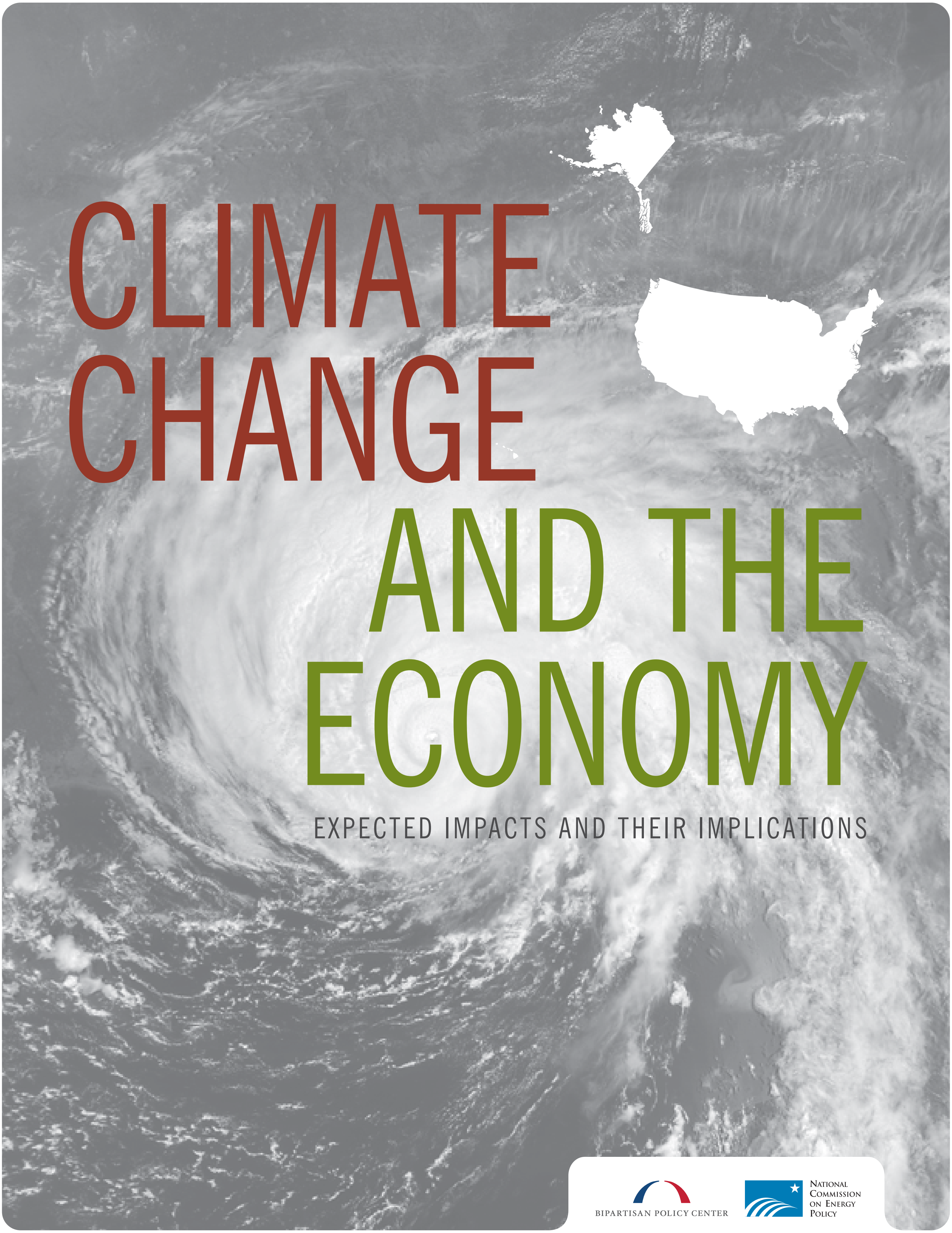

CLIMATE CHANGE AND THE ECONOMY

EXPECTED IMPACTS AND THEIR IMPLICATIONS

BIPARTISAN POLICY CENTER

National Commission on Energy Policy

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CONTENTS

IMPACTS OF CLIMATE CHANGE ON OUR ECONOMY

Climate change and its impacts are becoming apparent now throughout the United States and are projected to increase in the future. A variety of studies examining projected economic impacts of climate change in various U.S. locations yield a number of overarching lessons:

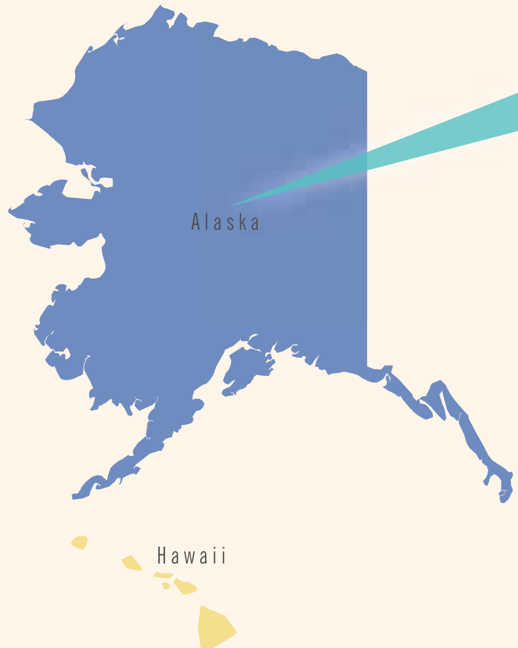
- Climate change will have wide-ranging impacts on key resources that affect Americans.
- The economic costs of these impacts will be significant; and the greater the warming, the larger the costs.
- The worst impacts can be avoided through proactive actions including reducing heat-trapping emissions and planning for those changes that are unavoidable.

As our nation strives to develop effective policies to respond to climate change, it is essential to consider the economic costs of both action and inaction. Much of the current conversation in the policy arena revolves around the potential economic costs of actions to reduce heat-trapping emissions. Relatively little attention is being paid to the much larger economic costs of unmitigated climate change.

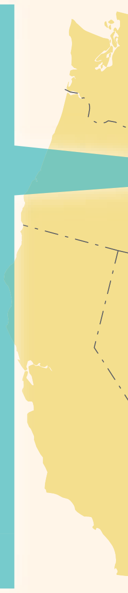
A series of climate change impact studies was undertaken by researchers at universities around the nation to evaluate some of the economic costs related to particular climate-sensitive resources, from water in New Mexico, to infrastructure in Alaska, to forests in Idaho and Montana, to coastlines in Florida, Texas, and North Carolina. The findings of these analyses illustrate and underscore the enormous risks posed by unmitigated climate change, and the increasing urgency of policy actions to reduce these risks.

Impacts are projected to be significant around the nation, though with strong regional variations. For example:

- Drought and water supply challenges are expected in a number of regions, notably the Southwest, which is also the fastest growing region of the country.
- Along the Atlantic Coast, sea-level rise, hurricanes, and associated storm surge are among the greatest expected challenges.
- In Alaska, where warming is proceeding especially rapidly, damage to infrastructure is a major concern as coastlines erode and permafrost thaws.
- In mountainous regions of the U.S. West, insect infestations and forest fires threaten a growing population as well as ecosystems on which society depends.



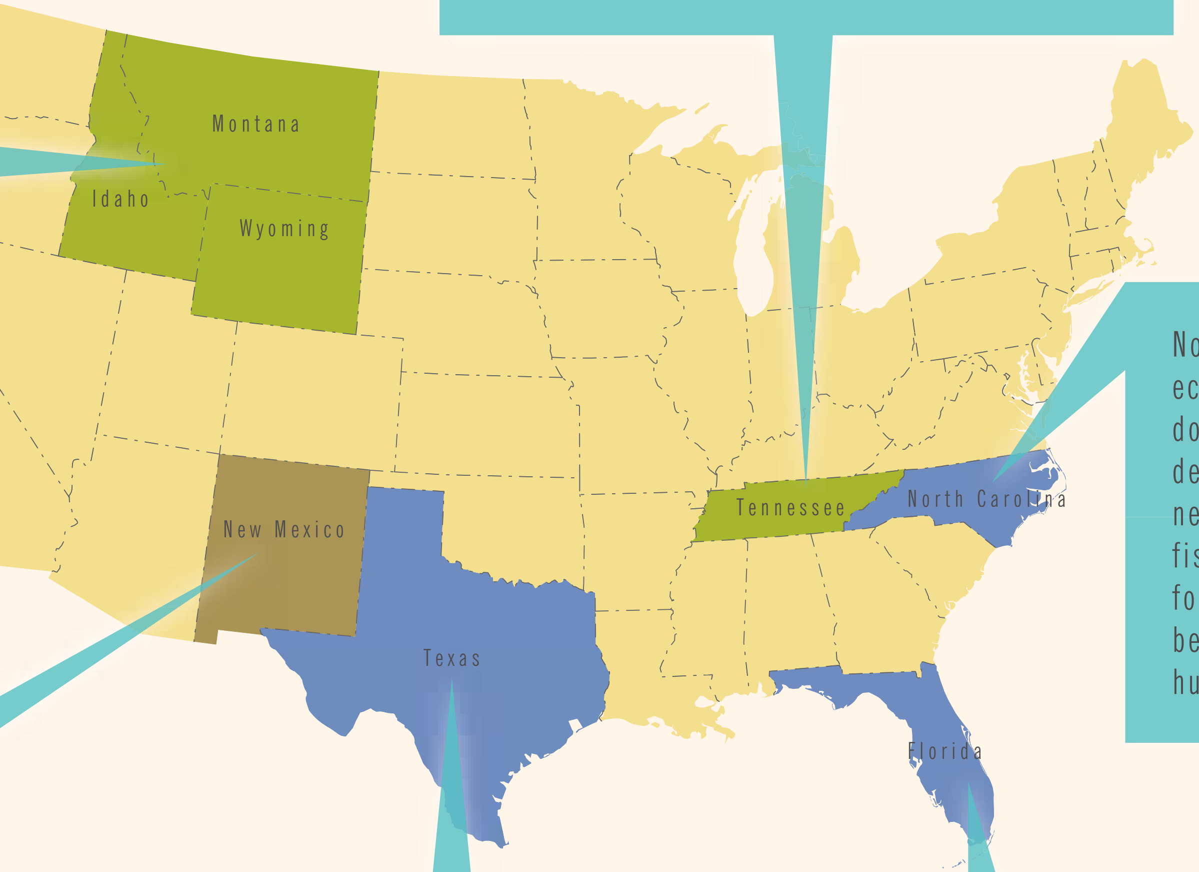
In the forests of Montana, Wyoming and Idaho, warming is projected to produce longer periods of drought stress each summer. Drought stressed trees, increasing insect infestations, and more frequent and severe wildfires threaten people, homes, and ecosystems in the northern Rocky Mountains.



New Mexico's economy is threatened by water scarcity as snowpack and stream flows shrink and more water is lost to evaporation as temperatures rise. There will be greater competition for water supplies to serve agriculture, energy, and urban uses for a growing population.

Alaska faces rising costs to maintain its public infrastructure as thawing ground undermines foundations of buildings and roads, retreating sea ice leaves coastlines exposed to erosion, and increasing heavy downpours raise the risk of flooding.

Tennessee's forests and the economic activity they support are projected to suffer with rising temperatures. Economically valuable oaks will be displaced by less valuable tree species. Trout fishing and other recreational pursuits will be negatively affected as temperatures rise.



North Carolina's coastal economy will suffer billions of dollars in losses as a result of declining property values, business interruptions, commercial fishing losses, damage to forests, and lost recreational benefits as sea level rises and hurricane intensity increases.

The Texas Gulf Coast faces increased risk of coastal flooding as sea level rises and hurricane intensity increases. Results include property damage, displacement of families and businesses, and economic impacts (such as from damage to oil refineries) that could be national in scope.

Florida's coastline can expect a dramatic increase in major storm surge events and associated property damage as sea level rises. And the amount of property at risk to permanent inundation is projected to increase in direct correlation with rising sea levels.

WATER

Providing adequate water supplies will be one of greatest challenges for the United States in a warming climate. Precipitation is coming in heavier downpours, and there are longer dry periods in between. This leads to alternating periods of drought and excessive wetness that will present problems in many regions. Even in places where precipitation increases overall, drier conditions can result as higher air temperatures lead to greater evaporation of moisture from soils and water loss from plants.

In general, wetter areas are projected to become wetter, while drier areas become drier. Thus, regions such as the Northeast and Midwest are expected to experience more precipitation, especially in the form of heavy downpours that can lead to flooding. At the same time, the southern states, especially those of the Southwest, are projected to experience reduced precipitation. This is of particular concern because the population of this region is the fastest growing in the nation.

Impacts of climate change on water will interact with other climate change impacts, causing additional challenges. For example, water and energy are tightly interconnected. Water is used for hydro-electric power production, steam production, and for cooling of power plants. Energy is used by the water sector for pumping, drinking water, and wastewater treatment. As climate continues to change, and water becomes increasingly scarce, competition for water among the various uses will increase. Meanwhile, demand for electricity will increase as the climate warms. This will be compounded by the fact that U.S. population is increasing fastest in the hottest regions. At the same time, less water may be available for steam production and for cooling of power plants. Ninety percent of our nation's electricity is currently generated in coal, natural gas, and nuclear power plants that require large amounts of water for cooling. The timing of these interactions could pose real problems. During heat waves and droughts, which often occur simultaneously, water availability will be low when electricity needs are high.

NEW MEXICO CASE STUDY – "IMPACTS OF GLOBAL WARMING ON NEW MEXICO'S WATER RESOURCES: AN ASSESSMENT OF THE RIO GRANDE BASIN"

New Mexico's social, economic, and environmental systems are highly vulnerable to the increasing water scarcity that is projected to affect the state as a result of future climate change. The health of New Mexico's economy, cultures, and ecosystems is tightly hinged to water supply. Currently, there is no spare water in the Rio Grande Basin. Virtually all surface water resources are used by people, plants, and animals, either directly consumed or indirectly used in growing food and providing other services. Projections suggest significantly less water in a warmer future, and at the same time, significantly more people. Major changes will be required in patterns of water use, and even with such changes, there are likely to be significant disruptions in important services provided by the State's water resources.

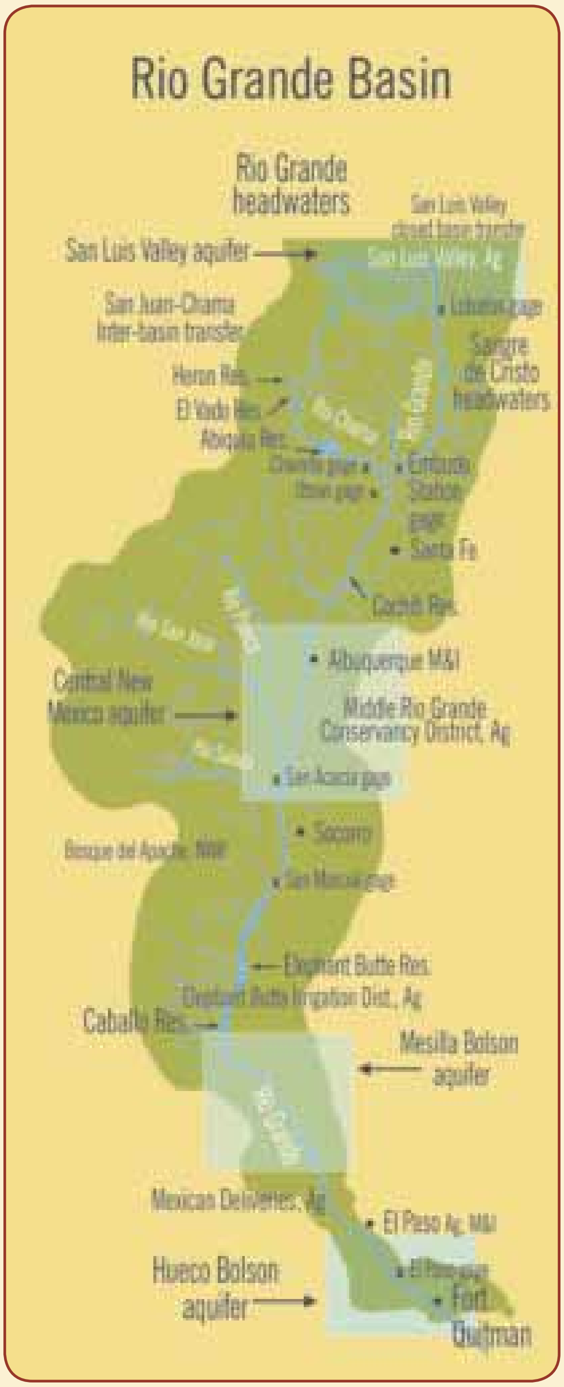
WARMING IS PROJECTED TO LEAD TO:

- A RELATIVE SHIFT FROM SNOW TO RAIN
- LESS SNOWPACK
- EARLIER SNOWMELT
- MORE WATER LOST TO EVAPORATION
- EARLIER PEAK STREAMFLOWS
- REDUCED TOTAL STREAMFLOWS

THIS IS PROJECTED TO CAUSE:

- SHRINKING WATER SUPPLIES
- GREATER COMPETITION FOR WATER
- TRANSFERS FROM AGRICULTURAL TO URBAN USES
- SUBSTANTIAL ECONOMIC LOSSES
- LOSSES TO WILDLIFE AND CULTURAL VALUES

In this context, a scientific study was undertaken by researchers at two New Mexico universities to evaluate the potential impacts of future warming on water resources in the Rio Grande Basin.



MAJOR CHANGES WILL BE REQUIRED IN PATTERNS OF WATER USE, AND EVEN WITH SUCH CHANGES, THERE ARE LIKELY TO BE SIGNIFICANT DISRUPTIONS IN IMPORTANT SERVICES PROVIDED BY NEW MEXICO'S WATER RESOURCES.

This study used a moderate assumption about future greenhouse gas emissions, not a best or worst case scenario. Even under such middle-of-the-road scenarios, surface water supplies are projected to decline. Forecasts of future reductions in streamflow come from recent observed changes and projections from climate and hydrological models using monthly averages. Furthermore, reconstructions of past streamflows from tree-ring data show that even drier conditions have existed in this region in the past. As the continued build-up of greenhouse gases in the atmosphere increasingly warms the Earth's climate, water supplies in New Mexico's Rio Grande basin could become all the more scarce in the coming decades.

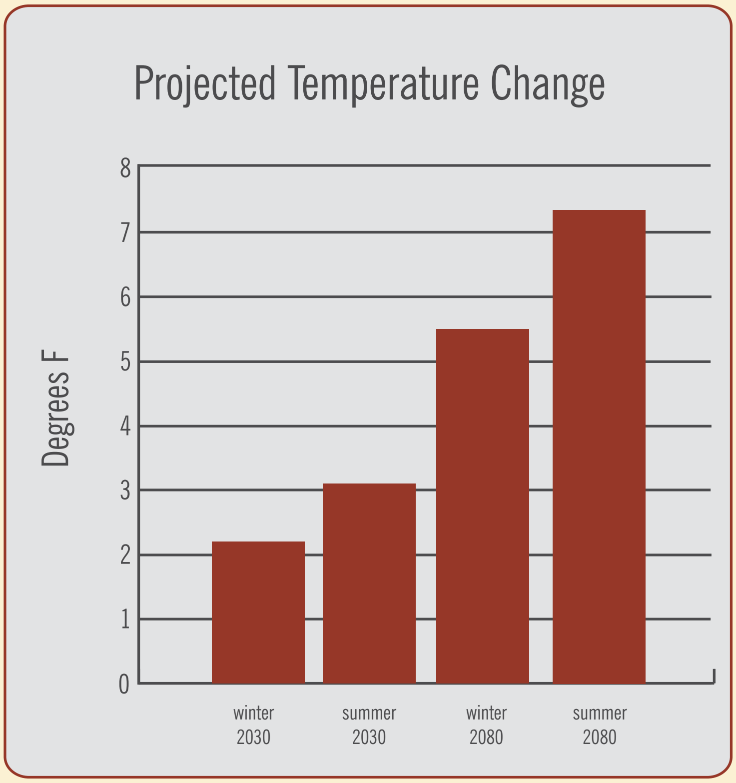
> "SHRINKING SURFACE WATER SUPPLIES AND RISING POPULATIONS WILL INCREASE COMPETITION FOR WATER AND RAISE THE ECONOMIC PRESSURE TO TRANSFER WATER FROM AGRICULTURAL TO URBAN AND INDUSTRIAL USERS."

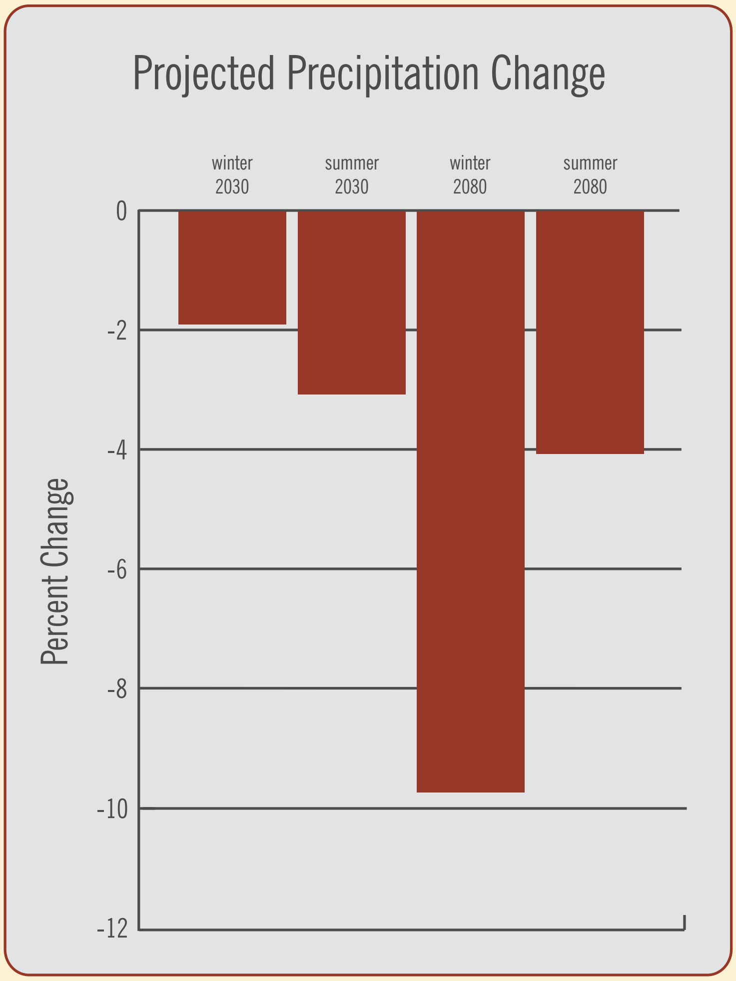
Key Findings

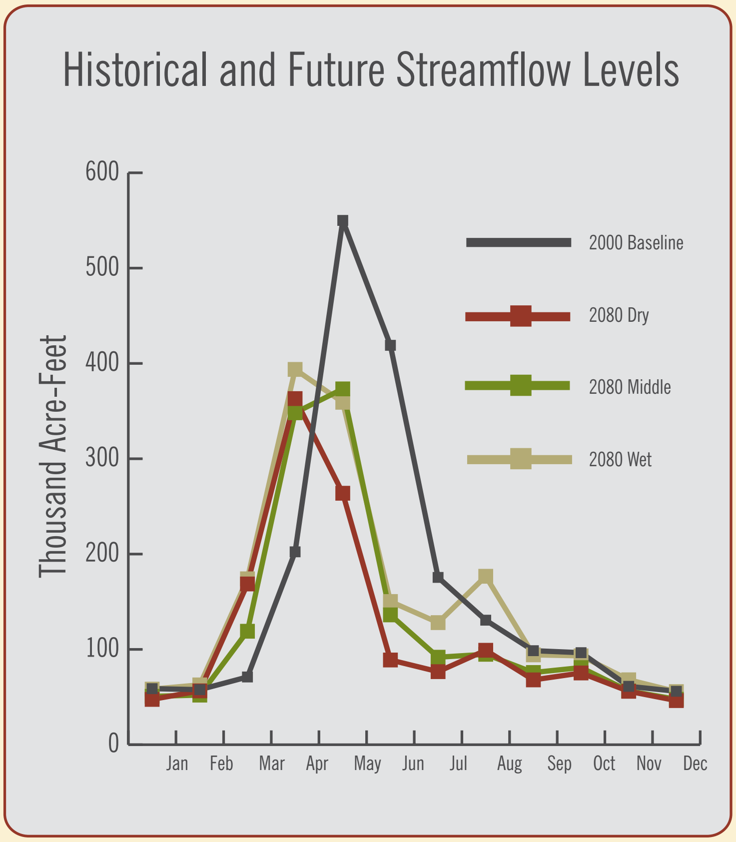
1. Warming is projected to result in less snowpack, earlier snowmelt, and more water lost to evaporation. Peak flow and total streamflow are projected to decline while peak runoff occurs a month earlier. Such changes in runoff would affect water storage systems and patterns of water availability, which in turn could seriously disrupt current human water use patterns, vegetation, and wildlife habitat.

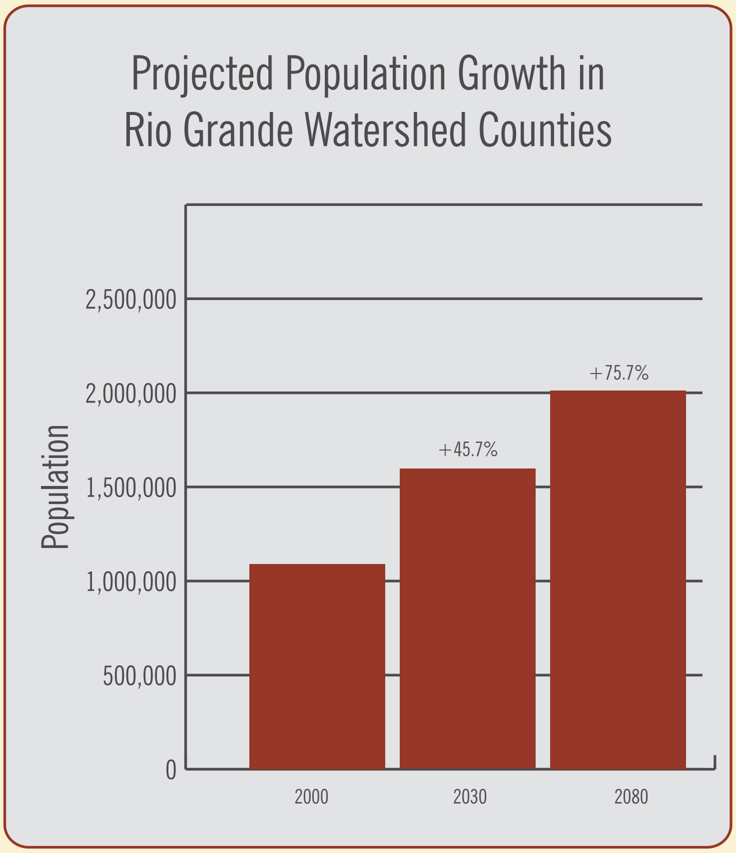
2. Shrinking surface water supplies and rising populations will increase competition for water and raise the economic pressure to transfer water from agricultural to urban and industrial users.

3. Some water uses could be curtailed as surface water supplies are significantly diminished. The drier scenarios considered in this analysis lead to declines in surface water availability and use of about 12% by 2030, and 33% by 2080. Even the wettest scenarios project water use declines of 5% by 2030 and 8% by 2080 due to higher evaporation losses.









4. Substantial and transformational disruption to New Mexico's agricultural and rural economy is projected in a warmer and drier future. Under optimistic economic and institutional assumptions, direct and indirect economic losses are projected by 2030 to range from about $13 million under a relatively mild climate scenario to $115 million under the driest scenario, with losses that rise by 2080 to range from $21 million to more than $300 million.

5. Agriculture's real value – and potentially the real loss to New Mexico's residents, tourists, and wildlife – goes far beyond this market value to the services that agriculture provides to the environment and quality of life. Losses and transfers amounting to over 30% of current water use levels will dramatically and negatively affect communities and environments across the region.

> "SUBSTANTIAL AND TRANSFORMATIONAL DISRUPTION TO NEW MEXICO'S AGRICULTURAL AND RURAL ECONOMY IS PROJECTED IN A WARMER AND DRIER FUTURE."

INFRASTRUCTURE

Around the nation, climate change is increasingly placing infrastructure at risk. For example, in the Gulf Coast region, energy and transportation infrastructure is placed at risk by rising sea level and storm surge. Oil and gas drilling facilities in the Gulf of Mexico, and ports, refineries, roads, and rail lines are at increasing risk of damage and inundation. For example, in the Gulf Coast area alone, an estimated 2400 miles of major roadway and 250 miles of freight rail lines are at risk of permanent flooding within 50 to 100 years due to sea-level rise.

In Alaska, infrastructure faces particular risks as temperatures rise. Warming in Alaska has been twice as great as the rest of the nation in recent decades, as the Arctic warms more rapidly than the rest of the globe. Rapidly declining sea ice leaves coastal areas more exposed to wave action during storms, increasing their vulnerability to erosion. Thawing permafrost destabilizes roads, buildings and other infrastructure. And the increase in heavy downpours increases risks related to flooding and erosion.

ALASKA CASE STUDY – "COSTS OF GLOBAL WARMING FOR ALASKA'S PUBLIC INFRASTRUCTURE"

No place on Earth is warming faster than Alaska. Temperatures in the state have risen by several times the global average over the past 50 years. Warming is already having significant impacts throughout Alaska and is expected to cause more extensive damage in the future. Among the observed changes resulting from this warming are melting glaciers, rising sea levels, retreating sea ice, declining snow cover and lake ice, thawing permafrost, increasing rain in autumn and winter, and increasing insect infestations and wildfires.

A WARMING CLIMATE RESULTS IN:

THAWING GROUND

- UNDERMINING FOUNDATIONS OF BUILDINGS, ROADS AND RUNWAYS

RETREATING SEA ICE

- INCREASING COASTAL EROSION DUE TO STORMS AND WAVE ACTION
- COASTS ONCE PROTECTED BY ICE BECOME INCREASINGLY VULNERABLE

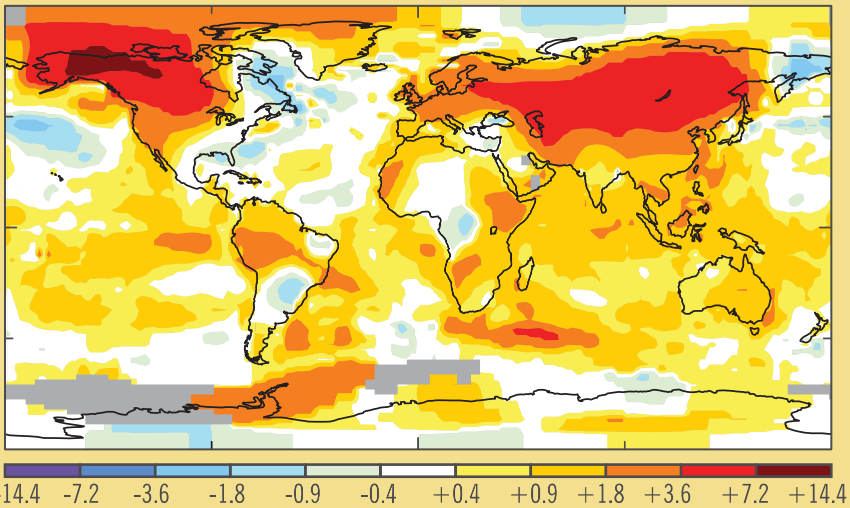
INCREASING PRECIPITATION

- WITH MORE RAIN COMING IN HEAVY DOWNPOURS
- COASTAL AND RIVERSIDE LOCATIONS MOST VULNERABLE TO FLOODING AND EROSION

These changes are already affecting people in Alaska. Subsistence hunters are having increased difficulty acquiring food and maintaining their way of life. Marine fisheries and migratory patterns of wildlife are shifting. Freshwater fish such as arctic char and salmon are decreasing. Transportation routes are being disrupted as permafrost thaws and ice roads melt. Coastal towns are facing relocation at enormous expense. Insects are thriving in the warmer conditions, destroying entire forests. The impacts of warming are expected to worsen, with higher levels of warming causing more destructive impacts. The total costs of these impacts have

Observed Temperature Change (°F)

Winter (Dec., Jan., Feb.) - 1949-2005

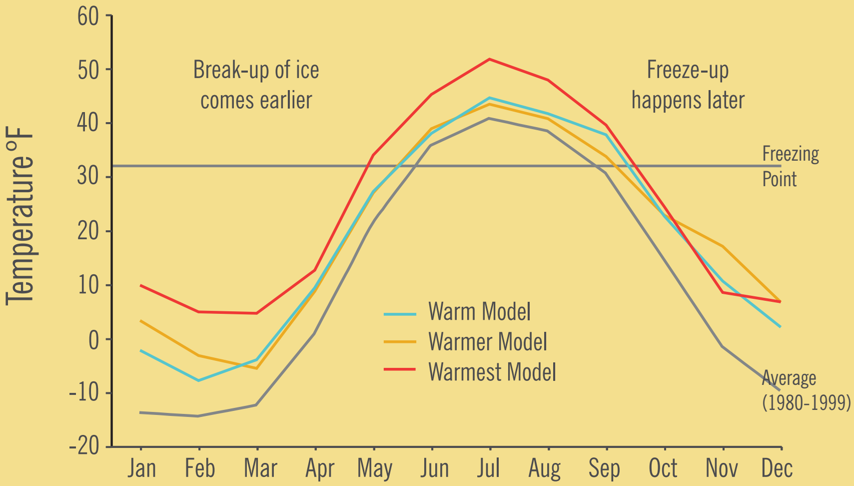


©NASA-GISS, 2007

As the map illustrates, winter temperatures in Alaska have already risen between 5 and 10ºF. In general, higher latitudes are warming more rapidly than the global average.

Monthly Average Temperature in Barrow, AK

Observed and Projected (2080)



©ISER, 2007, Source: IPCC, Special Report on Emissions Scenarios: AIB

The figure shows observed recent average temperatures for each month of the year during the period from 1980 to 1999 for Barrow, Alaska (gray line), along with climate model projections of these monthly temperatures by the year 2080. Note that under all of the model projections, ice break-up will come earlier and freeze up later than at present.

> THE COST TO MAINTAIN ALASKA'S PUBLIC INFRASTRUCTURE IS EXPECTED TO INCREASE BY 10 TO 20% BY 2030.

Seward Peninsula, Estimated Permafrost Distribution

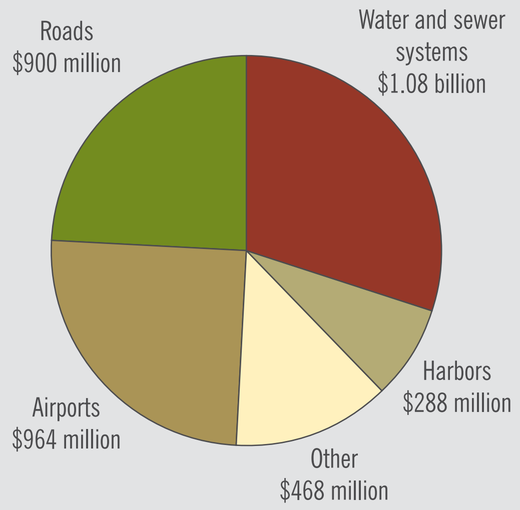
©Hinzman et al — GFDL CM 2.0 SRES A I B Scenario

Continuous – Frozen ground occupies 90-100% of the land area
Discontinuous – Frozen ground occupies 10-90% of the land area

The maps show the extent of thawing projected to occur on Alaska's Seward Peninsula in this century under a moderate warming scenario.

never been estimated. For the first time, researchers in Alaska have attempted to estimate what just a few of the results of a warming climate – thawing permafrost, increasing rain, and retreating sea ice along the coast – are likely to cost for one aspect of Alaska's economy: public infrastructure, such as roads, bridges, airports, schools, and water and sewer systems. Although the results are preliminary, they offer a general picture of the extra costs public agencies face as warming proceeds, and provide much–needed and new information for those considering the best policy approaches for addressing the myriad challenges presented by climate change.

Likely Share of Extra Costs by 2030



This study involved assembling a database of Alaska's public infrastructure, estimating its value, and mapping its location. Climate model projections of future warming due to global emissions of greenhouse gases were then used to estimate how much extra the projected warming would cost the state in maintaining its existing infrastructure. This study assumed a middle-of-the-road increase in global greenhouse gas emissions, and assuming that strategic adaptations are made (anticipating and planning for continuing warming and its impacts on infrastructure). There are plans to update and extend this research as more information becomes available.

Key Findings

1. The cost to maintain Alaska's public infrastructure is expected to increase by 10 to 20% by 2030, costing the state an additional $4 to $6 billion.

Estimated Protection and Relocation Costs for Three Alaskan Communities

Community	Costs of Future Erosion Protection	Costs to Relocate
Kivalina	$15 million	$95-125 million
Newtok	$90 million	$80-130 million
Shishmaref	$16 million	$100-200 million

One example of costs not included in this analysis is the estimated cost of protecting and/or relocating coastal communities that are under imminent threat of destruction due to factors including sea-level rise, sea-ice retreat, and thawing of coastal permafrost. Three of these towns and the costs of erosion protection and relocation estimated by the U.S. Army Corps of Engineers are shown in this chart. Further, a report by the U.S. General Accounting Office found that 184 of 213 or 86% Alaska Native villages are threatened by erosion and flooding, and that rising temperatures are increasing their susceptibility.

2. Roads and airport runways are projected to account for about half of the additional costs between now and 2030. Water and sewer systems would account for nearly a third of the costs.

3. Public infrastructure most vulnerable is located on exposed coastal plains that are susceptible to flooding and erosion from both sides. As sea level rises, coastal permafrost thaws, and sea ice that once protected the coast retreats, coastal areas face more erosion from storms and the higher waves they produce. At the same time, intensifying precipitation increases the risk of rivers overflowing their banks.

4. The adaptations assumed in the analysis have a large effect on projected costs. Without these adaptations, the costs are projected to be much higher. For example, under the warmest model projections analyzed here, without adaptations, the extra costs due to warming would be about $12.3 billion by 2080.

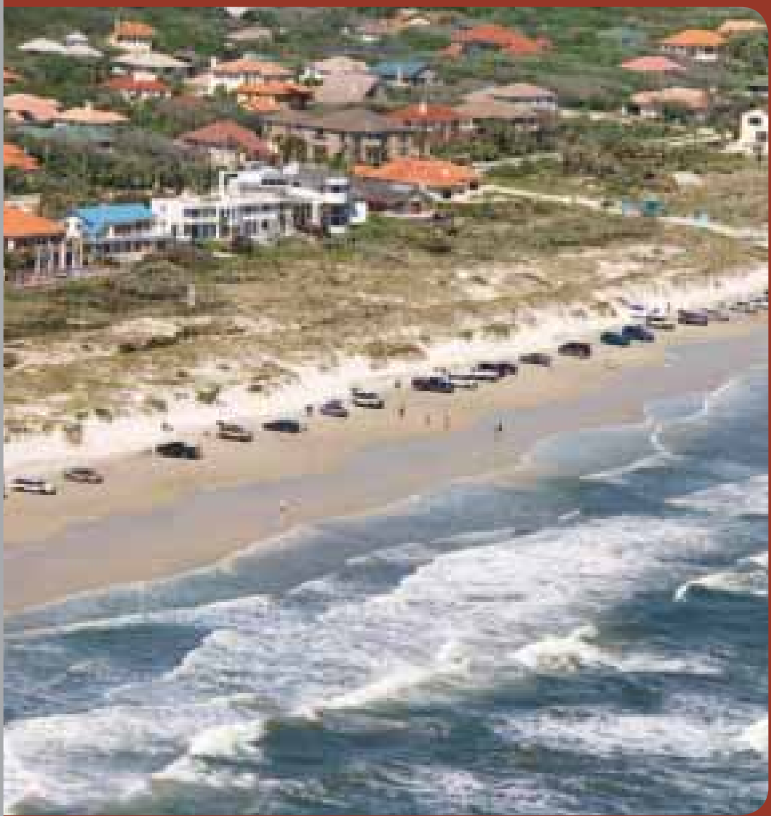
5. By 2030, strategic adaptation could reduce the costs imposed by warming from 0 to 13%, depending on the extent of warming. By 2080, such adaptations could save from 10 to 45% of those costs. The projected savings are larger later in the century because agencies would have more time to apply strategic adaptations to changing conditions.

"AS SEA LEVEL RISES, COASTAL PERMAFROST THAWS, AND SEA ICE THAT ONCE PROTECTED THE COAST RETREATS, COASTAL AREAS FACE MORE EROSION FROM STORMS AND THE HIGHER WAVES THEY PRODUCE."

COASTS

Almost half of the world's people live within 100 miles of the coast. Many of these coastal communities, particularly those in lower-lying, hurricane-prone regions, are vulnerable to the devastating impacts of coastal storm surge. These impacts were recently illustrated in the United States by the impacts of hurricanes Katrina, Rita, and Ike. Global sea-level rise is projected to accelerate and hurricane intensity to increase with continued global warming. Both of these are expected to cause higher coastal flooding and an increase in related damages.

Global warming causes sea level to rise through two major mechanisms. First, as water warms, it expands, taking up more space. Second, as ice on land melts (including mountain glaciers around the world as well as the polar ice sheets), this water flows to the oceans. The thermal expansion of the oceans and the melting of mountain glaciers are well understood. Increased melting and loss of ice on parts of the polar ice sheets has recently been observed, especially on Greenland, although how much and how fast the ice sheets will increase sea-level rise is not well known.



Thus, many projections of sea-level rise, including those used in the studies that follow, do not account for large potential contributions from the polar ice sheets, and are therefore considered conservative. Recent studies suggest that sea-level rise between 1.5 and 6.5 feet by the end of this century is possible, with increases of around to 3 to 4 feet considered most likely. This is an area of active research.

FLORIDA CASE STUDY – "CLIMATE CHANGE IN COASTAL FLORIDA: ECONOMIC IMPACTS OF SEA LEVEL RISE"

Florida's economy and way of life are closely tied to its coasts. The vast majority of Floridians (80%) live or work in one of the state's 35 coastal counties—most of them within ten miles of the coast. In addition, tourism is a major sector of the state economy that is also strongly linked to its coastal resources. In 2005, nearly 86 million tourists visited Florida, generating more than $63 billion in revenue (roughly 10% of Florida's economic output) and creating more than 944,000 jobs. Finally, Floridians are highly vulnerable to property losses and other adverse impacts from hurricanes. Damages from recent storms, including Hurricane Wilma in 2005, have run into the hundreds of millions and even billions of dollars.

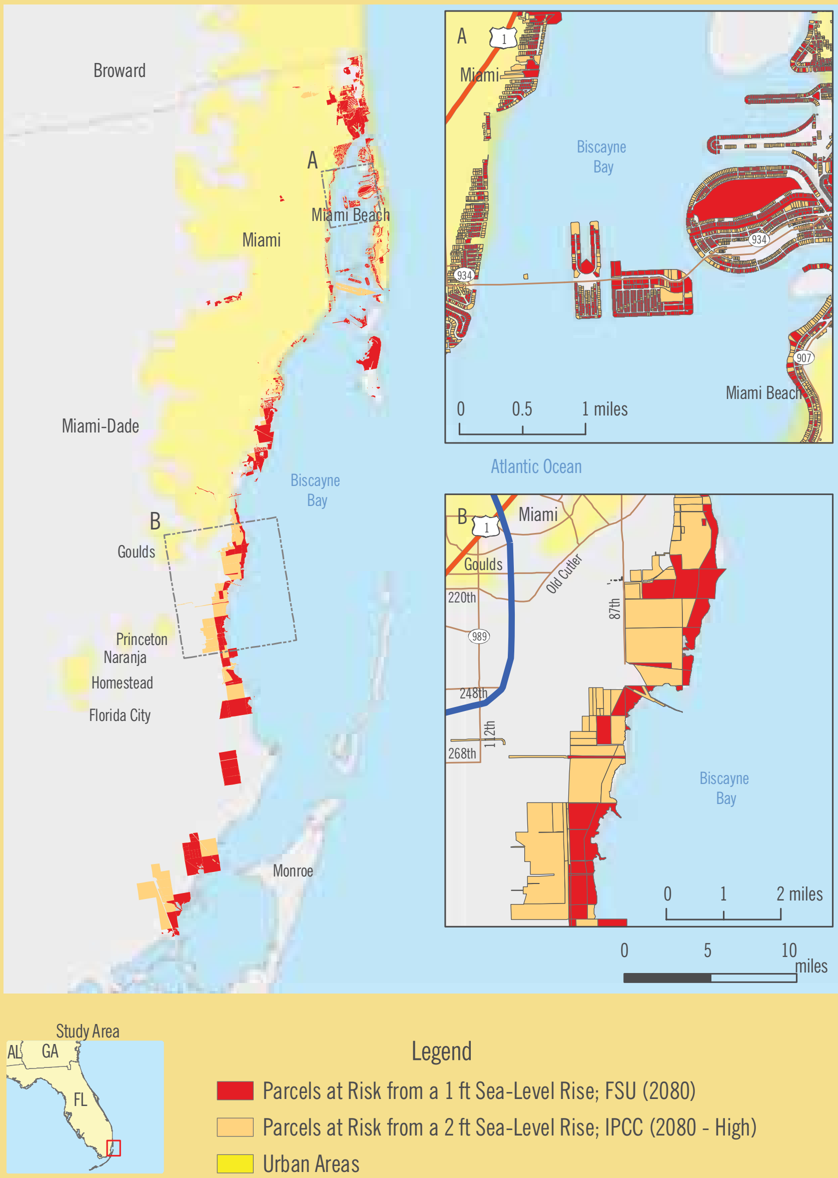
GLOBAL WARMING IS EXPECTED TO CAUSE:

- SEA-LEVEL RISE
- INCREASED FREQUENCY OF MAJOR STORM EVENTS

THESE CHANGES WOULD LEAD TO:

- SALT-WATER INTRUSION AFFECTING DRINKING WATER SUPPLIES
- HIGHER STORM SURGE AND INCREASED RISK OF FLOODING
- EROSION OF BEACHES AND BARRIER ISLANDS
- GREATER PROPERTY DAMAGES
- ADVERSE IMPACTS ON COASTAL ECO-SYSTEMS INCLUDING FISHERIES.

Land in Red is at Risk Due to Sea-Level Rise in Dade County



The sea-level rise projections for this area range from about 0.16 feet to 2.3 feet within this century, with additional increases later.

Key Findings

1. Sea level is already rising and will continue to rise in the future. This analysis used conservative estimates extrapolated from past trends. An increasing rate of sea-level rise is now being observed, and is projected to continue as polar ice sheets melt. This analysis assumed a range of sea-level rise from about 8 inches to about 2 feet. Recent studies

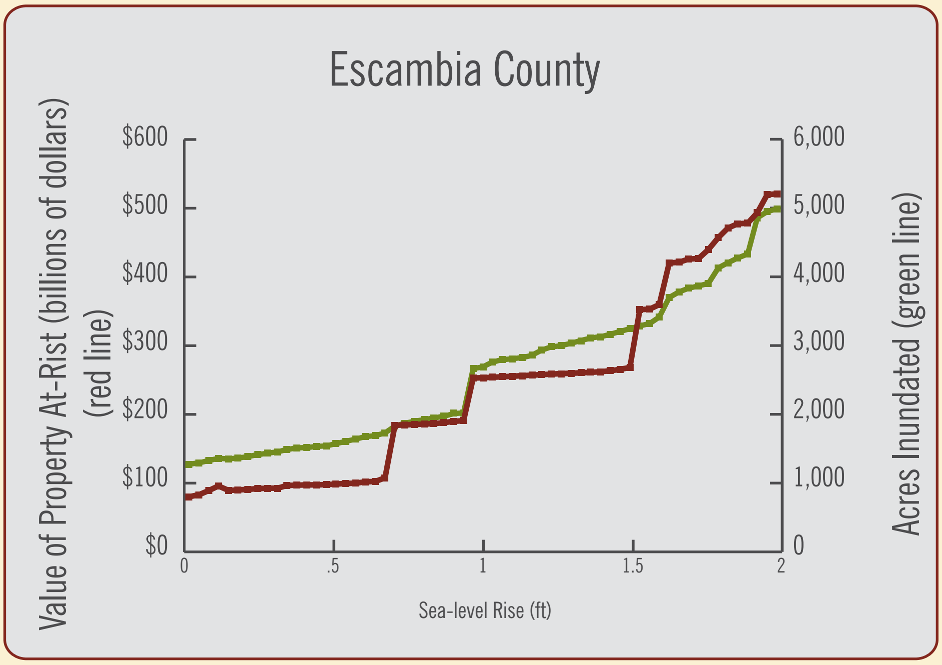
suggest that 3 to 4 feet of sea-level rise is likely in this century.

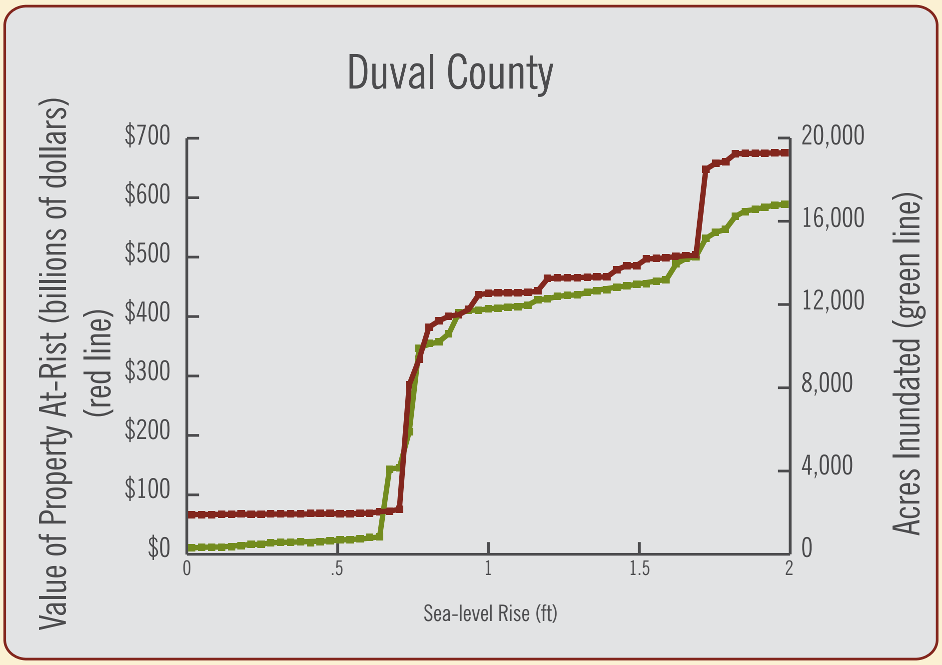
2. As sea level rises, coastal Florida can expect a dramatic increase in the frequency of major storm surge events, even if hurricane intensity and frequency are unchanged. For example, assuming sea-level rise of about 2 feet, the projected frequency of a 7-foot storm surge in Dade County (like the surge that accompanied Hurricane Wilma) would increase from the current frequency of once every 76 years to once every 5 years.

3. Damage costs associated with such storm surge events (assuming no increase in storm intensity) are projected to increase from 10 to 40 percent, depending on the extent of sea-level rise and other factors.

4. Florida's flat topography means that sea-level rise will cause major losses of land to the sea.

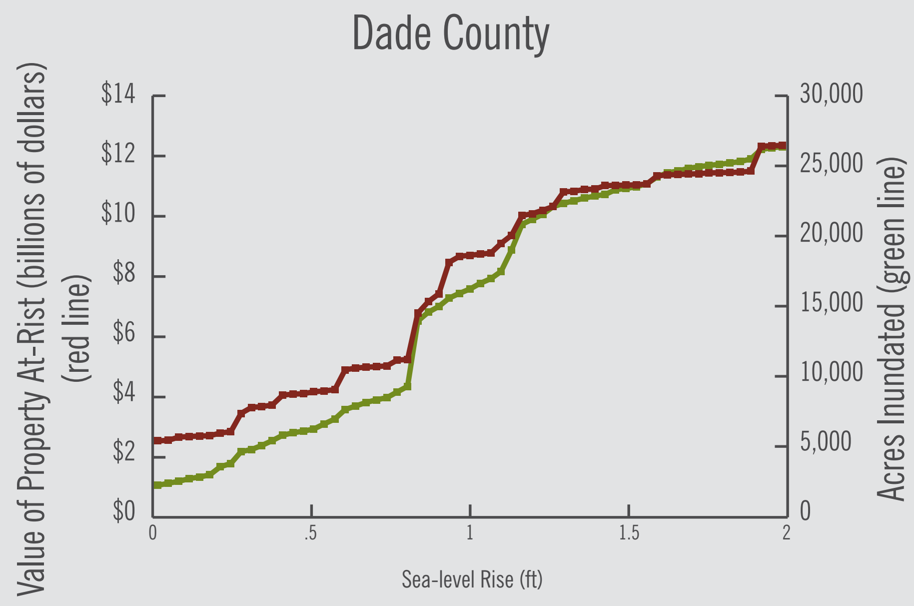
"AS SEA LEVEL RISES, COASTAL FLORIDA CAN EXPECT A DRAMATIC INCREASE IN THE FREQUENCY OF MAJOR STORM SURGE EVENTS, EVEN IF HURRICANE INTENSITY AND FREQUENCY ARE UNCHANGED."





For example, if sea level rises about 2 feet, nearly 26,500 acres of land in Dade County alone would be inundated and permanently lost.

5. Property losses would increase in direct correlation to rising sea levels. If sea level rises by about 2 feet, property losses in Dade County alone would exceed $12 billion. These results, which do not account for future increases in coastal population or property values, suggest that significant property values are at risk along Florida's coast.



PROPERTY LOSSES WOULD INCREASE IN DIRECT CORRELATION TO RISING SEA LEVELS. IF SEA LEVEL RISES BY ABOUT 2 FEET, PROPERTY LOSSES IN DADE COUNTY ALONE WOULD EXCEED $12 BILLION.

Effect of Storm Surge and Sea-Level Rise on Future Damage Costs

County	Hurricane	Historical Damage Cost	Future Damage Cost
Dade	Wilma	$2.21 billion	$2.9 billion
Dixie	Dennis	$0.06 million	$0.08 million
Duval	Frances	$72.3 million	$98 million
Escambia	Dennis	$70.7 million	$95 million
Monroe	Wilma	$215.3 million	$370 million
Wakulla	Dennis	$4.42 million	$6.9 million

NORTH CAROLINA CASE STUDY – "IMPACTS OF GLOBAL WARMING ON NORTH CAROLINA'S COASTAL ECONOMY"

"THE NORTH CAROLINA COAST IS PARTICULARLY VULNERABLE TO SEA-LEVEL RISE."

Global warming is projected to have significant impacts on North Carolina coastal resources as sea level rises and hurricanes become more intense. Extensive development in the coastal zone in recent decades has put more people and property at risk for these impacts.

GLOBAL WARMING WILL RESULT IN:

SEA-LEVEL RISE

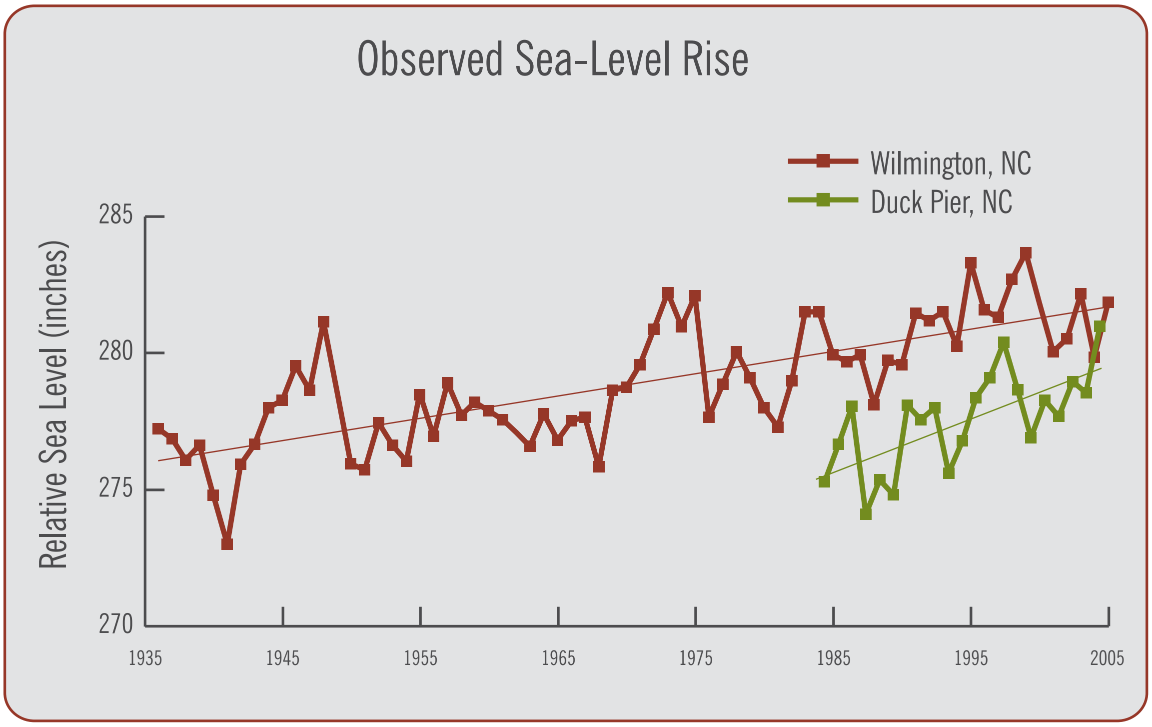
- BILLIONS IN LOST PROPERTY VALUES
- LARGE LOSSES IN RECREATIONAL BENEFITS
- COMPLETE LOSS OF MANY BEACHES

HURRICANE INTENSITY INCREASES

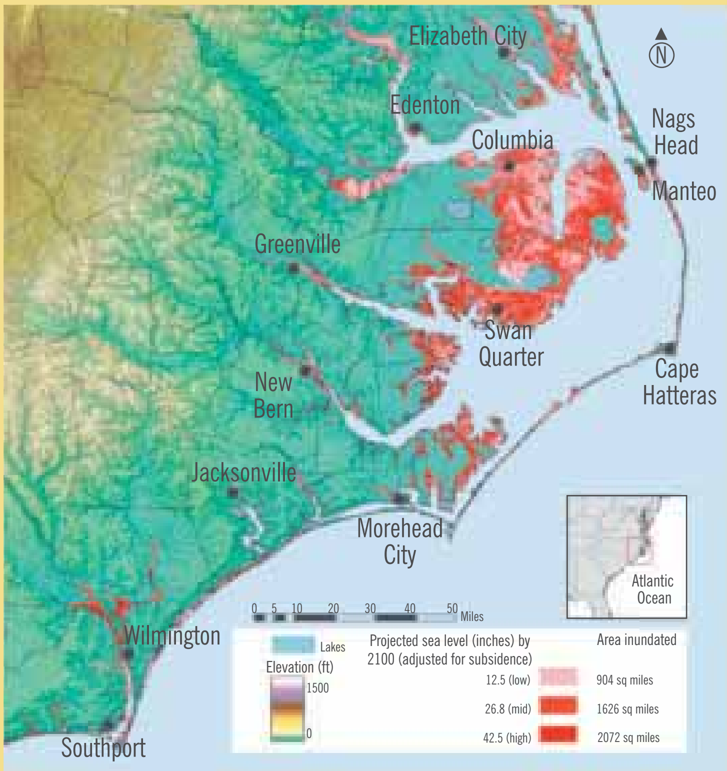
- LOSSES DUE TO BUSINESS INTERRUPTIONS
- INCREASING AGRICULTURAL LOSSES
- GREATER DAMAGE TO FORESTS
- INCREASING COMMERCIAL FISHING LOSSES

In this context, a scientific study was undertaken by researchers at four North Carolina universities to consider three important aspects of the coastal economy and their vulnerability to a changing climate: the impacts of sea-level rise on the coastal real estate market, the impacts of sea-level rise on coastal recreation and tourism, and the impacts of stronger tropical storms and hurricanes on business activity. It does not attempt to provide a comprehensive analysis of all potential impacts. This study used a range of moderate assumptions, not a best- or worst-case scenario.

The North Carolina coast is particularly vulnerable to sea-level rise for several reasons: the land has very little slope, meaning that even small increases in sea level result in a wide expanse of coastal land being inundated and lost. In addition, while sea level is rising globally due to warming, the coastal land in this area is slowly sinking due to tectonic forces, so the relative sea level rise is larger here than in places where the coastline is stable or rising. Thus the current rate of sea-level rise in this area is about twice the global average.



Land in Red is at Risk of Loss Due to Sea-level Rise by 2100



The sea-level rise projections for this area range from about one to three feet within this century, with additonal increases later.

Key Findings

Property Losses

1. The value of property at risk to sea-level rise in just four counties over the next 75 years is $6.9 billion.

2. Projected losses in residential property values vary by county, with the northern counties comparatively more vulnerable than the southern. The property at risk in Dare County ranges from 2% to 12% of the total property value.

Recreation and Tourism Losses

3. The lost recreation value of climate change-induced sea-level rise to local beach goers is projected to be $93 million a year by 2030 and $223 million a year by 2080 for the southern North Carolina beaches.

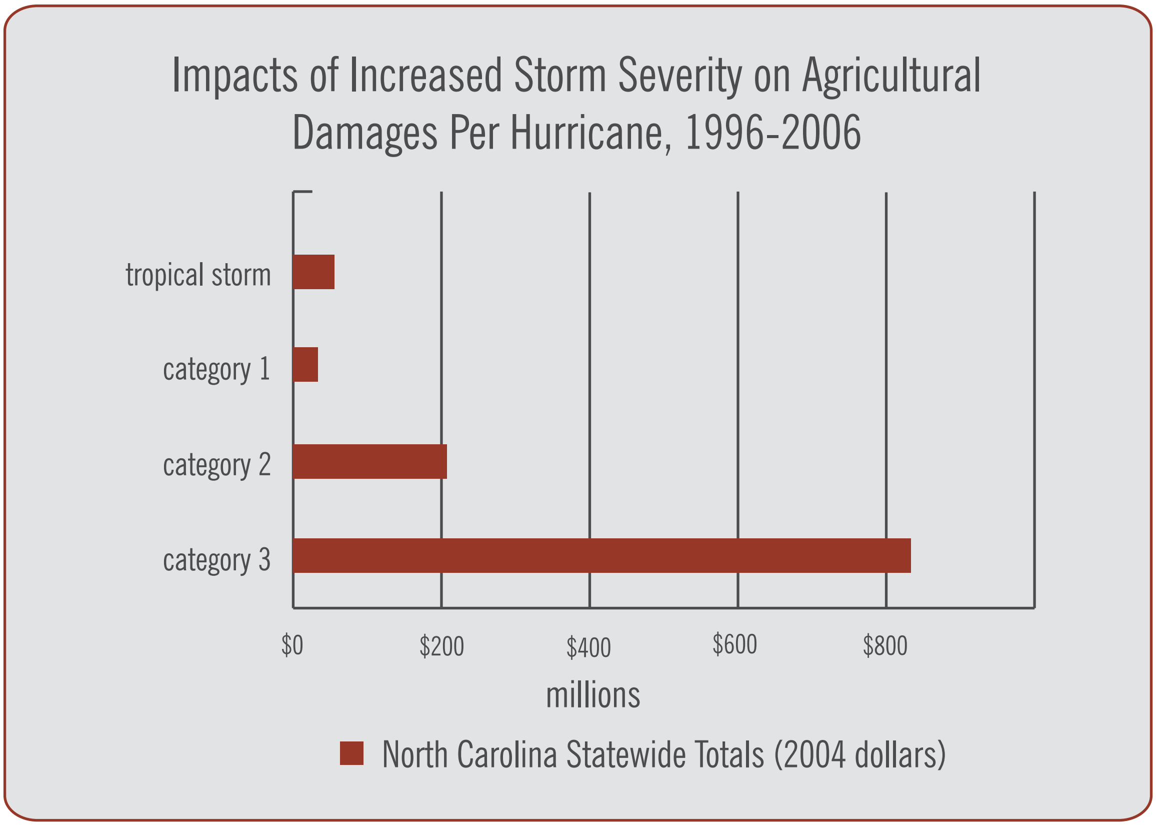
4. Spending by non-local North Carolina residents on beach trips would fall significantly with warming-induced sea-level rise, dropping by 16% per year by 2030 and by 48% per year by 2080.

5. Reduced opportunities for beach trips and fishing trips are projected to result in lost recreational benefits totaling $3.9 billion for the southern North Carolina beaches over the next 75 years.

Impacts to Business, Agriculture, and Forests

6. Increased hurricane intensity will interrupt businesses, reducing economic output to varying degrees, depending on location and the severity of warming. Business interruption losses in just four North Carolina counties due to increases in category 3 hurricane severity (excluding increases in all other categories) are projected to rise by $34 million per storm

> "REDUCED OPPORTUNITIES FOR BEACH TRIPS AND FISHING TRIPS ARE PROJECTED TO RESULT IN LOST RECREATIONAL BENEFITS TOTALING $3.9 BILLION FOR THE SOUTHERN NORTH CAROLINA BEACHES OVER THE NEXT 75 YEARS."



> INCREASED FOREST DAMAGE ASSOCIATED WITH AN INCREASE IN STORM SEVERITY FROM CATEGORY 2 TO CATEGORY 3 IS ABOUT 150% PER STORM EVENT, OR ABOUT $900 MILLION MORE IN DAMAGES.

2030, and by $157 million per storm in 2080. Assuming no increase in hurricane frequency, the projected cumulative losses from 2004 to 2080 due to increased category 3 severity in these four counties amount to $1.44 billion.

7. Increasing storm intensity is expected to have serious impacts on agriculture. A category 1 hurricane now causes about $50 million in agricultural damage, a category 2, about $200 million, and a category 3, about $800 million, illustrating how significant an increase in hurricane intensity would be for this sector.

8. Increased forest damage associated with an increase in storm severity from category 2 to category 3 is about 150% per storm event, or about $900 million more in damages.

9. The four counties (New Hanover, Dare, Carteret, and Bertie) selected for the hurricane intensity analysis represent a range of geographic location and urbanization intensity. Changes among low-intensity hurricane categories were identified as the most likely impacts of climate change on storm intensity. Though low-intensity storms cause less physical damage than do high-intensity storms, low-intensity storms occur with much greater frequency, especially in North Carolina; thus, their cumulative economic impacts can be very large.

TEXAS CASE STUDY – "IMPACTS OF GLOBAL WARMING ON HURRICANE-RELATED FLOODING IN CORPUS CHRISTI, TEXAS"

An analysis of impacts to Corpus Christi, Texas was undertaken to help understand and quantify the potential impacts of global warming on coastal flooding and related damages. Corpus Christi is home to a diverse industry base, including petroleum refineries, a naval base, a university, and businesses supporting coastal tourism. The city's location on the Gulf of Mexico makes it particularly vulnerable to climate change impacts.

If sea-level rise projections and the hurricane intensification scenarios used in this analysis are realized, significant increases in flood levels are projected, especially under higher emissions scenarios. This would lead to major economic consequences resulting from increased property damage and displacement of families and businesses.

GLOBAL WARMING IS PROJECTED TO INCREASE:

- SEA-LEVEL RISE
- HURRICANE INTENSITY
- COASTAL FLOODING

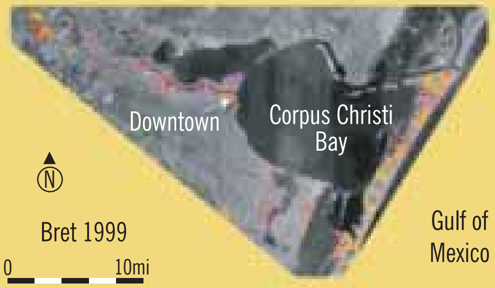
CAUSING INCREASED:

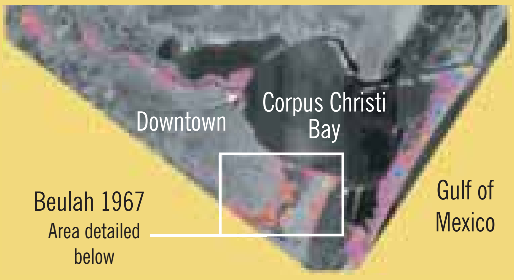
- PROPERTY DAMAGE
- DISPLACEMENT OF FAMILIES AND BUSINESSES
- LOCAL AND NATIONAL ECONOMIC IMPACTS

To evaluate the impact of global warming on future coastal flooding in Corpus Christi, three historical storms were chosen. These allowed the validation of the hurricane-surge model used in the analysis and served as a benchmark for comparing future hurricane scenarios. The study assumed that these storms occur in the future as they did in the past, but with higher sea levels and greater intensity resulting from climate change under various scenarios, providing analogs for future occurrences of these historical storms.

Projections of Flooding

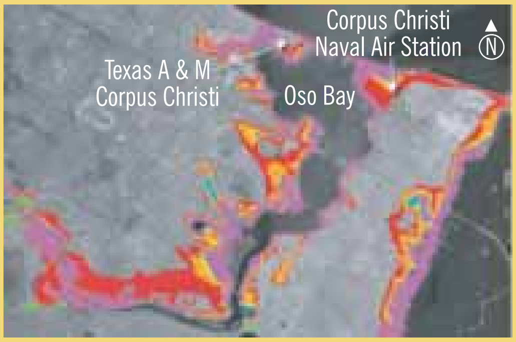
(if these hurricanes were to occur in the future under various scenarios)





Flood Levels		Flooded Area (Square Miles)	Structural Damages (2008 prices & values)
Historical (2000s)	Bret	12	$ 7,500,000
	Beulah	32	124,750,000
Low Estimate 2000s	Bret	15	17,250,000
	Beulah	36	174,500,00
High Estimate 2030s	Bret	19	35,000,000
	Beulah	39	226,000,000
Middle Estimate 2080s	Bret	33	143,250,000
	Beulah	44	362,250,000
High Estimate 2080s	Bret	39	286,000,000
	Beulah	51	499,000,000

Detail of Hurricane Beulah



"IF SEA-LEVEL RISE PROJECTIONS AND THE HURRICANE INTENSIFICATION SCENARIOS USED IN THIS ANALYSIS ARE REALIZED, SIGNIFICANT INCREASES IN FLOOD LEVELS ARE PROJECTED, ESPECIALLY UNDER HIGHER EMISSIONS SCENARIOS."

SEA LEVEL AROUND CORPUS CHRISTI IS PROJECTED TO RISE BY ABOUT 2.6 FEET BY THE 2080S UNDER A HIGH HEAT-TRAPPING GAS EMISSIONS SCENARIO.

The coastal area around Corpus Christi is particularly vulnerable to sea-level rise for several reasons. First, the coastal land in this area is slowly sinking due to geologic forces and oil extraction, and this subsidence combines with global sea-level rise to produce more relative sea-level rise here than in places where the coastline is stable or rising. Second, while the city has historically benefited from the protection of barrier islands, these islands are eroding as sea level rises, becoming narrower and lower in elevation, thus providing less protection from storm surge and a greater probability that the islands will be breached or over-washed.

Key Findings:

1. Sea level around Corpus Christi is projected to rise by about 2.6 feet by the 2080s under a high heat-trapping gas emissions scenario (but not including the potential for larger rises due to increased ice sheet melt). This would come on top of the 1.7 feet of sea-level rise already experienced over the past 100 years in this area. Higher sea level means higher flood levels. It also affects the barrier islands, reducing the protection they provide.

2. Hurricanes are projected to become more intense as ocean waters continue to warm. In particular, models project increases in wind speeds and rainfall rates for the strongest hurricanes. Intensity (measured by the fall in central pressure) is projected to increase by about 8 percent for every 1.8°F increase in sea surface temperature.

3. By the 2030s, hurricane flood levels could increase by 3 to 27 percent, depending on emissions scenario. By the 2080s, hurricane flood levels could increase by up to 100 percent.

4. Structural damage to homes and buildings affected by flooding due to a major hurricane is projected to rise by 60 to 100 percent, depending on storm size, by the 2030s and by more than 250 percent by the 2080s.

5. For a catastrophic storm surge event in Corpus Christi, such as the surge that would have accompanied Hurricane Carla if it had followed a more southerly track, by the 2030s, structural damages are projected to increase by $102 million to $265 million, depending on the heat-trapping gas emissions scenario; by the 2080s, property damages are expected to increase between $265 million to more than $1 billion. The higher the emissions scenario, the more damage is projected.

"THE VALUE OF PROPERTY AT RISK TO SEA-LEVEL RISE IN JUST FOUR COUNTIES OVER THE NEXT 75 YEARS IS $6.9 BILLION."

FORESTS

Forests cover nearly one-third of the United States, providing wildlife habitat, clean air and water, cultural and aesthetic values, carbon storage, and recreational opportunities such as hiking, camping, and fishing. Forests also provide products that can be harvested such as timber, pulpwood, fuelwood, wild game, mushrooms, and berries. This natural wealth depends on forest biodiversity (the variety of plant and animal species) and forest functioning (water flows, nutrient cycling, and productivity). These aspects of forests are strongly influenced by climate. And these goods and services are vital to the economy in many regions and in the nation as a whole. The studies that follow illustrate a few of the significant impacts climate change will have on the economic value derived from forests around our nation.

TENNESSEE CASE STUDY – "ECONOMIC IMPACTS OF CLIMATE CHANGE ON TENNESSEE'S FORESTS"

The U.S. forestry industry is concentrated in the southeastern region, where forests are especially diverse and where impacts from climate change are expected to be severe.

PROJECTED CLIMATE CHANGES INCLUDE:

- ALTERED SEASONAL WEATHER PATTERNS
- CHANGING PRECIPITATION

THIS COULD LEAD TO:

- CHANGES IN SOIL MOISTURE
- LOSS OF FOREST BIOMASS
- LOSS OF WILDLIFE HABITAT
- CHANGES IN THE DISTRIBUTION AND DIVERSITY OF PLANT AND ANIMAL SPECIES
- IMPACTS ON TOURISM AND RECREATION
- IMPACTS ON FOREST-RELATED INDUSTRIES

In Tennessee, the forestry industry directly and indirectly supports 257,700 jobs and contributes $22.8 billion to the state's economy. Tennessee's forests are home to more than 71 tree species and a great variety of other plants and animals – some of the most diverse forest ecosystems of the inland United States. Climate-related impacts on forests are therefore of special concern and potential economic significance. Changes in forest composition and temperature are likely to affect recreational pursuits – such as trout fishing – that play an important role in the state's economy and quality of life.

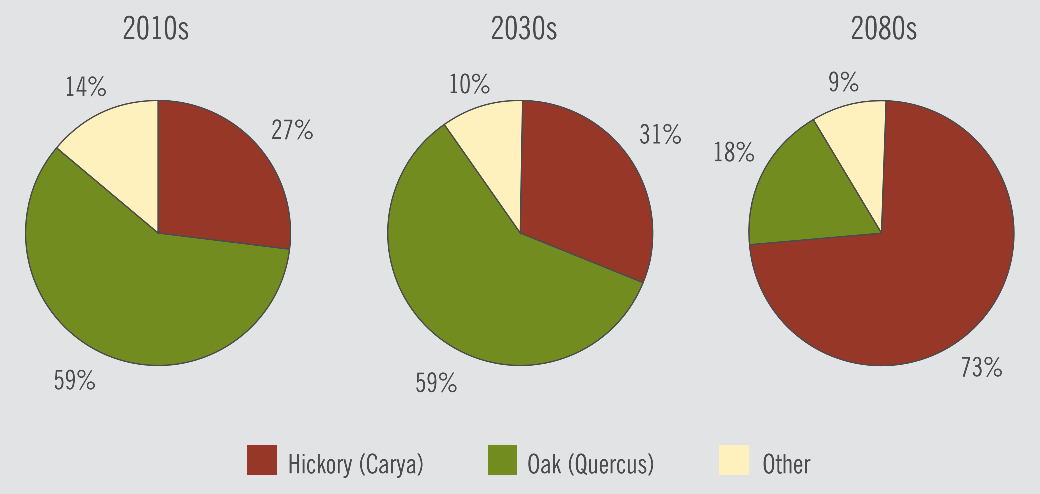
Key Findings:

1. Temperatures are projected to rise in all seasons. Projected changes in precipitation patterns are less certain and more complex.

2. Under most climate scenarios, total forest biomass is projected to decline over this century, with the largest reductions expected under dry scenarios. Southern Mixed Forest is projected to suffer significant forest die-off and substantial loss of biodiversity, losing nearly 90 percent of its biomass by 2080 under a dry scenario. Over the long term, on a time scale of several centuries, total forest biomass

> "CHANGES IN FOREST COMPOSITION AND TEMPERATURE ARE LIKELY TO AFFECT RECREATIONAL PURSUITS – SUCH AS TROUT FISHING – THAT PLAY AN IMPORTANT ROLE IN THE STATE'S ECONOMY AND QUALITY OF LIFE."

Central Tennessee Broadleaf Forest Composition Change
(Dry Scenario)



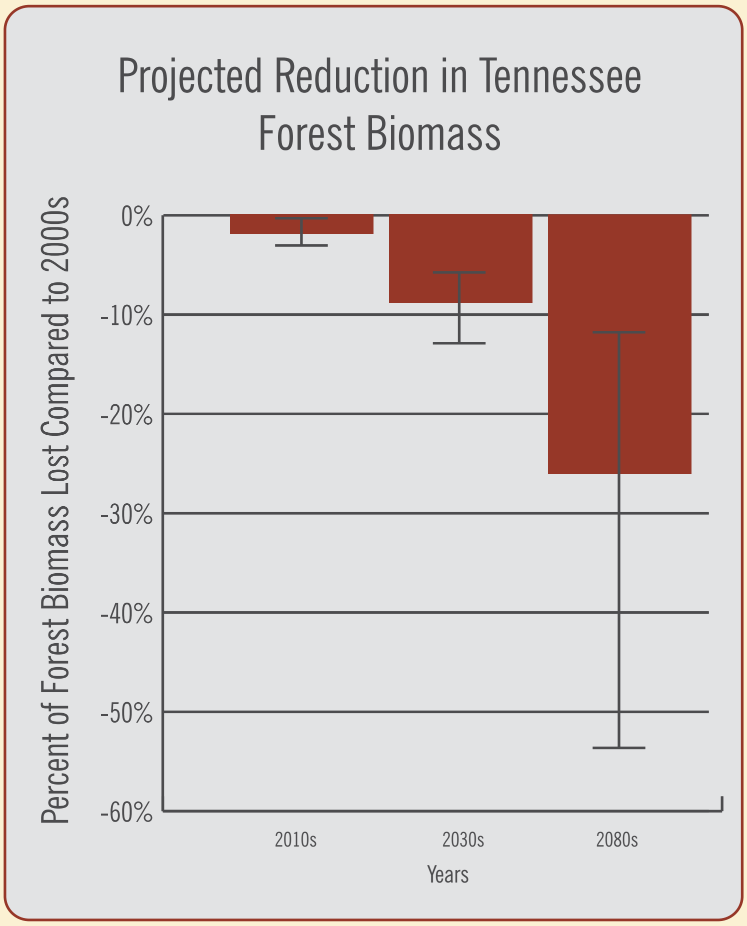
is expected to recover as tree species shift to those more suited to the new climate conditions.

3. Oak and other commercially important hardwoods are projected to decline, while hickories and other less valuable woods increase, with significant effects on the forests products industry.

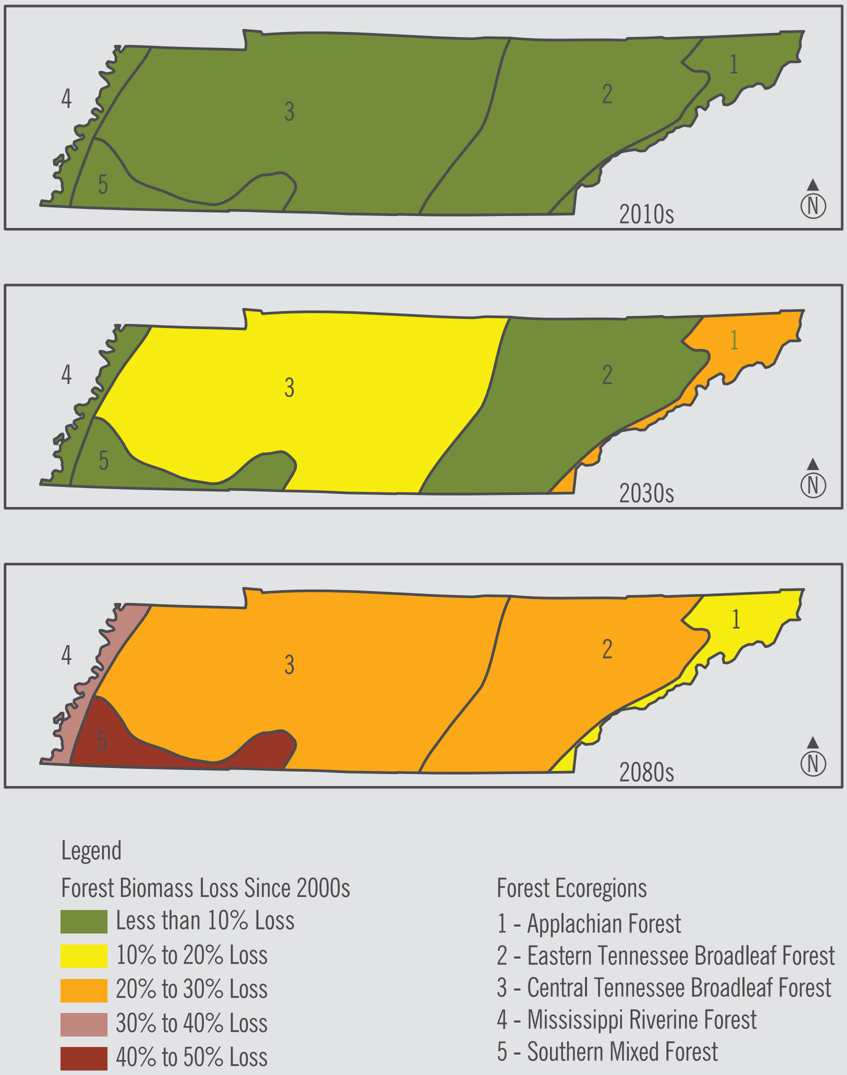
4. Tennessee's climate is projected to become less suitable and comfortable for tourism and recreation in the summer months, and more so from late fall to early spring. Activities such as rock climbing and whitewater boating are likely to benefit in the winter months. Winter activities dependent on snow are expected to decline, as are summertime activities such as lake recreation and camping.

5. A major decline in trout populations is expected as stream temperatures rise. This would have significant effects, as trout fishing is a popular and economically important activity in Tennessee. Loss of high-elevation spruce-fir forests will affect recreational pursuits including backpacking and bird watching.

> "WINTER ACTIVITIES DEPENDENT ON SNOW ARE EXPECTED TO DECLINE, AS ARE SUMMERTIME ACTIVITIES SUCH AS LAKE RECREATION AND CAMPING."



Tennessee Forest Biomass Loss (Base Year 2000s)



“OAK AND OTHER COMMERCIALLY IMPORTANT HARDWOODS ARE EXPECTED TO DECLINE.”

MONTANA, WYOMING, AND IDAHO CASE STUDY — "IMPACTS OF CLIMATE CHANGE ON FORESTS OF THE NORTHERN ROCKY MOUNTAINS"

"FORESTS ARE ALREADY RESPONDING TO OBSERVED CLIMATE CHANGE, AND THESE CHANGES ARE PROJECTED TO INTENSIFY IN THE COMING YEARS."

The forests of the U.S. Northern Rocky Mountains are highly sensitive to projected climate change. Even under conservative projections of future climate change, dramatic effects on these forests are expected. Documented climatic changes in the last 50 years have significantly altered the conditions in which forests grow. Forests are already responding to observed climate change, and these changes are projected to intensify in the coming years.

CLIMATE CHANGE WILL CAUSE:

- RISING TEMPERATURES
- LESS SNOW, MORE RAIN
- LESS WATER STORED IN SNOWPACK
- EARLIER SPRING SNOWMELT AND PEAK RUNOFF
- LOWER STREAM FLOWS IN SUMMER

THESE CHANGES WILL LEAD TO:

- LONGER SUMMER DROUGHT
- INCREASED WATER STRESS
- MORE INSECT INFESTATIONS
- MORE INTENSE WILDFIRES
- LARGE ECONOMIC IMPACTS

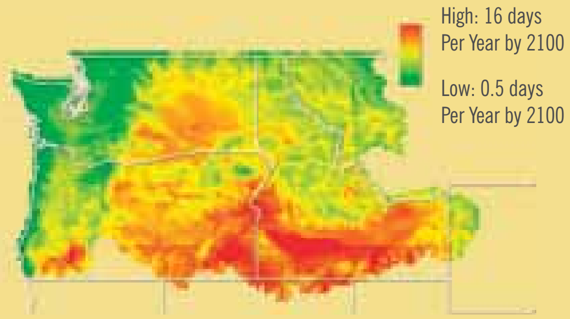
Forests in relatively dry regions like the northern Rocky Mountains live in a perpetually water-limited state. During most of the growing season, when light and low temperatures do not limit growth, water is the most important limiting factor. Productivity depends on moisture conditions during the main part of the growing season. Spring, summer, and autumn temperatures, summer precipitation levels, and the previous winter's snowpack determine those moisture conditions.

Water from Snowpack

Water storage in snowpack in the Mountain West is very important. Up to 75 percent of all stream water originates from snowmelt. Further, cold-season processes play an important role in the development of summer drought and fire risk. This study confirms the well-documented shift toward earlier runoff in recent decades attributed to more precipitation falling as rain instead of snow, and earlier snowmelt. Climate models project a continuation of these trends with an average of one-month earlier peak snowmelt and a significant decline in the number of days with snow on the ground per year.

Less snow is likely to increase the summer drought period, further increasing the number of days that trees experience water stress. At sites that presently depend on snowpack to maintain a forest canopy during summer months, models indicate that by the 2080s there would be little to no snowpack left.

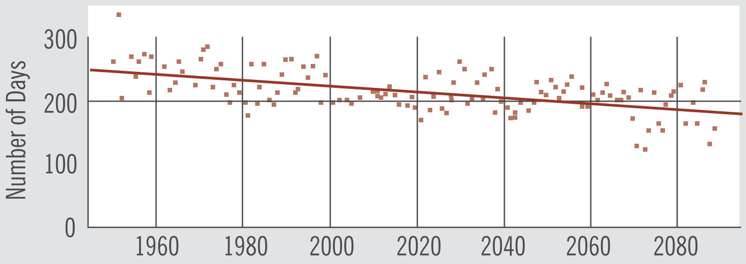
Increase in Number of Moisture Stress Days



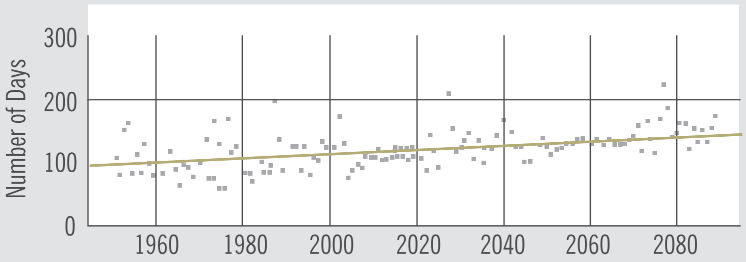
Key Findings

1. As temperatures rise, projected changes in Northern Rocky Mountain forests include fewer days with snow on the ground, earlier peak snowmelt, a longer growing season, and about two months of additional summer drought stress each year by late this century.

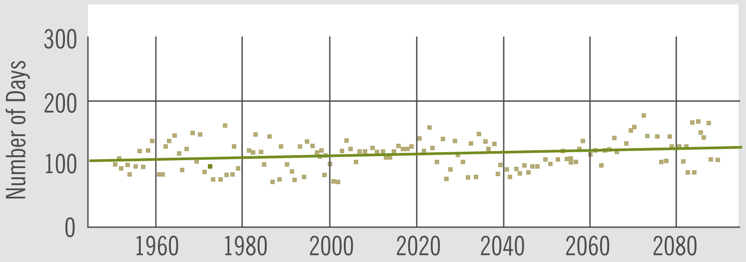
Projected Snow Pack Decline at a High-Elevation Wet Site (Glacier, MT)



Projected Increase in Water Stress at a Lower-Elevation Dry Site (Missoula, MT)



Projected Growing Season Increase at a High-Elevation Dry Site (Deer Point, ID)



2. Increasing drought stress will increase forest disturbances including insect epidemics and wildfires. These disturbances have large impacts on society and the natural world.

3. If climate becomes drier, carbon uptake would be reduced to the extent that most forests in the region would switch from absorbing carbon to releasing it by late this century.

4. The economic impact of highest concern is the potential for a truly catastrophic wildfire in the region. There are now 360,000 people living in homes valued at $21 billion in the forest-urban interface in this region that are directly vulnerable to wildfire.

Future Climate Change

Climate projections for the northern Rocky Mountains over the course of this century include an annual average warming trend of 3.6 to 7.2°F. Lower emissions of heat-trapping gases will result in temperature increases near the lower end of this range and higher emissions near the higher end. Winter temperatures are projected to increase more than those in the other seasons. Precipitation, runoff, and streamflow patterns will also change, with both the amounts of water and the timing of runoff and streamflow being affected.

Over the course of this century, the growing season in the northern Rocky Mountains is expected to increase by about two months. Spring snowmelt will occur four to six weeks earlier, and the summer drought period will be six to eight weeks longer. The growing season will shift one to two months earlier in the spring. Late summer drought will be extended by six to eight weeks. One of the results of this extended drought will be an increased risk that small streams will dry up.

> "THERE ARE NOW 360,000 PEOPLE LIVING IN HOMES VALUED AT $21 BILLION IN THE FOREST-URBAN INTERFACE IN THIS REGION THAT ARE DIRECTLY VULNERABLE TO WILDFIRE."

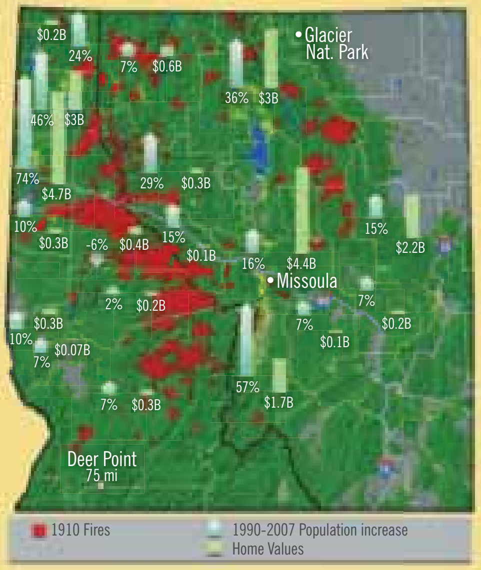
> THE LONGER AND MORE INTENSE SUMMER DROUGHT PERIOD PROJECTED FOR THIS REGION LIMITS THE POTENTIAL POSITIVE EFFECTS OF A LONGER GROWING SEASON.

Forest Productivity

Warming increases growing season length, which is often associated with increased forest productivity, especially in high latitudes where temperatures constrain productivity in certain parts of the year, as is the case in this region. Under non-water-limited conditions, temperature is most likely a major driver of plant productivity. However, the longer and more intense summer drought period projected for this region limits the potential positive effects of a longer growing season.

A longer growing season and increased carbon dioxide in the air might be expected to increase plant productivity and carbon uptake, but this study shows limited productivity increases and a one- to three-month increase in the number of days in which trees are water stressed across the region, despite increases in growing season length, suggesting that in these forest ecosystems, water availability is the main control on productivity.

Increased Population and Monetary Value at Risk to Wildfire



Forest Carbon Storage

Some forests that are now net absorbers of carbon dioxide from the air on an annual basis may begin releasing carbon dioxide by the end of the century. This would occur as carbon released through plant respiration exceeds carbon taken up by photosynthesis during the longer drought season. Even more significantly, the potential for large-scale insect outbreaks and wildfire will increase, causing even more carbon to be released and reducing the number of trees available to absorb carbon dioxide.

Pronounced declines in forest carbon uptake in parts of this region are projected, especially if climate becomes drier. Under drier scenarios, much of the region is actually projected to switch from absorbing carbon to releasing it – that is, becoming a carbon source rather than a carbon sink. This could have enormous significance given the importance of high-latitude mountainous forest sites in global carbon uptake.

CONCLUSIONS

Many aspects of climate change, including rising temperature, increasing heavy downpours, rising sea level and hurricane intensity, and reduced water supplies will present increasing challenges around the nation. Economic impacts in the United States will be substantial, and will increase with additional warming.

The good news is that it is not too late to prevent the worst of these impacts. All analyses show that reducing heat-trapping emissions will reduce warming and associated impacts. The science is also clear that choices made now will determine the severity of the impacts we will face in the decades and centuries to come. The need to change the trajectory of heat-trapping gas emissions is urgent if we are to avoid dangerous climate change. The cost of inaction will be much higher than the cost of action.

"THE GOOD NEWS IS THAT IT IS NOT TOO LATE TO PREVENT THE WORST OF THESE IMPACTS. ALL ANALYSES SHOW THAT REDUCING HEAT-TRAPPING EMISSIONS WILL REDUCE WARMING AND ASSOCIATED IMPACTS."

LIMITATIONS TO STATE CASE-STUDIES

Water resources

"Impacts of Global Warming on New Mexico's Water Resources: An Assessment of the Rio Grande Basin"

There are many limitations in the capability to measure and express the economic consequences projected to result from changes that affect the regional character and economy in such profound ways, much less the social and ecological values that cannot be expressed in economic terms. These limitations, coupled with some optimistic assumptions suggest that this analysis underestimates some of the future economic impacts of warming on New Mexico's hydrologic system. First, the analysis assumed that changes in future water use would reflect the uses with the highest monetary value. The analysis also assumes efficiently functioning water markets in which buyers and sellers are motivated by their private economic interests. In actuality, the potential for significant economic and legal conflict could be costly and unavoidable. Another assumption that reduces the projected costs is that this study assumes that future runoff and streamflow conditions are known with certainty and that adjustments and adaptations, in the form of storage and use decisions, would be optimally executed without errors in amount or timing of adjustments.

There are other issues not considered in this study that might contribute to economic losses. Decreasing agriculture will mean a reduction in open space and the many services it provides, such as wildlife habitat and scenic landscapes, that are not valued in monetary terms. Damaging effects are projected to result from the potential increases in flooding due to more frequent and intense monsoonal storms. This study is based on monthly averages and does not consider the effect of individual storms. Warming-induced drying of New Mexico's soils will further stress rangeland vegetation, adversely affecting the beef cattle industry that provides 40% of New Mexico's agricultural income. Drying increases the frequency and severity of forest fires. Tourism may be adversely affected by the degradation of scenic and recreational opportunities. Finally, detrimental impacts on water quality could result as reduced streamflows lower the capacity of streams to assimilate pollutants

Infrastructure

"Costs of Global Warming for Alaska's Public Infrastructure"

Privately owned infrastructure, such as homes, businesses, and industrial facilities, are excluded from this analysis. Counting of public infrastructure is incomplete due to data limitations (for example, data are not available for many military installations due to security issues). The Trans-Alaska pipeline was not included. The analysis only considers infrastructure already built today; it does not anticipate future infrastructure and the extra costs warming would impose on such projects as a planned natural gas pipeline. Many assumptions about future warming as well as its impacts on infrastructure had to be extrapolated from a limited number of data points. Sea-level rise was not taken into account in this analysis. Although three different climate models are used to illustrate three possible levels of future warming, all three models used the same emissions scenario, a middle-of-the-road scenario that assumes high economic growth and energy use, low population growth, and rapid technological advances. Higher and lower emissions scenarios were not analyzed. Thus the range of economic costs shown here is only a small part of the possible range. The actual costs will depend largely on the level of emissions of heat trapping gases, with higher emissions resulting in more warming and higher costs.

Sea-Level Rise and Major Storm Events

"Climate Change in Coastal Florida: Economic Impacts of Sea Level Rise"

Estimates of future sea level rise vary widely because there is still substantial uncertainty about this category of climate-change impact. Linking changes in sea level to future storm impacts and damages compounds these uncertainties. Because the Florida State University study did not account for changes in property values over time or the likelihood that population and development along the coast would continue to grow it likely understates future impacts from sea-level rise. On the other hand, the study also did not account for adaptation measures that might be undertaken by property owners to reduce losses or damages in the future. Finally, the study does not address the possibility that global warming will likely increase the intensity or severity of Atlantic hurricanes—all of the damage estimates are based on changes in expected storm surge due solely to sea level rise. Accounting for a likely increase in storm intensity would almost certainly push damage estimates higher, perhaps significantly.

"Impacts of Global Warming on North Carolina's Coastal Economy"

This study used a range of moderate assumptions about warming and sea-level rise, not best- or worst-case scenarios. Its focus was only the specific economic impacts mentioned in the text, and as such, it does not attempt to provide a comprehensive analysis of all potential impacts, such as the possible loss of species or the natural ecosystems in which they live.

"Impacts of Global Warming on Hurricane-related Flooding in Corpus Christi, Texas"

This analysis looked only at damages due to flooding by storm surge and sea-level rise. It is not a comprehensive analysis of the wide array of hurricane-related damages. Other simplifying assumptions were made and there were limitations due to lack of data. For example, no data on historical flood damage to oil refineries was available to the researchers. In addition, the study assumes that the barrier island retains its elevation and volume as sea level rises, though under high rates of sea-level rise, the relative condition of the barrier island would be expected to weaken, posing additional risk for erosion of the island and for flooding in the bay, both of which would increase economic damages. For large storm surges, structural damage on the barrier islands might be as much as $1.3 billion, if all homes on the island were completely destroyed.

Further, the appraised property values used in the study are lower than the values of properties listed for sale. Damage estimates using the listed values of homes would be more than 30% higher. Actual property damages for future scenarios will also likely be higher than projected in this study in response to the current trends of increased population and infrastructure construction along the coast. Other factors not considered in this analysis include future population growth, the possible acceleration in property values, and adaptation measures that might be taken by property owners to reduce losses.

While the results presented here offer an indication of the expected increase in damages as a result of global warming, the estimates are most likely low. Furthermore, the broader impact of hurricane damage to the local and national economy was not considered. Because Corpus Christi is a tourist area, local tourism revenue and other business-related revenue will likely be slower to recover following storms of higher intensity. There is also an increasing risk to the national economy, mainly because of Corpus Christi's role in the petroleum industry. Finally, potential community adaptation to accelerating flood levels was not included in this analysis.

Forest Resources

"Impacts of Climate Change on Tennessee's Forest Ecosystems"

Predicting the effects of global warming on forests is inherently difficult given the complexity of these ecosystems and the wide variation in results produced by different climate models and input assumptions. The uncertainties are compounded when one attempts to extrapolate to estimates of economic and other impacts. Several factors were not accounted for in this analysis, including the effect of higher atmospheric carbon dioxide concentrations on tree growth, the possibility that global warming would continue into the next century (the analysis assumes that the climate stabilizes in 2080), the potential for climate change to intensify the risk of southern pine beetle infestations, and the possible impact of warming temperatures and lower moisture on the frequency and severity of forest fires. Ultimately, the future of Tennessee's forests will also be affected by a host of external forces – such as shifting land-use patterns, economic changes, and adaptations by the forestry industry – that will inevitably interact with the changes wrought by a warming climate.

"Impacts of Climate Change on Forests of the Northern Rocky Mountains"

Processes not yet included in the models, including disturbances such as fires, may initiate unforeseen feedbacks. Forests themselves have significant effects on the hydrologic cycle and atmospheric composition, but are barely considered in the current generation of models. Also omitted were changes in species composition, and changes in patterns of factors such as precipitation that may have potentially stronger effects on ecological systems than do changes in average conditions used in this study. Recently reported increases in drought-induced death of trees would also change the landscape and forest dynamics.

The omission that most affects this study is that of large-scale disturbances such as wildfires and insect outbreaks. These disturbances are already on the rise and are projected to increase further due to increases in the number of water-stress days and reductions in snowpack. Water stress levels and snowpack levels are the two main predictors of wildfire vulnerability and factors in insect outbreaks. Reduced winter precipitation and earlier spring snowmelt already contribute to the recent increase in large wildfire activity. The Northern Rockies forests are very sensitive to changes in the water balance. The impacts of disturbance in reducing carbon stocks and productivity have been demonstrated. The results of this study point toward increased fire and insect activity.

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