Findings on impact of management activities on forest and range soils

The impact of management activities on forest and range soils varies by the site and the management practice, both past and present. Fragile, upland range soils will be very different from deeper soils in different locations. Shallow forest soils that come from granitics on south-facing slopes will be much less tolerant of disturbance than gentle slopes that have developed from marine sediments (Boyle, 2000).

The oak canopy and oak litter may give some protection from raindrop impact, yield increased soil organic matter, and provide for a more porous soil structure. Photo by David Cavagnaro.

Rangeland soil impacts

There is no current statewide survey of the condition of range soils in California. See the Assessment document Rangeland Area and Condition for more information. The most significant potential impact of ranching on rangeland soils comes from intense grazing. The ability of rangeland soil to hold water is affected by its porosity (George and Menke, 1996). Heavy grazing may lower bulk density through trampling and less residue leading to lower soil organic matter. There may also be less root and shoot production that can turn into organic matter. Raindrops on bare soil tend to seal the soil surface, reduce water infiltration, and increase runoff (George and Menke, 1996).

Researchers and managers have noted in a number of cases that livestock-free rangelands have surface soils that are more friable and more resilient. Other studies also have compared bulk density of rangeland soils that are grazed with those that have not been grazed. Results of the studies indicate that the oak canopy and oak litter may give some protection from raindrop impact, yield increased soil organic matter, and provide for a more porous soil structure (George and Menke, 1996).

Range managers today are aware of the potential impact of intensive grazing on soils and usually follow practices that avoid this situation. For example, see Range and Pasture Leaflets distributed by University of California Division of Natural Resources. With regard to grazing impacts, most range management depends on monitoring the condition of rangeland browse vegetation and distributing animals accordingly. Animal distribution can be controlled by such things as placement of nutrient blocks, water developments, and control of access to watering locations (Howery et al., 2001).

As appropriate, the condition of range soils and related sedimentation are dealt with on private lands by the California Rangeland Water Quality Management Plan (CRWQMP) and by monitoring of grazing allotments on federal lands (Institutional Framework: Governance Shifts in the 1990s). For example, the CRWQMP delineates prescribed grazing practices as including controlling season, intensity, frequency and distribution of grazing. Among the goals to be achieved by these practices is to reduce accelerated soil erosion and maintain or improve soil condition (BLM, 1997b). See the online document Rangeland health standards and guidelines for livestock grazing: Northeastern California and Northwestern Nevada (Appendix C) for more information.

Forest soil impacts

In the case of forest soils, most studies and monitoring efforts have focused on actual or potential erosion. The factors often associated with erosion on forestlands are slope steepness, weak bedrock, high groundwater, lack of soil cohesion, and the ability to move water horizontally (McKittrick, 1994). Other factors, such as changes in vegetation, rainfall duration, and rain-on-snow events can have a significant impact but are much more time related.

A number of studies have indicated that most human-caused erosion occurring on lands logged before the 1970s came from gullies created by diverted streams and road building on steep hillsides (California Forest Products Commission, 1999). On private lands, impacts like these were dealt with by a variety of new Forest Practice Rules (FPRs) including:

- classification of streams by biologic and physical features and relating protections to these categories;
- use of Erosion Hazard Rating (EHRs), with site-specific elements of weather, slope, and soil determinations, has substantially reduced erosion problems;
- required maintenance of erosion control structures for at least three years following harvest;
- more stringent road design specifications including planning for 50-year flood events; and
- more focus on cumulative watershed effects (Gasser, 2002).

Historically, monitoring the impact of forestry practices on soil in California has been driven by the desire to protect water quality from sedimentation. Erosion from forest roads can be a persistent source of sediment in a watershed. Road networks are often extensive and difficult to maintain. Recent studies suggest that the connectivity of roads to stream channels increases sediment delivery and affects runoff processes. With forest roads, the highest erosion rates tended to be associated with the initial road construction period overlapping with major storms. However, a high incidence of landslides (mass wasting) is also correlated with steep slopes, unstable soils, and road location and design. Controlling road drainage and avoiding construction of roads are shown to prevent fill failures and major debris torrents. Less erosion is observed with improved road design and location as well as roadside erosion control practices.

Other erosion control practices associated with timber harvesting have also improved. Monitoring results from the mid-1990s regarding both the implementation and effectiveness of forest practice rules on hillslopes show a high level of both effectiveness and implementation (BOF, 2002).

History of Monitoring Study Group and hillslope monitoring on non-federal timberland: After the passage in 1983 of amendments to the FPRs that specified protection based on the beneficial uses of water present, the State Water Resources Control Board (SWRCB) conditionally certified the FPRs and Review Process as meeting Best Management Practice (BMP) standards for Section 208 of the Clean Water Act (CWA). As part of this certification, the SWRCB required that a monitoring and assessment program be implemented. To meet this requirement a one-year qualitative assessment of forest practices was undertaken in 1986 by a team of four resource professionals. The team reviewed 100 Timber Harvesting Plans (THPs) from across the State and produced a document that came to be known as the “208 Report.” The team found that the Rules generally were effective when properly implemented on terrain that was not too sensitive. They also found that poor rule implementation was the most common cause of observed water quality impacts.

Based largely on the 208 Report, CDF, BOF, and the SWRCB entered into a Management Agency Agreement (MAA) in 1988 that required BOF to improve forest practice regulations for better protection of water quality. Subject to several additional tasks, the SWRCB then approved certification of the FPRs and Review Process as meeting BMP standards for Section 208 of the CWA. The U.S. Environmental Protection Agency, which had final approval of the certification, did not agree. Rather it withheld certification until the conditions of the MAA were satisfied, one of which implemented a long-term monitoring program to determine the effectiveness of the FPRs and Review Process in protecting water quality.

In response, BOF established a Monitoring Study Group (MSG) to determine the effectiveness of the FPRs in protecting water quality. Between 1991 and 1996, the MSG developed hillslope monitoring protocols, comprised of a list of 1,300 separate items related to protection of water quality. These items included plan development, a review process, and field application requirements. A significant portion of the review examined how the rules dealt with the movement of soil and sediment through control of road building, skid trails, operations on sensitive areas, retention of cover, and many other things (BOF, 1999). These protocols have subsequently been reviewed and revised.

Between 1996 and 2001, 300 THPs were evaluated. Of these, 295 were regular THPs and five were Notice of Timber Operations under Non-Industrial Timber Management Plans (NTMPs) (BOF, 2002). About 60 percent of the plans were on large land holdings. About 60 percent of all plans were in the Coast Forest Practice District. For each plan, a review was made of roads, skid trails, landings, watercourse crossings, and watercourse protection zones. Results indicate a high percentage of proper implementation for FPRs related to water quality. When properly implemented, individual practices required by the rules are highly effective at preventing hillslope erosion. Overall, implementation ratings exceeded 90 percent for landings as well as for road, skid trail, and watercourse protection zone transects (areas where measures were taken). Watercourse crossing implementation was less, at an 86 percent rate (BOF, 2002).

Observations of erosion on roads. Photo courtesy of CDF.

Erosion problems on landing surfaces, cut slopes, and fill slopes were uncommon. Rill and gully erosion showed up much less frequently than on road transects, where erosion is still an issue. According to BOF, nearly half of the road transects had at least one rill present and about 25 percent had at least one gully. About 13 percent of the rills and almost 25 percent of the gullies showed movement of sediment into the high flow channel of a watercourse (BOF, 2002). Erosion on road transects was found due to improper design, construction, and maintenance of drainage structures (BOF, 2002).

The Monitoring Study Group identified large erosion events as significant causes of erosion. In 250 THP and NTMP projects, 50 large erosion events were identified (BOF, 2002). These events included sites with 100 cubic yards or more on hillslopes, and 10 cubic yards or more at failed watercourse crossings. These events were seen on 15 percent of the THPs. Furthermore, nine plans had multiple events. Of these, 39 events were related to current timber management activities. Most of the large erosion events were related to roads.

Monitoring Study Group field team discussing observations. Photo by CDF.

The most frequent causes associated with large erosion events were the following: 1) cutbanks with slope support removed; 2) culverts with the inlet plugged; 3) fill slopes with overloaded, deep sidecast; 4) fill slopes with poorly compacted material; and 5) surface water concentration.

Nearly all the shallow debris slides described were found in the Coast Forest Practice District, as well as half of the deep-seated rotational failures. The actual frequency of catastrophic crossing failures recorded is much higher in inland districts. This is largely due to the very large tropical storm (100+ year in many Sierra watersheds) that rained on a heavy snow pack in the Sierra in January 1997, causing large volumes of water to flow and overwhelming erosion and drainage control measures (BOF, 2002).

The impact of large erosion events does show that certain places in California can expect such events, especially under intense rainfall or rainfall on snow conditions. This indicates that road and crossing design and construction are critical as preventive measures. Landslides can be active or dormant and can vary in type. In general, management practices have avoided areas where landslides are a potential problem, keeping activities and water off such areas, and minimizing ground disturbance (DOC, 1999).

Forest management practices on national forest lands were certified as providing Best Management Plans (BMPs) during the 1980s. Monitoring the effectiveness of these measures has focused on measures such as erosion control and site disturbance. The USFS has conducted a hillslope monitoring program that has focused on both implementation and effectiveness of practices since 1992. Data has been summarized through 2001. Implementation of BMPs has risen from about 80 percent in 1992 to about 90 percent in 2001. Effectiveness of BMPs as implemented has risen from about 70 percent in 1992 to about 80 percent in 2001 (Stabb, 2002).

Since 1999, research was also conducted on both the Eldorado National Forest and Sierra Pacific Industries land in the central Sierra Nevada to quantify natural and man-caused hillslope erosion rates related to cumulative impacts. Results to date show that native surface roads are the main man caused source of sediment. High severity wildfires and areas used for off-road vehicles have also shown high rates of sediment production. Recently graded native surface roads produced more sediment than roads not graded, with the majority of sediment coming from a few road segments (MacDonald and Coe, 2001; Coe and MacDonald, 2002). See Assessment Chapter on Watershed Quality and Assessment for more discussion of cumulative effects.

Some analysis of concerns related to forest and range soils at the watershed level has been done in Southern California (USFS, 1999). At the watershed level, perhaps the most significant impacts on soils come from very large wildfires in chaparral-dominated habitats. There have been a number of large fires over the last few decades, especially in the Los Padres National Forest. These fires have a tendency to cause high amounts of erosion and stream siltation (USFS, 1999). Recreational activities are also a source of concern, especially the increased flow of sediment into streams from unpaved roads (USFS, 1999). At the watershed-scale level on the Los Padres, Los Angeles, Cleveland, and San Bernardino national forests in southern California, the U.S. Forest Service found that many drainages that have the smallest percentage of land that falls within 250 acres of an active road have high potential for maintaining aquatic ecological integrity (USFS, 1999).

Concluding observations

During the 1990s, there was increased understanding of the importance of forest and rangeland soils as part of ecosystem dynamics. With little known about sustaining the long run productivity of forest and rangeland soils in California, it is hard to assess the status of forest and rangeland soils. Numerous research efforts are now underway to investigate factors related to long run soil productivity, the importance of soil microorganisms, and the kinds of management practices that can maintain soil fertility. Given this, the Assessment has attempted to describe the importance of forest and range soils, the status of mapping and related information, major types of damage to soil resources, typical causes of this damage, and how management responds.

Forest and rangeland soils in California are highly varied. The factors that affect their productivity can be very site specific. For the most part, forest and range soils are mapped, though the currency and accuracy differs. Similarly, the susceptibility of soils to damage changes from site to site and soil to soil. The most commonly noted soil damage comes from erosion, litter loss, and compaction. Other damage can come from alterations of a soil's chemical or physical properties.

Reasons for damage to soil can be natural events such as wildfire or human causes such as disturbance by heavy equipment. Historically, wildfire has raised significant public concern because of the fear of downstream flooding in subsequent intense rainfall on disturbed slopes. In recent years, there has also been concern about the downstream impacts of sediment coming from upstream land use activities. As a result, both post-fire restoration and management practices by forest and rangeland managers have tried to minimize erosion, litter loss, and compaction. Monitoring programs are in place on both private and public lands that review both the implementation and effectiveness of practices to prevent degradation of water quality, including efforts designed to prevent erosion. Results so far suggest high percentage rates of success in both implementation and effectiveness of these practices on forestlands. Practices to lessen soil erosion and sedimentation are also important following wildfire, especially near urban areas.

Glossary

animal unit month: The amount of forage needed by an "animal unit" (AU) grazing for one month. The animal unit in turn is defined as one mature 1,000-pound cow and calf.

anthropogenic: Caused by humans.

biota: Having to do with living things. Something that is caused by or produced by living things. Having to do with the biological aspects of an environment (as opposed to geological, etc. aspects).

BLM: U.S. Bureau of Land Management.

BMP: Best Management Practice.

BOF: California State Board of Forestry and Fire Protection.

CDF: California Department of Forestry and Fire Protection.

CGS: California Geological Survey.

colluvial: A loose deposit of rock debris accumulated through the action of gravity at the base of a cliff or slope.

cryptogamic: Relating to a member of a formerly recognized taxonomic group that included all seedless plants and plantlike organisms, such as mosses, algae, ferns, and fungi.

cumulative impacts: Cumulative impacts may occur when the following events take place: 1) multiple impacts transpire at different locations in a larger area such as a watershed or an airshed; or 2) as a result of sequential activities on the same site if impacts of past actions persist (such as repeated soil compaction on the same site. The impacts are greater than the impact of a single action at any location at any point in time. In most cases, they result from multiple activities in a larger area and persist in time.

CWA: Clean Water Act.

DOC: California Department of Conservation.

EHR: Erosion hazard rating.

ESI: Ecological Site Inventory.

ESIS: Ecological Site Information System.

FLMMP: California Farmland Mapping and Monitoring Program.

fluvial: Of, relating to, or inhabiting a river or stream.

FPR: Forest Practice Rule.

grazing capacity: Maximum stocking rate possible without damage to vegetation or related resources.

geomorphology: Comprises the classification, description, nature, origin, and development of present landforms.

gully: A deep ditch or channel cut in the earth by running water after a prolonged downpour.

gullying: The creation of gullies.

humus: leaves and litter that have begun to decompose.

lithology: The description of rocks based on physical characteristics such as their origin, composition, and texture.

litter: the uppermost layer of the forest floor consisting chiefly of fallen leaves and other decaying organic matter.

microphytic: Referring to a plant of microscopic size.

MSG: Monitoring Study Group.

NCWAP: North Coast Watershed Assessment Program.

NRCS: U.S. Natural Resources Conservation Service.

NTMP: Non-Industrial Timber Management Plan.

Planning belt: A geographic aggregation of life forms (conifer, shrub etc) grouped based on their expected response to wildfire.

RCD: resource conservation district.

RDM: See residual dry matter.

residual dry matter: The amount of dry plant material left on the ground from the previous year's growth.

rhizosphere: The soil zone that surrounds and is influenced by the roots of plants.

rill: A very small brook; a streamlet.

rilling: The creation of rills.

SSURGO: Soil Survey Geographic.

STATSGO: State Soil Geographic.

SWRCB: California State Water Resources Control Board.

Timberland Production Zone: A statutory designation for lands assessed for taxes based on growing and harvesting timber as the highest and best use of the land.

THP: Timber Harvesting Plan.

TPZ: See **Timberland Production Zone**.

tractor yarding: The use of tractors for movement of logs to a central location for loading onto log trucks.

USFS: U.S. Forest Service.

USGS: U.S. Geological Survey.

USLE: Universal Soil Loss Equation.

WEPP: Water Erosion Prediction Project.

Literature cited

Boyle, J. R. 2000. Managing our grandchildren's forests: the role of soil biology and soil ecology. General Technical Report PSW-GTR-178. U.S. Forest Service. Web site accessed February 6, 2003. http://www.psw.fs.fed.us/Tech_Pub/Documents/gtr-178/gtr-178-ch7.pdf.

Butler, Larry D., James B. Cropper, Rhett H. Johnson, Arnold J. Norman, Patrick L. Shaver, Frederick B. Pierson, and Mark A. Weltz. 1997. National range and pasture handbook. 190-VI-NRPH. Natural Resources Conservation District. Web site accessed January 7, 2003. http://www.ftw.nrcs.usda.gov/glti/pdf/NRPHrev1.pdf.

California Association of Resource Conservation Districts. 2002a. RCD Watershed Information Sharing Project. Web site accessed January 7, 2003. http://carcd.org/wisp/rcdmap1.htm.

California Association of Resource Conservation Districts. 2002b. Resource conservation district source book preview. Web site accessed January 7, 2003. http://carcd.org/wisp/sourcebk-1.htm.

California Fire Plan. 1996.

California Department of Conservation. 1999. Factors affecting landslides in forested terrain. Web site accessed January 9, 2003. http://www.consrv.ca.gov/cgs/information/publications/cgs_notes/note_50/note50.pdf.

California Department of Conservation. 2000. Landslide maps available from the California Geological Survey. California Geological Survey. Web site accessed January 7, 2003. http://www.consrv.ca.gov/cgs/rghm/landslides/ls_index.htm.

California Department of Conservation. 2002. Generalized geologic map of California. California Geological Survey. Web site accessed March 10, 2003. http://www.consrv.ca.gov/cgs/information/publications/cgs_notes/note_17/note_17.pdf.

California Forest Products Commission. 1999. Forest management in California: yesterday and today. Web site accessed January 9, 2003. http://www.calforests.org/foundation/salmon_paper/management.html.

California Rangeland Trust. 2002. Position on resource management. Web site accessed January 8, 2003. http://www.rangelandtrust.org/News/resource_management.htm.

California State Board of Forestry and Fire Protection. 1999. Hillslope Monitoring Program: monitoring results from 1996 through 1998. Web site accessed January 8, 2003. http://www.fire.ca.gov/CDFBOFDB/pdfs/rept9.PDF.

California State Board of Forestry and Fire Protection. 2002. Hillslope monitoring program results from 1996 through 2001. Sacramento, CA: Monitoring Study Group. Web site accessed December 14, 2002. http://www.fire.ca.gov/CDFBOFDB/pdfs/MSGComboRpt12_02.pdf.

CH2M HILL. 1989. California livestock industry economic model. Sacramento, CA.

Clawson, W. J., N. K. McDougald, and D. A. Duncan. 1982. Guidelines for residue management on annual range. Leaflet 21327. University of California Division of Agriculture and Natural Resources.

Coe, D. and L. H. MacDonald. 2002. Magnitude and interannual variability of sediment production from forest roads in the Sierra Nevada, California. Web site accessed January 9, 2003. http://danr.ucop.edu/wrc/snssweb/post_aquatic.html#coe.

Committee on Rangeland Classification. 1994. Rangeland health: new methods to classify, inventory, and monitor rangelands. Washington, DC: National Academy Press. Web site accessed January 8, 2003. http://www.nap.edu/books/0309048796/html/.

Conner, M. 2003. Personal communication. Superintendent University of California Sierra Foothill Research and Extension Center. April 15, 2003.

Coursegold Resource Conservation District. 1995. Voluntary oak woodland management guidelines. Web site accessed January 8, 2003. http://www.crcd.org/voloak.html.

DeBano, L. F., D. G. Neary, and P. F. Ffolliott. 1998. Fire's effects on ecosystems. New York: John Wiley & Sons.

DeBano, L. F., R.M. Rice, and C.E. Conrad. 1979. Soil heating in chaparral fires: effects on soil properties, plant nutrients, erosion, and runoff. Research Paper PSW-145. Berkeley, CA: U.S. Forest Service.

Fire and Resource Assessment Program (FRAP). 2002. Multi-source Land Cover, v02_1. Sacramento, CA. Web site accessed April 10, 2003. http://frap.cdf.ca.gov/projects/frapgisdata/select.asp.

Fire and Resource Assessment Program (FRAP). 2002a. Area burned by vegetation type and ownership. Sacramento, CA. Web site accessed August 15, 2002. http://frap.cdf.ca.gov/projects/_Area_Burned_by_Veg/index.html.

Forrest, C. L. and M. V. Harding. 2002. Erosion and sediment control: preventing additional disasters after the southern California Fires. In: Watershed 96 proceedings: Moving ahead together. U.S. Environmental Protection Agency. Web site accessed February 20, 2003. http://www.epa.gov/owow/watershed/Proceed/forrest.html.

Francis, M. J. 2000. Manter Fire, burned area emergency rehab report: private land analysis. U.S. Bureau of Land Management. Web site accessed January 8, 2003. http://www.ca.blm.gov/baer/private.htm.

Gasser, D. P. 2003. Lessons from California's Forest Practice Act. Food and Agriculture Organization of the United Nations. Web site accessed January 9, 2003. http://www.fao.org/docrep/w3646e/w3646e0g.htm.

George, M. R. and J. W. Menke. 1996. Fact sheet number 30: soil surface management of annual rangelands. University of California Cooperative Extension. Web site accessed January 7, 2003. http://danr.ucop.edu/uccelr/h30.htm.

Howery, L. D., J. E. Sprinkle, and J. E. Bowns. 2001. A summary of livestock grazing systems used on rangelands in the western United States and Canada. In: Tronstad, Russell, Jim Sprinkle and George Ruyle (eds.). 2001. Arizona ranchers' management guide. Publication AZ1279. pp 79-88. Tucson, AZ: The University of Arizona Cooperative Extension. Web site accessed February 6, 2003. http://ag.arizona.edu/arec/pubs/rmg/1%20rangelandmanagement/12%20livestockgrazingsystem01.pdf.

Imler, B. L. 1998. Erosion prediction and management on rangelands. University of Arizona. Tucson, AZ. Web site accessed January 7, 2003. http://www.srnr.arizona.edu/wsm/wsm462/ErosionPredictionAndManagementOnRangelands.html.

James, A., L. Bryant, E. Schroder, and S. Loadholt. 2000. Manter Fire, burned area emergency rehab report: soils report. U.S. Bureau of Land Management. Web site accessed January 8, 2003. http://www.ca.blm.gov/baer/soils.html.

Kocher, S. D. and J. W. LeBlanc. 1998. Why is my forest the way it is: soils. University of California Division of Agriculture and Natural Resources. Web site accessed January 7, 2003. http://www.cnr.berkeley.edu/departments/espm/extension/SOILS.HTM.

MacDonald, L.H. and D. Coe. 2001. Sediment production and delivery from forest roads in the Central Sierra Nevada, California. Vallejo, CA: U.S. Forest Service.

McKittrick, M. A. 1994. Erosion potential in private forested watersheds of northern California: a GIS model. California Department of Forestry and Fire Protection. Web site accessed January 8, 2003. http://www.fire.ca.gov/CDFBOFDB/pdfs/ErosionPotentWatershed2.pdf.

Powers, R. F. 2002. Effects of soil disturbance on the fundamental, sustainable productivity of managed forests. In: Symposium on the Kings River Sustainable Forest Ecosystems Project: progress and current status, January 26, 1998, Clovis, CA. pp. 63-82. General Technical Report PSW-GTR-183. Albany, CA. U.S. Forest Service.

Powers, R. F., D. L. Hauxwell, and G. M. Nakamura (technical coordinators). 2000. Proceedings of the California Forest Soils Council conference on forest soils biology and forest management; February 23-24, 1996; Sacramento, California. General Technical Report PSW-GTR-178. Albany, CA. U.S. Forest Service. http://www.psw.fs.fed.us/Tech_Pub/Documents/gtr-178/gtr-178-index.html

Rice, R.M. and S.A. Sherbin. 1977. Estimating sedimentation from an erosion-hazard rating. Research Note PSW-323. U.S. Forest Service. Web site accessed January 8, 2003. http://www.rsl.psw.fs.fed.us/projects/water/sherbin.pdf.

Robichaud, P. R., J. L. Beyers, and D. G. Neary. 2000. Evaluating the effectiveness of post-fire rehabilitation treatments. General Technical Report RMRS-GTR-63. Fort Collins, CO: U.S. Forest Service. Web site accessed January 8, 2003. http://www.fs.fed.us/rm/pubs/rmrs_gtr63.pdf.

Roth, D. 2002. Soil science and the U.S. Forest Service. U.S. Forest Service. Web site accessed January 7, 2003. http://fs.jorge.com/archives/West_Roth/Roth_Soil_Science.htm.

Spittler, T. E. 1995. Pilot monitoring program: geologic input for the hillslope component. California Department of Forestry and Fire Protection. Web site accessed January 8, 2003. http://www.fire.ca.gov/CDFBOFDB/pdfs/PMP-geology.pdf.

Stabb, B. 2002. USDA Forest Service water quality management program. PowerPoint presentation prepared for the Central Valley Regional Water Quality Control Board Silvicultural Waivers Workshop, September 5, 2002, Redding, CA. Vallejo, CA: U.S. Forest Service.

U.S. Bureau of Land Management. 1997a. Rangeland health standards and guidelines for California and northwestern Nevada, chapter 2: description of the alternatives. Web site accessed March 10, 2003. http://www.ca.blm.gov/eis/rangeland_health/chapter02.html#anchor319656.

U.S. Bureau of Land Management. 1997b. Rangeland health standards and guidelines for California and northwestern Nevada, appendix 8: best management practices for water quality – California. Web site accessed March 10, 2003. http://www.ca.blm.gov/eis/rangeland_health/appendix.08.html.

U.S. Forest Service, 1999. Southern California Mountains and Foothills Assessment – habitat and species conservation issues. General Technical Report PSW-GTR-172. Pacific Southwest Research Station. Website accessed February 11, 2003. http://www.psw.fs.fed.us/Tech_Pub/Documents/gtr-172/gtr-172-ch3.pdf

U.S. Forest Service. 2002a. Ecological subregions of California: sections. Web site accessed January 7, 2003. http://www.r5.fs.fed.us/ecoregions/ca_sections.htm.

U.S. Forest Service. 2002b. A look from bald mountain. Web site accessed January 8, 2003. http://www.r5.fs.fed.us/sequoia/incident/Carol/images/pics.htm.

U.S. Forest Service. 2002c. Environmental assessment: McNally fire hazard tree abatement project. Web site accessed January 8, 2003. http://www.r5.fs.fed.us/sequoia/press_releases/mcnally_fire_ea/EA%20McNally%20Hazard%20draft_11_25.html.

U.S. Forest Service. 2002d. Sample soil family. Sacramento, CA: Pacific Southwest Remote Sensing Lab.

U.S. Geological Survey. 1998. Wildfires, debris flows, and El Niño in southern California. Web site accessed January 8, 2003. http://landslides.usgs.gov/html_files/landslides/scfires/scfires.html.

U.S. Natural Resources Conservation Service. 1994. State Soil Geographic (STATSGO) database: data use information. Miscellaneous Publication Number 1492. Web site accessed January 7, 2003. http://www.ftw.nrcs.usda.gov/pdf/statsgo_db.pdf.

U.S. Natural Resources Conservation Service. 1999. Soil taxonomy: a basic system of soil classification for making and interpreting soil surveys. Web site accessed January 7, 2003. http://soils.usda.gov/classification/taxonomy/tax.pdf.

U.S. Natural Resources Conservation Service. 2001. SSURGO certified surveys with DOQ complete coverage. Web site accessed January 7, 2003. http://www.ftw.nrcs.usda.gov/jpg/ssurgo_comp.jpg.

U.S. Natural Resources Conservation Service. 2002a. Soil education. Web site accessed January 7, 2003. http://soils.usda.gov/education/facts/soil.htm.

U.S. Natural Resources Conservation Service. 2002c. Soil formation and soil classification. Web site accessed January 7, 2003. http://soils.usda.gov/education/facts/formation.htm.

U.S. Natural Resources Conservation Service. 2002d. What is a soil survey? Web site accessed January 7, 2003. http://soils.usda.gov/education/facts/survey.htm.

U.S. Natural Resources Conservation Service. 2002e. Ecological site information system. Web site accessed January 7, 2003. http://plants.usda.gov/esis/.

U.S. Natural Resources Conservation Service. 2002f. Pacific southwest major land resource area soil survey office, region # 2. Web site accessed January 7, 2003. http://www.ca.nrcs.usda.gov/mlra/.

Waddell, K.L. and P.M. Bassett. 1996. Timber resource statistics for the north coast resource area of California. Resource Bulletin PNW-RB-214. Portland, OR: U.S. Forest Service, Pacific Northwest Research Station.

Waddell, K.L. and P.M. Bassett. 1997. Timber resource statistics for resource areas of California. Resource Bulletins PNW-RB-220, PNW-RB-221, PNW-RB-222, and PNW-RB-224. Portland, OR: U.S. Forest Service, Pacific Northwest Research Station.

Waters, J. R., K. S. McKelvey, C. J. Zabel, and D. Luoma. 2000. Northern flying squirrel mycophagy and truffle production in fir forests in Northeastern California. pp. 73-97. In: Powers, R. F., D. L. Hauxwell, and G. M. Nakamura (technical coordinators). 2000. Proceedings of the California Forest Soils Council conference on forest soils biology and forest management; February 23-24, 1996; Sacramento, California. General Technical Report PSW-GTR-178. Albany, CA: U.S. Forest Service. Web site accessed January 8, 2003. http://www.rsl.psw.fs.fed.us/projects/wild/waters/waters6.pdf.

Wilent, S. 2001. Here's how to protect forest soil productivity. The Forestry Source. Web site accessed January 8, 2003. http://www.safnet.org/archive/protectsoil501.htm.