

# Indicator 3.15:

U.S. Forest Sustainability Indicators <https://www.fs.fed.us/research/sustain/>

## Area and percent of forest affected by biotic agents (e.g., insects, disease, invasive alien species) beyond reference conditions

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### What is the indicator and why is it important?

The forests of the United States continue to face a variety of biotic threats to long-term health and sustainability. Indicator 15 quantifies observed activity and effects from key biotic agents, such as insects, disease, and invasive alien species. Current analysis of these agents, systematically measured at regular intervals and contrasted with reference conditions, provides evidence of changing ecological conditions and can be used to support practical forest health planning and management.

Primarily, the indicator is based on Insect and Disease Survey (IDS) data compiled by U.S. Department of Agriculture (USDA), Forest Service, Forest Health Protection. These geospatial data are collected mainly through aerial detection surveys, supplemented by ground surveys and remote sensing with modeling and analysis techniques. The IDS methodology does not provide complete geographic coverage of the Nation's forests. In particular, Hawaii, Puerto Rico, and other U.S. territories have not been surveyed consistently. Nevertheless, it does cover a substantial portion of the United States—more than 500 million acres annually—via a targeted approach. Data generation and attribution methods (i.e., demarcation of damaged areas and identification of causal agents) have become increasingly standardized and consistent since 1997. Notably, the IDS data are not limited to insects and diseases: they document a variety of biotic and abiotic disturbances, including drought and other weather-related phenomena. The two principal types of forest damage recorded in the IDS data are mortality and defoliation; only data documenting forest mortality caused by biotic agents are reported here. Additionally, plot data from USDA Forest Service, Forest Inventory and Analysis (FIA) were used in a separate examination of the distributions of invasive alien plant species in U.S. forests.

### What does the indicator show?

Figure 15-1 shows, for the United States and five regions, total forest acres with mortality caused by biotic agents annually from 1997 to 2017. Nationally, the annual totals exceeded 5 million acres, or 0.5 percent of the U.S. forest area, every year from 2002 onward. The peak mortality year for the United States was 2009, when nearly 12 million forest acres experienced mortality from biotic agents. This coincided with the peak year in the Rocky Mountain Region, which saw mortality on 8.4 million forest acres, representing 5.4 percent of the region's forest area. Likewise, elevated levels of biotic mortality observed nationally from 2015 to 2017 are explained by a substantial increase in mortality in the Pacific Coast Region, particularly in 2016, when 5.7 million forest acres (5.8 percent of the region's forest area) experienced mortality caused by biotic agents. In sharp contrast, Alaska and the South Region saw little mortality from biotic agents, regardless of year.

Figure 15-1 also indicates the proportion of the annual mortality acreage caused by invasive biotic agents versus agents of native or unknown origin. Only the North Region showed a significant impact from invasive biotic agents. In fact, most of the biotic mortality observed in the North Region throughout the 21-year data period was due to invasive agents. For example, in 2005—the peak mortality year in the region—invasive agents were responsible for 99.4 percent of the 5.1 million forest acres with mortality. Mortality in the North Region due to agents of native or unknown origin exceeded mortality from invasive agents only in 2008 and 2009, when the former accounted for 697,000 out of 977,000 forest acres (71.3 percent) and 608,000 out of 825,000 forest acres (73.6 percent), respectively.

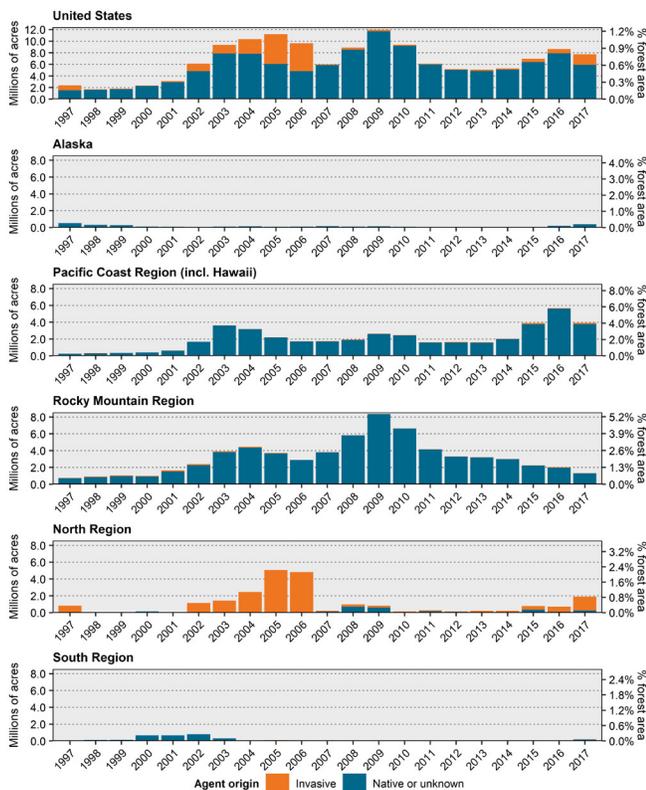


Figure 15-1—Forest acres with mortality caused by biotic agents, summarized annually from 1997 to 2017 by agent category (invasive vs. native/non-invasive). Hawaii is included in the totals for the Pacific Coast Region for years when data were reported (2013 and 2015–2017). Forest area defined using National Land Cover Database 2011 percent tree canopy data (conterminous United States and Hawaii) and classified land cover data (Alaska). Agent data source: Forest Health Protection, National Insect and Disease Survey Database.

Maps provide added context regarding some of the trends shown in figure 15-1. Figure 15-2 depicts the combined extents of forest mortality caused by biotic agents in the conterminous United States during the 2008-2012 and 2013-2017 periods. As noted from figure 15-1, most of the mortality reported for the United States during the 2008–2012 period occurred in the Rocky Mountain Region, but the map for this period (fig. 15-2, top) illustrates further that the mortality was pervasive in the forests of the Central and Northern Rockies, particularly in Colorado, Idaho, and Montana. Similarly, the map for the 2013–2017 period (fig. 15-2, bottom), when much of the mortality from biotic agents occurred in the Pacific Coast Region, reveals that the mortality was mainly concentrated in California’s Sierra Nevada Mountains, especially in the southern portion of the range.

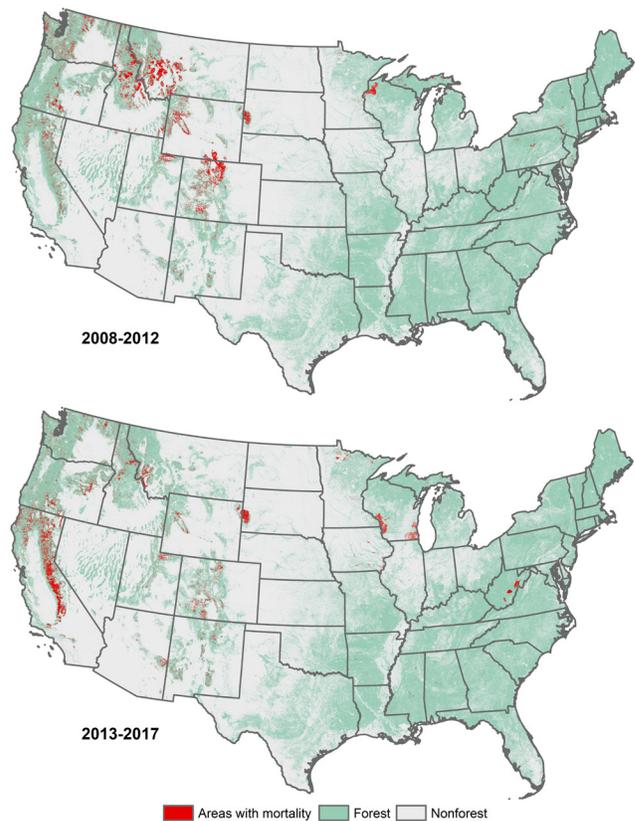


Figure 15-2—Maps of the conterminous United States showing the combined geographic extent of all areas with forest mortality caused by biotic agents during the 5-year periods 2008–2012 (top) and 2013–2017 (bottom). Forest area masks developed from National Land Cover Database 2011 percent tree canopy data. Data source: Forest Health Protection, National Insect and Disease Survey Database.

## What has changed since 2010?

On average, the annual forest acreage of the United States with mortality from biotic agents has been lower since 2010 (average = 6.5 million acres) than it was during the previous decade (average = 8.6 million acres). While total U.S. mortality exceeded 9 million acres six times between 2001 and 2010, it has not surpassed this threshold since, even with the uptick in mortality that began in 2015. Nevertheless, it would be inappropriate to interpret this as a meaningful decrease in biotic mortality at the national scale. The annual mortality totals from the last three years of available data (2015–2017) may indicate the start of an increasing trend. They are also three to

four times greater than the national mortality totals in the years prior to 2001. Fundamentally, forest mortality is a spatially and temporally variable phenomenon. This is markedly true for mortality caused by biotic agents: the mortality observed nationally in any given year is mostly determined by the activities of a few key agents operating at the regional level. For example, the mountain pine beetle (*Dendroctonus ponderosae*) was responsible for most of the mortality in the Rocky Mountain Region in 2009; by extension, this pest accounted for fully 75 percent of total mortality at the national scale (fig. 15-1). Thus, regional-scale patterns are more relevant for evaluating the status of this indicator.

To this end, figures 15-3 through 15-7 show the most important biotic mortality agents through time in each of five regions. Recently, Alaska (fig. 15-3) has seen a resurgence of the spruce beetle (*Dendroctonus rufipennis*) after almost 2 decades of low mortality. In fact, 2017 saw more spruce beetle mortality (nearly 400,000 forest acres) than any year since 1997. Spruce beetle outbreaks have tended to be cyclical in Alaska, but changing climatic conditions (e.g., milder winters and warm summers) could allow the outbreaks to persist longer and become more widespread. Still, other biotic agents exhibited much less impact during the data period, and as noted earlier, the percentage of Alaska's forest area that experienced mortality from the spruce beetle or any other agent remained low (< 0.3 percent) throughout the period.

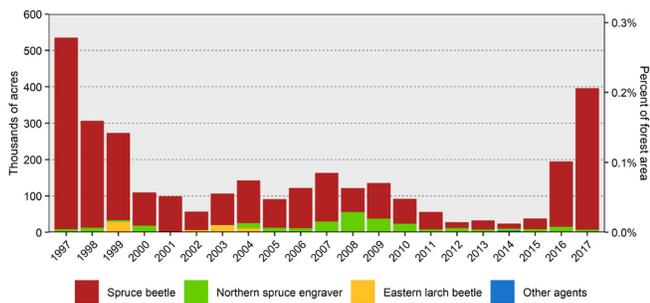


Figure 15-3—Total forest acres with mortality caused by biotic agents, 1997–2017, in Alaska. The three agents with the most extensive impacts are depicted separately: spruce beetle (*Dendroctonus rufipennis*), northern spruce engraver (*Ips perturbatus*), and eastern larch beetle (*D. simplex*). Forest area defined using National Land Cover Database 2011 classified land cover data. Agent data source: Forest Health Protection, National Insect and Disease Survey Database.

Forest mortality in the Pacific Coast Region (fig. 15-4) has been caused by an assortment of biotic agents, including bears (*Ursus* spp.). From 2005 to 2014, the mountain pine beetle was responsible for the largest share of the mortality,

but it was not particularly dominant, only exceeding 40 percent of the region's total mortality acreage in 2007 and 2008. Furthermore, its relative importance as an agent has declined during the region's recent surge in mortality. Instead, the fir engraver (*Scolytus ventralis*) and the western pine beetle (*Dendroctonus brevicomis*) have become more prominent. Persistent and intense drought conditions in the Pacific Coast Region, probably amplified by climate change, have facilitated outbreaks of these agents. Since 2015, mortality caused by the fir engraver and western pine beetle has far surpassed the levels observed earlier in the data period.

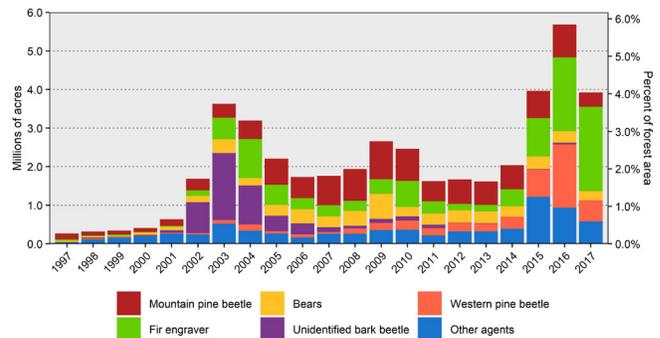


Figure 15-4—Total forest acres with mortality caused by biotic agents, 1997–2017, in the Pacific Coast Region. Hawaii is included in the regional totals for years when data were reported (2013 and 2015–2017). The five agents with the most extensive impacts are depicted separately: mountain pine beetle (*Dendroctonus ponderosae*), fir engraver (*Scolytus ventralis*), bears (*Ursus* spp.), unidentified bark beetle species, and western pine beetle (*D. brevicomis*). Forest area defined using National Land Cover Database 2011 percent tree canopy data. Agent data source: Forest Health Protection, National Insect and Disease Survey Database.

Historically, the mountain pine beetle has been the most destructive biotic agent in the Rocky Mountain Region (fig. 15-5). In 2008 through 2010, when mountain pine beetle populations were at epidemic levels, the insect accounted for more than 85 percent of all biotic mortality in the region. Since 2010, its impact has decreased dramatically: in 2017, the mountain pine beetle caused mortality on just 102,000 forest acres (<0.1 percent of the forest area) region-wide. This decrease has occurred as susceptible pines have been depleted from the region's forests by the insect. Spruce beetle mortality has become more prevalent as mountain pine beetle has declined, but in 2017, total biotic mortality in the Rocky Mountain Region dropped to a level almost as low as in years before 2001.

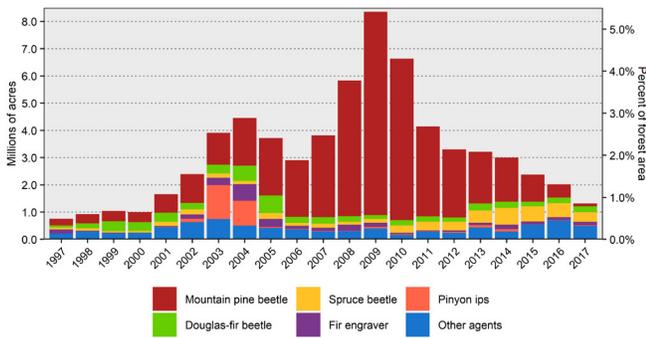


Figure 15-5—Total forest acres with mortality caused by biotic agents, 1997–2017, in the Rocky Mountain Region. The five agents with the most extensive impacts are depicted separately: mountain pine beetle (*Dendroctonus ponderosae*), Douglas-fir beetle (*D. pseudotsugae*), spruce beetle (*D. rufipennis*), fir engraver (*Scolytus ventralis*), and pinyon ips (*Ips confusus*). Forest area defined using National Land Cover Database 2011 percent tree canopy data. Agent data source: Forest Health Protection, National Insect and Disease Survey Database.

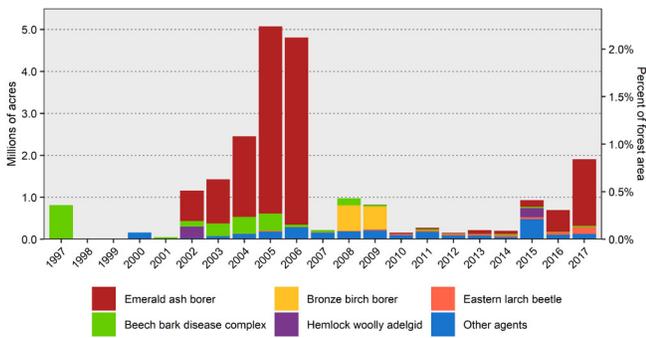


Figure 15-6—Total forest acres with mortality caused by biotic agents, 1997–2017, in the North Region. The five agents with the most extensive impacts are depicted separately: emerald ash borer (*Agrilus planipennis*), beech bark disease complex, bronze birch borer (*A. anxius*), hemlock woolly adelgid (*Adelges tsugae*), and eastern larch beetle (*Dendroctonus simplex*). Forest area defined using National Land Cover Database (NLCD) 2011 percent tree canopy data. Agent data source: Forest Health Protection, National Insect and Disease Survey Database.

The emerald ash borer (*Agrilus planipennis*), an invasive beetle from Asia, has emerged as the most consequential biotic agent in the North Region (fig. 15-6). The insect was responsible for two-thirds of all forest mortality due to biotic agents since 1997. Most of that mortality occurred in the 5 years after the insect’s initial discovery (2002–2006) or in 2016 and 2017, when the data suggest that its range

expanded considerably. Two other invasive species—the hemlock woolly adelgid (*Adelges tsugae*) and the beech scale (*Cryptococcus fagisuga*), the insect vector for beech bark disease—also ranked among the region’s important biotic agents, but mortality by agents besides the emerald ash borer, invasive or otherwise, totaled less than 1 million forest acres (<0.5 percent of the forest area) annually.

In the South Region (fig. 15-7), most of the biotic mortality during the data period was caused by the southern pine beetle (*Dendroctonus frontalis*). From 1998 to 2002, the insect accounted for 99.9 percent of all mortality from biotic agents. However, its regional impact decreased sharply after 2002; in 2010 and 2011, mortality caused by the southern pine beetle occurred on less than 800 forest acres. This may be explained by better management and improved conditions (e.g., less overstocking) in the region’s pine forests. Conversely, the increase in southern pine beetle mortality in 2016 and 2017 can be traced to a localized resurgence of the insect on overstocked stands in Alabama and Mississippi. Regardless, total biotic mortality stayed below 0.3 percent of the region’s forest area, even in the peak years of southern pine beetle activity. Notably, the invasive hemlock woolly adelgid spread into the South Region and began causing mortality in the mid-2000s. The IDS data suggest that its impact has been limited to date, but this is at least partially an artifact of the restricted distribution of hemlocks in the region.

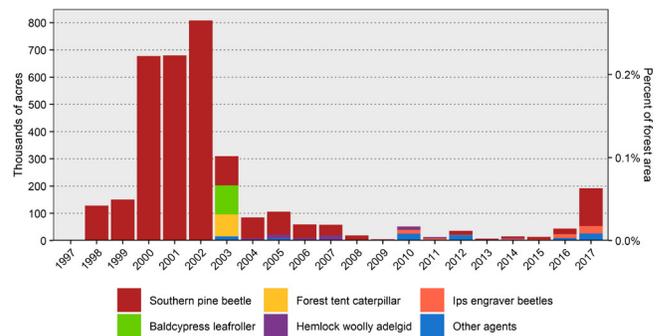


Figure 15-7—Total forest acres with mortality caused by biotic agents, 1997–2017, in the South Region. The five agents with the most extensive impacts are depicted separately: southern pine beetle (*Dendroctonus frontalis*), baldcypress leafroller (*Archips goyerana*), forest tent caterpillar (*Malacosoma disstria*), hemlock woolly adelgid (*Adelges tsugae*), and ips engraver beetles (*Ips* spp.). Forest area defined using National Land Cover Database 2011 percent tree canopy data. Agent data source: Forest Health Protection, National Insect and Disease Survey Database.

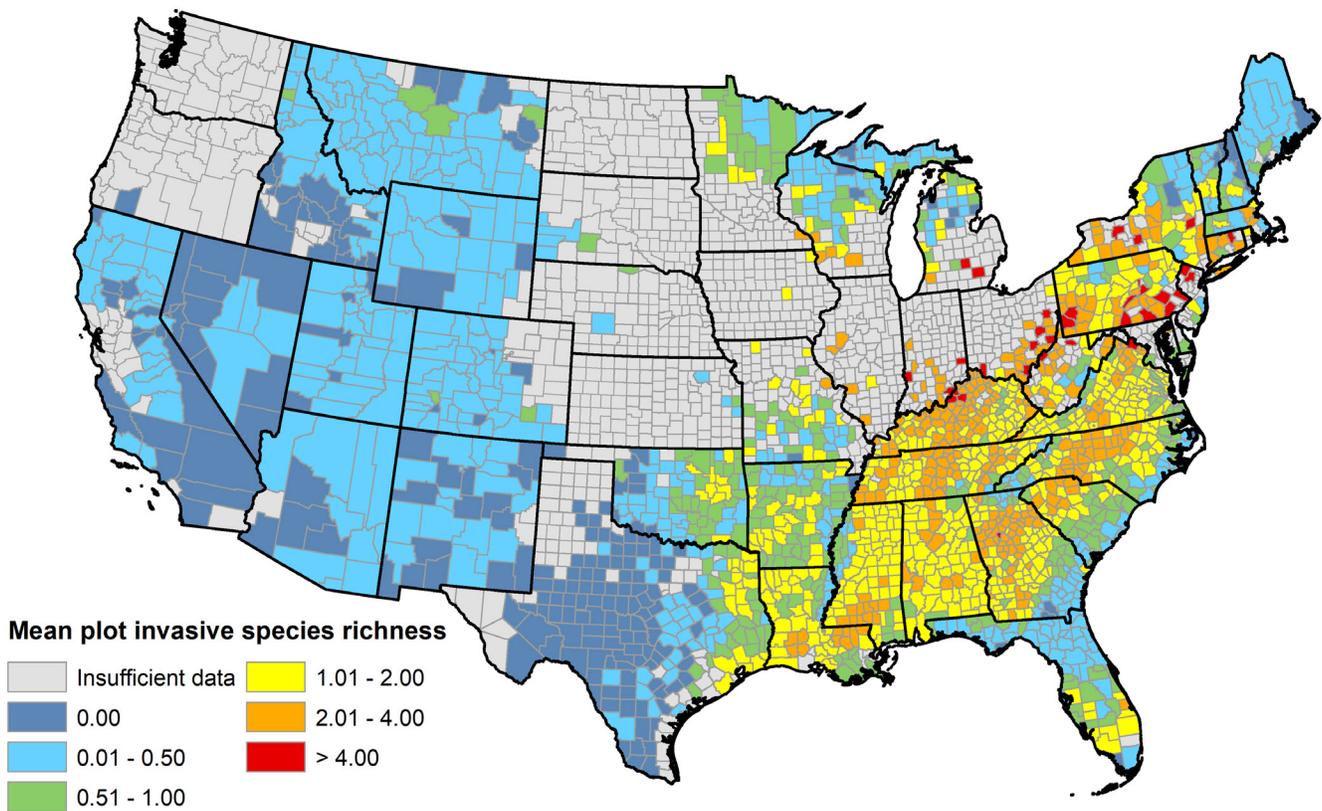


Figure 15-8—Map of the conterminous United States showing mean richness of invasive plant species on surveyed Forest Inventory and Analysis (FIA) plots in each county. Counties where an insufficient number of FIA plots were surveyed for invasive plants are displayed in grey. Data source: USDA Forest Service, Forest Inventory and Analysis.

## Are there important regional differences?

In all regions but the North Region, the most consequential mortality-causing agents are native bark beetle species. Each of these species has a documented history of periodic outbreaks in forests of its native region (or regions). These outbreaks can be widespread regionally, depending on the condition and distribution of host trees, as well as predisposing factors such as persistent drought. Analysis and monitoring of these predisposing factors will become increasingly critical as changing climatic conditions lead to altered dynamics of drought and other forest disturbances, both within and between regions.

As highlighted earlier (fig. 15-1), a distinctive characteristic of the North Region is the relative significance of invasive biotic agents. This pattern is consistent across taxa. For example, figure 15-8 depicts the average number (i.e., richness) of invasive plant species found on surveyed FIA plots in counties of the conterminous United States. Most of the counties with the highest richness (>4.0) are in the North Region. More generally, invasive plant species richness is considerably higher in the eastern portion of the country than in the West, which can be explained by its longer history of trade and human settlement, as well as denser transportation networks. This disparity between regions will probably diminish through time as invasion pathways continue to proliferate.