# Economic Impacts of Climate Change on North Dakota

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**A Review and Assessment Conducted by**
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## 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 impacts 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 North Dakota 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).

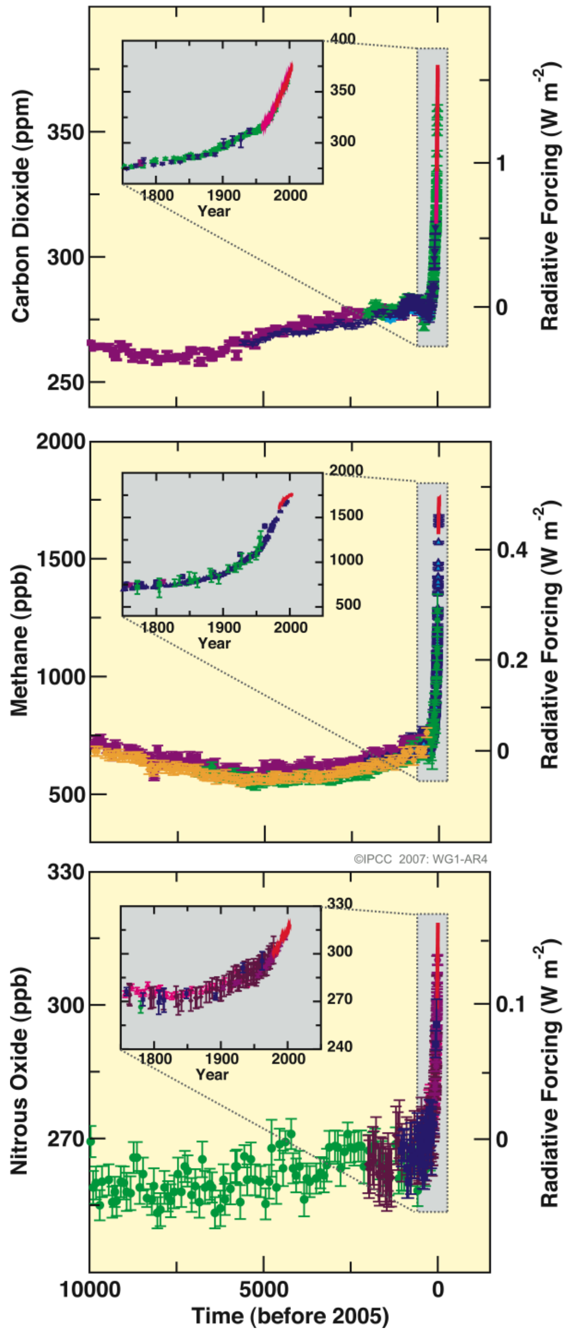


**Figure 1: Atmospheric Concentrations of Carbon Dioxide, Methane and Nitrous Oxide** (Source: IPCC 2007)

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 per cent since the 1950s (IPCC 2007).

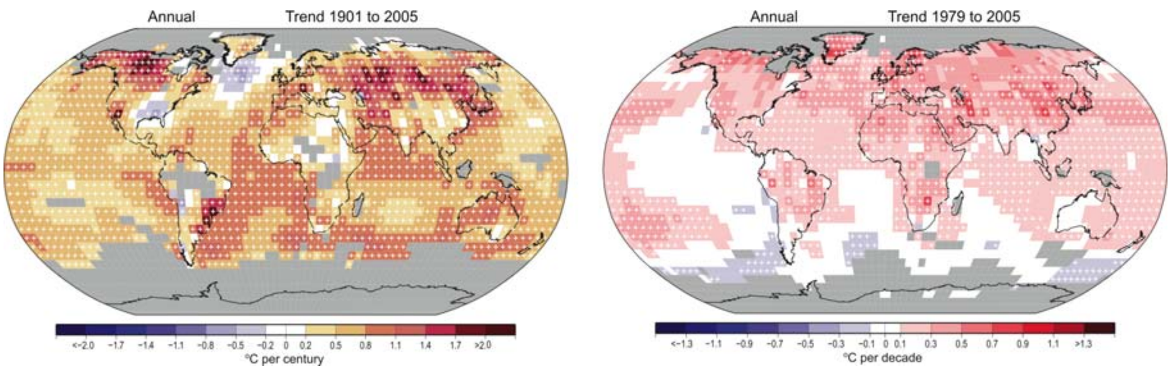


**Figure 2: Annual Temperature Trends** (Source: IPCC 2007)

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, may result in altered frequency and severity of climate extremes around the globe (Easterling, et al. 2000). For example, it is likely that there has been a 2 to 4 per cent 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 North Dakota 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 North Dakota 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 NORTH DAKOTA

The climate in North Dakota is characterized by its unpredictability. The state is subject to blizzards, floods, droughts, tornadoes, hail storms, thunderstorms, high winds, severe cold spells, and extreme heat (USGCRP 2000). Scientific research has shown that cyclical droughts are a characteristic feature of North Dakota. Semi-arid conditions with low annual rainfall prevail in the western half of the state; the eastern portion experiences more precipitation, with an average of 22 inches, mostly as rain in the spring and summer (Info Please 2007). Atmospheric models predict that North Dakota will become drier in the future, with drought patterns becoming more intense as a consequence of global warming (Handwerk 2005).

The average annual temperature for the state of North Dakota ranges from 37º F in the northern part to 43º F in the south. In the past 100 years the average annual temperatures in the northern and central Great Plains have risen by about 2° F. The latest IPCC report predicts the state could experience an increase in temperature of nearly 7° F by 2100. Another projected change is an increased frequency of extreme weather events (USGCRP 2000).

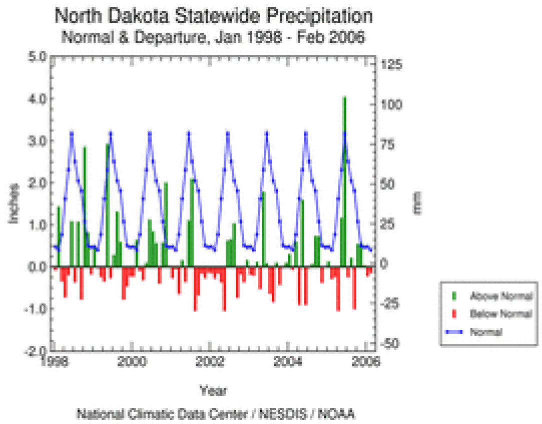


**Figure 3: North Dakota State Wide Precipitation** (Source: National Climatic Data Center, 10 March 2006)

Projected climate change effects will likely cause significant economic losses to North Dakota's vital agricultural sector, as both droughts and unpredictable weather events damage crops and the livestock industry. Infrastructure-related losses are also likely to increase. Additional impacts are expected to the tourism sector and hydroelectric power production.

## MAJOR ECONOMIC IMPACTS

### *Agriculture*

The most important industry to North Dakota's economy is agriculture. Wheat production – the state's most important overall economic activity - generates about $4.5 billion in revenue each year (North Dakota Wheat Commission 2007). Along with wheat, North Dakota produces flax and seed potatoes (in the east), and barley, sugar beets, oats, soybeans, and sunflowers (in the west) (Info Please 2007). North Dakota is also an important exporter of agricultural products. In 2006, North Dakota was 11th in the nation in agricultural exports, with an estimated value of $1.9 billion. Farm cash receipts totaled $4.21 billion. The agricultural sector supports about 22,300 jobs both on the farm and in the food processing, storage, and transportation industries.

The agricultural sector is adversely impacted by both droughts and intensified weather events, such as heavy precipitation. In the past, the state has suffered great losses due to drought and general weather unpredictability. In 2002, the state's economy suffered an estimated $223 million loss due to damages to agricultural crops caused by drought (Jossi 2002). And heavy rains in 2005 were responsible for ruining over one million acres of cropland and preventing another million from being planted.

Drought affects not only agricultural crops, but livestock as well. By September 25, 2006, North Dakota State University's agriculture economists estimated the cost of that year's drought to the livestock industry alone to be over $32 million. The losses occurred largely due to an increase in the cost of feed - which went up over 50 percent in some areas because of reduced harvests. The same drought inflicted over $425 million damages on crop production; stimulating an additional societal loss of nearly $310 million in form of crop insurance indemnity payments (North Dakota Department of Agriculture 2007). Grazing was also drastically reduced under drought conditions. Producers were forced to sell livestock as well as land, and many cows died due to poisoning and lung diseases caused by concentration of disease agents in stagnant water (US Corps of Engineers 2006).

An additional stress on the state's agricultural sector is an increased vulnerability to pests; erratic weather conditions and higher winter temperatures, among other factors, can contribute to a rise in pests (Rosenzweig, et al. 2000). Plant diseases cause losses exceeding $1 billion annually due to reduced yield and quality of crop commodities as well as indirect losses to the rural and state economy from reduced business activities in the state. Specifically, estimated losses caused by scab (Fusarium head blight) in wheat, barley, and durum from 1993-2005 have been estimated at $4.89 billion. In 2005, direct losses to farmer's income from the disease were estimated at $171.06 million. The overall impact to the state's economy was over $544.76 million in economic losses.

Other diseases and insects, such as white mold, tan spot, rust, bacterial diseases, blight, root rots, viruses, aphids, leafhoppers, and flea beetles, in a range of commodities important to the state also reduce the revenue to the state by several hundred million dollars annually (North Dakota State University 2007). A recently published report by the Harvard Medical School found that projected climate change impacts – such as droughts, higher temperatures, and more frequent intense weather events – will aid the spread of plant pests and diseases, likely inflicting even larger economic damages on the agricultural sector (Rosenzweig, et al. 2000).

An economic analysis by researchers at Towson University estimated that due to pest outbreaks, 2,500 people lose their jobs each year, while the economic impact tops $1.5 billion dollars annually (RESI 2008).

***Water Supplies and Infrastructure***

Like with agriculture, both droughts and rainfall events can be economically damaging to the water supply network and the built infrastructure. The worst drought in North Dakota's history was very recent, lasting from about 2000 to mid-2006. Public water supplies became compromised throughout the period. On August 23, 2006 the US Army Corps of Engineers was forced to increase flows from the Garrison Dam in North Dakota to supplement the low water levels of the Oahe Reservoir along the Missouri River. Lake Oahe's elevation was at a record low of 1,571.3 feet above sea levels (compared to an average of 1,610 feet in 1998) (USGS 1999). This affected hydropower production directly and contributed to the worst fire season on record (US Corps of Engineers 2006).

Drought in North Dakota can also have corrosive effects on the civil infrastructure of cities, such as Fargo, by drying the clay material underneath the city. The clay shrinks because of lack of moisture, which can lead to cracked sidewalks, driveways, and streets.

Precipitation increases will likely occur in spurts of heavy rain events, which is also problematic for both the water system and infrastructure. Moreover, as drought conditions reduce soil permeability, the incidence of flash floods is likely to rise. In 2002, the state experienced $2.35 million worth of flood damages to roads, streets, bridges and water drainage systems in rural areas (North Dakota Office of the Governor 2002). In 2004, 679 housing units were damaged due to floods (IRI 2004). Since climate change models project more extreme weather events coupled with drier conditions, North Dakota will likely experience further damages to its infrastructure, disrupting critical services and inflicting economic losses.

## OTHER ECONOMIC IMPACTS

### *Hunting and Fishing*

In 2006, nearly 400,000 sportsmen and women spent more that $259.21 million hunting and fishing in North Dakota. The industry provided about 5,000 jobs. Rainbow trout alone brings in over a million dollars in retail sales annually, as outlined in Table 1 below.

| Retail Sales | Industrial Output | Jobs | Job Income |
|---|---|---|---|
| $1,332,911 | $2,274,969. | 21 | $490,127 |

**Table 1: NFH Rainbow Trout Stocking: 2004 Economic Impacts on North Dakota** (Source: Economic Effects of Rainbow Trout Production by the National Fish Hatchery System 2004)

However, rising temperatures and lower stream flows will have adverse effects on cold-water fish such as rainbow trout (US Corps of Engineers 2006). This may reduce the number of fishing excursions in the area and reduce the economic benefit to the region.

For example, low levels in Lake Sakakawea – which is one of the largest man-made lakes in the country – will likely result in a loss of the cold-water habitat necessary to sustain the forage fish species that serve as the food base for bigger game fish (North Dakota Office of the Governor 2005). Local businesses are suffering since there has been a reduction in the space available for boats to dock as the water levels recede – reducing the number of sportsmen visiting the area. Other businesses affected are local bars, gas stations, and convenience stores. Further changes to the water levels and temperatures will likely undermine this economically important recreational activity.

Hunting will likely be affected by projected climate change impacts as well. Currently, North Dakota's yearly waterfowl production averages 3.8 million, more than any other state (Magstadt 2006). By the 2080s, wetlands in the Prairie Pothole Region and areas in the northern Great Plains could be reduced by 91 percent. This could lead to a drastic reduction in duck breeding. Similarly, other bird species such as the greater prairie chicken are declining with loss of habitat. Waterfowl hunting is a profitable industry in the state, with trip and equipment expenditures topping $44 million in 2001. Additional economic contributions of the activity are outlined in Table 2. Reductions in the hunting industry directly impacts small businesses in the region with an estimated $7.38 million spent in 2006 on food, lodging, transportation and equipment (Business Management of Operations: Division of Economics 2007.

| **Trip and Equipment Expenditures** | **Total Output** | **Job income** | **Jobs** | **State Tax Revenue** | **Federal Tax Revenue** |
|---|---|---|---|---|---|
| $14,351 | $20,942 | $5,319. | 236 | $1,015 | $1,398 |

**Table 2: Economic Impact of Waterfowl Hunting—State Totals for 2001** (Dollar values are in thousands.) (Source: National Survey of Fishing, Hunting, and Wildlife-Associated Recreation)

Changes in species' habitat ranges are expected to adversely impact another outdoor recreational activity – bird watching. In 2006, around $23 million was spent in North Dakota by wildlife watching enthusiasts (US Fish and Wildlife Service 2006). Nearly 35 bird species found in North Dakota today are predicted to exclude North Dakota as their summer habitat if climate change progresses unchecked; and around 20 bird species will have a diminished habitat in the state (Price 2002). It should be noted that birds are an extremely important link in ecosystems, providing pollination, seed dispersion and insect control for agricultural production. The economic impact on the agricultural industry from reduced bird numbers may be significant.

### *Hydroelectric dams*

Nearly all the electricity produced in the state is generated by coal, which is responsible for the greatest amount of greenhouse emissions (EIA 2008). With just over half a million residents, North Dakota has a relatively small population. However, its power plants produce 68 percent more carbon dioxide than New Jersey, which has 13 times North Dakota's residents (Borenstein 2007). As the nation moves to curb greenhouse gas emissions, states are exploring alternative generation sources. However, the scope of options may be reduced because of upcoming impacts on the state's climate.

For example, hydroelectric power represents an important alternative energy source, accounting for 4 percent of the state's total electricity production (USDE 2008). In future years, however, maintaining this level of production and expanding it might be compromised due to climate change, reducing options for renewable energy production in the state. Climate models suggest drier conditions, which will lower water levels in crucial reservoirs and undermine hydroelectric energy production.

Garrison Dam on the Missouri River is the fifth largest dam in the United States and is responsible for the creation of Lake Sakakawea, the third–largest man-made reservoir in the United States. The dam is also the fifth largest electricity generation plant by capacity in the state (EIA 2008), and is used for flood control and irrigation purposes. It is also a source of recreation, fish and wildlife, and is a designated National Fish Hatchery. Over the years the hatchery's role has expanded to host migratory fishes, such as the paddlefish, and restoring endangered species, like the pallid sturgeon (US Fish and Wildlife Service 2001).


**Figure 5: Missouri River** (Source: USGS, 2008 Dams and Reservoirs of the Upper Missouri River; nd.water.usgs.gov/lewisandclark/dams.html)

Lake Oahe is the fourth largest man-made reservoir and spans both North and South Dakota. The dam is also maintained for the production of hydroelectric power, flood control, regulation of downstream flows for navigation, recreation, fish and wildlife, water supply and irrigation (US Geological Survey 2001). The fishery in Lake Oahe yielded $27.64 million per year in revenue in the mid- 90s, yet by 2004 it produced less than $11.25 million per year (South Dakota Drought Task Force 2008).

The potential electricity production from both of these dams may be greatly diminished in the future as water levels decrease. Additional externalities from lower water levels will likely include changes to the recreational activities on the reservoirs and their contribution to the public water supply system.

## MISSING INFORMATION AND DATA GAPS

General climate predictions relating to the entire state of North Dakota must be made cautiously due to its variable topography. Additionally, this study is subject to uncertainties regarding predictions about climate change and its potential impacts. There are many possible scenarios that could result from climate change, which will vary predicted economic impacts. Further research is necessary to examine the contribution climate change will have in exacerbating the already unpredictable nature of North Dakota's climate.

## CONCLUSIONS

North Dakota will experience an increase in the unpredictability of droughts, floods and pests. This will make it hard for farmers –and especially small farmers- to remain in the agricultural industry. Damages to the agricultural industry will in turn have negative effects on the livestock industry. Furthermore, the hunting, fishing and tourism industries will suffer losses due to reductions in habitats and receding water levels. These losses can, and are likely to be, devastating to North Dakota's economy, which has a small population and relies heavily on the revenue procured by these industries.

### *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 this century.

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.

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