Chapter 2: Sustainable Rangelands



Arroyo Seco Grant Ranch, Amador County. Photo provided by Larry Costick, USFS (retired).

INDICATORS

- ⓘ 2.1 Rangeland Conversion
- ⓘ 2.2 Beef Cattle Farms by Size Class
- ⓘ 2.3 Federal Grazing Allotments

INTRODUCTION

California's rangelands are vast, originally spanning nearly 68 million acres of oak woodlands and oak savannas, shrubland, open annual grasslands and native grass/forblands, wetlands, and deserts, and covering a region larger than the entire state of Colorado (Figure 2.1). Among the globe's most biologically diverse temperate ecosystems, the concentration of native—and particularly endemic—species harbored in state rangelands is unparalleled in the U.S. These landscapes provide a suite of important ecosystem services that include wildlife habitat, water filtration and storage, open space, recreation, and carbon storage. Rangelands also produce forage for grazing by domestic livestock, which can be an important component of rural economies. Here, rangelands are defined not by land use but by vegetation cover type (see Executive Summary).

Since European colonization, the majority of conversions to development and to intensive agriculture in California have been from rangelands. As California has grown to nearly 40 million inhabitants, the development pressure on these lands for the past 175 years has been severe: over 10 million acres of former rangelands have been converted to agriculture or development. While protective laws and conservation programs have slowed the pace of development and helped maintain the ranching industry in recent decades, development and conversion threats to these lands persist today.

Climate change and invasive species pose additional threats to rangelands. State policies and programs have been responsive to the threat of climate change and include the establishment of nature-based solutions climate targets (CNRA 2024). Invasive species, particularly non-native annual grasses, began to take a foothold in many of California's rangelands with the arrival of Europeans and their livestock, and continue to threaten biodiversity, wildlife habitat, and natural fire regimes.

Despite these threats, rangelands remain the most common natural landcover type in California, although much reduced today at about 57.5 million acres (or about 57% of the state). Grasslands, deserts, and shrublands comprise most of the remaining rangelands, but rangeland also includes several types of woodland vegetation. Nearly all naturally vegetated landcover types that are not forested (i.e., those with ≤10% tree canopy cover) in the state are classed here as rangeland. And even today, California rangelands still cover more land than the total area of all but 12 other U.S. states.

SUMMARY

The indicators covered in this chapter provide a mixed picture of the status of rangeland sustainability in California. Conversion of rangeland vegetation types to developed uses is still occurring, but at a relatively low average annual rate for more than a decade (ⓘ2.1). The economic and social sustainability of ranching operations, which is important for deterring such conversion where development pressure is high, continues to decline, as evidenced by the number of beef cattle farms in all size classes decreasing over the past decade (ⓘ2.2). Federal grazing allotments can enhance the economic viability of some private grazing operations that also operate on private lands, and the total Animal Unit Months (AUMs) permitted for these allotments remains steady to slightly declining (ⓘ2.3). Grazing permits are also important on non-federal public lands.

Several additional economic, social, and management challenges on rangelands are addressed in detail in this chapter. Population and demographic shifts, societal perceptions of grazing, a challenging economic and regulatory environment for livestock producers, changing land ownership and estate planning hurdles, and international markets for beef all influence the viability of rangelands as sustainable working landscapes.

Major biophysical challenges to the sustainability of California's rangeland vegetation include climate change and extended drought events, invasive species, and wildfire. All three of these impacts interact on rangelands in ways that often exacerbate threats to native vegetation. The widespread presence of non-native annual grasses is driving ecosystem type conversion within oak woodlands, deserts, chaparral, and formerly native grass/forblands. These grasses provide more continuous and highly flammable fuels, which alter fire regimes and, in some areas, can lead to a grass-fire cycle that inhibits native vegetation dominance. Climate change can influence this process in several ways, such as by changing the length or timing of the dry season, increasing precipitation variability, and intensifying drought.

Other concerns on California's rangelands relate to water quality, oak regeneration, and rare plant and animal species and their habitats. Water quality on rangelands is impacted by grazing, wildfire, roads, and development. Grazing impacts to water quality can include soil erosion, soil compaction, loss of streambank stability, degraded water quality, and lowered habitat quality. Improved range management practices, including controlling livestock access, densities, and seasonality, can mitigate many of these impacts. Inadequate rates of oak regeneration can be caused by a multitude of factors, including overgrazing and competition from non-native annual grasses, but successful planting methods have been developed for many oak species. Rare species of rangeland vegetation types face similar threats as native species statewide, such as habitat conversion and degradation, competition from invasive species, and ongoing changes to climate and disturbance regimes. Additionally, inappropriate grazing practices may present a threat to wildlife habitat.

In the face of a multitude of challenges to rangeland vegetation types and the important biodiversity and ecosystem services provided by them, opportunities exist for enhancing rangeland sustainability, including through existing state, local government, and nonprofit organization programs. For example, throughout the state, public agencies are using grazing to manage vegetation and meet resource management objectives including watershed management, fire fuels reduction, and wildlife habitat management. Grazing leases are often used on rangeland acquired by non-profit organizations and public agencies for conservation (S. Barry, personal communication, June 7, 2025). Funding could be increased to agencies and organizations that purchase conservation easements. To enhance the economic viability of livestock operations, livestock operators could be paid for ecological services rendered, such as managing invasive non-native species in favor of native vegetation, and economic support could be provided for grazing infrastructure that supports conservation goals, such as fencing, watering infrastructure/stock ponds, and wetland protection measures.

A major opportunity for enhancing rangeland sustainability exists on recently fallowed farmlands in the San Joaquin Valley, which could benefit from funding to restore native vegetation and sustainable hydrological processes. Additionally, opportunities exist for the increased use of targeted grazing to manage invasive species and for fuels management to reduce risk of catastrophic wildfire.

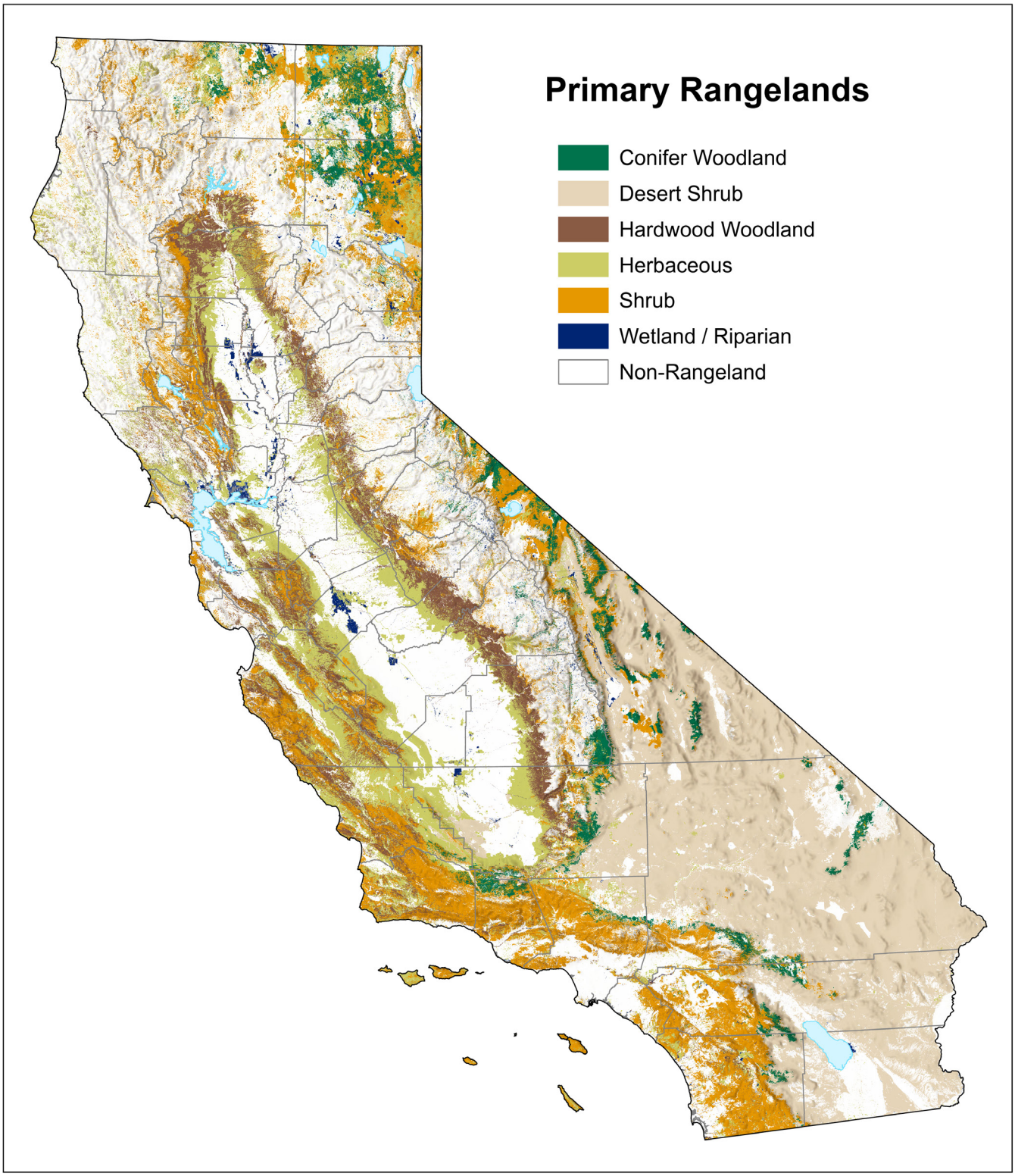


Figure 2.1. Distribution of rangeland major vegetation types in California. Data Source: CAL FIRE (2022).

Indicator 2.1: Rangeland Conversion

Which Sustainable Rangelands Roundtable (SRR) Criteria does the indicator evaluate?

SRR Criterion II: Indicators for conservation and maintenance of plant and animal resources on rangelands (same as Montreal Process Criterion 1, but for rangelands).

SRR Criterion III: Maintenance of rangeland productive capacity (same as Montreal Process Criterion 2, but for rangelands).

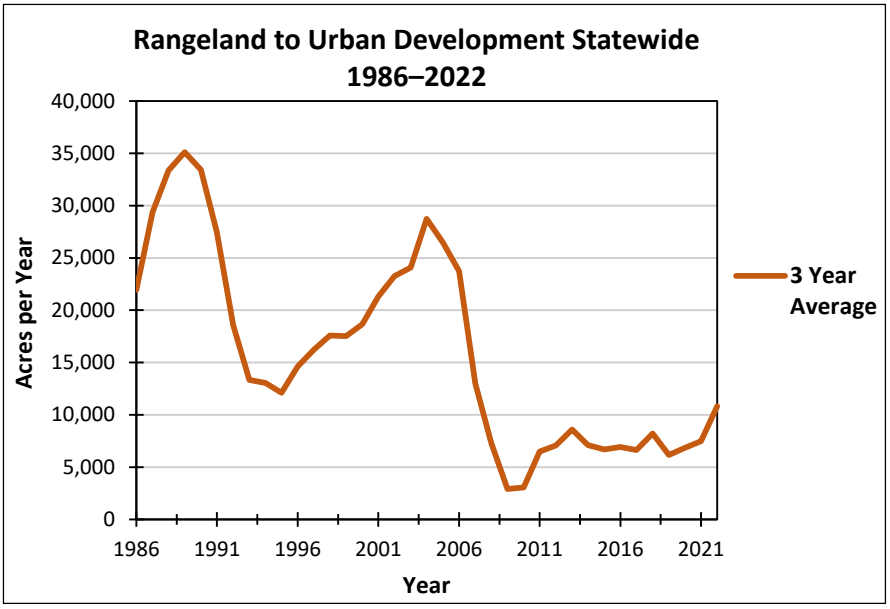
Why is this indicator important?

Reduction in total rangeland due to conversion to other land uses can reduce ecosystem services (such as wildlife habitat, water quality, and recreation) and the availability of forage for wildlife and grazing livestock.

What does the indicator show?

The three-year rolling average number of rangeland acres annually converted to urban development from 1986 to 2022.

Key Findings:



- After a steep decline in annual rangeland conversion to development during the recession of 2007–2009, the number of rangeland acres converted has held relatively steady at around 7,500 acres per year. The last few years have seen a slight uptick in rangeland development to above 10,000 acres per year.
- Two regions—the Inland Empire (mostly Riverside County) and the southern San Joaquin Valley—dominated the new developments on rangeland. Trends in other regions of the state have been close to flat.
- Recent state-level legislation encouraging urban and suburban infill housing has spurred the highest level of new housing starts in 2022 since the housing crash of 2008. This, along with slowed overall statewide population growth and the high cost of development, has helped to reduce development pressure on rangelands.
- The conversion of approximately 10,000 acres in 2022 represents a 0.02% loss of state rangelands. While small, local impacts and cumulative resource impacts over time can be considerable.

Data Sources

United States Geological Survey, National Land Cover Database (USGS 2024).

Indicator 2.2: Beef Cattle Farms by Size Class

Which Sustainable Rangelands Roundtable (SRR) Criterion does the indicator evaluate?

SRR Criterion IV: Social and economic indicators of rangeland sustainability (similar to Montreal Process Criterion 6).

Why is this indicator important?

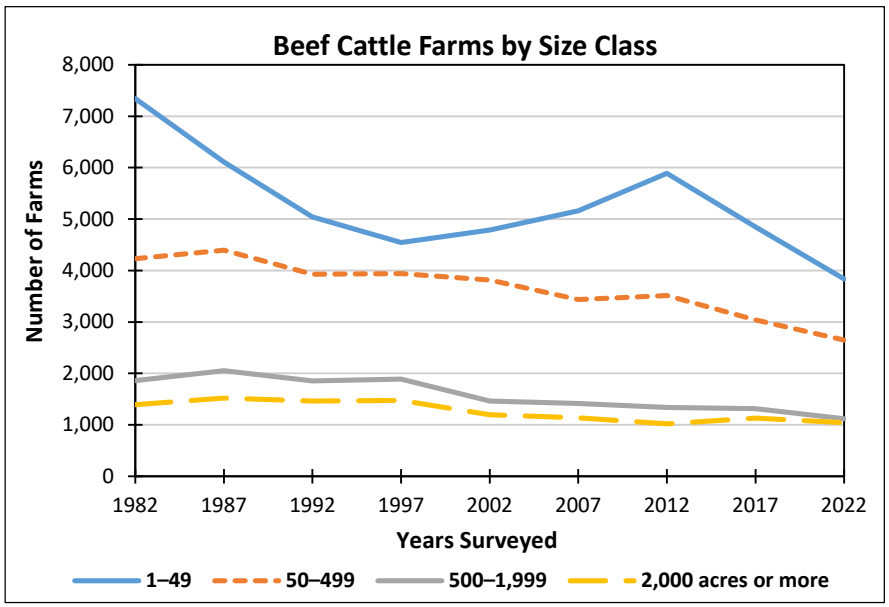
Larger cattle farms tend to have less human disturbance, provide a higher level of ecosystem services, and are prime candidates for maintaining the working landscape through conservation easements or other mechanisms.

What does the indicator show?

The number of beef cattle farms by four size classes from 1982 to 2022.

Key Findings:

- The data show a steep decline (-33%) since 2012 in the two smaller-acreage beef farm classes (<500 acres) in the state. This trend indicates that smaller cattle operations have been shutting down recently in significant numbers.
- The trend shows a slower decline in the number of beef farms in the middle size class for the past two decades. The largest size class has been relatively stable for the past decade after declining during the two decades prior.



- The stability in the largest size ownership class is a positive factor as these ownerships may be the best candidates for protective measures such as conservation easements, which can take significant effort to put into effect.

Data Sources

United States Department of Agriculture, National Agricultural Statistics Service, Census of Agriculture (USDA 2022).

Indicator 2.3: Federal Grazing Allotments

Which Sustainable Rangelands Roundtable (SRR) Criterion does the indicator evaluate?

SSR Criterion III: Maintenance of rangeland productive capacity (similar to Montreal Process Criterion 2).

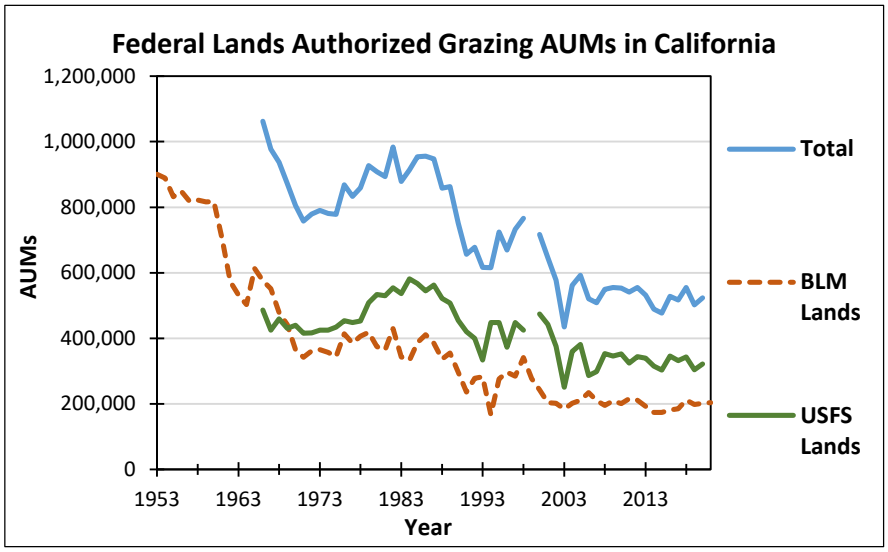
Why is this indicator important?

Public land grazing allotments are important for keeping some private ranches economically viable, particularly in the regions of northeastern California and the eastern Sierra Nevada. These ranches can play an important role in local rural economies. Further, in areas where there are development pressures, economically viable ranching helps keep the private ranches from being converted to more intensive land uses, thereby maintaining their ecosystem services.

What does the indicator show?

The number of federal grazing Animal Unit Months (AUMs) in California from 1966 to 2022.

Key Findings:



- Since about 2000, the total number of AUMs authorized by the U.S. Department of Agriculture Forest Service (USFS) and the Bureau of Land Management (BLM) on federal lands in California has averaged around 575,000. This is a decline from a peak of above 1,000,000 AUMs in the 1960s, caused in part by reassessments of livestock carrying capacity of many allotments, as mandated by the National Environmental Policy Act (NEPA), to help manage for more sustainable grazing.

- The USFS overall has fewer acres of allotments than the BLM in the state; however, the forage productivity of USFS lands tends to be higher per acre than for the BLM lands. Where other factors are equal (e.g., move-in/move-out costs, needed improvements, water availability), ranchers typically prefer higher productivity allotments.

- Most remaining desert grazing allotments are being systematically retired to ensure adequate forage for native bighorn sheep and to provide habitat protection for other desert species.

Data Sources

Bureau of Land Management, Public Land Statistics (BLM 2025).
USDA Forest Service, Grazing Statistical Summary Reports (USDA 2025).
High Country News (Wiles and Warren 2016).

DISCUSSION

Historical Background

California has a rich and varied history, and changes in rangelands reflect and have been influenced by much of that history over the past two centuries. From the genocide of the native peoples in the 18th and 19th centuries, to permanent ecological and land use changes implemented by European-American colonists, to the threats from climatic changes, tremendous changes have taken place—the effects of which continue today.

At the time of the first colonization by Europeans, about two-thirds of what is now the state of California was rangeland (Kuechler 1977). Prairies, grasslands, deserts, shrublands, wetlands, and various woodlands covered about 67.6 million acres—larger than the total area within each of 43 other U.S. states. In the non-desert rangelands, the abundance of water, wildlife, and food resources at that time sustained a large and diverse population of Indigenous people.

Beginning in the post-colonial era, important and permanent changes began to occur across these lands. Colonists systematically eliminated the Native inhabiting people from their homes. A huge number died from imported diseases, were killed, or were enslaved in the system of missions. The earliest colonists brought cattle, which rapidly became feral with huge populations. They also brought foreign annual plants that soon created different ecosystems on the prairies and grasslands throughout the lower and more coastal valleys. The elimination of Indigenous use of fire as a management tool also allowed encroachment of woody species into many landscapes previously maintained in earlier seral stages of vegetation (Greenler et al. 2024, Keeley 2002, Timbrook et al. 1982).

Extensive grasslands of California historically have produced more livestock forage per acre than other natural ecosystems west of the Midwestern tallgrass prairies. Beginning in the early 19th century, rangelands were the primary land base on which missions, towns and cities, and cultivated farmlands were developed. Soon after the Gold Rush of 1849, with the arrival en masse of new American colonists, large areas of natural rangelands became converted to dry farms, were grazed by domestic livestock, or converted from extensive wetlands for irrigated crops (Olmstead et al. 2003). Water from snow-fed mountain streams was increasingly diverted into hundreds of miles of constructed canals and ditches. Once-abundant wildlife was greatly reduced through loss of habitat and commercial hunting to feed the large numbers of incoming miners, as well as for export of animal parts globally, while the nascent modern cities and towns began to grow.

Since the Gold Rush, about 68% of modern commercial/residential and intensive agricultural development in California has occurred on what were formerly rangeland vegetation types. On the non-desert and non-shrubland natural rangelands that remain, livestock grazing has continued as the major commercial use, particularly in the now-altered prairies, grasslands, and oak woodlands of the valleys and lower elevations. To many Californians living outside of urbanized areas, rangelands have provided a place to live and, with livestock grazing and other less prevalent economic uses, the means for making a living off the land.

Current Status of the Resource Base

Ecological Importance

Rangelands in California encompass an incredibly diverse array of ecosystem types and thus provide a wide variety of important ecological benefits and ecosystem services, such as wildlife habitat, water quality and soil stability, open space, recreation, cultural value, pollination of agricultural crops, forage production for livestock, and carbon storage and sequestration (CDFW 2015, Chaplin-Kramer et al. 2016, CRCC 2025). Many of these benefits and services are discussed in detail in other Assessment chapters.[1]

1 *See Chapter 7 (Climate Change) for opportunities that promote carbon storage on rangelands. Water quality and wildlife habitat related to rangelands are addressed in Chapters 9 (Water Resources) and 10 (Wildlife Habitat), respectively.*

California's rangelands contribute to biodiversity by providing habitat for numerous species as well as critical habitat connectivity (Cameron et al. 2014). The California Floristic Province, covering 70% of the state and encompassing the portion of the state with a Mediterranean-type climate and including both forest and rangeland vegetation, is considered a global biodiversity hotspot due to high species endemism and a high level of threat from habitat loss (Myers et al. 2000). Ecoregions with significant rangeland areas within this Province include the Central Valley, Central Coast, and South Coast. Further, California comprises 3% of the land area of the U.S. but is home to >30% of its plant and vertebrate species (Tershy et al. 2016). It is also the U.S. state with the second highest percentage of threatened species (31%), due primarily to habitat loss and invasive species (Tershy et al. 2016).

Economic Uses

The economic sustainability of California's private rangelands affects their ecological sustainability. Although most rangeland economic uses can have both positive and negative ecological consequences, when privately owned rangelands cease to be economically sustainable, they may be at risk of conversion to more profitable uses such as intensified agriculture or housing development (Roche et al. 2021).

California's rangelands serve as a robust economic resource with various uses. The annual grassland and hardwood woodland types are primarily used for livestock grazing, contributing significantly to livestock production (Biggs 2022). They also provide opportunities for diversified businesses beyond ranching, including hunting clubs, vacation rentals, and wedding venues (Biggs 2022). The California Department of Fish and Wildlife (CDFW) Private Lands Management Program offers economic incentives to ranchers for managing their lands to improve wildlife habitat. Oil and gas development and mineral extraction can also be important sources of diversified income in some rangeland areas (e.g., BLM lands in the San Joaquin Valley), along with solar and wind farms (see Chapter 12, Renewable Energy, and Chapter 10, Wildlife Habitat). Solar farm development has taken off on rangelands in the past decade, reaching close to 80,000 acres by 2023 (Figure 2.2), driven in part by the state's initiative to increase its renewable energy portfolio. While such infrastructure could be considered conversion to development, in cases where it is small scale or interspersed in a matrix of natural vegetation, it may be considered an economic use of rangelands (albeit with disturbance impacts) where livestock still can graze under solar panels (Brazil 2020). Tourism and outdoor recreation are income sources in and around publicly accessible rangelands of all vegetation types. The diverse economic applications of California's rangelands underscore their role in the state's economy.

In past decades, portions of private rangelands were sold and converted to developmental use at high rates, but this has slowed in the last 10 years (see Chapter 6, Population Growth and Development). Further, due to Sustainable Groundwater Management Act (SGMA) compliance, repurposing or reclamation of intensively cultivated agricultural lands in the San Joaquin Valley may result in the significant addition of rangelands in coming decades, as an estimated 500,000 to 900,000 acres may need to be fallowed (Hanak et al. 2023). Converting fallowed farmland back to rangeland may involve removing planted orchard trees and using management practices like seeding with appropriate species, including nitrogen-fixing plants, deep-rooted perennials, and annuals that are adapted to the area (Peterson 2022).

On private rangelands utilized for grazing, conservation easements are another growing source of diversified income for ranchers and serve to limit urban development and preserve open space and wildlife habitat. The trend of "amenity" ranching, or rural gentrification, is also increasing, with landowners seeking more than just property income and appreciating non-monetary benefits such as viewshed and cultural values. These rangeland landowners may pay ranch managers or lease their lands for grazing (Biggs 2022). Organically raised and/or grass-fed beef cattle are also diversified sources of income for ranchers.

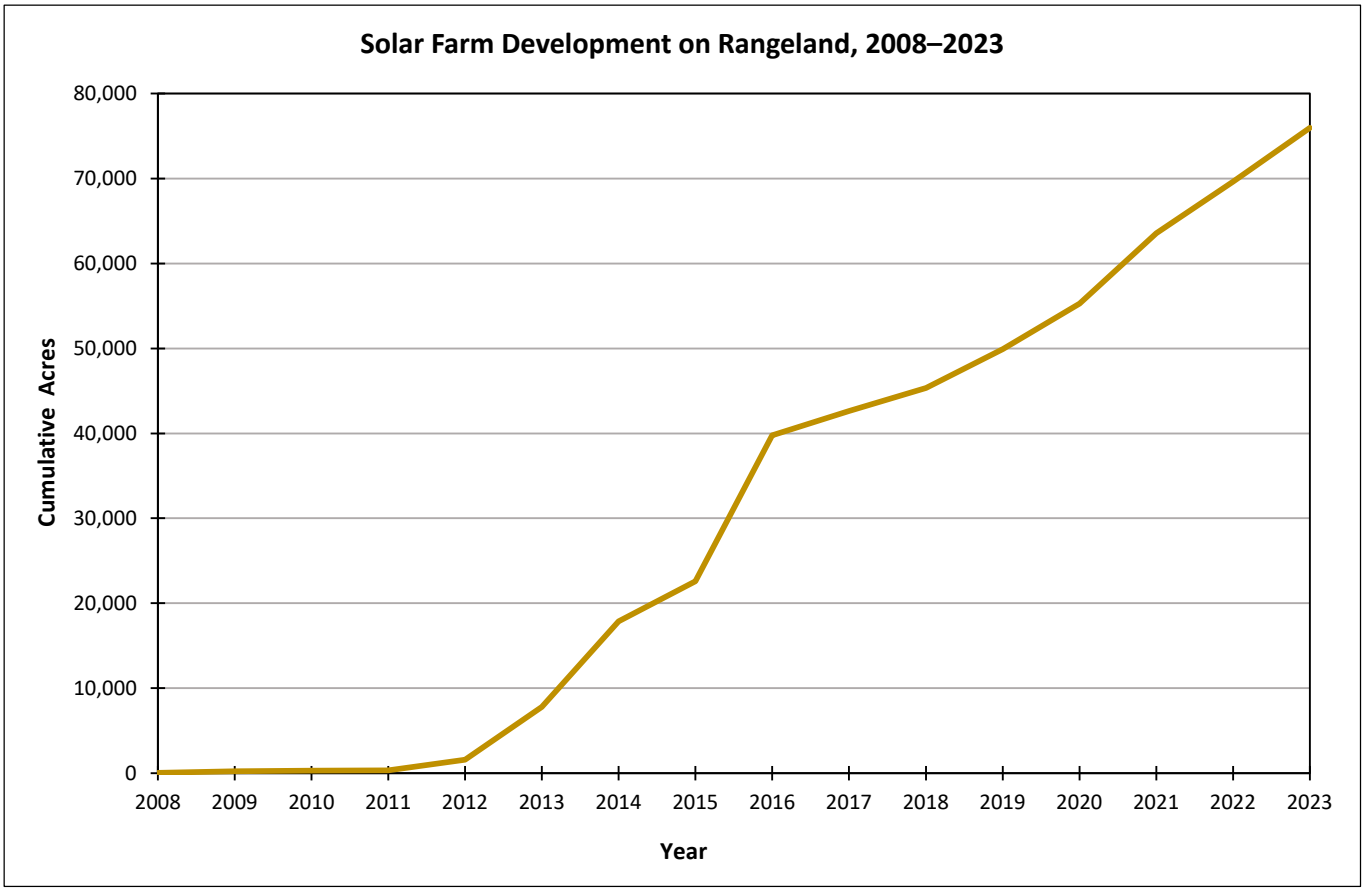


Figure 2.2. Growth of solar farms on California rangeland since 2008. Some traditional uses of rangeland, such as sheep grazing and some wildlife habitat, can be retained under and around these solar panel arrays. Data Source: CEC (2024).

Rangeland Public and Private Ownership and Productivity by Vegetation Type

Rangelands in California are unequally distributed between public and private lands among the different vegetation types. The most productive lands for grazing, the herbaceous-dominated annual grasslands and hardwood woodlands (e.g., Figure 2.3), are held primarily in private hands (Tables 2.1 and 2.2). Nearly two-thirds of all livestock grazing capacity statewide is produced in these vegetation types. Due to their relative accessibility and value to livestock, European colonization of these low-elevation lands near the coast began during the Franciscan mission era. In more interior regions of the Central Valley, they were colonized by Euro-Americans who came en masse during the Gold Rush with their herds of cattle and sheep. Currently, more than three-fourths of all annual grasslands and hardwood woodlands in the state are in private ranches, with the remaining one-fourth managed primarily by the federal BLM.[2]

In comparison to annual grasslands and hardwood woodlands, other rangeland vegetation types (Figure 2.1, listed in Table 2.1) offer fewer direct economic benefits to landowners. Desert shrublands and desert woodlands comprise about 48% of non-grassland rangeland vegetation area, and while providing some forage for livestock, they tend to be so sparse that grazing is uneconomical. Nonetheless, historically grazing occurred widely across these landscapes, primarily because they had so little value for other economic

2 *Non-federal publicly owned rangelands (e.g., state lands, water districts, municipalities, open space districts) and non-profit organization owned rangelands (e.g., The Nature Conservancy, Audubon Society, Save Mount Diablo, Wildland Conservancy, Pepperwood Foundation, Sonoma Land Trust) are also present in California.*

uses. In recent decades, grazing as a management tool has been largely abandoned in desert regions, due to adverse ecological impacts to these fragile ecosystems. The retirement of (usually sheep-grazed) desert federal BLM grazing allotments is progressing steadily. Desert shrublands and woodlands, which are overwhelmingly held in public ownership, provide important recreational opportunities and bring economic benefits to the private sector via tourism.

Conifer woodlands (largely pinyon pine and juniper dominated), shrublands (primarily chaparral of various types), and wetland riparian vegetation types comprise the remaining balance of California rangelands. Grazing is common in the Great Basin region of California and is regionally important to its economy. But these lands in the colder east side of the Sierra Nevada mountains, predominantly held by public agencies, are not nearly as productive as those to the west.

Trends in Ranch Size

The size of beef cattle farms has been changing in California over the past four decades due to several factors, including past droughts, high operating costs, and climate change (ⓘ2.2). Large ranches are generally considered to have higher habitat value and levels of ecosystem services, and the ranchers tend to be committed to ranching as a long-term objective (Ferranto et al. 2011, Ferranto et al. 2014). As a result, they often provide the best opportunity to maintain working ranches and their associated ecosystem and economic values. The number of beef cattle farms over 2,000 acres, however, has declined from a peak of 1,521 in 1987 to a low of 1,020 in 2012. Their numbers then rose slightly to 1,130 in 2017 before falling back to 1,042 in 2022. Overall, the number of large ranches has remained relatively constant over the past decade. Small beef cattle farms less than 50 acres numbered 5,893 in 2012 and were reduced to 3,836 in 2022, a decline of 35%. There has also been a steady decline in the number of beef cattle farms in the 50–499 acre category. Together, these two smallest size classes have seen a 33% decrease since 2012, likely due to the difficulty of operating a small-scale cattle business. The majority of new ranchers are managing sheep (53%), with fewer than half



Figure 2.3. Eastern San Luis Obispo County rangelands with California goldfields, a native annual. Photo: CAL FIRE.

Table 2.1. Estimated mean annual forage production by rangeland major vegetation type

Major Vegetation Type	Grazing Capacity (AUMs/acre)	Area (million acres)	Total AUMs (millions)
Conifer Woodland	0.2	3.1	0.6
Hardwood Woodland	0.7	6.2	4.3
Shrub	0.3	13.3	4
Herbaceous	0.7	11.5	8.1
Desert	<0.1	22.6	2.3
Wetland/Riparian	1.8	0.9	1.6
Total	**3.8**	**57.5**	**20.9**

Data Sources: CAL FIRE (2022), FRAP (2003).

Table 2.2. Rangeland major vegetation types in public and private ownership (thousand acres)

Major Vegetation Type	Private Ownership	Public Ownership	Total
Conifer Woodland	579	2,479	3,058
Hardwood Woodland	4,907	1,291	6,198
Shrub	4,123	9,192	13,315
Herbaceous	8,680	2,859	11,539
Desert Shrubland	2,980	18,500	21,480
Desert Woodland	207	872	1,079
Wetland/ Riparian	429	447	875
Total	**21,905**	**35,640**	**57,545**

Data Sources: CAL FIRE (2022, 2024).

raising beef cattle. The average new rancher raises two types of livestock, and one-third of them also produce crops, illustrating that diversification is a key economic strategy (Munden-Dixon and Roche 2020).

Challenges

Social Context

Rangeland vegetation types in California are comprised of both private (38%) and public (62%) ownership (Table 2.2).[3] Public rangelands are primarily administered by the BLM and the USFS. The most recent available figures show that BLM has about 6.1 million acres of rangeland in California grazing allotments (USDI 2017) while the USFS has about 7.6 million acres (USDA 2014). Historically, nearly all private rangelands have been managed as "working landscapes"—i.e., expanses of land that are not in reserved status but are utilized for economic purposes including the grazing of livestock, and limited harvesting of hardwoods for fuel and other uses. Maintaining these working landscapes in a sustainable manner can be key to their long-term preservation. A primary objective for sustaining working rangelands is to help enable ranch owners to remain in the commercial livestock business. As land ownership changes to public agencies or amenity landowners, grazing is often reduced or removed (S. Barry, personal communication, June 7, 2025).

There are several challenges to maintaining the economic viability of ranching businesses. Hence, most family-owned livestock operations receive supplementary income from non-ranching endeavors on their rangelands and/or from one or more family members being employed outside of the ranching business, a trend that goes back to at least the mid-20th century (Biggs 2022, Roche 2021). Transfer of the family ranching business from one (usually aging) generation to the next can be fraught for a variety of reasons, making the persistence of such businesses precarious due to decreasing workforce and interest in continuing the family business. This also increases the likelihood of land sale and conversion in areas where development pressure is high. Financial factors like accessibility of grazing allotments, state and federal tax codes, land use planning, and incentive programs like conservation easements influence land ownership changes (Brunson and Huntsinger 2008, Haggerty et al. 2018). In some cases, children do not want to take over the family ranch (Brunson and Huntsinger 2008). Further, estate and inheritance taxes could inhibit intergenerational transfer of ranches (Biggs 2022, Liffmann et al. 2000, Nolte 2021, Patterson 2021), although California imposes estate taxes and federal taxes for a married couple transferring ownership only to the value above $30 million in 2026. Conservation easements can be a tool to reduce property value and hence estate taxes at the time of intergenerational property transfer, while they also provide landowners with payments (if the easement is sold) or tax deductions (if the easement is donated to a qualified entity) at the time of easement establishment.

Population and Demographic Shifts

Political, social, and economic factors influence state and regional population trends and may drive residents away from rural areas; for example, government regulations, such as water quality regulations, have been cited as deterrents to ranching (Hurst et al. 2017). Population trends of rangeland-dominated counties are subject to the opposing forces of emigration due to declining economic opportunities for rural residents versus migration of people from urban areas for retirement, quality of life, affordability, or due to increased remote work opportunities.

3 *Rangeland ownership includes public land managers such as the U.S. Fish and Wildlife Service (USFWS); U.S. National Park Service; U.S. Department of Defense; municipalities; water districts; park districts; open space districts; state agencies including the Department of Water Resources (CDWR), California State Parks, California State Lands Commission, and California Department of Fish and Wildlife (CDFW); the Metropolitan Water District of Southern California (MWD); Los Angeles Department of Water and Power (LADWP); and private entities including utility and timber companies. Although the acreage of non-federal public land is small compared to the BLM and USFS, these lands include some of the most productive rangelands in the state and support significant numbers of AUMs (S. Barry, personal communication, June 7, 2025).*

Since 2000, California experienced the slowest rates of population growth recorded in modern history; growth rates decreased during the pandemic, from July 2020 to July 2023 (Johnson et al. 2025), and the state's population decreased in 2021 and 2022 (Cain and Hehmeyer 2023) for the first time since 1849 (see Chapter 6, Population and Development). Stagnant or downward population trends in more remote rangeland counties are contributing to a declining rural labor force. However, remote work, decreased transportation costs, opportunities in the digital and service sectors, and idealization of rural life may contribute to increases in immigration into rural areas (reviewed in Biggs 2022). Many of these residents do not derive income from production of agricultural products, or if they do, may produce very niche products and not large agricultural commodities (Wilmer et al. 2018). Therefore, this change in the rural population, along with the overall decrease in population, is likely to mean a net decrease in the labor force available to contribute to ranch management.

An aging population in California has contributed to a decrease in the long-term statewide labor force, with labor force participation declining from 67% in 2000 to 62% in 2024, while the post-pandemic work force is still lower than in 2020 (Lafortune et al. 2024). Ranchers tend to be older, with the median age in recent decades at approximately 60 years old (Roche et al. 2015).

Workforce Development on Grazing Rangelands

Clear workforce pathways are limited in the ranching workforce, and rangeland science degrees are not commonly offered in California. Range science education opportunities in California trended downward for decades (Marshall 2020), but recently they have begun to increase. The recent growth in service-grazing business enterprises, stimulated by land managers seeking alternatives to mechanical thinning and herbicide treatment of vegetation to mitigate wildfire behavior, and related state support for the use of livestock for this purpose, is expected to create greater interest in range education and Certified Range Manager licensing (M. Horney, personal communication, June 9, 2025). Additionally, self-initiated, often no-cost or low-cost online courses and in-person workshops are abundant today, although a variety of factors contribute to the likelihood of attendance and completion, including age, education, income, goals, size of farm, land tenure, and level of community participation. Factors influencing participation in the grazing sector may include consideration of profitability, regulations, business and technical aspects (e.g., estate planning, marketing, forage production), and long-term sustainability of the ranching operation (Richards and George 1996).

Examples of learning opportunities include the Ranch Water Quality Planning (RWQP) Short Course (Doran et al. 2020), courses in rangeland management offered by University of California (UC) Cooperative Extension (UCCE) (George and Clawson 2014, Richards and George 1996), continuing range education offered through the Society for Range Management (George and Clawson 2014), or range management education at certain UC or California State University (CSU) campuses, along with more local hands-on efforts, such as trainings provided by the Grazing School of the West.

Rangeland Conversion

Brief Historical Perspective and Summary of Changes Over Time

Rangelands have historically been the primary land type subjected to conversion to irrigated agriculture and residential/commercial development. Since European colonization in the late 1700s, over 16 million acres of California have been converted to development and irrigated agriculture, of which about 10 million acres (68%) was former rangeland. Soon after the Gold Rush of 1849, with the arrival of large numbers of new American colonists, vast areas of native rangelands were quickly converted to dry farms, grazed by herds of domestic livestock, or converted from extensive wetlands to irrigated crops (Larson-Praplan 2014, Olmstead et al. 2003).

From 1850 until present, the long-term historical rate of land conversion to urban and intensive agricultural uses has averaged about 92,000 acres (about 0.09% of the state) per year. Rates of rangeland conversion were exceptionally high during the early colonial period but have greatly decreased in the modern era.

From 2000 to 2023, the rate of permanent conversion from rangelands to development averaged about 12,000 acres per year (0.01% of the total state) (see ⓘ2.1). Recent conversions of rangelands to urban have occurred primarily in Southern California, the San Francisco Bay Area, and Central Valley regions, particularly on the margins of large urbanized areas.

With nearly 40 million inhabitants in California, development pressures remain on these lands, although protective laws including the California Environmental Quality Act and conservation programs have slowed the pace of development and helped maintain the ranching industry in recent decades.

Recent and Planned New Development

Although California's population has continued to grow (ⓘ6.1), the rate has significantly slowed in recent years. In addition, an increasing proportion of new development has occurred within existing urban areas, known as "infill" development, and on former croplands (e.g., in the Central Valley) (see Chapter 6, Population and Development).

After a steep decline during the recession of 2007–2009, the number of rangeland acres being converted to development recovered and has held relatively steady at around 7,500 acres per year. The last few years have seen a slight uptick in rangeland development to above 10,000 acres per year (ⓘ2.1).

Based on statewide acreage, the largest threat to rangeland from development is subdivision of land to smaller parcels at the margins of large urbanized areas, especially those in proximity to major transportation corridors. Recent examples of new development on the urban fringe include the Sacramento Valley, southern San Joaquin Valley, and the Perris and Coachella valleys of Riverside County. Due to habitat fragmentation, invasive species, impacts from domestic pets, and other adverse impacts associated with human habitation, the overall value of these rangelands for ecosystem services is typically lower than for other larger, more intact and remote locations. On the other hand, the value of rangelands on the urban fringe may be high for purposes such as open space and recreation. Rangelands that may be compromised in other respects can fulfill that vital role when protected and restored as public parks and open space.

In a handful of more remote rural areas, whole new housing communities have been or are being established across significant tracts of rangelands with high ecological value. Some communities are extensive and actively growing, such as Bear Valley Springs and Stallion Springs in the Tehachapi region of Kern County and the Carmel Valley of Monterey County. Centennial, a wholly new municipality planned as a part of Tejon Ranch, is slated to eventually house more than 70,000 residents on 18 square miles of rangeland (Centennial Tejon Ranch 2025).



Figure 2.4. Fragmented patch of remnant valley oak woodland in agricultural matrix, Sonoma County (ESRI Image). Photo: UCCE.

More than 1 million acres of oak woodland have already been developed for urban and rural residential uses (Gamen and Firman 2008). Between 1984 and 1994, 29,000 acres of oak woodland were estimated to be lost to development, agriculture, and vineyards (Waddell and Barrett 2005). In response to development threats, the Oak Woodland Conservation Act was passed in 2004. Since then, 21 counties have adopted oak woodland management plans to help conserve oak woodlands and to qualify them for conservation funding from the Wildlife Conservation Board (J. Walsh, personal communication, n.d.). An estimated 6.2 million acres of hardwood woodland remain in California (see Table 2.1), 91% of which is oak dominated (CAL FIRE 2022).

Development that results in fragmentation of rangeland landscapes has several negative effects on rangeland sustainability (Figure 2.4). Fragmentation decreases habitat connectivity and disrupts wildlife corridors, disrupts rangeland hydrology, and creates more "edge effects" that increase vulnerability to encroachment by invasive species (see Chapter 10, Wildlife Habitat). Fragmentation also makes livestock transport more difficult, which takes away from ranchers' bottom lines, further eroding economic sustainability of these operations (Sayre et al. 2012). Moreover, smaller property owners are less likely than larger property owners to be contacted by natural resource organizations that provide technical assistance to support conservation efforts (Ferranto et al. 2012).

Rangeland Property Tax Protections, the California Land Conservation Act (i.e., "Williamson Act"), and Current Status

The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), as well as numerous other state and federal public agencies and private conservation organizations, have programs to protect working rangeland landscapes from conversion, through means including regulation, land acquisitions, Williamson Act contracts, and conservation easements (ⓘ6.2).

In 1965, the California Land Conservation Act, also known as the "Williamson Act" (WA), was established to help relieve development pressures on working rangelands and agricultural lands (Thompson 2009). The WA substantially reduces the property tax burden for landowners who waive their development rights for a 10-year period. Prior to this legislation, the potential market value of the land often resulted in escalating property taxes, leading many agricultural landowners to sell their land to be subdivided for conversion. In lieu of the lost revenue, the state was to make annual subvention payments to local governments. Due to budgetary shortfalls, however, these payments were drastically reduced in 2009 and eliminated entirely in 2011.

Despite losses in annual tax revenue and lack of program administration monies, 51 of 52 originally participating counties are still honoring their local WA contracts. Currently, enrolled landowners with WA contracts are seeing a 20 to 70% reduction in their property taxes (CDOC 2022). However, the continuing lack of state program funding has led several counties to roll back or cease reporting of changes in landowner WA participation. It is also likely that sporadic and underreporting of enrollment will persist going forward, as the state has given no indication that it will resume subvention payments.

In some areas there have been significant decreases in the number and extent of parcels receiving tax benefits under the WA. For instance, Imperial County has completely withdrawn from the WA program, and some less-affluent counties have stopped accepting new WA contract applications for their agricultural lands. Moreover, there is an apparent downward trend in enrolled acres, from over 16 million acres enrolled in 2004. The Department of Conservation reported in 2022 that over 90,000 acres had been removed from protection under the WA, and an additional 317,882 acres were earmarked for non-renewal over the next decade (CDOC 2022). These numbers are somewhat tenuous, given the increasingly sporadic reporting.

Where the discontinuation of state subvention payments in 2011 leads counties to discontinue WA property tax reductions, the higher property tax payments faced by landowners could lead to an increase in rates of conversion of range and agricultural lands to urban uses, particularly in locations closer to urban and suburban zones. Increased conversion may compromise the maintenance of wildlife habitat and other ecosystem services and values on those natural and working lands. Previous analyses have indicated that 72% of rangeland parcels enrolled in the WA have contained critical habitats for state conservation goals, while 20% of these parcels could be sold off if the contracts were terminated (Roche et al. 2015, Wetzel et al. 2012).

Conservation Easements and Trends Over Time

Sustaining the level of ecosystem services provided by rangelands, including working ranches, is a major challenge. Increased use of conservation easements (ⓘ6.2),

particularly in areas most at risk of land use conversion, is a positive sign that the importance of these lands is being recognized. In the past two decades, there have been approximately 34,000 acres per year of new conservation easements on rangelands, contributing to the total of just under 1.6 million acres (ⓘ6.2). Conservation easements keep working rangelands in livestock production, thereby maintaining the ecosystem services they provide while sustaining livelihoods (Barry 2022, Cheatum et al. 2011, Ferranto et al. 2014, Liffmann et al. 2000, Lubell et al. 2013, Nolte 2021, Roche et al. 2015, Wetzel et al. 2012). Most ranchers, particularly those in more rural areas, want to see livestock grazing remain the primary land use even if they are selling the ranchland (Liffmann et al. 2000), and conservation easements provide a mechanism supportive of that outcome for ranchers who do not have a feasible succession plan. However, demand exceeds funding for conservation easements in California (Biggs et al. 2021, Ferranto et al. 2014). Conservation easements are often implemented with non-governmental organizations such as the American Farmland Trust, The Nature Conservancy, the California Rangeland Trust, and the state-administered California Strategic Growth Council and California Wildlife Conservation Board (see Table 2.4) (Biggs et al. 2021).

Production livestock owners are much more likely to participate in these kinds of programs as compared to amenity landowners (i.e., on smaller subdivided "ranchettes" with more niche products) (Wilmer et al. 2018). These voluntary, conservation-based land protection programs contribute to efforts to reduce land conversion (Barry 2022, Nolte et al. 2019). Conservation easement programs that allow flexibility for adaptive management may better promote ecosystem health and resilience by allowing landowners to monitor and manage for ecological objectives (Jones et al. 2025, Stroman and Kreuter 2015).

Management Context of Grazed Rangelands

Grazing Agreements/Federal and State Grazing Allotments (ⓘ2.3)

Under public grazing allotments, ranchers pay agencies by the AUM or other agreed upon unit to permit them to utilize the land for grazing. Profitability of some livestock operations is directly dependent on leased grazing land from public agencies (federal, state, and local), as well as private owners. Historically, contracts for leasing of federal lands (i.e., grazing allotments) have played a major role in providing forage for regional livestock. However, the role of federal grazing allotments is diminishing on more marginal grazing lands and in poor forage production areas such as deserts (ⓘ2.3).

Since the mid-1960s, USFS grazing authorizations have dropped about 40%, from 500,000 AUMs to close to 300,000 in recent years (ⓘ2.3). The number of active allotments and permitted AUMs have been reduced for a variety of reasons, such as to improve rangeland ecological conditions or reduce conflicts with other uses. In some formerly grazed areas such as meadows, encroachment by trees and shrubs (often due to fire exclusion) has greatly reduced forage available to livestock (see Chapter 9, Water Resources). In some cases, the cost of maintaining the infrastructure necessary for grazing of livestock (e.g., fences, access roads, watering sites) exceeds the benefit to the rancher from the available cattle forage.

Grazing on federal lands may soon increase slightly for the near term, as livestock are used to manage post-wildfire regrowth of grasses and shrubs in formerly forested areas. Some large grazing allotments with no applicants for grazing permits in recent years may now be of interest to ranchers where there has been regrowth of forage-rich vegetation (L. Sevy, personal communication, 2021). The costs of maintaining grazing infrastructure on federal lands by rancher allotment permitees will remain an issue for ranchers in many areas.

To set yearly federal allotment AUM fees (stemming from the Public Range Improvement Act of 1978 [PRIA]), the USFS and BLM track standardized metrics of costs incurred by beef ranchers and prices received by beef ranchers on an annual basis (Vincent 2019). Since 1986, the rates charged to livestock owners for allotments have been set near or close to the allowable minimum of $1.35 per AUM, where it has remained for the past seven years (BLM 2024). Calculation of grazing

fees is a controversial issue, and many critics believe that the PRIA-set fees have not accurately reflected the value of the benefit received by the livestock operators that have public land grazing permits and should be set much higher (Vincent 2019). They point to the fact that grazing fees charged on nearby private lands can exceed the PRIA rate by a factor of 10 or more. The low pricing can lead some producers to abuse the privilege, and provide them with an unfair (i.e., taxpayer subsidized) competitive advantage over those without federal allotments. However, the ranching industry believes the low rates are largely offset by numerous non-AUM related costs to the livestock owner associated with having an allotment permit, such as constructing and maintaining expensive grazing infrastructure, transporting and overseeing the herd, and managing and reducing potential on-site conflicts with other uses (Vincent 2019). In some cases, federal allotment fees and terms may be cost-prohibitive to ranching operations.

Grazing agreements and permits also exist on California state-owned lands, managed by entities such as CDFW and the California State Lands Commission. These agencies often charge AUM rates set by a competitive bid process or with cattle markets (S. Barry, personal communication, June 7, 2025). Grazing agreements on state lands are limited to a maximum of five years, and some may be limited to fewer years. These limited terms are a major impediment to grazing. Graziers are often unable or unwilling to invest time and money into proper management and maintenance of a parcel that they may not be allowed to access over a longer period of time, e.g., 10 or more years, particularly given that they may not see the benefit of their stewardship for several years (BOF 2025).

A major challenge to the feasibility of public grazing agreements are renewals based on performance criteria and/or compliance constraints, such as contracts that dictate the minimum or maximum amount of vegetation that can or must be removed, min/max number of animals allowed on the parcel, or rigid on/off dates that do not allow for bioclimatic variability. Successful and well-managed grazing requires flexible grazing contracts that allow for a variety of production conditions in any given year and adaptive frameworks to guide managers to make the best grazing management decisions for the conditions present at any given time (Derner et al. 2022).

Additional Management Constraints

The cost of replacing, retrofitting, or installing fencing and development and maintenance of water sources is often prohibitive and may thus limit applications of grazing where it could be beneficial economically to the rancher or environmentally to the ecosystem. Usually these infrastructure upgrades and maintenance costs are not eligible for grant or cost-share funding. Moreover, these major infrastructure installations can be cost-prohibitive, and ranchers are unable to recoup the expense of such investments in the short time periods allowed by grazing agreements on public lands.

Many ranchers cite environmental regulations (such as water quality and supply regulations) and policy hurdles (e.g., land use restrictions) as a constraint to the continuity of a ranching enterprise (Biggs 2022, Liffmann et al. 2000, Roche et al. 2015). Conservation restrictions on rangelands developed without input of ranching experts may not adequately incorporate economic viability of ranching operations (Biggs 2022).

Public and organizational perceptions that livestock grazing is always damaging (sensu Molvar 2018) may result in landscapes not receiving any grazing treatment whatsoever, thus increasing risk of wildfire and causing cascading negative impacts to local and surrounding communities (e.g., to health, infrastructure, safety, and other ecosystem services) (Brunson 2020, Papanastasis 2009). However, livestock producers are more likely to actively manage for habitat improvement and contribute to the support and provisioning of ecosystem services than residential landowners (Plieninger et al. 2012). Therefore, supporting continued ownership and management by ranchers may support improved ecological outcomes, particularly where ranching sustains large, unfragmented rangelands that may otherwise be divided into small parcels or “ranchettes.”

Conflicts may arise between different users or value systems in areas where they come into contact (Biggs 2022). This can come in the form of interactions between livestock, guardian animals, wildlife, recreationists, ranchers, and authorized or unauthorized users (Liffmann et al. 2000, Macon et al. 2018, Wolf et al. 2017). Public perception of predator controls may limit rancher options for protecting livestock, aggressive guardian animals may be incompatible with recreational uses in areas heavily utilized by the public, and lethal methods of predator control may be socially unacceptable in some areas (Macon et al. 2018, Volski et al. 2021).

The growing gray wolf (*Canis lupus*) population in California represents an emerging and complex conflict between wildlife and ranching operations. This species is protected as Endangered under both the California Endangered Species Act and the federal Endangered Species Act. After being extirpated in the 1920s, wolves have recently re-established packs in California via migration from other states. Today there are ten confirmed packs in California from Siskiyou to Tulare County and the population continues to increase (CDFW 2025). From 2015 through 2024, there were 152 confirmed livestock (primarily cattle) killed or injured by wolves in California (CDFW 2025). Since 2021, CDFW has managed the Wolf-Livestock Compensation Program (WLCP), which compensates livestock owners for confirmed wolf predation. Prior to 2024, the program also compensated owners for substantial harassment of livestock and funded wolf predation prevention measures, but this funding has not been renewed (CDFW 2025). Reinstatement of this funding could reduce livestock-wolf conflicts. Habitat restoration to combat decreases in native ungulate populations could alleviate wolf pressure on livestock. It is unknown whether wolves meaningfully affect mule deer populations in California, but research on this topic is underway (A. Hunnicutt, personal communication, 2025).

Predation challenges also include mountain lions and coyotes, especially in coastal areas (S. Barry, personal communication, June 7, 2025) (UCCE 2025). On federal grazing allotments, graziers could benefit from increased flexibility regarding timing of herd presence

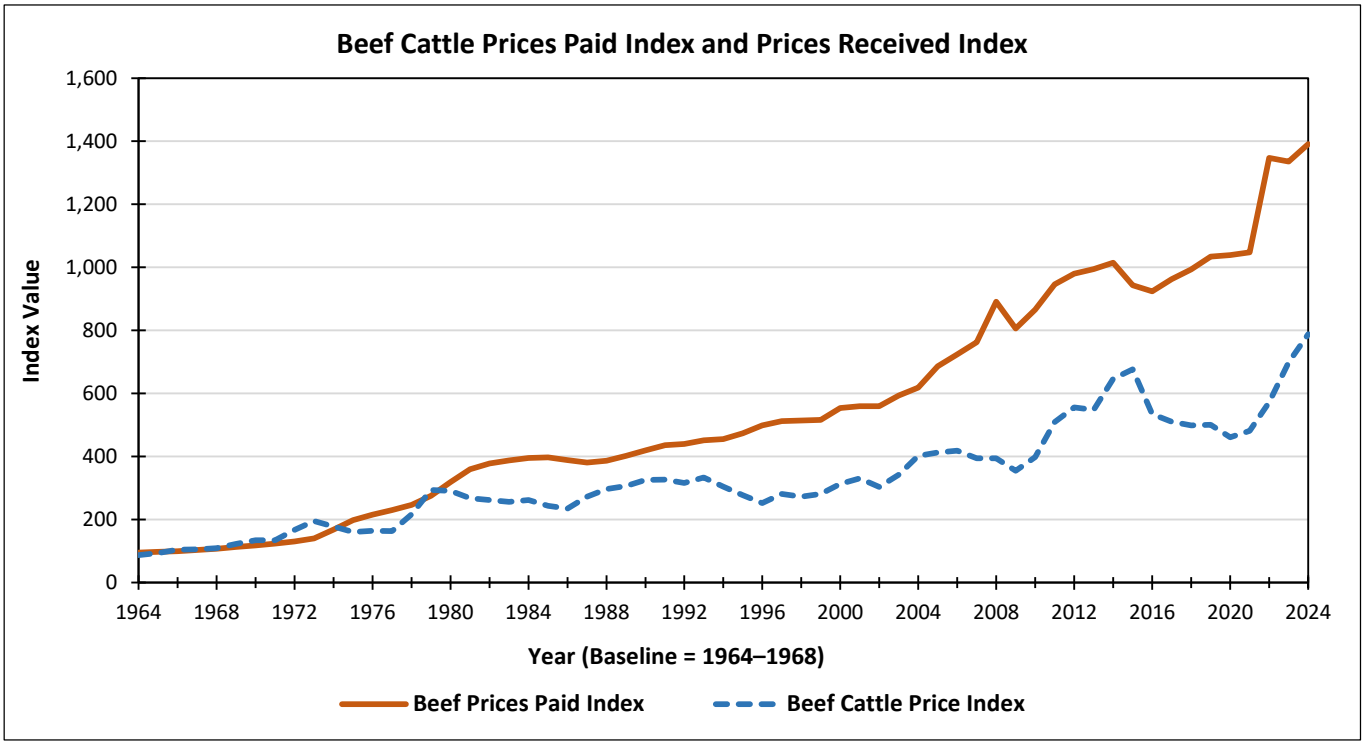


Figure 2.5. Beef Cattle Price Index (prices received by ranchers) versus Prices Paid Index (prices paid by ranchers) per hundredweight (cwt) of beef cattle, using the period from 1964–1968 as the baseline (= 100). The Beef Cattle Price Index is derived for the 11 Western states. Data Source: USDA (2024).

to avoid calving on remote or large allotments where it is difficult to actively protect livestock herds from predators (A. Hunnicutt, personal communication, 2025).

Economic Factors and Operation Viability

Livestock producers have historically faced a high degree of economic uncertainty from year to year in California and the Western states. The price of beef in the U.S. was high in August 2024 at $185 per hundredweight (cwt), up from $98 in July 2020, due to reduced cattle herds and strong demand. The August 2024 steer price was 56% higher than the 2018–2022 average (Nelson 2024). While the cash price for cattle is currently elevated (as of late 2024), increased costs for supplies and market instability are among the numerous factors contributing to slim profit margins and impacting the profitability of beef cattle ranching in California. As profit margins can decrease over time or even disappear in some years, most ranchers now rely on diversified household income streams, effectively decoupling land ownership from livelihoods (Wilmer et al. 2018).

Since at least the late 1970s, the price of beef received by ranchers has been diverging relative to the prices paid by ranchers for the various inputs needed to raise it (Figure 2.5). The continuing divergence of the two trends has greatly eroded the profitability of domestic livestock operations.

Most beef cattle producers in California are selling calves (i.e., stockers) that are finished on grass pasture or feedlots, often out of state (S. Barry, personal communication, June 7, 2025) (Barry and Huntsinger 2021). Cow-calf operations are the first stage in the beef supply chain, raising calves until they are about seven months old. Calves are generally sold to stocker operations that feed them on pasture until they are one year old. Yearling cattle are then sold to feed lots, often in the Midwest, and fattened with grain before slaughter (Saitone 2020).[4]

A key factor in reduced profit margins is the corporate concentration of the beef processing industry, which often requires shipping cattle to distant markets and slaughterhouses. The lack of USDA-certified processing facilities is one of the largest barriers to small and medium sized producers in the Western states, with only four beef packing companies owning over 80% of the meat production in the U.S. (Dimock et al. 2021). Many of the USDA-certified slaughter plants operating in California are inaccessible to smaller producers due to constraints put in place by the packing plants themselves, essentially limiting use to only very large producers (Quinton 2021). While smaller processing facilities may not concentrate profits at the same rates as larger slaughter plants, they contribute to market diversification, reliability, and stability (Dimock et al. 2021).

Forage cost (rangeland leases) may be a major expense for cow-calf producers in California. California's 2022 drought reduced forage availability and increased the cost of forage for cattle (Medellín-Azuara et al. 2022). The earlier drought from 2012 to 2016 greatly reduced available rangeland forage as well.

Other economic factors for livestock producers in California include difficulty in obtaining liability insurance, particularly in high-risk wildfire zones where ranchers are also more likely to operate; the high cost of land; and federal, state, and local agency regulations.

The labor cost for prescribed and targeted grazing[5] is an additional emerging constraint on grazing businesses. The 2016 Overtime for Agricultural Workers Act (Assembly Bill [AB] 1066) (Gonzalez et al. 2016) increased salaries for goat and sheep herders by roughly 50%. A subsequent decision by the

4 *In 2023, cattle and calves ranked as the third highest value agricultural commodity in California, with a value of $4.76 billion (CDFA 2025). See the Rangelands section in Chapter 8 (California's Non-Metro Regional Economy) for additional information.*

5 *"Targeted grazing" and "prescribed grazing" are often used interchangeably but have subtle differences. Targeted grazing focuses on using grazing animals to achieve defined vegetation or landscape goals, such as reducing wildfire risk or controlling invasive weeds. Prescribed grazing is a broader term that encompasses managing grazing animals to achieve a range of ecological, economic, and management objectives, including maintaining or improving vegetation health and productivity.*

California Department of Industrial Relations resulted in a requirement to pay goatherders an hourly wage, plus overtime, resulting in concerns about the viability of the industry. AB 156 (Committee on Budget et al. 2022) introduced a clause that would maintain similar labor standards for goat and sheep herders, but it was slated to sunset in January 2024, leading to concerns and uncertainty for the goat grazing industry (Toohey 2023). Two bills were introduced during the 2024–25 legislative session to address these issues: Senate Bill (SB) 801 (Hurtado 2025) would exempt sheep and goat herders from California's agricultural overtime law, and SB 628 (Grove 2025) would offer tax credits to offset overtime costs to herd operators. AB 156 did not sunset in 2024; subsequent legislation SB 143 (Committee on Budget and Fiscal Review 2023) extended equal sheep and goatherder minimum monthly wages through June 30, 2026.

Climate Change and Rangelands

Climate change is having increasingly detrimental effects on rangelands. Impacts are arising from erratic weather; increased wildfire frequency, intensity, and extent; and increased frequency and duration of drought. Shorter rainy seasons, warmer summer temperatures, and drought conditions lead to lower productivity and earlier senescence in grasslands (Chavez Rodriguez et al. 2023, Copeland et al. 2016, Reeves et al. 2014, Warter et al. 2021), or changes in the seasonality of vegetation growth (Hufkens et al. 2016). Precipitation in April and November tends to be most influential on annual grass production (Liu et al. 2021), so changes to precipitation in these months, as occurs with a shortening rainy season (e.g., Swain 2021), can have a greater effect on forage.

Impacts from climate change can vary across the state due to geoclimatic differences and the responses of different plant communities to climate change impacts. For example, Southern California had greater loss of vegetation productivity during the 2012–2016 drought compared to Northern California, which had increases in productivity in some areas (Dong et al. 2019b). And within Southern California, drought during that time had a greater impact on chaparral-dominated ecosystems than coastal sage, while coastal sage had more interannual variability in growth. Deep-rooted chaparral is less sensitive to short term drought than coastal sage (Okin et al. 2018), but chaparral is impacted by multiyear drought, particularly at lower, warmer elevations (Keeley et al. 2022). In Southern California, chaparral is also the most sensitive community to increasing temperatures and frequency of wildfire, and in some areas has been replaced by invasive annual grasses (see *Wildfire Impacts*, below) (Dong et al. 2019a). Coastal grassland sites may be more buffered than inland sites from increasing evaporative demand due to higher humidity from fog, however under some climate change predictions coastal grasslands may become vulnerable as well (Warter et al. 2021).

Climate change also impacts rangeland vegetation indirectly through its effects on wildfire (for more detail, see *Wildfire Impacts*, below). Earlier senescence of annual plants resulting from drier conditions increases the probability of wildfire spread and can be particularly problematic when following sporadic years of higher precipitation and plant productivity that increase biomass available as fuel (Warter et al. 2021). Shrub dieback due to drought likely causes greater fire spotting and spread (Keeley et al. 2022). These impacts to vegetation are compounded by increasing aridity and fuel availability. Southern California is predicted to have a greater number of large fire spread days, up from 36 days per year to an estimated 58–71 days per year (Dong et al. 2022). Later initiation of the rainy season in the fall leads to more frequent coincidence of dry fuels with Santa Ana winds that can cause rapid fire growth and spread (Goss et al. 2020), as exemplified by the Los Angeles County wildfires of January 2025.

Climatic and environmental factors make California rangelands highly diverse, and this variability appears to be increasing with climate change. In particular, the interannual variability of rangeland precipitation, along with fluctuations in seasonal distribution, air temperature, and solar energy, cause large variations in grassland forage production (Li et al. 2023, Liu et al. 2021). The year-to-year ups and downs can make livestock herd management difficult and uncertain (Roche et

al. 2015). Increased climate variability can also make landscapes conducive to non-native plant invasion and replacement (or contraction) of native plant populations. Non-native annual grasses and herbaceous plants tend to rebound more quickly than native species following drought (Puritty et al. 2019).

In the first half of the 20th century, prior to concerns about climate change, rangeland management focused on homogenizing landscapes, utilizing as much forage as possible, and stocking based on a static estimate of annual forage production (Heady 1999). Moving into the second half of the century and into the 2000s, range science research has shown that high natural spatial and temporal heterogeneity of rangelands both necessitates and has supported development of more flexible and adaptive management in response to highly dynamic conditions (Espeland et al. 2020).

Today's range managers understand that stocking rates must be managed dynamically, and ranchers must recognize local and ephemeral conditions to most appropriately manage the timing, intensity, and duration of grazing, as well as the species and type of livestock (Sayre et al. 2012). Surveys of ranchers following the 2012–2016 drought in California reflected a tendency to consider climate change an important factor in planning ranching operations, and they also showed that many ranchers feel confident in their skills to cope with long-term drought that may become more pervasive in a warming climate (Woodmansee et al. 2021).

Multiple state climate change programs and policies, based on governor and legislative direction, recognize the climate change threats to rangelands and seek to address them. These include the California Climate Adaptation Strategy (CCAS 2024), the Natural and Working Lands Climate Smart Strategy (CNRA 2022), and California's nature-based solutions climate targets (CNRA 2024). The latter report provides the most specific goals for rangelands, broken out as shrublands and chaparral (32.9 million acres), sparsely vegetated lands (10.2 million acres), and grasslands (9.7 million acres), as well as benchmark years of 2030, 2038, and 2045 (Table 2.3). Proposition 4, the Safe Drinking Water, Wildfire Prevention, Drought Preparedness, and

Table 2.3. Nature-based solutions climate targets for rangelands (acres per year)

Cover Type and Nature-Based Solutions		Benchmark Year		
Shrublands and Chaparral		**2030**	**2038**	**2045**
	Conservation: Conserve chaparral and shrublands, with a focus on old growth and undeveloped areas.	104,600	104,600	104,600
	Restoration: Restore chaparral and shrublands with a focus on threats from invasive species and fire; post-disturbance restoration; transitional zones; enhancing native vegetation; and re-establishing wildlife connectivity.	37,000	40,000	45,000
Grasslands				
	Conservation: Protect grasslands with a focus on remaining native grasslands, oak trees, and foothill pines.	33,000	33,000	33,000
	Restoration: Restore degraded grasslands to native vegetation communities and diverse, perennial, deep-rooted grasses; soil amendments and prescribed grazing in line with the Natural and Working Lands Climate Smart Strategy; re-establishing a sustainable fire regime; riparian restoration.	55,100	55,100	55,100
Sparsely-Vegetated Lands[1]				
	Conservation: Conserve lands to prevent conversion and/or disturbance.	20,000	30,000	40,000
	Restoration: Restore native vegetation on previously disturbed areas (or on those otherwise dominated by invasive species) including through invasive species removal and restoration of riparian zones.	55,100	55,100	55,100
TOTAL Acres/Year		304,800	317,800	332,800

Data Note 1: Comprised of areas of California's Mojave, Colorado, and Great Basin deserts that have low levels of above-ground vegetation; beach and dune areas with less than 10% vegetation cover; bare rock landscapes; areas covered in ice or snow such as those above the tree line in mountainous regions; barren lands with hostile growing conditions.

Data Source: CNRA (2024).

Clean Air Bond Act of 2024, approved by the voters in November 2024, has the potential to fund hundreds of millions of dollars of work toward state climate targets for rangelands through various state programs including the State Coastal Conservancy, Wildlife Conservation Board, and Department of Conservation.

Ecological Factors and Interactions/Environmental Impacts

Invasive Species

Invasive species alter nutrient cycles, soil moisture availability, fire frequency and intensity, and the structure and suitability of habitats for wildlife, and they affect the availability and quality of livestock forage on rangelands. For example, as cheatgrass (*Bromus tectorum*) and red brome (*Bromus rubens*) continue to spread throughout the California deserts and Great Basin sagebrush, they change wildfire behavior and the historical fire regimes by increasing fire frequency, thus inhibiting recovery of native species adapted to longer fire-free intervals (Balch et al. 2013, Fusco et al. 2019).

Non-native plant species make up more than 90% of plant cover in most grassland areas of California (Eviner 2016), particularly annual *Bromus* species (Reeves et al. 2023), but also mustard (*Brassica* spp.), filaree (*Erodium* spp.), and other forbs. Many non-native annual grasses are generally considered desirable as productive livestock forage species (DiTomaso et al. 2017). However, they have had profound effects on native biodiversity, type-converting vast landscapes from a rich mix of native forbs, geophytes, and perennial and annual grasses to species-poor annual grasslands dominated by non-natives (Minnich 2008).

Invasive, noxious, exotic species such as cheatgrass, medusahead (*Elymus caput-medusae*), yellow starthistle (*Centaurea solstitialis*), and barbed goatgrass (*Aegilops triuncialis*) continue to persist and invade rangelands, lowering the forage quality for livestock and wildlife over large areas of grasslands and oak woodlands. In addition, several species of invasive thistles, including bull (*Cirsium vulgare*), Scotch (*Onopordum acanthium*), and Italian (*Carduus pycnocephalus*), degrade oak woodlands and grasslands across the state. California rangeland managers and restoration practitioners have identified yellow starthistle and medusahead as the most common problematic plants (Schohr et al. 2020). These species, along with barbed goatgrass, can form monotypic stands that may decrease forage production by as much as 50–75% (Eviner 2010). Riparian ecosystems can be invaded by other species, including Himalayan blackberry (*Rubus armeniacus*), perennial pepperweed (*Lepidium latifolium*), giant reed (*Arundo donax*), tamarisk (*Tamarix* spp.), and numerous exotic herbaceous species, which tend to form monotypic stands and choke out native vegetation.

Invasive plants cost California $82 million per year to monitor and control (Cal-IPC 2008), and the cost is likely substantially higher now. Increases in the spread of invasive plant species that are less palatable to livestock are a continuing management challenge (DiTomaso 2000, Schohr et al. 2020, Shapero et al. 2018). Invasive exotic rangeland plants reduce primary productivity and quality of forage, lowering livestock production; interfere with grazing and can be toxic or deadly; increase the cost of land management; and reduce economic profits (DiTomaso 2000, James et al. 2022, Shapero et al. 2018).

Strategies to reduce the impacts associated with invasive plant species on rangelands include prescribed fire, prescribed/targeted grazing, mowing, herbicide use, and seeding (Schohr et al. 2020), but all of these approaches have advantages and disadvantages. Prescribed burning has been found to be a viable tool for promoting native grasses over non-native invasive species when implemented with appropriate timing (Keeley et al. 2023, Roche et al. 2016), but can have utilization limits due to air quality concerns, staffing, and permitting. Herbicides can be effective, but are expensive, can have nontarget effects, and may have issues with public perception (Schohr et al. 2020). Livestock grazing has been found to be more beneficial than grazing exclusion for control of invasive plants, particularly for medusahead, but it must take place late in the growing season when defoliation can reduce plant seed production (Davy et al. 2015, Shapero 2016). Similarly, mowing can be effective if timed appropriately, but it

is often infeasible over large areas, on steep slopes, or on rocky terrain (Shapero 2016). Native species seeding can enhance biodiversity and reduce invasive species (Gornish 2018), but treatment effects are highly transient and often unpredictable (James et al. 2015).

In addition to invasive plants, invasive animals can have significant adverse impacts on California rangelands. These animals include feral pigs, burros, and feral horses. Feral pigs are primarily found in oak woodlands, and their population has expanded considerably over the past decade. They are known to cause extensive damage to rangelands through their rooting, wallowing, and foraging (Finzel and Baldwin 2015). Feral pig populations can degrade water quality and harm numerous sensitive species, as well as degrade riparian and oak woodland communities, damaging oak seedlings and thereby limiting regeneration (CBI 2009, Sweitzer and Van Vuren 2002). Burros have the potential to rapidly expand their populations in desert areas such as Death Valley National Park, damaging native vegetation and competing with native wildlife species such as bighorn sheep for limited resources (NPS 2023). Similar to burros, wild horse populations can grow at rates of 18–20% per year, far above what many rangelands can sustain, leading to overgrazing (Environmental Literacy Council (ELC) 2025). Feral horse and burro populations on BLM managed lands across the Western U.S. increased from 25,000 in 1971 to over 96,300 in 2014 (TWS 2014). Various management approaches are available to address these invasive animal issues, including hunting for feral pigs (Finzel and Baldwin 2015) and removal of excess horses and burros (TWS 2017).

Rare, Threatened, Endangered, and Protected Species

The impacts of livestock grazing on wildlife and their habitats have long been debated and researched. Improved grazing management in recent decades—due to increased environmental regulation, voluntary conservation grazing practices, and public scrutiny—has resulted in improved rangeland outcomes for various ecosystem services, including improvements to wildlife habitats (Huntsinger and Oviedo 2014). While livestock grazing has been identified by the U.S. Fish and Wildlife Service (USFWS) as a threat to 73% of plant and animal species sharing grazing lands in California, 59% of those species are also noted to be benefited by managed grazing. Much overlap exists for both threats and benefits to many of these species, and is likely highly contingent on climatic variability, management approaches, and the interactions thereof (Barry and Huntsinger 2021). Overall, 51%, or 143, of the federally listed species in 2021 were found in habitats with livestock grazing (Barry and Huntsinger 2021).

Variable impacts from livestock grazing are frequently due to differences in ecosystem types and the implemented management practices (e.g., Hayes and Holl 2003, Jones 2000, Schieltz and Rubenstein 2016). For lands historically grazed by large herbivores, removal of domestic livestock grazing can result in significant degradation to biodiversity (Papanastasis 2009). Grazing can benefit flowering plants, mammals, insects, reptiles, amphibians, fish, crustaceans, and bird species by managing introduced vegetation and providing and maintaining habitat structure and ecosystem functions (Barry and Huntsinger 2021, Barry 2015). For example, research has shown that grazing is strongly linked to maintaining habitat for some special-status species on coastal lands in California (Larson 2016). At the landscape level, livestock grazing has been shown to maintain open space by reducing land use conversion, fragmentation of habitat, and vegetation type conversion (Larson 2016). It has been identified as the most feasible strategy to manage habitat at the landscape scale for the San Joaquin kit fox (*Vulpes macrotis mutica*), an endangered species (Barry 2015). Federal agencies seek to carefully regulate stocking levels, seasons of use, and intensity of grazing by livestock to protect and maintain biodiversity.

One example of federal agency modifications is the change in large commercial livestock grazing allotments on BLM lands, which have been reduced in both the Mojave and Colorado deserts. The value of these areas for native wildlife such as bighorn sheep, protected under California state law since 1971, has been deemed higher than the value of livestock production from these

lands. Domestic livestock and feral animals can reduce the availability and quality of resources (e.g., water and forage) required by bighorn sheep, as well as transmit disease (Rubin 2000). Poor forage conditions resulting from livestock grazing have been found to substantially increase bighorn sheep foraging effort, which reduces their fitness (Garrison et al. 2016).

Benefits from grazing have been reported for some species using aquatic habitats, including riparian, wetlands, and ephemeral vernal pools (Barry and Huntsinger 2021).[6] Vernal pools have high plant and animal diversity, including many threatened or endangered species. They are being negatively impacted in California due to high non-native grass density and thatch buildup, which can shorten pool inundation times, reduce water depth, and outcompete native species. Removal of cattle grazing has been reported to adversely impact vernal pools (Marty 2007, Marty 2015); in fact, moderate intensity grazing has been shown to increase the cover of native plant species and improve ecosystem function in vernal pools (Michaels et al. 2021). Endangered species such as the California tiger salamander (*Ambystoma californiense*), Conservancy fairy shrimp (*Branchinecta conservatio*), and vernal pool tadpole shrimp (*Lepidurus packardi*) are dependent on keeping these small waterbodies intact across California (Robinson and Snow 2022).

Proactive collaborations between wildlife conservation organizations and the ranching community illustrate that grazing can benefit wildlife species. For example, the California Cattleman's Association and the Defenders of Wildlife, along with several other conservation-focused agencies and organizations, formed the California Rangeland Conservation Coalition in 2005 to conserve and enhance the ecological values and economic viability of California's working rangelands. Additionally, CDFW has been using grazing to maintain habitats on a number of wildlife refuges throughout the state (M. Horney, personal communication, June 9, 2025).

Wildfire Impacts to Rangeland Vegetation/Type Changes

Chaparral

Chaparral in California is typically adapted to a fire regime characterized by infrequent high severity crown fire, wherein most plants are top-killed, and the dominant shrub species regenerate by resprouting from surviving underground material and/or from fire-stimulated seed germination. Ten or more years between high severity fires are required for regenerating chaparral species to mature and produce new seed crops (Keeley and Brennan 2012), although optimal fire return intervals are likely 30–90 years (Van de Water and Safford 2011). Obligate seeding shrubs (those with no resprouting ability) may fail to regenerate under short fire return intervals (Grupenhoff and Safford 2024, Keeley and Brennan 2012), thus opening up space for non-native annual grasses and forbs to colonize sites post-fire (Syphard et al. 2019). For species with the ability to resprout, shorter intervals between fires can also increase fire-caused mortality, with associated increased risk of invasion by non-native annuals (Grupenhoff and Safford 2024). For example, non-native annual grass and herbaceous plants recovered more quickly than native plant communities after the 2018 Woolsey Fire in Los Angeles and Ventura counties (Stork et al. 2023).

A potential consequence of repeated short intervals between fires in chaparral is type conversion to vegetation dominated by non-woody plants, particularly non-native annual grasses and forbs. This type conversion may happen gradually over the course of several fires as post-fire regeneration of the native woody vegetation declines incrementally and cover of non-native annual grasses increases (Syphard et al. 2019). This in turn may elevate the probability of a subsequent short-interval, large-area fire, further perpetuating the

6 *The fresh emergent wetland vegetation type has one of the lowest percentages of intactness of all the California Wildlife Habitat Relationship (CWHR) types, indicating high levels of spatial discontinuity or fragmentation of habitat (see Chapter 10, Wildlife Habitat).*

transition to non-native annual vegetation dominance (D'Antonio and Vitousek 1992).

Prior to widespread Euro-American settlement in California, Indigenous people used fire to manage the encroachment of chaparral into native grass/forblands (Anderson and Keeley 2018), especially along the coast and in the Coast Ranges. This amounted to intentional maintenance of early seral vegetation patches within a broader landscape mosaic of multiple vegetation types. Indigenous people frequently burned the surroundings of village sites, travel corridors, and areas where food and materials were enhanced by fire, creating a patchy mosaic of grass/forblands, scrublands, chaparral, and sometimes woodland or forest (Anderson and Keeley 2018). Spanish and Euro-American colonists and settlers likely maintained many of the open grass/forbland areas through intentional grazing (Keeley and Fotheringham 2003). This practice also introduced non-native annual grasses, such that today—when native chaparral in California is repeatedly disturbed via burning or livestock grazing—the resulting plant community largely consists of ruderal non-native species (Syphard et al. 2018).

Grasslands

California's grasslands likely burned frequently prior to Euro-American settlement due to intentional use of fire by Indigenous people and, in some areas, also due to lightning. Estimates of fire frequency in grasslands are difficult to make due to the lack of a fire scar record, but multiple lines of evidence point to likely fire frequencies of one to 15 years (Bartolome et al. 2007, Greenlee and Langenheim 1990, Lightfoot and Parrish 2009).

What are referred to as grasslands today were actually diverse mixtures of perennial and annual grasses and abundant forbs; today these areas are typically dominated by non-native annual grasses introduced from Europe via livestock. Wildfire and prescribed fire in these systems can reduce thatch and create soil and surface temperature conditions more conducive to native and non-native forb germination (Reiner 2007), but the relative increase in forbs versus annual grasses is small and generally disappears within a few years after fire (D'Antonio et al. 2002).

Annual wildfire area in California grasslands has been linked to prior-year precipitation, likely via increased biomass and therefore fuel loading (Keeley and Syphard 2017). Predictions of the future risk of wildfire in grassland systems (where wildfire activity is linked to precipitation) are more difficult than for forests (where wildfire risk is more related to temperature) because precipitation is more variable than temperature in global climate models (Westerling and Bryant 2007).

Desert Ecosystems

Similar to other rangeland vegetation in California, the vegetation of the state's three major deserts (Great Basin, Mojave, and Colorado or Sonoran), along with their fire regimes, have been altered by the introduction of non-native annual grasses and by climate change. The interaction between these two drivers of change is resulting in more frequent, hotter, and larger wildfires (van Etten et al. 2022). Localized differences in desert fire regimes correlate positively with elevation due to its association with vegetation, topography, and lightning occurrence (Brooks et al. 2018).

Introduced annual grasses, in particular cheatgrass and red brome, have increased fire frequency and fire size within portions of California's deserts by adding a continuous fuel source between otherwise sparse, and largely fire-sensitive, desert vegetation (Balch et al. 2013, Brooks and Matchett 2006, Syphard et al. 2017). The effects and magnitude of these changes vary locally across the diverse topography, climate, and vegetation in California's deserts. Fire occurrence is associated with precipitation in preceding years due to increased biomass production of primarily non-native species, especially in lower and middle elevations with otherwise sparse vegetation (Brooks et al. 2018).

Use of Livestock to Address Wildfire Concerns

As with forestland, there has been a significant increasing trend in area of rangeland burned throughout the Western U.S. and in California (Li et al. 2021; see Chapter 4, Wildfire). The increasing rangeland area

burned in the state is due in part to large increases in cover of non-native grass species. Examples include the 2020 Dome Fire (43,273 acres) and the 2023 York Fire (93,078 acres), which killed thousands of iconic Joshua trees. Additionally, invasive grasses have increased fire risk and fire frequency in Southern California for the coastal sage scrub vegetation type (Bell et al. 2009, Lambert et al. 2010). This is further amplified by increasing aridity in a warming climate, especially when hot temperatures follow periods of high precipitation and growth of annual plants, thus leading to rapid drying and increased fuel amount and flammability (Swain et al. 2025).

Rangeland wildfires on grazed lands reduce annual grassland forage for cattle, other domestic livestock, and wildlife, as well as having substantial effects on other vegetation types, human lives, and property. To address the increased risk of wildfire on rangelands, there is growing interest in using grazing as a management tool (Roche and Macon 2025). In general, well-managed grazing can be beneficial for reducing fire risk, but it requires selecting the correct type of livestock for the vegetation type present and having the correct treatment timing and stocking levels. Factors to consider when utilizing grazing for fuel reduction include risk to animals from predation, vegetation toxicity, and potentially reduced livestock performance or gains. Also, a single grazing entry will not eliminate undesirable species and fuels in a similar manner to herbicides and mechanical removal, and repeated treatments will be required (UC ANR 2025), as with most (if not all) other fuels treatments.

Livestock grazing impacts wildfire fuels on two timescales: over a growing season, it reduces herbaceous fine fuels on rangelands, and over multiple years to decades, it produces long-term changes in species composition, such as inhibiting shrub and tree encroachment (e.g., coyote brush [*Baccharis pilularis*]). Grazing has been shown to be effective in reducing fire risk in grasslands, shrublands, and woodlands (Siegel et al. 2022, Starrs et al. 2024). It can also improve the effectiveness of fire suppression efforts by decreasing flame length, rate of fire spread, and fire severity, and by improving emergency responder access and safety (Davies et al. 2022, Ratcliff et al. 2022). For example, in Napa and Sonoma counties, Starrs et al. (2024) estimated that cattle grazing reduces average burn probability by 45% (from 9.9% to 5.4%) compared to ungrazed conditions, and by 82% on high priority landscapes identified by CAL FIRE. Similarly, grazing was found to reduce annual burn probability in north Bay Area and Central Coast rangelands. At lower cattle stocking levels in the Central Valley and Sierra Nevada foothills, however, burn probability was modeled to increase with grazing intensity, illustrating that the impact of grazing on burn probability can vary by region and vegetation type (Siegel et al. 2022), and very likely management tactics.

Grazing on rangelands is one of the few tools available that can be applied at the scale needed to have significant effects on wildfire behavior (Figure 2.6). Currently, however, only about half of California's rangelands are grazed by livestock. Therefore, grazing by livestock must be utilized in conjunction with other fuel management approaches, particularly prescribed and cultural fire. Grazing can be particularly valuable in high priority areas in and around the wildland urban interface (WUI), where use of prescribed fire may pose an excessive risk to structures (Starrs et al. 2024, Roche and Macon 2025). It can also complement prescribed and cultural fire by reducing fine fuels before burns and maintaining appropriate fuel loads between burns.

In addition to large-scale cattle grazing, prescribed grazing/herbivory or "targeted grazing" is being actively utilized by numerous public entities to attain specific management goals, such as to reduce fuels and maintain or improve habitat for native plants.[7] Targeted grazing is often accomplished with sheep or goats (Taylor 2006), although cattle may also be utilized, with payment often to livestock owners for fuel treatment reduction work. Grazing usually occurs during a specified season and for

7 *See Chapter 9 (Water Resources) for additional information related to prescribed grazing.*



Figure 2.6. Sheep grazing in grassland vegetation near Ojai, California. Photo: Kristina Wolf, Board of Forestry and Fire Protection.

a short duration. It is a valuable tool to establish and maintain strategic fuel breaks, particularly when shrub cover is below 18% (Schachtschneider et al. 2024).

However, targeted grazing has a relatively high cost and generally treats small areas; to date its use has been limited in scope in California (<100,000 acres per year) (S. Barry, personal communication, June 7, 2025) (Huntsinger and Barry 2021).

Prescribed herbivory is a covered activity under the California Vegetation Treatment Program (CalVTP) for use in the eligible treatable landscape for creating fuel breaks, managing vegetation in the WUI, and promoting ecological restoration. One example of prescribed herbivory is a Santa Barbara County Fire Safe Council project that will treat 26 areas covering 3,000 acres, strategically located adjacent to transportation corridors and WUI areas, by 2026 (SBCFSC 2024). The draft California Wildfire and Forest Resilience Task Force (WFR Task Force) 2026 Landscape Resilience Action Plan includes prescribed grazing for wildfire prevention (see item 1.39) (WFR Task Force 2026).

Also, the Board of Forestry and Fire Protection's (BOF) Range Management Advisory Committee (RMAC) is in the process of finalizing a grazing agreement template for state agencies to use with prescribed/targeted grazing projects. That agreement comes with guidelines on developing and refining grazing management plans for state lands, with chapters that address specific land treatment practices for invasive weeds, fuels, wildlife habitat conditions, etc. It addresses best practices and monitoring to evaluate the effects of grazing for achieving land management objectives (M. Horney, personal communication, June 9, 2025).

Water Quality Impacts from Grazing

Grazing impacts can be significant to water resources on rangelands, causing soil erosion, soil compaction, loss of streambank stability, and degraded water quality (Belsky et al. 1999). Threats to water quality include increased sediment, pathogens and bacterial contamination, and nutrients. Microbial and nutrient pollution are often considered significant issues, since stream pathogenic bacteria pollution from livestock grazing can present a risk to both human health and ecological

conditions (Roche et al. 2013). In general, rangeland streams have been found to be in poorer condition than forestland area streams using the California Stream Condition Index (CSCI), which evaluates stream health by comparing benthic macroinvertebrate species present against expected species composition at reference sites. CSCI data averaged from 2000 to 2022 reveal that approximately 30% of grazed rangeland streams were likely intact (i.e., good condition) and 70% were possibly, likely, or very likely altered (see Chapter 9, Water Resources, ⓘ9.1).

Impacts of grazing depend on the season of use, intensity, and type of livestock, and studies have reported mixed results in terms of the effects on water quality. Cattle grazing on the Stanislaus National Forest in the Sierra Nevada was found to cause substantial fecal coliform pollution, violating state and federal regulatory standards for recreational contact (Myers et al. 2017). An earlier study of 19 streams located throughout California with grazing found concentrations of nutrients to be low relative to water quality standards, but fecal coliform commonly exceeded recommended standards (UC Davis 2026). In contrast, other studies have found cattle grazing and recreation to be compatible with water quality standards in California. A study of grazing on 12 national forest grazing allotments throughout Northern and Central California found that over 90% of water samples on grazed lands were under U.S. Environmental Protection Agency-designated benchmarks for fecal bacteria and that nutrient concentrations were at least one order of magnitude below levels of ecological concern (Roche et al. 2013). Additionally, water quality impacts from cattle grazing were compared with those from recreation and rural residences in three watersheds in the Sierra Nevada and Cascade Range. Fecal bacteria were lowest at recreation sites, followed closely by grazing sites, and highest at sites associated with rural residences (Derose et al. 2020b).

Rangeland practices are not regulated under a comprehensive system similar to the California Forest Practice Rules that apply to non-federal forestlands. Water quality regulation for ranchers is done by the Regional Water Quality Control Boards (RWQCBs) and there are no statewide regulations on grazing aside from the State Water Resources Control Board's (SWRCB) Vegetation Treatment General Order that includes prescribed grazing in line with the CalVTP. The SWRCB and RWQCBs are developing a new, non-regulatory guidance document on livestock grazing management to replace the voluntary 1990s era California Rangeland Water Quality Management Plan. The federal Clean Water Act, under the Total Maximum Daily Load (TMDL) process, provides a regulatory approach to take corrective action when necessary. There are 20 grazing-related TMDL listings in the state, spread across five of the nine Water Quality Regions (SWRCB 2023).

Improved range management practices have been shown to be effective in protecting water quality and human health. Implementation of grazing best management practices (BMPs), including wildlife-friendly fencing to eliminate or control cattle access,[8] hardened stream crossings, and off-stream drinking water systems were found to reduce fecal coliform concentrations in coastal Marin County (Lewis et al. 2019, Voeller et al. 2021). Additionally, reducing livestock densities and residence times can lower nutrient and microbial pollution (George et al. 2011) and improve mountain meadow conditions (Oles et al. 2017). Limiting winter use (i.e., via seasonal grazing) can limit sediment inputs. Riparian health in cattle grazed stream reaches, as indexed with benthic macroinvertebrate metrics, was found to improve where managers implemented livestock distribution practices in the Sierra Nevada and Cascade Range (Derose et al. 2020a).

8 *Virtual fencing is increasingly being used in California rangelands. It uses GPS (Global Positioning System) collars to contain livestock without physical fences. Ranchers set virtual boundaries across their pasture from a computer, which are transmitted to the collars via cellular signal. The collar emits audio cues, and if needed electric pulses, to keep the animal within the boundary (UCCE 2025).*

Oak Regeneration

California has approximately 6.2 million acres of hardwood woodlands (Gamen and Firman 2008), all considered rangelands, of which about 80% are privately owned (Figure 2.7).[9] Concerns related to lack of adequate regeneration of oak woodland species in California are well documented for blue oak (*Quercus douglasii*), valley oak (*Q. lobata*), and Engelmann oak (*Q. engelmannii*), all of which are deciduous white oaks (McCreary 2001). Additionally, coast live oak (*Q. agrifolia*) may have inadequate regeneration in certain areas. Cattle and sheep overgrazing, rodent activity, and competition from invasive European annual grasses have been shown to adversely impact oak regeneration (Hart 2020). Burning is generally not a significant factor for regeneration with low-moderate fire severity in the absence of grazing (McCreary 2011). In general, the literature suggests that many different factors are affecting oak regeneration and they are often site-specific (McCreary 2004).

Cattle and sheep can consume acorns and browse and trample seedlings. The severity of browsing damage is related to both the intensity and timing of grazing. Excessive trampling by grazing livestock can increase soil compaction and decrease soil organic matter, lowering acorn survival. Extensive research has been done related to minimizing grazing impacts on oak regeneration, and approaches include modified grazing practices such as utilizing lower stock densities (McCreary and George 2005). Rodent activity can also significantly impact oak regeneration. Several different species of rodents eat acorns and oak roots, including voles, western gray and California ground squirrels, deer mice, and pocket gophers. Seed predation and herbivory by small mammals (gophers and ground squirrels) were found to significantly reduce oak seedling recruitment in Santa Barbara County (Tyler et al. 2002).

Fortunately, most oaks sprout after intense fire or harvesting, with sprouting more common for live oaks than deciduous oaks, for smaller diameter stumps, and for trees in moister areas (McCreary 2001). Grazing may suppress deciduous oak seedlings and sprouts, while the more prolific evergreen oak sprouts have been shown to be better able to survive grazing pressure (Merenlender and Brooks 1998). Successful artificial regeneration methods are well known, and tree shelters placed around seedlings have been shown to provide protection from browsing (McCreary 2011, McCreary and Tecklin 2005). Modified grazing practices and artificial regeneration are both important approaches for improving oak regeneration in California (McCreary and George 2005).



Figure 2.7. Oaks and annual grasslands in spring at Crane Creek Regional Park, Sonoma County. Photo: CAL FIRE.

Landowner Assistance

Technical assistance programs and incentive programs promote sustainable rangeland management and support ecosystem services. Resource Conservation Districts (RCDs) in particular play a crucial role in

9 *Broader oak-related concerns are addressed in several other Assessment chapters. Oak loss from forest pests, including from the goldspotted oak borer, Mediterranean oak borer, and Phytophthora ramorum (cause of sudden oak death), are covered in Chapter 5 (Forest Pests). Chapter 10 (Wildlife Habitat) discusses the protected status of oak woodlands from conversion and the intactness of oak woodland habitat types. The impacts of climate change on oak woodlands are addressed in Chapter 7 (Climate Change) and Chapter 10 (Wildlife Habitat). Type conversion of conifer forestland to oak woodlands from disturbances is addressed in Chapter 1 (Resilient Forests), Chapter 10 (Wildlife Habitat), and Chapter 9 (Water Resources). Conifer encroachment into oak woodlands is addressed in Chapter 1 (Resilient Forests) and the fire return interval departure for oak woodlands is covered in Chapter 4 (Wildfire).*

rangeland conservation efforts. These districts are responsible for assessing local conservation needs and subsequently developing priorities and programs to meet these needs. RCDs provide a range of services, including education and outreach, demonstration projects, and the promotion of BMPs. Moreover, they can serve as a conduit for funding to support various types of projects, including those aimed at erosion control, fuels reduction, water conservation or quality improvements, and watershed plans.

The NRCS administers Farm Bill programs that support the development of fencing and watering infrastructure. These programs not only enhance grazing management but also reduce soil erosion. They include the federal Environmental Quality Incentives Program (EQIP), the Conservation Stewardship Program (CSP), and the Agricultural Conservation Easement Program (ACEP). Additional programs available to ranchers include the federal Wildlife Habitat Incentives Program (WHIP), and state-funded programs including the Rangeland, Grazing Land and Grassland Protection Program (California Wildlife Conservation Board), and CAL FIRE's California Forest Improvement Program (CFIP). These programs are instrumental in promoting responsible land management and conservation practices across the state. Table 2.4 provides a list of various agencies and organizations that provide programs to assist rangeland owners.

In addition to agencies and organizations, several online webtools are now available to assist rangeland owners, including a tool to match livestock owners with landowners seeking graziers (UC ANR 2020) and the suite of spatial data products available through the Rangeland Analysis Platform (Allred et al. 2021). UCCE also provides education and outreach to assist ranchers, and RMAC advises state agencies on rangeland resource issues pertinent to ranchers. Additionally, the BOF maintains a list of active Certified Range Managers on their website who can assist landowners in finding valuable range-related resources.

Recent actions by the current federal administration have led to significant cuts and freezes in landowner incentive programs, particularly those funded through the Inflation Reduction Act. This includes payments for EQIP and CSP.

Table 2.4. Selected landowner assistance programs for rangelands

Agency or Organization, Program(s)		Assistance Provided
Federal Programs	**Natural Resources Conservation Service (NRCS)**	
	Conservation Stewardship Program (CSP)	Payments for conservation practices
	Environmental Quality Incentives Program (EQIP)	Cost-share for protecting/enhancing ecosystem services
	Conservation Innovative Grants (CIG)	Grants for innovative watershed, regional or state conservation projects
	Agriculture Conservation Easement Program (ACEP)	Funding for conservation easements on working farms and ranches
	Wildlife Habitat Incentives Program (WHIP)	Technical assistance and cost-share program for development of wildlife habitat plans
	Farm Service Agency	
	Emergency Conservation Program (ECP)	Funding and technical assistance to repair disaster damage and for drought relief and water conservation projects
	Farm Loan Programs	Loan programs to help farmers and ranchers get financing to maintain a family farm
	U.S. Fish and Wildlife Service	
	Partners for Fish and Wildlife Program	Technical and financial assistance for wildlife habitat improvement

Data Source: CAL FIRE.

Table 2.4. Selected landowner assistance programs for rangelands		
State Agencies, Departments, or Boards	**California Department of Forestry and Fire Protection (CAL FIRE)**	
	California Forest Improvement Program (CFIP)	Funding for forestland conservation practices/fish and wildlife habitat improvement
	Vegetation Management Program (VMP)	Funding for treatments such as prescribed fire
	California Forest Legacy Program	Funding for conservation easements associated with working forest and rangelands
	California Department of Food and Agriculture	
	State Water Efficiency and Enhancement Program	Funding for water conservation measures
	California Department of Conservation	
	Working Lands and Riparian Corridors Program	Grants to restore or enhance working lands and riparian corridors
	Sustainable Agricultural Lands Conservation (SALC) Program	Purchase of agricultural conservation easements
	Resource Conservation District (RCD) Financial Assistance Program	Funding to increase RCD capacity
	California Department of Fish and Wildlife	
	Private Lands Incentive Programs	Technical assistance for waterfowl habitat, wetlands, and nesting bird habitat improvement
	Sierra Nevada Conservancy (SNC)	
	Various grant programs	Grants for planning, restoration, acquisitions and easements
	California Wildlife Conservation Board	
	Rangeland, Grazing Land and Grassland Protection Program	Program to protect rangelands with conservation easements
Other Programs	Ducks Unlimited	Funding to enhance wetlands and increase waterfowl populations
	National Fish & Wildlife Foundation Conservation Partners Program	Funding to maximize benefits of Farm Bill programs on working lands
	BOF Range Management Advisory Committee (RMAC)	Maintenance of a list of Certified Range Managers (CRMs), advise on rangeland resource issues
	University of California Cooperative Extension (UCCE)	Education, technical assistance for ranchers
	California Rangeland Trust	Help ranchers partner with funders to protect working lands through conservation easements
	American Farmland Trust	Conservation easements for agricultural lands
	California Grazing Lands Coalition	CA Rangeland Conservation Coalition (CRCC) project to find solutions to issues on grazing lands
	California Association of Resource Conservation Districts	Support California's 96 Resource Conservation Districts, which provide technical assistance
	Local government/special districts, conservation organizations	Technical assistance, easements, and acquisitions

Data Source: CAL FIRE.

OPPORTUNITIES

Opportunities to promote rangeland conservation, restore or enhance ecosystem services, keep rangelands working, and support the solvency and stability of the state's livestock businesses include:

- Support funding to agencies that have active programs that purchase conservation easements on private rangelands.

  - Parcels that are large in size, contain rare species or habitats, support other important ecosystem services, and/or provide continuity between other conserved lands are high priorities for conservation easements.
  - There are multiple non-governmental organizations (NGOs) who can partner with agencies and landowners to facilitate development, funding, monitoring, and enforcement of easements on rangelands.
  - Easements typically restrict future development, thereby protecting working rangelands, while also providing property tax relief to the rangeland owner.
  - Easements should allow flexibility for landowners to manage their lands for ecosystem health and resilience using an adaptive management and monitoring framework.
  - Easement endowments should fund resource management activities that protect habitats and ecosystem services in perpetuity.
- Incentivize rural land use planning that considers rangeland conservation and economic sustainability at a landscape scale.
- Support ecological and economic sustainability of rangelands by continuing to honor Williamson Act contracts in cases where there is a clear conservation and/or economic benefit.
- Provide support for organizations that work towards rangeland sustainability goals via finding common ground between conservation and economic interests.
- Encourage strategic land and grazing planning.
  - Coordinate scheduling with local ranchers of available proximate grazing lands, particularly among governmental and private conservation land managing entities.
  - In lieu of charging grazing fees, consider paying livestock owners for ecological services rendered (e.g., to thin out non-native graminoids and foster native forbs, in units like Carrizo Plain National Monument).
  - Plan timing of grazing to strategically reduce grassland invasives when they are palatable to livestock.
- Provide assistance to ranchers in bringing livestock to market.
  - Augment major livestock processing facilities to lower the distance and costs of shipping to markets for livestock owners.
  - Work to sustain saleyards (i.e., auction markets where cattle are bought and sold) throughout the state that are vital for moving beef cattle from rangelands to market.
- Support diversified rancher income and niche products.
  - Promote marketing of locally raised organic and grass-fed beef as demand in urban areas of the state is growing for these products. Specialty products generally command higher prices, which are attractive to livestock producers and offset the accompanying increased management investments.
  - Where environmentally acceptable, support solar and wind energy installations on ranch lands.
  - Continue to support funding for increased targeted grazing/prescribed herbivory to reduce fuel loads, improve wildlife habitat, or manage invasive weed species, such as the local assistance grant program being established by RMAC following adoption of SB 675 in 2024 (Limón 2024).
- Provide grant opportunities to ranchers needing to maintain and upgrade watering infrastructure to support livestock grazing and install wildlife friendly fencing for protecting water quality.

- On public lands where grazing can be conducted without significant adverse impacts to ecosystem values, utilize grazing agreements and targeted grazing contracts that are economically viable to graziers and beneficial to ecological goals.
    - Ensure pricing of public land grazing fees is fair to the public and graziers, currently calculated under the PRIA formula.
    - Ensure public lands grazing agreements allow for flexible and adaptive management based on variable conditions (e.g., forage availability, predator presence, access to water) and are of sufficient duration for investment in infrastructure improvements to be economically feasible for graziers.
    - Incentivize multi-year targeted grazing contracts to increase the economic feasibility to high-quality operators and to increase the quality of targeted grazing outcomes.
    - Expand grazing opportunities on state and other non-federal public lands to support conservation objectives.
- Encourage ranchers to manage their lands in ways that contribute to climate change mitigation by promoting carbon sequestration (e.g., using managed grazing that controls grazing intensity and timing, allowing vegetation to recover and carbon to be stored in range soils).
- Assist with repurposing of fallow lands (e.g., in the San Joaquin Valley) to restored native vegetation and/or to ranchlands for grazing with continued implementation of the Sustainable Groundwater Management Act.
- Restore funding to programs to reduce the conflicts between gray wolves and livestock and provide economic compensation to ranchers for confirmed losses. Such state support could lower livestock losses while reducing antipathy towards the increasing presence of wolves.
- Restore native ungulate habitat by actively managing land to support populations of wild large mammals such as deer and elk, which may reduce wolf pressure on livestock and would have numerous other benefits to wildlife, native plants, and other ecosystem services.
- Incentivize land use practices that reduce the cover of non-native species and increase resistance to frequent wildfire on rangeland vegetation types that are especially sensitive to frequent fire (such as desert shrublands and chaparral).
- Recognize the risks of too-frequent fire (including wildfire and prescribed fire) and other disturbance types (e.g., grazing and mechanical fuels reduction) to native vegetation recovery in chaparral and desert shrubland ecosystems and incorporate such risks into vegetation management and fire protection planning.
- Continue to support technical and financial assistance programs.
    - Support ranching-related workforce development, training, and education, including online tools, to assist ranchers.
- Support work to achieve California's nature-based solutions climate targets for rangelands.
- Integrate prescribed grazing consistent with regional plans being developed by RMAC under SB 675 and the WFR Task Force Action Plan goals.

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