System Indicators

Forest Health and Carbon Storage

Forest Health Indicators Related to Fire (2010)

December 2012

Forest Indicators

The goal of this document is to report on the status and health of Sierra Nevada forests through a series of indicators developed from publicly available geospatial data. Indicator data presented here is collected regularly by state and federal agencies using established protocols and quality control procedures. Use of these data will allow for periodic review in the status of Sierra Nevada forests. Results from recent research on Sierra forests is included here to help inform and interpret the meaning of indicator data. Forest indicators presented here reflect different components of Sierra "forest health". Though forests are more than their individual trees, trees are the keystone species defining the forest and an examination of their health and conditions can offer much insight on the health of forested ecosystems overall.

Individual tree health can be measured by the current rate of mortality caused by wildfires, insects and disease. However, current levels of mortality may not be an indication of future levels of mortality during drought or fire. Currently healthy trees may be at risk from insects during droughts. A tree in overcrowded forests where fires have been suppressed for nearly a hundred years is at much higher risk of future mortality than a tree in a more open and resilient forest though both are currently "healthy". Lastly, climate is changing. Since current and future warming will cause new stresses on trees and forests in the Sierra, current patterns of forest health cannot be assumed to indicate future patterns.

Data presented here sheds light on insects and diseases in Sierra forests as well as the overall standing biomass contained therein. Information on the amount and type of wildfire experienced in Sierra forests is also included here as an indicator about the health of forest ecosystems.

Forest Health Indicators Related to Fire

The relationship between wildfire and forest health is a complicated one. In the recent past, fire was a profound sculptor of the entire California landscape. Frequent low intensity wildfire was the key "disturbance" mechanism shaping Sierra Nevada forests before fire suppression, mining, logging, and development started in the middle of the 19th century. Recent estimates of prehistoric fire are that between 4½ and 12 million acres burned in California every year, or about 5% to 12% of the states' lands (Stephens et al., 2007).

The exclusion of wildfire from western forests has had a number of profound ecological impacts, especially in the Sierra Nevada. Frequent fires used to consume dead wood and fuels on the forest floor and thin out the small trees in the understory. Without fire, fuels and small trees have proliferated, leading to increased stress on larger trees due to water competition, increases in tree species that are less tolerant of fire such as white fir, displacement and reduction of understory plants due to shade, displacement of deciduous vegetation by conifers, especially in riparian areas, reduction and loss of mountain meadows to conifer encroachment and reduction and loss of more open and non-forested habitats. There is also some evidence that fire suppression, by increasing moisture stress, increases a forest's susceptibility to insects and disease (Savage 1997).

Adding to the effects of fire suppression, large areas of Sierra forests were logged in rapid succession in the last century and a half, causing a new generation of forest to grow up that is of relatively uniform age and size in many areas. This combined history of impacts has led to a huge build up in forest fuels and small trees, which has in turn led to an increase in the size and frequency of high severity fires where most or all trees are killed. The average and maximum sizes of patches of high severity fire doubled in the Sierra Nevada between 1984 and 2006 from about 7 and 124 acres to 13 and 292 acres (Miller et al., 2008). Wildfires now routinely kill many large trees over larger areas than would have been the case before fire suppression. High-severity fire where all trees were killed did occur before settlement, however recent studies estimate the average size of high severity fire patches to have been only about four acres in the upper mixed conifer of the Sierra Nevada (Collins and Stevens 2010).

Fire Return Interval Departure

The change in time between fires in Sierra Nevada forests can be examined to shed light on the health of the Sierra forest ecosystem. The larger the departure from the frequency of fire under which forested ecosystems evolved, the less "healthy" the forest, because low severity fires have not been cleaning out the understory of brush and small trees. Forest managers have been conducting forest fuels treatments such as forest thinning, masticating brush, and creating fuel breaks over large areas to reduce these impacts. These treatments act as a surrogate to fire in that they mitigate a number of the ecological impacts of fire suppression. Research confirms that these treatments do indeed reduce the density of forests and so the health of individual trees without many negative side effects (Stephens et al., 2012). Fuels reduction projects have also been shown to reduce the severity of wildfires and so the likelihood of survival of trees in the burned areas (Safford et al., 2012).

Treatments have also been widely undertaken to reduce the ecological impacts described above including conifer removal from meadows and aspen stands. However, although these treatments are somewhat effective, they do not fully replace fire as the primary shaper of Sierra forests. For example, aspen restoration is most effective after fire stimulates new shoots to grow up where old trees have burned. The seeds of some rare plants need the chemical stimulus of fire to germinate and recolonize a site. Unfortunately, many of the ecological effects of low severity fire on forest ecosystem function are not well understood. Therefore, the length of absence of low severity fire from the forest can be seen as one indicator of its ecological health.

Fire return interval departure data is available for the state of California as a whole from the U.S. Forest Service and a subset was analyzed for the productive forest areas of the Sierra Nevada. The pre-settlement or "reference" fire return interval is an estimate of how often, on average, a given forest type likely burned in the three or four centuries prior to Euro-American settlement in the middle of the 19th century. Reference FRI has been determined by researchers through analysis of fire scars in tree rings in live and dead trees. Results show that forested areas previously burned every 11 years on average in the warmer and drier lower elevation forests such as ponderosa pine up to only every 133 years for sub-alpine forests where it takes much longer for fuels to accumulate and dry (Stephens et al 2007) (see Figure 4). The current fire

Figure 4. Mean Reference Fire Return Interval

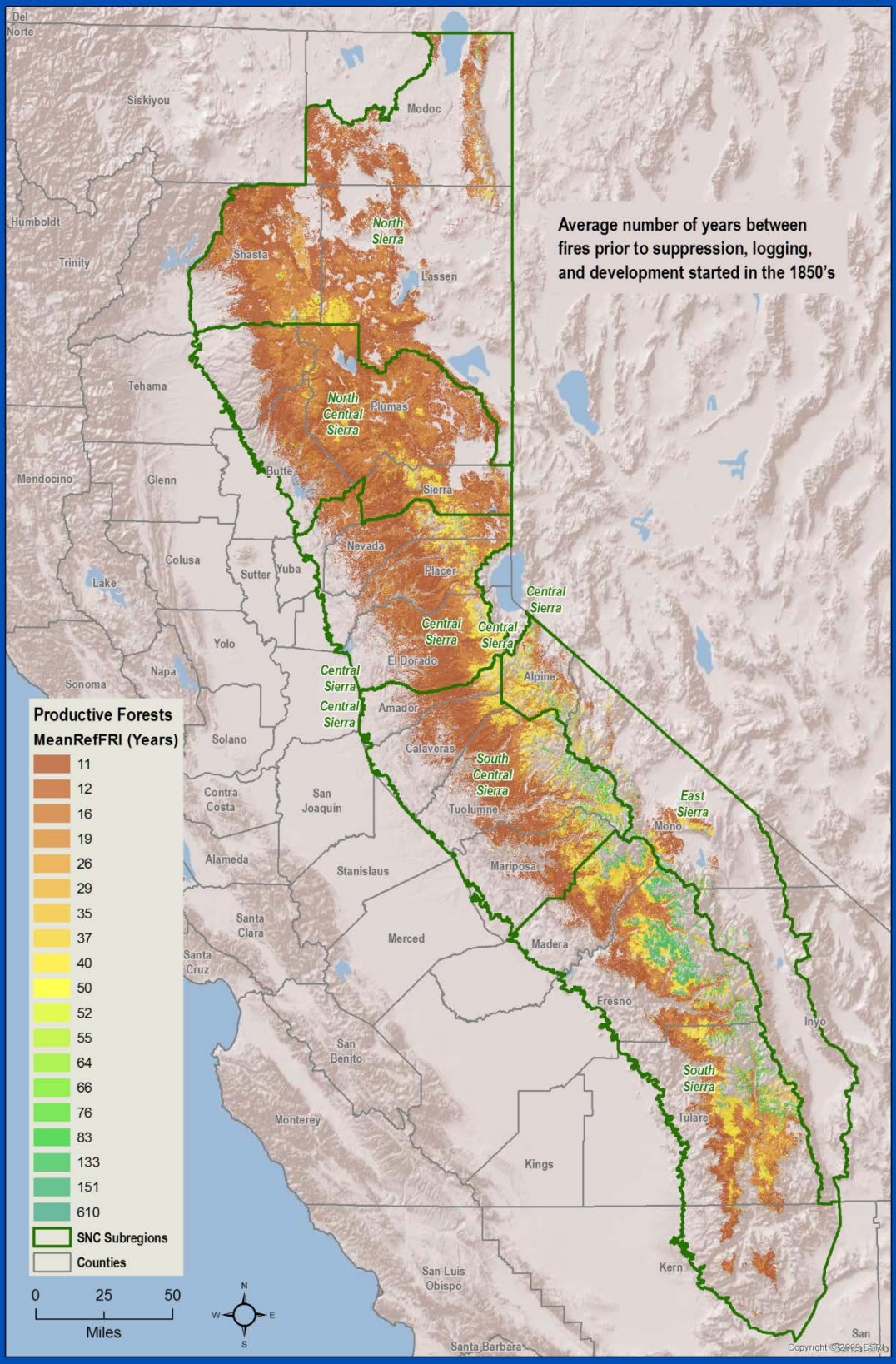
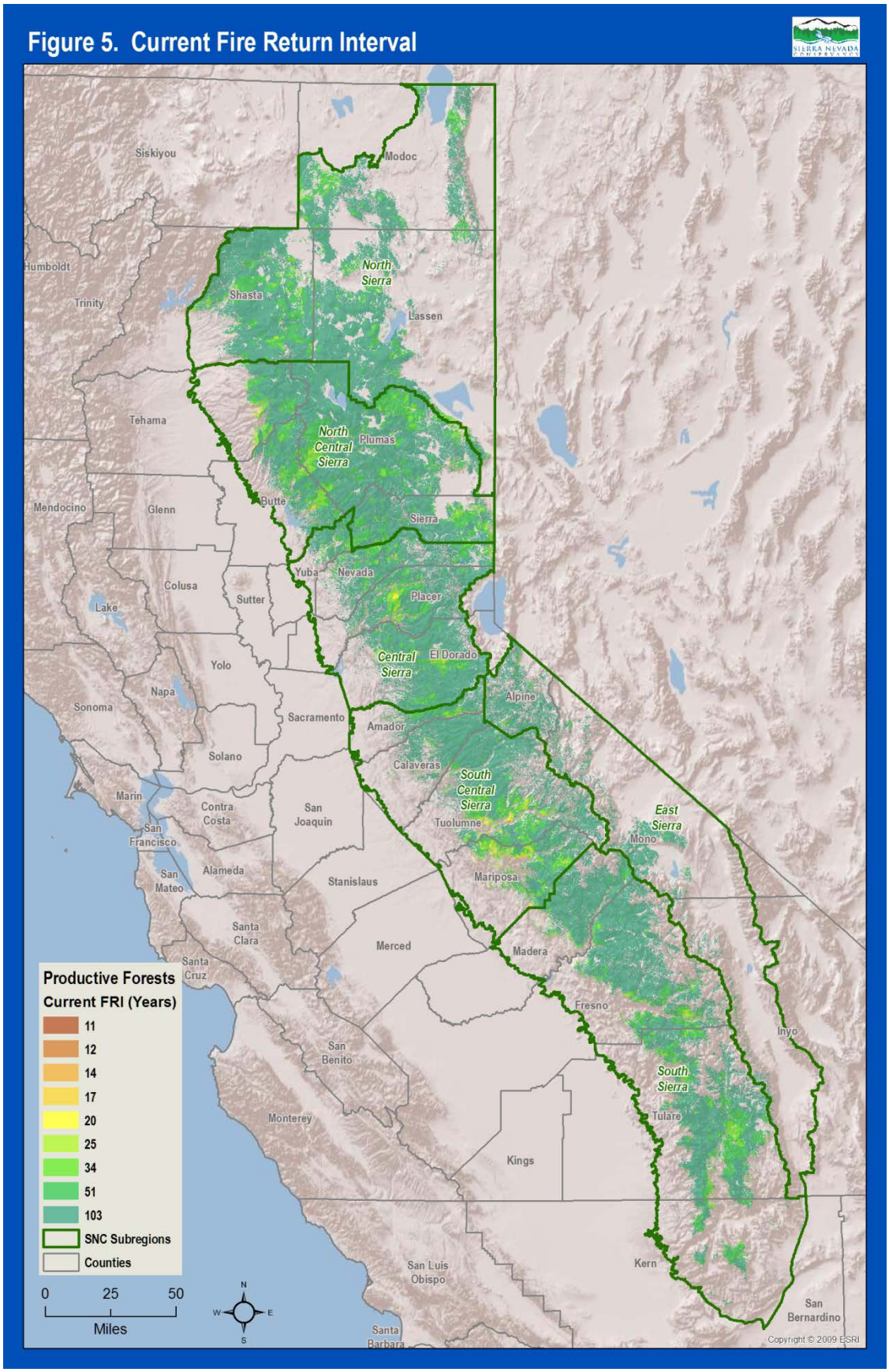


Figure 5. Current Fire Return Interval



return interval is calculated by dividing the number of years in the fire record (2010-1908=103 years) by the number of fires occurring between those dates in a given area.

Looking at Sierra forests as a whole, about 46% of the ten-and-a-half million acres would have burned at least every 12 years on average, and 76% would have burned at least every 20 years on average. This compares to less than 0.2 percent that currently burns at least every 20 years, most of which is in the National Parks, which more regularly use prescribed fire and managed wildfire (natural fires that are allowed to continue burning under suitable conditions and control) to achieve fuels reduction and forest management objectives (North et al., 2012). A total of 74% of the Sierra landscape has not had a single wildfire or prescribed burn in the last 103 years (see Figure 5).

Condition Class is a measure of the extent to which fires since 1908 are burning at frequencies similar to before Euro-American settlement (a comparison between current and mean reference FRI). Classes include Class 1 where there has been up to a 33% departure; Class 2 with 33 to 67% departure; and Class 3 with more than a 66% departure from pre-settlement fire return interval. Condition classes are positive where fires are burning less often than under pre-settlement conditions, while negative classes are found where fires are burning more often. Both positive and negative Condition Class 1 are grouped together because they are both within 33% of the mean pre-settlement value.

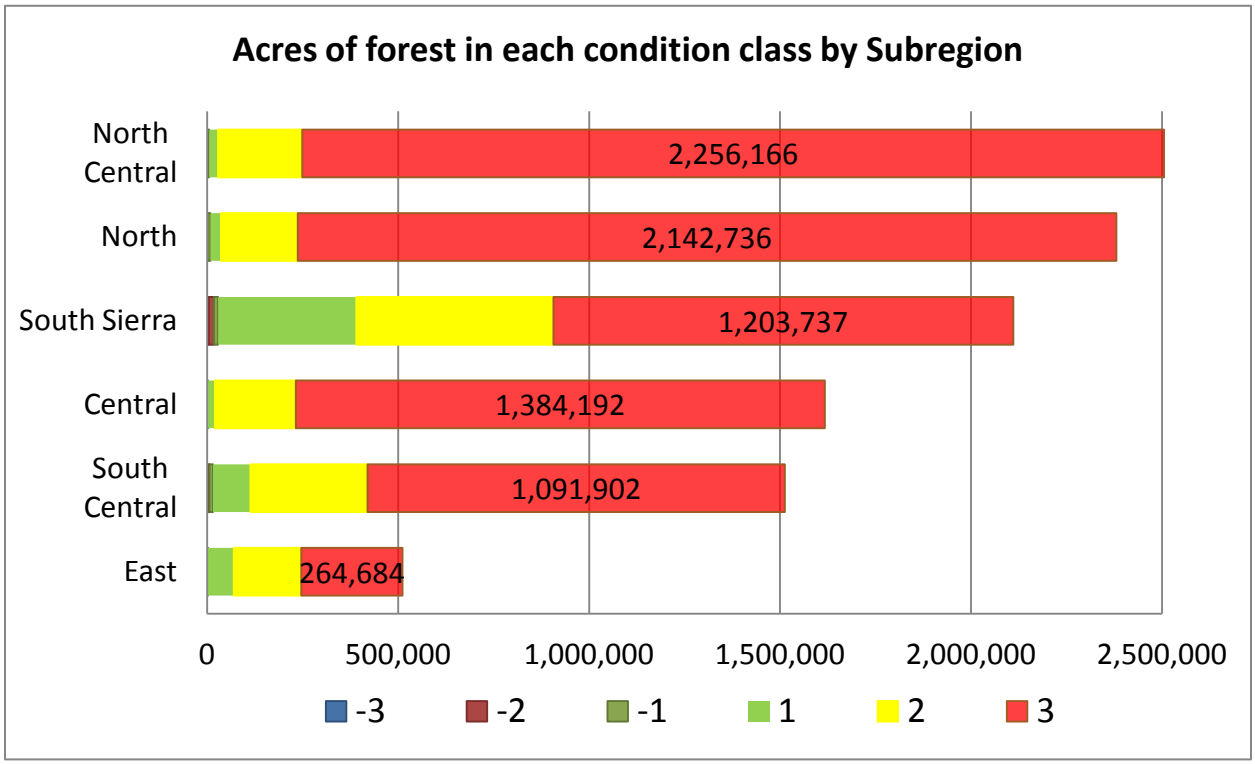


Figure 6. Acres in each fire condition class in Sierra Nevada Subregion, 2010. Class 1 has a 33% departure; Class 2 has a 33 to 67% departure; and Class 3 has more than a 66% departure from pre-settlement fire return interval. Fires burn less often in positive condition classes than under pre-settlement conditions, while fires burn more often in negative classes.

Seventy-eight percent of the productive forests in the Sierra are in Class 3, 15% are in Class 2 and 6% are in Class 1. The Subregions of the Sierra with the highest percentage of forests in Class 3 are the North and North Central Sierra, each with 90%. The Central and South Central Subregions have 85% and 72% in Class 3 respectively. The South and East Subregions have the smallest percentages of forest areas in Class 3 at 56% and 51% respectively (see Figure 6).

The ownership with the lowest percentage of acres in Class 3 is the National Park Service where many years of prescribed burning have re-introduced fire into forests. NPS lands are also more likely to be at higher elevations where fires were less frequent so they are not as far "behind" in years in which burns would have happened under a natural fire regime (North et al., 2012). The U.S. Forest Service is second with 75% of their Sierra forest acreage in Class 3. Private landowners have 98% of their forests in condition class 3 (see Figure 7).

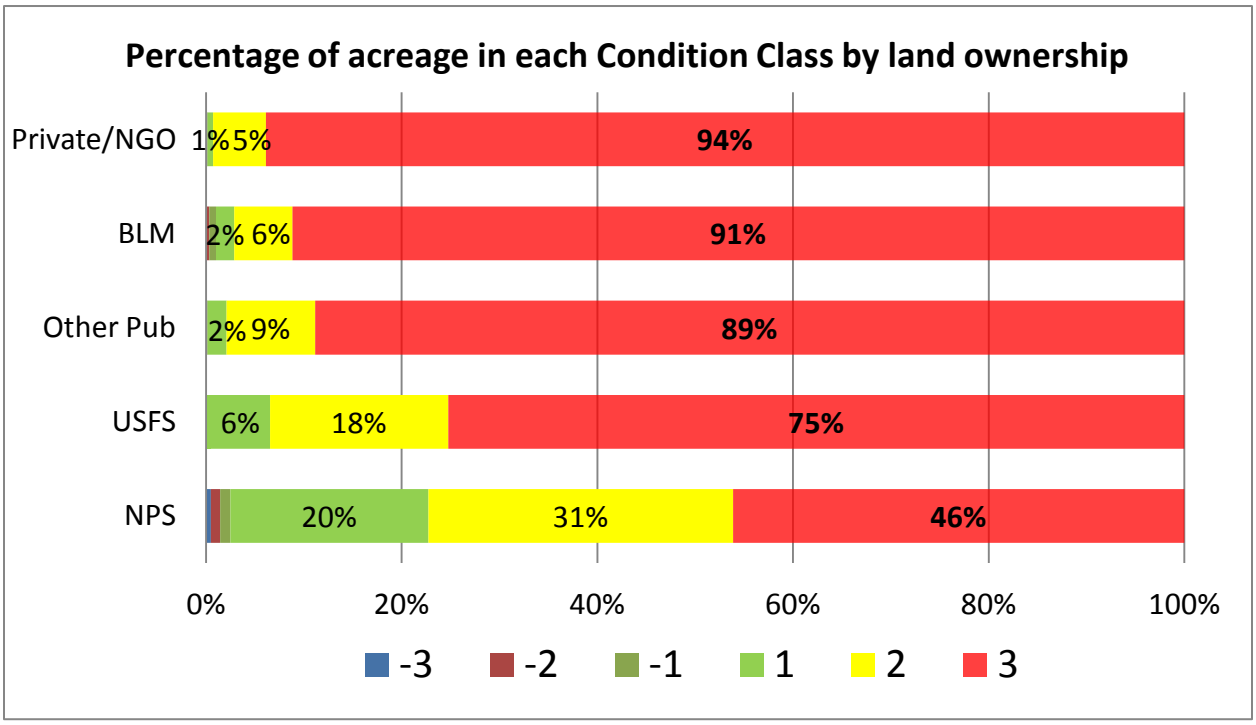


Figure 7. Ownership of Sierra Nevada forests by fire condition class.

Severe Wildfire Threats to Ecosystems

Although Sierra Nevada forests evolved under a regime of frequent low severity fire, wildfires today typically burn at higher severity over larger areas, meaning that most if not all, of the trees are killed (Miller et al., 2008). High severity fire, burning over a large area, threatens the ecosystem services provided by forests including drinking water, soil stabilization, wildlife habitat and recreation. So, although lack of fire can be seen as an indicator of lack of forest heath, too much high severity fire kills many trees and causes other dramatic negative impacts on forest ecosystems.

Data about severe wildfire threats to ecosystems in California was assembled by the CALFIRE Fire and Resource Assessment Program (FRAP) in 2010 (CALFIRE 2010). CALFIRE identified ecosystems where the threat of high severity wildfire to ecosystem services is highest and classified them into low, medium, and high priority landscapes for addressing the threats. These areas were identified as locations where treatments to reduce fire impacts such as fuels reduction through prescribed fire, mechanical thinning, grazing and other approaches were needed. These types of treatments have been shown to effectively reduce the severity of fire and so, the impacts to forested ecosystems (Safford et al., 2012).

CalFire identified Sierra mixed conifer forests as the ecosystem with the largest area of high priority landscape of any in California, with 3.7 million acres. Within Sierra Nevada forests, almost 5½ million acres, or half the total acreage, was classified as high priority for treatment to prevent severe wildfire threats to forest ecosystems (see Figure 9).

Within the Sierra Nevada, the North Central Subregion had the most high priority acres with 1.6 million, followed by the North Subregion with about 1.5 million. The South and South Central Subregions had about half that much. The East Subregion had very little forest area where ecosystems were prioritized for action to relieve the threat of severe wildfires (see Figure 8).

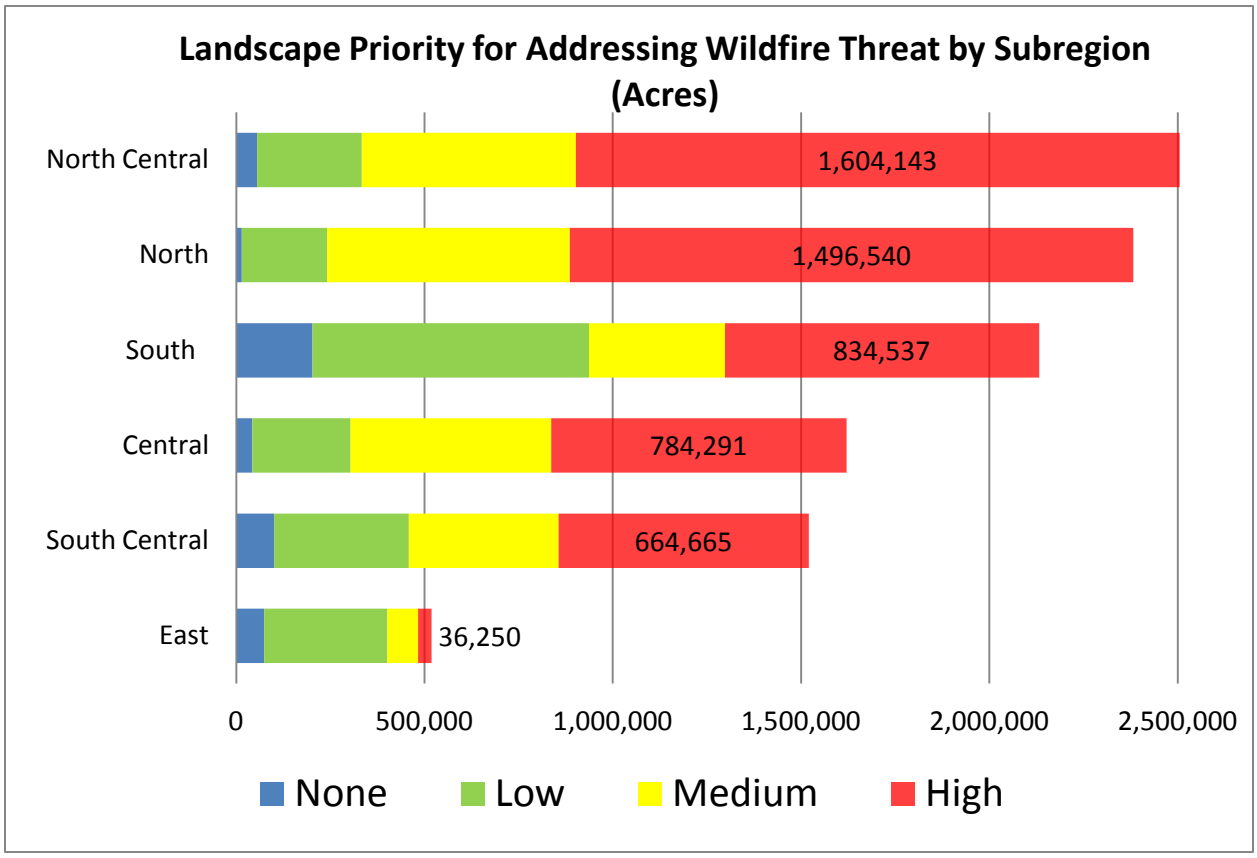
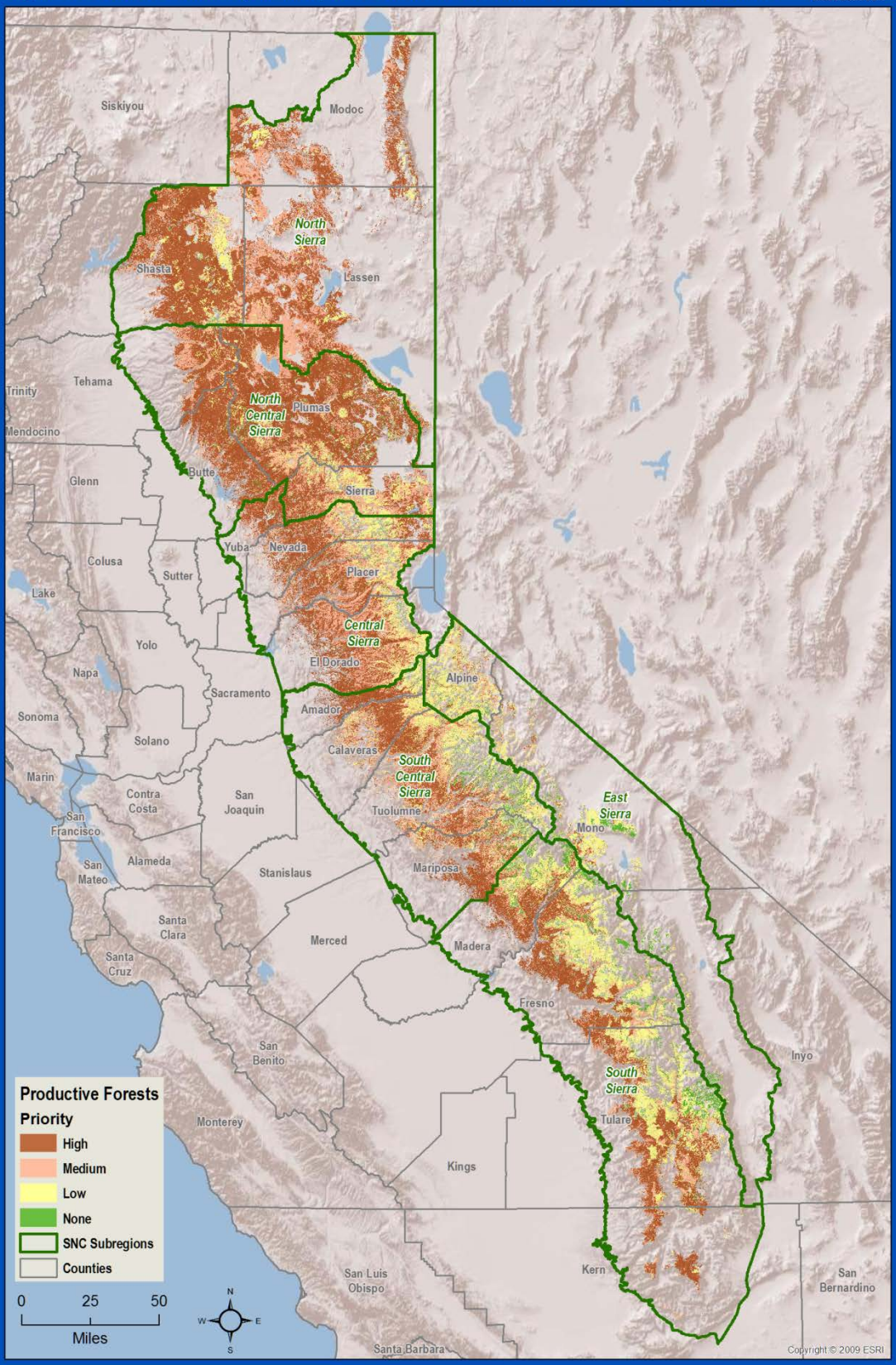


Figure 8. Landscape Priority for addressing severe wildfire threats to ecosystems for each Subregion

Figure 9. CAL FIRE Landscape Priority for Prevention of Wildfire Threat to Ecosystem Health



The National Park Service, again, has the lowest percentage (25%) of its acres in high priority for addressing severe wildfire threat (see Figure 10). The U.S. Forest Service is second with 48% of its acres rated as high priority. Other public agencies including the Bureau of Land Management, private landowners and NGOs all have around two-thirds of their acres in High Priority status.

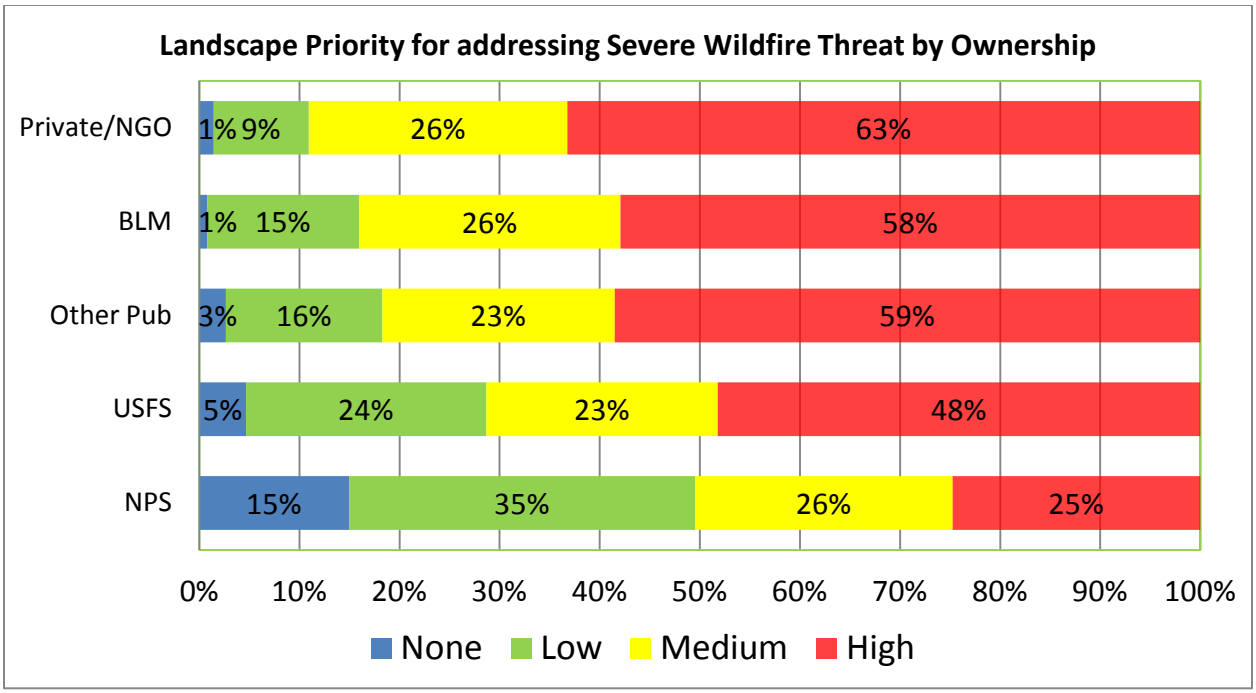


Figure 10. Landscape priority for addressing wildfire threats to ecosystems for different ownerships

CALFIRE did an additional analysis to identify watersheds where a high percentage of the landscape is at risk for damage from severe wildfires. The Sierra Nevada Region data is shown in Figure 12. High severity fire can have dramatic impacts on watershed function, including increasing the volume and likelihood of increased sediment delivery. Fires consume the litter layer, exposing soils to erosive precipitation and killing plants whose roots give the soil strength to avoid slumps. The larger the area within a watershed that is threatened by high severity fire, the greater the concern.

The Subregions with the highest threat to watersheds are the North and North Central Subregions, with an average percentage of watersheds threatened of 63% and 64% respectively (see Figure 11).

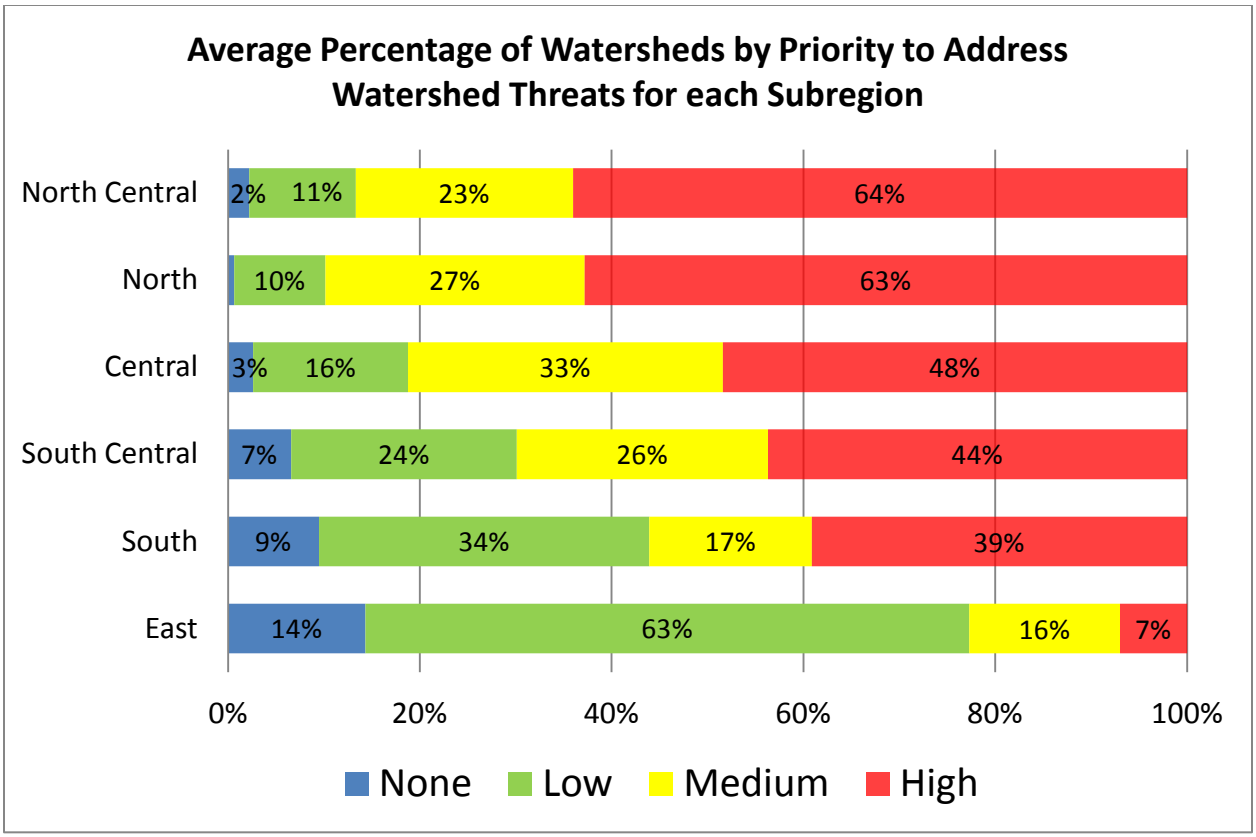
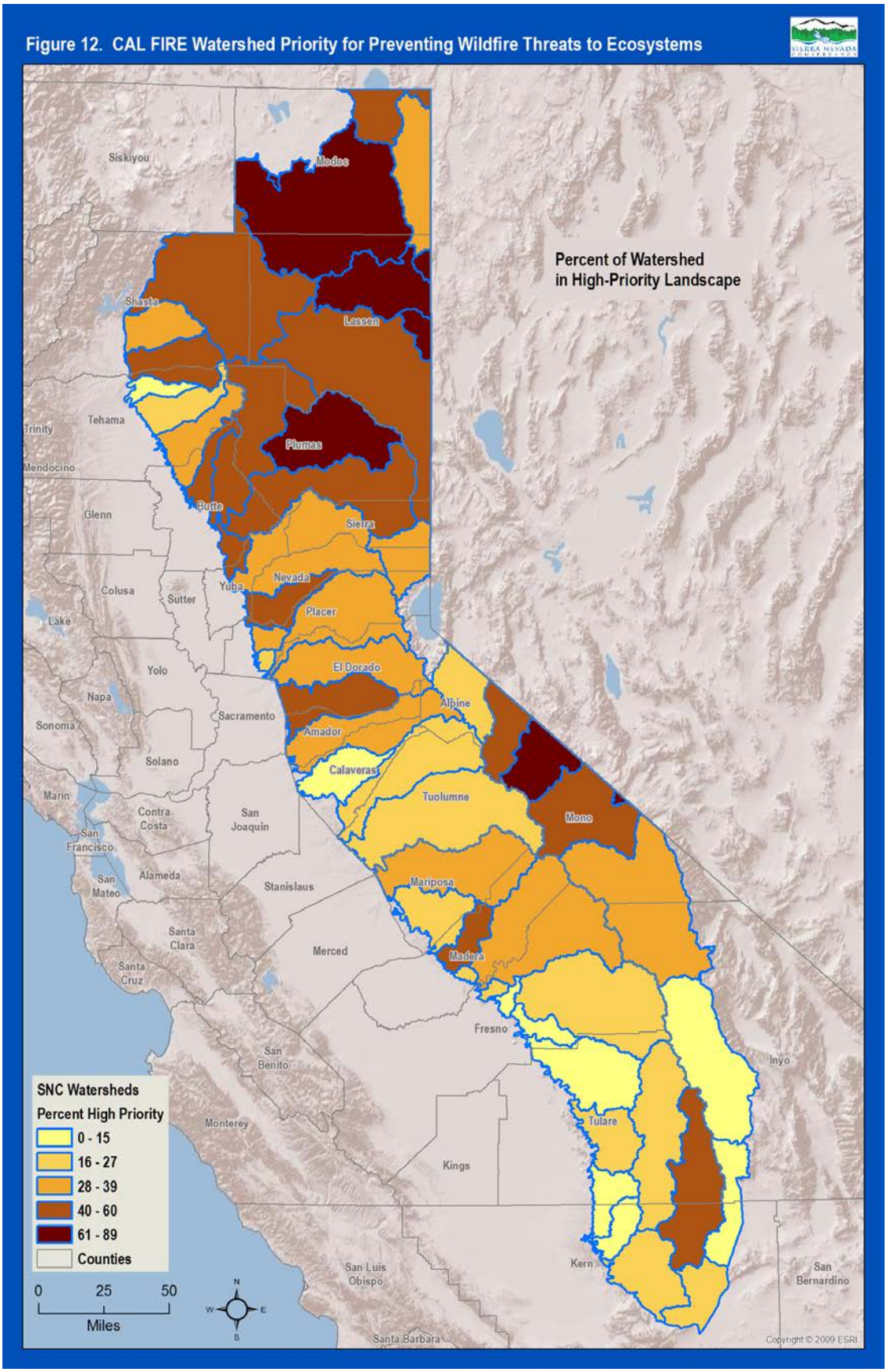


Figure 11. Average percentage of watershed by Subregion in each priority to address severe wildfire threat

Watershed areas which have already withstood wildfire damage to their ecosystems and so are at high priority for restoration of their forests were identified by CALFIRE (see Figure 13.) The Sierra Nevada watersheds with the highest percent of forested areas to be restored are found in the North Central Subregion. The Butte Creek Watershed in Butte County and the East Branch of the North Fork Feather River in Plumas County had 10% and 9% of their area in high priority to restore damage from wildfire damaged ecosystems during the 2010 assessment. Significant areas of the Feather River Watershed have burned since this assessment was completed.

Figure 12. CAL FIRE Watershed Priority for Preventing Wildfire Threats to Ecosystems



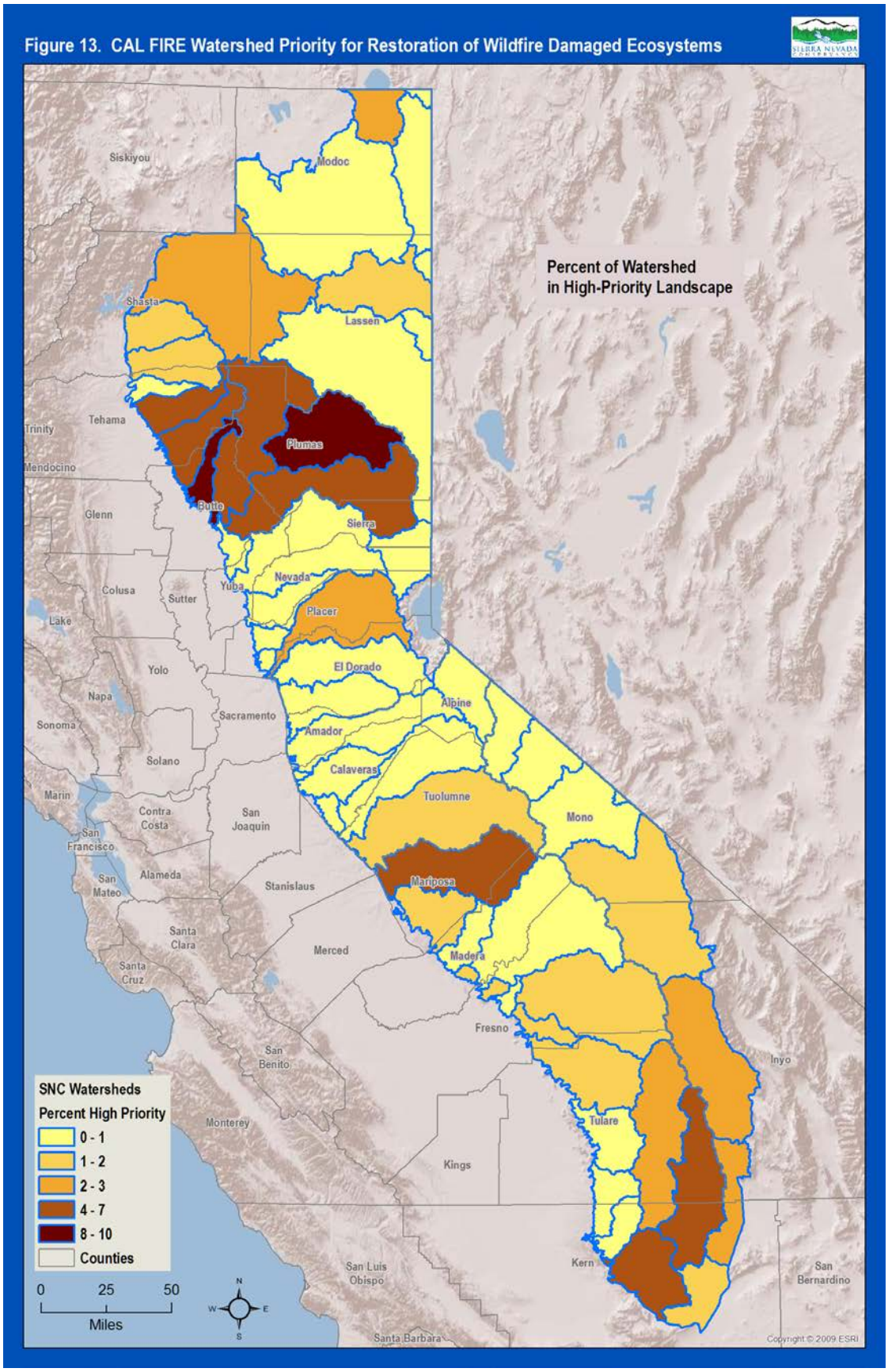


Figure 13. CAL FIRE Watershed Priority for Restoration of Wildfire Damaged Ecosystems
Percent of Watershed
in High-Priority Landscape
Siskiyou
Modoc
Shasta
Lassen
Trinity
Tehama
Plumas
Mendocino
Butte
Glenn
Sierra
Nevada
Colusa
Sutter
Yuba
Placer
Lake
El Dorado
Yolo
Napa
Alpine
Sacramento
Sonoma
Amador
Solano
Calaveras
Marin
Tuolumne
Mono
Contra
Costa
San
Joaquin
San
Francisco
Alameda
Mariposa
San
Mateo
Stanislaus
Santa
Clara
Merced
Madera
Santa
Cruz
Fresno
San
Benito
Inyo
Monterey
Tulare
Kings
San Luis
Obispo
Kern
San
Bernardino
Santa Barbara
SNC Watersheds
Percent High Priority
0 - 1
1 - 2
2 - 3
4 - 7
8 - 10
Counties
0
25
50
Miles
N
W
E
S
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