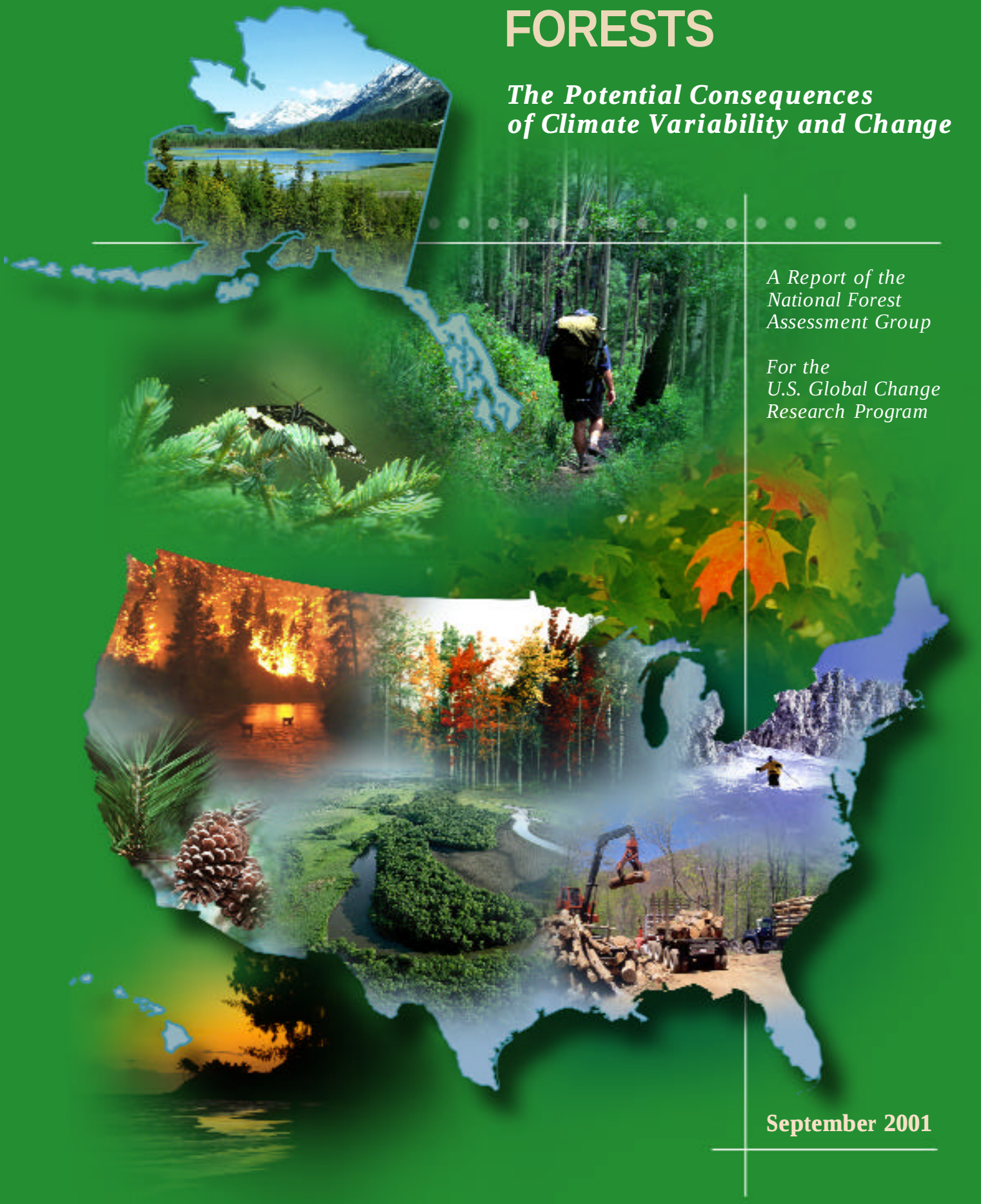
FORESTS

The Potential Consequences of Climate Variability and Change



A Report of the National Forest Assessment Group

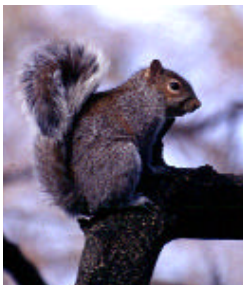
For the U.S. Global Change Research Program

September 2001

The Issues

Forests cover about one-third of the US, totaling almost 750 million acres, or an estimated 7% of the world's forestland area. There are many different types of forests, stretching from the subtropical forests along the Florida Coast to the boreal forests in Alaska, and from the deciduous forests of the eastern US to the conifer forests of the West. These diverse ecosystems provide habitat for wildlife; help to cleanse the air and water; supply timber, fuelwood, and other harvested products; and serve as places for hiking, camping, and fishing.

Forests have always been subjected to natural disturbances and, more recently, human-caused stresses. Across the US, forests are altered by harvesting, by fire management practices, and by conversion to agriculture or through expansion of urban areas, roads, and recreation. Now, climate change is starting to exert its influence, through changes in the environment. These climate changes are likely to influence plant growth, reproduction, and survival.



The key challenge is to determine how best to manage our forest resources as stresses resulting from climate change build.

A recent scientific assessment analyzed how future climate variability and change may affect forests in the United States. The assessment, sponsored by the USDA Forest Service, and supported, in part, by the US Department of Energy, and the National Atmospheric and Space Administration, describes the suite of potential impacts on forests. The study was conducted by a team of scientists from academia, industry, and government laboratories as part of the US National Assessment of the Potential Consequences of Climate Variability and Change.

This pamphlet summarizes the key findings of the Forest Sector team in four broad areas:

- Forest productivity and hydrology,
- Disturbances,
- Biodiversity, and
- Socioeconomic impacts.

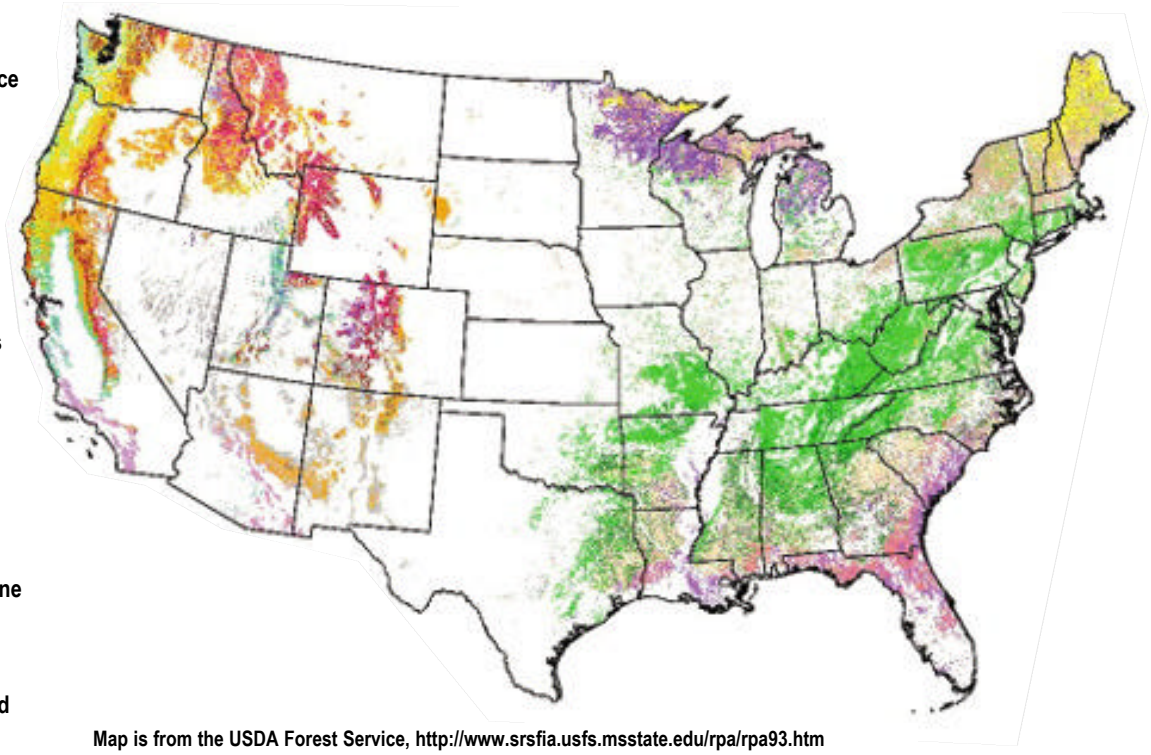
Current Distribution of Forests in the Contiguous United States

Western Forests

- douglas-fir
- hemlock-sitka spruce
- ponderosa pine
- western white pine
- lodgepole pine
- larch
- fir-spruce
- redwood
- chaparral
- pinyon-juniper
- western hardwoods
- aspen-birch

Eastern Forests

- white-red-jack pine
- spuce-fir
- longleaf-slash pine
- loblolly-shortleaf pine
- oak-pine
- oak-hickory
- oak-gum-cypress
- elm-ash-cottonwood
- maple-beech-birch
- aspen-birch



Map is from the USDA Forest Service, http://www.srsfia.usfs.msstate.edu/rpa/rpa93.htm

Potential socioeconomic impacts include:

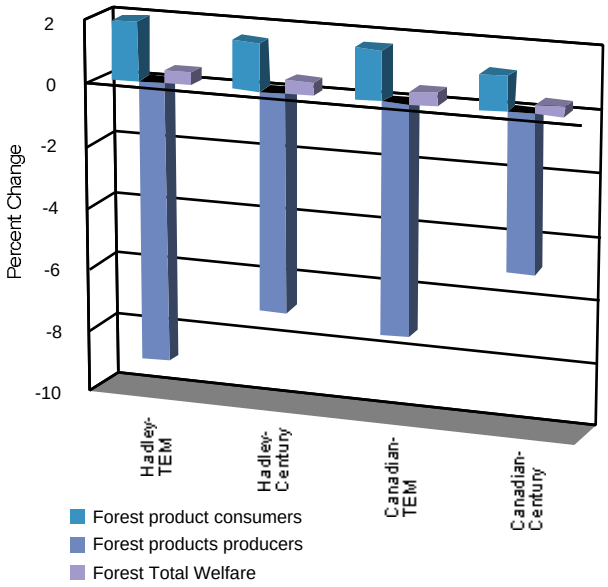
Recreational Value. Forests provide many recreational opportunities including hiking, camping, hunting, bird watching, skiing, autumn leaf tours, and water-related activities such as fishing, boating, and swimming. These activities provide income and employment in every forested region of the US.

- Expansion of recreation is likely in mountainous areas where warmer lowland temperatures will attract people to higher elevations.
- Habitat for cold-water fish species will likely decrease in area as habitat for warm water fish species increases.
- Skiing opportunities will likely be reduced with fewer cold days and snow events. Thus the making of artificial snow will increase, which will have environmental implications such as increased water and energy usage. In marginal climate areas, the inability to maintain downhill skiing may result in the closure of some ski areas.

Wood and Paper Products. The market for wood products in the US is highly dependent on the area and species composition of forests, supplies of wood, technological change in production and use, availability of substitutes, demand for wood products, and international competition.

- US per capita consumption of wood has been relatively stable over the last several decades; demand for wood is projected to follow population growth over the next 50 years.
- With possible increases in timber productivity and more forest inventory to harvest, the costs of wood and paper products to consumers would likely decrease, as would the returns to owners of timberland. It is possible that under these climate scenarios and warmer climate scenarios, the separate effects on producers and consumers of timber products, especially in different regions, could be large and in opposite directions.
- Nationally, timber products welfare changed little in this analysis. Markets for forest products adjusted through altering prices for wood products. Changes in climate and the consequent impacts on forests will very likely change market incentives for investment in intensive management and in wood-conserving technologies. Changes in climate will also likely shift some land uses between agriculture and forestry.

Change in Timber Product Welfare from 2001 to 2100



Reductions in log prices are likely to decrease producers'welfare (profits), but generally benefit consumers through lower wood-product prices over the 2001-2100 period.

Photo credits: cover: Alaska, Kenai Peninsula, Rear Admiral Harley D. Nygren, NOAA Corps (ret.); butterfly on pine, © Melody Warford; Hiker in aspen, © Melody Warford; maple leaves, © Melody Warford; Hawaiian beach, © Melody Warford; elk in Bitteroot fire, John McColgan, BLM, Alaska Fire Service; aspen trees, Nick Sundt; skier in Northeast, © P.G. Pearl; loblolly pine leaf and cones, © K. Hall and R. Braham; riparian forest, USDAFS/NRCS National Agroforestry Center; timber trucks, Bill Lea, USDAForest Service; inside: boy fishing, © California Department of Water Resources; squirrel, © Melody Warford; bird in tree, © Melody Warford; leaves, © Melody Warford; sunset, © Melody Warford; figures extracted from National Assessment Foundation Report.

Adaptation

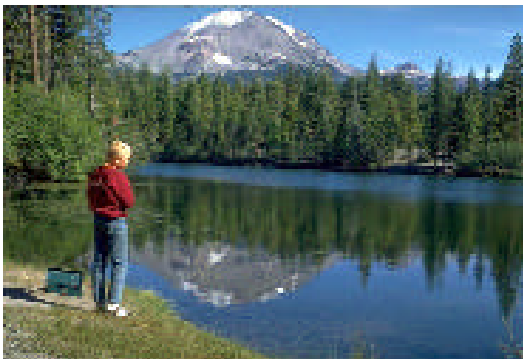
The value of forests, changes in natural disturbance regimes, and available environmentally and economically acceptable management options help to determine the potential viability of various coping strategies. Forests may be aided by:

- Decreasing other stresses, such as air pollution;
- Managing for the disturbance, such as decreasing the density of tree planting to reduce susceptibility to drought;
- Mitigating the forest disturbance itself, such as increasing the use of prescribed fire or limiting the introduction of non-native species;
- Manipulating forests after disturbance, such as altering species composition to reduce vulnerability of forests to future fires, wind, insects and pathogens.

There are also a number of options to reduce the vulnerability of forest plantations, such as species selection and genetic improvements to increase drought resistance.

Research Needs

The Forest Sector Assessment is based on the available state-of-the-science. Significant gaps in understanding of climatic, ecological, social, and economic processes have limited the accuracy of projections of future conditions. Several important questions need to be addressed to improve future confidence in assessments of climate change impacts to US forests. Examples of critical research needs include:



- Improved understanding not only of the direct effects of CO_2, ozone, temperature, precipitation, and nitrogen and sulfur deposition on forests, but also of the interactive effects of these environmental factors on forests.
- Better data and knowledge on how climate affects disturbances and how forests respond to them. Information from monitoring programs could update risk management assessments.
- Integrated models to better analyze forest practices and community needs to adapt to climate change. For example, integrated models of land use and climate are needed to project the interactions of these two influences on biodiversity. Continued evaluation of climate change impacts is needed on a wide range of forest goods and services including water supply, carbon storage, non-wood forest products, timber, and recreation.

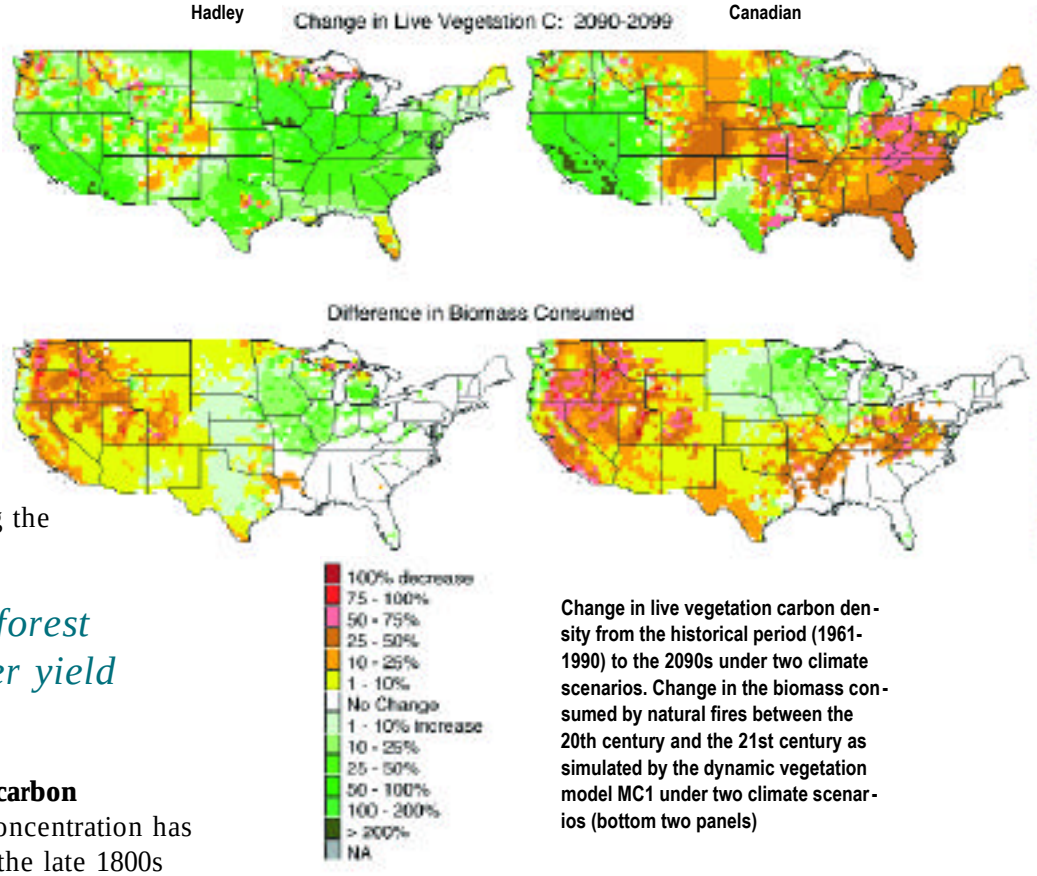
For More Information

Visit the National Assessment web site at http://www.nacc.usgcrp.gov for more information on the US National Assessment of the Potential Consequences of Climate Variability and Change. The National Assessment Overview and Foundation reports to Congress were published by Cambridge University Press (http://us.cambridge.org/). To view this report on-line, link to: http://www.usgcrp.gov/usgcrp/Library/nationalassessment/default.htm. Detailed analyses are found in the September 2001 issue of *BioScience*, the November 2000 issue of *The Science of the Total Environment*, and the April 2001 issue of *Ecosystems*

FOREST PRODUCTIVITY AND HYDROLOGY

Forest processes are critical to providing clean air and water, moderating stream flows, and maintaining aquatic habitats. These processes control responses of forests to environmental factors. Several environmental factors are changing rapidly and simultaneously. Changes in the atmospheric concentration of carbon dioxide (CO_2) interact with the impacts of climate change on forest productivity. Understanding how climate change will impact forests is needed to assure that supplies of water and wood are adequate during the next century.

Patterns of Live Vegetation and Biomass Consumed in Fire for Two Climate Scenarios



Change in live vegetation carbon density from the historical period (1961-1990) to the 2090s under two climate scenarios. Change in the biomass consumed by natural fires between the 20th century and the 21st century as simulated by the dynamic vegetation model MC1 under two climate scenarios (bottom two panels)

Potential impacts on forest productivity and water yield include:

Interactions with atmospheric carbon dioxide. Atmospheric CO_2 concentration has increased by about 30% since the late 1800s and could increase more than two times today's concentration by the early 2100s.

- A synthesis of laboratory studies, field experiments, and modeling indicates that forest productivity increases with the fertilizing effect of atmospheric CO_2. However, these increases are likely to be short-lived when water and mineral nutrients become limiting to plant growth.
- Across a wide range of scenarios, studies indicate that modest warming increases carbon storage in most forest ecosystems in the conterminous US. However, greater warming, particularly in the Southeast and the Northwest, could lead to drought-induced losses of carbon, possibly exacerbated by increased fires.
- Climate and ecological models suggest overall forest productivity could increase and this could increase yield for forest product industries. However, this national trend will be the net effect of increased productivity in some regions and decreased productivity in others. In some regions, realization of potential increases in productivity will require foresight in silvicultural practices.

Air quality impacts. Other environmental factors, such as nitrogen deposition and ground-level ozone concentrations, also affect forest productivity.

- Current ozone levels have offset wood production by 10% in northeast forests and by 5% in southern pine plantations. Reductions in forest growth from ozone may be offset by increased growth from increased nitrogen deposition and carbon dioxide.
- Climate models project an increase of a few degrees in summer and winter temperatures, which should tend to increase productivity in many forests (especially as a result of a longer growing season), but could also exacerbate the harmful effects of ozone.

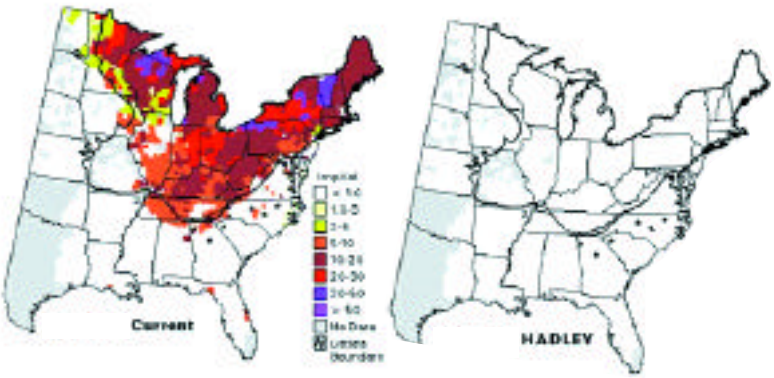
Interaction with hydrological changes. Water resources and hydrologic processes are tightly coupled with ecosystem dynamics and forest carbon cycle.

- With increased temperatures, longer growing seasons and greater leaf area, vegetation may transpire more water, even with CO_2-induced increases in water use efficiency. Increased transpiration reduces runoff, affecting other uses of water.
- Several climate scenarios indicate moderate increases in leaf area in the Southeast and Great Plains which could greatly reduce runoff. The Northwest, California, and Great Basin regions could see large increases in runoff, primarily in winter. Shifts in runoff seasonality could severely stress western water resources.

DISTURBANCE

Natural disturbances having the greatest impact on forests include insects, diseases, introduced species, fires, droughts, hurricanes, landslides, wind storms, and ice storms. Climate variability and changes can alter the frequency, intensity, timing, and spatial extent of these disturbances. Many potential consequences of future climate change are expected to be buffered by the resilience of forests to natural climatic variation. However, an extensive literature suggests that new disturbance regimes under climate change are likely to result in significant perturbations to US forests, with lasting ecological and socioeconomic impacts.

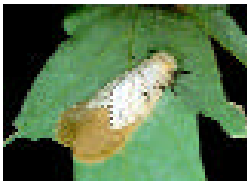
Projected Declines in Distribution of Sugar Maple



Projected distribution for sugar maple under current climate and the Hadley climate scenarios. These potential maps imply no barriers to migration.

Future disturbance impacts are likely to include:

Forest Fires. Fire suppression in many US forests has led to increased forest density and biomass, changes in plant composition and increased outbreaks of insects and disease. With rising temperatures and the absence of much increased rainfall, the seasonal severity of fire hazard is likely to increase by 10% over much of the US, with possibly larger increases in the Southeast and Alaska.



Epidemic levels of insects and disease. Native and introduced insects and diseases—such as gypsy moth, chestnut blight, Dutch elm disease, spruce budworm, and bark beetles—alter forests. As climate change leads to increased disturbances such as fire or drought, these disruptions are very likely to create the type of environment ripe for the invasion and spread of introduced species. Insects and pathogens, by virtue of their mobility and short reproduction times, can respond to climate change much more rapidly than tree populations. As a result, insects and disease are likely to cause some of the early impacts of climate change on forests.

Interactions with Current and Future Land Use Changes. Agricultural, urban and suburban areas are expanding into forestland. This expansion of human influences into the rural landscape alters disturbance patterns associated with fire, flooding, landslides, native and introduced species. These land-use changes are very likely to interact with and potentially exacerbate stresses on forests associated with climate change.

BIODIVERSITY

The current richness of forests depends on forest biodiversity - the variety of plant and animal species, the ecosystems they create, and the variety of landscapes they inhabit. The abundance and distribution of plants and animals in forests supply material products, foods, and medicines, all of which are important to local economies, human health, and social well-being.

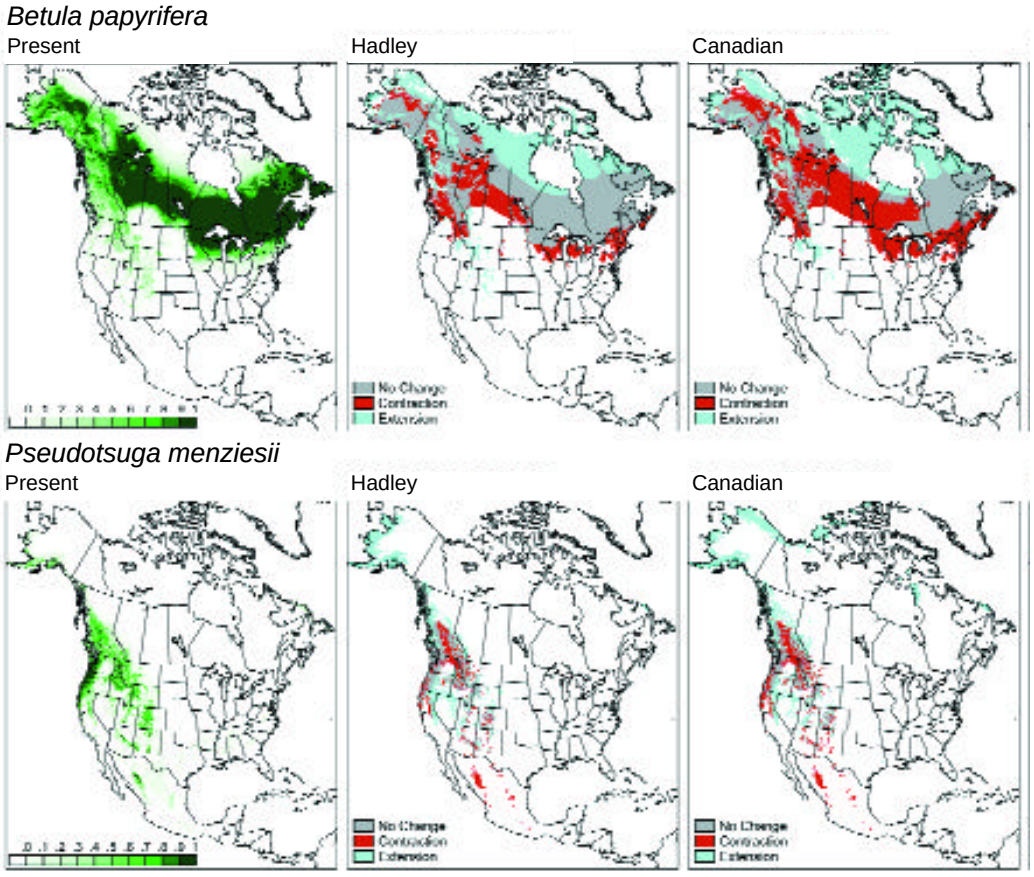
In addition, the number and kinds of species present affect how ecological systems respond to climate change, often in ways we cannot foresee.

Potential impacts on biodiversity include:

Plant and animal species.
Climate influences the distribution and abundance of plant and animal species through changes in resource availability, fecundity, and survivorship.

- The ranges of tree species favoring cool climates are likely to shift north. For example, the ranges of sugar maple and birch are projected to contract dramatically in the US and largely shift into Canada. The ranges for subalpine conifers such as Engelmann spruce, mountain hemlock, and several species of fir will be reduced in western US.
- Expansion of potential habitats is possible for oaks, hickory, and pines in the East and for ponderosa pine and arid woodlands in the West. Southeastern mixed (deciduous and coniferous) forests are projected to increase in area under moderately warm scenarios, but would be converted to savannas and grasslands under hotter climate scenarios.
- The ability of plant and animal species to migrate under climate change is strongly influenced by their dispersal abilities and by disturbances to the landscape. Human influences have resulted in an increasing number of species listed as threatened and endangered in the US, currently at about 1,200. Land-use changes will continue to challenge the ability of plant and animal species to adapt to climate change.

Paper Birch and Douglas Fir Tree Distributions under the Hadley and the Canadian Climate Change Scenarios



Estimated probablilities of occurance for Paper Birch (Betula papyrifera) and Douglas-fir (Pseudotsuga menziesii). Simulated with observed modern climate (left panel). The observed distributions are compared with the future distributions simulated under the Hadley (HADCM2) and Canadian (CGCM1) scenarios for 2090-2099 (right panels). Gray indicates where the taxon is observed today and is simulated to occur under future climate conditions; red indicates where the taxon is observed today but is simulated to be absent under future conditions; and blue indicates where the taxon is absent today but is simulated to occur under future conditions.

SOCIOECONOMICS

Forests significantly enhance the environment in which people live, work and play. Population levels, economic growth, and personal preferences influence the value of forests, and consequently the resources demanded from forests. Changes caused by human use of forests could exceed impacts from climate change. However, climate change could have long-term impacts on many of the amenities, goods and services from forests, including productivity of locally harvested plants such as berries or ferns; local economics through land use shifts from forest to other uses; forest real estate values; and tree cover and composition in urban areas and associated benefits and costs.

Forest Sector Contribution to the National Assessment on the Potential Consequences of Climate Change for the United States

The overall goal of the National Assessment is to analyze and evaluate what is known about the potential consequences of climate variability and change for the Nation in the context of other pressures on the public, the environment, and the Nation's resources. The National Assessment process has been broadly inclusive, drawing on inputs from academia, government, the public and private sectors, and interested citizens. Starting with broad public concerns about the environment, the Assessment is exploring the degree to which existing and future variations and changes might affect issues that people care about.

The National Assessment has three major components:

1. Regional analyses: Workshops and assessments are characterizing the potential consequences of climate variability and change in regions around the United States. The reports from these activities address the interests of those in particular regions by focusing on the regional patterns and texture of changes where people live. Most workshop reports are available and assessment reports become available as they are completed.

2. Sectoral analyses: Workshops and assessments are being carried out to characterize the potential consequences of climate variability and change for major sectors that cut across environmental, economic, and societal interests. The sectoral studies analyze how the consequences in each region affect the Nation, making these reports national in scope and of interest to everyone. The sectors being focused on in this first phase of the ongoing National Assessment include: Agriculture, Forests, Human Health, Water Resources, and Coastal Areas and Marine Resources.

3. National overview: The National Assessment Synthesis Team has responsibility for summarizing and integrating the findings of the regional and sectoral studies with the broader literature, and then drawing conclusions about the importance of climate variability and change for the United States. Their Overview and Foundation documents are available on the web and in hard copy.

Each of the regional, sectoral, and synthesis activities is being led by a team comprised of experts from both the public and private sectors, from universities and government, and from the spectrum of stakeholders. For more information on the National Assessment, including copies of documents, see the website: http://www.nacc.usgcrp.gov.

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