CHAPTER 3.
Large-Scale Patterns of Forest Fire Occurrence in the Conterminous United States and Alaska, 2009

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INTRODUCTION

Wildland fire represents an important ecological mechanism in many forest ecosystems. It 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. Current fire regimes on more than half 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).

METHODS

The Moderate Resolution Imaging Spectroradiometer (MODIS) Active Fire Detections for the United States database (USDA Forest Service 2010) allows analysts to spatially display and summarize fire occurrence on a yearly basis (Coulston and others 2005; Potter 2012a, Potter 2012b). Fire occurrences are defined as the satellite detection of wildland fire in a 1-km^2 pixel for one day. 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 2010). 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 2009. 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 United States and in Alaska was also calculated.

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 greater fire

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occurrence density than expected by chance in 2009. The spatial units of analysis were cells of approximately 2500 km^2 from a hexagonal lattice of the conterminous United States, intensified from Environmental Monitoring and Assessment Program (EMAP) North America hexagon coordinates (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 (10 000 ha) 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.

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 ($p < 0.025$) local clustering of higher fire occurrence densities and values less than -1.96 representing significant ($p < 0.025$) local clustering of lower fire occurrence densities, since 95 percent of the observations under a normal distribution should be within approximately 2 standard deviations of the mean (Laffan 2006). Values between -1.96 and 1.96 have no statistically significant concentration of high or low values; a hexagon and its six neighbors, in other words, have neither consistently high nor consistently low fire occurrence densities per 100 km^2 of forested area. The threshold values are not exact because the correlation of spatial data violates the assumption of independence required for statistical significance (Laffan 2006). The Getis-Ord approach does not require that the input data be normally distributed because the local G_i* values are computed under a randomization assumption, with G_i* equating to a standardized z score that asymptotically tends to a normal distribution (Anselin 1992). The z scores are reliable, even with skewed data, as long as the distance band is large enough to include several neighbors for each feature (ESRI 2006).

RESULTS AND DISCUSSION

The MODIS Active Fire database captured 76,611 wildland forest fire occurrences across the conterminous United States in 2009, the third most since the first full year of MODIS data collection in 2001, but fewer than in the 2 previous years (fig. 3.1). The annual mean number of forest fire occurrences since 2001 was 48,368. The database captured 33,331 fire occurrences in Alaska, also the third highest number since initial MODIS data collection. With a few exceptions, the conterminous United States and Alaska have seen opposite year-to-year trends in the number of forest fire

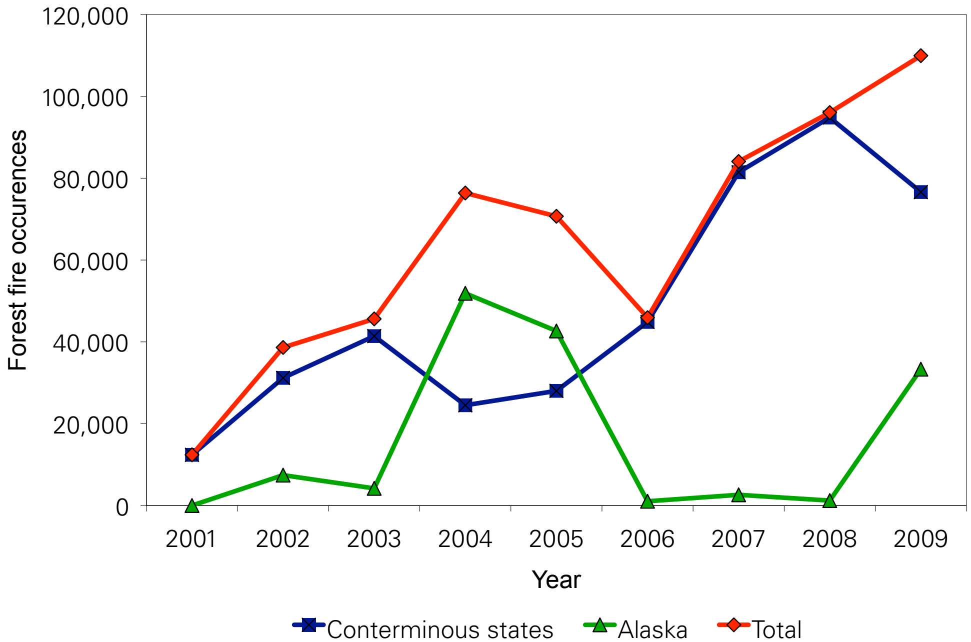

Figure 3.1—Forest fire occurrences detected by MODIS from 2001 to 2009, for the conterminous United States, Alaska, and the two regions combined. (Data source: U.S. Department of Agriculture Forest Service, Remote Sensing Application Center)

occurrences. This was the case between 2008 and 2009, with the number of fires decreasing in the conterminous United States and increasing in Alaska (fig. 3.1). The increase in total number of fire occurrences across both regions is consistent with the official wildland fire statistics, which show a 12-percent increase in the overall area burned nationally between 2008 (2 141 801 ha) and 2009 (2 397 484 ha) (NICC 2010).

In 2009, ecoregion section M262A-Central California Coast Ranges experienced the highest number of fire occurrences relative to its area of forest, with 38.5 fires per 100 km^2 of forested area (fig. 3.2). Two adjacent ecoregion sections also had high numbers of forest fire occurrences: M262B-Southern California Mountain and Valley and 261B-Southern California Coast, with 22.4 and 12.9 fires per 100 km^2 of forested area, respectively. The southern plains of Oklahoma and Texas also had high densities of forest fire occurrences: 15.8 in ecoregion section 315G-Eastern Rolling Plains and 15.0 in ecoregion section 255A-Cross Timbers and Prairie.

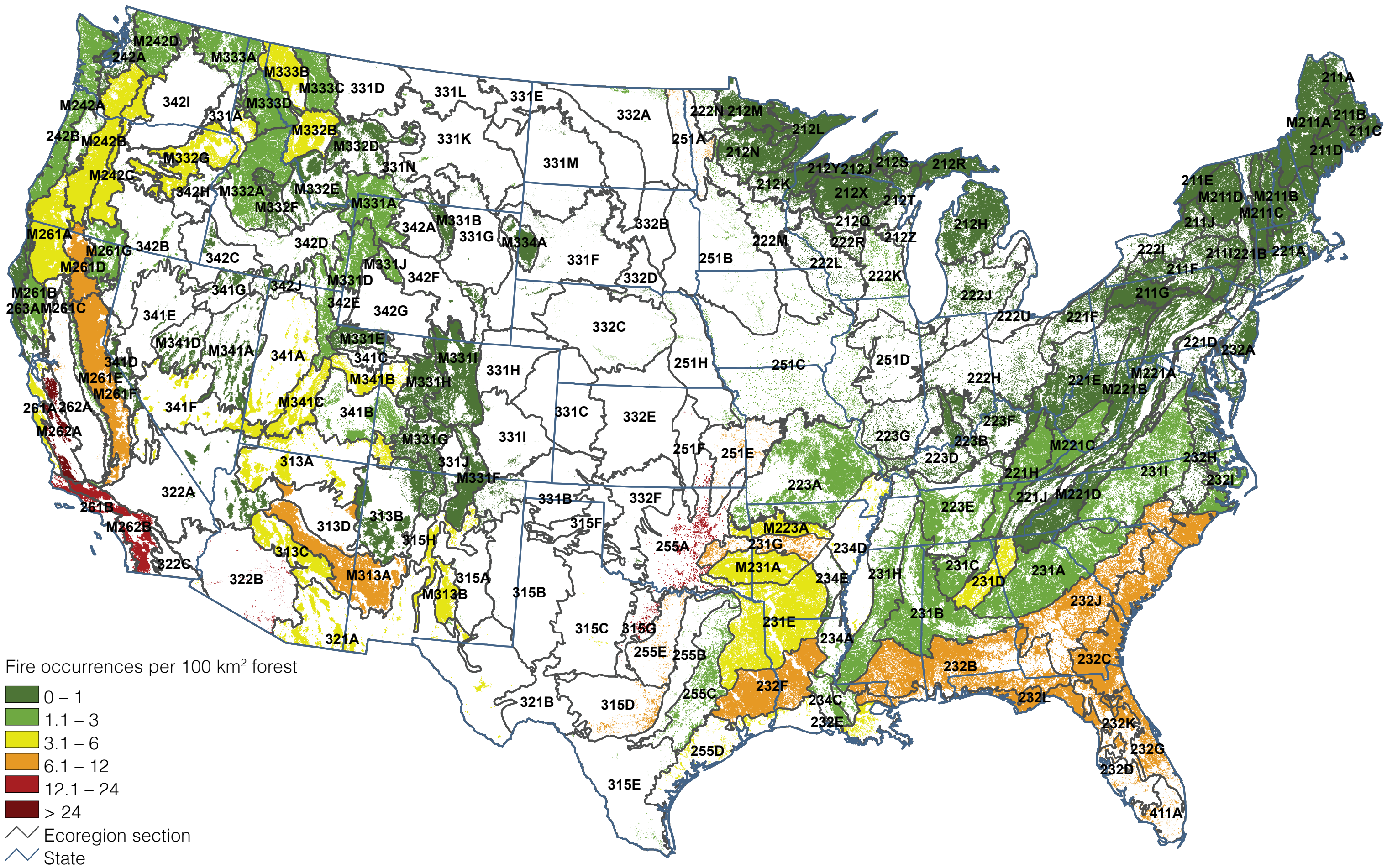

Figure 3.2—The number of forest fire occurrences, per 100 km² (10 000 ha) of forested area, by ecoregion section within the conterminous United States, for 2009. The gray lines delineate ecoregion sections (Cleland and others 2007). Forest cover is derived from MODIS imagery by the U.S. Forest Service Remote Sensing Applications Center. (Source of fire data: U.S. Department of Agriculture Forest Service, Remote Sensing Application Center)

Regions with moderately high forest fire density in 2009 included much of the Southeastern Coastal Plain and all of Florida as well as ecoregion sections 231G-Arkansas Valley of Oklahoma and Arkansas, 255E-Texas Cross Timbers and Prairie and 315D-Edwards Plateau of Texas, M313A-White Mountains and 313C-Painted Desert of Arizona and New Mexico, and M261E-Sierra Nevada and M261D-Southern Cascades of California (fig. 3.2).

In Alaska, the most fire occurrences in 2009 (28.2 per 100 km^2 of forest) were recorded in ecoregion section 139A-Yukon Flats (fig.3.3). Ecoregion sections 131A-Yukon Bottomlands and 131B-Kuskokwim Colluvial Plain also experienced a high density of forest fire occurrences, with 15.0 and 13.1 per 100 km^2 of forest, respectively. Three Alaska ecoregion sections had moderately high density of forest fire occurrences: M139B-Olgivie Mountains, 135A-Copper River Basin, and M131C-Kuskowkim Mountains.

While summarizing fire occurrence data at the ecoregion scale allows for the summary of fire density over time in a relatively large geographic area, a geographical hot spot analysis can offer insights into where fire occurrences are concentrated at a finer scale during a given length of time. Analyses of MODIS Active Fire data from previous years (Potter 2012a, Potter 2012b) indicated that geographical hot spots of fire occurrence density were limited almost entirely to the Pacific Coast, the Rocky Mountains, and the Southeastern Coastal Plain. In 2009, however, no hot spots existed in the Rocky Mountains, although hot spots were concentrated in Southern California and were scattered across the Southeastern Coastal Plain (fig. 3.4). Unlike previous years, which each encompassed at least one high-density geographic hot spot, the highest-density hot spots in 2009 were only moderately so. These hot spots were located in ecoregion sections 261B-Southern California Coast, M262B-Southern California Mountain and Valley, 261A-Central California Coast, and M262A-Central California Coastal Ranges. This pattern suggests that fires in 2009 were more evenly distributed across the conterminous United States, with slightly higher concentrations in a few areas.

These lower-density hot spots included these ecoregion sections:

- M261E-Sierra Nevada and M261F-Sierra Nevada Foothills of California
- M242B-Western Cascades and M242C-Eastern Cascades of southern Oregon
- M341C-Utah High Plateau and 341F-Southeastern Great Basin of southwestern Utah
- M313A-White Mountains-San Francisco Peaks-Mogollon Rim, 313C-Tonto Transition, and 313D-Painted Desert and 313A-Grand Canyon of Arizona
- 255A-Cross Timbers and Prairie, 231G-Arkansas Valley, and M231A-Ouachita Mountains of Oklahoma

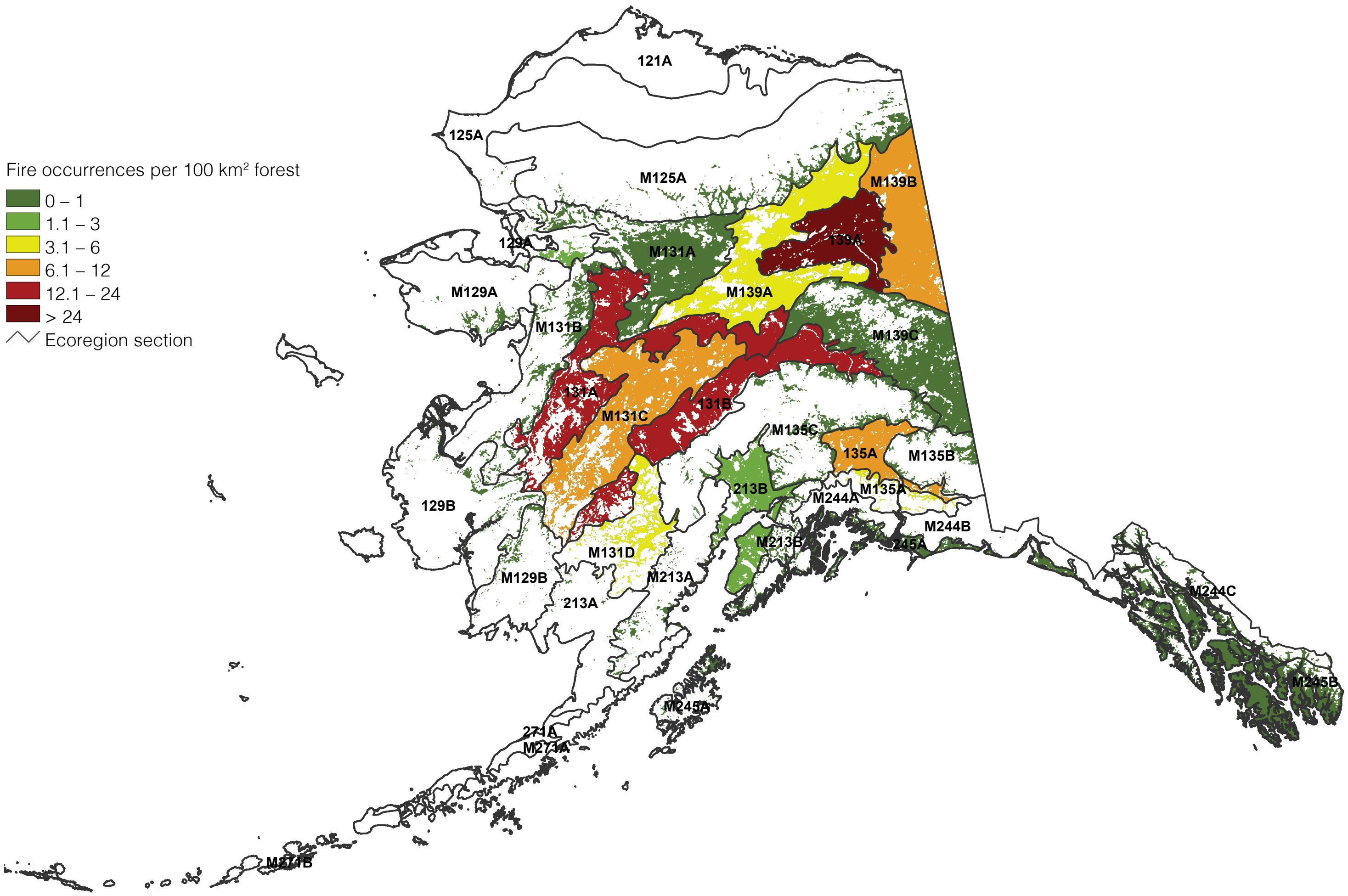

Figure 3.3—The number of forest fire occurrences, per 100 km² (10 000 ha) of forested area, by ecoregion section within Alaska, for 2009. The gray lines delineate ecoregion sections (Nowacki and Brock 1995). Forest cover is derived from MODIS imagery by the U.S. Forest Service Remote Sensing Applications Center. (Source of fire data: U.S. Department of Agriculture Forest Service, Remote Sensing Application Center)

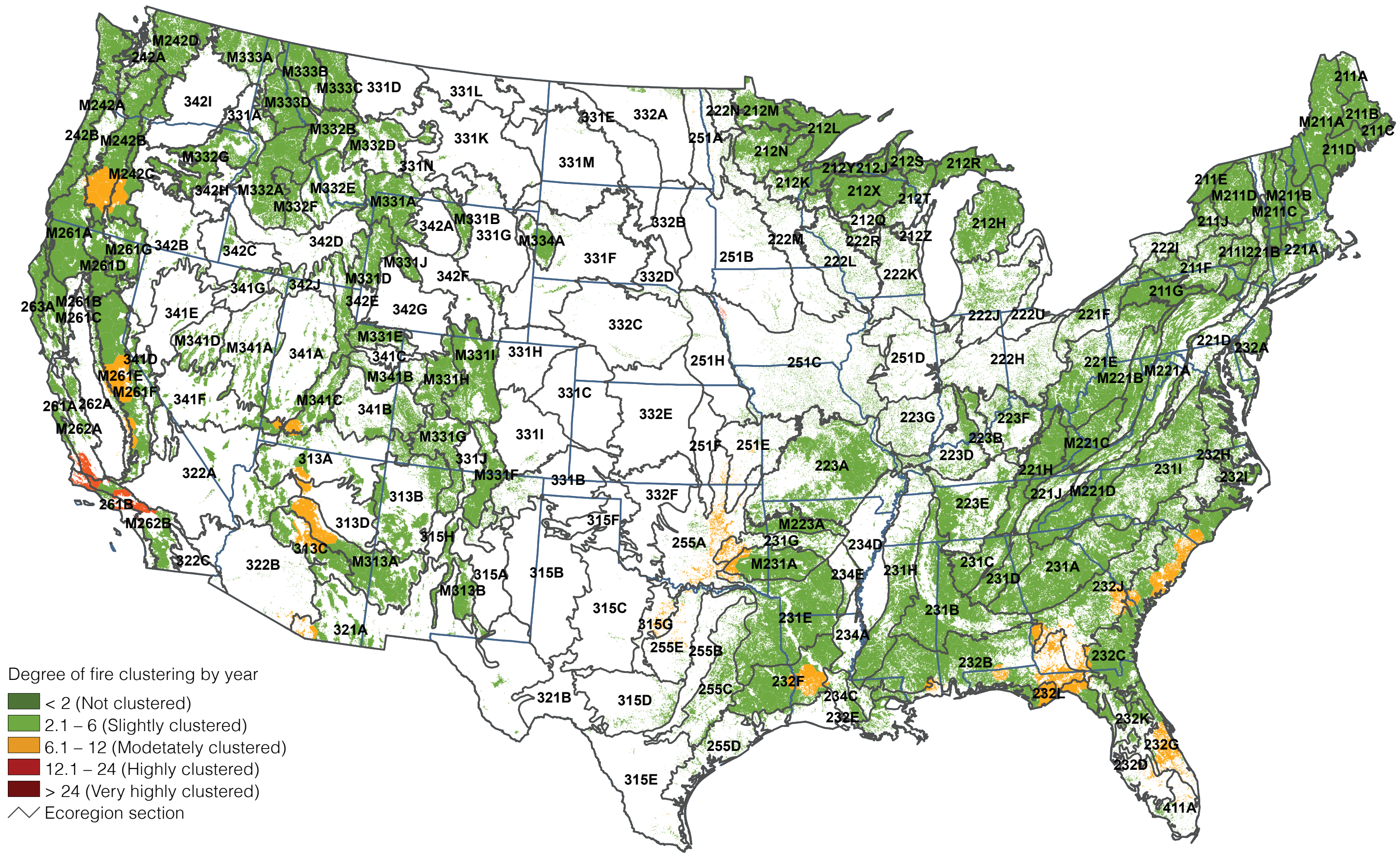

Figure 3.4—Hot spots of fire occurrence across the conterminous United States for 2009. Values are Getis-Ord G_i** scores, with values greater than 2 representing significant clustering of high fire occurrence density values. (No areas of significant clustering of low fire density occurrence values, -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: U.S. Department of Agriculture Forest Service, Remote Sensing Application Center)*

- 315G-Eastern Rolling Plains and 255E-Texas Cross Timbers and Prairie of Texas
- 232F-Coastal-Plains and Flatwoods-Western Gulf of Louisiana
- 232B-Gulf Coastal Plains and Flatwoods and 232L-Gulf Coastal Lowlands of northern Florida and southern Georgia and Alabama
- 232C-Atlantic Coastal Flatwoods and 232J-Southern Atlantic Coastal Plains and Flatwoods of South Carolina and Georgia
- 232G-Florida Coastal Lowlands-Atlantic, 232D-Florida Coastal Lowlands-Gulf, and 411A-Everglades of southern Florida

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

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