USGS Wildland Fire Research

Figure 1. Wildfire in the Pacific Northwest.

Introduction

Wildland fire (fig. 1) is a serious and growing hazard over much of the United States, posing a great threat to life and property, particularly when it moves from forest or rangeland into developed areas. However, wildland fire is also a natural process, and its suppression is now recognized to have created a larger fire hazard, as live and dead vegetation accumulates in areas where fire has been excluded. In addition, the absence of fire has altered or disrupted the cycle of natural plant succession and wildlife habitat in many areas. Consequently, U.S. land management agencies are committed to finding ways, such as prescribed burning to reintroduce fire into natural ecosystems, while recognizing that fire fighting and suppression are still important. The U.S. Geological Survey (USGS) conducts fire-related research to meet the varied needs of the fire management community and to understand the role of fire in the landscape; this research includes fire management support, studies of postfire effects, and a wide range of studies on fire history and ecology.

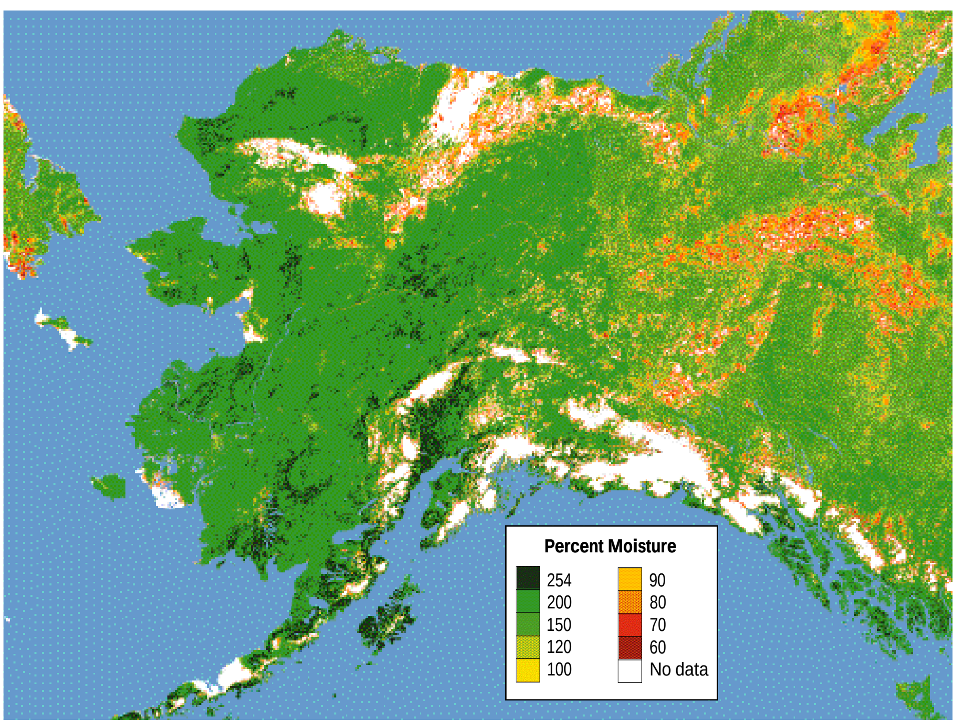

Figure 2. Greenness map for Alaska, for the period of August 1998. Percent moisture is a measure of how much more water is in live vegetation than in completely dry vegetation.

Fire Management Support

Greenness Mapping

Land and fire managers rely upon accurate and timely information to help reduce wildland fire hazards. Since the early 1990's, the EROS Data Center (EDC) in Sioux Falls, S. Dak., has been producing weekly and biweekly maps for the 48 contiguous States and Alaska that display plant growth and vigor, vegetation cover, and biomass production, using multispectral data from satellites of the National Oceanic and Atmospheric Administration (NOAA). The ability to measure vegetation greenness over time provides fire managers vital information concerning vegetation conditions for any 2-week period (fig. 2). EDC also produces maps that relate current vegetation conditions for the 2-week period to average (normal) conditions for the same period during the past 7 years. The two types of images provide comprehensive growing season profiles for forests, rangelands and grasslands, and agricultural areas. They are used by fire and land managers to assess the condition of all vegetation throughout the growing season, so they provide a foundation for planning for fire suppression, scheduling prescribed burns, or studying long-term vegetation changes resulting from human or natural factors. For example, the U.S. Forest Service (USFS) uses greenness maps to generate national maps of selected fire weather and fire danger components of their Wildland Fire Assessment System (http://www.fs.fed.us/land/wfas/welcome.html).

Fire Potential Index

The Fire Potential Index (FPI) is a valuable fire management tool that has been developed by USGS scientists in collaboration with scientists at the USFS. The FPI characterizes relative fire potential for forests, rangelands, and grasslands, both regionally and locally, so that land managers can develop plans for minimizing the threat from fires. The FPI

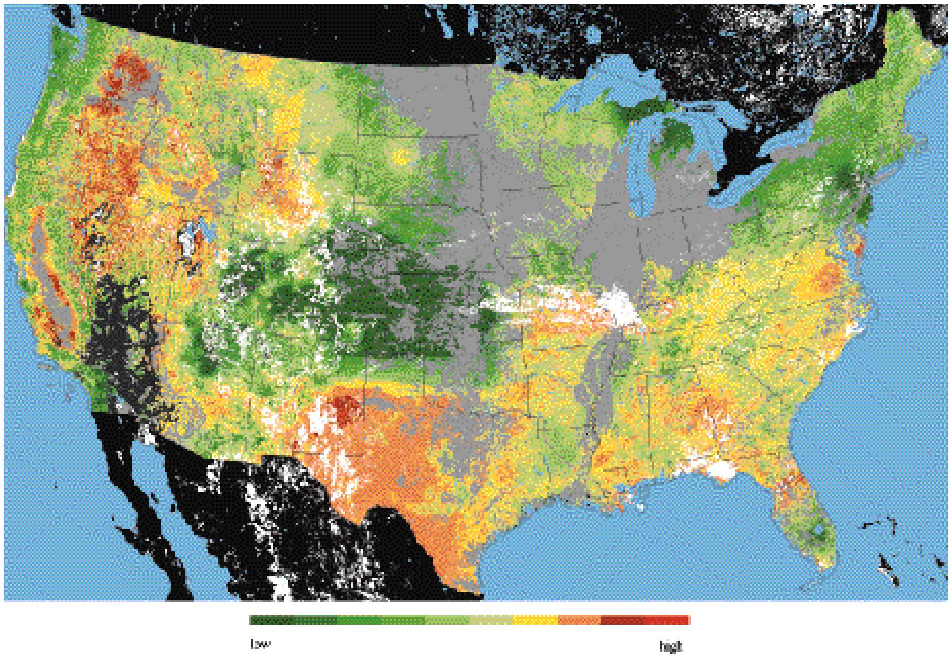

Figure 3. Fire potential index map of the conterminous United States , for August 13, 1998. White areas are cloud cover, gray are agricultural lands (not rated by the FPI).

combines multispectral satellite data from NOAA with geographic information system (GIS) technology to generate 1-km resolution fire potential maps. Input data include the total amount of burnable plant material or fuel load (derived from vegetation maps), plus the water content of the dead vegetation, and the fraction of the total fuel load that is live vegetation. Water content of dead vegetation is calculated from temperature, relative humidity, cloud cover, and precipitation, and the proportion of living plants is derived from the greenness maps described above. The FPI is updated daily to reflect the changing weather conditions and is posted by the USFS on their Web site. Figure 3 is the FPI map for August 13, 1998.

The Bureau of Land Management (BLM), Bureau of Indian Affairs, and USFS are working with the USGS to validate the model. Fire management staffs in Oregon, Nevada, and California are using the FPI in their decision-making process daily to supplement their traditional information sources. They use these data for purposes such as establishing priorities across the area for prevention activities to reduce the risk of wildland fire ignition and spread, and planning the allocation of suppression forces to improve the probability that initial attack will control fires occurring in areas of high concern. The FPI is also being tested in Argentina, Chile, Mexico, and Spain with the support of the Pan American Institute for Geography and History.

Postfire Effects

Fire and Debris Flows: A Double Hazard

Wildfires leave problems behind them, even when the last ember is extinguished. In July 1994, a wildfire burned 2,000 acres of forest and scrub on the steep slopes of Storm King Mountain, near Glenwood Springs, Colo. In September 1994, torrential rains triggered debris flows, which poured from this burned area and inundated a 3-mile stretch of Interstate 70 with tons of mud, rock, and other debris (fig. 4). The flows engulfed 30 cars, sweeping 2 into the Colorado River. Some travelers were seriously injured, but fortunately there were no deaths.

Scientists from the Landslides Hazards Program of the USGS are studying the linkage between wildfires and debris flows at Storm King Mountain and sites in several other States. During an intense wildfire, all vegetation may be destroyed; also the organic material in the soil may be burned away or may decompose into water-repellent substances that prevent water from percolating into the soil. As a result, even normal rainfall may result in unusual erosion or flooding from a burned area; heavy rain can produce destructive debris flows, as happened at Storm King Mountain.

In 1997, wildfires charred many areas of southern California, leaving them bare before the 1997-98 winter's heavy El Niño rainfall. A map delineating perimeters of 25 of the 1997 southern California wildfires that burned more than 300 acres can be found at http://geohazards.cr.usgs.gov/html_files/landslides/scfires/scfiresloc.html. Ten of these burns produced debris flows after the first major winter storm, and flooding dominated in eight areas. Only four showed little or no erosion or runoff. The relative importance of topography, vegetation conditions, and the amount and pattern of rainfall are being investigated at each of the sites develop a model for debris-flow susceptibility from recently burned areas.

Effects of Fire on Water Supplies

Water supplies are also affected by fire: the loss of ground-surface cover, such as needles and small branches, and the chemical transformation of burned soils make watersheds more susceptible to erosion from rainstorms. In May 1996, an 11,900-acre (4,820 hectares) fire burned most of the Buffalo Creek and Spring Creek watersheds; these small watersheds feed into the Strontia Springs Reservoir, which supplies more than 75 percent of the municipal water for the cities of Denver and Aurora (fig. 5). Two months after the fire, a severe thunderstorm caused flooding from the burned area, killing two people. In addition, the Denver Water Department immediately experienced a deterioration of water quality from floating burned debris and high levels of manganese. Two years after the fire, phosphate levels in the water remain high, and the Denver Water Department is concerned about loss of reservoir capacity and impaired water quality.

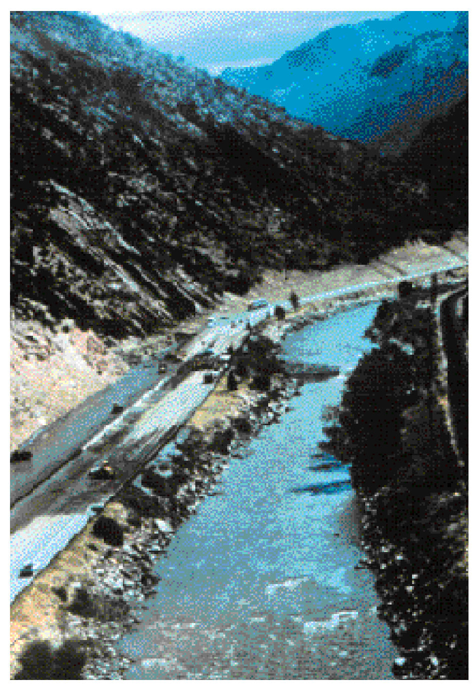

Figure 4. Debris flows cover parts of Interstate 70 below Storm King Mountain, Colo.

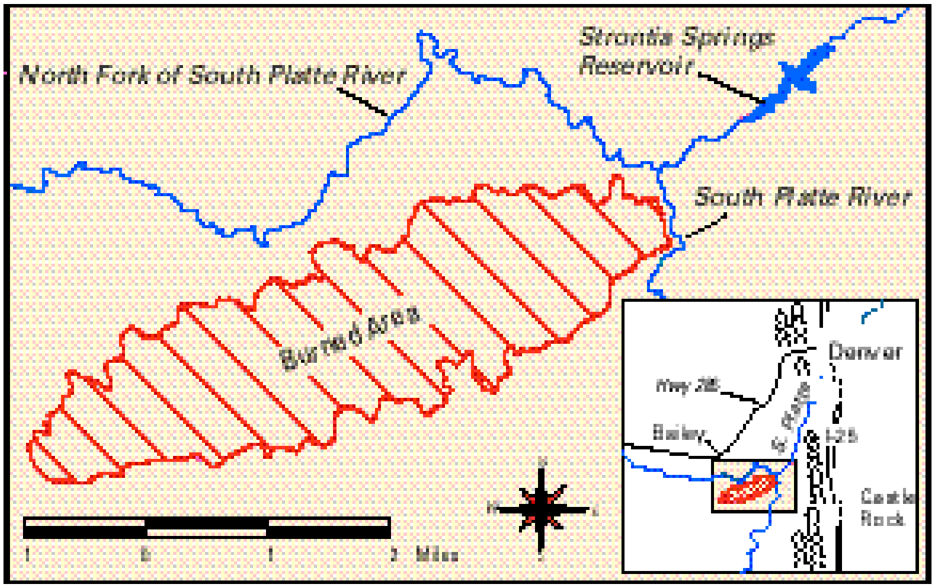

Figure 5. Map showing location of Buffalo Creek and Spring Creek fires relative to Strontia Springs Reservoir, near Denver, Colo.

USGS researchers are studying the post-fire hydrogeology of Buffalo and Spring Creeks to understand the processes of runoff generation, sediment production, and the transport of sediment out of the watersheds and into the reservoir. Although the burned hillslopes are showing signs of revegetation, 2 years later sediment is still being eroded. Between September 1996 and August 1998, about 260,000 cubic yards of coarse sediment were trapped in a delta at the upper end of the reservoir. The postfire accumulation rate is about 10 times that calculated by the engineers who designed the reservoir. Furthermore, this was not an unprecedented event: stratigraphic studies in the Buffalo Creek watershed suggest that there may have been about seven similar fire-flood events in the last 2,000 years. The Buffalo Creek Fire has produced disastrous consequences for Denver and surrounding communities. However, the postfire evaluation is expected to help land managers along the Colorado Front Range better anticipate the effects of wildfire on other watersheds and other reservoirs.

Fire in the Landscape: History, Ecology, and Regional Behavior

Fire Effects in Sequoia and Kings Canyon National Parks

In the giant sequoia groves of the Sierra Nevada, Calif., cooperative research by the USGS and the University of Arizona has used fire scars found in giant sequoia tree rings (fig. 6) to develop the world's longest and most detailed fire histories. The annual- and seasonal-resolution fire records span two millennia, and show that during most of that period, low- to moderate-intensity surface fires burned in parts of individual sequoia groves, on average, about every 3 to 8 years. With the loss of fires set by Native Americans and the suppression of lightning fires that followed Euroamerican settlement, most grove areas today have experienced a 100- to 130-year period without fire—a fire-free period that is unprecedented in the past 2,000 years.

The consequences of fire exclusion for sequoia groves are beginning to show: almost no new giant sequoias have begun to grow in the last 130 years, because sequoia seedling establishment depends on fire to expose bare mineral soil and to create clearings, which with their extra sunlight and soil moisture, are especially favorable for the growth of new trees. Fire exclusion has also allowed the growth of dense thickets of flammable, shade-tolerant tree species. Forest litter and woody debris have accumulated, causing a huge buildup of surface fuels, which has led to an increased hazard of intense wildfires sweeping through groves, severe enough to damage or even kill full-grown sequoias.

Figure 6. Section of a giant sequoia, showing fire scars.

This fire history information is being used by giant sequoia managers to guide the restoration and preservation of sequoia ecosystems for present and future generations. Managers are using low- to moderate-intensity prescribed fires (fig. 7) to reduce hazardous fuel loads, to thin shade-tolerant tree species, and to open small holes in the forest canopy. The results are sequoia groves that are less vulnerable to high-intensity wildfires and that are experiencing their first abundant sequoia reproduction in more than a century.

Fire Ecology Research in South Florida

Prescribed fire has a long history in the southeastern United States, where it has been used to improve forage quality, reduce pest populations, and decrease the likelihood of destructive wildfires. Fire has been so pervasive that most of the familiar habitats in the southeast require periodic fire to perpetuate themselves: if pine forests remain unburned for long periods, they are replaced by hardwood forests that do not support the flora or fauna native to the area. If left unburned for as little as 5 to 10 years, pine forests accumulate large amounts of fuel, making them susceptible to destructive wildfires such as occurred this spring in northern Florida. The understory vegetation may

Figure 7. A prescribed burn smolders on the floor of a sequoia grove.

Figure 8. Prescribed fire in Big Cypress National Preserve, Fla.

recover quickly from such wildfires, but the canopy of pine trees may be completely killed. This spells disaster for species such as the endangered red-cockaded woodpecker that depends on large, live pine trees for its nesting cavities.

USGS scientists are studying the ecological effects of prescribed fire in south Florida pinelands. The National Park Service (NPS) has a vigorous prescribed burning program in south Florida in Big Cypress National Preserve and Everglades National Park (fig. 8). The USGS is researching the response of pine forest vegetation, including trees, shrubs, and herbs, to different seasons and frequencies of prescribed fire. Results of the study will allow NPS fire managers to better meet the ecological objectives of their prescribed burning program.

In the Lower Florida Keys, much of the habitat of the endangered Key deer is pine forest managed by the Fish and Wildlife Service (FWS). Relatively little burning has occurred here in the last several years, and the accumulation of fuel and succession of other vegetation are objects of concern. To complicate matters, houses are scattered throughout the pineland, and residential neighborhoods adjoin some of the larger pine forest areas. Therefore, smoke management and protection of private property are primary considerations, along with ecological objectives. USGS scientists and collaborators from Florida International University are studying the ecological effects of burns during the winter dry season and the summer wet season. In developing a fire management program for the National Key Deer Refuge, the FWS will consider how unique herbaceous plants, pine trees, and food plants of the Key deer respond to the different seasons of burns, along with logistical fire management considerations.

Regional Effects of Fire on Vegetation

In cooperation with the USDA Forest Service, USGS scientists are developing tools for the accurate assessment of fire effects at regional scales. Fire is the dominant ecological disturbance in forests of the Interior Columbia River Basin in the Pacific Northwest. Historical fire-disturbance regimes in this region have varied widely with respect to fire frequency and severity, but the number of available fire-history studies is limited. We know that fire-return intervals in the Interior Columbia River Basin during the past century are longer than in previous centuries because of landscape fragmentation (caused by timber harvesting, agriculture, and roads), fire suppression, and lack of deliberate burning as formerly practiced by all inhabitants of the area. The lack of frequent fire means that forest fuels per acre are greater in many locations than they would have been during the past few centuries.

Resource managers are reintroducing fire into these landscapes to reduce fuel loadings and the intensity of future fires. Accurate estimates of historical fire-return intervals are necessary to implement reasonable forest management plans. USGS scientists, in cooperation with Forest Service scientists, have developed a model that uses existing fire-history data for the region and calculates statistical relationships between fire occurrence and latitude, altitude, forest type, and other variables to create a regional map for fire-return intervals (fig. 9). Rather than having a number of widely scattered points of information on fire history, we now have a complete map for all forest types in the Interior Columbia River Basin. This model is informative and cost effective, and it can be used by scientists and resource managers as a basis for further studies or land management practices. This approach should be applicable for other regions of North America as well.

Information

For information on these and other USGS products and services, call 1-800-USA-MAPS, use the EARTHFAX fax-on-demand system, which is available 24 hours a day at 703-648-4888, or visit the general interest publications Web site at http://mapping.usgs.gov/www/products/mappubs.html.

Please visit the Wildfire home page at http://www.usgs.gov/themes/wildfire.html and the USGS home page at http://www.usgs.gov/.

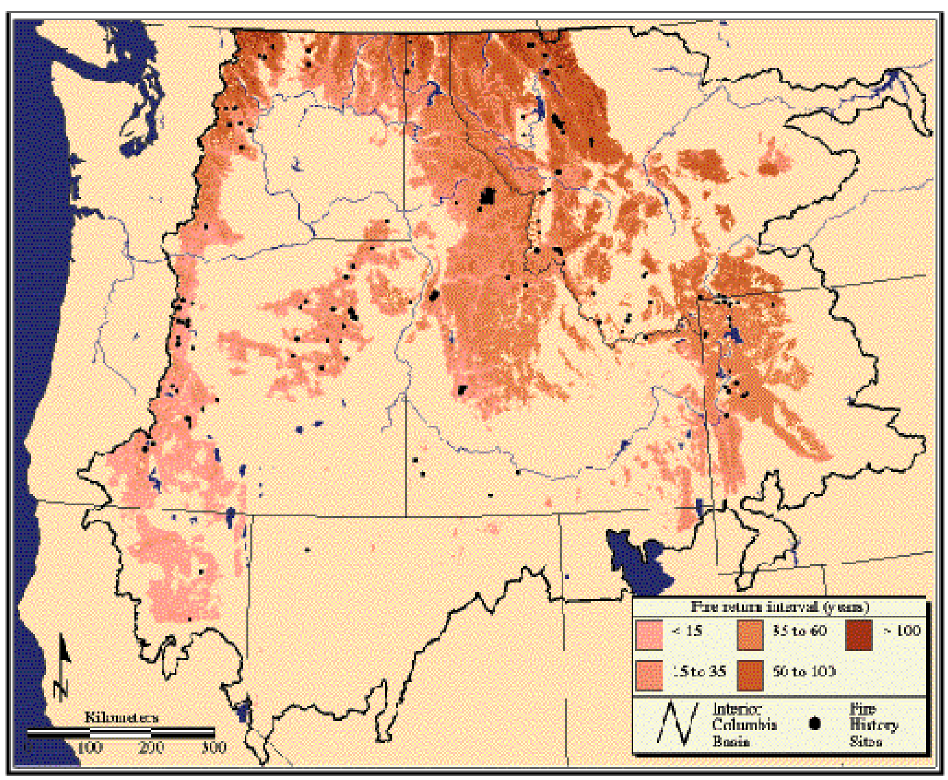

Figure 9. Fire history sites and model fire return intervals in the Columbia River Basin.