Forest Health

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Forests in the United States provide a multitude of services: clean drinking water, clean air, forest products, economic stability, wildlife habitat, recreation, and aesthetic value. Regardless of the type of forest, a healthy forest is able to provide unique services in a sustainable manner. Factors influencing forest health and productivity in the United States include nonnative invasive species, insects and pathogens, forest fuels and wildfire, and air pollution. This section of chapter 4 reports on forest health data collected by the following Forest Service organizations: the Forest Inventory and Analysis (FIA) program, Forest Health Monitoring, Forest Health Protection, the Remote Sensing Application Center, and the National Interagency Coordination Center.

Invasive Species

Invasive species have the potential to severely affect the health of the Nation's forests. Many of the most aggressive insects and pathogens infesting trees in the United States are nonnative species that have become invasive. Nonnative invasive plant species have tremendous potential to negatively alter forest ecosystems.

Invasive Plants

Nonnative invasive-plant species data collection is currently optional on FIA plots. Each FIA region collects data on nonnative invasive plants using slightly different methods. Therefore, data are not directly comparable between States or FIA regions. Efforts are underway to standardize invasive-plant data-collection protocols, much like the plot design that is now standard nationwide. In this report, nonnative invasive-plant data are reported by FIA region, where available. Degree of infestation by nonnative species differed by State in the North region. More than 80 percent of sampled forest plots in Iowa and more than 60 percent of sampled plots in Indiana and Illinois contained at least one invasive species, and less than 10 percent of the plots in Minnesota contained one or more invasive plants (fig. 4c.1). Agriculture and development, combined with forest fragmentation, help to account for the differences between States (Moser et al. 2008). At the regional level, the percent of all forest plots sampled is similar between the North region and the Pacific Coast region. There appears to be much less variation in the degree of infestation among States on the Pacific coast (Washington, Oregon, and California); however, these States detected at least one invasive plant on between 15 and 25 percent of forest plots sampled. In the South region more than 20 percent of sampled plots in Tennessee, Kentucky, Virginia, and east Texas contained at least one invasive species. The remainder of the South region detected invasive plants on less than 20 percent of sampled plots.

Japanese Stilt Grass (*Microstegium vimineum*) in Tennessee.

Photo courtesy of Chris Oswalt.

States in the Great Plains region collected invasive species information only on a subset of forest plots. This phase-3 sample is 1/16th of the total FIA plot sample. Therefore, sample sizes are much smaller for the States in the Great Plains region. At the regional level, at least one nonnative invasive plant was found on 98 percent of forest health (phase-3) plots sampled. Extensive agricultural areas may account for some of the occurrence.

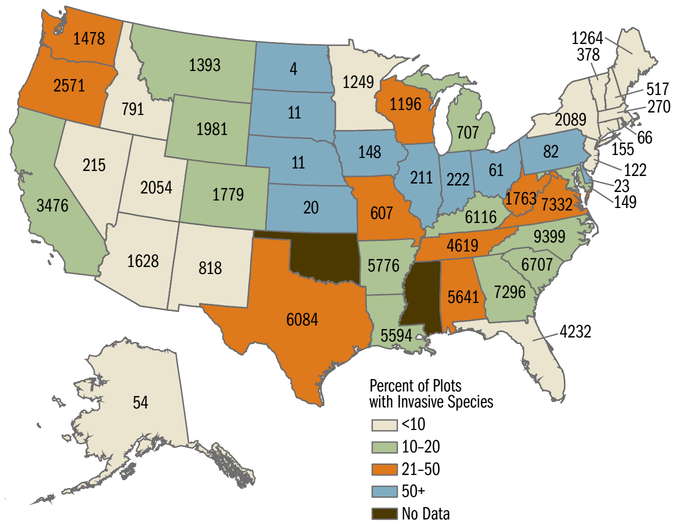

Figure 4c.1. Percent of forested plots containing at least one invasive species. Note: Total sample size is indicated on each State.

Source: Forest Inventory and Analysis plot data.

Insects and Diseases

Insects and diseases can have beneficial, neutral, or detrimental effects on forest ecosystems, depending on their geographic extent and severity and on the desired forest condition. Impacts range from defoliation, decay, reduced growth, increased susceptibility to other stressors, or outright mortality. As such, insects and diseases have great potential to affect ecosystem structure, composition, and function.

Mortality and defoliation from insects and diseases are detected on millions of acres annually in the United States (fig. 4c.2; Forest Service 2007a). In 2006, 5.3 million acres had mortality detected by aerial survey. (Note: Not all forested lands are surveyed; in 2006, about 400 million acres were surveyed.) Mountain pine beetle alone caused 50 percent of the mortality that was detected. Insect-caused defoliation occurred on 8.5 million acres, with forest tent caterpillar, budworms (western spruce, spruce, and jack pine), aspen leaf miner, and gypsy moth accounting for most of the defoliation (more than 90 percent) (Krist 2007). Diseases caused by dwarf mistletoes, root pathogens, and canker fungi are not easily detected by aerial survey but are present on millions of acres as well, causing growth loss and mortality, and contributing to mortality by other agents, such as bark beetles.

Potential Climate Change Impacts on Forests and Birds

Louis Iverson, Anantha Prasad, Stephen Matthews, Matthew Peters

This group has been using FIA data from the Eastern United States for 14 years to better understand how environmental factors relate to the ecology of today's forests and to model the potential impacts of climate change on 134 individual tree species. With more than 100,000 FIA plots and nearly 3 million trees of data, the FIA data were used to create importance values for each species, which form the basis of their statistical models. By relating current climate, soil, landscape, and elevation variables with the FIA data, they have ranked the species drivers and created models that match the FIA data mapped at 20x20 km. Then they changed the climate variables according to various general circulation models and emission scenarios to assess potential changes in suitable habitat for each species. The outputs from the tree models, plus climate and elevation data, were also used as inputs for similar kinds of models generated for 150 bird species (via Breeding Bird Survey data). More than 20 peer-reviewed publications have resulted from this work. A recently created Web site provides detailed analyses for each species: http://nrs.fs.fed.us/atlas.

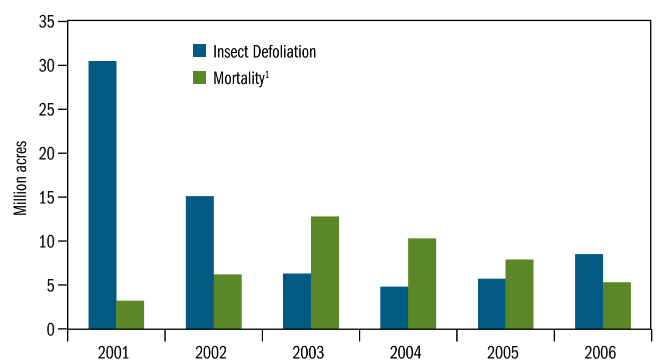

Figure 4c.2. Acres with insect and disease defoliation and mortality detected by aerial survey, 2001–06.
[1]Mortality acres do not include areas with sparse mortality.

Source: Forest Health Protection, Forest Health Technology Enterprise Team.

In some FIA regions, specific damaging agent information is collected on FIA ground plots so that estimates can be made of the affected number of trees, acres, and volume for specific tree species or owner groups caused by each recorded damaging agent. Risk of future mortality or growth losses from insects and diseases can also be evaluated and displayed spatially using vegetation data from FIA plots along with site and host susceptibility factors (Forest Service 2007b). In 2006, it was estimated that more than 58 million acres will have more than 25 percent of the standing live volume at risk of mortality within the next 15 years (fig. 4c.3).

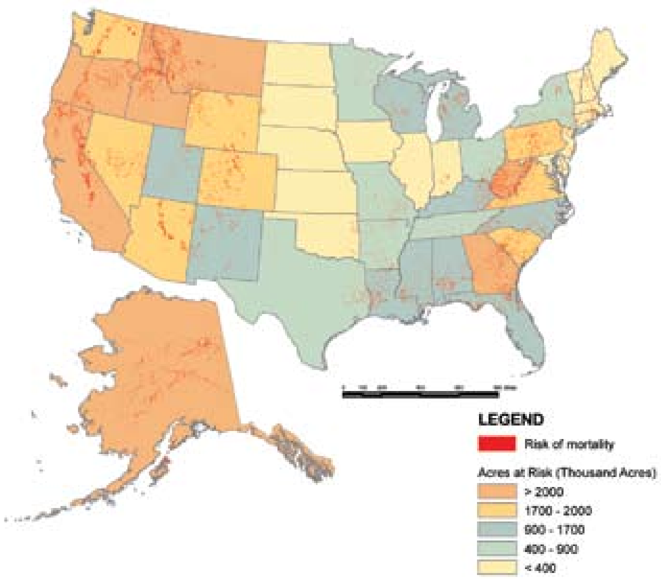

Figure 4c.3. The expectation that 25 percent or more of the standing live volume of trees greater than 1 inch in diameter will die over the next 15 years. Total acres at risk: Approximately 58 million

Sources: Forest Health Protection, Forest Health Technology Enterprise Team. Risk map Web site: http://www.fs.fed.us/foresthealth/technology/nidrm.shtml.

Forest Fuels and Wildfire

Dead wood—standing and down—is an important component of forested systems. Dead wood affects soil nutrient content and wildlife habitat availability, influences global carbon stores, and affects forest fire behavior. The ecological benefits of down woody material (DWM) are recognized along with its contribution to fire risk. Establishing a balance between the dead wood necessary to sustain a healthy, productive forest while addressing growing concerns over wildfire in our Nation's forests is one of many essential elements in maintaining healthy forest systems.

Warner Mountains, Fremont National Forest.

Photo courtesy Tom Iraci.

Forest Fuels: Down Woody Materials

Down woody material data from 5,505 plots spanning the years 2001 to 2006 indicate that total DWM tons per acre is highest along the west coast, in the northeast, along the Atlantic seaboard, in the Appalachian Mountains, and in the Northern Great Lakes ecological regions. Not surprisingly, fuel levels are lowest in the arid regions of Texas, southern California, and throughout the Plains States (fig. 4c.4). Carbon sequestered in DWM follows similar trends, with coarse woody material (CWM) carbon levels highest along the marine west coast and lowest in the North American desert, paralleling differences in tree sizes (fig. 4c.5). Carbon sequestered in fine woody material (FWM) is highest in the Atlantic highlands, the eastern temperate forests, and along the west coast, where deciduous trees and storms contribute to higher levels of small material on the forest floor. The Great Plains region had some of the lowest levels of carbon contained in FWM, as did the arid and semiarid desert regions, although, in most cases, carbon from FWM was still greater than carbon from CWM in those dry zones where trees may not reach their full growth potential.

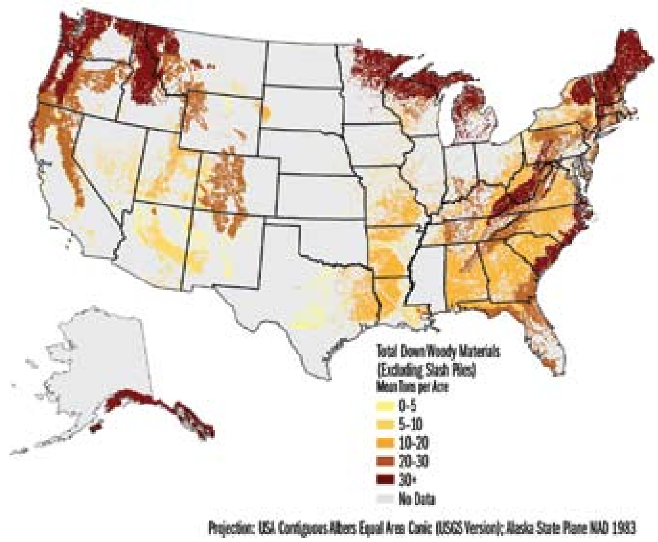

Figure 4c.4. Down woody material (tons per acre) averaged within U.S. Environmental Protection Agency ecological regions.

Source: Forest Inventory and Analysis plot data.

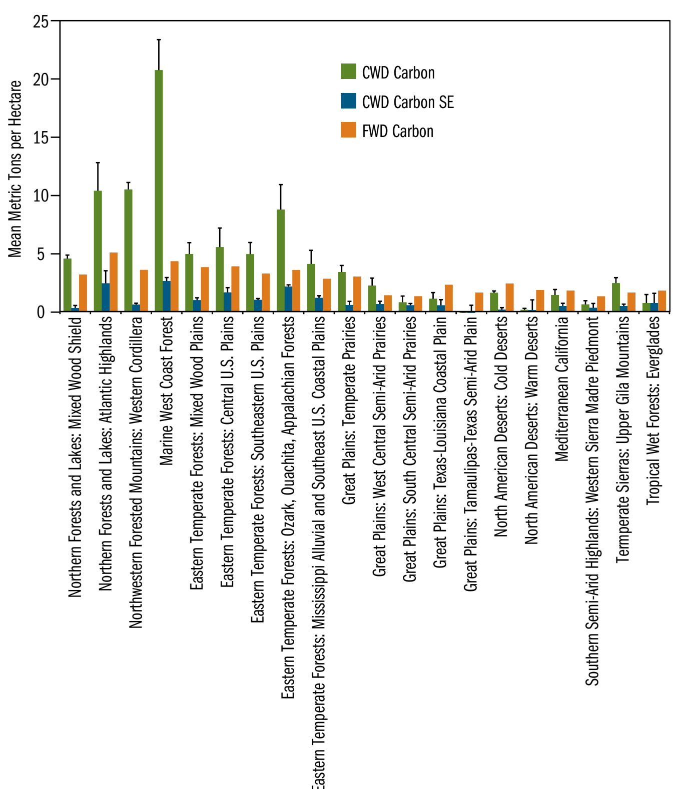

Figure 4c.5. Means and standard errors of carbon in fine and coarse woody materials by U.S. Environmental Protection Agency ecological region.

Source: Forest Inventory and Analysis plot data.

Impacts of Wildfire

For 10 years (1997 through 2006), the area of wildfire on wildlands averaged almost 6 million acres across the United States. In the 3 years after that (2004 through 2006), yearly acres have exceeded 8 million (NIFC 2008) (fig. 4c.6). Using remote sensing to delineate fire perimeters, information about forest characteristics can be summarized within burned areas. For example, for 2004 fires, the most prevalent forest-type groups within the burned areas were pinyon-juniper and oak-hickory (fig. 4c.7), and 10 percent of the forest fires on forest land were classified as moderate or high intensity in the East and 30 percent were classified as such in the West. The volume and value of wood also can be estimated from FIA plots within wildfire areas. For example, in Georgia and Florida, where more than 400,000 wildland acres burned in 2007, the wood volume and value, as shown in table 4c.1, were estimated for the burned area (Harper et al. 2007):

Product	Volume[1]	Value[2]	Assessed Mortality Value[3]
Total pulpwood	5,888,738 cords	$114,631,863	$65,787,411
Total sawtimber	974,668,000 board feet (International log rule)	$228,120,103	$133,372,705
Precommercial area	–	$19,176,000	$10,161,401
Total	**551,194,974 cubic feet**	**$342,751,966**	**$209,321,517**

Table 4c.1. Estimated volume and value of wood within wildfire areas in Georgia and Florida, 2007

[1]Total volume within the burn area. Precommercial timber land area estimated at 76,704 acres with no commercial volume; reestablishment per acre value was estimated and applied to precommerical area to assess a total value.

[2]Timber Mart-South, average price, 1st quarter 2007 for Georgia, Region 2, and Florida, Region 1 for value of pulpwood and sawtimber.

[3]Georgia assessment was 65 percent mortality; Florida assessment was 25 percent mortality. These values are for demonstration and do not reflect the final assessed values by Georgia and Florida.

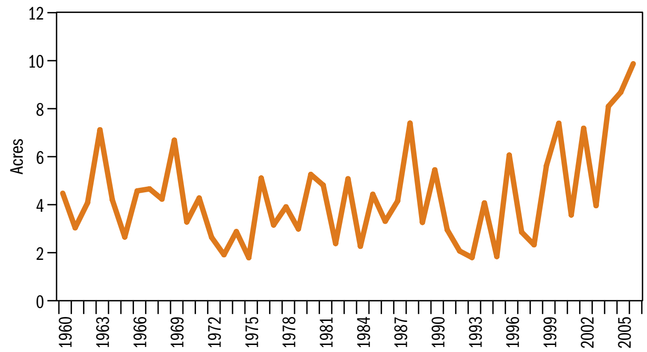

Figure 4c.6. Acres of Wildland Fire in the United States, 1960–2006.

Source: National Interagency Fire Center, 2008.

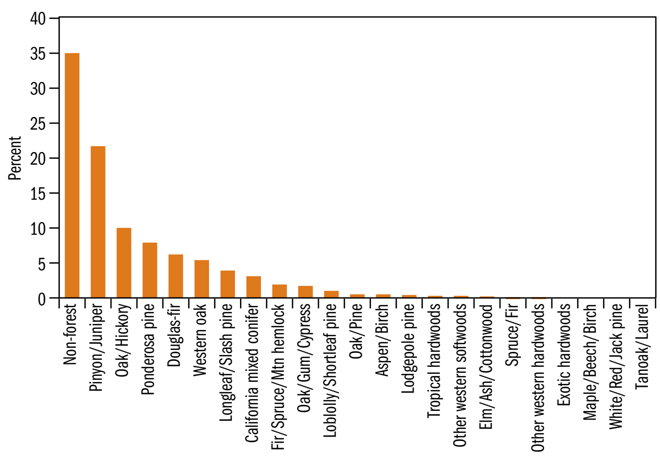

Figure 4c.7. Estimated percentage of acres within 2004 wildfire areas by forest-type group, United States.

Source: Forest Service Remote Sensing Applications Center, Salt Lake City, UT, May 2007.

Air Pollution

Poor air quality affects the health of all living organisms, including trees. FIA measures two indicators of air quality—lichen communities and ozone (O_3) injury to forest plants. Lichens are highly sensitive to pollutants such as acid rain, sulfur dioxide, and nitrogen and, as such, are excellent air quality bioindicators. Using multivariate models, lichen community data are used to assess air quality at each FIA plot and to identify risks to forest health. Ozone is a chemical compound that occurs naturally in the Earth's atmosphere but is also formed in the troposphere by reaction of vehicle and manufacturing emissions with sunlight. Ozone directly damages forest vegetation and has a variety of ecological effects on forested landscapes, with the potential to alter species composition, soil moisture, and fire regimes and to influence pest interactions (Coulston et al. 2004; Lefohn 1997).

Air Pollution—Lichen Community Diversity

With 12 years of data from 2,486 FIA and Forest Health Monitoring plots spanning the 48 contiguous States, we have found that lichen species diversity is correlated with air quality. Species richness, defined as the number of lichen species found on a FIA lichen plot, is the simplest of the Lichen Indicator metrics and the only metric available for all sampled plots. Species richness reflects many influences on lichens at a plot, including climate, stand structure, and air quality. These influences on eastern forests are different than on western forests, so we look at lichen diversity patterns in the two halves of the country separately (fig. 4c.8).

In the East, lichen species richness tends to be lower in areas of higher nitrate (NO_3) and ammonium (NH_4) pollution, as determined in a recent study by Will-Wolf et al. (N.d.). These two pollutants, together with elevation, are important predictors of large-scale lichen diversity patterns in eastern forests. Pollution peaks in the Central Midwest, extending to the Ohio Valley and Boston-Washington, DC, urban/industrial corridors, where high-diversity plots are conspicuously lacking (Will-Wolf et al., N.d.). This region is part of the Eastern Deciduous ecoregion analysis group, which has the lowest average species richness. By contrast, lichen diversity across the western half of the contiguous United States is not so closely associated with NO_3 and NH_4, which occur at far lower concentrations than in the East. Pollution in the West is more closely linked to scattered hot spots of agriculture and urbanization as dictated by the various mountain ranges (Jovan and McCune 2006). Lichen species richness is instead intimately tied to elevation, especially when considered at the large geographic scale presented in figure 4c.8. Smaller-scale investigations of lichen communities, however, have indeed documented more localized air quality impacts in which NO_3 and especially NH_4 both are believed to play an important role (Geiser and Neitlich 2007, Jovan and McCune 2005).

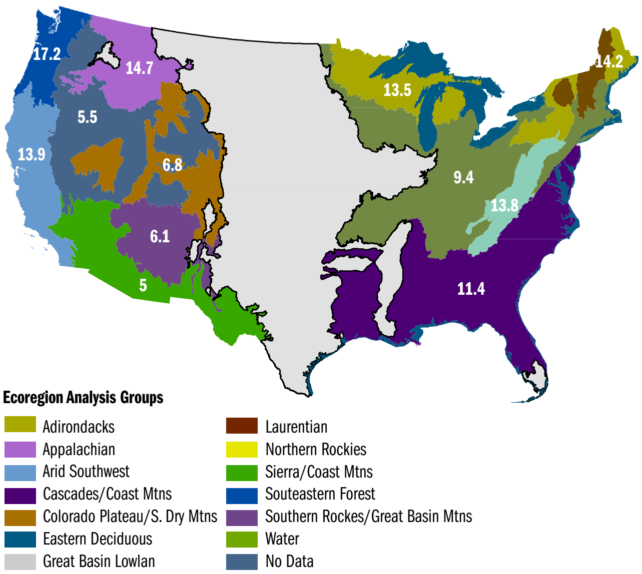

Figure 4c.8. Average lichen species richness by ecoregion group.

Sources: Bailey (1983, 1989), Cleland et al. (2005), Forest Inventory and Analysis plot data.

Air Pollution—Ozone Concentrations

The U.S. Environmental Protection Agency (EPA) provides information on the ozone concentration at points across the United States. Combined with FIA data collected on plots designed to detect ozone damage on sensitive species, this information can be used to locate sites for further research regarding air quality impacts on forest species.

U.S. EPA data show ambient ozone concentrations to be highest at points in the Sierra Nevada, some areas of the semiarid Western States, and scattered points along the Southern Appalachian piedmont, northeast coast, and Great Lakes ecological regions, where major cities and travel corridors occur (fig. 4c.9). Plot data from FIA show similar trends with more damage detected on sensitive plant species in the following areas than anywhere else in the United States: the Sierra Nevada; the area east of Los Angeles; the travel corridor of Interstate 85 across the Southern States of Georgia, South Carolina, and North Carolina; the urban hotspots of Atlanta, GA, Cincinnati, OH, and Buffalo, NY; and the greater Washington, DC, area (fig 4c.10) (Campbell et al. 2007). The Midwestern and Northwestern States, along with Maine, Vermont, and New Hampshire, appear to have the lowest levels of ozone concentration and damage to forest species in the entire United States (Appendix C, table 51).

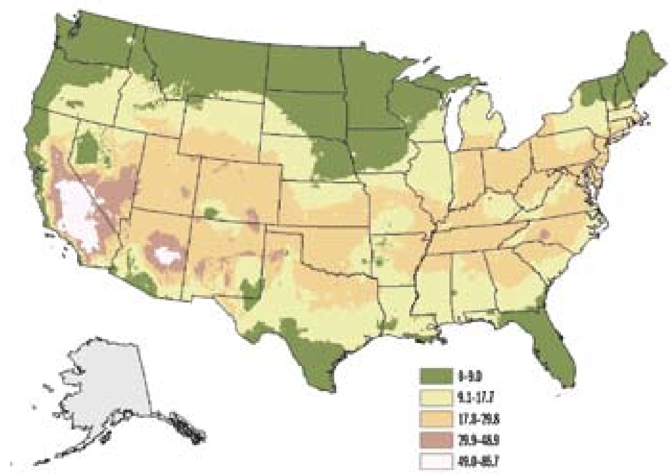

Figure 4c.9. Mean SUM06 values for 2000-2004. SUM06 is "a measure of vegetation exposure to ozone during the growing season."

Source: EPA (2007). Modeled map by Teague Pritchard, Wisconsin Department of Natural Resources, Madison, WI.

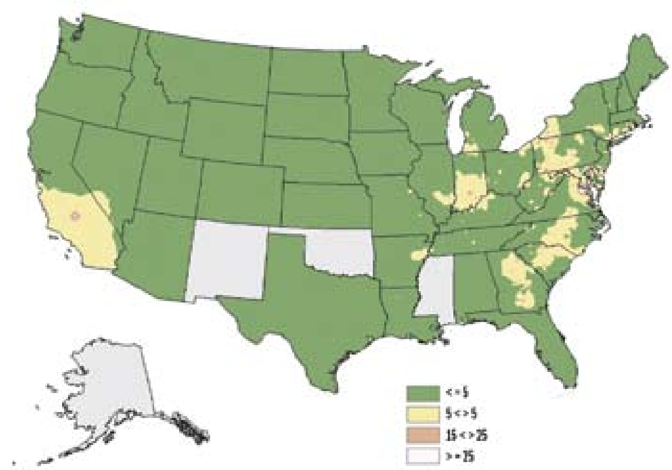

Figure 4c.10. Mean biosite index estimates and risk to forests of injury from ozone exposure, 2000–06: (<5 = little foliar injury; 5<>15 = light foliar injury; 15<>25 = moderate injury; ≥ 25 = severe foliar injury).

Source: FIA ozone plot data. Modeled map by John Coulston, FIA, Knoxville, TN.

Literature Cited

Amacher, M.C.; O'Neil, K.P.; Perry, C.H. 2007. Soil vital signs: a new Soil Quality Index (SQI) for assessing forest soil health. Res. Pap. RMRS-RP-65WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 12 p.

Bailey, R.G. 1983. Delineation of ecosystem regions. Environmental Management. 7: 365-373.

Bailey, R.G. 1989. Explanatory supplement to ecoregions map of the continents. Environmental Conservation. 16: 307-309.

Blackard, J.; Finco, M.; Helmer, E. [et al.]. [In press]. Mapping U.S. forest biomass using nationwide inventory data and MODIS-based information. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Campbell, S.J.; Wanek, R.; Coulston, J.W. 2007. Ozone injury in west coast forests: 6 years of monitoring. Gen. Tech. Rep. PNW-GTR-722. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 53 p.

Cleland, D.T.; Freeouf, J.A.; Keys, J.E. [et al.]. 2005. Ecological subregions: sections and subsections for the conterminous United States [colored map, 1:3,500,000; CD-ROM, GIS coverage in ArcINFO format]. Washington, DC: U.S. Department of Agriculture, Forest Service.

Cost, N.D.; Howard, J.O.; Mead, B. McWilliams, W.H.; Smith,.W.B.; VanHooser, D.D.; Wharton, E.H. 1990.The forest biomass resource of the United States. Gen. Tech. Rep. WO-57, Washington, DC: U.S. Department of Agriculture, Forest Service. 21 p.

Coulston, J.W.; Riitters, K.H.; Smith, G.C. 2004. A preliminary assessment of Montreal Process indicators of air pollution for the United States. Environmental Monitoring and Assessment. 95: 57-74.

Cronan, C.S.; Grigal, D.F. 1995. Use of calcium/aluminum ratios as indicators of stress in forest ecosystems. Journal of Environmental Quality. 24(2): 209-226.

Doran, J.W.; Parkin, T.B. 1994. Defining and assessing soil quality. In: Doran, J.W. [et al.], eds. Defining soil quality for a sustainable environment. SSSA Spec. Pub. 35. Madison, WI: SSSA: 3-21.

Forest Service. 2007a. Forest insect and disease conditions in the United States, 2006. Forest Health Protection Report. Washington, DC: U.S. Department of Agriculture, Forest Service. 176 p.

Forest Service. 2007b. Forest insect and disease risk map. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team. http://www.fs.fed.us/foresthealth/technology/nidrm.shtml. (24 March 2008).

Geiser, L.H.; Neitlich, P.N. 2007. Air pollution and climate gradients in western Oregon and Washington indicated by epiphytic macrolichens. Environmental Pollution. 145: 203-218.

Harper, R.; Turner, J.; Coulston, J. [et al.]. 2007. Personal communication. Analysis of Georgia and Florida timber volume and value in wildfire areas. Southern Research Station, Forest Inventory and Analysis Program, 4700 Old Kingston Pike, Knoxville, TN 37919.

Jovan, S.; McCune, B. 2005. Air-quality bioindication in the greater Central Valley of California, with epiphytic macrolichen communities. Ecological Applications. 15: 1712-1726.

Jovan, S.; McCune, B. 2006. Using epiphytic macrolichen communities for biomonitoring ammonia in forests of the Greater Sierra Nevada, California. Water, Air, and Soil Pollution. 170: 69-93.

Krist, F. 2007. Personal communication. Aerial survey defoliation acres. Forest Health Technology Enterprise Team. U.S. Department of Agriculture, Forest Service, FHP/FHTET 2150 Centre Ave., Bldg. A, Suite 331, Fort Collins, CO 80526.

Lefohn, A.S., Jackson, W.; Shadwick, D.S.; and Knudsen, H.P. 1997. Effect of Surface Ozone Exposures on Vegetation Grown in the Southern Appalachian Mountains: Identification of Possible Areas of Concern. Atmospheric Environment. 31(11): 1695-1708.

McBride, M. 1994. Environmental chemistry of soils. New York: Oxford University Press. 406 p.

Moser, WK; Hansen, M.H.; Nelson, M.D.; McWilliams, W.H. 2008. The relationship of invasive groundcover plant presence to evidence of disturbance in the forests of the Upper Midwest of the United States. In: Kohli, R.K.; Jose, S.; Batish, D.R.; Singh, H.P., eds. Invasive Plants and Forest Ecosystems. CRC Press/Taylor and Francis. 53 p. In press.

National Interagency Fire Center (NIFC). 2008. http://www.nifc.gov/fire_info/fire_stats.htm. (24 March 2008).

O'Neill, K.P.; Amacher, M.C.; Perry, C.H. 2005. Soils as an indicator of forest health: a guide to the collection, analysis, and interpretation of soil indicator data in the Forest Inventory and Analysis program. Gen. Tech. Rep. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 53 p.

Smith, J.E.; Heath, L.S.; Nichols, M.C. 2007. U.S. forest carbon calculation tool user's guide: forestland carbon stocks and net annual stock change. Gen. Tech. Rep. NRS-13, Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 28 p. [CD-ROM]

Smith, W.B.; Miles, P.D.; Vissage, J.S. Pugh, S.A. 2004. Forest Resources of the United States, 2002. Gen. Tech. Rep. NC-241. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 137 p.

U.S. Environmental Protection Agency (EPA). 2007. http://www.epa.gov. (24 March 2008) .

U.S. Environmental Protection Agency (EPA). 2007. Inventory of U.S. greenhouse gas emissions and sinks: 1990-2005. EPA 430-R-07-002. Washington, DC: U.S. Environmental Protection Agency, Office of Atmospheric Programs. 393 p.

Will-Wolf, S.; Ambrose, M.; Morin, R. Manuscript in preparation. Relationship of a lichen species diversity indicator to environmental factors across the continental United States. In: Conkling, B.L., ed. Forest health monitoring 2007: national technical report. Author can be reached at Department of Botany, University of Wisconsin, 430 Lincoln Drive, Madison, WI 53706.

Woodall, C.W.; Charney, J.J.; Liknes, G.C.; Potter, B.E. 2005. What's the fire danger now? Linking fuel inventories with atmospheric data. Journal of Forestry. 103: 293-298.