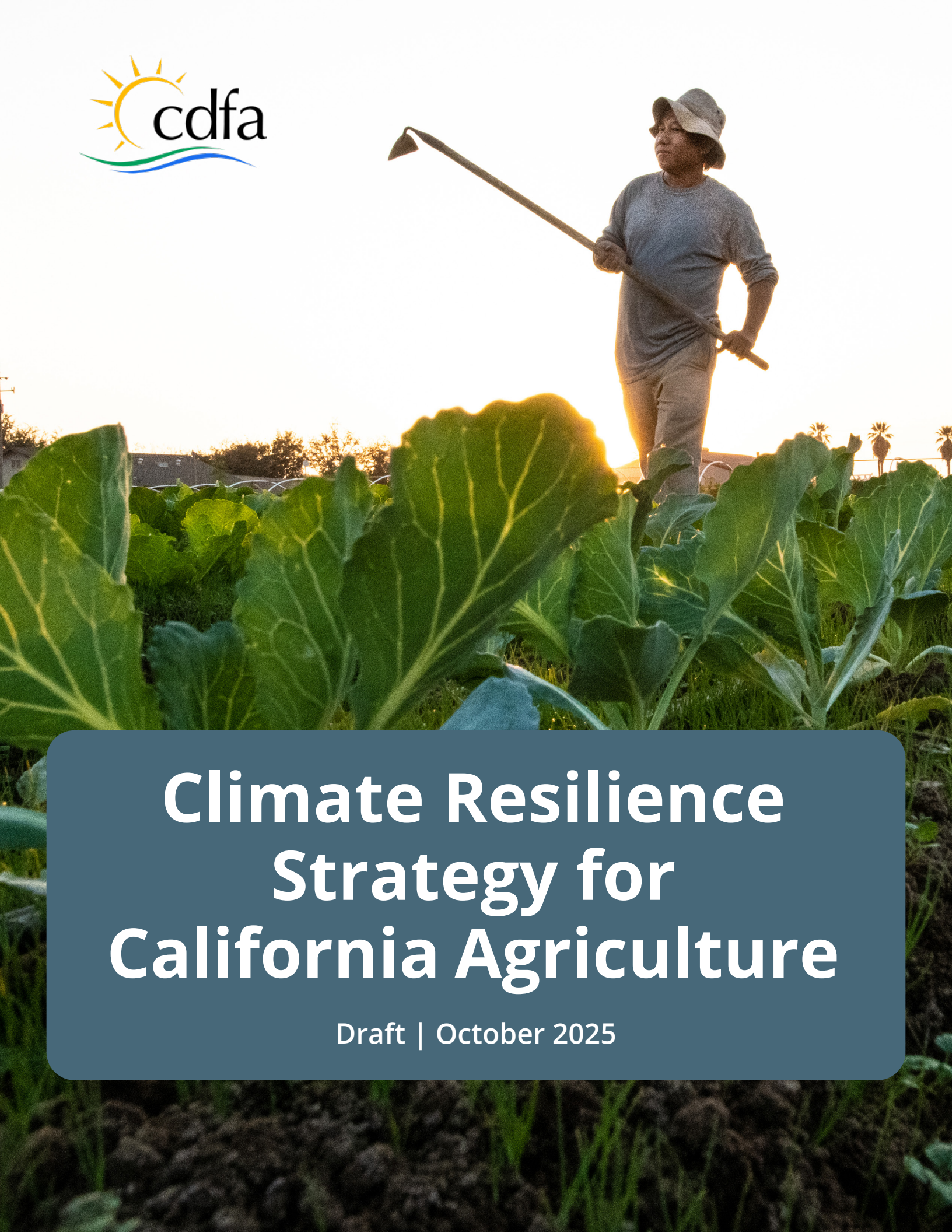


Climate Resilience Strategy for California Agriculture

Draft | October 2025

Forward from the Secretary

[To be added]

Purpose and Need

The California Food and Agriculture Code defines "agriculture" as "the art and science of cultivating the soil, producing crops, and raising livestock; and the preparation and marketing of the resulting products." In California, this can mean anything from the cultivation of wild plants and animals by Indigenous land stewards to urban farms to small- and large-scale rural operations.

Climate change is affecting all aspects of agriculture, and protecting our food system requires a concerted response.

Every few years, the State Board of Food and Agriculture develops a set of priorities for the agricultural sector, guided by input from community partners including farmers, ranchers, brand leadership, academia, nonprofits, and others. These sets of priorities are gathered into visioning documents known as "Ag Vision," which recognizes that California farmers and ranchers are essential to the fabric of our state and identifies key areas of focus for CDFA. The most recent document, known as Ag Vision 2030, is intended to set the focus for this decade and identifies as the number one priority of California agriculture the need to "Foster climate-smart, resilient, and regenerative food systems." This top priority recognizes that maintaining the abundance of California's agricultural system requires ensuring that we foster resilience in the natural systems that support farms and ranches, the infrastructure that has allowed us to develop one of the most efficient, safe and productive food systems in the world, and in the farming and ranching communities doing the work to feed our planet.

There is work to do to achieve this vision. This Climate Resilience Strategy for California Agriculture (RSA) sets out to capture the myriad of efforts underway and to identify the additional needs to ensure California agriculture not only thrives in the face of climate change but is part of the solution. These efforts will build resilience for the future and help ensure that California agriculture stays a premiere industry in the world. All work must center and uplift the diversity of our state's farmers and ranchers, invest in tools and innovations, and cultivate healthier land, water, air, and communities. The costly impacts of climate change to our agricultural communities and their livelihoods drive urgency in this work, reinforcing the need to integrate climate resilience into the vision for California Agriculture.

Table 1: Ag Vision 2030

AG Vision 2030: California agriculture is a growing opportunity – for farmers and ranchers, farmworkers, individuals and communities – and is demonstrating leadership on climate action.
Strategic Priorities
Foster climate-smart, resilient, and regenerative food systems—Support efforts that improve agriculture's effect on the environment, encourage wise stewardship of water and natural resources, eliminate waste and are regenerative, e. g., practices that enhance ecosystems and improve the land.
Build healthy, local communities—Invest in local and socially disadvantaged communities—with emphasis on the diverse populations who often work at and with, and live adjacent to California farms—while supporting equity and the California economy through nutritious, California-grown farm products.
Drive next-generation talent and tools—Support workforce development programs aimed at attracting, supporting, and providing high-quality jobs and leadership opportunities for a diverse agricultural workforce, while also driving research and real-time feedback from farmers and ranchers to stimulate and accelerate innovation to solve problems and build opportunities.
Enhance understanding of agriculture—Serve as the voice for California farmers and ranchers within the administration and with other agencies and support the engagement of urban and rural audiences.
Collaborate on smarter regulations—Work with other state agencies, stakeholders, and the administration to explore and support smarter regulations that rethink ways to both meet public obligations and support farmers with simplified, less expensive regulatory compliance, reporting, and implementation.

State Agencies Working Towards a Resilient Food System

The California Department of Food and Agriculture (CDFA) contains multiple divisions and programs to serve Californians by regularly promoting and protecting a safe, healthy food supply, and enhancing local and global agricultural trade through efficient management, innovation, and sound science, with a commitment to environmental stewardship.

However, many state agencies are charged with helping to monitor and manage the water, land, human health, infrastructure, and natural resources needed to support California's agricultural industry. As such, this document will highlight not only the work and possible opportunities by and for CDFA, but also many other state agencies and partners whose people and programs are contributing to building a resilient agricultural food system. Resilience requires a coordinated effort, and this document is a step towards fostering the collaboration needed for building resilience in California agriculture.

Strategic Framework

Below is the Strategic Framework that highlights the major elements described in the following chapters. The Framework provides a high-level overview of three key organizational elements: Objectives, Goals, and Equity Principles.

- **Key Objectives –** These are the broad, long-term outcomes that the Strategy aims to achieve, organized into three primary pillars with key objectives under each pillar. The key objectives are the RSA's chapters.
- **Goals –** These are the high-level tenets of the Strategy. All actions listed in the document support at least one of the Goals.
- **Equity Principles –** Equity is a guiding element of the Strategy, with six principles guiding priorities and implementation.

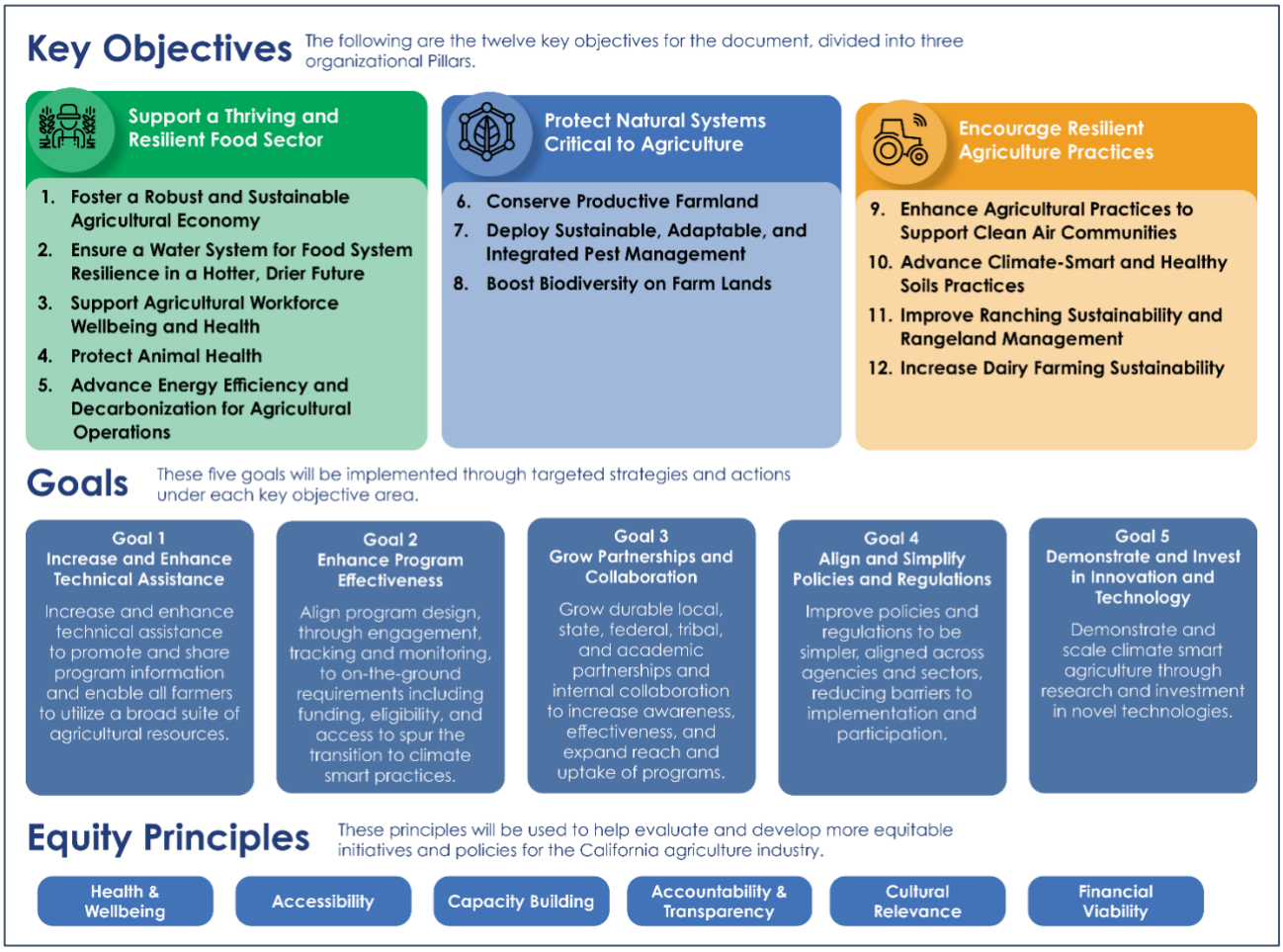


Figure 1: RSA Framework

Plan Organization

The Climate Resilience Strategy for California Agriculture, or RSA, is organized by three pillars, as outlined above in Figure 1 above. The twelve Key Objectives are organized within these pillars and encapsulate the overall outcomes that the RSA aims to work towards.

The first pillar, *Support a Thriving and Resilient Food Sector*, addresses operational considerations, workers, the economy, and the elements that are essential to an economically sustainable and adaptable industry in the face of climate impacts.

The second pillar, *Protect Natural Systems Critical to Agriculture*, concerns the protection and enhancement of the natural systems that may be impacted by agricultural practices and/or support a vibrant agricultural industry.

The third pillar, *Encourage Resilient Agricultural Practices*, considers how to inspire and encourage new approaches, innovations, and behaviors that will help increase long-term resilience for farmers and the industry overall.

Within each of the pillars are key objectives, each representing a unique aspect of the California agricultural system. As agriculture is an expansive topic, the authors acknowledge that there may be topics that span multiple pillars. For example, there is a chapter focused on water in the *Support a Thriving and Resilient Food Sector* pillar, though we know that water is an integral part of the agricultural system as a whole. Each chapter includes:

1. Context: Summarizes high-level background information and overall climate-related challenges relating to each chapter topic.
2. Strategies and Actions: Summarizes information related to each action, including relevant existing programs and policies.
3. Case Studies: Share relevant case studies in sidebars.
4. Implementation Table: At the end of each chapter, an implementation table with actions and lead implementer is included.

Goals

While the strategies and actions throughout the RSA are organized by chapter, they fit within five goal categories.

1. Increase and Expand Technical Assistance
2. Enhance Program Effectiveness
3. Grow Partnerships and Collaboration
4. Align and Simplify Policies and Regulations
5. Demonstrate and Invest in Innovation and Technology

Engagement Process

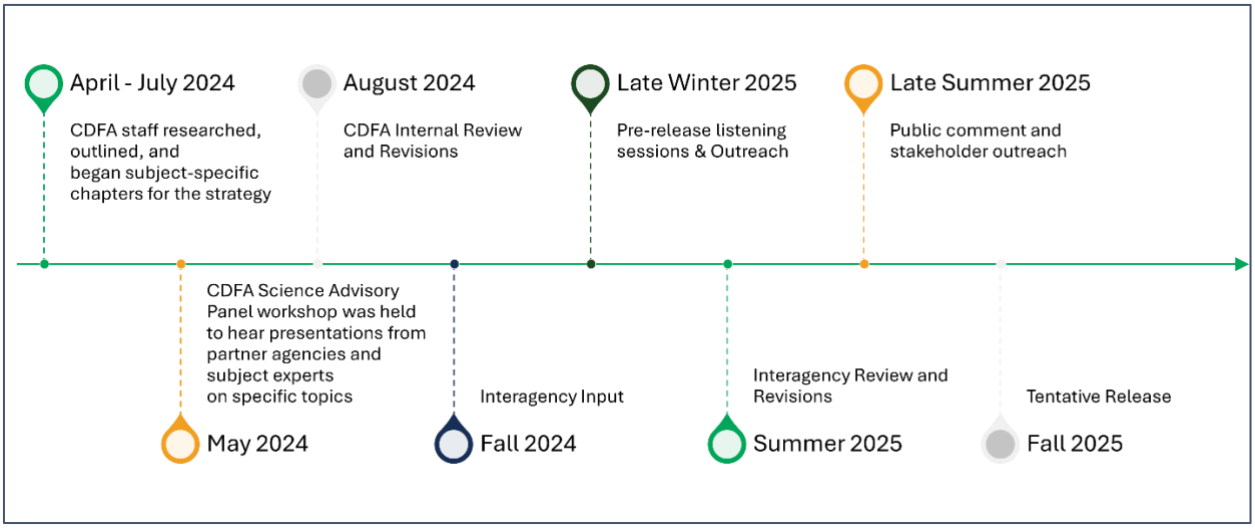


Figure 2: RSA Creation Timeline

This Strategy was informed by many voices across the state and throughout the agricultural system. CDFA staff initially drafted this Strategy after holding information-gathering sessions during the spring of 2024. In addition, CDFA staff interviewed colleagues both within the department and at other state agencies, gave presentations and solicited feedback from our Environmental Farming Act Science Advisory Panel (a public body consisting of farmers, scientific experts, and representatives from multiple state agencies), and workshopped the document internally with the CDFA Climate Working Group. These drafts built on previous efforts by CDFA to gather and synthesize climate impacts and needs by its interested parties, including the Climate Change Consortium for Specialty Crops and Farmer and Rancher-Led Climate Change Solutions.

Once an initial draft was developed, CDFA held public listening sessions, sharing the major elements of the Strategy and gathering input. CDFA also held small listening

sessions with several agricultural groups that represented a diversity of voices within the agricultural industry. The feedback received during this period was integrated into the document.

This initial draft will include a public review period, during which listening sessions, including targeted sessions for reaching underserved groups, will be hosted to target information gathering. A final draft will be created after incorporating the public review and will then be reviewed by state agencies before publication.

Serving the Diversity of California Farms and Farmers

There are more than 400 commodity crops grown across California, including a significant portion of all fruits, vegetables, and nuts for the United States. At the time of this writing, approximately 63,134 farms are located in California, 90 percent of which are family owned. Most California farms are small compared with those in other states: two-thirds of California farms average 383 acres and bring in less than $150,000 gross cash income per year.[1] At the heart of the agricultural industry are California's farmers, ranchers, and farmworkers. More than 40 percent of farms in California rely on hired farm laborers. In 2023, just over 400,000 farmworkers worked in California agriculture.[2]

Throughout all of the state's work is a focus on improving the lives of hardworking farmers, ranchers, and farmworkers. This is achieved by ensuring programs, policies and support is accessible to all who need it. Starting with the Farmer Equity Act in 2017, the CDFA has worked to ensure the diversity of California's farmers and ranchers have the tools and resources needed to thrive and be resilient.[3]

[1] United States Department of Agriculture, National Agricultural Statistics Service. (2024). 2022 Census of Agriculture United States summary and state data: Volume 1, Geographic area series, Part 51 AC-22-A-51. United States Department of Agriculture. https://www.nass.usda.gov/Publications/AgCensus/2022/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

[2] California Employment Development Department. (n.d.). Agricultural Employment in California. State of California. https://labormarketinfo.edd.ca.gov/data/ca-agriculture.html#Maps

[3] California Department of Food and Agriculture. (2020). 2020 Report to the California Legislature on the Farmer Equity Act (Publication No. 2020). California Department of Food and Agriculture. https://www.cdfa.ca.gov/farmerresources/pdfs/2020FarmerEquityReport.pdf

Tribal Stewardship and Cultivation

While only three percent of the state's farms are managed by American Indian or Alaska Native producers, California Native American tribes continue to steward California lands. This is despite centuries of violent land theft and exclusion that underlie today's inequities. Tribal land stewardship includes the cultivation and stewardship of culturally significant foods – often those plants or animals native to a tribe's region. For example, California has over 20 native species of oak tree. Once a dietary mainstay for many tribes in California, the acorn remains connected to cultural identity.[4] Today's California Native American tribes and the State of California work together to advocate for Native voices, provide resource and learning opportunities, and create initiatives and grant programs by and for tribal entities to bolster stewardship, though there is more work to do.[5] State agencies and tribes are leaning into government-to-government engagement and seeking opportunities to enter into agreements for the co-management of and access to state lands for tribal groups.

[4] Lake, F. (2011). Past and Present Acorn Use In Native California. California State University Sacramento. https://sipnuuk.karuk.us/system/files/atoms/file/AFRIFoodSecurity_UCB_FrankLake_003_007.pdf

[5] Indigenous Stewardship Network. (n.d.). Programs. https://www.indigenousstewardship.org/

Equity Principles

To help evaluate, improve, and develop equitable initiatives and policies that California state agencies implement, a set of Equity Principles was developed. These Equity Principles ensure that CDFA and partner agencies serve all farmers, ranchers and land stewards by providing a consistent set of guiding concepts to embed within plans, programs, policy development and implementation, to ensure access for all scales, crops and types of agricultural businesses in California

The six Equity Principles describe the objective of each Principles, a short description of what it considers, and a set of guiding questions for CDFA and other relevant agencies to use in initiative (i.e., policies, plans, and programs) evaluation and further customize according to their needs. Agency staff can use each set of guiding questions to incorporate equity considerations into design and implementation. An objective can be considered to have been "incorporated" when staff respond positively to the prompts overall. These objectives are not designed as the only indicators or questions that should be addressed, but as a starting point for a robust and detailed exploration of equity.

The following is a summary of the Equity Principles, but the full guide is located in Appendix A.

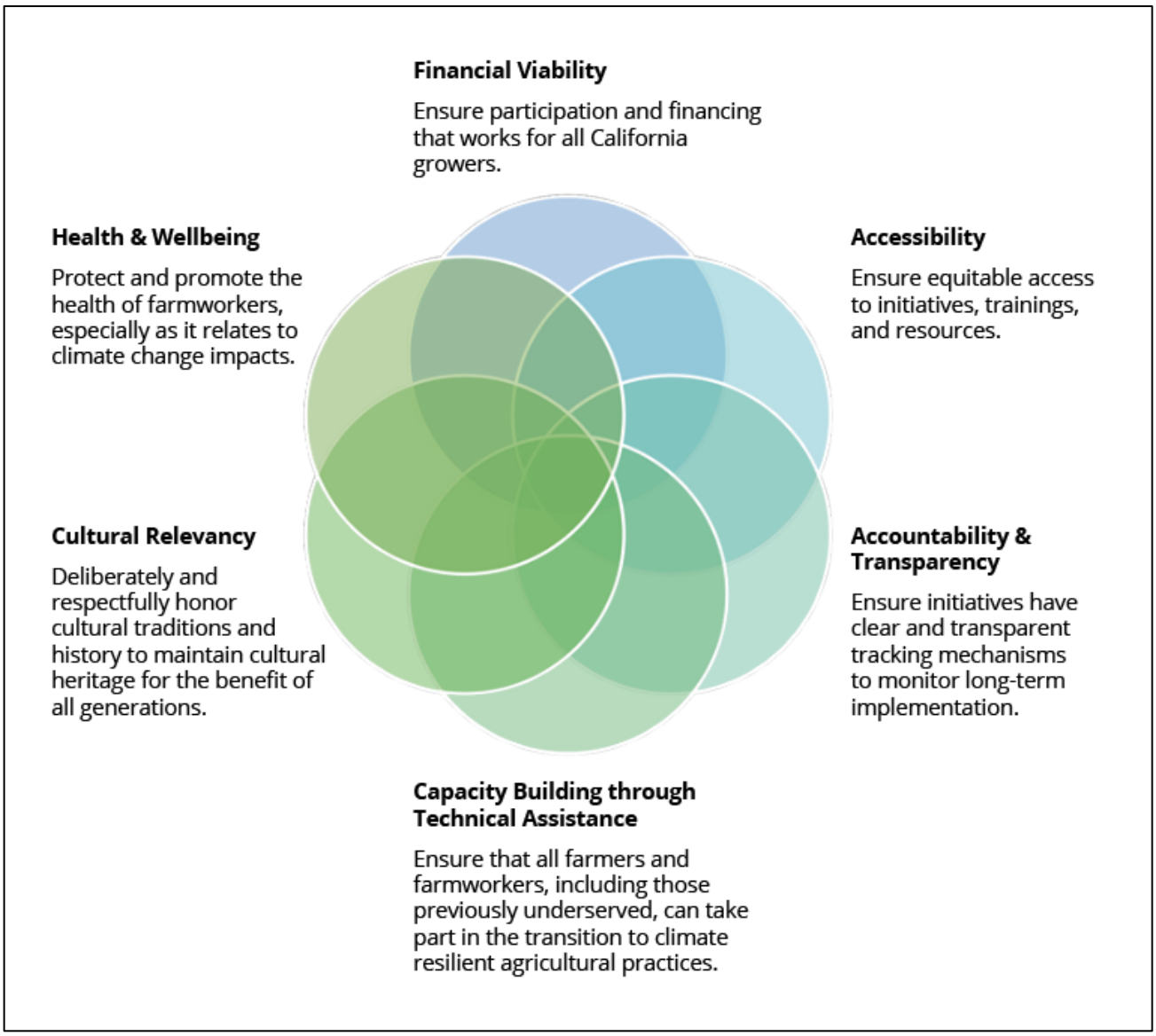


Figure 3: Equity Principles and their Objectives

California Geography, Climate, and Agricultural Regions

The Original Stewards of the Land

Since time immemorial, the land that is now known as California has been home to hundreds of Native American tribes, each with a unique culture and set of traditions. These tribes are stewarding and managing the land, utilizing the abundant natural resources that characterize these lands. Under their care, the lands now called California met the needs of Native American tribes until the arrival of Spanish colonists. European colonialism nearly destroyed the cultures, traditions, and way of life of the tribes. Tribal peoples were killed and enslaved, and their cultures suppressed. Still, tribal stewardship of much of California's landscape continues today despite this violent history.

California Agriculture Today

In the years since European settlement, the agricultural landscape has changed dramatically. Today, California agricultural land comprises 9.5 million acres of irrigated farmland and 9.7 million acres of grasslands (which includes some of the land used for livestock grazing) spread across multiple agricultural regions in the state.[6] The geography of California lays the foundation for the unique and wide-ranging growing environments that make the state an agricultural powerhouse. California is framed by the Sierra Nevada and Cascade Mountain ranges to the east and the Coast Ranges, Transverse Range, and Peninsular Ranges to the west. In the middle of these two ranges sits the wide and long Central Valley. To the north sits the Klamath mountains and the Modoc Plateau and to the south and east are the Basin and Range, Mojave Desert, and Colorado Desert. The state spans much of the West Coast of the United States (U.S.) and contains both the highest and lowest elevations in the continental U.S.

California's agricultural diversity is a testament to its varied microclimates. Each region's unique climate conditions and soils support different types of produce, crops, and other agricultural products; coupled with investments in irrigation infrastructure, it has become an agricultural wonder.

California produces over 400 crops and commodities, many of which are grown year-round. The state boasts the most "specialty crops" in the nation – that is, crops are defined by law as fruits and vegetables, tree nuts, dried fruits, horticulture, and nursery crops. This includes a wide variety of produce, herbs, spices, and flowers. Many of these

[6] Natural and working lands climate smart strategy. (2022). https://resources.ca.gov/-/media/CNRA-Website/Files/Initiatives/Expanding-Nature-Based-Solutions/CNRA-Report-2022---Final_Accessible.pdf

crops are grown nowhere else in the continental U.S., including almonds, walnuts, pistachios, prunes, grapes and raisins, olives, kiwis, figs, nectarines, and pomegranates. In 2024, California's agriculture brought in $61.2 billion in cash receipts.

Much of California has a Mediterranean climate, characterized by cool wet winters and hot dry summers. However, variations in this climate across the state are shaped by topography, proximity to the ocean, elevation, and latitude. In the mountainous regions like the Sierra Nevada, Klamath, and some of the Transverse Range, average winters are defined by freezing temperatures and feet of snowfall. In contrast, deserts in Southern California see minimal rainfall and record setting high temperatures in the summer months. Average coastal temperatures are moderated by proximity to the Pacific Ocean, keeping those regions' daily highs and lows relatively close together, while inland in the Central Valley temperatures can range by 30 degrees or more daily between minimum and maximum.[7]

Deep in the Colorado Desert and bordering Mexico lies the Imperial Valley, a hot and dry region that hosts one of the most productive agricultural zones in the state. The Imperial Valley hosts about half a million acres of farmland, supported by irrigation from the Colorado River. Agricultural production in the Imperial Valley is year-round and supplies 75 percent of the nation's winter produce. Major crops in the region include salad vegetables, asparagus, carrots, onions, cantaloupes, chili peppers, and alfalfa.[8]

Along the central and southern coasts of California, ocean-mediated temperatures and coastal fog create milder winters and cooler summers which translates to a long growing season. Complementing the long growing season is fertile soil, built by rivers and streams draining from the adjacent Coast Range mountains. These soils and microclimates are fit for growing a wide variety of crops. Berries and leafy greens thrive on the central coast, and subtropical fruits such as avocados, dates, and citrus are all grown on the southern coast.[9]

Stretching between the Sierra Nevada and Coast Range lays California's Central Valley. Once a vast wetland, the valley is filled with nutrient-rich sediment brought by rivers descending from the surrounding mountains. This 450-mile-long fertile basin is well-suited for farming. Two large rivers (the Sacramento River from the north and the San Joaquin River from the south) meet here and drain to the Pacific Ocean forming a great inland delta where temperatures are moderated by proximity to the ocean and soils are high

[7] National Centers for Environmental Information. (2022). California - State Climate Summaries 2022. NOAA. https://statesummaries.ncics.org/chapter/ca/

[8] University of California Cooperative Extension. (2020, August). Imperial County Agriculture. UC Davis. https://vric.ucdavis.edu/virtual_tour/imp.htm

[9] Foodwise. (2005, October). California Farming Regions: The Central Coast and Southern California. Foodwise. https://foodwise.org/articles/california-farming-regions-the-central-coast-and-southern-california/

in organic matter. These high organic matter soils are also incredibly fertile and support high productivity. The main crops grown in the Delta area include corn, alfalfa, wheat, wine grapes, almonds, and processing tomatoes. Recently rice cultivation has been on the rise in the Delta region.[10] Inland from the Delta, the Central Valley's temperature range is more extreme than that of the Delta's, but the hot summers and still relatively mild winters coupled with access to water, via modern ground and surface water infrastructure, has created one of the most productive growing regions on earth. Tulare, Fresno, and Kern County combined for an ag production value of over $24 billion in 2022, which is about 44 percent of California's total ag production value.[11] The north of the Central Valley is known for crops such as rice and tree nuts, along with grazing land for cattle. To the south, common crops include cotton, citrus, olives, and grapes, in addition to dairies and cattle ranches.[12]

The Klamath Mountains, and the Modoc Plateau surround and cap the Central Valley in the north of the state. Cooler temperatures, hilly and mountainous terrain, and higher precipitation values on average in these regions create more acidic soil conditions which are suitable for blueberries and fruits such as apples. Dairies dominate the hills of the North Coast, providing butter, cheese, and milk. Wine grapes are also grown in this region, with wine growing areas such as Napa Valley receiving international acclaim. California produces 80 percent of U.S. made wine and is the 4th largest producer in the world.[13] In the northeast corner of the state, the Modoc Plateau produces potatoes, alfalfa, hay, and grains such as barley and wheat.[14]

California's unique geography and historic investments have made the state an agricultural powerhouse and an important part of its economic engine, providing high-quality nutrition, vital not just to the domestic food supply but to countries around the world.

California agriculture is considered among the safest and most environmentally conscious in the world due to a combination of strong regulations, cutting-edge research, and a strong focus on sustainability. The state enforces some of the strictest environmental and pesticide safety standards in the country, safeguarding the health

[10] https://delta.ca.gov/wp-content/uploads/2025/03/2025-03-20-Item-13-Socioeconomic-Indicators-508.pdf; https://delta.ca.gov/delta-rice/

[11] California Ag Network. (2023, October). Tulare Surpasses Fresno as #1 Ag County in the Nation. California Ag Net. https://californiaagnet.com/2023/10/30/tulare-surpasses-fresno-as-1-ag-county-in-the-nation/

[12] Foodwise. (2005, November). California Farming Regions: The Great Central Valley. Foodwise. https://foodwise.org/articles/california-farming-regions-the-great-central-valley/

[13] Wine Economy. (n.d.). Highlights. Wine Economy. https://www.wine-economy.com/impact/national/

[14] County of Modoc. (2022). Modoc County Annual Crop Report 2022. California Department of Food and Agriculture. https://cms5.revize.com/revize/modoc/Agriculture/Crop%20Report/2022%20Modoc%20County%20Crop%20Report%20-%20FINAL.pdf

of both consumers and farmworkers. A myriad of state agencies provide oversight and programming that protect air quality, water, and soil health while promoting safe working conditions.

California farmers lead in adopting advanced technologies and approaches like precision irrigation, satellite data, and integrated pest management (IPM). These tools help reduce water and chemical use while improving yields and protecting ecosystems. Grant programs like CDFA's Healthy Soils and State Water Efficiency and Enhancement Program provide financial support to farmers implementing climate-smart practices, like planting cover crops or installing efficient irrigation systems.

Efforts to protect biodiversity, improve soil health, and support pollinator populations are also front and center. The state is the nation's top producer of organic crops, and many growers voluntarily participate in third-party certification programs to ensure sustainability, traceability, and food safety.

Maintaining high standards for environmental quality, investment in research and development for climate-ready crops and soil health improvements, and ongoing improvements in resource-use efficiency will be critical for California to continue to produce the safe, nutritious foods for which it is known. The state is already making critical investments in modernizations of systems for the management of water, adoption of technology, workforce development, local and regional food system infrastructure, community leadership and equity, and coordination across state agencies, universities, and the private sector.

In short, climate change requires that we take proactive steps to prepare for the future. This strategy will describe the steps that are being taken now and point the way toward resilience-building measures that will help us continue to farm into the future.

Defining Key Terms	
Resilience	A state of readiness to face climate risks.[15] In this strategy, we explore gaps in readiness for California agriculture, actions taken, and actions needed to fill these gaps.
Adaptation	An action or set of actions that reduce physical climate risk.[16] Many of the actions described in our strategy are adaptations, or avenues to reduce climate risk.
Working Lands	Defined in paragraph (1) of subdivision (d) of Section 9001.5 of the Public Resources Code, "Working Lands" means lands used for farming, grazing, or the production of forest products.[17]
Climate-Smart Agriculture (CSA)	CSA is an approach to agriculture that seeks to achieve three objectives, 1) the sustainable increase in agricultural productivity and incomes to boost the economy, the social well-being of people and animals, and the environment; 2) agriculture adaptation and resilience to climate change; and 3) the decrease or elimination of greenhouse gas emissions.[18]
Regenerative Agriculture	While formulating Ag Vision 2030, and especially through the first priority, to "Foster climate-smart, resilient, and regenerative food systems," the State Board of Food and Agriculture recognized that while the term "regenerative" is relatively new, the philosophy behind the term goes beyond "doing no harm" to improve new agricultural production systems. The Board also recognized that there is no one agreed-upon definition of the term, and in 2022, launched a public process to create a definition for the purposes of state policies and programs. In January 2025, the California State Board of Food and Agriculture finalized a recommendation to the CDFA Secretary on Defining Regenerative Agriculture for State Policies and Programs. This recommendation fulfills a Board project outlined within California's Ag Vision for the Next Decade. This recommendation is to inform State Agencies, Boards and Commissions on CDFA's definition of regenerative agriculture as it

[15] State of California. (2025). Overview of the California Climate Adaptation Strategy. California Climate Adaptation Strategy. https://climateresilience.ca.gov/overview/index.html

[16] State of California. (2025). Overview of the California Climate Adaptation Strategy. California Climate Adaptation Strategy. https://climateresilience.ca.gov/overview/index.html

[17] California. Public Resources Code § 9001.5. (2020). Public Resources Code – Division 9 – Resource Conservation – Chapter 1 – General Provisions – Article 1 – Policy of State. https://law.justia.com/codes/california/2020/code-prc/division-9/chapter-1/article-1/section-9001-5/

[18] United Nations Framework Convention on Climate Change. (2021, October 15). Climate-smart agriculture. UNFCCC.; Lipper, L., Zilberman, D. (2018). A Short History of the Evolution of the Climate Smart Agriculture Approach and Its Links to Climate Change and Sustainable Agriculture Debates. In: Lipper, L., McCarthy, N., Zilberman, D., Asfaw, S., Branca, G. (eds) Climate Smart Agriculture. Natural Resource Management and Policy, vol 52. Springer, Cham.

	relates to state policies and programs. This is not a definition for certification or a recommendation for incorporation into state statute. For more details, including the full recommended definition, see https://www.cdfa.ca.gov/RegenerativeAg/.
Greenhouse Gases	Greenhouse gases (GHGs) refer to heat-trapping gases in the atmosphere that contribute to increasing global temperatures and climate change. This includes carbon dioxide, nitrous oxide, methane, among others.
Nature-based Solutions (NBS)	NBS that deliver on California's climate change goals are land management practices that increase the health and resilience of natural systems, which supports their ability to serve as a durable carbon sink. To learn more about nature-based solutions, check out the California Natural Resources Agency's Natural and Working Lands Climate Smart Strategy and the AB 1757 Nature-Based Solution Climate Targets.
Bioeconomy	The bioeconomy refers to the sector of the economy based on products, services, and processes from biological resources like plants and microorganisms that contribute to a sustainable and circular economy.

Climate Change Impacts and Effects on California Agriculture

Generally, climate change in California is driving warmer temperatures and increasingly variable precipitation. Although all regions are experiencing warmer temperatures, the effects of climate change are felt differently region by region and require regionally appropriate approaches. For example, the Central Valley and Southern Desert regions are experiencing warmer winter temperatures, while coastal regions are expecting dramatic increases in nighttime temperatures. Additionally, climate change effects in one region may affect conditions in others. For example, shifts in precipitation from snow to rain and earlier snowmelt is expected to result in declining streamflow in northern California during summer months. Due to the state's interconnected surface water infrastructure, less surface water could be available for irrigation across the state. Additionally, sea level rise and the threat of more winter flooding increases the flood and saltwater intrusion risk in the Sacramento-San Joaquin Delta region. Ongoing subsidence of Delta organic soils increases flood risk and associated potential water quality impacts for both the region, including its agricultural lands, and California's water supply, and contributes significantly to greenhouse gas (GHG) emissions.

The changing climate has a number of varying impacts on agriculture, such as:

- Decreasing crop yields (though impacts vary crop to crop). Decreases in winter chill hours, or the time a tree is exposed to temperatures below a specific threshold, is hurting yields in fruits and nuts.
- New research indicates that increasing concentrations of CO_2 in the atmosphere may be decreasing the nutritional value of foods, heightening the risk of increased nutritional deficiencies including in essential nutrients such as protein, iron, and zinc for millions of people around the world.[19] While there is evidence that increased concentrations of CO_2 could increase photosynthesis and accelerate plant growth, research indicates that there are significant trade-offs.[20]
- Diminishing meat and milk production as animals experience extreme heat events causing impacts ranging from discomfort to mortality.

[19] Smith, M.R., Myers, S.S. Impact of anthropogenic CO2 emissions on global human nutrition. Nature Clim Change 8, 834–839 (2018). https://doi.org/10.1038/s41558-018-0253-3

[20] Taub, D. (2010) Effects of Rising Atmospheric Concentrations of Carbon Dioxide on Plants. Nature Education Knowledge 3(10):21

- Pest and disease pressure increase with climate change, further impacting agricultural operations and lowering crop yields.[21] These effects are already present – the life cycle of navel orange worm has sped up due to the warming temperatures.[22]
- Extreme heat events can worsen working conditions for those in the agricultural industry and can affect plant water hydraulics even when sufficient moisture exists, leading to plant death.[23]
- Reduced surface water and increased demand for crop evaporative water result in an increased need to pump groundwater. This pushes up the cost of electricity for farmers. This cost increases over time as groundwater levels decrease over many years of droughts. Moreover, some wells may go dry due to low water levels, increasing well replacement costs. [24]
- Rising sea levels are causing saltwater intrusion that is impacting aquifers beneath low-lying coastal farms.

Compounding the effects of climate change, production costs have also been on the rise. Since 2020, production costs (e.g. fertilizers, pesticides, feed, repair and maintenance for equipment, seeds, labor, etc.) paid by U.S. farmers increased more than $100 billion (U.S. Senate Committee on Ag, Nutrition, and Forestry). The combination of climate change and increasing production costs narrow profit margins for California's farmers and ranchers. These margins are even narrower for those with fewer resources, particularly groups who have been historically underserved.

[21] California Natural Resources Agency. (2022, August). California's Water Supply Strategy - Adapting to a Hotter, Drier Future. California Natural Resources Agency. https://resources.ca.gov/-/media/CNRA-Website/files/initiatives/water-resilience/CA-water-supply-strategy.pdf

[22] California Office of Environmental Health Hazard Assessment. (2022). Indicators of climate change in California: 2022 report (Publication No. 22-0001). California Environmental Protection Agency. https://oehha.ca.gov/media/downloads/climate-change/document/2022caindicatorsreport.pdf

[23] Schönbeck, L. C., Schuler, P., Lehmann, M. M., Mas, E., Mekarni, L., Pivovaroff, A. L., Turberg, P., & Grossiord, C. (2022). Increasing temperature and vapour pressure deficit lead to hydraulic damages in the absence of soil drought. Plant, Cell & Environment, 45(11), 3275–3289. https://doi.org/10.1111/pce.14425

[24] https://cawaterlibrary.net/document/economic-impacts-of-the-2020-22-drought-on-california-agriculture/

Guiding State Policies

California is a leader in taking action to mitigate climate change through GHG emission reductions and carbon sequestration, and in addressing the effects of climate change on its land, waters, people, infrastructure, animals, and plants. California agriculture is a relatively small slice of California's greenhouse gas emissions pie – eight percent of total emissions – but has the potential to be part of the solution to the climate crisis.

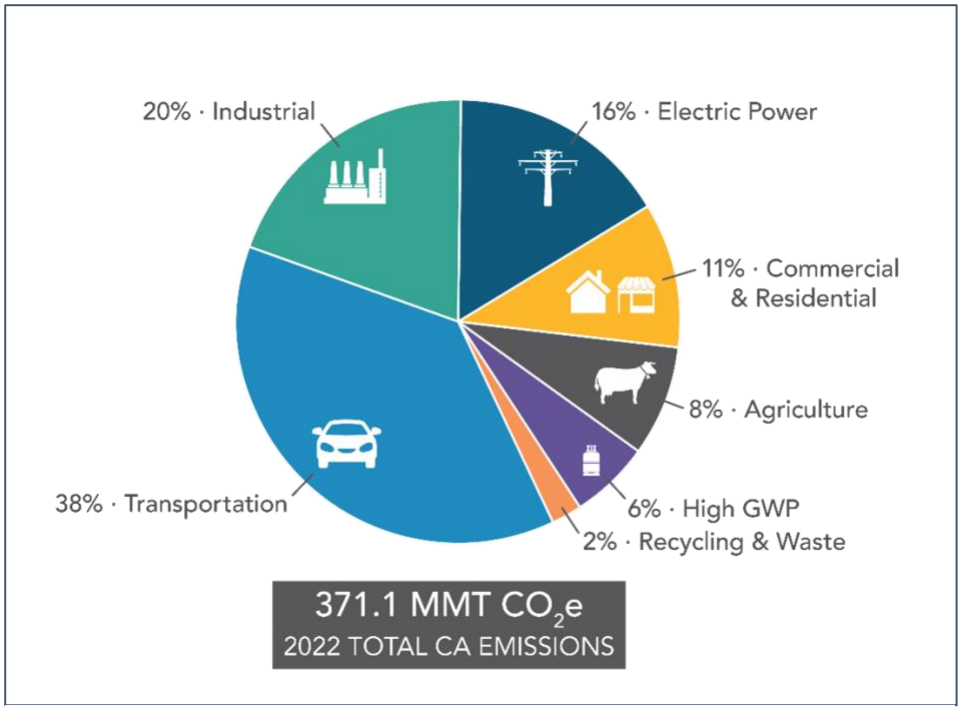


Figure 4: California's 2022 Greenhouse Gas Emissions Broken out by Category

Further, cropland and grassland carbon stocks represent only about seven percent of the total ecosystem carbon. These landscapes are well suited for implementing climate-smart practices which sequester carbon and reduce GHG emissions.[25]

However, the benefits of practices that sequester carbon in soil and reduce emissions go far beyond carbon accounting: practices that build carbon also build resilience to climate change. Healthy soils practices, for example, increase the water holding capacity of soil and improve nutrient retention. They build soil organic matter and develop structure that allows air and water to penetrate more easily, facilitating root growth and plant nutrient uptake. Healthy soil acts as a living system, reducing the

[25] California Air Resources Board. (2018). An inventory of ecosystem carbon in California's natural and working lands. California Environmental Protection Agency. https://ww2.arb.ca.gov/sites/default/files/classic/cc/inventory/NWL%20Inventory%20Report%20Website.pdf

need for expensive inputs and increasing resilience to heat, drought, pests, and intense rains.

For this reason, many of California's guiding documents on climate change emphasize practices that improve the health and resilience of our crop and rangelands rather than solely focusing on maximizing carbon sequestration or reducing emissions.

Emissions Reductions Efforts

California has set statutory and regulatory requirements that guide our State towards achieving carbon neutrality by 2045, which will require reducing GHG 85 percent below 1990 levels and supporting carbon dioxide removal, as designated by AB 32, the Global Warming Solutions Act and updated with AB 1279.

Another complimentary law, SB 1383, mandates that California reduce methane emissions by 40 percent below 2013 levels by 2030. Dairy, livestock, and rice are agricultural contributors to methane emissions in California, and CDFA and other state agencies have been working to reduce those emissions *(see chapter 12 on Dairy Farming Sustainability)*, which will aid the State in achieving its overall carbon neutrality goal.

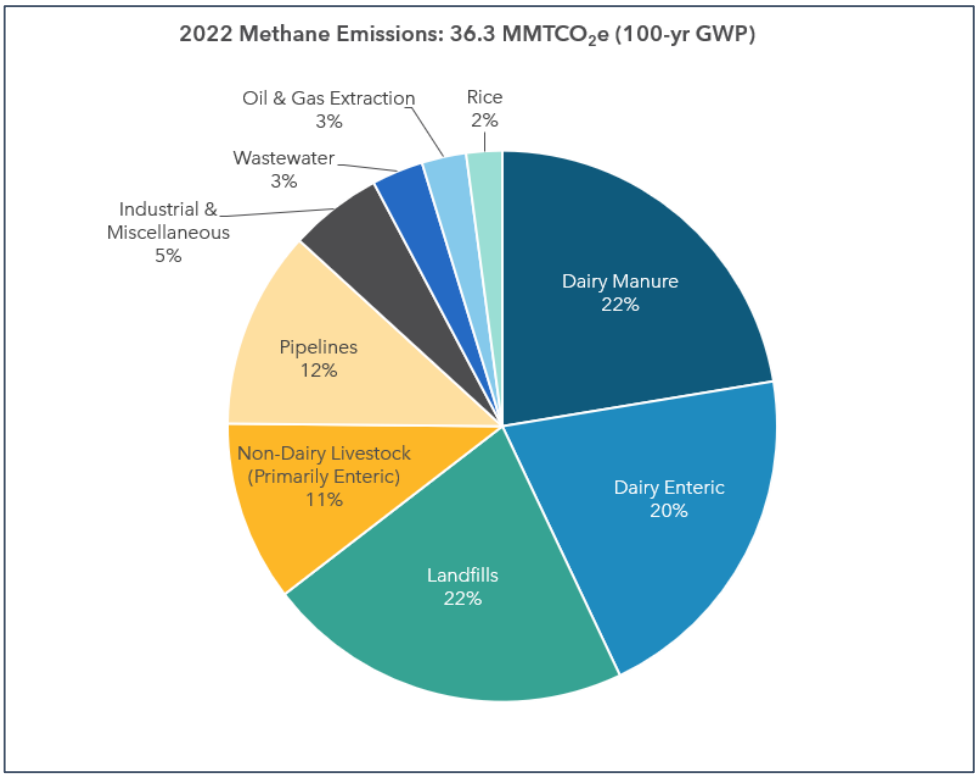


Figure 5: 2022 Methane Emissions in California

The following documents guide California's efforts:

- **AB 32 Climate Change Scoping Plan:** Sets the overall strategy for California to achieve its GHG reduction and carbon neutrality goals and is updated every 5 years by the California Air Resources Board in consultation with CDFA and other State agencies. The Scoping Plan includes strategies relevant to agriculture, such as agricultural sector energy use, nature-based solutions, and dairy methane reduction. The most recent Scoping Plan, the 2022 Scoping Plan Update, also includes a carbon target for natural and working lands for the first time. To achieve the carbon target for natural and working lands, the 2022 Scoping Plan Update identifies nature-based strategies that prioritize restoration, public health and safety, ecosystem resilience, and enhancement of ecosystem functions, including diversified, and sustainable carbon stocks that are resilient against climate change impacts. For agricultural lands, the Scoping Plan calls for increasing the use of climate-smart practices, increasing organic production, management to improve ecosystem health and reduce fire fuels, and conserving agricultural land to protect it from conversion to development.
- **Short-Lived Climate Pollutant Strategy:** The Short-Lived Climate Pollutant (SLCP) Reduction Strategy, mandated by SB 605, and approved by the Air Resources Board in March 2017, is California's plan for reducing emissions of high global-warming potential gases with short atmospheric lifetimes. SLCPs include the greenhouse gases methane and hydrofluorocarbons (HFC), and anthropogenic black carbon. Methane from California's dairy and livestock sector represents over half of the total agricultural greenhouse gas emissions. The SLCP Reduction Strategy outlines a number of actions to help reduce agricultural methane emissions. Additional legislation, SB 1383, requires that the state reduce methane 40 percent below 2013 levels by 2030.

Resilience and Adaptation Efforts

California also has a number of guiding strategies and policies focused on efforts toward adaptation and resilience, including nature-based solutions:

- **California's Climate Adaptation Strategy:** Mandated by AB 1482, the Strategy provides actionable steps on six climate priorities to build resilience to the impacts of climate change. In addition to accelerating nature-based solution implementation, the Adaptation Strategy highlights actions to build social infrastructure and economic resilience. Some of the notable actions from this Strategy for agriculture include: supporting and growing technical assistance to build capacity in climate vulnerable communities, increasing access to locally and traditionally grown food and produce in low-income communities to build climate resilient food systems and increase agricultural economic sustainability,

conserving water (including protecting groundwater as a water source for future generations), protecting natural resources and agriculture from invasive species, increasing landscape connectivity, and establishing climate refugia through conserving agricultural lands at risk of development.

- **California's Nature-Based Solutions Climate Targets:** Mandated by AB 1757, these are nature-based solutions (NBS) climate targets for 2030, 2038, and 2045 that contribute to California's goals of achieving carbon neutrality and protecting Californians from the climate crisis. This includes implementing healthy soils practices on 3.4 million acres of croplands to boost healthy soils, drought resilience, and below-ground biodiversity. These targets provide agency level actions for CDFA and include the creation of a climate resilience strategy, as well as several other objectives that will further the adoption of climate-smart practices, such as compost and mulch application. The list of actions can be found in Section 3 of the California's Nature-Based Solutions Climate Targets.
- **Climate Smart Lands Strategy:** Governor Newsom's 2020 Executive Order N-82-20 called upon state agencies, including CDFA, to identify and implement actions to accelerate natural removal of carbon, build resilience in soils, and conserve land. In 2022, these actions were incorporated into the state's first Climate Smart Lands Strategy. The Climate Smart Lands Strategy serves as a framework for using nature-based climate solutions to deliver on the state's climate goals and to support pathways for sectors like agriculture and forestry to participate in the transition to a carbon neutral economy. This strategy is currently undergoing updates pursuant to AB 1757 to include the NBS climate targets, barriers to action, and other expansions.

  Regional profiles in Section 4 of the Climate Smart Lands Strategy highlight stakeholder-identified nature-based solutions. Several agriculture- and nature-based solutions were highlighted as applicable across major agricultural regions in the state:

  1. Regenerative agriculture, including practices that build healthy soils, like organic amendments application, managed grazing, establishing hedgerows, fostering drought-resilient plantings, and restoring riparian areas.
  2. Building tribal and community capacity to steward lands, including the implementation of practices such as cultural burning.
  3. Increasing land access, especially for tribal groups, through land returns, co-management, and land agreements.
  4. Workforce development to implement climate smart land management.
  5. Protection of water supply, including groundwater and rain/floodwater capture strategies.

- **Delta Adapts: Creating a Climate Resilient Future:** is the first climate adaptation plan that encompasses the entire Sacramento-San Joaquin Delta and considers climate resilience from the perspectives of communities, watersheds, ecosystems, and critical infrastructure. The adaptation plan lays out four strategies for agricultural resilience in the Delta:
  1. Expand adoption and support implementation of climate-smart farming practices across Delta agricultural lands
  2. Build a sustainable, equitable regional food system
  3. Support diversification of income/revenue opportunities on operation agricultural lands
  4. Cooperatively identify strategic agricultural land retirement opportunities, where other land uses would be of high monetary or non-monetary value.

Examples of Nature Based Solutions in Agriculture

- Healthy soils practices, examples include cover cropping, compost application, hedgerow planting, and reduced tillage
- Water savings and storage through groundwater recharge
- Flood plain reactivation and riparian restoration
- Improved irrigation systems
- Integrated pest management and sustainable pest management
- Protection and restoration of native grasses
- On-farm compost production and use
- Planting, harvesting, and sustaining culturally and historically significant food crops by California Native American tribes
- Prescribed grazing

A comprehensive list of NBS practices outlined for agriculture can be found in the California Natural Resource's Agency's Natural and Working Lands Climate Smart Strategy.

A Path Forward

This Climate Resilience Strategy for California Agriculture (RSA) outlines many impacts of climate change to our agricultural communities and their livelihoods, what the state is

already doing to ease these impacts and prevent new issues from arising, and highlighting areas where the state could expand its efforts so that all Californians can thrive. The RSA is another step in the path towards a climate-smart, resilient, and regenerative food system.

Pillar 1: Support a Thriving and Resilient Food Sector

The following section covers the following chapters, which represent each key objective in the RSA:

1. Foster a Robust and Sustainable Agricultural Economy

Improve the economic resilience of California farms and ranches in the face of climate change.

2. Ensure a Water System for Food System Resilience in a Hotter, Drier Future

Create sustainable and reliable water access for ensuring a resilient food system.

3. Support Agricultural Workforce Wellbeing and Health

Improve on-farm safety and community wellbeing for California's agricultural workforce.

4. Protect Animal Health

Protect the health and welfare of our livestock and poultry from climate-related threats.

5. Advance Energy Efficiency and Decarbonization for Agricultural Operations

Increase energy efficiency and access to a reliable and clean energy grid for all agricultural operations.

Chapter 1. Foster a Robust and Sustainable Agricultural Economy

Key Objective: Improve the economic resilience of California farms and ranches in the face of climate change.

Context

California boasts the largest and most diverse agricultural economy in the United States. In 2024, sales totaled over $61.2 billion, solidifying California's position for another year as the leading state in cash farm receipts. California agriculture produces over 400 crops and commodities and has the largest dairy industry in the nation, accounting for just over 18 percent of the country's milk supply in 2022.[26] The state's more than 63,000 farms grow over a third of the vegetables and almost three-quarters of the fruits and nuts in the United States.

Climate change-driven economic losses financially impact the backbone of the agricultural economy – farmers and ranchers. Natural disasters like wildfires, floods, and extreme weather events have damaged crops and livestock, leading to financial setbacks. Drought has affected agricultural production across California in recent years, leading to the fallowing of hundreds of thousands of acres (750,000 acres in 2022).[27] For lands that stay in production, pumping and other production costs increase during droughts; the 2021 drought increased pumping costs statewide by $184 million.[28] Unpredictable weather patterns make long-term planning difficult. Disruptions in previously reliable weather patterns like winter chill, rainfall, and extreme heat can have long-lasting effects on the yield and quality of crops. Droughts, fires, floods, and heat all pose a threat to farmers' profitability, as they may lose time and financial investments and forgo crop income for a year or more as a result; these impacts are even more disruptive for small farms. Finally, managing climate-driven pest pressure continues to be a significant financial challenge for farmers that is likely to continue to intensify (see the

[26] California Department of Food and Agriculture. (2022). CALIFORNIA AGRICULTURAL STATISTICS REVIEW 2021-2022. USDA's National Agricultural Statistics Service California Field Office. https://www.nass.usda.gov/Statistics_by_State/California/Publications/Annual_Statistical_Reviews/2022/2022_Ag_Stats_Review.pdf

[27] UC Merced. (2022, May 24). *Continued drought conditions add billions to California agriculture losses, UC Merced report finds*. UC Merced.

[28] Medellín-Azuara, J., Escriva-Bou, A., Rodríguez-Flores, J., Cole, S., Abatzoglou, J., Viers, J., Santos, N., Sumner, D., Medina, C., Arévalo, R., Naumes, S., & Bernacchi, L. (2022). Economic Impacts of the 2020-22 Drought on California Agriculture Prepared for: The California Department of Food and Agriculture. https://wsm.ucmerced.edu/wp-content/uploads/2023/01/Economic_Impact_CA_Drought_V02-1.pdf

Pest Pressure Chapter for more information). These climate impacts are only expected to worsen into the future.[29]

Slim Profit Margins

In addition to climate change impacts, California farmers and ranchers are currently experiencing severe financial pressure. Inflation and rising input costs, increasing labor costs, and the cost of land and equipment are just some of the factors putting the squeeze on farm businesses. Production costs for farmers and ranchers in California are high. As a result, the profit margins for farmers and ranchers are relatively small. Farmers receive on average 16 cents from each consumer dollar spent on domestic food.[30]

Fluctuating Market Demand

These challenging economic conditions are further compounded by fluctuations in consumer market demand, foreign market volatility and inconsistent trade policies, and pressure from retailers and supply chains. Food production is driven by market demand, and rapid demand fluctuations are difficult for the agricultural industry to respond to, whatever the cause. This is because of the significant investments in infrastructure and the lag-time between planting crops and harvest time.[31] A farmer's ability to respond to shifting demand is based on many factors, including whether a crop is annual or perennial, input costs and investment requirements including machinery or processing equipment, the availability of labor, marketing mechanisms, whether a supply chain has been established, and more.

International exports constitute nearly half the state's agricultural economy, and global trade issues, federal trade policy, fluctuating commodity prices, and competition from imports put pressure on profit margins. In 2022, California agriculture was responsible for $23.6 billion worth of agricultural exports.[32] While producing food for export brings money into the state's agricultural economy, it also means global market trends, trade agreements, and international conflict drive significant swings in demand, putting pressure on California's farmers and ranchers.[33]

---

[29] https://ucanr.edu/sites/default/files/2024-02/394023.pdf

[30] Martin, P., Goodhue, R., & Wright, B. (2020). California Agriculture Dimensions and Issues. https://s.giannini.ucop.edu/uploads/pub/2021/01/26/chapter_1_introduction_2020.pdf

[31] chapter_1_introduction_2020.pdf

[32] California Agricultural Exports. (2022). California Department of Food and Agriculture. https://www.cdfa.ca.gov/Statistics/PDFs/2022-2023_california_agricultural_exports.pdf

[33] Carter, C. (n.d.). International Trade and California Agriculture Chapter 14. International Trade and California Agriculture.

Strategies and Actions

There are a number of solutions that California can adopt to help our farms and ranches thrive even as climate change progresses. In this chapter, we will focus on policy, program, and investment solutions that address climate-driven risk and financial resilience responses, including policy and regulatory support opportunities, technological innovations, market and supply chain strengthening measures, and opportunities to build a climate-smart agricultural workforce.

1.1 Support financial risk reduction measures for farmers.

As climate change continues to increase the likelihood of natural disasters, pest pressure, diseases, among others, farmers are looking to protect their crops and financial livelihood. Supporting financial risk reduction measures for farmers, through existing mechanisms like on-farm resilience-building practices, crop insurance, and disaster relief, and through new tools like parametric insurance, will alleviate some of the burden on farmers from the impacts of climate change. In addition, programs that provide recovery funding are critical in filling gaps that crop insurance may not cover or cover completely.

1.1.1 Expand insurance options for specialty crops, especially to reduce risk from extreme weather-related losses.

Goal 2: Enhance Program Effectiveness

Crop Insurance and Specialty Crops

Crop insurance is a type of insurance that protects farmers from natural disasters, pest destruction, poor harvests, and other unforeseen circumstances. In fact, losses are seen as inevitable in farming. Crop insurance is essential to farming because it provides financial stability and helps manage risks associated with adverse growing conditions and market conditions. Crop insurance fills gaps that private insurance coverage may not cover, ensuring that farmers can recover and continue farming.

Crop insurance is managed through a public-private partnership between the federal government, specifically, the USDA Risk Management Agency (RMA), and private insurance providers. Farmers buy insurance through an approved provider, and the federal government subsidizes the insurance premium. While policies are set by the RMA, ensuring that prices are the same for the same policy no matter where it's purchased, the price can still vary depending on the value of the crop and the risk of

loss. Farmers purchase crop insurance from an insurance agency and pay a portion of the premium to their insurance agency (the federal government also helps offset the premium cost for the farmer). If the farmer experiences crop losses that year, the farmer must shoulder a "deductible" of losses before then receiving compensation from their insurance company. If the losses for the farmer exceed the premium paid to the insurance company, that insurance company takes on the losses but can have some of the losses remediated by the federal government.[34] This system provides significant risk mitigation for farmers. However, climate change is increasing the number and intensity of natural disasters which lead to widespread crop failures. One study found that higher temperatures increased crop insurance payments for the U.S. by $27 billion from 1991 to 2017.[35] On-farm action is needed to help build resilience against the impacts of climate change to mitigate the need for such pay outs.

Most farms in California are small farms.[36] The increasing frequency of disaster events is making crop insurance more expensive, and specialty crop insurance in particular is already more limited than crop insurance for major U.S. commodity crops like corn, wheat, and soy (which is a disincentive for growing diverse crops). It is estimated that more than 70 percent of the Agricultural Risk Coverage program (one of the current federal insurance programs) payouts will be to corn, soybeans, and wheat[37]. Furthermore, traditional crop insurance relies on historical data, which may not reflect new climate realities.

Crop insurance eligibility is also an equity issue, as minority farmers are less likely to participate in crop insurance programs than white farmers.[38] This may be because of lasting effects of historical racial discrimination against minority groups.[39] Recent actions by the federal government to address these equity issues include the Micro Farm Crop Insurance option, the Whole-farm Revenue protection option, and new expansion

[34] Munch, Daniel. "Farmers held over 2.3 million crop insurance policies in 2023." American Farm Bureau Federation, 2 May 2024, https://www.fb.org/market-intel/crop-insurance-101-the-basics.

[35] Garthwaite, Josie. "Global warming increased U.S. crop insurance losses by $27 billion in 27 years, Stanford study finds." Stanford Report, 4 Aug. 2021, https://news.stanford.edu/stories/2021/08/04/climate-change-crop-insurance.

[36] "California State and County Data." 2022 Census of Agriculture, National Agriculture Statistics Service, 2022, 217-229.

[37] Bekkerman, A., Belasco, E. J., & Smith, V. H. (2018, January 18). Where the money goes: The distribution of crop insurance and other farm subsidy payments. American Enterprise Institute - AEI. https://www.aei.org/research-products/report/where-the-money-goes-the-distribution-of-crop-insurance-and-other-farm-subsidy-payments/

[38] Belasco, Eric J., et al. The Identification and Relevance of Racial and Ethnic Disparities in Federal Crop Insurance. American Enterprise Institute, Oct 2023.

[39] https://www.jstor.org/stable/resrep53326

options for specialty and organic growers. However, more work is needed to assure equity and bolster our state's farmers in the face of climate change.[40]

Parametric Insurance

Parametric insurance is a newer insurance model which makes payments to farmers automatically when certain environmental triggers occur, such as specific weather conditions. This enables farmers to get faster payouts after cataclysmic events, vs. having to undergo loss assessments which can drive up costs and delay replanting. Parametric insurance also encourages farmers to adopt climate-smart practices like efficient irrigation systems and planting cover crops because those measures reduce risk.

Government can play a role in supporting new models of crop insurance by supporting the infrastructure needed for parametric insurance, like weather stations and satellite technology. Until recently, U.S. farmers routinely benefited from the Earth observations and weather and climate services of the National Oceanic and Atmospheric Administration (NOAA); however recent cuts to the agency are creating uncertainty about the availability of these services in the future. In California, the Department of Insurance is trialing a form of parametric insurance for a town in the Delta that lies within the 100-year floodplain.[41] The program is financed by the Department of Water Resources and run through a special district in the area, the Delta Geologic Hazard Abatement District. During a flood, the program will automatically distribute small payments to inhabitants to help with repairs or evacuation costs. This parametric insurance trial can help growers living in the area deal with disasters which uproot their homelife and also showcase the effectiveness of parametric insurance such that this model can be adopted into crop-specific policies.

1.1.2 Effectively promote and deploy the California Underserved and Small Producers (CUSP) program.

Goal 2: Enhance Program Effectiveness

Crop insurance has traditionally been the primary safety net for anticipated risks; however, climate change is driving events that are hard to anticipate and cause

[40] Whole-Farm Revenue Protection | Risk Management Agency; Micro Farm 2025 | Risk Management Agency; Specialty Crops | Risk Management Agency

[41] https://www.insurancebusinessmag.com/us/news/catastrophe/california-launches-firstever-communitybased-flood-program-510367.aspx

damage outside typical insurance coverage. Additionally, crop insurance does not always completely cover losses after an extreme weather event, because damage may affect more than crops; for example, infrastructure like barns, irrigation systems, or extreme soil erosion. Disaster recovery funding then becomes a backstop to address damage after an extreme weather event.

Programs such as CDFA's California Underserved and Small Producers (CUSP) Program are critical in improving access to emergency financial relief and disaster preparedness funding for farmers. The CUSP program is designed to facilitate support for small and medium scale California agricultural producers, including small and medium scale socially disadvantaged farmers and ranchers, through direct relief grants. The program works through Direct Assistance Providers who act as administrators of the CUSP Direct Relief Grant Program and distribute relief grants to aid in addressing specific financial needs due to drought, extreme weather, and other climate impacts in California. These grants are available through partnering organizations listed on the CUSP website, and are available on a rolling basis through 2026. CDFA works to promote CUSP through outreach through Direct Assistance Providers to ensure small and medium farmers are aware of the program and can apply for disaster relief grants.

The CUSP program also provides funding to Technical Assistance (TA) providers who assist farmers and ranchers with applications to other disaster relief funds, including federal economic and disaster relief programs, as well as farm business management, financial planning and marketing assistance to mitigate immediate concerns and needs related to drought and extreme weather. Increased TA is critical for greater utilization of relief funds and other financial assistance.

1.2 Reduce workload associated with meeting or exceeding regulatory goals.

A much-discussed facet of economic resilience in California agriculture are the compliance, reporting, and operational costs associated with regulations. California agriculture is the most highly regulated in the nation.

1.2.1 Simplify and streamline regulatory compliance reporting.

Goal 4: Align and Simplify Policies and Regulations

The interpretation and administration of agricultural regulations should be improved and aligned to reduce the cost and difficulty of compliance while meeting or exceeding regulatory goals. This high degree of regulation provides certainty in the market for buyers of California agricultural products and protects California's communities and natural resources. California's regulations require producers to comply with many different government regulations covering things such as environmental quality, food safety, and farm labor standards. Compliance often requires paperwork be filed with many different state agency regulators. These regulations were adopted to protect Californians' health, the environment, and those who work in the fields; and the progress that producers have made in complying with them has resulted in improvements in each of these areas.

However, in some cases, the regulations are duplicative, conflicting, uncoordinated, inconsistently administered, or needlessly burdensome. The global competitiveness of California agriculture is at risk in part because of the increasing burden of regulation. A 2006 study estimated that the annual cost of regulations to California producers is $2.2 billion or roughly 6.5 percent of the total market value of the state's agricultural production.[42]

California must look for ways to improve the effectiveness of current regulations and reduce compliance costs while still achieving the benefits the regulations were designed to achieve, including through smarter, more coordinated regulation. Ag Vision 2030 identified collaboration on smarter regulations as a strategic priority. CDFA supports this priority through the following means:

[42] (PDF) An Estimation of the Regulatory Cost on California Agricultural Producers

1) Mapping existing regulations and processes (i.e., what information is required, when, and for what purpose) as part of a Smarter Agriculture Regulatory Framework Initiative, which upon initiation, will examine regulatory areas that present the biggest reporting burden for farmers, with the aim of identifying areas of excessive and/or redundant reporting.[43]
2) Identifying strategies to reduce burdens, especially for small and underserved producers, while meeting obligations. Strategies may include information sharing between agencies and groups; removing requirements to report information that does not need to be collected; and exploring technical solutions to streamline how information is reported to the state.
3) Supporting technical assistance for farmers and ranchers implementing existing regulations, with the aim of easing compliance time and cost for farmers of all sizes, including small and mid-size farmers.
4) Collaborating, convening and forming partnerships that help address water related concerns and opportunities.

Currently CDFA, CalEPA, and the State Water Resources Control Board are undertaking a regulatory alignment study identify opportunities to streamline reporting requirements for food safety and water quality and optimize information collection by the state. The study is focused on four regulatory program areas: CDFA's Produce Safety Program, and the State Water Resources Control Boards Irrigated Lands Regulatory Program, Confined Animal Facilities Program, and State Winery Order.

Beyond this study, the state should continue to seek opportunities to standardize data requirements across agencies, regularly review regulatory impacts, and seek to streamline existing regulations and remove outdated ones.

[43] https://www.cdfa.ca.gov/agvision/docs/AgVision_2023_Plan.pdf

1.3 Invest in research and development to provide new options for building resilience on farms.

While the agricultural sector is facing growing challenges, there are opportunities for new and upgraded solutions. New technologies, ways to connect and share improvements and best practices, and research areas are all providing farmers and ranchers with innovative ways to address these challenges. Ensuring that these solutions are available across the state is critical in ensuring that California agriculture continues to thrive.

1.3.1 Invest in research for Precision Agriculture technology to identify how to optimize inputs and improve efficiency.

Goal 5: Demonstrate and Invest in Innovation and Technology

Agriculture faces growing challenges from rising input costs and the increasing impacts of climate change. However, advancements in precision agriculture - a farming concept referring to utilizing advanced technology like artificial intelligence (AI), machine learning, and remote sensing to optimize fertilizer, pesticide, and water use, are transforming farming practices and allowing farmers to reduce input costs and build resilience. By optimizing resource use, improving efficiency, and enabling better decision-making, these technologies can help farmers adapt to climate uncertainty while maintaining profitability. Expanding investments in research and technology development for precision agriculture technology can further its impact.

The most significant cost-saving benefit of precision agriculture is efficient resource management. AI-powered irrigation systems, for example, use real-time soil moisture data and weather predictions to apply water only where and when it is needed. This increases water efficiency and lowers electricity costs for pumping, a crucial advantage in a hotter, drier future. Similarly, precision nutrient management, aided by soil sensors and machine learning algorithms, ensures fertilizers are applied in optimal quantities, preventing excess use and reducing expenses on inputs.

Pest and disease management also see major improvements through technology solutions. Early and accurate identification and control of pests are essential to minimize crop losses and reduce the use of chemical pesticides. With machine learning models analyzing pest patterns and drones detecting early infestations, farmers can target problem areas with precision, minimizing chemical usage and reducing expenditures

on pesticides. This targeted approach not only saves money but also enhances soil and ecosystem health.

Moreover, AI and satellite data contribute to better yield prediction and risk management. Machine learning models analyze historical and real-time data to forecast crop yields, allowing farmers to plan for market fluctuations and avoid financial losses. Additionally, satellite imagery helps monitor crop health, detecting stress from drought, pests, or nutrient deficiencies before they become widespread issues. By addressing problems early, farmers can prevent severe losses and maintain stable production levels despite unpredictable weather patterns.

Beyond cost savings, precision agriculture strengthens climate resilience by promoting climate-smart practices. Reduced water and fertilizer use mitigate environmental degradation, while AI-driven carbon sequestration analysis helps farmers adopt climate-smart agriculture techniques that enhance soil health. Furthermore, precision tillage and cover cropping strategies, informed by satellite data, protect farmland from erosion and extreme weather effects, ensuring long-term productivity.

In an era of economic and climatic uncertainty, precision agriculture offers additional means for farmers to cut costs while increasing their adaptability. By utilizing AI, machine learning, and satellite technology, farmers can make informed decisions that improve efficiency, safeguard resources, and strengthen their resilience against climate change. As these technologies continue to advance, they will play an increasingly vital role in shaping the future of sustainable and profitable agriculture.

In 2015, the University of California, Agriculture and Natural Resources (UCANR) established The VINE, an agriculture, food, and biotechnology innovation network. The mission of The VINE is "to harness the power of open innovation and to help industries and entrepreneurs grow and scale globally, while catalyzing technology innovation and commercialization for productive, sustainable, and equitable food systems." The VINE aims to provide entrepreneurs in the industry access to the wealth of agricultural expertise present in Cooperative Extension and Research and Extension Centers throughout California. They collaborate with ag tech startups, providing support and mentorship for growth, as well as helping investors understand the unique dynamics and opportunities within agriculture.

Another collaborative effort toward bringing innovation to the food system is the F3 (Farms Food Future) Initiative. F3 includes three programs – F3 Innovate, F3 AgTEC Workforce, and F3 Local – which support agriculture in the Central Valley by developing new ag technology, growing food sustainably with regenerative practices, and by offering cutting-edge job training. F3 Innovate connects university and industry research with communities and growers; Fresno State, UCANR, UC Merced, and CDFA are state

partners who work together to deliver engineering and entrepreneurial solutions to the food system.

1.3.2 Ensure equitable deployment of technical tools and support for small and under-resourced farmers.

Goal 1: Increase and Enhance Technical Assistance

To ensure that all farmers benefit from technological advancements, as listed above, the State of California is playing a role in making these tools more accessible to small and underserved farmers. By dedicating resources to support technical tool adoption and training and technical assistance for small and under resourced farmers, these tools can be utilized more effectively.

While some of CDFA's programs offer grants for certain technologies, such as soil moisture sensors (available through the State Water Efficiency and Enhancement Program, see Chapter 2: Ensure a Water System for more information), there is a lot that can still be done to address equitable adoption. Examples include everything from providing direct grants and subsidies to tax credits, investments in agricultural extension services that can provide trainings, digital literacy support programming, rural broadband extension, supporting open data platforms where farmers can access satellite data including weather forecasts, for free, equipment sharing programs (CDFA has been appropriated 2024 Climate Bond funding to develop an equipment sharing program in the coming years), and by supporting research and development (R&D) for cost-effective precision farming solutions tailored for small operations. Generally, equitable deployment of technical tools for small and under resourced farmers should include technical assistance for how to utilize these emerging technologies and available open data sources (such as state supported tools from Cal-Adapt). The California Jobs First Economic Blueprint specifically calls out agtech and farm equipment as areas of focused accelerated development.

The work of F3 Local focuses on technology adoption for small-scale farmers and producers with an aim of increasing profitability and sustainability. This work takes the form of technical assistance, capacity building support, and access to capital and markets.

1.3.3 Provide infrastructure support for broadband upgrades.

Goal 2: Enhance Program Effectiveness

Strong internet connectivity is key to rural community economic development, improved healthcare, education, and public safety.[44] Improving internet connectivity can also enable farmers to use advanced technologies, both on their farms and in their personal lives, increasing operational efficiency and improving quality of life. Unfortunately, accessing high-speed internet is often a challenge in rural California. The state is investing in rural broadband to bring high-speed broadband service to all Californians. Broadband for All is the state's overarching program to close the digital divide, aiming to connect regions of the state to the internet. CDFA is a member of the California Broadband Council, which recommends strategic policy for providing internet access. The 12-member Council is run by the California Department of Technology's Office of Broadband and Digital Literacy which provides support by managing the statewide ecosystem of individuals and organizations dedicated to closing the digital divide. Broadband for All also works with the California Public Utilities Commission to complete last mile infrastructure projects. Additionally, Senate Bill 156 provided $3.25 billion to build connectivity to rural and urban areas across the state through an open-access statewide broadband middle-mile network administered by the California Department of Technology. Senate Bill 156 also provided funding, administered by the CPUC, to support last-mile infrastructure and provide technical assistance to local governments and tribal entities.[45] The state is advancing work on rural broadband infrastructure development is critical to ensuring that farmers can benefit from a variety of technologies.

1.3.4 Invest in R&D for climate adaptive, heat- and drought-resistant crop varieties.

Goal 5: Demonstrate and Invest in Innovation and Technology

[44] https://broadbandforall.cdt.ca.gov/about/

[45] California Public Utilities Commission. (n.d.). *Broadband implementation for California*. California Public Utilities Commission. Retrieved August 8, 2025, from https://www.cpuc.ca.gov/industries-and-topics/internet-and-phone/broadband-implementation-for-california

A changing climate may provide opportunities to increase production of some crops not traditionally grown in California's higher latitudes, such as avocados, mangos, and agave. Additionally, university researchers and farmers are working to breed crops with attributes that make them better able to tolerate hotter, drier conditions, and fewer chill hours. Plant varieties which are adapted to pest pressures, drought, or heat can provide farmers with options for continued growing in the face of climate change and less water availability. However, changing crops is not as easy as switching which seeds or nursery starts a farmer plants; typically, bringing a crop to market involves ensuring that there is infrastructure to harvest and process the crop; creation of market demand to ensure the crop will be purchased, advertising to attract consumers, and a buyer or many buyers lined up to take it at the end of the season. Each element of a crop's lifecycle from seed to final sale typically involves a chain of researchers, growers, shippers, and retailers.

Artificial Intelligence (AI) – in agriculture, this refers to data collection and analytics, algorithms, the internet of things, and geospatial analytics.

Machine Learning (ML) – a branch of artificial intelligence using data and algorithms to simulate human evaluation. ML algorithms leverage vast data from various sources to provide insights and manage and optimize various aspects of farming. For example, ML can help in weed and pest detection by analyzing images from drones or sensors and accurately identifying them, enabling targeted application of treatments.

Remote Sensing – the use of satellite, airplane, and drone imagery and sensors to monitor conditions on the ground and collect data without physical contact. It can be used to identify and classify types of land cover, assess crop health, estimate yields, and identify areas affected by pests and diseases.

Internet of Things (IOT) – IOT refers to a network of physical devices – in this case tractors, smartphones, irrigation systems, pumps, and more – that are embedded with sensors and software, and that connect to the internet and enable the collection and sharing of data.

As part of the effort to invest in climate adaptive crops, CDFA awards federally sourced funding to organizations, governments, and universities to enhance the competitiveness of specialty crops grown in California through the Specialty Crop Block Grant program. Many of these grants address climate adaptation and extreme weather events. In recent years, CDFA funded $4.6 million in grants to improve crop breeding for heat and drought resistance, as well as for irrigation efficiency strategies.

1.4 Strengthen local and regional food systems to build resilience.

Establishing local and regional food systems can help both farmers and communities withstand and adapt to climate change. This is because longer supply chains are more vulnerable to disruptions like floods, wildfires, and other extreme weather events that can delay goods transport (this also applies to non-climate events, as we saw during the early days of the COVID-19 pandemic). When national or global supply chains are stressed, local communities benefit from local and regional food production, and agricultural producers benefit from consistent local markets for their food and fiber. Small farmers in particular face greater barriers to marketing and distributing their products and regionally focused efforts can help reduce these barriers. Additionally, local food networks strengthen relationships between farmers, consumers, and policy makers, making it easier to coordinate emergency responses during climate crises. Local food systems also mean that more money stays within communities.

1.4.1 Strengthen farm-to-market pathways, direct-to-consumer sales, and localized processing to reduce reliance on vulnerable supply chains.

Goal 2: Enhance Program Effectiveness

Expanding institutional procurement opportunities beyond the agricultural sector and developing regional supply chains can support bringing climate-smart and nutritious food to more Californians. The state has been hard at work securing procurement opportunities, particularly in schools. In 2024, CDFA, in cooperation with the USDA, awarded $21.5 million for 117 projects through the Resilience Food Systems Infrastructure Program. The goal of the program is to support more and better processing options for local and regional producers across specialty crops, dairy, and food grains, and to provide more and better markets to small farms and food businesses. Projects will support activities like processing, packaging, value-added processing like cooking, cold storage, warehousing, distribution, worker education and more.

The state is also investing in entities called "community food hubs," which serve as supply chain intermediaries by providing aggregation, distribution, and marketing services for multiple producers. These organizations use a common facility such as a warehouse or virtual coordination of producers to help reach markets. CDFA's Farm to

Community Food Hubs Program, established in 2025, seeks to incentivize the creation of public-serving aggregation and distribution enterprises to help communities. Awards are expected to be made in Fall 2025.

Making investments in local procurement has myriad benefits. CDFA's Office of Farm to Fork coordinates the California Farm to School Incubator Grant Program, which provides funding to support projects that connect children to locally-sourced, whole foods in the cafeteria, classroom, and garden. Specifically, the program funds schools and childcare centers to increase local procurement and hands on food education; technical assistance for school food leaders, educators, and producers; and supply chain infrastructure for producers and food hubs to scale farm to school activities. Schools provide a stable marketplace less impacted by market fluctuations, allowing producers and buyers to plan for consistent demand and invest in longer term infrastructure to meet the needs of their consumers. CDFA Farm to School Regional Staff positions establish relationships with producers and food systems organizations that can bend and flex to match the shape of any food system challenge. These regional staff positions are key to open institutional market access and maximize impacts for producers, educators, and students. CDFA Farm to School Program also has a goal outlined in Planting the Seed: Farm to School Roadmap for Success that 30 percent of resources support producers with verifiable climate-smart agricultural practices. In three rounds of funding since 2021, the program has provided over $86 million in awards to projects across the state.

The Cold Chain

One of the most critical aspects of fresh produce production in California is the "cold chain." This term refers to the system of cold shipping infrastructure from field to processing center to grocery store or other point of sale. Farm teams harvest fruits and vegetables and load them into a cold storage facility for short or long periods of time until they are ready for distribution, at which point they are loaded into refrigerated trucks for delivery. This system keeps food fresh on the way to the consumer, thereby reducing food waste. As temperatures rise, cold transport and storage will become increasingly necessary in all parts of the state, requiring investments in refrigerated trucks and processing facilities, and additional energy will be required to run them.

1.4.2 The circular bioeconomy: supporting the creation of new income streams for farmers.

Goal 2: Enhance Program Effectiveness

Farms in California have always looked to make the most of their resources, including what others might describe as "waste" – for example, byproducts of harvest and processing like nut shells, citrus peels, tomato and grape pomace, trimmings and pruning from trees and vines, and livestock manure. Those materials have traditionally been used for everything from mulch to livestock feed to fertilizer. However, there is burgeoning recognition that in addition to returning valuable biomass to the soil, some biomass can be a potentially valuable feedstock for value-added uses, which may produce new income streams for farmers and ranchers, helping them achieve greater financial sustainability. For example, nursery pots made from livestock manure that can be put in the ground with the plants they contain, minimizing root disturbance. Additional investment in the research and development of new products that can be made from diverse feedstocks is key, which will need to be supported by additional investment and planning related to the development of supply chains.

CalRecycle is emphasizing the importance of the "circular economy" for reducing waste by moving from a disposable system that uses products once before sending them to a landfill to a circular economy that collects and reuses what would have been waste and makes them into new products; a key example of this is CalRecycle's work on diverting organic materials from landfills and turning it into compost that can be applied to California farms and ranches to build soil health (which also helps California meet its SB 1383 methane reduction goals). California Jobs First has identified this emerging "bioeconomy" sector as one with significant investment potential and strategic importance to in its California State Economic Blueprint.

State agencies, non-profits, scientific, and for-profit organizations are working to intentionally design a circular bioeconomy in the agricultural sector as a way to minimize waste and maximize resource utilization while still bolstering soil health through the return of some of the biomass to the soil. This efficient and intentional circular bioeconomy will add regional value and materials reuse while creating new jobs and products and fostering more climate-friendly agricultural processes. Because of the diversity of feedstocks in California agriculture, it is critical to design products and processes that can utilize a diversity of agricultural byproducts. This will ensure that the

infrastructure and stakeholders for each step in a circular process are identified and material pathways and timing are considered.

Developing these supply chains will require building infrastructure such as processing facilities, identifying participating farmers, and developing and hiring local workers to increase efficiencies in the timing between inputs, outputs, and energy usage. (For more information on efforts to build local workforce and bolster underserved communities' access to resources, see the Workforce and Tools section.) With investment, an agriculture-based circular bioeconomy promises a more climate resilient agricultural industry that creates local jobs, provides food, and promotes economic vitality while conserving resources.

Beam Circular

One investment made by California Jobs First is with the nonprofit organization BEAM Circular (BEAM stands for BioEconomy, Agriculture, & Manufacturing). BEAM Circular is working to bring together public and private projects aimed at scaling innovations to support bioindustrial manufacturing and economic and environmental outcomes for North San Joaquin Valley communities. This work includes manufacturing chemicals, materials, energy, and consumer products by repurposing the organic biomass residues that come from agriculture, forestry, and municipal waste. Their work is intentionally focused on building a local bioeconomy – training a local workforce, using local materials, and manufacturing new products – all in the same region. In 2024, California Jobs First awarded BEAM Circular $3.6 million to launch activities including community engagement and technical assistance for local businesses.[46]

[46] 2023 Moments & Milestones — BEAM Circular

Payment for Ecosystem Services

Farmers and ranchers can access financial incentives in exchange for managing their lands in such a way that provides a climate or ecological service, a process called Payments for Ecosystem Services. The world's longest running Payments for Ecosystem Services program is the USDA's Conservation Reserve Program, which pays farmers to take certain croplands out of production and plant vegetative cover to prevent erosion, improve water quality, and benefit wildlife. In addition to governmental programs, payment systems may also be funded by non-profit organizations or corporations interested in offsetting assets not owned or controlled by companies but essential to their business operations, or within a company's value chain.[47]

[47] U.S. Environmental Protection Agency. (2023, April 12). Scope 3 inventory guidance. U.S. Environmental Protection Agency

1.5 Private investment in climate-smart agriculture via voluntary carbon markets.

Voluntary carbon markets (VCMs) also have the potential to provide farmers with additional private funding for on-farm activities that reduce greenhouse gases or sequester carbon. VCMs are self-governed markets that are not legally mandated, in which companies purchase carbon credits to help offset their emissions. A carbon credit refers to measurable avoidance, reduction or sequestration of CO2 or other greenhouse gas emissions, with one carbon credit equivalent to one metric ton of CO2 equivalent. In the VCM, there are designated protocols and verification processes implemented by third-party private carbon registry and verification services that determine how carbon credits are generated.[48]

One way this can be done is through the adoption of climate-smart agricultural practices. Corporations and policy makers, who have ambitious climate goals, are highly interested in using climate-smart agricultural practices as part of a suite of solutions to reduce GHG emissions.

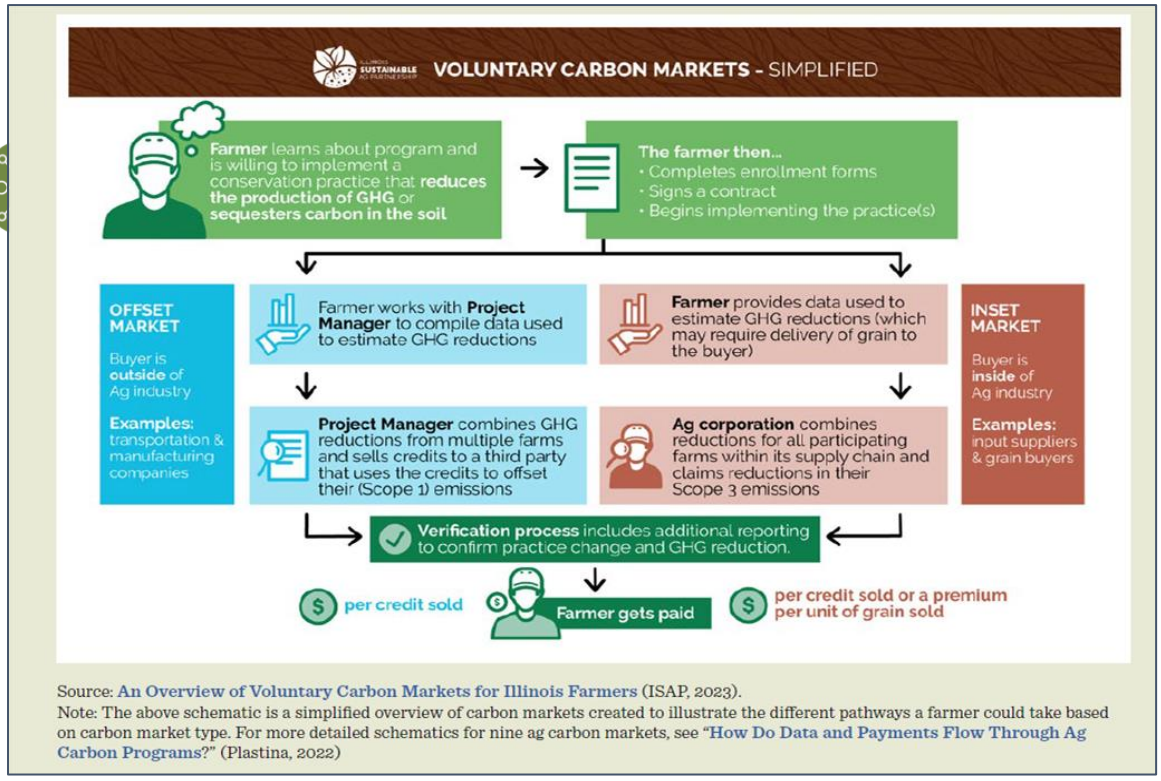
Many companies are interested in using VCMs to facilitate financial transactions for carbon emission reductions. Farmers and ranchers can participate in VCMs by implementing carbon offset projects through climate-smart agricultural practices on their lands that reduce greenhouse gas emissions and sequester carbon. Examples of these projects include applying compost, growing cover crops, reducing tillage, or de-watering manure to use as a soil amendment. Voluntary offset protocols typical require farmers and ranchers to continue implementing the practices over specified period of time (e.g. 5 years, 10 years, or more) to assure continued GHG emission reductions and/or carbon sequestration and prevent a re-release of emissions back into the atmosphere.

In VCMs for natural and working lands, farmers and ranchers can generate carbon credits from their operations and then sell them to companies that have set their own GHG emission reduction targets and seek to purchase credits to offset those emissions. Non-profit organizations have developed the standards protocols for offsets and are tracking the status of carbon offset projects and the ownership of carbon credits through "carbon registries." A simple schematic of voluntary carbon markets is shown in Figure 6. According to Bloomberg NEF, there is huge potential for growth in the voluntary carbon market, due to more and more companies setting their own science-

[48] USDA Report to Congress: A General Assessment of the role of Agriculture and Forestry in U.S. Carbon Market. Oct. 2023. https://www.usda.gov/sites/default/files/documents/USDA-General-Assessment-of-the-Role-of-Agriculture-and-Forestry-in-US-Carbon-Markets.pdf; Jennifer, L. Carbon Credits Explained (2023 Guide). https://carboncredits.com/carbon-credits-explained-2023-guide/

based targets or climate goals. While estimates vary, it is anticipated that the voluntary carbon market will grow globally from $2 billion in 2022 to between $30-500 billion in 2025-2026.

Additionally, in 2023 California passed the Climate Corporate Data Accountability Act (SB 253) which requires entities doing business in California with total annual revenues in excess of $1 billion to publicly disclose their GHG emissions, which incentivizes businesses to look for ways to reduce emissions throughout their supply chains. The California Air Resources Board is tasked with developing regulations to implement SB 253, and while this effort is still under development, future implementation of SB 253 requirements may also provide another opportunity for companies to invest in climate-smart agriculture practices to reduce their overall emissions they must report to comply with SB 253.



Source: An Overview of Voluntary Carbon Markets for Illinois Farmers (ISAP, 2023).
Note: The above schematic is a simplified overview of carbon markets created to illustrate the different pathways a farmer could take based on carbon market type. For more detailed schematics for nine ag carbon markets, see "How Do Data and Payments Flow Through Ag Carbon Programs?" (Plastina, 2022)

Figure 6: A Simple Schematic of Voluntary Carbon Market

1.5.1 Coordinate with sister agencies to develop outlines and methods to facilitate voluntary investment in climate-smart agriculture practices.

Various state agencies play a role in encouraging the adoption of climate-smart agricultural practices. Because of their respective roles related to the quantification of greenhouse gas emissions and encouragement of climate-smart land and agricultural practices, CalEPA, CNRA, and CDFA coordinate with each other often around these activities. For example, SB 27 (Skinner, 2001) requires the three agencies to work together to develop a Carbon Sequestration and Climate Resiliency Project Registry. The Registry is intended to facilitate private funding of nature-based and direct air capture projects that deliver on California's climate goals.

Another pathway to voluntary investment in climate-smart agriculture practices is through the voluntary carbon market. While many farmers and ranchers are familiar with the concept of carbon markets, so far, few are participating. For more California farmers and ranchers to participate in carbon markets, it will be important to establish rigorous accounting and verification standards and streamlined participation pathways that can be utilized by producers in a cost-effective way. Limited resources create inherent risk in adopting new practices and can limit participation in carbon markets. Research shows that farmers have interest in carbon markets, but the financial benefits are not yet clear. One survey of farmers in the Midwest found that only 3 percent showed interest in carbon market participation while the rest indicated they are not ready to participate. In the survey, most of the farmers (59 percent) said they would join the carbon markets if they had more incentives to participate. Overall, the farmers surveyed were convinced that carbon sequestration is beneficial for soil health and plant growth, but they saw participation in the current markets as onerous and providing insufficient financial benefits.

Similarly, another study surveyed both conventional and organic farmers who were participating and not participating in agricultural carbon markets.[49] This research found that both conventional and organic farmers were motivated to participate in carbon markets due to the overall profitability and resilience gained by maintaining soil health. However, all the participating farmers indicated that the prices of carbon credits are too low, and that the paperwork burden is too high. This study also notes that non-participating farmers felt it was unfair that carbon markets were built on an industrial monocrop model that would not be easily applied to their small, diversified farms. As such, participation in carbon markets may actually disincentivize diversified production practices and undermine climate resilience goals. The authors concluded that only farmers who are already convinced of changing their soil management for improving soil health are likely to participate; carbon market incentives alone are currently

[49] Clare T. Barbato and Aaron L. Strong. 2023. Farmer perspectives on carbon markets incentivizing agricultural soil carbon sequestration. Climate Action, 2:26. https://doi.org/10.1038/s44168-023-00055-4.

insufficient. They also concluded that the carbon markets are most accessible for large conventional farmers who are not currently using climate-smart practices.

This research highlights that current carbon markets tend to be an option only for farmers and ranchers with significant resources and highlights the work needed to open access for farmers and ranchers with less resources and/or have been underserved and to develop new models for these producers to access financial compensation for the ecosystem services they provide. Overall, the barriers to participation for farmers and ranchers include low return on investment, market confusion, upfront costs to implement projects, high transaction costs that include quantification, verification, registration cost, record keeping and data collection, and additionality and permanence problems.[50]

Measuring the impacts of climate-smart agriculture on carbon and GHGs is currently costly and may not always show any measurable carbon benefits from practice changes in the short term. However, data collection and empirical work are critical elements to maintain and bolster the integrity of carbon credits.

Various Measuring, Monitoring, Reporting, and Verification (MMRV) protocols must be developed that will ensure the integrity of the carbon market while also allowing the myriad of California's crop types, farming systems, and diverse producers and farm sizes to participate. It is important to ensure that processes to bring credits to market are accessible to farmers across a range of income levels. This would enable farmers to take advantage of benefits from any number of financial incentive programs and investments from the private sector, while also ensuring that practices that mitigate climate change are incentivized.

CDFA is currently working with sister agencies including CARB and CNRA to better understand gaps and opportunities in MMRV and to coordinate these efforts across multiple scales for multiple purposes (e.g. program reporting, inventory updates, voluntary carbon markets and accessing other funding).

Measuring, Monitoring, Reporting, and Verification (MMRV) for Carbon Crediting

[50] USDA Report to Congress: A General Assessment of the role of Agriculture and Forestry in U.S. Carbon Market. Oct. 2023. https://www.usda.gov/sites/default/files/documents/USDA-General-Assessment-of-the-Role-of-Agriculture-and-Forestry-in-US-Carbon-Markets.pdf

A well-functioning carbon market provides credit buyers with confidence and trust that the GHG emissions reductions they are paying for meet certain criteria, typically that they are real, measurable, verifiable, additional, and permanent, or of known duration. The multi-step Measuring, Monitoring, Reporting, and Verification (MMRV) process to verify the GHG emissions benefits typically includes measuring the amount of GHG emissions reduced by a specific mitigation activity over a period, including sampling or modeling beforehand; monitoring the project implementation; recording all activities; and presenting these findings to an accredited third party for validation. Generally, third parties verify overall project implementation so that the results can be certified, and a carbon credit can be issued.

The quantification of the GHG emissions reductions of agricultural practices is challenging due to the dynamic nature of practice management, and varying soil and climatic conditions. These variables can make the direct measurement of GHG fluxes and/or carbon storage difficult and expensive. Agriculture-related carbon market protocols often rely upon site-specific sampling and modelling approaches to estimate GHG reductions. The results from these approaches have a degree of uncertainty, which is usually quantified statistically.

Generally, process-based models, which simulate plant and microbial activity in the soil, are used to quantify GHG emission reductions in croplands. The validation of these models – the testing to determine their accuracy – occurs before their use in carbon markets, but then typically continues while they are in use, as they continue to be improved over time. Model validation requires detailed, site-specific, long-term data for soils, weather and crop management, although validation does not have to be carried out for every site or scenario that the model covers. Remote sensing, or the detection of information (in this case GHG emission reductions or carbon sequestration) without physical contact with the observed area, is a growing field for MMRV. Remote sensing techniques can improve uncertainty and reduce reliance on extensive management records; however, more science-based research data is required for training and ground-truthing of remote sensing data.

Remote Sensing and MMRV

The state has set Nature-Based Solutions Targets for croplands that include implementing more than 3 million acres of healthy soils practices on the landscape by 2045. In order to understand how these practices will influence cropland carbon stocks and cropland greenhouse gas emissions, CARB will be incorporating remote sensing, reported land management data, and other state-wide agronomic data to model the effects of these practices. The model will calculate carbon stocks and greenhouse gas (GHG) emissions from California's croplands under annually updated conditions and also future scenarios that include changing land use and climate conditions. The project will utilize a model that can represent carbon, water, and nitrogen dynamics in California's croplands. The model inputs will include remote sensing data as well as agronomic data to not only simulate the nutrient and water dynamics, but also allow the model to infer what crop management practices are happening to the land and how those crop management practices influence the carbon stocks and ghg emissions. This work will inform the Natural and Working Lands Carbon Inventory. In its current State, this MMRV is designed for monitoring large areas, such as counties or larger, to understand the collective impact that farming practices are having in the state's efforts towards carbon neutrality and would likely need further advancements to be sensitive enough to produce measured values for GHG emission or carbon stock changes at the individual farm or practice level.

Rice Cultivation Credits

The Nature Conservancy (TNC) converted the lower half of Staten Island to 4,000 acres of rice and 1,000 acres of managed wetlands (where land is too wet to farm). TNC is currently in process of validating this project with the American Carbon Registry (ACR, third party verifier for voluntary carbon markets) approved California Deltaic and Coastal Wetlands Restoration Methodology. With funding from the Delta Conservancy, The Metropolitan Water District of Southern California (MWD) is converting the whole of Webb tract to a mosaic of rice and managed wetlands (1,500 acres rice, 3,000 managed wetlands). MWD will validate these projects with ACR. The Delta Conservancy funded a TNC program to enroll up to 5,000 acres of rice conversion with small farmers. All of these projects are intended to address subsidence and related carbon emissions while improving the long-term economic viability and climate resilience of the islands.

1.5.2 Train technical assistance providers with protocols for implementation, monitoring, and verification for voluntary carbon markets.

Goal 1: Increase and Enhance Technical Assistance

Consistent and regional technical assistance by experts trained in the implementation, monitoring, and verification protocols of VCMs will be essential to allowing widespread participation in carbon markets. In 2018, the Climate Smart Agriculture Technical Assistance (CSA TA) program was established by AB 2377 and prioritizes delivering TA to farms and ranches that are 500 acres or less. CSA TA enables the implementation of conservation and climate-smart agriculture practices by providing support with project design, grant application assistance, project implementation, and grant management. As carbon markets develop, expanded technical assistance from the CSA TA program of HSP would benefit from training on MMRV protocols.

1.6 Support workforce development through programs and training.

Workforce development is critical to ensuring that the current workforce has the tools and knowledge to succeed and access to technical assistance, while also ushering in a new generation of farmers, farmworkers, and ranchers. The State of California is dedicated to strengthening agricultural production, accelerating agricultural technology and farm equipment production, and betting on the emerging circular bioeconomy.[51]

Much workforce development work is occurring through partnerships – with higher education systems, state agencies, nonprofits, and more. These partnerships provide opportunities to students in high school and college, farmworkers, and career farmers. This system should be expanded and coordinated to ensure that California's farms and ranches are able to keep abreast of the latest climate-smart practices and technologies.

1.6.1 Coordinate with California higher education systems to expand training and career development in agriculture.

Goal 2: Enhance Program Effectiveness

The state, the University of California, the California State University systems, and community colleges work on a range of initiatives to expand training and development in climate-smart agriculture.

The California Natural Resources Agency is supporting the development of a workforce and economic impact study of nature-based solutions, including soil health practices, cropland conservation, conversion to organic cropland production, and grazing for wildfire risk reduction. This study, planned for publication in 2026, will project the workforce needs associated with achieving California's nature-based solutions climate targets and provide recommendations to meet those needs.

Focusing on the development of educational pipelines in agricultural communities into technical assistance careers is an opportunity to leverage existing community knowledge and skill, address technical assistance gaps, and provide employment opportunities in rural areas. Expanding these opportunities could allow many young

[51] https://jobsfirst.ca.gov/

people with agricultural labor backgrounds who already have the foundational agricultural knowledge, speak multiple languages, and have the social and cultural competencies to conduct highly effective technical assistance in regions where it is often difficult to recruit an outside skilled workforce. California State University Chico's Center for Regenerative Agriculture and Resilient Systems program is training the next generation of technical assistance providers (TAPs) through it's TAP Certification Program. Funded by USDA, the TAP Certification Program trains participants to carry out holistic farm and ranch planning to support the expansion of systems-based conservation practices on California farms and ranches.

The F3 Initiative's AgTEC Workforce program is working to transform agricultural training and education by fostering collaboration between industry, colleges, and workers. It includes a curriculum based on practical, competency-based education informed by extensive farmworker surveys and industry collaboration, and provides an AgSystems Certificate through seven community colleges.

In March 2025, the Employment Development Department awarded $10 million as part of the Farmworker Advancement Program to twelve California-based organizations for creating programs that help farmworkers adjust to the ever-changing demands of the farming industry. An additional $1 million was awarded to Jobs for the Future to assist these organizations in the development and rollout of their programs. The Farmworker Advancement Program, part of the California Jobs First Initiative, aims to enhance job creation and economic development across the state.

1.6.2 Promote Jobs First programs to increase the agricultural workforce.

Goal 2: Enhance Program Effectiveness

Jobs First Economic Blueprint

In an effort to guide state investment to bolster local economies and create good paying jobs, including for the agricultural sector, Governor Newsom launched the California Jobs First Economic Blueprint in 2025. Critical to this effort is the emphasis on a bottom-up approach to invest and build up those communities and peoples who have previously not received support. Efforts directed at the agricultural communities include bolstering the agricultural economy by strengthening food production and processing, accelerating the growth and expansion of agricultural technologies and farm equipment, and exploring innovative economic opportunities such as the bioeconomy. These agricultural economic opportunities are themselves dependent on expanding a

skilled workforce, building out infrastructure like internet, transportation, electricity, and water, and promoting wellbeing through housing, healthcare, and childcare.

CDFA's Secretary is a member of the Jobs First Council, supporting actions in the Economic Blueprint that include bolstering the agricultural workforce, strengthening food production and processing, accelerating the growth and expansion of agricultural technologies and farm equipment, and exploring innovative economic opportunities such as the bioeconomy.

There are a variety of current programs that help fund agricultural workforce development opportunities to support Jobs First. This includes the CalAgPlate Grant Program, which was established in 2014 with revenue earned from California Agriculture Special Interest License Plates. The CalAgPlate Grant Program provides funding to organizations to support agricultural education. Since 2014, CDFA has awarded nearly $2 million to Future Farmers of America (FFA) through this program. FFA is a school-based agricultural education and leadership program that prepares students for careers in global agriculture, food, fiber and natural resource systems. The FFA student organization has over 100,000 student members across 360 school chapters located throughout the state.

CDFA's Farm to School Program advances the next generation of food systems leaders through both partnership and funding. The CA Farm to School Incubator Grant Program has provided over $86m to food systems programs to expand Career Technical Education programs in schools and on farms, and the program reaches 49 percent of all CA schoolchildren. Funding is also complemented by the role of CDFA Farm to School Regional Staff who develop partnerships and collaborations with statewide initiatives growing the agricultural workforce. By weaving together the CA Jobs First initiatives, Career Technical Education programs, culinary and agricultural apprenticeships, and institutional market development programs, CDFA Farm to School Regional Staff also contribute to the development of resilient food systems.

The California Department of Education's Agricultural Education Unit has provided support for agriculture education and the development of an agricultural workforce since the early 20th century. Since 1928, the Unit has been the official sponsor for the California Association of Future Farmers of America. The Unit also administers the Agricultural Career Technical Education Incentive Grant to provide local educational agencies with funds to improve the quality of their agricultural vocational education programs. The goal is to maintain a high-quality, comprehensive agricultural vocational program in California's public school system to ensure a constant source of employable, trained and skilled individuals. In 2023, the California Department of Education and the California Community Colleges Chancellor's Office published the

California State Plan for Career Technical Education with the goal of improving equity in educational access and outcomes across the state and supporting the development of a high-skilled workforce. The plan is based on four key themes:

1) Supply that meets demand,
2) Effective delivery and support,
3) Data that informs investments, and
4) Systems alignment.

Workforce development through Corps programs enables immersive, hands-on education and training for future agricultural workforce needs. The California Conservation Corps (CCC) seeks to protect and enhance California's natural resources and communities while empowering and developing young adults through hard work and education. In addition to resources and energy projects, CCC Corpsmembers also response to natural and man—made disasters, including pest infestations and other agricultural emergencies. The CCC also awards local conservation corps and California Native American tribes to support similar work – this includes $10 million in funding to 5 California Native American tribes to provide educational and career pathways for native youth and young adults while preserving and protecting native land.[52] Additionally, in 2020, Governor Gavin Newsom launched the California Climate Action Corps through CalVolunteers, which is the first state-level climate corps in the nation and seeks to advance community climate action.

[52] Grants – California Conservation Corps

F3 Innovate

Fresno-Merced Future of Food Innovation (F3 Innovate) Coalition is led by the Central Valley Community Foundation and creates economic and employment opportunities in the Fresno-Merced Region through agricultural workforce development and technological innovation. This region is one of the most productive agriculture regions in the world, home to approximately 5 million acres of irrigated farmland, 13,500 farming enterprises, and an industry concentration of 10-30 times more crop and animal products relative to the rest of the world. The coalition represents a commitment to the global effort to export sustainable food technology with the simultaneous goal of enhancing the local food system and improving the quality of life for the food and ag tech workforce. The goal of the coalition is to establish California's Central Valley as the nation's leading agri-food tech and engineering hub by accelerating the integration of technology and skills in the region's agriculture industry to improve productivity and job quality for existing farmworkers while driving more resilient and sustainable food systems. The coalition will create 10,000 jobs paying an average of 60 percent more than low skilled jobs and is expected to add $500 million in value in GDP. In 2023, the initiative was awarded $65.1 million by the Biden-Harris Administration and is supported by CDFA alongside academic, federal and local partners. F3 Innovate is an example of the power of public-private partnerships to spur action to meet goals and drive industry leadership.

1.7 Expand climate-smart agricultural marketing efforts.

While this chapter includes many efforts aimed at operational considerations, workers, the economy, and overall building resilience and adaptability into the food system, consumer-driven demand for climate-smart products is also driving change.

1.7.1 Expand the CA Grown Marketing Campaign to include climate-smart products.

Goal 2: Enhance Program Effectiveness

Incorporating climate-smart agricultural products into existing marketing efforts can help grow procurement of climate-smart agricultural products. CA Grown, or the Buy California Marketing Agreement, is a marketing campaign designed to promote California commodities. Since 2001, the California Grown campaign uses a variety of strategies including storytelling and logo branding to promote California-grown agricultural products and the people who produce them. There is an opportunity to bolster marketing efforts for climate-smart agricultural products into the existing CA Grown campaign.

1.7.2 Expand marketing efforts to highlight products from the circular economy.

Goal 2: Enhance Program Effectiveness

As described in Action 1.4.2, this document aims to support the development of the circular bioeconomy, including the development of supply chains that minimize waste and maximize resource utilization, adding regional value and materials reuse while creating new jobs and products and fostering more climate-friendly agricultural processes. In addition to research and development that supports the technical development of more sustainable products, it will also be important to create a market and demand for these products. Expanded marketing and outreach efforts to educate consumers will also be required to raise awareness about the importance of locally-derived and biodegradable products vs. single use products.

1.8 Engage in international and subnational partnerships and collaboration.

Climate change is exacerbating existing challenges faced by farmers and ranchers around the world, as well as creating new ones. Rather than face these challenges alone, farmers around the world, supported by government institutions, among others, are collaborating and sharing information on innovative partnerships that will enable our farms and food systems to adapt to and build resilience against climate change.

1.8.1 Grow international climate partnerships and collaboration with other national and subnational governments.

Goal 3: Grow Partnerships and Collaboration

International Climate Agreements and Networks

CDFA has a long history of international engagement, beginning with trade missions to help identify how California and other nations and sub-nations can engage in mutually beneficial trade in agricultural products. As climate change has moved to the forefront of topics affecting agriculture, CDFA's trade missions increasingly focus on discussions of climate change impacts and solutions, setting the stage for deeper cooperation. Following many trade missions, CDFA has entered into MOUs (memorandums of agreement) and signed Letters of Intent (LOIs) with national governments to identify specific areas of cooperation. CDFA is also party to broader MOUs along with other state agencies, which span topics including agriculture, but also encompassing transportation, energy, natural resource conservation, and more. California has signed MOUs with countries and provinces such as Canada, Mexico, China, and the Netherlands, to name a few. A full list of bilateral climate agreements can be found here.

Participation in foreign delegations: CDFA frequently hosts foreign delegations—including government officials, researchers, and farmers—to showcase California's leadership in climate-smart agriculture, such as methane digester projects, soil carbon sequestration, and drought-resilient cropping. CDFA leadership also joins outbound trade and research missions, often with a climate component, to learn from international counterparts and promote California's agtech and sustainability solutions.

United Nations Conference of the Parties: State agency leadership, including CDFA leadership, frequently participates in the annual United Nations Framework Convention on Climate Change Conference of the Parties (UNFCCC COP), where they present

California's agricultural climate actions, participate in panel discussions on topics like healthy soils and livestock methane reduction, and forge new partnerships. These conferences also provide platforms for bilateral discussions with ministers and agricultural leaders from other countries.

Increased Collaboration at the Subnational Level

As more states adopt agriculture-related climate policy and programs, there is an increased opportunity for collaboration and coordination between subnational governments. California and its various departments are party to multiple climate-focused subnational alliances:

- Subnational Methane Action Coalition (SMAC) - In December 2023, California kicked off the SMAC at the UNFCCC COP28 in Dubai. The effort includes fifteen signatories from nearly every continent. California has a goal of reducing methane emissions 40 percent compared to 2013 levels by 2030, the most ambitious methane reduction goal in the world. Because methane is such a potent greenhouse gas with a short atmospheric lifespan, reducing methane is critical to lessening the impacts of climate change in the short term. The SMAC creates collaboration with jurisdictions that oversee and regulate key sources of methane such as agriculture, energy and landfills to share goals and best practices in reducing the short-lived climate pollutant that accounts for almost 30 percent of current global warming and is 80 times more potent than carbon dioxide over a 20-year period.
- Mediterranean Climate Action Partnership (MCAP) - Another partnership launched at COP28 in Dubai, the MCAP includes fifteen inaugural members from Mediterranean regions around the globe. Mediterranean regions are characterized by hot, dry summers and cold, rainy winters, and many Mediterranean regions around the world are experiencing similar challenges related to climate change including intensifying droughts, wildfires, and extreme heat. The MCAP provides a venue for these regions to discuss their approaches to shared impacts through technical work groups, which are tasked with supporting on-the-ground projects, developing actionable knowledge products, and scaling collective action.
- Under2 Coalition – The Under2 Coalition was formed in 2015 by the governments of California and Baden-Württemberg to galvanize climate action by city, state, and regional governments around the world. It has grown to a network of 183 states and regions. The Under2 MOU was revised in 2021 to align with the Paris Agreement goal of limiting global temperatures to a 1.5 degree increase; signatories must now commit to reaching net zero emissions by 2050 (California's target is 2045).

- America Is All In – This coalition was created to help America meet the Paris Climate Agreement obligations in the absence of federal leadership. Led by Governor Newsom, Illinois Governor Prtizker, former White House National Climate Advisor, and 13th U.S. Environmental Protection Agency Administrator McCarthy, and Cleveland Mayor Bibb, America is All In brings together leaders from cities, states, tribal nations, businesses, schools, and institutions of faith, health, and culture, to help cut our nations emissions in half by 2030 and achieve net zero emissions by 2050. This coalition is working to achieve these goals by developing a national climate strategy to cut emissions and build resilience and scaling climate action that both empowers workers and also protects public health.

National Action

California is also a founding member of the U.S. Climate Alliance, a bipartisan coalition of 24 governors advancing state-led climate action since 2017. Members are committed to achieving the goals of the Paris Agreement. Currently, Governor Gavin Newsom is co-chair of the Alliance.

This coordination is critical to creating more effective climate mitigation and resilience across state lines and creating cost-efficient actions and programs. Collaborating on state and local polices also scales up effective climate action, including Climate Action Plans from local governments which can influence the availability of water for agriculture and determine land use in the area.

Implementation

Strategy/ Action	Goal Alignment	Lead Agency	Supporting	Status	Implementation Phase
1.1 Support financial risk reduction measures for farmers.					
1.1.1 Expand insurance options for specialty crops, especially to reduce risk from extreme weather-related losses.	2: Enhance Program Effectiveness	USDA RMA	DWR, CDI		
1.1.2 Effectively promote and deploy the California Underserved and Small Producers (CUSP) program.	2: Enhance Program Effectiveness	CDFA	DWR		
1.2 Reduce workload associated with meeting or exceeding regulatory goals.					
1.2.1 Simplify and streamline regulatory compliance reporting.	4: Align and Simplify Policies and Regulations	All			
1.3 Invest in research and development to provide new options for building resilience on farms.					
1.3.1 Invest in research for Precision Agriculture technology to identify how to optimize inputs and improve efficiency.	5: Demonstrate & Invest in Innovation and Technology	GoBiz	CDFA		

1.3.2 Ensure equitable deployment of technical tools and support for small and under-resourced farmers.	1: Increase and Expand Technical Assistance	CDFA	GoBiz		
1.3.3 Provide infrastructure support for broadband upgrades.	2: Enhance Program Effectiveness	CPUC, CDT (OBDL)			
1.3.4 Invest in R&D for climate adaptive, heat- and drought-resistant crop varieties.	5: Demonstrate & Invest in Innovation and Technology	CDFA	DWR		
1.4. Strengthen local and regional food systems to build resilience.					
1.4.1 Strengthen farm-to market pathways, direct-to-consumer sales, procurement opportunities, and localized processing to reduce reliance on vulnerable supply chains.	2: Enhance Program Effectiveness	CDFA			
1.4.2 The circular bioeconomy: supporting the creation of new income streams for farmers.	2: Enhance Program Effectiveness	CalRecycle, GoBiz			
1.5 Private investment in climate-smart agriculture via voluntary carbon markets.					

1.5.1 Coordinate with sister agencies to develop outlines and methods to facilitate voluntary investment in climate-smart agriculture practices	3: Grow Partnerships and Collaboration	All			
1.5.2 Train technical assistance providers with protocols for implementation, monitoring, and verification for voluntary carbon markets.	1: Increase and Expand Technical Assistance	CDFA	DWR		
1.6. Support workforce development through programs and training.					
1.6.1 Coordinate with California higher education systems to expand training and career development in agriculture.	2: Enhance Program Effectiveness	CDFA	DWR, GoBiz, CNRA		
1.6.2 Promote Jobs First programs to increase the agricultural workforce.	2: Enhance Program Effectiveness	GoBiz	CDFA, CDE, CNRA		
1.7 Expand climate-smart agricultural marketing efforts.					

1.7.1 Expand the CA Grown Marketing Campaign to include climate-smart products.	2: Enhance Program Effectiveness	CDFA			
1.7.2 Expand marketing efforts to highlight products from the circular economy.	2: Enhance Program Effectiveness	CalRecycle, CDFA, GoBiz			
1.8 Engage in international and subnational partnerships and collaboration.					
1.8.1 Grow international climate partnerships and collaboration with other national and subnational governments.	3: Grow Partnerships and Collaboration	CDFA			

Chapter 2. Ensure a Water System for Food System Resilience in a Hotter, Drier Future

Key Objective: Create sustainable and reliable water access for ensuring a resilient food system.

Context

Agriculture is one of the largest users of water in the State, consuming approximately 40 percent of the state's water across hundreds of thousands of acres.[53] Water reaches California's farms and ranches through a complex system of conveyance infrastructure. Designed to distribute water from winter snowpack and spring snowmelt in mountains, infrastructure projects such as the California State Water Project, the Central Valley Project, the Colorado River Project, and other large water conveyance projects connect canals, pipelines, reservoirs, and hydroelectric power facilities that stretch the length of the state, playing a key role in the success of California agriculture. Beyond large infrastructure water projects, water moves through California through natural freshwater ecosystems starting with mountain headwaters, and can be drawn from surface sources, extracted as groundwater, or taken from recycled sources from local agencies.[54] Even with the impressive infrastructure to move water around the state, climate change presents a threat to the state's water resources as a result of less average snowfall, greater evaporation, greater consumption of water by vegetation and soil, and more water held in the atmosphere. Over the next 20 years, California's water supplies could be reduced by an estimated 10 percent, about 6-9 million acre-feet. (For more information, see the Water Project Delivery Capability Report 2023 and the California's Water Supply Strategy: Adaption to a Hotter, Drier Future).

California agriculture not only depends on a secure water supply but can also play an important role in supporting the sustainability of California's water supply by protecting and restoring headwaters, safeguarding existing infrastructure, contributing to groundwater recharge, and using water efficiently.[55]

[53] Public Policy Institute of California. (2019, June). Fact sheets: California water storage and water system needs. California Water Commission. https://cwc.ca.gov/-/media/CWC-Website/Files/Documents/2019/06_June/June2019_Item_12_Attach_2_PPICFactSheets.pdf

[54] California Department of Water Resources. (2023, December). California Water Plan Update. State of California. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/California-Water-Plan/Docs/Update2023/Final/California-Water-Plan-Update-2023.pdf

[55] https://www.pnas.org/doi/epub/10.1073/pnas.2310079121

Water Supply Variability

Historically, California's Mediterranean climate has been characterized by seasonal precipitation that results in hot and dry summers and wet winters. On top of seasonal variability, annual variability can exacerbate wet and dry conditions. The state experienced the most severe drought on record between 2012 and 2016, with thirteen of the driest months occurring during this period. That was followed by extreme precipitation in 2017, and then another drought beginning in 2020 through 2022, and then another round of extreme precipitation in 2023. Climate change is increasing this "weather whiplash:" oscillations between extreme dry and extreme wet periods and increasing variability, with greater frequency and intensity of droughts and extreme precipitation events.[56] The following paragraphs highlight some of the key challenges related to water supply and agriculture, including water supply variability, reduced water flows, and crop impacts.

The flood and drought periods bring unique challenges to California's water infrastructure and threaten water security in the state. California's Sierra Nevada snowpack is a critical source of water, particularly in the summer months. When winter precipitation falls as snow at higher elevations, water is effectively stored until it is released as run-off in the late spring and summer. However, a warming climate means more precipitation is falling as rain rather than snow, leading to less water stored as snowmelt, flooding, and decreased summer water availability.[57] California has experienced a series of record-breaking extreme precipitation events caused by specific weather phenomena such as atmospheric river storms. On average, 30-50 percent of California's annual precipitation comes during atmospheric rivers, and this proportion will only increase as the climate warms.[58]

Even with the potential for extremely wet periods in California's future, drought is persistent; available water supplies are estimated to decrease by 10 percent by 2040. California's water infrastructure was originally designed to capture, store, and convey water under 20th century climate conditions rather than 21st century conditions with warmer temperatures and more variable and extreme precipitation patterns. This will mean decreasing reliability in surface water exports and more reliance on other water

[56] Swain, D. L., Langenbrunner, B., Neelin, J. D., & Hall, A. (2018). Increasing precipitation volatility in twenty-first-century California. Nature Climate Change, 8, 427–433. https://doi.org/10.1038/s41558-018-0140-y

[57] California Office of Environmental Health Hazard Assessment. (2022). Indicators of climate change in California: 2022 report (Publication No. 22-0001). California Environmental Protection Agency. https://oehha.ca.gov/media/downloads/climate-change/document/2022caindicatorsreport.pdf

[58] Office of the State Climatologist. (2021). Hydroclimate Report Water Year 2021. California Department of Water Resources. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Flood-Management/Flood-Data/Climate-summaries/Hydroclimate_Report_2021-ADA-FINAL.pdf

sources such as groundwater, recycled water, and desalinated water, which, without intervention to build these water sources' volumes, would threaten water security for the state.[59]

This threatens water security because warmer temperatures reduce snow storage and contribute to snow droughts, heavy rains cause excess runoff that can't be captured due to limitations on existing storage capacity and can lead to soil erosion. Hotter weather and increased evaporation also reduce plant cover and drain water from reservoirs and soils, leading to soil degradation from organic matter break down and wind erosion, and the soil can lose structure and become compacted[60], which reduces infiltration and on-farm water storage. All of these factors, along with aging infrastructure, make it harder to store and deliver water reliably.[61]

Groundwater Depletion

With greater water needs and less surface water available in recent decades, producers have become increasingly reliant on groundwater. During the drought in 2020-2022, agricultural surface water deliveries in the Central Valley were reduced by almost 43 percent, which lead to a 33.7 percent increase in groundwater use.[62] Even so, increased pumping was not enough to maintain farming at the previous level: irrigated crop acreage decreased by up to 10 percent during this two-year period. Increased reliance on groundwater led to an overall decline in availability and water levels in 45 percent of wells throughout the state, including for farming and for some farming communities, between 2003 to 2023.[63]

Drought and groundwater depletion result in undesirable effects for agricultural communities, including drying of local wells, deterioration of water quality, increased pumping costs, and land subsidence that can damage infrastructure and impair agriculture in the long term.[64] During the 2022 drought, it is estimated that irrigated

[59] California Department of Water Resources. (2023, December). California Water Plan Update. State of California. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/California-Water-Plan/Docs/Update2023/Final/California-Water-Plan-Update-2023.pdf

[60] Managing Soil Compaction in California Vegetable Farms | Live to Plant

[61] California Water Plan Update 2023; Circle of blue 2024; Caltrans Soil Infiltration Guidance 2018

[62] Medellín-Azuara, J., Escriva-Bou, A., Rodríguez-Flores, J. M., Cole, S. A., Abatzoglou, J. T., Viers, J. H., Santos, N., & Sumner, D. A. (2022). Economic impacts of the 2020–2022 drought on California agriculture. A report for the California Department of Food and Agriculture. Water Systems Management Lab, University of California, Merced. https://drought.ucmerced.edu

[63] California Department of Water Resources. (2023, December). California Water Plan Update. State of California. water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/California-Water-Plan/Docs/Update2023/Final/California-Water-Plan-Update-2023.pdf

[64] Water Science School. (2018, June). Groundwater Decline and Depletion. United States Geological Survey. https://www.usgs.gov/special-topics/water-science-school/science/groundwater-decline-and-depletion

farmland acreage decreased by 752,000 acres or about 10 percent of 2019 levels. The total economic impact of the 2022 drought year was approximately $2 billion including losses from agriculture and food processing.[65] Scientists estimate that drought could result in $3 billion in economic losses to agriculture annually.[66] *(The impact of drought and groundwater regulations on land use is discussed further in the Land Use chapter.)*

Flooding

Extreme precipitation is also problematic for farming. Flooding can result in significant crop loss by decreasing the availability of oxygen and nutrients for crops. The resulting damage is dependent on the specific crop, time of year, and flood water depth and velocity.[67] In 2022 and 2023, flooding occurred in multiple parts of the state, and many agricultural areas were hard-hit. Flooding through Kings County affected 47,000 acres of farmland, significantly decreasing the county's crop value and creating substantial damages. Levees broke near Salinas, Pajaro, Consumnes River, and Allensworth, in each case causing loss of human life, flooding of agricultural lands, loss of livestock, infrastructure, equipment, and more. In the Central Valley, flooding caused 180 square miles of the historic Tulare Lake to flood for the first time in many decades. In many cases this flooding affected communities that were the least equipped to deal with it: Planada and Pajaro, two majority-Latino agricultural towns, experienced severe flooding. In Planada, 83 percent of households experienced some degree of economic loss and households experienced a median of 21 days of lost work. Fifty-seven percent of households there completely lacked eligibility for unemployment insurance.[68] In Pajaro, the flooding damaged almost 275 homes and enrollment for the Pajaro Valley Unified School District dropped by just over 2,000 students in the year following the flooding.[69]

Flooding can also impact agricultural production and production systems by impacting habitat diversity and migration patterns, creating food safety risks, and changing on-farm planning. Inundation of normally dry areas and sedimentation can alter or destroy

[65] Medellín-Azuara, J., Escriva-Bou, A., Rodríguez-Flores, J. M., Cole, S. A., Abatzoglou, J. T., Viers, J. H., Santos, N., & Sumner, D. A. (2022). Economic impacts of the 2020–2022 drought on California agriculture. A report for the California Department of Food and Agriculture. Water Systems Management Lab, University of California, Merced. https://drought.ucmerced.edu

[66] California Farms Face $3 Billion Loss From Historic Drought (1)

[67] Monteleone, B., Giusti, R., Magnini, A., Arosio, M., Domeneghetti, A., Borzì, I., Petruccelli, N., Castellarin, A., Bonaccorso, B., & Martina, M. L. V. (2023). Estimations of crop losses due to flood using multiple sources of information and models: The case study of the Panaro River. Water, 15(11), 1980. https://doi.org/10.3390/w15111980

[68] Foy, N. (2023). California flooding harmed 4 out of 5 households in this city, A study tallies the damage. Cal Matters. https://calmatters.org/california-divide/2023/06/california-flooding-3/

[69] Natural Hazards Center | | Toward Equitable Recovery for Unincorporated Areas

natural habitat and/or croplands and displace and kill wildlife and farm animals.[70] Flood water can contain sewage microorganisms or other contaminants, compromising the safety of exposed crops.[71] Further, it is recommended that farmland be left fallow for 30-60 days after flooding to ensure that the land is cleared of pathogens.[72] All of this disrupts on-farm activities ranging from planning to planting to pesticide applications *(further discussed in the Pest Pressure chapter in Pillar 2)*.

In 2020 DWR released the Water Resilience Portfolio (and subsequent progress reports) as a blueprint for how California will deal with more extreme drought, flooding, and increasing temperatures, along with other water-related climate challenges. The Portfolio aims to maintain and diversify water supplies, protect and enhance natural ecosystems, and build connections and preparedness. Some of the actions outlined in the Portfolio include assessing future water needs, including surface water requirements and availability for agriculture, and continued support for research and technical assistance for conservation practices on California agricultural lands to improve water and nutrient use efficiency.[73]

Water Quality

In addition to water supply, water quality is critical for humans, wildlife, livestock, and plants to thrive. Mismanaged fertilizer application leads to excess nitrates and other nutrients leaching into the water supply and can lead to negative health effects. Climate change compounds water quality challenges. Reduced water flow during periods of drought also promotes the growth of harmful pathogens that favor warm, still water and that can impact the health and well-being of people who come into contact with it. Additionally, reduced flow in the Sacramento-San Joaquin Delta region

[70] Zhang, Y., Li, Z., Xu, H., Ge, W., Qian, H., Li, J., Sun, H., Zhang, H., & Jiao, Y. (2024). Impact of floods on the environment: A review of indicators, influencing factors, and evaluation methods. Science of The Total Environment, 951, 175683. https://doi.org/10.1016/j.scitotenv.2024.175683

[71] Department of Health and Human Services. (2011, October). Guidance for Industry on Evaluating the Safety of Flood-Affected Food Crops for Human Consumption; Availability. Food and Drug Administration. https://www.federalregister.gov/documents/2011/10/24/2011-27382/guidance-for-industry-on-evaluating-the-safety-of-flood-affected-food-crops-for-human-consumption

[72] California Department of Food and Agriculture Produce Safety Program. (n.d.). FACT SHEET: FARM FLOODING. California Department of Food and Agriculture. https://www.cdfa.ca.gov/oars/dairyplus/

[73] California Natural Resources Agency. (2022, August). California's Water Supply Strategy - Adapting to a Hotter, Drier Future. California Natural Resources Agency. https://resources.ca.gov/-/media/CNRA-Website/files/initiatives/water-resilience/CA-water-supply-strategy.pdf

can increase the risk of saltwater intrusion into freshwater zones which are part of the water delivery system for Californians across the state.[74]

[74] California Department of Water Resources. (n.d.). Saltwater intrusion and drought: Salinity barriers. California Department of Water Resources. https://water.ca.gov/Water-Basics/Drought/Saltwater-Intrusion-and-Drought-Salinity-Barriers

Strategies and Actions

While water is a complex and often sensitive issue throughout California, there are strategies that ensure the resilience of our water system into the future. By implementing strategies and actions that not only reduce demand and increase efficiency, but also work to ensure groundwater supply, protect freshwater ecosystems, and to build needed infrastructure, the state can continue to support farmers and ranchers.

California Water Plan

Water management at the state is a coordinated effort between state, federal, and county governments, local water districts, and local and regional entities. California's plan for guiding these entities in the management and development of water resources is laid out by the California Water Plan Update 2023. This plan builds on previous water-related strategies and legislation such as the Sustainable Groundwater Management Act, the Water Resilience Portfolio, and California's Water Supply Strategy.

The California Water Plan creates a master plan for the sustainable and equitable management of water resources in the state and is tasked to guide the orderly and coordinated control, protection, conservation, development, management, and efficient utilization of the state's water resources. The 2023 edition of the plan addresses this goal at multiple scales, from statewide to watershed level, and features three themes - climate urgency, watershed resilience, and equity – which encompass challenges and desired outcomes. Through these themes, the Plan outlines actions that focus on the development and support needed to build an equitable and resilient future for the state's watersheds, water systems, and communities.[75]

With respect to agricultural actions for building resilience for water resources, the Plan calls for:

1) Improving the integration of water, energy, and agricultural systems,
2) Increasing coordination with land use planning, and
3) Supporting urban and agricultural water use efficiency efforts to reduce water demands in all sectors.

Water Supply Strategy

In 2022, the state released California's Water Supply Strategy, which outlines a plan to address the water needs of the state in the face of climate change and a hotter, drier

[75] Department of Water Resources. (2023, December). California Water Plan Update. State of California. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/California-Water-Plan/Docs/Update2023/Final/California-Water-Plan-Update-2023.pdf

future. The plan outlines a pathway to meet AB 685, which states that every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes. The Supply Strategy strives to ensure that California has the water needed for generations to come by developing new water supplies, expanding water storage, reducing demand, and improving forecasting, data, and management. The actions in this strategy aim primarily to support the urban and suburban water systems that serve most Californians and to stabilize water supplies for agriculture. Those served by more rural water systems, such as rural agricultural communities, are overseen by the State Water Resources Control Board's Safe and Affordable Funding for Equity and Resilience (SAFER) program. This program is working to ensure safe, clean, and affordable, and accessible drinking water for human consumption for those who have previous lacked access. Benefits from these actions will also extend to environmental protection and fulfillment of the right of every Californian to safe drinking water.

2.1 Bring aquifers into balance to ensure groundwater supply.

Sustainable Groundwater Management Act

The Sustainable Groundwater Management Act (SGMA) of 2014 set a framework for the protection and management of groundwater resources in California. Until recently, groundwater consumption in California was unregulated. In many basins, groundwater pumping had exceeded the replenishment rate for many decades, resulting in groundwater depletion. With the frequency and severity of dry periods expected to increase, driving even more groundwater reliance, the careful management of groundwater resources is essential to protecting the long-term productivity, character, and success of California agriculture. SGMA allows the formation of groundwater sustainability agencies (GSAs) in high and medium priority basins. The local agencies formed, covered the basins completely, and developed groundwater sustainability plans to avoid undesirable results, including consideration of drought conditions. While SGMA provides local control for managing groundwater resources through GSAs, the Department of Water Resources (DWR) and the State Water Board are working to monitor the progress of SGMA actions and GSAs. (*See the Land Use section for more information on how SGMA may affect agricultural land use.)*

Drought and groundwater depletion have major impacts on agricultural communities, including drying of local wells, deterioration of water quality, increased pumping costs, and land subsidence that can damage infrastructure and impair agriculture in the long term.[76] By increasing technical assistance around water regulation and compliance for farmers, supporting monitoring efforts to improve irrigation efficiency, coordinating to find new solutions, and relying on existing programs, the state can improve the health of critical aquifers.

2.1.1 Increase and expand technical assistance support to help farmers understand water regulation and navigate compliance.

Goal 1: Increase and Enhance Technical Assistance

DWR's Underrepresented Communities, California Tribes, and Small Farmers Groundwater Technical Assistance Program is working to determine the needs, risks,

[76] Water Science School. (2018, June). Groundwater Decline and Depletion. United States Geological Survey. https://www.usgs.gov/special-topics/water-science-school/science/groundwater-decline-and-depletion

and vulnerabilities of communities impacted by the implementation of SGMA. This program identifies eligible communities within SGMA-regulated medium and high priority basins that have water supply challenges and provides technical assistance. Small farms are part of the eligible groups for technical assistance. This program is also funding legal assistance for small farmers to navigate SGMA and other water issues.[77]

2.1.2 Support monitoring capabilities to improve our understanding of drivers of change.

Goal 2: Enhance Program Effectiveness

The California Irrigation Management Information System (CIMIS), run by DWR, consists of more than 145 automated weather stations across California intended to assist those irrigating with planning and decision making to improve irrigation efficiency. In addition to weather data like temperature, precipitation, relative humidity, dew point, and wind speed, CIMIS also provides soil temperature and reference evapotranspiration to over 40,000 registered users across the state.[78] This program is critical in improving irrigation efficiency for farmers, gathering robust climate information.

2.1.3 Coordinate across agencies to develop new groundwater use and recharge strategies.

Goal 3: Grow Partnerships and Collaboration

While it is the goal of SGMA to ensure that aquifers are brought back into balance through reduced pumping and careful monitoring of water extraction, there is an opportunity in some areas to recharge aquifers. Recharge occurs when water percolates into the underground aquifers. The Water Supply Strategy has set a goal of expanding the state's groundwater recharge by at least 500,000 acre-feet.

This can be done by intentionally directing water towards aquifers, whether by injection or by capturing floodwaters and allowing the water to percolate down. Flood-Managed Aquifer Recharge (Flood-MAR) is a voluntary resource management strategy to address flooding conditions and groundwater aquifer depletion. Flood-MAR uses

[77] https://law.ucdavis.edu/clinics/small-farmer-clinic

[78] California Department of Water Resources. (n.d.). California Irrigation Management Information System (CIMIS). California Department of Water Resources. https://cimis.water.ca.gov/Default.aspx

flood water resulting from precipitation events on working lands, like agricultural land, to prevent flooding in undesirable locations and allow the water to infiltrate and recharge groundwater aquifers. For agricultural land to be used for managed aquifer recharge, it is important to consider a number of factors including the permeability of the underlying geology, what infrastructure will be required to divert floodwaters, and crop health. Currently the Flood-MAR Research and Data Development Plan outlines the research, data, tools, and guidance for Flood-MAR project implementation.

DWR, other state agencies including CDFA, the federal government, tribal groups, and local entities are currently working together to expand implementation of these projects to identify the best lands for recharge and streamline permitting in advance of storms that will bring floodwater flows.

Capturing and storing surface water, including floodwaters, usually requires an appropriative water right. However, greater coordination with land owners, GSAs, and flood managers to define flood flows can allow for diversions of high flows without the need of an appropriative right under California Water Code 1242.1. The State Water Resources Control Board (SWRCB) is granting streamlined processing for standard groundwater recharge rights to Groundwater Sustainability Agencies (GSAs) to help them meet their groundwater sustainability goals.

2.1.4 Work with water users to assist with groundwater use and recharge.

Goal 2: Enhance Program Effectiveness

In recent years, the state has made investments in programming to help ease the pressure growers and communities while bringing aquifers into balance:

DWR's LandFlex program provided $25 million in grants to Groundwater Sustainability Agencies (GSAs) to incentivize growers to reduce agricultural water use near vulnerable drinking water wells, prioritizing areas of highest impact providing payments per enrolled acre. Growers were enrolled per acre to limit agricultural water use in areas where reducing pumping would benefit drinking water wells. The program awarded three GSAs for a total of $17 million in 2023.[79] While some program results are still pending until the end of 2025, so far the program has been able to save over 100,000 acre-feet of groundwater at a cost of $216 per acre-foot, strategically utilize fallowed

[79] California Department of Water Resources. (n.d.). LandFlex. California Department of Water Resources. https://water.ca.gov/landflex

agricultural land for floodwater capture and groundwater recharge, and identify lands where additional subsidence is likely to cause infrastructure damage and mitigating groundwater overdraft in those areas.

California has also introduced the Multibenefit Land Repurposing Program (MLRP), administered by the Department of Conservation (DOC), to help reduce groundwater use, repurpose irrigated agricultural land, and provide wildlife habitat. It does so by providing funding to create community capacity to plan for the retirement of SGMA impacted farmland, while providing community health, economic wellbeing, water supply, habitat, and climate benefits, as well as compensating farmers who choose to take their land out of production or support groundwater recharge projects. To date, the program has received $90 million in appropriations, and has been allocated another $200 million through Proposition 4.

2.2 Build new water storage capacity and maintain conveyance infrastructure.

California's ability to store and move water efficiently is critical to its long-term water security, especially as the state faces more frequent droughts, floods, and shifting weather patterns caused by climate change. To respond to these challenges, the state is investing in both new water storage projects and the repair and modernization of water conveyance systems. These efforts include collaborative work with local stakeholders, large-scale funding programs like State Water Efficiency and Enhancement Program (SWEEP) and Proposition 1 Water Storage Investment Program, and critical infrastructure upgrades such as the California Aqueduct Subsidence Program, Delta Conveyance Project, and work on the Delta-Mendota Canal and Friant-Kern Canal. Together, these initiatives aim to strengthen regional water reliability, improve ecosystem health, and support long-term sustainability for communities, agriculture, and the environment.

2.2.1 Support collaborative work between community groups, regulatory agencies, and project implementors for least conflict siting and plans for new infrastructure.

Goal 3: Grow Partnerships and Collaboration

As climate change drives shifts in weather patterns which in turn affect the timing of water availability, storage projects can be used to help mitigate against these effects – creation of wetland habitat and improvement of flows critical for fish reproduction.

In alignment with Goal 2.2.1's focus on collaborative planning for new water infrastructure, the State Water Efficiency and Enhancement Program (SWEEP) supports farmers and ranchers with the installation of on-farm water storage components, such as storage compensation reservoirs, to help growers manage surface water deliveries that occur outside typical irrigation schedules. SWEEP also supports the installation of on-farm surface water turnouts to expand access to fields previously solely reliant on ground water. These efforts, especially when paired with the program's technical assistance resources that support project planning, not only enhance local water reliability but also foster collaboration.

Similarly, the Proposition 1 Water Storage Investment Program provides $2.7 billion for water storage projects that offer public benefits. The program focuses on benefits like flood protection, ecosystem and fish habitat improvements, better water quality,

emergency response, and recreation. So far, six major projects like Chino Basin, Sites Reservoir, Harvest Water, and Kern Fan have received funding and are moving through planning, construction, and permit stages. These projects are expected to increase California's water storage by 2.65 million acre-feet, with final completion dates estimated between 2028 and 2036, depending on each project.

Both initiatives demonstrate how collaborative, multilevel planning and investment can address water availability challenges intensified by climate change while delivering benefits at the farm, community, and regional levels.

2.2.2 Advance critical infrastructure projects for water conveyance.

Goal 5: Demonstrate and Invest in Innovation and Technology

To improve how water is moved across California, the state is investing in projects that upgrade and repair important water delivery systems like canals, pipelines, and pumps.

One major effort is the Delta Conveyance Project, which aims to modernize the infrastructure that delivers water from Northern California through the Delta to over 27 million people and 750,000 acres of farmland. These conveyance systems are critical for moving water from where it's stored to where it's needed, especially for farms and communities during drought. The project will help to protect against future water supply losses caused by climate change, sea level rise, and earthquakes. It also helps ensure that the State Water Project can capture, move and store water to make the most of big, though infrequent, precipitation events. Important to this project is the concept of dual conveyance, which encompasses both isolated conveyance facilities and local infrastructure improvements, such as levee improvements within the Delta, to build localized resilience to climate disasters. Dual conveyance is emphasized as a Water Supply Reliability Strategy in the Delta Adapts Plan to improve local infrastructure to minimize the impacts of through-delta conveyance on inhabitants in the Delta.[80]

One of the most critical challenges is land subsidence, which has damaged major water conveyance systems due to decades of groundwater overdraft in regions. This has damaged critical conveyance infrastructure like the Friant-Kern Canal, Delta-Mendota Canal, and California Aqueduct, making it harder for water to flow. [81] Fixing these canals is important to bring them back to full capacity and prevent water loss, for example, Friant-Kern Canal, which is owned by the U.S. Bureau of Reclamation, lost 60 percent of its capacity due to damage along a 33-mile stretch in eastern Tulare

[80] https://deltacouncil.ca.gov/pdf/delta-plan/2025-06-26-delta-adapts-adaptation-plan.pdf

[81] https://data.cnra.ca.gov/dataset/finaldcr2023/resource/478ff1a8-b7fb-4d3f-95de-3bc90cf047f0?inner_span=True

County. In 2022, DWR released $29.8 million to the Friant Water Authority to repair damage to the canal in accordance with the Water Resilience Portfolio. This is one of four repair projects funded as part of a $100 million initiative in the California Budget Act of 2021 to improve water conveyance systems in the San Joaquin Valley. DWR is working on agreements for projects on the Delta-Mendota Canal, San Luis Canal, and California Aqueduct. These infrastructure projects, coupled with SGMA-induced groundwater management, are designed to minimize subsidence and address issues from existing subsidence.

California is also using new technologies, like real-time monitoring systems and automated gates, to make water delivery more efficient and reliable. Some of these upgrades are supported by state and federal funding programs, helping the state build a more climate-resilient and modern water system. State agencies including DWR, CDFA, and SWRCB are supporting these efforts.

For example, the Real-Time Data Direct Grant Program led by DWR supports upgrades through the deployment of real-time reservoir gaging systems. The Surface Water Ambient Monitoring Program, or SWAMP program from the SWRCB strengthens these efforts by monitoring surface water quality using continuous and real-time data collection tools. Meanwhile, CDFA's SWEEP program funds on-farm projects using soil sensors, weather stations, and variable Frequency Drives (VFDs) to improve irrigation efficiency. By helping growers reduce water and energy use, SWEEP projects also effect on regional water reservoirs.

2.3 Improve headwaters management and restore freshwater ecosystems.

2.3.1 Promote ecologically appropriate prescribed grazing designed to improve ecosystem health in headwater areas.

Goal 1: Increase and Enhance Technical Assistance

"Headwaters" are the places where our rivers begin: they are the places where surface runoff from rain, melting snow, or springs accumulate to form running water, and ultimately, they are the source of much of California's surface water. Healthy headwater ecosystems, which include intact forests, wetlands, shrublands, grasslands, and soils, support the capture, storage, and release of clean water. In recent decades, California's headwaters have been threatened by drought, insect attacks, and wildfires, leading to forest die-off. These conditions are exacerbated by a complicated patchwork of ownership, including state, federal, and private ownership, and varying management regimes. Approximately two-thirds of California's headwaters originate in the Sierra Cascade mountains and North Coast.[82] Between 50 and 75 percent of these lands are owned by the federal government; about 30 percent are privately owned or owned by tribes or state entities.[83]

Effective management practices, such as restoring degraded headwater landscapes, managing forests to reduce wildfire risk, and protecting wetlands and meadows, help maintain cooler water temperatures, reduce erosion, and support diverse plant and animal species. These upstream interventions also enhance groundwater recharge and sustain more reliable water supplies for agriculture, communities, and ecosystems further downstream. By investing in the resilience of headwaters, land managers and policymakers can strengthen the overall health of entire watersheds and better adapt to the impacts of climate change.

In addition to forest management, there is a role for agriculture to play in ensuring healthy headwaters management. Ecologically appropriate prescribed grazing supports the goal of improving ecosystem health and is a way of managing grazing that focuses on achieving clear environmental goals instead of following fixed rules. These goals include things like healthier soil, increased infiltration and water holding

[82] https://www.ppic.org/publication/headwaters-and-wildfire-in-california/

[83]https://www.ppic.org/publication/headwaters-and-wildfire-in-california/

capacity, more native plants, and allowing ranchers to adjust their grazing practices as needed. Ranchers can change their practices based on the land's condition, as long as they reach these outcomes. This flexible approach supports long-term land health and works well in headwater areas and sensitive ecosystems. In California, it has helped restore meadows, reduce erosion, and improve water flow. Projects have shown early success with stronger vegetation, better infiltration, and less runoff during storms.[84] California's Nature Based Solutions Climate Targets list prescribed herbivory as a solution for managing lands were consistent with ecological purposes and also for fuel reduction and grassland restoration. Further, SB 675 (Limon, 2024) directs the state's Range Management Advisory Committee to develop guidance for the creation of grazing plans to help ranchers better achieve ecological goals with grazing. For more information on ecologically appropriate prescribed grazing, see the Ranching and Rangeland Management Chapter). Finally, conservation of existing agricultural lands reduces the pressure to convert forests and woodlands to rangelands and vineyards.

2.3.2 Expand implementation of riparian zone restoration practices in agricultural land.

Goal 2: Enhance Program Effectiveness

Expanding riparian zone restoration practices on agricultural land in California is essential for protecting water quality, enhancing biodiversity, and building climate resilience. Riparian buffers help filter runoff from farms, trapping sediments, nutrients like nitrogen and phosphorus, and pesticides before they reach rivers and streams. This reduces pollution, improves downstream drinking water quality, and helps prevent harmful algal blooms. These vegetated zones also provide critical habitat for fish, birds, pollinators, and other wildlife, while serving as migration corridors that support regional biodiversity.

In addition to their ecological benefits, riparian areas contribute to groundwater recharge by slowing surface water flow and allowing more infiltration into aquifers—an increasingly important function given California's prolonged droughts. They help protect farmland from erosion and flooding, offer shade that cools waterways and reduces evaporation, and create cooler microclimates that can buffer extreme heat

[84] Point Blue Conservation Science. (2023). RangeC Monitoring Program: Handbook of field methods. Petaluma, CA. FINAL_Monitoring Handbook_Dec2022_V1.0.docx ; Outcome-Based Grazing — Partners in the Sage; Gennet, S., Spotswood, E., Hammond, M., & Bartolome, J. W. (2017). Livestock grazing supports native plants and songbirds in a California annual grassland. PLoS ONE, 12(6). Livestock grazing supports native plants and songbirds in a California annual grassland - PubMed

and reduce stress on crops, livestock, and farmworkers. Properly managed riparian vegetation can even act as natural fire breaks, adding a layer of wildfire resilience. The importance of riparian zone restoration and management is emphasized through California's Nature-Based Solutions Climate Targets, that list acreage targets for conservation and restoration of riparian zones in forests, grasslands, sparsely vegetated lands, and as buffer zones through croplands.

The Department of Conservation's Working Lands and Riparian Corridors Program provides grants to restore or enhance working lands and riparian corridors through restoration projects on agricultural lands. The program supports Resource Conservation Districts (RCDs) in multiple counties such as San Luis Obispo, Ventura, and Santa Cruz to improve watershed health and resilience. Funded projects focus on riparian restoration, soil and water conservation, and flood management through local collaboration and on-farm practices that integrate environmental and agricultural benefits. Funding rounds have supported site-specific restoration work through both planning and implementation phases.

The California Riparian Habitat Conservation Program, administered by the Wildlife Conservation Board (WCB), was created to protect and restore riparian ecosystems across the state. Funded through the Habitat Conservation Fund and guided by Senate Bill 906, the program supports a wide range of activities—such as restoring native riparian vegetation, improving floodplain connectivity, managing invasive species, and installing wildlife-friendly fencing. It also funds the reconfiguration of degraded streams to restore natural water flow and improve habitat conditions for fish and wildlife. The program emphasizes coordinated regional planning and long-term ecological benefits.

CDFA's Healthy Soils Program (HSP) helps protect and restore riparian areas through support for specific on-farm practices. Funded activities like cover cropping, compost application, reduced tillage, and mulching support soil structure and increase soil organic matter. These practices improve water infiltration and retention along riparian zones, which can reduce runoff and help prevent flood damage.[85] In addition to protecting soil and water, they provide co-benefits such as reduced erosion and improved biodiversity. Through its incentive and demonstration grants, HSP supports farmers in adopting these practices over multiple years, with the goal of strengthening

[85] https://www.canr.msu.edu/news/compost_increases_the_water_holding_capacity_of_droughty_soils

long-term ecosystem health on agricultural lands discussed further in the Soil Health section).[86]

2.3.3 Promote responsible nutrient management to reduce nutrient leaching runoff from agricultural land.

Goal 2: Enhance Program Effectiveness

The development of the Haber-Bosch fixation process in 1908 gave humanity the ability to take unreactive N_2 nitrogen gas from the atmosphere and form it into synthetic nitrogen fertilizers. These fertilizers have allowed us to feed many more people than was previously possible. From 1908 to 2008, the number of people supported per hectare of farmland increased from 1.9 to 4.3. The Green Revolution, which began in the 1940s, combined improved high-yielding crop varieties, irrigation, and fertilizers to significantly boost global food production and saved a billion people from starvation.[87] Synthetic N fertilizer has supported about 4 billion people born since 1908.[88] However, overapplication of synthetic N fertilizers leads to N loss into ecosystems, via leaching or runoff into water systems and/or release of greenhouse gases.[89]

Agricultural leaching and runoff containing nitrogen enters rivers, lakes, estuaries, and the marine environment, contributing to eutrophication[9091]. A combination of elevated nitrogen and phosphorus loads from agriculture, urban wastewater, and stormwater can lead to intensified cyanobacterial harmful algal blooms in freshwater systems and coastal blooms of toxic phytoplankton (including domoic-acid-producing Pseudonitzschia), impairing water quality, fisheries, livestock health, and marine ecosystems[92]. Eutrophication can also lead to ocean acidification and hypoxia (OAH) – a decline in pH and oxygen levels that can be harmful to marine organisms. Studies

[86] Hensel, Eliza. (2024, November). Compost can increase the water holding capacity in droughty soils. Michigan State University

[87] https://twin-cities.umn.edu/news-events/man-who-saved-billion-lives

[88] Erisman, J., Sutton, M., Galloway, J. et al. How a century of ammonia synthesis changed the world. Nature Geosci 1, 636–639 (2008). https://doi.org/10.1038/ngeo325

[89] Greenhouse gas emissions from global production and use of nitrogen synthetic fertilisers in agriculture | Scientific Reports

[90] https://www.pnas.org/doi/full/10.1073/pnas.2018856118

[91] https://pmc.ncbi.nlm.nih.gov/articles/PMC6084699/pdf/TSWJ-2001-1-856429.pdf

[92] https://www.usgs.gov/news/featured-story/science-harmful-algal-blooms; https://www.sciencedirect.com/science/article/abs/pii/S1568988308000978; https://www.sciencedirect.com/science/article/abs/pii/S0272771414001553

have demonstrated that coastal eutrophication is prominent in areas with extensive agricultural development and has been linked to a decline in pH and dissolved oxygen levels[93]. Recognizing agricultural runoff's crucial role in causing HABs and OAH, smart fertilizer practices, nitrogen and phosphorus load reductions, and watershed-level nutrient control may help to mitigate eutrophication and to protect marine ecosystems and fisheries along California's coast.

Furthermore, intensive farming can reduce soil nutrient availability, including nitrogen, which can lead farmers to increase their use of synthetic fertilizers over time. [94] The synthetic production of nitrogen fertilizers through the Haber-Bosch process includes fossil-fuel derived methane gas, which is also a major source of global GHG emissions.[95] Those fertilizers' transformation in agricultural soils underpins 75 percent of U.S. emissions of the GHG nitrous oxide, which increases when N fertilizer is applied in excess.[96] It is estimated that fertilizer production consumes approximately 1.2 percent of the world's total energy.[97]

Responsible nutrient management practices, such as soil testing, precision and timing of fertilizer application to match crop needs, use of organic and other slow-release forms of fertilizer, and companion planting or cover cropping with nitrogen-fixing plants, help farmers improve soil health, reduce input costs, and protect nearby waterways. These practices not only safeguard the ecological integrity of riparian zones but also support the long-term sustainability and productivity of agricultural operations.

CDFA and its sister agencies are engaged in the promotion of safe and responsible use of fertilizers and the discharge of wastewater from irrigated farmland. The SWRCB's Irrigated Lands Regulatory Program also regulates water and waste discharge from irrigated agricultural lands to prevent contamination of California's waters and ensure safe drinking water. Currently over 50,000 farms, comprising more than six million acres are following waste discharge requirements for the program.

CDFA's Fertilizer Research and Education Program (FREP) funds technical assistance and research on the environmentally safe and agronomically sound use and handling

[93] https://www.sciencedirect.com/science/article/abs/pii/S0272771414001553; https://www.jstor.org/stable/24862133?seq=1;

[94] https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020EF001641

[95] Greenhouse gas emissions from global production and use of nitrogen synthetic fertilisers in agriculture | Scientific Reports

[96] United States Environmental Protection Agency. (2021). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019. United States Environmental Protection Agency. https://www.epa.gov/sites/default/files/2021-04/documents/us-ghg-inventory-2021-main-text.pdf

[97] Amenumey, S.E., & Capel, P.D. (2014). Fertilizer Consumption and Energy Input for 16 Crops in the United States. Natural Resources Research 23, 299–309. https://doi.org/10.1007/s11053-013-9226-4

of fertilizing materials. FREP has funded over 220 research and education projects to improve knowledge and optimize fertilizer use, aiming to minimize runoff, leaching, and contamination of surface and groundwater sources. The Healthy Soils Program funds a "nutrient management" practice that requires a 15 percent reduction of synthetic nitrogen fertilizers.

Synthetic Fertilizer and the Future

The synthetic production of nitrogen fertilizers through the Haber-Bosch process requires as an input fossil-fuel derived methane gas, which is also a major source of global GHG emissions.[98]

Fortunately, alternatives are on the horizon. Ammonia, another key ingredient in nitrogen-based fertilizers, can be produced by using renewable energy and derives its hydrogen from water and nitrogen from the air. Cheaper renewable energy prices are helping bring down the cost of producing ammonia this way, and have the potential not only to reduce reliance on fossil fuels for fertilizer, but can help states that are net importers of fertilizer California become more self-sufficient and further decarbonize agriculture as a sector, potentially driving down its carbon footprint by 90 percent for some crops.

[98] Greenhouse gas emissions from global production and use of nitrogen synthetic fertilizers in agriculture | Scientific Reports

2.4 Continue improving on-farm water use efficiency.

Farmers and ranchers are proactively reducing pressure on the water supply by implementing water efficiency measures in their operations. CDFA is supporting this effort by assisting producers in investing in more efficient irrigation systems, providing technical assistance to promote water-efficient farming, and providing grants or other funding sources for farmers and ranchers to larger infrastructure improvements. DWR is helping growers improve water use efficiency through the implementation of Agricultural Water Management Plans.

2.4.1 Upgrade equipment to be water efficient and conduct on-farm measurements to track water use.

Goal 2: Enhance Program Effectiveness

The State Water Efficiency and Enhancement Program (SWEEP) was established in 2014 in response to severe drought. SWEEP provides financial incentives for California agricultural operations to invest in irrigation systems that save water and reduce greenhouse gas emissions. To date, SWEEP has had ten rounds of funding and awarded $126.2 million dollars in funds to California growers, funding over 1,100 projects and creating GHG savings of more than 93,000 $MTCO_2$ per year.

In addition to incentives programs, CDFA also offers technical assistance programming through the Water Efficiency and Technical Assistance (WETA) program. Assembly Bill 180 appropriated $15 million from the California Emergency Relief Fund to CDFA for the WETA program to fund irrigation water efficiency and nutrient management technical assistance grants. This program was intended to reduce barriers for improving water use and energy efficiency to create resilience on farms in the face of reduced water availability in drought. The program provides a swath of testing, support, and training opportunities for farms as it relates to water efficiency and nutrient management, including pump testing, integrated water management trainings, and distribution uniformity testing. In its two rounds of funding, WETA has awarded 28 projects a total of $12.4 million.

The Water Conservation Act of 2009 requires agricultural water suppliers serving above a specific acreage to create an Agricultural Water Management Plan[99]. DWR oversees these plans, ensuring implementation status updates for Efficient Water Management Practices (EWMP) are incorporated. EWMPs include best management practices for

[99] https://water.ca.gov/Programs/Water-Use-And-Efficiency/Agricultural-Water-Use-Efficiency

irrigation scheduling, water pricing, on-farm irrigation system audits and improvements, and the creation of the Drought Plan and climate change analysis which prompts long term sustainability in the District.

2.4.2 Use nature-based solutions/healthy soils practices to improve water-holding capacity and percolation on farm and ranch lands.

Goal 2: Enhance Program Effectiveness

Management practices that utilize nature-based solutions to support healthy soil, such as planting cover crops, minimizing tillage, and applying mulch and compost can build and retain soil organic matter which helps to improve the water holding capacity of soils and increase the amount of water that percolates into the ground.[100] Modeled increases in soil organic matter of 3 percent improved water benefits and decreased the impacts from climate change for almost all working lands.[101] On rangelands, deeply rooted trees, such as those of native oaks, can mine water from deeper in the soil and release excess water into shallow soils through a process called hydraulic redistribution. This process helps to ameliorate the effects of drought conditions on soil life.[102] These practices are described in depth in Chapter 10 on Soil Health Practices and Chapter 11 on Ranching and Rangeland Management.

SWEEP in the Southern Desert Region

The tenth round of SWEEP was a pilot program focused on providing funds to the Southern Desert Region (SDR) of California, which encompasses Imperial and Riverside Counties, east of the Santa Rosa and San Jacinto Mountains. This region is a hugely productive agricultural region that often uses unpressurized surface water for irrigation, which had historically disqualified the program from SWEEP because baseline greenhouse gas emissions associated with irrigation and pumping were not a factor. With the pilot program, projects focused on reducing the total water applied while maintaining production. The SWEEP SDR Pilot Program awarded $2.72 million dollars in funding to 17 projects located in the SDR of California. SWEEP also offered block grants in 2023, awarding $42.5 million to 9 different entities to provide regionally supported water and energy efficiency projects.

[100] Hensel, Eliza. (2024, November). Compost can increase the water holding capacity in droughty soils. Michigan State University Extension. https://www.canr.msu.edu/news/compost_increases_the_water_holding_capacity_of_droughty_soils

[101] https://www.energy.ca.gov/sites/default/files/2019-11/Agriculture_CCCA4-CNRA-2018-006_ADA.pdf

[102] https://www.sciencedirect.com/science/article/abs/pii/S003807170600366X

Implementation

Strategy/ Action	Goal Alignment	Lead Agency	Supporting	Status	Implementation Phase
2.1 Bring aquifers into balance to ensure groundwater supply.					
2.1.1 Increase and expand technical assistance support to help farmers understand water regulation and navigate compliance.	1: Increase and Expand Technical Assistance	CDFA			
2.1.2 Support monitoring capabilities to improve our understanding of drivers of change.	2: Enhance Program Effectiveness	DWR			
2.1.3 Coordinate across agencies to develop new groundwater use and recharge strategies.	3: Grow Partnerships and Collaboration	DWR, SWRCB	CDFA		
2.1.4 Work with water users to assist with groundwater use and recharge.	2: Enhance Program Effectiveness	DWR, DOC			
2.2 Build new water storage capacity and maintain conveyance infrastructure.					
2.2.1 Support collaborative work between community groups, regulatory agencies, and project implementors for least conflict siting and plans for new infrastructure.	3: Grow Partnerships and Collaboration	CDFA			

2.2.2 Advance critical infrastructure projects for water conveyance.	5: Demonstrate & Invest in Innovation & Technology	DWR	CDFA, SWRCB		
2.3 Improve headwaters management and restore freshwater ecosystems.					
2.3.1 Promote ecologically appropriate prescribed grazing designed to improve ecosystem health in headwater areas.	1: Increase and Expand Technical Assistance	CDFA			
2.3.2 Expand implementation of riparian zone restoration practices in agricultural land.	2: Enhance Program Effectiveness	CDC, WCB, CDFA			
2.3.3 Promote responsible nutrient management to reduce nutrient leaching runoff from agricultural land.	2: Enhance Program Effectiveness	CDFA, SWRCB			
2.4 Continue improving on-farm water use efficiency.					
2.4.1 Upgrade equipment to be water efficient and conduct on-farm measurements to track water use.	2: Enhance Program Effectiveness	CDFA			
2.4.2 Use nature-based solutions/healthy soils practices to improve water-holding capacity and percolation on farm and ranch lands.	2: Enhance Program Effectiveness	CDFA			

Chapter 3. Support Agricultural Workforce Wellbeing and Health

Key Objective: Improve on-farm safety and community wellbeing for California's agricultural workforce.

Context

Despite the size and national and international importance of California's agricultural economy, agricultural communities continue to be some of the most socially and economically disadvantaged in the state, with high rates of health and educational disparities. In California's Central Valley, agricultural production totals $41.7 billion and provides 25 percent of the nation's fruits and nuts; however many farmers and farmworkers that harvest this bounty struggle financially and experience high rates of poverty and food insecurity.[103] Additionally, the region is ranked with some of the lowest education levels in the nations, creating further barriers for people in these regions to rise out of generational poverty.

Climate change is necessitating the way work on-farm looks to protect those working on agricultural operations. Farmworkers and agricultural communities are disproportionately affected by climate-related challenges, including impacts like extreme heat and poor air quality from a variety of sources, including wildfire smoke and dust.[104]

Building climate resilience within agriculture means ensuring that the agricultural workforce have both the adequate protections and resources to work safely, respond to, and recover from extreme weather events. Policies for what the workday should look like in the face of climate change, tools for making the workday safer, support for handling the mental health impacts of climate change, and resources for agricultural communities and populations are all vital adaptations to ensure the prosperity and health of farmers and farmworkers.

[103] Annual report to the legislature on California Climate Investments Using Cap-and Trade Auction Proceeds. Greenhouse Gas Reduction Fund. May 2024. https://ww2.arb.ca.gov/sites/default/files/auction-proceeds/cci_annual_report_2024.pdf

[104] https://www.nature.com/articles/s43247-025-02306-0

Strategies and Actions

The following strategies and actions aim to support the agricultural workforce's wellbeing and health.

3.1 Enable a safer and healthier work experience for those in the agricultural industry.

As climate related health hazards continue to affect those working in the agricultural industry, the state is refining its policies to promote workplace health and safety. Additionally, new research is producing tools that support health and safety. There is also a need for programs that support health – from mental health to physical infrastructure improvements to support resilience. Protecting the agricultural workforce will not only ensure that the workforce is safer and healthier but will also support a strong agricultural industry.

3.1.1 Support state policies for better working conditions for hotter, drier conditions.

Goal 2: Enhance Program Effectiveness

The state is already working to ensure that the agricultural workforce has policies in place to promote resilience, but there are additional policies that could further these efforts. These policies could promote access to shade, water, and bathrooms in the workplace, and support alternative work hours to move workday to lower temperature periods in the day.

Currently, California policy for climate-smart workforce and tools is directed towards the protection of agricultural workers and the facilitation of new economic opportunities to bolster community resilience. California's Code of Regulations (Section 3395) has a section dedicated to heat illness prevention, specifically calling out the need for access for shade, water, and training for outdoor workers, including for agriculture.

Expanding on the outdoor heat standards in the Code of Regulations, California released an Extreme Heat Action Plan in April 2022 to create an all-of-government approach to building resilience to extreme heat and mitigating the impacts of extreme

heat on health, the economy, and ecological and social impacts.[105] The plan emphasizes actions and outreach to raise awareness and address heat illness for outdoor workers, including farmworkers. It also includes goals to address food system vulnerabilities to extreme heat by implementing agricultural practices that identify crops most damaged by extreme heat events, supporting research for heat tolerant crops, improving food products' resilience to extreme heat, and investing in healthy refrigeration infrastructure.

In 2024, Governor Newsom signed SB 1105 (Padilla), which allows farmworkers to use accrued paid sick leave during heat, flooding, or smoke conditions when there is a local or state emergency.

3.1.2 Support research and collaboration into on-farm tools for health and safety.

Goal 5: Demonstrate and Invest in Innovation and Technology

The UC Davis Center for Farm Health and Safety funds research for agricultural workforce safety and wellbeing. Staff conducts research on high hazard topics and common causes of injuries and illness in agriculture. Their research is around the following topic areas: co-exposures to agriculture and wildfire emissions, sustainable alternatives to pesticides, agricultural all-terrain vehicle safety, surveillance of occupational health and injuries, and farmer housing.

The state, in partnership with University of California awarded three Climate Action Seed Grants on outdoor worker health and safety in the face of climate change. Funded work included projects that map and mitigate farmworker exposure to heat stress, implementation of heat stress and chemical exposure strategies for farmworkers, and the creation of an app to identify hotspots of environmental vulnerability for farmworkers.[106]

The California Department of Industrial Relations' (DIR) Division of Occupational Safety and Health (Cal/OSHA) is California's leading agency on mitigating the occupational risks, including climate-driven risks, through regulatory enforcement, programs, research and outreach initiatives. For example, the Worker Occupational Health and Safety

[105] State of California. (2022, April). Protecting Californians from extreme heat: A state action plan to build community resilience. California Natural Resources Agency. Protecting Californians From Extreme Heat: A State Action Plan to Build Community Resilience

[106] https://uckeepresearching.org/wp-content/uploads/2023/08/Climate-Action-Seed-and-Matching-Grants_2023.pdf

Training and Education Program (WOSHTEP) seeks to reduce occupational injuries and illnesses through worker training. The program has a range of specialized materials including Outdoor and Indoor Heat Illness Prevention Materials. DIR also convenes a Heat Advisory Committee, which recently published a California Heat Illness Prevention Study and a Wildfire Smoke Map and worker safety guide that provide live information of wildfire smoke risk.

California's Employment Development Department also offers the Migrant and Seasonal Farmworker Outreach Program, which provides multilingual outreach workers who travel to areas where farmworkers work, live, and gather to share information about job opportunities, labor rights, and support services. It also houses the Monitor Advocate System, a state and federal program that can help farmworkers address complaints related to their living and working conditions, such as access to shade, unpaid wages, lunch and break times, and health and safety issues.

One particular challenge facing the agricultural workforce is extreme heat. Rising temperatures and increasing numbers of heat health events pose a serious health risk for workers. In the short-term, workers can be at risk for heat related illnesses such as dehydration, heat exhaustion, or heat stroke, while long term effects include concerns such as an increased risk for kidney disease. "Heat health" is the study of the effects of heat exposure on human health and well-being and captures the public-health risks of rising temperatures, regardless of absolute temperature. "Heat health events" occur when there are consecutive days and nights of high temperatures, and, along with extreme heat, are also projected to increase in frequency, intensity, and duration. Heat health events provide a useful metric to understand the public health risks associated with rising temperatures and to understand how heat is affecting communities across the state (Protecting Californians from Extreme Heat). The California Heat Assessment Tool shows an overlap of counties that are most affected by heat health events and counties with high numbers of outdoor workers, many of which are agricultural workers.

Figure 7 shows how agricultural communities are some of the most affected by heat health events. The map on the left shows the annual number of heat health events for each county in California. The map on the right shows average maximum temperature of health heat events for each county. Bolded areas are high priority census tracts due to a high number of outdoor workers.

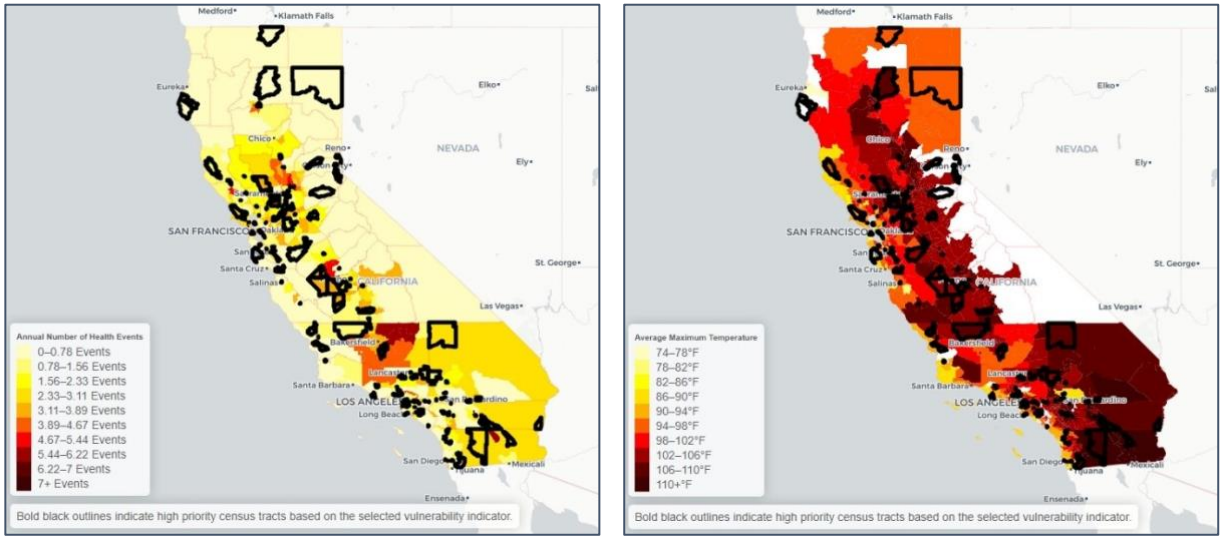


Figure 7: California Heat Assessment Tool

In 2025, California launched CalHeatScore, the state's extreme heat early warning system.[107] CalHeatScore was created to protect all Californians from extreme heat, especially those most vulnerable like outdoor workers. Similar to existing hurricane or tornado indices, CalHeatScore ranks the severity of upcoming heat events. It gives a daily heat risk score of 0-4 to each California ZIP code based on localized weather and emergency department data. CalHeatScore not only communicates heat risks, it also connects people to locally available resources to help them stay safe, like locations of nearby cool centers. The Office of Environmental Health Hazard Assessment (OEHHA), in partnership with the Governor's Office of Land Use and Climate Innovation (LCI), the Los Angeles Regional Collaborative for Climate Action and Sustainability (LARC), and the UCLA Luskin Center for Innovation, is organizing a series of cohort meetings to gather input on CalHeatScore from vulnerable communities. One of the cohorts will focus on outdoor and warehouse workers to ensure the tool meets their needs and reflects their experiences. CalHeatScore contains supplemental data, such as the number of outdoor workers in every ZIP code, to inform users about additional factors influencing vulnerability to heat.

Figure 8 shows the CalHeatScore mapping system, showing color-coded severity of heat events at all ZIP codes throughout California. Darker colors show higher CalHeatScore ranks, which indicate increased risk to communities for heat-related illness on that day. The panel on the left shows some factors that influence a

[107] https://calheatscore.calepa.ca.gov/

community's vulnerability to heat, including the percent of the population in that works outdoors.

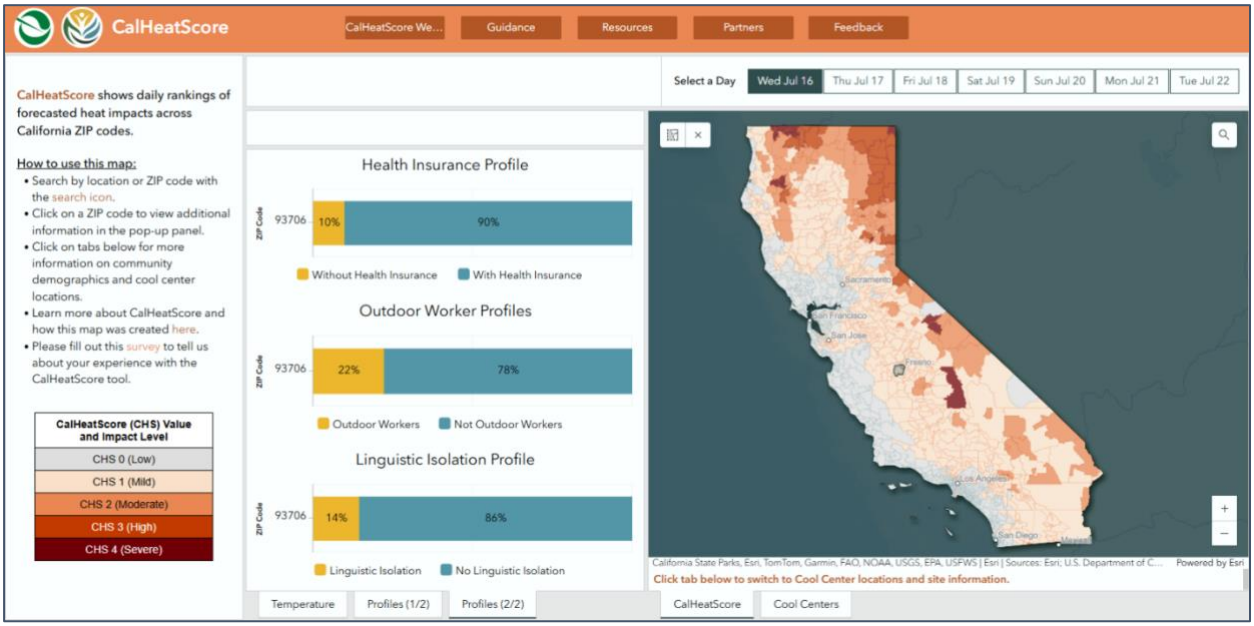


Figure 8: CalHeatScore Platform

3.1.3 Support programs that give resources and training for all peoples working on farms for mental health.

Goal 2: Enhance Program Effectiveness

Climate change is among a list of factors impacting the mental health of farmers and farmworkers globally.[108] CDFA maintains a webpage that lists resources for farmer and farmworker mental health. This work is supported by Farm and Ranch Stress Assistance Network from the USDA National Institute of Food and Agriculture. The site lists a number of hotlines for mental health emergencies, disaster assistance resources, and tips for dealing with stress.

[108] https://pmc.ncbi.nlm.nih.gov/articles/PMC6926562/

3.1.4 Implement programs that build and improve infrastructure in rural agricultural communities to better support resilience to extreme weather events.

Goal 2: Enhance Program Effectiveness

On Farm Planning

CDFA is funding the development of plans that will help California farmers and ranchers identify actions for climate change mitigation and adaptation, further environmental stewardship on farms and ranches, as well as ensure food security for the future. CDFA's Conservation Agriculture Planning Grant Program provided $17 million in grant awards for technical assistance to help farmers and ranchers develop a range of plans for their farms, including nutrient management, carbon farming, energy design, irrigation water management, and more. The program is supporting the development of 203 conservation management plans.

Community Resilience and Planning

The Governor's Office of Land Use and Climate Innovation (LCI) provides collaboration and guidance opportunities focused on land use and community development, climate risk and resilience, and high road economic development. Agriculture specific topics include work through the Integrated Climate Adaptation and Resiliency Program (ICARP), which includes the following:

- The Extreme Heat and Community Resilience Program was created from SB155 Public Resources trailer bill and supports local, regional, and tribal efforts to reduce the impacts of extreme heat – by building long-lasting infrastructure solutions, while also strengthening the community resilience needed to withstand extreme heat events. The first round of the program awarded 32 million to support 46 Californian communities protect people from the dangers of extreme heat. Future rounds of the program include funding from Green House Gas Reduction Fund and Prop 4. Those expected to benefit from these grants include farmworkers, who are often exposed to extreme heat conditions while working in agricultural fields.
- The Vulnerable Communities Platform is a tool in development to identify statewide those peoples most vulnerable to the impacts of climate changing, including climate hazards such as flooding or extreme heat, and to assist with funding and effort prioritization for climate adaptation. This is particularly relevant

to agriculture, which relies on field laborers, who often have less capacity and fewer resources to cope with and adapt to climate change.

- The California Department of Housing and Community Development (HCD) operates the Joe Serna Jr. Farmworker Housing Grant Program, which helps fund new construction, rehabilitation, and acquisition of owner-occupied and rental units for agricultural workers, with a priority for lower income households. Over the past 5 years, HCD has awarded more than $300 million for the development of 56 new projects for farmworkers with approximately 3,577 housing units. Additionally, in the 2023 funding round, HCD awarded $110M for 10 new Serna projects that include 618 additional housing units. These 4,195 homes will serve many tens of thousands of Californians during the 55-year affordability period.
- LCI provided one-time funding through its Adaptation Planning Grant Program to help local, regional, and tribal planning needs, provide communities the resources to identify climate resilience priorities, and support the development of climate resilient projects across the state. Projects could include identifying water efficiency and infrastructure needs to assist with water planning for irrigation demand and flood risk. Funding was awarded in 2023 and the state provided $8 million in grant awards.
- LCI's Regional Resilience Planning and Implementation Grant Program funds public entities, California Native American tribes, Community-Based Organizations, and academic institutions that form regional partnerships to advance climate resilience for regions through planning or implementation of projects. In 2023, $21.8 million was awarded in grant funding, including projects focused on addressing drought and flood risks in agricultural areas.

Resource Availability

In 2021, the California Department of Community Services and Development created the Farmworker Resource Center Grant Program to better connect farmworkers with a range of services, including labor and employment rights and health and human services. The program provided one-time funds to community-based organizations to develop and deliver services designed to meet the identified needs of farmworker populations and reach culturally diverse and historically underserved populations.

Providing Shelter and Emergency Response Infrastructure

The Fairs and Expositions branch of CDFA oversees 80 fairgrounds across the state that can be used as evacuation sites, animal shelters, and emergency response centers during disasters. During the 2020 wildfire season, a total of 50 fairgrounds were

activated for a combined 978 days.[109] During the 2023 flooding in Tulare County, the county's fairground supported evacuees and livestock for 42 days. The Fairs and Expositions branch also runs the Fairground and Community Resilience Centers Programs which provides community-based solutions as a response to extreme weather events stemming from climate change and enables local fairgrounds and other community facilities to be utilized in preparation for evacuees and emergency responders. In 2023, a one-time allocation of $89 million in grant funding was awarded to five local governments, counties, and businesses to equip facilities and provide spaces that can be used for emergencies and also year-round as community centers.

Assessing Vulnerability

The State of California is actively engaging in research on climate change, its current impacts on the state, and scenarios for future impacts, such as through the regularly updated Indicators of Climate Change in California Report put out by CalEPA's Office of Environmental Health Hazard Assessment. The Report identifies indicators which are measurable trends and conditions relating to climate change and explores how these indicators affect people, land, and resources. The Report is critical for understanding climate change impacts on water resources in the state.[110] Additionally, the Climate Change Assessment is another regularly updated resource that compiles the best available science and information about California's climate future, including unique community-level climate-related vulnerabilities. The Assessment provides downscaled climate change projections and scenarios, alongside a suite of original research on climate impacts and adaptation responses to assist with planning and decision-making at the state, regional, and local level. The Assessment's unique approach to uplifting original research helps fill critical research gaps specific to California communities; the upcoming Fifth Assessment will include reports pertinent to water-related vulnerabilities for agriculture including the sustainability of water for groundwater basins, a multi-sector analysis on adaptions in California agriculture, and detail on the impacts of atmospheric rivers on water infrastructure.[111]

[109] California State Assembly Committee on Agriculture. (2020, November). The Impact of Wildfires on California Agriculture Informational Hearing Report. State of California. https://agri.assembly.ca.gov/sites/agri.assembly.ca.gov/files/The%20Impact%20of%20Wildfires%20on%20California%20Agriculture%20Informational%20Hearing%20Report.pdf

[110] California Office of Environmental Health Hazard Assessment. (2022). Indicators of climate change in California: 2022 report (Publication No. 22-0001). California Environmental Protection Agency. https://oehha.ca.gov/media/downloads/climate-change/document/2022caindicatorsreport.pdf

[111] https://lci.ca.gov/climate/docs/20240829-CoreClimateResearch-Profiles.pdf

Implementation

Strategy/ Action	Goal Alignment	Lead Agency	Supporting	Status	Implementation Phase
3.1 Enable a safer and healthier work experience for those in the agricultural industry.					
3.1.1 Support state policies for better working conditions for hotter, drier conditions.	2: Enhance Program Effectiveness	Cal/OSHA	CNRA, CDFA		
3.1.2 Support research and collaboration into on-farm tools for health and safety.	5: Demonstrate & Invest in Innovation and Technology	DIR, Cal/OSHA, EDD	CNRA, CDFA		
3.1.3 Support programs that give resources and training for all peoples working on farms for mental health.	2: Enhance Program Effectiveness	CDFA	USDA		
3.1.4 Implement programs that build and improve infrastructure in rural agricultural communities to better support resilience to extreme weather events.	2: Enhance Program Effectiveness	CDFA, LCI, HCD, DCSD			

Chapter 4. Protect Animal Health

Key Objective: Protect the health and welfare of our livestock and poultry from climate-related threats.

Context

California's livestock commodities represent a significant proportion of the state's agricultural value. In 2022, Dairy Products/Milk and Cattle and Calves were the first and third ranked commodities in the state, bringing in just over $14 billion in market value. Climate change brings many challenges to livestock production, threatening the health of animals, food safety and security, and commodity production. Climate change driven effects such as increasing temperatures and periods of extreme heat, and pests and diseases are just a few of the climate-driven challenges facing livestock production, as shown in Figure 9, which can drive production losses and livestock mortality.

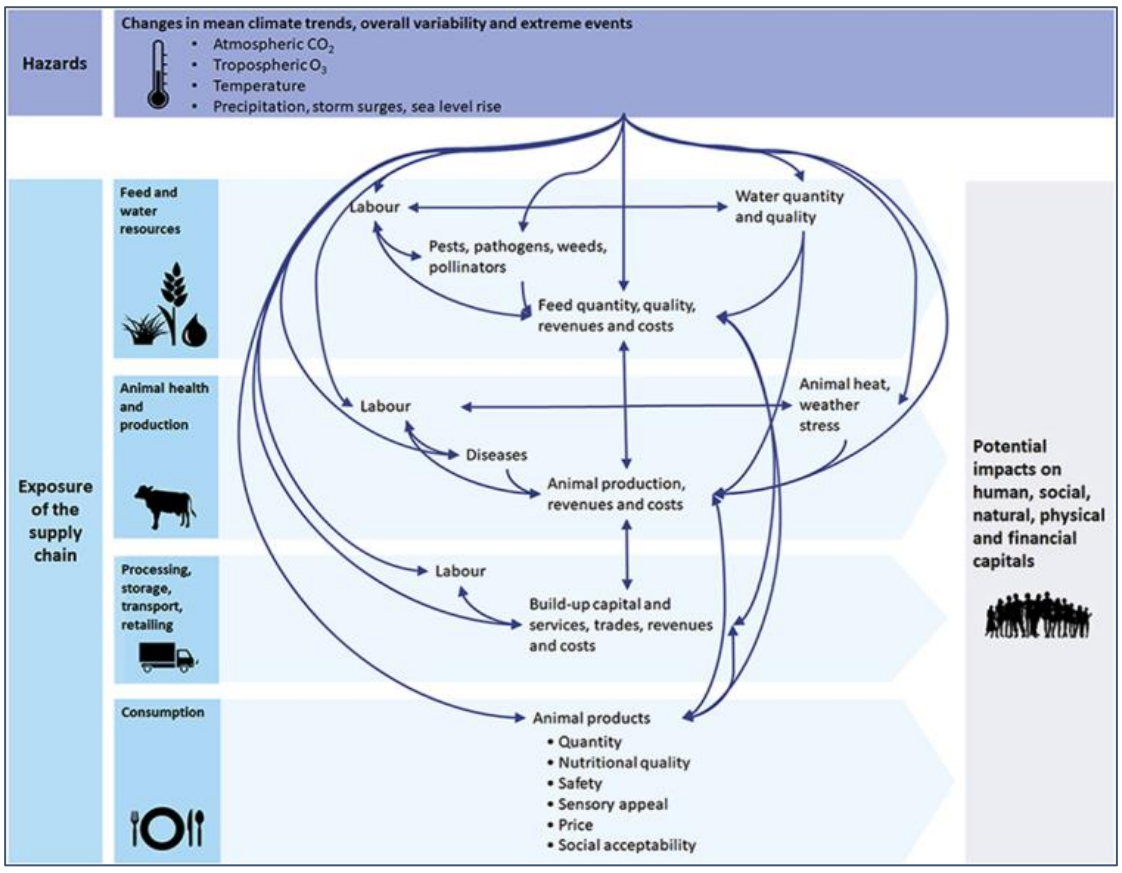


Figure 9: Impacts of Climate Change on Livestock Food Supply Chain

Heat Stress and Livestock Welfare

As the frequency and intensity of extreme heat events increases in California, heat stress is a growing concern for livestock welfare.[112] Since 1985, average annual air temperatures in the state have increased by about 2.5° F.[113] By 2050, the daily maximum average temperature is expected to increase by 4.4° F, and by the end of the century will reach 5.8° F, following the RCP4.5 IPCC's climate projection scenario. [114] Extreme heat events, when temperatures are at or above the highest 5 percent of historical values, are also increasing.[115] Extreme heat events suppress livestock appetites and increase sweating rates, which can lead to metabolic disorders and lameness. Cows are sensitive to temperatures above 72° F, and heat stress for them can also lead to oxidative stress and immune suppression, making cows more vulnerable to pathogens.[116] High heat conditions also disrupt reproduction and decrease milk production for dairy cows.[117] Heat stress also causes mortality; extreme heat events like the one in the Central Valley in summer 2017 can kill thousands of cows and create local states of emergency as localities struggle to handle carcasses.

Effects on Animal Feed Supply

The quality and quantity of animal feedstocks and water availability may also be negatively affected by climate change, indirectly impacting livestock production. Arid and semi-arid locations may see negative impacts on pasture and livestock production with an increase of 2°C in temperature.[118] Water-stressed regions may become more water limited, leading to lower forage productivity for grazing livestock.[119] Heat stress and water limitations can also decrease the nutrient content of animal feed.

---

[112] Bernabucci, U. (2019). Climate change: impact on livestock and how can we adapt. Animal frontiers : the review magazine of animal agriculture, 9(1), 3–5. https://doi.org/10.1093/af/vfy039

[113] California Office of Environmental Health Hazard Assessment. (2022, November 1). Air temperatures. California Environmental Protection Agency. https://oehha.ca.gov/climate-change/epic-2022/changes-climate/air-temperatures

[114] National Oceanic and Atmospheric Administration. (n.d.). Climate model: Temperature change (RCP 4.5) - 2006 - 2100. Science On a Sphere. https://sos.noaa.gov/catalog/datasets/climate-model-temperature-change-rcp-45-2006-2100/

[115] California Office of Environmental Health Hazard Assessment. (2022). Indicators of climate change in California: 2022 report (Publication No. 22-0001). California Environmental Protection Agency. https://oehha.ca.gov/media/downloads/climate-change/document/2022caindicatorsreport.pdf

[116] Lacetera, N. (2018). Impact of climate change on animal health and welfare. Animal frontiers : the review magazine of animal agriculture, 9(1), 26–31. https://doi.org/10.1093/af/vfy030

[117] Wolfenson, D. & Roth, Z. (2019, January). Impact of heat stress on cow reproduction and fertility. Animal Frontiers, 9(1), 32–38. https://doi.org/10.1093/af/vfy027

[118] Rojas-Downing, M. M., Nejadhashemi, A. P., Harrigan, T., & Woznicki, S. A. (2017). Climate change and livestock: Impacts, adaptation, and mitigation. Climate Risk Management, 16, 145-163. https://doi.org/10.1016/j.crm.2017.02.001

[119] Godde, C. M., Mason-D'Croz, D., Mayberry, D. E., Thornton, P. K., & Herrero, M. (2021). Impacts of climate change on the livestock food supply chain; a review of the evidence. Global food security, 28, 100488. https://doi.org/10.1016/j.gfs.2020.100488

Disease and Pest

Rising temperatures can increase the growth and survival rate for pathogens, transmission rates, and host susceptibility.[120] The proliferation of diseases is especially an issue, as the spread of vector-borne pests is increasing with warming climate and precipitation shifts and transmission between hosts is more likely to occur in warmer conditions.[121] Research shows that an increase of temperature by 2°C could drive an extensive spread of *Culicoides imicola*, the major vector of the bluetongue virus.[122] Currently, state and federal agencies are working to treat and prevent the spread of Highly Pathogenic Avian Influenza (HPAI), which has recently been detected in cattle in California.[123] HPAI is spread predominantly by wild birds, but also transmittable within a herd, and from cows to poultry. The disease threatens multiple commodities within the state and creates a significant biosecurity hazard. The spread of vector-borne diseases poses a threat to human health, where these diseases are able to be passed from vertebrate animals such as livestock to humans (zoonotic diseases).[124]

The spread of HPAI is connected with intensifying global climate change where extreme weather events and longer-term weather shifts drive migration expansion and allow for disease spread and more rapid wildlife to agriculture transmission. Furthermore, climate change can shift host population dynamics, immune function, and the evolution and environmental persistence of the virus itself, making the spread and duration of viruses harder to predict.[125]

[120] Harvell, C. D., Mitchell, C. E., Ward, J. R., Altizer, S., Dobson, A. P., Ostfeld, R. S., & Samuel, M. D. (2002, June 21). Climate warming and disease risks for terrestrial and marine biota. Science, 296(5576), 2158–2162. https://doi.org/10.1126/science.1071708

[121] Rojas-Downing, M. M., Nejadhashemi, A. P., Harrigan, T., & Woznicki, S. A. (2017). Climate change and livestock: Impacts, adaptation, and mitigation. Climate Risk Management, 16, 145-163. https://doi.org/10.1016/j.crm.2017.02.001

[122] Wittmann, E. J., Mellor, P. S., & Baylis, M. (2001). Using climate data to map the potential distribution of Culicoides imicola (Diptera: Ceratopogonidae) in Europe. Revue scientifique et technique (International Office of Epizootics), 20(3), 731–740. https://doi.org/10.20506/rst.20.3.1306

[123] California Department of Food and Agriculture. (n.d.). Highly pathogenic avian influenza (HPAI). California Department of Food and Agriculture. https://www.cdfa.ca.gov/AHFSS/Animal_Health/HPAI.html

[124] Leal Filho, W., Ternova, L., Parasnis, S. A., Kovaleva, M., & Nagy, G. J. (2022). Climate Change and Zoonoses: A Review of Concepts, Definitions, and Bibliometrics. International journal of environmental research and public health, 19(2), 893. https://doi.org/10.3390/ijerph19020893

[125] Prosser, D. J., Teitelbaum, C. S., Yin, S., Hill, N. J., & Xiao, X. (2023). Climate change impacts on bird migration and highly pathogenic avian influenza. Nature Microbiology, 8, 2223–2225. https://doi.org/10.1038/s41564-023-01538-0

Strategy and Actions

As climate change continues to cause threats to animal health, the state can continue to implement programs, provide technical assistance, and support research that protects California's livestock industries and consumers.

4.1 Establish and support proactive approaches to threats against animal health.

The state is already working to prevent threats to animal health from occurring, detect outbreaks, and provide information and support when these events happen. The continuation of these programs, in addition to investing in new technology and tools, will help to protect livestock around the state.

4.1.1 Be proactive to threats against animal health with ongoing technical assistance.

Goal 1: Increase and Enhance Technical Assistance

California has two programs--the Wildlife Services Program and California Avian Heath Education Network technical assistance program--that provide vital assistance to poultry and wildlife operations that reduce the risk and impacts of animal health.

Wildlife Services Program

The Wildlife Services Program, a partnership between USDA's Animal and Plant Health Inspection Service (APHIS) and state and county agencies, plays a crucial role in enhancing resilience against the impacts of climate change by managing wildlife-related health and safety threats, property damage resulting from contamination, and resource protection. As climate change alters habitats and disrupts ecosystems, human-wildlife-domestic animal conflicts and food safety issues are expected to increase, making the program's efforts more vital than ever. The Wildlife Services Program provides California residents with professional assistance to resolve these conflicts, ensuring public safety and protecting valuable resources.

California Avian Health Education Network

In 2018, a substantial portion of Southern California's backyard and commercial poultry flocks were significantly impacted by a devastating outbreak of virulent Newcastle Disease (vND) that lasted more than two years. The CDFA and USDA worked jointly to identify infections and halt rapid spread of the vND virus before its eradication midyear 2020. As a result of this outbreak and in an effort to prevent more in the future, CDFA established the California Avian Health Education Network. This program is dedicated

to offering education, training, outreach, testing, and vaccination options for backyard poultry flock owners, other bird enthusiasts, and those dedicated to avian health in Southern California. By working together, CDFA, USDA, University of California extension groups and community partners aim to keep California free of foreign animal diseases to prevent similar devastation in the future, thereby enhancing the region's overall resilience to diseases that may become more prevalent due to changes in climate.

4.1.2 Support research and predictive tool development.

Goal 5: Demonstrate and Invest in Innovation and Technology

There is ongoing opportunity to further research, develop, and utilize decision making tools to help farmers be alerted to climate related risks for their livestock operations. In 2021, legislation established the California Veterinary Emergency Team in the University of California, Davis (UCD) Veterinary Medical School through a Memorandum of Understanding between CDFA, California Office of Emergency Services (OES), and UCD. In 2022, the Animals in Disasters Working Group was established to consult on the development and improvement of resources for large animals and livestock during disaster. One example of the types of tools that could be further developed is from the USDA Agricultural Research Service. This agency developed a smartphone app that provides heat-stress forecasts to farmers available on their smartphone.[126]

Shade as a Co-Benefit

Shade and ventilation are critical for livestock during extreme heat events. Extreme heat events stress dairy cows, decreasing their appetites and altering their calving schedules. As a result, milk production decreases during periods of extreme heat. However, infrastructure improvements are costly. The Alternative Manure Management Program, offered by CDFA, provides financial incentives for improved manure management for the purpose of reducing methane emissions. Some of the practices funded, including practices such as compost bedded pack barns, offer shade to provide dairy cows respite from the heat. The Healthy Soils Program, offered by CDFA, provides financial incentives to improve soil health, in addition many of the offered practices for rangelands and pasture, such as silvopasture, windbreaks, or hedgerows can also offer shade to grazing livestock.

[126] Suszkiw, J. (2016, August 29). New USDA App Protects Cattle from Heat Stress. United States Department of Agriculture. https://www.ars.usda.gov/news-events/news/research-news/2016/new-usda-app-protects-cattle-from-heat-stress/

4.1.3 Prepare for emergency situations with state agency coordinated procedures and infrastructure.

Goal 3: Grow Partnerships and Collaboration

CDFA's Animal Health Branch protects animal health, food safety and security by preventing, detecting, and responding to catastrophic livestock diseases and natural disasters. There are many programs that this Branch administers or helps to run in the state, outlined below.

Disease Tracing

In the context of climate change, the ability to rapidly trace the movements of sick or at-risk animals exposed to disease is increasingly critical. As climate change can amplify the spread and emergence of animal diseases through altered ecosystems, migration patterns, and extreme weather events, swift and accurate tracing is essential for a prompt and effective response. While tracing animal disease does not prevent disease, it is a key element of ongoing disease control programs and is vital for animal health officials responding to emergency disease events.

Federal and state animal health officials, in collaboration with livestock industry stakeholders, have developed an animal traceability framework to enhance the ability to trace the movement of livestock. This framework is now more crucial than ever, given the potential for climate-related disruptions to animal health. In 2024, USDA's APHIS mandated the use of electronic identification ear tags as official means of identification for cattle and bison. The intent of this regulation is to bolster the United States' ability to quickly respond to significant animal disease outbreaks. Incorporating these traceability measures into a broader climate change strategy strengthens our resilience to the unpredictable impacts of a changing climate on animal health.

EPRS and CARES

The Animal Health Branch Emergency Preparedness and Response Section (EPRS) is a critical component of climate readiness, as it addresses the growing threats posed by climate change to animal health and food safety. One of EPRS' primary mission areas is overseeing the California Animal Response Emergency System (CARES).

EPRS is comprised of five functional programs—Planning, Training, Exercise, Outreach, and Epidemiology/Analysis—each of which plays a vital role in enhancing the resilience of California's agricultural and food systems in the face of climate change. By preparing for and responding to emergencies that affect animal health, EPRS helps safeguard the state's food supply and mitigate the impacts of climate-related disruptions.

The CARES Program is an essential part of the state's emergency management strategy for animals in disasters, like wildfire, floods, earthquakes, extreme heat, and more. As climate change leads to more frequent and intense natural disasters, the CARES Program provides critical operational guidance and support for animals affected by these events. Supported by a partnership of public and private organizations, CARES is dedicated to preparing for and responding to animals in disasters, ensuring their protection and welfare during climate-induced emergencies. Growing animal disaster preparation collaboration as part of ongoing communications from EPRS can catalyze and swiften emergency response.

Rendering

The Meat, Poultry, and Egg Safety (MPES) program is crucial to a comprehensive climate change strategy due to its oversight of the rendering industry, which plays a key role in recycling animal byproducts and organic waste. During extreme heat events or wildfires, where animal causalities may be high, the rendering services are important for the safe handling of these deceased animals. By licensing and inspecting renderers who process animal carcasses and pack house waste and inedible kitchen grease, MPES ensures that these materials are handled safely, thereby protecting human and animal health and the environment. The rendering process not only prevents the entry of these inedible materials into the human food chain but also contributes significantly to the reduction of greenhouse gases by diverting organic waste from landfills. This is particularly important in California, where SB 1383 mandates the diversion of organic waste to reduce greenhouse gas emissions. Furthermore, the rendering industry supports the production of biodiesel, with about 75 percent of California's biodiesel coming from inedible kitchen grease, contributing to the energy sector's efforts to lower carbon emissions. While the loss of livestock is never desirable, CDFA's actions provide safe and economical options for handling deceased livestock in and outside of emergency situations.

Addressing Animal Mortality Emergencies

CDFA, in consultation with CalRecycle, Water Boards, and the California Air Resources Board, created an advisory procedure for use during large animal mortality events caused by emergencies like extreme heat. The advisory provides guidance for potential alternate disposal options such as carcass composting to prevent the transmission of disease and groundwater contamination when rendering capacity is diminished or insufficient. In June 2017, the Fresno Agricultural Commissioner reported that between 4,000-6,000 cattle were killed in one month in Fresno County due to extreme heat; the situation was exacerbated by mechanical failures at the local rendering facility that halted pickup and processing. Mechanical upgrades between 2022-2023 have led to significantly fewer failures in the last year; however, there are still very few rendering facilities left in the state.

Food Security

The California Secure Food Supply (SFS) program provides enhanced biosecurity that protects California agriculture during a Foreign Animal Disease or Notifiable Animal Disease outbreak and provides a pathway to economic survival for the industry through conditions that provide safe, permitted movement of animals and animal products. The SFS Program is designed to allow business operations that are unaffected by the disease (i.e. test negative for the disease) but located within a quarantine Control Area to maintain some business operations to maintain economic viability.

Implementation

Strategy/ Action	Goal Alignment	Lead Agency	Status	Implementation Phase
4.1 Establish and support proactive approaches to threats against animal health.				
4.1.1 Be proactive to threats against animal health with ongoing technical assistance.	1: Increase and Expand Technical Assistance	USDA, CDFA		
4.1.2 Support research and predictive tool development.	5: Demonstrate & Invest in Innovation and Technology	CDFA, OES	USDA	
4.1.3 Prepare for emergency situations with state agency coordinated procedures and infrastructure.	3: Grow Partnerships and Collaboration	CDFA, USDA	CalRecycle, Waterboards, CARB	

Chapter 5. Advance Energy Efficiency and Decarbonization for Agricultural Operations

Key Objective: Increase energy efficiency and access to a reliable and clean energy grid for all agricultural operations.

Context

Energy is a critical input to every part of the food supply chain. From water conveyance to traditional on-farm equipment such as pumps, tractors, and harvesters, to newer technologies like seeding drones, soil-moisture monitors, and weeding robots, access to reliable energy is a requirement. Energy is just as vital further down the supply chain, for food processing warehouses where products are cleaned and packaged and refrigerated trucks that carry food to neighborhood grocery stores. Much of this fleet of equipment has historically been powered by fossil fuels and is a significant source of GHG emissions.[127] In recent years, wildfire weather conditions and extreme weather events have resulted in strains on the grid and highlight the importance of energy efficiency and reliable sources of energy to maintain agricultural operations.

Our state has already been working hard to match energy demand while creating a resilient and decarbonized energy supply. There have been exponential increases over the last decade in the state's capacity to deliver power and to diversify the source of that power to continue to expand the renewable component. Several recent legislative bills build on the state's ongoing efforts to provide a suite of guidance regarding energy in California's agriculture industry. The 2022 Scoping Plan calls for electrifying 25 percent of the agriculture industry by 2030 and 75 percent by 2045, and SB 100 establishes a goal of generating 100 percent of retail electricity from renewable and zero carbon energy sources by 2045.

Agencies involved in the administration of programs to meet these goals in the agriculture industry include CDFA, CEC, CPUC, CARB, the California Department of Water Resources (DWR), and are supported by programming at the USDA and United States Department of Energy (DOE). At the local level, air quality management districts, investor and publicly owned utilities (IOUs/POUs), and community choice aggregators (CCAs) all have important roles.

The state's plan revolves around decarbonizing the agricultural economy and boosting energy efficiency. Multiple programs have been developed to help the agricultural

[127] California Air Resources Board. (2022, October 26). California greenhouse gas emissions for 2000 to 2020: Trends of emissions and other indicators. California Air Resources Board. https://ww2.arb.ca.gov/sites/default/files/classic/cc/inventory/2000-2020_ghg_inventory_trends.pdf

sector improve energy efficiency either through reduction in energy consumption or shift electric usage to the times of day when renewable energy is more abundant, both on and off-farm. Many of these programs utilize incentives to address energy usage and electrification. Those focusing on agricultural operations typically fall into two categories:

1) Non-technological programs aimed at behavioral changes or usage efficiency improvements.
2) Technological programs aimed at facilitating equipment and vehicle electrification as well as distributed generation projects. On-farm energy consumption and efficiency are largely tied to water-use consumption and efficiency; it is estimated that pumping for irrigation represents 7 percent of California's electricity use.[128] This water-energy nexus is at the core of many of the programs available to improve on-farm efficiencies. Additionally, there is ongoing research into emerging technologies for the generation of electricity, fuels, and other value-added products from agricultural byproducts. Programs to study, develop, and scale these various technologies are underway.

Coupling these projects and programs with needs assessments and planning and implementation enables better resource management and informs planning at the local level.

To achieve California's climate goals, while providing safe, reliable, affordable, and high-quality agricultural products means the transition to carbon-free and renewable sources of energy must be approached holistically. In this section, we present several strategies, both ongoing and planned, which will help the State, the energy industry, and the agricultural industry plan holistically for the energy needs of the agriculture industry.

[128] https://www.energy.ca.gov/sites/default/files/2021-10/CEC-500-2021-044.pdf

Strategies and Actions

Energy is both an opportunity and potential stressor across the agricultural industry. The aim of the state is to help agriculture, and its related industries electrify agricultural operations and equipment, become more energy efficient, and increase load flexibility while addressing existing issues of equipment, cost, and availability.

5.1 Support energy needs assessment and planning for local jurisdictions.

Understanding the barriers that exist for agricultural operations to efficiently electrify will help improve program offerings that the state provides to target harder-to-reach operations. Results from regional needs assessments (described below) could elucidate these barriers, as well as provide information to state and local government on the potential load from operational expansion, including switching to electrification from fuel substitution.

5.1.1 Conduct energy demand assessments for rural and agricultural areas, taking into consideration future demand for electrified equipment, to support state and local planning efforts.

Goal 2: Enhance Program Effectiveness

The agriculture industry has had fairly low and constant energy demand and is located in more rural and remote areas. Growth in operations and on-site generation, including but not limited to electrification by fuel-substitution requirements, has resulted in opportunities to make the industry more efficient but also presented challenges with timely interconnections as well as the need for distribution system upgrades.

Facilitating electrification in agriculture while decarbonizing the economy requires multi-agency collaboration. This is especially important for ensuring that agricultural operations continue to have access to clean, renewable energy sources, as well as decarbonized facilities, equipment, and vehicles. One important step towards facilitating a smooth transition to alternatives such as electrification is to enhance energy demand forecasts, which informs processes such as grid system planning by identifying and understanding operational needs of the agricultural sector.

Various agencies, including the CEC, CPUC, utilities, and CARB are already working with key stakeholders to better understand operational capacity needs and electrification challenges through workshops and surveys. Each year the CEC provides an energy

demand forecast as part of the Integrated Energy Policy Report. In the 2024 report, special listening sessions with investor-owned utilities and industry experts were held to better understand the load growth in the agricultural sector.[129] From these listening sessions, a joint survey from CEC and CARB to assess the fleet inventory for the agricultural sector in order to understand the electricity demand forecast is in planning, for incorporation into future Integrated Energy Policy Reports. Utilizing these surveys and listening sessions, state agencies such as CDFA, CEC, and CPUC can work together to not only better understand demand, but also promote opportunities for energy efficiency improvements.

One example of state investment in planning efforts at the local level is the Sierra San Joaquin Jobs (S2J2).[130] Funded through the California Jobs First Initiative, this effort provides a holistic planning and implementation project to provide high quality, climate resilience, and accessible jobs for Madera, Fresno, Kings, and Tulare counties. This effort will inform economic development plans for the region, including climate-smart improvements to businesses, that will inform the evolving energy demand for the region. Currently, the effort is in the implementation stage, enacting projects based on the planning efforts.

[129] https://www.energy.ca.gov/publications/2024/2024-integrated-energy-policy-report-update

[130] https://www.s2j2initiative.org/

5.2. Support energy efficiency projects that reduce energy consumption in the food system, both on and off-farm.

The legislature has established programs that will assist with electrification. These programs work to both incentivize behavioral changes and implement new technologies while efficiently accessing clean energy from the electric grid. Previously funded work in this vein included the Renewable Energy for Agricultural Program administered by the California Energy Commission (CEC) and the agricultural sector focused energy efficiency programs authorized by the California Public Utilities Commission (CPUC).

5.2.1 Support demand flexibility and improve energy efficiency through incentivized behavior changes.

Goal 2: Enhance Program Effectiveness

The CPUC is the primary agency responsible for setting electricity rates for agricultural operators, aside from those receiving service from a publicly owned utility. The CPUC, through the regulation of the investor-owned utilities, has made available programs which provide rate incentives to encourage changes in operational electricity use. These changes can result in shifting electricity usage to non-peak hours when renewable energy is more abundant and greenhouse gases on the electric grid are lower, and improved energy efficiency.

For instance, time-of-use (TOU) pricing structures are available for agricultural customers to help encourage a shift of energy consumption away from peak hours in the late afternoon and evening. This shift away from peak electricity demand hours, when electricity rates are the highest and grid is most stressed, can help reduce operational costs and lower GHG emissions and also reduces state reliance on GHG-emitting energy sources such as natural gas-powered combustion turbines which are often utilized most during peak hours.[131] A recent UC Berkeley study provides evidence that agricultural electricity customers are particularly responsive to TOU prices to shift demand away from peak hours in comparison to other customer classes such as residential.[132] This highlights the importance of these programs as well as the

[131] Natural gas-fired combustion turbines are generally used to meet peak electricity load - U.S. Energy Information Administration (EIA)

[132] Burlig, Fiona, Davis, Lucas, Preonas, Louis, and Woerman, Matt. "Do California Farmers Respond to Electricity Prices?" Energy Institute Blog, July 29, 2024, https://energyathaas.wordpress.com/2024/07/29/do-california-farmers-respond-to-electricity-prices/

infrastructure which allows for the implementation of these price programs, such as individual customer meter upgrades.

Similarly, the IOUs provide demand response programs that enable a temporary reduction in electricity consumption in response to economic or reliability signals. For example, Southern California Edison (SCE) administers the Agricultural and Pumping Interruptible Program as a demand response program. In exchange for monthly bill credits, SCE installs a load control device to remotely shut off service during emergency events where the California Independent System Operator provides notification of a need to reduce energy load. Demand response programs offer the opportunity for agricultural operators to be compensated for reducing load during times of high demand.

Programs such as Pacific Gas & Electric's Peak Day Pricing tariff offer similar discounts for using energy during non-peak hours in exchange for peak pricing on days which reflect the greatest demand on the electric grid throughout the year. The CEC's Electric Program Investment Charge (EPIC) funded a Polaris research project to test new demand response technology for agricultural operations. The results of the project showed two-thirds of load from the peak window was shifted and resulted in financial and operational benefits for the farmers.[133] Demand response as an option may be more desirable for operations which do not have the flexibility to temporarily shut down.

Utilities also offer tariffs that pair with on-farm supply of renewable energy generation. The CPUC's recently adopted net billing tariff (NBT) for instance, allows customers to install self-generation electricity systems while staying connected to the rid and using it as needed.

In the wake of successful limited demand flexibility rate pilots for agricultural customers, the CPUC recently directed California's IOUs to launch expanded demand flexibility (dynamic pricing) pilots for participation by agricultural customers. The expansion of the existing demand flexibility pilots is driven by the urgent need for additional resources to enhance summer reliability and grid resilience. A recent Joint Agency Reliability Planning Assessment Report emphasized the continued risk to system reliability from extreme weather patterns and increasing demand forecasts. The report projected that California would be at risk of a capacity shortfall if it experienced the same type of heatwaves as in 2022, coupled with wildfires. These expanded pilots help to address these risks while providing critical opportunities to agricultural customers to benefit from

[133] Meyers, D., & Hardy, M. (2021, October). Technologies and strategies for agricultural load management to meet decarbonization goals (Final Project Report, CEC-500-2021-044). California Energy Commission. https://www.energy.ca.gov/sites/default/files/2021-10/CEC-500-2021-044.pdf

efficient operations and lower bills through peak load shifting of electricity usage, which in turn can incentivize further electrification.

5.2.2 Improve energy efficiency and flexible electricity demand through technological upgrades.

Goal 2: Enhance Program Effectiveness

Equipment & Vehicle Upgrades

Several programs administered by sister state agencies address the need to fund farm operation facility upgrades to accelerate the pace of industry electrification and GHG emissions reductions. The California Air Resources Board (CARB) oversees a variety of incentive programs that fund zero-emission and the cleanest available combustion agricultural equipment and vehicles, including Clean Off-Road Equipment (CORE), the Carl Moyer Air Quality Standards Attainment Program, and the Funding Agricultural Replacement Measures for Emission Reductions (FARMER) Program. The FARMER program funds vehicle and equipment upgrades to reduce criteria pollutants, toxic air contaminants, and GHG emissions. Eligible vehicles and equipment include agricultural harvesting equipment, heavy-duty trucks, agricultural pump engines, tractors, and other equipment used in agricultural operations. For more information on air quality and electrification, please see the Air Quality section.

The CEC's Responsive, Easy Charging Products with Dynamic Signals (REDWDS) grant funding opportunity recently funded a project aimed at testing and deploying charging technology on farms and at other rural locations that is responsive to dynamic grid signals. This project will reduce the operational cost of electric agricultural tractors and support farm vehicle electrification. The REDWDS grant complements another project with Gridtractor called Electric Farm Vehicles as Reliable Grid Assets funded through CEC's Electric Program Investment Charge (EPIC) program. Together, the outcome of these projects will demonstrate the technology employed to enable electric farm vehicles to charge or discharge to power other on-farm loads in response to grid conditions through dynamic price signals, demand response events, and backup power capabilities during weather related public safety power shut offs.

The CEC also administers the Food Production Investment Program (FPIP), which provides grant funding to support the adoption of advanced energy efficiency, decarbonization, and renewable energy technologies at food processing facilities. FPIP supports updates to food processing facilities that reduce energy demand and operation costs, lower GHG emissions, and improve the electrical grid reliability, while maintaining product quality and output levels.

Since its launch in 2018, FPIP has supported 60 projects across California, demonstrating a wide range of advanced decarbonization solutions in the food sector. In November 2024, the CEC awarded five projects, including comprehensive refrigeration system upgrades, energy-efficient process improvements, and a solar-powered microgrid system. An active funding opportunity is currently available to support additional projects that drive clean energy adoption and support decarbonization in the food processing sector.

USDA's Natural Resources Conservation Service manages the Environmental Quality Incentives Program (EQIP) On-Farm Energy Initiative which helps farmers and ranchers with energy efficiency upgrades. EQIP funding can be used for the purchase, installation, or retrofit of a variety of energy efficiency improvements, such as lighting, ventilation and fans, irrigation pumps, grain dryers, greenhouse improvements, heating and refrigeration units, insulation and building envelope sealing, motor controls, and variable speed drives.

The CPUC has also authorized PG&E to administer the Agricultural Energy Savings Action Plan, which is an agricultural retrofit program that offers cash incentives and financing to agricultural operations to upgrade to more energy-efficient equipment. The program encourages these retrofit installations by offsetting the incremental cost of higher efficiency equipment. The program also offers several technical services to support the customer, including energy auditing and identification of energy efficiency opportunities.

Water & Energy Use Efficiency

Pumping water from underground aquifers and moving water from one location to another, (i.e. water conveyance), consumes a significant amount of energy. The Department of Water Resources estimates that approximately 12 percent of all energy used in California is related to moving water.[134] Further, groundwater supplies an average of 40 percent of the water consumed by municipalities and agriculture. It is estimated that a total of 6.8 terawatt hours (TWh) are consumed for groundwater pumping in the Central Valley alone under normal hydrologic years. This number increases to 9 TWh during dry years and can cost up to $21.3 billion per year.[135] In addition, there are embedded energy savings in water use efficiency in general (less water use equates to less energy used for pumping, collection/conveyance, storage, treatment, delivery, maintenance, heating for end use, etc.

[134] California Department of Water Resources. (n.d.). Water Energy Nexus. California Department of Water Resources. https://water.ca.gov/Programs/All-Programs/Climate-Change-Program/Water-Energy-Nexus

[135] Blum, H., & Ke, J. (2023, June). Estimates of Groundwater Pumping Electricity Use and Costs in California. California Energy Commission. https://www.energy.ca.gov/sites/default/files/2023-06/CEC-500-2023-041.pdf

During a drought year, the use of groundwater increases to make up for the shortfall in surface water which is due to lower rainfall, reduced snowpack, and higher evaporation. A series of droughts in consecutive years, such as those that occurred in 2007-2009, 2012-2016, and 2020-2022, cumulatively reduce the groundwater depth. Groundwater depths may not go back to normal quickly after a drought episode because rainfall in a non-drought year may not fully replenish the wells.

The amount of energy used to pull groundwater depends on two factors: the amount of water extracted and the depth of the well. During a drought, both the amount of water extracted, and the depth of the groundwater well increases, resulting in greater energy demand. The situation could get worse over time as climate change increases the frequency of droughts, reducing water levels in wells.

CDFA's State Water Efficiency and Enhancement Program (SWEEP) directly tackles this energy use by funding irrigation system upgrades that reduce GHG emissions as well as water use and operator costs. Examples of eligible system components include soil moisture monitoring, drip systems, low pressure irrigation systems, pump retrofits, variable frequency drives and installation of renewable energy systems.

Community choice aggregators (CCAs) are also providing valuable services to improve water-energy use efficiency. Recently, the CPUC approved a $3.25 million, 5-megawatt pilot program for Valley Clean Energy, a CCA within PG&E's service territory, to deploy automation systems, mainly for irrigation, at subsidized or no cost to farmers, that are responsive to the dynamic conditions of the power grid and utilize the hourly dynamic rate.

Incorporating Electrification of the Agricultural Sector into Energy Planning

As more farming operations and other industries and residential customers electrify, their needs for grid capacity will increase. Electrification of on-farm equipment and vehicles may necessitate service line extensions and/or upsizing from customers to meet their additional energy demand. In September 2024, the CPUC established energization timelines for California's three large investor-owned utilities to expedite the process for new and upgraded electrical services, enhance utility accountability, and offer greater transparency for customers. Recently, California was awarded over $600 million from DOE's Grid Resilience and Innovation Partnerships program. The funds will allow the CEC, CPUC, CAISO, PG&E, and SCE to develop a public-private partnership designed to drive large-scale expansion to transmission capacity and improvements to the interconnection process.[136] This grant will help accelerate equitable access to renewable energy across California by supporting a variety of transmission line improvements and modernization efforts, including increasing the state's system

[136] California receives more than half a billion dollars in federal funds to improve power grid | Governor of California

capacity to integrate more renewable energy onto the grid. The state must continue system-level energy planning for the agricultural sector.

Agrivoltaics provides an on-farm energy production opportunity that provides the flexibility to fit a variety of applications in the future. The coproduction of solar energy on a working agricultural field, which provides the opportunity for energy generation without displacing farmland (for more information on agrivoltaics and land use, see the Land Use Section). Research at UC Davis is looking at how to optimize the sun's light spectrum to make agrivoltaics systems more efficient in arid agricultural regions found in California, optimizing electricity production and crop growth. This type of research takes aim at solving a common problem associated with agrivoltaics, the shading out of crops. Recently, CEC released an EPIC funded grant funding opportunity, GFO-24-301 Environmental Sustainability of a Clean Energy Transition (Enviro-SET)[137], in August 2024 that will provide up to $700k for research aimed at automated mapping of solar energy footprints and modeling land suitability for agrivoltaics. Other applications for solar photovoltaics (PV) in agricultural settings include the option of utilizing solar panels over irrigation canals or ponds or on top of crop processing facilities, food processing facilities, farm equipment storage facilities, and other related structures.

On-Farm Fuel Production

On-farm bioenergy production has many environmental and economic benefits. Farms may be able to reduce their GHG emissions and produce fuel and power from the byproducts of their primary agricultural operations which can then be used to offset their own energy use or be sold. Anaerobic digestors are one way to convert a variety of agricultural byproducts such as manure, wastewater biosolids, food waste, and crop residues into electricity, renewable natural gas, and hydrogen. Another method for fuel and power production via agricultural wastes such as nut shells, rice hulls, and orchard prunings is through thermochemical processes.[138]

CDFA's Dairy Digestor Research & Development Program (DDRDP) provides financial assistance for anaerobic digestion for dairy manure through the installation of dairy digesters. Dairy digesters are a renewable technology that captures methane from livestock manure. That methane can then be converted into biogas used for electricity generation or transportation fuel. For more information on DDRDP and electricity and natural gas production from these anaerobic digestion projects, see the Sustainability in Dairy Section.

[137] https://www.energy.ca.gov/solicitations/2024-08/gfo-24-301-environmental-sustainability-clean-energy-transition-enviro-set

[138] Lee, K.-T., Chen, W.-H., Sarles, P., Park, Y.-K., & Ok, Y. S. (2022). Recover energy and materials from agricultural waste via thermochemical conversion. One Earth, 5(11), 1200–1204. https://doi.org/10.1016/j.oneear.2022.10.010

In 2019, the CPUC approved a decision implementing an Incentive Reservation System for the Biomethane Monetary Incentive Program. The Biomethane Monetary Incentive Program provides up to $3 million for non-dairy clusters and $5 million for dairy clusters (defined as three or more dairies in proximity) that successfully interconnect with the natural gas pipeline system and operate by December 31, 2026. Shortly after this CPUC decision, Southern California Gas Co. (SoCalGas) announced a $5 million award to Calgren to produce pipeline-quality renewable natural gas from cow manure collected from four dairy farms located in Pixley, CA. Calgren also received a grant from CDFA's DDRDP.

CEC and CDFA have funded other fully operational dairy digester projects which sell power back to the grid through the CPUC's Bioenergy Feed-in Tariff Program and the Bioenergy Market Adjusting Tariff (BioMAT) program.[139] Some of these projects include the West Star North Dairy Biogas-to-Electricity project in Visalia, the Lakeview Farms Dairy Biogas-to-Electricity project in Visalia, and the Carlos Echeverria and Sons Dairy Biogas project near Bakersfield.

On-farm fuel production is starting to expand beyond renewable natural gas, towards the production of hydrogen. Depending on how it is produced, hydrogen can be a clean fuel which has important use applications. The carbon intensity of hydrogen is dependent on the source of its production. For example, hydrogen produced from fossil natural gas, or "gray" hydrogen, has a high carbon intensity, whereas hydrogen produced from dairy renewable natural gas (RNG), or "green" hydrogen, has a comparatively lower carbon intensity.

Hydrogen can be used in fuel cells or in a conventional internal combustion engine (ICE), providing a direct alternative to petroleum-based fuels. Applications in a fuel cell can convert hydrogen energy directly into electricity with only water as a byproduct. Hydrogen fuel cell technology can be applied to heavy duty trucks used for long distance hauling, for portable power, and other applications where traditional internal combustion engines or electric motors are used, such as farm equipment. Locally produced hydrogen from RNG or biomass can also be used to produce low CI ammonia for fertilizer. Further, ongoing research is being conducted to test the limits of injecting hydrogen into natural gas pipelines, which result in blends that can be used to generate heat and power with lower emissions than using natural gas alone.[140]

[139] California Public Utilities Commission. (n.d.). Bioenergy Feed-in Tariff Program (SB 1122). California Public Utilities Commission. https://www.cpuc.ca.gov/industries-and-topics/electri cal-energy/electric-power-procurement/rps/rps-procurement-programs/rps-sb-1122-biomat

[140] Office of Energy Efficiency and Renewable Energy. (2022, December). HyBlend: Opportunities for Hydrogen Blending in Natural Gas Pipelines. United States Department of Energy. https://www.energy.gov/sites/default/files/2022-12/hyblend-tech-summary-120722.pdf

Recent research on hydrogen includes the role of ammonia as a vector for hydrogen transport and storage, hydrogen production from wastewater (including from wineries) and production from anaerobic digestion.[141] Further, ARCHES H2, a public-private partnership within the state, aims to create a sustainable statewide clean hydrogen hub, utilizing local renewable resources to produce hydrogen with the objective to fully decarbonize the economy including "hard to electrify" industries such as agriculture.[142] Further research and pilot projects on sustainable hydrogen production and utilization is needed to decarbonize hard-to-electrify sources in the agricultural industry.

Recently in 2023, Bar 20, a California dairy, began conversion of dairy manure to electricity through a partnership with California Bioenergy, a dairy digester company, and Bloom Energy, a hydrogen fuel cell company. This first of its kind project was funded in part by CDFA's DDRDP, the CPUC's Self Generation Incentives Program, and access to revenue generated by California's Low Carbon Fuel Standard (LCFS) credit, a market-based program aimed at reducing the carbon intensity of transportation fuels produced and used throughout the state. The project, in collaboration with BMW, will power over 17,000 BMW electric vehicles throughout California, as well as an onsite microgrid for dairy operations.

New Technologies

The CPUC's Emerging Technology Program (ETP) evaluates emerging and underutilized energy efficiency (EE) technologies for possible inclusion into the portfolio. This is a statewide third-party implemented program that is split into an Electric Program (CalNEXT) and Gas Program (GET). ETP currently has two completed and four active projects focusing on emerging technologies in the agricultural sectors. The completed projects are the Controlled Environment Agriculture and Greenhouse HVAC & Market Technology Study and the Characteristics of EE Emerging Technologies for Wineries. All other active projects were completed by the Electric Program and are as follows: CO2 Chillers for the Agricultural Sector, Cooling and Dehumidification for Indoor Farming, Onsite Wastewater Treatment and Process Water Recycling Systems for Agricultural Dairy Farm, and Smart Controls for Data-Driven Indoor Agriculture Field Evaluation.

Biomass Utilization
Woody biomass from agriculture is a potential opportunity to reduce GHG emissions and promote economic benefits. The cultivation of some crops, especially orchard

[141] Serpell, O., Hsain, Z., Chu, W.-Y. A., & Johnsen, W. (2023, March 17). Ammonia's role in a net-zero hydrogen economy. Emerging Tech. Kleinman Center for Energy Policy. https://kleinmanenergy.upenn.edu/research/publications/ammonias-role-in-a-net-zero-hydrogen-economy/

[142] ARCHES. (n.d.). About. ARCHES. https://archesh2.org/about/

and vineyard crops, requires regular pruning of tree limbs and vines and often replacement of whole orchards, which creates woody biomass that then must be disposed. California produces approximately 29 million bone dry tons of woody feedstock annually from forests, farms, and orchards.[143] Historically, these materials were burned in the field or "recycled" via methods such as chipping. But as the state has worked to improve air quality, agricultural burning is being phased out. Additionally, increased efforts around forest management mean that there is likely to be a steady supply of biomass into the future. There are some opportunities to use excess woody biomass to produce fuels such as hydrogen from renewable natural gas, as well as low-carbon intensity ammonia for fertilizer.

California's Transition to Zero Emissions Vehicles

In September 2020, Governor Gavin Newsom issued Executive Order N-79-20, later reaffirmed with Executive Order N-27-25, which set targets for California's transition to zero-emission vehicles (ZEV) where feasible, including for medium and heavy-duty vehicles used by agriculture. These targets include 100 percent zero-emission vehicle sales for new passenger cars and trucks by 2035, 100 percent zero-emission vehicle operations for medium- and heavy-duty vehicles by 2045, and by 2035 for drayage trucks (used to transport cargo to and from seaports and intermodal railyards), and setting a goal to transition to 100 percent zero-emission off-road vehicles and equipment by 2035. To meet these goals, the Assembly Bill 2127 Second Electric Vehicle Charging Infrastructure Assessment reports that California will need 1 million public and shared electric vehicle chargers by 2030 to accommodate the energy demand of an estimated 7.1 million passenger plug-in electric vehicles. Additionally, approximately 109,000 low-powered depot chargers and 5,500 high-powered en-route chargers will be required to meet the demand of medium- and heavy-duty plug-in electric vehicles in 2030.[144] As of the start of 2025, California has a total of 178,549 public and shared private EV chargers installed statewide, compared to 120,000 gasoline nozzles. There are significantly more than 178,000 EV charging ports when also including private chargers at homes and other locations. However, significant continued investment and installation of charging stations and the electric system infrastructure to support them is essential to meeting California's rapidly increasing demand.

[143] https://business.ca.gov/wp-content/uploads/2022/02/GO-Biz-Interagency-Biomass-Market-Development-Framework.pdf

[144] Davis, Adam, Tiffany Hoang, Thanh Lopez, Jeffrey Lu, Taylor Nguyen, Bob Nolty, Larry Rillera, Dustin Schell, Micah Wofford. 2023. Assembly Bill 2127 Second Electric Vehicle Charging Infrastructure Assessment: Assessing Charging Needs to Support Zero-Emission Vehicles in 2030 and 2035. California Energy Commission. Publication Number: CEC-600-2024-003-CMR Assembly Bill 2127 Second Electric Vehicle Charging Infrastructure Assessment: Assessing Charging Needs to Support Zero-Emission Vehicles in 2030 and 2035 | California Energy Commission

ZEV Transportation and Fueling Infrastructure: The Role of CDFA's Division of Measurement Standards

Enforcement of California weights and measures laws and regulations is the responsibility of CDFA's Division of Measurement Standards (DMS). The Division works closely with county sealers of weights and measures who carry out the vast majority of weights and measures enforcement activities at the local level on behalf of CDFA. Ensuring fair competition for industry and accurate value comparison for consumers are the primary functions of the county/state programs.

While historically a prominent role of DMS and County Agricultural Commissioners (who are also the local Sealers of Weights and Measures) in the transportation space was to oversee the fuel quality, dispenser accuracy, advertising, and labeling of all motor vehicle fuels sold at retail, its responsibility has now extended to including low- and zero-emission alternative fuels, including for both zero-emissions vehicles (ZEVs) and hydrogen fuel powered vehicles.

The development of ZEV transportation and fueling infrastructure is an interagency effort. DMS communicates with the California Energy Commission, as well as other state and federal and local governments to meet the demands of a changing market and to facilitate California's transformation toward fully developed ZEV transportation and fueling infrastructure.

CDFA conducts research on existing and available electrical measurement technology and the state of Electric Vehicle Supply Equipment (EVSE) designs. Through this research, CDFA developed field and primary "testing standards," or testing devices, to test and evaluate commercial EVSE designs. DMS requires commercial EVSE to comply with mandates and be approved by DMS before they may legally be used for commercial [145] Testing standards are intended to be loaned to local county weights and measures offices so that they can ensure the accuracy of local charging infrastructure and comply with DMS regulations.
Currently, there is no single testing standard in the field, which limits the ability of EV charging stations to be put into service. Testing standards capable of testing high powered DC fast chargers can cost well over $50,000 and are not yet widely deployed, which remains a bottleneck in the deployment of EV charging stations.

Sustainable Aviation Fuel

[145] CDFA - DMS - Zero Emission Vehicle Projects

Sustainable aviation fuel, or SAF, is a low-carbon fuel alternative made from renewable biomass or waste. It can be produced from a variety of sources, known as feedstocks, including green waste and non-food crops, as well as waste oil and fats. SAF is designed to be a drop-in product that can be directly blended into existing fuel infrastructure and aircraft.

In October 2024, Governor Gavin Newsom and the California Air Resources Board (CARB), and Airlines 4 America announced a first-of-its-kind partnership to reduce carbon emissions by accelerating the use of sustainable aviation fuels (SAF) for flights within California. Aviation is one of the most difficult industries to decarbonize, and SAF provides a way forward. The agreement sets a goal of increasing the availability of SAF by 200 million gallons by 2035, which would meet 40 percent of in-state travel demand – ten times current levels. The agreement creates a SAF working group to report progress and address barriers to deploying the fuel.

Implementation

Strategy/ Action	Goal Alignment	Lead Agency	Supporting	Status	Implementation Phase
5.1 Support energy needs assessment and planning for local jurisdictions.					
5.1.1 Conduct energy demand assessments for rural and agricultural areas, taking into consideration future demand for electrified equipment, to support state and local planning efforts.	2: Enhance Program Effectiveness	CEC, CPUC, CARB	CDFA		
5.2. Support energy efficiency projects that reduce energy consumption in the food system, both on and off-farm.					

5.2.1 Support demand flexibility and improve energy efficiency through incentivized behavior changes.	2: Enhance Program Effectiveness	CPUC, CEC			
5.2.2 Improve energy efficiency and flexible electricity demand through technological upgrades.	Goal 2: Enhance Program Effectiveness	CARB, CEC, CDFA	DWR		

Pillar 2: Protect Natural Systems Critical to Agriculture

The following section covers the following chapters:

6. Conserve Productive Farmland

Employ a climate resilience lens to identify and protect the most productive and valuable farmland to support a thriving and diverse food system.

7. Deploy Sustainable, Adaptable, and Integrated Pest Management

Manage emerging and accelerated pests, plant diseases, and noxious weeds pressure through sustainable and integrated pest management practices through methods of least harm on human, animal, and environmental health.

8. Boost Biodiversity on Farmlands

Increase beneficial biodiversity on-farm to improve resilience of farms, plants, and animals to climate change.

Chapter 6. Conserve Productive Farmland

Key Objective: Employ a climate resilience lens to identify and protect the most productive and valuable farmland to support a thriving and diverse food system.

Context

California's lands produce the bulk of the most nutritious foods grown in the United States, including half of all vegetables, two-thirds of its fruits and nuts, and one-fifth of milk production. These foods are nutritionally dense and make up more than half of the diet recommended by the United States Department of Agriculture.[146] Many crops grown here are not grown anywhere else in the United States, and in some cases, anywhere else in the world. Because of our rich soils, robust water conveyance infrastructure investments, pest free status for harmful invasive fruit flies, and historically favorable weather conditions, more than 400 specialty crops can be grown year-round in California, providing Californians, the nation, and global populations with a continuous supply of fresh and nutritious food.[147] Agriculture is also a major pillar of California's economy, providing $61.2 billion in farm gate value as of 2024. Of California's 100 million acres of land, agricultural land uses account for approximately 41 million acres. Nine million acres is used for irrigated crops, while livestock grazing accounts for approximately 32 million acres.

California is converting farmland for other uses: The state ranks in the top three states for high rates of conversion of farmland, converting an average of 37,000 acres per year to other uses.[148] The Department of Conservation's Farmland Mapping and Monitoring Program has recorded the conversion of over 1.6 million acres of agricultural land to non-agricultural uses since it began tracking in 1984. These conversions have occurred on productive farmlands rated based on soil quality and other factors as Prime Farmland (816,123 acres) and Farmland of Statewide Importance (455,287 acres). Farmlands have been converted to various other uses, including housing, warehouses to support growing e-commerce, and renewable energy projects, largely for solar energy, in the last few decades. These conversions could provide alternative revenue streams for agriculture lands that continue to face climate pressures that would otherwise be driven out of production largely due to water availability.[149] Once productive farmland is transitioned to other uses, it can't be easily brought back into

[146] https://www.usda.gov/about-usda/news/press-releases/2020/12/29/make-every-bite-count-usda-hhs-release-dietary-guidelines-americans-2020-2025

[147] https://www.aphis.usda.gov/news/agency-announcements/usda-cdfa-declare-california-free-invasive-fruit-flies

[148] Farmland Mapping and Monitoring Program - FMMP

[149] https://www.conservation.ca.gov/dlrp/fmmp/Pages/Fast-Facts.aspx ; https://www.ppic.org/publication/managing-water-and-farmland-transitions-in-the-san-joaquin-valley/

production, which means California loses a unique and critical resource. The state is undertaking multiple efforts to ensure that California will continue to produce food and fiber, but there are challenges ahead.

SGMA-Related Fallowing

In addition to conversion to other uses besides agriculture, growers are opting to take farmland out of production to limit water pumping to comply with local plans to replenish California's aquifers. In 2014, California enacted the Sustainable Groundwater Management Act, or SGMA, which directs local groundwater sustainability agencies (GSAs) to develop and execute plans to bring aquifers into balance at 2015 conditions. SGMA was initiated because the groundwater available was already in decline due to overdraft pumping, as evidenced by occurrence of dry wells and expanding subsidence that is impacting the delivery of surface water. The chronic lowering of groundwater levels forced many to drill ever deeper wells chasing the water level. SGMA is likely to be a major driver of land-use change in California's agricultural regions as groundwater availability will decrease and land that was previously irrigated will go out of production. Farmers who may have previously been able to rely on surface water to meet the needs of their crops had begun to rely more and more on groundwater during recent droughts and water shortages, and with less water to arrest overdraft and stabilize conditions, that reliance on groundwater has led to land subsidence and other undesirable consequences such as sea water intrusion, water quality degradation, and depletions of interconnected surface water in many parts of the state.

The total acreage that will be affected remains to be seen, though the Public Policy Institute of California estimates that between 500,000 and 1,000,000 acres of farmland may be retired from farming. Which land goes out of production will be determined at the local level by GSAs; however, there is a risk that if land transition doesn't happen in a coordinated, orderly way, it could lead to a "patchwork" of lands that are either planted or left fallow and unmanaged, which could result in pest and weed infestations, soil erosion, and reduced air quality from dust.

While bringing aquifers into balance is a critical strategy to prevent further subsidence and bolster groundwater supplies, reduced pumping inevitably means that agriculture will be impacted due to lack of access to water but is also due to greater disparities in land values across California resulting from SGMA. Farmland in basins with secure, sustainable water supplies tend to command higher prices, while farmland with over drafted groundwater basins is declining in value, and some farms are going out of business. Furthermore, underserved producers are more likely to farm marginal lands with more tenuous water supplies to begin with, putting them at even greater risk of losing their farms, and putting farmworker communities at the front lines of negative health impacts of fallowed lands.

Healthy, robust farmland is intrinsically required to support our state's food system. Ensuring protection of the state's agricultural land base is fundamental to the resilience of California agriculture and the food system at large. Protecting the land base enables us to be able to continue to rely on the myriad soils, microclimates, and other conditions that allow for a diverse and nutritious food supply.

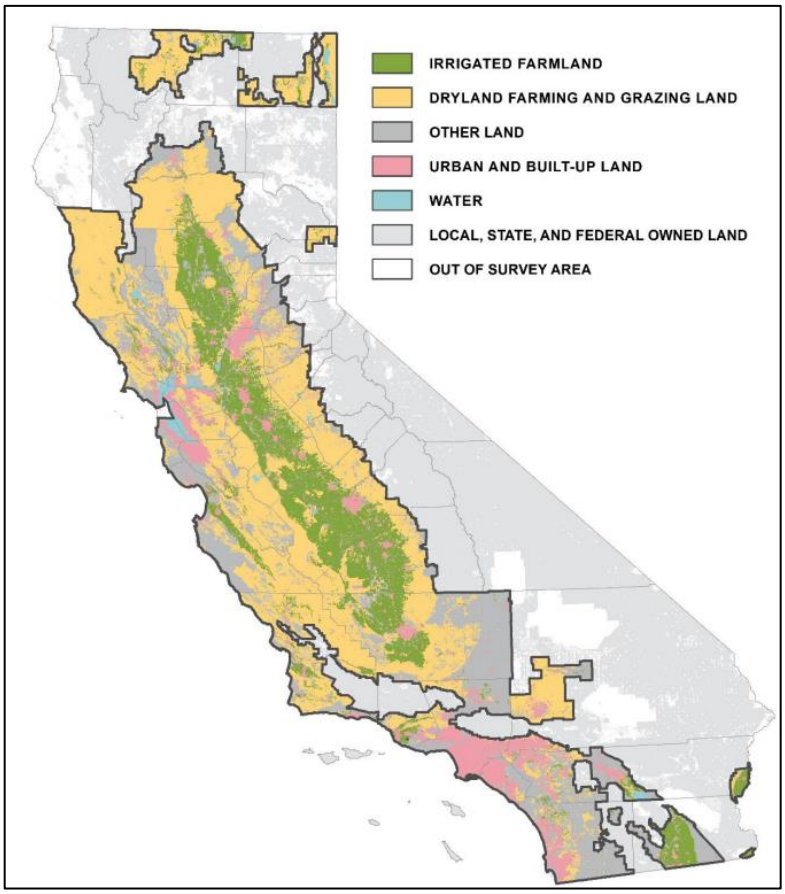


Figure 10: California Farmland Conversion Report

Land Use Classifications in FMMP

The Department of Conservation's Farmland Mapping and Monitoring Program (FMMP) classifications include Prime Farmland, Farmland of Statewide Importance, Unique Farmland, Farmland of Local Importance, and Grazing Land. FMMP prepares, updates, and maintains Important Farmland Series Maps, and prepares and maintains an automated map and data base system to record and report changes in the use of agriculturally designated lands every two years. Agricultural land is rated according to soil quality and irrigation status; the best quality land is called Prime Farmland. In preparing Maps, the Department considers all information collected or received on the amount of land converted to or from agricultural use, and between agricultural categories.

Strategies and Actions

The state has laid a framework for the protection of agricultural lands but will need to rely on partnerships and coordination with other entities, especially local governments, to be successful in achieving its targets.

6.1 Implement policies and initiatives to support the protection and conservation of agricultural lands

One of the best ways to protect agricultural land is to ensure that farming operations are thriving economically. Many ways of doing that are described in Pillar 1.

In addition, the state has established a number of policies and initiatives to protect and conserve agricultural lands. One of the critical ways to protect agricultural land is to ensure it can be economically resilient into the future; many of the state programs provide financial assistance with conservation for this reason. Because most land use decision-making happens at the local level, the state is providing a number of programs and tools to integrate agricultural land conservation in planning processes.

2022 State Nature Based Solutions Targets

CDFA's 2010 California Agricultural Vision: Strategies for Sustainability called on the State Board of Food and Agriculture to maintain sufficient land and water resources to sustain all sectors of an economically viable California agriculture industry through the year 2050 and beyond. In 2022, the state established Nature Based Solutions climate targets for cropland conservation:

- 12,000 acres per year between 2030 and 2037
- 16,000 acres per year between 2038 and 2044
- 19,500 acres per year in 2045

This would total an additional 275,000 protected acres through 2045. Additionally, the state set a target for the conservation of grasslands, which includes lands used for grazing: 33,000 additional acres per year between 2030 and 2045 for a total of 528,000 acres of additional protected acres of grasslands, including grazing lands.

Williamson Act

In 1965, the state established the Williamson Act, also known as the California Land Conservation Act of 1965. This legislation enables local governments to enter into contracts with private landowners, providing a lower tax assessment in exchange for a commitment by the landowner to restrict the land to agricultural uses. Contracts typically last either ten or twenty years and are renewed automatically on a rolling basis unless explicitly non-renewed by the landowner. Currently, approximately 12.2 million acres of farm and grazing land are enrolled in Williamson Act contracts, more than any other program. This does not mean those lands are permanently protected, however;

during the period of 2020-2021 the Department of Conservation's Williamson Act program recorded contracts on 90,488 acres of land being non-renewed and received notifications of an additional 317,882 acres planned for non-renewal over the next ten years. Nonetheless, the Williamson Act is a key tool for the state and local governments to keep agricultural land in production and guide orderly development.

6.1.1 Permanently protect strategic agricultural lands.

Goal 2: Enhance Program Effectiveness

There are currently two State programs in place that permanently protect croplands. The California Legislature created the California Farmland Conservancy Program (CFCP) Act of 1995 to encourage the voluntary, long-term, private stewardship of agricultural lands and to protect farming and ranching lands from conversion to other uses and enhance long-term sustainable agricultural use. CFCP has historically received bond and one-time general fund appropriations to carry out conservation projects on individual parcels of land, as well as to provide planning grants to cities and counties to encourage orderly development. To date, the program has permanently protected approximately 60,000 acres of farm and ranch land.

In 2014, in recognition of the importance of protecting agricultural land to curbing urban sprawl and encouraging infill housing development, California's Strategic Growth Council, in collaboration with the Department of Conservation, established the Sustainable Agricultural Lands Conservation program (SALC). The SALC program aims to permanently protect farmlands at risk of development and prioritizes projects that have multiple benefits such as protecting habitat and other values. To date, SALC has permanently protected nearly 200,000 acres of farm and ranch land.

6.1.2 Build local government capacity to identify and protect agricultural lands.

Goal 2: Enhance Program Effectiveness

Land-use planning in California is complex and subject to many local laws and policies alongside statewide policies. Planning and land-use decisions are primarily made by county boards of supervisors and city councils, oftentimes advised by appointed planning commissions that have the authority to oversee city and county General Plans and other related land use plans and policies. Many city and county governments in California have begun to recognize the connection between efficient development, farmland and open space conservation, and climate change: farmland conservation is complementary to infill development and maintenance of open space by promoting

efficient land use. Further, farmland conservation can complement urban and peri-urban green infrastructure goals such as flood risk mitigation. Continuing to expand programs that assist local governments in land use planning will go a long way towards agricultural conservation.

Mechanisms for protecting farmland can include short-term solutions like zoning designations for agriculture to longer-term solutions like urban growth boundaries or greenbelts to limit the encroachment of cities on agricultural land. Because an important function of local planning is to identify important natural resources and direct development in a way that protects or enhances those resources, the SALC program also funds the development of plans such as Agricultural Elements for General Plans, Climate Action Plans, and other types of planning efforts that can be used to maintain land for agriculture. So far, the SALC program has awarded thirty planning grants to cities and counties. The program has also funded 20 grants to help local conservation organizations build capacity to accelerate their conservation and land-use work.

Santa Clara Open Space Authority

Some jurisdictions have gone to greater efforts to ensure a vibrant local agricultural sector into the future; the Santa Clara Open Space Authority, for example, developed the "Santa Clara Valley Agricultural Plan" to reduce conversion of farmland and greenhouse gas emissions while growing its local food economy. The Plan focuses on land use policies that protect agricultural land, voluntary measures like conservation easements, and local agricultural economic development strategies including branding, education, and awareness of the importance of agriculture in a region otherwise known for information technology.

6.1.3 Update General Plan guidelines to better address and prevent farmland loss.

Goal 2: Enhance Program Effectiveness

General Plans cover all land within a jurisdiction and are the foundation for local land use planning and are typically intended to create a vision for planning horizons of 10-20 years. General Plans are long-term planning documents done by local government and cover a variety of topics, including land use, circulation, housing, conservation, open space, and safety, but elements specifically dedicated to agriculture are optional and not adopted by all jurisdictions. While General Plans are developed at the local level, they are required to adhere to minimum standards. Those statutory requirements and other guidance for local long-range planning are provided in the

state's General Plan Guidelines. The State General Plan Guidelines serve as a blueprint to guide the future growth and development of local jurisdictions across California.

The Office of Land Use and Climate Innovation is currently conducting an update of its General Plan Guidelines, to be released in early 2027. This update will provide strengthened guidance on integrating agricultural and natural lands considerations across multiple elements of the general plan. Key updates will include:

- Clearer direction on farmland conservation, land use compatibility, and minimizing conflicts between urban and agricultural uses in the Land Use Element;
- Emphasis on natural and working lands as critical climate mitigation, resilience, and biodiversity assets in the new Natural and Working Lands Element, as well as in the Safety and Open Space Elements;
- A focus on soil and its importance for agricultural production in the Conservation element;
- Water analysis for land uses including agriculture;
- Recognition of farmworker communities, agricultural equity, and access to infrastructure and services in the Environmental Justice Element; and
- Support for agriculture-based economies, workforce development, and value-added industries in the optional Economic Development Element.

By embedding these priorities across the General Plan Guidelines, the update aims to better support local jurisdictions in preserving agricultural land, integrating working lands into climate strategies, and preventing farmland conversion while advancing equitable, climate-resilient land use planning statewide.

6.2 Facilitate informed land use decisions that support resilient agricultural systems.

As jurisdictions across the state undergo land use decision making processes, the state can provide and refine tools that encourage them to make strategic decisions. This requires effective and accessible community engagement - ensure all languages, cultures have access to these discussions so that those who are affected are also given a seat at the table.

6.2.1 Enable community decision-making using land-use mapping tools.

Goal 1: Increase and Enhance Technical Assistance

To further assist communities in making strategic decisions that realize multiple benefits from land use changes, the Department of Conservation has developed Geographic Information Systems-based mapping tools. These help communities visualize the opportunities and constraints present in their regions as they explore scenarios that represent locally defined priorities such as natural resources (including quality of farmland), infrastructure, habitat, and more. These tools are being piloted by the Sierra San Joaquin Jobs Initiative funded in part by California Jobs First. Expanding these pilots, with technical assistance and outreach efforts, can help shape the way that land-use planning is done and provide ways for communities and agricultural communities to be more meaningfully engaged in the process.

6.2.2 Track existing processes that identify resource needs to support state climate goals.

Goal 2: Enhance Program Effectiveness

The replacement of fossil fuels with renewable energy poses opportunities and considerations for land use. Farmers who are facing challenges like reduced water allocations because of SGMA implementation may find leasing their land for solar development to be an attractive alternative. Whether farmland can be brough back into production at the end of the life of the solar installation depends on many factors such as how much soil compaction happens because of the project, and how the soil was managed during the life of the project(for example, was it planted with a cover crop or over vegetation, or left subject to erosion).

As described in greater detail in Chapter 5 on Energy and Agriculture, California has set a goal of meeting 100 percent of the state's retail electric sales with renewable and

zero-carbon energy resources by 2045, as established by SB 100. This will require using a variety of new energy sources including solar energy paired with battery storage development. Solar development is increasingly affecting farmland in California; for the first time in 2016, solar development surpassed housing development as the main driver of farmland conversion.[150]

The state's primary electricity planning process – the CPUC's Integrated Resource Planning Process (IRP) - both identifies the mix of resource attributes needed to reliably serve state electric load and meet state climate goals. Through the IRP process, known as resource-to-busbar mapping, CPUC and CEC staff translate these portfolios into a geographic map format and consider higher resolution information about transmission infrastructure and land use. The busbar mapping process accounts for a host of considerations, including the CEC's Cropland Index Model that identifies cropland with higher and lower implications to screen out areas associated with high-value cropland. In identifying substations for resources, staff seek to prioritize mapping to areas in the lower potential implications category.[151] Where those resources are eventually developed will depend on numerous factors, but in the 2025-2026 portfolio development cycle, for example, no resources were mapped to high-value cropland areas.

6.2.3 Where land conversion occurs, enable orderly, equitable, community-driven land use decisions.

Goal 2: Enhance Program Effectiveness

Considering the impact of potential land use transitions on California's lands, it is important to expand efforts that facilitate thoughtful and cohesive decisions about how to utilize these newly converted lands in ways that benefit the community and protect neighboring farmland from pest and invasive species threats. To address this and ensure resilient landscapes in California's uncertain groundwater future, the California legislature appropriated funds for the Department of Conservation to launch the Multibenefit Land Repurposing Program, or MLRP, which provides block grants to regional organizations who can coordinate strategic land repurposing while providing community health, economic well-being, water supply, habitat, and other benefits. To date, the program has been appropriated $290 million that has been awarded to eight projects throughout the state, as well as to a nonprofit organization, Self Help Enterprises, which serves as a "statewide support entity" to provide technical assistance

[150] https://www.conservation.ca.gov/dlrp/fmmp

[151] See CPUC's Methodology for Resource-to-Busbar Mapping for the Annual TPP: https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/2024-2026-irp-cycle-events-and-materials/assumptions-for-the-2025-2026-tpp/mapping_methodology_vruling_2024-09-06.pdf

and help awardees administer their grants. Awardees are taking several unique and locally tailored approaches to reducing groundwater use, such as strategically retiring farmland, facilitating groundwater recharge, reconnecting floodplains, and building solar power projects. Awardees are required to conduct extensive community engagement to ensure that project outcomes provide for community needs and benefits for historically underserved and disadvantaged communities. An additional $200 million of Prop 4 dollars will be allocated to the Multi-benefit Land Repurposing Program.

6.3 Facilitate equitable land access to promote local food production and economic growth.

American farmers are the nation's oldest workforce. With a median age of 58 years old and one-third of farmers over the age of 65, the United States Senate has identified vanishing family farms as a growing threat to U.S. food security and rural communities and that because the global population will increase by over two billion by 2050, farmers will need to produce 70 percent more food to meet demand. In California in 2022, the average age of a farmer was 59.9. In order for the state's agricultural system to remain strong, CDFA and other state agencies not only need to support existing farmers but also bring in new farmers and ranchers. There are many barriers for small, new farmers, and underserved farmers and ranchers, particularly when it comes to accessing land and maintaining tenure. The following actions aim to alleviate some of these challenges.

6.3.1 Address challenges with agricultural land access.

Goal 2: Enhance Program Effectiveness

Access to farmland is a critical issue for farmers or potential farmers in California. As California's farmers near retirement, significant amounts of farmland are expected to change hands as they retire. Access to this land is often limited to those with capital or family ties (such as those with existing large farming operations). The resulting consolidation in ownership can make it harder for small, beginning, and underserved farmers and ranchers to compete for land, reducing the diversity of farming operations and favoring large-scale operations over small farms.

According to the 2022 Census of Agriculture, (allowing for multiple producers per farm) white producers operate over 94 percent of farms (from a total of 63,134 farms in the state) and own over 96 percent of farmland (from a total of 24,190,604 acres of farmland in the state), compared to the almost 17 percent and just over 11 percent for Hispanic, Latino, or Spanish producers, almost 7 percent and near 4 percent for Asian producers, about 3 percent and almost 4 percent American Indian or Alaska Native producers, 1 percent and 1 percent for Native Hawaiian or other Pacific Islander, and almost 1 percent and half a percent for Black or African American producers, respectively.[152] Women and minority producers represent 37 percent and 9 percent of all farmers in the state, respectively.[153] As noted in the Farmer Equity Act of 2017, these

[152] https://www.nass.usda.gov/Publications/AgCensus/2022/Full_Report/Volume_1,_Chapter_1_State_Level/California/st06_1_063_063.pdf

[153] (Frazier and Kennedy, March 2024)

current disparities reflect centuries of discriminatory practices that have impacted who can own and hold onto land.

The difficulty new and underserved farmers face in accessing and maintaining access to land has contributed to the decline in small farms, as large-scale farming becomes more dominant.[154] From 2017 to 2022, the smaller farms, which are also the most common farm types, saw the largest declines in number. The number of farms smaller than 10 acres dropped by 17 percent and those under 50 acres decreased by 11 percent. On the other hand, farms between 1,000 to 2,000 acres increased slightly, and those larger than 2,000 acres increased by 6 percent. This pattern points towards smaller farmers being more vulnerable to going out of business or being bought by larger operations, leading to consolidation and a disproportionate loss of small farms. This is confirmed by the fact that while the total number of farms decreased by 10 percent between these years, the total farmland in acres only decreased by 1 percent.[155] This shift in land use patterns may have broader social and environmental impacts, such as reduced agricultural biodiversity and decreased rural community vitality.

Land Affordability and Use Pressures

High land prices contribute significantly to this issue as well. California's agricultural land is among the most expensive in the U.S., particularly in prime growing areas such as the Central Valley, the Salinas Valley, and coastal regions. High demand for farmland, driven by the profitability of certain crops (like almonds, wine grapes, and avocados) as well as interest from investors, has made it difficult for new farmers to afford land.

Additionally, as discussed above, urbanization and suburban sprawl, particularly in areas near cities, continue to drive up speculation and land prices. Competition between agricultural uses and real estate development often leads to farmland being sold to developers, further limiting the availability of affordable land for new farmers. As urban areas expand, the available agricultural land is reduced. Similarly, as agricultural lands are fallowed due to SGMA implementation, there is less agricultural land available.

Difficulty Securing Financing

Beginning farmers often struggle to secure financing to purchase land due to high costs and the perceived riskiness of agricultural investments. Without access to traditional loans, new farmers are frequently unable to compete with larger, established farmers or investors. This lack of financial access limits their ability to acquire land and enter the agricultural sector, resulting in fewer small-scale or new farming operations. Accessing capital can be especially difficult for underserved farmers and ranchers; wealth

[154] https://farmland.org/blog/2022-census-of-agriculture-california

[155] https://www.nass.usda.gov/Publications/AgCensus/2022/Full_Report/Volume_1,_Chapter_1_State_Level/California/st06_1_001_001.pdf

disparities resulting from discriminatory lending practices and policies, coupled with additional barriers like language access, make it difficult for underserved producers to access conventional loans.

Land Tenure

Many new and underserved farmers rely on leasing land rather than purchasing it outright. Land leases can vary in tenure, pricing and access to infrastructure. Short-term lease arrangements can limit the long-term planning and investment new farmers can make for the land. This is especially true of short-term leases, which result in significant insecurity for tenants. Because climate-smart farming practices require long-term planning and investment of time and resources, short-term leases can discourage farming practices like long-term soil health management. Short-term leases also make it much more difficult for tenants to access funding through programs like the Healthy Soils Program that are critical to meeting the healthy soils practice goals established by the state's AB 1757 Nature-Based Solutions Targets.

Current Efforts

Various initiatives in California, such as land trust programs, farm incubators, and cooperative ownership models are being developed to support new farmers by providing access to farmland, education, and resources. These programs help mitigate the challenges posed by high land costs and create pathways for new farmers to establish themselves.

6.3.2 Provide an in-road to agriculture for the state's urban residents.

Goal 2: Enhance Program Effectiveness

Urban agriculture has sparked a lot of interest as a way to inspire people without a farming background to get into farming. There are different models of urban agriculture, from commercial urban farms to community-based non-profit farms and gardens. Urban agriculture also interests those who hope to address a myriad of challenges in urban areas: lack of green space, food deserts, heat islands, workforce training needs, food miles, and more.[156] Urban agriculture offers multiple benefits to communities, providing exposure to agriculture, educational opportunities for children and communities, and a source of fresh, local, and seasonal food produced closer to where it is consumed. Urban farms and gardens can have a positive effect on property values in the surrounding area, making them a valuable neighborhood amenity. Urban agriculture can also be undertaken creatively, utilizing rooftop spaces and vertical growing systems.

[156] https://smallfarms.cornell.edu/wp-content/uploads/2022/06/Promise-of-Urban-Ag_Full_102919.pdf

There are many challenges associated with starting and maintaining urban agriculture projects. Higher land costs within urban areas are a hurdle, and these types of projects are sometimes pitted against the potential for infill housing development projects, particularly at a time when housing supply is limited, as it currently is in California. The cost of production of urban agriculture is very high compared to agriculture in rural settings, due to the higher costs of land, living, labor, utilities, and a lack of agricultural suppliers.[157] Zoning restrictions can also prevent the establishment of urban agricultural operations.

Within State of California programing, urban agriculture is supported by several programs, including at CDFA. CDFA's Urban Agriculture program was launched in 2023 and awarded $12 million in projects in early 2024. Since 2018, the Strategic Growth Council's Transformative Climate Communities program has funded $434 million urban farms and gardens in Compton, Fresno, Sacramento, and other urban areas as part of housing and community development projects focused on making climate resilience improvements. SGC's Affordable Housing and Sustainable Communities program also funds housing projects that support urban farms and gardens in order to ensure green space is part of projects. Finally, CalRecycle's Community Composting for Green Spaces Grant Program aims to increase the capacity of small-scale composting programs in disadvantaged and low-income communities.

What is Urban Agriculture?

Urban Agriculture refers to the cultivation, processing, and distribution of agricultural products in urban settings, including things like inground small plot cultivation, raised beds, vertical production, warehouse farms, mushroom growing, urban forestry and tree care, community gardens, rooftop farms, hydroponic, aeroponic, and aquaponic facilities, and other innovations. Urban farmers and gardeners work among diverse populations to expand access to nutritious foods, foster community engagement, offer workforce development opportunities, educate communities about food and farming, and expand green spaces. CDFA defines "urban" as a geographic area no more than 25 miles adjacent to or outside of one Urbanized Area containing a population of 50,000 or more people.

[157] https://smallfarms.cornell.edu/wp-content/uploads/2022/06/Promise-of-Urban-Ag_Full_102919.pdf

Implementation

Strategy/ Action	Goal Alignment	Lead Agency	Supporting	Status	Implementation Phase
6.1 Implement policies and initiatives to support the protection and conservation of agricultural lands					
6.1.1 Permanently protect strategic agricultural lands.	2: Enhance Program Effectiveness	DOC, SGC,			
6.1.2 Build local government capacity to identify and protect agricultural lands.	2: Enhance Program Effectiveness	DOC, SGC, LCI			
6.1.3 Update General Plan guidelines to better address and prevent farmland loss.	2: Enhance Program Effectiveness	LCI			
6.2 Facilitate informed land use decisions that support resilient agricultural systems.					
6.2.1 Enable community decision-making using land-use mapping tools.	1: Increase and Expand Technical Assistance	DOC, GoBiz			
6.2.2 Track existing processes that identify resource needs to support state climate goals.	2: Enhance Program Effectiveness	CEC			
6.2.3 Where land conversion occurs, enable orderly, community-driven land use decisions.	2: Enhance Program Effectiveness	DOC			
6.3 Facilitate equitable land access to promote local food production and economic growth.					

6.3.1 Address challenges with agricultural land access.	2: Enhance Program Effectiveness	SGC	CDFA		
6.3.2 Provide an in-road to agriculture for the state's urban residents.	2: Enhance Program Effectiveness	CDFA, SGC			

Chapter 7. Deploy Sustainable, Adaptable, and Integrated Pest Management

Key Objective: Manage emerging and accelerated pests, plant diseases, and noxious weeds pressure using sustainable and integrated pest management practices through methods of least harm on human, animal, and environmental health.

Context

Agricultural pests pose a significant threat to food production systems by undermining crop yields, which in turn can drive the use of chemical pest control practices, cause significant adverse economic impacts, and exacerbate food insecurity. Climate change impacts of higher temperatures, changing precipitation patterns, and an increasing concentration of atmospheric CO_2 are anticipated to increase pest impacts by altering pest development, reproduction rates, lifespan, behavior, and geographic range, while simultaneously weakening plant defenses and complicating and altering the implementation of pest management strategies which may also lead to changing and broadening pest dispersal. With these changes, California may accommodate a wider range of pests and diseases compounding with increasing crop susceptibility. It is necessary to build resilience in our cropping systems to help mitigate these effects and support successful food production systems.

Pest pressure refers to the intensity of pest activity in an area and the potential for local or invasive pest populations to inflict damage on agricultural crops. Any biological organism that negatively affects crop production can be considered an agricultural pest; however, these most commonly include arthropods such as insects and mites, weeds, plant pathogens (e.g. bacteria, virus, fungi), and nematodes. Animal pests can damage crops directly through feeding on plant structures such as leaves, roots, and fruit, impairing both plant growth and marketable crop yield. They can also transmit bacterial and viral pathogens that cause disease. Insects that vector harmful or deadly diseases have the ability to inflict severe damage across a wide area, even when pest populations are low. Similarly, fungal pathogens can harm or kill crops and are spread by spores through various modes such as wind, water, insects, or incidental introductions via human movement or machinery. Finally, weeds harm crop growth and yield by outcompeting crop plants for critical resources such as nutrients, light, and water.

Pest management refers to a range of practices used to control and mitigate pest pressure. Current agricultural pest management relies on chemical, biological, and

cultural control practices; however, climate change will impact the efficacy and feasibility of some current pest management practices. Increasing climate resilience in agriculture, from a pest management standpoint, means enabling practices that alleviate increasing pest pressure. This includes supporting the development of not only new tools but also building expertise in the agricultural workforce to address increasing pest pressure.

Integrated Pest Management and Sustainable Pest Management

Traditional agricultural pest management can rely heavily on chemical management through pesticides. However, in California, there is also a long history of practicing integrated pest management (IPM), which is defined as "an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and nontarget organisms, and the environment."[158] Although increased pest pressure due to climate change has the potential to drive increased pesticide use, pesticides represent only one component of IPM programs. California agencies including CDFA and DPR actively promote IPM and the development and adoption of pesticide alternatives through technical assistance, outreach, and research grant opportunities. Additionally, DPR takes regulatory and other actions as appropriate to restrict or eliminate the use of, or otherwise mitigate the impacts of, certain higher-risk pesticides. Indeed, the use of higher-risk pesticides has declined markedly in the past decade.[159] Additionally, total pesticide use fell by more than 5 percent from 2021 to 2022.

Sustainable Pest Management (SPM) is a more recent concept that emerged from a working group convened by the California Department of Pesticide Regulation (DPR) and that was subsequently established in state statute through Assembly Bill 2113. SPM. SPM is defined as a holistic, whole-system approach to pest management that builds on the concept of IPM to include the wider context of the three sustainability pillars of human health and social equity, a broad view of environmental protections, and economic vitality.

[158] https://ipm.ucanr.edu/what-is-ipm/#gsc.tab=0

[159] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.cdpr.ca.gov/wp-content/uploads/2024/12/pur_2022_data_summary.pdf

Sustainable Pest Management Roadmap

DPR and CDFA are working to support statewide adoption of SPM through various means, including education and outreach, modeling to improve pest predictions, grants for research and implementation projects, data analysis, and regulatory activities. In January 2023, a working group convened by DPR, in collaboration with the CDFA and California Environmental Protection Agency (CalEPA), released a new guidance document, Sustainable Pest Management: A Roadmap for California, which serves as a guide for driving a widespread transition to sustainable pest management approaches in both agricultural and urban settings.

In July 2024, the state legislature embraced the broad goals and recommendations of the SPM Roadmap, which includes a goal for the state transition to SPM as the de facto pest management practice by 2050. One of the many recommended responsive actions in the SPM Roadmap to enable this transition includes proactive efforts by DPR and CDFA to address climate-mediated impacts on pest pressure such as those described above. It stresses the importance of implementing preventative measures to reduce the spread of invasive pests as well as building resilience against pests and environmental challenges. Coupled with proactive measures, the state is considering how to balance the risks from pesticide use with the need to manage pests, particularly as pest pressure continues to rise.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) establishes authority for the United States Environmental Protection Agency (U.S. EPA) to regulate pesticides in the United States. Pesticides must first be registered with the U.S. EPA before being registered in the state through California DPR, which has primary responsibility to establish and oversee the enforcement of state pesticide laws and regulations. The County Agricultural Commissioners (CAC), following the direction of DPR, oversee local enforcement of state pesticide use laws and regulations.

Continued efforts are needed to ensure compliance with FIFRA. Every pesticide label must be followed to ensure that the pesticide is used safely and effectively. An illegal use occurs when someone uses a pesticide that is not registered with DPR, does not follow the label directions, or violates a California pesticide law or regulation. In addition, DPR designates certain pesticides as "restricted material," which have additional application requirements including a permit requirement from the CAC. Growers, pest control businesses, and others who either use a pesticide illegally or do not follow California's pesticide laws are at risk of being fined, losing their license or permit to legally apply pesticides, or being criminally prosecuted. DPR conducts thousands of inspections each year to ensure and assess pesticide use compliance.

Climate Impacts on Agricultural Pests

Climate change is expected to significantly impact a wide range of agricultural pests including insects, weeds, and disease pathogens, adding new challenges to pest management programs. For insects, temperature is a key driver of population dynamics, altering their survival, development, geographic distribution, and impact on agricultural crops. Rising temperatures can increase population growth by accelerating insect metabolism, shortening the length of development and increasing reproductive rates. Warmer winters can also lead to sustained insect activity, greater survival, and earlier emergence of pests in the season, extending the period when pests must be monitored and controlled. Conversely, if temperatures in a region exceed an insect pest's thermal tolerance, development, reproduction, and survival will be impaired.

Navel Orange Worm

Navel orangeworm (NOW), *Amyelois transitella* (Walker), is the primary pest of tree nut production in California. A recent study showed that the lifecycle of NOW is speeding up with the warming climate, increasing the number of generations of NOW expected.[160] This change is expected to increase NOW pressure in host crop orchards and pose significant risk to the state's tree nut production. Changes in pest management practices will be needed to address the increase in pest pressure.

However, research suggests that pest predators, parasitoids, and other natural enemies may be more susceptible to increased heat and aridity, potentially limiting natural pest control services in the environment.[161] This could decrease the use of biological pest control practices and necessitate increasing non-biological (e.g. cultural, chemical) controls.

Altered temperature and humidity conditions can also shift or expand the geographic range of pests, enabling them to thrive in regions previously unsuitable for their survival, or vice-versa. A study by Huang et al. found a significant positive relationship between mean temperature and the rate of invasion by insect species, supporting the idea that, on average, new pest invasions will become more frequent as the climate warms. *See Invasive Fruit Flies call-out box for more information.*

[160] California Office of Environmental Health Hazard Assessment. (2023, August 23). *Navel orangeworm abundance*. California Environmental Protection Agency. https://oehha.ca.gov/climate-change/epic-2022/impacts-vegetation-and-wildlife/navel-orangeworm-abundance

[161] (Skendžić et al.)

Disease outbreaks in agricultural crops are also highly dependent on environmental conditions. Changes in temperature and humidity can create more favorable conditions for the spread of pathogens that cause plant diseases. Warmer temperatures may extend the growing season, allowing pathogens to survive and reproduce for longer periods, while increased humidity can create moist environments conducive to disease development. Additionally, altered precipitation patterns, such as more frequent or intense rainfall events, can directly impact the spread and severity of plant diseases. Excessive rainfall can spread spores and lead to waterlogging of soils, promoting the growth of soil-borne pathogens.

Weeds cause the most substantial yield loss of all agricultural pests (34 percent), surpassing insect pests (18 percent) and diseases (16 percent).[162] Weed pressure in agricultural fields may also increase under climate change. The benefits of elevated CO_2 on photosynthesis and plant growth are well-documented for a wide range of plant species, including many crops. However, studies suggest that certain weeds and invasive plants disproportionately benefit from elevated CO_2 conditions.[163] Some weeds become more resistant to herbicides under higher CO_2 levels.[164] Therefore, climate change may put agricultural crops at a greater competitive disadvantage against weeds.

Climate Impacts on Crop Plant Susceptibility to Insect Pests

Changing temperatures and rainfall patterns and elevated levels of CO_2 can make plants more vulnerable to pests and diseases. Changing temperatures can alter the geographic production region and the onset and duration of the growing season for certain crops, as well as affect soil moisture levels, which affects soil quality and crop yields and exposes the crops to more or different pests. Crops and native plants may become more vulnerable to pests and disease, while weeds can adapt in ways that increase their relative competitive advantage.[165] Elevated atmospheric CO_2, increased temperature, and drought stress have all been shown to increase feeding by insect

[162] Kaur R, Kumar S, Ali SA, Kumar S, Ezing UM, et al. (2024) Impacts of climate change on crop-weed dynamics: Challenges and strategies for weed management in a changing climate. Open J Environ Biol 9(1): 015-021

[163] (Ziska; Ramesh)

[164] Ziska, Teasdale & Bunce (1999) – "Future atmospheric carbon dioxide concentrations may increase tolerance to glyphosate in weedy species" (Weed Science).

[165] Ziska, Teasdale & Bunce (1999) – "Future atmospheric carbon dioxide concentrations may increase tolerance to glyphosate in weedy species" (Weed Science).

herbivores.[166] This can occur by reducing plant nutritional quality, requiring insects to consume more, or by reducing plant defenses, making crops less resistant to herbivores.

For plant nutrition, elevated levels of CO_2 in particular have been shown to change the nutritional composition of plants by promoting the accumulation of starch and sugars in leaves, which lowers the nitrogen content. Because nitrogen is a critical component of herbivore diets, insects have been found to increase leaf consumption to meet their dietary requirements.

Beyond plant growth and crop production, plant defenses can also be impaired when exposed to elevated CO_2, drought stress and increased temperature. Each of these environmental factors can disrupt the production of defense compounds such as secondary metabolites, phenolics and phytohormones, making crops more susceptible to damage from insect herbivores. Susceptible crop plants will need increased pest management to maintain yields.

Climate Impacts on On-Farm Pest Management

Increased temperature and shifts in precipitation may also impact pesticide applications and their efficacy. For instance, many pesticide labels prohibit applications near rain events, meaning frequent storms can disrupt applications and effective management. Rain and heat events can also impact the efficacy of pesticide applications, meaning growers may need to re-apply to achieve sufficient pest control. Therefore, weather patterns are important drivers of pesticide use.

[166] Pathak, T. B., Maskey, M. L., Dahlberg, J. A., Kearns, F., Bali, K. M., & Zaccaria, D. (2018). Climate Change Trends and Impacts on California Agriculture: A Detailed Review. *Agronomy*, *8*(3), 25. https://doi.org/10.3390/agronomy8030025

Precipitation and Fungicide Use

Variability in rain events as a result of climate change could significantly affect future use of fungicides in agriculture. For example, most almonds often receive fungicide treatments in the spring and early summer to prevent outbreaks of fungal diseases. However, UC-IPM recommends most fungicides be re-applied 7-10 days after rain events. In years with high precipitation, almond orchards have received around twice the number of fungicide treatments on average relative to drier years. Drought events induced by climate change could reduce the need for fungicide applications, while heavy spring rains could lead to more frequent applications.

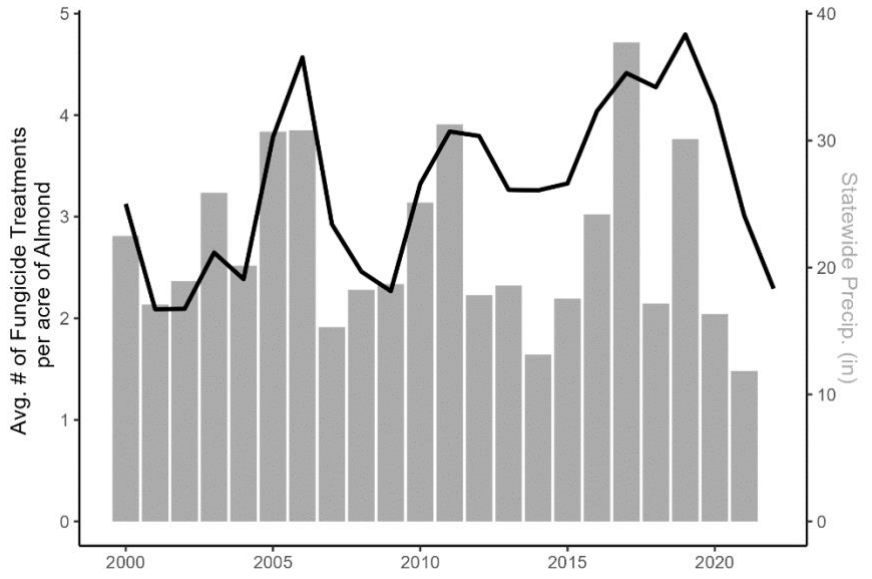


Figure 11: OEHHA Climate Change Indicators 2022; PUR 2024

Figure 11 shows the fungicide use in almonds and statewide precipitation in California from 2000-2021. The black line shows the average number of fungicide applications to almonds across the state. The grey bars show total statewide precipitation.

Impacts of Changing Pest Pressure on Management, Economy, and Equity

The effects of climate change on pest development, population dynamics, and survival will make pest outbreaks more difficult to predict and complicate management decisions. For instance, extended periods of pest activity and increased population growth due to warmer temperatures may reduce the accuracy of existing predictive tools such as phenology models and disease forecasts. Many growers rely on these

tools to help ensure treatments only occur when pests reach economically damaging levels – which minimizes management costs while maximizing yield. Consequently, growers may be forced to choose between adopting more intensive management programs or risking substantial yield loss. Either decision could result in net revenue loss. Additionally, increased food production costs and reduced yield would likely have downstream effects on consumers in the form of higher food prices. Low-income consumers would disproportionately be affected by this change.

The economic risks posed by invasive species also go beyond the costs of increased pest management or yield loss. When pest infestations are detected, regional or statewide quarantines may be enacted based on specific triggers to prevent the spread of the population to new areas. Commodities grown within a quarantine destined for export are impacted by pre-harvest, post-harvest, or pre-quarantine treatment requirements that affect harvesting and processing time, which may severely limit market access and reduce the availability of fresh products at their intended destination. Quarantine procedures also prevent residents from moving any host material from their properties to prevent further spread outside the quarantine zone. For farmers and ranchers with small-scale operations (the majority of California farms) and those underserved farmers and ranchers, the effects of pest pressure have a disproportionate impact.

Invasive Fruit Flies

Invasive fruit flies are among the most destructive fruit and vegetable pests in the world and a top threat to California agriculture. These and other invasive pests have not become established in California due to:

1) A comprehensive pest detection program
2) Strict federal exterior and state interior quarantines, and
3) Swift and aggressive eradication programs when an infestation is detected.

However, climate change is expanding the climatically suitable regions for invasive fruit flies and increasing temperatures are changing the metabolic rate of the fly—affecting population growth and selection of evolved traits. In California at-risk regions have expanded both northward and to higher elevations.[167]

In 2023-24 California experienced not only the state's, but the country's largest outbreak of invasive fruit flies in a single season, with a total of 957 flies detected in 2023 compared to 109 flies in 2022 and 60 flies in 2021. This outbreak was also the first outbreak of Queensland fruit fly and Tau fruit fly in the state's/nation's history. CDFA successfully eradicated the 2023-24 outbreak with heavy collaboration and support

[167] Szyniszewska et al.

from USDA, County Agriculture Commissioner offices, Cooperative Agriculture Support Services, California Conservation Corps, and contractor services.

University of California estimates that if Oriental fruit fly established in California, it would cost $44 to $176 million in crop losses, additional pesticide use and quarantine activities. For California-grown commodities in 2021, it was estimated that $24.27 billion of gross production value could be affected by fruit flies.

Table 2: Fruit Fly Species and Commercial Commodities Affected

Fruit Fly Species	2021 gross production value of host commercial commodities potentially affected by fruit flies
Mediterranean fruit fly	$17.94 billion
Oriental fruit fly	$12.46 billion
Peach fruit fly	$10.82 billion
Tau fly	$10.09 billion
Melon fly	$4.22 billion
Mexican fruit fly	$2.92 billion
Sapote fruit fly	$2.20 billion
Total CA commodity value targeted by one or more fruit flies	California = $24.27 billion

The stakes for effective pest prevention are extremely high, and the 2023-24 fruit fly season underscored the capacity limitations of the pest prevention system. Sufficient staffing and resources to address ongoing and ever-increasing detections was a significant challenge, and the success of the 2023-24 season was only possible due to the immense support from USDA and County Agricultural Commissioners. Early detection and rapid response are paramount, but the detection system was overwhelmed. In some instances, pest detections went straight to quarantine projects as all triggers were hit within a very short time period. The stress and strain placed on staff was extremely high, and while they stepped up to meet the challenging circumstances, such level of effort would be unsustainable if required years in a row. If the system fails, then establishment of pest species will occur, not only affecting California, but all other areas in the U.S. with suitable hosts and climates. As pest pressure and the pest approach rate continue to increase under climate change, ensuring that the pest prevention system has the capacity to respond to these threats is essential to the overall protection and prosperity of California agriculture and the environment.

Strategies and Actions

As one of CDFA's mandates and an important factor affecting California agriculture, pest management is a focus for the agency.

7.1 Expand and enhance the state's ability to deploy and proactively address pest issues related to climate.

CDFA, along with other state agencies, works to prevent the introduction and suppress the spread of invasive species within California. These agencies that are responsible for conducting pest monitoring and invasive species response are also expected to face logistic and fiscal challenges resulting from climate change. As new pest invasions become more frequent, greater resources will be needed to prevent invasive pest establishment and further spread into new regions. Moreover, monitoring efforts will need to be expanded both spatially and temporally as previously unsuitable regions of the state become hospitable and warmer winters extend pest activity. Although investment and interest in developing alternative pest management solutions is increasing, many of these actions are recent and there are several areas for continued research, investment, and focus.

7.1.1 Bolster CDFA's capacity for monitoring for, treatment, and prevention of invasive species, pests, and diseases

Goal 2: Enhance Program Effectiveness

A variety of programs run through CDFA's Plant Health and Pest Prevention Services Division aim to curb the spread of invasive species. In order to enhance the effectiveness of these programs, continued pest monitoring and treatment efforts are needed.

Pest Detection and Prevention Programs

CDFA Pest Detection and Prevention Programs Food and Agriculture Code establishes the Plant Health and Pest Prevention Services (PHPPS) Division in CDFA to promote and protect California agriculture through the exclusion and eradication of invasive pests. PHPPS conducts a range of programs and activities aimed at preventing the introduction, establishment, and spread of new pests in California. These include exclusion, early detection activities, and rapid eradication response efforts when detections occur.

CDFA's Pest Exclusion branch within PHPPS manages 16 Border Protection Stations which support pest exclusion efforts through the inspection of private and commercial vehicles entering California. California Border Protection Stations provide the first line of defense for CDFA's pest exclusion efforts. Today, California is the only state to monitor the movement of at-risk materials into the state to prevent agricultural pests and diseases. CDFA's Interior Pest Exclusion Unit enforces federal and state plant pest quarantines through programs that monitor and inspect agricultural products entering California via multiple pathways including nurseries and garden centers, markets, parcel carriers, and through the use of detector dog teams.

CDFA's Pest Detection and Emergency Projects Branch is responsible for the early detection and prompt eradication of serious agricultural pests in California, with a goal of preventing permanent establishment and subsequent spread in California. The branch operates a statewide detection trapping program, conducts special detection surveys, and maintains emergency projects response teams. Included in these efforts are around 100,000 fruit fly detection traps in urban neighborhoods throughout California to monitor for the presence of invasive fruit flies. Each year, CDFA also places tens of thousands of traps for the detection of Japanese beetle, spongy moth, invasive wood-boring beetles, and many other pests and diseases that may change from year to year. The branch also performs visual surveys in commercial aircraft to ensure that the Japanese beetle federal domestic quarantine is effectively limiting Japanese beetle introductions in the state from known infested areas in eastern, south-eastern, and mid-western states; conducts visual surveys for Spotted Lanternfly; and works cooperatively with the rail industry to abate tree-of-heaven on their properties to help reduce risk of tree establishment.

The Integrated Pest Control Branch operates a wide range of pest management and eradication projects. The Branch works with other state agencies, federal and county agencies, researchers, agricultural industries, and non-governmental organizations on several species- or disease-specific monitoring, managing, and eradicating programs such as the Curly Top Virus Control Program and Hydrilla Eradication Program, among many others. The Branch also operates the Biological Control Program which facilitates the import and establishment of co-evolved natural enemies to minimize economic impacts from invasive weeds and exotic insect pests. The Branch also runs a Vertebrate Pest Control Research Program which maintains field-use rodenticide registrations and provides public education on wildlife damage management.

PHPPS is working with researchers from the University of California and California State University systems on a statewide study, *The Comprehensive Pest Prevention Program Analysis* (C3PA). Researchers will be evaluating existing and new pest prevention systems. The study intends to improve the existing pest prevention system and

strengthen the regulatory framework to better address increasing invasive species detections. A component of the analysis will involve assessing ecommerce and travel, including the influence of international air travel, consumer shifts towards online purchases, and climate change and availability of resources (e.g. land, water, labor), that may be impacting the spread of invasive species.

Importantly, activities described above are just a few examples of the many and continuous efforts of PHPPS. PHPPS is always seeking to improve processes by leveraging the existing internal CDFA data analytics research group, partnerships with University of California, and collaboration with USDA-ARS and USDA-APHIS scientists.

7.1.2 Prepare for emergency situations with coordinated procedures in place and sufficient infrastructure.

Goal 3: Grow Partnerships and Collaboration

When invasive pests are detected, CDFA quickly implements delimitation/eradication activities to prevent the further spread and possible establishment of an invasive pest population. This work often involves state-wide coordination and collaboration across agencies. The Pest Detection and Emergency Projects Branch works to prepare "action plans" for such unwanted agricultural pests and maintains properly trained and equipped pest response teams situated at strategic locations around the State. The response activities may include enhanced trapping, treatment of host material, larval survey, and host removal. Quarantine zones may also be established to prevent further spread of invasive pests by restricting the artificial movement of host material. For example, the residents within a fruit fly quarantine zone cannot move host material outside of their properties, and growers and nurseries within the quarantine area must meet pre-harvest treatment and processing standards before harvesting or moving products. Quarantines are enacted to prevent the spread of pests from infested areas and ensure treatment activities and restrictions occur in the smallest possible geographic area. CDFA and CalRecycle should continue to coordinate to ensure that the compliance agreement requirements are clearly communicated to those responsible for movement of host material, such as organic waste haulers and processors. This helps to ensure that response efforts have ample time to efficaciously eradicate an incipient population.

7.1.3 Be proactive to threats against plant and animal health with ongoing technical assistance to facilitate widespread and equitable adoption of sustainable and integrated pest management.

Goal 1: Increase and Enhance Technical Assistance

Aligned with the pathways established in the SPM Roadmap, CDFA administers a number of programs that support SPM for invasive species and provide growers with these new tools and training, and technical assistance so that they can better adapt to changing conditions.

CDFA's Office of Pesticide Consultation and Analysis (OPCA) manages several grant programs that support development of pest management alternatives. The Biologically Integrated Farming Systems (BIFS) is an OPCA-managed grant program that funds grower outreach for innovative, effective, and economically feasible pest management programs that reduce the use of pesticides of high regulatory concern. OPCA has awarded approximately $5 million to five BIFS projects between 2019-2024. As climate change alters pest pressures and population dynamics, outreach programs like BIFS could be used to provide technical information and assistance to growers on how to adapt and implement new pest management strategies.

DPR's Alliance Grants Program funds projects that promote or increase the implementation, expansion, and/or adoption of effective, proven, and affordable IPM systems or practices that reduce risks to public health and the environment in agricultural, urban, or wildland settings. Since 2007, this Program has awarded over $9.6 million to 45 projects. DPR's School IPM and Child Care IPM Programs also facilitate the adoption of safer, more sustainable IPM practices at California's schools and child care centers by developing and disseminating data-informed IPM/SPM resources, coordinating education and outreach events for school and child care staff and community partners, and providing compliance support for the Healthy Schools Act, which established IPM as the preferred method for managing pests at school sites to protect children from the risks of pesticide exposure. Finally, DPR's annual IPM Achievement Awards is building a community of leaders in the state by recognizing and awarding organizations and individuals who are promoting SPM.

Ensure Direct Support for Small-scale and Underserved Farmers and Ranchers

The impacts of pest pressure can disproportionately hurt small-scale operations. With the majority of farms in CA being small-scale, a targeted approach is needed for addressing, treating, and preventing pest outbreaks on these farms. Research,

technical assistance, and guiding policy all need to include scenarios, tools and strategies to mitigate impacts of pest pressure.

Expansion of Pest Control Advisory Workforce

Workforce development is an overarching component of building climate resilience across California agriculture, and pest prevention is no exception. As new protocols and management programs are developed, training and certifying staff to implement these strategies is essential. Ensuring the workforce is able to provide information in all languages spoken in the agricultural field will ensure all farmers and ranchers have access to current and relevant pest prevention strategies and information.

7.1.4 Be proactive to threats against plant and animal health through research and predictive tool development.

Goal 5: Demonstrate and Invest in Innovation and Technology

Several grant programs are designed to research and help prevent threats to plant and animal health, and additional work is needed to expand these programs. Another one of OPCA's several grant programs is the Adaptive Integrated Pest Management Solutions program that incentivizes the development of IPM practices for invasive pests that are not yet in California but are expected to arrive and cause significant economic damage. The program is an important example of a proactive and adaptive approach to increasing pest pressure. The program has awarded more than $4 million to 9 projects since its inception in 2019.

OPCA also provides annual funding to the IR-4 Project to help register pest control products for small acreage specialty crops. New products often require additional safety testing before getting approval for use in specialty crops, and this program helps ensure California growers have access to the newest, most effective tools. Products aimed at managing newly introduced invasive pests are prioritized, providing important tools that allow growers to address emerging pest problems.

DPR has several programs and efforts that likewise support a transition from traditional pest management approaches to wide-scale adoption of SPM to encourage implementation of SPM in agricultural, urban, and wildland settings, champion SPM in the field, and embed SPM principles across state agencies. DPR's IPM Branch hosts several programs that specifically focus on fostering the adoption of IPM and SPM in agricultural, urban, and wildland settings. DPR's Research Grants Program funds research projects that advance IPM knowledge in agricultural, urban, and wildland settings. Since 2012, this Program has awarded $17 million to 61 projects, including

projects measuring the effectiveness of pest preventive design elements incorporated into affordable housing units, investigating the biology and management of an invasive cockroach species, and evaluating sterile insect technique (SIT) as a pesticide-free tool for eradicating new infestations of Asian citrus psyllid (ACP).

There is also a need for updated models to predict how climate change will impact pest pressure throughout the state by incorporating changes in pest development and migration and identifying susceptible production regions. These models can assist government agencies in their effort to prevent or detect new pest introductions. Growers similarly would benefit from updated predictive tools to forecast pest and disease outbreaks. Revised economic thresholds will be needed to help them determine when treatments are needed.

Implementation

Strategy/ Action	Goal Alignment	Lead Agency	Supporting	Status	Implementation Phase
7.1 Expand and enhance the state's ability to deploy and proactively address pest issues related to climate.					
7.1.1 Bolster CDFA's capacity for monitoring for, treatment, and prevention of invasive species, pests, and diseases	2: Enhance Program Effectiveness	CDFA		Ongoing	
7.1.2 Prepare for emergency situations with coordinated procedures in place and sufficient infrastructure.	3: Grow Partnerships and Collaboration	CDFA		Ongoing	
7.1.3 Be proactive to threats against plant and animal health with ongoing technical assistance to facilitate widespread and equitable adoption of sustainable and integrated pest management.	1: Increase and Expand Technical Assistance	CDFA/DPR			
7.1.4 Be proactive to threats against plant and animal health through research and predictive tool development.	5: Demonstrate and Invest in Innovation and Technology	CDFA			

Chapter 8. Boost Biodiversity on Farmlands

Key Objective: Increase beneficial biodiversity on-farm to improve resilience of farms, plants, and animals to climate change.

Context

Agricultural practices cultivated in the 20th century largely decreased on-farm biodiversity: seeking efficiency, uniformity and food safety, farmers grow crops as monocultures from meticulously bred stock and use strategies that suppress weeds and pests, but also often suppress native flora and fauna. More modern experience and research, however, has demonstrated that enhancing on-farm biodiversity in strategic ways can have more benefits than drawbacks to productivity and resilience both on-farm and off-farm. A diverse range of crops, livestock, soil organisms, and pollinators contributes to healthy ecosystems that maintain soil fertility, control pests and diseases naturally, and support water regulation. As ecological and agricultural systems face increasing pressure from climate change, protecting and enhancing on-farm biodiversity is key to ensuring long-term food security, support off-farm biodiversity, and enhancing overall ecosystem health.

According to the California Natural Resources Agency, California is home to about one third of all species found in the nation.[168] Of an estimated 5,500 plant species found in California, 40 percent are found nowhere else on Earth. California's diverse geography, which contains both the highest and lowest points in the contiguous U.S. and both mountains and ocean, are the foundation for this globally exceptional species richness. However, this biodiversity is increasingly at risk, which makes California a global "biodiversity hotspot" – one of 36 places on Earth with exceptional concentrations of native species that are experiencing unprecedented challenges. Climate change will alter biodiversity in many ways, including but not limited to changing life cycles, habitat and connectivity loss, habitat shifts, and increasing numbers of invasive species. While historically thought of as antagonistic to biodiversity, farms are positioned to mitigate some challenges from climate change, mainly by providing habitat and habitat connectivity in landscapes that lack significant natural habitat.[169]

Biodiversity is the backbone of a resilient food system, one that is necessary to weather climate disasters. It is a matter of food security that we continue to shift our agricultural practices to protect and restore biodiversity both on and off farms. Reversing biodiversity loss in and around agricultural will require a multifaceted approach

[168] https://resources.ca.gov/Initiatives/Protecting-Biodiversity

[169] https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0267263

combining conservation, incentives and policy tools, technical assistance for farmers, changing farming practices, and scientific innovation. Navigating the tensions between production agriculture and native biodiversity protection requires an approach that balances food production with ecological stewardship. Ultimately, reframing biodiversity not as a constraint but as a foundation for resilient and climate-smart agriculture can help bridge the divide and foster mutually beneficial outcomes. Similarly, reframing farming not as a solely negative influence for off-farm biodiversity but rather a place to build and connect habitats can support conservation goals.

Many practices that have limited on-farm biodiversity and impacted off site biodiversity are related to ease of farming, pest management, and food safety. As described further in the strategies of this chapter, lots of work is needed to address knowledge and implementation gaps to successfully boost biodiversity on farms. Bringing nature back to farms and ranches can help bolster California agriculture and our food system against climate change and help stem the loss of biodiversity in our state.

Guiding Policies

Over the years, the California government has been working to set out pathways and initiatives for addressing declining biodiversity. Governor Jerry Brown in 2018 led biodiversity efforts to set goals consistent with the Convention on Biological Diversity and created a roadmap to outline steps for progress and called for state agencies to work together in meeting those goals.[170]

Recent biodiversity plans and policies are driven by the state goal of conserving 30 percent of California's lands and coastal waters by 2030 – known as 30x30. The 30x30 goal is intended to help accelerate conservation of our lands and coastal waters by meeting three objectives: conserve and restore biodiversity, expand access to nature, and mitigate and build resilience to climate change. Actions towards these objectives are voluntary and collaborative.

Executive Order N-82-20, the Executive Order that created 30x30 also called upon CDFA to advance efforts to conserve biodiversity by taking the following actions:

1) Coordinate with other relevant state agencies and private partners to reinvigorate populations of pollinator insects across the state, which restore biodiversity and improve agricultural production.

2) Implement strategic efforts to protect California's native plants and animals from invasive species and pests that threaten biodiversity and economic activities.

[170] "Biodiversity"; Executive Order B-54-18 https://www.californiabiodiversityinitiative.org/pdf/executive-order-b-54-18.pdf ; CA Biodiversity Initiative Roadmap

3) Enhance soil health and biodiversity through the Healthy Soils Initiative.[171]

New legislation has been proposed to cogovern and comanage tribal ancestral lands.[172] California's Native American tribes have been managing the lands through Traditional Ecological Knowledge (TEK), or the evolving knowledge acquired by Native Americans over many generations of direct engagement with the lands and waters of homelands. TEK is cited as a more holistic management of the land that can help mitigate the effects of climate change and protect biodiversity.[173] If passed, this legislation would require state agencies to work with tribal communities for land management decisions on a tribe's ancestral lands which should help meet the state's 30x30 initiatives.

The State Wildlife Action Plan (SWAP) examines the health of wildlife and prescribes actions to conserve wildlife and vital habitat before they become more rare and more costly to protect. The plan also promotes wildlife conservation while furthering responsible development and addressing the needs of a growing human population.[174] There is a companion SWAP focused on agriculture, the Agriculture Companion Plan, which identifies priority pressures and strategies across sectors, potential collaboration resources, how to evaluate implementation, desired outcomes, and next steps. The top five strategy categories for this sector are data collection and analysis; direct management; economic incentives; land acquisition easement, and lease; and outreach and education. The next steps identified to ensure successful implementation of the companion plan are partnerships and collaboration; human and financial resources; communication and outreach; monitoring, evaluation, and adaptive management.[175]

One of the primary mandates of CDFA is to protect against invasive species, as described in Chapter 7.[176] The Food and Agriculture Code establishes authority for the Plant Health and Pest Prevention Services (PHPPS) Division in CDFA to promote and protect California's agriculture through the exclusion and eradication of invasive pests. PHPPS conducts a range of programs and activities aimed at preventing the introduction, establishment, and spread of new pests in California. Many invasive pests have not become established in California due to (1) a comprehensive pest detection program, (2) the promulgation and enforcement of state quarantines to prevent the entry and spread of pests within the state, and (3) swift and efficient eradication programs when an infestation is detected. While this program is designed to protect

[171] Executive Order. No. N-82-20

[172] https://a45.asmdc.org/press-releases/20240827-ramos-measure-include-tribal-voice-and-experience-natural-resource

[173] http://climate.calcommons.org/article/tek

[174] https://wildlife.ca.gov/SWAP

[175] https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=136122&inline

[176] https://www.cdfa.ca.gov/CDFA-Mission.html

agriculture, invasive agricultural pests can and do establish in natural environments, causing habitat loss and degradation.

Strategies and Actions

California's farmers and ranchers are worldwide leaders and innovators in food production. They are also among the foremost stewards of California's working lands. These strategies detail the ongoing and needed efforts to increase biodiversity on farms, including an increase in research, technical assistance, and collaboration on biodiversity efforts and programs.

8.1 Build understanding of resources available to limit and/or reduce negative impacts to on-farm biodiversity.

Concerns around food safety and pest impacts underpin pest management decisions and can lead to decreased on-farm biodiversity and decreased biodiversity of surrounding ecosystems. The following actions will discuss opportunities to create a mutually beneficial system where agriculture supports biodiversity on and off-farm and benefits from improved ecosystem services.

8.1.1 Create multi-faceted resources that can help address food safety concerns while limiting negative impacts to biodiversity.

Goal 1: Increase and Enhance Technical Assistance

For a farm, there should be no choice between climate resilience and producing safe food, as both are key to their long-term sustainability and economic success and should not be treated as competing priorities. However, more work is required to transfer known information regarding animal intrusion, soil health, and food safety to landowners, suppliers, processors, retailers, and consumers. Information regarding holistic land management approaches that create climate-smart and food-safe products requires continued research, constant compilation, and dissemination. Coordination of researchers and technical assistance providers capable of addressing both food safety concerns and climate-smart agriculture is needed to not only fill the knowledge gap but make sure the knowledge is brought to the fields and processors for implementation.

8.1.2 Increase knowledge of best practices to treat pests while minimizing damage to biodiversity.

Goal 1: Increase and Enhance Technical Assistance

Uplifting a consistent, local, and well-informed technical assistance workforce to help guide farmers and ranchers' decision making for pest management is critical to minimizing damage to on-farm biodiversity.

The State is continually taking action on pest management solutions that can protect the environment as well as the crops through sustainable pest management. One example of a state-sponsored program designed to address pest management and biodiversity is DPR's Endangered Species Program. This program encourages and supports pesticide applicators in using IPM practices and best management practices to protect endangered species. DPR also provides many IPM technical assistance resources aimed at common pest problems to guide the public in choosing SPM practices.

The US EPA determined that three of the most popular neonicotinoid pesticides were likely to drive more than 25 insect species and 160 insect pollinator-dependent plant species to extinction.[177] DPR also enacted regulations to mitigate risks from neonicotinoids, but farmers need more resources to rebuild effective pest management strategies with new tools.

Another example of effective technical assistance is through the creation of outreach materials - invasive species information pamphlets or identification cards such as the Species ID Cards for Early Detection and Rapid Response from the California Invasive Plant Council can provide growers critical information for identifying pests.[178] *For more information on pest management, see the Pest Pressures Chapter.*

[177] https://biologicaldiversity.org/w/news/press-releases/epa-three-popular-neonicotinoid-pesticides-likely-to-drive-more-than-200-endangered-plants-animals-extinct-2023-05-05/?ref=hir.harvard.edu

[178] https://www.cal-ipc.org/solutions/management/edrr/species-id-cards/

8.2 Increase beneficial biodiversity on farms.

Many of our state's farmers and ranchers are already proactively working to support biodiversity through on-farm practices. However, there are opportunities to increase ongoing efforts to bolster beneficial biodiversity on farms.

8.2.1 Utilize programs to effectively build and protect beneficial biodiversity on farms.

Goal 2: Enhance Program Effectiveness

In California, many wildlife species are dependent on privately owned agricultural lands for habitat. Agricultural lands can provide significant habitat and connectivity with protected wildlife areas. In many cases agricultural landowners are willing to integrate wildlife habitat benefits into the management and operations of their properties. The State of California has several programs that provide technical assistance and resources to help them do so. Effective implementation of these programs is needed to help build back biodiversity.

The Pollinator Habitat Program (PHP) is a CDFA-administered direct-to-producer grant program established by the Budget Act of 2021 with one-time funding allocation. PHP aims to incentivize the establishment of pollinator habitat on agricultural lands throughout California and to prioritize the planting of native habitats for the benefit of native biodiversity and the use of locally appropriate native plant seed mixes when feasible. The program's primary objective is to support pollinators through provision of floral resources, host plants, and other elements of suitable habitat. However, projects funded through the PHP can have additional benefits to California's biodiversity and agricultural production that align with other programs and goals, including CDFA's suite of Climate Smart Agriculture incentive programs. For example, projects can support sustainable pest management (*see more on this in the Pest Pressures Chapter*), support beneficial species (beyond pollinators), enhance carbon sequestration, and improve soil health, among other co-benefits. The program has a total of nine block grants totaling $11.25 million. These block grantees work directly with farmers and ranchers to install habitat and implement management practices that support pollinators.

Practices key to organic agriculture, such as the reduction or elimination of external inputs like conventional pesticides and synthetic fertilizers, can protect and enhance biodiversity by limiting beneficial species loss. AB 1757 (2022, Garcia) established a 20 percent goal for transition from conventional to organic systems in annual and perennial croplands in 2045. Efforts from the state to help achieve this goal include the Organic Transition Pilot Program. Created by the Budget Act of 2022 and supported

with allocations from the Budget Acts of 2022 and 2023, the purpose is to provide support to farmers and ranchers who prepare land for organic certification. The program seeks to support diverse farmers and ranchers in their transition to organic production. Over $6.1 million was awarded between four block grantees who will work with farmers and ranchers. Subsequent to the program's implementation in Ventura County by the Rodale Institute, it received a major endorsement through a $1M cost match by the Holdfast Collective, the nonprofit shareholder of Patagonia, Inc.

The Healthy Soils Program (HSP) has funded multiple rounds of climate-smart agriculture practices that support pollinators and can benefit biodiversity such as hedgerows, windbreaks, and range planting. *For more information on the Healthy Soils Program, please see Chapter 10, Advance Healthy Soils Practices.*

The intent of the Wildlife Conservation Board's Ecosystem Restoration on Agricultural Lands Program is to collaborate with the agricultural community in identifying and implementing projects that provide long-term habitat benefits for wildlife, consistent with landowner objectives, including economic sustainability, and have the potential for replication on a statewide scale. In many cases agricultural landowners are willing to integrate wildlife habitat benefits into the management and operations of their properties but lack the capital and/or expertise to implement these practices.

Voluntary Local Programs (VLPs) are locally-designed programs that encourage farmers and ranchers to voluntarily enhance and maintain habitat for endangered, threatened, or candidate species in ways compatible with routine and ongoing agricultural activities. They are one way to create and foster habitat for endangered, threatened, or candidate species on farms and ranches that do not interfere with ongoing agricultural activities. Farmers and ranchers can opt in or out of these programs for maximum flexibility. These programs are authorized by CDFW and run by local or regional entities. Of note, the Tricolored Blackbird Voluntary Local Program is run by the California Farm Bureau Federation and covers a wide swath of the Central Valley.

Another opportunity relates to riparian areas, or areas which are the transitional zones between land and water bodies like rivers and streams. These areas serve as buffers between land and water, supporting both hydrology and ecosystem health[179]. Unfortunately, 90 percent of California's riparian areas are degraded.[180] The California Department of Conservation's Working Lands and Riparian Corridors Program (WLRC) has awarded funds for watershed restoration planning and implementation on

[179] https://extension.oregonstate.edu/water/riparian-areas/overview-riparian-systems-potential-problems

[180] https://publishing.cdlib.org/ucpressebooks/view?docId=ft1c6003wp&chunk.id=d0e45190&toc.depth=1&brand=ucpress

agricultural lands.[181] Using this funding, landowners can work with restoration and conservation professionals who can help restore riparian areas. The WLRC program has been allocated 2024 Climate Bond funding and will release a request for proposals utilizing this funding.

Likewise, the Wildlife Conservation Board's California Riparian Habitat Conservation Program helps develop coordinated conservation efforts to protect and restore riparian areas. The program can fund efforts to restore floodplain connectivity, invasive species removal or control, wildlife-friendly fencing to keep livestock out of waterways, and reconfiguration of degraded streams to restore native habitat.

Tribal Nature Based Solutions Grant Program was established in 2023 within CNRA. This program provides funding to California Native American tribes to support the tribes' priorities for multi-benefit nature-based land management. The funding returns ancestral lands to tribal ownership and stewardship and supports planning and implementation of nature-based restoration projects. This program was created in response to feedback and consultation during state strategy planning and listening sessions for Executive Order N-82-80, 30x30, and the Natural and Working Lands Climate Smart Strategy. In 2023, rapid response funding was awarded to the Hoopa Valley Tribe to return 10,395 acres back to tribal stewardship. In 2024, $107.7M in funding was awarded for 33 projects. Additional funding for the Tribal Nature-Based Solutions Program was included in the 2024 Climate Bond.

The USDA's NRCS has a Regional Conservation Partnership Program (RCPP), created by the 2014 Farm Bill, that provides funding for a range of conservation activities. It is a partner-driven approach to conservation that funds solutions to natural resource challenges on agricultural land. By leveraging collective resources and collaborating on common goals, RCPP demonstrates the power of public-private partnerships in delivering results for agriculture and conservation. In 2019, *The Protection, Restoration and Enhancement of Tri-Colored Blackbird Habitat on Agricultural Lands*, was awarded funding through RCPP to provide financial and technical assistance to eligible agricultural producers and landowners in Central Valley counties to implement land management practices that will protect silage colonies, develop long term solutions to silage colonies, and restore and enhance habitat.[182] This RCPP featured a partnership between Dairy Cares, Western United Dairies, Audubon California, and numerous other groups to protect, restore, and enhance the habitat of the Tricolored Blackbird in the San Joaquin Valley, where nests on dairy farms are often destroyed during harvest.[183]

[181] Working Lands and Riparian Corridors Program

[182] Protection, Restoration and Enhancement of Tri-Colored Blackbird Habitat on Agricultural Lands

[183] 2022 Protection, Restoration and Enhancement of Tricolored Blackbird Habitat

This project has been successful in increasing the Tricolored Blackbird populations. From 2017 to 2021, the number of colonies in silage increased by two-thirds and the number of breeding adults increased by 127 percent.[184]

8.2.2 Convene committees and coalitions to identify pathways to build biodiversity on farms.

Goal 3: Grow Partnerships and Collaboration

Work to build biodiversity often needs cooperation and collaboration between state and local governments, private landowners, and for-profit and non-profit organizations. Continued state participation in these types of committees can often bring together diverse perspectives and knowledge bases to build more comprehensive and effective strategies to build biodiversity on farms.

The California Biodiversity Network brings together key environmental experts and community leaders who are united to conserve California's globally renowned and highly threatened natural heritage. The network is a key partner in the launch and implementation of California's 30×30 initiative, designed to bring together experts in a forum for biodiversity protection, stewardship, education, and research.

The California Multi-agency Monarch and Pollinator Conservation Collaborative was developed to support the long-term conservation of pollinators in California through cooperative partnership. The Collaborative is a working group created to inform and promote integrated science, natural resource management, and policy to conserve pollinators throughout California, subject to the unique authorities, constraints, and priorities of each partner. Led by the CDFW, partners include thirteen state and federal agencies, including the CDFA, that actively manage natural resources within California, conduct research that informs management decisions, or whose policies impact resource management that can benefit pollinators. The Collaborative strives to inform partners on issues concerning the long-term conservation of pollinator species within California, including the western population of the migratory monarch butterfly and its habitats, through a coordinated multi-jurisdictional conservation effort that is rooted in the best available science and based on population and habitat conservation goals. The Collaborative is currently working on identifying and promoting ecosystem-based management approaches that can be applied within each Partner's jurisdiction to support pollinator conservation in California.

[184] 2022 Protection, Restoration and Enhancement of Tricolored Blackbird Habitat

The California Pollinator Coalition brings together the Pollinator Partnership, CDFA, and The Almond Board of California to boost habitat creation for pollinators on farms and ranches. Created in 2021, the Coalition's goals include improving the coordination between agriculture and environmental organizations to not only grow food but also benefit biodiversity and the environment. The outcomes will include research, technical assistance, pollinator-friendly practice implementation, and progress tracking towards their goal. Achieving this goal benefits farmers and the environment in California by increasing biodiversity, improving pollination success, supporting SPM practices, and sequestering more carbon in the soil. The Coalition also hopes their success will serve as a model for more collaboration among stakeholders who have not always been aligned, but who are willing to come together in partnership to confront common challenges.

The Tricolored Blackbird Working Group is a collaborative alliance of farmers, agricultural associations, governmental agencies, and environmental organizations that recognize the importance of a multi-faceted and cooperative approach to promote the long-term persistence of the Tricolored Blackbird. This working group strives to reverse the population decline of the species and increase the population to more than 750,000 over the next 20 years. The working group is guided by the Tricolored Blackbird Conservation Plan, which lays out short-term actions and long-term conservation planning.[185]

The Floodplain Forward Coalition is an innovative collaboration between over 30 organizations based in conservation, biology, water management, farming, and local government. A memorandum of understanding was signed by federal and state government agencies the oversee water, agriculture, fish and wildlife, public lands and flood control to enhance the collaboration on landscape-scale, multi-beneficial floodplain water projects in the Sacramento River basin. The Coalition supported supports the signing as it will improve communications between the agencies, enhance flood protection, create and protect habitat for fish and wildlife, and increase long-term health for farms and communities.[186]

Two important projects Floodplain Forward Coalition members work on are the Nigiri Project and the Fish Food Project. The Nigiri Project manages flooding on agricultural lands farmed for rice to create habitat for self-sustaining fish and wildlife populations in the Central Valley. The Project creates critical floodplain rearing habitat for all runs of salmon as well as producing annual export of food to the Delta, even in critically dry years, benefiting the Smelt populations in the Sacramento River and Delta ecosystems.

[185] https://www.audubon.org/california/news/collaborative-conservation

[186] https://norcalwater.org/2024/10/24/sacramento-river-basin-floodplains-at-the-heart-of-landmark-agreement/

The Fish Food on Floodplain Farm Field Project is a collaborative project with farmers, conservationists, universities, and state and federal agencies to boost imperiled salmon populations using California's rice lands. This project reactivates critical farm fields to produce and deliver an abundance of zooplankton, a key food source for salmon, to the Sacramento River for consumption by salmon.

The San Joaquin Valley Monarch Recovery Strategy was led by River Partners and formed by the National Fish and Wildlife Foundation, Grassland Water District, and other partners who are seeking strategies to improve monarch conservation and recovery efforts in California, including the San Joaquin Valley. This project used lessons learned from the Grasslands Wildlife Management Area (WMA) in western Merced County. The Grasslands WMA is composed entirely of privately-owned lands on which perpetual conservation easements for the benefit of wildlife have been established between landowners and the U.S. Fish and Wildlife Service - consisting of private waterfowl hunting clubs, as well as wildlife-friendly agricultural lands. The San Joaquin Valley Monarch Recovery Strategy incorporated the elements of private and working lands into their strategy with the inclusion of irrigation ditches, roadside, fence lines, and farm edges (i.e. hedgerows) for eligible locations for monarch habitat establishment.[187]

8.2.3 Understand the need for seed supply to support biodiversity efforts across the state.

Goal 3: Grow Partnerships and Collaboration

Native and pollinator plantings play a critical role in creating habitat for on and off-farm biodiversity. When done at an impactful scale these plantings require a significant seed and plant supply. The California Native Seed Strategy offers a pathway to increase the availability of native seeds and their use in ecological restoration and land management. Published in January 2024 with funding from the Bureau of Land Management (BLM) and guidance from the California Seed Strategy Steering Committee. The steering committee members include representatives from the National Park Service, U.S. Fish and Wildlife Service, CDFA, California Department of Fish and Wildlife, BLM, non-profit and industry partners, and more. The California Native Seed Strategy aims to revitalize native seed supply by addressing the policy, grants, contracts, capacity, collaboration, science, and technology needed to get the right seed in the right place at the right time. The Strategy has four main goals: identify native seed needs and ensure the reliability of genetically appropriate seed; improve

[187] https://plantingseedsblog.cdfa.ca.gov/wordpress/?p=27084 ; National Wildlife Federation Monarch Recovery Strategy

guidelines and identify research needs for native seed production and use; develop tools that enable native seed producers and users to make timely, informed decisions; develop strategies and tools for communication. Successful implementation of the strategy will require coordination with state agencies, organizations, tribes, and farmers and ranchers throughout the state.

8.2.4 Expand science that addresses uncertainties around biodiversity, agriculture, and climate.

Goal 5: Demonstrate and Invest in Innovation and Technology

Creating higher biodiversity farming systems is often through the implementation of climate-smart practices and utilizing a diversified farming system, or a farming system that integrate crops and non-crop vegetation in and around the farm. These diversified farms are increasingly recognized for boasting large concentrations of biodiversity; whereas farming systems that are large areas of monoculture that may look 'cleaner' but lack significant biodiversity.

Ongoing research is needed to continue to understand the connections between biodiversity, agricultural practices, and climate resilience – looking at not just the impacts of agriculture and changing climate on biodiversity, but how biodiversity supports a productive agricultural economy. Research is also needed to better understand climate-driven changes in hydrology to better mitigate impacts from longer droughts and wetter storm and their impacts on farmlands and adjacent ecosystems.

At the state level, DPR has established the Emerging Technologies Workgroup (ETW) for pesticide application technologies in 2021 to:

1) Gain knowledge on and track emerging pesticide application technologies;
2) Share information and resources between regulatory entities with jurisdictional overlap or whose work may be impacted by such technologies;
3) Identify data gaps that may inhibit the development of appropriate drift models or regulations; and
4) Inform future regulations if needed.

ETW has worked with stakeholders in the emerging application technologies space to gather information on technologies that align with SPM strategies, including targeted, smaller-dose pesticide applications using aerial (e.g., unmanned aerial vehicles) and ground-based (e.g., tractors) equipment. ETW members have also worked directly with equipment manufacturers, end users, and growers to support the safe use of these technologies and to minimize off target movement. This continued work will further

support biodiversity through more targeted use of pesticides and enabling SPM practices.

Further work from the OPCA has resulted in several recent reports including Food safety and sustainable agricultural practices: conflicts and their effects on policy and programs in California and Balancing Bees and Pest Management: Projected Costs of Proposed Bee-Protective Neonicotinoid Regulation in California.

Belowground biodiversity is an emerging area of interest for agricultural operations and climate resilience. Research shows belowground biodiversity is critical for supporting essential ecosystem function such as nutrient cycling. A decline in belowground biodiversity via climate change and some land management practices removes a critical role in ecosystem function.[188] However more work is needed to understand how climate-smart practice implementation can build and protect belowground biodiversity. To start to fill this gap in knowledge CDFA, with leadership through the departments Environmental Farming Act Science Advisory Panel, developed the Soil Biodiversity in California Agriculture: Framework and Indicators for Soil Health Assessment in 2023. The assessment provides targeted recommendations for policymakers and stakeholders to enhance soil health and conserve biodiversity, which plays an important role in climate resilience and food production. The report provides recommendations including using soil biodiversity as a key metric for assessing and prioritizing soil health and multi-functionality, integrating a soil biodiversity assessment into CDFA's Healthy Soils Program, and developing an adaptive management framework that incorporates soil biodiversity assessment at the farm scale.[189] The report also recognizes that efforts to manage, track, and assess belowground biodiversity at the landscape scale are nascent and operationalizing such efforts will require continued research and collaborative development to select appropriate indicators, establish monitoring protocols, and produce decision-support tools.

8.2.5 Implement policies that support farms incorporating biodiversity to improve climate resiliency.

Goal 4: Align and Simplify Policies and Regulations

While conservation of working lands, including farms and rangelands, are included in the Pathways to 30x30 strategy as an important mechanism for supporting biodiversity, work is needed to uplift the role of agricultural lands into 30 x 30 efforts. Sustainably

[188] https://onlinelibrary.wiley.com/doi/full/10.1002/sae2.12108?msockid=26622aca12736c8a3f443cd6133f6d3c

[189] CDFA Releases Belowground Biodiversity Report noting Essential Nature For Soil Health, Climate Resilience, Food Production and Nutrition Security

managed private grazing lands, ranches, and working forests with durable protections like conservation easements for biodiversity contribute directly to the "count" toward the 30 percent, however there are many working lands that are protected for their agricultural value that can complement that conservation by preserving open space, habitat connectivity, and enhancing ecosystem values while supporting economic activity and food security.

However, some farmers have been reticent to protect species or their habitat, especially species listed as threatened or endangered. This is because the presence of such a species may prevent them from managing their land or farming operation the way they need to without being cited or fined, because that management action may result in an "incidental take." An "incidental take" is defined as the "take" or death of a plant or animal that happens over the course of carrying out an otherwise lawful activity. An important voluntary program private landowners can participate in is the CDFW California State Safe Harbor Agreement (SHA) Program. This program enables private landowners to manage their land for the net conservation benefit of threatened, endangered, candidate, declining, or vulnerable species without risk of consequences for the incidental take of species later on. The landowner is then authorized for acts that are or may become prohibited, such as incidental take of a protected species. A landowner must apply for a SHA and work with the CDFW to develop and implement management actions that will provide a net conservation benefit for the covered species. A landowner can modify their property, even if it results in incidental take of the covered species, if the baseline conditions are maintained.[190] Voluntary Local Programs also provide aide to private landowners in the protection of species. Upon CDFW authorization of a VLP, take of covered or endangered, threatened, or candidate species incidental to routine and ongoing agricultural activities is not prohibited, provided that the take occurs while implementing the management practices specified in the VLP. Currently, there are only a handful of VLPs.[191]

[190] Safe Harbor Agreements

[191] https://wildlife.ca.gov/Conservation/CESA/Voluntary-Local-Programs

Climate Change Mitigation, Habitat Creation, and Rice Cultivation

The Pacific Flyway migratory route stretches from the Arctic tundra down to South America and part of the route follows through the Sacramento Valley. Land use and climate change has significantly reduced the acreage of wetlands used as temporary habitat during migration.[192] Some of the land is used for agriculture, and in regions like the Sacramento – San Joaquin Delta, these organic rich soils are drained to grow crops like corn or tomatoes. The draining of these organic rich soils is leading to greenhouse gas emissions as the carbon stored in the soil is released through the oxidation, or breakdown, of the organic matter. Furthermore, as the organic matter breaks down, the land collapses, creating widespread subsidence throughout the Delta region.

California farmers and ranchers, in coordination with state agencies and conservation groups, are taking action to not only mitigate climate change but also create habitat for the millions of migrating birds by converting formerly drained wetlands to rice from other crops.[193] Farms converting their growing operations to rice in the Delta can help slow the land subsidence, may reduce greenhouse gas emissions, and if they reflood their rice fields during the winter migrating, create habitat. One example of these efforts is on Staten Island - owned by The Nature Conservancy since 2001, the island has undergone a careful planning and conservation process to create a mosaic of land uses including wetlands, dry land row crops, and now rice - all designed to keep the region economically productive but also create habitat for migrating birds.[194] Rice growers throughout the northern Sacramento Valley are also participating in the reflooding of their rice fields for winter migratory habitat. In total, rice growers can provide around 300,000 acres of wetland substitute for the migrating birds.[195]

[192] https://www.sacramentoaudubon.org/pacific-flyway-conservation

[193] https://norcalwater.org/wp-content/uploads/01_26_18_Sac-Valley-Waterfowl-F012418.pdf

[194] https://deltacouncil.ca.gov/pdf/delta-plan/2025-06-26-delta-adapts-adaptation-plan.pdf; https://www.nature.org/en-us/get-involved/how-to-help/places-we-protect/staten-island/

[195] https://calrice.org/wildlife/

Implementation

Strategy/ Action	Goal Alignment	Lead Agency	Supporting	Status	Implementation Phase
8.1 Build understanding of resources available to limit and/or reduce negative impacts to on-farm biodiversity.					
8.1.1 Create multi-faceted resources that can help address food safety concerns and limit negative impacts to biodiversity.	1: Increase and Expand Technical Assistance	CDFA			
8.1.2 Increase knowledge of best practices to treat pests while minimizing damage to biodiversity.	1: Increase and Expand Technical Assistance	EPA, DPR	CDFA		
8.2 Increase beneficial biodiversity on farms.					
8.2.1 Utilize programs to effectively build and protect biodiversity on farms.	2: Enhance Program Effectiveness	CDFA, CDC, WCB, DOC, CNRA, USDA			
8.2.2 Convene committees and coalitions to identify pathways to build biodiversity on farms.	Goal 3: Grow Partnerships and Collaboration	CDFW	CDFA		

8.2.3 Understand the needs for seed supply to support biodiversity efforts across the state.	3: Grow Partnerships and Collaboration	CNPS			
8.2.4 Expand science that addresses uncertainties around biodiversity, agriculture, and climate.	5: Demonstrate and Invest in Innovation and Technology	DPR,OPCA			
8.2.5 Implement policies that support farms incorporating biodiversity to improve climate resiliency.	Goal 4: Align and Simplify Policies and Regulations	CDFW, CNRA			

Pillar 3: Encourage Resilient Agriculture Practices

The following section covers the following chapters:

9. Enhance Agricultural Practices to Support Clean Air Communities

Reduce air pollutants from agricultural operations and practices while ensuring health of surrounding communities and workers while meeting air quality standards.

10. Advance Climate-Smart and Healthy Soils Practices

Meet state nature-based solution climate targets by 2030, 2038, and 2045 and support healthy and resilient soil ecosystems for growing food and fiber.

11. Improve Ranching Sustainability and Rangeland Management

Utilize climate-smart and emissions-reducing agricultural practices to promote resilience ranching and rangeland management.

12. Increase Dairy Farming Sustainability

Foster a robust and environmentally friendly dairy industry and reduce methane emissions by 40 percent per SB 1383.

Chapter 9. Enhance Agricultural Practices to Support Clean Air Communities

Key Objective: Reduce air pollutants from agricultural operations and practices while ensuring health of surrounding communities and workers while meeting air quality standards.

Context

In California, some of the most productive agricultural areas, particularly the Central Valley is also amongst the most polluted areas in the nation. The mountain ranges encompassing the Central Valley trap air pollutants emitted from heavy trucks traffic on two major interstate highways, Highway I-5 and Highway 99, as well as from agricultural operations, and other sources such as wood burning stoves and fireplaces. This poor air quality is a critical problem for farmers, farmworkers, and surrounding communities who suffer from health difficulties such as asthma as a result.[196] Contamination of the air with pollutants like ozone, fine particulate matter (PM2.5), coarse particulate matter (PM10), nitrogen oxides, carbon monoxide, sulfur oxides, volatile organic compounds (VOC), and metals such as lead can cause both long-term as well as short-term health effects ranging from asthma to cancer, in humans and animals.

State and federal air quality regulations protect the health of humans, animals, and the environment by setting standards defining clean air and maximum allowable pollutant levels. California Ambient Air Quality Standards were originally adopted in 1969 shortly before the National Ambient Air Quality Standards (NAAQS) were first set in 1970. State standards function as targets for the state but are not enforceable by law; however, there are consequences for failing to attain and meet planning requirements for NAAQS, and thus NAAQS often drive the required objectives for the State's air quality.[197]

While a highly productive farming region, the Central Valley registers highly for pollution impacts on the Cal Enviro Screen 4.0 map, which helps identify communities disproportionately burdened by pollution. In the Central Valley, one in six children suffer from asthma.[198] The Central Valley is also home to one of the state's highest

[196] Schenker, Marc B. MD, MPH; Farrar, Jeffrey A. DVM, MPH, PhD; Mitchell, Diane C. PhD; Green, Rochelle S. PhD; Samuels, Steven J. PhD; Lawson, Robert J. CIH, CSP; McCurdy, Stephen A. MD, MPH. Agricultural Dust Exposure and Respiratory Symptoms Among California Farm Operators. Journal of Occupational and Environmental Medicine 47(11):p 1157-1166, November 2005. | DOI: 10.1097/01.jom.0000181174.02282.0c

[197] California Air Resources Board. (n.d.). *California Ambient Air Quality Standards*. California Air Resources Board. https://ww2.arb.ca.gov/resources/california-ambient-air-quality-standards?keywords=2025

[198] California Air Resources Board. (n.d.). *Agriculture*. California Air Resources Board. https://ww2.arb.ca.gov/our-work/topics/agricultureAgriculture | California Air Resources Board

concentrations of Disadvantaged Communities, who suffer from a variety of economic, health, and environmental burdens, including issues plaguing the region such as extreme heat and high levels of particulate matter.

Not only does poor air quality affect people and animals, but crop production suffers as well. Tropospheric, or ground-level, ozone, can damage plants and prevent growth. Tropospheric ozone forms when nitrogen oxides (a family of poisonous, highly reactive gases that form when fuel is burned, also known as NOx) from trucks and other engines or soil over-fertilization react with volatile organic compounds in the presence of sunlight. Researchers have found that ozone reduces yields for perennial crops, such as those in the orchards and vineyards that dominate valley agriculture.[199] In fact, there is evidence that ozone may be even more damaging to yields than the warming effects of climate change and already cost California agriculture up to $1 billion per year.[200] Nitrogen oxides directly damage plants and hurt yields, can also mix with ammonia to create an aerosol compound which is a main component of PM2.5 in the valley, and can scatter sunlight and reduce plant growth and yields.[201]

On the positive side, there is evidence that pollution reduction measures have already had a positive impact on perennial crop yields, and that further pollution reduction will create further benefits for the agricultural industry and human health.

The State Implementation Plans lays out the strategy for regions with unhealthy air quality measures for pollutants such as ozone, inhalable particulate matter, carbon monoxide, nitrogen dioxide, and sulfur dioxide to improve air quality and achieve attainment with NAAQS. Given the makeup of emissions in California's agricultural regions, this includes consideration of controls on agricultural sources. More than half of Californians still live in areas that exceed the standard for ozone pollution, including a high proportion of low-income and disadvantaged communities. Coordinated through CARB in conjunction with the California Department of Pesticide Regulation (DPR) and local air districts, the 2022 State Strategy for the State Implementation Plan describes the plan for reducing ozone (smog) pollution by controlling nitrogen oxides (NOx).

[199] Hong, C., Mueller, N.D., Burney, J.A. *et al.* Impacts of ozone and climate change on yields of perennial crops in California. *Nat Food* **1**, 166–172 (2020). https://doi.org/10.1038/s43016-020-0043-8

[200] Hong, C., Mueller, N. D., Burney, J. A., AghaKouchak, A., Zhang, Y., Moore, F. C., Qin, Y., Tong, D., & Davis, S. J. (2020). Impacts of ozone and climate change on yields of perennial crops in California. *Nature Food*, 1(10), 595-603. https://doi.org/10.1038/s43016-020-0043-8

[201] Lobell, D. B., Di Tommaso, S., & Burney, J. A. (2022, June 1). Globally ubiquitous negative effects of nitrogen dioxide on crop growth. *Science Advances*, 8(22). https://doi.org/10.1126/sciadv.abm9909

Air Pollution Sources

As discussed above, there are many sources of air pollution in California and in the highly impacted Central Valley, and many efforts underway to address that pollution. The following discussion will focus on those most directly related to agriculture.

Fossil Fuel-Powered Equipment

Agricultural activities that can negatively impact air quality include petroleum-powered farm and trucking equipment such as tractors and pumps. The process of burning petroleum, particularly diesel, in internal combustion vehicles such as tractors or trucks releases PM2.5 and nitrogen oxides in the exhaust.[202]

Mobile sources constitute a large source of NOx emissions, therefore much of the state policy is focused on addressing these sources. These include cars, trucks, and other on-road vehicles, as well as off-road equipment, such as tractors, that require fossil fuels to run. The California Air Resources Board's 2020 Mobile Source Strategy provides scenario planning to identify technology trajectories and programs to meet air pollution and greenhouse gas emission reduction goals from mobile sources. Pertinent to the agricultural industry, the Mobile Source Strategy proposes a comprehensive suite of actions including manufacturer requirements, in-use requirements, incentive programs, outreach and education programs, infrastructure and planning and development, and enforcement strategies to make progress on zero-emission fleets for on-road medium- and heavy-duty vehicles and off-road vehicles and equipment. The State Strategy for the State Implementation Plan and the Mobile Source Strategy position California to meet federal clean air requirements as well as emission reductions goals for mobile sources set by Executive Order N-79-20. This executive order calls for 100 percent of California sales of new passenger cars and trucks to be zero-emission by 2035, all drayage trucks to be zero-emission by 2035, all off-road equipment to zero-emission where feasible by 2035, and the remainder of medium- and heavy-duty vehicles to be zero-emission by 2045 where feasible. Transitioning mobile sources of air pollutants to zero-emission will go a long way towards improving air quality in California; however, there is more work to do regarding non-mobile sources. The California Air Resources Board (CARB) is currently drafting a 2025 update to the Mobile Source Strategy.

Non-mobile sources: Agricultural Burning, Dust, and Fertilizer

Management of agricultural waste is critical for maintaining productive operations. "Agricultural waste" refers to the byproducts and residues generated from farming, livestock, and food production activities. This includes crop residues, or materials left

[202] Mersmann, K. (2021, November 17). *Reducing Emissions to Mitigate Climate Change Could Yield Dramatic Health Benefits by 2030*. National Aeronautics and Space Administration. https://www.nasa.gov/earth-and-climate/reducing-emissions-to-mitigate-climate-change-could-yield-dramatic-health-benefits-by-2030/

over after harvest; animal waste, e.g. manure and other byproducts from livestock; and processing waste, such as byproducts from food processing activities. As discussed in Chapter 1, there is a concerted effort to reconceptualize agricultural waste as useful inputs to return to the soil and/or for new products in the new circular bioeconomy.

CARB and the San Joaquin Valley Air Pollution Control District have been working for two decades to phase out open burning of crop residues since the passing of SB 705. For example, perennial crops like orchards have a natural lifespan after which trees must be replaced to maintain yields. Or, in some cases, grapevines may become infected by disease and need to be removed. Burning these crop residues or woody biomass is a cost-effective method; however, the combustion of these materials releases fine particulate matter such as PM2.5.[203] To combat this, a near-full ban on agricultural burning went into effect on January 1, 2025 in the Central Valley. Drought, disease, and poor market conditions have complicated the phase out of agricultural burning, requiring swaths of orchards and vineyards to be removed long before the end of the useful life of the plantings. To facilitate the transition from burning to alternative measures, the San Joaquin Valley Air Pollution District hosts the Alternatives to Agricultural Open Burning Incentive Program. This program, started in 2018 to encourage other sustainable options to open burning, provides incentives to growers for the recycling of crop residues via chipping and incorporation into the soil, use as mulch, removal off-site, or air-curtain burning. Additionally, extra funding per acre is available for small agricultural operations. Since program initiation, almost 50,000 acres of orchards and vineyards have been removed using alternative to burning practices, avoiding the emissions of 2,715 tons of NOx and 4,836 tons of particulate matter.[204] Furthermore, this program has expanded the options for handling crop residues for growers, making transitioning away from open burning more feasible.

[203] California Air Resources Board. (2021, February 5). *Staff Recommendations San Joaquin Valley Agricultural Burning Assessment*. California Air Resources Board. https://ww2.arb.ca.gov/sites/default/files/2021-02/Staff_Recommendations_SJV_Ag_Burn.pdf

[204] California Air Resources Board. (2021, October 8). *Staff Report Agricultural Burning Alternatives Analysis Report*. California Air Resources Board. https://ww2.arb.ca.gov/sites/default/files/2021-10/Agricultural_Burning_Alternatives_Analysis_Report.pdf

Air Curtain Burners

An air curtain burner, also known as a destructor or incinerator, is designed primarily as a pollution control device for open burning. It places a high-velocity curtain of air over a defined burn chamber, which can be a temporary pit in the ground or an above-ground structure with refractory walls. Air curtain burners are used for debris management, providing better air quality and reduced emissions. In some cases, air curtain burners can be designed to produce biochar, a charcoal-like substance that can be used as a soil amendment.[205]

Another common source of air pollution comes from the storage and breakdown of manure from dairies. Uncovered manure storage from livestock operations is susceptible to the volatilization of ammonia and the decomposition of organic material, which releases methane.[8] Dairy digesters provide a pathway for manure processing to capture methane, reducing the greenhouse gas emissions from dairy operations. However, traditional biogas combustion technology for electricity generation powered by digesters have received criticism for potentially increasing criteria pollutants directly and indirectly, including oxides of nitrogen (NOx) and PM2.5 in communities proximal to the dairy digesters. Other digester biogas utilization options, such as biomethane injection or biomethane use in solid-oxide fuel cells provide alternatives to combustion engines and have fewer localized emissions.

In addition, the over-application of nitrogen fertilizer can lead to nitrous oxide and ammonia emissions.[206] Proper fertilizer usage is critical – nitrogen fertilizer is the largest use of nitrogen in the state and research shows that crops in California capture only about 50 percent of the applied synthetic fertilizer.[207] Recently a CARB expert panel evaluated nitrogenous emissions from soils in California to improve the accuracy of the state's inventory and provide guidance for future research. This report identifies a likely underestimate of soils contributions to NOx and recommends additional data collection to better validate modeling results.[208]

---

[205] Air Burners Inc. *Principle of air curtain burners*. https://airburners.com/technology/principle/

[206] UC Davis Agricultural Sustainability Institute. (2016). *The California Nitrogen Assessment Challenges and Solutions for People, Agriculture, and the Environment Executive Summary*. University of California Agriculture and Natural Resources. https://asi.ucdavis.edu/sites/g/files/dgvnsk5751/files/inline-files/Executive%20Summary%20Layout_FINAL_reduced.pdf

[207] Tomich, T., Brodt, S., Dahlgren, R., & Scow, K. (n.d.). *The California Nitrogen Assessment Challenges and Solutions for People, Agriculture, and the Environment*. https://asi.ucdavis.edu/sites/g/files/dgvnsk5751/files/inline-files/Executive%20Summary%20Layout_FINAL_reduced.pdf

[208] Horwath, W., Silver, W., Burger, M., Aneja, V., & Zhu-Barker, X. (2025). *Scientific Evaluation of Nitrogenous Emissions from Soils* . California Air Resources Board. https://ww2.arb.ca.gov/sites/default/files/2025-06/Soil%20N%20SMERP_Final%20Report_20250527.pdf

Dust

Though the term "dust" many sound innocuous enough, dust presents a significant and growing challenge to public health and ambient air quality in California. Dust particles of PM2.5 and PM10 can impact human health because they can be inhaled into the lungs, and are associated with asthma, bronchitis, valley fever, and other cardiovascular and respiratory symptoms.[209] California's desert and desert-like regions have climates already prone to dust, and conditions are being exacerbated by climate change-driven drought and post-wildfire conditions. Anthropogenic, or human-caused dust, is created by activities ranging from transportation to construction, and by farming operations. While some of the dust caused by agriculture is produced in the course of growing and harvesting crops - for example, intensive tilling, leaving soil bare during non-growing periods, and the traditional almond harvesting requires the shaking of almonds to the ground and then sweeping them up, which produces significant dust, including particulate matter like PM2.5 and PM10 – there is growing concern about dust created as farms are left fallow as a result of drought or implementation of the Sustainable Groundwater Management Act or SGMA (more on SGMA in Chapter 5 on water). [210]

Wildfire and Wildfire Smoke

As the frequency and intensity of wildfires increase, wildfire smoke is also becoming a challenge for residents across the state. However, the outdoor and rural nature of agriculture means that farmers and farmworkers are particularly affected.[211] When wildfires affect crops, this can impact livelihoods, and wildfire smoke can cause long lasting respiratory problems and other health issues for those exposed.

Crops are also affected by wildfire smoke. Soot reduces photosynthesis in crops ranging from strawberries to citrus, grapes are susceptible to being ruined by smoke taint, and long-term exposure to wildfire smoke can decrease yields of nut trees by lowering their energy reserves.[212]

---

[209] California Air Resources Board. (2015). *Inhalable Particulate Matter and Health (PM2.5 and PM10)*. CA.gov. https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health

[210] Faulkner, W. B., & Capareda, S. C. (2012). Effects of sweeping depth on particulate matter emissions from almond harvest operations. *Atmospheric Pollution Research*, 3(2), 219-225. https://doi.org/10.5094/APR.2012.024; Fallowed agricultural lands dominate anthropogenic dust sources in California"

https://www.nature.com/articles/s43247-025-02306-0

[211] Clarke, K.; Manrique, A.; Sabo-Attwood, T.; Coker, E.S. A Narrative Review of Occupational Air Pollution and Respiratory Health in Farmworkers. *Int. J. Environ. Res. Public Health* **2021**, *18*, 4097. https://doi.org/10.3390/ijerph18084097

[212] Orozco, J., Guzmán-Delgado, P., & Zwieniecki, M. A. (2024). Megafire smoke exposure jeopardizes tree carbohydrate reserves and yield. *Nature Plants*, 10, 1635–1642. https://doi.org/10.1038/s41477-024-01819-4

Wildfires and Vineyard Damage

Increasing temperatures and drought condition lengthen duration of heat and dryness, prolonging and worsening wildfire conditions. This is compounded by increased growth of vegetation that grows during winter months and subsequently dies in proceeding dry conditions. As a result, the state has experienced a significant increase in the size and severity of wildfires. As of this writing, seven of the ten largest wildfires in California history have occurred since 2020, with 4.2 million acres burned.[213] Coastal ranges and Sierra foothill communities have been the most impacted agricultural areas, causing damage to vineyards and grazing lands in particular. While vineyards often act as a fire break and don't actually burn, the crop can be ruined by "smoke taint," wherein grapes exposed to smoke absorb compounds that result in a smokey or burnt flavor, typically undesirable in grapes or wine, resulting in total loss of the crop.[214]

A Hotter, Drier Climate

Hotter and drier weather, extreme dry and wet events, economic conditions, and efforts to bring aquifers into balance through reduced pumping may lead to extensive land idling and/or fallowing in California's agricultural regions. Drier conditions will also require more irrigation and less surface water, which may mean running diesel pumps to access groundwater. If the fallow land is left bare, drying and degraded soils can produce dust consisting of fine particulate matter that worsens air quality. Finally, in periods of prolonged drought, lack of rain means poor air quality can persist much longer without rainstorms to flush the air of pollutants.[215]

[213] (California Department of Forestry and Fire)

[214] *Wildfire Impact on CA Grapes and Wine*. (2025). Viticulture and Enology; UC Davis. https://wineserver.ucdavis.edu/industry-info/viticulture-resources/wildfire-impact-ca-grapes

[215] Rott, N. (2014, January 22). *California Air Quality Affected By Lack Of Rain*. NPR. https://www.npr.org/2014/01/22/264742844/calif-air-quality-affected-by-lack-of-rain%22%20/l%20%22:~:text=California%27s%20drought%20is%20having%20a%20big%20impact%20on,staying%20stagnant%20and%20could%20present%20a%20health%20risk.

Climate-Smart Agriculture Solutions for Dust Mitigation

In 2025, researchers found that fallowed farmland is a key source of anthropogenic dust in California, contributing to dust storms that cause reduced visibility for miles and traffic accidents.[216] They found that as fallowed land areas increased between 2008 and 2022 due to drought, there were more incidences of dust storms. The researchers found that fallowed land areas have higher daytime surface temperatures that contributes to drier soil and increased potential evaporation. These findings are of particular concern, given that by some estimates, including by the Public Policy Institute of California, up to 1 million acres of farmland may go out of production as SGMA is implemented.

Fortunately, this is not agriculture's first rodeo when it comes to mitigating potential dust hazards. Climate-smart agricultural practices have roots going back to the Dust Bowl of the 1930's, which was brought on by a number of factors including drought and bare farmland, and which led to the destruction of topsoil in the Great Plains. The Dust Bowl affected 100 million acres and caused economic losses of $570 million in 2024 dollars and caused the migration of tens of thousands of people from Oklahoma, Arkansas, Missouri, Iowa, Kansas, Texas, Colorado, and New Mexico to California. This catastrophe was the impetus for the creation of the USDA Natural Resource Conservation Service and the development of soil conservation measures, including cover cropping, which we now know has benefits beyond simply anchoring soil to the land; this includes increasing the water-holding capacity of soil, increasing water infiltration and improving water quality, supporting soil biodiversity, scavenging excess nutrients to project water quality, and adding additional fertility.

However, for all their benefits, establishing a cover crop does typically require applying water in drier years, which can be a difficult decision to make for a farmer with limited funding, no future prospects for a productive crop, and a small or non-existent water budget. During the 2022 drought, there was concern in the farming community that cover cropping would be discouraged by GSAs seeking to reduce groundwater pumping. In fact, the latest science indicates that water evapotranspired from cover cropped ground is comparable to what is evaporated from bare ground, and given the infiltration and water-holding benefits described above, cover crops may, in some circumstances, have a net-positive impact on water budgets in addition to their other benefits.[217]

[216] Adebiyi, A.A., Kibria, M.M., Abatzoglou, J.T. *et al.* Fallowed agricultural lands dominate anthropogenic dust sources in California. *Commun Earth Environ* **6**, 324 (2025). https://doi.org/10.1038/s43247-025-02306-0

[217] Borum, J., Bruno, E., Castle, S., Chiartas, J., Crowley, R., Decock, C., Delgado, C., DeVincentis, A., Dufour, R., Edwards, A., Flaherty, R., Flynn, M., Grimm, R., Hale, L., Light, S., Little, C., Lowell, K., Minshew, H., Nocco, M., Peterson, C., Roby, M., Roseman, J., Roth, A., Sandoval, S., Silva, S.A., Smet, E., Smither-Kopperl, M., Suvočarev, K., Waterhouse, H.,Wauters, V., Williams, S., and Zaccaria, D. (2024). Cover Cropping in the SGMA Era: A Comprehensive Overview of Water Impacts, Policy Implications, and Recommendations for California's Water Managers. The Soil-Water Interface Expert Convening Series: Cover Crop Impacts on Water Budgets, California.

In 2022-2023, CDFA sponsored and participated in a collaborative effort by Sustainable Conservation, USDA-NRCS, UC Agriculture and Natural Resources, and the California Association of Resource Conservation Districts to host a series of convenings examining the impact of cover cropping on water budgets. This question is important because of limitations on groundwater use related to the implementation of SGMA and the perception that Groundwater Sustainability Agencies were discouraging the use of cover crops because of the water required to grow them. Based on the convenings, over 30 cross-disciplinary experts developed a white paper evaluating how cover crops impact water cycles, how GSAs are treating cover crops in their water management strategies, and how the agricultural community can ensure that cover crops continue to be an available option for growers.

Fortunately, in its conversations with GSAs, Sustainable Conservation encountered willingness to engage on this topic. At this time, Sustainable Conservation is developing case studies highlighting GSAs that have integrated the water benefits of cover crops into their management plans, plus a suite of guidance documents related to cover cropping in the SGMA era—including recently released grower guidance developed in partnership with the Community Alliance for Family Farmers, USDA NRCS and the University of California, with support from CDFA.[218]

[218] Ayala, E., Castle, S., Light, S., Smither-Kopperl, M., Wauters, V., & Williams, S. (2025). *Cover Cropping in California's Water Scarce Environments*. Sustainable Conservation. https://suscon.org/wp-content/uploads/2025/05/Cover-Cropping-in-Californias-Water-Scarce-Environments-5.2.25.pdf

Strategies and Actions

Limited funding for agricultural equipment and limited technical assistance can pose barriers to uptake of agricultural operations improvements that reduce air pollution. The actions listed below describe the opportunity to expand the use of climate-smart land management practices and increase equipment upgrades to improve air quality.

9.1 Improve air quality from agricultural operations.

Senate Bill 700 (Chapter 479, Statutes of 2003) incorporated agricultural activities and operations into air quality regulations. Of note, the bill removed the permitting exemption for agricultural equipment that may cause emission of air contaminants; required areas with poor air quality to regulate best available control measures and retrofit control technology for agricultural practices at stationary agricultural sources of air pollution; and required large confined animal facilities in areas with poor air quality to obtain permits to reduce as feasible emissions of air contaminants. While this bill did provide loan opportunities to agricultural operations in pursuit of air pollution control measures, the cost for most farmers to make the needed or required technological and management practice upgrades result in a significant financial barrier.

To address the air quality concerns stemming from agricultural operations, further research into the impacts should be supported. Additionally, as air quality improvements are made, the state has an opportunity to coordinate outreach and messaging, providing farmers and ranchers with clear guidance.

9.1.1 Support research of air quality impacts related to agricultural operations.

Goal 5: Demonstrate and Invest in Innovation and Technology

CARB is dedicated to sponsoring a research program to better understand air pollution causes, effects, and solutions. Created in 1971, the research program operates through series of multi-year strategic plans informed by the public to address pertinent research needs regarding air quality.[219] The research projects inform CARB program priorities of air quality standards, environmental justice, climate change, mobile sources, and sustainable communities. Each year CARB funds 8-10 research contracts for $4-8 million dollars. Upcoming new research priorities for the department include health, natural and working lands, agriculture and climate/air quality interactions, and continuing

[219] *Research Planning*. (2025); California Air Resources Board. https://ww2.arb.ca.gov/our-work/programs/research-planning

topics are air quality and mobile sources. Research findings result in five additional dollars for each dollar CARB invests, supporting climate, environment, and health.[220]

9.1.2 Coordinate outreach for state programs between state agencies.

Goal 3: Grow Partnerships and Collaboration

Implementation of management practices and installation of upgraded equipment requires technical assistance to reach the appropriate audiences and provide the needed information for transitions without operation interruptions. Coordinating existing technical assistance programs across state agencies to streamline outreach for air quality improvements along with soil health, energy efficiency, and other agricultural climate mitigation and adaptation solutions can reduce the cost and time burden on growers receiving assistance and those groups providing technical assistance. Coordinated outreach to highlight air quality benefits in these solutions can bring in new parties and investments not previously connected to improving agricultural resilience.

9.1.3 Increase access to equipment upgrades and changing agricultural operation practices that improve air quality.

Goal 2: Enhance Program Effectiveness

The State recognizes the need for financial assistance and outreach to help the agricultural industry adopt cleaner air practices, and has also shown that investments in agricultural operations to reduce pollutants are some of the most cost effective.[221] Incentive programs through the state and in partnership with Air Quality Management Districts and Commodity Groups can fund equipment upgrades and management practices which can reduce the contribution of air pollutants by agricultural operations.

Equipment Upgrade Programs

CARB is responsible for protecting the public from the harmful effects of air pollution through the regulation, program facilitation, monitoring, and reporting of greenhouse

[220] *Public Meeting – Funding Year 2026-2027 Research Priorities*. (2025). California Air Resources Board. https://ww2.arb.ca.gov/sites/default/files/2025-05/2025_05_28_Public%20Meeting.pdf

[221] California Air Resources Board. (2023, October). *Appendix F: Cost-Benefit Analysis of Mobile Source Incentive Programs*. California Air Resources Board. https://ww2.arb.ca.gov/sites/default/files/2023-10/Appendix%20F%20fy2023_24_funding_plan.pdf

gas emissions and air pollutants for the State. CARB offers several programs for equipment upgrades that apply to agricultural operations.

The Carl Moyer Program is a voluntary grant program that reduces air pollution from vehicles and equipment by providing up to 85 percent of the cost to repower engines and replace equipment, and up to 100 percent of the cost to purchase a CARB-verified retrofit device. Agriculture specific vehicle and engine eligibilities include on-road trucks over 14,000 pounds, farm equipment, and stationary or portable agricultural equipment stationary or portable agricultural equipment. Created in 1998, this program has encumbered over $1.31 billion in funding which resulted in almost 70,000 projects implemented, 191,000 tons of NOx reductions, and 7,440 tons of PM reductions.[222]

Funding Agricultural Replacement Measures for Emission Reductions (FARMER) was established in 2018 and supports the agricultural sector's transition to the cleaner technologies. The program provides funding to local air districts to distribute monies for agricultural harvesting equipment, heavy-duty trucks, agricultural pump engines, tractors, and other agricultural operation equipment. FARMER invests heavily in supporting disadvantaged and low-income communities by allocating 80 percent of the project funding to the San Joaquin Valley Air Pollution Control District (SJVAPCD) which is in extreme non-attainment with federal ozone standards and has the highest overlap between farmland and these underserved populations. Since the program inception, FARMER has implemented $601.8 million in projects, resulting in more than 11,000 vehicle and equipment replacements, which reduced 30,600 tons of NOx and 1,810 tons of PM2.5.

The Clean Off-Road Equipment Voucher Incentive Project (CORE) provides incentives to purchase or lease zero-emission off-road equipment. In 2022, agricultural equipment was added as an eligible category with up to $500,000 available for the voucher and up to $30,000 available for infrastructure enhancements. Since initial funding in 2017, CORE is responsible for 1,430 vehicles, engines, and equipment implemented resulting in 52.6 tons of NOx reductions and 0.841 tons of PM reductions.[223]

CARB also works in conjunction with Air Quality Control Districts to incentivize upgrading agricultural equipment. The SJVAPCD offered $12.5 million in assistance for the purchase of low-dust nut harvesters in 2021. CARB provided $2.5 million through the Community Emission Reduction Program targeted to the community of Shafter within

[222] *Carl Moyer Memorial Air Quality Standards Attainment Program*. (n.d.). California Air Resources Board. Retrieved August 7, 2025, from https://ww2.arb.ca.gov/our-work/programs/carl-moyer-memorial-air-quality-standards-attainment-program

[223] California Air Resources Board. (n.d.). *Outcomes and Results for Clean Off-Road Equipment Vouchers*. California Air Resources Board. https://ww2.arb.ca.gov/our-work/programs/clean-road-equipment-voucher-incentive-project-core/outcomes-and-results-clean

the San Joaquin Valley. The SJVAPCD also secured $10 million in funding for all counties within the San Joaquin Valley from the federal Targeted Air Shed Grants program hosted by the Environmental Protection Agency. The program aims to reduce PM2.5 and PM10 emissions from the almond harvesting process by requiring low-dust equipment purchased to have at minimum 40 percent reduction compared with standard practice equipment.[224]

Co-benefits from Climate-Smart Agriculture Programs

CDFA's Office of Agricultural Resilience and Sustainability hosts multiple programs designed to mitigate climate change, improve the environment, and build resilience for agricultural operations. These programs also offer air quality improvements as a potential co-benefit. For example, the Healthy Soils Program and Pollinator Habitat Program incentivize the planting of hedgerows and windbreaks; these woody plantings can also help decrease wind speed across a field, reducing wind erosion and dust transmission.[225] These type of woody vegetation buffer zones at field edges are called for in the California's Nature-based Solutions Climate Targets for Developed Lands - establish tree line buffers between croplands and communities to reduce chemical exposure and enhance access to green space.

The State Water Efficiency and Enhancement Program offers energy efficiency upgrades which can include load flexibility, which would reduce fossil fuel usage and cut down on air pollutants emitted from fossil fuel burning engines. Dairy programs such as the Alternative Manure Management Program, the Dairy Digester Research and Development Program, and the Dairy Plus Program reduce methane emissions, and several of the practices which involve solid-liquid-separation and covering manure piles lagoons can help cut down on the ammonia and hydrogen sulfide emissions.[226] (*More information on these programs' direct climate mitigation and agricultural operation benefits can be found in the Soil Health, Water Resources, Biodiversity, and Dairy Sustainability chapters.)*

Feedback on efforts to phase out agricultural burning indicated that a significant barrier was lack of available equipment needed for grinding, chipping, shredding, and

[224] San Joaquin Valley Air Pollution Control District. (n.d.). *Low Dust Nut Harvester Emission Reduction Program Plan*. San Joaquin Valley Air Pollution Control District. https://ww2.valleyair.org/grants/low-dust-nut-harvester-replacement-program/

[225] Tibbs, R. (2024, August 2). *Taming the Dust: Proven practices to combat erosion and dust storms in Central Illinois, Part 2*. College of Agricultural, Consumer & Environmental Sciences Illinois Extension. https://extension.illinois.edu/blogs/farm-focus/2024-08-02-taming-dust-proven-practices-combat-erosion-and-dust-storms-central

[226] Aguirre-Villegas, H. A., Besson, C., & Larson, R. A. (2024). Modeling ammonia emissions from manure in conventional, organic, and grazing dairy systems and practices to mitigate emissions. *Journal of Dairy Science*, 107(1), 359-382. https://doi.org/10.3168/jds.2023-23782

incorporation into the soil.[227] For example, low-dust nut harvesters are critical to reducing PM2.5 and PM10 in regions of the state growing ground-harvested nuts. Equipment scarcity can also drive-up costs for these air-quality improving management practices, preventing growers with less resources from participating. Furthermore, infrastructure needs such as charging capacity and equipment for electrifying on-farm vehicles and equipment must go hand-in-hand with CORE projects. Efforts to improve air quality through upgrades in agricultural equipment and management practices will require easily available appropriate agriculture equipment, at a cost-effective and accessible price for purchase or rent, and with the accompanying infrastructure installation.

[227] California Air Resources Board. (2021, October 8). *Staff Report Agricultural Burning Alternatives Analysis Report*. California Air Resources Board. https://ww2.arb.ca.gov/sites/default/files/2021-10/Agricultural_Burning_Alternatives_Analysis_Report.pdf

Implementation

Strategy/ Action	Goal Alignment	Lead Agency	Supporting	Status	Implementation Phase
9.1 Improve air quality from agricultural operations.					
9.1.1 Support research of air quality impacts related to agriculture operations.	5: Demonstrate & Invest in Innovation and Technology	CARB			
9.1.2 Coordinate outreach for state programs between state agencies.	3: Grow Partnerships and Collaboration	CARB	CDFA, CNRA CPUC, CEC		
9.1.3 Increase access to equipment upgrades and changing agricultural operation practices that improve air quality.	2: Enhance Program Effectiveness	CARB, EPA, CDFA			

Chapter 10. Advance Climate-Smart and Healthy Soil Practices

Key Objective: Meet state nature-based solution climate targets by 2030, 2038, and 2045 and support healthy and resilient soil ecosystems for growing food and fiber.

Context

What is healthy soil?

Healthy soil is the foundation for productive, sustainable, and resilient agriculture. Soil health can be defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.[228] Soils are a mixture of minerals, organic matter, including (micro)organisms, liquids, and gases that support the life of plants and animals. In most soils, the mineral portion (sand, silt, and clay) is the largest component of soil, typically accounting for up to half of the volume, and organic matter typically comprises up to about 5 percent. Water and air constitute the remaining half. Additionally, a teaspoon of soil can contain billions of organisms made up of thousands of species, mostly microbes, although there are larger species that many people would recognize, like earthworms.

A healthy agricultural soil generally has structure, meaning more aggregates or small clumps, that will allow for spaces between them for air and water. Those spaces will make the soil more workable, more drainable, and able to host more biological activity as compared to compacted soil. Increased biological activity and higher plant diversity will also generally increase the soil's organic matter, which in turn boosts nutrient cycling beneficial for crops and nutrient use efficiency and also feeds back to improved aggregation and better soil structure.

Healthy soils also have benefits for more than crops. They are associated with lower pest pressure and pesticide use because their highly functioning biological systems are less vulnerable to widespread damage. Improving soil health leads to lower pathogen presence and reduces the prevalence of crop pathogens. Healthy soils also contribute to cleaner water by reducing runoff, improving water infiltration, filtering contaminants, tightening nutrient cycling, and improving nutrient use efficiency. Additionally, healthy soils are less susceptible to erosion and thus can reduce the presence of dust, improving

[228] Natural Resources Conservation Service. (n.d.). Soil Health. United States Department of Agriculture. https://www.nrcs.usda.gov/conservation-basics/natural-resource-concerns/soils/soil-health#:~:text=Soil%20health%20is%20defined%20as%20the%20continued%20capacity

air quality. Actively managing soil to improve its health can result in increased fertility, reduced need for inputs, carbon protection and sequestration, and beneficial impacts on water holding capacity.

Farmers and ranchers can build soil health through changes in their management systems. In row crop systems, practices such as planting cover crops or applying compost and mulch to reduce erosion and enhance moisture infiltration and retention, rotating the crops grown to improve soil nutrient status and reduce pest pressure, dedicating space for permanent plantings of native plants to build up biodiversity and create habitat for pollinators, reducing or eliminating tillage to minimize soil disturbance to preserve soil structure and reduce erosion. In orchards, there may be additional opportunities to reduce tractor passes, or use animals like sheep or goats for weeding or mowing, as well as returning orchard biomass to the soil via whole orchard recycling. On grazing land, ranchers can plant trees and shrubs or use practices like prescribed grazing to strategically move animals around large pastures, giving the soil and plants time to recover and depositing manure more evenly *(for more climate-smart agriculture solutions on rangeland, see chapter 12 on Ranching Sustainability)*. These practices can be broken into different categories as illustrated below – each with their own subset of associated soil health benefits. These soil health benefits are all in addition to the climate mitigation benefits of carbon sequestration, and nitrous oxide and methane emission reductions. As agricultural systems are complex, these practices must be thought of as part of an overall management system, including how practices interact with one another and with their broader agricultural and ecological context.

2024 State Targets Related to Healthy Soils

- Implement 3.1 million acres of healthy soils practices on croplands
- Conserve an additional 270,000 acres of cropland
- Manage 20 percent of cropland organically
- Conserve 33,000 acres of grassland per year
- Restore 55,100 acres of degraded grasslands to native and deep-rooted perennials

Principles of Soil Health

The USDA Natural Resource Conservation Service cites four principles of managing soil health based on soil health research:

1) Maximizing soil cover. Keeping soil covered by plants or mulch conserves moisture, keeps temperatures down, suppresses weed growth, prevents erosion, provides material for the creation of soil organic matter, and provides habitat.

2) Maximizing the presence of living roots. Living plant roots feed microorganisms in the soil and aid in maintaining soil structure, nutrient cycling, and carbon storage.

3) Minimizing disturbance. Minimizing soil disturbance helps build soil aggregates (clumps of soil formed by physical, chemical, and biological activity), pore spaces that allow oxygen, water, and nutrients to pass through, and builds soil organic matter. Disturbance can result from overgrazing, tillage, and overapplication of inputs like fertilizers and pesticides.

4) Maximizing soil biodiversity. Soil organisms, including plants, animals, and microorganisms, are the primary mechanism for driving nutrient cycling, sequestering carbon, improving soil structure, and enhancing plant health. Maintaining or enhancing diversity can help build resilience to stressors and support the long-term health and functioning of soils.

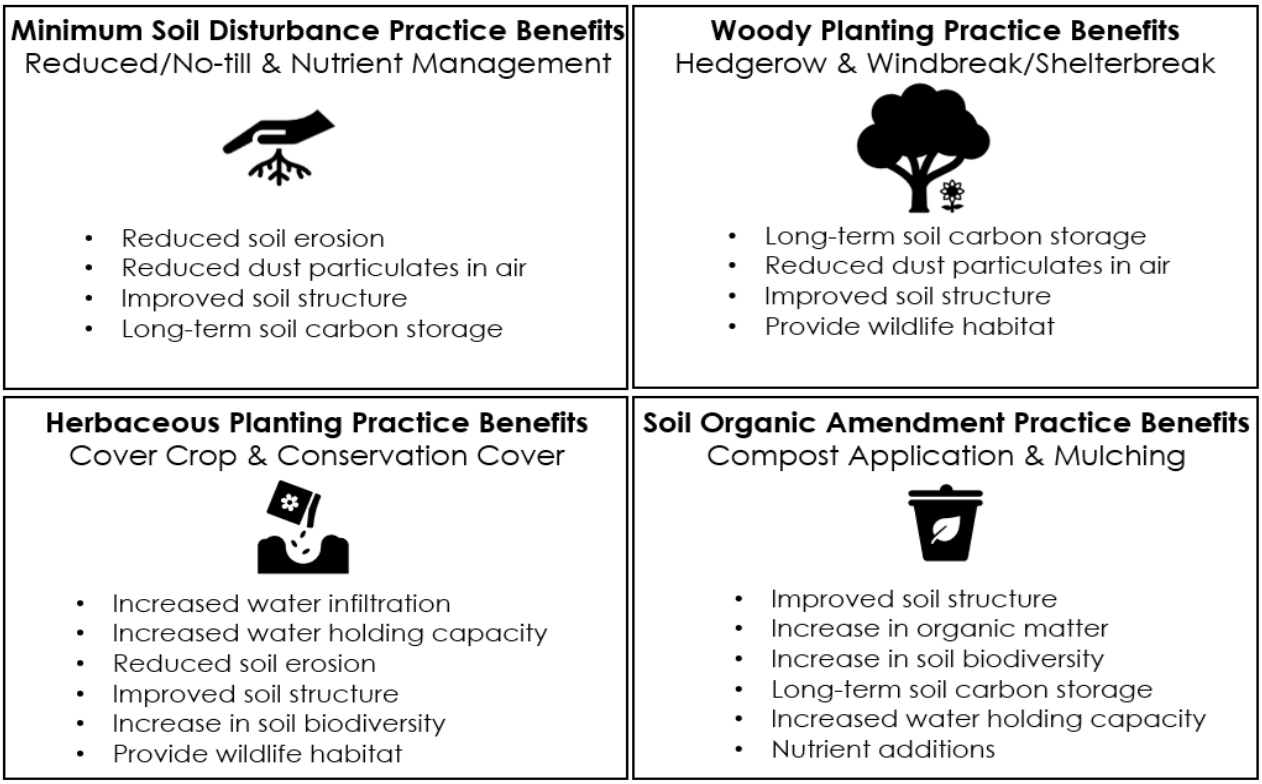


Figure 12: Healthy Soil Practices

There is overlap between what are considered "healthy soils practices" and "climate-smart agriculture practices." Climate-smart agriculture, as defined earlier in this report, calls for meeting three objectives: sustainably increasing food security through increases in productivity and incomes, building resilience and adapting to climate change, and reducing greenhouse gas emissions as compared to business as usual.[229] The healthy soils practices funded through CDFA's Healthy Soils Program (HSP), such as planting cover crops or applying compost, fit within this definition. As shown in Figure 12, healthy soils practices also have been shown to have several positive benefits that build soil health and make agricultural systems better able to adapt to our changing climate. Examples of outcomes from utilizing healthy soils practices include increased soil organic matter that helps soil soak up and hold onto water better, improving water use efficiency and buffering the impacts of heat and drought.

Healthy soil and climate-smart practices are not one-size-fits-all. Different crops, orchards, and grazing systems in different microclimates with different soils may all have different needs and requirements. Additionally, some practices may have dramatic

[229] Lipper, L., & Zilberman, D. (2018). A short history of the evolution of the climate-smart agriculture approach and its links to climate change and sustainable agriculture debates. Climate smart agriculture, 15-31. Springer. https://doi.org/10.1007/978-3-319-61194-5_2

results in some circumstances and not in others. For example, it may be possible to build soil organic matter with compost and cover crops in one region but using the same practices may not result in a measurable increase in soil organic matter in another location due to characteristics of the local soil and microclimate. This means that practices need to be curated to suit a specific farm's needs and location.

Climate Change Impacts on Soil

In addition to human management, soil is impacted by larger ecosystem factors, such as climate change, including droughts, heatwaves, heavy precipitation, and storm surges for coastal and deltaic communities.[230] Climate-smart agriculture and healthy soils practices help build the resilience of agricultural systems to these climate change impacts.

Droughts

Drought can impact soil health in several ways. Organic carbon in soil is shown to decrease during droughts, primarily due to decreased plant material input and changes in microbial growth, activity, and diversity that can alter plant material decomposition. Prolonged drought can result in fallowing and bare ground, making soils susceptible to crusting, which can diminish water infiltration, increase runoff, promote erosion, and induce dust deflation. Diminished water availability can also indirectly impact soil health by changing the availability of nutrients, negatively impacting the soil structure, and reducing the binding capacities of soils.[231] Additionally, higher temperatures can decrease the snowpack availability in the Sierra mountains and foothills for mid-summer agricultural irrigation, worsening the "drought" impacts on irrigated agricultural soils.

Extreme Heat

Climate change can include increased frequency, intensity, and duration of heatwaves. From a soil health perspective, increased heat can lead to higher carbon

[230] Seneviratne, S.I., X. Zhang, M. Adnan, W. Badi, C. Dereczynski, A. Di Luca, S. Ghosh, I. Iskandar, J. Kossin, S. Lewis, F. Otto, I. Pinto, M. Satoh, S.M. Vicente-Serrano, M. Wehner, and B. Zhou, 2021: Weather and Climate Extreme Events in a Changing Climate. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change[Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1513–1766, doi: 10.1017/9781009157896.013.

[231] Kallenbach, C. M., Wallenstein, M. D., Schipanski, M. E., & Grandy, A. S. (2019). Managing agroecosystems for soil microbial carbon use efficiency: Ecological unknowns, potential outcomes, and a path forward. Frontiers in Microbiology, 10, 1146. https://doi.org/10.3389/fmicb.2019.01146

losses associated with decomposition rates of organic matter and carbon within the soil.[232]

Extreme Precipitation and Flooding

Heavy precipitation events, while sometimes relieving dry conditions, can also cause soil issues. When soils are exposed, intense rainfall events can destroy beneficial soil structure at the surface causing crusting, which leads to less water infiltration and exacerbates runoff.[233] During these events, increased runoff leads to soil erosion and mudslides. One of the major agricultural impacts of flooding is crop loss, with economic loss estimates in the hundreds of millions of dollars for California in 2023.[234] Even if the crop is not washed away entirely, food safety regulations prohibit growing or harvesting food from flooded farmland for 30-60 days to avoid the risk of food-borne illness from contaminated floodwaters.

[232] https://www.annualreviews.org/content/journals/10.1146/annurev-ecolsys-110617-062614

[233] Duiker, S. W. (2025, February 24). Soil Crusting. Penn State Extension. https://extension.psu.edu/soil-crusting

[234] Bloomberg. (2023, March 23). Battered California faces billions in storm damage to crops, homes and roads. The Mercury News. https://www.mercurynews.com/2023/03/23/battered-california-faces-billions-in-storm-damage-to-crops-homes-and-roads/

Strategies and Actions

The following strategies and actions aim to increase adoption of healthy soils practices in the state, while also ensuring that healthy soils practices are continuously being improved and integrated throughout the agricultural industry.

10.1 Encourage the adoption of climate-smart and healthy soils practices to bolster California's lands against the impacts of climate change.

The state is already working to ensure that climate-smart and healthy soils practices continue throughout the state. These efforts should continue to be coordinated across state agencies and throughout the state's farmers and ranchers.

10.1.1 Coordinate state agency efforts to improve soil health.

Goal 3: Grow Partnerships and Collaboration

Healthy Soils Initiative

In his 2015 inaugural address, Governor Brown announced the launch of the Healthy Soils Initiative, a state-level collaboration of agencies and departments, led by CDFA, promoting the development of healthy soils through a combination of innovative farm and land management practices employed and incentivized by the state. State agencies and departments involved in this effort with CDFA include CalRecycle, the California Air Resources Board, the California Natural Resources Agency, and the California Water Boards. Coordinating efforts with other state agencies will help avoid redundancy and prevent silos between agencies. Specifically, coordination is necessary to create the conditions in which a circular economy for soil organic amendments can develop. CDFA's efforts to incentivize adoption of these products will have limited effects in the long run if the products themselves remain difficult or expensive to secure in many agricultural areas. Some relevant commitments were made in the Healthy Soils Action Plan of 2016, including the pursuit of regulatory consistency. Below are some examples of how CDFA's sister agencies help promote healthy soils.

CalRecycle

CalRecycle's Compost and Mulch Use Toolbox provides a one-stop reference for guidance on the use of compost and mulch on different landscapes and for different

purposes, including carbon sequestration, fire remediation, stormwater management, and more.

Department of Water Resources

The Department of Water Resources (DWR) is working to implement healthy soils practices on the lands under their control. Practices such as conservation cover, vegetative barriers, filter strips, or grassed waterways can reduce soil erosion of fallowed lands, build soil carbon and even help retain water.

For lands leased to other entities, healthy soils practices are implemented for new leases where practical - including practices such as rotational grazing, limitation of herd size, limitations for grazing species and crop types, restriction of significantly soil-disturbing agricultural practices, and limitation or restriction of pesticides and herbicides.

CDFA also works with DWR to promote practices that save water or build soil water retention in the critically over drafted groundwater sub-basins being regulated by the Sustainable Groundwater Management Act.

State Coordination in the Delta

The Delta Stewardship Council, Delta Conservancy, Delta Protection Commission, and DWR seek to fight soil loss from oxidation of drained organic soils in the Delta. At the same time, they seek to protect farmland that could be lost to salinization or levee failure if the Delta's hydrological challenges are not adequately addressed. These are difficult problems, but strategic conversion to rice cultivation, ecological restoration at key locations, and the exploration of other productive uses of flooded soils, including carbon sequestration, wetland biomass harvesting and tribal resource management are key efforts underway.

10.1.2 Facilitate the adoption of climate-smart and healthy soils practices by farmers, ranchers, and private landowners.

Goal 2: Enhance Program Effectiveness

Healthy Soils Program

A key outcome of the Healthy Soils Initiative was the creation of the Healthy Soils Program (HSP) in 2017. The program has received multiple Greenhouse Gas Reduction Fund (through the Cap-and-Invest Program) and General Fund funding appropriations totaling $205.5 million to date. To date, the program has funded healthy soils practices on 2,200 farms. More recently, AB 1757 (Garcia, 2022) built on the work done in the 2022

Scoping Plan for Achieving Carbon Neutrality by requiring that nature-based solution climate targets to be set for each land type. The targets for croplands require significant additional acreage of healthy soils practices be implemented each year between now and 2045 to result in over 3 million new acres of cropland managed using healthy soils practices.[235]

The Healthy Soils Program's objectives are to increase statewide implementation of climate-smart agricultural practices that improve soil health and resilience to climate change, sequester carbon, and reduce atmospheric greenhouse gases. These objectives are implemented by:

1) Providing financial incentives to California growers and ranchers to implement these practices;
2) Providing technical assistance to make practice adoption less intimidating and increase success; or
3) Funding on-farm demonstration projects that conduct research and/or showcase these practices.

HSP initially have grants directly to farmers and researchers, and more recently, in the form of block grants to local organizations to work directly with farmers in their region. Block grants build capacity at the local level and provide more integrated technical assistance to local producers.

HSP grants serve to incentivize and de-risk the implementation of healthy soils practices. The program currently funds 27 different practices based on USDA NRCS "conservation management practices." The outcomes of practices are quantified using the Healthy Soils Quantification Methodology developed by CARB and estimations of future GHG benefits from the Comet Planner Tool (developed in collaboration with USDA, Colorado State University, and CARB). To be funded, a practice must have been shown to reduce GHG emissions.

Within the program, the most commonly selected practices have been compost application, cover cropping, and hedgerow planting.

To help support applicants interested in applying for the program, HSP provides grants to technical assistance providers (TAPs) and UC Community Education Specialists (CES) to assist interested applicants with their applications. This TAP/CES network assistance continues through the entire life of the grant, free of charge to the applicants and grantees. The partnership HSP has had with the TAP/CES network has been beneficial to

[235] California Natural Resources Agency. (2024, April 22). Californias NBS Climate Targets 2024. California Natural Resources Agency. https://resources.ca.gov/-/media/CNRA-Website/Files/Initiatives/Expanding-Nature-Based-Solutions/Californias-NBS-Climate-Targets-2024.pdf

applicants, grantees, and HSP staff alike and has been critical to the success of the program. (*See* Chapter 1, *Foster a Robust and Sustainable Agricultural Economy* for further discussion.*)*

While HSP primarily supports the implementation of established practices, its Demonstration Grants also support research into experimental practices that have not been sufficiently studied for CARB to model their GHG reduction benefits. Demonstration grantees collect on-farm GHG emissions data, crop yield, and soil water parameters, such as soil water infiltration and aggregate stability. They also host field days so that their projects serve as demonstration sites where farmers and ranchers can see practice implementation methods in action and ask questions. The theory of change is that facilitating this interface between researchers, experienced farmers, and potential adopters will better prepare farmers and ranchers for practice adoption.

Regional Planning

At the regional level, many local governments are working on healthy soils efforts through the planning and implementation of Climate Action Plans. These are efforts implemented by counties and cities to influence and reduce GHG emissions sources within their jurisdictions, to help the state achieve its climate goals outlined in CARB's 2022 Scoping Plan. To help guide plan development, CARB has created a Climate Action Planning resource guide for local governments in order to design plans that best meet their regional needs, including a step-by-step guide for climate action planning and a Climate Action Plan map showing the ongoing local governments' efforts already in place to help mitigate climate change.[236] While climate action plans have historically focused only on emissions reductions, some counties have begun representing climate-smart agriculture and carbon sequestration into their plans. Examples include the San Mateo County Community Climate Action Plan (CCAP), San Diego County Climate Action Plan, the Yolo County Climate Action and Adaptation Plan, and the Marin County Climate Action Plan. The Marin County RCD receives sales tax money that it puts towards healthy soils practices on farms and ranches, directly influenced by the inclusion of agriculture in their county climate action plan. Other counties are working on developing similar programs as well, also made possible by the inclusion of agriculture and agricultural carbon sequestration in their county climate action plans.

Some regional air districts incentivize practices through their own grant programs - practices which have benefits to the farmer, air quality, and soil health. The San Joaquin Valley Air Pollution Control District, for example, runs an Ag Burn Alternative

[236] Climate Action Planning. (2022). California Air Resources Board. https://ww2.arb.ca.gov/our-work/programs/local-actions-climate-change/climate-action-planning

Grant Program, which funds several management practices, including whole orchard recycling (WOR). Also incentivized by CDFA's Healthy Soils Program, this practice involves reincorporating ground-up trees back into the soil via on-site grinding or chipping of whole trees during orchard removal and subsequent incorporation of the biomass into the topsoil. This process adds back the carbon from the trees into the soil to bolster soil organic matter.[237]

Additionally, at the local level, NGOs and special districts play an important role in facilitating the adoption of healthy soils practices. As just one example, a network of "Regional Carbon Farming Hubs" have been developed across California by collaborations of RCDs and through the partnership of the California Association of Resource Conservation Districts (CARCD) and the nonprofit Carbon Cycle Institute. There are seven of these "hubs" that are working to accelerate adoption and scaling of carbon farming in California through strategic stakeholder engagement and coordination, education and outreach, regional and statewide needs assessments, and funds development.

Federal Efforts

At the federal level, recent policy changes have shifting funding priorities and sources regarding soil health practices. The 2022 Inflation Reduction Act (IRA) directed federal efforts and resources towards addressing climate change through several investment programs, including agriculture and conservation programs. Two long-running federal programs received funding through IRA - The National Resource Conservation Service's (NRCS) Environmental Quality Incentives Program, known as EQIP, and the Conservation Stewardship Program (CSP). These programs work with producers to develop or update conservation plans for their operations and can provide financial assistance for implementation. These conservation plans can help address on-farm resource issues and have environmental benefits such as improving soil health. These two programs NRCS programs are expected to continue, but now under Farm Bill with apparent increases in funding per year and increased minimum payments for CSP.[238] Total IRA funding for conservation will decrease by 1.795B.[239] Soil monitoring programs from previous administrations are under review and appear to not have funding

[237] Wolff, M., Guo, L., & Gunasekara, A. (2020, February 27). Whole orchard recycling (WOR) inclusion in the CDFA Healthy Soils Incentive Program. California Department of Food and Agriculture. https://www.cdfa.ca.gov/oefi/healthysoils/docs/CDFA_WOR_Report.pdf

[238] Arrington, J. (2025). Text - H.R.1 - 119th Congress (2025-2026): One Big Beautiful Bill Act. Congress.gov. https://www.congress.gov/bill/119th-congress/house-bill/1/text; Conservation Stewardship Program. (n.d.). Natural Resources Conservation Service. https://www.nrcs.usda.gov/programs-initiatives/csp-conservation-stewardship-program

[239] Wang, M., & Gammans, M. (2025, July 4). The One Big Beautiful Bill's USDA Conservation Spending Shuffle. Agricultural Risk Policy Center; NDSU. https://www.arpc-ndsu.com/post/the-one-big-beautiful-bill-s-usda-conservation-spending-shuffleming

attached as of now.[240] Additionally, some funds like Trade & Ag Research Funding Boosts could be used for climate-resilient crops.[241]

[240] Soil Carbon Monitoring and Research Network. (n.d.). Natural Resources Conservation Service. https://www.nrcs.usda.gov/about/priorities/inflation-reduction-act/soil-carbon-monitoring-and-research-network

[241] Farmers: Don't Miss What's in the Big Beautiful Bill. (2025, July 13). Morning Ag Clips. https://www.morningagclips.com/farmers-dont-miss-whats-in-the-big-beautiful-bill/

10.2 Create and standardize methodologies for measurement and tracking of soil health properties in connection with soil health practices over time.

While the state is working to increase soil health, there is a need for new and standardized methodologies to track these efforts.

10.2.1 Adopt long-term measuring and monitoring of practice implementation impact, including multisystem indicators, such as water data metrics.

Goal 2: Enhance Program Effectiveness

Long Term Soil Organic Matter and Soil Health Data Collection

Many healthy soils practices build or protect soil organic matter. The current requirement under HSP is that each grantee collect soil organic matter (SOM) measurements from project fields prior to practice implementation each year and then one year after the end of the grant term – 4 years of measurements to monitor the changes of the soil organic matter over the term of the funded project. The primary goal of this data collection is to familiarize recipients with monitoring their soil health. However, research has shown that while soils with lower SOM may see changes within 3-5 years, larger SOM changes may take 7-10 years, or even longer, to become apparent. Additionally, early HSP SOM data is inherently variable due to inconsistencies in sampling methods, sample locations, and different laboratories used to conduct the analyses.[242] A goal of the HSP in coming years is to standardize SOM data collection and analyses, and to start sampling from long term adopters of HSP practices to have longitudinal data sets looking at SOM changes. Alongside that, seeing that much progress has been made in recent years in the definition and analysis of soil health, HSP is launching a pilot effort to measure soil health changes, which are more likely to be measurable over the course of three years, and are more likely to be of direct interest to farmers.

[242] California Department Of Food And Agriculture (CDFA) Environmental Farming Act Science Advisory Panel. (2023, November 9). cdfa.ca.gov; Office of Environmental Farming and Innovation.. https://www.cdfa.ca.gov/oefi/efasap/docs/2023/20231109_efa_sap_minutes.pdf

HSP Demonstration Grants Soil Water Metric Data Collection

The passing of the Sustainable Groundwater Management Act has put a greater focus on on-farm water usage and conservation. In response to this growing concern, as of 2023, HSP requires soil water data metrics to be collected through the Demonstration Grant projects. These parameters include soil water infiltration, aggregate stability, and soil water content. The desired goal for these additions is to provide insight into the water savings of healthy soils practices.

Long-term Adoption and Affordability for Healthy Soils Practices

The HSP at its core promotes the adoption of healthy soil practices and works to incentivize first-time implementation. As discussed earlier in this chapter, soil health benefits may not be realized within the three years of the grant term, and longer adoption of the practices may be needed to see significant soil health benefits. CDFA is investigating the mechanisms and financial benefits to encourage long term adoption of practices. This could include research into the market affordability of organic vs. synthetic inputs, particularly regarding on-farm composting, as composting continues to be the most implemented practice within the HSP. Lastly, as discussed later, incentive programs that target adoption are benefited by coordinated public actions to make technical assistance, appropriate soil amendments, planting stock, and machinery accessible and affordable to farmers over the long term.

10.3 Expand inclusivity of soil health programs.

The management of soil health is complex and has historically been studied and incentivized for conventional and organic agricultural improvements. However, urban land managers are also very interested in healthy soils, and programs like HSP and EQIP have not historically recognized practices used by tribal communities that support soil health. Outlined below are action opportunities CDFA has identified to promote and invest in climate-smart agriculture practices related to soil health to reach a wider audience.

10.3.1 Identify land eligibility requirements that enable expanded participation in the Healthy Soils Program and work to determine solutions to expand eligibility.

Goal 2: Enhance Program Effectiveness

To be eligible for HSP, producers must own or lease the land they are farming. In an effort to expand eligible participants, the Healthy Soils Program recently updated leasing requirement to allow for lessees with lease terms shorter than the program duration to be eligible. Future expansions of land eligibility could include expanding the definition of agricultural operation to be more inclusive to Indigenous food production practices.[243] Examples for expanded inclusion within existing CDFA programs include the Farm to School Incubator Grant Program, where eligible producers can be a person, group of individuals, non-profit organization, or California Native American tribe that leases, rents, or owns land in California (whether the land is publicly owned, privately owned, or tribal land) and cultivates crops, raises livestock, and/or uses Indigenous food production practices on this land, and/or a California seafood harvester.[244]

[243] HEALTHY SOILS PROGRAM INCENTIVE GRANTS. (2024, January 22). cdfa.ca.gov; Office of Environmental Farming and Innovation. https://www.cdfa.ca.gov/oefi/healthysoils/docs/2024/2024_hsp_incentives_rga2.pdf

[244] 2023-24 California Farm to School Incubator Grant Program: Track 4. (2023). California Department of Food and Agriculture. https://www.gotomygrants.com/Public/Opportunities/Details/7060a7bd-8e00-4c25-88e5-446260a9df06

10.3.2 Create quantification methodologies for holistic soil health practices and Traditional Ecological Knowledge practices for expanded eligible practices under the Healthy Soils Program.

Goal 2: Enhance Program Effectiveness

HSP incentivizes 27 different conservation management practices, and 11 experimental practices through Demonstration Grants. These practices must sequester carbon and/or reduce GHG emissions to be incentivized by the program, a requirement that is crucial in years that the program receives funding from the Greenhouse Gas Reduction Fund. As the program evolves, there have been requests from the agricultural community to include practices in the program that have Native American tribal significance. For example, CDFA is currently working with CARB to analyze a potential quantification methodology for cultural burning. This practice has been shown to boost soil carbon and nitrogen and reduce soil density, improving soil health.[245] Adoption of cultural burning, and other Traditional Ecological Knowledge practices would incorporate land management solutions in practice by tribal communities in such a way program outcomes could be more equitable and expand the program's eligibility.

[245] Dosseto, A., Haynes, K., Brook, L., Channell, V., & The Conversation. (2024, March). Cultural knowledge key to understanding Australian soils. Phys.org. https://phys.org/news/2024-03-cultural-australian-soils.html

10.4 Promote technical assistance for healthy soil practices and ensuring successful implementation.

Farmers and ranchers may need support to incorporate new practices promoting soil health into their agricultural operations. This support can come from both regional technical assistance and also from the state. TA providers also serve the agricultural community by building awareness of healthy soils practices, disseminating knowledge about how to implement practices, connecting farmers with resources, and assisting them through adaptive management decisions.

10.4.1 Utilize technical assistance to help growers understand their soil and crop nutrition to make smart growing decisions regarding fertilizer use.

Goal 1: Increase and Enhance Technical Assistance

Establishing trusted connections with local technical assistance providers can be critical for successful implementation. Technical assistance providers may teach farmers and ranchers implementation techniques and practices themselves or also often facilitate knowledge sharing among producers to learn from each other. Many technical assistance providers provide their services for charge, including Certified Crop Advisors and agricultural Pest Control Advisors. Other organizations often provide technical assistance free of charge to growers, including UCANR Community Education Specialists, statewide Resource Conservation Districts, regional Climate Hubs, and non-profit organizations are all examples of current technical assistance providers that offer these services.[246] However, these organizations also have limited capacity and would benefit from increased investment. (*For more information on how technical assistance can help build climate resilience in agriculture, see Chapter 1, Foster a Robust and Sustainable Agricultural Economy.)*

[246] Carbon Cycle Institute. (n.d.). What is Carbon Farming? | Carbon Cycle Institute. Www.carboncycle.org. https://www.carboncycle.org/what-is-carbon-farming

10.4.2 Promote and disseminate information for TA providers to assist with regional climate-appropriate crop and agriculture processes.

Goal 5: Demonstrate and Invest in Innovation and Technology

Farmers and ranchers make important decisions every day when developing their agricultural operations, and CDFA and its sister agencies utilize research findings to promote management decisions that boost soil health and are appropriate for local conditions for a grower. Continued and expanded promotion of the following practices can help address local environmental goals and support biodiversity, both of which contribute to healthy soils:

Promoting the planting of crops in agricultural systems that fit local soil and water sustainability goals. For example, the Delta Protection Commission and Delta Conservancy are promoting the planting of rice within the Delta to slow subsidence, reduce greenhouse gas emissions, and provide habitat for migratory birds. DWR and the Delta Conservancy are additionally exploring the potential for wetland biomass harvesting, or paludiculture, as a potential agricultural practice that generates revenue, reverses subsidence, and sequesters carbon.

Promoting climate resilience for soil health and biodiversity (above and below ground), through the incorporation of traditional ecological knowledge practices and the planting of native and non-native pollinator plant species. CDFA Healthy Soils Program is currently working with tribal communities to expand its quantification methodology to include traditional ecological practices.

CDFA's Fertilizer Research and Education Program provides educational opportunities to help farmers and ranchers adequately predict the contributions from amendments to their crops' nutrition in a timely fashion for fertilization decisions.

10.5 Ensure the availability of high-quality compost for agricultural operations statewide.

Compost is not the only organic amendment that is useful in agricultural soils, but it is an important tool for improving soil health and increasing organic matter and an important tool for cycling carbon and nutrients through the agroecosystem and food system. California is poised to develop a steady stream of compost that will provide vital nutrients to soils and reduce the need for petroleum-based and imported fertilizers. There are a number of challenges to overcome; however, the availability of high-quality compost can increase through ensuring compliance with regulations and standards, implementation of best management practices at compost facilities, and adequate testing and monitoring. Prioritizing education and outreach regarding collection programs to maximize participation and reduce contamination as well as infrastructure to remove contamination pre- and post-processing are other ways to support clean feedstocks entering the composting process.

The importance of Compost

Compost is a biologically stable soil amendment that can be used to build soil health and provide nutrients to plants.[247] Creating compost requires a controlled process of decomposing organic (carbon-based) materials in an aerobic (oxygen-required) environment using microorganisms. The organic materials can include food waste, crop byproducts, biomass from forest management, and Municipal green waste such as grass clippings, leaves, and yard and tree trimmings. Microorganisms, which are naturally present, feed on organic materials during the composting process, using nitrogen to grow and reproduce, water to digest materials, and oxygen to breathe.[248] When properly managed, the activity and growth of microbes causes the compost to heat up to temperatures beyond 131 degrees F, killing pathogens and weed seeds in the process.

Compost can be created at a variety of scales. Compost can be created at home using food scraps, leaves, and plant material from the yard. Private companies, cities, and counties operate large-scale facilities to create compost using food scraps and green waste collected from urban and suburban waste management customers. Farmers can create compost on-farm, using organic materials left behind after harvest or food processing.

[247] Environmental Protection Agency. (2025, April 15). Composting At Home. US EPA. https://www.epa.gov/recycle/composting-home

[248] Environmental Protection Agency. (2025, April 15). Composting At Home. US EPA. https://www.epa.gov/recycle/composting-home

Compost has a number of attributes that make it a highly desirable soil amendment. Finished compost is:

- Reduced of potential contaminants, such as pathogens, pests, and viable weed seeds, because of the heat produced during the composting process;
- Considerably lighter than its original materials, making it more transportable;
- A soil "conditioner" that can increase water retention, soil organic matter, and workability;
- Relatively odor-free;
- Stable over a few months in the open, even if exposed to rain;
- High-carbon and rich in micro-and macronutrients;
- Relatively slow to break down in soil, releasing nutrients to crops gradually ;
- Widely shown to increase biological activity in soils; and
- A much lower emitter of GHGs than most alternative disposal methods for organic wastes.

California agriculture currently consumes about 2/3 of municipal compost statewide and is well-positioned to utilize most of the state's future compost production. It is predominantly used in organic farming operations, although conventional growers are increasingly applying compost.[249] Compost is one of the most popular practices funded by the Healthy Soils Program, and the majority of HSP awardees who use compost cite improved soil structure and partial replacement of fertilizers as benefits.

This is good news for the state's climate efforts, because the creation and utilization of compost is also a critical strategy for reducing methane from landfills. Until recently, Californians disposed of food waste in their normal trash cans, which meant that those food scraps ultimately ended up in landfills where it was buried and decayed, releasing methane gas, a potent greenhouse gas. In 2016, the California legislature passed SB 1383, which focuses on the reduction of short-lived climate pollutants including methane, principally by reducing organic waste disposal in landfills. CalRecycle is one of the lead agencies implementing SB 1383, and its programs include requiring jurisdictions to begin diverting organic waste from landfill-bound waste streams.

SB 1383 built on prior legislation, AB 1981 of 2018, which requires CalEPA, CalRecycle, SWRCB, CARB, and CDFA to develop and implement policies to aid in diverting organic waste from landfills by promoting the composting and the appropriate use of that

[249] Abbs, A., & Reul-Chen, C. (2018, August). Composting in California: Addressing air quality permitting and regulatory issues for expanding infrastructure. California Air Pollution Control Officers Association & California Air Resources Board. https://californiacompostcoalition.org/mobius/wp-content/uploads/2022/01/CA-Compost-Comments-2018.pdf

compost throughout the state, and to achieve the goal of reducing by at least 5 million metric tons of GHGs per year through the development and application of compost on natural and working lands (which includes agricultural and forest lands).

These legislative actions drive healthy soils efforts by directing the production, use, and funding of compost (on and off-farm composting facilities), which is the principal organic soil amendment used by farmers.

10.5.1 Support local jurisdictions in investing in organics diversion infrastructure including food and green waste processing.

Goal 2: Enhance Program Effectiveness

To meet SB 1383 waste diversion goals, counties and local jurisdictions are investing in planning and infrastructure to produce compost on a large scale.[250] CalRecycle provides overarching guidance and permitting for compostable material handling facilities and operations, including type and amount tiers that have specific regulations.[251] Additional permitting for compost facilities comes at the local level through water and air boards. Recent legislation has improved the process for local jurisdictions so that each jurisdiction's plan can be catered to the population size and existing diversions. AB 2346 (Lee, 2024) modifies the process set by SB 1383, authorizing local jurisdictions to:

1) Set per capita targets based on local studies on waste characterization,
2) Allow for investments in infrastructure and equipment to count towards recycled organic waste product procurement goals,
3) Expand compost procurement sources to include compost from community composters, vermicompost and mushroom compost, and mulch from tree trimming and recovered edible food, and
4) Allow the consideration of other pathways to prioritize local use of compost. CalRecycle is also providing training materials, tools, and guidance documents for local jurisdictions to facilitate this process.

[250] CalRecycle. (n.d.). Capacity Planning. CalRecycle Home Page. https://calrecycle.ca.gov/organics/slcp/capacityplanning/

[251] CalRecycle. (n.d.-b). Permitting Compostable Material Handling Facilities and Operations. CalRecycle Home Page. Retrieved August 7, 2025, from https://calrecycle.ca.gov/swfacilities/permitting/facilitytype/compost/#Tier

10.5.2 Provide guidance for choosing and applying compost.

Goal 1: Increase and Enhance Technical Assistance

Compost consists of many feedstocks from various sources, and with the rise in popularity of using compost and incentivization from Federal, State and local programs, it is critical that compost meets state quality standards before land application. CalRecycle sets standards for, and permits, compost production facilities to ensure potential contaminants such as weeds, pests, pathogens, and other contaminants are reduced. CalRecycle provides resources to the public through their SWIS Website and Map of composters to find permitted compost facilities, as well as resources on composting at all scales. The Association of Compost Producers (ACP) also provides resources to users to source compost with US Compost Council's Seal of Testing Assurance. For organic amendments, CDFA registers organic and fertilizing input materials, including organic composts, through the Fertilizing Materials Inspection Program and the Organic Input Material Program. CDFA's Healthy Soils Program is currently working to help ensure, and incentivize, quality compost is used on agricultural land, and other state agencies such as RCD's and UC ANR can help provide education to farmers and ranchers to make the best choices for their soils and crops and to set guidance for compost quality.

10.5.3 Continue state agency coordination to clarify on-farm composting regulations.

Goal 3: Grow Partnerships and Collaboration

Currently on-farm compost production is limited by the amount of compost and feedstocks held on-site, the amount of compost allowed to be sold or given away annually, and the source of the materials. To increase these amounts can require intensive permitting process, and coordination between local Air Districts, LEAs, and Water Boards, that can deter those interested. In an effort to increase local bioeconomies and improve efficiency of on-farm waste management, state agencies and legislators are currently working on clarification and updates for on-farm composting, including assurances for food safety and implementation functionality.

10.5.4 Identify compost and digestate research gaps and support research to address gaps.

Goal 5: Demonstrate and Invest in Innovation and Technology

There are significant research gaps that should be identified and addressed with broad state agency coordination. More research is needed to further assess composting infrastructure development and future compost availability to agriculture that takes into account available feedstocks, transportation costs (both in terms of dollars and greenhouse gas emissions), and locations of potential demand. For example, more than half of the population of California lives in a group of southern counties that contain about 10 percent of the state's cropland, and less of its grazing land. If the valuable green-and food-wastes from these counties are to be used for agriculture, it may become necessary to support transport of some of these resources to more northern counties as compost and optimize compost production with respect to the spatial distribution of feedstock sources and their carbon/nitrogen composition.

Scientific subjects requiring study include the remediation of contaminants, the use of biosolids, the processing of food waste in wastewater treatment plants, and recapture of organics from digester slurries. Then, research aimed at regulatory improvements could compare compost's GHG, VOC, and ammonia emissions with likely alternative fates, which is often not done.

Soils in Urban Environments

Soils within the urban or "built" environment can vary dramatically and are often influenced by the environment itself – including human-transported materials, chemical contamination, or layers impervious to water infiltration. These soils are found throughout the urban landscape in vegetated, landscaped areas, and urban gardens.[252] Despite the number and variety of inputs urban soils may receive, they can still harbor high levels of biodiversity: a 2017 study found the incidence of springtails (soil mesofauna) was eight times more abundant in an urban vegetable garden than in some agricultural environments.[253] However, these soils can be shallow in comparison to their agricultural counterparts, so organisms must adapt to life on the surface, which makes the protection and development of these soils all the more important.

While the incorporation and development of "green" (plants) and "blue" (water) corridors are now common fixtures in urban planning design, the development of "brown" (soil) corridors should be considered to support soil health in our urban environments. The management of urban soils, and the improvement of their health, goes hand in hand with reduction of heat islands, the provision of safe local food in disadvantaged urban communities, and flood risk mitigation.

[252] ScienceDirect. (2019). Urban soils. ScienceDirect. https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/urban-soils

[253] Joimel, S., Grard, B., Vieublé Gonod, L., Chenu, C., & Waine, O. (Trans.). (2024, April 2). How cities function ecologically: The importance of urban soils. Metropolitics. https://metropolitics.org/How-Cities-Function-Ecologically-The-Importance-of-Urban-Soils.html

Implementation

Strategy/ Action	Goal Alignment	Lead Agency	Status	Implementation Phase
10.1 Encourage the adoption of climate-smart and healthy soils practices to bolster California's lands against the impacts of climate change.				
10.1.1 Coordinate state agency efforts to improve soil health.	Goal 3: Grow Partnerships and Collaboration	CDFA, CalEPA, DWR, DSC, Delta Conservancy		
10.1.2 Facilitate the adoption of climate-smart and healthy soils practices by farmers, ranchers, and private landowners.	Goal 2: Enhance Program Effectiveness	CDFA, CARB, CARCD, USDA	Local governments	
10.2 Create and standardize methodologies for measurement and tracking of soil health properties in connection with soil health practices over time.				
10.2.1 Adopt long-term measuring and monitoring of practice implementation impact, including multisystem indicators, such as water data metrics.	2: Enhance Program Effectiveness	CDFA		
10.3 Expand inclusivity of soil health programs.				
10.3.1 Identify land eligibility requirements that enable expanded participation in the Healthy Soils	2: Enhance Program Effectiveness	CDFA		

Program and work to determine solutions to expand eligibility.				
10.3.2 Create quantification methodologies for holistic soil health practices and Traditional Ecological Knowledge practices for expanded eligible practices under the Healthy Soils Program.	2: Enhance Program Effectiveness	CDFA		
10.4 Promote technical assistance for healthy soil practices and ensuring successful implementation.				
10.4.1 Utilize technical assistance to help growers understand their soil and crop nutrition to make smart growing decisions regarding fertilizer use.	1: Increase and Expand Technical Assistance	CDFA		
10.4.2 Promote and disseminate information for TA providers to assist with regional climate-appropriate crop and agriculture processes.	5: Demonstrate and Invest in Innovation and Technology	CDFA	Delta Conservancy, DPC	

10.5 Ensure the availability of high-quality compost for agricultural operations statewide.				
10.5.1 Support local jurisdictions in investing in organics diversion infrastructure including food and green waste processing.	2: Enhance Program Effectiveness	CalRecycle		
10.5.2 Provide guidance for choosing and applying compost.	1: Increase and Expand Technical Assistance	CalRecycle	CDFA	
10.5.3 Continue state agency coordination to clarify on-farm composting regulations.	Goal 3: Grow Partnerships and Collaboration	CalRecycle, CDFA, EPA		
10.5.4 Identify compost and digestate research gaps and support research to address gaps.	5: Demonstrate and Invest in Innovation and Technology	OPC, DTSC, USDA, EPA		

Chapter 11. Improve Ranching Sustainability and Rangeland Management

Key Objective: Utilize climate-smart and emissions-reducing agricultural practices to promote resilience ranching and rangeland management.

Context

Livestock grazing is one of the most extensive uses of agricultural land statewide. In California, 32 million acres of state, federal, and private land are used for livestock grazing.[254] "Livestock" may refer to cattle, sheep, goats, llamas, alpacas, and other species.

Land suitable for grazing, which is uncultivated (not tilled, irrigated, or fertilized) and dominated by grasses and shrubs, is referred to as rangeland.[255] In California, there are a number of additional landscape types beyond grasslands and shrublands (i.e., rangeland) that support grazing, including irrigated pasture, forested lands, and perennial croplands.

As of 2020, California had roughly 1.8 million beef cattle, with cattle grazing happening in almost every county in California, though eighty percent of herds consist of under 200 cows.[256] The state is also the second in the nation for sheep and lamb production, with around 600,000 animals.[257] Drought, land use change, and wildfires threaten the ranching industry – driving the urgency for climate resilient and multi-purpose grazing and rangeland management in California.[258]

At the same time, methane emissions from non-dairy livestock constitute approximately 11 percent of the state's methane emissions.[259] As discussed in this strategy, California

[254] Cole, S., Hanak, E., & Peterson, C. (2024). *Agricultural Land Use in California*. Public Policy Institute of California. https://www.ppic.org/wp-content/uploads/agricultural-land-use-in-california.pdf

[255] Rangeland Systems. (2017). In D. D. Briske (Ed.), *Springer Series on Environmental Management*. Springer International Publishing. https://doi.org/10.1007/978-3-319-46709-2

[256] California Cattle Council. (n.d.). *Getting to Know California's Ranching Families*. California Cattle Council. https://static1.squarespace.com/static/61845798cdfe5046e1f596e5/t/659ef5533051ca19b316ce40/1704916309025/Foundation-getting+to+know+california%27s+ranching+families%5B17%5D.pdf

[257] Saitone, T. (n.d.). *Livestock and Rangeland in California Chapter 9. Livestock and Rangeland in California*. University of California Giannini Foundation of Agricultural Economics. https://s.giannini.ucop.edu/uploads/giannini_public/94/c1/94c100fd-9626-47d4-8b82-0bfdb1081a57/livestock_and_rangeland.pdf

[258] Roche, L. (n.d.). *Building climate resilience across California's rangelands*. UC Davis. https://rangelands.ucdavis.edu/sites/g/files/dgvnsk13956/files/media/documents/RRSS2025_ROCHE_reduced.pdf

[259] California Air Resources Board. (2024). *2000-2022 GHG Inventory (2024 Edition)*. GHG Current California Emission Inventory Data. https://ww2.arb.ca.gov/ghg-inventory-data

has set a target to reduce methane emissions from dairy and livestock sectors 40 percent below 2013 levels by 2030 as mandated by Senate Bill 1383 (Lara, 2016). Non-dairy livestock emissions present unique challenges, as will be discussed below.

Rangeland Ecosystem Health

As discussed in the introduction to this strategy, geologic history and precipitation patterns play a primary role in establishing baseline soil conditions across all lands, including ecosystems used for grazing in California.[260] Research has shown that the presence of grazing can positively affect soil carbon in California soils with higher clay content, but more work is still needed to understand the effects of grazing on soil carbon in specific circumstances.[261] A growing body of research finds that specific grazing practices like adaptive multi-paddock grazing can increase soil organic carbon compared to other grazing practices.[262] Managed grazing can also promote the growth of healthy forage, positively impact species composition and biodiversity, and minimize erosion.[263] Other rangeland practices can also contribute to healthy ecosystems. For example, silvopasture, or the integration of trees into rangelands, can help enhance soil fertility by catching nutrients from dust and rain, through litter inputs, increased soil fauna activity, while also providing shade for grazing animals, which is becoming increasingly important with climate change and heat stress.[264] Managed livestock grazing, in conjunction with other climate-smart agriculture practices, is one method to promote healthy lands and promote durable carbon in the soil and building resilience to climate change.

Strategies and Actions

Climate-smart agricultural practices offer a multitude of benefits – including better soil health, fuel load management, maintaining natural lands, and much more. California is taking a multi-pronged approach to reducing emissions from livestock while bolstering the health of rangelands and sequestering carbon.

---

[260] Biggs, N. B., & Huntsinger, L. (2021). Managed grazing on California annual rangelands in the context of state climate policy. *Rangeland Ecology & Management*, 76, 56-68. https://doi.org/10.1016/j.rama.2021.01.007

[261] Carey, C. J., Gravuer, K., Gennet, S., & et al. (2020). Supporting evidence varies for rangeland management practices that seek to improve soil properties and forage production in California. *California Agriculture, 74*(2). https://doi.org/10.3733/ca.2020a0015

[262] Stanley, P., Roche, L., & Bowles, T. (2025). Amping up soil carbon: soil carbon stocks in California rangelands under adaptive multi-paddock and conventional grazing management. *International Journal of Agricultural Sustainability*, *23*(1). https://doi.org/10.1080/14735903.2025.2461826

[263] Center for Regenerative Agriculture and Resilient Systems. (n.d.). *Regenerative Grazing Systems*. California State University Chico. https://www.csuchico.edu/regenerativeagriculture/regen-ag-systems/regen-grazing-systems.shtml

[264] Carey, C. J., Gravuer, K., Gennet, S., & et al. (2020). Supporting evidence varies for rangeland management practices that seek to improve soil properties and forage production in California. *California Agriculture, 74*(2). https://doi.org/10.3733/ca.2020a0015

11.1 Promote multi-benefit rangeland management

Proactive Grazing Management

While there are many benefits to grazing, poorly managed livestock grazing can cause degradation of the landscape. Overgrazing occurs when the impact of a given number of animals on a piece of land exceeds the land's ability to regenerate native plant and animal communities and maintain baseline biogeochemical function. This should be avoided as it does not allow for proper vegetation recovery and leads to deteriorated lands, bare and compacted soil, weakened root systems, and accelerated erosion.

Carefully managed grazing around riparian areas is especially important as livestock can have a direct impact on water quality. When livestock enter riparian areas, they can increase the amount of sediment and manure entering waterways, as well as increase compaction, erosion, and degradation of vegetation.[265]

Wildfire Mitigation

Proper livestock grazing in conjunction with other land management practices can play a cost-effective role in creating a more resilient ecosystem.[266] One important goal of managed grazing is fuel reduction for wildfire mitigation and to create fuel breaks. Livestock grazing can reduce fire fuels by selectively removing vegetation as the animals graze and incorporate plant matter into the soil with their hooves. Fuel-reduction benefits of grazing will be most pronounced in areas where it can meaningfully lower hazardous fuel loads and where other vegetation management options are limited, such as steep hillslopes and the wildland-urban interface.[267] The selection of appropriate livestock for grazing is dependent on land manager's goals and the type of forage available.[268] Cows with calves tend to prefer grass species and hills with gentle slopes (under 20 percent grades) and feeding within half of a mile of water sources. Yearling cattle, on the other hand, tend to feed longer distances from water and readily utilize areas of steep terrain. Sheep tend to eat forbs, such as clovers, dandelions, and other broad leaf plants. Goats are more likely to eat shrubs followed by forbs and grasses. While goats may be more effective at removing small (less than an

---

[265] Davies, K. W., Boyd, C. S., Bates, J. D., Svejcar, L. N., & Porensky, L. M. (2024). Ecological benefits of strategically applied livestock grazing in sagebrush communities. *Ecosphere, 15*(5), e4859. https://doi.org/10.1002/ecs2.4859

[266] Ratcliff, F., Rao, D., Barry, S., Dewees, S., Macaulay, L., Larsen, R., Shapero, M., Peterson, R., Moritz, M., & Forero, L. (2022). Cattle grazing reduces fuel and leads to more manageable fire behavior. *California Agriculture*, *76*(2-3), 60–69. https://doi.org/10.3733/ca.2022a0011

[267] Rao, D. (2020, August). *Benefits of Cattle Grazing for Reducing Fire Fuels and Fire Hazard*. University of California Agriculture and Natural Resources. https://ucanr.edu/blog/livestock-range/article/benefits-cattle-grazing-reducing-fire-fuels-and-fire-hazard

[268] UCCE Sonoma County. (n.d.). *Grazing Management Fact Sheets*. University of California Agriculture and Natural Resources. https://ucanr.edu/county-office/ucce-sonoma-county/grazing-management-fact-sheets

inch) woody material, cattle are more effective at removing grassy fuel. In addition, animals do not consume all plants equally which can lead to a shift in plant species if overgrazed, reinforcing the need to properly manage rangelands and grazing animal amounts.[269] In areas where grazing has been removed, encroachment of shrub cover often increases, which can significantly increase fire risks.[270]

11.1.1 Facilitate grazing on public lands for ecological health and fuel load reduction.

Goal 2: Enhance Program Effectiveness

Continuing efforts to promote grazing for fuel reduction and other environmental benefits, especially on public lands, the Board of Forestry and Fire Protection convenes the Range Management Advisory Committee (RMAC) to provide guidance to CDFA, CNRA, EPA, and the Board of Forestry and Fire Protection to promote rangeland resilience and help address resource challenges and management in rangelands. This committee led the creation of an informational document, Prescribed Herbivory for Vegetation Treatment Projects. This document outlines how the intentional use of livestock to remove, rearrange, or convert vegetation in wildlands, including rangelands, to reduce the impacts of wildfires and enhance ecosystem functioning. Recently the RMAC approved a State Lands Grazing Packet to provide guidance for state lands grazing agreements to help streamline and standardize the application process. The guidance packet is designed to help ensure sustainable grazing operations and achieve local environmental goals (Livestock Grazing Management Resources), but it does not explicitly focus on fuels reduction projects. Expanding on the guidance packet, SB 675 (Limon, 2024) requires the RMAC to develop guidance for local or regional prescribed grazing plans – as of Summer 2025, this work is ongoing.[271]

CDFW leases state lands for grazing to help with excess vegetation management. This process provides ranchers access to state-owned land for their livestock grazing while also helping to maintain ecosystem health. Additionally, CalFIRE's California Vegetation Treatment Program utilizes prescribed herbivory, which is the targeted grazing by

[269] Frost, R., & Mosley, J. (2016, April). *Introduction to grazing management*. Rangelands Gateway. https://rangelandsgateway.org/topics/uses-range-pastureland/introduction-grazing-management

[270] Davies, K. W., Vavra, M., Schultz, B., & Rimbey, N. (2014). Implications of longer term rest from grazing in the sagebrush steppe. Journal of Rangeland Applications, 1, 14-34. https://www.fs.usda.gov/pnw/pubs/journals/pnw_2014_davies001.pdf

[271] Limon, M. (2023). *Bill Text - SB-675 Prescribed grazing: local assistance grant program: Wildfire and Forest Resilience Task Force.* California Legislative Information. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202320240SB675; 6d-external-stakeholder-resources-sb-675-local-regional-grazing-guidance-prescribed-herbivory.pdf

livestock, to reduce wildland plant populations. While there is a growing market for community and private contracting for grazing to assist with vegetation management, more adoption is always needed, as one third of California is grazed by livestock.[272] Another CDFA program, the Alternative Manure Management Program (AMMP), provides incentive funding for pasture-based management practices in order to decrease methane emissions from manure. AMMP funds the conversion of a non-pasture dairy or livestock operation to pasture-based management and increasing the amount of time livestock spend at pasture at an existing pasture operation. This reduces methane production in manure by creating more aerobic conditions. In 2024, AMMP set aside one million dollars of funding strictly for pasture-based practices. Continued adoption of managed grazing practices is important for the management of rangelands, pasture, and grasslands to lower the risk and impact of forest fires.

11.1.2 Increase the adoption of climate-smart agricultural practices on rangeland.

Goal 1: Increase and Enhance Technical Assistance

Support for the adoption of climate-smart agricultural practices for rangelands requires outreach and technical assistance to increase the awareness of and proper implementation of available practices as well as support for maintenance and long-term adaptive management. For instance, silvopasture, or the integrating of trees with forage crops in pastures, can provide food and shelter for livestock and also windbreaks to help prevent erosion and habitat for building biodiversity. However, it is important to select tree species appropriate for the pasture location and also make sure tree management and grazing plans are aligned so that the animals and young perennial plants can thrive.[273] Boosting the dissemination of information on how to implement silvopasture is needed for successful projects. Lastly, technical assistance with decision making tools can improve implementation of practices and help build the capacity of range managers and ranchers for dealing with climate change.

The state supports the adoption of climate-smart agricultural practices for rangelands through a number of programs. The CDFA Healthy Soils Program (HSP), described in Chapter 10, supports eight climate-smart practices for grazing land including riparian forest buffer planting, silvopasture, hedgerow planting, tree/shrub establishment, windbreak/shelterbelt establishment, compost application, range planting, and prescribed grazing. Range managers can work with technical assistance providers to

[272] Biggs, N. B., & Huntsinger, L. (2021). Managed grazing on California annual rangelands in the context of state climate policy. *Rangeland Ecology & Management*, 76, 56-68. https://doi.org/10.1016/j.rama.2021.01.007

[273] California State University Chico. (n.d.). *Silvopasture – Center for Regenerative Agriculture and Resilient Systems*. Csuchico.edu. https://www.csuchico.edu/regenerativeagriculture/ra101-section/silvopasture.shtml

select practices based on their land management goals, which may include maintaining native plant and wildlife habitat, protecting scenic viewsheds, managing fire fuel loads, managing invasive plant species, and improving soil health.[274]

[274] Huntsinger, L., Bartolome, J. W., & D'Antonio, C. M. (2007). Grazing management on California's Mediterranean grasslands. In M. Stromberg (Ed.), *California grasslands: Ecology and management*, 232-253. University of California Press. https://doi.org/10.1525/california/9780520252202.003.0020

11.2 Conserve and restore rangelands to protect natural ecosystems.

There is a long-standing belief that grazing can negatively impact the environment, and while overgrazing is detrimental, research over the past few decades shows a positive relationship between managed grazing and environmental health. [275] Grassland landscapes, which offer many ecosystem services, are disturbance-dependent and require grazing or fire to remain as such. With shifts in wild ungulate populations, livestock grazing serves an important role in keeping these grasslands as grasslands. As grazed areas decline with land use change and climate pressures, increasing adoption of beneficial grazing and rangeland management practices is critical for both a sustainable ranching industry and also climate resilient and thriving landscapes.

11.2.1 Uplift the role of rangelands in conserving and improving biodiversity, especially in conjunction California's 30 x 30 Initiative.

Goal 1: Increase and Enhance Technical Assistance

In 2022, the state set a goal to protect 30 percent of California's lands and coastal waters by 2030, known as "30x30". The California Natural Resources Agency's Pathways to 30 x 30 highlights 10 strategies for the state to meet its conservation goals for biodiversity. Strategy 9 is to advance and promote complementary conservation measures on areas like rangelands. This can look like utilizing grazing as a tool to manage non-native species or boost native plant and animal populations, especially in those areas where non-native species dominate the landscape.[276] Further restoration and management of areas that are grazed can also create habitat for native species. In 2002, the California legislature enacted the Rangeland, Grazing Land, and Grassland Protection Act and created the California Rangeland, Grazing Land and Grassland Protection Program at the California Wildlife Conservation Board (WCB). The program is designed to promote long-term sustainability of livestock grazing and to ensure continued wildlife, water quality, watershed and open-space benefits to the state from livestock grazing through preventing rangeland, grazing land, and grassland conversion to nonagricultural uses (*for more information on land use and conservation, see*

[275] Wilcove, D., Rothstein, D., Dubow, J., Phillips, A., & Losos, E. (1998). Quantifying Threats to Imperiled Species in the United States. *BioScience*, *48*(8), 607–615. ; Smith Vaughn, L., Panlasigui, S., & Spotswood, E. (2020, October). *San Francisco Estuary Institute*. Www.sfei.org.

[276] Barry, S., & Huntsinger, L. (2021). Rangeland Land-Sharing, Livestock Grazing's Role in the Conservation of Imperiled Species. *Sustainability*, *13*(8), 4466. https://doi.org/10.3390/su13084466

Chapter 6). Elevating the role of rangelands in boosting biodiversity can help bring awareness for implementable actions, preserve rangelands, and support for these actions through various state and partner programs.

11.2.2 Improve riparian areas in rangelands for improved water filtration, flood protection, and habitat connectivity.

Goal 2: Enhance Program Effectiveness

The Wildlife Conservation Board has created the California Riparian Habitat Conservation Program with the mission to develop coordinated efforts aimed at protecting and restoring California's riparian ecosystems. The program offers grant funds to projects, including those that restore riparian vegetation and re-establish floodplain connectivity, riparian area repair, fencing installation to manage livestock, and stream restoration. The California Department of Conservation additionally funded $2.4 million in 2023 through the Working Lands and Riparian Corridors Program to fund watershed restoration planning and implementation projects on agriculture lands in several counties in California. Each grant was given to a local Resource Conservation District to implement plans in specific counties within the state.

Bolstering the information on water source types and locations for prescribed grazing is critical for riparian health in the rangelands and goes hand in hand with program implementation. Livestock require water, and without additional water sources, livestock will seek water in riparian areas, potentially causing environmental damages. Stock ponds on grazing lands can be an important source of drinking water for livestock and other wildlife animals as well as create habitat for endangered species, such as the California red-legged frog and the California tiger salamander.[277] Stock ponds, or man-made ponds designed to be used by both humans and animals, can also promote groundwater recharge and are used by CalFire. These ponds are regulated by the State Water Resources and Control Board and ranchers must comply with all regulations pertaining to their use.[278] Programs which assist with regulatory compliance, but also proper implementation of stock ponds can help protect riparian areas and enable the rancher to better implement a prescribed grazing plan.

[277] Barry, S., Larson, S., & Bush, L. (2015, July). *Understanding Working Rangelands*. University of California Agriculture and Natural Resources. https://ucanr.edu/sites/default/files/2017-07/266367.pdf

[278] Forero, L., Satomi, R., Bali, K., Zaccaria, D., Fulton, A., & Davy, J. (2020, July). *Determining Volume in a Small Pond with a Staff Gauge and Depth-Capacity Curve*. University of California Agriculture and Natural Resources. https://anrcatalog.ucanr.edu/pdf/8681.pdf

11.3 Reduce enteric methane from grazing livestock.

As described above, 11 percent of California's methane emissions are attributable to non-dairy livestock. Methane is produced during the digestive process in ruminant animals. Many people learn in grade school that cows have four stomachs; the rumen is the largest of the four compartments in the stomach of a cow. It serves as a fermentation chamber where bacteria digest food that the cow has eaten and turn them into amino acids and fatty acids, which are essential to the production of milk. As the microbes decompose plant material in the rumen, methane is expelled by the animal through burping. Manure also produces methane as it decomposes, and the amount of methane produced during the decomposition process is strongly influenced by how the manure is managed. Manure from animals grazing in pastures is considered "dry" management *(for information on manure management in dairy systems, see Chapter 12 on Dairy Farming Sustainability)*.[279]

11.3.1 Research and promote novel enteric methane mitigating practices for grazing livestock.

Goal 5: Demonstrate and Invest in Innovation and Technology

California's legislation directed at curbing methane emissions (SB 1383) applies to livestock raised for meat, as well as to dairy cattle (see Chapter 12). Compared with concentrated animal feeding operations, where manure production and enteric methane output are centralized, grazing animals are dispersed across a landscape. This makes addressing methane both from manure and enteric pathways a challenge. This is because enteric emissions solutions that work well in dairy (manure management techniques and feed additives) are harder to implement when the animals and their manure are spread across great distances and they are eating vegetation rather than being fed.

Therefore, non-dairy or less intensive livestock system methane emissions require tailored interventions, many of which are under development now. For the past three years, CDFA and the UC Davis's Clarity and Leadership for Environmental Awareness and Research Center, (or CLEAR Center), and Spark Climate Solutions have organized a global summit, the State of the Science Summit: Reducing Methane from Animal Agriculture. This summit has brought together experts from around the world to describe

[279] Jun, P., Gibbs, M., & Gaffney, K. (n.d.). CH4 and N2O Emissions from Livestock Manure. In *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* . Intergovernmental Panel on Climate Change. https://www.ipcc-nggip.iges.or.jp/public/gp/bgp/4_2_CH4_and_N2O_Livestock_Manure.pdf

and discuss the current state of research, connect the dots between the scientific and regulatory aspects of enteric emissions, and identify opportunities to help the livestock sector meet climate goals.

One very promising solution for addressing enteric methane is selective breeding. Research into genomics shows that methane production is a heritable trait (can be passed from parents to offspring), and breeding and genetics programs are already identifying DNA markers associated with methane production and selectively breeding for lower methane producing cattle.[280]

Other methods for reducing methane emissions from cattle include vaccinations or application of a bolus device (or time-release tablet inserted into the rumen) which reduce the return interval for treating the cow unlike feed management or additives that can reduce enteric methane emissions.[281] Vaccines that create antibodies in the animal's saliva to limit or prevent the development of methanogens, or the methane-producing microbe, in the cow's rumen, have shown promise but more research on effectiveness and side effects is needed before this strategy is incorporated into common practice.[282] Methane-controlling feed additives or bolus are another pathway researchers are pursuing; for grazing animals, it is particularly important that an additive or bolus is effective with one-time application as human interaction with the animals is often limited.[283] For all of these strategies, continued testing and research is needed.

In 2022, CDFA's Office of Agricultural Resilience and Sustainability was appropriated $10 million to fund demonstration trials evaluating additives and dietary modifications that have potential to reduce emissions in the dairy and livestock sector. CDFA's program, the Livestock Enteric Methane Emissions Reduction Research Program (LEMER-RP) made awards in 2023, and research is ongoing. For more information on methane-related research funded by CDFA, please see Chapter 12.

---

[280] UC Davis CLEAR Center. (2024, May). *State of Science Reducing Methane From Animal Agriculture*. UC Davis. https://clear.ucdavis.edu/sites/g/files/dgvnsk7876/files/inline-files/UC-Davis-State-of-the-science-report.pdf; Gonzalez-Recio, O., Scrobota, N., López-Paredes, J., Saborío-Montero, A., Fernández, A., López de Maturana, E., Villanueva, B., Goiri, I., Atxaerandio, R., & García-Rodríguez, A. (2023). Diving into the cow hologenome to reduce methane emissions and increase sustainability. *Animal, 17* (Supplement 2), 100780. https://doi.org/10.1016/j.animal.2023.10078

[281] Fouts, J. Q., Honan, M. C., Roque, B. M., Tricarico, J. M., & Kebreab, E. (2022). Enteric methane mitigation interventions. *Trans Anim Sci*, *6*(2), txac041. https://doi.org/10.1093/tas/txac041

[282] Baca-González, V., Asensio-Calavia, P., González-Acosta, S., Pérez de la Lastra, J. M., & Morales de la Nuez, A. (2020). Are Vaccines the Solution for Methane Emissions from Ruminants? A Systematic Review. *Vaccines, 8*(3), 460. https://doi.org/10.3390/vaccines8030460

[283] Lileikis, T., Nainienė, R., Bliznikas, S., & Uchockis, V. (2023). Dietary Ruminant Enteric Methane Mitigation Strategies: Current Findings, Potential Risks and Applicability. *Animals: an open access journal from MDPI, 13*(16), 2586. https://doi.org/10.3390/ani13162586

Implementation

Strategy/ Action	Goal Alignment	Lead Agency	Supporting	Status	Implementation Phase
11.1 Promote multi-benefit rangeland management.					
11.1.1 Facilitate grazing on public lands for ecological health and fuel load reduction.	2: Enhance Program Effectiveness	CalFIRE, CDFW	CDFA, CNRA, EPA		
11.1.2 Increase the adoption of climate-smart agricultural practices on rangeland.	1: Increase and Expand Technical Assistance	CDFA			
11.2. Conserve and restore rangelands to protect natural ecosystems.					
11.2.1 Uplift the role of rangelands in conserving and improving biodiversity, especially in conjunction with 30 x 30 initiatives.	1: Increase and Expand Technical Assistance	CNRA, WCB			
11.2.2 Improve riparian areas in rangelands for improved water filtration, flood protection, and habitat connectivity.	2: Enhance Program Effectiveness	WCB, DOC, SWRCB			
11.3 Reduce enteric methane from grazing livestock.					
11.3.1 Research and promote novel enteric methane	5: Demonstrate and Invest in Innovation	CDFA			

mitigating practices for grazing livestock.	and Technology				

Chapter 12. Increase Dairy Farming Sustainability

Key Objective: Foster a robust and environmentally friendly dairy industry and reduce methane emissions by 40 percent per SB 1383.

Context

In 2020, California dairies were the single largest contributor to farm gate value in California, with nearly $7.5 billion in economic output. A 2019 report attributed $57.7 billion in direct, indirect and induced economic activity to the California dairy industry, including 180,000 jobs. However, dairies are also among the state's highest emitters of methane and may negatively impact water quality and air quality that must be addressed to protect surrounding communities, the environment, and the long-term viability of the dairy industry itself.[284]

California is taking steps to curb the environmental impacts of the dairy and ranching industries while also promoting sustainability pathways for these industries. Senate Bill 1383 (Lara, 2016) established a methane emission reduction target of 40 percent below 2013 levels by 2030 across several sectors, which includes the dairy and livestock sector. To meet its ambitious climate goals, the state has developed a number of strategies for reducing greenhouse gas emissions each year through waste diversion, manure management, and energy creation.

[284] Office of Agricultural Resilience and Sustainability. (n.d.). *Manure Recycling and Innovative Products Task Force*. Retrieved August 7, 2025, from https://www.cdfa.ca.gov/oars/mrip/

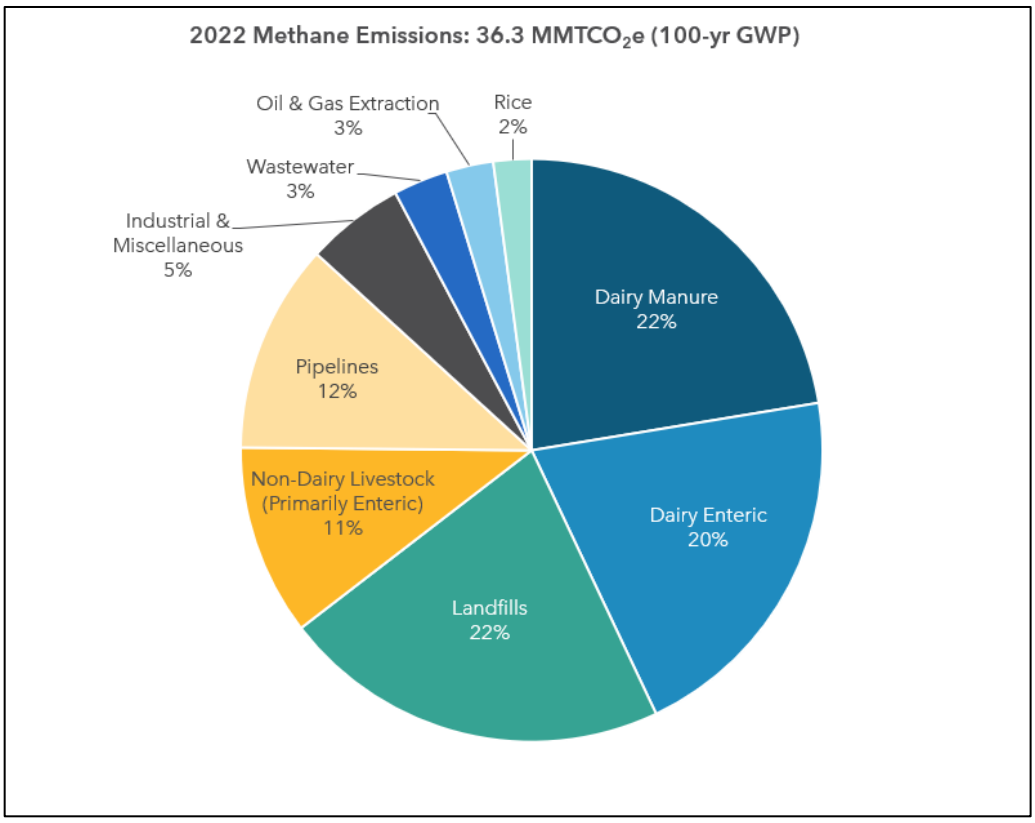


Figure 13: 2022 data from the 2024 edition of the Current California GHG Emission Inventory Data | California Air Resources Board

Methane Reduction

For California dairies, methane reduction presents as one of the greatest challenges but also could present as one of the greatest opportunities for mitigating climate change. Methane is a greenhouse gas with approximately 25 times the warming potential of carbon dioxide over a 100-year period.[285] Ruminants like cows produce methane through their digestive process, known as enteric methane. Manure also produces methane when it is decomposed anaerobically. Nitrous oxide, another greenhouse gas with high warming potential, can also be released during the breakdown of manure after land application when nitrogen is converted into a gaseous form.[286] Dairies and ranches are responsible for about 70 percent (5.7 percent of the state's total emissions)

[285] California Air Resources Board. (n.d.). *GHG Global Warming Potentials*. California Air Resources Board. https://ww2.arb.ca.gov/ghg-gwps

[286] Bernhard, A. (2010). The Nitrogen Cycle: Processes, Players, and Human Impact. *Nature Education Knowledge, 3*(10), 25. https://www.nature.com/scitable/knowledge/library/the-nitrogen-cycle-processes-players-and-human-15644632/

of greenhouse gas emissions attributable to agriculture and represent 44 percent of the state's methane emission budget.[287]

Animal manure (including dairies) contributes an estimated 33 percent of all nitrogen loading to groundwater in parts of California's agricultural regions, with other irrigated agriculture contributing most of the remainder. For dairies, inefficient and/or overapplication of manure to cropland may be a source of N2O emissions, but is also the main source of nitrogen loading, causing nitrate contamination of groundwater drinking sources in many agricultural areas.[288]

Dairy Consolidation

Dairies in the United States and California have been consolidating in recent decades, as the cost of production and declining commodity prices mean that larger dairies, with more efficient cost per cow, are better able to survive.[289] In California, strict air and water quality standards which work to create healthier communities also create compliance challenges that can be better borne by larger operations.[290] The number of dairy farms in California has dropped from almost 1,500 in 2013 to less than 725 in 2022, while the average dairy herd size has increased by more than 200 mature cows per farm in the same period.[291]

Air Quality

There is concern with the environmental impact of dairies, as many of our state's leading counties for dairy production are also among the worst in air quality nationwide.[292] Building resilience within the dairy sector means not only creating sustainable operations across a range of herd sizes, but also operations that minimize air pollution and contribute to building stronger economies and healthier communities.

---

[287] California Air Resources Board. (n.d.). *Current California GHG Emission Inventory Data*. California Air Resources Board. https://ww2.arb.ca.gov/ghg-inventory-data

[288] Frost, R., & Mosley, J. (2016, April). *Introduction to grazing management*. Rangelands Gateway. https://rangelandsgateway.org/topics/uses-range-pastureland/introduction-grazing-management

[289] MacDonald, J. M., Law, J., & Mosheim, R. (2020, July). *Consolidation in U.S. dairy farming*. United States Department of Agriculture, Economic Research Service. https://ers.usda.gov/sites/default/files/_laserfiche/publications/98901/ERR-274.pdf?v=71092

[290] ERA Economics. (2024, September). *Economic Analysis of California Dairy Consolidation, Attrition, and Policy Leakage*. California Cattle Council. https://calcattlecouncil.org/wp-content/uploads/2024/10/2.-ERA_CCC_FinalReport_Sept2024.pdf

[291] California Air Resources Board. (2024, August). *California Dairy Sector Workshop*. California Air Resources Board. https://ww2.arb.ca.gov/sites/default/files/2024-08/CARB_Dairy_Sector_Workshop_Staff_Presentation_08-22-2024.pdf

[292] California Department of Food and Agriculture. (2023). *California Agricultural Statistics Review 2022-2023.* California Department of Food and Agriculture. https://www.cdfa.ca.gov/Statistics/PDFs/2022-2023_california_agricultural_statistics_review.pdf

Strategies and Actions

Strategies to reduce emissions and increase the sustainability of dairy farming represent a great opportunity for the industry. By increasing knowledge and implementation of methane reduction technologies, carrying out additional research to bring new methods, and collaborating across agencies to offer additional revenue streams, CDFA and its sister agencies can assist producers in achieving a more sustainable future for dairy farming.

12.1 Increase knowledge and implementation of currently available methane reduction technologies.

Using a voluntary, incentive-based approach to changing management practices, combined with investments in research and technical assistance and linkages to other market mechanisms, CDFA and its state agency partners have made significant headway in addressing methane emissions from California's dairy and livestock industries.

12.1.1 Promote on-farm manure management strategies at all dairies.

Goal 2: Enhance Program Effectiveness

Alternative Manure Management Program

Within the wide variety of dairy and livestock operations across the state, factors such as size, management style, location and proximity to infrastructure, and economic feasibility can impact the options for manure management systems. CDFA's Alternative Manure Management Program (AMMP) complements its sister program, DDRDP, by providing incentives for a diverse range of non-digester manure management practices that provide options to dairy and livestock operations looking to reduce methane emissions. Eligible practices for AMMP funding are those for which there are current methods to quantify GHG emission reductions, including pasture-based management (such as the conversion of a non-pasture operation to pasture or increasing time animals spend on pasture), alternative manure storage options (such as compost bedded pack barn or slatted floor pit storage manure collection), separation of manure solids in conjunction with drying or composting of solids, and conversion of a flush-based system to a scrape system in conjunction with drying or composting of solids. Where an anaerobic digester might not be practical, operations are still able to reduce manure methane emissions through practices that support the management of

manure solids in a dry form and keep them out of an anaerobic environment, where most methane emissions occur.

As of August 2025, AMMP has funded 193 incentive and demonstration projects for over $122 million since the program was established in 2017. While match funding is not required for AMMP, producers have committed over $29 million for these projects. Collectively, these projects are estimated to reduce 1.61 million $MTCO_2e$ over a five-year period (the calculated lifespan used in the program's Quantification Methodology and Benefits Calculator Tool), or 322,000 $MTCO_2e$ per year. Many AMMP funded projects are located in and provide benefits to disadvantaged and/or low-income communities, that is, approximately 90 percent of the AMMP's 2020 projects and 69 percent of the AMMP's 2022 projects.

Dairy Plus Program

CDFA has partnered with the dairy industry, leveraging state and federal funds to support dairies' efforts in further decreasing methane emissions through advanced manure management practices. To support this effort, the California Dairy Research Foundation (CDRF), in collaboration with CDFA and several other organizations, has been awarded $85 million in funding by the USDA (initially under the Partnerships for Climate-Smart Commodities Program, now reconfigured by the Trump Administration as the Advancing Markets for Producers program), leveraging state funds to match. Over five years (from 2023 - 2028), Dairy Plus will provide incentives for dairy producers to adopt advanced manure management practices, assess GHG emission reduction and nutrient benefits associated with implemented practices, and provide outreach and technical assistance.

The Dairy Plus Program, which represents the largest share of this project, is awarding competitive grants to California dairy farms for the implementation of advanced manure management practices that address both methane emissions and nutrient surplus. Eligible practices for the Dairy Plus Program must have quantifiable GHG emission reductions. This includes practices such as advanced solid-liquid separation through centrifuge, vermifiltration, solid separation through a weeping wall, and solid-liquid separation assisted by flocculants and/or bead filters. The Dairy Plus Program also funds post-processing practices to further utilize manure products, such as the implementation of subsurface drip irrigation and aerated composting infrastructure. Over the course of three funding rounds, the program is providing approximately $75 million in incentive funds to dairy operators interested in pursuing a more comprehensive project than what CDFA supports through AMMP or DDRDP funding alone, addressing both manure methane emission and nutrient surplus (from 2023 to 2025).

Technical Assistance for Dairy Farmers

Technical assistance increases the accessibility of incentive funding to California farmers and ranchers who otherwise may not have the resources or technical expertise to apply for and participate in climate-smart agriculture incentive programs. CDFA's Technical Assistance Grant Program, which provides technical assistance to several climate-smart agriculture programs including AMMP, funds outreach and education, application assistance, assistance with project design, project implementation, and reporting. The goal of the program is to further promote on-farm methane reduction and sustainability regardless of a farm's size and number of staff.

Technical assistance is also provided to participants of the new Dairy Plus Program through a partnership with the California Dairy Research Foundation.

The availability of technical assistance to all applicants and participants of AMMP and Dairy Plus helps ensure farmers and ranchers provided the regional, individual support they may need to apply for and implement climate-smart practices on farms, which can vary greatly in management styles, needs, and feasible solutions.

12.1.2 Increase adoption of anaerobic digesters.

Goal 2: Enhance Program Effectiveness

The most effective technology for reducing methane emissions on dairy farms is the anaerobic digester. Dairy digesters break down manure in an environment without oxygen to produce digestate and methane biogas. Digesters contain the manure during the breakdown process, trapping the methane, preventing its escape to the atmosphere, and using it instead as an energy source, for example, for fuel or for generating electricity. CDFA's Dairy Digester Research and Development Program (DDRDP) delivers some of the most cost-effective GHG emissions reductions on a per-metric ton carbon dioxide equivalent (MTCO2e) basis compared to other California Climate Investment funded programs to date.[293]

To date, DDRDP has awarded $230 million for 143 incentive projects, of which 133 projects are set to produce renewable natural gas (RNG) to be utilized as heavy-duty vehicle fuel, and 10 projects are set to produce electricity either to be utilized on the farm, as fuel for electric vehicles, or as feedstock for the production of hydrogen. Current and former DDRDP recipients have provided approximately $531 million in matching funds, demonstrating their commitment to dedicate resources to

[293] California Climate Investments. (2024, May). *Annual Report to the Legislature on California Climate Investments Using Cap-and-Trade Auction Proceeds*. California Air Resources Board. https://ww2.arb.ca.gov/sites/default/files/auction-proceeds/cci_annual_report_2024.pdf

implement and adopt methane mitigation strategies voluntarily with assistance from CDFA funding. The collective GHG emission reduction estimated from the DDRDP awarded projects is 25.11 million $MTCO_2e$ over 10 years. Of all the funds allocated for the DDRDP, CDFA awarded approximately 69 percent of the funds to projects located in and providing benefits to priority populations, helping to provide jobs, economic, environmental, and financial benefits to local communities and economies.[294] The program requires that all funded projects meet high standards for water quality protection including measures to prevent lagoon seepage and nitrate leaching.

(Left - 4K Dairy, 2018 DDRDP Recipient / Right - Ahlem Farms Dairy Digester Project, 2020, Maas project)

(Left – Compost Bedded Pack Barn with a recently tilled loafing area installed for a 2017 AMMP project. / Middle - Kooistra 2022 AMMP Recipient Manure solid-liquid separator / Right - Windrows for composting separated manure solids at a 2019 AMMP project)

[294] California Climate Investments. (2024, May). *Annual Report to the Legislature on California Climate Investments Using Cap-and-Trade Auction Proceeds*. California Air Resources Board. https://ww2.arb.ca.gov/sites/default/files/auction-proceeds/cci_annual_report_2024.pdf

Dairy Program Co-Benefits

Building resilience for dairy operations includes helping foster productive and healthy communities where they are located. CDFA programs for dairies and ranches provide benefits beyond GHG emission reductions that drive positive changes for air quality, nutrient management, job creation, and additional economic pathways.

Since 2019, DDRDP has funded 74 renewable natural gas and three electricity projects that have resulted in significant air pollutant emissions reductions (measured in pounds over a ten-year period). These project benefits include:

- 2 million pounds of total NOx
- 18 million pounds of total Reactive Organic Gases (ROG)
- 19,000 pounds of total diesel PM,
- 7,000 pounds of local PM 2.5.

Additionally, these DDRDP projects have generated over 5,000 full-time jobs.[295] Beyond job creation and air quality improvements, DDRDP projects can produce byproducts which contribute to the circular economy (see Chapter 1). Additional co-benefits include reduced use of heavy-duty equipment to clean out manure storage ponds, the reduction of odor due to the physical and chemical removal of hydrogen sulfide, and the decrease in the number of flies and pathogens.

Co-benefits for AMMP include reduction in air pollutants:

- Approximately 124,000 pounds NOx
- 16,000 pounds ROG
- 5,000 pounds Diesel PM
- 4,000 pounds of PM2.5

Other benefits that may result from AMMP projects include the reduction of odors and flies, the generation of value-added products such as compost that can reduce carbon-intensive fertilizer inputs and promote soil health, reduced fossil fuels required for transportation when importing bedding for cows and commercial fertilizers, improved efficiency in water use and recycling, improved nutrient management for the facility (including the ability to export nutrients and to better control nutrient application to fields), and reduction in the use of heavy-duty equipment to clean out manure storage ponds.

[295] California Air Resources Board. (n.d.). *California Climate Investments Quantification, Benefits, and Reporting Materials | California Air Resources Board*. Ca.gov. https://ww2.arb.ca.gov/resources/documents/california-climate-investments-quantification-benefits-and-reporting-materials

12.2 Collaborate with sister agencies and other partners to carry out additional research to bring on new methane reduction methods.

CDFA is working with other state agencies and partners to develop new and innovative strategies for reducing enteric methane and novel methane.

12.2.1 Develop methodologies and program processes for new enteric methane reduction programs.

Goal 5: Demonstrate and Invest in Innovation and Technology

In 2023, the state budget allocated an initial $2 million to CDFA to develop a framework for producers to adopt enteric methane-reducing strategies. CDFA conducted focus groups with a variety of stakeholders on how to incentivize enteric reductions and rigorously quantify and track them.

12.2.2 Support research dedicated to enteric emissions reduction strategies.

Goal 5: Demonstrate and Invest in Innovation and Technology

CDFA has funded significant research intended to fill gaps in what is known about various methane reduction solutions. A main area of focus is enteric emission reduction strategies- mitigating the methane produced during rumination that is burped out of cows. Enteric emissions from dairies represent 20 percent of the state's methane emissions, but solutions are only now beginning to be developed.

Since 2022, CDFA has been implementing two research programs to find cost-effective, scientifically proven methods for reducing livestock methane emissions that do not harm animal health, public health, or consumer acceptance of dairy products.

The 2022 California Livestock Methane Measurement, Mitigation and Thriving Environments Research Program (CLIM3ATE-RP) was established to provide funds allocated from the Budget Act of 2021 to research projects that evaluated verification of methane reduction strategies, alternative methane reduction strategies, and manure recycling and innovative products development. CLIM3ATE-RP awarded projects for a total of $4.74 million.

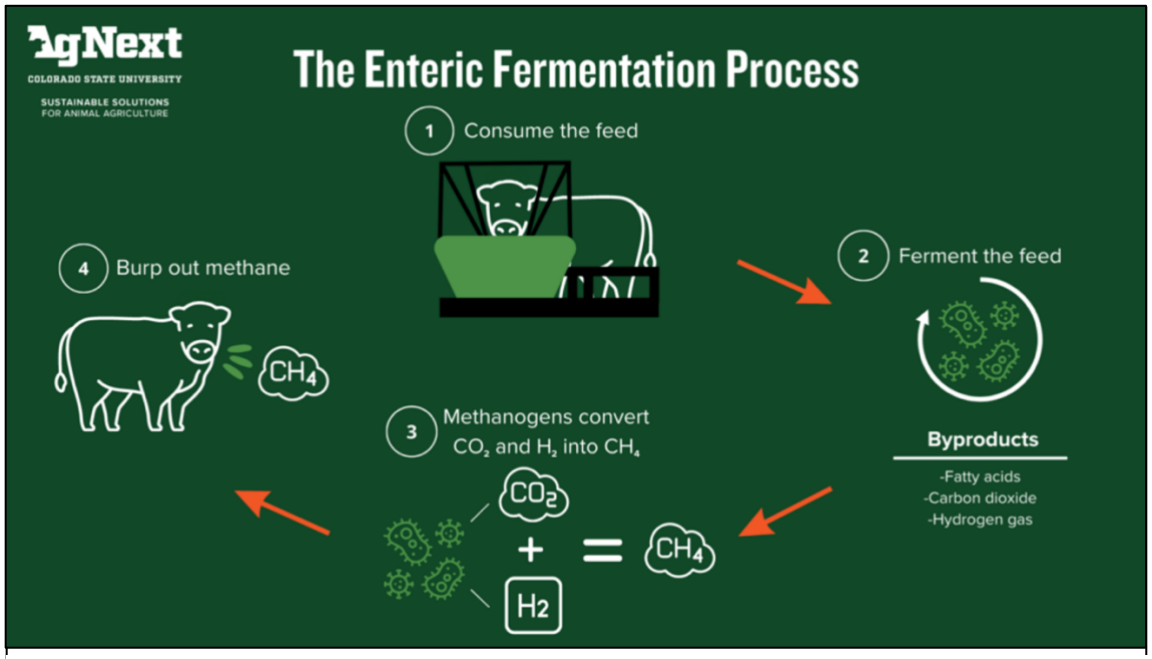


Figure 14: Photo Credit: AgNext, Colorado State University

The Livestock Enteric Methane Emission Reduction Research Program (LEMER-RP) awarded $9.46 million in competitive grants to fund demonstration trials evaluating additives and dietary modifications that have the potential to reduce enteric methane emissions in the dairy and livestock sectors. These research projects will help identify the most effective and safe feed additives and strategies that can practically be implemented on-farm to decrease enteric methane emissions.

12.2.3 Promote research and development for novel methane reduction strategies.

Goal 5: Demonstrate and Invest in Innovation and Technology

CDFA convened the Manure Recycling and Innovative Products Task Force (MRIP) to develop recommendations on how to improve the use of manure from dairies. Manure, far from being a useless waste product, can be recycled into beneficial products. Manure is rich in nutrients like nitrogen, phosphorus, and potassium, and can be applied to land to improve soil fertility; it contains organic matter that can help build soil organic matter, and it can support soil erosion control and sustainable pest management. Manure is a good source of phosphorus, which is a comparatively expensive, globally limited non-renewable resource. However, fresh manure is heavy, which can make transporting it more difficult than commercial fertilizer.

The MRIP task force released a final report providing recommendations on using dairy manure. The following is a summary of their recommendations for methane management reduction methods:

- Prioritization and increased adoption of simpler manure management strategies that improve utilization of liquid manure on farm or divert liquid manure away from liquid storage. These strategies are thought of as more conventional and less complex manure management techniques; however, these strategies do help facilitate application to more distant forage crop fields and use up surplus nitrogen.
- Increase the production and application of compost from on-farm composting. Utilization of manure for compost production and application to agricultural lands provides an example of climate-beneficial practices that can improve environmental quality and also create new income streams for dairies and ranches.
- Increase research and outreach for innovative nitrogen surplus and manure management techniques such as vermifiltration, algae raceway systems, evaporative liquid waste processing systems, and polymer flocculant-based solids/liquids separation. While some of these technologies are in use on a very limited basis in the United States generally and California specifically, they may offer potential to address nitrogen surplus issues through improved manure management. However, more research and development of these systems is needed to make widespread adoption economically feasible.

12.2.4 Support research to better quantify emissions from dairies.

Goal 5: Demonstrate and Invest in Innovation and Technology

The California Dairy Emissions Model (CADEM) is a process-based tool designed to estimate emissions of greenhouse gases, such as methane (CH4), carbon dioxide (CO2), and nitrous oxide (N2O), as well as ammonia (NH3) from dairy and livestock operations. While CADEM can produce reliable modeled results, it requires extensive and detailed input data, making it difficult to use and challenging to adapt into a more user-friendly calculator. A CARB sponsored research project will bring CADEM closer to becoming a more user-friendly calculator that can let producers, policymakers, and researchers estimate emissions from individual dairy and livestock facilities.[296] It can also support the evaluation of different emission mitigation strategies and help identify

[296] California Air Resources Board. (2025, July). *Streamlining CADEM for a Web-Based Emissions Calculator*. https://ww2.arb.ca.gov/sites/default/files/2025-07/23RD031%20Project%20Outline.pdf

approaches that are both practical for producers and aligned with the methane emission reduction goal set under Senate Bill 1383.

12.3 Support new dairy waste utilization pathways that offer additional revenue streams for agricultural operations.

Collaborating with other state agencies will allow the state to better incentivize methane capture and conversion to biogas, and to promote utilization of manure soils as inputs for soil amendment products.

12.3.1 Incentivize methane capture and conversion to biogas to participate in low carbon fuel programs.

Goal 2: Enhance Program Effectiveness

Dairy farmers are finding innovative ways to address methane and reduce their environmental impact. Dairy digesters are specialized systems that capture the methane produced in manure lagoons and prevent it from escaping into the atmosphere. One of the benefits of dairy digesters, in addition to capturing methane emissions that contribute to climate change, is the ability to convert the captured methane into renewable energy. The captured biogas can be conditioned to meet pipeline quality standards, transformed into renewable natural gas, and used as a transportation fuel for medium and heavy-duty vehicles, displacing more carbon-intensive fossil fuels like gasoline and diesel. It can also be used to decarbonize the natural gas pipeline system and hard-to-electrify applications such as high-heat industrial facilities.

Implementation of programs in California, like DDRDP, the LCFS, the Renewable Fuel Standard (RFS), the Renewable Gas Standard (RGS), and other programs have provided opportunities for dairy farmers to turn waste manure methane into renewable energy and to generate funding that assists in covering the costs of building and operating these projects. Each of these programs has a different energy focus, and dairy farmers should evaluate which program may be the best fit for their operation. The LCFS program provides revenue by generating credits for the low-carbon transportation fuels produced from biogas to reduce emissions. US EPA's RFS program also offers credits for qualifying renewable fuels. CPUC's RGS program is another alternative, that can fund anaerobic digester projects through long-term RNG offtake contracts, potentially providing greater financial stability to participants if they can offer cost effective contracts to gas utilities. This biogas can also be used to power on-site generators, producing renewable electricity for the farm.

In 2024, the California Public Utilities Commission established biomethane procurement targets pursuant to SB 1440.[297] This program procures methane from organic feedstocks, such as dairy manure, agricultural wastes, and SB 1383-compliant diverted landfill organic waste, and upgrades it to biomethane for injection into California natural gas pipelines.

12.3.2 Promote utilization of manure solids as inputs for soil amendment products.

Goal 2: Enhance Program Effectiveness

Another benefit of digester and non-digester manure management practices is through vermifiltration. This process is where separated manure solids are processed through a technique that involves the conversion of untreated manure solids by earthworms to produce a nutrient-rich vermicompost. This valuable soil amendment can be sold, providing another revenue source for farmers. Alternatively, the treated manure can be traditionally composted and sold as a soil amendment product. These are just two examples of how nutrient-rich soil amendments can be produced from advanced manure management. By leveraging these diverse revenue streams - from renewable natural gas and electricity sales to regulatory credit programs and value-added products such as compost and vermicompost - dairy farmers are finding that their manure management challenges can be transformed into profitable opportunities. As more farmers adopt dairy digester and non-digester manure management technologies, they are not only reducing greenhouse gas emissions, but also developing an economic and more resilient agricultural system.

Dairy Manure and Irrigation Innovation

CDFA's State Water Efficiency and Enhancement Program, or SWEEP, has now added sub-surface drip irrigation, including manure effluent mixing and application systems, as an allowable component of the program. This component can now be quantified for water savings and is in beta-testing for greenhouse gas emissions reductions. Farmers should also consider additional soil moisture measurements, crop needs, the amount of available land, and the amount of manure effluent available.

[297] (Laird, Dahle, Gallagher, 2024)

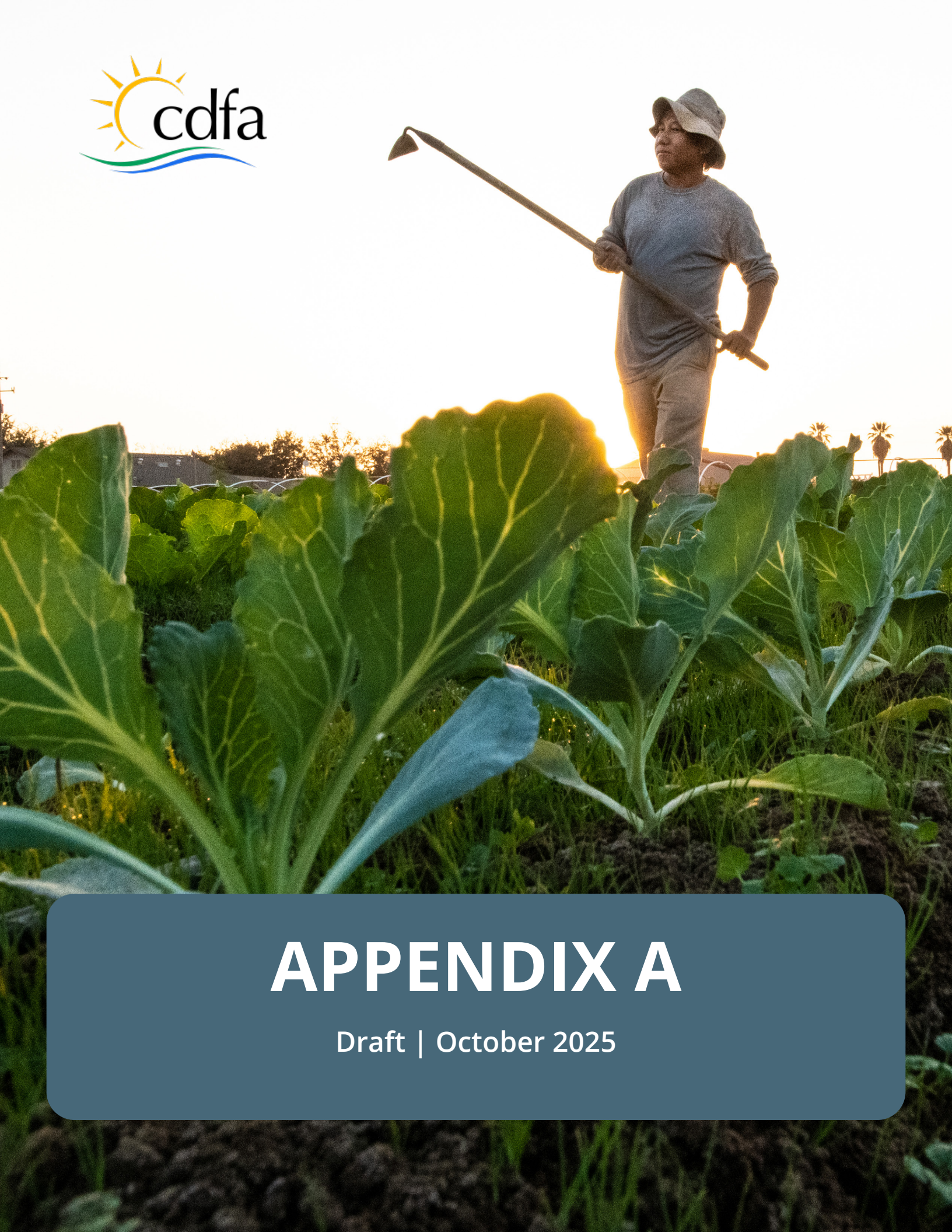
Implementation

Strategy/ Action	Goal Alignment	Lead Agency	Status	Implementation Phase
12.1 Increase knowledge and implementation of currently available methane reduction technologies.				
12.1.1 Promote on-farm manure management strategies at all dairies.	2: Enhance Program Effectiveness	CDFA		
12.1.2 Increase adoption of anaerobic digesters.	2: Enhance Program Effectiveness	CDFA	CARB	
12.2 Collaborate with sister agencies and other partners to carry out additional research to bring on new methane reduction methods.				
12.2.1 Develop methodologies and program processes for new enteric methane reduction programs.	5: Demonstrate and Invest in Innovation and Technology	CDFA		
12.2.2 Support research dedicated to enteric emissions reduction strategies.	5: Demonstrate and Invest in Innovation and Technology	CDFA		
12.2.3 Promote research and development for novel methane reduction strategies.	5: Demonstrate and Invest in Innovation and Technology	CDFA		
12.2.4 Support research to better quantify emissions from dairies.	5: Demonstrate and Invest in Innovation and Technology			

12.3 Support new dairy waste utilization pathways that offer additional revenue streams for agricultural operations.				
12.3.1 Incentivize methane capture and conversion to biogas to participate in low carbon fuel programs.	2: Enhance Program Effectiveness	CDFA, CPUC		
12.3.1 Promote utilization of manure solids as inputs for soil amendment products.	2: Enhance Program Effectiveness	CDFA		

Summary and Conclusion

To be added.



APPENDIX A

Draft | October 2025

CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE

Integrating Equity Principles for Agriculture – PUBLIC COMMENT DRAFT

Introduction

These principles are designed to help evaluate and improve accessibility to state programs that benefit or affect agriculture. The intent of this section is to enable CDFA and other agencies to consider a consistent set of concepts and questions specific to agriculture to guide the development and implementation of their programs.

This guide is based on Executive Order N-16-22 which directed state agencies and departments to take action to embed equity analysis and considerations in their missions, policies, and practices, findings from the CDFA 2020 Report to the California Legislature on the Farmer Equity Act, as well as a review of existing CDFA and partner equity efforts.

Equity Principles

The following six equity principles aim to ensure that initiatives related to agriculture (e.g., programs, policies, plans) are financially viable, accessible, and culturally relevant for all farmers.

For each principle, this guide includes questions for state agencies to use to help develop their initiatives. A principle can be considered to have been "incorporated" when there are overall positive responses to the prompts below. While all principles are important, some may not be applicable to every initiative. Finally, these principles are not designed as the only indicators or questions that should be addressed, but as a starting point for a robust and detailed exploration of equitable access to initiatives that address agriculture. We encourage additions and updates to this guide as more ideas and insights are developed.

Financial Viability

Objective: Ensure participation and financing that works for all California growers.

While most farmers and ranchers own their land, about nine percent of farms are on leased land[1]. Many of these leases are short-term, which can make it difficult to participate in initiatives aimed at soil conservation and sustainable farming practices.

Guiding Questions:

- Are farmers who lease their land eligible for this initiative?
- Is there an opportunity to support or promote access to farmers who lease land through technical assistance or otherwise?
- Can farmers of all income levels participate in this initiative (e.g., are there stipends, reimbursements for costs, etc.)?

[1] st06_1_076_076.pdf

Capacity Building through Technical Assistance

Objective: Ensure that all farmers and farmworkers, including those previously underserved, can take part in the transition to climate resilient agricultural practices.

Technical Assistance increases the capacity of farmers and farmworkers transition to a climate-smart food system with high-road jobs; that is, jobs that improve the quality of life for workers by providing access to skills and economic opportunity and that use natural resources and human capital more efficiently. This includes upskilling and training farmers and farmworkers to participate in the shift to a low carbon economy, which utilizes alternative and regenerative agricultural methods.

Guiding Questions:

- Can all farmers access trainings and relevant resources to learn climate-smart agricultural practices?
- Can all farmers access technical assistance and/or other resources to enable underserved farmers to implement new practices and approaches?

Accessibility

Objective: Ensure equitable access to initiatives, training, and resources.

Initiative design must center the needs of all Californian farmers, including those previously underserved. This includes ensuring accessibility and flexibility around applications and participation in design processes. Initiatives should be available and advertised sufficiently to all farmers. For example, CDFA and other agencies are already doing work to translate materials into major languages. Documents should be written in clear language that minimizes jargon (see the California Office of Data and Innovation's Plain Language Checklist). Initiatives that involve training must also consider the geographic location of farmers and should work to diversify training locations to reach a broader audience. Maximizing the accessibility of documents and educational opportunities will ultimately increase the reach, and therefore, success of initiatives.

Guiding Questions:

- Is the application process designed for all farmers, including those previously underserved? Do the timeline and budget requirements create burdens for beginner, veteran, or low-resourced farmers?
- Can everyone easily access information/education on the impacts of climate change?
- Are materials accessible for people who speak languages other than English?
- Can documents be easily understood?
- Is comprehensive technical assistance available throughout the process?
- Are trainings geographically accessible or accessible online?
- Are materials available and accessible to farmers without internet or with limited internet access?
- Have you conducted engagement with the target population to inform the design of the initiative?

Health and Wellbeing

Objective: Protect and promote the health of the agricultural workforce, especially as it relates to climate change impacts.

There are many climate change-related health risks for that agricultural workers, such as extreme heat, wildfire smoke, dust and particulate matter, and airborne illness and allergens. It is important to center the wellbeing of the agricultural workforce in the pursuit of farm programs and policies, while providing resources for agricultural communities impacted by climate change.

Guiding Questions:

- Does the initiative consider and seek to mitigate climate change related health impacts?
- Are the health impacts of to the agricultural workforce, especially from climate change and related impacts (e.g. extreme heat, dust and particulate matter, mold and fungus, etc.) considered and mitigated?
- Are protective equipment or technologies available if needed to mitigate impacts?
- Does the initiative provide information to help understand health risks and address impacts?

Cultural Relevancy

Objective: Deliberately and respectfully honor cultural traditions and history to maintain cultural heritage for the benefit of all generations.

All food production is derived from ancient practices, and many traditions may have their own specific practices. As such, agencies should ensure that their initiatives aimed at climate smart farming practices support culturally relevant farming practices including traditional ecological knowledge.

Guiding Questions:

- Does the design of the program allow for the inclusion of culture and traditions, including traditional ecological knowledge?
- Do the design and decision-making processes uplift shared values and accommodate cultural differences throughout implementation?

Accountability and Transparency

Objective: Ensure initiatives have clear and transparent mechanisms to monitor long-term implementation.

Agencies who are responsible for developing and updating their suite of initiatives must ensure that equity actions are properly implemented. Agencies should track and monitor the progress and benefits of their initiatives.

Guiding Questions:

Does the initiative regularly collect and report data?

- What constitutes success in the short-term and long-term? How will the initiative meet the goals?
- Is there a process to provide feedback and to address any concerns raised in that process?
- Is there a process for upgrading and improving the initiative based on feedback?
- Are there adequate resources to achieve designed goals?
- What data or qualitative information will be used to assess success on goals?
- How will success be communicated to people supported by the initiative?