UNIVERSITY OF CALIFORNIA
Agriculture and Natural Resources

UC ANR Publication 8542 | December 2020
https://doi.org/10.3733/ucanr.8542
http://anrcatalog.ucanr.edu

UC PEER REVIEWED

Ecology and Management of Annual Rangelands Series

Part 3: Soils

ANTHONY O'GEEN, Cooperative Extension Soil Resource Specialist, Land, Air and Water Resources, University of California, Davis; and

KERRY ARROUES, Soil Scientist (retired), USDA Natural Resources Conservation Service, Hanford, California

Ecology and Management of Annual Rangelands Series Technical Editor:

MELVIN GEORGE, Extension Rangeland Management Specialist Emeritus, Department of Plant Science, University of California, Davis

Publications in this series:

1 Mediterranean Climate (8540)

2 Ecological History (8541)

3 Soils (8542)

4 History of Range Livestock Production (8543)

5 Range Plant Growth and Development (8544)

6 Vegetation Change and Ecosystem Services (8545)

7 Livestock Production (8546)

8 Grazing Management (8547)

9 Vegetation Management (8548)

CLASSIFYING SOILS AND LAND

Soil Classification

Researchers and managers like to organize the world they live in so that they can explain their environment. Soil scientists have developed soil taxonomy procedures to help them classify soils and understand soil similarities and differences. Plant ecologists and range scientists have developed several vegetation classification methods, and the USDA Natural Resources Conservation Service (NRCS) has classified land with similar vegetation and soils into ecological sites.

Using the USDA Soil Taxonomy (Soil Survey Staff 1999), soils can be classified into several levels: order, suborder, great group, subgroup, family, and series. There are 12 soil orders, but not all occur on rangelands. Soil orders are frequently defined by a single dominant characteristic affecting soils in that location—for example, the prevalent vegetation (Mollisols, Histosols), the type of parent material (Andisols, Vertisols), the climate variables such as lack of precipitation (Aridisols), or the presence of permafrost (Gelisols). Also significant in several soil orders is the amount of physical and chemical weathering present (Oxisols, Ultisols, Alfisols, Inceptisols, Entisols) and/or the relative amount of soil profile development that has taken place. These soil orders can be subdivided into suborders and great groups. Great groups are a midlevel classification point in the hierarchy of soil taxonomy. In California most annual rangeland soils fall into five great groups: Haploxerolls, Haploxeralfs, Xerorthents, Argixerolls, and Haploxererts. The soil series is the lowest taxonomic class and consists of soils within a family that has horizons similar in color, texture, structure, reaction, consistency, mineral composition, and arrangement in the profile. There are more than 100 soil series in the annual rangelands (table 1). Soil great groups and example soil series of the Coast Range and Sierra Nevada foothills will be described in this publication.

Soil Science Terminology

Soil science, and especially soil taxonomy, has a unique vocabulary that is unfamiliar to most readers. The Soil Science Society of America has published a glossary of terms on the Internet: https://www.soils.org/publications/soils-glossary. A glossary can also be found on New England's NEsoil.com website, http://nesoil.com/gloss.htm. USDA Natural Resources Conservation Service has published an *Illustrated Guide to Soil Taxonomy* (Soil Survey Staff 2015).

Table 1. Soil series of the annual rangelands

Series	Subgroup	Family	Vegetation type*
Ahwahnee	Mollie Haploxeralfs	coarse-loamy, mixed, thermic	OW
Alo	Aridic Haploxererts	fine, smectitic, thermic	AG
Altamont	Aridic Haploxererts	fine, smectitic, thermic	AG

*AG = annual grassland; OW = oak-woodland; CH = chaparral; CalSage = California sagebrush; brush = mixed brushland.

Table 1. Soil series of the annual rangelands, *continued*

Series	Subgroup	Family	Vegetation type*
Amador	Typic Haploxerepts	loamy, mixed, superactive, thermic, shallow	
Anaverde	Pachic Haploxerolls	fine-loamy, mixed, active, mesic	OW/AG
Andregg	Ultic Haploxerolls	coarse-loamy, mixed, superactive, thermic	AG/OW
Anita	Xeric Duraquerts	clayey, smectitic, thermic	AG
Antioch	Typic Natrixeralfs	fine, smectitic, thermic	AG
Apollo	Calcic Haploxerolls	fine-loamy, mixed, superactive, thermic	AG
Arbuckle	Typic Haploxeralfs	fine-loamy, mixed, superactive, thermic	AG/OW
Arburua	Typic Xerorthents	fine-loamy, mixed, superactive, calcareous, thermic	AG
Argonaut	Mollie Haploxeralfs	fine, mixed, thermic	OW
Arnold	Typic Xeropsamments	mixed, thermic	CH/OW
Arujo	Pachic Argixerolls	fine-loamy, mixed, superactive, thermic	OW
Asolt	Chromic Haploxererts	fine, smectitic, thermic	AG
Auberry	Ultic Haploxeralfs	fine-loamy mixed thermic	OW
Auberry	Ultic Haploxeralfs	fine-loamy mixed thermic	OW
Auburn	Lithic Haploxerepts	loamy, mixed, superactive, thermic	OW
Ayar	Typic Haploxererts	fine, smectitic, thermic	AG
Azule	Mollic Haploxeralfs	fine, smectitic, thermic	AG
Balcom	Typic Calcixerepts	fine-loamy, mixed, superactive, thermic	AG
Beam	Xeric Haplocambids	loamy, mixed, superactive, thermic, shallow	AG
Bearwallow	Ultic Haploxeralfs	fine-loamy, mixed, superactive, thermic	AG
Bellota	Abruptic Durixeralfs	fine-loamy, mixed, superactive, thermic	AG
Bellyspring	Mollic Haploxeralfs	fine-loamy, mixed, superactive, thermic	AG
Blasingame	Typic Haploxeralfs	fine-loamy, mixed, superactive, thermic	AG/OW
Boar	Mollic Haploxeralfs	fine, smectitic, thermic	AG/OW
Botella	Pachic Argixerolls	fine-loamy, mixed, superactive, thermic	AG/OW
Bressa	Typic Haploxeralfs	fine-loamy, mixed, active, thermic	AG/OW
Briones	Typic Xeropsamments	mixed, thermic	AG/OW
Buttes	Mollic Haploxeralfs	loamy-skeletal, mixed, superactive, thermic	AG/OW
Calla	Typic Calcixerepts	fine-loamy, mixed, superactive, thermic	AG
Calodo	Calcic Haploxerolls	loamy, mixed, superactive, thermic, shallow	OW
Camatta	Xeric Petrocalcids	loamy, mixed, superactive, thermic, shallow	AG
Capay	Typic Haploxererts	fine, smectitic, thermic	AG
Capitan	Entic Haploxerolls	loamy-skeletal, mixed, superactive, thermic, shallow	AG
Carbona	Vertic Haploxerolls	fine, smectitic, thermic	AG
Chamise	Ultic Palexerolls	clayey-skeletal, mixed, active, thermic	AG/OW/CH
Chanac	Calcic Haploxerepts	fine-loamy, mixed, superactive, thermic	
Choice	Typic Xerorthents	fine, mixed, superactive, calcareous, thermic	AG
Chualar	Mollie Haploxeralfs	fine-loamy, mixed, thermic	AG
Cibo	Aridic Haploxererts	fine, smectitic, thermic	AG

*AG = annual grassland; OW = oak-woodland; CH = chaparral; CalSage = California sagebrush; brush = mixed brushland.

Table 1. Soil series of the annual rangelands, *continued*

Series	Subgroup	Family	Vegetation type*
Cibo	Aridic Haploxererts	fine, smectitic, thermic	
Cieneba	Typic Xerorthents	loamy, mixed, superactive, nonacid, thermic, shallow	CH
Clear Lake	Xeric Endoaquerts	fine, smectitic, thermic	AG
Climara	Aridic Haploxererts	fine, magnesic, thermic	AG
Coarsegold	Mollic Haploxeralfs	fine-loamy, mixed, superactive, thermic	OW/CH
Cochora	Typic Torriorthents	loamy, mixed, superactive, calcareous, thermic, shallow	AG
Concepcion	Xeric Argialbolls	fine, smectitic, thermic	AG
Contra Costa	Mollic Haploxeralfs	fine, mixed, superactive, thermic	OW/AG/CH
Corning	Typic Palexeralfs	fine, mixed, thermic	AG
Corning	Typic Palexeralfs	fine, mixed, active, thermic	AG
Cropley	Aridic Haploxererts	fine, smectitic, thermic	AG
Crow Hill	Pachic Haploxerolls	fine-silty, mixed, superactive, thermic	AG
Curry Mountain	Typic Argixerolls	fine-loamy, mixed, superactive, mesic	OW
Cyvar	Typic Durixeralfs	loamy, mixed, superactive, thermic, shallow	AG
Daulton	Lithic Xerorthents	loamy, mixed, superactive, nonacid, thermic	AG/OW
Diablo	Aridic Haploxererts	fine, smectitic, thermic	AG
Diamond Springs	Ultic Haploxeralfs	fine-loamy, mixed, mesic	OW/FOR
Dibble	Typic Haploxeralfs	fine, smectitic, thermic	AG/OW
Doemill	Lithic Haploxeralfs	loamy, mixed, superactive, thermic	
Exclose	Calcic Haploxerepts	fine-loamy, mixed, superactive, thermic	AG
Fagan	Typic Argixerolls	fine, smectitic, thermic	AG/OW
Fallbrook	Typic Haploxeralfs	fine-loamy, mixed, superactive, thermic	CH/AG
Feliz	Cumulic Haploxerolls	fine-loamy, mixed, superactive, thermic	AG
Fifield	Ultic Argixerolls	loamy-skeletal, mixed, superactive, thermic	OW
Fontana	Calcic Haploxerolls	fine-loamy, mixed, superactive, thermic	AG
Fouts	Ultic Argixerolls	clayey-skeletal, mixed, superactive, thermic	AG
Franciscan	Typic Argixerolls	fine-loamy, mixed, superactive, thermic	OW
Friant	Lithic Haploxerolls	loamy, mixed, superactive, thermic	CH/AG
Garey	Lamellic Haploxeralfs	coarse-loamy, mixed, superactive, thermic	AG
Gaviota	Lithic Xerorthents	loamy, mixed, superactive, nonacid, thermic	CH
Gazos	Pachic Haploxerolls	fine-loamy, mixed, superactive, thermic	AG/OW/CH
Gilroy	Typic Argixerolls	fine-loamy, mixed, active, thermic	AG/OW/CH
Gloria	Abruptic Durixeralfs	fine, illitic, thermic	AG
Godde	Lithic Haploxerolls	loamy, mixed, superactive, mesic	CH/AG
Goldeagle	Typic Haploxeralfs	fine, mixed, superactive, thermic	AG/OW/CH
Gonzaga	Typic Palexerolls	fine, mixed, superactive, thermic	OW/AG
Guenoc	Typic Rhodoxeralfs	fine, kaolinitic, thermic	AG/OW/CH

*AG = annual grassland; OW = oak-woodland; CH = chaparral; CalSage = California sagebrush; brush = mixed brushland.

Table 1. Soil series of the annual rangelands, *continued*

Series	Subgroup	Family	Vegetation type*
Haire	Typic Haploxerults	fine, mixed, superactive, thermic	AG
Hambright	Lithic Haploxerolls	loamy-skeletal, mixed, superactive, thermic	OW/AG
Havala	Pachic Argixerolls	fine-loamy, mixed, superactive, thermic	AG/OW
Henneke	Lithic Argixerolls	clayey-skeletal, serpentinitic, thennic	
Hillbrick	Lithic Xerorthents	loamy, mixed, superactive, calcareous, thermic	JU/AG
Hillgate	Typic Palexeralfs	fine, smectitic, thermic	AG
Honker	Mollic Palexeralfs	fine, mixed, superactive, thermic	AG
Hopland	Typic Haploxeralfs	fine-loamy, mixed, active, mesic	OW
Hytop	Typic Palexeralfs	fine, mixed, superactive, thermic	AG
Inks	Lithic Argixerolls	loamy-skeletal, mixed, superactive, thermic	OW
Jokerst	Lithic Haploxeralfs	loamy, mixed, superactive, thermic	OW
Keyes	Abruptic Durixeralfs	clayey, mixed, active, thermic, shallow	AG
Kilmer	Typic Xerorthents	fine-loamy, mixed, superactive, calcareous, thermic	AG
Kimball	Mollie Palexeralfs	fine, montmorillonitic, thermic	AG
Kimberlina	Typic Torriorthents	coarse-loamy, mixed, superactive, calcareous, thermic	AG
Las Posas	Typic Rhodoxeralfs	fine, mixed, thermic	AG/CHAP
Laughlin	Ultic Haploxerolls	fine-loamy, mixed, superactive, mesic	OW
Laveaga	Typic Argixerolls	fine, mixed, active, mesic	OW
Leesville	Pachic Haploxerolls	fine-loamy over sandy or sandy-skeletal, magnesic, thermic	AG
Linne	Calcic Pachic Haploxerolls	fine-loamy, mixed, superactive, thermic	AG/OW/CS
Livermore	Typic Haploxerolls	loamy-skeletal, mixed, superactive, thermic	AG/OW
Lockwood	Pachic Argixerolls	fine-loamy, mixed, superactive, thermic	AG/OW/CH
Lodo	Lithic Haploxerolls	loamy, mixed, superactive, thermic	OW/CH
Lopez	Lithic Ultic Haploxerolls	loamy-skeletal, mixed, superactive, thermic lithic	AG/OW/CS
Los Gatos	Typic Argixerolls	fine-loamy, mixed, active, mesic	CH
Los Osos	Typic Argixerolls	fine, smectitic, thermic	AG
Maxwell	Typic Haploxererts	fine, smectitic, thermic	AG
Maymen	Typic Dystroxerepts	loamy, mixed, active, mesic, shallow	CH
Mcmullin	Lithic Ultic Haploxerolls	loamy, mixed, superactive, mesic	OW
Mendi	Typic Xerorthents	fine-loamy, mixed, superactive, calcareous, thermic	AG
Millsholm	Lithic Haploxerepts	loamy, mixed, superactive, thermic	OW
Milpitas	Mollic Palexeralfs	fine, smectitic, thermic	AG/OW/CS
Mokelumne	Typic Haploxerults	fine, kaolinitic, thermic	OW/CH
Montara	Lithic Haploxerolls	loamy, magnesic, thermic	AG
Muranch	Aridic Haploxerolls	loamy-skeletal, mixed, superactive, thermic	AG
Myers	Aridic Haploxererts	fine, smectitic, thermic	AG

*AG = annual grassland; OW = oak-woodland; CH = chaparral; CalSage = California sagebrush; brush = mixed brushland.

Table 1. Soil series of the annual rangelands, *continued*

Series	Subgroup	Family	Vegetation type*
Nacimiento	Calcic Haploxerolls	fine-loamy, mixed, superactive, thermic	AG
Newville	Mollic Palexeralfs	fine, smectitic, thermic	AG/OW/CS
Nodhill	Typic Haploxeralfs	fine-loamy, mixed, superactive, thermic	AG
Oneil	Calcic Haploxerolls	fine-silty, mixed, superactive, thermic	AG
Orognen	Typic Palexeralfs	fine, mixed, superactive, thermic	AG
Padres	Typic Calcixerepts	coarse-loamy, mixed, superactive, thermic	AG
Panoza	Calcic Haploxerepts	coarse-loamy, mixed, superactive, thermic	AG
Parkfield	Vertic Argixerolls	fine, smectitic, thermic	OW/AG
Pentz	Ultic Haploxerolls	loamy, mixed, superactive, thermic, shallow	AG
Perkins	Mollic Haploxeralfs	fine-loamy, mixed, superactive, thermic	AG/OW
Peters	Typic Haploxeroll	clayey, smectitic, thermic, shallow	AG
Pinnacles	Ultic Palexeralfs	fine, smectitic, thermic	AG/CH
Placentia	Typic Natrixeralfs	fine, smectitic, thermic	AG
Polonio	Calcic Haploxerepts	fine-loamy, mixed, superactive, thermic	AG
Positas	Mollic Palexeralfs	fine, smectitic, thermic	AG/OW
Pyxo	Typic Haplocambids	coarse-loamy, mixed, superactive, thermic	AG
Quiensabe	Typic Argixerolls	fine, mixed, superactive, thermic	OW/brush
Rackerby	Ultic Palexeralfs	fine, kaolonitic, mesic	OW/brush
Ramona	Typic Haploxeralfs	fine-loamy, mixed, thermic	CHAP
Redding	Abruptic Durixeralfs	fine, mixed, thermic	AG
Redvine	Ultic Palexeralfs	fine, mixed, semiactive, thermic	OW
Reliz	Lithic Xerorthents	loamy-skeletal, mixed, active, nonacid, thermic	AG/OW
Rescue	Mollie Haploxeralfs	fine-loamy, mixed, thermic	AG/brush
Rincon	Mollic Haploxeralfs	fine, smectitic, thermic	AG
Ryer	Mollie Haploxeralfs	fine, montmorillonitic, thermic	AG
Sagaser	Typic Argixerolls	fine-loamy, mixed, superactive, mesic	OW
Saltos	Lithic Mollic Haploxeralfs	loamy, mixed, superactive, thermic	CH/AG
San Andreas	Typic Haploxerolls	coarse-loamy, mixed, superactive, thermic	AG
San Benito	Calcic Pachic Haploxerolls	fine-loamy, mixed, superactive, thermic	OW/AG
San Timoteo	Typic Xerorthents	coarse-loamy, mixed, superactive, calcareous, thermic	CalSage/AG
Santa Lucia	Pachic Ultic Haploxerolls	clayey-skeletal, mixed, superactive, thermic	CS/OW/AG
Santa Ynez	Ultic Palexerolls	fine, smectitic, thermic	OW
Saucito	Lithic Haploxeralfs	loamy-skeletal, mixed, superactive, thermic	AG
Seaback	Calcic Haploxerepts	loamy, mixed, superactive, thermic, shallow	AG
Sehorn	Aridic Haploxererts	fine, smectitic, thermic	OW/AG
Semper	Gypsic Haploxerepts	coarse-loamy, mixed, superactive, thermic	AG
Sesame	Typic Haploxeralfs	fine-loamy, mixed, superactive, thermic	AG/OW

*AG = annual grassland; OW = oak-woodland; CH = chaparral; CalSage = California sagebrush; brush = mixed brushland.

Table 1. Soil series of the annual rangelands, *continued*

Series	Subgroup	Family	Vegetation type*
Shedd	Typic Xerorthents	fine-silty, mixed, superactive, calcareous, thermic	AG
Shenandoah	Aquic Palexeralfs	fine, smectitic, thermic	AG/OW
Sheridan	Pachic Haploxerolls	coarse-loamy, mixed, superactive, thermic	AG/OW
Sierra	Ultic Haploxeralfs	fine-loamy, mixed, thermic	OW
Skyhigh	Mollic Haploxeralfs	fine, smectitic, thermic	OW
Sleeper	Mollic Haploxeralfs	fine, smectitic, thermic	OW
Sobrante	Mollie Haploxeralfs	fine-loamy, mixed, thermic	OW
Squawrock	Typic Haploxeralfs	loamy-skeletal, mixed, superactive, thermic	AG/OW
Still	Cumulic Haploxerolls	fine-loamy, mixed, superactive, thermic	AG/OW
Stonyford	Lithic Mollic Haploxeralfs	loamy, mixed, superactive, thermic	CH
Suther	Aquic Haploxeralfs	fine, smectitic, mesic	AG/OW/CH
Sween	Typic Argixerolls	fine, smectitic, thermic	AG/OW
Tajea	Typic Argixerolls	fine-loamy, mixed, superactive, thermic	OW
Talmage	Fluventic Haploxerolls	loamy-skeletal, mixed, superactive, thermic	AG/SH/OW
Tierra	Mollic Palexeralfs	fine, smectitic, thermic	AG
Timbuctoo	Typic Rhodoxeralfs	fine, parasesquic, thermic	OW
Todos	Typic Argixerolls	fine, smectitic, thermic	AG/CH/OW
Toomes	Lithic Haploxerepts	loamy, mixed, superactive, thermic	OW/AG
Trabuco	Mollic Haploxeralfs	fine, mixed, superactive, thermic	OW/AG
Tunis	Typic Haploxerolls	loamy, mixed, superactive, thermic, shallow	AG
Tuscan	Typic Durixeralfs	clayey, smectitic, thermic, shallow	AG
Vallecitos	Lithic Ruptic-Inceptic Haploxeralfs	clayey, smectitic, thermic	AG/OW/CH
Vaquero	Aridic Haploxererts	fine, smectitic, thermic	AG
Vernado	Pachic Haploxerolls	coarse-loamy, mixed, superactive, mesic	OW/AG
Vista	Typic Haploxerepts	coarse-loamy, mixed, superactive, thermic	AG/CH
Wadesprings	Pachic Argixerolls	fine-loamy, magnesic, thermic	OW/AG
Walong	Typic Haploxerolls	coarse-loamy, mixed, superactive, thermic	OW/AG
Wisflat	Lithic Xerorthents	loamy, mixed, superactive, calcareous, thermic	AG
Wisheylu	Ultic Haploxeralfs	fine-loamy, kaolinitic, thermic	OW
Witherell	Typic Haploxerepts	fragmental, mixed, thermic	AG
Wyman	Mollic Haploxeralfs	fine-loamy, mixed, thermic	AG
Yokohl	Abruptic Durixeralfs	fine, montmorillonitic, thermic	AG
Yorktree	Ultic Argixerolls	fine, mixed, superactive, mesic	OW
Yorkville	Typic Argixerolls	fine, mixed, superactive, thermic	AG
Zaca	Vertic Haploxerolls	fine, smectitic, thermic	AG

*AG = annual grassland; OW = oak-woodland; CH = chaparral; CalSage = California sagebrush; brush = mixed brushland.

Major Land Resource Areas

The USDA NRCS has organized the United States into Major Land Resource Areas (MLRAs). Major Land Resource Areas can be subdivided into ecological sites. An ecological site is a kind of land with a specific potential natural community and specific physical site characteristics, differing from other kinds of land in its ability to produce vegetation and to respond to management. Soil characteristics, precipitation, elevation, and aspect play significant roles in determining the kind and amount of vegetation produced. This publication primarily focuses on soil characteristics on MLRA 15 along the Coast Range (fig. 1) and MLRA 18 along the Sierra Nevada foothills (fig. 2). Annual rangeland also occurs on the edge of the Sacramento and San Joaquin Valleys (MLRA 17, fig. 3) and the southern California mountains (MLRA 20, fig. 4).

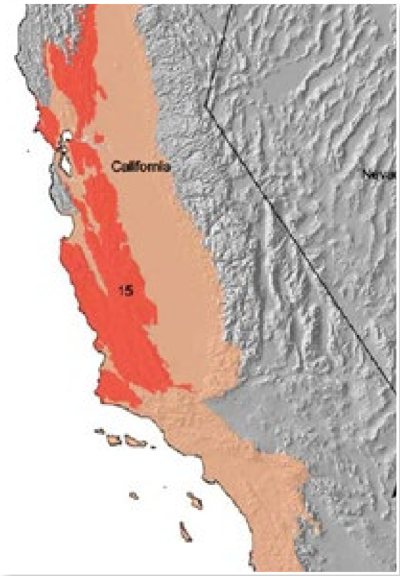

Figure1. Major Land Resource Area 15 (Coast Range).

Figure 2. Major Land Resource Area 18 (Sierra Nevada foothills).

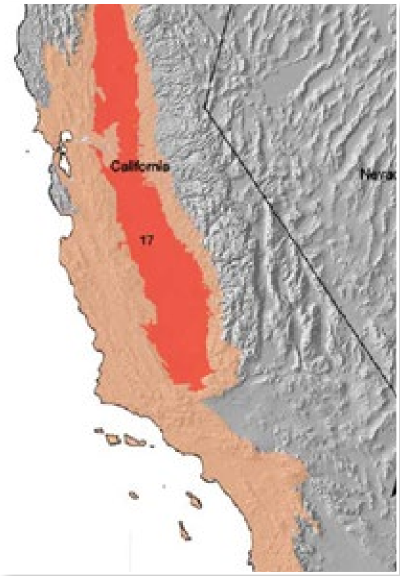

Figure 3. Major Land Resource Area 17 (Sacramento and San Joaquin Valleys).

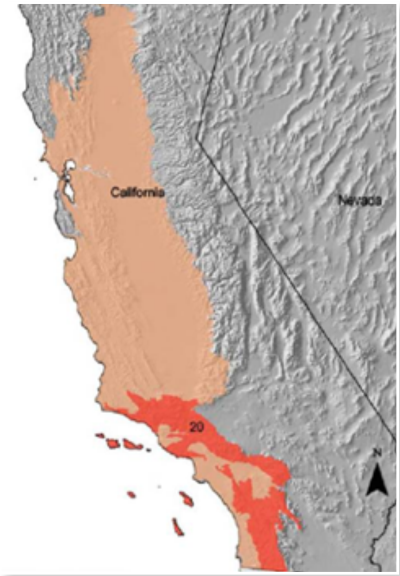

Figure 4. Major Land Resource Area 19 (southern California mountains).

Following a brief discussion of soil formation, this publication focuses on the characteristics of soils in the Coast Range and the Sierra Nevada foothills, highlighting important soil series in each region.

Soil Formation

Because California is at the confluence of several tectonic plates (see the second publication in this series, *Ecological History*), it has a diverse geology that gives rise to diverse parent materials (fig. 5). This results in a mosaic of soils that vary in their ability to support trees, shrubs, and herbaceous vegetation. Hans Jenny (1941) described five soil-formation factors that account for differences in soils. The characteristics and properties of soil are determined by physical, biological, and chemical processes that result from the interaction of these soil-forming factors. The five factors (parent material, climate, topography, organisms, and time) are discussed here, as they relate to different annual rangeland soils.

Parent material is an important factor, particularly in the formation of upland soils. Parent material is generally defined as the unconsolidated material from which soils form. Parent material can be transported by wind, water, ice, or gravity. It can also exist as bedrock that has weathered in place. Upland soils are fairly youthful in their developmental stage, and the parent material has a great effect on what the soil eventually looks like. Soil texture, pH, and mineral constituents are some of the soil characteristics that come from parent material.

Climate is often considered the most powerful soil-forming factor. Climate is expressed as both temperature effects and rainfall effects. Temperature controls the rates of chemical reactions. Many reactions proceed more

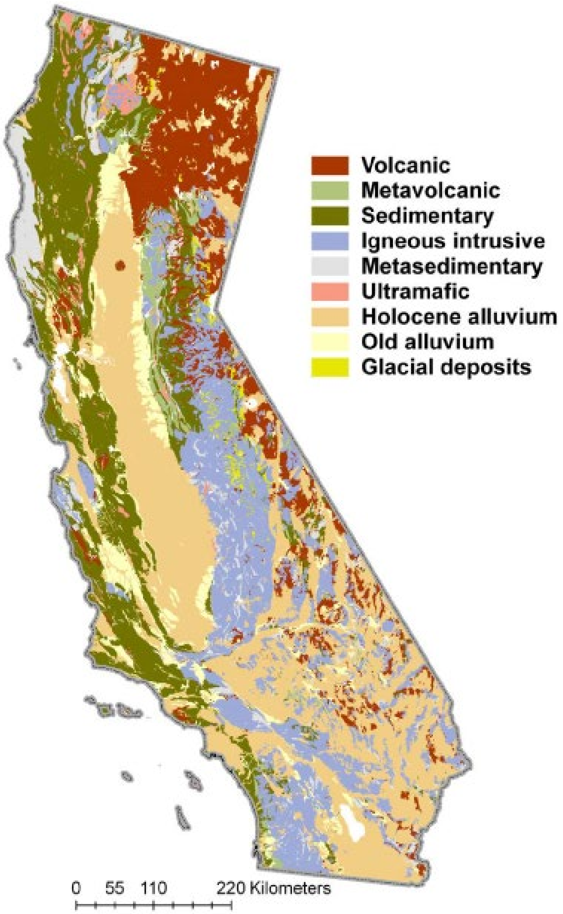

Figure 5. California soil lithology. *Source:* UC Davis California Soil Resource Lab, http://casoilresource.lawr.ucdavis.edu/drupal/node/776.

quickly as temperature increases. Warm-region soils are therefore normally more developed or more mature than are cool-region soils. Rainfall affects leaching, pH, and soil aeration. In many settings the timing of precipitation is as important as the amount. In addition to its direct effects, climate also profoundly affects vegetation, which, in turn, also affects soil formation.

Topography governs soil formation by controlling the fate of water and sediment across the landscape. In general, the steeper the slope, the shallower the soil, because water runs off steep slopes readily, which means that less moisture percolates into the soil. Moreover, high runoff causes erosion—and on steep slopes, the rate of erosion tends to outpace that of soil formation. On gentle slopes and flat areas, deeper soils can develop because there is more effective rainfall and less erosion. The influence of aspect (the direction a slope faces) has a large effect on soil temperature, and therefore soil formation, especially in the southern and dryer parts of the Coast Range. Commonly, soils are shallower on the hotter and drier south-facing aspects and deeper on the cooler north-facing aspects. In the southern and dryer parts of the Coast Range, organic matter content in soils formed on south-facing aspects is usually lower than that found on north-facing aspects.

Organisms affect and are affected by soil formation. Trees, grass, and shrubs each have different influences on soil, and a relationship exists between the soil and what grows on it. Different soils form in a grassland than under shrub or woodland vegetation. Much of this difference is due to the rapid nutrient cycling in grasslands. Vegetation intercepts rainfall, thereby influencing runoff and therefore erosion. Vegetation type and amount directly influence the type and amount of organic matter accumulation on the soil, thereby influencing soil chemical properties such as pH and nutrient supply. Finally, vegetation is the food source for most microorganisms, so the vegetation exerts a strong influence on soil microbial populations. Burrowing organisms such as pocket gophers, ground squirrels, and earthworms mix the soil.

Time is the magnifier of other soil-forming factors. Soils develop and change over time. The length of time a soil has been in place has a tremendous influence on the soil profile. For example, the Columbia series is a recent alluvial soil, maybe a thousand years or less in age, and it is uniform, sandy, pale brown, and deep. In contrast, the San Joaquin series is older, approximately 150,000 to 300,000 years old, and, as a result, it contains reddish brown, clay-rich horizons and cemented layers that impede roots and percolating water. As soils weather over time, iron is released from primary minerals. The iron forms new minerals in the soil, termed iron oxides, that impart reddish brown and/or orange-brown colors. Generally, soils that display a greater degree of reddening are more highly weathered or are older.

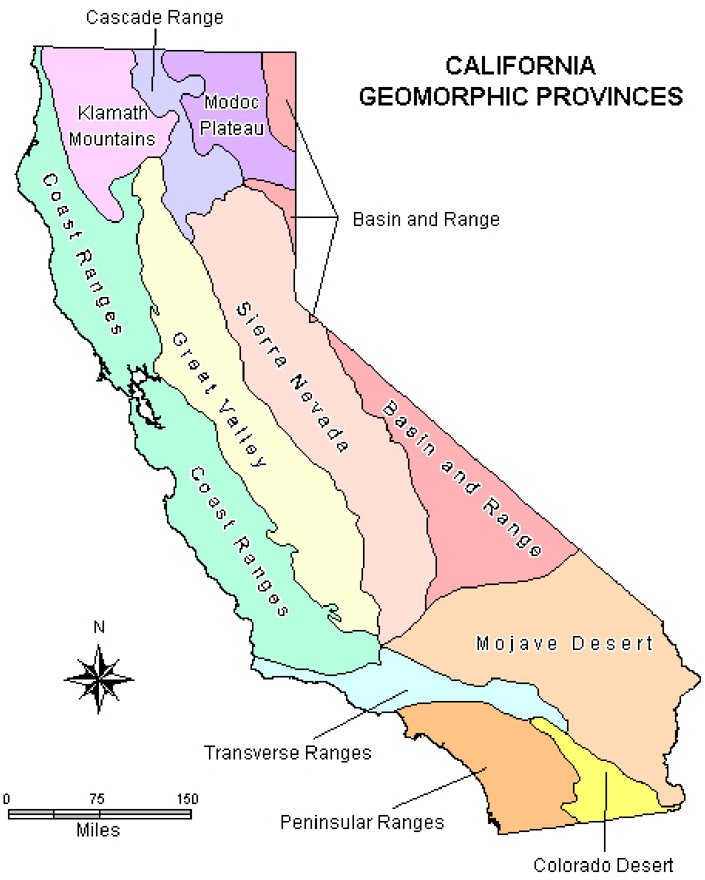

Figure 6. Coast Range Province.

The Coast Range Region

Geography

Physiographically, the Coast Range is part of the Pacific Mountain System. Most of MLRA 15 is made up of the Coast Range, with the Klamath Mountains at the extreme northern end and the Los Angeles Ranges at the southwest corner. The town of Clearlake is almost in the center of the northern part of this MLRA, and the towns of Suisun City and Benicia are at the south end of the northern half. The towns of Martinez and Concord are in the north end of the southern half of the area. The towns of Atascadero and Paso Robles are in the south end of the southern half. Interstate 80 crosses the junction of the northern and southern halves of the area, directly north of the Carquinez Straits, which connect the Sacramento-San Joaquin Delta with San Pablo Bay (USDA NRCS 2006).

Geology

The Coast Range Province extends from the Transverse Ranges to the Oregon border (fig. 6) for approximately 1,000 kilometers. From the Pacific Ocean, the Range extends roughly 130 kilometers to the Central Valley. The east-west extension of the Coast Range is considerably less in northern California, where it borders the Klamath Mountains. The general topography of the Coast Range is characterized as tectonically controlled, north-west trending mountains, interspersed by parallel valleys. The terrain is rugged in most places, with steep slopes reaching elevations as high as 2,300 meters in places (Harden 2004).

The Coast Range is derived from rocks of the Franciscan Assemblage, Great Valley sequence, and Salinian block. The Franciscan Assemblage and Great Valley Sequence consist primarily of interbedded sandstone (greywacke) and mudstone (shale). Chert, conglomerates, schists, and serpentinite are commonly encountered in this terrain, but to a lesser extent. Uplift, faulting, compression, and folding of the interbedded marine deposits of the Franciscan assemblage and the Great Valley Sequence have resulted in a highly complex sequence of contrasting lithology throughout the Coast Range. The Salinian Block occurs west of the San Andreas Fault line, primarily in the southern half of the Coast Range. It consists mainly of granite. Volcanic rocks consisting of rhyolite, basalt, pyroclastic flows, and andesite are exposed along the Central Coast and east of the San Andreas Fault. The age of these rocks becomes progressively younger from the south, where rocks are up to 15 million years old, to the north in the Clear Lake Volcanic Fields, where events took place as recently as 10,000 years ago (Harden 2004).

Climate

Coastal temperatures are mild, often with small differences (< 6°C) between summer and winter mean annual soil temperatures. Warm soil temperatures are common throughout the inland areas, with mean annual soil temperatures from 15° to 22°C. Cooler mean annual soil temperatures (8° to 15°C) are found at elevations above 1,220 meters, particularly on north-facing slopes (O'Geen et al. 2008).

Mean annual precipitation ranges from 510 to 3,050 millimeters in the north to 150 to 1,015 millimeters in the southern and central Coast Ranges. These differences in climate influence soil development. Cool moist regions support Mollisols and Alfisols. Ultisols are found on stable landscapes where precipitation is highest. Entisols, Inceptisols, and Aridisols are found in dry and hot regions.

Upland Soils

The Coast Range was created by transform motion and compression along the Pacific and North American Plate boundary approximately 3.5 to 5 million years ago. Thus, the Coast Range is quite young, and the associated topography reflects this with steeply sloping, dissected uplands separated by ephemeral stream valleys. A common geomorphic feature, particularly in hillslopes formed from sandstone and shale, are spoon-shaped hollows, which are concave hillslopes mantled by thick colluvium. In this geomorphic setting, deep soil series such as Los Osos and Yorkville are commonly observed where sediment has accumulated. Landscape positions where sediment is lost by erosion and mass wasting support soil series such as Bonnydoon (fig. 7). The initial formation of these hollows is believed to occur by landslides caused by rapid uplift and slope failure along contact zones of different rock types and along joints and fractures. Over time, these hollows fill with sediment. Periodically, during winter storm events, soils towards the base of these hollows become super saturated with water, and, due to the high pore water pressures, cause debris flows and soil creep (Dietrich and Dorn 1984). The hummocky surface throughout the Franciscan terrain reflects the dynamic nature of this landscape (fig. 8).

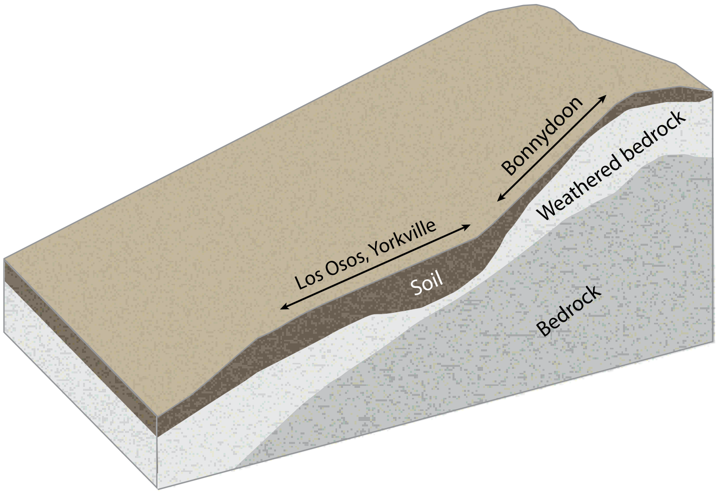

Figure 7. Diagram of a hillslope.

Figure 8. Recent landslide creating hummocky terrain in the Coast Range.

Despite the complex lithology and topography of the region, soil variability is relatively low from a taxonomic standpoint. This is because rangelands were not mapped with the same level of detail as cropland, since, at the time of mapping, it was thought that range management did not require such a detailed understanding of soil landscape relationships. As a result, rangeland soil map units typically contain more than one soil type. Thus, a significant amount of variability is documented within map units as minor components and inclusions. Despite being named after one or two soils, map units typically contain several soils, and their percent composition within the map unit is documented. Inclusions are soils that occupy a limited extent (< 15%) within a map unit. Minor components are soils that occupy more of the map unit than inclusions but are not the dominant soil within the map unit.

Over 5 million hectares of land are inventoried by soil surveys in the region. Over 77 percent of this land consists of five soil great groups (Haploxerolls, Haploxeralfs, Xerorthents, Argixerolls, and Haploxererts). A majority of the region supports Haploxerolls, part of the Mollisol soil order. These soils are typically referred to as grassland soils, having thick topsoils rich in soil organic carbon. Mollisols are common throughout the west side of the Coast Range, where temperatures are mild relative to warmer inland soils, which may encourage soil organic matter accumulation by slowing microbial activity and decomposition of plant residues. Mollisols are also common in parent materials derived from shale, because such soils weather rapidly to smectite clays. Soil organic matter has been shown to accumulate preferentially on smectite clays (Gonzalez and Laird 2003), and thus clay mineralogy inherited from certain parent materials may partially control the distribution of Mollisols in the Coast Ranges.

Intermediately weathered soils (Haploxeralfs) are also common in the Coast Ranges, occupying approximately 766,841 hectares in the region. These soils have thinner topsoils with less soil organic matter compared with Haploxerolls, but they are more developed, displaying an illuvial clay increase in the subsoil. Haploxeralfs are common throughout the inland areas of the Coast Ranges, where precipitation is moderate and temperatures are high. Weakly developed soils (Haploxerepts and Xerorthents) occupy a combined 1.5 million hectares, typically occurring on steep slopes, convex landforms, and steep, south-facing slopes in semiarid regions of the Coast Range (Beaudette and O'Geen 2008). These weakly developed soils commonly occur on granitic parent materials, Haploxerolls included. Desert soils (Torriorthents and Haplocambids) are found in the southeastern Coast Range, particularly on south-facing slopes. Weathered soils (Ultisols), characterized by low base saturation and clay-rich subsoils, are found on old, stable landscape positions in the northern portion of the Coast Range, where precipitation is high. Soils derived from volcanic rocks such as the Pinnacles formation include Argixerolls on gentle slopes and terraces, Haploxerolls on steep north-facing slopes, and Xerorthents on steep south-facing slopes. Valley landscape positions typically support Haploxererts, clay-rich soils with high shrink-swell capacity. These soils are also common on lower slope angles of hillslopes from parent material derived from shale.

The eastern and southeastern portions of the southern and central Coast Ranges are dominated by Moreno shale, which is an old sea floor containing selenium-rich pyrite (iron sulfide). When the minerals are exposed to oxygen, sulfides are oxidized to sulfuric acid, which creates an extremely acidic soil environment with pH values below 4.0. In more arid areas within this zone of parent material, sulfate-bearing secondary minerals such as jarosite and gypsum form. Many arid soils in this region are rich in selenium, which commonly substitutes for sulfur in the mineral precursors. Toxic levels of selenium are encountered in drainwater from these soils (Tanji et al. 1986; O'Geen et al. 2007).

The nature of upland soils throughout the Coast Range is controlled by additions, losses, and translocations. Processes such as sediment transport, bioturbation, clay illuviation, and organic carbon accumulation are influenced by hillslope characteristics (slope, aspect, and curvature) and primary productivity. In soil landscapes derived from sandstone, hillslope positions that shed water and sediment—such as convex positions and steep slopes—typically support shallow soils with low soil organic carbon content and more sand and gravel relative to clay. In contrast, landscape positions that accumulate water and sediment—such as concave positions, foot slopes, and toe slopes—tend to support deep soils with thick, carbon-rich topsoils and well-mixed distributions of sand, silt, and clay (Gessler et al. 2000; Beaudette and O'Geen 2008). Well-developed soils with argillic horizons are present at lower slope angles (Argixerolls, Haploxeralfs, and Palexerolls), where the rate of erosion and soil formation are at a steady state. These soils are typically classified as Haploxeralfs and Argixerolls. Sheet and rill erosion by overland flow has been discovered to be negligible at lower slope angles (Prosser and Dietrich 1995). Similar findings of limited overland flow on well-vegetated landscapes have been reported in soils derived from shale.

Gopher *(Thomomys bottae)* disturbance is a dominant process in soil formation in

Figure 9. Well-mixed topsoil.

the Coast Range. Gopher burrowing creates homogenized soils, with thick, well-mixed topsoils (fig. 9) (Yoo and Amundson 2005). Moreover, on steeper slopes, soil mixing by gopher activity brings subsoil material to the surface in the shape of mounds, which are subsequently transported downslope (Black and Montgomery 1991). In soils derived from shale, thickening of the soil profile at down-slope positions has been attributed to shrink-swell processes, soil creep, and bioturbation (McKean et al. 1993).

Lowland Soils

Low-order stream systems have aggrading valleys, typically with deeply incised stream channels, where stream power is not high enough to evacuate valley fill. Progressive headcutting of hillslopes may account for the consumption and breaching of drainage divides, termed stream piracy or stream capture. Stream capture occurs when tectonically induced elongation of a drainage system breaches a divide through headward erosion. The significance of stream piracy is evident in the complexity of lowland soils that are encountered in parts of the Coast Ranges. A sequence of different-aged valley landforms (floodplains and terraces) can be encountered because stream capture is a nonsynchronous process over the evolution of a drainage system. As a result, the degree of soil development across stranded valley landforms versus more contemporary floodplains and terraces can be very different. Older soils found in stranded valleys typically have redder hues and argillic horizons. Younger soils of the main drainage lack Bt horizons and show no evidence of reddening (Munk 1993).

High shrink-swell soils (Vertisols) are also common in lowland positions. The clay minerals that characterize these soils (smectite clays) form in landscape positions where silica and base cation concentrations are high, such as toe slope positions that receive weathering products from upslope positions. Vertisols also commonly form in low-energy depositional environments in valley alluvium.

Extensive Soil Series

Haploxerolls Soil Great Group

Five extensive soil series exist in MLRA 15 at this great group level (Haploxerolls) of Soil Taxonomy:

- Nacimiento
- Santa Lucia
- Linne
- San Benito
- Sheridan

The spatial extent of soil series can be viewed in the “Series Extent Explorer” at the UC Davis California Soil Resource Lab website, http://casoilresource.lawr.ucdavis.edu/see/. Nacimiento, Santa Lucia, and Linne soils all have similar parent material in that they formed from colluvium and residuum. They all weathered from shale and sandstone rock sources and occur in a similar climate. All three of these soils have soil depth that ranges from 51 centimeters to 1 meter deep to the underlying bedrock. All three soils are also in a fine-loamy particle size class. Two of these soil series (Linne and San Benito) have a dark-colored surface horizon (identified in the taxonomic class as a Pachic Epipedon) with more than 1 percent organic matter that extends to at least a depth of more than 50 centimeters. Linne, Nacimiento, and San Benito soil series are further separated by the occurrence of carbonate in the soil profile, which Santa Lucia and Sheridan soil series do not have.

Sheridan soils have granite parent material, which separates them from Santa Lucia soils that formed in hard Monterey shale parent material. Both of these soil series also have a dark-colored surface horizon (identified in the taxonomic class as a *Pachic Epipedon*) with more than 1 percent organic matter that extends to at least a depth of more than 50 centimeters. They are, however, strongly distinguished by their particle size class, with Santa Lucia soils in a clayey-skeletal particle size class and Sheridan soils in a coarse-loamy particle size class. This physical distinguishing characteristic is very significant, since Santa Lucia soils have many more clay and rock fragments (> 2 mm in diameter) than Sheridan soils.

Haploxeralfs Soil Great Group

Vallecitos soils in MLRA 15 are a dominant soil series in the Haploxeralfs soil great group. Vallecitos soils are shallow soils that are only 25 to 51 centimeters deep over hard metamorphosed sandstone and shale parent material. They are in a clayey-skeletal particle size class, which distinguishes them from the Fallbrook soil series, another dominant soil classified in the Haploxeralfs great group that is in a fine-loamy particle size class. Fallbrook soils are moderately deep soils that are 100 to 152 centimeters deep over granitic rock parent material. They are also distinguished from Fallbrook soils by their location in California (Fallbrook soils occur in MLRA 20 primarily but also in MLRA 18).

Haploxerepts Soil Great Group

Millsholm soils in MLRA 15 are an extensive soil series in the Haploxerepts soil great group. Millsholm soils are shallow soils that are only 25 to 51 centimeters deep over hard shale and sandstone parent material. They are in a fine-loamy particle size class that has 18 to 30 percent clay content in the subsoil.

Xerorthents Soil Great Group

There are five extensive soil series in MLRA 15 at this great group level of soil classification that illustrate differences in soil characteristics. Differences in soil characteristics can often be explained in the context of differences in soil formation factors. These five dominant and extensive soil series are

- Cieneba
- Gaviota
- Shedd
- Wisflat
- Arburua

Cieneba soils are one of the most extensive soil series mapped in California. Cieneba soils are mapped predominantly in MLRA 20 and MLRA 15—and, to a lesser extent, in MLRA 18. They have granitic parent material that separates them from the other four dominant soil series in the Xerorthents great group, which formed in material weathered from sandstone or shale. Cieneba soils are very shallow or shallow soils that are less than 51 centimeters deep to granitic parent material. Clay content is less than 18 percent throughout the soil profile. Soil depth and the prevalence of chaparral limit the grazing potential of this extensive soil.

Gaviota soils are mapped predominantly in MLRA 15 and, to a lesser extent, in MLRA 20. They are shallow soils, between 15 and 51 centimeters deep to hard sandstone or meta-sandstone parent material. Wisflat is a similar shallow soil mapped in the same great group that has sandstone and shale parent material. Gaviota soils do not have carbonates, which distinguishes them from Wisflat soils, which have carbonates in most of the soil profile. Wisflat soils are another extensive soil series that are shallow soils (28–51 cm deep) over hard sandstone or shale parent material. These soils are in a loamy particle size class with clay content of 5 to 18 percent.

Shedd and Arburua soils, classified in the Xerorthents great group, are also extensive. Shedd soils are moderately deep soils, between 61 to 100 centimeters deep over shale parent material. Arburua soils are also moderately deep, from 51 to 100 centimeters over sandstone and shale parent material. Shedd soils are in the fine-silty particle size class as opposed to the fine-loamy particle size class for Arburua soils. Soils that are in the fine-silty particle size class usually have a higher available water capacity than those in a fine-loamy particle size class.

Argixerolls Soil Great Group

Los Osos soils in MLRA 15 are an extensive soil series in the Argixerolls soil great group. Los Osos soils are moderately deep soils, 51 centimeters to 1 meter deep over sandstone or shale. They have a significant increase in clay in the subsoil, which averages 35 to 50 percent clay content. Los Gatos soils are another extensive soil series in this soil great group; however, very steep slopes and the prevalence of chaparral limit grazing potential of this soil. Los Gatos soils are moderately deep soils, 61 centimeters to 1 meter deep over hard sandstone. They have a significant increase in clay in the subsoil, which has less than 35 percent clay content.

Haploxererts Soil Great Group

Diablo and Altamont soils in MLRA 15 and, to a much lesser extent, MLRA 20, are extensive soil series in the Haploxererts soil great group. These clay-rich, high shrink-swell soils are often referred to as Vertisols, since they are in the Vertisols soil order in the *Keys to Soil Taxonomy* (Soil Survey Staff 2014). Diablo soils range from deep to very deep (1–2 m) to shale or fine-grained sandstone parent material. Altamont soils are deep (1–1.5 m) to fine-grained sandstone and shale parent material. Ayar soils in MLRA 15 are another soil series that is classified in the Haploxererts soil great group. Ayar soils are deep or very deep (1–2 m) to shale or sandstone parent material. Sehorn soils located primarily on the eastern slopes of the northern Coast Range, north and west of the Sacramento Valley, are an extensive soil series in the Haploxererts soil great group. Sehorn soils are moderately deep (51 cm to 1 m) to shale and fine-grained sandstone parent material. Climara soils are another important niche soil in the MLRA 15 Haploxererts soil great group. Climara soils are moderately deep (51 cm to 1 m) to hard serpentine-related parent material. Landslides and soil creep, as well as high shrink-swell properties of Climara soils, make fencing difficult.

The effects of mineralogy in the Vertisol soil order and Haploxererts soil great group are expressed by large cracks in the soil when dry—and closure of these same cracks when wet. Excessive shrinking and swelling of these soils may force fence posts and even some trees out of the ground. Vertisols in MLRA 15 are often dominated by grass vegetation with some areas of oaks, pines, or junipers cropping up closer to bedrock parent material, where the trees gain a foothold as the roots follow the water in cracks between the rocks.

Palexeralfs Soil Great Group

Pinnacles soils are an example of highly weathered rangeland soils. Pinnacles soils are moderately deep (64 cm to 1 m) to parent material of sandstone or tuffaceous and arkosic consolidated sediments. They have a pronounced clay increase in the subsoil of 15 to 20 percent more clay (absolute) than the A horizon. Clay content in the subsoil averages 35 to 45 percent.

The Corning series is an extensive soil in MLRA 17. Large areas of this soil are used for livestock grazing. This series formed in alluvium weathered from mixed rock sources on high terraces with mound intermound microrelief. These reddish-colored soils have a pronounced clay increase in the subsoil. Clay content in the upper 51 centimeters of the subsoil averages 35 to 55 percent. Content of rock fragments (> 2mm in diameter) may be as high as 50 percent with 0 to 15 percent cobbles. These characteristics make this soil difficult to farm for crops.

Positas soils are moderately extensive soils in the Palexeralfs soil great group that occur in MLRAs 14, 15, 17, 18, and 20. According to the official series description, the primary use of these soils is range. They formed in alluvium weathered from mixed rock sources on stream terraces. These reddish-colored soils have a pronounced clay increase in the subsoil with 20 to 35 percent more total clay than the overlying A horizon, which also has up to 35 percent rock fragments. These characteristics make this soil difficult to farm for crops.

Xerofluvents Soil Great Group

Cortina soils are moderately extensive soils in the Xerofluvents soil great group. They occur in small valleys, alluvial fans, and floodplains in MLRAs 14, 15, and 17. They are formed in very deep gravelly alluvium from mixed rock sources. They are in a loamy-skeletal particle size class and have rock fragment content that averages 35 to 65 percent in all parts of the soil profile. Organic matter decreases irregularly with depth, which indicates the episodic nature of sediment deposition. The low position of Cortina soils in the landscape is ideal for capturing runoff from surrounding hills; however, the high percentage of rock fragments reduces the available water capacity in the soil. Soil in numerous small valleys within areas of hills or mountains in MLRAs 15, 18, and 20 has potential for storage of runoff water from surrounding landscapes. Generally, landforms such as floodplains, stream terraces, and fan remnants that are associated with these valleys produce good forage for livestock grazing. Many areas in these landforms are now used for crops.

Torriorthents Soil Great Group

Delgado soils in MLRA 15 are a good example of Aridic Moisture Regime soils in the Torriorthents soil great group. Delgado soils are shallow (18–51 cm) to hard sandstone or shale parent material. Communications with local ranchers in the Kings County area indicate that some of their highest-producing soils for production of forage for livestock grazing are shallow soils such as Delgado. In these arid areas during somewhat normal rainfall patterns, all precipitation that falls is able to enter the soil with very little loss through the soil profile.

Haplocambids Soil Great Group

Kettleman and Mercey soils in MLRA 15 are good examples of Aridic Moisture Regime soils in the Haplocambids soil great group. They are moderately deep (51 cm to 1 m) to sandstone or shale parent material. Mercey soils are in the fine-silty particle size class, as opposed to the fine-loamy particle size class for Kettleman soils. Soils that are in the fine-silty particle size class usually have a higher available water capacity than those in a fine-loamy particle size class.

Haplargids Soil Great Group

Milham soils in the south part of the San Joaquin Valley (MLRA 17) are an extensive soil in the Haplargids soil great group. Much of this soil is farmed for crops, but the lack of available irrigation water in this arid region has resulted in some areas of this soil still being used for livestock grazing. These soils formed in alluvium from granitic and sedimentary rock on alluvial fans, alluvial plains, low terraces, and fan remnants. The A horizon has clay content of 5 to 20 percent, and there is an increase in clay content to 20 to 35 percent in the subsoil. Gravel content is 0 to 10 percent.

Natrargids Soil Great Group

Polvadero soils on the west side of Fresno County in the San Joaquin Valley (MLRA 17) are moderately extensive soils in the Natrargids soil great group. Much of this soil is farmed for crops, but the lack of available irrigation water in this arid region has resulted in some areas of this soil still being used for livestock grazing. These soils formed in alluvium from calcareous sedimentary rock on fan remnants. The A horizon has clay content of 6 to 18 percent, and there is an increase in clay content to 18 to 30 percent in the subsoil. Gravel content is 0 to 10 percent. The sodium adsorption ratio of the subsoil is 13 to 50. The calcium carbonate equivalent is 5 to 30 percent in the subsoil.

The Sierra Nevada Foothill Region

Geography

Annual rangelands—including annual grasslands, oak woodlands, and chaparral— generally occur along the Sierra Nevada foothills, below 900 meters elevation. MLRA 18 (see fig. 2) and the eastern edge of MLRA 17 (see fig. 3) are within this region. California State Highway 49 traverses the middle third of MLRA 18, and Interstate 80 crosses the midpoint of the region. The communities of Oroville, Auburn, Folsom, Sonora, Mariposa, Coarsegold, and Auberry are in this region.

Geology

The Sierra foothill region (MLRA 18) has a complex assemblage of many different rock types. The northern foothills consist mainly of metavolcanic and volcanic rocks (basalt, greenstone, and andesite). The central foothill region consists of a complex mixture of rock types, including metasedimentary, metavolcanic, sedimentary, volcanic and igneous intrusive, which include schist, slate, phyllite, greenstone, serpentinite, chert, marble, granite, and quartzite. The southern foothill region is largely granitic with some volcanic rocks interspersed. Volcanism was common in the Sierras between 20 and 5 million years ago. Volcanic activity that originated east of what is now the Sierra crest extruded massive basaltic lava flows and andesitic lahars that followed ancient drainage systems all the way to the Sacramento Valley floor. The remnants of these deposits can be seen as table mountains throughout the region. This inverted topography was formed where ancient river valleys were impounded with volcanic rock and the surrounding older terrain was removed by erosion (fig. 10). To a lesser extent, rhyolitic ash and lahars were deposited, particularly in the northern and central Sierra.

Figure 10. Example of a table mountain.

Climate

The average annual precipitation for most of the Sierra foothill region ranges from 45 to 114 centimeters, increasing from south to north and with elevation. Precipitation is as little as 20 centimeters in the southern end of the region. The climate is Mediterranean, with cool, moist winters and hot, dry summers. Mean annual air temperature ranges from 8° to 19°C. The frost-free period is near 275 days per year, ranging from 180 to 365, and it decreases in duration from south to north and with elevation.

Upland Soils

Much of the foothill region (MLRA 18) consists of steep slopes drained by very steep-sided canyons. The granitic foothill landscapes are typically hillier, with rounded hilltops, convex and concave hillslopes, and a network of small, interconnected lowlands.

Soils developed from marble, serpentinite, and metavolcanic rocks display the greatest degree of development in areas where water is not limiting. These soils typically have subsurface clay contents that exceed 30 percent and strong red colors throughout much of the profile. Soils derived from andesitic materials display similar trends. Moreover, soils derived from greenstone often have claypans, horizons that show abrupt clay increase (> 10%) over a short vertical distance (< 2 cm). These horizons create seasonal perched water tables that, in sloping terrain, result in subsurface lateral flow. This flow supplies a significant component of streamflow in ephemeral streams (Swarowsky et al. 2012). Sierra foothill soils derived from metasedimentary and granitic rocks tend to show less evidence of pedogenic transformations. These soils have less red coloration, which suggests lower pedogenic iron content and a release of iron from primary minerals through chemical weathering. Clay contents tend to gradually increase with depth, typically to a maximum of 30 percent. With the exception of soils derived from granite, most foothill soils have considerable rock fragment content, with median values exceeding 20 percent, particularly in the subsoil.

Soil depth is perhaps the most important soil property governing the quantity of water and nutrients in semiarid landscapes. At elevations below 450 meters, weathering is limited by lack of precipitation, and thus soil thickness is generally low. Typically, soils derived from granite are moderately deep, with depths between 50 and 100 centimeters However, soil depth increases dramatically at elevations that exceed 450 meters, where precipitation increases. Soils derived from marble tend to be very deep. Soils derived from metavolcanic and metasedimentary rock are often around 1 meter in thickness. Soils derived from serpentinite and slate are commonly less than 1 meter deep, and in many instances they are shallow (less than 50 cm). Moreover, soils formed from more recent basaltic lava flows are also shallow to bedrock and occupy a microtopographic sequence of mounds and swales on the flow surface, giving rise to vernal pool landscapes (O'Geen et al. 2007).

Extensive Soil Series

This section examines the 11 most extensive soils used for livestock grazing in MLRA 18. They are mapped and classified in five soil great groups. All of them are in the xeric soil moisture regime.

Haploxeralfs Soil Great Group

Auberry soils are the most extensive soil series in MLRA 18. Auberry soils are deep (1–1.5 m) to weathered, intrusive, acid igneous rocks, principally quartz diorite or granodiorite parent material. They have an increase in clay in the subsoil that averages 20 to 30 percent clay content.

Blasingame, Ahwahnee, and Coarsegold soils are all extensive soils in MLRA 18 in the Haploxeralfs soil great group. All three soil series are moderately deep (51 cm to 1 m) to weathered bedrock parent material. Blasingame soils formed in material weathered from basic igneous rocks, while Ahwahnee soils formed in material weathered from granitic rock. Coarsegold soils formed in material weathered from schist. All three soils have an increase in clay in the subsoil; however, Ahwahnee soils have less than 18 percent clay content in the subsoil and are in a coarse-loamy particle size class. Blasingame and Coarsegold soils have reddish brown color in the subsoil and are in a fine-loamy particle size class with loam, clay loam, or sandy clay loam textures in the subsoil.

Xerorthents Soil Great Group

Cieneba soils are one of the most extensive soil series mapped in California. Cieneba soils are mapped predominantly in MLRAs 20 and 15—and, to a lesser extent, in MLRA 18. They formed in material weathered from granitic parent material. Cieneba soils range from shallow to very shallow, less than 51 centimeters deep to weathered granitic parent material. Clay content is less than 18 percent throughout the soil profile. Soil depth and the prevalence of chaparral limit the grazing potential of this extensive soil.

Haploxerepts Soil Great Group

Auburn soils in MLRA 18 are extensive soils that are shallow to moderately deep (25–71 cm) to material weathered from metabasic or metasedimentary rock such as amphibolite schist, greenstone schist, or diabase parent material. Auburn soils have textures of loam, silt loam, or clay loam or gravelly, stony, or very stony equivalents.

Toomes soils are extensive soils in MLRA 18 on plateaus and ridges of volcanic flows and on foothills of volcanic uplands. They are very shallow or shallow (10–51 cm) and formed in material weathered from tuff breccia, basalt, and andesite parent material. Toomes soils have textures of loam, silt loam, or clay loam. Pebble, cobble, and stone content is 10 to 35 percent.

Vista soils are extensive soils that occur in MLRA 18 and also in MLRAs 20 and 15. They are moderately deep (51 cm to 1 m) soils that formed in material weathered from decomposed granitic rock parent material. Textures are coarse sandy loam, sandy loam, or loamy sand.

Argixerolls Soil Great Group

Arujo soils are moderately extensive soils in MLRA 18 in the Argixerolls soil great group. These are deep (1–1.5 m) soils formed in material weathered from metamorphic and igneous (primarily granitic) rock parent material. Organic matter content is more than 1.2 percent to a depth of 51 centimeters or more. The subsoil has loam, clay loam, or sandy clay loam texture that has about 5 to 11 percent more clay content (absolute) than the A horizon.

Haploxerolls Soil Great Group

Pentz soils are extensive soils in MLRA 18 in the Haploxerolls soil great group. They are shallow (25–51 cm) soils formed in material weathered from parent material of weakly consolidated basic andesitic tuffaceous sediments. Organic matter content in the upper 18 centimeters is 1 to 3 percent. They have fine sandy loam, sandy loam, or loam texture with clay content of 8 to 20 percent with gravelly or cobbly equivalents.

Walong soils are extensive soils in MLRA 18 in the Haploxerolls soil great group. They are moderately deep (51 cm to 1 m) soils formed in material weathered from granitic rock parent material. Organic matter content is more than 1 percent to a depth of 36 to 46 centimeters. They have sandy loam, gravelly sandy loam, or coarse sandy loam textures.

Soils on the Web

SoilWeb website (http://casoilresource.lawr.ucdavis.edu/soilweb-apps/**)**

SoilWeb was developed by California Soil Resources Lab in the Department of Air and Water Resources at the University of California, Davis, and it is available on their website. Using mobile or desktop interfaces, users can explore mapped soil survey areas using interactive Google Maps or Google Earth. They can view detailed information about map units and their components. The lab has a variety of apps that allow users to interact with soil surveys in different ways.

USDA NRCS Soils website (http://www.nrcs.usda.gov/wps/portal/nrcs/site/soils/home/)

This website provides access to USDA's Web Soil Survey, Official Soil Series Descriptions, Soil Data Access, Soil Data Viewer, Soil Lab Data, technical resources, and published soil surveys.

SUMMARY

Soil formation results from the action of climate and organisms on parent material. Because of California's complex geology, the number of distinct soils is great and their arrangement complex. The type of soil available on rangeland is important not only for the limits it places on vegetation but also for other ecosystem services such as clean water.

Soil is the medium that supports rangeland vegetation and moderates the effects and fate of precipitation. While rainfall varies with longitude and elevation, it influences vegetation structure (trees, shrubs, and herbaceous layers), species composition, and productivity. Soil depth, texture, and water-holding capacity strongly influence the length of the growing season, when adequate soil moisture is available. Influencing plant productivity and water quality, nutrient cycling is strongly influenced by parent material and organisms (vegetation and soil biota).

Soil also limits the type of management that can be applied to a particular site. By classifying soils and land types, rangeland managers are able to develop management objectives that are within the capabilities of the land being managed. Recognizing soil and site differences during conservation planning encourages selection of practices that can effectively support management objectives. Thus, it is crucial that scientists and managers continue to learn about soils and improve the management of the soil component of ecological sites.

REFERENCES

Beaudette, D., and A. T. O'Geen. 2008. Quantifying the aspect effect: An application of solar radiation modeling for soil survey. Soil Science Society of America Journal 73:1345–1352.

Black, T. A., and D. R. Montgomery. 1991. Sediment transport by burrowing mammals, Marin County, California. Earth Surface Processes and Landforms 16:163–172.

Dietrich, W. E., and R. Dorn. 1984. Significance of thick deposits of colluvium on hillslopes: A case study involving the use of pollen analysis in the coastal mountains of northern California. Journal of Geology 92:147–158.

Gessler, P. E., O. A. Chadwick, F. Chamran, L. Althouse, and K. Holmes. 2000. Modeling soil-landscape and ecosystem properties using terrain attributes. Soil Science Society of America Journal 64:2046–2056.

Gonzalez, J. M., and D. A. Laird. 2003. Carbon sequestration in clay mineral fractions from 14C-labeled plant residues. Soil Science Society of America Journal 67:1715–1720.

Harden, D. R. 2004. California geology. Saddle River, New Jersey: Pearson/Prentice Hall.

Jenny, H. 1941. Factors of soil formation. NY, NY: McGraw-Hill Book Company.

McKean, J. A., W. E. Dietrich, R. C. Finkel, J. R. Southon, and M. W. Caffee. 1993. Quantification of soil production and downslope creep rates from cosmogenic 10Be accumulations on a hillslope profile. Geology 21:343–346.

Munk, L. P. 1993. Stratigraphy, geomorphology, soils and neotectonic interpretation of the Dunnigan Hills, California. Ph.D. dissertation, University of California, Davis.

Norton, J. B., L. J. Jungst, U. Norton, H. R Olsen, K. W. Tate, and W. R. Horwath. 2011. Soil carbon and nitrogen storage in upper montane riparian meadows. Ecosystems 14:1217–1231.

O'Geen , A. T., W. A. Hobson, R. A. Dahlgren, and D. B. Kelley. 2007. Soil properties and horizon stratigraphy in vernal pool landscapes of northern California. Soil Science Society of America Journal 72:727–740.

O'Geen, A. T., R. A. Dahlgren, and D. Sanchez-Mata. 2008. California soils and examples of ultramafic vegetation. In M. G. Barbour, T. Keller-Wolf, and A. A. Schoenherr, eds., Terrestrial vegetation of California. 3rd ed. Berkeley: University of California Press. 71–106.

Prosser, I. P., and W. E. Dietrich. 1995. Field experiments on erosion by overland flow and their implication for a digital terrain model of channel initiation. Water Resources Research 31:2867–2876.

Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd ed. Washington, DC: Natural Resources Conservation Service. U.S. Department of Agriculture Handbook 436.

Soil Survey Staff. 2014. Keys to soil taxonomy, 12th ed. USDA-Natural Resources Conservation Service, Washington, DC.

Soil Survey Staff. 2015. Illustrated guide to Soil Taxonomy, version 2. Lincoln, NE: U. S. Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center.

Swarowsky, A., R. A. Dahlgren, and A. T. O'Geen. 2012. Linking subsurface lateral flowpath activity with stream flow characteristics in a semiarid headwater catchment. Soil Science Society of America Journal 76:532–547.

Tanji, K., A. Lauchli, and J. Meyer. 1986. Selenium in the San Joaquin Valley. Environment 28:6–39.

USDA NRCS (U.S. Department of Agriculture, Natural Resources Conservation Service). 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. Washington, DC: U. S. Department of Agriculture Handbook 296. USDA NRCS website, http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/home/?cid=nrcs142p2_053624.

Yoo, K., and R. Amundson. 2005. Erosion of upland hillslope soil organic carbon: Coupling field measurements with a sediment transport model. Global Biogeochemical Cycles 19(3): 1–17.

FOR FURTHER INFORMATION

To order or obtain ANR publications and other products, visit the ANR Communication Services online catalog at http://anrcatalog.ucanr.edu/ or phone 1-800-994-8849. You can also place orders by mail or FAX, or request a printed catalog of our products from

University of California
Agriculture and Natural Resources
Communication Services
2801 Second Street
Davis, CA 95618

Telephone 1-800-994-8849
E-mail: anrcatalog@ucanr.edu

Publication 8542

ISBN-13: 978-1-60107-939-8

The University of California, Division of Agriculture and Natural Resources (UC ANR) prohibits discrimination against or harassment of any person in any of its programs or activities on the basis of race, color, national origin, religion, sex, gender, gender expression, gender identity, pregnancy (which includes pregnancy, childbirth, and medical conditions related to pregnancy or childbirth), physical or mental disability, medical condition (cancer-related or genetic characteristics), genetic information (including family medical history), ancestry, marital status, age, sexual orientation, citizenship, status as a protected veteran or service in the uniformed services (as defined by the Uniformed Services Employment and Reemployment Rights Act of 1994 [USERRA]), as well as state military and naval service.

UC ANR policy prohibits retaliation against any employee or person in any of its programs or activities for bringing a complaint of discrimination or harassment. UC ANR policy also prohibits retaliation against a person who assists someone with a complaint of discrimination or harassment, or participates in any manner in an investigation or resolution of a complaint of discrimination or harassment. Retaliation includes threats, intimidation, reprisals, and/or adverse actions related to any of its programs or activities.

UC ANR is an Equal Opportunity/Affirmative Action Employer. All qualified applicants will receive consideration for employment and/or participation in any of its programs or activities without regard to race, color, religion, sex, national origin, disability, age or protected veteran status.

University policy is intended to be consistent with the provisions of applicable State and Federal laws.

Inquiries regarding the University's equal employment opportunity policies may be directed to: Affirmative Action Contact and Title IX Officer, University of California, Agriculture and Natural Resources, 2801 Second Street, Davis, CA 95618, (530) 750-1397. Email: titleixdiscrimination@ucanr.edu. Website: http://ucanr.edu/sites/anrstaff/Diversity/Affirmative_Action/.

An electronic copy of this publication can be found at the ANR Communication Services catalog website, http://anrcatalog.ucanr.edu/.

UC PEER REVIEWED

This publication has been anonymously peer reviewed for technical accuracy by University of California scientists and other qualified professionals. This review process was managed by ANR Associate Editor for Land, Air, and Water Sciences Allan Fulton.

web-12/20-LR/SO