Protection of Soil

Soil as a resource

Soil is a basic forest and range resource. As part of forest and range ecosystems, soils hold roots, water, and nutrients, store and transmit organic matter, and serve as habitats for many organisms that are vital to maintaining natural processes.

Rangeland in Sonoma County. Photo courtesy of Lynn Betts, USDA Natural Resources Conservation Service.

In a technical sense, soil is the natural body consisting of minerals, organic matter, liquids, and gases that occur on the land surface overlaying hard rock or other earthy materials that do not have animals, roots, or other biological activity (U.S. Natural Resources Conservation Service (NRCS), 2002a). Soil may support rooted plants in a natural environment and may be characterized by horizons or layers that are separate from underlying materials. These layers result from the gains, losses, transfers, and transformations of energy and matter.

Soils and their horizons differ based on how and when they formed. Five factors are commonly associated with soil formation (Table 1).

Table 1. Five factors commonly associated with soil formation

Factor	Description
Parent material (geologic source)	Soils can occur on the same site as their original underlying material, but typically soil is created from gravel, rocks, sand, and fine sediments transported by gravity, rivers, streams, lakes, ice, and wind to other locations.
Climate	Temperature, rainfall, moisture, and wind influence processes such as weathering, leaching, chemical balances, and biological activity.
Topography	Slope, aspect, and relative location (such as ridge or bottom of slope) can affect things such as moisture and temperature.
Biological factors	Vegetation (roots, organic matter, microclimate impact), animals, microorganisms, and humans can affect rates of soil formation, chemical balances, density and other characteristics.
Passage of time	Soils are formed and lost over time as materials gather, decompose, are used or lost, and then replenish.

Source: NRCS, 2002a

Parent material

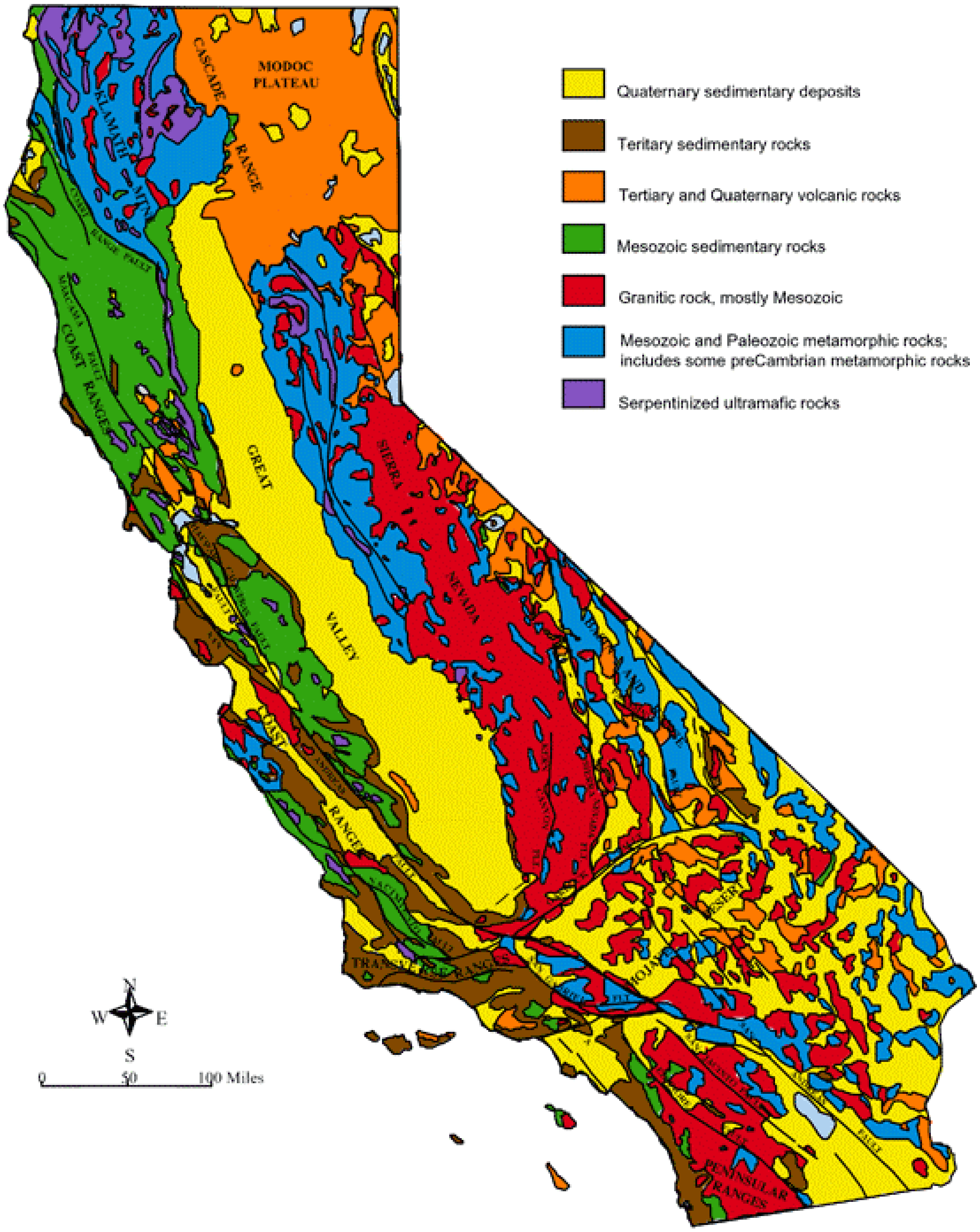
Of the factors associated with soil formation, one of the most significant in California is the parent material or rock. Rocks are classified by their age and their origin. Age can be Precambrian (before 570 million years in age), Paleozoic (from 570 million years ago to 245 million years), Mesozoic (from 245 million years ago to 66 million years), or Cenozoic (from 66 million years ago to under a million years). Based on origin, rocks can be sedimentary (from layers of mineral material in oceans or land), igneous (from crystallization of minerals from molten rock), or metamorphic (from changes to preexisting rocks by natural processes). This leads to a general categorization of rocks underlying soils in California shown in Table 2 and reflected in Figure 1.

Table 2. California soil categories

Rock	Description
Quaternary sedimentary rocks	Gravel, sand, silt, and clay deposited mostly in valleys and lowlands.
Tertiary sedimentary rocks	Sandstone, shale, and conglomerate typically deposited in shallow marine water near the continental edge. These rocks are exposed mostly in the coastal regions of California.
Tertiary and Quaternary volcanic rocks	These involve lava flows from volcanoes. They are widespread in eastern California and make up much of the Cascade Range and the Modoc Plateau.
Mesozoic sedimentary rocks	These are sandstone and shale that were deposited mostly in the ocean. The rocks make up the bulk of the Coast Ranges. They also occur in coastal southern California.
Mesozoic granitic rocks	These are igneous rocks formed when molten material cool slowly inside the earth and are later exposed by erosion. Granitic rocks occur throughout the state, but are most common in the areas such as the Klamath Mountains, the Sierra Nevada, and the Peninsular Ranges.
Mesozoic and Paleozoic metamorphic rocks.	These rocks are made from natural process working on existing rocks. Metasedimentary and metavolcanic rocks that make up much of the Klamath Mountains and the Sierran foothills. They are also common in the Basin Range, Mojave Desert, Transverse Ranges, and the Peninsular Ranges.
Serpentinized ultramafic rocks	A special type of rock that does not fit into the three common categories of rocks. The most common rock is serpentine.

Source: Department of Conservation (DOC), 2002

Figure 1. Generalized Geologic Map of California



Source: DOC, 2002

Productivity of forest and range soils

Soil productivity, or the ability of soil to grow plants, is related to its chemical and physical properties. These properties include texture, structure, organic matter content, nutrients, and soil acidity (pH) (Table 3).

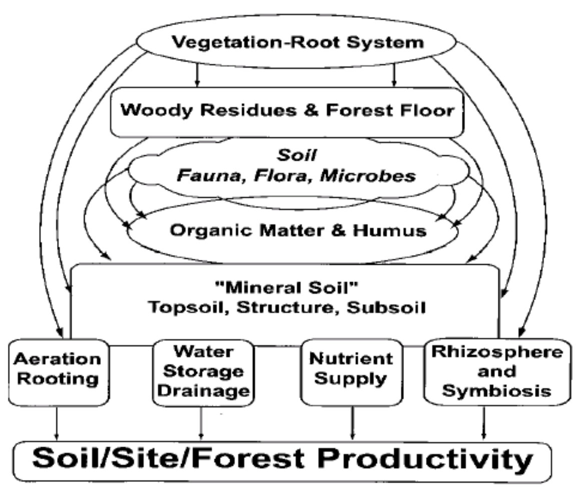
Table 3. Chemical and physical properties of soil productivity

Properties	Description
Texture	Soil is made of particles of clay and silt, sand, and larger rocks (gravel, cobble, boulders). Particles vary in size; clay is the smallest, boulders are the largest. The texture of soil describes the mix of particles in it. Particle size determines its capacity to hold on to water, other soil particles, and nutrients. Productive soils tend to have particles neither too coarse nor too fine.
Structure	Soil has different horizontal layers that have specific names such as humus and A, B, and C horizons. Humus refers to leaves and litter that has begun to decompose. The A Horizon is topsoil and usually contains a significant portion of organic matter. The B Horizon (subsoil) is the location where many chemicals such as iron and salts have gathered. The C Horizon is the bedrock or parent material where little weathering has taken place or biological activity occurs. Soil structure affects the available nutrients, soil storage of chemicals and water, and the ability of plants to root.
Organic matter	As organic matter decomposes, it helps hold soil particles together and acts as a source of phosphorus, sulfur, and nitrogen. Organic matter influences physical and chemical properties of soil often to a critical extent. By promoting aggregation, soil organic matter affects erodibility, infiltration, water retention, and shear strength of soil. Organic matter is essential to coarse-grained materials for providing nitrogen and higher exchange capacities.
Nutrients	Soil nutrients are required for plants to grow. Key elements include nitrogen, phosphorus, potassium, calcium, and magnesium. Trace elements such as zinc are also important. Forest soils in California are often low in nitrogen.
Soil acidity (pH)	The acidity or alkalinity of soil influences the ability of plants to take up nutrients such as iron, manganese, and zinc. Forest soils are generally acidic (pH 5.0-6.5) in California and conifer forests have adapted to these kinds of soils.

Source: Kocher and LeBlanc, 1998

In forest and range communities, vegetation and soils are intimately interconnected. Vegetation provides carbon in the form of leaves, needles, and other litter. Soil organisms transform and transport this carbon and make it useful to plants as part of replenished soil. These organisms chew, mix, burrow, or otherwise change the surface area and chemistry of fresh materials (Figure 2).

Figure 2. Complexity of soil organisms



Source: Powers et al., 2000

Forest and range site productivity is related to the capability of a site to produce timber, forage, wildlife, or other outputs. No single measure can adequately delineate the productivity of forest and range sites for all outputs. Measurements of productivity are usually cited as the volume or board feet of timber or the weight of forage produced per acre annually (Imler, 1998).

The productivity of range sites in California is highly varied. Rangeland soils tend to be more productive where they are deeper and there is more rainfall. Less productive soils usually are shallower and climates are more arid. Soils that are more fragile also occur on steep slopes with a harsh environment. The most productive rangeland soils tend to be associated with grassland, hardwood woodland, and wetland/riparian land cover types. Based on vegetative cover type, the site productivity of rangelands, expressed by Aminal Units Months of grazing capacity, is estimated (Table 4).

Table 4. Total annual grazing capacity on available primary rangeland cover types

Land cover type	Grazing capacity in animal unit months per acre	Area (million acres)
Conifer woodland	0.2	1.6
Grassland	0.7	9.2
Shrub	0.3	11.6
Desert	<0.1	14.3
Hardwood woodland	0.7	4.6
Wetland/riparian*	1.8	0.4
Total	0.4	41.7

**includes Montane, Riparian, and Valley Foothill Riparian*

Source: FRAP, 2002; CH2M HILL, 1989; Conner, 2003

Forestland productivity can be measured in several ways. The most common is to group areas by general forest types and then rate sites by how long it takes to grow a tree to a specified height (usually 100 years). Soil quality is a key element in why trees grow fast, but other factors such as aspect and rainfall are also reflected in the ability of a site to grow wood.

Table 5. Area of timberland by site class and resource area, 1994 (thousand acres)

Resource area	Site class (cubic feet/acre/year)						All classes	Percentage total timberlands in high site classes (120-164, 165-224 and >225 site classes)
	20-49	50-84	85-119	120-164	165-224	>225		
North Coast	68	523	1002	938	486	396	3,413	53
Central Coast	6	15	27	124	63	72	307	84
San Joaquin/Southern	494	707	711	659	63	34	2,688	28
Sacramento	556	995	1377	1,137	208	25	4,298	32
North Interior	606	2,328	1916	851	211	33	5,945	18
Total	1,730	4,568	5053	3,709	1,031	560	16,651	32

Source: compiled by FRAP from Waddell and Bassett, 1996; Waddell, 1997

Agencies that deal with forest and range soils

There are several agencies that deal with forest and range soils in California (Table 6). Collectively they provide information about the basic geology and soil distribution across California. To varying degrees they also monitor impacts of management on soil resources.

Table 6. Agencies dealing with forest and range soils

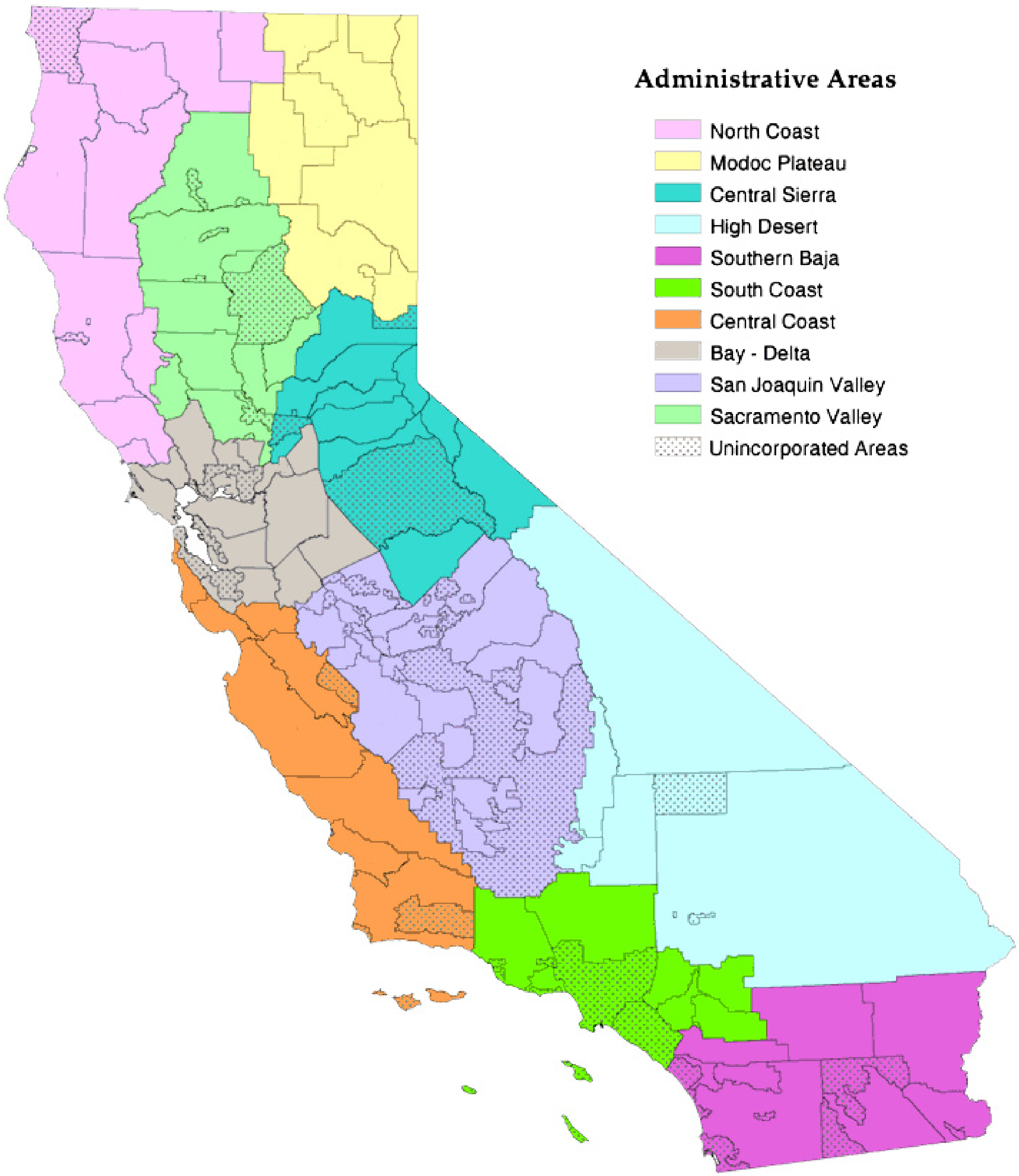
Agency	Role
Federal	
Natural Resources Conservation Service (NRCS)	NRCS, formerly the Soil Conservation Service, is the lead federal agency for soils conservation and information. It oversees the National Cooperative Soil Survey that provides periodic updated maps of soils in California and other states. NRCS staff works closely with Resource Conservation Districts and landowners in California.
US Geological Survey (USGS)	USGS provides for mapping of geologic resources, together with related properties such as stability.
US Forest Service (USFS)	Historically, the USFS has developed soils information as needed to manage the national forests. Under the National Forest Management Act of 1976, the USFS is required to ensure that management will not substantially damage the productivity of the land. To carry out this mandate, the USFS has established the National Long-Term Soil Productivity Study. The study quantifies the impacts of soil disturbance on soil productivity, improves understanding of relationships between soils and the impacts of management, and validates standards and methods for soil quality monitoring. In California this research is focused in mixed conifer forest in the Sierra.
Bureau of Land Management (BLM)	Historically, BLM has developed soils information as needed to manage BLM lands.
State	
DOC	DOC is the home of CGS, which provides geological mapping and review. It also houses the Farmland Mapping Program (FMMP). Until 1991, CGS produced numerous maps showing landslide features and delineating potential slope-stability problem areas. Since 1998, CGS has conducted watersheds mapping as part of the North Coast Watershed Assessment Program (NCWAP).
Department of Forestry and Fire Protection (CDF)	Part of CDF's mandate is to protect soil productivity as part of ongoing review of timber harvesting plans and operations. It conducts Hillslope Monitoring Program on state-owned and private timberlands.
State-authorized local	
Resource Conservation Districts (RCD)	Once known as Soil Conservation Districts, RCDs are special districts under California law. Originally the districts were authorized to manage soil and water resources for conservation. Powers have been extended to include "related resources" including fish and wildlife habitat.

BLM – U.S. Bureau of Land Management; CDF – California Department of Forestry and Fire Protection; CGS – California Geological Survey; DOC – California Department of Conservation; FLMMP – California Farmland Mapping and Monitoring Program; NRCS – U.S. Natural Resources Conservation Service; RCD – Resource Conservation District; USFS – U.S. Forest Service; USGS – U.S. Geological Survey

Source: *Roth, 2002; DOC, 2000*

Within California, the Resource Conservation District is the basic unit of delivery for technical and educational assistance in soil conservation to private landowners. There are 103 RCDs in California covering most of the State (Figure 3).

Figure 3. Resource Conservation Districts within California



Source: California Association of Resource Conservation Districts, 2002a

Resource Conservation Districts continue to provide landowner assistance in soil and water conservation and management. In many places they also facilitate larger scale cooperative conservation efforts at the watershed level such as Coordinated Resource Management Planning (CRMP) efforts (California Association of Resource Conservation Districts, 2002b).

Forest and range soils in California

The basic source of information on forest and range soils in California comes from soil surveys completed under the National Cooperative Soil Survey, which was managed by the NRCS. The survey identifies and maps over 20,000 soils in the United States. Soils are named and classified on the basis of physical and chemical properties in their horizons. This classification or "soil taxonomy" utilizes color, texture, structure, and other properties of the surface two meters deep to key the soil into an ordered system for common reference (NRCS, 2002c). Soils are usually given a name, often referencing the location where the soil was first mapped. Named soils are referred to as soil series (NRCS, 2002d).

The development of vegetation, soil, and hydrology of an area are interdependent. This includes characteristic soils that have developed over time, as well as characteristic hydrology (such as rainfall infiltration and runoff). Soils with similar properties that grow and support a typical native plant community are grouped into the same ecological site. For example, NRCS classifies rangeland landscapes into ecological sites for the purposes of inventory, evaluation, and management. A rangeland ecological site has specific physical characteristics that differ from other kinds of land in its capability to produce specific kinds and amounts of vegetation. An ecological site is determined by all of the environmental factors responsible for its development, including vegetation, soil, hydrology, fire history, and pests (Butler et al., 1997).

The NRCS Ecological Site Information System (ESIS): NRCS site inventory information is stored in the Ecological Site Inventory (ESI) database. The database can be accessed from the online document Ecological Site Information System (NRCS, 2002e).

NRCS provides three soil geographic databases representing various kinds of soil maps. The maps come in different intensities and scales of mapping. The three soil geographic databases are the Soil Survey Geographic (SSURGO), State Soil Geographic (STATSGO), and National Soil Geographic (NATSGO). Components of map units in each database usually are phases of soil series that allow the most precise interpretation. The Soil Interpretations Record database contains physical and chemical soil properties for about 18,000 soil series recognized in the United States.

The STATSGO database is designed mostly for regional, state, river basin, multi-county planning, management, multi-state, and monitoring. STATSGO data are not detailed enough to make interpretations at the county level (U.S. Natural Resources Conservation Service, 2001). Access the online figure SSURGO Certified Surveys With DOQ Complete Coverage for an example of STATSGO.

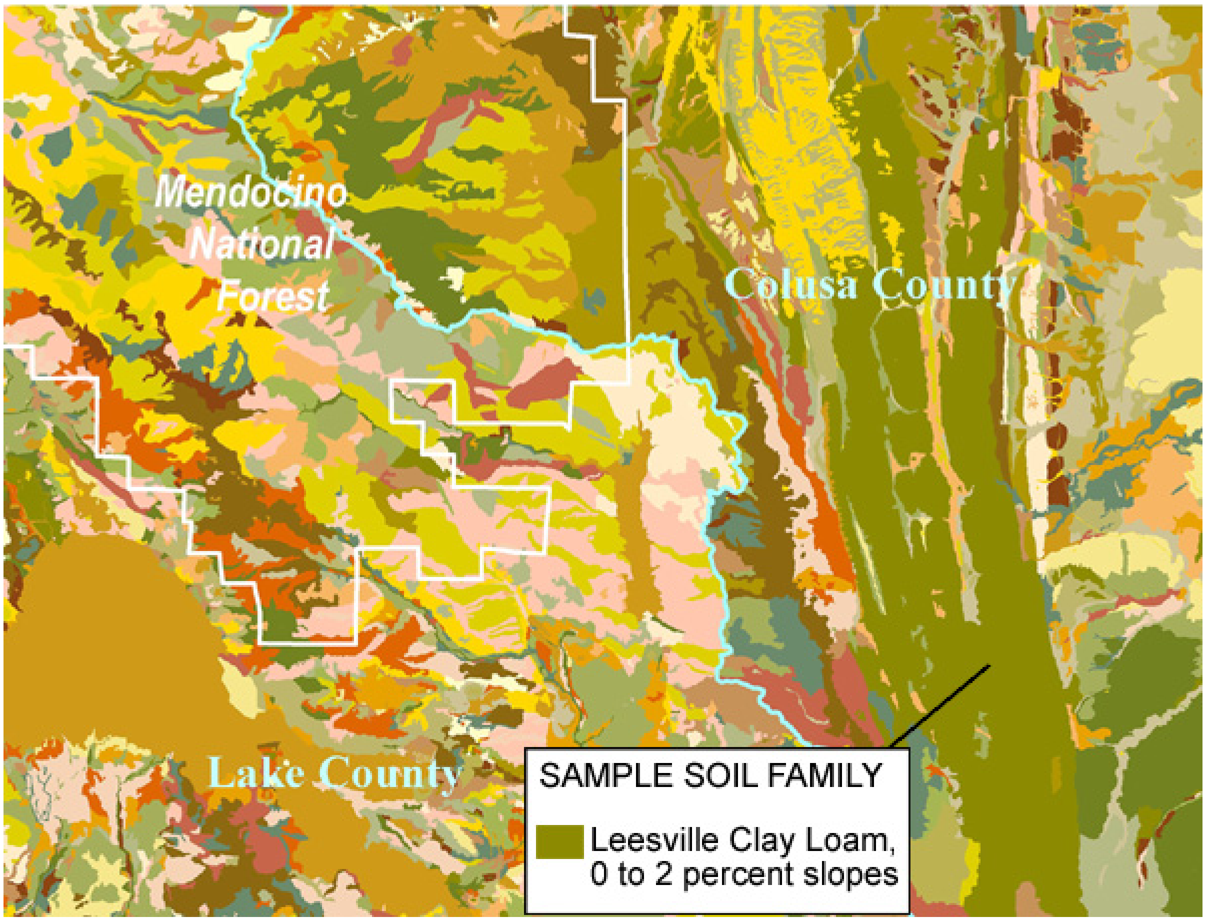
The SSURGO database provides the most detailed level of information. Mapping scales generally range from 1:12,000 to 1:63,360. SSURGO digitizing duplicates the original soil survey maps. This level of mapping is designed for use by landowners, townships, and county natural resource planning and management. A portion of California is covered by the completed SSURGO database (NRCS, 2001). See the online map SSURGO Certified Surveys with DOQ Complete Coverage.

The NATSGO database is used primarily for national and regional resource appraisal, planning, and monitoring. The boundaries of the major land resource areas and regions were used to form the NATSGO database (NRCS, 1994). See the online document State Soil Geographic (STATSGO) Data Base for more information.

Soil surveys have been conducted in California since the early 1900s. They are periodically updated (NRCS, 2002f). Refer to Pacific Southwest Major Land Resource Area Soil Survey Office, Region # 2 for the status of these surveys in California.

The U.S. Forest Service (USFS) has also mapped soils on national forests to the level of families of soil series (Figure 5). Each color in the map represents a soil type and slope class. For example, an extensive soil family type in Colusa County is shown in Figure 4.

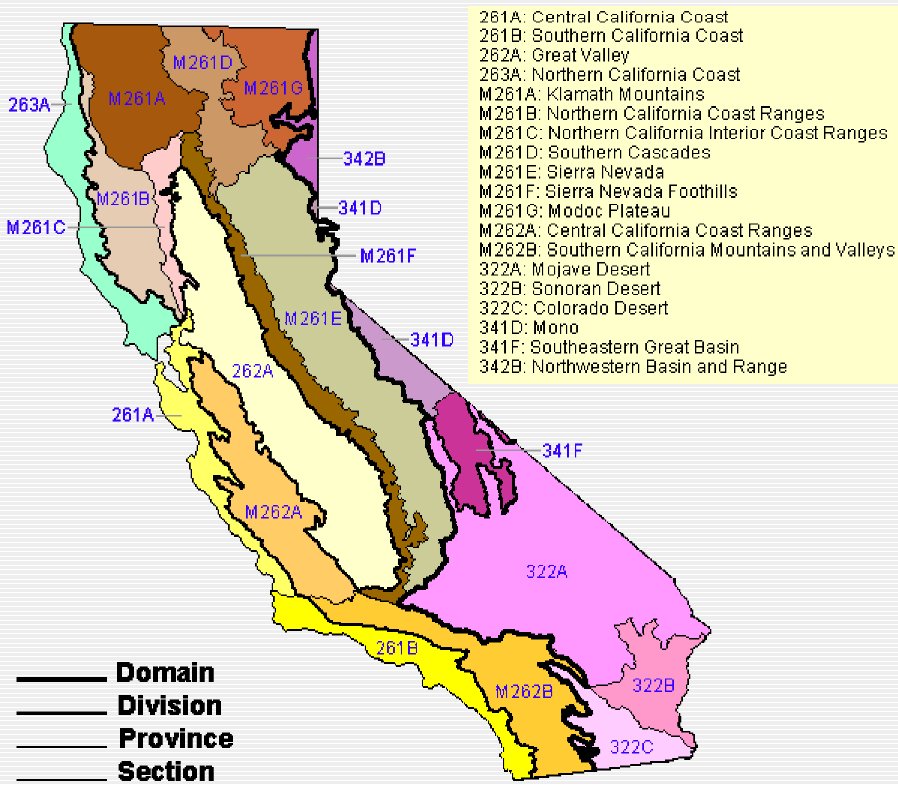
Figure 4. U.S. Forest soil surveys on national forests



Source: USFS, 2002d

Characterization of California's soils: During 1993, maps at a 1:250,000 scale were developed by the USFS and cooperating agencies for various parts of California, including forests and rangelands. Map units were formed using various combinations of line determinants from 1:250,000 scale geology, general soils, topography and vegetation maps, LANDSAT imagery, and local personal knowledge. A 1:1,000,000 scale map (titled "Ecological Units of California, Subsections") was compiled from the 1:250,000 scale maps and published in August 1994. The map is an overall reference point for regional categorization of geomorphology, lithology, soil taxa, and vegetative cover. Geomorphology comprises the classification, description, nature, origin, and development of present landforms. Lithology is the description of rocks based on physical characteristics such as their origin, composition, and texture. Soil taxa indicate the soil orders that typify the map unit, supplemented by soil moisture and temperature regimes (Natural Resources Conservation Service, 1999).

Figure 5. Ecological Units of California



Refer to the online document Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys for an explanation of soil taxonomy

Source: USFS, 2002a

Findings on damage to soil resources

From a "systems view" of soils, damage occurs when elements that support sustained soil productivity are lost. Examples would be changes in soil that hinder effective plant rooting, water supply, plant nutrition, symbioses, and rhizosphere processes. Other examples of damaged soil could be reflected in alteration of inputs of matter and energy to soils, as well as transformation processes and other properties within soils (e.g., soil structure) (Boyle, 2000).

Causes of damage to soil may be natural such as wildfire or intense rain. They may also be related to land use activities such as road building, removal of vegetation, and site disturbance sometimes associated with rural subdivisions, timber harvesting, and intense grazing. Common factors in soil damage are loss of the litter layer, compaction, and erosion.

The physical presence of an organic layer over soil helps reduce erosion and maintain favorable soil moisture and temperature regimes during hot summers in California (Powers, 2002). Incorporation of organic matter into the soil surface is also an important process affecting soil productivity. Soil organic matter is the primary source for most of the available phosphorous and sulfur, and almost all of the available nitrogen (Imler, 1998).

On annual rangelands, soil surface conditions strongly influence vegetation. Most seeds germinate on the soil surface or at depths to one centimeter (0.4 inches) beneath it. The presence of litter on the surface also seems to impact species composition. Range weeds grow where there is not much surface litter and taller annual grasses such as wild oats tend to grow where litter accumulates (George and Menke, 1996).

The loss of soil cover may substantially increase surface soil erosion (Powers, 2002; George and Menke, 1996). Loss of organic residues may also increase soil temperatures and moisture loss much earlier in the year, thus lessening the period of available soil moisture for forest vegetation. Since they develop primarily in the organic layer and mineral soil, organisms such as truffles (food source of small mammals such as Northern Flying Squirrel) and related microorganisms can be negatively affected by loss of these litter and soil components (Waters et al., 2000).

Soil compaction results from external pressure such as the impact of bulldozer tires, treads, or skidded logs on the surface. This increases soil bulk density that results from the rearrangement of soil particles and makes it more difficult for water to penetrate the soil. It can be harder for roots to grow in compacted soils. Soil can also "puddle" which happens when soil structure is destroyed from working the soil when wet. Puddled and compacted soils may have less aeration porosity and lower hydraulic conductivity and infiltration rates. Compaction occurs most easily in clay soils but may actually increase the water holding capacity of sandy soils such as decomposed granite (Wilent, 2001).

The biological impact of soil compaction relates to soil texture. Moderate compaction lessens vegetative growth on fine-textured soils but under some conditions can increase it on coarse-textured soils (Powers, 2002). In experimental trials, compaction associated with mechanized thinning can reduce soil-rooting volume by up to one half; however, this can be mitigated by tilling (subsoiling).

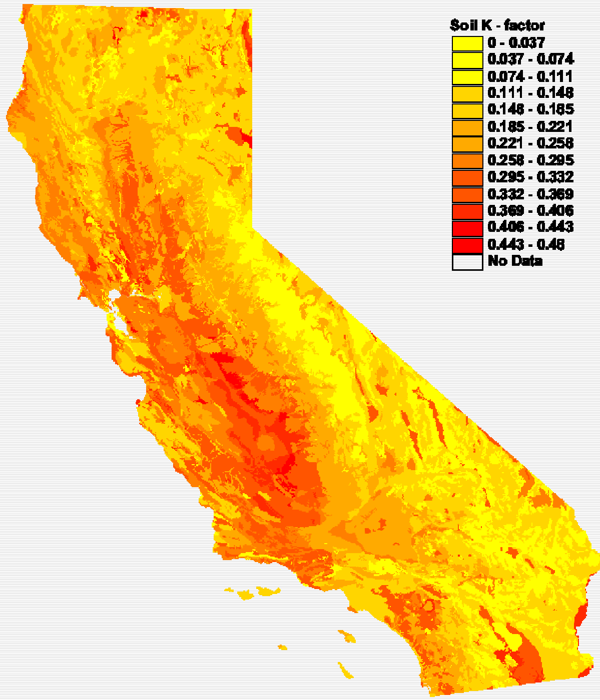
Soil erosion

Erosion is the movement of individual soil particles by a force such as raindrops, overland flow, ice, gravity, wind, and even animal activity. Movement can be by detachment, transport, or deposition. Soil erosion is a natural process, but it can be increased by other processes such as wildfire or by site disturbance and excavation activities associated with land use. At a particular site, the tendency for soil particles to be loose or detached and susceptible to erosion relates to factors such as rainfall, vegetation and ground cover (litter), soil texture, and slope stability. For its part, the influence of slope stability on erosion comes from its steepness, shape, water content, and stability (Rice and Sherbin, 1977).

Universal soil loss equation: Federal agencies, namely the Natural Resources Conservation Service, developed the Universal Soil Loss Equation (USLE) model to predict erosion from croplands and rangelands. In 1996, the Agricultural Research Service, USFS, and the BLM cooperated in the Water Erosion Prediction Project (WEPP). The goal of WEPP was to develop an improved soil loss model based on better understanding of hydrologic and soil erosion processes. In January 1997, a revised version of the USLE was released. It predicts erosion based on estimating longtime average annual soil loss due to water from specified slopes in specified cropping and management systems and from rangeland. However, even with these revisions, it is still difficult to predict erosion in a wide variety of rangeland sites (Imler, 1998).

Soil erodibility factors (Kw) and (Kf) quantify the susceptibility of soil detachment by water. Factor Kw considers the whole soil, and factor Kf considers only the fine-earth fraction or material less than 2.0 millimeters in diameter. They are used in the Universal and Revised USLE calculations. These factors predict the long-term average soil loss that comes from sheet and rill erosion under various types of crop systems and conservation techniques. They are of limited use in forest and rangeland soils because of the difficulty of specifying management regimes. However, they do offer some indication of susceptibility to erosion. FRAP used NRCS data and calculated these factors for soil types in California adapting the calculations to a GIS mapping grid. This yielded a map of K factors for California as shown below. Based just on the physical properties of soils, soils in the Central Valley and some locations in Southern California are the most susceptible to erosion (Figure 6).

Figure 6. Location of soil erodibility and K-factors



Source: California Fire Plan

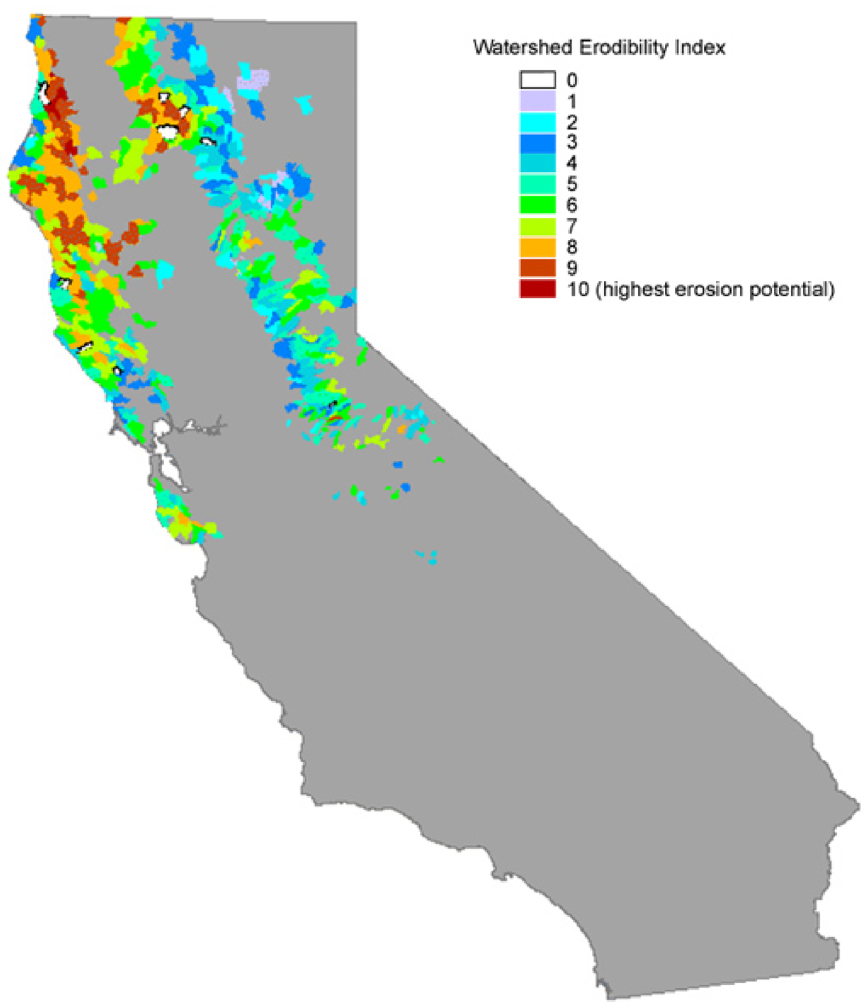
Erosion can come from surface erosion, debris slides, or landslides (McKittrick, 1994). Surface erosion includes processes such as sheetwash, ravelling, rilling, and gullying. Forest ground cover provides protection to the soil from raindrop impact and surface runoff, thus allowing for infiltration rates usually at or above rainfall intensity. Land use impacts resulting from mechanical site disturbance (including road building, tractor yarding, site preparation, and fire) remove litter and vegetative cover, locally compact the soil, and expose bare soil to the erosive energy of rainfall and runoff. On private timberlands, surface erosion ratings are low to moderate for the Coast Ranges, low to moderate in the Klamath province, and low in the Cascade, Modoc Plateau, and Sierra Nevada Mountains (McKittrick, 1994). Debris slides include debris flows, mudflows, debris avalanches, soil flows, and soil slips. Debris slides often occur where thin colluvial deposits cover less permeable bedrock or soil material. Once full of water, the weight of these deposits exceeds the resisting forces and fails. On private timberland, the potential for debris slides is low to moderate in the Coast Ranges, highly variable in the Klamath province, low in the Cascade and Modoc plateaus, and generally low in the Sierra (McKittrick, 1994).

Mass failures occur when there is movement downslope of debris that occurs when the internal strength of a soil is exceeded by gravitational and other stresses (California State Board of Forestry and Fire Protection (BOF), 1999). In the case of hillslopes, mass failures are at least a void of 100 cubic yards left on a hillslope. Mass erosion processes involve slow moving, deep-seated earthflows and rotational failures, as well as rapid, shallow movements on hillslopes (debris slides) and downstream channels (debris torrents) (BOF, 1999).

Landslides are largely a function of the geology, geologic history, geomorphology, ground slope, and precipitation intensity and duration of an area (Spittler, 1995). An example of this tendency is the central and eastern belts of the Franciscan Complex on the North Coast of California. The area of highest landslide potential on private timberlands exists in the Coast Range province where underlying rock is sedimentary in nature. In the Klamath province the potential is highly varied; in the Sierra Nevada, Modoc, and Cascade provinces, the potential generally is low (McKittrick, 1994).

Under contract to the California Department of Forestry and Fire Protection (CDF), the California Geological Survey (CGS) under the DOC developed ratings of relative susceptibility to erosion on private timberlands in 1994. This rating was a combination of landslide, debris slide, and surface erosion ratings within surveyed watersheds. The relative susceptibility to erosion shows a high potential in the northern Coast Ranges, moderate in the Klamath province, moderate to low in the Sierra Nevada Mountains, and low in the Modoc Plateau and Cascade provinces. However, widely divergent geomorphic processes (such as inner gorge characteristics and steepness) limited understanding of relationships between sediment transport and landscape variables, and use of generalized and limited data make this rating scheme best applicable at the watershed level (Figure 7) (McKittrick, 1994).

Figure 7. Watershed erosion potential on private lands



Source: McKittrick, 1994

Standards for healthy forest and range soils

California has a wide variety of rangeland sites and management regimes. Various standards have been developed for such things as residual dry matter (RDM), grass stubble height, wood vegetation, and other things (Clawson et al., 1982). Perhaps the most significant relate to managing RDM since this is the primary method by which a rancher can influence soil surface conditions and related characteristics such as permeability and water holding capacity (George and Menke, 1996). RDM is the amount of dry plant material left on the ground from the previous year's growth. As such, RDM provides desirable microenvironments for early seedling growth, sod protection, organic matter, and a source of low-moisture forage for livestock feed in the fall.

One example of RDM standards is found in voluntary oak-woodland management guidelines adopted for Eastern Madera County by the Coarsegold Resource Conservation District in 1995. The following bullet list represents what the "crown closure" and RDM remaining should average per acre at the various elevational zones following treatment. These numbers are considered minimal levels under most conditions and do not pertain to grazing areas:

- Less than 1,000 feet: retain 25 percent crown closure and provide 500 pounds RDM;
- 1,000 to 2,500 feet: retain 30 percent crown closure (thin up to 50 percent of the canopy) and provide 700 pounds RDM; and
- Greater than 2,500 feet: retain 30 percent crown closure of single stemmed oaks, 15 percent multi-stemmed oaks (thin up to 60 percent of the total canopy), and provide 1,000 pounds RDM (Coarsegold Resource Conservation District, 1995).

Suggested BLM standards: BLM proposed alternative standards for soil protection and RDM as part of its Rangeland Health Standards and Guidelines Environmental Impact Statement Chapter 2 (BLM, 1997a). One set was developed by the three Resource Advisory Councils for their areas (Tables 7a and 7b).

Table 7a. Standards and guidelines for Soil in Ukiah and Susanville Districts proposed by Range Advisory Councils

Ukiah District	Susanville District
Soils: Soils exhibit characteristics of infiltration, fertility, permeability rates, and other functional biological and physical characteristics that are appropriate to soil type, climate, desired plant community, and land form.	Upland soils: Upland soils exhibit infiltration and permeability rates that are appropriate to soil type, climate, and landform and exhibit functional biological, chemical, and physical characteristics.
Meaning that: Precipitation is able to enter the soil surface at appropriate rates, the soil is adequately protected against accelerated erosion, and the soil fertility is maintained at appropriate levels.	Meaning that: Precipitation is able to enter the soil surface and move through the soil profile at a rate appropriate to soil type, climate, and landform. The soil is adequately protected against human caused wind or water erosion, and the soil fertility is maintained at or improved to the appropriate level.
Ground cover (vegetation and other types such as rock) sufficient to protect sites from accelerated erosion. Litter/RDM evident, accumulating in place, and showing negligible movement by water. A diversity of plant species, including native plants with a variety of root depths, is present and plants are vigorous during the growing season (Committee on Rangeland Classification, 1994). There is minimal evidence of accelerated erosion in the form of rills, gullies, pedestaling of plants or rocks, flow patterns, physical soil crusts/surface sealing, or compaction layers below the soil surface. Biological (microphytic or cryptogamic) soil crusts, if present, are intact.	Evidence of wind and water erosion, such as rills and gullies, pedestaling, scour or sheet erosion, or deposition of dunes is either absent or if present does not exceed what is natural for the site. Vegetation is vigorous, diverse in species composition and age class, and reflects the potential natural vegetation or desired plant community for the site.

Source: BLM, 1997a; BLM 1997b

Table 7b. Residual Dry Matter (RDM) guidelines for annual uplands

Precipitation	Slope 0-25 percent	Slope 26-45 percent	Slope 46 percent and up
10" - 40"	500 pounds	600 pounds	800 pounds
40" - 60"	750 pounds	1,000 pounds	1,250 pounds
60" +	1,000 pounds	1,500 pounds	2,000 pounds

Note: definition is pounds/acre by slope and precipitation

Source: BLM, 1997a; BLM 1997b

However, range scientists have differing opinions about how the standards should apply to grazing management alternatives, the approach and timeframe for monitoring, and how standards link to other parts of rangeland ecosystems. For example, it is unclear how per acre standards for residual dry matter relate to the extent of bare ground. Standards, especially if used as part of grazing permits or the conditions of a conservation easement, can be important because they may control the amount of forage a landowner may utilize. This in turn can limit the income producing potential of the land (California Rangeland Trust, 2002).

In the case of forest resources, the USFS soil quality standards have been related to operational area, erosion, loss of soil cover, organic matter, infiltration, compaction, and displacement (Powers, 2002).

However, there has been a growing consensus that better measures are needed concerning the impact of management activities on soil biota and other factors related to soil productivity (Boyle, 2000). This has led to the creation of the North American Long-Term Soil Productivity cooperative research program. It is the most extensive effort to coordinate research into sustainable forest productivity in managed forests in the world. The program conducts research at 62 core installations and 40 affiliated installations in the U.S. and Canada. Twelve sites are in the mixed conifer belt in the western Sierra Nevada of California, with the first starting in 1991 at the Challenge Experimental Forest.

The objectives of the program are to:

1) define how site carrying capacity is related to changes in soil porosity and organic matter;
2) develop an understanding of the controlling natural processes;
3) produce practical, soil based measures for monitoring changes in site carrying capacity; and
4) develop generalized estimation models for site carrying capacity, subject to soil and climatic variables (Powers, 2002).

Some private timber companies have developed their own measures of soil quality. Weyerhauser, for example, has developed a post-harvest soil monitoring program that uses a visual classification scheme for soil disturbances caused by mechanical equipment or log movement. This facilitates assessment of post-harvest soil conditions and locations that need rehabilitation. Consistent with research done by Roseburg Resources in California, Weyerhauser has found that tilling is usually an effective treatment where soil disturbance is light (Wilent, 2001).

Impact of natural events on forest and range soils

Soil loss or movement can be caused by natural factors such as gravity, wind, and water flow. For example, erosion due to wind on non-federal pasture land in California is estimated to be 0.4 tons per acre per year. Wildfire also can increase the chance of erosion due to wind and rain by removing vegetation, litter, and even creating a burned layer on top of the soil that resists penetration by water. Many mass failures related to wildfires are correlated with development of water repellency in soils (DeBano et al., 1979; DeBano et al., 1998). For example, in chaparral vegetation of southern California, sediment delivery from mass wasting to channels can increase greatly where wildfire has made soils more resistant to water penetration.

In southern California, large debris flows often occur after wildfires. However, the impacts of burning the mixed chaparral vegetation that grows on the hillsides of southern California are complex and varied (Forrest and Harding, 2002). The fire-flood history of southern California wildfires demonstrates that recently burned areas produce more debris flows than unburned areas. Compared to vegetated hills, debris flows in burned areas commence earlier—without prior rainfall being required—and after less intense, shorter storms because the soil absorbs almost no rainfall (USGS, 1998).

There has been no overall compilation of acres of forests and rangelands in California where litter layers have been lost or physical properties of soils altered. Probably the most detailed estimates are contained in individual Burned Area Emergency Rehabilitation (BAER) reports developed by federal agencies following some wildfires. These reports can include estimates of areas subject to intense fire and subsequent potential for erosion.

For purposes of the Assessment, however, an upper estimate of areas where litter has been affected by wildfire can be approximated using fire statistics for California (Table 8). Fire sizes include ten acres and larger on federal jurisdictions and 300 acres or larger on state jurisdictions. Within fires of these sizes, it can be assumed that some or the entire litter layer has been affected by the wildfire. The time period for wildfires used is five years, because after this time, it is reasonable to assume that vegetation has recovered and some litter is being provided.

Table 8. Area burned at least once from 1995-2000, by bioregion and county

	Planning belt (acres)			
Bioregion	**Conifer**	**Woodland**	**Brush**	**Grass**
Bay Area/Delta				
Alameda	-	-	-	3,305
Contra Costa	84	14	-	3,393
Marin	6,437	-	5,104	411
Napa	5,936	1,066	26,685	2,749
San Francisco	-	-	-	-
San Mateo	-	-	-	-
Santa Clara	154	34	-	2,022
Solano	449	494	1,690	1,113
Sonoma	2,478	-	892	488
Total	15,538	1,608	34,371	13,481
Central Coast				
Monterey	58,259	4,779	57,805	10,846
San Benito	-	524	3,755	709
San Luis Obispo	13,380	4,703	121,159	28,983
Santa Barbara	2,389	-	32,747	9,629
Santa Cruz	-	-	-	-
Ventura	971	-	38,085	24,692
Total	75,000	10,006	253,551	74,859
Colorado Desert				
Imperial	-	-	-	-
Modoc				
Lassen	2,659	9,958	-	-
Modoc	6,060	35,909	21,251	-
Total	8,718	45,867	21,251	-
Mojave				
Riverside	758	30,346	89,705	11,525
San Bernardino	5,860	5,448	61,856	-
Total	6,618	35,794	151,562	11,525
North Coast/Klamath				
Del Norte	3,612	-	141	-
Humboldt	78,577	-	1,418	539
Lake	64,653	2,596	23,135	1,674
Mendocino	9,942	-	7,868	141
Siskiyou	11,816	14,118	806	2,011
Trinity	86,013	-	2,496	-
Total	54,613	16,713	35,863	4,364
Sacramento Valley				
Butte	7,903	-	22,676	17,541
Colusa	1,238	2,488	3,884	-
Glenn	777	335	1,075	-
Sacramento	-	486	-	1,976
Shasta	17,740	22,524	4,843	5,136
Sutter	-	-	-	-
Tehama	10,587	39,849	23,561	26,742
Yolo	-	501	11,571	2,588
Yuba	5,313	2,683	9,060	1,619
Total	43,558	68,866	76,669	55,602

Table 8 (cont). Area burned at least once from 1995-2000

Bioregion	Planning belt (acres)			
	Conifer	Woodland	Brush	Grass
San Joaquin Valley				
Fresno	4,692	4,459	1,549	12,080
Kern	1,910	7,495	24,093	63,504
Kings	-	-	120	635
Madera	10	34	29	3,957
Merced	-	190	-	25,255
San Joaquin	-	-	-	1,318
Stanislaus	-	-	30	4,976
Tulare	20,231	34,599	41,089	5,246
Total	26,842	46,778	66,911	116,971
Sierra				
Alpine	3,387	26	-	-
Amador	-	-	40	-
Calaveras	3,906	256	306	1,493
El Dorado	118	563	442	5,803
Inyo	1,433	1	9,054	-
Mariposa	4,060	601	14,334	2,799
Mono	632	368	2,153	33
Nevada	765	-	26	-
Placer	1,204	311	186	1,042
Plumas	89,093	1,760	9,050	
Sierra	87	-	-	-
Tuolumne	49,744	12,809	39,299	8,516
Total	154,429	16,695	74,890	19,686
South Coast				
Los Angeles	14,804	1,575	75,228	1,998
Orange	-	-	6,913	398
San Diego	1,900	12	92,916	2,317
Total	16,704	1,587	175,056	4,713
STATEWIDE	602,021	243,914	890,124	301,202

Source: FRAP, 2002a

Between 1995 and 2000, nearly 2.1 million acres, or two percent, of California's landscape was affected by wildfire. This is an upper bound on the potential of fire to alter the forest and range litter layer. The largest impact of fire is seen in brush planning belts, with almost 900,000 acres burned at least once between 1995 and 2000. Over half of this total occurs in just three bioregions: Central Coast, South Coast, and the Mojave. The second largest impact of fire is seen in the conifer planning belt with just over 600,000 acres burned at least once between 1995 and 2000. Over half of this total comes from just two bioregions: the North Coast/Klamath and the Sierra.

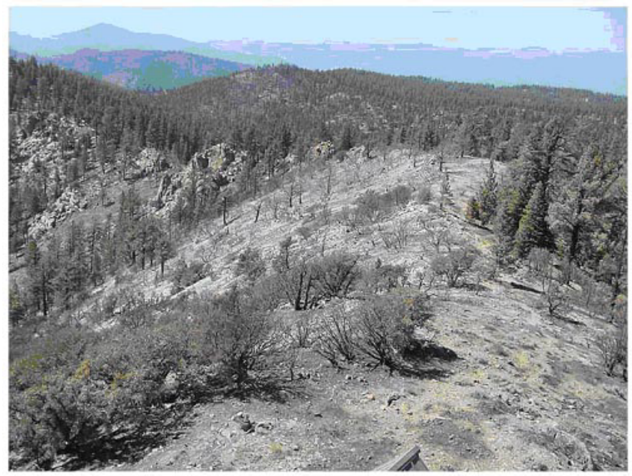
In some cases, where intense wildfire has occurred, the physical characteristics of the soil may also have been affected. The impacts vary and are not easy to quantify. The USFS has developed a burn severity classification system based on post-fire appearances of litter and soil as well as soil temperature profiles. Burn severity or fire severity is a qualitative measure of the effects of fire on a site (Table 9).

Table 9. Burn severity classification based on post-fire appearances of litter and soil and soil temperature profiles

Soil and litter parameter	Burn severity		
	Low	Moderate	High
Litter	Scorched, charred, consumed	Consumed	Consumed
Duff	Intact, surface charred	Deep charred, consumed	Consumed
Woody debris – small	Partly consumed, charred	Consumed	Consumed
Woody debris – logs	Charred	Charred	Consumed, deeply charred
Ash color	Black	Light colored	Reddish, orange
Mineral soil	Not changed	Not changed	Altered structure, porosity, etc.
Soil temperature at 0.4 inches (10 millimeters)	Greater than 120 degree F (greater than 50 degree C)	210-390 degrees F (100-200 degree C)	Greater than 480 degrees F (greater than 250 degree C)
Soil organism lethal temperature	To 0.4 inches (10 millimeters)	To 2 inches (50 millimeters)	To 6 inches (160 millimeters)

Source: Robichaud et al., 2000; DeBano et al., 1998

The potential impact of wildfire can be especially significant on increased runoff, erosion, and downstream damage. An example of this concern is found in the 2002 McNally Fire in Tulare County. The McNally Fire burned over 150,000 acres with approximately 12,000 acres at high severity and 60,000 acres at moderate severity. In their post fire report, USFS staff believed that, absent rehabilitation, sediment yield could increase up to 870 percent of normal and water flow could increase up to 1,000 percent of normal due to effects of the fire (USFS, 2002b). They reported that runoff might cause accelerated surface erosion and move stored sediments to stream channels. These effects could be severe during the first storm season following the fire. The potential for increased erosion potential could last longer in high severity areas (USFS, 2002c).

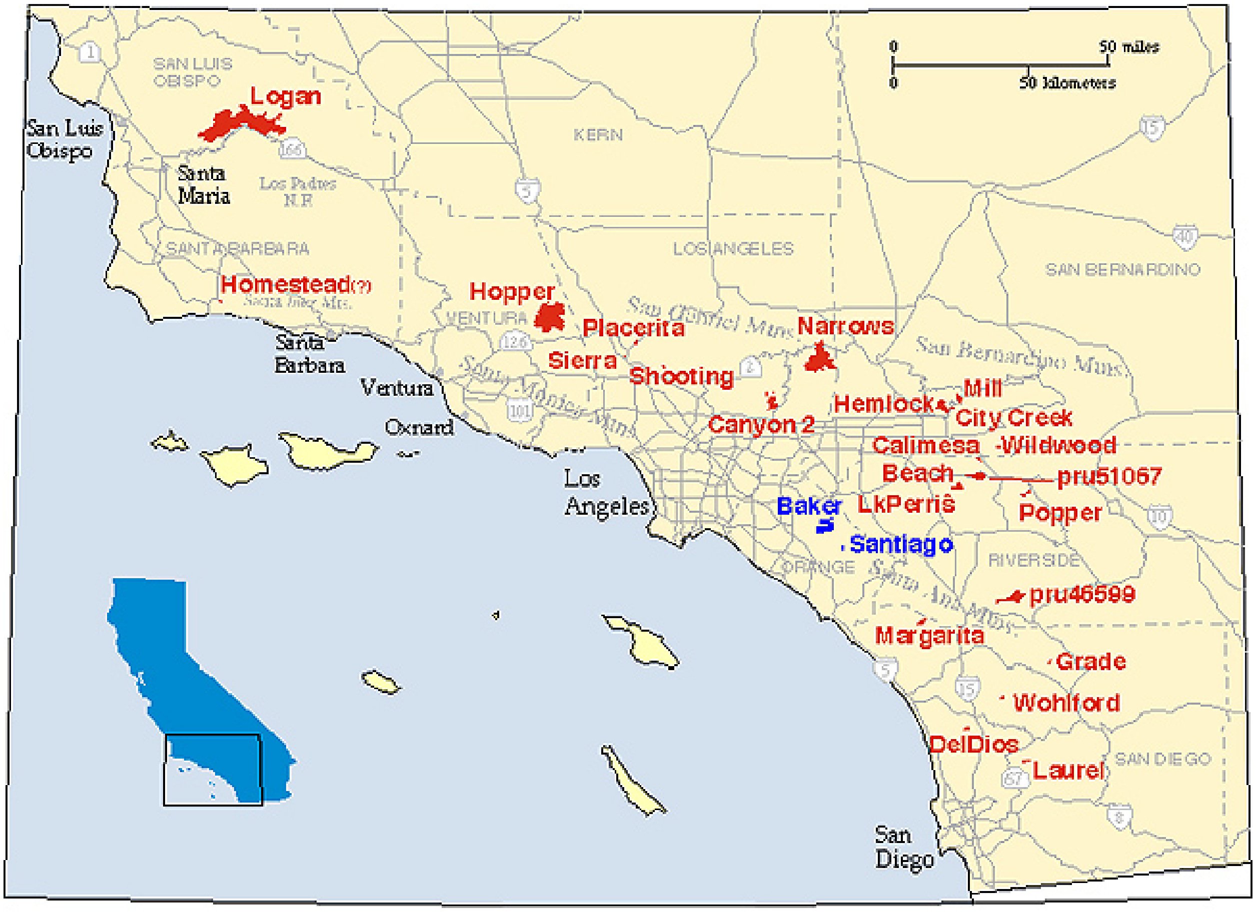


McNally Fire, Westridge. Photo courtesy of USFS.

The potential impact of wildfire can be especially significant on increased runoff, erosion, and downstream damage.

One of the most significant public concerns historically, especially in southern California, has been flooding that can follow intense rainfall on an area severely burned by wildfire. This has been called the fire-flood sequence. By way of illustration, following the wildfires of 1997 in southern California, the US Geological Survey mapped perimeters of the fires greater than 300 acres on the theory that areas within these perimeters can undergo extreme surface run-off from hillslopes (USGS, 1998) (Figure 8). In the event of significant rainfall, downslope areas could perhaps experience flooding and debris flows that overran existing flood control facilities.

Figure 8. 1997 wildfires greater than 300 acres in southern California



Source: USGS, 1998

Another example of this kind of concern was expressed over the Manter fire in 2000. During the summer of 2000, the Manter fire burned 79,224 acres in the Kern River drainage. About 46 percent of the fire area was rated as having a high or very high erosion hazard rating (EHR). About 84 percent of the fire area was judged to be very susceptible to erosion by blowing wind. The average post-fire erosion rate in the entire burned area was calculated to be 27 tons per acre per year, compared to the pre-fire erosion rate for the entire burn of eight tons per acre per year (James et al., 2000). According to the hydrologist's calculations, a 25-year storm event would generate 2.5 times the normal runoff quantities after the drainage area is intensely burned. Likewise, a 50-year storm event would generate 4.2 times the normal runoff. High runoff rates increase the potential hazard for soil erosion.

In explaining the need for rehabilitation, this situation led to the observation that the impact of post-fire threat to the Kern River area and downstream properties could be catastrophic. Potential threats to life, health, and property from debris flows, rockslides, and snow pack tree movement were considered imminent (Francis, 2000).

In light of the these concerns, federal agencies have spent substantial sums on emergency rehabilitation following wildfire in California. For example, $2.6 million was spent on emergency rehabilitation following the 1987 Stanislaus Complex Fire in the Stanislaus National Forest, nearly $1.9 million on the 1997 Fork Fire in the Mendocino National Forest, and about $1.3 million on the 1988

Clarks Incident in the Plumas National Forest. From 1973 through 1998, 32 percent of all emergency rehabilitation funds were spent in USFS Region 5 (California and Pacific Islands) (Robichaud et al., 2000). The majority of these funds were spent on aerial seeding and channel treatments.

Estimating the potential for loss of soil productivity after fire is difficult because there is no simple method of measuring productivity reduction due to changes in soil material and nutrients. Depending on the severity of the fire, soil productivity may improve by such things as mineralization of nutrients tied up in organic matter. However, productivity may decrease through such things as causing loss of nutrients and changing water transport properties. The potential impact of wildfire on soil erosion has led CDF to improve its 1996 California Fire Plan to better reflect the potential impact of wildfire on surface erosion. It has also led to observations of the need to better use sediment control practice, especially near the urban forest interface, to reduce the downslope impact of sediment from wildfire until soil stabilization measures can be implemented (Forrest and Harding, 2002).