Economic Impacts of Climate Change on North Carolina

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CIER
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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 Carolina 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 2007a).

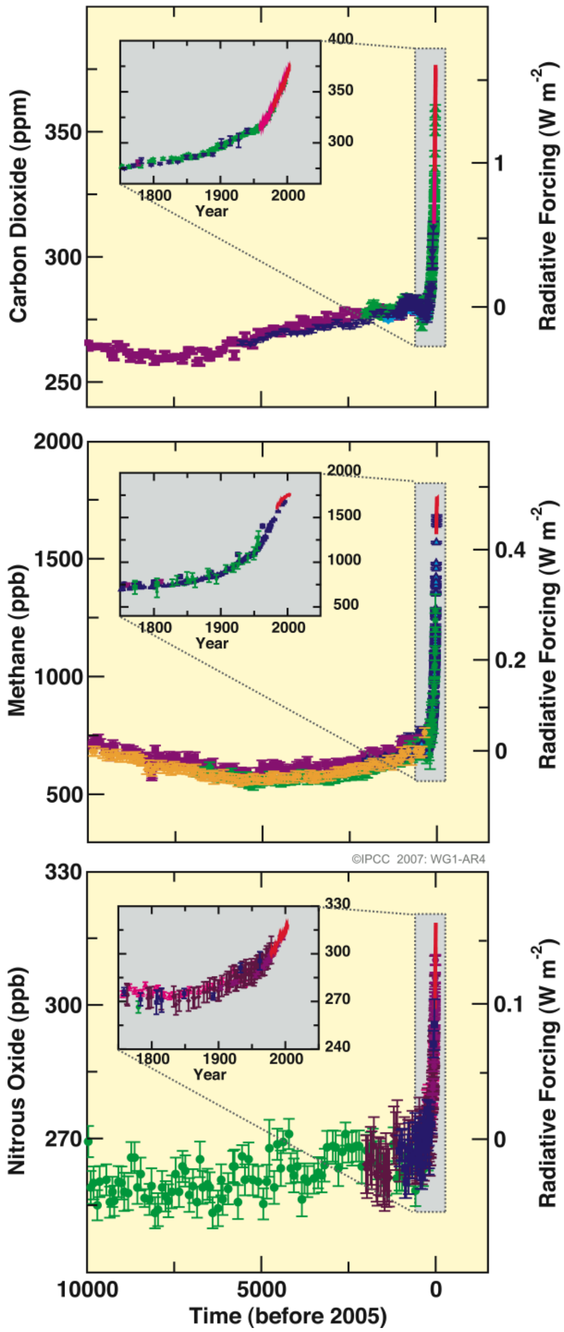

Figure 1: Atmospheric Concentrations of Carbon Dioxide, Methane and Nitrous Oxide (Source: IPCC 2007a)

A change in average temperatures may serve as a useful indicator of changes in climate (Figure 2: Annual Temperature Trends (Source: IPCC 2007a), 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 2007a).

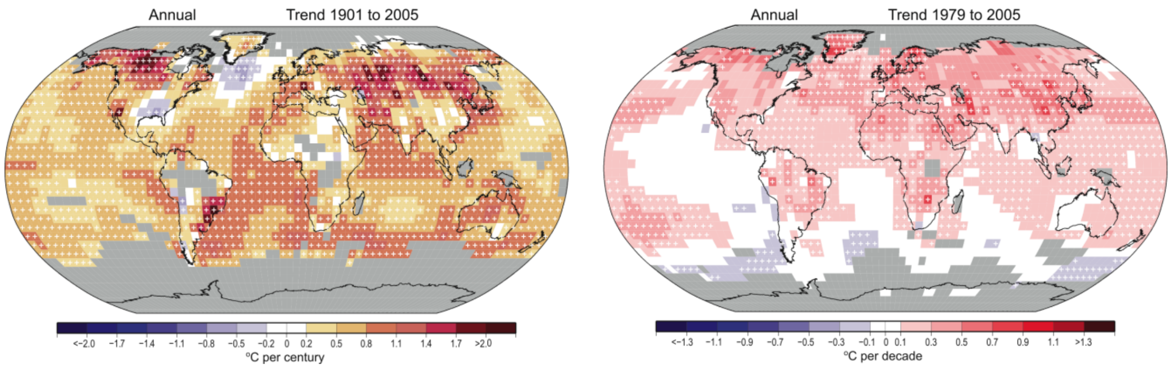

Figure 2: Annual Temperature Trends (Source: IPCC 2007a)

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 (IPCC 2007a; Barnett 1984; Douglas 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 and Mehl 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 North Carolina 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 Carolina, 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 CAROLINA

In the last century, average temperature in North Carolina has risen by 1.2° F and precipitation has increased by 5 percent in many parts of the state (USEPA 1998). Although there are variations in the temperature and precipitation within the state, overall, the last decade was warmer and wetter than the previous four decades. The maximum summer temperature rose near the coast, whereas in the rest of the state the change was negative or negligible. The minimum temperature on average has been rising for all seasons and all parts of the state. Precipitation has increased over the past fifty years during the fall and spring, but decreased during the summer (Boyles and Raman 2003).

Over the next century, climate models predict a continuation of the same trends. Temperature is expected to increase uniformly across the state - a conservative estimate suggests an increase of 4.1° F for the whole of south-eastern United States over the next century (USGCRP 2001). Increases in frequency and duration of extreme hot days during the summer have also been predicted as a result of the general warming trend in North Carolina (USEPA 1998). Precipitation is estimated to increase by 15 percent in winter and spring and by a greater amount over the summer. A recent assessment report by the Intergovernmental Panel on Climate Change predicts more climate variability coupled with temperature increases resulting in more frequent droughts and other extreme weather events in North America (IPCC 2007).

Climate change will also intensify the trend of global sea-level rise. The IPCC report estimates a worldwide rise in sea-level of 7 to 23 inches over the next century (IPCC 2007b). Further exacerbating the coastal impacts of climate change is the predicted increase, both in intensity and frequency, of hurricane activity; and warmer ocean temperatures may fuel the formation of more intense hurricanes (IPCC 2007b; Trenberth 2007). Rising sea levels might be particularly disastrous to coastal North Carolina as many parts of the coast may experience subsidence by about 7 inches per century, resulting in a higher level of inundation (Munger and Shore 2005). In fact, the "National Assessment of Coastal Vulnerability to Sea-Level Rise" undertaken by the US Geological Survey found that when relative vulnerabilities are considered, more than half the state's shoreline is at very high risk to sea-level rise. The rest of the coast is at high or moderate risk.

MAJOR ECONOMIC IMPACTS

Coastal Impacts

Sea level rise due to climate change will inflict major economic impacts on the tourism, recreation, and real estate industries of North Carolina. Impacts of sea level rise on coastal areas include more frequent and severe inundation of wetlands and marshes, as well as permanent land erosion and landward migration of beaches, saltwater intrusion in freshwater streams and aquifers, and infrastructure damage (USRCGC 2008).

The IPCC Fourth Assessment projects a mean global sea level rise of 7 to 23 inches by 2095 (IPCC 2007b). Many variables, such as regional coastal slopes, shoreline erosion rates, and the shape of the coastal formation, determine how vulnerable a particular area will be to increased water levels. Figure 3 shows the vulnerability of the North Carolina coastline to impacts associated with higher sea levels. Red represents coastal shores at highest level of risk to sea level rise. Orange shows regions at high level of risk, and the shoreline in yellow is at moderate risk of vulnerability to sea level rise. More than half of the state's coast is at high or very high risk level.

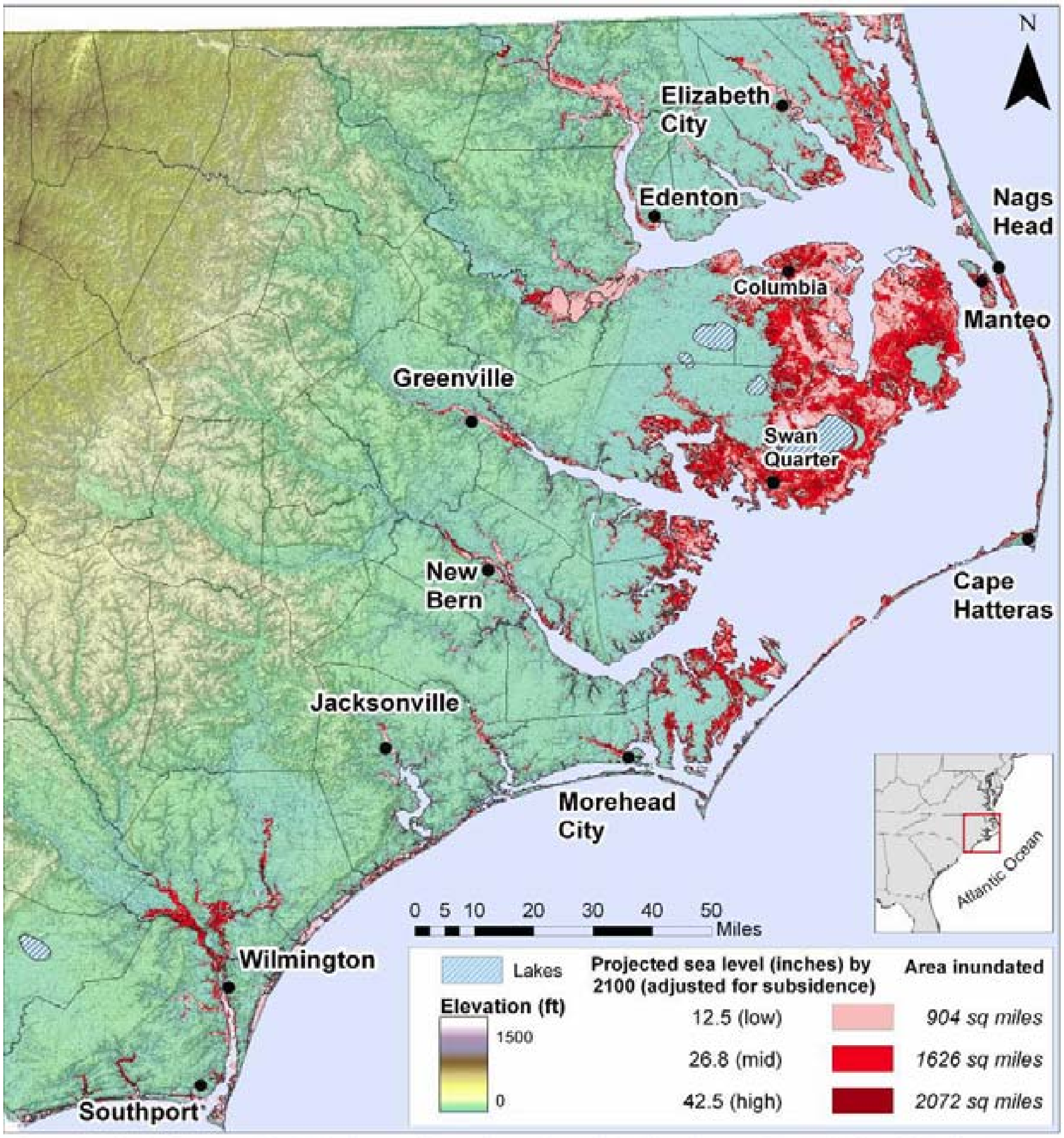

Figure 3: Map of Coastal North Carolina and Sea Level Rise (Source: Poulter and, Halpin 2008).

Property values of coastal real estate are at risk because of climate change-induced sea level rise. The coastal population in the US increased 37 percent between 1970 and 2000 and the average coastal property is worth 8-45 percent more than a comparable inland property (Bin et al. 2007). In North Carolina, South Carolina, and Georgia, the value of insured coastal property increased 88 percent, or $62 billion, between 1988 and 1993 (Neumann et al. 2000). One study estimates that with a 46-cm (around 18 inches) rise in sea level by 2080, the total loss in residential and nonresidential property values for four coastal counties in North Carolina could amount to over $2.8 billion (2007 dollars) (Bin et al. 2007). The total value of the real estate industry in North Carolina was $34.1 billion in 2005 (BEA 2008, $2007). In addition, real and perceived dangers of coastal subsidence and flooding have increased the costs of insurance coverage in the US Southeast (Mills 2005).

County	**Residential Property Value Loss**	**Non-residential Property Value Loss**
New Hanover	$99 million	$35 million
Dare	$988 million	$1.42 billion
Cataret	$100 million	$183 million
Bertie	$5.45 million	$3.8 million

Table 1: Estimates of lost coastal property value in 2080 under an 18 inch sea level rise scenario for four counties in North Carolina. (Source: Bin et al. 2007, converted to 2007 dollars)

North Carolina is no stranger to hurricanes. In fact, the state is fourth in the number of recorded hurricane strikes with 50 hurricanes landing on its coastline from 1851-2006 (NWS 2007). Economic damages vary with each event, but can be significant. For example, Hurricane Isabel made landfall in North Carolina as a category 2 hurricane in 2003. The hurricane reached category 5 as it moved northward through Virginia, Maryland, Pennsylvania and other states as far north as New York, inflicting billions of dollars in damages along the way. Isabel caused nearly $200 million in insured property losses in North Carolina (2007 dollars); as much as $1.8 billion in Virginia; over $470 million in Maryland; and over $200 million in damages in five other states. The entire economic cost of Hurricane Isabel was estimated at $3.9 billion (2007 dollars) in the region (National Weather Service 2003). On the other hand, Hurricane Fran, which hit the state in 1996, caused a total of $6.7 billion (2007 dollars) in damages in North Carolina alone (NCDC 1996).

The economic losses can be very significant, and since the regional distribution of those costs is dependent on the pathway of the storm, states may be affected less or more significantly with each event. However, a projected increase in the number and intensity of storms will likely impose further economic impacts on North Carolina and its neighboring states.

In addition to their impacts on property, sea level rise and more intense hurricane activity will hurt the tourism industry in North Carolina. Costs to tourism include losses of beach area due to sea level rise and decrease in demand for beach trips due to more unpredictable weather patterns. These costs also include losses to area businesses because of decreases in tourism. Estimates suggest that the present value of the welfare costs to beach recreation inflicted by an increase of 46 cm (18 inches) in sea level by 2080 could be as high as $10.6 billion, assuming a 2 percent discount rate (Bin et al. 2007).

Other revenue losses could occur in the fishing sector of the economy. Recent estimates suggest that aggregate consumer welfare losses for anglers in North Carolina could amount to $17 million per year by 2080 (Bin et al. 2007).

One proposed method to protect coastal infrastructure from rising sea levels is building a seawall or bulkhead along the coast. Officials commonly estimate the cost of such a structure at about $1,190 per linear foot (2007 dollars) (Neumann et al. 2000). For North Carolina's 301-mile coast, building such a structure would cost the state $1.89 billion (NC Department of Commerce 2008).

OTHER ECONOMIC IMPACTS

Agriculture and Forestry

The agriculture sector in North Carolina will also be affected by climate change. Droughts, hurricanes and increased temperature in general would severely affect the farming, livestock and forestry related industries. An AEI-Brookings Joint Center for Regulatory Studies report estimates a 22.6 percent climate-change induced loss in agricultural profits for the state (Deschenes 2006).

North Carolina ranks second in the country in hog production with nearly $2 billion generated in cash receipts in 2006 (NCDACS 2007a; NCDACS 2007). Adams et al. (1998) have estimated that a 9° F degree increase in temperature reduces livestock yield in animal and dairy operations by about 10 percent in the Appalachian region. A study by St. Pierre et al. (2003) suggested that the heat stress with minimal abatement caused a loss of $2.6 million per year in the poultry sector in North Carolina alone. With poultry and eggs comprising 36 percent of the total farm sales, or a value of $3.9 billion dollars in 2006, increasing temperature could mean significant impacts on the industry as well as increased costs for heat abatement measures.

Higher temperature is also expected to increase the frequency and intensity of droughts in the state. The National Drought Mitigation Center commented that in 2007 the epicenter of droughts for the whole of United States had shifted from the mid-west to the south-east with North Carolina being among the states which experienced the driest year in the last century (Fuchs 2008).

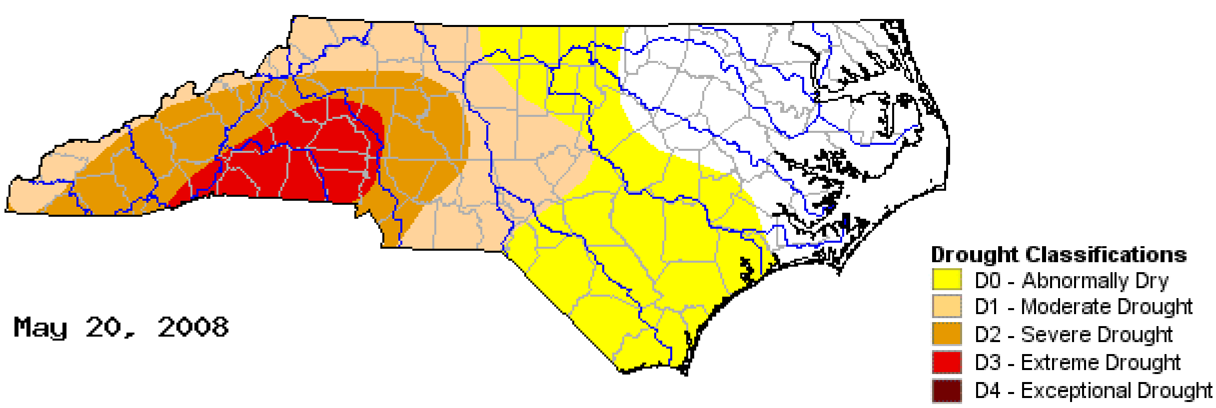

Figure 4: US Drought Monitor of North Carolina. 2008. (Source: North Carolina Drought Management Advisory Council, 2008)

In 2002, drought-induced losses totaling $398 million was incurred by the agricultural sector (Hayes et al. 2004). The multiplier effects of those impacts amounted to an additional $233 million; 4,337 North Carolina jobs were also affected by the drought (direct and indirect) (RESI 2008).

Hurricanes and storms will further add to the damages to the agricultural sector. Within the 10-year period between 1996 and 2006, 14 tropical storms or hurricanes caused agricultural damages, including crop damage and impacts on livestock, totaling $2.4 billion throughout the state (Bin et al. 2007).

Increasing severity and frequency of tropical storms and hurricanes due to climate change over the next century will also affect North Carolina's forests and forestry related industries. The category 3 Hurricane Fran in 1996 damaged about 8.3 million acres of forest lands statewide with total damages estimated to be $1.69 billion (2007 dollars). In North Carolina, a study estimated that forest damages rise by $500 million for every increase in the category level (Bin et al. 2007). Taking into account the ripple effects throughout the economy, the total – direct and indirect – economic damages to North Carolina could amount to around $860 million (RESI 2008).

Furniture and related manufacturing industries that rely on the forestry sector contribute significantly to North Carolina's economy – in 2005, they totaled $3.1 billion (BEA 2005). In addition to the damage caused by hurricanes and tropical storms, the composition of the forests might change due to result of climate change. Pests that thrive in warmer climate might pose additional risk to the existing timber resources. The most recent beetle outbreak, ending in 2001, cost the Southern lumber industry $1 billion, with studies estimating seven times the impacts as summer gets warmer and winter milder in response to the changing climate (Clabby 2007). The indirect economic costs from the $1 billion beetle outbreak amounted to $723 million (RESI 2008), which underscores the extent of damages from the projected rise in harmful pests.

Public Health

As North Carolina temperatures rise due to climate change, air quality could diminish, compromising the health of residents. Higher temperatures can contribute to the formation of ground-level ozone and smog, contributing to and exacerbating respiratory conditions such as asthma. The American Lung Association ranked the Charlotte-Gastonia-Salisbury metropolitan areas among the top twenty (16th, specifically) most ozone-polluted cities in the United States (American Lung Association 2007). With a total at-risk population of 2.1 million, health care costs for asthma amounts to $7.5 billion annually. North Carolina has witnessed an increasing trend in asthma patients among children as well as adults (Physicians for Social Responsibility 2001). In 2003 alone, asthma cost North Carolina $631 million (Jensen 2006). These health ailments and associated costs could increase as a result of climate change and points to the possible increases in healthcare costs we can expect because of pollution that is causing and is exacerbated by climate change.

Despite North Carolina's already hot temperatures, residents could still be prone to risks associated with extreme heat stress and heat waves. According to the EPA, one Greensboro study projects that deaths resulting from heat distress during a typical summer could increase by 70 percent, from nearly 20 heat-related deaths per summer to over 35 fatalities (Physicians for Social Responsibility 2001).

Water Resources

North Carolina is likely to experience water shortages due to the coastal flooding and saltwater intrusion into aquifers, as well as severe droughts decreasing water resources available for drinking, industry and agricultural sectors. More than half of the state's population depends upon ground water for drinking purposes with about 98 percent of all public supply systems relying on ground water (Ground Water Protection Council 1999). Surface water supplies are mostly concentrated in use by the thermoelectric plants in the Piedmont regions (Moreau 2008). During the 2007 drought, 340 public water systems (53 percent of total) called for water use restrictions affecting a population of about five million (North Carolina Department of Environmental and Natural Resources 2007). Increased severity of droughts in the future from unmitigated climate change could put an even greater strain on the already stressed water supply systems in North Carolina.

Low water flows and higher temperature could increase the pollution level of waters, necessitating higher costs of drinking water purification. Increased precipitation in North Carolina for the next century has been predicted to occur more intensely, which could increase flash floods. The flooding could result in more runoff, washing pesticides, fertilizers or other toxins into the water source for agricultural usage in the Coastal Plains (USEPA 1998).

Sports and Recreational Activities

The skiing industry in western North Carolina generated revenue of $23 million for 2002-2003 year alone. The direct and indirect impacts of expenditure for skiing and related activities in the state for the same years totaled to about $120 million and comprised a total of over 100,000 jobs (Millsaps and Groothuis 2003). Global warming scenarios have consistently predicted a decrease in total number of skiing days (Balazik 2000). Although the industry already somewhat relies on snowmaking to extend the season, a decline in the number of natural winter days would increase the costs of running extensive snowmaking operations.

Wildlife viewing in North Carolina in 2001 supported 55,500 jobs in the state – nearly 3 million people spent almost $2.5 billion that year (National Wildlife Federation). Changes in the habitat and population of wildlife in the state could reduce the attraction for tourists and negative impact the related businesses.

MISSING INFORMATION AND DATA GAPS

Incomplete data availability limits the results of this study. For example, uncertainty about crop yields and productivity stemming from counteracting effects of increasing temperature, decreasing water availability, and higher levels of ozone in the atmosphere makes the potential economic impacts difficult to predict. Analyses on many aspects related to projected changes in the state's climate could serve as stepping stones in devising adaptation plans. Transportation infrastructure, energy demand and usage, as well as water resource availability should be analyzed on the state-level. Likewise, full economic impacts from changes to the complex ecosystems and their role in regulating and providing essential services to the man-made economy should be analyzed and use to implement an aggressive mitigation strategy.

CONCLUSIONS

Increases in temperature and levels of precipitation, coupled with sea level rise along the coast, are projected to impact multiple economic sectors in North Carolina. Coastal developments are at risk from the global trend of sea level rise, which may be exacerbated in the state due to the geological formation of its coastline.

Agriculture, most types of tourism, and water resources may be affected by the predicted drier conditions, since precipitation increases will likely produce concentrated storm events rather than alleviate higher temperatures. More frequent storms will further threaten coastal and inland infrastructure, strain agricultural activities, and disrupt water and energy supply networks necessary for domestic, agricultural, and industrial uses. North Carolina should evaluate state-level adaptation techniques to prepare the state for inevitable impacts of climate change. At the same time, the state should advocate for an aggressive national policy to reduce greenhouse gas emissions in order to avoid the most severe projected consequences.

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.

WORKS CITED

Adams, R., B. McCarl, K. Segerson, C. Rosenzweig, K. Bryant, B. Dixon, R. Connor, R. Evenson, D. Ojima. (1998). 'The Economic Effect of Climate Change on US Agriculture'. *The Impacts of Climate Change on the US Economy.* R. Mendelsohn and J. Neumann. Cambridge: Cambridge University Press.

American Lung Association. 'State of the Air: 2007. Table 2b: People at Risk In 25 Most Ozone-Polluted Cities.' American Lung Association. New York, NY. Available online: http://lungaction.org/reports/sota07_table2b.html

Balazik, Matthew R. (2000). 'Economic impacts of climate change on the mid-atlantic region's downhill skiing industry.' Thesis submitted to the *Department of Economics, The Pennsylvania State University.*

Barnett, T.P. (1984). 'The estimation of "global" sea level change: a problem of uniqueness'. *Journal of Geophysical Research*. 89: 7980-7988. Washington, DC: American Geophysical Union.

Bin, O., C. Dumas, B. Poulter, and J. Whitehead. (2007). 'Measuring the Impacts of Climate Change on North Carolina Coastal Resources.' Final Report Prepared for:

National Commission on Energy Policy, Washington, DC. Available online: http://econ.appstate.edu/climate/NC-NCEP%20final%20report.031507.pdf

Boyles, Ryan P. and Raman S. (2003). 'Analysis of climate trends in North Carolina (1949-1998)' *Environment International* 29 (2003) 263– 275. Amsterdam, Netherlands: Elsevier.

Bureau of Economic Analysis (BEA), (2008). Available online: www.bea.gov/index.htm

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

Burkett V., Ritschard R., McNulty S., O'Brien J. J., Abt R., Jones J., Hatch U., Murray B., Jagtap S., and Cruise J. 'Potential Consequences of Climate Variability and Change for the Southeastern United States.' pp 137-166: Chapter 5. in: *The Potential Consequences of Climate Variability and Change: Foundation Report*, Report by the National Assessment Synthesis Team for the US Global Change Research Program, Cambridge University Press, Cambridge, UK. Available online: www.usgcrp.gov/usgcrp/Library/nationalassessment/05SE.pdf

Clabby, Catherine. (2007). 'Warming may redefine what flourishes: Scientists examine implications for plants, animals, pests.' *The News & Observer.* July 15, 2007. Available online: www.newsobserver.com/2660/story/637853.html

Deschenes, Olivier and Michael Greenstone (January 2006). *The Economic Impacts of Climate Change: Evidence from Agricultural Profits and Random Fluctuations in Weather.* Washington, DC: AEI-Brookings Joint Center for Regulatory Studies.

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

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

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

Fuchs, B. (2008) '2007 Drought in Review' *Droughtscape*. Lincoln, NE: National Drought Mitigation Center. Available online: www.drought.unl.edu/droughtscape/2008Winter/dswinter08-2007review.htm

Ground Water Protection Council. (1999). 'North Carolina Ground Water Conditions.' *Ground Water Report to Congress State Fact Sheets.* Available online: www.gwpc.org/e-library/e-library_documents/e-library_documents_state_fact_sheets/north%20Carolina.pdf

Hayes, M.J., Svoboda, M.D., Knutson C. L., and Wilhite D.A. (2004). 'Estimating the Economic Impacts of Drought.' Joint Session 2, Drought: Variability Monitoring, Impacts, and Prediction (Joint between the 15th Symposium on Global Change and Climate Variations and the 14th Conference on Applied Climatology; Room 6C).

Infoplease. (2008). 'States with Longest Coastlines.' *Information Please, Pearson Education.* Boston, MA. Available online: www.infoplease.com/toptens/longestcoastlines.html

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/

IPCC (2001)a. 'Working Group II: Impacts, Adaptation and Vulnerability.' Cambridge, England and New York, NY: Cambridge: Cambridge University Press.

IPCC. (2007). Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton. '2007: Regional Climate Projections.' In: *Climate Change 2007: The Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment Report of the IPCC [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Chapter 14. Cambridge, England and New York, NY: Cambridge: Cambridge University Press. Available online: www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter14.pdf

IPCC. (2007)a. 'Working Group I: The Physical Science Basis.' Cambridge, England and New York, NY: Cambridge: Cambridge University Press.

IPCC. (2007)b. 'Working Group II: Impacts, Adaptation and Vulnerability.' Cambridge, England and New York, NY: Cambridge: Cambridge University Press.

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

Jensen, K. (2006). 'Burden of Asthma in North Carolina.' Raleigh, NC: N.C. Department of Health and Human Services.

Mills, E. (2005). 'Insurance in a Climate of Change.' *Science* 309(5737):1040-44, doi:10.1126/science.1112121, LBNL- 57943. Washington, DC: American Association for the Advancement of Science. Available online: www.sciencemag.org/cgi/content/full/309/5737/1040

Millsaps, S.W. and Groothuis, P.A. (2003). ‘The Economic Impact of North Carolina Ski Areas on the Economy of North Carolina: 2002-2003 season.’ *Final Report Prepared for the North Carolina Ski Areas Association.*

Moreau, D. H. (2008). ‘Water Storage in Steep Decline Relative to Population.’ *WRRI NEWS*, Number 361 January-April 2008. Water Resources Research Institute (WRRI). Available online: www.ncsu.edu/wrri/news/WRRINews_361.pdf

Munger, A. and Shore M. (2005). ‘Understanding global warming for North Carolina: Sound science for making informed decisions.’ *Environmental Defense*. Available online: www.environmentaldefense.org/documents/3053_NCClimateReport.pdf

National Climatic Data Centre (NCDC). (1996). ‘North Carolina Hit By Frantastic Storm!’ NCDC: Washington, D.C. Available online: www.ncdc.noaa.gov/oa/reports/fran/fran.html

National Weather Service (NWS). (2003). ‘Tropical Cyclone Report: Hurricane Isabel.’ National Oceanic and Atmospheric Administration. Available online: www.nhc.noaa.gov/2003isabel.shtml

National Weather Service (NWS). (2007). ‘National Oceanic and Atmospheric Administration (NOAA) Technical Memorandum.’ National Hurricane Center, Miami, Florida (NHC Miami). Blake E., Rappaport E.N., Landsea C.W., TPC-5. *“The Deadliest, Costliest, and most Intense United States Tropical Cyclones from 1851 to 2006 (and other frequently requested hurricane facts)*”. Available online: www.nhc.noaa.gov/pdf/NWS-TPC-5.pdf

National Wildlife Federation. (2007). ‘Global Warming and North Carolina.’ *Change the Forecast for Wildlife Solutions to Global Warming.* Available online: www.ncwildlifefederation.org/home/climatechange.pdf

Neumann, J.E., Yohe G., Nicholls R. and Manion M. (2000). ‘Sea level rise and global climate change: a review of impacts to US coasts.’ Pew Center on Global Climate Change. Washington, DC.

North Carolina Department of Agriculture and Consumer Services (NCDACS). (2007). ‘Farm Income: Cash Receipts from Farming by Commodity, North Carolina 2003-2006.’ *2007 Annual Statistics Book.* NCDA&CS Agricultural Statistics Division, Raleigh NC. Available online: http://www.agr.state.nc.us/stats/2007AgStat/CashReceiptsfromFarming.pdf

North Carolina Department of Agriculture and Consumer Services (NCDACS). (2007a). 'North Carolina's Rank In Us Agriculture, 2006.' *2007 Annual Statistics Book.* NCDA&CS Agricultural Statistics Division, Raleigh NC. Available online: www.agr.state.nc.us/stats/2007AgStat/NCRankHighlights.pdf

North Carolina Department of Environmental and Natural Resources. (2007). 'Water Conservation level status, Statewide.' Available online: www.ncwater.org/Drought_Monitoring/reporting/displaystate.php

North Carolina Drought Management Advisory Council. (2008). NC. Available online: www.ncdrought.org/index.php

Physicians for Social Responsibility. (2001). 'Death by Degrees: The Health Threats of Climate Change in North Carolina.' Available online at: http://www.p2pays.org/ref/16/15294.pdf

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

Poulter, B. and Halpin P.N. (2008). 'Raster modeling of coastal flooding from sea level rise.' *National Commission on Energy Policy.* International Journal of Geographic Information Sciences. 22: Issue 2: 167-182.

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

Trenberth, K. E. (2007). 'Warmer Oceans, Stronger Hurricanes.' *Scientific American Magazine*. Available online: www.sciamdigital.com/index.cfm?fa=Products.ViewIssuePreview&ARTICLEID_CHAR=0C90D702-2B35-221B-6DF06998B4F07800

US Environmental Protection Agency (USEPA). (1998). 'Climate Change and North Carolina.' Available online: http://yosemite.epa.gov/oar/GlobalWarming.nsf/UniqueKeyLookup/SHSU5BUTX6/$File/nc_impct.pdf

US Geological Survey (USGS). National Assessment of Coastal Vulnerability to Sea-Level Rise: Preliminary Results for the US Atlantic Coast. Available online: http://pubs.usgs.gov/of/1999/of99-593/pages/res.html