Exhibit C

Climate Change Impacts on the United States: Assessment Overview

CLIMATE CHANGE IMPACTS ON THE UNITED STATES

The Potential Consequences of Climate Variability and Change

Overview

Humanity's influence on the global climate will grow in the coming century. Increasingly, there will be significant climate-related changes that will affect each one of us.

We must begin now to consider our responses, as the actions taken today will affect the quality of life for us and future generations.

A Report of the National Assessment Synthesis Team

US Global Change Research Program

This report was produced by the National Assessment Synthesis Team, an advisory committee chartered under the Federal Advisory Committee Act to help the US Global Change Research Program fulfill its mandate under the Global Change Research Act of 1990. The National Science and Technology Council has forwarded this report to the President and Congress for their consideration as required by the Global Change Research Act.

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US Global Change Research Program, Washington DC, 2000

ABOUT THIS DOCUMENT

What is this Assessment?

The National Assessment of the Potential Consequences of Climate Variability and Change is a landmark in the major ongoing effort to understand what climate change means for the US. Climate science is developing rapidly and scientists are increasingly able to project some changes at the regional scale, identifying regional vulnerabilities, and assessing potential regional impacts. Science increasingly indicates that the Earth's climate has changed in the past and continues to change, and that even greater climate change is very likely in the 21st century. This Assessment has begun a national process of research, analysis, and dialogue about the coming changes in climate, their impacts, and what Americans can do to adapt to an uncertain and continuously changing climate. This Assessment is built on a solid foundation of science conducted as part of the United States Global Change Research Program (USGCRP).

What is this document and who is the NAST?

This document is the Assessment Overview, written by the National Assessment Synthesis Team (NAST). The NAST is a committee of experts drawn from governments, universities, industry, and non-governmental organizations. It has been responsible for broad oversight of the Assessment, with the Federal agencies of the USGCRP. This Overview is based on a longer, referenced "Foundation" report, written by the NAST in cooperation with independent regional and sector assessment teams. These two national-level, peer-reviewed documents synthesize results from studies conducted by regional and sector teams, and from the broader scientific literature.

Why was this Assessment undertaken?

The Assessment was called for by a 1990 law, and has been conducted under the USGCRP in response to a request from the President's Science Advisor. The NAST developed the Assessment's plan, which was then approved by the National Science and Technology Council, the cabinet-level body of agencies responsible for scientific research, including global change research, in the US government.

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This report is also based on the work of hundreds of individuals and organizations participating in regional and sector activities across the country without whose input,support, and expertise,it would not have been possible.In addition,many reviewers provided comments on drafts of the report.Additional credits and acknowledgements can be found in the appendix.

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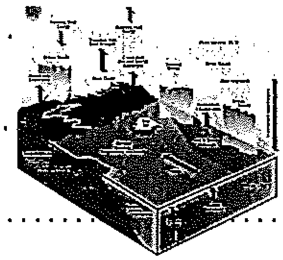

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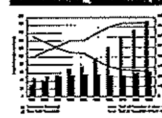

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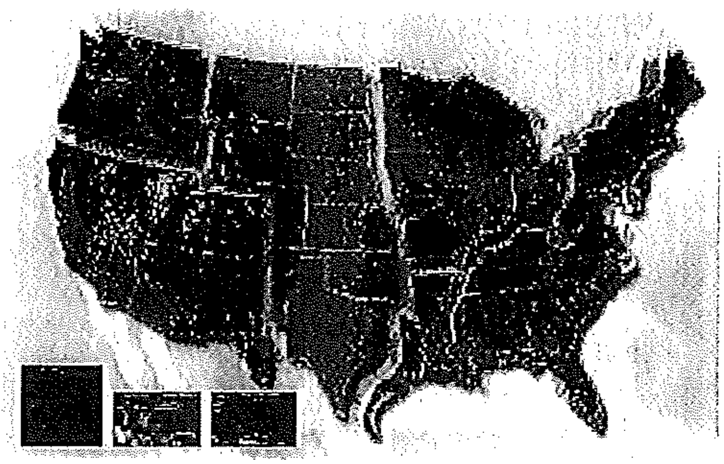

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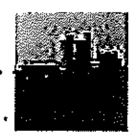

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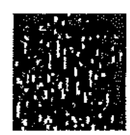

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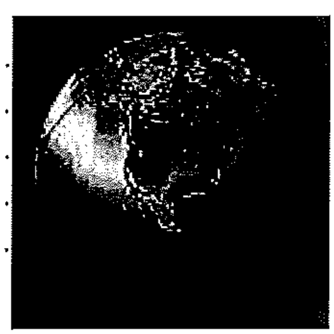

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ABOUT THE ASSESSMENT PROCESS

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The Assessment's purpose is to synthesize, evaluate, and report on what we presently know about the potential consequences of climate variability and change for the US in the 21st century. It has sought to identify key climatic vulnerabilities of particular regions and sectors, in the context of other changes in the nation's environment, resources, and economy. It has also sought to identify potential measures to adapt to climate variability and change. Finally, because present knowledge is limited, the Assessment has sought to identify the highest priority uncertainties about which we must know more to understand climate impacts, vulnerabilities, and our ability to adapt.

How did the process involve both stakeholders and scientists in this Assessment?

This first National Assessment involved both stakeholders and scientific experts. Stakeholders included, for example, public and private decision-makers, resource and environmental managers, and the general public. The stakeholders from different regions and sectors began the Assessment by articulating their concerns in a series of workshops about climate change impacts in the context of the other major issues they face. In the workshops and subsequent consultations, stakeholders identified priority regional and sector concerns, mobilized specialized expertise, identified potential adaptation options, and provided useful information for decision-makers. The Assessment also involved many scientific experts using advanced methods, models, and results. Further, it has stimulated new scientific research in many areas and identified priority needs for further research.

[illegible]

Although global change embraces many interrelated issues, this first National Assessment has examined only climate change and variability, with a primary focus on specific regions and sectors. In some cases, regional and sector analyses intersect and complement each other. For example, the Forest sector and the Pacific Northwest have both provided insights into climate impacts on Northwest forests.

The regions cover the nation. Impacts outside the US are considered only briefly, with particular emphasis on potential linkages to the US. Sector teams examined Water, Agriculture, Human Health, Forests, and Coastal Areas and Marine Resources. This first Assessment could not attempt to be comprehensive: the choice of these five sectors reflected an expectation that they were likely to be both important and particularly informative, and that relevant data and analytic tools were available – not a conclusion that they are the only important domains of climate impact. Among the sectors considered, there was a continuum in the amount of information available to support the Assessment, with some being at far earlier stages of development. Future assessments should consider other potentially important issues, such as Energy, Transportation, Urban Areas, and Wildlife.

Each regional and sector team is publishing a separate report of its own analyses, some of which are still continuing. The Overview and Foundation reports consequently represent a snapshot of our understanding at the present time.

[illegible]

Responses to climate change can be of two broad types. One type involves adaptation measures to reduce the harms and risks, and maximize the benefits and opportunities, of climate change, whatever its cause. The other type involves mitigation measures to reduce human contributions to climate change. After identifying potential impacts, this Assessment sought to identify potential adaptation measures for each region and sector studied. While this was an important first step, it was not possible at this stage to evaluate the practicality, effectiveness, or costs of the potential adaptation measures. Both mitigation and adaptation measures are necessary elements of a coherent and integrated response to climate change. Mitigation measures were not included in this Assessment, but are being assessed in other bodies such as the United Nations Intergovernmental Panel on Climate Change (IPCC).

[illegible]

No. An integrated climate policy will combine mitigation and adaptation measures as appropriate. If future world emissions of greenhouse gases are lower than currently projected, for whatever reason, including intentional mitigation, then the rate of climate change, the associated impacts, and the cost and difficulty of adapting will all be reduced. If emissions are higher than expected, then the rate of change, the impacts, and the difficulty of adapting will be increased. But no matter how aggressively emissions are reduced, the world will still experience at least a century of climate change. This will happen because the elevated concentrations of greenhouse gases already in the atmosphere will remain for many decades, and because the climate system responds to changes in human inputs only very slowly. Consequently, even if the world takes mitigation measures, we must still adapt to a changing climate. Similarly, even if we take adaptation measures, future emissions will have to be curbed to stabilize climate. Neither type of response can completely supplant the other.

How are computer models used in this Assessment?

State-of-the-science climate models have been used to generate climate change scenarios. Computer models of ecological systems, hydrological systems, and various socioeconomic systems have also been used in the Assessment, to study responses of these systems to the scenarios generated by climate models.

What additional tools, besides models, were used to evaluate potential climate change impacts?

In addition to models, the Assessment has used two other ways to think about potential future climate. First, the Assessment has used historical climate records to evaluate sensitivities of regions and sectors to climate variability and extremes that have occurred in the 20th century. Looking at real historical climate events, their impacts, and how people have adapted, gives valuable insights into potential future impacts that complement those provided by model projections. In addition, the Assessment has used sensitivity analyses, which ask how, and how much, the climate would have to change to bring major impacts on particular regions or sectors. For example, how much would temperature have to increase in the South before agricultural crops such as soybeans would be negatively affected? What would be the result for forest productivity of continued increases in temperature and leveling off of the CO_2 fertilization effect?

[illegible]

This Overview and the underlying Foundation document have been extensively reviewed. More than 300 scientific and technical experts have provided detailed comments on part or all of the report in two separate technical reviews. The report was reviewed at each stage for technical accuracy by the agencies of the US Global Change Research Program. The public also provided hundreds of helpful suggestions for clarification and modification during a 60-day public comment period. A panel of distinguished experts convened by the President's Committee of Advisors on Science and Technology has provided broad oversight, and monitored the authors response to all reviews.

ABOUT SCENARIOS AND UNCERTAINTY

[illegible] and why are they used?

Scenarios are plausible alternative futures – each an example of what might happen under particular assumptions. Scenarios are not specific predictions or forecasts. Rather, scenarios provide a starting point for examining questions about an uncertain future and can help us visualize alternative futures in concrete and human terms. The military and industry frequently use these powerful tools for future planning in high-stakes situations. Using scenarios helps to identify vulnerabilities and plan for contingencies.

Why are climate scenarios used in this Assessment and how were they developed?

Because we cannot predict many aspects of our nation's future climate, we have used scenarios to help explore US vulnerability to climate change. Results from state-of-the-science climate models and data from historical observations have been used to generate a variety of such scenarios. Projections of changes in climate from the Hadley Centre in the United Kingdom and the Canadian Centre for Climate Modeling and Analysis served as the primary resources for this Assessment. Results were also drawn from models developed at the National Center for Atmospheric Research, NOAA's Geophysical Fluid Dynamics Laboratory, and NASA's Goddard Institute for Space Studies.

For some aspects of climate, virtually all models, as well as other lines of evidence, agree on the types of changes to be expected. For example, all climate models suggest that the climate is going to get warmer, the heat index is going to rise, and precipitation is more likely to come in heavy and extreme events. This consistency lends confidence to these results.

For some other aspects of climate, however, the model results differ. For example, some models, including the Canadian model, project more extensive and frequent drought in the US, while others, including the Hadley model, do not. The Canadian model suggests a drier Southeast in the 21st century while the Hadley model suggests a wetter one. In such cases, the scenarios provide two plausible but different alternatives. Such differences can help identify areas in which the models need improvement.

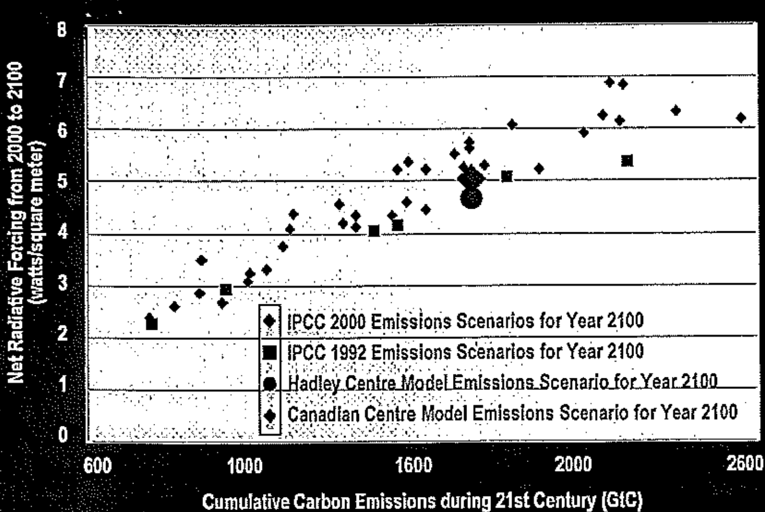
Many of the maps in this document are derived from the two primary climate model scenarios. In most cases, there are three maps: one shows average conditions based on actual observations from 1961-1990; the other two are generated by the Hadley and Canadian model scenarios and reflect the model's projection of change from those average conditions.

Many of the maps in this document are derived from the two primary climate model scenarios. In most cases, there are three maps: one shows average conditions based on actual observations from 1961-1990; the other two are generated by the Hadley and Canadian model scenarios and reflect the model's projection of change from those average conditions.

What assumptions about emissions are in these two climate scenarios?

Because future trends in fossil fuel use and other human activities are uncertain, the Intergovernmental Panel on Climate Change (IPCC) has developed a set of scenarios for how the 21st century may evolve. These scenarios consider a wide range of possibilities for changes in population, economic growth, technological development, improvements in energy efficiency, and the like. The two primary climate scenarios used in this Assessment are based on one mid-range emissions scenario for the future that assumes no major changes in policies to limit greenhouse gas emissions. Some other important assumptions in this scenario are that by the year 2100:

- world population will nearly double to about 11 billion people;
- the global economy will continue to grow at about the average rate it has been growing, reaching more than ten times its present size;
- increased use of fossil fuels will triple CO_2 emissions and raise sulfur dioxide emissions, resulting in an atmospheric CO_2 concentration of just over 700 parts per million; and
- total energy produced each year from non-fossil sources such as wind, solar, biomass, hydroelectric, and nuclear will increase to more than ten times its current amount, providing more than 40% of the world's energy, rather than the current 10%.



The graph shows a comparison of the projections of total carbon dioxide emissions (in billions of metric tons of carbon, GtC) and the human-induced warming influence due to all the greenhouse gases and sulfate aerosols for the emissions scenarios prepared by the IPCC in 1992 and 2000. As is apparent from the graph, both the emissions scenario and the human-induced warming influence assumed in this Assessment lie near the mid-range of the set of IPCC scenarios. Further detail can be found in the Climate chapter in the Foundation report.

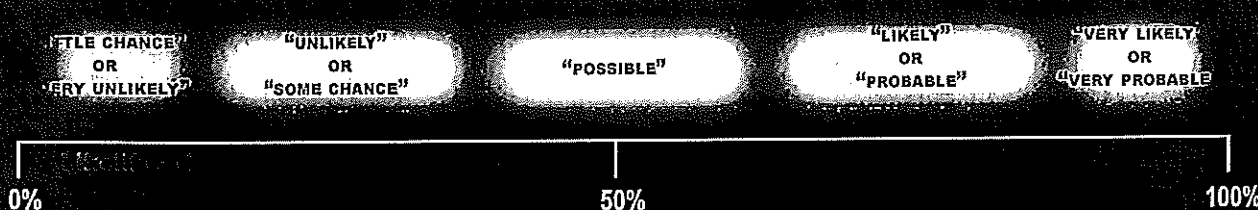
Both the emissions scenario and the human-induced warming influence assumed in this Assessment lie near the mid-range of the set of IPCC scenarios.

How is the likelihood of various impacts expressed?

To integrate a wide variety of information and differentiate more likely from less likely outcomes, the NAST developed a common language to express the team's considered judgement about the likelihood of results. The NAST developed its collective judgements through discussion and consideration of the supporting information. Historical data, model projections, published scientific literature, and other available information all provided input to these deliberations, except where specifically stated that the result comes from a particular model scenario. In developing these judgements, there were often several lines of supporting evidence (e.g., drawn from observed trends, analytic studies, model simulations). Many of these judgements were based on broad scientific consensus as stated by well-recognized authorities including the IPCC and the National Research Council. In many cases, groups outside the NAST reviewed the use of terms to provide input from a broader set of experts in a particular field.

Language Used to Express Considered Judgement

Common Language



SUMMARY

CLIMATE CHANGE AND OUR NATION

The findings in this report are based on a synthesis of historical data, model projections, published scientific research, and other available information, except where specifically noted.

Long-term observations confirm that our climate is now changing at a rapid rate. Over the 20th century, the average annual US temperature has risen by almost 1°F (0.6°C) and precipitation has increased nationally by 5 to 10%,mostly due to increases in heavy downpours. These trends are most apparent over the past few decades. The science indicates that the warming in the 21st century will be significantly larger than in the 20th century. Scenarios examined in this Assessment, which assume no major interventions to reduce continued growth of world greenhouse gas emissions,indicate that temperatures in the US will rise by about 5-9°F (3-5°C) on average in the next 100 years,which is more than the projected *global* increase. This rise is very likely to be associated with more extreme precipitation and faster evaporation of water, leading to greater frequency of both very wet and very dry conditions.

This Assessment reveals a number of national-level impacts of climate variability and change including impacts to natural ecosystems and water resources. Natural ecosystems appear to be the most vulnerable to the harmful effects of climate change,as there is often little that can be done to help them adapt to the projected speed and amount of change. Some ecosystems that are already constrained by climate,such as alpine meadows in the Rocky Mountains,are likely to face extreme stress,and disappear entirely in some places. It is likely that other more widespread ecosystems will also be vulnerable to climate change. One of the climate scenarios used in this Assessment suggests the potential for the forests of the Southeast to break up into a mosaic of forests,savannas, and grasslands. Climate scenarios suggest likely changes in the species composition of the Northeast forests,including the loss of sugar maples. Major alterations to natural ecosystems due to climate change could possibly have negative consequences for our economy, which depends in part on the sustained bounty of our nation's lands, waters,and native plant and animal communities.

A unique contribution of this first US Assessment is that it combines national-scale analysis with an examination of the potential impacts of climate change on different regions of the US. For example,sea-level rise will very likely cause further loss of coastal wetlands (ecosystems that provide vital nurseries and habitats for many fish species) and put coastal communities at greater risk of storm surges,especially in the Southeast. Reduction in snowpack will very likely alter the timing and amount of water supplies,potentially exacerbating water shortages and conflicts,particularly throughout the western US. The melting of glaciers in the high-elevation West and in Alaska represents the loss or diminishment of unique national treasures of the American landscape. Large increases in the heat index (which combines temperature and humidity) and increases in the frequency of heat waves are very likely. These changes will,at minimum,increase discomfort,particularly in cities. It is very probable that continued thawing of permafrost and melting of sea ice in Alaska will further damage forests,buildings, roads,and coastlines,and harm subsistence livelihoods. In various parts of the nation,cold-weather recreation such as skiing will very likely be reduced,and air conditioning usage will very likely increase.

Highly managed ecosystems appear more robust, and some potential benefits have been identified. Crop and forest productivity is likely to increase in some areas for the next few decades due to increased carbon dioxide in the atmosphere and an extended growing season. It is possible that some US food exports could increase,depending on impacts in other food-growing regions around the world. It is also possible that a rise in crop production in fertile areas could cause prices to fall,benefiting consumers. Other benefits that are possible include extended seasons for construction and warm weather recreation, reduced heating requirements,and reduced cold-weather mortality.

Climate variability and change will interact with other environmental stresses and socioeconomic changes. Air and water pollution,habitat fragmentation, wetland loss,coastal erosion,and reductions in fisheries are likely to be compounded by climate-related stresses. An aging populace nationally, and rapidly growing populations in cities,coastal areas,and across the South and West are social factors that interact with and alter sensitivity to climate variability and change.

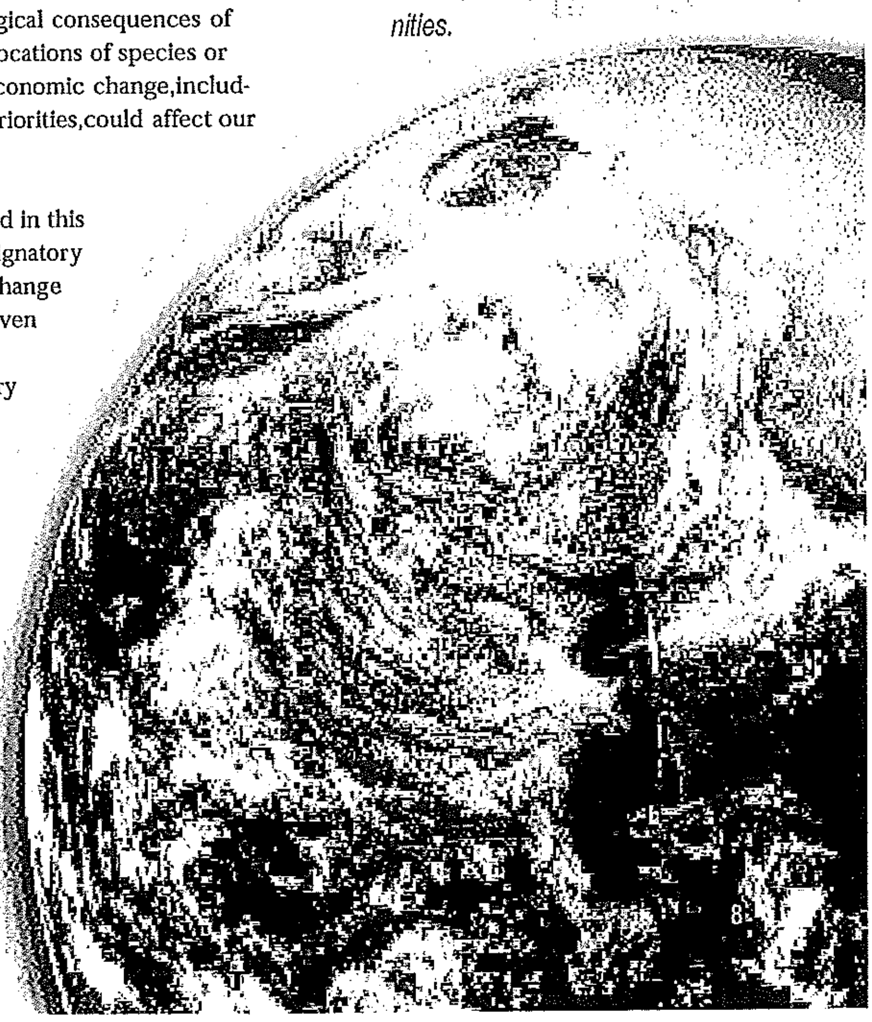
There are also very likely to be unanticipated impacts of climate change during the next century. Such "surprises" may stem from unforeseen changes in the physical climate system,such as major alterations in ocean circulation, cloud distribution,or storms;and unpredicted biological consequences of these physical climate changes,such as massive dislocations of species or pest outbreaks. In addition,unexpected social or economic change,including major shifts in wealth,technology, or political priorities,could affect our ability to respond to climate change.

Greenhouse gas emissions lower than those assumed in this Assessment would result in reduced impacts. The signatory nations of the Framework Convention on Climate Change are negotiating the path they will ultimately take. Even with such reductions,however, the planet and the nation are certain to experience more than a century of climate change,due to the long lifetimes of greenhouse gases already in the atmosphere and the momentum of the climate system. Adapting to a changed climate is consequently a necessary component of our response strategy.

The warming in the 21st century will be significantly larger than in the 20th century.

Natural ecosystems, which are our life support system in many important ways, appear to be the most vulnerable to the harmful effects of climate change...

Major alterations to natural ecosystems due to climate change could possibly have negative consequences for our economy, which depends in part on the sustained bounty of our nation's lands, waters, and native plant and animal communities.



SUMMARY

The magnitude of climate change impacts depends on time period and geographic scale. Short-term impacts differ from long-term impacts, and regional and local level impacts are much more pronounced than those at the national level.

For the nation as a whole, direct economic impacts are likely to be modest, while in some places, economic losses or gains are likely to be large. For example, while crop yields are likely to increase at the national scale over the next few decades, large increases or decreases in yields of specific crops in particular places are likely.

Through time, climate change will possibly affect the same resource in opposite ways. For example, forest productivity is likely to increase in the short term, while over the longer term, changes in processes such as fire, insects, drought, and disease will possibly decrease forest productivity.

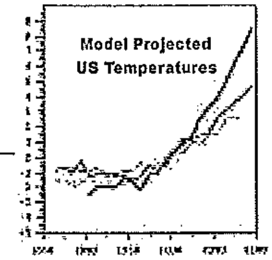
CLIMATE CHANGE AND OUR NATION

Adaptation measures can,in many cases, reduce the magnitude of harmful impacts,or take advantage of beneficial impacts. For example,in agriculture, many farmers will probably be able to alter cropping and management practices. Roads,bridges,buildings,and other long-lived infrastructure can be designed taking projected climate change into account. Adaptations,however, can involve trade-offs, and do involve costs. For example,the benefits of building sea walls to prevent sea-level rise from disrupting human coastal communities will need to be weighed against the economic and ecological costs of seawall construction. The ecological costs could be high as seawalls prevent the inland shifting of coastal wetlands in response to sea-level rise, resulting in the loss of vital fish and bird habitat and other wetland functions,such as protecting shorelines from damage due to storm surges. Protecting against any increased risk of water-borne and insect-borne diseases will require diligent maintenance of our public health system. Many adaptations, notably those that seek to reduce other environmental stresses such as pollution and habitat fragmentation,will have beneficial effects beyond those related to climate change.

Vulnerability in the US is linked to the fates of other nations,and we cannot evaluate national consequences due to climate variability and change without also considering the consequences of changes elswhere in the world. The US is linked to other nations in many ways,and both our vulnerabilities and our potential responses will likely depend in part on impacts and responses in other nations. For example,conflicts or mass migrations resulting from resource limits,health,and environmental stresses in more vulnerable nations could possibly pose challenges for global security and US policy. Effects of climate variability and change on US agriculture will depend critically on changes in agricultural productivity elsewhere,which can shift international patterns of food supply and demand. Climate-induced changes in water resources available for power generation,transportation,cities,and agriculture are likely to raise potentially delicate diplomatic issues with both Canada and Mexico.

This Assessment has identified many remaining uncertainties that limit our ability to fully understand the spectrum of potential consequences of climate change for our nation. To address these uncertainties,additional research is needed to improve understanding of ecological and social processes that are sensitive to climate,application of climate scenarios and reconstructions of past climates to impacts studies, and assessment strategies and methods. Results from these research efforts will inform future assessments that will continue the process of building our understanding of humanity's impacts on climate,and climate's impacts on us.

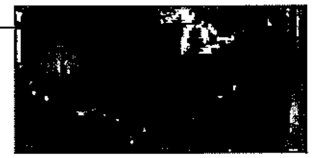
KEY FINDINGS



1. Increased warming

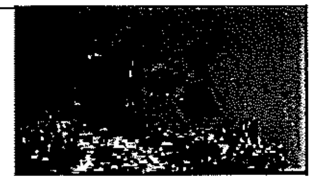
Assuming continued growth in world greenhouse gas emissions, the primary climate models used in this Assessment project that temperatures in the US will rise 5-9°F (3-5°C) on average in the next 100 years. A wider range of outcomes is possible.

2. Differing regional impacts



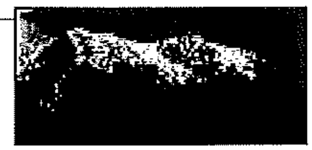
Climate change will vary widely across the US. Temperature increases will vary somewhat from one region to the next. Heavy and extreme precipitation events are likely to become more frequent, yet some regions will get drier. The potential impacts of climate change will also vary widely across the nation.

3. Vulnerable ecosystems



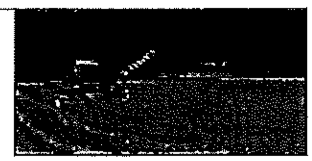
Many ecosystems are highly vulnerable to the projected rate and magnitude of climate change. A few, such as alpine meadows in the Rocky Mountains and some barrier islands, are likely to disappear entirely in some areas. Others, such as forests of the Southeast, are likely to experience major species shifts or break up into a mosaic of grasslands, woodlands, and forests. The goods and services lost through the disappearance or fragmentation of certain ecosystems are likely to be costly or impossible to replace.

4. Widespread water concerns



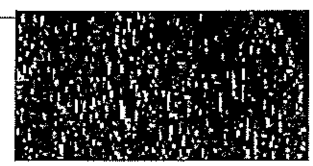
Water is an issue in every region, but the nature of the vulnerabilities varies. Drought is an important concern in every region. Floods and water quality are concerns in many regions. Snowpack changes are especially important in the West, Pacific Northwest, and Alaska.

5. Secure food supply



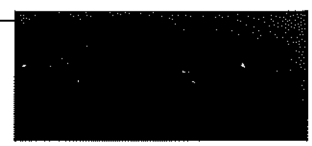
At the national level, the agriculture sector is likely to be able to adapt to climate change. Overall, US crop productivity is very likely to increase over the next few decades, but the gains will not be uniform across the nation. Falling prices and competitive pressures are very likely to stress some farmers, while benefiting consumers.

6. Near-term increase in forest growth



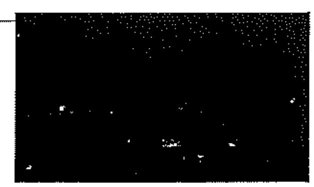
Forest productivity is likely to increase over the next several decades in some areas as trees respond to higher carbon dioxide levels. Over the longer term, changes in larger-scale processes such as fire, insects, droughts, and disease will possibly decrease forest productivity. In addition, climate change is likely to cause long-term shifts in forest species, such as sugar maples moving north out of the US.

7. Increased damage in coastal and permafrost areas



Climate change and the resulting rise in sea level are likely to exacerbate threats to buildings, roads, powerlines, and other infrastructure in climatically sensitive places. For example, infrastructure damage is related to permafrost melting in Alaska, and to sea-level rise and storm surge in low-lying coastal areas.

8. Adaptation determines health outcomes



A range of negative health impacts is possible from climate change, but adaptation is likely to help protect much of the US population. Maintaining our nation's public health and community infrastructure, from water treatment systems to emergency shelters, will be important for minimizing the impacts of waterborne diseases, heat stress, air pollution, extreme weather events, and diseases transmitted by insects, ticks, and rodents.

9. Other stresses magnified by climate change

Climate change will very likely magnify the cumulative impacts of other stresses, such as air and water pollution and habitat destruction due to human development patterns. For some systems, such as coral reefs, the combined effects of climate change and other stresses are very likely to exceed a critical threshold, bringing large, possibly irreversible impacts.

10. Uncertainties remain and surprises are expected

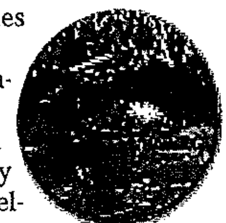
Significant uncertainties remain in the science underlying regional climate changes and their impacts. Further research would improve understanding and our ability to project societal and ecosystem impacts, and provide the public with additional useful information about options for adaptation. However, it is likely that some aspects and impacts of climate change will be totally unanticipated as complex systems respond to ongoing climate change in unforeseeable ways.

IMPACTS OF CLIMATE CHANGE

It is very likely that the US will get substantially warmer. Temperatures are projected to rise more rapidly in the next one hundred years than in the last 10,000 years. It is also very likely that there will be more precipitation overall, with more of it coming in heavy downpours. In spite of this, some areas are likely to get drier as increased evaporation due to higher temperatures outpaces increased precipitation. Droughts and flash floods are likely to become more frequent and intense.

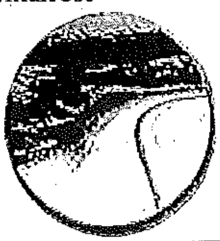
SPECIES DIVERSITY

While it is possible that some species will adapt to changes in climate by shifting their ranges, human and geographic barriers, and the presence of invasive non-native species will limit the degree of adaptation that can occur. Losses in local biodiversity are likely to accelerate towards the end of the 21st century.



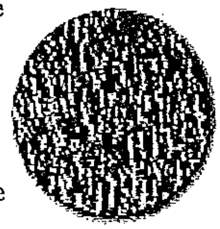
PERMAFROST AREAS

It is very probable that rising temperatures will cause further permafrost thawing, damaging roads, buildings, and forests in Alaska.

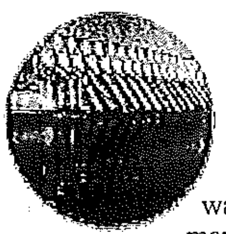


FORESTRY

Timber inventories are likely to increase over the 21st century. Hardwood productivity is likely to increase more than softwood productivity in some regions, including the Southeast.



WATER SUPPLY



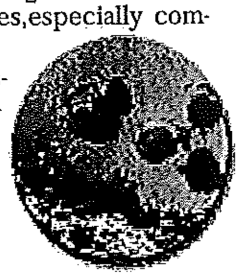
Reduced summer runoff, increased winter runoff, and increased demands are likely to compound current stresses on water supplies and flood management,especially in the western US.

ISLANDS

Sea-level rise and storm surges will very likely threaten public health and safety and possibly reduce the availability of fresh water.

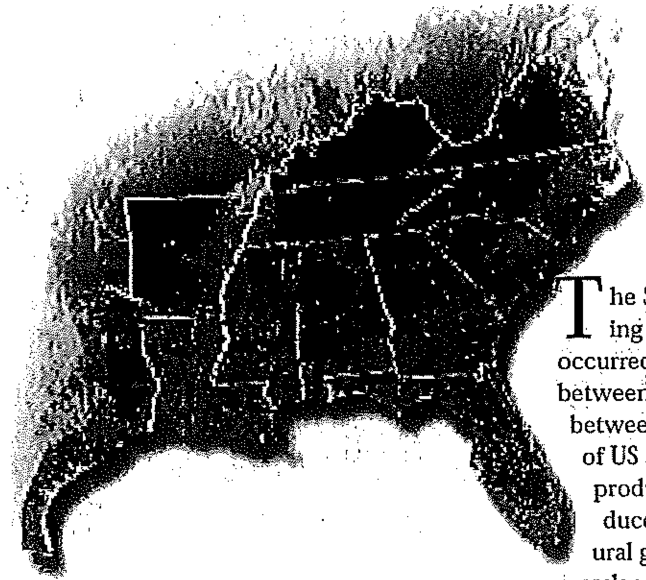
CORAL REEFS

Increased CO_2 and ocean temperatures,especially combined with other stresses,will possibly exacerbate coral reef bleaching and die-off.



FRESHWATER ECOSYSTEMS

Increases in water temperature and changes in seasonal patterns of runoff will very likely disturb fish habitat and affect recreational uses of lakes,streams, and wetlands.



SOUTHEAST

The Southeast "sunbelt" is a rapidly growing region with population increasing by more than 30% between 1970 and 1990. Much of this growth occurred in coastal counties,which are projected to grow another 40% between 2000 and 2025. The number of farms in the region decreased 80% between 1930 and 1997,but the Southeast still produces roughly one quarter of US agricultural crops. The Southeast has become America's "woodbasket," producing about half of America's timber supplies. The region also produces a large portion of the nation's fish,poultry, tobacco,oil,coal,and natural gas. Prior to European settlement,the landscape was primarily forests, grasslands,and wetlands,but most of the native forests were converted to managed forests and agricultural lands by 1920. Roughly half of the remaining wetlands in the lower 48 states are located in the Southeast,and more than three-quarters of the Nation's annual wetland losses over the past 50 years occurred in this region. Although much of the landscape has been altered,a wide range of ecosystem types exists and overall species diversity is high.

KEY ISSUES

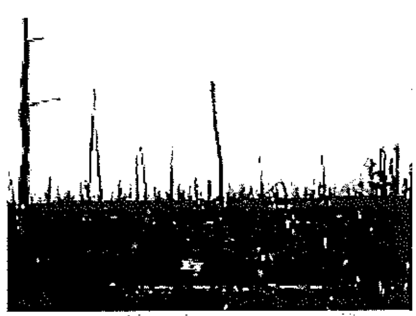
- Weather-related Stresses on Human Populations
- Agricultural Crop Yields and Economic Impacts
- Forest Productivity Shifts
- Water Quality Stresses
- Threats to Coastal Areas

Observed Climate Trends

Temperature trends in the Southeast vary between decades,with a warm period during the 1920s-1940s followed by a cooling trend through the 1960s. Since the 1970s,temperatures have been increasing,with the 1990's temperatures as warm as the peaks in the 1920s and 30s. Annual rainfall trends show very strong increases of 20-30% or more over the past 100 years across Mississippi,Arkansas,South Carolina,Tennessee,Alabama,and parts of Louisiana, with mixed changes across most of the remaining area. There has been a strong tendency for more wet spells in the Gulf Coast states,and a moderate tendency in most other areas. The percentage of the Southeast landscape experiencing severe wetness increased approximately 10% between 1910 and 1997. There are strong El Niño and La Niña effects in the Southeast that can result in dramatic seasonal and year-to-year variations in temperature and precipitation. El Niño events also tend to create atmospheric conditions that inhibit Atlantic tropical storm development, resulting in fewer hurricanes. La Niña events have the opposite effect, resulting in more hurricanes.

Ghost Forests

Vast stands of coastal forest are dying along the Gulf of Mexico shoreline. Sea-level rise resulting in saltwater intrusion is the suspected cause, and the sun-bleached remnants of dead stems have given rise to the common term "ghost forest" in parts of

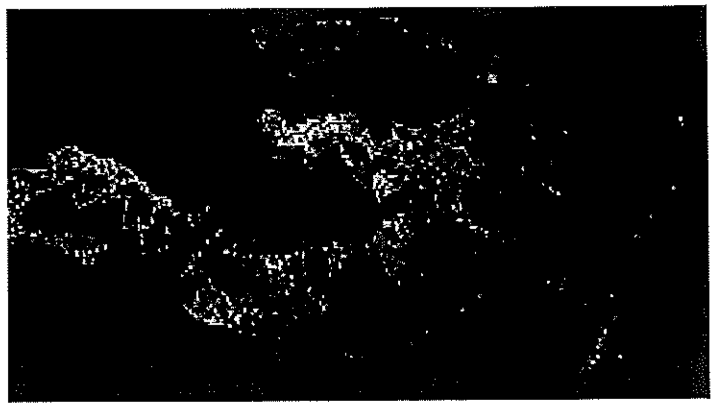


South Florida and Louisiana. Over the past 30 years, hundreds of acres of southern baldcypress trees have died in Louisiana coastal parishes, with losses most acute in areas where subsidence and navigation channels have accelerated the rate of salt-water encroachment due to rising sea level. Baldcypress and live oak mortality have occurred as far as 30 miles inland. In

Scenarios of Future Climate

Climate model projections exhibit a wide range of plausible scenarios for both temperature and precipitation over the next century. Both of the principal climate models used in the National Assessment project warming in the Southeast by the 2090s,but at different rates. The Canadian model scenario shows the Southeast experiencing a high degree of warming, which translates into lower soil moisture as higher temperatures increase evaporation. The Hadley model scenario simulates less warming and a significant increase in precipitation (about 20%). Some climate models suggest that rainfall associated with El Niño and the intensity of droughts during La Niña phases will be intensified as atmospheric CO_2 increases.

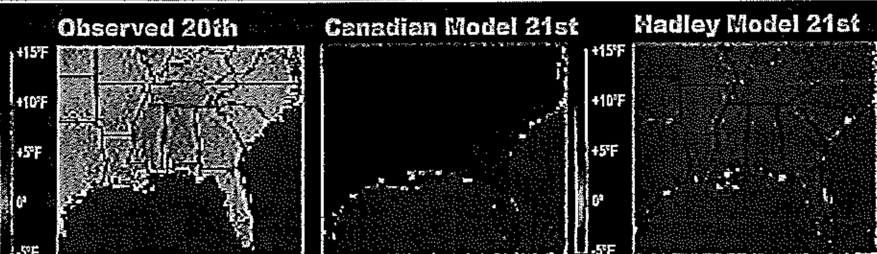
Louisiana's Coastal Land loss
Between 1956 and 1990 (Shown in Red)



Rising sea level is one of several factors that have caused the loss of about one million acres of Louisiana wetland since 1900. Natural and human-induced processes contributing to these losses include subsidence due to groundwater withdrawal and natural sediment compaction, wetland drainage, and levee construction. The white line designates the coastal zone and red designates land that has been converted to open water.

Temperature Change - 20th & 21st Centuries

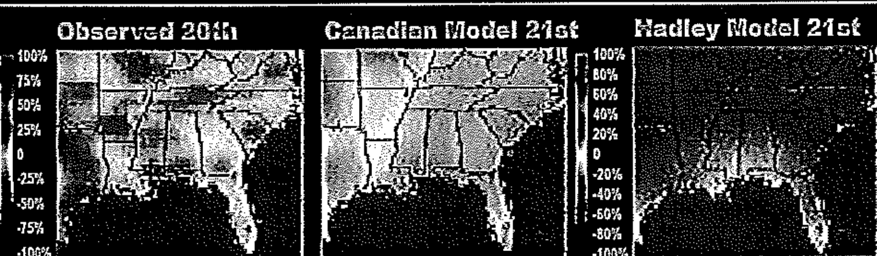
The largest warming during the last century has occurred along the coastal region (as much as 4°F), with some inland cooling.



Model scenarios project relatively uniform increases in annually averaged temperatures. However, the Canadian model projects increases that are twice as large as the Hadley model.

Precipitation Change - 20th & 21st Centuries

Observed precipitation changes during the last century are a patchwork of moderate increases and decreases.



The Canadian model scenario for the 21st century indicates near neutral trends or modest increases, while the Hadley model projects increases of near 25% for the region.

Florida, chronic saltwater contamination of forest soils occurs nearer the shoreline.

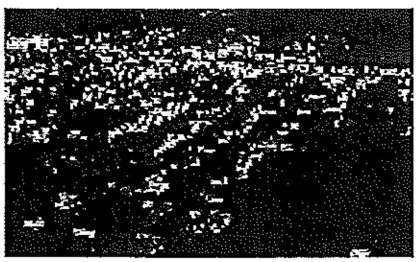
Since 1991 landowners and public land managers in Florida have observed massive die-offs of sabal palm along a 40-mile stretch of coast between Cedar Key and Homosassa Springs. Ed Barnard, a forest pathologist with Florida's Forestry Division, compares what he has seen with the aftermath of Hurricane Hugo in South Carolina, and he attributes the Florida problem to saltwater.

Analyses also attribute the forest decline to salt water intrusion associated with sea-level rise. Since 1852, when the first topographic charts of this region were prepared, high tidal flood elevations have increased approximately 12 inches. Coastal forest losses will be even more severe if sea-level rise accelerates as is expected as a result of global warming.

SOUTHEAST KEY ISSUES

Weather-related Stresses on Human Populations

The Southeast is prone to frequent natural weather disasters that affect human life and property. Over half of the nation's costliest weather-related disasters of the past 20 years have occurred in the Southeast,costing the region over $85 billion in damages,mostly associated with floods and hurricanes. Across the region,intense precipitation has increased over the past 100 years,and this trend is projected to continue.

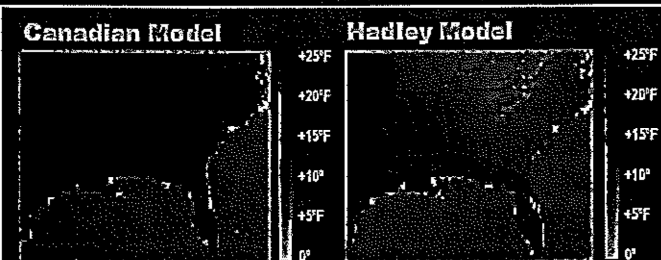


Flooded community along Bayou Lafourche in South Louisiana after landfall of Hurricane Juan in 1985.

The southern heat wave and drought of 1998 resulted in damages in excess of $6 billion and at least 200 deaths. Human health concerns arise from the projected increases in maximum temperatures and heat index in the region. These concerns are particularly great for lower income households that lack sufficient resources to improve insulation and install and operate air conditioning systems. Air quality degradation in urban areas is also a concern associated with elevated air temperatures and increased emissions from power generation, which can increase ground-level ozone. Increased flooding in low-lying coastal counties from the Carolinas to Texas is also likely to adversely impact human health; floods are the leading cause of death from natural disasters in the region and nationwide.

Adaptations: Traditional approaches such as flood levees,elevated structures,and building codes are no longer adequate by themselves,particularly in the coastal zone,as sea-level rise alone continues to increase the propensity for storm-surge flooding in virtually all southeastern coastal areas. Improvements in risk assessment,coastal and floodplain management,linking insurance to policies for mitigating flood damage, and local mitigation planning are strategies that are likely to decrease potential costs. Changes in climate and sea-level rise should be an integral consideration as coastal communities develop strategies for hazard preparedness and mitigation.

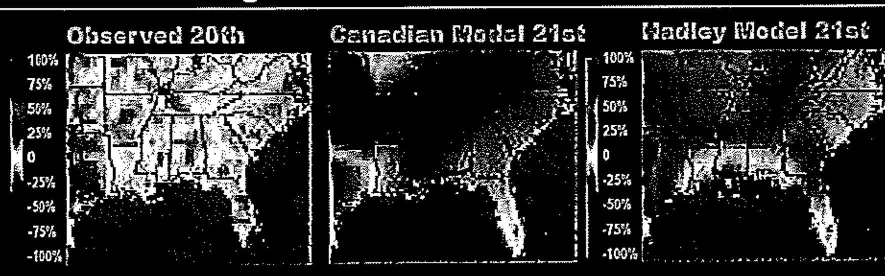
July Heat Index Change - 21st Century



The changes in the simulated heat index for the Southeast are the most dramatic in the nation with the Hadley model suggesting increases of 8 to 15°F for the southern-most states, while the Canadian model projects increases above 20°F for much of the region.

Summer Soil Moisture Change - 20th & 21st Centuries

The observed record of soil moisture illustrates mixed changes across the region.



The Hadley model projects soil moisture will increase substantially in most of the region. In contrast, the Canadian model, with larger projected warming and little change in rainfall, suggests large decreases in soil moisture.

Agricultural Crop Yields and Economic Impacts

Crop yield and economic impact estimates vary by climate scenario,area,and crop. The Hadley scenario simulates decreases in the yield of most dryland (non-irrigated) crops in the Gulf Coast area but increases elsewhere in the region through both the 2030s and 2090s. Average yields of irrigated soybean,wheat,and rice increase under the Hadley scenario by 10% in 2030 and by more than 20% in 2090. Under the hotter and drier Canadian climate scenario,dryland soybean yields decrease 10-30% in some key locations by 2030 and decrease by 80% by 2090. Economic impact simulations follow patterns similar to the yield maps below.

Of the major crop growing areas of the Southeast,the lower Mississippi Valley and Gulf Coast areas are likely to be more negatively affected,while the northern Atlantic Coastal Plain is likely to be more positively affected.

Adaptations:Expected impacts on agricultural productivity and profitability will very likely stimulate adjustments in management strategies. Producers can switch crops or vary planting dates,patterns of water usage,crop rotations,and the amounts,timing,and application methods for fertilizers and pesticides. Analyses indicate that farmers, except those in the southern Mississippi Delta and Gulf Coast areas,will likely be able to mitigate most of the negative effects and possibly benefit from changes in CO_2 and moisture that enhance crop growth. Improvements in understanding climate and forecasting weather would enhance the ability of agricultural resource managers to deal effectively with future changes. In addition,plant breeders could respond by developing new and improved varieties to accommodate the changed climate conditions.

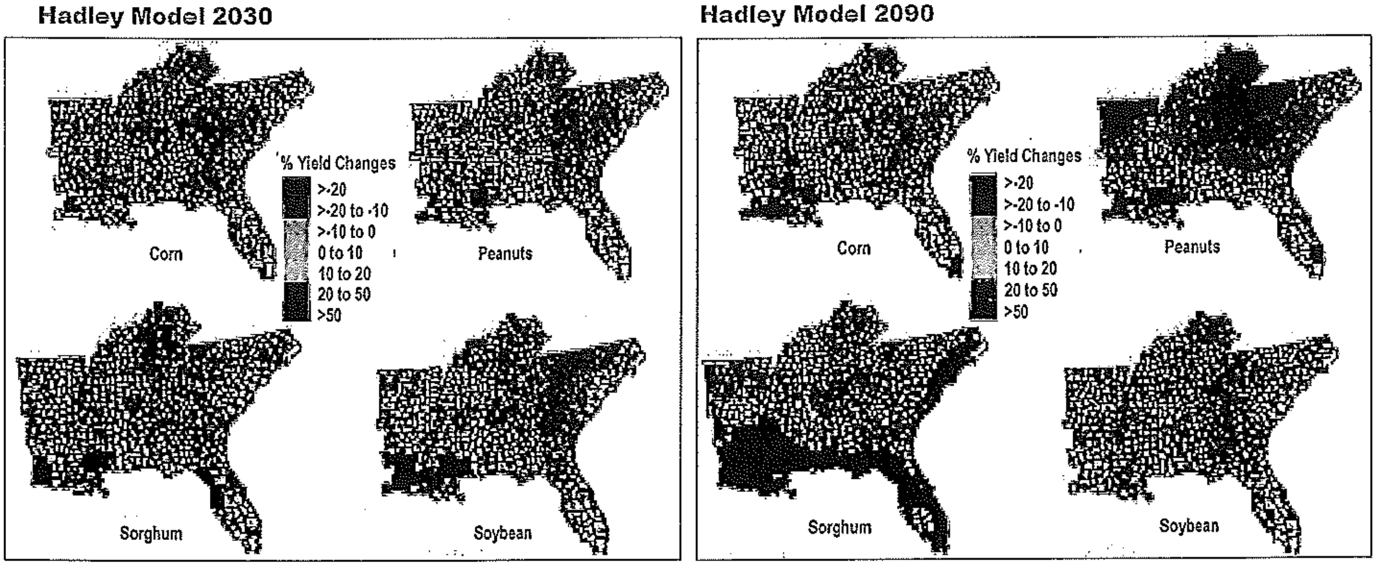
The southern heat wave and drought of 1998 resulted in damages in excess of $6 billion and at least 200 deaths.

Human health concerns arise from the projected increases in maximum temperatures and heat index in the region.

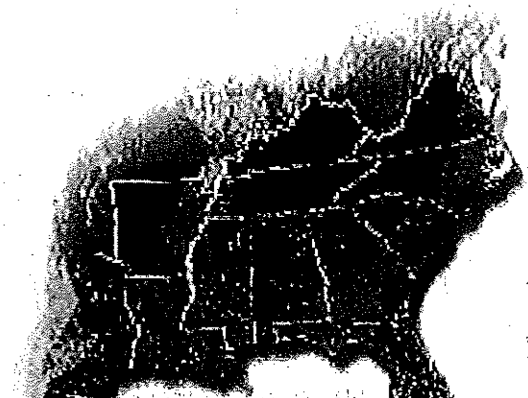
Improvements in risk assessment, coastal and floodplain management, linking insurance to policies for mitigating flood damage, and local mitigation planning are strategies that are likely to decrease potential costs.

Changes in Yields of Rainfed Crops
30 year Average

Hadley Model 2030 | **Hadley Model 2090**



Projected changes in 30-year average rainfed yields of four major crops in the Southeast by the years 2030 and 2090 using the Hadley model scenario.



SOUTHEAST KEY ISSUES

Forest Productivity Shifts

A forest process model (PnET-II) was used to evaluate the impact of the Hadley climate scenario and increasing atmospheric CO_2 on southeastern forest productivity. The model simulates an increase in the productivity of southern loblolly pine plantations of approximately 11% by 2040 and 8% by 2100;the productivity of hardwood and mixed pine hardwood forest (which represent 64% of the total forest area) would increase 22% by 2040 and 25% by 2100,compared to 1990. The model indicates that the greatest increases in productivity of both pines and hardwoods would occur in the northern half of the region.

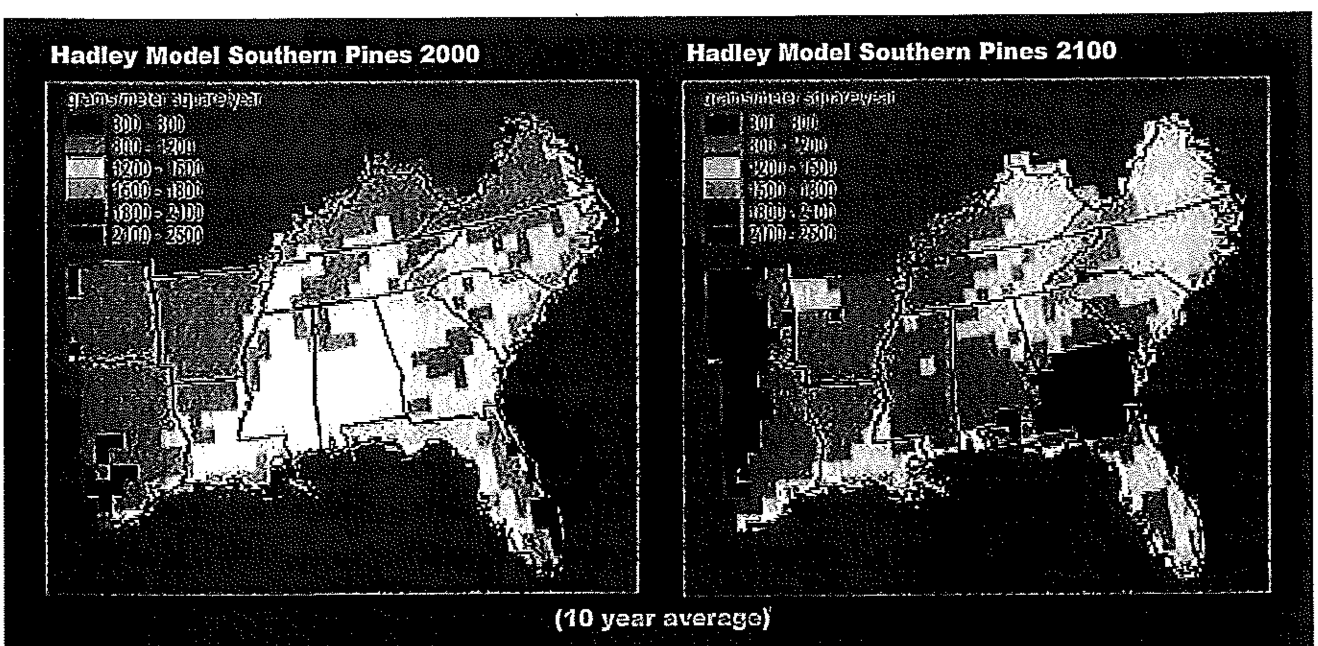
Other VEMAP ecosystem models used with the Hadley Scenario also project increases in productivity across southern forests by 2100. However, when these models are run with the Canadian climate scenario,they simulate decreases in productivity in parts of the Southeast. Furthermore,several models that are designed to project changes in vegetation distribution as a consequence of climate change simulate a breakup of the pine-dominated forests in parts of the Southeast by the end of the 21st century under the Canadian scenario. These simulations suggest that part of the forest will possibly be replaced by savannas and grasslands due to decreased soil moisture and fire (see Ecosystems).

Adaptations: As the northern parts of the region become relatively more productive as a result of climate change and the southern parts are more negatively affected,timber harvesting could be shifted northward. Other adaptation strategies include the use of more drought-hardy strains of pine and other silvicultural and genetic improvements that could increase water use efficiency or water availability. Improved knowledge of the role of hurricanes, droughts, fire,El Niño-related changes in seasonal weather patterns,and other natural disturbances will be important in developing forest management regimes and increases in productivity that are sustainable over the long term. Under a hotter, drier climate,an aggressive fire management strategy could prove to be very important in this region.

Water Quality Stresses

Surface water resources in the Southeast are intensively managed with dams and channels,and almost all are affected by human activities. In some streams and lakes, water quality is either below recommended levels or nearly so. Stresses on water quality are associated with intensive agricultural practices,urban development,coastal processes,and mining activities. The impacts of these stresses are likely to be exacerbated by climate change. For example,higher temperatures reduce dis-

Potential Southern Pines and Hardwoods Net Primary Productivity (NPP)

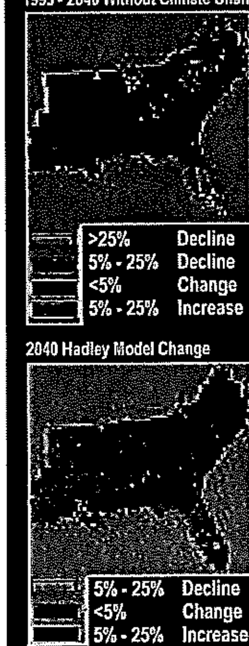


solved oxygen levels in water. The 1999 flooding of eastern North Carolina offers a graphic example of how water quality can also be affected by extreme precipitation events, the frequency of which are likely to continue to increase; flood waters fouled with sewage, rotting farm animal carcasses,fuel,and chemicals swamped water treatment plants and contaminated public water supplies.

Threats to Coastal Areas

Sea-level rise is one of the more certain consequences of climate change. It has already had significant impacts on coastal areas and these impacts are very likely to increase. Between 1985 and 1995,southeastern states lost more than 32,000 acres of coastal salt marsh due to a combination of human development activities,sea-level rise,natural subsidence,and erosion. About 35 square miles of coastal land were lost each year in Louisiana alone from 1978 to 1990. Flood and erosion damage stemming from sea-level rise coupled with storm surges are very likely to increase in coastal communities. Coastal ecosystems and the services they provide to human society are likely to be negatively affected. Projected impacts are likely to include the loss of barrier islands and wetlands that protect coastal communities and ecosystems from storm surges, reduced fisheries productivity as coastal marshes and submerged grass beds are displaced or eliminated,and saltwater intrusion into surface and ground water supplies. The extent of the ecological impacts of sea-level rise is largely dependent upon the rate of rise and the development that has occurred along the shoreline. Other threats to these ecosystems come from changes in rainfall in coastal watersheds which are likely to alter fresh water inflows into estuaries,altering salinity patterns that determine the type and distribution of coastal plant and animal communities. There are few practical options for protecting natural ecosystems as a whole from increasing temperature, changes in precipitation,or rapidly rising sea level. As noted for other coastal regions, one possibility is the acquisition of lands contiguous to coastal wetlands to allow for their inland migration as sea level rises.

Timberland Acreage Shifts



The change in forest productivity under the Hadley-based scenario is expected to cause slightly higher softwood timber prices and lower hardwood prices than would be the case without climate change. Harvests and inventory would also shift northward, reflecting the northward productivity shifts.

Simulations of Net Primary Productivity (the net amount of carbon fixed by green plants over the course of a year) of southern pines and hardwoods as projected by one ecological model, PnET, using the Hadley model scenario. By 2100, PnET projects that southern hardwoods will be much more productive than pines under the climate projected by the Hadley model.