CHAPTER 3.
Large-Scale Patterns of Forest Fire Occurrence in the Conterminous United States and Alaska, 2010

Kevin M. Potter

INTRODUCTION

Free-burning fire has been a constant ecological presence on the American landscape, the expression of which has changed as new climates, peoples and land uses have become predominant (Pyne 2010). It is an important ecological mechanism that shapes the distributions of species, maintains the structure and function of fire-prone communities, and is a significant evolutionary force (Bond and Keeley 2005).

At the same time, fire outside the historic range of frequency and intensity can have extensive economic and ecological impacts. As a result of intense suppression efforts during most of the 20th century, the number of acres burned annually decreased from approximately 16-20 million ha in the early 1930s to about 2 million ha in the 1970s (Vinton 2004). In some regions, plant communities are undergoing rapid compositional and structural changes as a result of fire suppression (Nowacki and Abrams 2008). At the same time, fires have become larger, more intense, and more damaging because of the accumulation of fuels (Pyne 2010). Current fire regimes on more than half of the forested area in the conterminous United States have been either moderately or significantly altered from historical regimes, potentially altering key ecosystem components such as species composition, structural stage, stand age, canopy closure, and fuel loadings (Schmidt and others 2002).

Fire suppression and the introduction of nonnative plants, in particular, have dramatically altered fire regimes (Barbour and others 1999). Additionally, fire regimes altered by global climate change could cause large-scale shifts in vegetation spatial patterns (McKenzie and others 1996). Quantifying and monitoring broad-scale patterns of fire occurrence across the United States can help provide a fuller understanding of the ecological and economic impacts of fire, and of the appropriate management and prescribed use of fire. Specifically, large-scale assessments of fire occurrence can help identify areas where specific management activities may be useful, or where research into the ecological and socioeconomic impacts of fires may be necessary.

METHODS

Annual monitoring and reporting of active wildland fire events using the Moderate Resolution Imaging Spectroradiometer (MODIS) Active Fire Detections for the United States database (USDA Forest Service 2011) allows analysts to spatially display and summarize fire occurrences (Coulston and others 2005, Potter 2012a, Potter 2012b, Potter 2013). These are defined as the satellite detection of wildland fire in a 1-km^2 pixel for one day, in a given year. The data are derived using the MODIS Rapid Response System (Justice and others 2002) from the thermal infrared bands of imagery collected daily by two satellites at a resolution of 1 km^2, with the center of a pixel recorded as a fire occurrence when the satellites' MODIS sensors identify the presence of a fire at the time of image collection (USDA Forest Service 2011). The data represent only whether a fire was active, because the MODIS sensors do not differentiate between a hot fire in a relatively small area (0.01 km^2, for example) and a cooler fire over a larger area (1 km^2, for example). The MODIS Active Fire database does well at capturing large fires, but may underrepresent rapidly burning, small and low-intensity fires, as well as fires in areas with frequent cloud cover (Hawbaker and others 2008).

The number of fire occurrences per 100 km^2 (10 000 ha) of forested area was determined for each ecoregion section in the conterminous United States (Cleland and others 2007) and Alaska (Nowacki and Brock 1995) for 2010. This forest fire occurrence density measure was calculated after screening out wildland fires on non-forested pixels using a forest cover layer derived from MODIS imagery by the Forest Service Remote Sensing Applications Center (USDA Forest Service 2008). The total number of fire occurrences across the conterminous States and Alaska was also calculated. The same approach was used to calculate the mean number of annual fire occurrences, per 100 km^2 (10 000 ha) of forested area, by ecoregion section for the first 10 full years of MODIS Active Fire data collection (2001-10).

Additionally, a Getis-Ord hot spot analysis (Getis and Ord 1992) in ArcMap 9.2 (ESRI 2006) was employed to identify forested areas in the conterminous United States with higher-than-expected fire occurrence density in 2010. The spatial units of analysis were cells of approximately 2 500 km^2 from a hexagonal lattice of the conterminous United States, intensified from hexagon coordinates for North America from the Environmental Monitoring and Assessment Program (White and others 1992). This cell size allows for analysis at a medium-scale resolution of approximately the same area as a typical county. Fire occurrence density values for each hexagon were quantified as the number of forest fire occurrences per 100 km^2 of forested area within the hexagon.

The Getis-Ord G_i* statistic was used to identify clusters of hexagonal cells with fire occurrence density values higher than expected by chance. This statistic allows for the decomposition of a global measure of spatial association into its contributing factors, by location, and is therefore particularly suitable for detecting non-stationarities in a data set, such as when spatial clustering is concentrated in one subregion of the data (Anselin 1992). Non-stationarities are processes whose statistical properties vary over time or space.

Briefly, G_i* sums the differences between the mean values in a local sample, determined in this case by a moving window of each hexagon and the six neighboring hexagons, and the global mean of all the forested hexagonal cells in the conterminous United States. G_i* is standardized as a z score with a mean of 0 and a standard deviation of 1, with values greater than 1.96 representing significant local

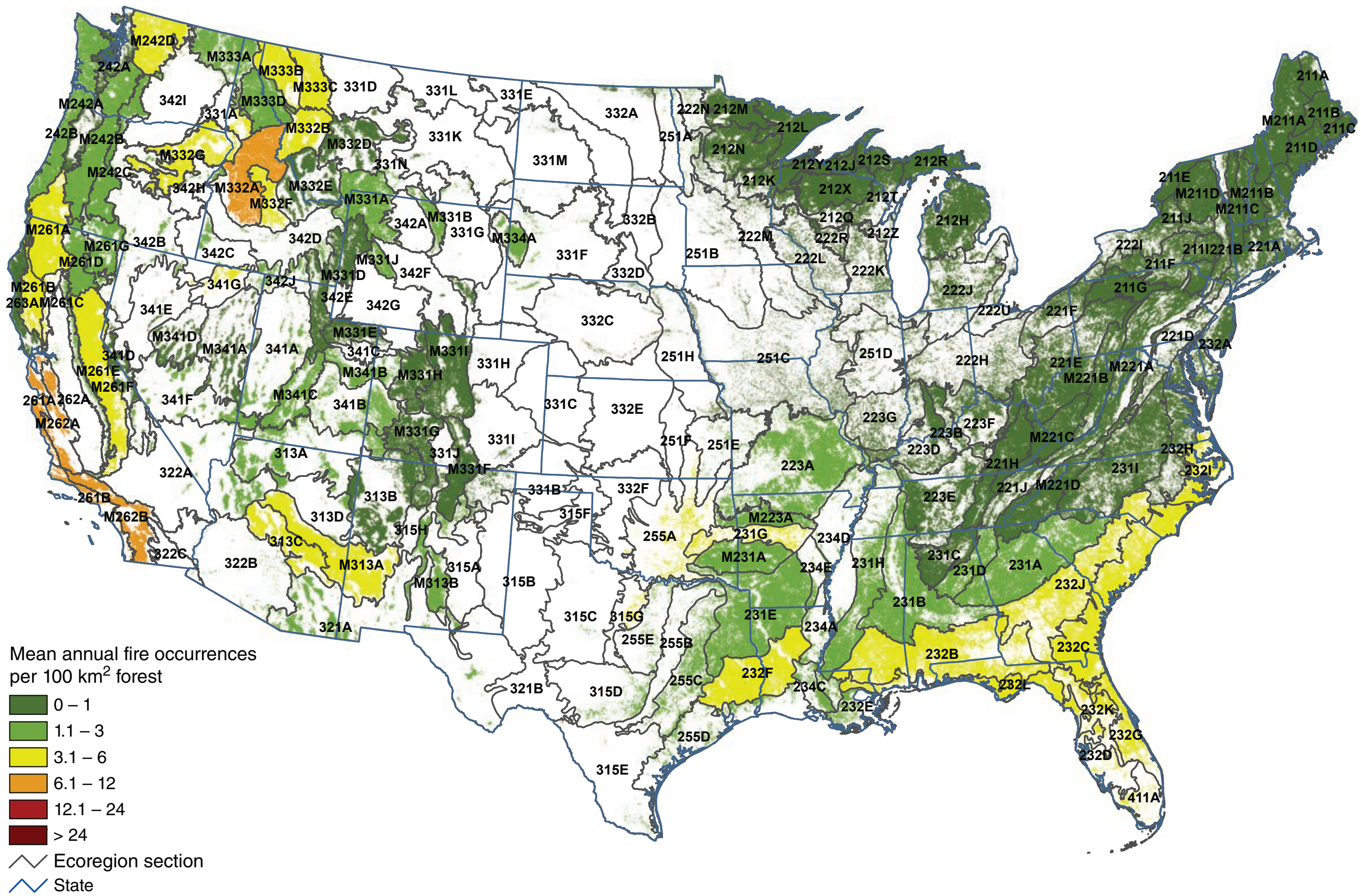

Figure 3.4—Mean number of forest fire occurrences, per 100 km² (10 000 ha) of forested area from 2001 to 2010 by ecoregion section in the conterminous United States. The gray lines delineate ecoregion sections (Cleland and others 2007). Forest cover is derived from MODIS imagery by the U.S. Forest Service Remote Sensing Applications Center. (Source of fire data: USDA Forest Service, Remote Sensing Application Center.)

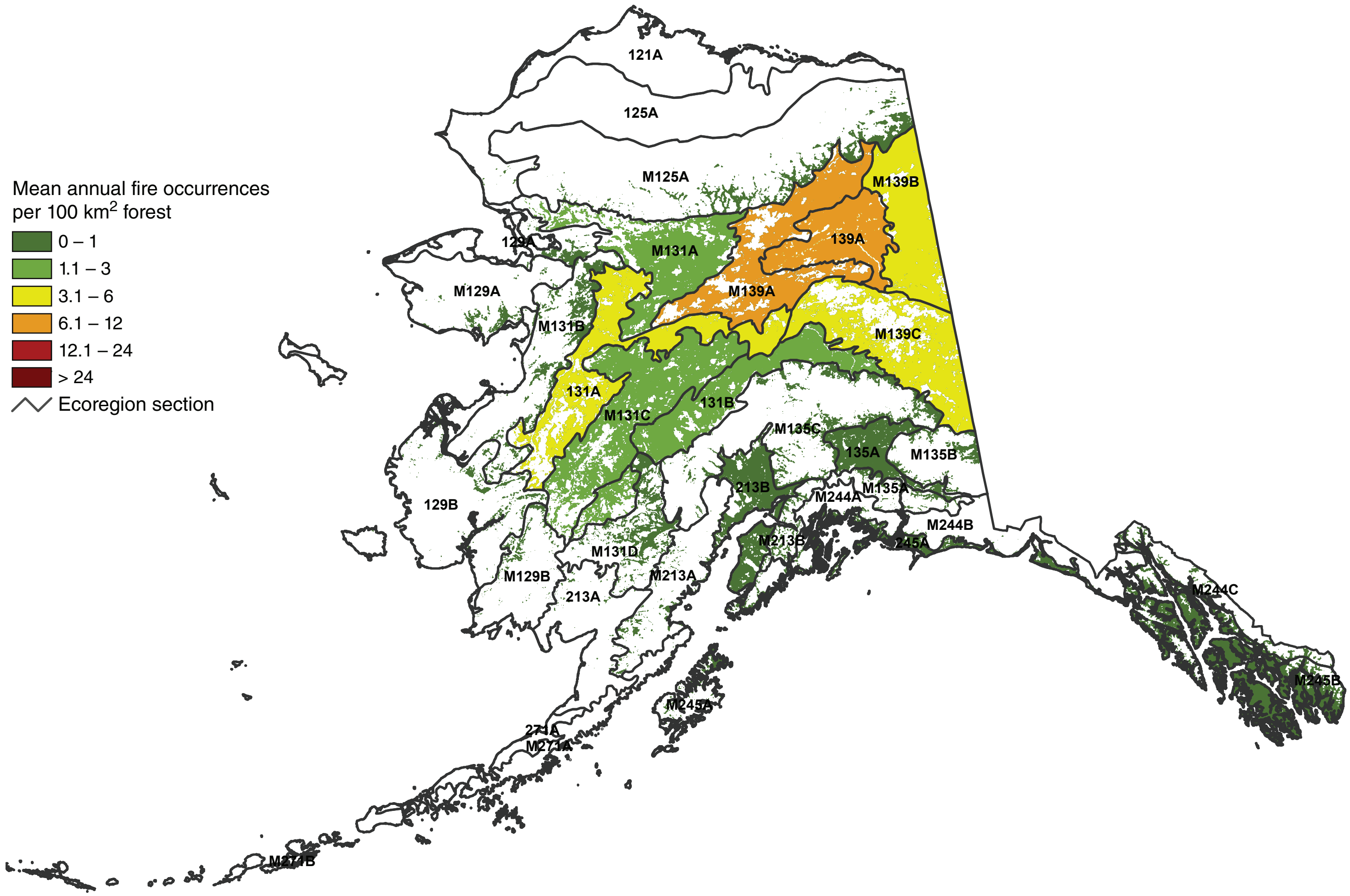

Figure 3.5—Mean number of forest fire occurrences, per 100 km^2 (10 000 ha) of forested area for 2001 to 2010, by ecoregion section within Alaska. The gray lines delineate ecoregion sections (Nowacki and Brock 1995). Forest cover is derived from MODIS imagery by the U.S. Forest Service Remote Sensing Applications Center. (Source of fire data: USDA Forest Service, Remote Sensing Application Center).

ecoregion sections each had an average of three to five fires per year per 100 km^2 of forested area: M139B-Olgivie Mountains, M139C-Dawson Range, and 131A-Yukon Bottomlands.

While summarizing fire occurrence data at the ecoregion scale allows for a comparison of fire occurrence density over time in an area, a geographical hot spot analysis can offer insights into where fire occurrences are concentrated during a given length of time. In 2010, geographical hot spots of fire occurrence within the conterminous United States were limited to several fairly large hot spots in the Southeastern Coastal Plain, four small hot spots in the central part of the country, and a handful of small hot spots across the West (fig. 3.6). This pattern of mostly small and mostly low-intensity hot spots scattered widely across the country suggests, as in 2009 (Potter 2012b), that wildland forest fires in 2010 were relatively evenly distributed across the conterminous United States, with slightly higher concentrations in a few areas.

The most intense fire hot spot was small, occurring in three ecoregions of eastern Oregon: M332G-Blue Mountains, 342B-Northwestern Basin and Range, and 342H-Blue Mountain Foothills (fig. 3.6). A moderately intense, but large, hot spot was detected in Georgia, Alabama, and Florida, centered on 232B-Gulf Coastal Plains and Flatwoods and 232J-Southern Atlantic Coastal Plains and Flatwoods.

Other low-intensity geographic hot spots of fire occurrence were detected in the following ecoregion sections:

- 232G-Florida Coastal Lowlands-Atlantic, 232D-Florida Coastal Lowlands-Gulf, 232K-Florida Coastal Plains Central Highlands, and 411A-Everglades in southern Florida
- 232C-Atlantic Coastal Flatwoods in South Carolina
- 232F-Coastal-Plains and Flatwoods-Western Gulf in Louisiana and east Texas, and 224C-Atchafalaya and Red River Alluvial Plains in Louisiana
- 234D-White and Black Alluvial Plains and 231H-Coastal Plains-Loess in southeastern Missouri, western Kentucky and Tennessee, and northeastern Arkansas
- 255A-Cross Timbers and Prairie, 251E-Osage Plains, and 251F-Flint Hills in northeastern Oklahoma and southeastern Kansas
- M313A-White Mountains-San Francisco Peaks-Mogollon Rim and 313C-Tonto Transition in central Arizona
- M341C-Utah High Plateau and 341A-Bonneville Basin in southwestern Utah
- M333D-Bitterroot Mountains, M333A-Okanogan Highland, and 331A-Palouse Prairie in northern Idaho
- M261E-Sierra Nevada, M261F-Sierra Nevada Foothills, 341D-Mono, and 341F-Southeastern Great Basin in east-central California

The results of these geographic analyses are intended to offer insights into where fire occurrences have been concentrated, but

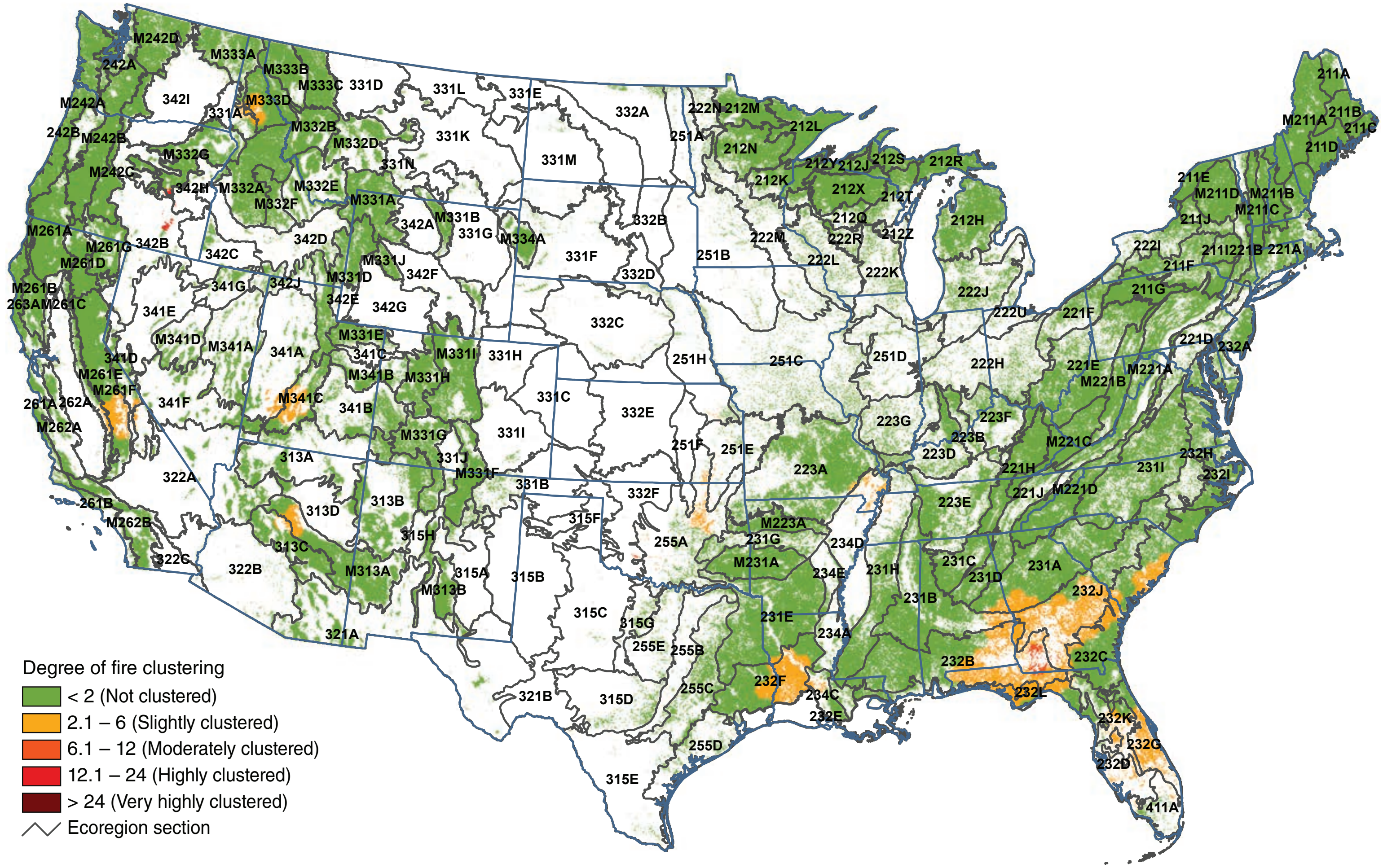

Figure 3.6—Hot spots of fire occurrence across the conterminous United States for 2010. Values are Getis-Ord G_i** scores, with values greater than 2 representing significant clustering of high fire occurrence densities. (No areas of significant clustering of low fire occurrence densities, -2, were detected). The gray lines delineate ecoregion sections (Cleland and others 2007). Background forest cover is derived from MODIS imagery by the U.S. Forest Service Remote Sensing Applications Center. (Source of fire data: USDA Forest Service, Remote Sensing Application Center.)*

are not intended to quantify the severity of a given fire season. Information about the concentration of fire occurrences may be useful for the identification of areas for management activities and for follow-up investigations related to the ecological and socioeconomic impacts of fires that may be outside the range of historic frequency.

LITERATURE CITED

Anselin, L. 1992. Spatial data analysis with GIS: an introduction to application in the social sciences. Tech. Rep. 92-10. Santa Barbara, CA: National Center for Geographic Information and Analysis. 53 p.

Barbour, M.G.; Burk, J.H.; Pitts, W.D. [and others]. 1999. Terrestrial plant ecology. Menlo Park, CA: Addison Wesley Longman, Inc. 649 p.

Bond, W.J.; Keeley, J.E. 2005. Fire as a global 'herbivore': the ecology and evolution of flammable ecosystems. Trends in Ecology and Evolution. 20(7): 387-394.

Cleland, D.T.; Freeouf, J.A.; Keys, J.E., Jr. [and others]. 2007. Ecological subregions: sections and subsections for the conterminous United States. Sloan, A.M., tech. ed. Gen. Tech. Rep. WO-76. Washington, DC: U.S. Department of Agriculture Forest Service. Map, presentation scale 1:3,500,000; Albers equal area projection; colored. Also as GIS coverage in ArcINFO format on CD-ROM or at http://fsgeodata.fs.fed.us/other_resources/ecosubregions.html. [Date accessed: March 18, 2011].

Coulston, J.W.; Ambrose, M.J.; Riitters, K.H.; Conkling, B.L. 2005. Forest Health Monitoring 2004 national technical report. Gen. Tech. Rep. SRS-90. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 81 p.

Environmental Systems Research Institute. 2006. ArcMap 9.2. Redlands, CA: Environmental Systems Research Institute Inc.

Getis, A.; Ord, J.K. 1992. The analysis of spatial association by use of distance statistics. Geographical Analysis. 24(3): 189-206.

Hawbaker, T.J.; Radeloff, V.C.; Syphard, A.D. [and others]. 2008. Detection rates of the MODIS active fire product. Remote Sensing of Environment. 112: 2656-2664.

Justice, C.O.; Giglio, L.; Korontzi, S. [and others]. 2002. The MODIS fire products. Remote Sensing of Environment. 83(1-2): 244-262.

Laffan, S.W. 2006. Assessing regional scale weed distributions, with an Australian example using *Nassella trichotoma*. Weed Research. 46(3): 194-206.

McKenzie, D.; Peterson, D.L.; Alvarado, E. 1996. Predicting the effect of fire on large-scale vegetation patterns in North America. Res. Pap. PNW-RP-489. U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station. 38 p.

National Interagency Coordination Center. 2011. Wildland fire summary and statistics annual report: 2010. http://www.predictiveservices.nifc.gov/intelligence/2010_statssumm/intro_summary.pdf. [Date accessed: May 26, 2011].

Nowacki, G.J.; Abrams, M.D. 2008. The demise of fire and "mesophication" of forests in the Eastern United States. BioScience. 58(2): 123-138.

Nowacki, G.; Brock, T. 1995. Ecoregions and subregions of Alaska, EcoMap. Version 2.0. Juneau, AK: U.S. Department of Agriculture Forest Service, Alaska Region. Map, presentation scale 1:5,000,000; colored.

Potter, K.M. 2012a. Large-scale patterns of forest fire occurrence in the conterminous United States and Alaska, 2005-07. In: Potter, K.M.; Conkling, B.L., ed. Forest health monitoring: 2008 national technical report. Gen. Tech. Rep. SRS-158. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 73-83. Chapter 6.

Potter, K.M. 2012b. Large-scale patterns of forest fire occurrence in the conterminous United States and Alaska, 2001-08. In: Potter, K.M.; Conkling, B.L., ed. Forest health monitoring: 2009 national technical report. Gen. Tech Rep. SRS-167. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 151-162. Chapter 9.

Potter, K.M. 2013. Large-scale patterns of forest fire occurrence in the conterminous United States and Alaska, 2009. In: Potter, K.M.; Conkling, B.L., ed. Forest health monitoring: national status, trends, and analysis 2010. Gen. Tech. Rep. 176. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 31-39. Chapter 3.

Pyne, S.J. 2010. America's fires: A historical context for policy and practice. Durham, NC: Forest History Society. 91 p.

Schmidt, K.M.; Menakis, J.P.; Hardy, C.C. [and others]. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. Gen. Tech. Rep. RMRS-GTR-87. Fort Collins, CO: U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station. 41 p.

U.S. Department of Agriculture Forest Service. 2008. National forest type data development. http://svinetfc4.fs.fed.us/rastergateway/forest_type/. [Date accessed: May 13, 2008].

U.S. Department of Agriculture Forest Service. 2011. MODIS active fire mapping program: Continental United States fire detection GIS data. http://activefiremaps.fs.fed.us/gisdata.php. [Date accessed: March 18, 2011].

Vinton, J.V., ed. 2004. Wildfires: issues and consequences. Hauppauge, NY: Nova Science Publishers, Inc. 127 p.

White, D.; Kimerling, A.J.; Overton, W.S. 1992. Cartographic and geometric components of a global sampling design for environmental monitoring. Cartography and Geographic Information Systems. 19(1): 5-22.