Chapter 2: Summary of Disturbances and Sustainability

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Introduction

The 2010 "National Report on Sustainable Forests" (USDA FS 2011) identified forest disturbance as the most immediate threat to forest sustainability in the United States, based on increased levels of insect activity and fire activity relative to levels reported in the 2003 edition of that report. This concern, combined with the prominent role that western forests play in national statistics, was the motivating factor behind this report. Key questions for this project were, are forest disturbances increasing, and will they affect forest sustainability in the Western United States? A simple answer to these questions is "yes." A more complete answer would be "yes, but in a complicated way."

The answer is complicated because disturbances are part of forest ecosystems, and the complex web of interactions between species and their environment has been shaped over millennia by disturbance processes, and more recently by anthropogenic disturbances, including fire use in the pre-European settlement era and fire suppression over the past century (e.g., Hessburg and Agee 2003). It also is complicated because the values and uses that people ascribe to forests are diverse and sometimes contradictory. Social and economic effects of forest disturbances are not evenly distributed, and even disturbances that cause substantial tree mortality can bring some benefits along with costs. Finally, it is complicated because of the heterogeneous and highly variable nature of forest disturbances over time, being the sum of numerous different events and biophysical processes. That said, in this report we highlight recent disturbances that are having the most impact on western forests and the communities that depend on them. We also provide some baseline estimates of disturbance amounts and trends where data were available.

Using a sample of LandSat data from 1985 to 2012, Cohen et al. (2016) estimated annual disturbances rate for the Western United States that ranged from near zero to

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About 22 percent of forests in the Western U.S. were affected by disturbance within a five-year time window.

9.61 percent per year and found a trend of increasing disturbance from 1985 to the early 2000s. According to the U.S. Forest Inventory and Analysis (FIA) disturbance protocol for data collected from 2004 to 2016, disturbances in the West affected an average of 22.3 percent of forest lands per 5-year time window. This protocol features a relatively low threshold, recording disturbances that cause damage or mortality to 25 percent of trees in a stand or 50 percent of any individual tree species. Diseases and insects were by far the most common disturbance types using this threshold. Disturbance was highly variable both spatially and temporally, with recent (2004–2016) FIA data indicating that California, Idaho, Montana, Oregon, and Washington each contained more than 2 million ha of disturbance within a 5-year window.

One of the primary motivating questions for this report was "Are disturbances in western forests increasing?" Although FIA disturbance data have not been collected long enough to provide trend information, we do know from a variety of sources that invasive plants, insects, and pathogens are increasing over time. We also know that as the world's climate continues to warm, drought is likely to increasingly affect forests of the Western States (Vose et al. 2016, 2018). Native pathogen and insect trends vary because of complicated relationships with hosts and the environment, and some species are difficult to monitor. Fire is the disturbance with the best and longest historical data records, which also show a complicated temporal pattern.

Fire

Average annual area burned by wildfires has more than doubled in recent decades.

Fire disturbances have increased in western forests in recent decades, as increased atmospheric aridity and regional droughts have interacted with high forest stand densities and fuels to increase fuel and forest flammability (Abatzoglou and Williams 2016, Holden et al. 2018). The average area burned in wildfires in the United States has more than doubled in recent decades, with average annual area burned in larger wildfires increasing from 1.2 million ha per year for the decade from 1985 to 1994 to 2.7 million ha for the decade from 2008 to 2017 (NIFC 2018). The area burned at moderate and high severities has similarly increased over this period, as the average proportion of area burned at low, moderate, and high severity has remained relatively stable over time (see chapter 4). Despite these recent trends in annual area burned, forest area burned remains well below historical levels prior to the presettlement and presuppression eras, likely owing to active fire suppression efforts (Marlon et al. 2012, Parks et al. 2015). Western forest area affected by fire remains less than that affected by insects, diseases, timber harvests, or grazing, as wildfire affected only 3.5 percent of western forests per 5-year window using the FIA threshold, but fire typically has the highest per-hectare management cost.

Wildfire area burned is strongly influenced by climate in both forested and nonforested ecosystems of the Western United States. Wildfire area burned is typically driven by climate and seasonal fire weather. Influential factors include fire season length, fuel moisture levels during the fire season, and the number of days with hot, dry, and windy weather (Abatzoglou and Kolden 2013, Littell et al. 2009). Much of the trend in wildfire area burned over the past 30 years can be attributed to observed trends in elements of climate associated with fire season length and fuel aridity (Holden et al. 2018, Jain et al. 2017, Jolly et al. 2015).

Economic costs associated with wildfire have increased in recent decades along with area burned. In recent decades, steady growth of the wildland-urban interface (WUI) in the West has increased the number of people living close to fire-prone wildlands, thereby increasing the number of human-caused wildfires (Balch et al. 2017, Nagy et al. 2018); putting more lives and property at risk; and increasing social and political pressure to maintain active and aggressive fire-suppression policies (Parisien et al. 2016). Suppression costs have been rising rapidly in response to increased wildfire area burned (Calkin et al. 2005), often reducing resources available for forest restoration and other fuel reduction activities.

Drought, Insects, and Diseases

Drought can increase the probability and severity of wildfires, as well as be a direct cause of tree mortality when drought is severe or prolonged. In recent years (2006–2015), average annual temperature has been higher than the preceding 30-year average (1975–2005) across the Western States, but below-normal precipitation was concentrated in the Southwest (Arizona, California, and Nevada), resulting in spatially variable drought severity across the West.

Higher than normal temperatures in recent years interacted with below-normal precipitation in some areas to increase drought severity, particularly in the southwestern United States.

Drought can also make forests more susceptible to the effects of insects and pathogens. Insects are essential components of western forests, representing most of the biological diversity and affecting virtually all trophic levels and processes. Although most insect species can be viewed as beneficial, others periodically become so abundant that they threaten current ecological, economic, social, or aesthetic values at local to regional scales.

Over the past 30 years, tree mortality caused by bark beetles in the West has exceeded tree mortality caused by wildfires, raising concerns about the sustainability of some western forests to provide certain goods and services over time. Most notably, mountain pine beetle (*Dendroctonus ponderosae*) affected ~10.3 million ha from 2000 to 2016, which represents almost half the total area affected by all bark beetles combined in the West during this period (Krist et al. 2014). Several wood-boring, defoliating, and sap-sucking insects are also important.

Mountain pine beetle impacted about 10.3 million hectares from 2000-2016.

Unlike in the Eastern States, few invasive insects are important disturbance agents in western forests currently. However, with observed and projected shifts in climate, human populations, and trade, invasive insects are expected to cause elevated impacts in the future. The recent establishment of goldspotted oak borer (*Agrilus coxalis*) in California (interstate introduction) and emerald ash borer (*A. planipennis*) in Colorado (intercontinental introduction) is of concern.

White pine blister rust, drought, and bark beetles are driving extensive mortality in high-elevation whitebark pine populations.

In contrast to invasive insects, exotic invasive pathogens, inadvertently introduced as a byproduct of trade, have already substantially affected western forests, and the number of detections continues to rise. Once introduced, pathogens are difficult to control; for example, white pine blister rust, (caused by *Cronartium ribicola*), entered the United States on nursery stock in the early 1900s and continues to spread and kill white pines today, despite extensive eradication efforts in the 1930s. Notably, white pine blister rust, along with drought and bark beetles, is driving extensive mortality in high-elevation whitebark pine (*Pinus albicaulis*) populations. A more recent introduction, *Phytophthora ramorum*, the cause of sudden oak death, was first recognized in the United States in the mid 1990s and has become established along parts of the central California coast into southwest Oregon, where each year it kills an average of more than a million tanoaks (*Notholithocarpus densiflorus*), coastal live oaks (*Quercus agrifolia*), and other oak species.

Native pathogens are also causing widespread impacts in western forests, especially root diseases (Armillaria root disease, Heterobasidion root disease, and laminated root rot [the latter is caused by *Phellinus sulphurascens* syn. *Coniferiporia sulphurascens* and *P. weirii* syn. *C. weirii*]).

Warmer and wetter conditions in some parts of the Western United States are causing outbreaks of foliage diseases.

Climatic influences on forest diseases are complex, as they are an expression of the interaction of the particular pathogen, host plants or trees, and other environmental conditions. Warmer and wetter conditions are causing outbreaks of foliage diseases such as Dothistroma needle blight (caused by *D. septosporum*) and Swiss needle cast (*Phaeocryptopus gaeumannii*). Warming is also responsible for yellow-cedar decline, an abiotic disease associated with a reduction in snow cover, which has caused root damage and mortality of yellow-cedar (*Callitropsis nootkatensis*) in southeast Alaska.

Changes in other forest disturbance patterns, such as drought and wildfire intervals, will change the impacts of pathogens and insects, creating novel forms of disruption to ecosystem services, as well as adding to safety concerns and management problems. Assisted migration and increased restoration plantings may introduce new pathogens to new areas. Tree mortality rates and growth responses will change over time, and pathogens and plant species will adapt to this change and to one another. If drought, fire, and other abiotic disturbances are extreme, the impact of pathogens may decrease because there will be fewer host plants for microbes to infect, and the weakest organisms in the plant or tree population will have been removed by other mortality agents.

Invasive Plants

Invasive plants are also affecting forests of the Western United States, with impacts on native species diversity, nutrient cycling, the probability of other disturbances like wildfire, and the productivity of desired species. The costs—in value lost in degraded ecosystems and the price for management attempts to control invasive plants—are substantial.

Based on recent FIA data, the proportion of forest covered by invasive plants was highest in Hawaii (46 percent), higher on the Pacific Coast (3.3 percent) than in the Rocky Mountains (0.75 percent), and lowest in coastal Alaska (0.01 percent). Mean cover of invasive plants was related to stand age, with less invasive cover in older stands. Invasive plant cover was also highest in recently disturbed forests and forest types common to drier areas and sparse or open tree canopies. Invasive plants were significantly more abundant in forests that were in proximity to nonforest land uses or ecosystems (e.g., roads or rangelands). Overall, nonnative cover appears to have increased substantially from the 2000s to the 2010s, and further increases are expected.

Invasive plants as a percentage of forest was an order of magnitude higher in Hawaii.

Cheatgrass (*Bromus tectorum*) was by far the most abundant nonnative plant species in western forests, covering 1.2 million ac (500 000 ha), or 0.5 percent of all forested land in the conterminous Western States. Because cheatgrass and other annual grasses dry out earlier and more completely than native perennial vegetation, they promote fire spread and tend to increase fire frequency and extent.

Cheatgrass, which can increase fire spread, was by far the most abundant non-native plant species in western forests.

Social and Economic Impacts of Disturbances

The increasing frequency and severity of forest disturbances pose significant challenges to the sustainable management of forests on public lands in the Western States and the variety of goods and services they provide (e.g., recreational opportunities, biodiversity protection, climate change mitigation). Estimates of the full economic impacts of forest disturbances could help inform forest management and policy under projected environmental and anthropogenic pressures. To illustrate this point, the economic impact of forest disturbances on outdoor recreation and climate mitigation was assessed in this report.

In the United States in 2016, about 900 million visits were made to federal lands, and visitors spent around $49 billion. The value of recreational activities to each national forest in the West is estimated to range from $11 million to more than

Disturbances affect outdoor recreation benefits through reduced participation, fewer available recreation days, and changes in the quality of outdoor amenities.

$1 billion. Forest disturbances affect outdoor recreation benefits through reduced participation, fewer available recreation days, and changes in the quality of outdoor amenities. For instance, on the Inyo National Forest, the 2007–2009 California drought affected downhill skiing in the mixed-conifer zone, with a 19 percent drop in annual visits between 2006 and 2011, and a corresponding reduction in recreational benefits estimated at $19 million.

Through their contribution to climate change, carbon dioxide (CO_2) emissions have a long-term impact on agricultural and forestry productivity, human health, energy and water security, and managed and unmanaged ecosystems. Recent vegetation and forest cover dynamics in the Western States have resulted in net increases in carbon stocks, mitigating emissions from other economic sectors. The analysis presented in chapter 9 shows that projected increases in net forest carbon are estimated to provide more than $11 trillion in social benefits by 2091. Nevertheless, CO_2 emissions owing to tree mortality from elevated disturbance regimes is still significant. Emissions from trees killed by fire and insect damage between 2003 and 2012 in the West are estimated to have social costs of about $26 billion. More effective management responses to forest disturbances could contribute to higher levels of carbon sequestration and a subsequent increase in social benefits.

Management and Monitoring

Although disturbances are embedded in the ecology of western forests, some management actions can be taken to reduce their impact. Reduction of insect, pathogen, and plant invasions would lessen degradation of western forests. Many options exist to address particular disturbances, such as prescribed burning and other fuel reduction treatments to increase resistance and resilience to fire; thinning to reduce tree mortality from drought; favoring non-host species to address particular insect or disease issues; or altering the timing and duration of recreational site visits. But it is important to recognize that the best choices will differ both by site-specific factors and by management goals. To reduce damage, management approaches should integrate local historical, current, and predicted risks and embed "best practices" into treatment strategies. Homeowner and community education programs, cooperative management and stewardship across multiple agencies and landowners, and local and regional planning can reduce the incidence and impact of disturbances. Because increasing temperatures usually exacerbate some of the most damaging disturbances (wildfire, drought, beetles), actions to ameliorate climate change, such as reducing greenhouse gas emissions or increasing carbon sequestration and storage, are also important.

Year-to-year variability is high for many disturbances, so consistency and duration of monitoring programs will be critical to understanding trends in disturbances. Better methods of integrating disparate data sources would help in gaining leverage from existing monitoring programs such as FACTS (Forest Service Activity Tracking System), Monitoring Trends in Burn Severity (https://www.mtbs.gov), FIA (https://www.fia.fs.fed.us), Insect and Disease Aerial Detection Surveys (https://www.fs.fed.us/foresthealth/aviation/aerialsurvey.shtml), and the National Visitor Use Monitoring program (https://www.fs.fed.us/recreation/programs/nvum/). Some causes of disturbances, notably diseases and pathogens, are only partially covered within existing monitoring programs, and alternative sources and types of monitoring would allow for a better understanding of impacts on forest growth and mortality so that changes can be recognized and addressed. For other disturbances such as drought, the development of better indices and prediction methods specifically tailored to impacts on tree growth and mortality would be helpful. Although we focused on the most recent data for disturbances and did not include predictive modeling, many of the disturbances discussed in this report, along with their associated socioeconomic impacts, are likely to increase in the next few decades given current trends in invasive species, climate change, and changing land use.

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