient methods, however, requires training and is often expensive. Policymakers can remove these obstacles through funding for education and installation.

The cost and regulation of irrigation water in the United States varies by location, source, and water management policies (Wilchelns 2010). These variables influence how farmers use and pay for their water. The price paid for irrigation water in the Great Lakes basin is minimal, so farmers lack the incentive to reduce their water use. For instance, a survey showed that 44 percent of residential water users and 60 percent of non-residential users paid for water based on a decreasing-block rate, which means the more water they use, the less they have to pay (Beecher 2010). Subsequently, water is currently managed as if it has minimal value. One way to move towards better water management is to place a price on water that reflects its value for agricultural systems in the Great Lakes basin.

-Authored by Kim Kramer and Victoria Lubner; Supervised by Dr. Jenny Kehl; Edited by Aaron Thiel

References

Beecher, J.A. & J.A. Kalmbach. 2011. *2010 Great Lakes survey*. General report. Ann Arbor, MI: Great Lakes Commission. Retrieved from http://www.ipu.msu.edu/research/pdfs/2010%20GLWRS%20Report.pdf

Bootsma, A. 2002. *A summary of some results of research on the potential impacts of climate change on agriculture in eastern Canada.* Conference proceedings from Climate Change and Agriculture in the Great Lakes Region: The Potential Impacts and What We Can Do. East Lansing, MI: Michigan State University.

Environmental Protection Agency. 2012. *Great Lakes monitoring.* Retrieved from http://www.epa.gov/glnpo/monitoring/great_minds_great_lakes/social_studies/without.html

Gage, S. 1996. *Agricultural profile of the Great Lakes.* Retrieved from http://atlantic.evsc.virginia.edu/regionalization/kbs/docs/great_lakes.htm

Great Lakes Coastal Resilience. 2013. *Great Lakes coastal resilience planning guide: People in the Great Lakes*. Retrieved from http://www.greatlakesresilience.org/climate-environment/people-great-lakes

Great Lakes Commission .2013. *Annual report of Great Lakes regional water use database*. Report prepared for the Great Lakes-St. Lawrence River Basin Water Resources Council. Ann Arbor, MI: Author. Retrieved from http://projects.glc.org/waterusedata/pdf/wateruserpt2012.pdf

Great Lakes Environmental Research Laboratory. 2014. *About our Great Lakes: Economy*. Retrieved from http://www.glerl.noaa.gov/pr/ourlakes/economy.html

Great Lakes Protection Fund. 2014. *Agriculture in the Great Lakes*. Retrieved from http://www.glpf.org/ideas-in-action/agriculture-in-the-great-lakes

Gregg, R., K. Feifel, J. Kershner, & J. Hitt. 2012. *The state of climate change adaptation in the Great Lakes region.* General report. Bainbridge Island, WA: EcoAdapt.

International Joint Commission. 2003. *Climate change and water quality in the Great Lakes basin.* Report of the Great Lakes Water Quality Board. Ottawa, Ontario & Washington, D.C.: Author. Retrieved from http://www.ijc.org/rel/pdf/climate_change_2003.pdf

Kling, G, K. Hayhoe, L.B. Johnson, J.J. Magnuson, S. Polasky, S.K. Robinson, B.J. Shuter, M.M. Wander, D.J. Wuebbles & D.R. Zak. 2005. *Confronting climate change in the Great Lakes region: Impacts on our communities and ecosystems*. Technical report. Cambridge, MA: Union of Concerned Scientists & Washington, DC: Ecological Society of America.

Lofgren, B., F. Quinn, A. Clites, R. Assel, A. Eberhardt, & C. Luukkonen. 2002. Evaluation of potential impacts on Great Lakes water resources based on climate scenarios on two GCMs. *Journal of Great Lakes Research, 28*(4), 537-554.

Mills. P.C. & J.B. Sharpe. 2010. *Estimated withdrawals and other elements of water use in the Great Lakes basin of the United States in 2005*. Scientific investigations report 2010-5031. Reston, Virginia: U.S. Geological Survey.

National Assessment Synthesis Team. 2000. *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change.* New York: Cambridge University Press.

Shaffer, K. 2008. *Consumptive water use in the Great Lakes basin*. Fact sheet 2008-3032. Reston, VA: U.S. Geological Survey. Retrieved from http://pubs.usgs.gov/fs/2008/3032/pdf/fs2008-3032.pdf

Southworth, J., J.C. Randolph, M. Habeck, O.C. Doering, R.A. Pfeifer, D.G. Rao, & J.J. Johnston. 2000. Consequences of future climate change and changing climate variability on maize yields in the Midwestern United States. *Agriculture, Ecosystems, & Environment, 82*(1), 139-158. Retrieved from http://www.sciencedirect.com/science/article/pii/S0167880900002231

Wichelns, D. 2010. *Agricultural water pricing: United States.* Background report. Paris: Organization for Economic Co-Operation and Development. Retrieved from http://www.oecd.org/unitedstates/45016437.pdf