forests cover a vast area of the United States, 304 million ha, or approximately one-third of the Nation’s land area (Smith and others 2009). These forests possess substantial ecological and socioeconomic importance. Both their ecological integrity and their continued capacity to provide goods and services are of concern in the face of a long list of threats, including insect and disease infestation, fragmentation, catastrophic fire, invasive species, and the effects of climate change.

Assessing and monitoring the health of these forests are critical and challenging tasks. This is reflected within the Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests (Montréal Process Working Group 1995), which the Forest Service, U.S. Department of Agriculture, uses as a forest sustainability assessment framework (USDA Forest Service 2004, 2011a). While there is no universally accepted definition of forest health, the current understanding of ecosystem dynamics suggests that healthy ecosystems are those that are able to maintain their organization and autonomy over time while remaining resilient to stress (Costanza 1992), and that evaluations of forest health should emphasize factors that affect the inherent processes and resilience of forests (Kolb and others 1994, Raffa and others 2009). This report, the 11th in an annual series produced by the Forest Health Monitoring (FHM) Program of the Forest Service, attempts to quantify the status of, changes to, and trends in a wide variety of such indicators of forest health. These indicators encompass forest insect and disease activity, forest fragmentation, introduced plant species, lichen diversity, and ozone injury.

This report has three specific objectives. The first is to present information about forest health from a national perspective, or from a multi-State regional perspective when appropriate, using data collected by the Forest Health Protection (FHP) and Forest Inventory and Analysis (FIA) programs of the Forest Service, as well as from other sources available at a wide extent. The chapters that present analyses at a national-scale, or multi-State regional scale, are divided between section 1 and section 2 of the report. Section 1 presents results from the analyses of forest health data that are available on an annual basis, allowing for the detection of trends over time and changes from one year to the next. Section 2 presents longer-term forest health trends, in addition to describing new techniques for analyzing forest health data at national or regional scales (the second objective of the report). While in-depth interpretation and analysis of specific geographic or ecological regions are beyond the scope of these parts of the report, the chapters in sections 1 and 2 present information that can be used to identify areas that may require investigation at a finer scale.

The second objective of the report is to present new techniques for analyzing forest health data as well as new applications of established techniques, presented in selected chapters of section 2. Examples in this report are chapter 6, which demonstrates an approach to improve national assessments of forest fragmentation by incorporating information about the specific forest types that are
fragmented; and chapter 7, which uses FIA phase 3 data to examine factors important in determining the regional distribution of invasive plants in the upper Midwest and in the Northeastern United States.

The third objective of the report is to present results of recently completed Evaluation Monitoring (EM) projects funded through the FHM national program. These project summaries, presented in section 3, determine the extent, severity and/or cause of forest health problems (FHM 2011), generally at a finer scale than that addressed by the analyses in sections 1 and 2. Each chapter in section 3 contains an overview of an EM project, key results, and contacts for more information.

When appropriate throughout this report, authors use Bailey’s revised ecoregions (Cleland and others 2007) as a common ecologically based spatial framework for their forest health assessments (fig. 1.1). Specifically, when the spatial scale of the data and the expectation of an identifiable pattern in the data are appropriate, authors use ecoregion sections or provinces as assessment units for their analyses. In Bailey’s hierarchical system, the two broadest ecoregion scales, domains and divisions, are based on large ecological climate zones, while each division is broken into provinces based on vegetation macro features (Bailey 1995). Provinces are further divided into sections, which may be thousands of square kilometers in extent and are expected to encompass regions similar in their geology, climate, soils, potential natural vegetation, and potential natural communities (Cleland and others 1997).
Figure 1.1—Ecoregion provinces and sections for the conterminous United States (Cleland and others 2007) and Alaska (Nowacki and Brock 1995). Ecoregion sections within each ecoregion province are shown in the same color.
DATA SOURCES

Forest Service data sources included in this report are FIA annualized phase 2 and phase 3 survey data and ozone bioindicator plant data (Bechtold and Patterson 2005), FHP insect and disease detection survey forest mortality and defoliation data for 2010, Moderate Resolution Imaging Spectroradiometer (MODIS) Active Fire Detections for the United States database for 2010 (USDA Forest Service 2011b), and forest cover data developed from MODIS satellite imagery by the U.S. Forest Service Remote Sensing Applications Center. Other sources of data are Parameter-Elevation Regression on Independent Slopes (PRISM) climate mapping system data (PRISM Group 2010) and the 2001 National Land Cover Database (NLCD) map (Homer and others 2007).

A major source of data for FHM analyses has been the FIA program, which collects forest inventory information across all forest land ownerships in the United States. FIA maintains a network of more than 125,000 permanent forested ground plots across the conterminous United States and southeastern Alaska, with a sampling intensity of approximately one plot per 2,428 ha. FIA phase 2 encompasses the annualized inventory measured on plots at regular intervals, with each plot surveyed every 5 to 7 years in most Eastern States, but with plots in the Rocky Mountain and Pacific regions surveyed once every 10 years (Reams and others 2005). The standard 0.067-ha plot (fig. 1.2) consists of four 7.315-m radius subplots (approximately 168.6 m² or 1/24 acre), on which field crews measure trees at least 12.7 cm in diameter. Within each of these subplots is nested a 2.073-m radius microplot (approximately 13.48 m² or 1/300th acre), on which crews measure trees smaller than 12.7 cm in diameter. A core-optional variant of the standard design includes four “macroplots,” each with radius of 17.953 m, or approximately 0.1012 ha, that originates at the center of each subplot (Woudenberg and others 2010).

Figure 1.2—The Forest Inventory and Analysis mapped plot design. Subplot 1 is the center of the cluster with subplots 2, 3, and 4 located 120 feet away at azimuths of 360°, 120°, and 240°, respectively (Woudenberg and others 2010).
FIA phase 3 plots represent a subset of these phase 2 plots, with one phase 3 plot for every 16 standard FIA phase 2 plots. In addition to traditional forest inventory measurements, data for a variety of important ecological indicators are collected from phase 3 plots, including tree crown condition, lichen communities, down woody material, soil condition, and vegetation structure and diversity, while data on ozone bioindicator plants are collected on a separate grid of plots (Woodall and others 2010, 2011). Most of these additional forest health indicators were measured as part of the FHM Detection Monitoring ground plot system prior to 2000\(^1\) (Palmer and others 1991).

**THE FOREST HEALTH MONITORING PROGRAM**

The national FHM program is designed to determine the status, changes, and trends in indicators of forest condition on an annual basis, and covers all forested lands through a partnership encompassing the Forest Service, State foresters, and other State and Federal agencies and academic groups (FHM 2011). The FHM program utilizes data from a wide variety of data sources, both inside and outside the Forest Service, and develops analytical approaches for addressing forest health issues that affect the sustainability of forest ecosystems. The FHM program has five major components (fig. 1.3):

---

• Detection Monitoring—nationwide standardized aerial and ground surveys to evaluate status and change in condition of forest ecosystems (sections 1 and 2 of this report);

• Evaluation Monitoring—projects to determine extent, severity, and causes of undesirable changes in forest health identified through Detection Monitoring (section 3 of this report);

• Intensive Site Monitoring—projects to enhance understanding of cause-effect relationships by linking Detection Monitoring to ecosystem process studies and to assess specific issues, such as calcium depletion and carbon sequestration, at multiple spatial scales (section 3 of this report);

• Research on Monitoring Techniques—work to develop or improve indicators, monitoring systems, and analytical techniques, such as urban and riparian forest health monitoring, early detection of invasive species, multivariate analyses of forest health indicators, and spatial scan statistics (section 2 of this report);

• Analysis and Reporting—synthesis of information from various data sources within and external to the Forest Service to produce issue-driven reports on status and change in forest health at national, regional, and State levels (sections 1, 2, and 3 of this report).

The FHM program, in addition to national reporting, generates regional and State reports. These reports may be produced with FHM partners, both within the Forest Service and in State forestry and agricultural departments. Some examples include reports on disturbance and forest conditions (Steinman 2004), urban monitoring methods (Lake and others 2006), health conditions in national forests (Morin and others 2006), urban forest health monitoring (Cumming and others 2006, 2007), crown conditions (Randolph 2010, Randolph and Moser 2009), and ozone monitoring (Rose and Coulston 2009). The Forest Health Highlights report series, available on the FHM Web site at www.fs.fed.us/foresthealth/fhm, is produced by the FHM regions in cooperation with their respective State partners.

The FHM program and its partners also produce reports and journal articles on monitoring techniques and analytical methods, including forest health data (Smith and Conkling 2004), soils as an indicator of forest health (O’Neill and others 2005), crown-condition classification (Schomaker and others 2007), sampling and estimation procedures for vegetation diversity and structure (Schulz and others 2009), and the overall forest health indicator program (Woodall and others 2010).

For more information, visit the FHM Web site at www.fs.fed.us/foresthealth/fhm.

This FHM national report is produced by national forest health monitoring researchers at the Eastern Forest Environmental Threat Assessment Center, which was established under the Healthy Forest Restoration Act to generate knowledge and tools needed to anticipate and respond to environmental threats. For more
information about the research team and about threats to U.S. forests, please visit www.
forestthreats.org/about.

LITERATURE CITED


Woodall, C.W.; Amacher, M.C.; Bechtold, W.A. [and others]. 2011. Status and future of the forest health indicators program of the USA. Environmental Monitoring and Assessment. 177:419-436.