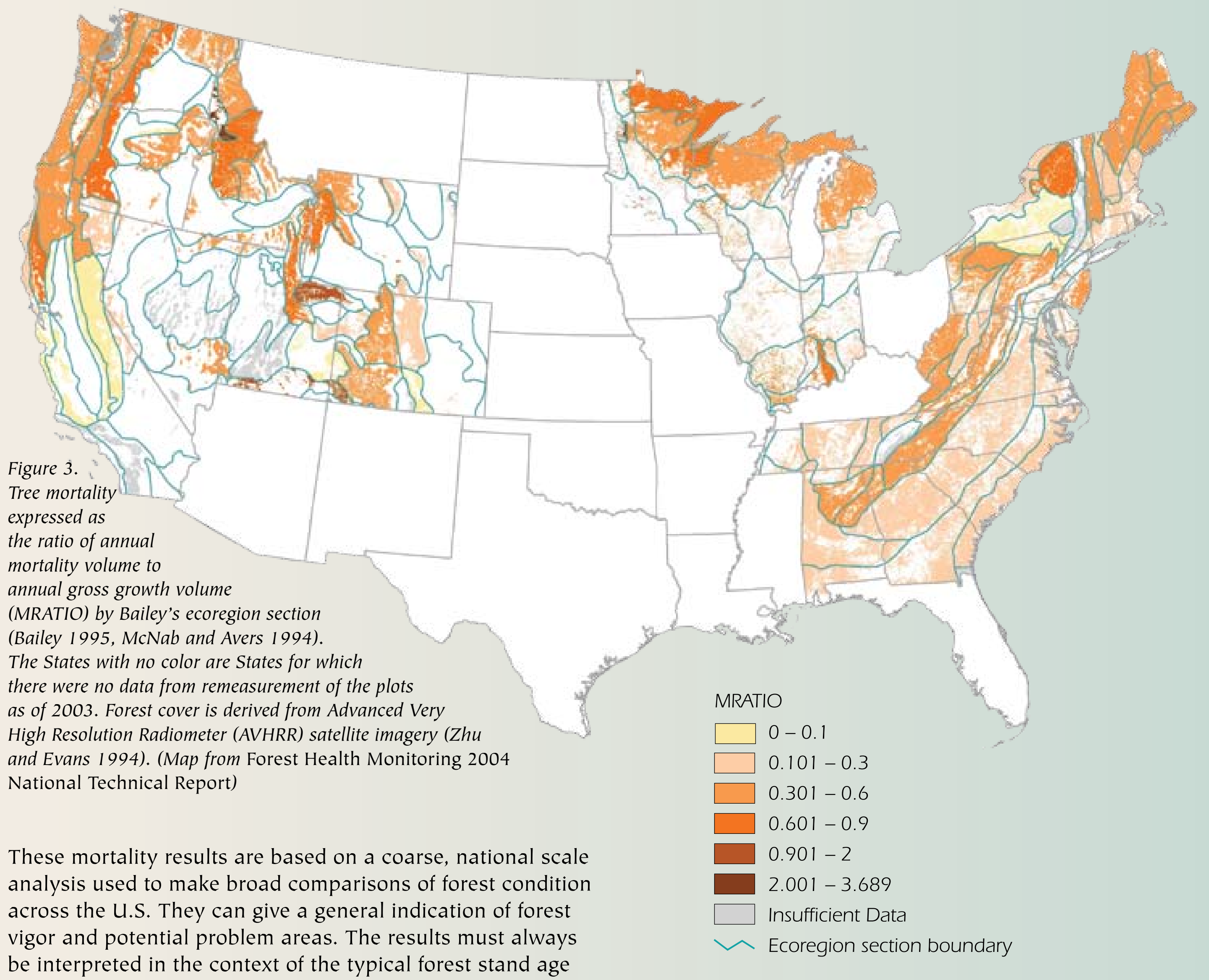

Figure 3. Tree mortality expressed as the ratio of annual mortality volume to annual gross growth volume (MRATIO) by Bailey's ecoregion section (Bailey 1995, McNab and Avers 1994). The States with no color are States for which there were no data from remeasurement of the plots as of 2003. Forest cover is derived from Advanced Very High Resolution Radiometer (AVHRR) satellite imagery (Zhu and Evans 1994). (Map from Forest Health Monitoring 2004 National Technical Report)

These mortality results are based on a coarse, national scale analysis used to make broad comparisons of forest condition across the U.S. They can give a general indication of forest vigor and potential problem areas. The results must always be interpreted in the context of the typical forest stand age and management regime in any given region. For example, in a region of mostly old-growth forest, one would expect to see an MRATIO of about 1 because in old-growth forests, growth is about equal to mortality. However, an MRATIO of 1 would indicate potential forest health problems in a region of mostly young, even-aged forest stands.

The value of this approach to analyzing mortality will increase as data are collected over longer time periods and we can analyze any long-term trends. It is our hope to apply this approach to finer scale forest inventory data being collected by FIA to produce improved estimates in the future.

The analyses presented here are explained in greater detail in the cited FHM National Technical Reports. These reports are available on the Web at: **www.srs.fs.usda.gov/pubs**. Printed copies of the reports may be requested by writing to:

Science Delivery
U.S. Forest Service
Southern Research Station
200 W.T. Weaver Boulevard
Asheville, NC 28804-3454

or by sending email to: **pubrequest@fs.fed.us**

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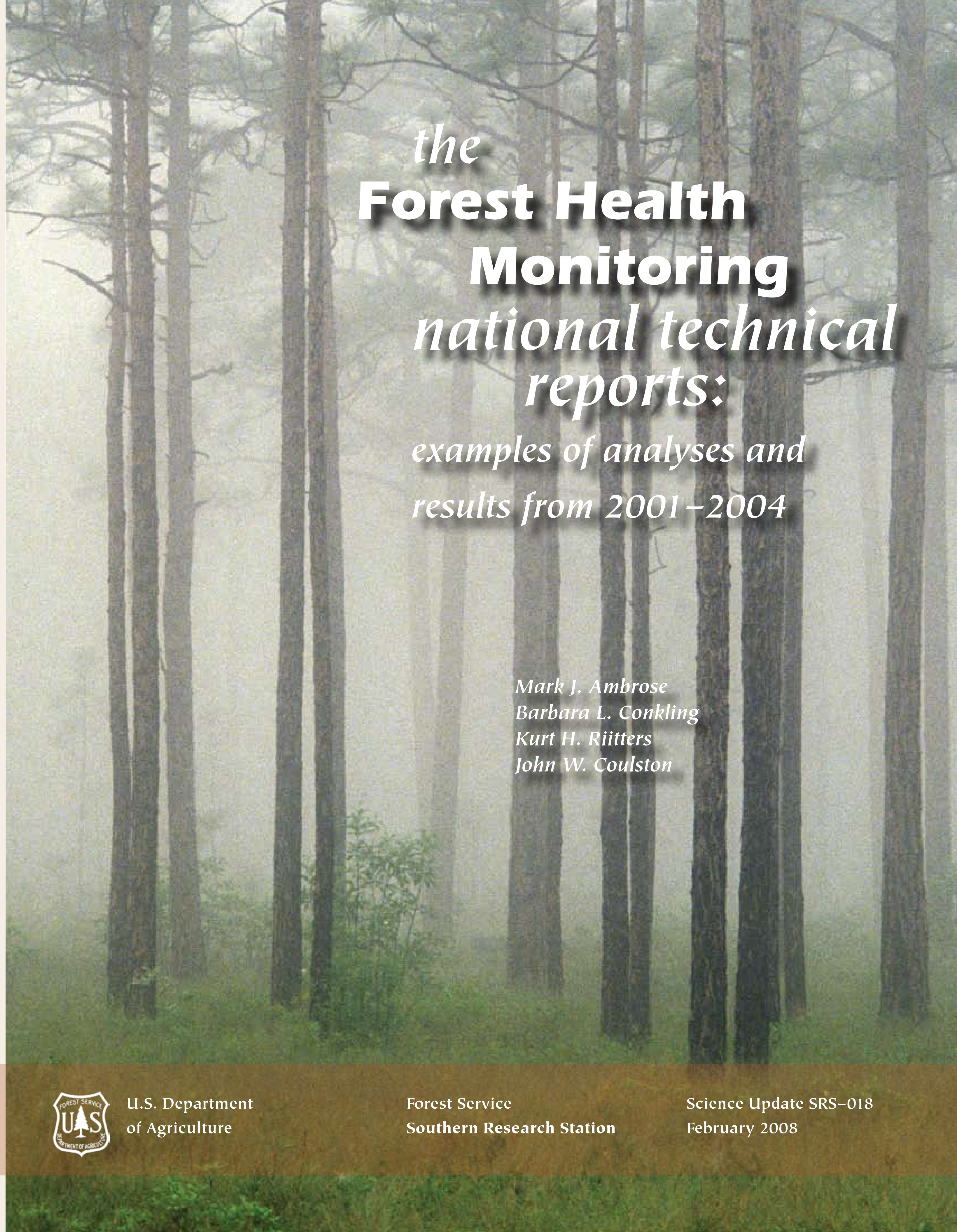

the Forest Health Monitoring *national technical reports:*

examples of analyses and results from 2001–2004

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Forest Service
Southern Research Station
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Forest Health Monitoring (FHM) is a national program designed to determine the status, changes, and long-term trends in forest condition on all forested lands in the U.S. FHM is a partnership including the U.S. Forest Service, National Association of State Foresters, other State and Federal agencies, and universities. Forest Service programs that cooperate in FHM activities include Forest Inventory and Analysis (FIA), which maintains a network of permanent ground plots on which forest health variables are measured, and Forest Health Protection (FHP), which conducts annual aerial and ground surveys of damage from forest insects and diseases.

FHM conducts extensive, coarse-scale monitoring, also known as detection monitoring, to detect potential forest health problems. The program also supports evaluation monitoring projects covering smaller regions to examine and evaluate changes in forest condition that may have been detected through monitoring, and intensive site monitoring research projects that will lead to a better understanding of how forest ecosystems function. Using data from ground plots and surveys, aerial surveys, and other data sources, FHM develops analytical approaches to address and interpret forest health issues that potentially affect the sustainability of U.S. forest ecosystems. Reports on forest health at national, regional, and State levels are regularly produced and provide assessments of important forest health issues for scientists, policy-makers, land managers, and the public. The reports are available on the FHM web site (www.fhm.fs.fed.us) or by contacting one of the FHM Program Managers listed on the back of this brochure.

FHM has recently published four national reports on the health of U.S. forests (Conkling and others 2005, Coulston and others 2005a, Coulston and others 2005b, Coulston and others 2005c). In these reports FHM examined a broad range of indicators of forest health using data from a variety of sources. Some indicator analyses used data from the FIA program such as tree mortality, crown condition, ozone bioindicator plant damage, lichen species diversity, various soils characteristics, understory vegetation characteristics, and characterization of down woody material. Other indicator analyses, such as forest insect and disease occurrence, forest fragmentation, climate, air pollution, and forest fires, used data from other Forest Service and non-Forest Service databases.

This brochure presents some examples from the first four FHM national technical reports as an introduction to the kinds of information available in the national technical reports. The example indicators that follow are drought and air pollution, which are stressors that affect forest health; landscape structure and forest fragmentation; and tree mortality. Indicators of forest health were generally analyzed by broad ecological regions, regions characterized by similar climate, vegetation, geology, and soils. A sample of analyses and results from these four reports follows.

Forest Fragmentation and Roads

Fragmentation refers to the direct loss of forest and the division of the remainder into smaller pieces. Although the actual extent of forest has increased in some areas of the U.S., the spatial patterns indicate extensive forest fragmentation, which affects the habitat quality for mammal, reptile, bird, and amphibian species found in forests. Some species are adapted to edges or other disturbed habitats. However, changes in forest spatial patterns more often result in decreased habitat suitability, reduced ability of wildlife to move through the landscape, and the spread of invasive species from disturbed edges. Even small perforations, areas of nonforest within forested areas, introduce these impacts deeper into the forest.

FHM used landcover maps derived from satellite images to model forest fragmentation across the conterminous U.S. (Riitters and Wickham 2003, Vogelman and others 2001). The findings indicate that forest fragmentation is pervasive and extensive, with three-fourths of all forest found in or near the edges of large, heavily fragmented regional forests. Most of the large interior forests in the U.S. are publicly owned, or unsuitable for agriculture or urban development.

Fragmentation caused by roads is of special interest because the effects of roads extend tens to hundreds of yards from the roads themselves, altering habitats and water drainage patterns, disrupting wildlife movement, introducing exotic plant species, and increasing noise levels. The land development that follows roads out into rural areas usually leads to more roads, an expansion process that only ends at natural or legislated barriers. To analyze nearness of roads at the regional scale, FHM used a national road map to estimate the proportion of land area within certain distances of roads (Geographic Data Technology 2002).

Results showed that 20 percent of all land area was located within 417 feet (127 meters) of the nearest road, and 50 percent was within 1253 feet (382 meters). Only 18 percent of U.S. land area was more than 0.6 miles (1000 meters) from a road, and only 3 percent was more than 3.1 miles (5000 meters) away. Overall, forest land was slightly more remote from roads than other landcover types. While the actual size of a road influence zone depends on local circumstances, the sheer pervasiveness of roads means that few places in the U.S. are immune to their influences.

Drought

Most forests periodically experience drought to some degree. Drought is a natural occurrence, and forests are adapted to survive periodic droughts. However plants grow more slowly during droughts, and droughts can make forests more susceptible to certain insects and more vulnerable to fire.

Climate data are collected by the National Climate Data Center (NCDC). With these data the NCDC calculates the Palmer Drought Severity Index (PDSI) monthly by climate division. The PDSI is based on total rainfall, the rainfall periodicity, and soil characteristics. The NCDC archive contains monthly estimates of PDSI from 1895 to the present.

The total number of months of drought over the period from 1895 through 2003 was calculated for each ecological region of the conterminous United States using the NCDC data (National Climate Data Center 1994). The drought occurrence over these 109 years served as a historical account or reference point for each ecological region. These historical accounts were then put on a 10-year basis and compared to the number of months of growing season drought from 1994 through 2003. Drought deviation (fig. 1) was calculated as the difference between the expected number of months of drought over a 10-year period (from the historical data) and the actual months of drought over this recent 10-year period.

The decade 1994 through 2003 was evaluated and the results are shown in figure 1. The negative values (greens) indicate less drought than expected; the positive values (browns) indicate more drought than expected. More than the expected amount of drought occurred across much of the Western U.S., while most of the Eastern U.S. experienced close to the expected amount of drought or less than the expected amount from 1994 through 2003; exceptions in the East were the Florida coastal lowlands, Blue Ridge Mountains, and southern New Jersey area.

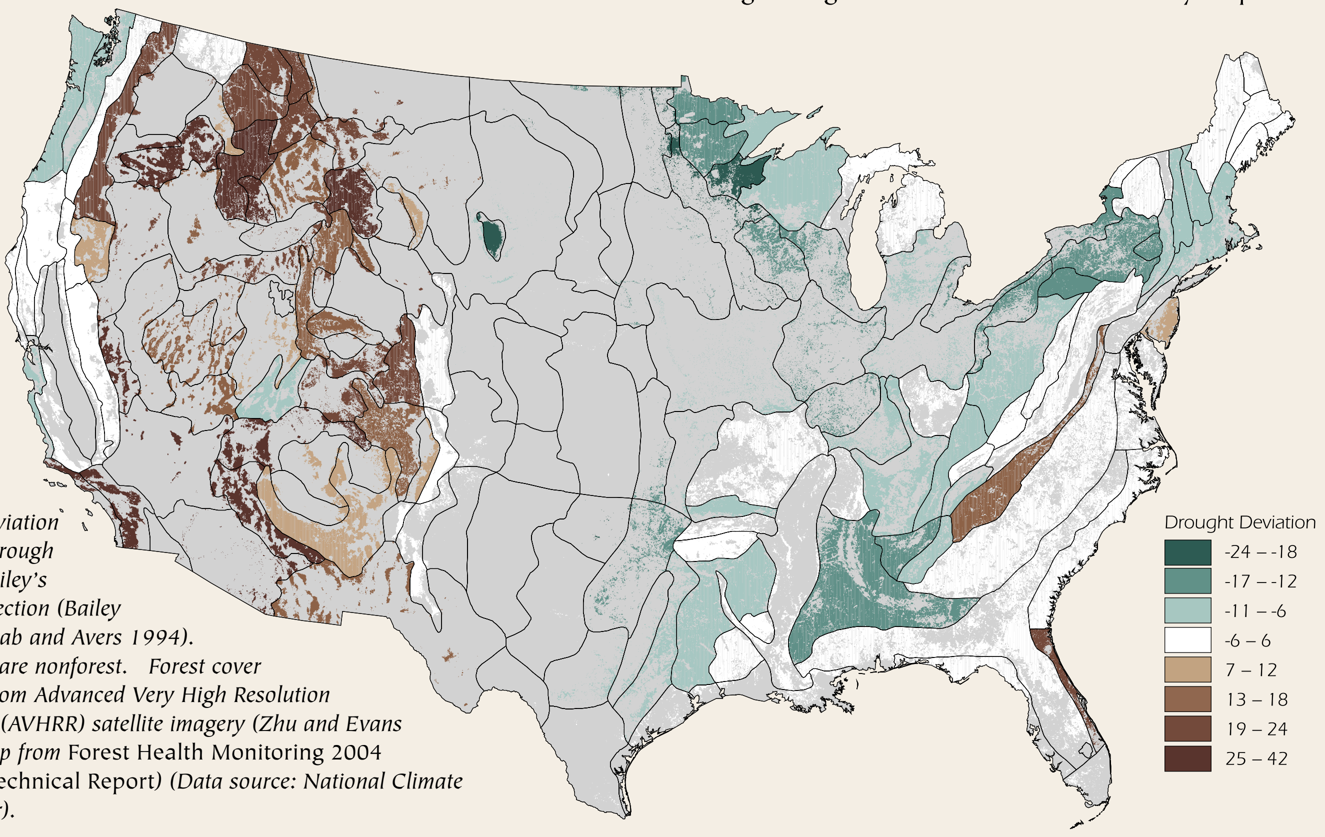

Figure 1. Drought deviation for 1994 through 2003 by Bailey's ecoregion section (Bailey 1995, McNab and Avers 1994). Gray areas are nonforest. Forest cover is derived from Advanced Very High Resolution Radiometer (AVHRR) satellite imagery (Zhu and Evans 1994). (Map from Forest Health Monitoring 2004 National Technical Report) (Data source: National Climate Data Center).

Ozone Bioindicator Plants

High levels of air pollution can be harmful to forest trees. Polluted air can sometimes travel very long distances, possibly affecting forests far from the urban areas that contain the major pollution sources. Ozone pollution can reduce tree growth, affect tree species composition, and make some trees more vulnerable to certain pests (Chappelka and Samuelson 1998). Ozone can also cause direct injury to the leaves of many species.

FHM developed a biomonitoring method to monitor ozone stress on forests. Bioindicator plant species are selected because they are known to be sensitive to ozone. Ozone exposure produces distinct visible foliar injury on these plants that is easy to identify. A network of ozone biomonitoring plots (currently maintained by the FIA program) has been set up across the U.S. in open areas containing ozone-sensitive species. Because it would be very difficult and expensive to monitor the damage to leaves at the tops of trees, FHM instead samples the foliage of ozone-sensitive herbs, shrubs and trees growing in open areas near the forest. The damage found on these bioindicator plants reflects the damage that ozone may be having on trees in the region.

A plot-level index was calculated based on the amount and severity of ozone damage to the leaves of each plant and the number of species evaluated at each site. The plot data were then used to calculate the average ozone biosite index for ecological regions of the U.S. Based on analyses presented in the Forest Health Monitoring 2003 National Technical Report (Coulston and others 2005b), ozone-induced foliar injury to bioindicator plants occurred more frequently in the Eastern U.S. than in the West from 1997 through 2001.

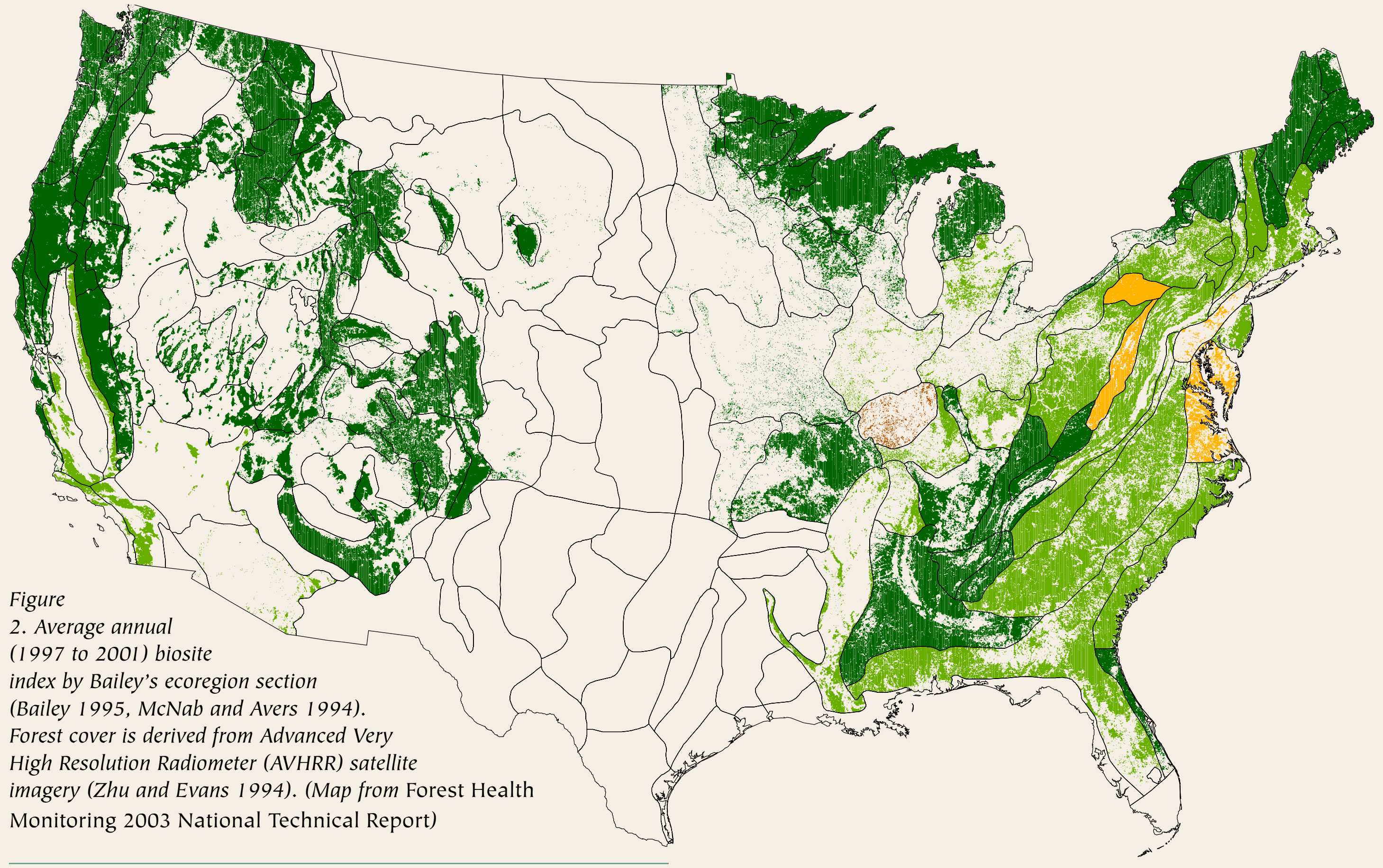

Figure 2. Average annual (1997 to 2001) biosite index by Bailey's ecoregion section (Bailey 1995, McNab and Avers 1994). Forest cover is derived from Advanced Very High Resolution Radiometer (AVHRR) satellite imagery (Zhu and Evans 1994). (Map from Forest Health Monitoring 2003 National Technical Report)

Bioindicator response	Presumed risk	Possible impact
Little or no foliar injury	None	Visible injury to highly sensitive species, e.g., black cherry
Light to moderate foliar injury	Low	Visible injury to moderately sensitive species, e.g., tulip poplar
Moderate to severe foliar injury	Moderate	Visible and invisible injury. Tree-level response.
Severe foliar injury	High	Visible and invisible injury. Ecosystem-level response.

There is not yet any evidence linking FHM ozone bioindicator response data to a specific tree health problem or a regional decline. Nevertheless, the mapped data demonstrate that plant-damaging concentrations of ozone air pollution are widespread in parts of the landscape. Continued monitoring and analysis will be important when determining probable or significant ozone impacts.

Mortality

Tree mortality is a natural process in forested ecosystems, and mortality rates can be expected to vary with forest type and region of the U.S. Therefore, mortality does not always indicate a forest health problem. However, very high mortality rates or unexpected changes in tree mortality can indicate possible forest health issues.

Using available FHM and FIA plot data through 2002, tree mortality was analyzed relative to tree growth rates. For each ecological region the MRATIO, which is the ratio of annual mortality volume to annual gross growth volume, was calculated. The MRATIO can be large if a forest stand is senescent and losing many older trees. If forests are not naturally senescing, a high MRATIO (> 0.6) may indicate high mortality due to some acute cause (insects or pathogens) or generally deteriorating forest health conditions. When MRATIO is greater than 1, mortality exceeds growth, meaning that live tree volume is decreasing.

Mortality estimates from the Forest Health Monitoring 2004 National Technical Report (Coulston and others 2005c) identify a few ecological regions that had an MRATIO greater than 0.6, indicating that the loss of trees relative to growth is fairly high, but the majority of areas for which there were data did not have a high MRATIO (fig. 3). Possible causes for high mortality in particular regions (for example fire or insects) are presented in the full national report.