

Economic Impacts of Climate Change on Georgia



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



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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 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 Georgia 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 (CO₂), methane (CH₄), nitrous oxide (N₂O) 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 CO₂, CH₄, N₂O 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.

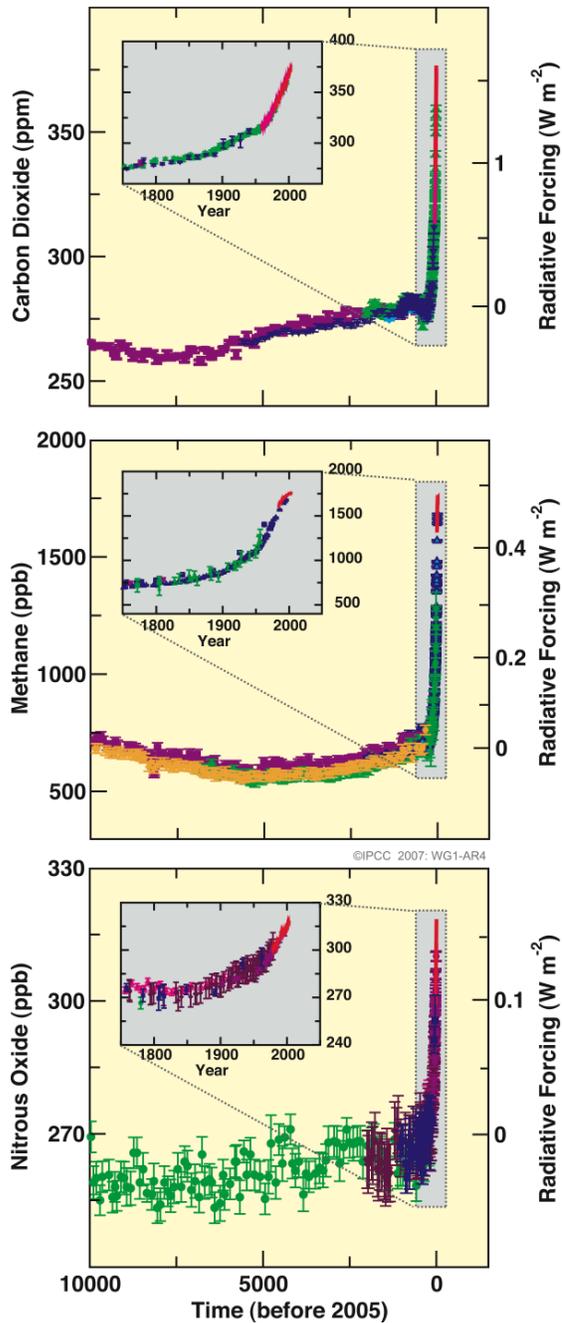


Figure 1: Atmospheric Concentrations of Carbon Dioxide, Methane and Nitrous Oxide (Source: IPCC 2007a)

A change in average temperatures may serve as a useful indicator of changes in climate (Figure 2), 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).

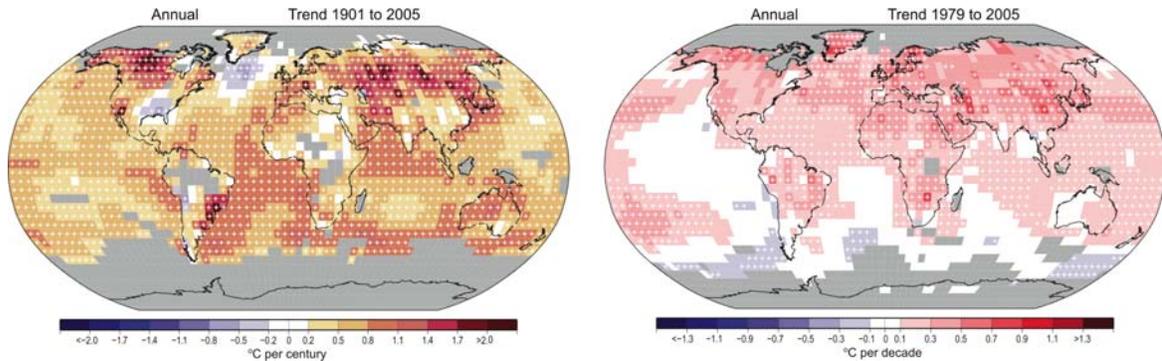


Figure 2: Annual Temperature Trends (Source: IPCC 2007a)

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 (Barnett 1984; Douglas et. al 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). 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 Georgia 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 Georgia 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 using 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 GEORGIA

Georgia Climate

The Georgia climate varies from the humid, marshy, low-lying coastal plains to the cooler inland foothills and the Appalachian Mountains. The entire state experiences all four seasons, with summer temperatures rising above 90 degrees F for at least 15 days each year (70 days for the southern parts of the state). The northern parts of the state experience low winter temperatures below freezing and receive 2-6 days of snow each year. The southern marshlands have more mild winter temperatures in the 40s and 50s and rarely receive any snow. Thunderstorms are common across the entire state in the spring and summer months; severe weather phenomena such as hail and tornadoes are also common (Georgia State Climate Office; National Weather Service Forecast Office). Hurricanes also regularly occur in Georgia during the summer and fall (Georgia State Climate Office).

Climate Change in Georgia

Global mean temperature has risen by 0.3-0.6 degrees C since the end of the 19th century. Temperatures in Georgia actually followed an opposite trend, with average annual temperatures decreasing slightly in the second half of the 20th century (Figure 1). Average annual precipitation in Georgia was highly variable from 1900-2000, and there was no statistically significant trend of increasing or decreasing precipitation (Figure 2) (Alexandrov and Hoogenboom 2001).

Figure 1. Mean annual temperature anomaly in Georgia, 1900-2000.

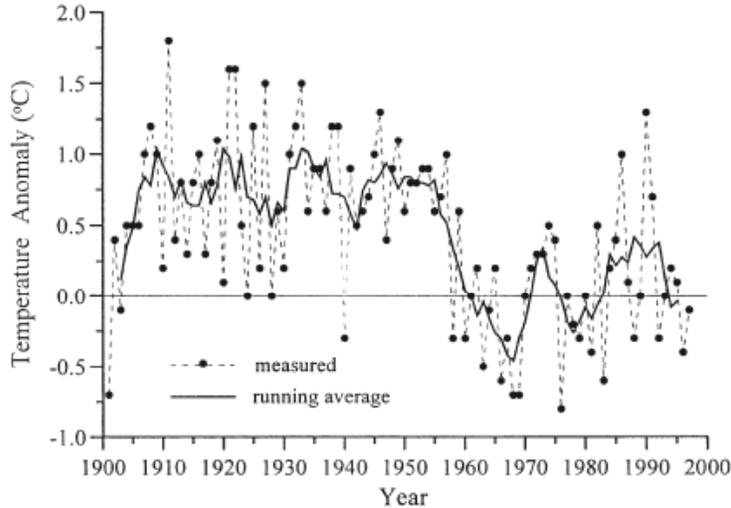
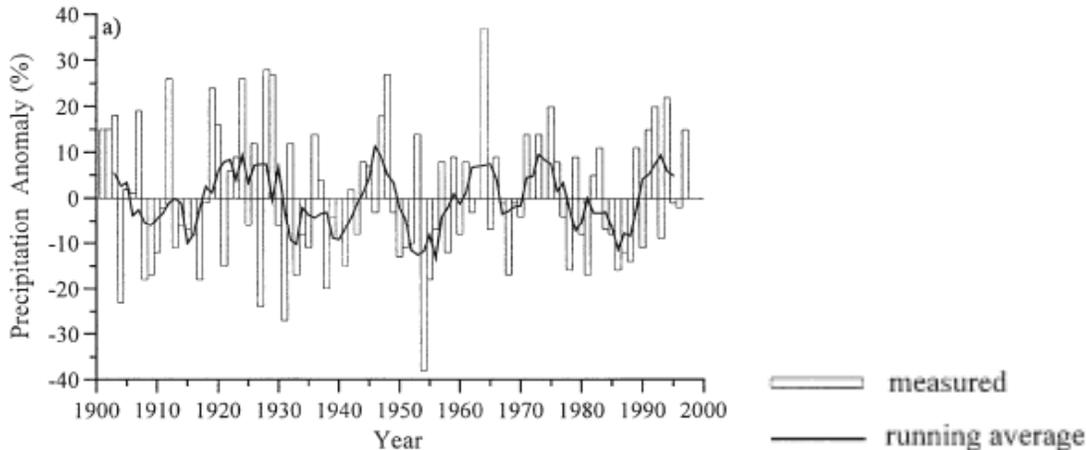


Fig. 2. Anomalies of annual mean air temperature in Georgia, relative to the period 1961–1990

Source: Alexandrov and Hoogenboom 2001

Figure 2. Mean annual precipitation anomaly, 1900-2000.



Source: Alexandrov and Hoogenboom, 2001

The climate change models run by the Intergovernmental Panel on Climate Change (IPCC) in 2007 predicted that Georgia could see increases in average temperatures of 2.5

degrees C in winter and 3 degrees C in summer, and a five percent annual increase in precipitation in this century (Christensen et. al 2007).

In addition to changes in average temperatures and precipitation, the IPCC found that climate variability, including more severe periods of drought coupled with wetter periods, might be an effect of climate change in North America (Christensen et. al 2007).

Another aspect of climate change that concerns Georgia is mean sea level rise. Records show sea levels at Fort Pulaski, on Georgia's coastal border with South Carolina, are rising at a rate of 13 inches per century and could rise 25 inches by 2100 (Earth Institute 2008).

ECONOMIC IMPACTS

Infrastructure

Georgia contains large and complex transportation, shipping and energy infrastructures, many parts of which are located on the state's 100-mile coastline. Changes to the climate in which they operate, such as higher temperatures, heavier precipitation, and sea level rise, could impose severe economic costs on Georgia.

Four major **interstates** traverse Georgia: I-95, I-85, I-75, and I-20. 6,800 registered interstate trucking carriers operate in the state. The manufacturing industry, which comprises 12 percent of the Georgia state GDP (\$46 billion 2007 dollars), relies heavily on the highway infrastructure to transport goods (The Chemical Industry in Georgia; BEA 2008). Georgia spent \$1.7 billion in 2007 on construction and maintenance of its highways and local roads. Its expenditures on transportation in maintenance alone accounted for 9.5 percent of the state budget in 2007 (OPB 2008). A 1 percent increase in the cost of maintenance from more intense storm activity due to climate change would cost the transportation sector \$17 million in additional costs, which would trigger \$12 million in economic losses for other sectors (RESI 2008). Most of the stretch of I-95 in Georgia lies within five miles of the coastline. This is advantageous for the shipping industry for distributing goods to freight trucks, but it creates a higher risk of storm damage to the interstate. For example, reconstruction of highways and bridges along the Gulf Coast after Hurricane Katrina cost \$2.1 billion (2005 dollars) (US Government Accountability Office 2006).

Georgia has an extensive **rail** system with 4700 miles of tracks. More than 80 freight trains pass through Atlanta each day (The Chemical Industry in Georgia). Increasingly, frequent damage to the railways due to increased precipitation, more frequent hurricanes, or more extreme temperatures could impact the annual cost of maintaining and operating the system. Climate change could impact both the physical rail infrastructure and the on-time frequency of trains.

Atlanta Hartsfield-Jackson International Airport is the busiest passenger **airport** in the country. Over 38 million passengers passed through its terminals in 2007 (BTS 2008b).

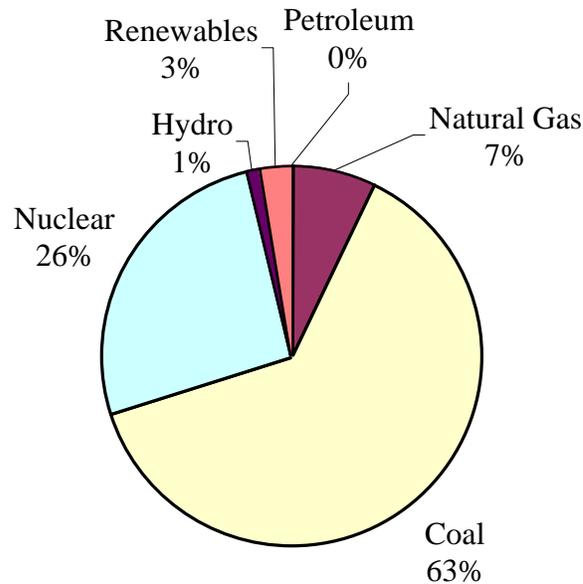
Air travel and freight are important components of Georgia's transportation infrastructure: Georgia contributes 8 percent of the US GDP from air transportation (BEA 2008). Inclement weather is the top cause of airline delays (BTS 2008a), and as severe weather becomes a more frequent occurrence because of climate change, delays could become even more crippling to the faltering air transportation industry.

Ports Brunswick and Savannah facilitated the trade of over 24 million short tons of goods in 2007 representing a 58 percent growth in trade volume over the past five years (Georgia Ports Authority 2008). Port Savannah is the fastest growing container port in the eastern United States, and Port Brunswick is the fourth largest auto port in the eastern US (The Chemical Industry in Georgia). Near Port Savannah is the Elba Island liquefied natural gas (LNG) terminal, one of only five in the nation (EIA 2008). Both ports are valuable conduits of goods to the southeastern United States because of their proximity to I-95, the easternmost north-south highway corridor in the United States. Hurricanes also pose a real threat to shipping ports in the Southeast US. For example, after Hurricane Katrina, the Port of New Orleans suffered \$435 million in damage, and damages to the Port of Gulfport were estimated to be between \$300 and \$400 million (US Government Accountability Office 2006). The Georgia Ports Authority needs to take measures to harden its facilities against climate change effects such as sea level rise and a possible increase in the intensity of hurricanes (Anthes et al. 2006).

Most of the **electricity** generated in Georgia comes from coal and nuclear power (Figure 3) (EIA 2008). The impacts of climate change on the energy sector will be heaviest on water use in thermoelectric plants. As sea level rises and associated freshwater salination occurs, thermoelectric power plants (those that burn fossil fuels or carry out nuclear reactions and therefore need large amounts of water for cooling) will increasingly compete with the residential sector for a limited supply of freshwater. In 2000, fossil fuel and nuclear power plants accounted for more than half of the total surface water used in Georgia (Barczak and Carroll 2007). Moreover, two proposed nuclear reactors would more than double the nuclear power generation capacity in Georgia and also increase the water consumption of the electricity sector substantially (Barczak and Carroll 2007; NRC 2008).[&] The increased scarcity of water for cooling could add to the costs of electricity generation.

Georgia ranks ninth among states in total industrial electricity consumption (EIA 2005). This is mostly because Georgia is a leader in the energy-intensive pulp and paper processing industry (EIA 2008). A second-order effect of an increase in the cost of electricity due to climate change will be higher operations costs for the pulp and paper industry.

Figure 3. Electricity Generation by Fuel Type in Georgia, December 2007.



Source: EIA 2008.

Industry

Paper and wood product manufacturing contributed \$3.3 billion and \$1.9 billion respectively to the state GDP in 2005 (the total state GDP was \$358 billion) (all 2007 dollars) (BEA 2008). These industries will feel both positive and negative affects of climate change. The raw materials needed for wood product and paper manufacturing will likely grow in abundance in Georgia due to climate change: the productivity of pine forests is predicted to increase by 11 percent by 2040 and that of hardwood forests is predicted to increase by 25 percent by 2090, both compared to regional productivity across the southeastern US (Burkett et al. 2000). An 11 percent increase in productivity in the wood manufacturing industry by 2040 would create 6,531 direct and indirect new jobs and also contribute nearly \$350 million to the economy (RESI, 2008). However, other inputs to the manufacturing process, including electricity and water, could increase in cost as freshwater becomes scarcer and industry has to compete with the power, residential, and agricultural sectors for water use.

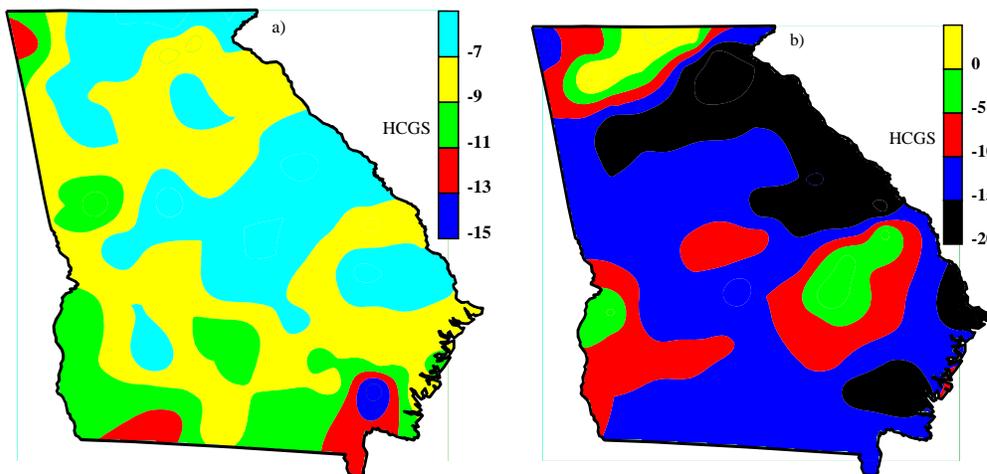
Hurricanes can have devastating effects on the timber industry, as well. For example, the USDA estimated that Hurricane Katrina destroyed or damaged over 19 billion board feet of timber in Mississippi, Alabama, and Louisiana. This loss translated to over \$5 billion in damage (Sheikh 2005). The Georgia Forestry Commission recorded losses of 51 million board feet of pine and 1.6 million cords of hardwood during 30 major reported storms in the state (Price 2005). The state is vulnerable to many types of storms. Tornadoes in the state inflict damages of nearly \$300,000 per occurrence, and ice storms

cost the economy an estimated \$6.5 million (Price 2005). If the frequency or the intensity of inclement weather events increases, the economic impact will likely rise as well.

Although it is difficult to predict the immediate and long term affects of climate change on the wood and paper manufacturing sectors, any changes in productivity will have secondary affects in the transportation and shipping sectors. In Port Savannah, wood pulp and paper products account for 30 percent of annual tonnage throughput (Georgia Ports Authority 2008). Other sectors involved in the transportation of wood and paper products (trucking, rail, air), will also feel the affects of any change in production volume of these industries.

The **agriculture** sector contributed \$2.6 billion to the Georgia economy in 2005 (2007 dollars) (BEA 2008). Because agriculture depends heavily and directly on the climate and day to day weather, crop yields are vulnerable to climate change. A study by Hoogenboom and Alexandrov in 2000 predicts that under a likely climate change scenario in Georgia, there will be various and significant changes to crop yield by the year 2020. For example, they predict the yield of maize will decrease by up to 15 percent and winter wheat yield will decrease by up to 20 percent in certain regions of Georgia. They also predict the soybean yield to increase by up to 25 percent in the northern area of the state, and that the peanut yield will decrease by 5 percent in the south and increase by 25 percent in the north (Alexandrov and Hoogenboom 2000). The variability of changes to crop yield makes it difficult to draw any correlation between yield and production value. More accuracy in projected production values could be accomplished using GIS and National Agricultural Statistical Service data, along with the maps of projected yield changes from Alexandrov and Hoogenboom in Figure 4.

Figure 4. Spatial distribution of maize (a), winter wheat (b), soybean (c) and peanut (d) yield departures (in %) under 2xCO₂ GCM climate change scenarios and irrigated conditions



Georgia's state parks provide residents and tourists with **recreation** opportunities and its historic sites perform an important function of the preservation of state history. Eight of Georgia's 77 state parks and historic sites are located along the Atlantic coast (Figure 5). Collectively, these coastal parks brought in nearly \$2 million in revenue to the state of Georgia in 2007 (Georgia State Parks 2007). With sea levels predicted to rise 25 inches by the end of the century, the Department of Recreation will need to allocate funds to protect these valuable recreation facilities and historical sites (Earth Institute 2008).

Beyond its state parks, Georgia attracts many people each year for **hunting, fishing** and **wildlife** watching. A survey by the National Fish and Wildlife Service found that Georgia attracted expenditures of \$1.2 billion from its fishing and hunting industries and \$628 million from wildlife-watching (2007 dollars) (USFWS 2001). But climate changes will endanger some of the animals and fish that attract this revenue. Rising sea levels will endanger the wetlands that are home to and serve as nurseries for many fish species in Georgia (Burkett et al. 2007).

Coastal Areas

Rising sea levels and more frequent and intense hurricanes pose a serious threat to properties along Georgia's 100-mile coastline. The value of insured coastal property in the United States rose 179 percent from 1980 to 1993 (Burkett et al. 2007), and the real estate sector makes up 10 percent (\$37 billion 2007 dollars) of Georgia's state GDP (BEA 2008). Property damages have increase 300 percent from an estimated \$500 million in annual losses between 1900-1940 to \$1.5 billion each year from 1960 to 1980 (Burkett et al. 2007). While much of the increased costs from hurricane damage can be attributed to the development of high-value properties on the coastline, scientific evidence suggests that hurricanes are increasing in number and intensity, and many attribute the cause to climate change (Anthes et al. 2006). Rising sea levels are another costly impact of climate change: the cumulative cost of sand replenishment for protecting Georgia's coastline from a 20-inch rise in sea level could amount to between \$154 million and \$1.3 billion by 2100 (Earth Institute 2008). The total cost of protecting coastal assets and communities from sea level rise would affect other sectors of the economy. For example, coastal erosion is projected to cost an additional \$135 million in annual costs to other sectors – totally nearly \$300 million in yearly expenses. Additionally, nearly 5,000 jobs are projected to be lost because of coastal erosion (RESI, 2008).

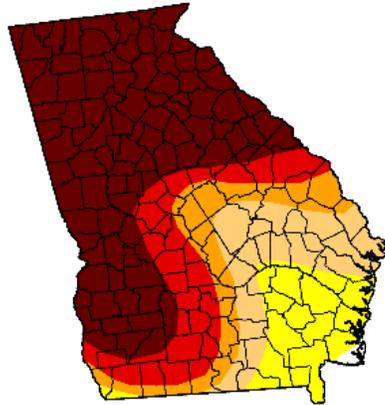
Drought

A higher incidence of drought is a possible consequence of climate change (Christensen et al. 2007). One example of extreme drought occurred in Georgia in late 2007. At one point, over 50 percent of the state was experiencing an "exceptional" drought, characterized by "exceptional and widespread crop/pasture losses" and "shortages of water in reservoirs, streams, and wells creating water emergencies" (see Figure 6) (Drought Monitor 2008).

Figure 6. Extent of drought in Georgia. Week of December 11, 2007.

U.S. Drought Monitor December 11, 2007
Valid 7 a.m. EST
Georgia

	Drought Conditions (Percent Area)					
	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.4	99.6	87.8	74.3	64.4	49.9
Last Week (12/04/2007 map)	5.9	94.1	81.6	68.1	58.8	43.4
3 Months Ago (09/18/2007 map)	20.2	79.8	66.5	54.2	41.0	28.5
Start of Calendar Year (01/02/2007 map)	12.2	87.8	3.7	0.1	0.0	0.0
Start of Water Year (10/02/2007 map)	24.2	75.8	64.2	52.6	39.4	27.0
One Year Ago (12/12/2006 map)	35.5	64.5	7.7	0.1	0.0	0.0



Intensity:
 D0 Abnormally Dry
 D1 Drought - Moderate
 D2 Drought - Severe
 D3 Drought - Extreme
 D4 Drought - Exceptional

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements



Released Thursday, December 13, 2007
 Author: Brian Fuchs, National Drought Mitigation Center

<http://drought.unl.edu/dm>

Source: <http://drought.unl.edu/dm>

Georgia is still in the process of recovering from this drought which gripped most of the Southeast in 2007. Overall, the drought caused \$1.3 billion in economic damage to Georgia, including crop losses of \$83.8 million in hay, \$160.1 million in cotton, \$92.5 million in peanuts, and \$63.1 million in corn (University of Georgia 2008). If an additional 5 percent of crop losses are experienced due to climate change impacts, the direct and indirect economic losses would total nearly \$110 million annually and result in a loss of 533 jobs (RESI, 2008). The drought also affected the real estate sector by making homes in drought-stricken areas more difficult to sell (Real Estate Webmasters 2007). Wealthy homeowners exacerbated the water shortage problem by digging their own wells to landscape their yards (see **Error! Reference source not found.**) (Hochberg 2007). And Georgia may not be finished with the drought yet: Georgia state officials announced public pools may not open this summer. This would hurt Georgia’s \$150 million per annum pool industry which provides maintenance and services for Georgia’s public pools (Lohr 2008).

Health

Rising temperatures and flooding events due to climate change will have health impacts on the population of Georgia. A study by the Johns Hopkins School of Public Health correlated daily mortality rates and temperatures for eleven east coast US cities from 1973-1974 and found that there is a “Minimum mortality temperature” above which heat-related deaths increase steadily. In Atlanta, for every degree centigrade above the MMT, the percent change in heat-related mortality increases by 5.41 percent (see Figure 9) (Curriero et al. 2002). In 1983, 35 people died in Georgia due to heat-related causes, while in 1982 there were only 3 such deaths, and the average summer temperature was 4-

5 degrees F cooler than in 1983 (Curriero, et al. 2002). The mortality rate increases faster than that of cities at close latitudes; this is possibly due to the compounding effect that surface air pollution has on heat-related mortality, as Atlanta has one of the worst air quality ratings in the country.

Figure 9. Average slopes of temperature-mortality relations for east coast US cities

City	Minimum mortality temperature (MMT)‡	Cold slope‡,§	Hot slope‡,¶
Boston, Massachusetts	69.71	-4.34	5.83
Chicago, Illinois	65.17	-2.25	2.45
New York, New York	66.42	-3.59	6.28
Philadelphia, Pennsylvania	70.58	-4.37	6.11
Baltimore, Maryland	70.46	-2.65	6.56
Washington, DC	70.56	-3.13	3.67
Charlotte, North Carolina	90.38	-3.27	NA#
Atlanta, Georgia	76.29	-2.91	5.41
Jacksonville, Florida	76.75	-3.76	3.71
Tampa, Florida	80.71	-7.12	1.43
Miami, Florida	80.92	-5.46	4.01

* Refer to the Materials and Methods section of the text for a description of these scores.

† Cities are listed by decreasing latitude.

‡ Percentage change in mortality per ($^{\circ}\text{C} = 5/9 \times (^{\circ}\text{F} - 32)$).

§ Cold slope = average slope of the estimated relative risk curves at temperatures lower than MMT.

¶ Hot slope = average slope of the estimated relative risk curves at temperatures higher than MMT.

NA, not available because the curve has no turning point.

Source: Curriero, et al. 2002.

Another study from the Johns Hopkins School of Public Health shows a positive correlation between higher-than-average precipitation events and outbreaks of waterborne diseases, which could be especially relevant for Georgia because of its extensive marshlands (Curriero et al. 2001). Increased annual precipitation and more intense storms can also damage septic tanks and water treatment plants, increasing the risk of releasing harmful particulates and chemicals into groundwater (Neff et al. 2000).

MISSING DATA

The analysis of crop yield variability from climate change by Alexandrov and Hoogenboom could be extended to predict some economic effects of climate change. Data would have to be collected on the productivity value of those crops by geographic region in Georgia, to at least the county level of resolution. More work could also be done on the full economic impacts of changes to coastal ecosystems due to climate change. The impact of climate change on human health in Georgia is also not fully understood at this time. Climate change effects on urban centers are another area for future research. Georgia's three biggest cities, Atlanta, Columbus and Savannah, will each have unique vulnerabilities to climate change.

While drought can have disastrous effects on Georgia's economy and population, the incidence of a drought cannot be attributed wholly to climate change. In the future, climate change may induce drought conditions more frequently, or an isolated drought

may be more severe because of climate change. Future work on the societal impacts of climate change should address the issue of how much economic hardship due to weather extremes results from climate change.

CONCLUSIONS

Climate change in Georgia is likely to place coastal infrastructure, some state industries, and growing coastal developments at risk. To hedge against these risks, a number of actions can be explored.

Protecting coastal developments and natural habitats—which will face increased risk for erosion from higher water levels and more intense storms—will be a leading concern. Since some sea level rise and climate change is likely regardless of greenhouse gas reduction efforts (the excess greenhouse gases already in the atmosphere "lock in" a certain degree of warming), integrating adaptation strategies into coastline development and habitat protection plans may be prudent. State conservation agencies can take steps to ensure the health of marshlands and coastal ecosystems: the first line of defense against coastal erosion. The state can also adapt sea and land transportation infrastructure to prepare for weather-related impacts and higher sea levels.¹

Policies that provide research and funding on how to best mitigate the effects of rising sea levels, stronger storms and increased storm intensity on sea and land transportation infrastructure may also provide benefit. Efforts that maintain a dependable and robust transportation system and help coastal areas adapt to these changes may work to preserve Georgia's valuable tourism trade.

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.

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