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

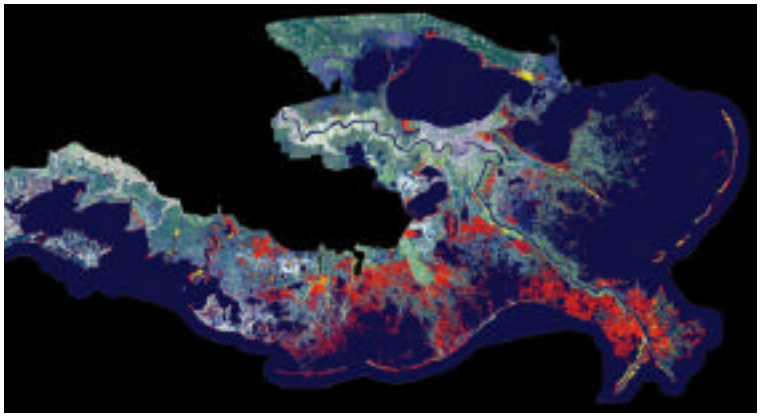
South Florida and Louisiana. Over the past 30 years, hundreds of acres of southern baldcypress trees have died in Louisiana coastal parishes, with losses most acute in areas where subsidence and navigation channels have accelerated the rate of saltwater encroachment due to rising sea level. Baldcypress 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

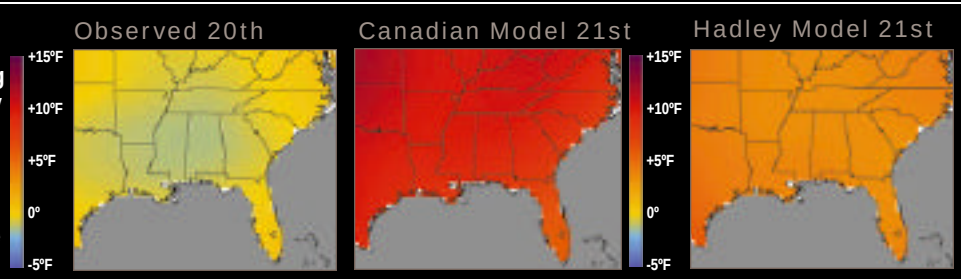
Between 1956 and 1990 (Shown in Red)



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

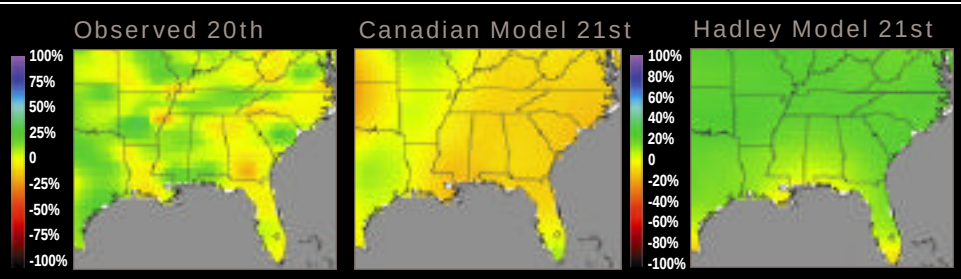
The largest warming during the last century has occurred along the coastal region (as much as 4ºF), with some inland cooling.



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

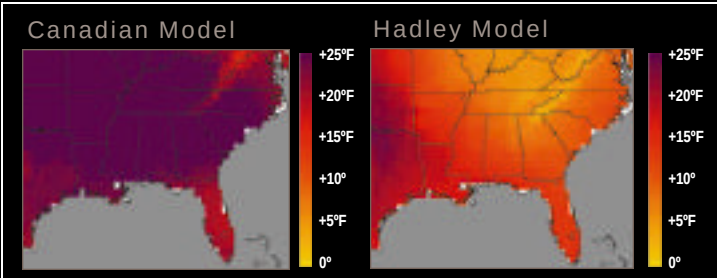
The Southeast is prone to frequent natural weather disasters that affect human life and property. Over half of the nation's costliest weather-related disasters of the past 20 years have occurred in the Southeast,costing the region over $85 billion in damages,mostly associated with floods and hurricanes.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

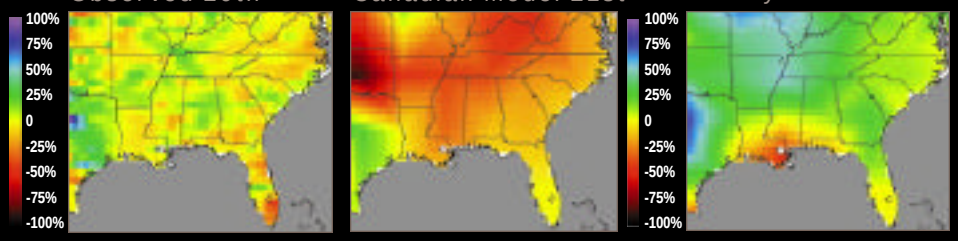
July Heat Index Change - 21st Century



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.

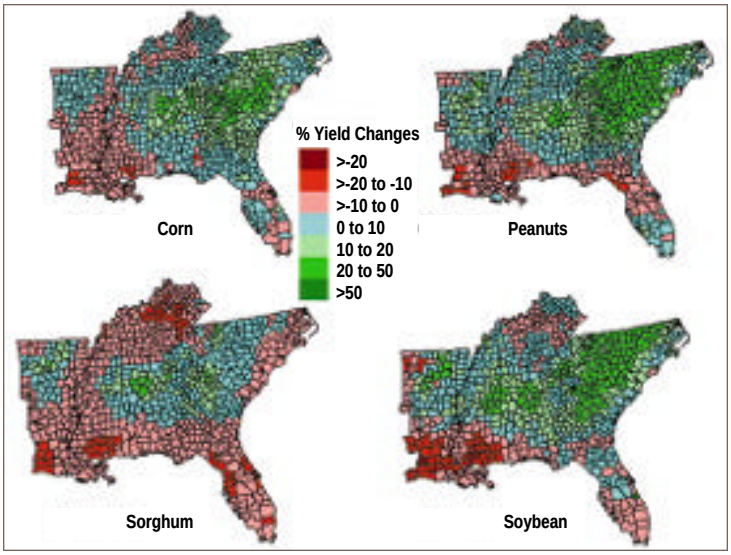
The southern heat wave and drought of 1998 resulted in damages in excess of $6 billion and at least 200 deaths.

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

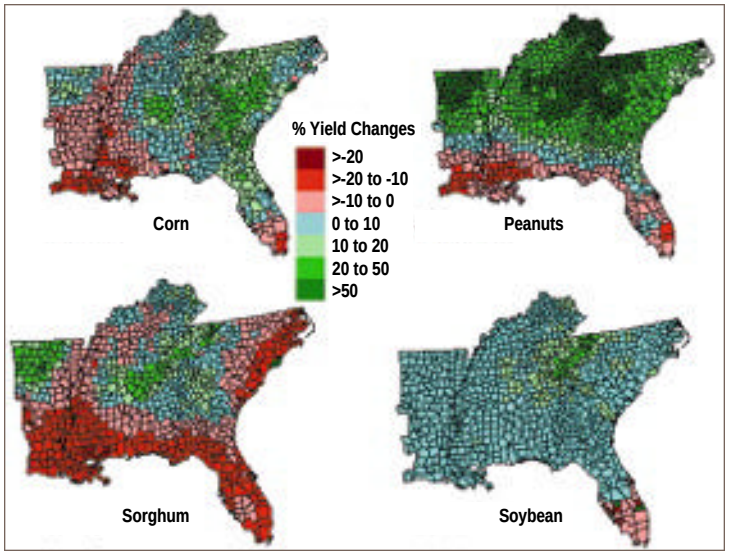
Improvements in risk assessment, coastal and floodplain management, linking insurance to policies for mitigating flood damage, and local mitigation planning are strategies that are likely to decrease potential costs.

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.

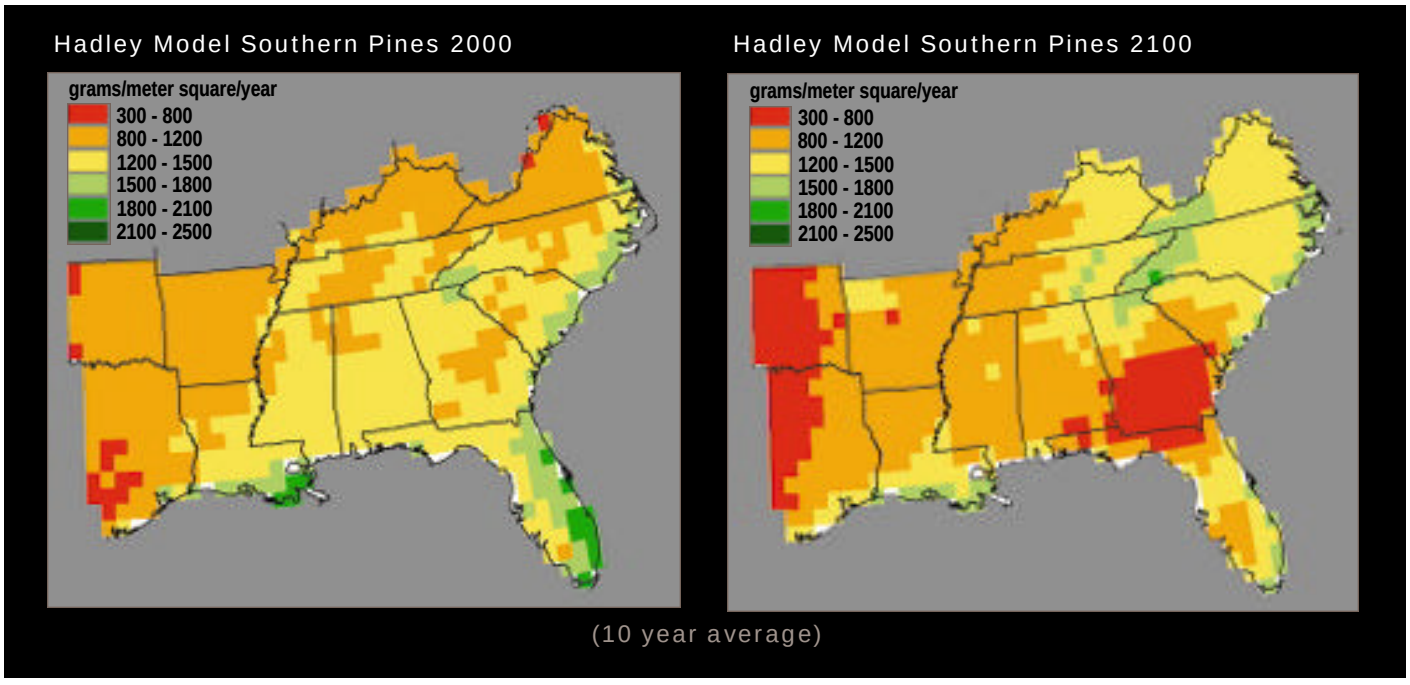
Other VEMAP ecosystem models used with the Hadley Scenario also project increases in productivity across southern forests by 2100. However, when these models are run with the Canadian climate scenario,they simulate decreases in productivity in parts of the Southeast. Furthermore,several models that are 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)

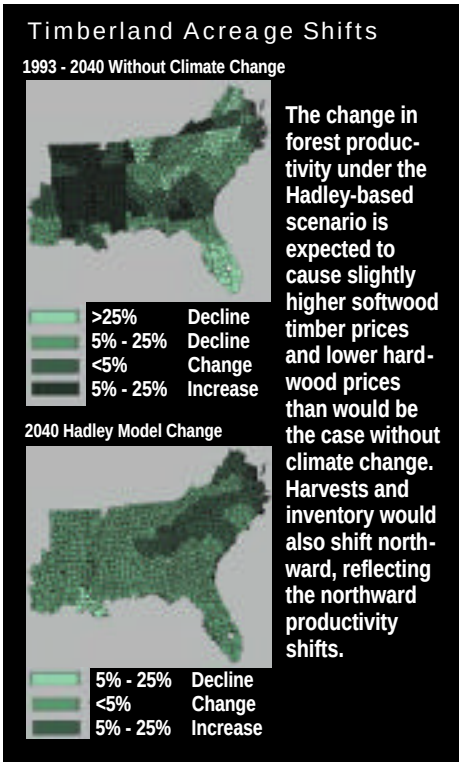


solved oxygen levels in water. The 1999 flooding of eastern North Carolina offers a graphic example of how water quality can also be affected by extreme precipitation events, the frequency of which are likely to continue to increase; flood waters fouled with sewage, rotting farm animal carcasses,fuel,and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



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.