Fire risks to ecosystem health

Wildfire can cause serious and long-lasting damage to ecosystems.

Wildfire can cause serious and long-lasting damage to ecosystems. Following National Fire Plan concepts, FRAP has utilized data specific to California to describe ecosystems and fire-related metrics used in other analyses to define and describe fire-related risks to ecosystems. Fundamental to this idea is that current expected fires are compared to historic fire regimes with respect to fire frequency, size and patchiness, and effects on key ecosystem elements and processes. Thus, these classes are then assigned based on current vegetation type and structure, an understanding of its pre-settlement fire regime, and current conditions regarding expected fire frequency and potential fire behavior. As a result of these efforts, "Condition Classes" were defined as the "relative risk of losing key components that define an ecosystem (Hardy et al., 2001). The conceptual basis is that for fire-adapted ecosystems, much of their ecological structure and processes are driven by fire, and disruption of fire regimes leads to changes in plant composition and structure, uncharacteristic fire behavior an other disturbance agents (pests), altered hydrologic processes and increased smoke production.

Condition Classes have been developed that relate wildfires relative to their historic regimes. These classes are then assigned based on current vegetation type and structure, expected fire frequency, and potential fire behavior.

Fire associated risk to ecosystems in the National Fire Plan: As part of the ongoing National Fire Plan strategy to protect ecosystems from degradation, loss of diversity, and possible loss or conversion, a classification system has been developed to assess fire-related risk to basic ecological health. A coarse-scale assessment of this measure, termed "Condition Class," was conducted for the lower 48 states in support of the initial policy development for the National Fire Plan (Hardy et al., 2001; Schmidt et al., 2002; USFS, 1999). The process is continuing to be refined to better meet the needs of local and regional planning and implementation in order to realize reduced risks to ecosystem health and stability, while still being conducted under a centralized and consistent approach nationwide (Hann, 2002).

The method used follows the existing Condition Class definitions at the national level (Hann, 2002). Lands are assigned one of three Condition Class levels indicating the relative risk to the ecosystem. Definitions are given in Table 5.

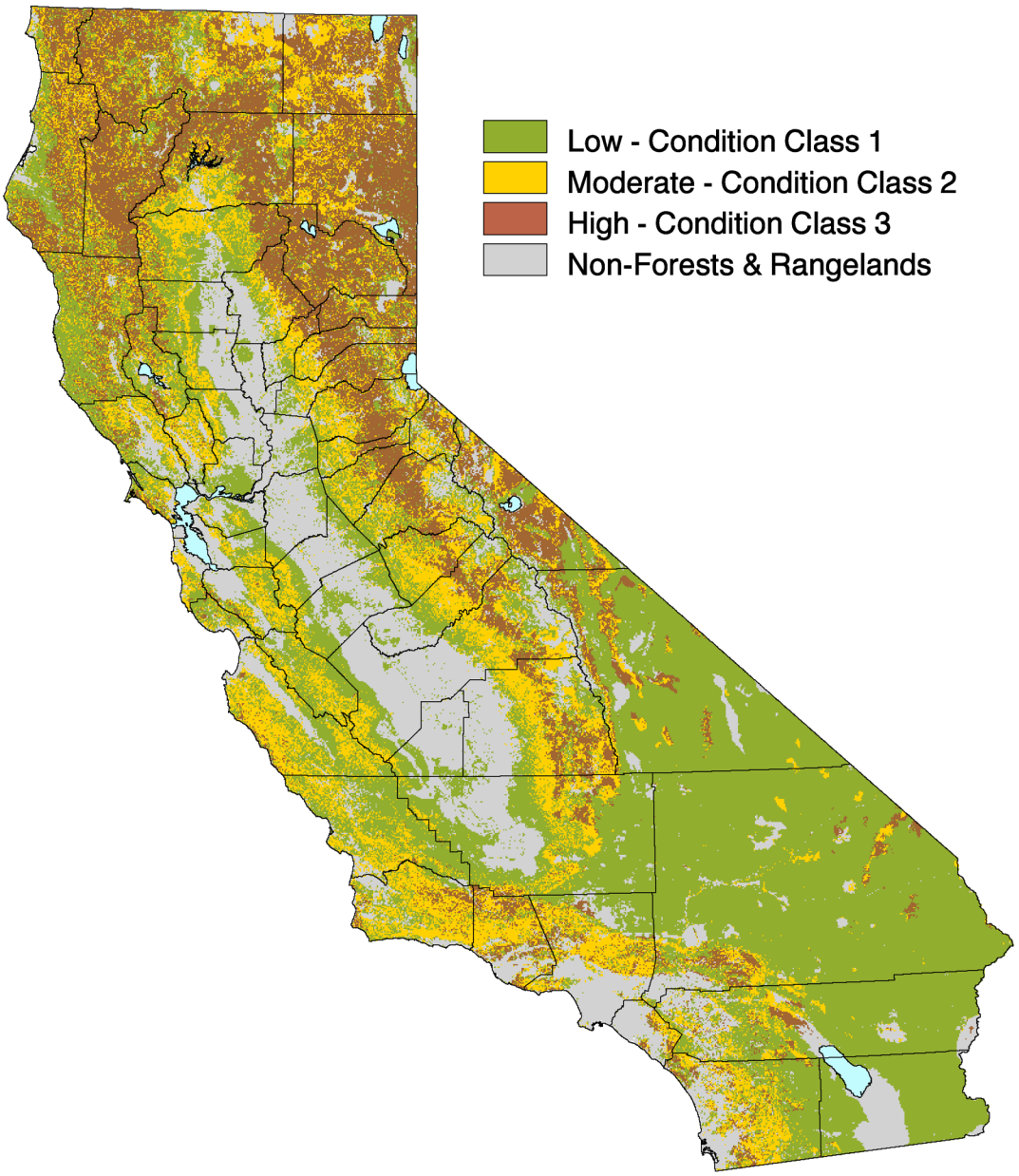
Table 5. Condition Class definitions used in assessment of risks to ecosystem health

Class	Departure from natural regimes	Vegetation composition, structure, fuels	Fire behavior, severity, pattern	Disturbance agents, native species, hydrologic functions	Increased smoke production
Low Condition Class 1	None, minimal	Similar	Similar	Within natural range of variation	Low
Moderate Condition Class 2	Moderate	Moderately altered	Uncharacteristic	Outside historical range of variation	Moderate
High Condition Class 3	High	Significantly different	Highly uncharacteristic	Substantially outside historical range of variation	High

Source: FRAP, 2003b

Condition Classes were assigned based on current vegetation type and structure as defined by California Wildlife Habitat Relationship type, size, and density (see the Assessment document Habitat Diversity) and the unique combination of expected fire frequency and potential fire behavior. The distribution of Condition Class throughout California is shown in Figure 4 and areas are estimated in Table 6.

Figure 4. Fire-related risks to ecosystem health as measured by condition class



Source: FRAP, 2003b

Table 6. Area of lands by Condition Class

Condition class	Acres	Percent
1 (Low)	43,764,634	43
2 (Moderate)	19,908,640	20
3 (High)	17,172,956	17
Non-wildland	20,044,612	20

Source: FRAP, 2003b

Roughly 37 million acres in California are ecologically at risk from fire, with 17 million acres of these at High risk (Table 6). These areas at risk span diverse ecosystems ranging from pine forests in the Klamath/North Coast to coastal sage scrub communities along the South Coast. Numerous areas of the State are dominated by ecosystems at risk from wildfire. The only area without significant widespread ecosystems at risk is the southeastern desert region, where fire has and continues to be largely a rare phenomenon.

Roughly 37 million acres in California are ecologically at risk from fire with 17 million acres of these at high risk.

A regional assessment of fire risk to ecosystems uses the total amount of area in the Moderate and High Condition Classes compared to the total forest and rangeland area. This regional summary also reveals the diverse types of habitats that Fire Threatens across California. Several of the forest bioregions have over 60 percent of the land base in Moderate or High Condition Classes (Table 7). These areas have vegetation structures and fire frequencies that have deviated from historical levels and pose High or Moderate risk to ecosystem health. Table 7 also shows the High risk typically associated with changed fire regimes of the South Coast. The Modoc region, dominated by sagebrush steppe and the pervasive influence of exotic annual grasses, has largely lost its basic ecological integrity and future fires only exacerbate the problem. Similarly, the forested area of the Klamath/North Coast and Sierra regions are at risk due to unnaturally severe fires, where post-fire succession may result in loss of forested cover for decades without active reforestation efforts.

The Modoc and other forested regions of the Klamath/North Coast and Sierras are at risk due to unnaturally severe fires.

Table 7. Percentage area of forests and rangelands in Condition Class 2 and 3 (Moderate and High) and habitats with large proportions of area in Condition Classes 2 and 3

Bioregion	Percentage	Habitats with large proportions of Condition Classes 2 and 3
Bay Area/Delta	42	Mixed Conifer
Central Coast	51	Sagebrush; Grassland
Colorado Desert	5	Sagebrush; Grassland
Klamath/North Coast	68	Klamath Mixed Conifer
Modoc	86	Sagebrush; Grassland
Mojave	6	Sagebrush; Grassland
Sacramento Valley	29	Ponderosa Pine
San Joaquin Valley	13	Sierran Mixed Conifer
Sierra	68	Ponderosa Pine
South Coast	70	Coastal Sage Scrub

Source: FRAP, 2003b

In summary, the massive extent of modified fire regimes and ecological conditions where long-term impact on the biodiversity, productive capacity, and ecological stability is expected is a striking finding of

the Assessment. It is one that warrants additional evaluation for fire and fuels management in order to restore vegetation and fire regimes to a condition that supports an acceptable level of ecological risk.

Fire risks to range forage

Range forage is an important economic resource to the ranchers of California. Fire can impose significant, short-term losses of forage when standing crops are consumed by fire. This loss is compounded when rangelands must be rested after fire for one to two full growing seasons to allow for range recovery.

Range value

Range forage is an important economic resource to the ranchers of California. Fire can impose significant, short-term losses of forage when standing crops are consumed by fire.

FRAP used the California State Fire Plan Assets at Risk analysis to form the basis of range forage valuation (1996). This work was based on combining estimates of forage production with estimates of replacement feed costs and assumptions of duration of rest from active grazing. For each acre of unique range (vegetation) type, region, and ownership class, productivity was assessed as carrying capacity and expressed in Animal Unit Months—a standard measure of range forage. The value assumed to be potentially lost from wildfire was based on the cost of replacement feed for 2.5 seasons (with the assumption that half of the current year forage would be directly lost in the fire) and the fact that the rangelands would be subjected to two years of rest for recovery of range condition. Actual costs of replacement feed were based on estimates for a mixture of oat-hay and alfalfa. For this analysis, the average loss from one acre of rangeland burning is $24, with average costs per unique land type ranging from a low of $4 to a high of $54.

Estimated range forage losses as a function of fire frequency

Range value at risk is not significantly affected by differences in expected fire behavior. If the rangeland burns, the forage is lost, and risk is realized. For a given area of rangeland, the more pressing concern regarding fire risk is the expected rate of fire occurrence. Higher probability of fire increases the risk of fire, causing the loss in range forage value.

FRAP utilized expected fire frequency to model the annual probability of a fire burning a particular piece of rangeland. See Trends in Wildland Fire. The expected annual loss (in dollars) was then calculated as the product of the probability of a fire occurring, times the cost associated with that acre burning and imposition of replacement forage cost (as calculated above), times the regional forage utilization coefficients that estimate the fraction of a region's forage that is actually used by domestic livestock (Figure 5).

Figure 5. Fire-related risks to ecosystems as measured by Condition Class for California's wildland ecosystems

The results (dollars per year) were then summarized at the regional scale (Table 8). Of the $138 million dollars of value ascribed to rangeland forage annually, a total of $2.5 million is estimated to be lost due to wildfire (CDF, 2003).

Of the $138 million dollars of value ascribed to rangeland forage annually, a total of $2.5 million is estimated to be lost due to wildfire.

Table 8. Value of rangeland forage lost to wildfire annually (nominal dollars)

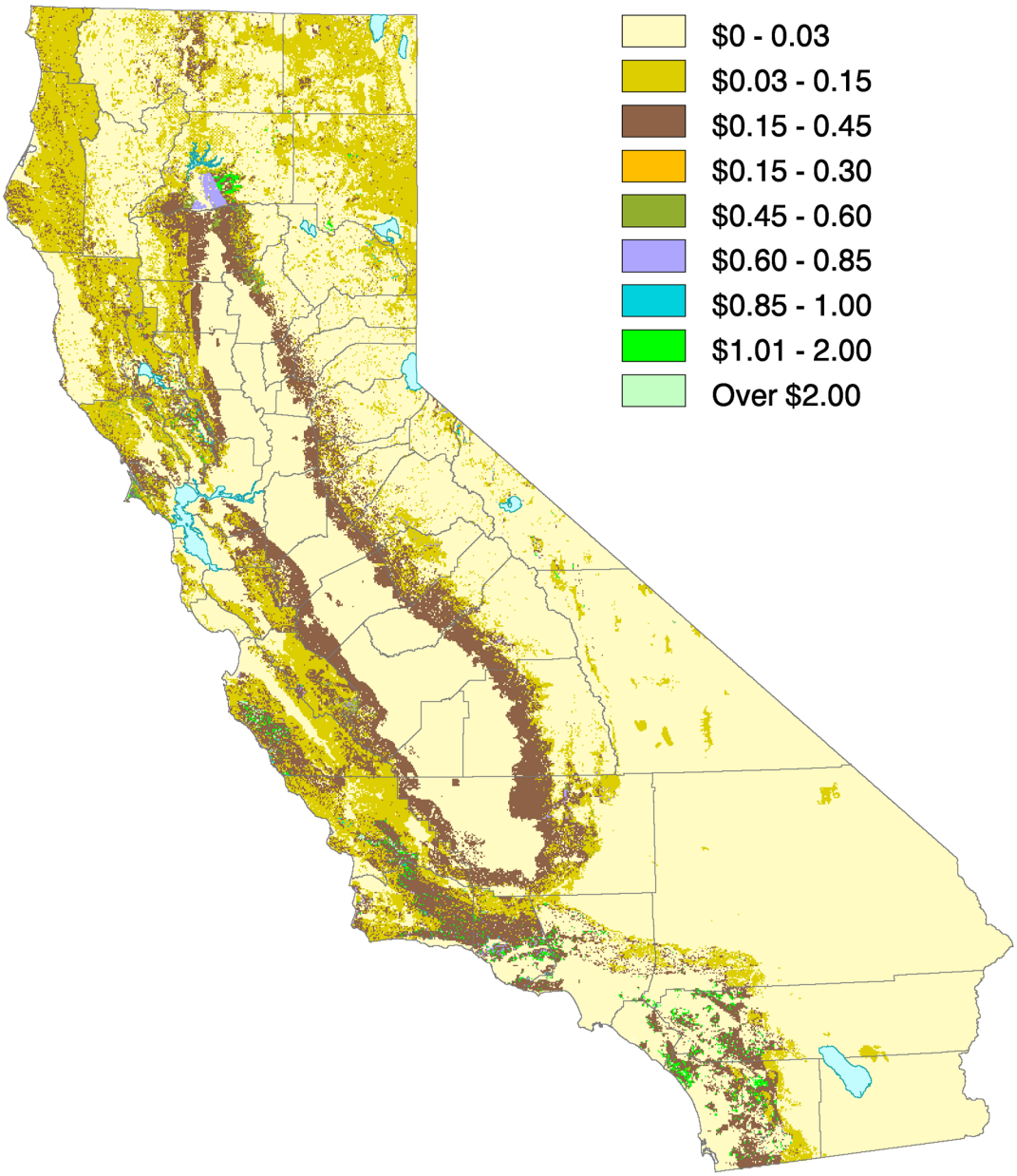
Bioregion	Rangeland loss
Bay Area/Delta	184,308
Colorado Desert	12,271
Modoc	229,642
Mojave	37,839
North Coast/Klamath	315,271
Sacramento Valley	158,098
San Joaquin Valley	114,992
Sierra	478,680
Central Coast	662,739
South Coast	331,781
Total	2,525,620

Source: FRAP, 2002a; FRAP 2002b

For mapping risk to range forage value, FRAP excluded the regional utilization factor and simply represented the expected value loss, assuming it was under forage utilization. As such, it represents a potential loss from wildfire, and not a net loss (Figure 6).

Photo courtesy of the Bureau of Land Management.

Figure 6. Potential annual value of loss expected due to wildland fire disrupting grazing activities, assuming lands under forage utilization (dollars per acre)



Source: FRAP, 2002a; FRAP 2002b

Fire Risk to Timberlands and Woodlands

Timberlands

Timberlands provide a significant economic resource base to California and are dominant elements of rural economies in some areas. Fire can pose significant risk to timber assets by direct loss from

Roughly three quarters of California's timberlands and two-thirds of its woodlands are in conditions that support High Fire Threat or greater.

combustion, mortality of growing stock, and fire-induced susceptibility to insect, pathogen, and decay mechanisms. The actual loss of timber value associated with a given fire event is a function of tree structure, fire severity and post-fire salvage opportunity. Here FRAP presents a simple measure of risk to timberlands as the intersection of a given acre of timberland with its underlying Fire Threat class. Timberlands here are defined as those conifer dominated habitat types that likely support 20 cubic feet of volume growth per year and are not in reserved status (See Forest Land Base). Table 9 shows the percentage distribution of Fire Threat across the roughly 17 million acres of Timberland Statewide.

Roughly three-quarters of the timberland land base is in conditions that support High Fire Threat or greater, and over half of these lands are in Very High or Extreme Fire Threat conditions (Table 9). Only roughly one-fifth of California's timberlands are in Moderate Fire Threat, where expected losses to timber assets are likely to be low. While there is the capacity to capture some of the standing timber value following wildfire through salvage harvest, it is clear that much of California's timber assets are exposed to significant risk from wildland fire.

Table 9. Percentage of timberland area by Fire Threat Class

Threat	Percent
None assigned	1
Moderate	21
High	37
Very High	40
Extreme	1
Total	100

Source: FRAP, 2003c

Woodlands

California has a large distribution of woodland vegetation that is highly prized as key wildlife habitat. Specifically, hardwood woodlands tend to provide extensive key habitat to many species. The risks associated with habitat loss in these areas due to fire is highly variable, due both to varying habitat quality and specific fuel and vegetation response characteristics unique to specific areas. Habitat structural characteristics such as tree canopy height and closure, presence or absence of a developed shrub understory, and occurrence of special habitat elements such as snags and down logs are recognized as important determinants of habitat quality for many species. Information is limited describing the structural characteristics of hardwood woodland as a determinant of level and value of associated wildlife use (Tietje et al., 1997). Consequently, reliably assessing the effects of fire as a habitat-altering agent on those wildlife species that occur is difficult. Indeed as recently as 2002, California researchers were unaware of any published research related to the effects of prescribed fire on California oak woodland habitats and associated wildlife species (Vreeland and Tietje, 2002).

In general, fire influences on hardwood woodland habitat suitability are specific to animal and plant species and are determined by fire intensity and frequency as an influence on landscape pattern of habitat and habitat structure. The latter includes such things as presence or absence of a shrub understory, post-fire oak resprouting ability, and amount of canopy cover present. Over the longer-term, fire frequency and

intensity also play a role in determining availability or composition of understory species, young tree recruitment to the woodland stand, and ecosystem sustainability. Sapling recruitment may also be adversely influenced indirectly by fire induced population increases of certain wildlife that browse or otherwise damage saplings (Swiecki and Bernhardt 2002). A light to moderately intense prescribed fire (flame heights less than one meter) recently conducted in mixed blue oak/coast live oak woodland in the central coast region of California resulted in no observed change in the relative abundance of small mammals, breeding birds, amphibians, or reptiles. Prescribed fire of this intensity was considered potentially beneficial by reducing competition from exotic annual grasses and stimulating shrub and tree vigor (Vreeland and Tietje 2002).

Habitat alteration that results in sparse to moderate levels of canopy closure may result in conditions that support higher levels of biological diversity in some types of hardwood woodland. The California Wildlife Habitat Relationships System provides one tool to evaluate the effects of change in habitat use and value to terrestrial vertebrates as a result of altered habitat structural conditions. Hardwood Woodland habitat types such as blue oak, coastal, and valley oak woodland support the greatest number of species finding optimal breeding habitat when canopy closure conditions are sparse to moderate (10 to 60 percent).

The percentage distribution of Fire Threat classes in Hardwood Woodland is shown in Table 10. Roughly two-thirds of California's Hardwood Woodlands are exposed to Very High or Extreme Fire Threat. While many areas may respond favorably to wildland fire, initial changes in the post-fire environment may cause temporary habitat loss (and species dislocation) following fires.

Table 10.Percentage of Hardwood Woodland area by Fire Threat class

Threat	Percent
None assigned	3
Moderate	7
High	25
Very High	64
Extreme	2
Total	100

Source: FRAP, 2003c

Fire risk to soils

Fire presents a significant risk to soil through accelerated erosion potential in the immediate post-fire environment, particularly when subjected to severe rainstorms prior to any vegetation recovery (Wells et al., 1979). FRAP has developed a Statewide risk assessment based on the expected marginal increase in surface erosion caused by a potential fire.

Factors used to model fire risks to soil

Roughly 29 million acres of California are expected to exhibit High or Very High levels of surface erosion following wildfire. An additional 35 million acres is expected to result in Moderate levels of surface erosion.

A modified form of the universal soil loss equation (Wischmeier and Smith, 1978) was used to predict a non-dimensional metric of soil loss resulting from fire. The main influence in this analysis is fundamental changes to vegetation cover resulting from fire. It approximates the marginal increase in surface erosion from future wildfire burning under current fuel conditions and severe fire weather. The model characterizes the influence of vegetation and other environmental factors on soil erosion. The inputs for the model include soils and precipitation data, topography, and vegetation cover (see table Factors Used in Universal Soil Loss Equation for Fire Risk to Soils). The data is then classified into four qualitative levels of erosion risk.

Approximately 29 million acres of California are expected to exhibit High or Very High levels of surface erosion following wildfire (Table 11). An additional 35 million acres are expected to result in Moderate levels of surface erosion, likely due to limited severity of wildfire on vegetation cover and intrinsic, low-erosion physical settings (gentle terrain, cohesive soils, moderate storm intensity, etc.). For areas with flat terrain (e.g., zero slope value), the model predicts no surface erosion on 37 million acres of California, irrespective of fire and other key characteristics.

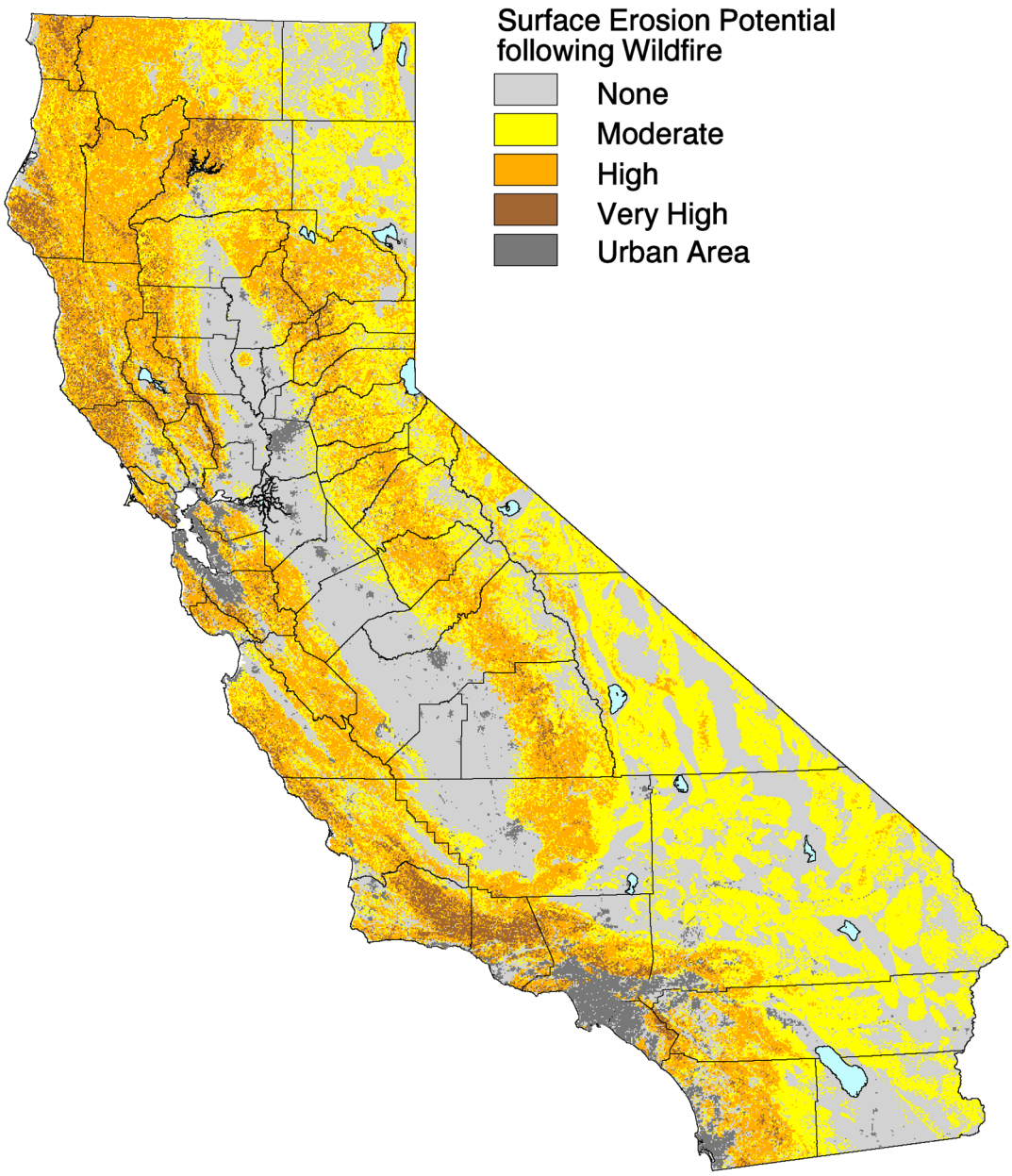
Table 11. Area of post-fire erosion risk classes

Erosion class	Acres	Percent
None	36,965,529	37
Moderate	34,827,443	35
High	24,644,072	24
Very High	4,003,522	4
Total	100,440,566	101

Source: FRAP, 2003c

Figure 7 illustrates the risk of fire-induced surface erosion across California. Most mountainous areas of the State are likely to result in High or Very High levels of post-fire erosion. When viewed under the context of variable fire probability, most of the North Coast region would expect much lower total fire-caused erosion due to its lower expected frequency of fire. In contrast, not only does the biophysical condition of the South Coast chaparral region indicate high risk, but this area has amongst the highest expected frequencies of fire and represents the highest expected levels of fire risk to erosion Statewide.

Figure 7. Post-fire risk of increased surface erosion



Source: FRAP, 2003c

Glossary

CDF: California Department of Forestry and Fire Protection.

expected fire frequency: A measurement that predicts the average time between fires.

fire regime: A measure of the general pattern of fire frequency and severity typical to a particular area or type of landscape. The Regime can include other metrics of the fire, including seasonality and typical fire size, as well as a measure of the pattern of variability in characteristics.

FRAP: Fire and Resource Assessment Program.

Geographic Information System: A computer based system used to store and manipulate geographical (spatial) information.

GIS: See **Geographic Information System**.

HRV: Historic range of variation.

NRV: Natural range of variation.

potential fire behavior: A measurement that predicts the characteristic magnitude of a fire event as described by the physical characteristics of the fire. Common fire behavior variables include rate of spread, intensity, fuel consumption and fire type (e.g., surface vs. crown fire).

risk: A potential damage or loss to a specific asset under concern.

wildfire: Any fire occurring on undeveloped land; the term specifies a fire occurring on a wildland area that does not meet management objectives and thus requires a suppression response. Wildland fire protection agencies use this term generally to indicate a vegetation fire. Wildfire often replaces such terms as forest fire, brush fire, range fire, and grass fire.

Wildland-Urban Interface: The geographical meeting point of two disparate systems, wildland and structures. At this interface, structures and vegetation are close enough that a wildland fire could spread to structures or fire could spread from structures to ignite vegetation.

WUI: See **Wildland-Urban Interface**.

Literature cited

Bachman, A. and B. Allgower. 1999. The need for a consistent wildfire risk terminology. In: Neuenschwander, L.F. and K.C. Ryan (technical editors). Proceedings from the Joint Fire Sciences Workshop "Crossing the millennium: integrated spatial technologies and ecological principles for a new age in fire management" June 15-17, Boise ID, Volume I. pp. 68-77. Moscow, ID: University of Idaho.

California Department of Forestry and Fire Protection. Various Years. Wildfire Activity Statistics. Sacramento, CA.

California Department of Forestry and Fire Protection. 2003. California Fire Plan. Sacramento, CA. Web site accessed March 5, 2003. http://www.fire.ca.gov/FireEmergencyResponse/FirePlan/FirePlan.asp.

Dissmeyer, G.E. and G.R. Foster. 1981. Estimating the cover-management factor in the universal soil loss equation for forest conditions. Journal of Soil and Water Conservation. 36(4):235-240.

Environmental Systems Research Institute. 2003. ESRI online support center: PC Arc/Info/Dak. Web site accessed March 21, 2003. http://support.esri.com/products/default.asp?p=12.

Finney, M.A. 2001. Design of regular landscape fuel treatment patterns for modifying fire growth and behavior. Forest Science 47(2):219-228.

Fire and Resource Assessment Program (FRAP). 2002a. Fire rotation, metadata and database. Sacramento, CA. http://frap.cdf.ca.gov/data/frapgisdata/select.asp

Fire and Resource Assessment Program (FRAP). 2002b. Multi-source Land Cover, v02_1. Sacramento, CA. http://frap.cdf.ca.gov/projects/frapgisdata/select.asp.

Fire and Resource Assessment Program (FRAP). 2003a. Wildland Urban Interface, v03_1. Sacramento, CA. http://frap.cdf.ca.gov/data/frapgisdata/select.asp.

Fire and Resource Assessment Program (FRAP). 2003b. Fire Regimes and Condition Classes, v03_1 Sacramento, CA. http://frap.cdf.ca.gov/data/frapgisdata/select.asp.

Fire and Resource Assessment Program (FRAP). 2003c. Fire Threat, v02_4. Sacramento, CA. http://frap.cdf.ca.gov/data/frapgisdata/select.asp.

Fischer, W.C. and S.F. Arno (compilers). 1988. Protecting people and homes from wildfire in the interior west: proceedings of the symposium and workshop. General Technical Report INT-251. Ogden, UT: U.S. Forest Service.

Hann, W.J. 2002. Mapping fire regime condition class: a method for watershed and project scale analysis. In: Tall Timbers Research Station. In Press. Proceedings of the Tall Timbers 22nd Fire Ecology Conference – fire in temperate, boreal, and montane ecosystems, Oct. 14-18, 2001, Alberta, CA. Tallahassee, FL.

Hann, W.J. and D.L. Bunnel. 2001. Fire and land management planning and implementation across multiple scales. International Journal of Wildland Fire 10(3&4):389-403.

Hardy, C.C., K.M. Schmidt, J.P. Menakis, and R.N. Sampson. 2001. Spatial data for national fire planning and fuel management. International Journal of Wildland Fire 10(3&4):353-372.

Martin, R.E. and D.B. Sapsis. 1994. A synopsis of large and damaging wildfires. In: Weise, D.R. and R.E. Martin (technical coordinators). 1994. The Biswell Symposium: fire issues and solutions in urban interface and wildland ecosystems. Feb 15-17, 1994, Walnut Creek, CA. pp. 35-39. General Technical Report PSW-GTR-158. Albany, CA: U.S. Forest Service.

Moore, I.D. and J.P. Wilson. 1992. Length-slope factors for the revised universal soil loss equation: simplified method of estimation. Journal of Soil and Water Conservation 24(1):423-428.

The National Fire Plan. 2001. Communities at risk. Web site accessed March 5, 2003. http://www.fireplan.gov/communities_at_risk.cfm.

The National Fire Plan. 2003. Home page of the National Fire Plan. Web site accessed March 5, 2003. http://www.fireplan.gov/index.cfm.

National Oceanic and Atmospheric Administration. 2002. Hydrometeorological design studies center. Web site accessed March 6, 2003. http://www.nws.noaa.gov/oh/hdsc/index.html.

Schmidt, K.M., J.P. Menakis, C.C. Hardy, W.J. Hann, and D.L. Bunnell. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. General Technical Report RMRS-GTR-87. Fort Collins, CO: U.S. Forest Service.

State of California, Division of Forestry. 1972. Recommendations to solve California's wildland fire problem. Report to Resources Agency secretary, June 1972. Sacramento, CA.

Swiecki T.J. and E. Bernhardt. 2002. Effects of fire on naturally occurring blue oak (*Quercus douglasii*) saplings. In: Standiford, R.B., D. McCreary, K.L. Purcell (technical coordinators). 2002. Proceedings of the fifth symposium on oak woodlands: oaks in California's changing landscape, October 22-25, 2001, San Diego, California. pp. 251-259. General Technical Report PSW-GTR-184. Albany, CA: U.S. Forest Service.

Tarboton, D.G. 1997. A new method for the determination of flow directions and upslope areas in grid digital elevation models. Water Resources Research 33(2):309-319.

Tietje, W.D., J.K. Vreeland, N.R. Siepel, and J.L. Dockter. 1997. Relative abundance and habitat associations of vertebrates in oak woodlands in coastal-central California. In: Pillsbury, N.H., J. Verner, and W.D. Tietje (technical coordinators). Proceedings of a symposium on oak woodlands: ecology, management, and urban interface issues. pp. 391-400. General Technical Report PSW-GTR-160. San Luis Obispo, CA: U.S. Forest Service.

U.S. Forest Service. 1999. Coarse-scale spatial data for wildland fire and fuel management. Web site accessed March 5, 2003. http://www.fs.fed.us/fire/fuelman/.

U.S. Forest Service. 2001. Wildland fire risk to flammable structures, v2000. Web site accessed March 5, 2003. http://www.fs.fed.us/fire/fuelman/hrisk.htm.

U.S. Forest Service. 2003. Sierra Nevada Forest Plan amendment. Web site accessed March 20, 2003. http://www.fs.fed.us/r5/snfpa/review/review-report/index.html.

Vreeland, J.K. and W.D. Tietje. 2002. Numerical response of small vertebrates to prescribed fire in a California oak woodland. In: Standiford, R.B, D. McCreary, K.L. Purcell (technical coordinators). 2002. Proceedings of the fifth symposium on oak woodlands: oaks in California's changing landscape, October 22-25, 2001, San Diego, California. pp. 269-279. General Technical Report PSW-GTR-184. Albany, CA: U.S. Forest Service.

Weatherspoon, C.P. and C.N. Skinner. 1996. Landscape-level strategies for forest fuel management. In: Centers for Water and Wildland Resources. 1996. Sierra Nevada Ecosystem Project: final report to Congress, Vol II. Assessments and scientific basis for management options. pp. 1471-1491. Davis, CA.

Weise, D.R. and R.E. Martin (technical coordinators). 1994. The Biswell Symposium: fire issues and solutions in urban interface and wildland ecosystems. Feb 15-17, 1994, Walnut Creek, CA. General Technical Report PSW-GTR-158. Albany, CA: U.S. Forest Service.

Wells, C.G., R.E. Campbell, R.F. Debano, C.E. Lewis, R.L. Fredrickson, E.C. Franklin, R.C. Froehlich, and P.H. Dunn. 1979. Fire effects on soil – a state-of-knowledge review. General Technical Report WO-7. Washington, DC: U.S. Forest Service.

Wischmeier, W.H, and D.D. Smith. 1978. Predicting rainfall erosion losses – a guide to conservation planning. Agricultural Handbook Number 537. Washington DC: U.S. Department of Agriculture.