FOREST SECTOR

Forests cover nearly one-third of the US,providing wildlife habitat, clean air and water, cultural and aesthetic values,carbon storage, recreational opportunities such as hiking,camping, fishing,and autumn leaf tours,and products that can be harvested such as timber, pulpwood,fuelwood,wild game, ferns, mushrooms,and berries. This wealth depends on forest biodiversity (the variety of plant and animal species) and forest functioning (water flows, nutrient cycling,and productivity). These aspects of forests are strongly influenced by climate. Native forests are adapted to their local climates; examples include the cold-tolerant boreal forests of Alaska,the summer-drought tolerant forests of the Pacific Northwest,and the drought-adapted piñon-juniper forests of the Southwest.

Human activities modify forests. Native forests have been converted to agricultural and urban uses. In some cases, forests have regrown on abandoned agricultural lands. Expansion of urban areas has fragmented forests into smaller, less-contiguous patches. Fire suppression has changed the species found in southeastern,midwestern,and western forests. Harvesting methods,where all trees or a few trees are cut, have also changed species composition. Trees have been planted for aesthetic and landscaping purposes in urban and rural areas that are often far outside of the species' natural range. Intensive management along with favorable climates in parts of the US has resulted in highly productive forests,such as southern pine plantations. Human activities will continue to modify forests while forests are also experiencing the effects of climate change.

KEY ISSUES

- **Effects on Forest Productivity**
- **Natural Disturbances such as Fire and Drought**
- **Biodiversity Changes**
- **Socioeconomic Impacts**

Modest warming could result in increased carbon storage in most forest ecosystems in the conterminous US. Yet under some warmer scenarios, forests, notably in the Southeast and the Northwest, could experience drought-induced losses of carbon, possibly exacerbated by an increased fire disturbance.

Key Issue: Effects on Forest Productivity

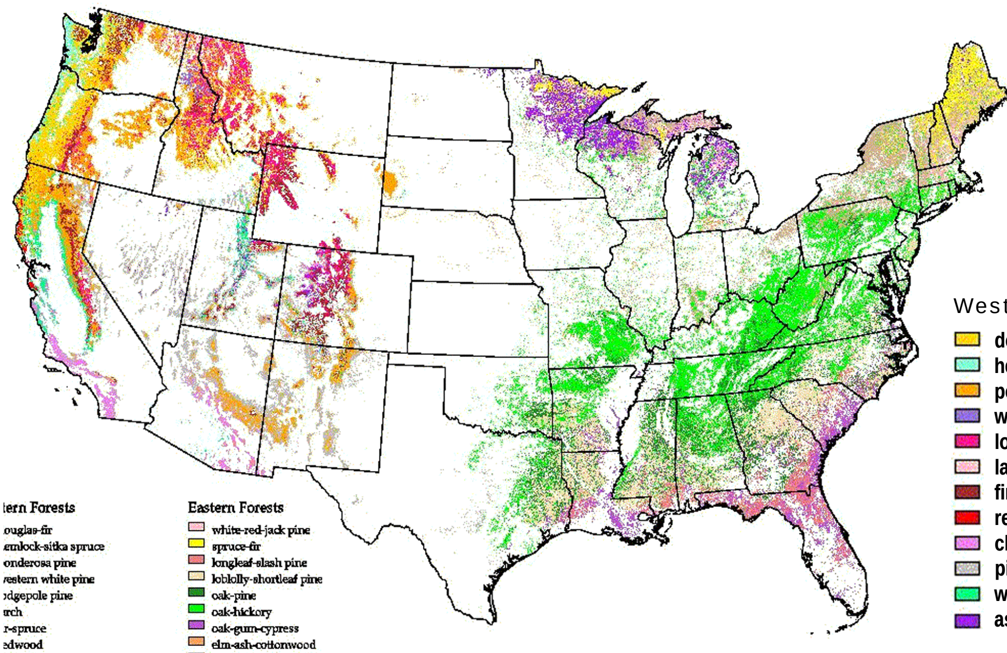
Several environmental factors that control the water and carbon balances of forests are changing rapidly and simultaneously. The global increases in atmospheric CO_2 concentrations are the best-documented factor. However, in some areas,other important atmospheric constituents are also increasing,including nitrogen oxides (a direct product of fossil fuel combustion that causes acid rain) and ground-level ozone ("smog," a product of chemical reactions between hydrocarbons and nitrogen oxides in the presence of sunlight).

A synthesis of laboratory and field studies and modeling indicates that forest productivity increases with the fertilizing effect of atmospheric CO_2 (see box in Agriculture section),but that these increases are strongly tempered by local conditions such as moisture stress and nutrient availability. Across a wide range of scenarios,it appears that modest warming could result in increased carbon storage in most forest ecosystems in the conterminous US. Yet under some warmer scenarios, forests,notably in the Southeast and the Northwest,could experience drought-induced losses of carbon,possibly exacerbated by increased fire disturbance. These potential gains and losses of carbon will be subject to changes in land-use,such as the conversion of forests to agricultural lands.

Other components of environmental change,such as nitrogen deposition and ground-level ozone concentrations,also affect forest processes. Models identify a synergistic fertilization response between CO_2 and nitrogen enrichment,leading to further increases in productivity. Ozone,however, can suppress these gains.Current ozone levels, for example,have likely decreased production by 10% in Northeast forests and 5% in southern pine plantations. Interactions among these physical and chemical changes and other components of global change are important in determining the future of US forests.

Intensive management along with favorable climates in parts of the US has resulted in highly productive forests, such as the southern pine plantations. Human activities will continue to modify forests while forests are also experiencing the effects of climate change.

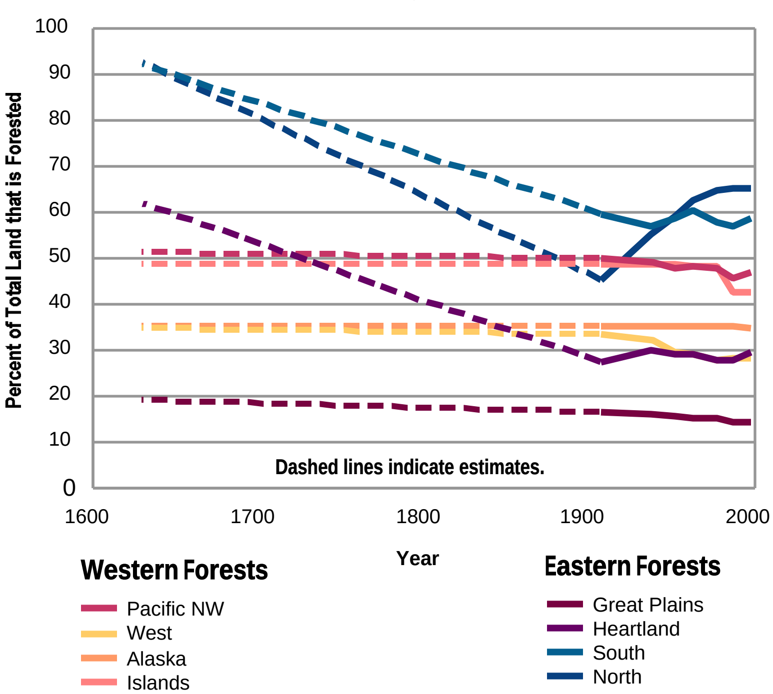
Current Distribution of Forests in the United States



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

Forest Land Percentages



Forest land area has declined in the East since 1600. Northern forests have regrown somewhat after being cleared for timber and agriculture in the late 1800s. Increases in the South reflect plantations, as well as regrowth from agricultural conversion. Midwest (Heartland) forests have been cleared for agriculture. Forest land area is a much smaller percentage of the western states, and has remained relatively constant since the 1600s.

FORESTS KEY ISSUES

Natural Disturbances Such as Fire and Drought

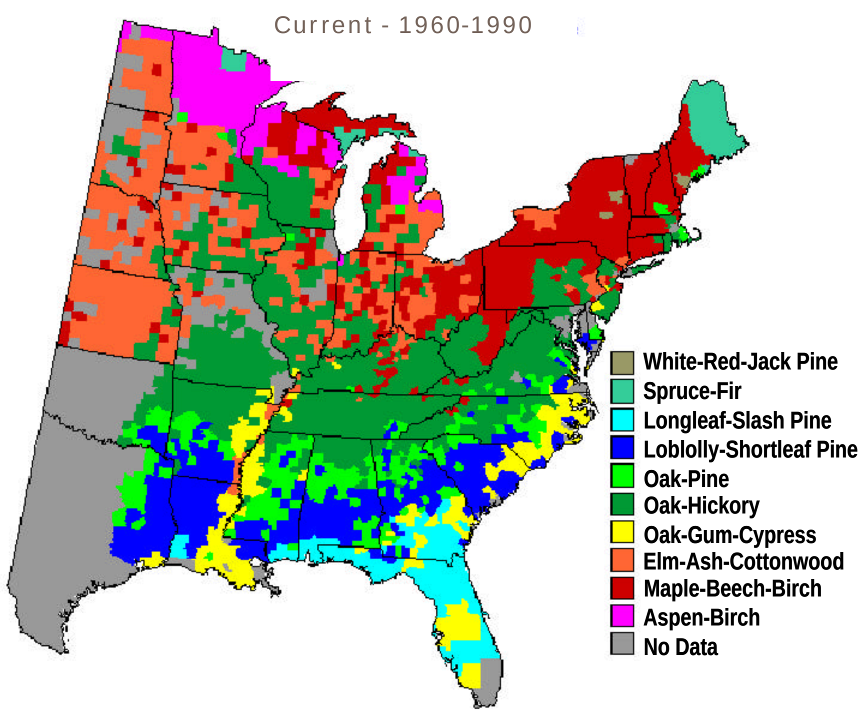
Natural disturbances having the greatest effects on forests include insects, disease,introduced species, fires,droughts,hurricanes,landslides,wind storms,and ice storms. Tree species have developed adaptations to some of these disturbances. For example,some tree species have developed very thick bark to protect them from repeated ground fires.

Regionally, the Hadley scenario projects small decreases in fire hazard in the northern Great Plains, and the Canadian scenario projects a 30% increase in fire hazard for the southeastern US and Alaska.

Over millennia,local, regional,and global changes in temperature and precipitation have influenced the occurrence,frequency, and intensity of these natural disturbances. These changes in disturbance regimes are a natural part of all ecosystems. However, forests may soon be facing rapid alterations in the nature of these disturbances as a consequence of climate change. For example,the seasonal severity of fire hazard is projected to increase about 10% over the next century over much of the US under both the Hadley and Canadian climate scenarios. Regionally, the Hadley scenario projects small decreases in fire hazard in the northern Great Plains,and the Canadian scenario projects a 30% increase in fire hazard for the southeastern US and Alaska.

The consequences of drought depend on annual and seasonal climate changes and whether the current drought adaptations offer resistance and resilience to new conditions. Under the Canadian and Hadley scenarios,the ecological models used in this Assessment indicate that increases in drought stresses will likely occur in the Southeast,southern Rocky Mountains and parts of the Northwest over the 21st century.

Dominant Forest Types



These maps show current and projected forest types for the eastern US. The current distribution of forest types reflects temperature and moisture gradients in this part of the nation. The simulated changes in forest types by the end of the 21st century are in response to the Hadley and Canadian climate scenarios using the DISTRIB model, a tree species distribution model. Pine-dominated types decline in the Southeast under both climate scenarios. Oak-pine and oak-hickory forest types are projected to expand northward.

The interactions between climate change and hurricanes,landslides,ice storms,wind storms,insects,disease, and introduced species are difficult to predict. But as climate changes, alterations in these disturbances and in their effects on forests are possible.

Biodiversity Changes

Changes in the distribution and abundance of plant and animal species reflect the birth, growth, death,and dispersal rates of individuals in a population. When aggregated, these processes result in the local disappearance or introduction of a species,and ultimately determine the species' range. While climate and soils exert strong controls on the establishment and growth of plant species,the response of plant and animal species to climate change will be the result of many interacting and interrelated processes operating over several scales of time and space. Migration rates, changes in disturbance regimes,and interactions within and between species will affect the distribution of plants and animals. In addition,human activities influence the occurrence and abundance of species on the landscape.

Analyses of ecological models over several climate scenarios indicate that the location and area of the potential habitats for many tree species and communities are very likely to shift. Potential habitats for trees favored by cool environments are very likely to shift north. Habitats of alpine and sub-alpine spruce-fir could possibly be eliminated. Aspen,and eastern birch communities are likely to contract dramatically in the US and largely shift into Canada. Potential habitats that could possibly expand in the US are oak/hickory and oak/pine in the eastern US,and Ponderosa pine and arid woodland communities in the West.

How well these species track changes in their potential habitats will be strongly influenced by their dispersal abilities and the disturbances to these environments. Some native species will have difficulty dispersing to new habitats because of the rapid rate of climate change and human land use along migration routes. For example, sagebrush and aspen communities are currently being reduced by conifer encroachment, grazing,invasive species,and urban expansion.

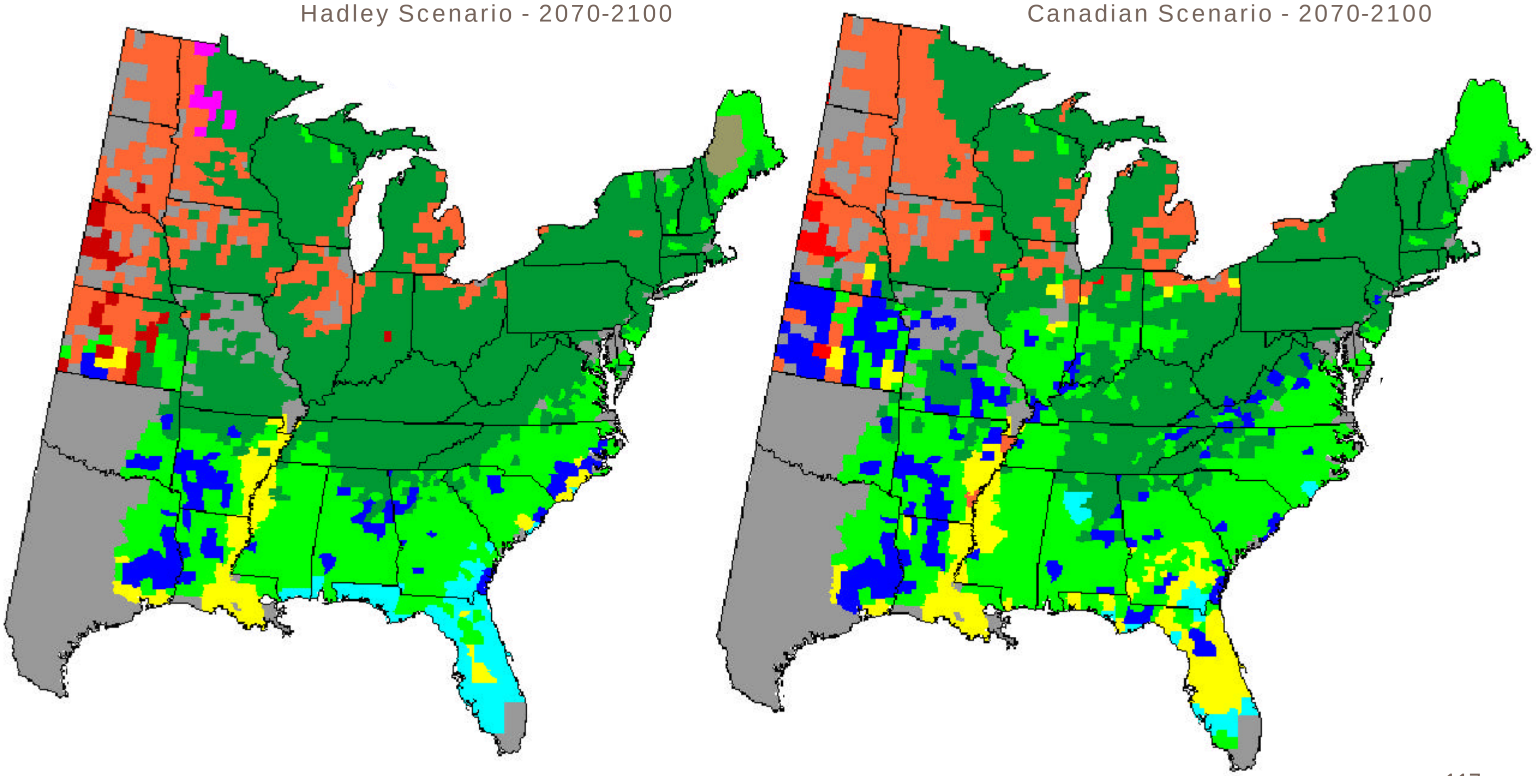
The effects of climate change on the rate and magnitude of disturbance (forest damage and destruction associated with fires,storms,droughts and pest outbreaks) will be an important factor in determining whether transitions from one forest type to another will be gradual or abrupt. If disturbances in New England, for example,do not increase,there is a possibility of a smooth transition from the present maple,beech,and birch tree species to oak and hickory. Where disturbances increase,transitions are very likely to be abrupt.

Invasive (weed) species that disperse rapidly are likely to find opportunities in newly forming communities. Thus,the species composition of these communities will likely differ substantially from those occupying similar habitats today.

Dominant Forest Types

Hadley Scenario - 2070-2100

Canadian Scenario - 2070-2100



FORESTS KEY ISSUES

Socioeconomic Impacts

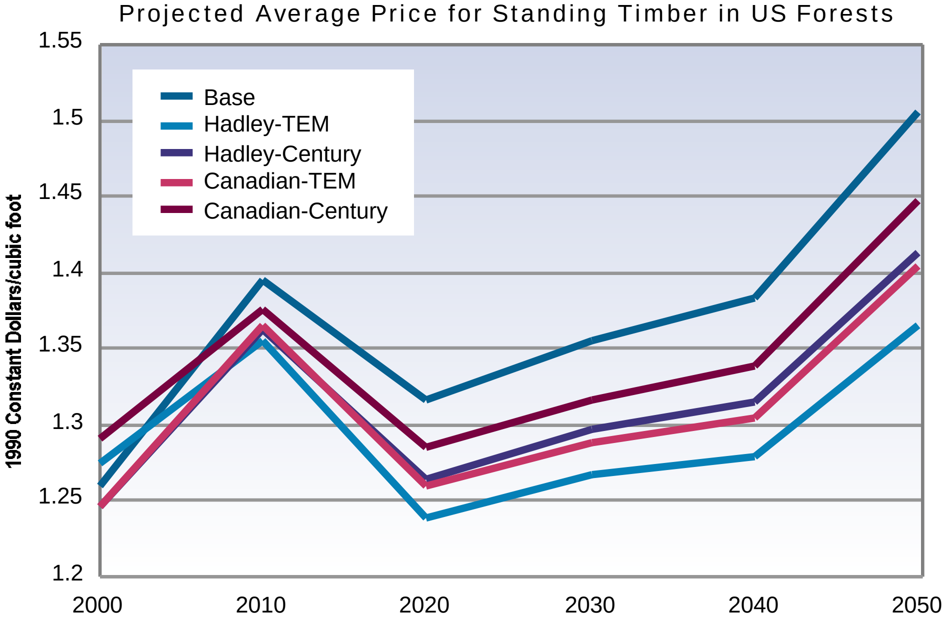
North America is the world's leading producer and consumer of wood products. The US has substantial exports of hardwood lumber, wood chips,logs, and some types of paper. However, the US also imports forest products,including 35% of its softwood lumber and more than half of its newsprint from Canada. The market for wood products in the US is highly dependent upon the future area in forests,species composition of forests,future supplies of wood,technological change in production and use, availability of substitutes such as steel and vinyl, demands for wood products,and competitiveness among major trading partners.

Analyses of the forest and agriculture sectors for a range of climate scenarios indicate that forest productivity gains are very likely to increase timber inventories over the next 100 years. Under these scenarios,the increased wood supply leads to reductions in log prices that,in turn,decrease producers'profits. At the same time, lower forest-product prices mean that consumers generally benefit. The projected net effect on the economic welfare of participants in both timber and agricultural markets increases about 1% above current values. Land will likely shift between forestry and agricultural uses as these economic sectors adjust to climate-induced changes in production. Although US total forest production generally increases, hardwood output is higher in all scenarios but softwood output increases only under moderate warming. Timber output increases more in the South than in the North.Sawtimber volume increases more than pulpwood volume.

Land will likely shift between forestry and agricultural uses as these economic sectors adjust to climate-induced changes in production.

It is very likely that outdoor recreation will be altered by climate change. Changes in benefits,as measured by aggregate days of activities and total economic value, will vary by type of recreation and location. In some areas,higher temperatures are likely to shift summer recreation activities,such as hiking,northward or to higher elevations. In winter, downhill skiing opportunities will very likely decrease with fewer cold days and reduced snowpack. Costs to maintain skiing opportunities are likely to rise in marginal climate areas. Effects on fishing will likely vary; warmer waters will increase fish production and opportunities for some warm water species,but decrease habitat and opportunities for cold water species.

Projected Average Price for Standing Timber in US Forests



Prices for standing timber under all climate change scenarios remain lower than in a future without climate change (base). Prices under the Canadian scenario remain higher than prices under the Hadley scenario when either the TEM or the Century model is used.

Adaptation Strategies

While projected climate changes are likely to alter forests,the motivation for adaptation strategies will be strongly influenced by the level of economic activity in the US,population growth,tastes,and preferences including society's perceptions about these changes in forests. Market forces are powerful when it comes to land use and forestry, and as such,influence adaptation on private lands. However, for those forests valued for their current biodiversity, strategies to maintain these plant and animal species under climate change remain to be developed.It is possible that such strategies will be unavailable or impractical.

Timber producers could possibly adjust and adapt to climate change under the scenarios used here, if new technologies and markets are recognized in a timely manner. Adaptations could include salvaging dead and dying timber and replanting species appropriate to a new climate.

Markets for forest products adjust through altering prices for timber, wood,and paper products. The changes in climate and the consequent impact on forests will very likely change the market incentives for investment in intensive forest management (such as planting,thinning, genetic conservation,and tree improvement) and the incentive to develop and invest in wood-conserving technologies.Although these price changes are likely to alter consumption patterns (for example,substitution between wood and non-wood products), overall increase in the consumption of wood products very likely will still be predominantly influenced by population growth,the level of economic activity in the US and internationally, and personal preferences.

Timber producers could possibly adjust and adapt to climate change under the scenarios used here, if new technologies and markets are recognized in a timely manner. Adaptations could include salvaging dead and dying timber and replanting species appropriate to a new climate. The extent and pattern of timber harvesting and prices in the US will also be influenced by the global changes in forest productivity and prices of overseas products.

Potential climate-induced changes in forests must be put into the context of other human-induced pressures,which will undoubtedly change significantly over future decades. While the potential for rapid changes in natural disturbances could challenge current management strategies,these changes will co-occur with human activities such as agricultural and urban encroachment on forests, multiple use of forests,and air pollution.

Increased forest growth overall leads to increased wood supply; reductions in log prices decrease producers' welfare (profits), but generally benefit consumers through lower wood-product prices. Welfare is present value of consumer and producer surplus discounted at 4% for 2000-2100.

Change in Timber Product Welfare from 2000 to 2100