Economic Impacts of Climate Change on Ohio

July 2008

A Review and Assessment Conducted by
The Center for Integrative Environmental Research
University of Maryland

Contributors to the Report

Sean Williamson
Graduate Research Assistant, Center for Integrative Environmental Research

Soyesh Lakhey
Graduate Research Assistant, Center for Integrative Environmental Research

Daria Karetnikov
Graduate Research Assistant, Center for Integrative Environmental Research

Matthias Ruth
Director, Center for Integrative Environmental Research and Roy F. Weston Chair for Natural Economics

Kim Ross
Executive Director, Center for Integrative Environmental Research

Daraius Irani
Director, Regional Economic Studies Institute (RESI) of Towson University

The Center for Integrative Environmental Research (CIER) at the University of Maryland addresses complex environmental challenges through research that explores the dynamic interactions among environmental, economic and social forces and stimulates active dialogue with stakeholders, researchers and decision makers. Researchers and students at CIER, working at local, regional, national and global scales, are developing strategies and tools to guide policy and investment decisions. For additional information, visit www.cier.umd.edu.

For additional information on this report, please contact:
Matthias Ruth, mruth1@umd.edu

The full report is available for free download at
www.cier.umd.edu/climateadaptation

INTRODUCTION

Policymakers across the country are now seeking solutions to curb greenhouse gas emissions and to help us adapt to the impending impacts triggered by past emissions. The debate to date has primarily focused on the perceived costs of alternative solutions, yet there can also be significant costs of inaction. Climate change will affect our water, energy, transportation, and public health systems, as well as state economies as climate change impact a wide range of important economic sectors from agriculture to manufacturing to tourism. This report, part of a series of state studies, highlights the economic impacts of climate change in Ohio and provides examples of additional ripple effects such as reduced spending in other sectors and resulting losses of jobs, wages, and even tax revenues.

A Primer on Climate Change

Earth's climate is regulated, in part, by the presence of gases and particles in the atmosphere which are penetrated by short-wave radiation from the sun and which trap the longer wave radiation that is reflecting back from Earth. Collectively, those gases are referred to as greenhouse gases (GHGs) because they can trap radiation on Earth in a manner analogous to that of the glass of a greenhouse and have a warming effect on the globe. Among the other most notable GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs). Their sources include fossil fuel combustion, agriculture, and industrial processes.

Each GHG has a different atmospheric concentration, mean residence time in the atmosphere, and different chemical and physical properties. As a consequence, each GHG has a different ability to upset the balance between incoming solar radiation and outgoing long-wave radiation. This ability to influence Earth's radiative budget is known as climate forcing. Climate forcing varies across chemical species in the atmosphere. Spatial patterns of radiative forcing are relatively uniform for CO_2, CH_4, N_2O and CFCs because these gases are relatively long-lived and as a consequence become more evenly distributed in the atmosphere.

Steep increases in atmospheric GHG concentrations have occurred since the industrial revolution (Figure 1). Those increases are unprecedented in Earth's history. As a result of higher GHG concentrations, global average surface temperature has risen by about 0.6°C over the twentieth century, with 10 of the last 12 years likely the warmest in the instrumental record since 1861 (IPCC 2007).

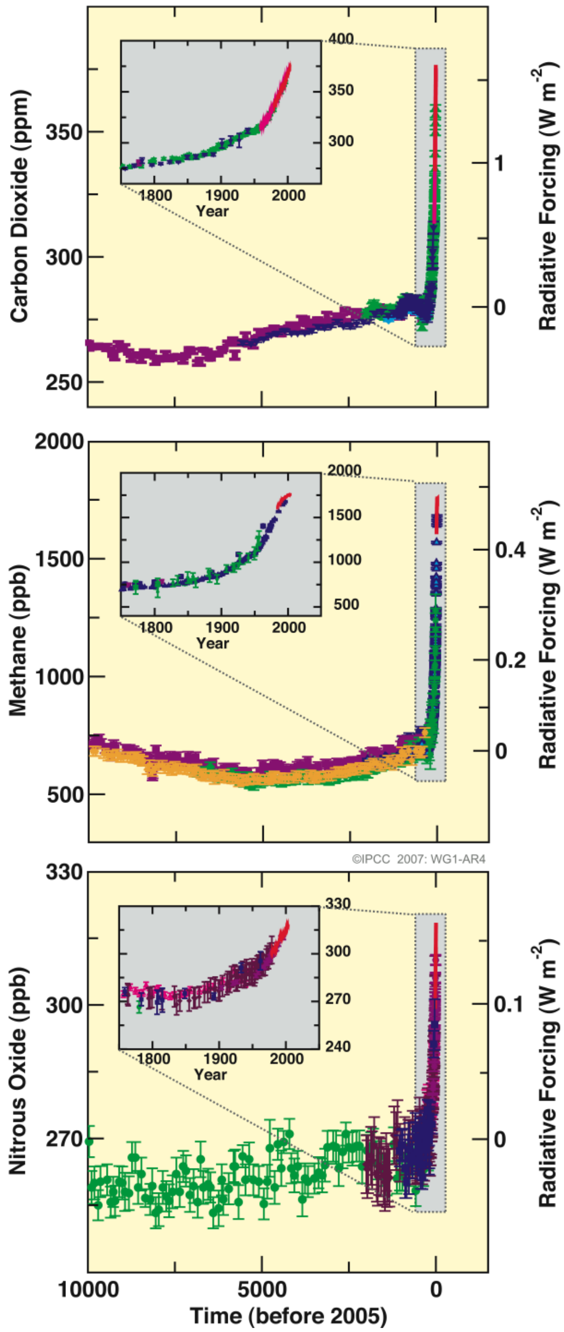

Figure 1: Atmospheric Concentrations of Carbon Dioxide, Methane and Nitrous Oxide (Source: IPCC 2007)

A change in average temperatures may serve as a useful indicator of changes in climate (Figure 2), but it is only one of many ramifications of higher GHG concentrations. Since disruption of Earth's energy balance is neither seasonally nor geographically uniform, effects of climate disruption vary across space as well as time. For example, there has been a widespread retreat of mountain glaciers during the twentieth century. Scientific evidence also suggests that there has been a 40 percent decrease in Arctic sea ice thickness during late summer to early autumn in recent decades and considerably slower decline in winter sea ice thickness. The extent of Northern Hemisphere spring and summer ice sheets has decreased by about 10 to 15 percent since the 1950s (IPCC 2007).

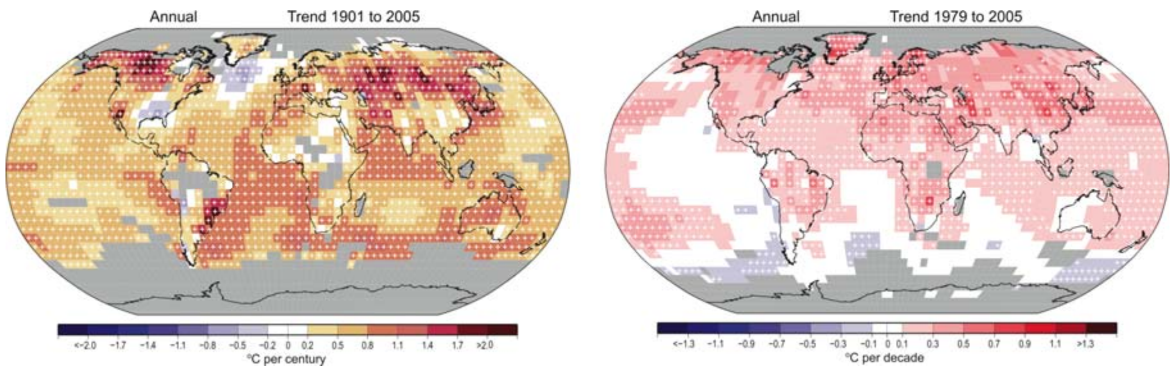

Figure 2: Annual Temperature Trends (Source: IPCC 2007)

The net loss of snow and ice cover, combined with an increase in ocean temperatures and thermal expansion of the water mass in oceans, has resulted in a rise of global average sea level between 0.1 and 0.2 meters during the twentieth century, which is considerably higher than the average rate during the last several millennia (Barnett 1984; Douglas 2001; IPCC 2001).

Changes in heat fluxes through the atmosphere and oceans, combined with changes in reflectivity of the earth's surface and an altered composition of may result in altered frequency and severity of climate extremes around the globe (Easterling, et al. 2000; Mehl, et al. 2000). For example, it is likely that there has been a 2 to 4 percent increase in the frequency of heavy precipitation events in the mid and high latitudes of the Northern Hemisphere over the latter half of the twentieth century, while in some regions, such as Asia and Africa, the frequency and intensity of droughts have increased in recent decades (IPCC 2001). Furthermore, the timing and magnitude of snowfall and snowmelt may be significantly affected (Frederick and Gleick 1999), influencing among other things, erosion, water quality and agricultural productivity. And since evaporation increases exponentially with water temperature, global climate change-induced sea surface temperature increases are likely to result in increased frequency and intensity of hurricanes and increased size of the regions affected.

Impacts of Climate Change throughout the US

This study on the economic impacts of climate change in the State of Ohio is part of a series of state-focused studies to help inform the challenging decisions policymakers now face. It builds on a prior assessment by the Center for Integrative Environmental Research, US Economic Impacts of Climate Change and the Costs of Inaction, which concluded that throughout the United States, individuals and communities depend on sectors and systems that are expected to be greatly affected by the impacts of continued climate change.

- The **agricultural sector** is likely to experience uneven impacts throughout the country. Initial economic gains from altered growing conditions will likely be lost as temperatures continue to rise. Regional droughts, water shortages, as well as excess precipitation, and spread of pest and diseases will negatively impact agriculture in most regions.

- Storms and sea level rise threaten extensive **coastal infrastructure** – including transportation networks, coastal developments, and water and energy supply systems.

- Current **energy** supply and demand equilibria will be disrupted as electricity consumption climbs when demand grows in peak summer months. At the same time, delivering adequate supply of electricity may become more expensive because of extreme weather events.

- Increased incidence of asthma, heat-related diseases, and other respiratory ailments may result from climate change, affecting **human health** and well-being.

- More frequent and severe **forest fires** are expected, putting ecosystems and human settlements at peril.

- The reliability of **water supply networks** may be compromised, influencing agricultural production, as well as availability of water for household and industrial uses.

As science continues to bring clarity to present and future global climate change, policymakers are beginning to respond and propose policies that aim to curb greenhouse gas emissions and to help us adapt to the impending impacts triggered by past emissions.

While climate impacts will vary on a regional scale, it is at the state and local levels where critical policy and investment decisions are made for the very systems most likely to be affected by climate change – water, energy, transportation and public health systems, as well as important economic sectors such as agriculture, fisheries, forestry, manufacturing, and tourism. Yet, much of the focus, to date, has been on the perceived high cost of reducing greenhouse gas emissions. The costs of inaction are frequently neglected and typically not calculated. These costs include such expenses as rebuilding or preparing infrastructure to meet new realities and the ripple economic impacts on the state's households, the agricultural, manufacturing, commercial and public service sectors.

The conclusions from our nation-wide study highlight the need for increased understanding of the economic impacts of climate change at the state, local and sector level:

- Economic impacts of climate change will occur throughout the country.
- Economic impacts will be unevenly distributed across regions and within the economy and society.

- Negative climate impacts will outweigh benefits for most sectors that provide essential goods and services to society.
- Climate change impacts will place immense strains on public sector budgets.
- Secondary effects of climate impacts can include higher prices, reduced income and job losses.

Methodology

This report identifies key economic sectors in Ohio which are likely affected by climate change, and the main impacts to be expected for these sectors. The report provides examples of the direct economic impacts that could be experienced in the state and presents calculations of indirect effects that are triggered as impacts on individual sectors in the economy ripple through to affect others.

The study reviews and analyzes existing studies such as the 2000 Global Change Research Program National Assessment of the Potential Consequences of Climate Variability and Change which identifies potential regional impacts. Additional regional, state and local studies are used to expand on this work, as well as new calculations derived from federal, state and industry data sources. The economic data is then related to predicted impacts of climate change provided from climate models. To standardize the results, all of the figures used in this report have been converted to 2007 dollars (BLS 2008).

Since the early 1990s, and especially during the 21st century, significant progress has been made in understanding the impacts of climate change at national, regional, and local scales. The Canadian and Hadley climate change models are cited most frequently and we look first to these, yet there are many other valuable models used by some of the specialized studies we cite in this report.

In addition to looking at data that illustrates the direct economic impacts of climate change, the report also provides examples of the often overlooked ripple economic effects on other sectors and the state economy. To calculate these, we employed a modified IMPLAN™ model from the Regional Economic Studies Institute (RESI) of Towson University. This is a standard input/output model and the primary tool used by economists to measure the total economic impact by calculating spin-off impacts (indirect and induced impacts) based upon the direct impacts which are inputted into the model. Direct impacts are those impacts (jobs and output) generated directly by the project. Indirect economic impacts occur as the project (or business owners) purchase local goods and services. Both direct and indirect job creation increases area household income and results in increased local spending on the part of area households. The jobs, wages, output and tax revenues created by increased household spending are referred to as induced economic impacts.

After reviewing climate and economic information that is currently available, the study identifies specific data gaps and research needs for further understanding of the significant economic impacts. There is no definitive total cost of inaction. Given the diversity in approaches among existing economic studies and the complexity of climate-induced challenges faced by society, there is a real need for a consistent methodology that enables more complete estimates of impacts and adaptation costs. The report closes with basic recommendations and concluding lessons learned from this series of state-level studies.

Not all environmentally induced impacts on infrastructures, economy, society and ecosystems reported here can be directly or unequivocally related to climate change. However, historical as well as modeled future environmental conditions are consistent with a world experiencing changing climate. Models illustrate what may happen if we do not act now to effectively address climate change and if adaptation efforts are inadequate. Estimates of the costs of adapting environmental and infrastructure goods and services to climate change can provide insight into the very real costs of inaction, or conversely, the benefits of maintaining and protecting societal goods and services through effective policies that avoid the most severe climate impacts. Since it is typically at the sectoral and local levels where those costs are borne and benefits are received, cost estimates can provide powerful means for galvanizing the discussion about climate change policy and investment decision-making.

These cost estimates may understate impacts on the economy and society to the extent that they simply cover what can be readily captured in monetary terms, and to the extent that they are calculated for the more likely future climate conditions rather than less likely but potentially very severe and abrupt changes. The broader impacts on the social fabric, long-term economic competitiveness of the state nationally and internationally, changes in environmental quality and quality of life largely are outside the purview of the analysis, yet likely not trivial at all. Together, the monetary and non-monetary, direct, indirect and induced costs on society and the economy provide a strong basis on which to justify actions to mitigate and adapt to climate change.

CLIMATE CHANGE IN OHIO

In the last century, Ohio has experienced rising temperatures, increased precipitation including more extreme weather events, and decreased water resources. Average annual temperatures for the Southern Great Lakes region increased by 1.3° F (.7° C) since 1895 while the average annual temperature in Columbus, Ohio has increased by 0.3° F (.2 ° C) over the same period (EPA 1998). Since 1900, precipitation has increased by 10 percent in Northern Ohio and decreased by 10 percent in Southern Ohio (Figure 3). Heavy precipitation events have increased during the summer months in the Southern Great Lakes region and winter snowfall has decreased in response to warmer winter temperatures. Between 1970 and 1990 evaporation on the Great Lakes increased by an average of 9mm/year, the spring thaw is occurring earlier in the season, and less precipitation has been falling as snowfall (Great Lakes 2003). Since 1997, unusually warm years have resulted in a 3.5 feet drop in Lake Erie’s water level and similar decreases are occurring throughout Ohio’s surface water resources (Lake Erie 2006).

These trends are predicted to continue or worsen if climate change progresses unchecked. Average yearly temperatures are expected to increase by 3-4° F (1.6-2.2° C) with winter and spring temperatures increasing the most (IPCC 2001). Precipitation is expected to increase in every season with the largest increase of 25 percent predicted to occur during the fall months (US EPA 1997). As climate change increases rates of surface water evaporation, decreases snow fall, and expedites the spring thaw, there will be significant changes in Ohio's surface water levels over the next century. Lake Erie is likely to be severely effected by a predicted 34 inch drop in water level over the next 60 years, reducing the total surface area of the lake by 15 percent (Lake Erie 2006). Similar reductions in water level will likely occur for all of the state's streams, rivers, and lakes.

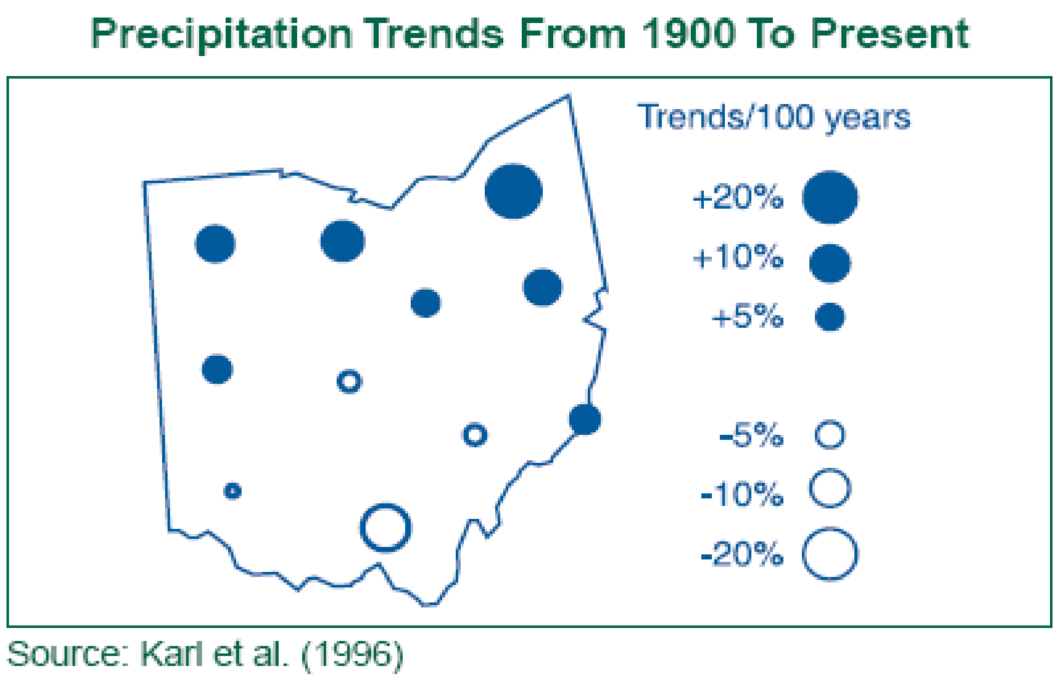

Figure 3. Precipitation Trends in Ohio, 1900-1996 (Source: EPA 1998)

MAJOR ECONOMIC IMPACTS

Shipping and Manufacturing

Shipping and manufacturing constitute one of the major industries in Ohio. Manufacturing alone accounted for nearly 20 percent of Ohio's GDP in 2006 (BEA 2006). Ohio's industries rely on the shipping routes through Lake Erie to receive their raw materials as well as export them to Canada and elsewhere. The Ohio Department of Development reports that the top eight export items in 2006 had a combined value of $27.8 billion dollars. Ohio's exports to Canada totaled about 18.8 billion dollars, 48 percent of its total exports, in 2006. A majority of these exports were sent through Lake Erie ports (Office of Strategic Research 2006).

The projected fall in the water level in Lake Erie would substantially affect the shipping industry as the carrier vessels lose their capacity. According to the Great Lakes Carriers'

Association, a 305 meter long vessel (of the type that is used for intra-lake transportation) loses 270 tons of capacity for each inch of draft loss[1]. Each carrier will have to carry lighter loads, losing nearly $30,000 per vessel (Moore 2002).

Even if there were only a 2 percent decrease in shipping activity each year, this will result in a direct economic impact on water transportation worth $556 million in 2007 and an almost equally large multiplicative impact on the rest of the economy, due to the shipping industry's importance to the rest of the state's economic sectors, worth approximately $452 million in 2007 (RESI 2008). Should that decrease continue, then direct economic impacts just ten years later would be $5.54 billion and indirect economic impact of in excess of $4.49 billion. By 2017, a combined direct and indirect 49,000 jobs would be at peril (RESI 2008).

Lower lake and river levels would also necessitate more frequent dredging of channels and harbors, dock adjustments, and other water infrastructure changes such as water intake pipes (Kling, 2003). Lower lake levels would not only increase the direct cost related to shipping, but also pose other threats related to ecosystem imbalance, higher concentrations of pollution and disposal of dredged sediments.

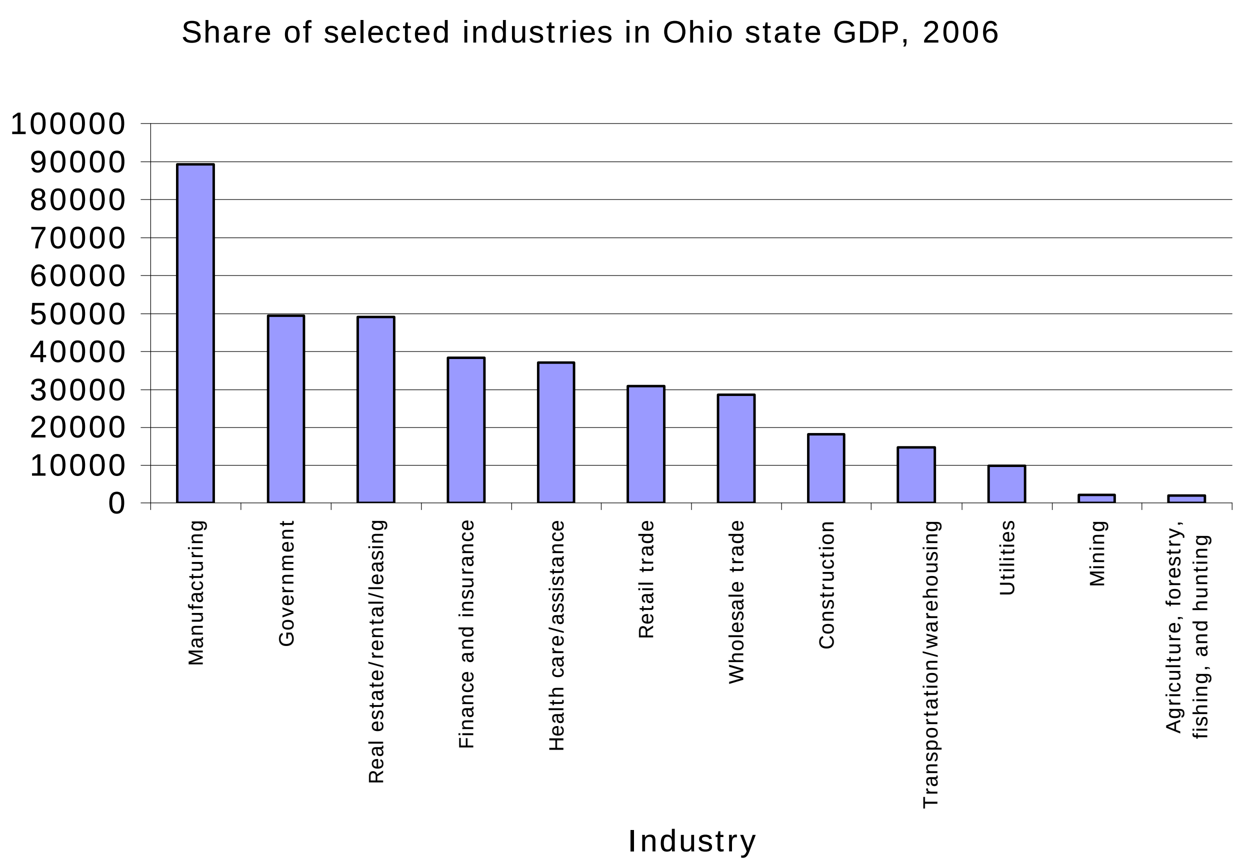

Figure 4. Breakdown of Ohio State GDP (Source: US Bureau of Economic Analysis 2006)

[1] Draft is the distance between the water line and the bottom of the vessel

Water Supply

Ohio's water supply will also be heavily affected as a drier climate, high rates of evaporation and reduced contributions from snow pack lead to decreased availability of surface water. Ohioans will turn to ground water to satisfy demand. The Ground Water Protection Council reported that 97 percent of all cities, villages, school, business, and industries in Ohio relied on ground water in 1996. Ohio farmers use about 2 billion gallons of ground water per year to irrigate their crops (Ground Water Protection Council 1996). Reliance on water for irrigation will increase in response to rising temperatures over the next century. As surface water supplies are strained through reduced levels or pollution concentration, look to see more water being extracted from ground reserves.

After the droughts of 1988 and 1991-1992, it was observed that there was an increased use of wells, which drew down water from a larger underground area, which concentrates pollutants and increases the risks of contamination. Some public ground water supplies dried up, and there was a scarcity of clean potable water (Rogers 1992).

Tourism, Recreation and Natural Resources

Lake Erie, forests, and natural locations throughout Ohio support a wide variety of tourism and recreational activities such as fishing and hunting. These activities are a major source of revenue for Ohio. A study conducted by Longwoods International for the Ohio Department of Development reports that visitors spent more than $33.8 billion in the year 2005 alone (Ohio Travel 2008b), which constituted nearly eight percent of Ohio's state GDP that year (BEA 2005). More than 560,000 people are employed in Ohio's travel and tourism industry. Tourism brings in $10.2 billion in wages for Ohio and direct taxes from tourism spending generate more than $2 billion (Ohio Travel 2008a). The Ohio Department of Natural Resources reported over two million hunting and fishing licenses and permits sold statewide in 2006 (Ohio Dept. of Natural Resources 2006). At an average price of $19[2], revenue from fishing and hunting licenses sale exceeded forty million dollars. Fishing, hunting and wildlife recreation also promote a range of other industries like restaurants, souvenir shops, fishing and hunting equipments. A survey by the United States Fish and Wildlife Services reported that about $2.96 billion was spent through fishing, hunting and wildlife recreation activities in Ohio in 2006 (US Fish and Wildlife Service 2006).

Increasing temperature in Ohio would result in range shifts and altered habitat for fish, which could significantly affect the recreational and commercial fishing in the state. Large changes in distribution and productivity of fisheries would indirectly impact industries closely associated with fishing. A report by Union of Concerned Scientists states that Lake Erie's world famous walleye fisheries could be affected by projected climate changes in the region. Jones et al (2006) in their study of walleye population in Lake Erie conclude that "in general, warmer lake temperatures led to increased habitat

[2] Price is quoted as the regular fishing and hunting license cost for adult resident applicants as listed on the license application at www.ohiodnr.com/wildlife/dow/regulations/vendor.aspx. The costs for out of state visitors are even higher, ranging from $40 for fishing to $125 dollars for standard hunting permits.

area and volume, particularly in the central and eastern basins, but reduced lake levels tended to offset these increases and lead to net declines in habitat area and volume in the western basin and in volume in the central basin" (Jones et al. 2006). Although many other factors need to be taken into account to derive the effects of such climate-related changes, a combined effect of summer stratification (a process by which oxygen supply is depleted in lower lake levels as warmer water rises to top) and possible accumulation of pollutants due to the lower water levels suggest significant impacts on fish populations and related industries. Furthermore, when rising water temperatures couple with other ecosystem changes, invasive species thrive and native fisheries are threatened. The Great Lakes and Lake Erie in particular, are notorious for their ability to draw in and harbor invasive species from around the world. Lake Erie has 34 non-native invasive fish species and a growing number of fish-damaging pathogens; these species vie for limited resources and deteriorate the native fish populations that are so vital to the local culture and economy of Ohio's Erie shoreline (Lake Erie 2006).

Ice fishing in the Lake Erie Islands is not only a favorite pastime among many local and visiting enthusiasts; it is also an important economic driver in the winter for the area's businesses. As temperatures warm up, the shallowest of the Great Lakes which typically freezes by late December is projected to stand unfrozen for longer periods. In the winter of 2002, for example, the Lake did not freeze throughout the winter, causing many businesses to shut down in their usually busiest season. At least $1 million in damages were reported at Put-in-Bay island, just one of Ohio's islands relying on tourism for its economic growth (Moore 2002).

A warming climate will also drive complex changes in the habitat food resources and other factors affecting bird diversity. For example, Ohio's Great Black Swamp, once about the size of Connecticut, has been reduced to 5 percent of its original area. Inventories of existing peat lands compared to inventories early in the 20th century estimate loss at 96 percent. The loss of these resources limits the habitat or food resources for migratory birds, shorebirds, and waterfowl and will affect Ohio's bird watching and hunting industries. Increasing likelihood of extreme weather events also may turn off many outdoor enthusiasts. Additionally, periodic droughts coupled with more frequent flooding could also have far reaching effects on the inner wetlands as sediments and pollutants reduce the flood absorbing capacities of the wetlands (Union of Concerned Scientists 2008). As the quality of wetlands deteriorates we can expect a reduction in the wildlife that depend on proper wetland functioning.

Since Ohio is part of the Mississippi River flyway, climate change could negatively affect migratory duck populations that breed in the prairie pothole region of the northern plains. Lower water levels in this area may decrease duck populations by as much as 70 percent, which will negatively affect the economy. A reduction in hunting would have negative effects on Ohio's economy and the 14,000 jobs generated by the hunting industry. Hunters spend about $600 million per year in the state, providing state tax revenues of more than $58 million (US Fish & Wildlife Service 2006). If interest in the sport is reduced by 40 percent due to loss of species, the annual impact on the economy would be a loss of over $23 million.

Forests cover 30 percent of Ohio and support many different forestry related industries like logging, furniture and paper pulp. Ohio's forest products industry contributes $15.9 billion to Ohio's economy and employs over 119,000 people with payrolls of $4.2 billion. The forest industry contributes over $426 million in sales and excise taxes annually and approximately $143 million in payroll taxes (Department of Natural Resources 2006). Climate change will stress forests with drier conditions, reductions in soil moisture and increased rates of evapotranspiration. Changes in species composition, geographic range of forests, and overall forest health and productivity will likely be the outcome of climate change. Ohio's forest areas could change little or decline by 30 to 50 percent, depending on how climate change and human management of forests plays out. Regardless of overall decline of forest density, the types of trees dominating forests and woodlands will likely change. In a warmer climate, forested areas could come to be dominated by pine and scrub oaks, replacing many of the economically valuable eastern hardwoods common throughout Ohio. In combination with Ohio's poor soils, an increase in temperature will expand the range of scrub oaks of little commercial value (e.g., post oak and blackjack oak). A decline of 50 percent in existing forest cover would amount to $8 billion in economic costs, and the loss of tens of thousands of jobs.

OTHER ECONOMIC IMPACTS

Agriculture

Agriculture will also be heavily affected by the climate changes projected in Ohio. The total market value of all agricultural products sold in 2002 was $4.9 billion, or about 1.25 percent of the total state GDP (NASS 2002). The main crops for Ohio include winter wheat, soybeans and corn; grains, oilseeds, and beans topped all agriculture products with sales of $1.5 billion. Dairy and livestock industries, which totaled $1.3 billion in sales (not including poultry), will also be affected by changes in temperature, precipitation cycles and severe weather (Census of Agriculture 2002).

While warmer weather, increased carbon dioxide and nitrogen may increase yield for some crops, higher ozone and severe weather, especially during the planting and harvest seasons, could decrease productivity (USEPA, Climate Change and Ohio, 1998). Drier conditions may also lead to shortage of water for irrigation adding to production costs. Studies have shown that increase in temperature decreases milk production in cows. A study by St. Pierre et al (2003) on the effect of heat stress on livestock in the United States found that without abatement measures, 320 Kg per cow per year of milk was lost due to increasing and prolonged exposure to temperature and humidity above a threshold level (St. Pierre et al. 2003).

Longer periods of drought may decrease agricultural yields, particularly in the southern portion of the state. This happened in 1999 after a late-season dry spell which decreased corn yields by over 11 percent. Farmers' incomes went down by nearly the same amount that year (Ohio State Extension and Purdue Extension Partnership 1999). A more severe yield loss was underway in 2007 when a drought caused some corn ears to become stunted, causing a 50-60 percent yield decrease (Pollock 2007). The same drought caused damages to hay harvests, as well, which are used for cattle feed. First-harvest yields were reported to be down by 20-70 percent in 2007 (Hay and Forage Grower 2007).

The effect of climate change on agriculture is dependent upon a host of other factors like adaptation strategies by farmers, technology and market demand. Additionally, increases in soil erosion from more precipitation and runoff and invasion from warm-climate pests will certainly have an impact on the people and industries in the Ohio agriculture sector.

Infrastructure

More frequent heavy rainstorms, flooding and high temperatures would add to the costs through infrastructure damage. With high temperatures the ground hardens and becomes less permeable to rainfall. Under these conditions precipitation and especially heavy rainstorms lead to more flooding. The Ohio valley has been subjected to a great deal of costly flooding as of recently. For example, the March flood of 1997 cost nearly $232.5 million and resulted in the evacuation of 20,000 people (Jackson 1998). Heavy rainstorms and flooding not only damages properties but also adds to the costs for emergency management, rebuilding costs and negatively affects the quality of water. Figure 5 shows the massive extent of flooding in Findlay, Ohio in August 2007. Severe floods caused over $115 million in damage across six states in the Midwest (Wikipedia 2007).

Figure 5. Extent of flooding in Findlay, Ohio, August 2007 (Source: US Geological Survey 2007)

Health Impacts

Various studies have also shown the negative health impacts of increasing temperature on human mortality and morbidity. A study released by Physicians for Social Responsibility in 2000 reported that increasing temperature and ground level ozone in Ohio would result in more heat related illness and deaths. Also increased flooding due to more frequent heavy rainstorms could cause water borne diseases like the Norwalk Virus to be more common (Physicians 2000). Although increased use of air conditioning and other measures will help people adapt to the increasing temperatures, the consumption of more energy causes more pollutants to be released by power plants, increasing health risks for the region (Physicians 2000). Lastly, increased winter temperatures will result in fewer cold-related deaths, but a rise in summer temperatures will increase the occurrence of heat stroke and heat-related deaths.

MISSING INFORMATION AND DATA GAPS

This study is subject to the uncertainties inherent in measuring global climate change and climate change itself and attempts to reflect this as best as possible through use of scenarios and ranges of confidence. Additionally, quantifying the economic impacts of climate change deserves significantly more focus as this paper and much of the literature on the topic primarily qualify the potential impacts. Further, data gaps exist between the effects of climate change in one particular sector and the ripple effects that manifest in interconnected sectors. Analysis of this sort would be useful to policy-makers and businesses at all levels and sizes. As policy-makers move forward in analyzing the economic costs of climate change in Ohio more information on the shipping and manufacturing details for particular regions and goods would prove valuable. Knowing the portfolio of goods that are shipped through Lake Erie and whether or not these goods can afford to be transported with smaller vessels or by other means will help elucidate policy alternatives.

CONCLUSIONS

The state of Ohio's greatest challenge is likely to be in adapting to climate change along its waterways and on Lake Erie, as this is where the most significant economic and ecological impacts will occur. Building and maintaining an alternative transportation infrastructure would allow Ohio to maintain its vibrant manufacturing industry amidst sea-shipping uncertainty, but the costs of the sort of adaptation needs to first be researched. Natural areas such as forests and lakes will suffer from climate change. The ecological integrity of Ohio’s natural landscape will be threatened in the coming century and it is recommended that management of resources be carefully monitored to ensure the wellbeing of the economic and cultural functions that depend on them. Lastly, because flooding events are likely to occur more often, preparations to prevent and mitigate floods and flood related disasters could be made ahead of time.

Lessons Learned

As we begin to quantify the potential impacts of climate change and the cost of inaction, the following five lessons are learned:

1. There are already considerable costs to society associated with infrastructures, agricultural and silvicultural practices, land use choices, transportation and consumptive behaviors that are not in synch with past and current climatic conditions. These costs are likely to increase as climate change accelerates over the century to come.

2. The effects of climate change should not be considered in isolation. Every state's economy is linked to the economies of surrounding states as well as to the national and global economy. While the economic costs of climate change are predicted to vary significantly from state to state, the negative impacts that regional, national and global markets may experience are likely to affect all states and many sectors.

3. While some of the benefits from climate change may accrue to individual farms or businesses, the cost of dealing with adverse climate impacts are typically borne by society as a whole. These costs to society will not be uniformly distributed but felt most among small businesses and farms, the elderly and socially marginalized groups.

4. The costs of inaction are persistent and lasting. Benefits from climate change may be brief and fleeting -- for example, climate does not stop changing once a farm benefited from temporarily improved growing conditions. In contrast, costs of inaction are likely to stay and to increase.

5. Climate models and impact assessments are becoming increasingly refined, generating information at higher spatial and temporal resolutions than previously possible. Yet, little consistency exists among studies to enable "summing up" impacts and cost figures across sectors and regions to arrive at a comprehensive, state-wide result.

6. To provide not just a comprehensive state-wide assessment of impacts and cost, but to develop optimal portfolios for investment and policy strategies will require support for integrative environmental research that combines cutting-edge engineering solutions with environmental, economic and social analysis. The effort and resources required for an integrative approach likely pales in comparison to the cost of inaction.

WORKS CITED

Barnett, T.P. (1984), ‘The estimation of “global” sea level change: a problem of uniqueness’, Journal of Geophysical Research, 89: 7980-7988.

Bureau of Economic Analysis.2006. Regional Economic Accounts. Available Online: www.bea.gov.

Bureau of Economic Analysis.2005. Regional Economic Accounts. Available Online: www.bea.gov.

Bureau of Labor Statistics (BLS). 2008. Consumer Price Indexes: Inflation Calculator. Available Online: www.bls.gov/cpi/.

Census of Agriculture. 2002. Available Online: www.nass.usda.gov/census/census02/volume1/us/st99_2_002_002.pdf

Division of Wildlife, Ohio Department of Natural Resources. License Sales by County 2006. Available online: www.ohiodnr.com/wildlife/dow/regulations/PDF/pub062-2006.pdf

Douglas, B.C. (2001), ‘An introduction to sea level’, in Sea level rise: history and consequences, B.C. Douglas, M.S. Kirney, and S.P. Leatherman (eds), San Diego, CA: Academic Press, pp. 1-11.

Easterling, D. R., G. A. Mehl, et al. (2000), ‘Climate extremes: observations, modeling, and impacts’, Science, 289: 2068-2074.

Frederick, K.D. and P.H. Gleick (1999), ‘Water And Global Climate Change: Potential Impacts on US Water Resources’, Washington, DC: Pew Center on Global Climate Change.

Great Lakes Water Quality Board. *Climate Change and Water Quality in the Great Lakes Basin*. (Ontario, Canada: International Joint Commission of the United States and Canada, 2003). Available online: www.ijc.org/php/publications/html/climate/index.html

Ground Water Protection Council (GWPC), Ohio Ground Water Conditions. 1996.Available online: www.gwpc.org/e-library/e-library_documents/e-library_documents_state_fact_sheets/ohio.pdf

Intergovernmental Panel on Climate Change (IPCC). 2001. The Scientific Basis. Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Eds. J.T. Houghton. Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell and C.A. Johnson. Cambridge, England and New York, NY: Cambridge University Press. Available online: www.grida.no/climate/ipcc_tar/

Intergovernmental Panel on Climate Change (IPCC) (2001), Climate Change 2001: Working Group II: Impacts, Adaptation and Vulnerability, Intergovernmental Panel on Climate Change, Cambridge: Cambridge University Press.

IPCC (2007), Climate Change 2007: Synthesis Report for the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Available Online: www.ipcc.ch/ipccreports/ar4-syr.htm

IPCC (2007), Climate Change 2007: Working Group II: Impacts, Adaptation and Vulnerability, Intergovernmental Panel on Climate Change, Cambridge: Cambridge University Press.

Jackson, K.S. and Vivian. S.A. United States Geological Survey. 1998. Flood of March 1997 in Southern Ohio. Available Online: http://oh.water.usgs.gov/reports/Flood/flood.rpt.html

Jones, M.L., B.J. Shuter, Y.M. Zhao and J.D. Stockwell, 2006: Forecasting effects of climate change on Great Lakes fisheries: models that link habitat supply to population dynamics can help. *Canadian Journal of Fisheries and Aquatic Science*, **63**, p. 466.

Kling, George W. et al. 2003. Confronting Climate Change in the Great Lakes Region, Impacts on Ohio Communities and Ecosystems. Cambridge, Massachusetts: Union of Concerned Scientists, 2003. Available online: www.ucsusa.org/greatlakes/glchallengereport.html

Lake Erie Lakewide Management Plan. Section 11: Significant and Ongoing and Emergent Issues (Washington, D.C.: US EPA, April 2006). Available online: www.epa.gov/lakeerie/2006update/Section_11.pdf

Moore, K. 2002. An Unfrozen Lake Erie. Morning Journal. Available online: www.zwire.com/site/news.cfm?newsid=3365213&BRD=1699&PAG=461&dept_id=46371&rfi=6%20

National Agricultural Statistics Service (NASS).2002. *2002 Census Publications – Ohio*. Available Online: www.agcensus.usda.gov/Publications/2002/Census_by_State/Ohio/index.asp

National Assessment Synthesis Team. 2001. *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change.* Report for the US Global Change Research Program. Cambridge University Press, Cambridge, UK. Available online: www.usgcrp.gov/usgcrp/nacc

Office of Strategic Research, Ohio Department of Development. March 2007. Ohio Exports 2006, Origin of Movement Series.

Ohio State Extension and Purdue Extension Partnership. "Ohio Drought Effects Vary by Region." AG Answers Online News, September 17, 1999. Available online: www.agriculture.purdue.edu/AgAnswers/story.asp?storyID=2058

Ohio Travel Association, 2008a. Ohio Travel and Statistics. Available Online www.ohiotravel.org/pages/statistics.html

Ohio Travel Association. 2008b. *Ohio travel & tourism statistics*. Available Online: www.ohiotravel.org/pages/statistics.html.

Ohio Department of Natural Resources. 2006. The Many Sides of Forest Industry. Available Online: www.dnr.state.oh.us/Portals/18/publications/pdf/OFA_manysidesreport.pdf

Physicians for Social Responsibility. Death by Degrees: The Emerging Health Crisis of Climate Change in Ohio. 2000. Available online: www.psr.org/site/DocServer/Death_By_Degrees_Ohio.pdf?docID=553

Pollock, C. "Ohio's Drought Causing Stunted Corn Ears." Ohio State Extension and Purdue Extension Partnership, Online News, September 18, 2007. Available online: www.ag.ohio-state.edu/~news/story.php?id=4292

RESI, 2008. Calculations using modified IMPLAN™ economic model from the Regional Economic Studies Institute (RESI) of Towson University.

Rogers, J. C. 1992. Drought Hazards and Statistics for Ohio. State Climatologist for Ohio, based on notes from the Governor's Drought Assessment Committee Meetings. Available online: www.geography.ohio-state.edu/faculty/rogers/drought.html

St. Pierre et al "Economic Losses from Heat Stress by US Livestock Industries" 2003. Journal of Dairy Sciences. 86: (E. Suppl.):E52–E77

Union of Concerned Scientists. 2006. Climate Change in Ohio. Available Online: www.ucsusa.org/greatlakes/glregionohi_agr.html. See also www.greatlakeshybrids.com/2006/06/30/ohio-soybeans-may-take-hit-from-flood-injury/ on effect of flooding on soybean crops in Ohio.

US Environmental Protection Agency (USEPA). 1998. *Climate Change and Ohio*. Available Online: http://yosemite.epa.gov/oar/GlobalWarming.nsf/UniqueKeyLookup/SHSU5BVJVM/$File/oh_impct.pdf.

US Fish and Wildlife Service. 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. State Overview. 2007. p.8. Available Online: http://library.fws.gov/nat_survey2006_state.pdf

US Geological Survey. 2008. Ohio Water Science Data. Available online: http://oh.water.usgs.gov/

Wikipedia. 2007. Midwest Flooding. Available online: http://en.wikipedia.org/wiki/2007_Midwest_flooding.